SMOS
Calibration Validation
&
Retrieval Plan

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DOCUMENT SIGNATURE TABLE

NAME	FUNCTION	SIGNATURE	DATE
S. Delwart C. Bouzinac (Authors)	SMOS Validation & Retrieval Manager SMOS Campaign & Validation Support		
Yann Kerr	SMOS Principal Investigator		
Jordi Font	Ocean Salinity Lead Investigator		
Achim Hahne	SMOS Project Manager		

DISTRIBUTION LISTS

Internal Distribution			
Centre	**Name**	**Centre**	**Name**
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	Mike Brown		Guillermo Buenadicha
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	Matthias Drusch		
	Malcolm Davidson		

External Distribution	
Company	**Name**
CESBIO (France)	Yann Kerr
ICM (Spain)	Jordi Font
CASA (Spain)	Isabel Cabeza
ARGANS (UK)	Paul Spurgeon
ARRAY (Canada)	Ali Mahmoodi
DEIMOS (Portugal)	Antonio Gutierrez
INDRA (Spain)	Antonio Martinez

DOCUMENT CHANGE RECORD

Issue / Revision	Date	Description
0.draft 04	23 Sept 2005	New issue, all pages
0.draft 05		Update of the requirements for validation
0.draft 05		Update of scientific issues with inputs from Jordi Font
0.draft 05		Inclusion of definition for retrieval
0.draft 06	11 Nov 2005	Inclusion of draft plans and general update before Avila meeting
draft CB	01 Dec 2006	General corrections and complete updates
draft CB	06 Feb 2007	Minor corrections from Zribi and Marczewski
draft CB	13 Apr 2007	Data distribution update, inputs from Wright and Brockmann
draft CB	19 Apr 2007	Norwegian contribution, inputs from Sorensen and Johannessen
draft CB	24 Apr 2007	ESA campaigns summaries and measurements protocols
draft CB	26 Apr 2007	European campaigns summaries
issue 1.0	01 Jun 2007	List of PI's outputs
issue 2.0	01 Nov 2007	General update and list of tools
issue 2.1	27 Nov 2007	Inputs from Berry
issue 2.2	28 Jan 2008	Methods of cal/val from Kerr and Waldteufel
issue 2.3	12 Feb 2008	Vanderborght becomes SM PI
Issue 2.4	26 Jun 2008	Marczewski is removed from the calibration plan
Issue 2.5	18 Sept 2008	Corrections and updates, new radiometers section
Issue 2.6	26 Sept 2008	COSMOS 2007 description in campaigns section
Issue 2.7	11 Dec 2008	Ocean data for cal/val support in data distribution section
Issue 2.8	06 Feb 2009	Updates on tools and inputs from Escorihuela and Skou
Issue 2.9	05 Jun 2009	Update of mailing list
Issue 3.0	01 Jul 2009	Update on Brockmann SMOS Box
Issue 4.0	01 Dec 2009	Last general update
Issue 4.1	01 April 2009	Last general update for ORR

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1 INTRODUCTION

The purpose of this document is to list all activities, including their interactions, required to perform the SMOS data calibration and validation.

It is based on the response to the Announcement of Opportunity (AO) for the validation of the SMOS products, as well as the core project activities related to the overall validation of the SMOS mission objectives.

It is assumed that readers of this document are knowledgeable of the SMOS mission objectives and system requirements ([RD 1], [RD 7], [AD 1]) and of the SMOS instrument characteristics [RD 5].

1.1 Applicable Documents

[AD 1]	SO-RS-ESA-SYS-0555	System Requirement Document
[AD 2]	SO-TN-CESBIO-SYS-1184	Overall System Performance Synthesis Report

1.2 Reference Documents

[RD 1]	EEOM-SMOS-MRD	Mission Requirement Document
[RD 2]	SO-DS-DME-L1PP-0011	ATBD L1 processor
[RD 3]	SO-TN-ESL-SM-GS-0001	ATBD Soil Moisture
[RD 4]	SO-L2-SSS-ACR-0001	ATBD Ocean Salinity
[RD 5]	http://eopi.esa.int/SMOS	AO document package
[RD 7]	SMOS PROPOSAL COP-16	Original proposal text
[RD 8]	SO-TN-CBSA-SYS-0001	Note on SMOS calibration
[RD 9]	SO-TN-UPC-PLM-0019	In-orbit calibration plan
[RD 10]	SO-TN-CBSA-GS-015	Level 2 SM Algorithm Validation Plan

2 SMOS MISSION OVERVIEW

2.1 SMOS Science Overview

Water in the soil and salt in the oceans may seem to be unconnected, however, in fact both variables are intrinsically linked through the Earth's water cycle and climate.
The SMOS mission is a direct response to the current lack of global observations of soil moisture and ocean salinity which are needed to further our knowledge of the water cycle, and to contribute to better weather and extreme-event forecasting as well as seasonal-climate forecasting.

Consequently, the main objective of the SMOS mission is to deliver those two crucial variables of the land surfaces: soil moisture, and of ocean surfaces: sea surface salinity fields. The mission should also deliver information on root zone soil moisture, vegetation and biomass, and lead to significant research in the field of the cryosphere.

Over land, water and energy fluxes at the surface/atmosphere interface are strongly dependent upon Soil Moisture (SM). Evaporation, infiltration and runoff are driven by SM while soil moisture in the vadose zone governs the rate of water uptake by vegetation. Soil moisture is thus a key variable in the hydrologic cycle. Soil moisture, and its spatio-temporal evolution as such, is an important variable for numerical weather and climate models, and should be accounted for in hydrology and vegetation monitoring.
Over sea, Sea Surface Salinity (SSS) plays an important role in the Northern Atlantic sub polar area, where intrusions with a low salinity influence the deep thermohaline circulation and the meridional heat transport. Variations in salinity also influence the near-surface dynamics of tropical oceans, where rainfall modifies the buoyancy of the surface layer and the tropical ocean-atmosphere heat fluxes. SSS fields and their seasonal and inter-annual variabilities are thus tracers and constraints on the water cycle and on the coupled ocean-atmosphere models.
Even though both SM and SSS are used in predictive atmospheric, oceanographic, and hydrologic models, no capability exists to date to measure directly and globally these key variables. It is therefore of prime importance to infer adequate means to validate such measurements.

2.2 SMOS Scientific Objectives

The principal objective of the SMOS mission is to provide maps of soil moisture and ocean salinity of specified accuracy, sensitivity, spatial resolution, spatial coverage and temporal coverage. In addition, the mission is expected to provide useful data for cryosphere studies.

Soil Moisture (SM)

From all the lower boundary conditions that drive the atmosphere, land-surfaces are of particular interest to mankind, as their direct and local impact is of great importance to human activities. Dealing with land-surfaces for meteorological and climatological applications is challenging, because they are very variable over a broad range of temporal and spatial scales. Diurnal variations of temperatures and fluxes are one order of magnitude larger than over the ocean. Another specificity is that moisture for evaporation, while available in limited supplies, constitutes at the same time a memory for the system. The surface hydrology is one of the keys to our understanding of the interaction between continental surfaces and the atmosphere, as it determines the partitioning of energy between different fluxes. The science issues considered here are related to the parameterisation of land surface processes, in order to improve the representation of surface fluxes, soil moisture content, soil hydraulic characteristics, and plant stress in mesoscale and global models. The initialisation of soil moisture in atmospheric (including numerical weather forecast) models is of great concern and a subject of active research. The current methods to estimate soil moisture are indirect: SMOS will provide new ways of inferring soil moisture, with global coverage.
For watershed hydrologic model applications, there is a need to have access to distributed soil water fluxes at regular temporal resolutions over large areas. The yearly-integrated land surface and base flow water budgets are generally well predicted by the recent generation of hydrologic models. However, the estimation of the ratio between base flow and surface runoff, as well as the ratio between deep drainage and soil

moisture content, are still very imprecise. The soil stratum and in particular the unsaturated zone between the soil surface and the groundwater table (vadose zone) plays a crucial role: the estimation of soil moisture in the vadose zone is an important issue for short and medium term meteorological modelling, hydrological modelling, and the monitoring of plant CO_2 assimilation and plant growth. The vadose zone hydrology being inaccurately described, attempts to monitor water quality and flooding risks often fail. SMOS will offer new ways to parameterise effective soil characteristics are needed.
In most cases, the vadose zone hydrology and the surface fluxes are controlled by vegetation. Modelling the rate of soil water extraction by the plant roots and the stomatal feedback is important for atmospheric, hydrologic, and environmental studies. The current models manage to describe first order responses but do not encompass the complete behaviour of the plant, especially at the mesoscale, where several landscape units may contribute to the surface fluxes. In most of the world, plant water supply is the dominant factor that affects plant growth and crop yields. Monitoring soil moisture is a valuable way to detect water stress period (excess or deficit) for yield forecasting or biomass monitoring, especially in areas where climatic stations are sparse. Time series of soil moisture at the mesoscale would be a very interesting input to the representation of vegetation in land surface schemes, also.
These objectives may be achieved by estimating near-surface SM content (w_S). In most cases, the root-zone or the vadose-zone soil moisture is required, also, together with effective hydraulic soil characteristics. In the next section, it is explained how the latter variables can be inferred from w_S, provided this variable is monitored with a good (3-4 days) temporal resolution.

Ocean Salinity (OS)

Ocean salinity is a key parameter in determining the ocean circulation and in understanding the water cycle. It is also an important circulation tracer for water masses. Unlike other oceanographic variables, until now, it has not been possible yet to measure salinity from space. However, large ocean areas lack significant salinity measurements. The only means to get consistent estimates of SSS at least at seasonal scales is the use of a satellite-based instrument.
Ocean circulation is mainly driven by momentum and heat flux through the atmosphere-ocean interface, but salinity is also fundamental in determining ocean density, and hence thermohaline circulation. In some regions (e.g. the Arctic), salinity is the most important variable in this respect, and then can control processes as the deep-water formation, a key component in the ocean conveyor belt.
Observed SSS changes can be used to improve the quality of ENSO (El Niño - Southern Oscillation) prediction in numerical models assimilating temperature and/or altimeter-derived sea level data only. The lack of salinity control in this type of models results in major discrepancies between near-surface modelled and observed currents. Such a failure is especially relevant in the western equatorial Pacific where there is a strong ENSO-related near-surface salinity signal, and where zonal advection is of main importance for ENSO mechanisms. Techniques presently used to assimilate data into ocean models must be adapted to assimilate either retrieved SSS or brightness temperatures. The compromise between measurement accuracy, spatial resolution and data delivery delay will have to be analysed.
Surface ocean salinity is correlated with estimates of net evaporation minus precipitation (E-P) balance. Global maps of SSS would provide a means to constrain the (E-P) estimations at global scale giving insights into the phenomena driving the thermohaline circulation and providing a check on the latent heat flux determinations. The water flux through the surface is critical for the stratification of the surface layer of the ocean, and hence strongly influences the mixed layer depth and the intensity of the surface currents.

Summary

In summary, the SMOS science requirements are to:
1. Globally monitor soil moisture over land surfaces,
2. Globally monitor surface salinity over the oceans, and
3. Improve the characterisation of ice and snow covered surfaces.

In order to:

1. Advance climatological, oceanographic, meteorological, hydrological, agronomical, and glaciological sciences, and
2. Assess the capability of such measurements to improve the management of water resources.

Measurement goals

For soil moisture:

Moisture is a measure of the amount of water within a given volume of material and is usually expressed as a percentage. From space, the SMOS instrument aims at measuring soil moisture with a sensitivity of 4%.

- Accuracy of 4% volumetric soil moisture
- Spatial resolution 35-50 km
- Revisit time 1-3 days

For ocean salinity:

Salinity describes the concentration of dissolved salts in water. It measures in practical salinity units (psu), which expresses a conductivity ratio. The average salinity of the oceans is 35 psu, which is equivalent to 35 grams of salt in 1 litre of water. SMOS aims to observe salinity down to 0.1 psu (averaged over 30 days on an area of 200 km x 200 km).

- Accuracy of 0.5-1.5 practical salinity units (psu) for a single observation
- Accuracy of 0.1 psu for a 30-day average for an open ocean area of 200 x 200 km^2

2.3 SMOS Mission Overview

For optimum results, SMOS will measure microwave radiation emitted from the Earth's surface at L-band (1.4 GHz) using an interferometric radiometer.

Measurement principles

Moisture and salinity decrease the emissivity of soil and seawater respectively, and thereby affect microwave radiation emitted from the surface of the Earth.
Due to the large dielectric contrast between dry soil and water, the soil emissivity ε at a microwave frequency F depends upon moisture content. Over bare fields, ε is almost linearly related to the moisture content of a soil layer whose thickness depends upon F (3-5cm at 1.4 GHz, 1-2cm at 5 GHz). The vegetation cover attenuates soil emission and adds a contribution to the radiation temperature T_B. However, at L-band, this attenuation is moderate; T_B is sensitive to soil moisture for vegetated areas with biomass $\leq$ 5 $kg.m^{-2}$ (circa 65% of the Earth's land surface).
The sensitivity of L-band (1.4 GHz) passive measurements of oceanic brightness temperature T_B to SSS is well established. The dielectric constant for seawater depends on both salinity and temperature. So, in principle, it is possible to obtain SSS information from L-band passive microwave measurements if the other factors influencing T_B can be accounted for.
At L band, the atmosphere is relatively transparent with minimal influence of clouds and water vapour. The wave band is protected for radio astronomy and thus assumed to be RFI free.
The main drawback is the spatial resolution as to achieve a 50 km spatial resolution from a 700 km orbit, an 8-meter diameter antenna is required. To solve this issue, SMOS uses interferometry.

Interferometry principle

A two-dimensional interferometer approach for earth observation provided by the Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) was proposed for SMOS as it offers a drastic stowed volume

improvement by comparison with the one-dimensional interferometer. The instruments consist of a Y shaped structure with equally spaced antenna elements. That structure exhibits many advantages in terms of ground resolution, grating lobes and is suitable for space borne instrumentation. The instrument is tilted by 32.5° with respect to the nadir to guarantee an incidence angle between 0° and 50°. In a nutshell, the principle of this instrument is to sample the Fourier transform of the scene. To do that, a set of elementary antennas are regularly distributed on a Y structure. The correlation between the output signals of all the couples of antennas gives an estimator of the visibility function. These visibility functions are transmitted to the ground where something roughly equivalent to an inverse Fourier transform is performed to retrieve the image.
MIRAS will use the interferometry principle, having 69 small receivers, which will measure the phase difference of incident radiation. The technique is based on cross-correlation of observations from all possible combinations of receiver pairs.
One of the advantages of the SMOS system is that if allows to image a large two-dimensional 'measurement image' every 1.2 seconds. Hence, as the satellite moves along its orbital path, each observed area is seen under various viewing angles.
From an altitude of 763 km, the antenna will view an area of almost 3000 km in diameter. However, due to the actual instrument design, the Y-shaped antenna, and the distance of the receivers to each other, the field of view (FOV) is limited to a hexagon-like shape of about 1000 km across called the alias-free FOV. This area corresponds to observations where there is no ambiguity in the phase difference (coherence criterium).

SMOS will achieve global coverage every three days.

Mission summary:

- Launch end 2009
- Duration minimum 3 years expected 5 years
- Instrument concept: passive microwave 2D-interferometer
- Frequency: L band (21 cm-1.4 GHz)
- Polarisation H & V (polarimetric mode optional)
- Spatial resolution 35 km at centre of field of view (43 km on average)
- Tilt angle 32.5 degrees
- Radiometric resolution 0.8 - 2.2 K
- Angular range 0-55 degrees
- Temporal resolution 3 days revisit at Equator
- Orbit Sun-synchronous, dawn/dusk
- Circular orbit at altitude 763 km, 06.00 hours local solar time at ascending node
- Payload Mission and Data Processing Centre in Villafranca, Spain (ESAC)

2.4 Validation Goals

This section should identify clearly level 1 and 2 data and parameters requiring cal/val and their associated performance requirements. This provides the context for cal/val and defined goals for cal/val activities.

SM algorithm validation plan is based on using made targets, realistic synthetic scenes and eventually real data collected during campaigns. Validation is described in RD10. The core of the validation plan consists of three parts, which differ mainly by the data used as input.

- assessing the retrieval validity domain on conditions similar to those of previous sensitivity studies, i.e. using fully simulated academic dataset in view of carrying out a systematic exploration of observing conditions for homogeneous scenes
- performing the retrieval on a large sample as provided by actual, realistic auxiliary data. The assessment is carried out through statistical analysis of the results.
- optimization of various operating parameters and assessment of retrieval efficiency
- specific test sites selected for product verification and repetition using actual SMOS data

The performance of the OS algorithm will be evaluated by comparing in-situ SSS with retrieved salinity. The correlation between algorithm results and in-situ data, limited with regression coefficients, will allow adjustments to be done. Salinity validation will be performed over selected test sites for different sea surface conditions (cold, warm, high and low winds, rainy, swell, frontal area) to assess the accuracy of the algorithm under different salinity conditions. Test sites associated with the salinity classes are selected where in-situ information is the most available (e.g. ARGO float locations).

Level 2 Models Input Parameters and their associated error standard deviation:

Polarization mixing coefficient	
Roughness coefficient	
Sand and clay fractions	
Bulk density	
Correlation length	
Soil salinity	
Volumetric soil moisture	
Roughness exponent	
Effective temperature	2 C
Vegetation water content	
Vegetation structure coefficients	
Polarization dependent single scattering albedo	
Leaf area index	1.15
Polarization mixing vegetation parameter	
Air temperature	2 C
Air pressure	10 mbar
Sea surface roughness	0.25 m
Wind speed and direction	2.5 m/s and 25 deg
Salinity first guess	0.25 PSU
Sea surface temperature	0.5 C

Error impact assessment on SM from:

• Radiometric noise	1.5 K at boresight	
• Image reconstruction	0.2K	random error impact on SM = 0.1 %
• Ionosphere	0.2K	random error impact on SM = 0.1 %
• Atmosphere	0.1K	random error impact on SM = 0.05 %
• Soil texture		bias error impact on SM <= 2 %
• Surface roughness		bias error impact on SM <= 2 %
• Surface temperature	1.7 K	
• Topography		
• Vegetation thickness	1.6 K	
• Vegetation type	1.6 K	
• Frozen soil		

Error impact assessment on OS from:

• Radiometric noise	1.5 K at boresight	
• Image reconstruction	0.2K	random error impact on OS = 0.39 PSU
• Ionosphere	0.2K	random error impact on OS = 0.16 PSU
• Atmosphere	0.1K	random error impact on OS =
• Foam and precipitation		
• Surface roughness		
• Surface temperature		
• Sun and galactic glints	3.4 K and 0.5 K	

- Air pressure at sea level 0.024 K
- Air temperature at sea level 0.002 K
- Sea ice concentration

2.5 Known Scientific Issues

Validation and science should be distinguished. The "Scientific Issues" here are rather "sources of uncertainty in the SMOS level 2 products". The distinction is important in steering discussions with scientists. The sources of uncertainty to be investigated by cal/val activities should be restricted to those used in the processing chains. The weight of parameter uncertainties on the product errors should be given.

Obviously, all is not known and the retrieval of surface salinity and soil moisture offers a number of challenges. Most of them are linked to the poor understanding of space borne L band measurements (with coarse resolutions) especially considering the relatively poor sensitivity of the instrument. These issues are currently addressed in a number of studies but the solutions are only expected after the calibration/validation exercise and the relevant activities during the commissioning phase. In order to set the scene, below is given a first attempt to itemise the expected issues. Some may be irrelevant in the end while others, not yet foreseen, will become major research topics.

Over land

- Some elements of the surface are yet not fully characterised. For instance:
  - The exact behaviour of very dry sand (dielectric constant) is yet to be fully ascertained.
  - Urban areas, with a varying mixture of flat and inclined roofs (either of slate, wood, brick or iron), mixture of asphalt, grass and mud, (not forgetting potential RFI) in proportion varying with habitat might prove a headache.
  - Snow with varying cover and characteristics (dry or wet, grain size and age) will be difficult to take into account.
- Some elements are complex in nature and behaviour and will thus require specific attention:
  - Water deposited on the vegetation will artificially increase the opacity by increasing the water content. The effect of rain interception has been identified, however it seems that dew does not play any significant role although this will have to be validated. Several field studies are currently under way looking at this, scaling to SMOS resolution will have to be performed and validated.
  - Topography will modify the signatures due to the slopes and the specific repartition of surface features. The unknown is how much and when will topography be so harsh as to make retrievals impossible.
  - Over natural vegetation, a layer of litter/mulsh may appear. This layer behaves as a sponge wrt rainfall and can quickly shift from totally transparent to totally opaque (black body).
  - Water bodies have a large impact on the signal and have to be accounted for even when they are small (canals in Holland, ponds in Sahel, rivers and lakes, gravitational irrigation, etc).
- Some elements change quickly (water bodies, tidal areas, swamps, rice fields, snow) when their impact on the data is either important (e.g. water) or not well modelled (e.g. snow).
- Some contributions will have to be accounted for even though not always well quantified (e.g. Sun – very variable- and galactic contributions).
- Last but not least and directly linked to the cal/val activities, sampling strategies over heterogeneous areas and disaggregation approaches, choice of reference targets considering SMOS viewing characteristics will also have to be ascertained.

Over sea

- Roughness measurement and modelling
- Simultaneity of auxiliary data
- Short period oscillations in data records (wiggles)

- Sun brightness temperature
- Bistatic scattering (galactic and sun reflections)
- Availability of adequate polarised galactic maps
- Diurnal SST cycle and surface layer stratification
- Scene dependent bias in brightness temperature (not corrected at level 1)
- Data correlation in averaging procedures (for level 3)

3 ORGANISATION

3.1 Activities

The SMOS Validation and Retrieval Team (SVRT) activities have been broken down into four main groups of activities (see Figure 1 below):

1. Instrument Calibration:
   Describe the Calibration Plan and the L1 Product Performance evaluation Plan
2. Geophysical Validation:
   Describe the validation and retrieval Plan and the L2 Product Performance evaluation Plan
3. Campaign Definition:
   Describe the Campaign Coordination Plan
4. Data Distribution.

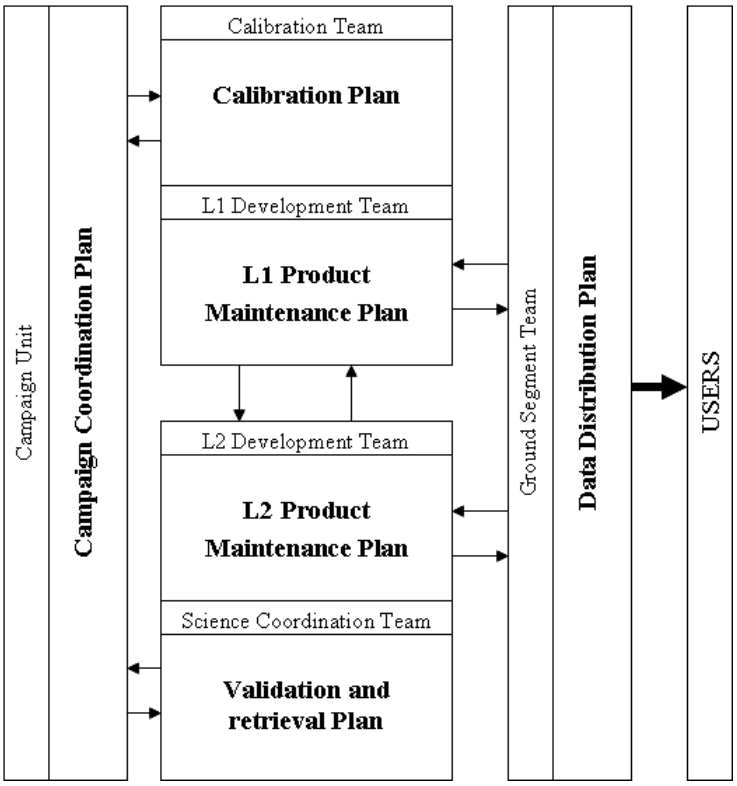


Fig.1 Plan Context Diagram

Each one of the above activities will be described in more details below.

Notes:

1. The instrument calibration has been broken down into two distinct tasks:
   a. Definition and execution of the Calibration Plan lead by the Calibration Team
   b. Verification of the L1 processor and implementation of the calibration results, lead by the L1 processor Development Team

2. The geophysical validation has been broken down into two distinct tasks as for L2:
   a. The Validation and Retrieval coordination team makes use of all the results of the analysis performed by the AO teams members, to improve the retrieval algorithms.

   Note: The validation and retrieval coordination team is split into 3 groups: Land Validation Team, Ocean Validation Team and Vicarious Calibration Team. Although the Validation and Retrieval

coordination team will perform the coordination of the vicarious calibration activities, the implementation of the results will be the responsibility of the Calibration team.

b. Verification of the L2 processor and implementation of the improvements in the retrieval algorithms, lead by the L2 processor Development Team.

Note: For the L2 product performance evaluation plan, two separate plans will be available for the validation of Soil Moisture and Ocean Salinity algorithms.

3. The campaign implementation plan is defined by the ESA campaign unit and executed by the AO teams under supervision from ESA.

4. The data distribution plan will be maintained by the SVRT coordinator.

Although this plan is intended to cover the complete set of activities identified in the introduction, it is intended to separate as stand alone documents the following project related plans:

- Calibration Plan (ESA, EADS-CASA, HUT-TKK and UPC)
- L1 Product Maintenance Plan (DEIMOS)
- L2 Product Maintenance Plan (ARRAY, ARGANS)
- Data Distribution to SMOS VRT (Brockmann Consult)

3.2 Responsibilities & Resources

Campaign Coordination Plan:
Responsibility: Campaign Unit lead by C. Bouzinac (ESTEC) and the support of the SMOS ESA-project team, the Lead or Principal Investigators and the AO Validation Teams.

Calibration Plan:
Responsibility: Calibration Team lead by M. Martin-Neira (ESTEC) with the support of the SMOS Post Launch Support Office (PLSO) team, the L1 Development Team and the Validation and Retrieval Team.

L1 Product Maintenance Plan:
Responsibility: L1 Development Team lead by A. Gutierrez (DEIMOS, Portugal) under ESA contract and supported by the L1 Expert Support Laboratories (ESL).

Validation and Retrieval Plan:
Responsibility: Validation and Retrieval Coordination Team lead by C. Bouzinac (ESTEC) in collaboration with the SMOS principal investigators Y. Kerr for SM and J. Font for OS, with the support of the SMOS ESA project team, the L2 Development Team, and the AO Validation Teams.

L2 Product Performance Evaluation Plan:
Responsibility: L2 Soil Moisture Development Team lead by A. Mahmoodi of ARRAY (Canada) under ESA contract and supported by the L2-SM ESL.
Responsibility: L2 Ocean Salinity Development Team lead by P. Spurgeon of ARGANS (UK) under ESA contract and supported by the L2-OS ESL.

Data Distribution Plan:
Responsibility: Data distribution to SMOS VRT lead by C. Bouzinac (ESTEC) with the support of Brockmann Consult as well as the Calibration & Validation and Retrieval Coordination Teams.

3.3 Schedule of Reviews

This plan and its sub-plans address activities taking place:

- Before the SMOS launch
- During the SMOS commissioning phase (also called phase E1)

- During the SMOS operational phase (also called phase E)

The phases between the sub-plans defined in this document and the SMOS mission key events are shown in the figures below:

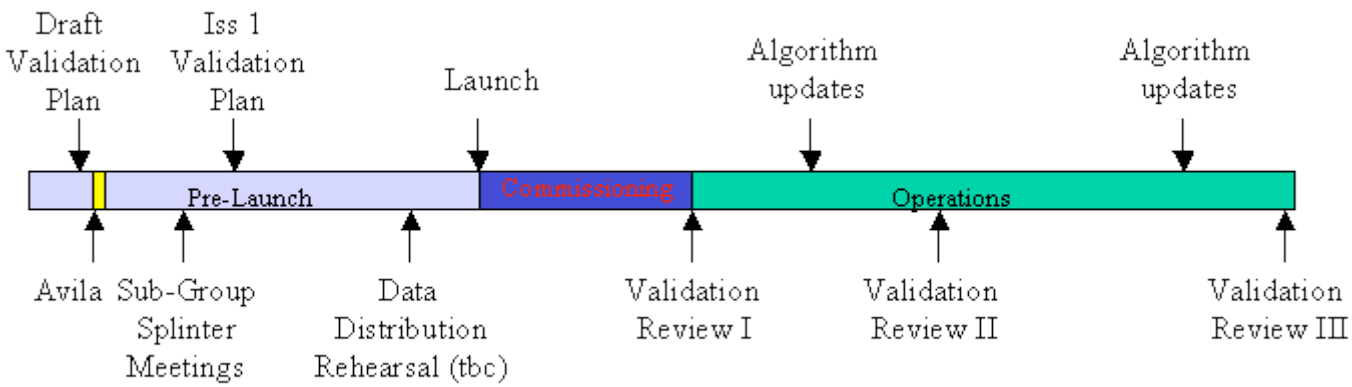
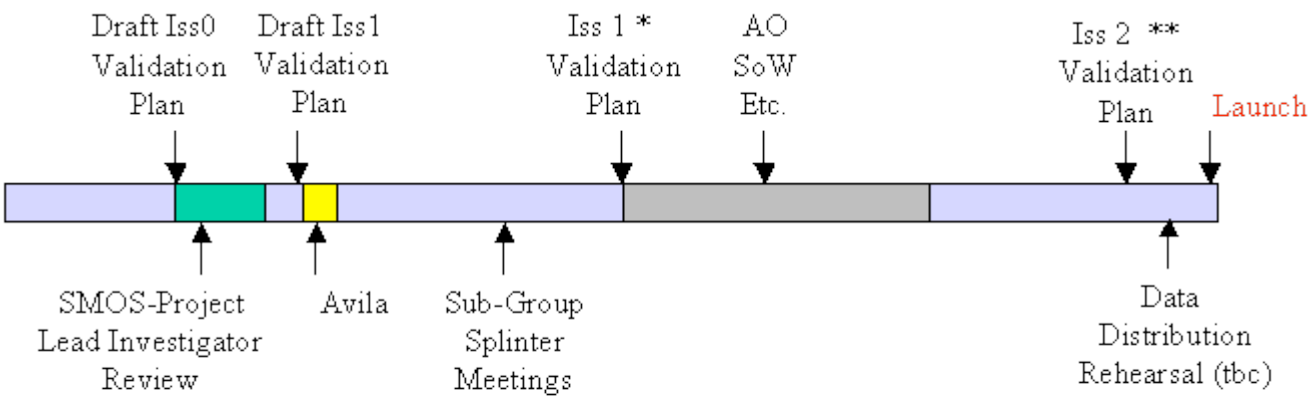


Fig 3. Overall Validation Plan development and execution



* Iss 1 Only Campaign Plan and Validation Retrieval Plans at issue 1.
** Iss 2 All sub-plans (I.e. including Product Maintenance and data distribution) at Iss 1.

Fig 4. Detailed Validation Plan development

Nobody in the Cal/Val teams can publish anything without the explicit permission of the project before the end of the commissioning phase. This is the only way to control the validation process and avoid early or premature complaints about the data quality. In return, ESA will organise a milestone event as soon as reasonable after launch, where Cal/Val team members and ESA present the results of the Cal/Val activities. Beyond that point in time, data will be released to all users, together with the freedom to publish that comes along with it (as described in the Terms of Conditions for ESA Category-1 use).

The plan definition and its execution include the following milestones before launch:

- Draft release of Calibration Validation and Retrieval Plan, Nov 2005
- Avila workshop, Nov 2005
- Splinter meetings, Feb 2006
- Issue 1 release of Calibration Validation and Retrieval Plan, April 2006
- Release of Agreements for all AO contributions. May-Sept 2006
- Issue 2 release of Calibration Validation and Retrieval Plan, November 2007
- Data distribution and tools rehearsal workshop, November 2008
- Validation Readiness Review, March 2009

The plan definition and its execution include the following milestones after launch:
(N.B: these dates are only to be considered as tentative dates)

- First L1 & L2 algorithms update, Launch+5months = March 2010
- Second L1 & L2 algorithms update, May 2010
- Commissioning Review I, Launch+6months = May 2010
- Reprocessing (TBC), June 2010
- 1st SMOS VRT meeting, October 2010
- Third L1 & L2 algorithms update, November 2010
- 2nd SMOS VRT (Review II) meeting, April 2011 (TBC)
- Fourth L1 & L2 algorithms update, May 2011
- 1st Reprocessing, June 2011
- 2nd SMOS VRT meeting October 2011
- Fifth L1 & L2 algorithms update, November 2011
- 3rd SMOS VRT meeting (Review III), April 2012
- Sixth L1 & L2 algorithms update, May 2012
- 2st Reprocessing, June 2012
- Seventh L1 & L2 algorithms update, November 2012

The plan is to have regular deliveries of the processing prototypes and DPGS updates available on a 6 monthly basis, while only two end to end reprocessing campaigns are foreseen during the nominal duration of the operational exploitation phase (2.5 years), even though these are foreseen to be performed on a yearly basis from there after.
SMOS VRT meetings are foreseen early in the operational exploitation phase to start the activity, while later, they will be phased with the algorithms updates and reprocessing cycles, but they are only foreseen on a yearly basis. Please note that specific working groups are encouraged to meet on a more regular basis.

4 OVERVIEW OF AO PROPOSALS

4.1 Introduction

The SMOS VRT Plan has been developed from the responses to the call for proposals to conduct calibration and validation activities for SMOS. Following the SMOS AO Review Panel Meeting held in ESA ESTEC 9-10 June 2005, about 40 proposals were accepted on the basis of their potential contribution for calibrating and validating SMOS products. These proposals form the basis of the SMOS VRT Plan as described in the following sections. At this stage, it is also possible to identify gaps in the planned activities where the determined validation requirements are not met.

4.2 Scope of Validation Activities

In broad terms, the proposals that have been accepted may be categorised as follows:
30 proposals involve soil moisture
14 proposals involve ocean salinity
3 of the above involve both soil moisture and ocean salinity activities
3 proposals deal only with brightness temperature
1 proposal is the calibration of geolocation biases

4.3 Summary Description of Activities

The proposals submitted under the AO SMOS cal/val have been summarised at the end of this document. PIs are requested to review these chapters and confirm that they include an accurate summary of their proposed activities, or provide corrected information.

4.4 Locations of Test Areas

Figure 5.1 and 5.2 provide the locations of the test sites for SM and OS activities, respectively.

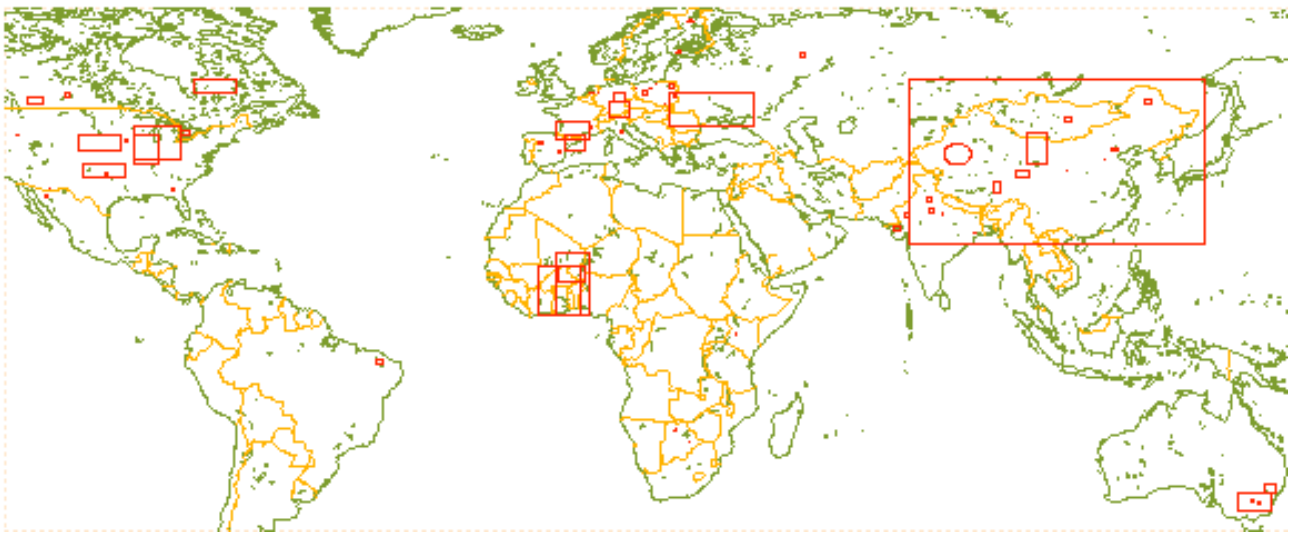


Figure 5.1 Location of soil moisture test sites

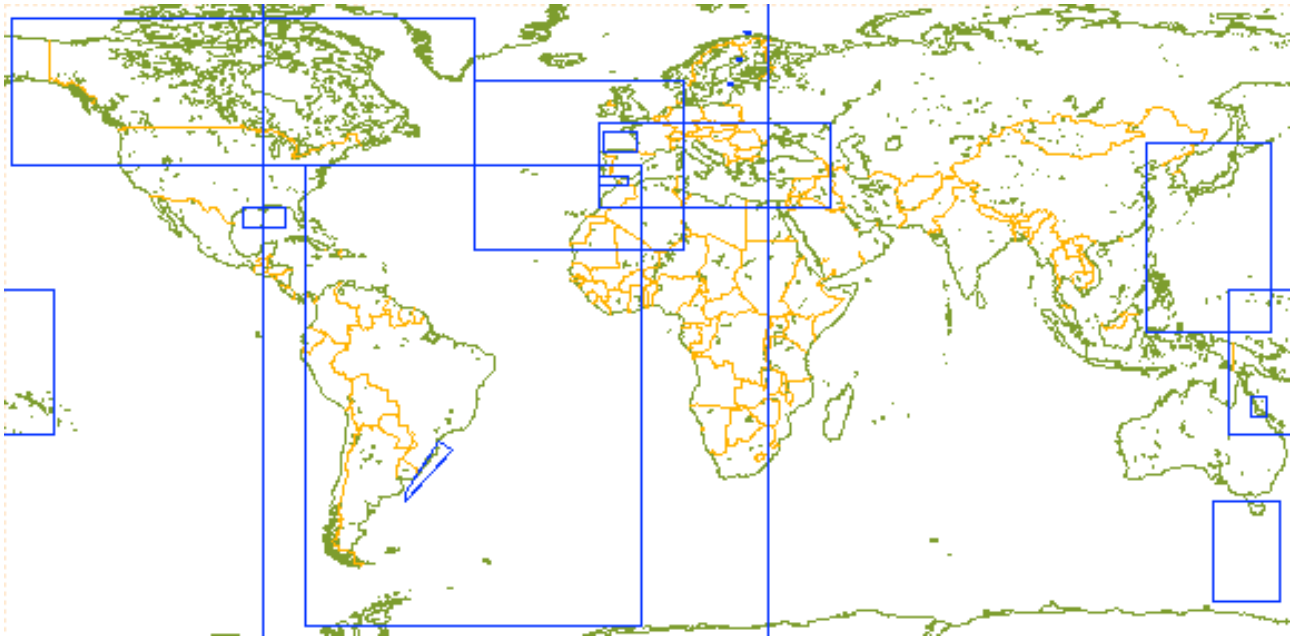


Figure 5.2 Location of ocean salinity test sites

The information provided in the above figures are tabulated below. Soil moisture test sites, table 5.4, are categorised according to land cover type in a global context. The ocean salinity locations, table 5.5, are listed by proposal.

Boreal forest	Magagi (Canada), Hallikainen (Finland), Pellarin (French Alps)
Temperate agriculture, Temperate forest	Calvet (France), Jackson (US), Martinez-Fernandez (Spain), Mauser (Germany), Vanderborght (Germany), Hornbuckle (US), Lopez-Baeza (Spain), Camps (Spain), Magagi (Canada), Paloscia (Italy), Zribi (France), Marczewski (Poland), Su (NL)
Tropical agriculture	Singh (India), Patel (North India)
Semi-arid grassland	Walker (SE Australia), Grippa (Sahel), Magagi (Sahel), Friesen (Volta Basin), Kaihotsu (Mongolian Plateau), Martins (Brasilian Caatinga), Berry (Australia)
Arid	Zhang (Takelimgan Desert), Walker (Simpson Desert)
Global	De Jeu, Robock, Wagner, Su (Eurasia and Africa)

Table 5.4 Soil moisture test areas by land cover type

Burrage	Gulf of Mexico	Gower	Canadian seas
Stammer	Western Pacific, North Sea	Martinez	Uruguayan coast
Poulain	Mediterranean Sea	Heron	Great Barrier Reef
Camps Zribi	Bay of Biscay, Mediterranean Sea	Hallikainen	Baltic and Arctic Seas
Gommengin. Johannesse.	Atlantic Ocean, Arctic Ocean	Gaillard	Tropical Pacific Ocean, Tasmania Antarctic Ocean
Navarro	Gulf of Cadiz	Le Vine	Global

Table 5.5 Ocean salinity test areas by proposal

4.5 Techniques Proposed for Calibration / Validation

The proposals submitted for SMOS cal / val include a wide range of techniques. Tables 5.6 (soil moisture) and 5.7 (ocean salinity) summarise the methods to be employed in the proposals. It is apparent that several proposals will be using a variety of techniques, especially those engaged in several levels of cal / val activities. The use of satellite data other than SMOS is summarised in tables 5.8 and 5.9.

Airborne data	Walker, Jackson, Camps, Kim, Zribi, Paloscia, Mauser, Vanderborght
In-situ data	All
Models	Calvet, Jackson, Mauser, De Jeu, Hornbuckle, Paloscia, Lopez-Baeza, Grippa, Magagi, Su, Walker, Robock, Martinez-Fernandez, Kim, Zribi, Marczewski, Zhang, Friesen, Berry, Vanderborght
Assimilation	Walker, Jackson, Mauser, De Jeu, Lopez-Baeza, Grippa, Magagi, Su, Friesen, Robock, Calvet, Zhang
Disaggregation and upscaling	Walker, Mauser, Paloscia, Lopez-Baeza, Grippa, Pellarin, Su, Kim, Zribi, De Jeu, Vanderborght, Zhang

Table 5.6 Data and techniques used in soil moisture cal / val.

Airborne data	Burrage, Camps, Martinez, Heron, Zribi, Hallikainen
In-situ data	All
Models	Poulain, Camps, Gommenginger, Gower, Gaillard, Burrage, Stammer, Johannessen
Assimilation	Burrage, Camps, Poulain, Gommenginger
Disaggregation and upscaling	Camps, Martinez, Gaillard, Hallikainen

Table 5.7 Data and techniques used in ocean salinity cal / val.

Kaihotsu	AMSR, PALSAR, PRISM
Jackson	AMSR, SMAP algorithms
Martinez-Fernandez	ASCAT
Wagner	ASCAT, ASAR, SMAP algorithms
Mauser	PALSAR, ASAR, MSG, AVHRR
De Jeu	AMSR, MODIS, SMMR, TMI, MERIS
Vanderborght	AATSR, ASAR, MERIS, SSMI, TMI, SMMR, AVHRR, AMSR
Paloscia	AMSR, SMAP algorithms, ASAR, SSMI, SRTM, ERS Scatt
Lopez-Baeza	ASAR, MERIS
Camps	ASAR, AVHRR, MERIS, AATSR, RA
Magagi	SSMI, AMSR, ERS Scatt, ASAR, RADARSAT, AATSR
Su	SSMI, ASCAT, ERS Scatt, ASAR, AATSR, TMI, MERIS
Marczewski	ASCAT, ASAR, AVHRR, MODIS, MERIS, AATSR
Zhang	SSMI, AMSR, MODIS, ASAR, SMMR
Friesen	AMSR, MSG, MODIS
Hallikainen	AMSR, PALSAR, ERS Scatt, QuikScat, ASAR
Patel	ASAR, RADARSAT,
Walker	ASAR, AATSR, MERIS
Singh	ASAR, SSMI, AVHRR, TMI, MERIS
Grippa	AMSR, ASAR, MERIS
Zribi	ASAR, ASCAT, MERIS
Martins	ASAR, AATSR
Robock	SMAP algorithms
Berry	RA, GRACE

Table 5.8 Satellite data to be used in SMOS cal / val activities for soil moisture.

Stammer	AATSR, ASAR, MERIS, RA, SSMI, TMI, SMMR, AVHRR, AMSR
Le Vine	AMSR, SSMI, AQUARIUS
Gaillard	ASCAT, SMMI, ERS Scatt, MERIS, RA
Hallikainen	AMSR, PALSAR, ERS Scatt, QuikScat, ASAR
Camps	ASAR, AVHRR, MERIS, AATSR, RA
Gommenginger	ASAR
Navarro	MERIS
Zribi	ASAR, ASCAT

Table 5.9 Satellite data to be used in SMOS cal / val activities for ocean salinity.

4.6 SMOS AO Proposals Versus Cal / Val Requirements

The activities contained in the cal / val proposals can be related and compared with a list of requirements, developed in advance, that are considered necessary to ensure that SMOS products are of the specified quality and consistency. Table 5.10 indicates where validation requirements are met by the contents of the cal / val proposals. It is accepted that many of the proposals do not provide sufficient detail to enable the table to be fully completed, and further reference to the AO groups is necessary. This table is still general and requires additional work from Principal Investigators, Mission Scientists, VRT and SAG members to define which types of measurement and activity are required for which source of error.

Land

Brightness Temperature	Ground based or airborne L-band radiometers	Calvet, Kaihotsu, Walker, Jackson, Mauser, De Jeu, Vanderborght, Hornbuckle, Paloscia, Lopez-Baeza, Camps, Anterrieu, Pellarin, ECMWF, Magagi, Zribi, Zhang, Hallikainen
Soil	Surface soil moisture and profile measurements	Calvet, Kaihotsu, Walker, Jackson, Singh, Martinez-Fernandez, Wagner, Mauser, De Jeu, Vanderborght, Hornbuckle, Lopez-Baeza, Grippa, Pellarin, ECMWF, Magagi, Su, Kim (snow&ice), Marczewski, Zhang, Friesen, Hallikainen, Patel
	Surface soil temperature and profile measurements	Kaihotsu, Walker, Jackson, Singh, Martinez-Fernandez, De Jeu, Hornbuckle, Lopez-Baeza, Magagi, Su, Friesen, Mauser, Vanderborght
	Soil surface roughness	De Jeu, Hornbuckle, Jackson, Zhang, Escorihuela
	Soil mineralogy and texture, bulk density	Kaihotsu, Singh, Mauser, De Jeu, Hornbuckle, Su, Zhang, Patel, Lopez-Baeza
	% sand and % clay	Zhang, Patel
	% rock fragments	
Cover and mixed pixel	% free water and local topography	Martinez-Fernandez, Mauser, De Jeu, Friesen, Patel
	% rugged terrain and local topography	Martinez-Fernandez, Mauser, De Jeu, Pellarin

	Freezing conditions, permafrost, permanent ice	
	% vegetation	Kaihotsu, Mauser, De Jeu, Hornbuckle, Lopez-Baeza, Zhang, Friesen, Patel
	% dry snow	Paloscia, Kim, Mauser
	% wet snow	Hallikainen, Mauser
	% urban cover	
Vegetation	Vegetation type	Kaihotsu, Singh, Mauser, De Jeu, Hornbuckle, Lopez-Baeza, Magagi, Su, Kim, Marczewski, Zhang, Hallikainen, Patel
	Vegetation optical thickness	Kaihotsu, De Jeu, Hornbuckle, Magagi, Kim, Friesen
	Vegetation temperature	Magagi
	Litter, mulch	Grippa
	Interception, dew	Hornbuckle
	Canopy roughness	Hornbuckle, Su, Kim
	NDVI/LAI	Walker, De Jeu, Patel
Atmosphere	Total column water content (liquid and vapour, precipitation)	Calvet, Kaihotsu, Jackson, Martinez-Fernandez, De Jeu, Hornbuckle, Su, Zhang, Friesen
	Total electron content	Paloscia
	Temperature	Calvet, Kaihotsu, Jackson, Singh, Martinez-Fernandez, De Jeu Hornbuckle, Su, Zhang, Friesen
	Pressure	Calvet, Kaihotsu, Jackson, Singh, Martinez-Fernandez, De Jeu, Hornbuckle, Su, Zhang, Friesen
	Wind speed and direction	Calvet, Kaihotsu, Jackson, Singh, Martinez-Fernandez, De Jeu, Hornbuckle, ECMWF, Su, Zhang, Friesen
	RFI	Le Vine, Anterrieu
	galactic/cosmic background	Le Vine

Additional considerations:

- Well equipped sites in various areas (long term monitoring on representative points, similar to SMOSREX)
- Large areas covered spatially but during smaller periods of time (typically campaigns) with ground and airborne equipments (similar to COSMOS or SMEX)
- Specific activities over troublesome targets (snow on trees, melting ice and other unknown behaviours)
- Required instrumentation as SM and T probes, flux-met stations, ground and aircraft radiometers
- Auxiliary data are also required.

Sea

Brightness Temperature		Camps, Le Vine, Anterrieu, ECMWF, Martinez, Zribi, Gaillard, Stammer

Sea Surface Salinity and Sea Surface Temperature	Surface drifters	Stammer, Poulain, Camps, Le Vine, Gower, Martinez, Hallikainen, Zribi
	Thermosalinographs in Voluntary Observing Ships and Research Vessels	Burrage, Camps, Le Vine, Gommenginger, Navarro, Gaillard, Zribi
	Instrumented Towers or Buoys	Camps, Gower, Stammer, Zribi
Surface layer salinity and temperature	ARGO floats	Stammer, Poulain, Le Vine, ECMWF, Navarro, Gower, Gaillard, Johannessen
	CTD profiles	Burrage, Navarro, Martinez, Heron, Gaillard
	Subsurface moorings	
Wind and waves (roughness)	Moored surface buoys	Burrage, Le Vine, Martinez, Zribi
	Instrumented towers	Stammer
	Aircraft	Burrage, Zribi
Foam coverage	Aircraft	Zribi
	Instrumented towers	Stammer
L-band and InfraRed emission	Aircraft	Burrage, Camps, Martinez, Heron, Zribi
	Instrumented towers	Stammer
Atmosphere	Total water content	
	Total electron content	Le Vine
	Temperature	ECMWF
	Pressure	
Earth aliasing		Burrage, Martinez, Cabot
Sun, Moon and galactic glints		Camps, Heron, Burrage

Table 5.10 Validation Requirements and Proposed Activities

Additional considerations:

- Instrumenting (measuring) specific areas with good spatial resolution (to map horizontal variability) in appropriate stable regions
- Coordination with the Aquarius Validation Data Segment
- Operational models of wind, waves, temperature and salinity, and adequate data assimilation methods

4.7 Expected Useful Results From AO Teams

ANTERRIEU 3260
statistics on the visibilities for each antenna
estimation of the principal coefficients (S parameters) and of their error bars

Preparation of the commissioning phase (6 months before launch):
-Definition of the statistical tests which will be performed during the commissioning phase in order to validate the level 1a and level 1b products.
-Definition of appropriate targets in order to assess the calibration performance and to perform a validation.
-Specification of visualization/statistics modules. I/O definitions. Modules implementation.
-Tests of the implemented modules from level 1a and level 1b simulated data.
Commissioning phase (6 months after launch):
-Adequate satellite manoeuvres to measure target areas for validation and calibration assessment.
-Visualization and statistical tests on the SMOS level 1a and 1b data products.

-Diagnostic. Extension of the visualization/statistics modules.
-Specification of the corrections to be implemented.
-Data reprocessing if needed and tests to check the products quality improvement.

BERRY 4682
comparisons between in-situ, modelled and radar backscatter derived SM with SMOS SM over Australia

BURRAGE 3229
Tb from airborne radiometer over a SMOS pixel in the Gulf of Mexico
in-situ SSS, SST, wind and wave data over a SMOS pixel in the Gulf of Mexico
correction in Tb for a mixed pixel with a coastal zone

Scheduled activity starting months and duration are relative to launch date (eg. L+3 (2) starts 3 months after launch and runs for 2 months):

L-6: Develop and test procedures to ingest simulated near-real time SMOS data and assimilate resulting SSS values into global and regional circulation models (3)
L-3: Prepare institutional and funding arrangements, plans for field activities, and preliminary schedules for field campaigns. Draft article on SMOS near-real time assimilation (2)
L+0: Finalize ship and aircraft scheduling and approvals (1)
L+1: Laboratory calibration. Preflight instrument calibration. Installation of airborne remote sensing and shipboard hydrographic equipment. (2)
L+3: Conduct of field experiments in Gulf of Mexico (GOM). (1)
L+4: Postflight calibration, preliminary analysis of GOM field data. Develop and test roughness algorithms. Consider impact of mixed pixels on SMOS observations spanning GOM. Draft Article on SMOS Validation. (3)
L+5: Complete analysis and report of first GOM field experiments. Submit article on SMOS SSS validation. (1)
L+6: Preflight instrument calibration. Conduct field experiment off South America (SA) East Coast (See complementary proposal by C. Martinez for details of deployment and data analysis) (2)
L+7: Postflight calibration, preliminary SA field data analysis (2).
L+8: Test near real time data assimilation procedures. Verify using GOM and SA field data sets (2) L+9: Submit journal article on SMOS SSS near real time data assimilation (1).
L+9: Project completion. Prepare and submit final reports. Conduct SMOS validation teams symposium presentations (1).
L+10: Draft and submit articles on SMOS aliases and roughness algorithms (2).
L+12: Final publications completion

CABOT 3282
geolocalisation biases with their error bar and stability

Method development in 2005, with the construction of the reference database.
Method assessment and simulations during 2006 and 2007.
Application on SMOS data will begin shortly after launch and will continue all along the commissioning phase.

CALVET 3168
Tb differences between SMOS data and simulations and SMOSMANIA in-situ network measurements
SM differences between SMOS data and simulations and SMOSMANIA in-situ network measurements

The SMOS data will be collected by Météo-France shortly after launch. One year before launch, an automatic procedure to compare the SMOS products and the SIM and ARPEGE simulations will be developed and tested. A scientific report will be issued after the first year of comparison.

CAMPS 3254
SST and SSS measurements from moored and drifting buoys and from research vessels in the Biscay Bay

T0 = SMOS launch, in months
Calibrated data sets T0+2, +4, +6
Analysed in situ SSS fields T0+4, +7
Final report on semi-empirical model improvement T0+9
Final report on pixel disaggregation techniques and results T0+9
Final report on roughness determination with GPS T0+9

DEJEU 3238
Comparisons between AMSR, SMOS and in-situ Tb and SM

GRIPPA 3257
Comparisons between SMOS and in-situ or simulated Tb and SM at different scales in west Africa

ECMWF 3262
comparisons between observed and modelled brightness temperatures over sea
comparisons between observed and modelled brightness temperatures over land

Launch + 6 weeks: Data delivery to ECMWF starts.
Set up the observation processing chain at ECMWF.
Convert data to BUFR format.
Launch + 24 weeks: Development of the observation and model collocation software
Launch + 40 weeks: Start of pre-operational data monitoring
Every three months: Short report on monitoring results over the ocean
End of study: Analysis of departure statistics and final report

ESCORIHUELA 6317
End of commissioning phase: report on SMOS Tb data compared with AMSR data and model simulations over the Uyuni Salar.
End of mission: analysis report of the emissivity spatial and temporal variations and electromagnetic modeling.

FRIESEN 3280
multiscale soil moisture observations and vegetation characteristics along a 1000 km from arid to humid transect through the Volta Basin in West Africa

GAILLARD 3276
In-situ data sets, qualified and flagged with respect to SMOS relevance
Gridded SSS/SST fields

Assuming launch = month 24 and final report = month 36.

months 1-24: depth issue
months 1-24: SSS intra-pixel variability
months 1-24: SST and rain sub-pixel variability
months 1-12: production of the gridded fields (2000-2006)
months 1-24: extraction of variability and error maps
months 1-12: definition of database
months 13-24: first version of database
months 25-36: upgrade of database

month 1-36: calibration sites
months 1-24: improve in-situ arrays
months 25-36: statistical analysis of Tb
months 25-36: consistency performances

months 22-27: validation pre-processing
months 1-24: neural network methods
months 25-36: improve the level 2 processor

months 25-36: analysis of Tb to improve geophysical dependencies
months 25-36: propose corrections

GOMMENGINGER 3265
SST and SSS measurements from moored and drifting buoys and from research vessels in the Atlantic Ocean

HALLIKAINEN 3281
Improved model for NIR and CAS as function of physical temperature, as well as evaluation of the stability of both subsystems. Modified vicarious (modified Ruf) algorithm, if successful, to provide information on the stability of the MIRAS sensor.
Maps of salinity for cold sea under various wave and temperature conditions, both for low-salinity water (Baltic Sea) and high-salinity water (Arctic Sea).

HERON 3271
SSS profiles from micro-profiling instruments penetrating the surface in the Great Barrier Reef.
Dual polarisation L-band measurements (PLMR), coupled with high resolution surface wind and wave observations to determine the influence of wind, wave and swell-related roughness on the observed Tb.
SMOS 'mixed pixels' observation using airborne radiometers, which, by virtue of design and low altitude, have higher spatial resolution than MIRAS. Sampling Tb over sea and land, and using known SMOS antenna patterns, empirical models will be developed to identify land contamination cases, and where the ocean yet dominates radiometer response (eg over islands and peninsulas), to mitigate its effects. The results will facilitate corrections for partial 'mixed pixels' and enable accurate delineation of MIRAS coverage.

HORNBUCKLE 3246
Corrected L-band brightness temperature for each pixel in the midwest US will be estimated to within 4 K. Daily canopy wetness presence and brightness temperature corrections will be available via the Internet in less than 48 hours.

JACKSON 3221
Estimates of the average soil moisture over watersheds and surrounding areas on the order of the AMSR-EOS and SMOS footprint size in North America.

JOHANNESSEN 4488
Assessment of the SMOS sea ice and ice edge detection capabilities in Greenland Sea and Barents Sea by routine comparison to coincident AMSR-EOS and METOP ASCAT data.
The surface temperature and salinity structures of the North East Atlantic and Nordic Sea connected with the front of the North Atlantic Current are fairly well known from SST observations, the MICOM climate model and the TOPAZ assimilation system. The latter three sources will be made available on a routine basis together with the near surface wind forcing for assessment of the SMOS retrievals of surface salinity.
Direct measurements of wind speed (and sea state) from oil drilling platforms in the North Sea can also be archived.

KAIHOTSU 3211
In-situ data from the Mongolia Plateau site (100 km x 100 km) and averaged soil moistures.

WALKER 3219
Expected accuracy of soil moisture retrieval for a range of land cover types present in two South-East Australian catchments. Efficiency of disaggregation schemes for downscaling coarse-scale soil moisture estimates. Root-zone soil moisture retrieval accuracy with data assimilation methods using coarse-scale (SMOS) L-band brightness temperature.

KIM 3273
Maps and statistics of L-band spatial homogeneity in the Dome-C area over a 50 km footprint.

LEVINE 3259
In-situ SSS measurements
Brightness temperature statistics
TEC profiles at selected sites

LOPEZ-BAEZA 3252
In-situ data over the VAS area during the commissioning phase and beyond.

MAGAGI 3268
In-situ data over African Sahel and over three agricultural areas in Canada and SMOS validation results 12 months after launch.

MARTINEZ 3270
In-situ and airborne measurements along the South American margin.

MARTINEZ-FERNANDEZ 3230
In-situ data over REMEDHUS and comparison with SMOS data until end 2009.

MARTINS 3934
In-situ data over the Brazilian Caatinga and analytical comparison with the corresponding SMOS pixel data.

MAUSER 3236
- analysis of SMOS data against hydrological model results at various levels and for different surface parameters, and validation of SMOS products against information derived from other EO data
- postlaunch regular reports to ESA of the observed accuracies and problems

NAVARRO 3266
SSS and SST measurements in the Gulf of Cadiz

PALOSCIA 3250
Radiometric data from tower will be collected at Dome-C together with snow data.
Comparison of ground measured L-band emission at Dome-C with SMOS data taken over the same area and with model simulations (after the commissioning phase).

PATEL 3284
In-situ and SAR data over four different sites in India and analytical comparison with the corresponding SMOS pixels data.

Activity	Start Date	End Date
SAR data acquisition and synchronous ground truth survey for four sites three times each	Launch + 6 weeks	Launch + 5 months
SAR derived spatial distribution of soil moisture map using the field level measurement of soil moisture collected during ground truth survey under crop covered and bare soil conditions under varying surface roughness	Launch + 2 months	Launch + 6 months
Accuracy assessment and validation of SAR derived soil moisture information	Launch + 6 months	Launch + 6 months
Calibration of derived soil moisture information received from SMOS for four test sites and three SAR acquisitions, i.e. at a total of 4x4 grid x 4 site x 3 time acquisition per site => 16x4x3 = 192. Hence a calibration of SMOS derived soil moisture information based upon a total of 192 data points will be carried out.	Launch + 6 weeks	Launch + 7 months
Deriving soil moisture information relating SMOS derived brightness temperature to the 25 km grid level soil moisture data obtained by two stage up-scaling approach	Launch + 7 months	Launch + 7 months
Validation of the SMOS derived soil moisture information using the two stage scaling approach at the four test sites	Launch + 7 months	Mission end

PELLARIN 3261
In-situ and S-band radiometric measurements over two sites in the French Alps (Vercors), and correlation with SMOS Tb.

POULAIN 3244
Preliminary work: Assessment of Mediterranean salinity, temperature and wind forcing variability using MFSTEP datasets and simulation products (preliminary report released at SMOS launch – 2 months).

Data acquisition: Once SMOS is operational, the level 2 SMOS salinity data and the MFSTEP datasets and simulation products will be acquired for at least six months. A report summarizing the collected data will be issued at SMOS launch + 6 months.
Final analysis: Statistical comparison analysis will be performed as soon as SMOS data become available. A progress report will be issued at SMOS launch + 3 months.
The data processing, the statistical validation work, and the interpretation of the results will continue for a period of three months beyond the cal/val phase. A final report will be published at the end of the project (SMOS launch + 9 months).

ROBOCK 3227
Continuous in-situ gravimetric observations of soil moisture, soil temperature, and vegetation phenology from a variety of locations and vegetation types in China, Ukraine and US.

GOWER 3267
Comparison of SMOS SSS patterns with historical climatology and with in-situ data.

Prelaunch: Compile historical climatology data and analyse rehearsal data
SMOS + 0 month: Reception of first SMOS data for project
SMOS + 0 to 6 months: Extraction and comparison of spatial patterns
SMOS + 6 months: Summary report on final data collection plan
SMOS + 6 months: Progress report on the project
SMOS + 7 to 12 months: Comparison with data from cruises
SMOS + 12 months: Final report
SMOS + 6 to 12 months (as applicable): Analysis of temporal variability as additional in-situ data become available and comparisons with ARGO floats data
SMOS + 6 to 14 months: Workshop presentation to report on partial or final results

SINGH 3223
validation of soil moisture and observed soil moisture over India,
relation of soil moisture with surface temperature over different agroclimatological regions of India,
quantitative information about the soil moisture over different geological terrains and different soil types,
monthly and annual variability of soil moisture over different geological terrains and different soil types,
relation of soil moisture with growth of vegetation,
soil moisture profiles of different regions in India,
relation of soil moisture deduced from SMOS and observed brightness temperature from TMI and SSM/I frequencies and polarisations,
relation of soil moisture deduced from SMOS and observed scattering index from ERS.

STAMMER/ VANDERBORGHT 3241
1) Ocean Salinity:
months 1-6: collection of in-situ data, quality control; collection of auxiliary data, such as scatterometer and SAR data; collection of ferry box data.
months 7-12: comparison of in-situ data with climatology; test of SSS measurements required for stable comparisons.
months 13-24: comparison of SMOS data with in-situ data; tower measurements and evaluation.
month 12 and month 24: reports.
2) Sea Ice and Land Ice:
months 1-5: defininition of reference regions for emissivity determination and brightness temperature monitoring, using AMS-EOS 6 GHz data as model for SMOS data
months 6-7: setup of emissivity model
months 8-12: develop and test procedures for emissivity determination, use AMSR 6 GHz data.
months 1-6: brightness temperature and emissivity of sea ice and land ice reference regions.
months 7-12: calibration and validation of emissivity model for various surface types.
months 13-18: weather influence on L-band emissivity of ice
months 19-24: young ice types: sensitivity study and retrieval algorithm
months 25-36: melting ponds: sensitivity study and retrieval algorithm

3) Soil Moisture:
Forest experiment:
months 1-6: preparation
months 2-11: data acquisition
months 3-13: analysis
months 14-15: report.
Plot experiment:
months 8-10: preparation
months 15-19: data acquisition
months 16-22: analysis
months 23-24: report.

SU 3269
Validation results in diverse ecosystems and land areas in Africa, China and the Netherlands.

Year 1 (pre-launch): Identification of validation plan and detailed data requests, conduction of preliminary field experiments, identification of requirements for algorithms and data processing procedures, progress report;
Year 2 (post-launch): Development of validation procedures, conduction of field experiments for calibration and validation purposes, data processing, progress report;
Year 3: Data processing, conduction of specific field experiments for validation purposes, set-up of operational processing chain, participation in SMOS workshop, progress report.

WAGNER 3233
1) Global and continental maps showing the mean difference between SMOS and ASCAT surface soil moisture products
2) Time series showing the temporal correlation between SMOS and ASCAT surface soil moisture products
3) For the REMEDHUS network, comparison between in-situ soil moisture and satellite products

SMOS launch: Software for reading SMOS Level 2 data ready
SMOS launch + 3 months: First SMOS Level 2 data obtained and analysed
SMOS launch + 6 months: Initial results of comparison with ASCAT and REMEDHUS data
SMOS launch + 9 months: Final results for commissioning phase

ZHANG 3279
In-situ radiometric measurements in the sand desert, and correlation with SMOS Tb.

ZRIBI 3274
Airborne L-band measurements over land and sea.

5 CAMPAIGN COORDINATION PLAN

Responsible:

- Campaign Unit lead by C. Bouzinac.

Objectives:

- To provide a detailed plan of experimental activities for the validation of the SMOS products. The plan includes information on the overall context for SMOS-related campaigns and a detailed summary of each of the planned experiments including information about the goals, schedules and the design of field experiments as well as a list of participants.

Inputs:

- Accepted AO proposals

Outputs:

- Campaign reports
- Campaign data
- Analysis reports
- Presentations at the validation workshops

5.1 Introduction

The various and numerous sets of actions described in the accepted AO proposals will require coordination so that SMOS data can be effectively calibrated and validated. The Campaign Coordination Plan defines certain actions, protocols and entities necessary to harmonise the planned activities, and facilitate the delivery of cal/val results to the L1 and L2 development teams. This process will be critical to ensure that SMOS products will meet, and continue to meet, the required standards.

5.2 Campaign Management Unit (CMU)

The SMOS cal / val plan is dependent on the activities of the AO proposals that comprise a wide range of activities running in parallel. The ESA CMU provides a single point for management, harmonisation, scheduling and coordination between the AO groups.

The CMU is a first point of contact for AO groups and provides the interface with ESA for all matters to do with cal/val activities. Essential to this activity, the CMU develops and maintains a complete understanding of the cal/val activities and effective working relationships with the scientists involved. Regular contact is established with the Principal Investigators for soil moisture and ocean salinity.

Starting at the first cal/val meeting (Avila, 21-24 November 2005), the CMU harmonises the cal/val plans, thereby maximising the effectiveness and efficiency of the actions proposed. This can only be achieved through close cooperation with the AO teams. In addition, where it becomes apparent that cal/val requirements are not being met by AO activities, the CMU works with the AO groups to provide the missing components.

5.3 Scheduling

An important part of the CMU activities is to harmonise all the individual schedules that have been submitted by the AO groups. The CMU progressively adds details to the schedule and takes account of the activities planned by the AO groups, but also of external constraints such as the launch date.

5.4 Reporting

The dissemination of results of cal/val activities will be via two reporting mechanisms:

- A rapid response system where the results of cal/val activities indicate serious problems with SMOS products

- A formalised reporting via a scheduled series of results review meetings and workshops and associated proceeding documents

The CMU will produce summaries of the performance of SMOS whenever individual project results are presented.

5.5 Campaign Database

In order to provide an accessible long term resource to support the analysis of SMOS products and those from future sensors, datasets comprising radiometer products and correlative data from in-situ or models are held within a dedicated cal / val campaign database. A document describing how data are submitted including information on protocols and formats is generated for each campaign.
The datasets and reports are available through the ESA EO campaign database (earth.esa.int/campaigns).

5.6 ESA Funded Campaigns Summaries

Campaign	Experiment Plan	Data Report	Final Report	Comments
WISE 2000	yes	yes	yes	workshop publication esa-sp-525 + 1 DVD
WISE 2001	yes	yes	yes	workshop publication esa-sp-525 + 1 DVD
LOSAC 2001-2003	no	yes	yes	workshop publication esa-sp-525 + 1 DVD
EUROSTARRS 2001 (NRL)	yes	no	no	workshop publication esa-sp-525
COSMOS 2005	yes	yes	yes	CD in preparation
COSMOS 2006	yes	yes	yes	2 DVD
DOMEX 1 (2004/2005)	no	no	yes	1 CD
DOMEX 2 (2008/2009)	no	no	yes	CD in preparation
SEA-ICE 2007	yes	yes	no	data analysis in progress
COSMOS 2007	yes	yes	no	data analysis in progress
COSMOS 2008 (rehearsal)	yes	yes	yes	data analysis in progress

LOSAC, WISE, DOMEX1 and COSMOS2006 are already available through the ESA EO campaign database (earth.esa.int/campaigns).

Some of the documents and datasets are available at:
ftp.smos.esa.int user: smos-public pswd: salinity

5.6.1 LOSAC 2001-2003

L-band Ocean Salinity Airborne Campaign
Technical University of Denmark (Niels Skou)
EMIRAD L-band radiometer full polarisation
Danish Air Force C-130 aircraft
23° depression angle
circular flights 25°-62° incidence
altitudes 1000, 2000, 3000 m
16 Jan 2001 (test)
15 Mar 2001 North Sea
23 Mar 2001 Kattegat
25 Oct 2001 North Sea
06 Mar 2003 Norwegian Sea

5.6.2 EUROSTARRS 2001

The EuroSTARRS campaign consisted of a coordinated set of activities primarily involving the airborne operation of the STARRS (Salinity Temperature and Roughness Remote Scanner) L-band radiometer. This instrument acquires angular observations of the brightness temperature as SMOS mission. STARRS is owned by the Naval Research Laboratory (NRL), USA, and was available for use by the EuroSTARRS

campaign which took place 17-24 November 2001. The instrument was installed onboard a Dornier 228 aircraft operated by DLR, Germany.
The activities included contributions from other campaigns such as WISE (Wind and Salinity Experiment) and LOSAC (L-band Ocean Salinity Airborne Campaign). This included the acquisition of data from a research vessel, instrumentation onboard the Casablanca platform and deployed buoys (WISE), and an L-band radiometer onboard the C-130 of the Danish Air Force (LOSAC).
EuroSTARRS acquired data over six sites:
• Valencia, Spain (land data: natural vegetation and agriculture).
• Agre Forest, France (land data: forest).
• Nezer (Les Landes), France (land data: forest).
• Pyrenees, France (investigation on the effects of topography).
• Gascogne (SSS).
• Casablanca, oil drilling platform, Mediterranean sea (SSS).
The objective of the airborne EuroSTARRS 2001 campaign was to provide data for the scientific studies supporting the SMOS mission. It provided data to advance the knowledge of the passive microwave multi-incidence observations at L-band for various surface types. The retrieved variables were validated by measurements performed in the field.
The campaign provided "SMOS like" data to address the following issues:
• Validation of soil moisture retrievals for different vegetation covers and wetness conditions,
• L-band emissivity over coniferous and deciduous forests,
• Development of soil moisture retrievals over rugged terrain,
• Sea surface salinity gradients.
The main airborne sensor used in this campaign was the STARRS L-band V-polarisation radiometer on loan from the Naval Research Laboratories, USA. The ICM activities provided the EuroSTARRS science team with in-situ data (temperature, salinity, wind and waves) in one of the sites: the area around the oil drilling station CASABLANCA owned by the company REPSOL and located near the coast of Tarragona, Spain.

5.6.3 WISE 2000-2001

The main objective of the ESA-sponsored Wind and Salinity Experiment (WISE) field experiments has been the improvement of the understanding of the sea state effects on Tb at different incidence angles and polarizations. This understanding helps to develop and improve sea surface emissivity models to be used in the SMOS SSS retrieval algorithms. The paper of Camps et al, IEEE transactions on geoscience and remote sensing 2004, vol. 42, no4, pp. 804-823, summarizes the main results of the WISE field experiments on sea surface emissivity at L-band and its application to a performance study of multiangular sea surface salinity retrieval algorithms. The processing of the data reveals a sensitivity of Tb to wind speed extrapolated at nadir of ~0.23-0.25 K/(m/s), increasing at horizonal (H) polarization up to ~0.5 K/(m/s), and decreasing at vertical (V) polarization down to ~-0.2 K/(m/s) at 65° incidence angle. The sensitivity of Tb to significant wave height extrapolated to nadir is ~1 K/m, increasing at H-polarization up to ~1.5 K/m, and decreasing at V-polarization down to -0.5 K/m at 65°. A modulation of the instantaneous brightness temperature Tb(t) is found to be correlated with the measured sea surface slope spectra. Peaks in Tb(t) are due to foam, which has allowed estimates of the foam brightness temperature and, taking into account the fractional foam coverage, the foam impact on the sea surface brightness temperature. It is suspected that a small azimuthal modulation ~0.2-0.3 K exists for low to moderate wind speeds. However, much larger values (4-5 K peak-to-peak) were registered during a strong storm, which could be due to increased foam. These sensitivities are satisfactorily compared to numerical models, and multiangular Tb data have been successfully used to retrieve sea surface salinity.

5.6.4 FROG 2003 IN EAST SPAIN

This campaign was not funded by ESA, but it was related to the SMOS project.
To minimize the high variability of the emissivity at sea, a specific campaign (FROG = Foam, Rain, Oil and GPS reflections) was performed during the spring 2003 at the Ebro river delta. The main objectives of the FROG 2003 experiment were:

- the acquisition of radiometric measurements of an artificially generated foam covered water surface,
- the acquisition of foam vertical profiles with the measurements of the associated parameters to be put in the two layer foam emission model,
- the acquisition of radiometric measurements of an artificially generated rain,

- the acquisition of radiometric measurements of a water surface covered by oil slicks.

Measurements were acquired in a wide range of salinities, from 1 to 37 psu, by mixing sea water and river water. The water salinity of each experiment was first roughly estimated with a salinometer (1 psu precision) and later measured accurately (0.001 psu precision) from water samples.
The paper of Camps et al, IEEE transactions on geoscience and remote sensing 2005, vol. 43, no5, pp. 925-937, presents the main results.

5.6.5 REFLEX 2003 IN EAST SPAIN

This campaign was not funded by ESA, but it was related to the SMOS project.
The Reference pixel L-band Experiment (REFLEX) was carried out in June-July 2003 at the Valencia Anchor Station, Spain, to study the effects of grapevines on the soil emission and on the soil moisture retrieval. A wide range of soil moisture (SM), from saturated to completely dry soil, was measured with the Universitat Politecnica de Catalunya's L-band Automatic Radiometer (LAURA). Concurrently with the radiometric measurements, the gravimetric soil moisture, temperature, and roughness were measured, and the vines were fully characterized. The opacity and albedo of the vineyard have been estimated and found to be independent on the polarization. The tau-omega model has been used to retrieve the SM and the vegetation parameters, obtaining a good accuracy for incidence angles up to 55 deg. Algorithms with a three-parameter optimization (SM, albedo and opacity) exhibit a better performance than those with one-parameter optimization (SM).

5.6.6 COSMOS 2005 IN SOUTH-EAST AUSTRALIA

The retrieval scheme developed for the SM is based on a decision tree accounting for the land surface heterogeneity that assigns different radiative transfer models according to the relevant land cover type. These radiative transfer models are constrained by auxiliary information such as soil texture and vegetation characteristics, accounting for the various contributors of the emitted brightness temperature at L-band. In order to validate the retrieval concept, a field campaign for validating the operation of SMOS (COSMOS-2005) has been designed.
COSMOS-2005 was performed in November 2005 in the Goulburn River catchment, located in South-East Australia, in association with the National Airborne Field Experiment 2005 (NAFE'05). The objective of this joint campaign was to simulate SMOS observations using an airborne L-band radiometer, supported by soil moisture and other relevant ground measurements for the development of the SMOS retrieval algorithms and the development of downscaling procedure of the low-resolution data from SMOS. All flights started at approximately 6.00AM to match land surface conditions corresponding to SMOS local overpass time (6:00AM/6.00PM).
The core COSMOS instrument was the Denmark Technical University (DTU) EMIRAD fully polarimetric L-band radiometer, flown aboard an AeroCommander aircraft, which was also equipped with a thermal infrared radiometer. Dedicated flight patterns in terms of location, repetition, duration and altitude (spatial resolution) were performed to address specific research issues related to the retrieval of surface SM from passive microwave radiometry.
The current analysis of the data set by CESBIO and INRA will provide a detailed assessment of deficiencies and limitations of the SM retrieval scheme and its validation with different effects (dew, sun glint, vegetation cover, scale of auxiliary information, etc) including recommendations for improvements and for the next campaign activities for the SMOS validation period.

5.6.7 COSMOS 2006 IN THE NORTH SEA

A detailed analysis of various geophysical error sources that influence the remote sensing of ocean surface salinity using spaceborne L-band radiometers has been performed by Yueh et al. (2001). The main geophysical sources of error that were identified are: sea surface temperature, atmosphere dry air and water vapour, clouds, sea surface roughness, ionospheric effects, and solar and galactic radiations.
Beyond these sources, sea surface roughness is found to have a dominant and critical effect. To enable an accurate SSS retrieval from L-band radiometric measurements, with the SST known at about 1 K accuracy, the impact of surface roughness induced by winds must be precisely corrected whatever incidence angle and polarization of the measuring device, and for the broadest range of geophysical conditions that can be potentially encountered within SMOS field of view. In particular, accurate correction of the roughness effects is essential for measurements over cold waters for which the dependence of brightness temperature on surface salinity and surface roughness is about the same.

Previous campaigns involving radiometric measurements at L-band over the sea therefore mostly focussed on estimating the roughness dependencies of the brightness temperature. The microwave brightness temperature dependence on sea state and surface wind speed arises from two effects. The first effect results from the increasing roughness of the compact water surface and the second effect from the increasing coverage of whitecaps and sea foam with increasing wind speed. An important scientific issue for an ocean salinity campaign was then to determine in which geophysical conditions the roughness-induced propagating error is most likely to occur in the retrieval processing of SSS anomalies.
The objectives of the COSMOS-2006 campaign and subsequent analysis included:
• Assessing the ability to detect the significant salinity gradient just off the coast of Norway,
• Assessing the possible impact on measured brightness temperatures of scattering by the rough sea surface of solar and galactic radiations towards the radiometer (to improve bistatic scattering models), and
• Clarifying possible causes for the unexplained “wiggles” seen in L-band radiometric data from previous campaigns.
The North Sea exhibits significant variability in wind and surface conditions, which makes it particularly suitable for addressing all of the above objectives. COSMOS-2006 was therefore performed in April 2006 in the North Sea. The aircraft was the Skyvan from the Helsinki Technical University (HUT/TKK). The airborne instrumentation included the L-band radiometer EMIRAD from the Denmark Technical University (DTU), fully polarimetric, and able to measure at two distinct incidence angles (nadir and 40°), and the GPS Open Loop Differential Real-Time Receiver, a Passive Reflectometric and Interferometric System (PARIS), assembled, tested and provided by the Institut d’Estudis Espacials de Catalunya (IEEC). The PARIS concept uses sources of opportunity, such as the GPS L-band navigation signals, rebounded on the sea surface to estimate the mean squared slope or the two-dimensional slope directional variance of the sea surface at L-band from the GPS reflected signals. The downward antenna beam is about 90 degrees.
BOOST and IFREMER are still analyzing the campaign data, including many auxiliary data sets to know the geophysical conditions. The final presentation is foreseen by June 2007. All data sets provided during this campaign or used for the final analysis are described in SO-RP-ESA-SY-5402.
As discussed during a COSMOS meeting in February 2007 in relation with EMIRAD data, DTU provided:
- the COSMOS data (Australia for Kauzar Saleh and Norway for Nicolas Reul) flagged for RFI (done),
- the description of checking procedures on any antennas polarisation mixing problem,
- a detailed technical note on all the calibration procedures,
- a brief technical note on the antennas alignment procedure in the aircraft.
These last three topics are now available in “EMIRAD-2 and its use in the COSMOS campaigns”, N. Skou, S. Sobjerg, J. Balling, S. Kristensen, A. Kusk, EMI/DTU report AR415, 25 september 2007

5.6.8 DOMEX 1

External calibration and assessment of long-term performance degradation or drifts in sensor performance can be performed with extremely stable natural targets. Compared to other natural scenarios, the ice sheets offer the advantage of presenting a cold, dry and uniform target surface. The Antarctic environment, and in particular the plateau which hosts the Italian French Dome Concordia (Dome-C) station, appears to be appropriate for this issue thanks to its size and uniform spatial structure accompanied by a detailed knowledge of the vertical profile of ice obtained in the European Project for Ice Coring in Antarctica (EPICA) where the ice properties of the entire pack such as mean particle size, density, temperature and impurities were measured from drilled ice cores [7]. The data provided by this and other experiments were fundamental to express firn properties, such as grain size, density and temperature, of each layer into which the medium was divided. In turn, these data could be used as input into the multi-layer electromagnetic model able to simulate the Tb.
The use of the Dome-C plateau as a suitable target for calibrating and monitoring the performance of low frequency microwave radiometers (L and C bands) needs a better understanding of its structure as well as of the physical effects governing microwave emission from deep ice sheets. Radiometric time series showed lagged seasonal Tb responses at different wavelengths. This lag implies a frequency dependent depth-weighting of thermal emission. The spectral response and polarization differences also vary as a function of the seasons.
The Dome-C experiment took place between December 2004 and January 2005. It included radiometric measurements from a tower at different incidence and azimuth angles and snow measurements, using conventional methods. The objective of the study was to improve the knowledge of the temporal variability of

the L- and C- band microwave brightness temperatures measured at different incidence and azimuth angles, over timescales from day to month, and to provide a first database of in-situ measurements to better evaluate and interpret low frequency satellite measurements.
Temperature measurements of the snow down to 10 m depth, performed over the years had confirmed that the variation in temperature concerned the first six meters, while down to this depth the temperature remained constant. This information is very important since model simulations have shown that the emission at L band is not influenced by this layer. Therefore the assumption that the emission, at this frequency, remains constant in time appears reasonable. DOMEX microwave measurement data confirmed the high stability of the mean value of the Tb measured at L-band on a monthly scale at an incidence angles between 20° and 60°. More details on the results are available in Macelloni et al. (2006).

5.6.9 DOMEX 2

The necessity for a new DOMEX is motivated by the need to increase the duration of the observation period and to monitor a larger area near the Dome-C base. The objective is to verify the spatial stability of the emission of the Antarctic plateau with respect to the size of the area observed by a SMOS pixel.
A plan for a new campaign during the 2008/2009 austral summer was included in the proposal submitted by IFAC-CNR for the SMOS calibration and validation activities, and approved by ESA. In order to comply with the mentioned objective, the most important activities of the new experiment are the following:
• Improvement of the long-term stability of the receiver, the characteristics of the L-band antenna and the platform pointing system.
• Realization of a new fully automatic high-stability two-frequency (L-band) radiometer, to be installed on the tower for at complete seasonal cycle, using the same tower configuration as in the first campaign.
• Development of an additional L-band radiometer to be installed on a snowmobile to monitor a relatively larger area (about 40 km x 40 km) near the base, or to be installed on an airplane (e.g. the Twin-Otter, which is operated to connect the Dome-C base to the Terra-Nova coastal base).

5.6.10 POL-ICE-SEA-ICE 2007

SMOS, primarily intended to retrieve soil moisture and ocean salinity, offers the unique capability of global observations at L band. The potential of geophysical information retrievable over the cryosphere is currently poorly explored. The three most promising application fields identified so far are:
retrieval of melt ponds, retrieval of thickness of thin ice and assessment of the information potential of the 3rd and 4th Stokes components over sea ice and land ice.
The SMOS Sea-Ice campaign was held near Kokkola, Finland, from March 8 to 14, 2007. The campaign was conducted as an add-on of the POL-ICE campaign which was performed in order to determine how operational sea ice monitoring in Finland can best benefit from the forthcoming dual-polarized RADARSAT-2 SAR images. The airborne and in-situ determinations of ice type and thickness during POL-ICE support the analysis of the fully polarized (all four Stokes components) L-band observations taken during the SMOS Sea-Ice campaign.

5.6.11 COSMOS 2007 IN THE GULF OF FINLAND

This campaign is also called the salinity demonstrator campaign, using the interferometric radiometer of TKK (HUT2D). It was performed in august 2007 and a boat was deployed for in-situ SSS and SST measurements during the low-altitude flights across a salinity gradient.
Kimmo Rautiainen and Juha Kainulainen (TKK) have checked the operation of the instrument and its subsystems from HUT-2D correlator data and confirmed that the instrument, all of its receivers and subsystems worked as expected during the campaign. They have analyzed the calibration data in order to get the optimum calibration parameters for each test line acquisition. This gave the possibility to insert the right values for the sensitivity and accuracy fields of the output files.
The aircraft position and attitude data were received from the EMIRAD team and prepared to be used together with HUT-2D correlator data. To get the best possible image reconstruction quality, they still needed to acquire the image of the sky with the instrument. It is important to acquire it when the galaxy is really away from the alias-free field of view, and if possible very close to the local horizon, to avoid spill-over energy, the instrument pointing to zenith.
During summer 2008, they acquired twice the Flat Target Response (sky reference image) of the HUT2D instrument and are now processing the salinity flights data of august 2007.

5.7 European Campaigns

Several campaigns are organised in Europe by the AO PI teams (*calibration teams are in italic*):

Mauser-3236 in the Upper Danube Catchment
DeJeu-3238 in the Netherlands (1 site)
Stammer-3241 in the North Sea
Vanderborght-3241 in the Rur-Erft catchment
Paloscia-3250 in Tuscany and at Dome-C
LopezBaeza-3252 at the Valencia Anchor Site
Camps-3254 in the Canary region, in the Mediterranean Sea and in the Biscay Gulf
Pellarin-3261 in the Vercors
Gommenginger-3265 in the North Atlantic Ocean
Navarro-3266 in the Gulf of Cadiz
Su-3269 in the Netherlands (3 sites)
Hallikainen-3281 in Finland, in the Baltic Sea and in the Arctic Ocean
Zribi-3274 in south-west France and in the Gulf of Biscay
Marczewski-3275 in Poland (10 sites)

The following sections give a short description of the European campaigns organised by the AO PI teams.

5.7.1 MAUSER-3236

Prof. Wolfram Mauser, University of Munich, Germany, w.mauser@iggf.geo.uni-muenchen.de

The land surface process model (SVAT: Soil Vegetation Atmosphere Transfer) will be used to simulate land surface parameters at a spatial scale of 1km2. The simulations will include subscale land use information. The model outputs will be validated against in-situ measurements and EO data. The PI will therefore build up a network of permanent registering Time Domain Reflectometry (TDR) probes during the comissioning phase to directly validate SVAT model results at local scale. TDR probes have to deployed.

Specific campaigns will be carried out in two test sites in Mid-Germany and South-Germany:

- Upper Danube catchment (South Germany)
- Saale catchment (Mid Germany)

In-situ measurements for SMOS SM validation:
The Upper Danube catchment is located in southern Germany. It has a size of about 77000 km² and mainly covers the northern alpine foreland as well as parts of the northern Alps. It is characterized by a large natural gradient in terms of climate, topography, land cover and hydrololgical conditions. Due to the large heterogeneity, it is expected, that SMOS soil moisture retrievals will be highly influence by the subpixel land cover compositions. The site is therefore best suitable to investigate the effects of different land cover types and dissagregation techniques within the test site. The size of the catchment is sufficient to obtain a representative statistical sample of SMOS pixels for the validation purposes.

The Upper Danube catchment has been extensively investigated and a unique database of surface conditions has been built within the framework of the GLOWA-Danube project. On the one hand, data from fixed micrometeorological and soil moisture stations will be available for the SMOS validation. On the other hand, additional field campaigns will be carried out and hydrological model results in combination with ancillary remote sensing data will be used to validate the SMOS SM products.

Surface temperature data and soil moisture data will be used to validate the SMOS data independently. To cover the scale of a SMOS pixel of more than 30 km, an integrated approach, combining field observations, remote sensing data and model results will be used to perform an upscaling of the in-situ data to the SMOS scale.

Methodology:

As part of the field campaigns within the test site, soil moisture and meteorological data will be sampled and analysed to validate the SMOS products. A state-of-the-art land surface process model will be used to simulate geophysical surface parameter fields and ancillary informations from measurement networks as well as satellite data will be used to improve the process model simulations by means of data assimilation. The following tasks are planned as part of campaigns to be conducted for the SMOS mission:

- Sampling of in-situ soil temperature and soil moisture data from existing networks. Existing measurement networks will be identified and collaborations will be established.
- Installation and maintenance of continuous soil moisture stations within the test site. To gather independent soil moisture and temperature data, independent stations will be installed by the PI within the test site at various locations.
- Compilation and formatting of in-situ data. The acquired data will be processed and integrated in a consolidated database to be the basis for the SMOS validation approach.
- Analysis of in-situ data in terms of spatiotemporal correlation statistics using geostatistical approaches.
- Extraction of soil moisture information from Level 2 SMOS soil moisture products and comparison with the in-situ data.

Executing Centres: Ludwig Munchen Universitat (LMU)

Involved Researchers: A. Loew (campaign responsible and hydrological modelling and data assimilation), I. Keding (in-situ data processing), H. Bach (SAR soil moisture data, snow cover data)

Saale Catchment - The river Saale springs at the Fichtelgebirge, runs through the Thuringian Forest and its forelands, and crosses the Thuringian Basin as well as the Magdeburger Bördelandscape to mouth into the Elbe north of Calbe. In total, the Saale River basin drains a catchment area of 23,719 km2 located in the south-east part of Germany with parts in Thuringia, Sachsen-Anhalt, Saxony, Bavaria and Lower Saxony.
The physiographic catchment structure is heterogeneous covering several gradients:
Geology: The catchment is characterized by shale bedrock of the mid-mountain range, the porous sandstone of its forelands, the karstic limestone bordering the Thuringian Basin, the keuper landscape and the lowland sediments of the loess region.
Climate: The basin is influenced by oceanic climatic conditions. There is a typical increase of precipitation, which is highly correlated with increasing altitude from the Magdeburger Börde (500 - 600 mm/yr) to the Thuringian Forest (>1300 mm/yr). The average air temperature shows an inverse behaviour.
Topography: Parts of the catchment belong to the midmountain range as well as to the basin and loess landscape.
Land use: Different characteristic types of landscape like forested (23%), agricultural areas (68 %) and urban areas can be differentiated.

The Saale catchment and its subcatchments have been extensively investigated over the last decade by many Umwelt Forschungs Zentrum (UFZ) research projects, thus a large basis of fundamental hydro-meteorological data is available. Also, within additional field campaigns land surface plant physiological, micrometeorological and soil moisture information in a hierarchy of spatial scales (lysimeter, field, subcatchment) will be collected using geophysical as well as ground-based spectral information. In combination with land surface hydrological modelling information relevant to the SMOS scale as well as some quality information will be available for a variety of different land surface characteristics.

Methods as described for the Upper Danube catchment will be used, with some temporarily advanced geophysical methods such as ERT (electric resistance tomography) to support field campaigns.

Executing Centres: UFZ - Centre for Environmental Research Leipzig- Halle, IMAF – Interdisciplinary Centre for Pattern Dynamics and Applied Remote Sensing, University of Potsdam

Involved Researchers: K. Schulz (campaign responsible, micrometeorological measurements, hydro-meteorological model, data assimilation, uncertainty analysis), P. Dietrich (geophysical measurements), E. Zehe (STDR - soil moisture monitoring), M. Volk (catchment hydrological model)

5.7.2 DEJEU-3238

Dr. Richard de Jeu, Vrije Universiteit Amsterdam, Netherlands, richard.de.jeu@falw.vu.nl

Field Observations from ELBARA Experiment
Between April 2003 and October 2003 a field study was carried out with an L-band radiometer at a controlled meteorological field site in Wageningen (NL, 51° 58' N and 5° 38' E). Three different plots, a bare soil, a soil with short grass, and a site with growing grass vegetation were selected. A Dicke horn 1.4 GHz radiometer (ELBARA) was used on a rotating platform, resulting in the ability to measure the three sites almost simultaneously with an interval of 10 minutes. Besides the measurements of the microwave signals, observations of soil moisture, soil and vegetation temperature, biomass, Normalised Difference Vegetation Index (NDVI), Leaf Area Index (LAI), water and energy fluxes were carried out. This database was developed by the PI (Dr. de Jeu) and is fully available to use for this project. Past and current hydro-meteorological data of this site can be obtained at www.met.wau.nl and more details about this project can be found at www.geo.vu.nl/~jeur/elbara.

5.7.3 STAMMER-3241

Prof. Detlef Stammer, Universitat Hamburg, Germany, stammer@ifm.zmaw.de

This project includes a measurement campaign in the North Sea aimed at measuring sea surface salinity data under a SMOS track with footprint resolution. This will be performed by the Bundesamt fur Seeschifffahrt und Hydrographie (BSH).

5.7.4 PALOSCIA-3250

Dr. Simonetta Paloscia, Istituto di Fisica Aplicata, Firenze, Italy, s.paloscia@ifac.cnr.it

Experimental campaigns with multi-frequency (L, C, X bands) airborne and ground sensors are planned over several forests and fields in Tuscany, Italy.

5.7.5 LOPEZBAEZA-3252

Dr. Ernesto Lopez-Baeza, Universitat de Valencia, Spain, ernesto.lopez@uv.es

Field campaign and emission model are prepared to characterise vineyards, shrubs, matorrals at L band. ELBARA radiometer (from ESA) will be set up in the VAS area in order to monitor TB fluctuations during the Commissioning Phase. Control of ELBARA may be done remotely through internet. The specific objective is to monitor a Cal/Val area with the radiometer and the soil sensors (soil moisture content, vegetation measurements, etc) during the commissioning phase of SMOS and during different periods of vegetation growth looking for different SM conditions.

5.7.6 CAMPS-3254

Dr. Adriano Camps, Universitat Politecnica de Catalunya, Barcelona, Spain, camps@tsc.upc.edu

ESA performed SAMIRAS (Small Airborne MIRAS: demonstrator with 4 elements per arm) flights in summer 2006 with the HUT Skyvan aircraft to check its technical behavior. A logical follow-on is to test that SAMIRAS is able to meet the expected performances in image generation from measured visibilities and in extracting from them SM and OS values. If ESA covers the airplane costs, SAMIRAS can also be used simultaneously with SMOS pass over some validation areas and take advantage of the low flight to verify several aspects of the data processing.

The Canary Islands are located in the eastern basin of the North Atlantic Subtropical Gyre, one of the most suitable regions for SMOS data validation, since a low seasonal variability in temperature and salinity has

historically been observed. To carry out SMOS validation, the project will use both data from a fixed location (moored station) and from some other locations within the Subtropical Gyre. On the one hand, data from the fixed location will be available by means of a mooring west of La Palma island, where data will be recorded and supplied with the satellite link. On the other hand, data within the Subtropical Gyre will be acquired by a number (tentatively 15) of drifting buoys deployed in the region. Moreover, temperature and salinity data acquired by other research cruises in the region will also be used, as well as the outputs from numerical models.

The moored buoy, maintained by IEO-Tenerife during this project, will allow a control on the temporal stability of the temperature and salinity characteristics even if the surface drifters have left the area, so that a monitoring of the quality of SMOS products can be performed after completion of the cal/val phase. Depending on the moment the equipment will be ready for deployment, data can be used for regional characterisation (mainly temporal stability) before SMOS launch.

Executing Centres: ULPGC, IEO, ICM-CSIC
Involved Researchers: F. Machín (campaign management and regional oceanography), F. Eugenio (drifters operation), J. Marcello (acquiring and reformatting in situ data, validation), M. Vargas (mooring operations and data analysis), C. Gabarró (in-situ analysis, SMOS).

Another proposed working area is limited by the Cantabric continental shelf edge (43.7º-44ºN) and the Gascogne Buoy (45.2ºN) and is between 3º and 6ºW. The IEO samples on a monthly basis the southern part of this area with the RV José Rioja. Three hydrological transects are sampled off Santander, Gijón and Cudillero. Twice a year (mainly in spring and autumn), the sampling is accomplished with a larger vessel and the sampled area is extended to 45ºN (also depending on meteorological and sea conditions).

The intention is to repeat this sampling strategy 6 times during the cal/val SMOS phase. The sampling will be conducted when the working area coincides with the vision centre of the satellite. This is intended to obtain the maximum spatial resolution with MIRAS (30 km). Once an emissivity model has been selected it will be to compare in-situ surface salinity with the values obtained in SMOS. This will increase the available database (both hydrographic data and wave and wind data). This database will finally be used to adjust the semi-empiric emissivity model. These data will also be used to eliminate the brightness temperature bias. Field works and result analysis (mainly those related to SMOS products validation) will be coordinated with the French groups working in the Gascogne-Brittany area.

Executing Centres: IEO, ICM-CSIC
Involved Researchers: F. Plaza (task management, “RV José Rioja” campaigns, data analysis), C. Rodríguez (sensors maintenance, salinity determination), C. Gabarró (in-situ and SMOS analysis), J. Font (joint analysis with French validation groups), A. Lavín (FerryBox).

The IEO carries out periodic surveys in the Spanish Mediterranean, collecting in-situ salinity and temperature data. These surveys are carried out off Málaga and Murcia (projects ECOMALAGA and ECOMURCIA, funded by IEO) and in the Balearic channels (project CIRBAL). Taking into account the size of the pixel to be obtained in SMOS, the area covered in the Balearic Islands could be suitable for comparison with the salinity values calculated from the satellite measurements. With this purpose the IEO will carry out a cruise coinciding with the SMOS cal/val phase in 2008. The extension covered by Málaga and Murcia hydrology transects is very reduced. For this reason the IEO is planning to sample two more transects off the coast of Granada and Cape Gata. The hydrology data along the Spanish southern coast should exhibit salinity gradients that can be used to validate SMOS data.

Other opportunity cruises by ICM-CSIC (within the frame of other projects) will be used to collect CTD and thermosalinograph data for satellite calibration. IEO and ICM-CSIC cruises or opportunity ships will be used to launch surface drifting buoys to measure surface salinity in other areas. The validation process will also use profiling floats from the program MedARGO which have already started in the frame of MFSTEP

(http://doga.ogs.trieste.it/WP4/). The approach will be a global analysis of in-situ data similar to the one described for the Canary region.

Executing Centres: ICM-CSIC, IEO
Involved Researchers: J. Salat (task management and float deployment), M. Emelianov (data analysis and MFSTEP diagnostic), C. Gabarró (in-situ/SMOS), M. Vargas-Yáñez and T. Ramírez (sampling and analysis in the Alborán Sea), J.L. López-Jurado (sampling and analysis in the Balearic Sea).

5.7.7 PELLARIN-3261

Dr. Thierry Pellarin, Laboratoire des Transferts en Hydrologie et Environnement, Grenoble, France, thierry.pellarin@hmg.inpg.fr

The aim is to provide ground-based soil moisture measurements representative of local scale soil moisture variability over two land-cover types and S-band radiometric measurements over about a 1 km2 area in the Vercors region. The objective is then to observe the correlation between SMOS L-band brightness temperatures (about 30x30 km2) and S-band brightness temperatures obtained at the 1 km2 scale.

5.7.8 GOMMENGINGER-3265

Dr. Christine Gommenginger, National Oceanography Centre, Southampton, UK, cg1@noc.soton.ac.uk

A large UK oceanographic presence is anticipated in the Arctic and the North Atlantic during the International Polar Year campaigns (currently planned to take place between March 2007 and March 2009), in which NOC is expected to participate. The location of the ships during the cal / val period is not known at the present time, but given the global coverage of SMOS, a small number of collocated ship-SMOS SSS measurements over the cal / val period are expected.

5.7.9 NAVARRO-3266

Dr. Gabriel Navarro, Instituto de Ciencias Marinas de Andalucia, Puerto Real, Spain, gabriel.navarro@uca.es

Monthly research cruises performed in the past from 2000 until now and others planned for the next future until 2008 will be used to measure sea surface salinity with a CTD probe in a wide coastal sector of the continental shelf of the Gulf of Cadiz. Sampling will be carried out on board the vessel Regina Maris of the Andalusian Government. A monitoring program has been already established to record several physico-chemical properties of the water column along with other biological parameters. The sampling grid consists of 30 fixed stations distributed over a coastal fringe (from 6 to 200 meters depth) between the Bay of Cadiz (next to the Guadalquivir River mouth) and the portuguese border on the Guadiana River mouth. The stations are positioned on ten radials quasi-perpendicular to the coastline. In that way, 20 of these stations are located at depths shallower or equal to 30 m, in order to achieve a complete spatial detailed resolution that covers most of the coastal fringe. At each station, vertical profiles of temperature, salinity, dissolved oxygen and chlorophyll fluorescence will be obtained with a Seabird-21 CTD probe, embedded in a rosette sampler composed by 24 bottles of 2 liters and sampling at different depths. Continuous underway measurements of temperature, salinity and chlorophyll fluorescence are also recorded at 5 meters below the surface level with a Seabird thermosalinometer and data logged every minute.

5.7.10 SU-3269

Prof. Bob Su, International Institute for Information Science and Earth Observation, Enschede, Netherlands, b_su@itc.nl

Dedicated field experiments will be conducted with concurrent international field experiments in Europe (3 sites in the Netherlands), China and Africa for the development and validation of algorithms.

5.7.11 ZRIBI-3274

Dr. Mehrez Zribi, Institut Pierre Simon Laplace, France, mehrez.zribi@cetp.ipsl.fr

Experimental campaigns will be carried out combining both airborne and in-situ measurements in the gulf of Biscay. As a first definition, chosen locations are where SSS and SST are homogeneous. This will allow focus on the sensitivity of the measurements to sea state effects. In particular this could enable to define an empirical radar inferred correction, allowing removing the wind-related sea state effects from the measured Tb. A major goal of such experiments would be to perform correlation studies between the simultaneous active and passive measurements, in order to determine the configurations of active measurements (in terms of incidence angles and polarisation, notably) which are the most efficient for removing the wind-related sea state effects from the L-band radiometric data. In a second step, flights over areas with variable SSS and/or SST would be performed, with the empirical corrections applied, and the results in terms of SSS and/or SST would be checked against in-situ measurements. For all the campaigns, all opportunities of coordination with in-situ deployments (buoys, drifters, ships) will be accounted, with the support of institutes such as Meteo-France, IFREMER in France or their counterparts in Europe (in particular with spanish colleagues).

5.7.12 MARCZEWSKI-3275

Dr. Wojciech Marczewski, Space Research Centre, Warsaw, Poland, wmar@cbk.waw.pl

Various campaigns in Poland at 10 different land sites, possibly synchronised with SMOS overpass.

5.7.13 HALLIKAINEN-3281

Prof. Martti Hallikainen, Helsinki University of Technology, Espoo, Finland, martti.hallikainen@tkk.fi

Various campaigns in Finland, in the Baltic Sea and in the Arctic Ocean.
Ground-based data will be acquired on a regular basis, where applicable, starting in 2006 in order to verify the feasibility of the database. HUT airborne sensors are used during the project to provide data that are more detailed concerning spatial resolution than SMOS data; airborne measurements are accompanied with appropriate ground-based data collection, where applicable. Additional satellite data are acquired. Data collection will be continued throughout the SMOS lifetime. Data can only be acquired in Finland and nearby areas from early spring to late fall.

5.8 Measurements Protocols for Key Validation Sites

The following section gives the requirements for key validation sites.
Key site leaders should provide the status of their upscaling model and a compliance matrix with a way forward for the requirements for which they are not compliant in order to see how ESA can help them to become fully compliant.
A validation site/area should be at least 100km away from any coastline.

5.8.1 MEASUREMENTS PROTOCOL OVER LAND

A validation site should have at least one station every 25km and one station per {soil type, vegetation type} couple.
Precipitation measurement at each station every 30min
Bulk density measurement at each station once
Upward TIR radiation measurement on the site every 30min
Downward IR radiation measurement on the site every 30min
Downward visible radiation measurement on the site every 30min
Snow on/off time measurement on the site
Dew on/off time measurement on the site
Air temperature measurement on the site every 30min
Air humidity measurement on the site every 30min
Wind speed measurement on the site every 30min
Vegetation biomass measurement at each station every month
Leaf Area Index measurement at each station every month
Fractional cover measurement at each station every month
Soil texture map of the site
Land use map of the site

DEM of the site
Ground water depth measurement on the site every month
Soil temperature and SM profiles at each station (-5cm and 3 others deeper) every 30min

5.8.2 MEASUREMENTS PROTOCOL OVER SEA

A validation area should have at least one station every 100km with a minimum water depth of 200m.
Wind vector (speed and direction) at each station every 20min
Significant Wave Height at each station every 20min
Directional wave spectrum at each station every 20min
Peak wave period at each station every 20min
Averaged wave period at each station every 20min
Sea Surface Temperature at each station every hour
Sea Surface Salinity at each station every hour
Air temperature at each station every hour
Precipitation on/off time measurement at each station
Sea ice map of the area every day
Bathymetry map of the area
Foam and slick observation

5.8.3 SOIL MOISTURE PROBES

During a SM informal meeting in Bordeaux (November 2008), a project of work about soil moisture probes and their calibration was discussed and planed. The first objective of this project is to gather information about performance, calibration and use of soil moisture probes in the experimental sites. This will give a clearer view of what is done in the field of soil moisture in-situ measurements at the scale of the SMOS cal/val community. This will also make comparisons between results of the different sites easier and more efficient. The responsible coordinator is Marc Crapeau at EPHYSE-INRA.

5.9 Ground Radiometers

Radiometer	Owner	Polarisation	Beams	3dB full beam width	Aperture
ELBARA 1	ESA	Dual	1	12 deg	Real
ELBARA 2	ESA	Dual	1	12 deg	Real
ELBARA 3	ESA	Dual	1	12 deg	Real
ELBARA J	FZJ	Dual	1	12 deg	Real
EMIRAD-1	TUD	Full	1	23 or 31 deg	Real
LAURA	UPC	Dual	1	20 deg	Real
LEWIS	CESBIO	Dual	1	13.6 deg	Real
IROE	IFAC	Dual	1	35 deg	Real
COMRAD	NASA/GWU	Dual	1	12.5 deg	Real
PAU	UPC	Dual	Multi	20 deg	Real
ISU-L	Iowa State University	Dual	1	19 deg	Real
RADOMEX	IFAC	Dual	1	35 deg	Real

5.9.1 ELBARA

ELBARA Upper Danube Catchement, PI W. Mauser, from SMOS launch to SMOS end
ELBARA Valencia Anchor Station, PI E. Lopez-Baeza, from SMOS launch to SMOS end
ELBARA Juelich, Rur Catchment, PI J. Vanderborght, from SMOS launch to SMOS end
ELBARA Mobile Opportunity (owned and provided by ESA)
From mid 2009 to mid 2010 at the Sodankyla site, north Finland, J. Pulliainen (with PI M. Hallikainen)

From mid 2010 to end 2011 at the Vercors site, east France, PI T. Pellarin
2011 at the polish wetland site, PI W. Marczewski

5.9.2 EMIRAD

EMIRAD, owned by the Technical University of Denmark, was operated near Bordeaux by JP Wigneron in spring and summer 2008 by INRA-CESBIO-CNRM. It might be used by PI B. Su during the first half of 2009 and then installed on the FINO platform over the North Sea for the second half of 2009 by PI D. Stammer, with a new antenna horn.

5.9.3 LAURA

- LAURA has a radome and was already used over the sea at the Casablanca platform
- it has a narrower beam than EMIRAD and ELBARA
- it can rotate in azimuth for roughness dependence study (ELBARA and EMIRAD cannot)
- it can rotate in incidence for sky/atmosphere measurements
- it gives full polarisation

LAURA was operated in April-May 2008 over sea by PI A. Camps (UPC) in the Canary Islands.
Then it has been installed in a trailer for easier transportation and operation from ground. Taking it to a sea tower is not an easy task, and at present, UPC do not have enough manpower to undertake these efforts as they did in the past for WISE 2000 & 2001. UPC has committed to take it to REMEDHUS (Salamanca) and the funds from the Spanish National Plan are there to make it possible.
LAURA operates now at the REMEDHUS site from sept 2008 to sept 2009 as a collaboration between PI A. Camps and PI J. Martinez-Fernandez.

5.9.4 LEWIS

http://www.cesbio.ups-tlse.fr/us/indexsmos.html
LEWIS, owned by CESBIO/ONERA, is operated near Toulouse since January 2003.
It might be operated at the Pic du Midi in 2009-2010.

5.9.5 OTHERS

IROE
The radiometer of IFAC-MSRG will be in the Italian Alps during winter 2008-2009. Then it will be in Montespertoli (Tuscany, Italy) during spring and summer 2009.

COMRAD
This radiometer of PI T. Jackson is in Maryland from April to October 2008, in collaboration with O'Neill and Lang.

PAU
PI A. Camps, summer 2008 over sea at the north of Gran Canaria

ISU-L
PI B. Hornbuckle with Rowlandson, Gleason, Anderson, US midwest, Iowa validation site
Summer 2008: soybean
Summer 2009: maize

RADOMEX
IFAC-MSRG (G. Macelloni) at Dome C from December 2008

5.10 Airborne Radiometers

Radiometer	Owner	Polarisation	Beams	3dB fullbeamwidth	Aperture	Platform
EMIRAD-2	TUD	Full	2	38 (nadir look) & 31 (aft look)	Real	Skyvan
HUT2D	HUT	Dual	Multi	7.5 deg	Synt.	Skyvan
CAROLS	CETP	Full	2	38 deg for both	Real	ATR42
AMIRAS	ESA	Full	Multi	10 deg	Synt.	Skyvan
STARRS	NRL	V-Pol	Multi	16 deg	Real	TBD
SLFMR	NOAA	V-Pol	Multi	20 deg	Real	TBD
PLMR	University Melbourne	Dual	Multi	13.6 deg	Real	Any
PALS	NASA JPL	Full	Multi	35 deg	Real	Twin Otter
ESTAR	NASA GSFC	H-Pol	Multi	12.5 deg	Synt.	TBD
2D-STAR	NASA	Dual (H & V)	Multi		Synt.	P-3
AESMIR	NASA	Full	Multi	20 deg	Real	TBD

PLMR (PI J. Walker) will fly about 100 hours in 2009 over the Simpson Desert and the Murrumbidgee Catchement in Australia, 50 hours in winter 2010 and 50 hours in summer 2010 over the Murrumbidgee Catchement (600km x 100km transect), and the same in 2011.

PALS (PI T. Jackson and Yeuh) will be used for HEX in summer 2009 and for CLASIC-II in June 2010.

6 VALIDATION AND RETRIEVAL PLAN

Responsible:

- Validation and Retrieval Coordination Team lead by S. Delwart and C. Bouzinac in collaboration with the SMOS Principal Investigators (PI) Y. Kerr and J. Font.

Objectives:

- To coordinate the validation studies from the different AO teams.
- To identify the areas where improvements in L2 processing are necessary, and propose a way forward in order to validate the geophysical products.
- To derive the error bars needed to validate the L2 products.
- To determine the stability of the L1 products, through vicarious calibration.
- To enhance the understanding of the underlying science in order to improve the retrieval algorithms.

Inputs:

- Results from field campaigns as described in the Campaign Coordination Plan
- Results from instrument networks
- Results from vicarious calibration activities
- Results from comparisons with other sensors

Outputs:

- Validated L2 products
- Commissioning Phase report

The validation and retrieval plan is not a plan as such, it should be more considered as a compilation of the activities proposed via the Cal/Val Announcement of Opportunity (AO) process. It aims at providing sufficient information to provide visibility between the different groups – as well as to ESA – of the different tasks foreseen as well as the approaches proposed by the different groups involved, to hopefully enhance the collaboration and the coordination between these different activities to maximize the scientific returns to the SMOS mission objectives.

Three groups are proposed:

Land Validation team
It will be lead by S. Delwart in collaboration with Y. Kerr, the SMOS Soil Moisture PI.

Ocean Validation team
It will be lead by C. Bouzinac in collaboration with J. Font, the SMOS Ocean Salinity PI.

Vicarious Calibration team
It will be lead by S. Delwart in close collaboration with the calibration team as well as the calibration key investigators A. Camps, E. Anterrieu, F. Cabot and M. Hallikainen.

The members list of the calibration and validation teams can be found in the annex; the list currently includes all the members of each team identified as participating to this activity. However, it is the intent of the SMOS project to assign a single contact point (PI) per AO proposal, whose task will be to coordinate the activities of the subgroups within each AO proposal consortium.

For the AO proposals identified as contributing to more than one VRT sub-group, the PI is requested to identify different individuals as contact points for the different sub-groups. This will enable the project to reduce the duration of future workshops by holding parallel sessions at sub-group levels.

6.1 Land Validation Team

6.1.1 LAND VALIDATION OBJECTIVES

Validation is the process of assessing by independent means, the quality of the data products derived from the system outputs. The scope of the land validation is to estimate the SMOS level 2 accuracy. SMOS validation has to demonstrate with statistical significance that SMOS derived products satisfy mission requirements. Data set for comparison with SMOS data must be of a known quality and must extend over significant geographical areas spanning various geophysical conditions and providing sufficient temporal coverage.

Different observing sites corresponding to various targets will be used for validation over land. SMOS will provide a number of products to validate depending on the information available for each particular pixel. Among them soil moisture is the most important product to validate over land. Specifically over homogeneous targets with low vegetation density the different contribution to the emission from the vegetation and the soil should be easily distinguishable and therefore these would be ideal targets for validation purposes. Both retrieved and independent soil moisture estimate values shall be compared in order to assess error limits on retrievals. Analysis should be focused on reliable independent quality measurements of soil moisture. When soil moisture measurements are not available, quality independent estimates would be appropriate for validation. It would be of primary importance to account for the fact that SMOS pixels size average over large areas and soil moisture present wide range of variations due to spatial variability on soil surface properties. The way to obtain average values over the pixel size should be confident enough and should provide its own error limits. Also differences in time of measurements and location of the observed area should be carefully considered.

In some cases, validation of other output products over land will be considered for validation (when retrieval of multiple parameter is successful). This independent information could be also used for estimating first guess on retrieved parameters. Near surface soil moisture is the key product but some other output products, when multiple variables retrieval is attempted, are: vegetation optical thickness (τ), τ factor for polarisation H (τ_H), ratio of τ factors for H and V polarisations (τ_H/τ_V), horizontal polarisation albedo (ω_H), difference of albedos (ω_H-ω_V), surface equivalent temperature and roughness parameter.

Validation of SMOS products could be done for each product or it could also be possible to validate land surface level brightness temperature.

The validation exercise will also evaluate the suitability of the SMOS level 2 products for assimilation into hydrological and general circulation models.

Over land, there are particular areas where validation seems feasible and some others where soil moisture validation is not possible. These sites include coastal zones, snow covered areas, frozen soil areas, dry sand deserts, urban areas, regions with steep topography and dense forest. Particular models for these cases are still under development although in some cases like forest, the specific model is already implemented. Therefore validation of SMOS products is also linked with improvements on algorithms, especially over particularly challenging targets.

The plan is structured in the following way:
Lists of proposed:

1. Campaigns to be executed,
2. Networks to be used,
3. Models to be used (and developed),
4. Assimilations to be performed,
5. Comparisons with other sensors to be performed,
6. Scientific issues to be addressed.

Each list includes a short description of sensors, models, etc, to be used and/or of the methods to be applied. It is intended to support the scientific community by providing visibility of the proposed activities from the different groups and to encourage cross-fertilization and collaboration between these groups.

At this stage, the plan does not include any schedule or link between activities within the overall SMOS Calibration Validation and Retrieval Team. However, this is intended for a future release of the document.

6.1.2 CAMPAIGNS

The list of campaigns described below are all these whose outputs have been identified as contribution to the objective of the land validation team. Although these campaigns will most probably cover a wider range of scientific issues than just SMOS calibration, the short description provided below will only cover the campaign's contribution to the land validation team objectives.

6.1.2.1 SMOSMANIA

Zribi–AO-3274

The SMOSMANIA project will provide independent L-band Tb observations over several specific SMOS Cal-Val sites. The main one is located in South-West of France and is mainly representative of agricultural areas. Since more than 20 years, numerous experiments dedicated to soil moisture processes have been conducted in this region (Hapex-Mobilhy in 1986-1987, MUREX in 1995-1998 and SMOSREX since 2001). 12 automatic meteorological weather stations are instrumented in order to provide continuous soil moisture measurements over a large area from the Mediterranean sea to the Atlantic ocean.
Airborne campaigns during the SMOS commissioning phase are planned over the instrumented test sites. Beyond the commissioning phase, other campaigns could be performed during the lifetime of SMOS.

For the ground network of SMOSMANIA please refer to proposal **AO-3168 of Dr. Calvet**.

6.1.2.2 Hydrology Experiment HEX08 HEX09

Jackson-AO-3221

Large scale field campaign in North-Central US including in-situ measurements and airborne radiometers. Also specific campaign linked with SCAN, Watershed & CEOP networks.

SMOS will require soil moisture field experiments to validate algorithms during mission development and post launch. A field experiment within the U.S. will be designed to provide both short-term (< 1 month) and longer (1 year) intensive sampling of soil moisture and other surface and atmospheric characteristics using a combination of automated and manual in-situ measurements and airborne radiometers. The data will be analyzed to provide spatial estimates of soil moisture at SMOS and AMSR-EOS footprint scales. The timing and duration of the experiment is intended to maximize the likelihood of encountering a diversity of surface wetness conditions, depending on precipitation patterns and local meteorology.

At the present time the project is anticipating at least one campaign during the SMOS post-launch period. This will be part of a full-year hydrology experiment in the upper Midwest of the U.S., possibly including sites in Canada. This will be conducted in cooperation with other NASA Mission Working Groups and will depend upon funding approval. It is anticipated that large-scale ground and aircraft soil moisture sampling will be conducted and that aircraft-based L-band instrumentation will be available for this campaign. The time frame will be 2008-2009.

6.1.2.3 ELBARA & EMIRAD

LopezBaeza–AO-3252

Dr A. Camps and Dr M. Vallosera (from TSC at UPC, see http://www.tsc.upc.edu/), in close collaboration with the Group of Climatology from Satellites (GCS at Valencia University, see www.uv.es/anchors), from the start of SMOS mission, will contribute with a ground radiometer (L-band) to the Valencia Anchor Site (VAS) characterisation, together with the EMIRAD radiometer operated by the GCS and INRA, and will monitor the

site in specific campaigns during the Commissioning Period (SMOS-CP) and during the operational phase of SMOS. This activity will be of significant value when this information will be introduced in the SEPS (SMOS End-to-end Performance Simulator) and applied to the whole VAS area (about 50 x 50 km2).

During SMOS-CP, the field campaign will set up a radiometer in the VAS area in order to monitor brightness temperature fluctuations. The specific objective is to monitor a representative area of the Cal/Val area with the ELBARA radiometer and the soil sensors (soil moisture content, vegetation measurements, etc).
During SMOS first operational period, field campaigns will set up ELBARA radiometer in the VAS area in order to monitor brightness temperature fluctuations. Control of ELBARA may be done remotely through internet. The specific objective is to monitor a representative area of the Cal/Val area with the radiometer and the soil sensors (soil moisture content, vegetation measurements, etc.) during different periods of vegetation growth and different soil moisture conditions

The campaigns with the ground radiometer will obtain the microwave signature from vineyards, Mediterranean forests, urban areas, and other land uses also considered as convenient to characterize L-band emission of the VAS area.

Zribi–AO-3274

The project has finished the construction of a radiometer funded by CNES (CAROLS is a copy of EMIRAD built in collaboration with N. Skou from the Technical University of Denmark). Airborne tests will be made in September 2008.

6.1.2.4 African Monsoon Multidisciplinary Analyses (AMMA)

Grippa–AO-3257

One of the objectives of AMMA (African Monsoon Multidisciplinary Analysis) project is to address the role of soil moisture on monsoon dynamics and variability. AMMA is based on optimal modeling and multispectral remote sensing approaches together with a unique intensive field instrumentation to address scientific questions related to the role of land surface and human effects monsoon intensity, variability and predictability.
Soil moisture remote sensing is a key component of AMMA project. It provides spatially integrated information on soil moisture at a scale relevant for atmospheric processes. METOP/ASCAT will provide soil moisture estimates for 2005-2007 from active measurements. AMSR microwave passive measurements have been providing soil moisture products since 2002. SMOS measurements for 2007-2010 are particularly relevant to AMMA project to enhance the quality of soil moisture products over West Africa. In turn, West Africa is a hot spot region where SMOS is expected to have a major scientific feedback and crucial innovative applications for seasonal forecast, water resources management. AMMA project is a unique opportunity for SMOS project to validate soil moisture products and inversion algorithms at different spatial scales along a strong climatic gradient, by using aggregation procedure, and for several annual cycles.
For 2007-2010, meteorological ground and space based monitoring over West Africa will be ensured in the context of the long-term observing period of AMMA. The project will ensure the continuity of soil moisture ground based measurements in AMMA sites, after the launch of SMOS, for 2007-2010.
This project proposes to keep the ground based continuous monitoring of soil moisture after the launch of SMOS for 2008-2009. Specific campaigns will complete this network of local scale soil moisture monitoring, by transect measurements of surface soil moisture to address the upscaling issue. The acquired soil moisture data set, combined with AMMA instrumental network, will provide distributed soil moisture information.

Friesen–AO-3280

The Volta Basin is one of the five agricultural research benchmark basins in Africa and houses several projects besides GLOWA Volta Project such as AMMA and the Small Reservoirs Project, that provide local expertise and measuring networks on regional hydrology, meteorology, and soil science. The presence of

these research projects underlines the importance of hydrological research in this region and the important role SMOS can play in West African water resources monitoring.

Magagi–AO-3268

Over the semi-arid areas, the project will take advantage of the AMMA enhanced observation periods that will take place in 2005-2007. Later on, soil moisture measurements, well distributed, at a reasonable sampling depth (2-5 cm) and coincident or very close to SMOS overpasses will be collected.

Zribi–AO-3274

Three sites in West Africa (Niger, Mali and Benin) are currently instrumented in the frame of the AMMA project (2005-2007).

6.1.2.5 Long-term S-band Radiometric Measurements

Pellarin–AO-3261

The approach is to develop an S-band radiometer derived from LEWIS L-band radiometer operating since 2002 in Toulouse and developed by ONERA and CNES in the framework of SMOS project. Then, continuous brightness temperature measurements will be carried out together with local ground-based in-situ soil moisture and temperature measurements over two land-cover surfaces (grassland and coniferous forest) in a french mountaneous region (Vercors).

6.1.2.6 National Airborne Field Experiment (NAFE)

Walker–AO-3219

The proposed project is motivated by the existence of unique long-term data sets acquired in the Goulburn and Murrumbidgee catchments in SE Australia (which are of the size of several SMOS pixels) and two National Airborne Field Experiments to be held in the Goulburn (NAFE05) and the Murrumbidgee (NAFE06) catchments in November 2005 and 2006. These two experiments will provide high-resolution maps of L-band brightness temperature and thermal infrared temperature for both catchments as well as a wide range of ground-based observations. The campaigns involve airborne remote sensing and ground measurements.
http://www.civenv.unimelb.edu.au/~jwalker/data
Jeff Walker just got word of funding for a 4-year project to commence in Jan 2008, with 100hrs of flying for each of 2009, 2010 and 2011. While there is some flexibility, his current plan is to fly a SMOS sized pixel in the Simpson Desert and as large a pixel as possible of tropical forest at several times of year in 2008, and then fly an approximately 100km x 600km transect across the Murrumbidgee catchment, including the monitoring network, for the remainder of the flight time. This would be coordinated for different seasons of the year with as wide a range of land surface conditions and moisture contents as possible.
Also, PLMR is so easy to install, it can be added on almost any aircraft already planned to fly.

6.1.2.7 Mongolian Plateau

Kaihotsu–AO-3211

In order to obtain ground truth data for the calibration and validation of MIRAS/AMSR-EOS/PALSAR with the various spatial resolutions, field experiments will be conducted in the large natural area of the Mongolian Plateau with ground based soil moisture and meteorological observations from an automatic network over the site.
In order to obtain the basic data of temporary surface conditions and various parameters of soils/plants, the project will have a few field campaigns as complementary intensive field observations in early and late summer in 2006, 2007 and 2008.

It will carry out soil moisture and surface temperature measurements and investigation of vegetation conditions (plant cover, plant height, leaf temperature, etc) at automatic weather stations and automatic stations for soil hydrology and some temporary points during the intensive observation in the study area of the Mongolian Plateau.

6.1.2.8 Kanpur and Kharagpur Campuses

Singh–AO-3223

The proposal aims to integrate the soil moisture derived from SMOS, SSMI, NCEP and ground data at various places in India. The ground data will be measured at two sites on Kanpur and Kharagpur campuses and also will be acquired from the agrometeorological stations in India over different geological terrains.

6.1.2.9 Agricultural Midwest in the United States

Hornbuckle–AO-3246

Two season-long field experiments will be conducted near the campus of Iowa State University in Ames. These two experiments, the first in soybean, the second in corn, will be at the plot-scale. The plot-scale is defined as an area on the order of 100 square meters. An assumption is made that results found at this scale can be transferred to the scale of SMOS pixels.

The effect of dew and intercepted precipitation on the L-band brightness of both corn and soybean will be characterized as a function of vegetation column density or leaf area index, canopy wetness amount, and incidence angle. This will occur during the two season-long field experiments that will occur during the first two years of the project in 2006 and 2007.

6.1.2.10 Canada

Magagi–AO-3268

Soil and vegetation parameters will be measured over two canadian specific sites located in the high latitudes (northern Canada) and in the agricultural area (western Canada).

6.1.2.11 Long-term in-situ Observations in Europe, China and Africa

Su–AO-3269

Long-term observations and dedicated field experiments in the Netherlands, China and Africa providing coverage of soil moisture observations with repetition and accuracy appropriate for climatological, meteorological and large-scale hydrological studies.

6.1.2.12 GLOWA Volta Basin & GLOWA Danube Catchment

Friesen–AO-3280

Specific campaign within the Volta Basin in Africa with the extensive network GLOWA Volta Basin.
http://www.glowa-volta.de
The complete ground observation network will be in place at the time of SMOS launch. A special intensive field campaign is foreseen to make additional near-real time measurements, especially of vegetation characteristics such as biomass and plant water content.
Before the launch, hydrotope campaigns at all three soil moisture test sites are to be conducted to provide sound hydrotope schemes fit to upscale point observations to pixel scale.

A post-launch campaign will be organized to collect ground truth data during satellite overpasses using the preliminary improved hydrotope schemes.

Mauser–AO-3236

Ground truth measurements of in-situ soil moisture and soil temperature will be made during the SMOS cal/val phase. The proposed campaign includes the maintenance of several soil moisture observation stations by the PI and an organized effort to bring together soil moisture information from various measurement networks within the test site of the Danube Catchment. The project will build up a network of permanent registering Time Domain Reflectometry (TDR) probes during the comissioning phase to directly validate SVAT model results at local scale.

6.1.2.13 Specific campaign for upscaling point measurement with SAR in India

Patel–AO-3284

Field measurements will be used to convert into spatial maps using SAR images, scaling the point soil moisture measurements to spatial scale and up to a scale comparable to SMOS on a two stage scaling approach.
Tentatively it is proposed to carry out the study at the following four test sites.
Test site 1: Jodhpur, Rajasthan
The study area falls between 72°00' – 73°00'E and 25°40' – 26°40'N.
Major parts of the study area falls under sandy soil, with a very small area under agricultural use. It is expected that contiguous areas of the order of SMOS resolution size would be under uniform soil moisture conditions, which would be very useful for calibration/validation activities.
Test site 2: Kutchh, Gujarat
The study area falls between 70°00' – 71°00'E and 22°40' – 23°40'N.
The area is a typical example of salt encrusted terrain. Attempts to understand the effect of salt encrustation on SAR backscatter and brightness temperature for calibrating and validating soil moisture estimation will be made.
Test Site 3: Sahranpur, Utter Pradesh
The study area falls between 77°00' – 78°00'E and 29°00' – 30°00'N.
This area is mostly irrigated agricultural area with major crops being Sugarcane, Wheat and Rice. Emphasis will be on scaling the high spatial variability in soil moisture to SMOS resolution.
Test Site 4: Agra, Utter Pradesh
The study area falls between 77°20' – 78°20'E and 26°40' – 27°40'N.
This area is a mixed of rain fed as well as some irrigated agricultural area with major crops being Mustard, Wheat and Jowar/Bajra. This will provide unique opportunity of having uniform patches as well as patches having high spatial variability within a single SAR coverage of 100x100km enabling to address the accuracy issues.

6.1.2.14 Soil Water and Energy Exchange (SWEX) in Poland

Marczewski–AO-3275

Soil Water and Energy Exchange: ground conditions monitoring over 10 sites in Poland.

6.1.2.15 ELBARA in Wageningen

DeJeu-AO-3238

Between April 2003 and October 2003 a field study was carried out with an L-band radiometer at a controlled meteorological field site in Wageningen (NL, 51º 58' N and 5º 38' E). Three different plots, a bare soil, a soil with short grass, and a site with growing grass vegetation were selected. A Dicke horn 1.4 GHz radiometer (ELBARA) was used on a rotating platform, resulting in the ability to measure the three sites almost

simultaneously with an interval of 10 minutes. Besides the measurements of the microwave signals, observations of soil moisture, soil and vegetation temperature, biomass, Normalised Difference Vegetation Index (NDVI), Leaf Area Index (LAI), water and energy fluxes were carried out. This database was developed by the PI (Dr. de Jeu) and is fully available to use for this project. Past and current hydro-meteorological data of this site can be obtained at www.met.wau.nl and more details about this project can be found at www.geo.vu.nl/~jeur/elbara.

6.1.2.16 German Campaign

Vanderborght-AO-3241

The primary region of interest is the highly structured Rhine Valley near Heidelberg where various agricultural usages are intertwined with urban areas and experiments above a forest site located in the FZJ (Juelich forest experiment) and the subsequent plot experiment.
Ground-truth for SMOS data will be obtained through subsoil and topsoil layers measurement of moisture content using ground penetrating radar (GPR) and time domain reflectometry (TDR). Validation of SMOS pixel will be provided for the Rur-Erft catchment.

6.1.2.17 Tuscany

Paloscia-AO-3250

Experimental campaigns with multi-frequency (L, C, X bands) airborne and ground sensors are planned over several forests and fields in Tuscany, Italy.

6.1.2.18 Boreal Forest

Hallikainen-AO-3281

A specific campaign will link the NorSEN network. This soil moisture test site represents the northern boreal forest zone and it is the northwestern extension of the vast Eurasian taiga belt. It will be equipped by 2007 with a number of permanent soil moisture sensors over a large area in order to provide continuous soil moisture information. NorSEN is a project that contains altogether 16 participants from Finland, Sweden and Norway. The project started in February 2005 and will last until the end of year 2007. The main aim of this project is to build a coordinated regional network of satellite data validation and application sites in Northern Fennoscandia, for terrestrial, marine, hydrological and atmospheric key parameters for environmental monitoring in the Arctic and sub-Arctic regions.
The Helsinki University of Technology (HUT) airborne sensors, including the interferometric HUT-2D and a conventional radiometer are available for operational use in late 2006.
The HUT-2D instrument along with the HUT conventional L-band radiometer are employed under snow-free conditions to collect data, using appropriate polarisations and incidence angle range, for the soil moisture test sites in southern Finland. These data are used to study in detail the effect of forest in mixed pixel. Occasionally, similar flights are carried out at the Sodankyla test site in northern Finland.

6.1.2.19 Caatinga Campaign

Martins-AO-3934

The primary objective of this proposal is to perform field-measurement of soil moisture under the Caatinga environment (Brazil) to improve the understanding of the soil moisture variability within the SMOS footprint, an issue closely related to SMOS uncertainty measures, which could also be translated to other remote sensing investigations. More specifically, the following points will be addressed in these campaigns: 1) Validation using ground experiments providing independent measurements of soil moisture (from surface soil moisture to 5 cm depth) to improve the understanding of L-band emissivity as a function of soil and

vegetation parameters (temperature, roughness, type and density of canopy, etc); and 2) Test of the SMOS validation approach.

6.1.3 NETWORKS

The list of networks described below are all these whose outputs have been identified as contributing to the objectives of the land validation team. Although these networks will most probably cover a wider range of scientific issues than just SMOS calibration, the short description provided below will only cover the networks contribution to the land validation team objectives.

6.1.3.1 SMOSMANIA

Calvet–AO-3168

The research centre of Météo-France, the CNRM, has decided to implement in 2006 a transect of 12 stations able to measure continuously a soil moisture profile in south-western France. Existing operational automatic stations of the ground network of Météo-France (RADOME) will be used. The observations will be collected on a half-hourly base (or better), and will be integrated into the operational real time acquisition system. The transect will cross south-western France along a strong climatic gradient from the Atlantic to the Mediterranean Sea. The lifetime of this system will be, at least, 4-5 years. The soil temperature will be measured in conjunction with soil moisture. This project is co-funded by CNES.

SMOSMANIA data will permit to validate the SMOS products, as well as the operational soil moisture products of Météo-France (derived from the SIM system), over SW France. Moreover, the SMOSMANIA network will provide a framework to assess the assimilation of SMOS products or brightness temperatures in land surface models.

Reliable automatic devices able to monitor soil moisture continuously now exist. During the long-term field experiments MUREX and SMOSREX, in SW France, the ML2X ThetaProbe (frequency domain reflectometry) of Delta-T Devices (UK) was used. This device proved to be robust and reliable during MUREX and SMOSREX. However, reference gravimetric measurements have to be made in contrasting soil moisture conditions, in order to calibrate the ThetaProbe signal.

Four ThetaProbes per station will be used. A surface probe, vertical, will sample the top soil layer (0-6 cm). The three deep probes, horizontal, will be placed at 10, 20, and 30 cm depths. Two temperature probes will be used, at the soil surface and at a depth of 10 cm. Ground data will be used to validate the SMOS products and analyse the bias between the models and the SMOS products.

For the airborne campaign of SMOSMANIA please refer to proposal **AO-3274 of Dr. Zribi**.

6.1.3.2 SCAN, CEOP & Watershed Networks

Jackson-AO-3221

Continuous long-term in-situ soil moisture observations in the United States.
Validation of SMOS product comparing with ground data.

As part of the AMSR-EOS validation activity, an augmented network of dedicated validation sites located at USDA ARS watersheds has been developed. These networks provide estimates of the average soil moisture over watersheds and surrounding areas that approximate the size of the AMSR-EOS or SMOS footprint. This is performed on a continuous basis (reporting every 15-60 minutes), partially in real time. A public database of the watershed data for all sites is being developed that will be made available via the Internet for research studies by the community. We feel that these sites are close to an ideal source of ground based validation of the SMOS soil moisture products.

To implement this network, additional surface soil moisture and temperature sensors (0-5 cm depth) were installed at and around existing instrument locations in four USDA ARS watersheds; Little Washita, OK, Little River, GA, Walnut Gulch, AZ, and Reynolds Creek, ID. The same soil moisture/temperature instrument has been used at all sites and watersheds, the Vitel Hydraprobe. This is the same instrument used at the SCAN sites. Each watershed also has a SCAN site and additional meteorological and hydrological information. We are currently installing a new and unique network near Ames, IA. Each watershed is located in a different climate region of the U.S. and each represents a different physiographic domain.

Regarding the new Iowa network, permanently installed sensing networks used for satellite calibration are often installed in non-representative areas. Points are often located at the boundaries of agricultural fields, meteorological data is subject to edge effects and soil sensors are often in trimmed grass instead of the field crop, resulting in a systematic bias in large scale estimations because of the differences at the surface. An experimental soil moisture network will be installed in the Walnut Creek watershed near Ames, Iowa which will address this problem. Walnut Creek is an agricultural watershed dominated by corn and soybeans (approximately 95% of the area) and a focus of SMEX. Approximately 50 km^2 in scale, the watershed and the surrounding region would provide a unique calibration and validation dataset for an agricultural setting, using data directly from the agricultural installations, which would be placed after planting each season within each field to better estimate the field conditions of soil moisture. There would also be a post harvest installation to capture the bare soil and residue conditions which occur during the winter months. The sensor network is approximately 10 sites with sensor installations at 5 cm with a sensing depth of 3-7 cm. Data will be collected instantaneously on an hourly basis and quality controlled.

Methods for scaling from the point measurements to the integrated watershed/footprint average are being developed as part of the AMSR-EOS validation effort. These sites will remain in operation through SMOS. We will compare the satellite soil moisture products to the watershed networks as a direct contribution to SMOS validation.

Soil Climate Analysis Network (SCAN) is operated by the USDA Natural Resources and Conservation Service (NRCS). Hourly observations are publicly available on the website within one hour of collection (http://www.wcc.nrcs.usda.gov/scan/). There are currently ~80 operational stations throughout the U.S. providing the same set of standard hourly observations. These stations all provide a 5 cm depth measurement, which is highly compatible with microwave soil moisture validation. The sensor is a capacitance device (Vitel Hydraprobe), which provides a measurement that is directly related to the dielectric properties of the soil.

SCAN is an especially valuable resource for soil moisture validation because of its extent and real time availability. We are currently conducting studies to establish the quality and reliability of these data and expect to complete much of this work before the launch of SMOS.

6.1.3.3 REMEDHUS network

Martinez-Fernandez–AO-3230

Long term observation of in-situ soil moisture including both surface and profile (in operation since 1999) over a spatial scale compatible with a SMOS footprint in the central part of the Duero basin (Spain). It will provide continuous observations of soil temperature and climatic data combined with soil and vegetation analysis. It has 24 automatic soil moisture stations (TDR) over an area of 1300 km2 approximately.

The network of soil moisture measuring stations of the university of Salamanca (REMEDHUS) occupies 1285 km2 in the central sector of the Duero basin at the confluence of the provinces of Salamanca, Valladolid and Zamora. It comprises 24 soil moisture measuring stations installed in March 1999 and these are currently fully operative. Each station has 4 TDR (Time Domain Reflectometry) probes inserted horizontally at 5, 25, 50 and 100 cm, respectively. Since April 2005, each station has had an automatic soil moisture-measuring

device in the first 5 cm of the soil, through a Hydra probe in which the soil temperature, the dielectric constant and soil moisture are measured every hour. At the same time, in the Villamor experimental catchment, included within REMEDHUS, an automatic profile was installed in the same type of probe (at 5, 25, 50 and 70 cm depth). Soil moisture measurements with TDR were begun in June 1999, once the profile had stabilised, at fortnightly intervals. The distribution of the stations was established based on criteria addressing the soil types, topography, land use, etc. Although the bioclimatic context is the same, all the stations are independent from the hydrological point of view.

Included in REMEDHUS is the Villamor Experimental Catchment (Province of Zamora), with 100 ha of surface area. It is equipped with the following instruments:
A) A complete Campbell weather station. Variables: global radiation; air temperature; precipitation; relative air humidity; vapour tension; vapour tension deficit; wind speed and direction, and potential evapotranspiration according to the Penman-Monteith model.
B) An automatic runoff station.
C) Eleven soil moisture measuring stations. Soil moisture has been measured with the TDR technique using a Tektronix 1502C tester and a two-wire probes. Each station has a variable number of probes, depending on the depth of the profile, inserted horizontally at different depths (e.g., 5, 15, 25, 50 and 100 cm). Measurements are made fortnightly.

Within REMEDHUS, we have compiled a complete database of the physical and hydrological properties of the soils. To do so, at the time of installing the TDR probes at each of the moisture-measuring stations and at each selected point in the profile, we collected unaltered soil monoliths, with a volume of 100 cm3, in which we analysed the following: texture; bulk density; organic matter content, water retention curve, and saturated hydraulic conductivity.

Recently, the REMEDHUS network has served as a basis for a research project between the candidate research team and the Institute of Photogrammetry and Remote Sensing (Vienna University of Technology) entitled “Monitoring soil moisture at different scales using TDR and radar measurement”. This has allowed us to validate, in Spain, the methodology for the estimation of soil moisture by the ERS scatterometer.

The proposed project will be carried out at the Spanish-Portuguese Centre for Agricultural Research (CIALE), a technological centre of the University of Salamanca, addressing all aspects related to laboratory and data analyses. This centre will house the database required for the development of the project and the server for collecting soil moisture data taken in the field (almost in real time), which will serve as a nexus between all the members of the research team. At the same time it will offer a portal for data distribution for the SMOS scientific community through the Internet.

Wagner-AO-3233

The objective of the work during the commissioning phase is to evaluate the quality of SMOS and ASCAT soil moisture data by comparing them against each other and by comparing both satellite data sets with independent reference data (in-situ soil moisture data from the REMEDHUS network, see SMOS CAL/VAL AO project 3230).
With respect to the long-term validation it is hoped that an international network of in-situ soil moisture observations will be established under the aegis of ESA in cooperation with other international organisations. This would be extremely important for the scientific analysis of SMOS, ASCAT and other remotely sensed soil moisture datasets.

6.1.3.4 Valencia Anchor Station Network

LopezBaeza–AO-3252

Valencia Anchor Station network (Spain) is a region of 10x10 km2 fully characterised with a number of soil moisture Delta-T probes (frequency domain reflectometry), being currently extended for the monitoring area

about the size of a SMOS pixel. It is a reference area for remote sensing validation activities to compare the data products with more accurate independent measurements of the same quantity over a statistically significant number of samples and wide variety of situations.

Zribi–AO-3274 will use this network as well.

6.1.3.5 African Monsoon Multidisciplinary Analyses (AMMA)

Grippa–AO-3257

This project proposes to keep the ground based continuous monitoring of soil moisture after the launch of SMOS for 2008-2009. In 2005, a ground based network of soil moisture monitoring was installed over the three mesoscale sites over West Africa in Benin, Mali, Niger. A total of 23 soil moisture profiles will be monitored continuously for 2005-2007.

Magagi–AO-3268

Over the semi-arid areas, the team will take advantage of the AMMA enhanced observation periods (EOP) that take place in 2005-2007.

Zribi–AO-3274

The aim of AMMA is to understand the role of soil moisture in monsoons dynamics and variability. It is a unique opportunity for SMOS to validate soil moisture products and inversion algorithms at different spatial scales along a strong climatic gradient by using aggregation procedure. It will provide distributed soil moisture information.

Friesen–AO-3280 see GLOWA Volta Basin Network

6.1.3.6 National Airborne Field Experiment (NAFE)

Walker–AO-3219

The aim is to provide access to a wide range of airborne and ground-based monitoring data in return for contributing to airborne and ground-based monitoring programs.
http://www.civenv.unimelb.edu.au/~jwalker/data/nafe
The project compares the inversed soil moisture from L band at several nested scales and the in-situ network of soil moisture measurements.

6.1.3.7 Mongolian Plateau

Kaihotsu–AO-3211

Ground based soil moisture and meteorological observations on the Mongolian Plateau with automatic network over the site.
The team has been carrying out the validation study of ADEOS II and AQUA in the study area between Mandalgobi (N45°46.175', E106°16.539') and Choyr (N46°21.133', E108°22.509'). The study area is flat and mostly covered with the pasture grass. It is located in the Mongolian Plateau and the central part of Mongolia. The area size is 120 km by 120 km.
Ground-based monitoring from 2006–2008 is planned for acquisition of routine data from the networks of AWS and ASSH (Automatic Weather Station and Automatic Station for Soil Hydrology) and Natural Environmental Monitoring Stations (NEMS) of Mongolia. Four AWS and eleven ASSH installed in the study area are used.
Measurement elements (instruments, techniques) by AWS and ASSH are as follows:

AWS elements:
- air temperature and humidity (special made sensor)
- air pressure (barometer: VAISALA PTB220)
- net radiation (net radiometer: REBS Q7)
- soil surface temperature (infrared radiation thermometer: EVEREST 4000.4G)
- soil temperature (special made sensor) at the 3, 20, 40 and 100 cm depths
- soil heat flux (soil heat flux plate: VAISALA) at the 5 cm depth
- soil moisture (TDR-TRIME-IT sensor) at the 3, 20, 40 and 100 cm depths
- wind speed and direction (aero-vane, YOUNG)
- rainfall (tipping bucket rain gauge: Davis)

ASSH elements:
- soil temperature (special made sensor) at the 3 and 10 cm depths
- soil moisture (TDR-TRIME-IT sensor) at the 3 and 10 cm depths

Routine (monitoring) data from network of NEMS:
- air temperature and humidity
- air pressure
- long wave radiation
- short wave radiation
- soil temperature
- precipitation (rain gauge and meteorological radar in Ulaanbaatar)
- soil moisture (sampling and drying)
- radiosonde data in Ulaanbaatar
- phenological data

6.1.3.8 Global Soil Moisture Data Bank

Robock–AO-3227

Network over Mongolia, Ukraine, China and Oklahoma with in-situ observations from more than 500 soil moisture stations. Gravimetric observations of soil moisture (surface and root-zone), soil temperature and vegetation state from a variety of locations and vegetation types.

The Global Soil Moisture Data Bank (http://climate.envsci.rutgers.edu/soil_moisture) at Rutgers University hosts the largest collection of soil moisture observations in the world, and they are distributed at no charge to the scientific community. The Data Bank began with multi-decadal data from the former Soviet Union, and later added extensive sets of observations from China, Mongolia, and other countries. The Russian, Ukrainian, and Chinese data have been used for many successful scientific studies, including validation and improvement of land surface models, evaluation of global climate models and reanalyses, studying scales and patterns of climate variability, and as ground truth for remote sensing. The data have been used as part of the Atmospheric Model Intercomparison Project (AMIP) and the Global Energy and Water Cycle Experiment Global Soil Wetness Project (GEWEX GSWP).

6.1.3.9 FLUXNET

DeJeu–AO-3238

FLUXNET is a globally distributed field observation network of meteorological flux measurements. It is a global network of micrometeorological tower sites that use eddy covariance methods to measure the exchanges of carbon dioxide, water vapour, and energy between terrestrial ecosystem and atmosphere. At present, over 200 tower sites are operating on a long-term and continuous basis. Researchers also collect data on site vegetation, soil, hydrological and meteorological characteristics at the tower sites. http://www.eosdis.ornl.gov/FLUXNET
FLUXNET is a global network of micrometeorological flux measurement sites that measure the exchange of carbon dioxide, water vapour, and energy between the biosphere and atmosphere. FLUXNET is an ideal

network to study microwave brightness temperatures over land from space because it presents 300 sites over a large variety of land surfaces including temperate conifer and broadleaf evergreen and deciduous forests, tropical and boreal forests, crops, grasslands, chaparral, wetlands, and tundra. Sites exist on five continents and their latitudinal distribution ranges from 70˚N to 30˚S. Data and site information are available online at the FLUXNET website, http://www.fluxnet.ornl.gov/FLUXNET. The FLUXNET sites will provide observed and modelled top soil moisture, temperature, and vegetation information for data assimilation.

6.1.3.10 GLOWA Volta Basin & GLOWA Danube Basin

Friesen–AO-3280

Within the Volta Basin area in Africa, an extensive network of test sites has been installed and is operational for soil moisture monitoring, soil moisture profile transects, evaporation measurements and weather stations are installed. It is a North-South transect of 1000 km along the West African climate gradient.
http://www.glowa-volta.de
The Volta Basin is situated in central West Africa. Most of the transboundary basin area, covering about 400.000 km², belongs to Ghana and Burkina Faso. The basin has a 1.000 km long north south spread covering ecozones from sahelian climate and vegetation in the extreme north to rain forested regions in the southern part. The GLOWA Volta Project and its partner projects have installed several meteorological stations within the Volta Basin. Three of these stations are equipped with soil moisture instrumentation transects installed along a catena transect. The soil moisture test sites are organized along the basinwide north south transect to provide data from the different rainfall and vegetation regions. A detailed description of the soil moisture observation network can be found at
www.zef.de/fileadmin/webfiles/downloads/research_docu/2005_1.pdf.

Mauser-AO-3236

An extensive network of different contributing disciplines exists for the Upper Danube catchment in Germany within the framework of the GLOWA-DANUBE project (www.glowa-danube.de). Operational soil moisture and microclimatological measurements are conducted and detailed information about the land surface as well as state-of-the-art process models are available.

6.1.3.11 Long-term in-situ Observations in Europe, China and Africa

Su –AO-3269

Long-term observations and dedicated field experiments in the Netherlands, China and Africa providing coverage of soil moisture observations with repetition and accuracy appropriate for climatological, meteorological and large-scale hydrological studies.

6.1.3.12 Kanpur and Kharagpur Campuses

Singh–AO-3223

The proposal aims to integrate the soil moisture derived from SMOS, SSMI, NCEP and ground data at various places in India. The ground data will be measured at two sites on Kanpur and Kharagpur campuses and also will be acquired from the agrometeorological stations in India over different geological terrains.

6.1.3.13 Germany Network

Vanderborght-AO-3241

The project includes direct comparison of SMOS products with in-situ measurements available from soil moisture measurement networks at several locations in Germany. The contribution to the SMOS cal/val

focuses on the accurate linking with true values of the water content. The approach consists of choosing a region where the footprint of SMOS covers a representative area element and to regularly sample this element with ground penetrating radar.

6.1.3.14 Midwest Network

Hornbuckle-AO-3246

Dr. Michael Cosh, USDA ARS Hydrology and Remote Sensing Laboratory, is establishing a permanent soil moisture network around the site of the Iowa State University campus. There is an opportunity to integrate the measurements made at ISU validation site with the measurements of his soil moisture network. This integration will result in an ability to measure surface soil moisture routinely, year-round, for an area of approximately 8 km by 16 km, approaching the dimensions of a SMOS pixel. When the remote sensing validation site has been established in 2007, data from the site will be freely available via the web.

6.1.3.15 Finland Network

Hallikainen-AO-3281

The Sodankyla NorSEN soil moisture test site represents the northern boreal forest zone and it is the northwestern extension of the vast Eurasian taiga belt. The soil moisture test site will be equipped by 2007 with a number of permanent soil moisture sensors over a large area in order to provide continuous soil moisture information. NorSEN is a project that contains altogether 16 participants from Finland, Sweden and Norway. The project started in February 2005 and will last until the end of year 2007. The main aim of this project is to build a coordinated regional network of satellite data validation and application sites in Northern Fennoscandia, for terrestrial, marine, hydrological and atmospheric key parameters for environmental monitoring in the Arctic and sub-Arctic regions.
The test sites in southern Finland employ soil moisture measurements by the Geological Survey of Finland. These data are accompanied by data from transferable soil moisture meters.

6.1.3.16 Caatinga Network

Martins-AO-3934

The soil moisture and temperature sensors network was designed to collect data on an hourly basis. The data will also be transmitted hourly by cell phone to FUNCEME headquarters in Fortaleza, and will be made available through FUNCEME website to the whole SMOS community during the SMOS experiment (Fall 2007 – Summer 2010). The atmospheric data collected by the automatic weather station, located in the region, will also be made available.
The network will be used to obtain a reliable estimate of the average and variance of soil moisture within a single satellite pass (MIRAS L-band 1.4 GHz) with footprint scale of about 50 square kilometers. Efforts will be made to obtain a nominal distance of 8-10 km between point measurements. This project will be funded by FUNCEME.

6.1.4 MODELS

The models described below have been identified for use by the land validation team. They will be used to compute either soil moistures (and perhaps any other SMOS product) to be compared with those derived by SMOS or brightness temperatures to be compared with those measured by SMOS.
Although these models will most probably cover a wider range of scientific issues than simply SMOS validation, the short description provided below covers only the model's contribution to the land validation team objectives.

6.1.4.1 SAFRAN-ISBA-MODCOU and ALADIN

Operational models at Meteo-France produce surface and root-zone soil moisture to compare with SMOS products. SIM is a coupled model composed of the ISBA surface scheme and of the distributed hydrological model MODCOU. ALADIN is a spectral limited area version of Meteo-France operational model ARPEGE. It is used to compute a forecast for a specific region only, whereas ARPEGE predicts weather for the entire globe.

Calvet–AO-3168

The assimilation of meteorological observations of air temperature and humidity measured at 2 meters is used operationally at Météo-France to initialise soil moisture in the global ARPEGE and in the limited area ALADIN NWP models. This method has proved its efficiency to improve meteorological surface fluxes (latent and sensible) on large geographical domains (the globe, Europe) but in general, it is considered that the realism of the resulting soil moisture is not sufficient for hydrological applications. Nevertheless, it is interesting to compare the SM “seen” by the atmosphere with the SMOS soil moisture products.

Météo-France has developed an operational tool permitting a real-time monitoring of the soil-vegetation water fluxes, for use in hydrology. This tool is called SIM (Safran-Isba-Modcou) and has been operational since 2003. Remote sensing data are used in SIM through the ECOCLIMAP land use database but no remote sensing data are assimilated in SIM at this stage. On the other hand, SIM makes full use of in-situ data. For real-time applications, the atmospheric variables required to drive the system are derived from the operational automatic network of ground stations of Météo-France. The simulations are regularly consolidated by using the non-real time precipitation measurements (the time series are reprocessed by using this additional information). An operational version of SIM is now available over France. A by-product of SIM is soil moisture (surface and root-zone). The root-zone soil wetness index (SWI) map over France is available on the Internet (http://www.eaufrance.fr/docs/bsh/, starting in April 2005). The surface soil moisture simulated by SIM should correlate well with the SMOS estimates.

The ISBA-A-gs model of Meteo-France is able to simulate the surface fluxes (water, heat, CO2), the soil moisture and the vegetation biomass, for different levels of nitrogen availability.

Zribi–AO-3274

The project will perform comparisons between surface soil moisture retrievals from SMOS measurements and operational Météo-France soil moisture products provided by the SIM (Safran-Isba-Modcou) procedure. The SIM product provides near real-time gridded soil conditions (temperature and moisture) over France (8x8 km2 resolution), using both meteorological measurements obtained over the whole country and outputs of the french weather forecast model ARPEGE. Airborne soil moisture measurements offer probably the best criterion to validate (or invalidate) SIM products.

Kaihotsu-AO-3211

The Advanced Regional Prediction System ARPS elaborated by the Center for Analysis and Prediction of Storms at the University of Oklahoma was chosen for this study as a mesoscale prediction model because it includes a land surface scheme that can reproduce surface fluxes exchanges, and a cloud microphysics module that describe precipitation development. It consists of four packages: an atmospheric module, a land surface scheme, a radiation package and parameterization of cloud microphysics package.
The land surface scheme originally included in ARPS is the ISBA (Interaction between Soil, Biosphere, and Atmosphere) developed by Noilhan & Planton (1989). Considering the improvement of soil moisture and fluxes estimation, the revised Simple Biosphere Model 2: SiB2 (Sellers et al., 1996) was chosen as an alternative to the ISBA. In fact the SiB2 is a dual-source model in which fluxes are originating from soil surface and from vegetation canopy. It incorporates simple representations of vertical soil moisture transport, plant-controlled transpiration, interception, evaporation, infiltration, and sensible and ground heat fluxes

through physically-based mechanisms. SiB2 includes three soil layers: a surface soil layer of a few centimeters, which acts as a significant source of direct evaporation when moist; a root zone, which is the supplier of soil moisture to the roots and accounts for transpiration; and a deep soil layer, which acts as a source for hydrological base flow and upward recharge of the root zone. Moreover SiB2 can handle satellite data to specify time-varying phenological properties (LAI, FPAR).

LopezBaeza-AO-3252

The current SM products generated by the operational HIRLAM system will be compared against in-situ data provided by the VAS. The current SM product is based on the ISBA surface scheme for the parameterization module and on an Optimal Interpolation (OI) scheme for the assimilation of SM. The validation will also be extended to aircraft L-band Tb (eventually) and to the SMOS SM product when available.

6.1.4.2 Hydrological Model of Soil Moisture

Validation of SMOS products comparing with forward modelling of brightness temperature and hydrological modelling of soil moisture.

Friesen–AO-3280

The objective is to produce a spatially distributed soil moisture monitoring system operating on a monthly time scale. This will be input into a system of data assimilation schemes that integrates models as well as ground observations and remotely sensed data. Specifically, SMOS product will be used to update soil moisture fields in WASIM (hydrological model) and MM5 (climatological model).
To ensure an easy implementation to climatological and hydrological models, the final product will be embedded into the GLOWA Volta Project modeling framework. Main links will therefore be established with the MM5 regional climate model and the WASIM hydrological model.
Modeled soil water contents and fluxes for different sub-basins of the Volta Basin will then be used to validate SMOS soil moisture estimates.

Jackson-AO-3221

Hydrologic modeling will generate soil moisture products at larger (basin-wide and continental) scales using assimilated data independent of SMOS data.

Walker-AO-3219

Simulated surface soil moisture by a distributed hydrological model will be used together with a geostatistical procedure to produce high-resolution surface soil moisture maps.

Su-AO-3269

The project will determine surface soil moisture (SM) and assimilate surface SM into a hydrological model to derive root SM. This approach uses microwave data to infer near surface SM which must be translated into SM information in the entire root zone via data assimilation. For this purpose a physically based hydrological model is necessary. The candidate is the VIC (Variable Infiltration Model) developed by the University of Washington and Princeton University via Prof. Eric Wood.

Marczewski-AO-3275

The project includes the hydrological model, CoupModel, for the region Polesie-Podlasie.
The institute IA PAS, Lublin (B. Usowicz and J. Lipiec) agreed a scientific cooperation between the polish academy of sciences and the royal swedish academy of agriculture and forestry for a polish-swedish joint research project in years 2007-2009, represented by Per-Erik Jansson (Royal Institute of Technology, Land

and Water Resources Engineering, Division of Environmental Physics, 10044 Stockholm, Sweden Tel: +46-8-790 82 86) on "Model of water and heat flows in relation with soil management". Soil water and thermal properties play an important role in the surface-energy partitioning and resulting water and temperature distribution. The properties influence the microclimate for plant growth and can be largely modified by soil management and land use practices.
In order to improve the understanding of how the management and land use modify the water and thermal processes, modelling is required.
In this research project, the CoupModel is used for prediction of soil water and temperature distribution developed by the Swedish team and statistical-physical model enabling predicting thermal properties developed by the Polish team. Combination of both modelling approaches in this project would provide substantial synergy.
The goals of the cooperation are:
to develop new modelling approaches for predicting water and thermal regimes,
to determine how soil management practices (soil tillage, compaction, mulching) influence water and temperature distribution in soil.
The partners aim comparing measured and predicted temperature and water content using CoupModel without and with statistical-physical model and attempt to derive new modelling approach combining both models.

DeJeu–AO-3238

Land Surface Microwave Emission Model (LSMEM) will be used to assimilate microwave brightness temperatures. The LSMEM is based on existing methodologies to retrieve soil moisture and vegetation optical depth from passive microwave signals and is an improved version of the proposed SMOS microwave emission model.
The basis of LSMEM will be the omega-tau zero order transfer model as the radiative transfer model, because this model has been selected for routine processing of global scale SMOS data.
The omega-tau model needs several input parameters to estimate brightness temperature including vegetation temperature, single scattering albedo, effective temperature of the emitting soil surface layer, soil surface emissivity, and vegetation transmissivity. The vegetation transmissivity will be modelled using a vegetation opacity model. The opacity model of De Jeu et al. (2006) will be used. This model is a refined version of the model of Jackson and O'Neill (1990) and uses both the internal vegetation water content and the external vegetation water content (e.g. dew and intercepted water) to model the vegetation transmissivity. De Jeu et al. (2006) showed that dew has a significant effect on the opacity of the vegetation and needs to be taken into account. SMOS will observe the Earth surface when dew is most likely, between 6-8 AM, which makes the use of such a model an obvious choice.
The surface emissivity will be estimated with the coherent air to soil transition model of Schneeberger et al. (2004) in combination with the dielectric mixing model of Wang and Schmugge (1980). This air to soil transition model is physically based and considers the surface as a transition layer with thickness h. It is a state of the art model to describe surface roughness. The temperature of the emitting layer will be estimated with the refined version of the effective temperature model of Choudhury et al. (1982).

Martinez-Fernandez–AO-3230

It will be possible to compare in-situ measurements for the proposed zone of validation with the final SMOS products and to compare brightness temperatures measured with SMOS and those obtained with the emission models used.
To validate the brightness temperature, the project shall use currently available models of radiation emission and will test several different parameterizations according to the in-situ measurements carried out at the surface and in concordance with the cover and distribution of the soil.
It is also necessary to point out that the comparison of final products will not be immediate and will require an intermediate step using algorithms with which to extrapolate individual measurements to obtain averages of more extensive areas, representative at SMOS scales. With these surface values at greater scale, statistical techniques will be used to identify possible deviations in order to search for possible solutions for their

correction within the algorithm in general. Some of these techniques have characteristics in common with those used for the comparison of data from other earth observation systems such as ASCAT, which will also be of use in this context.

Grippa–AO-3257

An intercomparison experiment of the land surface models from local sites to meso and regional scales will be held in the context of AMMA. The models will be forced by a relevant forcing and a parameter database that is built in the context of AMMA project, from an optimal combination of space borne and ground based measurements.

Magagi-AO-3268

The modelling of SMOS brightness temperature will be performed using a first-order radiative transfer model in Tau and Omega. It will be assumed that the vegetation optical thickness Tau is polarisation dependent and at L band the single scattering albedo Omega. Besides, considering SMOS mission overpasses at 06 AM local sun time, the assumption Tv = Ts (Ts and Tv are soil and vegetation temperatures, respectively) is justified. Naturally, SMOS pixel (~ 35 km resolution) appears as inhomogeneous so that the vegetation fractional cover is needed over sparse canopy. The project will work on the ratios between H and V polarisations brightness temperatures. Therefore, assuming vegetation fractional cover and soil roughness are determined from ancillary data, the above assumptions lead to three unknowns: soil moisture, TauH and TauV.

6.1.4.3 Forest Model

Paloscia-AO-3250

Forests will be described by using radiative transfer models.
Simulations of emission from forests will be carried out by using a first order discrete element radiative transfer model, which describes a forest as a two-layer medium (trunks and crowns) over a rough interface (soil).

Magagi-AO-3268 The project includes some modelling of the boreal forest (North Canada).

6.1.4.4 Distributed Land Surface Process Model

Mauser–AO-3236

PROMET model (SVAT) together with earth observation data will provide reference datasets for the validation of SMOS soil moisture products. There will be (have to be deployed) a network of continuous soil moisture records using TDR to directly validate SVAT model results at local scale. Comparison between SMOS data and simulation results will be made for soil moisture and brightness temperature.

The PROMET model (PRocess-Oriented Multiscale EnvironmenTal Model) is a raster based, deterministic, physically based SVAT model. The processes within the soil-vegetation-atmosphere continuum are simulated in a multi-layer scheme, covering all relevant energy and mass fluxes. It consists of coupled sub-models which describe the flow of water in the soil-plant atmosphere system, vegetation development, nitrogen formation and transport, soil temperature and agricultural management practice. PROMET provides open interfaces for the integration of remote sensing data and it has been shown to provide reliable data series for remote sensing studies and data assimilation purposes.

6.1.4.5 HIRLAM, CHJ, SEPS

LopezBaeza–AO-3252

The project will adapt the SMOS processing simulator SEPS, the operational HIRLAM (High Resolution Limited Area Model) system and the CHJ (Confederacion Hidrografica del Jucar) hydrological model to the VAS reference area to develop robust interpolation tools to obtain reliable independent large area integrated SM values as reference for SMOS product validation.
Basically, the methodology consists of the development of a strategically designed ground-based SM measuring network defined over a reasonable homogeneous area of about the size of a SMOS pixel, and the use of different reliable models such as the meteorological HIRLAM, the CHJ hydrological model, and the SMOS End-to-End Performance Simulator (SEPS).

6.1.4.6 ALEX

Hornbuckle–AO-3246

The Atmosphere Land Exchange (ALEX) model will be used to supplement experimental measurements of dew and intercepted precipitation and to analyse observed and modelled brightness temperatures.

6.1.5 ASSIMILATION

Data assimilation techniques are proposed for the validation of SMOS product in different ways. Data to assimilate and models used for assimilation have been identified for use by the land validation team. Although these models will most probably cover a wider range of scientific issues than simply SMOS validation, the short descriptions provided below only cover the contribution to the land validation team objectives.

6.1.5.1 SAFRAN-ISBA-MODCOU & ALADIN

Calvet–AO-3168

Assimilation will be used to characterise and reduce the bias between SMOS products and the models (SIM and ALADIN). A method to assimilate remote sensing products in ISBA-A-gs was designed and evaluated based on a field campaign devoted to the assimilation of multi-spectral satellite data. The 2D-VAR assimilation system was implemented in a near-operational software. The 2D-VAR system will be applied to South-Western France. EO-derived LAI (Leaf Area Index) will be assimilated together with SMOS brightness temperatures and/or SM products, in order to analyse the above-ground biomass and the root-zone soil moisture. The resulting simulations of LAI, biomass and fluxes of water, heat and CO2 will be validated by using the in-situ observations of the SMOSMANIA network.

6.1.5.2 Upscaling Soil Moisture with Assimilated Data

Jackson–AO-3221

The models used can be land-surface hydrologic models or more sophisticated surface-atmosphere coupled models. The models can operate at various time and space scales, and with varying schemes for data assimilation. Key parameters at the model grid scale, such as precipitation and surface net radiation, depend on the input data quality and parameterizations of the models, and their errors can be difficult to assess.
Thus, model output fields will be used mainly for consistency checking of the spatial and temporal patterns of SMOS-derived soil moisture rather than for quantitative validation of the soil moisture accuracy.
A sequential data assimilation strategy will facilitate the integration of SMOS surface soil moisture retrievals into a regional-scale root-zone soil moisture modeling system over agricultural regions of the United States.

Mauser-AO-3236

The project intends to develop an interface for the assimilation of SMOS data into a land surface process model and assess the potential of improving the results of the SVAT model using SMOS data.

6.1.5.3 Assimilation of SMOS Brightness Temperature into HIRLAM

Lopez-Baeza–AO-3252

The project includes the assimilation of SMOS brightness temperature into the operational HIRLAM system through the recently implemented and tested variational surface assimilation module developed in the ELDAS project framework.
The current SM product is based on the ISBA surface scheme for the parameterization module and on an OI scheme for the assimilation of SM.
Recently, a new variational surface assimilation module has been implemented and tested during the ELDAS project. This new module is the adequate frame to assimilate satellite data (either IR or MW) containing information on SM. The project intends to incorporate to the current code the corresponding observation operator for the land surface MW emissivity and pave the way for the direct assimilation of TB within the HIRLAM system.

6.1.5.4 Assimilation of SMOS Land Products to Derive Root Zone Soil Moisture

Grippa–AO-3257

A component of the project concerns the assimilation of the SMOS products in soil-vegetation-atmosphere-transfer schemes to retrieve the root zone soil moisture at both regional scale and SMOS pixel size. In coordination with activities conducted over the Murray Darling Basin (related proposed project of disaggregation of SMOS data at the catchment scale and assimilation into distributed hydrological models in Australia), disaggregation of SMOS soil moisture products will be investigated from multispectral assimilation.

Walker–AO-3219

One of the objectives is to test disaggregation and data assimilation techniques based on existing radiative transfer models and distributed hydrological models. The distributed surface soil moisture estimate obtained by the disaggregation algorithm will be assimilated to retrieve local-scale root-zone soil moisture.

Su–AO-3269

The project will determine surface soil moisture (SM) and assimilate surface SM into a hydrological model to derive root SM. This approach uses microwave data to infer near surface SM which must be translated into SM information in the entire root zone via data assimilation. For this purpose a physically based hydrological model is necessary. The assimilation approach will follow the one described in Troch et al. (2003).

6.1.5.5 Global Land Data Assimilation System at NASA

Robock–AO-3227

It will lead to more accurate reanalysis and forecast simulations by numerical weather prediction (NWP) models. Specifically, these systems will reduce the errors in the stores of soil moisture and energy which are often present in NWP models and which degrade the accuracy of forecasts.

Data assimilation of satellite-based soil moisture estimates is a core capability at NASA/GSFC, and their research into the problem has been substantial, cutting-edge, and well received throughout the world. The present proposal provides an opportunity to extend this capability by implementing soil moisture data assimilation for SMOS products, including evaluation and testing against in-situ data. The opportunity to apply GSFC data assimilation methodology in a testbed environment will undoubtedly enhance the capabilities for SMOS.

The European Centre for Medium-Range Weather Forecasting (ECMWF) is the premier weather forecasting organization in the world. By the launch of SMOS, they will be ready to include SMOS observations in their Integrated Forecasting System. Using a microwave radiative transfer model with input from the operational analysis system, the first guess field from the model will be compared with top-of-atmosphere brightness temperatures observed by SMOS and then the SMOS observations will be assimilated into the analysis system. This work will be done by ECMWF and I propose to use my observations to evaluate their simulations of the soil moisture field, including root zone soil moisture. Experiments will be conducted with and without SMOS assimilation, so its impact will be evaluated directly.

6.1.5.6 Brightness Temperature Assimilation for Validation of SMOS Land Products

DeJeu–AO-3238

Footprint brightness temperature will be assimilated using FLUXNET data in combination with a land surface model (e.g. the Common Land model (CLM) of Zeng et al. 2002) coupled with the LSMEM and high resolution satellite vegetation and temperature products (i.e the vegetation products of MODIS and MERIS and the Land Surface Temperature product of AATSR). The land surface model will be forced by observed hourly gauge/radar precipitation and FLUXNET data to derive soil moisture. The assimilation routine will take into account both model and measurement uncertainties and will be used to investigate the impact of heterogeneity within the footprint. The effects of variations in spatial variability of important geophysical parameters (i.e. soil moisture, temperature and vegetation) on the difference between assimilated and observed footprint brightness temperature will be analyzed. The performance of the assimilation will be compared to X-band (TRMM TMI), C-band (AQUA AMSR-EOS) and L-band (SMOS) observations.

6.1.5.7 Assimilation in Weather Forecast Model

Magagi–AO-3268

Realistic representation of soil moisture has been shown to improve both regional and global weather forecast models. Therefore, the project will include SMOS brightness temperature (L1b) into a land data assimilation system to provide soil moisture initial conditions for atmospheric model, and examine its impact on numerical weather prediction.

6.1.5.8 Assimilation into WASIM & MM5

Friesen–AO-3280

The expectation is that SMOS data will become part of a monitoring system for soil moisture availability and distribution within the Volta Basin. The final product will be assimilated in the hydrological and regional climate models developed within the GLOWA Volta Project. Specifically, SMOS will be used to update soil moisture fields in WASIM (hydrological model) and MM5 (climatological model).
The SMOS product will be assimilated in soil moisture models, together with ground-based observations and auxiliary satellite observations. Models, satellites and ground observations will together constitute a soil moisture monitoring system for the Volta Basin. The assimilation scheme uses the expectation maximization algorithm as described in detail by Amisigo and van de Giesen, 2005
SMOS soil moisture estimates will be used at two stages. One task is to initialize the model soil water content with SMOS soil moisture estimates. Sub-basin SMOS soil moisture estimates for the Volta Basin will be used as initial water content. The second task is to update the model soil water content during the modeling process. This will also be applied at sub-basin level at fixed time intervals (e.g. decadal, monthly).

6.1.5.9 Assimilation into Hydrological and Meteorological Models

Kaihotsu-AO-3211

The system relies on a mesoscale model as atmospheric part, a Land Surface Scheme as a model operator, a Radiative Transfer Model as an observation operator, satellite data and the Simulated Annealing method for minimization.
1) The atmospheric driver:
The Advanced Regional Prediction System (ARPS) elaborated by the Center for Analysis and Prediction of Storms at the University of Oklahoma was chosen for this study as a mesoscale prediction model because it includes a land surface scheme that can reproduce surface fluxes exchanges, and a cloud microphysics module that describe precipitation development. It consists of four packages: an atmospheric module, a land surface scheme, a radiation package and parameterization of cloud microphysics package.
2) The land surface scheme (Model Operator):
The land surface scheme originally included in ARPS is the ISBA (Interaction between Soil, Biosphere, and Atmosphere) developed by Noilhan & Planton (1989). Considering the improvement of soil moisture and fluxes estimation, the revised Simple Biosphere Model 2: SiB2 (Sellers et al., 1996) was chosen as an alternative to the ISBA. In fact the SiB2 is a dual-source model in which fluxes are originating from soil surface and from vegetation canopy. It incorporates simple representations of vertical soil moisture transport, plant-controlled transpiration, interception, evaporation, infiltration, and sensible and ground heat fluxes through physically-based mechanisms. SiB2 includes three soil layers: a surface soil layer of a few centimeters, which acts as a significant source of direct evaporation when moist; a root zone, which is the supplier of soil moisture to the roots and accounts for transpiration; and a deep soil layer, which acts as a source for hydrological base flow and upward recharge of the root zone. Moreover SiB2 can handle satellite data to specify time-varying phenological properties (LAI, FPAR).
3) The radiative transfer model (Observation Operator):
Based on the emission behaviour of dry soil and liquid water in the microwave region, a physically-based radiative transfer model was developed by Koike et al. (2000). This model includes the total emission and attenuation from the land surface, vegetation canopy, and rainfall drop.
4) The minimization scheme:
A heuristic optimization approach called Simulated Annealing (SA), which is capable of minimizing the cost function without using adjoint models is used in this system. SA allows avoiding problems due to strong non-linearity and discontinuity, in finding the global minimum in the hilly structure of the cost function. It is based on an analogous approach to the metal annealing in thermodynamics.

6.1.6 COMPARISONS

Satellites already in operation provides in some cases information that could be used for validation of SMOS products by comparison. Although in most cases direct data comparison is not feasible, at least it will be possible to correlate outputs at large scale in order to get some sort of comparison. Data from other microwave sensors on other satellites could provide independent check for algorithm performance. They will also provide independent information on surface temperature, vegetation cover, brightness temperature and radar backscatter that could be used to determine accuracy of the SMOS brightness temperatures and the effects of temperature, vegetation, topography and roughness on the SMOS soil moisture retrievals.

6.1.6.1 Comparison with Advanced Microwave Scanning Radiometer (AMSR)

The EOS AMSR is a one of the six sensors aboard AQUA. AMSR-EOS is a passive microwave radiometer, modified from the Advanced Earth Observing Satellite-II (ADEOS-II) AMSR, designed and provided by JAXA. It observes atmospheric, land, oceanic, and cryospheric parameters, including precipitation, sea surface temperatures, ice concentrations, snow water equivalent, surface wetness, wind speed, atmospheric cloud water, and water vapor.

DeJeu–AO-3238

The AQUA AMSR-EOS soil moisture products will be derived using an inverted version of the LSMEM. An error propagation analysis will be applied to estimate the uncertainty range of these soil moisture products all around the globe. A comparison study between the different soil moisture products will be carried out.

Jackson–AO-3221

Both the AQUA and ADEOS-II AMSR projects produce global soil moisture data products at a resolution comparable to the SMOS products. It is expected by the time of the SMOS launch that the AMSR teams will have a good understanding of their algorithm performance under various conditions and that for many of these conditions the accuracy will be good. Comparisons over validation sites and extended uniform regions will be performed.

Kaihotsu–AO-3211

The project will make a comparison with AMSR-EOS in the area of the Mongolian Plateau.

Friesen-AO-3280

For biomass detection available MODIS visible and infrared products, as tree vegetation, sub-pixel soil/vegetation ratio, NDVI, AMSR-EOS microwave polarisation indices, and growth models will be used. Over bare soil, the detection of land surface temperature (LST) via MODIS, MSG and AMSR-EOS and brightness temperature via AMSR-EOS will give information on soil moisture.

Paloscia-AO-3250

The comparison of SMOS data and products with AMSR-EOS will be performed for specific targets: the Antarctic plateau at Dome-C again and a series of forest areas selected in different climatic regions of the globe and already investigated with microwave passive (SSMI) and active (ERS-WindScatt) sensors. The synergy with multi-frequency/multi-sensor data from AMSR-EOS is a focal point. For this purpose, inversion multi-frequency/multi-angle algorithms based on statistical and iteration approaches have been developed. Moreover, the availability of global high-resolution data allows the comparison of model simulations of heterogeneous pixels and observations from satellite data. This can be tested at C-band using AMSR-EOS and extrapolated to the SMOS footprint size and wavelength.

Grippa-AO-3257

AMSR microwave passive measurements have been providing soil moisture products since 2002.

Magagi-AO-3268

The availability of a dynamic Soil Water Index (SWI) developped from SSMI data complements the current work on soil moisture estimation from AMSR-EOS data. The soil moisture derived from SMOS mission will be compared with the SWI and with soil moisture estimation using AMSR-EOS data.

6.1.6.2 Comparison with Meteosat Second Generation (MSG)

MSG is a two-satellite operational service, like the previous Meteosat system, with one operational satellite and one satellite available in orbit as a spare. Each satellite has an operating lifetime of seven years. The first satellite, Meteosat-8, was launched on 28 August 2002 and became operational in January 2004 at 3.3°W. The images taken by Meteosat-8 are rectified to a sub-satellite point of 0°. In a transition period, Meteosat-7 and Meteosat-8 will operate in parallel. In this period Meteosat-7 remains in its operational position at 0°.
Following launch on 21 December 2005 of MSG-2 (to be known as Meteosat-9 in operation), it will take over prime operations at 0°. Meteosat-8 will operate as backup.
The SEVIRI (Spinning Enhanced Visible and InfraRed Imager) radiometer is the main element of the MSG satellites. It scans the Earth surface sufficiently quickly to permit a repeat cycle of 15 minutes, using spectral

bands that can provide daylight images of the weather patterns, plus atmospheric pseudo-sounding and thermal information.
MSG satellites also carry the Geostationary Earth Radiation Budget (GERB) instrument. This instrument monitors the Earth radiation budget at the top of the atmosphere allowing short- and long-wave radiation calculations, essential for understanding the Earth climate balance.

Mauser–AO-3236

As MSG has the potential to provide fields of land surface temperature (LST) with a high temporal resolution, it might be suitable for a cross-validation of the surface temperature data used for the inversion of SMOS soil moisture products. The PI operates an MSG receiving station for this purpose. The LST retrieval algorithm is not implemented yet and will have to be developed if needed.

Friesen-AO-3280

Surface temperature via infrared remote sensing from either MODIS or MSG is used. Clouded conditions will be derived via a cloud model or through microwave remote sensing calibrated via MODIS or MSG. On the ground, radiation measurements in combination with MSG cloud information will be used to calibrate the cloud model. Over bare soil, the detection of land surface temperature (LST) via MODIS, MSG and AMSR-EOS and brightness temperature via AMSR-EOS will give information on soil moisture.

6.1.6.3 Comparison with Advanced Synthetic Aperture Radar (ASAR)

The Advanced Synthetic Aperture Radar (ASAR) onboard ENVISAT (launched in may 2002), operating at C-band, ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI. It features enhanced capability in terms of coverage, range of incidence angles, polarisation, and modes of operation. This enhanced capability is provided by significant differences in the instrument design: a full active array antenna equipped with distributed transmit/receive modules which provides distinct transmit and receive beams, a digital waveform generation for pulse "chirp" generation, a block adaptive quantisation scheme, and a ScanSAR mode of operation by beam scanning in elevation.

Mauser–AO-3236

Comparisons of SMOS soil moisture products with soil moisture products derived from ENVISAT ASAR data shall be made.

Wagner–AO-3233

The Technology University of Vienna (TU Wien) has developed a system for global processing of ENVISAT ASAR Global Monitoring (GM) mode data. The ASAR GM data have a spatial resolution of 1 km and temporal coverage is weekly or better in many parts of the world. Currently, TU Wien is developing a soil moisture information system for southern Africa within the ESA funded SHARE project. The two GM products are scaling layer and experimental soil moisture products. More information can be found under http://www.ipf.tuwien.ac.at/radar/. Depending on available field sites, TU Wien will process the ASCAT GM data also over other parts of the world and compare them to the SMOS level 2 soil moisture data.

Zribi–AO-3274

During the last decades, different methods have been developed to estimate continental surface parameters with radar data. The project proposes to use radar data for different research questions:

- Comparison between airborne radiometer CAROLS and radar estimation of soil moisture (based on ENVISAT/ASAR and STORM data);
- Analysis of the contribution of radar data to estimate surface roughness;
- Discussion of disaggregation of SMOS data with radar high resolution measurements.

LopezBaeza-AO-3252

High-resolution SM maps will be obtained from C-band microwave data. SAR images are sensitive to SM, although surface roughness and vegetation cover produce a similar effect on backscattered radar signals. It is very convenient to analyse vineyard and matorral, the major land uses in the VAS area, and it is possible to improve the retrieval of SM by using different polarizations and incidence angles.

Magagi-AO-3268

Over agricultural areas, soil roughness will be estimated from ENVISAT-ASAR data and then validated with ground measurements made accordingly to agricultural practices, after rainfall events, before and after irrigation.

Su-AO-3269

Energy balance method will be applied to VIS/NIR/TIR data to derive relative soil moisture in the rooting zone and will be compared to soil moisture products of SMOS using a cascade of up-scaling approach, from ASAR higher resolution to SMOS grid.

Patel–AO-3284

In the first stage upscaling from field level measurement to spatial scale using multiparametric satellite SAR data will be achieved by incorporating the effect of surface roughness, soil type and crop cover. In the second stage upscaling of the SAR derived spatial soil moisture maps at 100-meter scale to 25x25km grid will be attempted.

6.1.6.4 Comparison with Special Sensor Microwave Imager (SSMI)

The SSMI is a conically-scanning microwave radiometer with channels at 19, 22, 37 and 85 GHz. All measurements are obtained with dual polarization, except the 22GHz, which is only vertically polarized. The microwave images can "see" through most clouds. The SSMI sensors are located on the NOAA DMSP polar orbiting satellites.

Singh-AO-3223

The soil moisture deduced from SMOS data will be used to generate weekly and monthly images which will be superimposed over NDVI map generated from ERS backscattering coefficients, brightness temperature data from SSMI data for different frequencies and two polarizations, over different geological terrains and soil types in India.

Magagi-AO-3268

The dynamic Soil Water Index (SWI) developed from SSMI data complements the current work on soil moisture estimation from AMSR-EOS data in various agricultural landscapes and crops of Canada.

6.1.6.5 Comparison with METOP ASCAT

Compared to the scatterometers on the ERS satellites, which view only a single swath, ASCAT will realise enhanced coverage from its use of dual swaths.
ASCAT's two sets of antennae provide two 550 kilometres wide swaths. Each swath is centred at an inclination of 36° to the left and right of the satellite ground track, resulting in a gap of about 650 km between the two swaths. This so-called gap, however, is observed during later obits, achieving almost global coverage in five days.

From MetOp's polar orbit 800 kilometres above the surface of the Earth, ASCAT makes the observations for each swath sequentially. Each point on the ground is viewed three times, first by the fore-beam, then the mid-beam and finally by the aft-beam. One cycle is completed for one swath before the cycle begins for the other swath. Each beam takes 35.4 milliseconds, totalling 0.21 seconds to complete one transmit-receive cycle for all the six antennae, i.e. both swaths.
In its nominal operation, the instrument will yield wind vector measurements in 50 km resolution cells. It will be able of measuring wind speeds in the range of 4-24 m/s, with an accuracy of 2 m/s or 10% and wind direction in the range of 0-360° with an accuracy of 20°.

Martinez-Fernandez–AO-3230

The Institute of Photogrammetry and Remote Sensing (IPF) of Vienna University of Technology has a long background in research into microwaves remote sensing, in particular in the estimation of soil moisture and other hydrological variables (flood, wetland, ice, thaw). Currently, EUMESAT is developing a processor (near-real-time) for the generation of soil moisture data (level 2) from METOP ASCAT data. It is foreseen that this software will be implemented in a centralized fashion in EUMESAT, which will afford global data on soil moisture (25 km) for users 135 minutes after the satellite pass. Also investigated is the use of ENVISAT ASAR data (Global Monitoring Mode) to provide information about soil moisture. Currently, the IPF group is developing, in an ESA project, a system to provide data on soil moisture (1 km) for users in South African countries.

The METOP ASCAT and the ENVISAT ASAR are active microwave systems that operate at wavelength of 5.7 cm (C band). It is expected that SMOS will provide even more precise information about soil moisture since it operates at a much longer wavelength (L band). SMOS also uses a passive design that is believed to have more advantages with respect to the effects of soil roughness on the microwave signal. SMOS has a spatial resolution similar to that of ASCAT (>25 km).

The data obtained from REMEDHUS will allow the IPF team to validate SMOS and other high-resolution satellite products. This network is ideal because it provides information about a high number of points in the same pixel. This will permit study of phenomena of scale changes in the use of soil moisture data in-situ and from satellites. The results obtained for the validation of ERS scatterometer data from the ground data of REMEDHUS have been published in several works, and mainly in Ceballos et al. (2005).

The specific task of the IPF team in this proposal is the comparison of SMOS data on soil moisture (level 2) with the ground data from REMEDHUS and with a range of other soil moisture products deriving from different satellites. This will afford a better understanding of the content of the information provided by different satellites and methodological approaches. An example is the correlation of soil moisture data provided by the ERS scatterometer with those of three different AMSR-EOS products and with REMEDHUS observations. Recent experiments carried out by the IPF team have shown that the precision of the soil moisture data depends strongly on the recovery algorithm selected, whereas the type of instrument (for example, active or passive in the C band) is less important. In previous works, more significant differences between the three AMSR-EOS products have been seen than between the best results of AMSR-EOS and ERS scatterometer.

One very important aspect in this task will be the incorporation of the information on biomass and soil roughness. This information will allow the IPF team to gain a better understanding of the reasons for the differences (sometimes noteworthy) in the results of the different recovery algorithms.

Wagner–AO-3233

The Technology University of Vienna is currently developing an operational processing chain for processing METOP ASCAT level 2 surface soil moisture products. Already now, TU Wien processes ERS-2 scatterometer level 2 surface soil moisture data (50 km spatial resolution) in a preoperational fashion. The data are available from http://www.ipf.tuwien.ac.at/radar/. As soon as SMOS level 2 products will be

available, TU Wien can use the ERS and METOP level 2 data for direct comparison. Coverage is worldwide. Therefore the comparison can be carried out over different climate regimes and land cover types.

Zribi–AO-3274

METOP/ASCAT will provide soil moisture estimates for 2007-2009 from active measurements. The project proposes to do comparison between SMOS and ASCAT products (proposed by Hydrology SAF) particularly in West Africa (Gourma site).

6.1.6.6 Comparison with Advanced Very High Resolution Radiometer (AVHRR)

The AVHRR is a radiation-detection imager that can be used for remotely determining cloud cover and surface temperature. The term surface can mean the surface of the Earth, the upper surface of clouds, or the surface of a body of water. This scanning radiometer uses 6 detectors that collect different bands of radiation wavelengths.
The first AVHRR was a 4-channel radiometer, first carried on TIROS-N (launched in October 1978). This was subsequently improved to a 5-channel instrument (AVHRR/2) that was initially carried on NOAA-7 (launched in June 1981). The latest instrument version is AVHRR/3, with 6 channels, first carried on NOAA-15 launched in May 1998.

Mauser–AO-3236

An operational processing chain for NOAA AVHRR data exists at the PI lab. The received data are used to derive operationally land surface temperature (LST) and snow covered area (SCA). It is intended to provide these data products to the CAL/VAL team for cross-validation purposes.

Singh-AO-3223 Relation of soil moisture with NDVI derived from NOAA AVHRR data.

6.1.6.7 Comparison with Phased Array L-band Synthetic Aperture Radar (PALSAR)

PALSAR, onboard ALOS, is an active microwave sensor using L-band frequency for cloud-free and day-and-night land observation, and provides higher performance than the JERS SAR. The fine resolution mode is a conventional one. Other modes include the ScanSAR mode, allowing to acquire a 250 to 350 km width (depending on the number of scans) of SAR images at the expense of spatial resolution. This is three to five times wider swath than conventional SAR images.

Kaihotsu–AO-3211

The project will perform not only a cross-validation of soil moisture products but also a cross-calibration between SMOS brightness temperature and PALSAR backscatter radar cross section (RCS) in the study area of the Mongolian Plateau.

Mauser–AO-3236

ALOS PALSAR data should be used to investigate a joint model of active and passive microwave data to derive surface soil moisture. The PALSAR data is intended to provide subpixel informations about the surface variability within a SMOS resolution cell and thus help to improve the retrieval of surface soil moisture. A combined active/passive retrieval model shall be developed.

6.1.6.8 Comparison with S-band radiometer

Pellarin–AO-3261

Correlation between SMOS L-band Tb (30x30km2) and S-band Tb (1x1km2)

6.1.6.9 Comparison with Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes from south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands. The data will improve the understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change.

DeJeu-AO-3238

Footprint brightness temperature will be assimilated using FLUXNET data in combination with a land surface model (*e.g.* the Common Land model (CLM) of Zeng et al. 2002) coupled with the LSMEM and high-resolution satellite vegetation and temperature products (*i.e.* the vegetation products of MODIS and MERIS and the Land Surface Temperature product of AATSR).
The project will use AATSR and MODIS land surface temperature data, MODIS and MERIS vegetation data and precipitation products (e.g. NEXRAD, AMSR-EOS, SSMI, TRMM) in combination with a land surface model to study the effects of internal variations of the important land surface parameters (*i.e.* soil moisture, soil/vegetation temperature and vegetation characteristics) that drive the observed brightness temperature.

Friesen–AO-3280

For biomass detection, available MODIS visible and infrared products, as tree vegetation, sub-pixel soil/vegetation ratio, NDVI, AMSR-EOS microwave polarisation indices and growth models will be used. Surface temperature via infrared remote sensing from either MODIS or MSG is used. Clouded conditions will be derived via a cloud model or through microwave remote sensing calibrated via MODIS or MSG. On the ground, radiation measurements in combination with MSG cloud information will be used to calibrate the cloud model. Over bare soil, the detection of land surface temperature (LST) via MODIS, MSG and AMSR-EOS and brightness temperature via AMSR-EOS will give information on soil moisture.

6.1.6.10 Comparison with Scanning Multichannel Microwave Radiometer (SMMR)

SMMR on SEASAT was a multispectral, dual-polarization microwave radiometer observing at the following frequencies: 6.6 GHz (45.4 mm), 10.7 GHz (28 mm), 18.0 GHz (16.6 mm), 21.0 GHz (14.2 mm), and 37.0 GHz (8.1 mm). Six Dicke-type radiometers were utilized. Those operating at the four longest wavelengths measured alternate polarizations during successive scans of the antenna; the others operated continuously for each polarization. The antenna was a parabolic reflector offset from the nadir by 42º. Motion of the antenna reflector provided observations from within a conical volume along the ground track of the spacecraft. SMMR had a swath width of about 600 km and the spatial resolution ranged from about 22 km at 37 GHz to about 100 km at 6.6 GHz. The absolute accuracy of sea surface temperature obtained was 2 K with a relative accuracy of 0.5 K. The accuracy of the wind speed measurements was 2 m/s for winds ranging from 7 to about 50 m/s. On NIMBUS-7, microwave brightness temperatures were observed with a 10-channel (five-frequency dual polarized) scanning radiometer operating at frequencies of 37 (0.81 cm), 21 (1.42 cm), 18 (1.66 cm), 10.69 (2.8 cm), and 6.6 (4.54 cm) GHz.

DeJeu-AO-3238

The TRMM TMI and SMMR soil moisture products will be derived using an inverted version of the LSMEM. An error propagation analysis will be applied to estimate the uncertainty range of these soil moisture products all around the globe. A comparison study between the different soil moisture products will be carried out.

6.1.6.11 Comparison with RADARSAT SAR

RADARSAT, with a planned lifetime of five years, is equipped with a Synthetic Aperture Radar (SAR). Using a single frequency (C-Band), the RADARSAT SAR has the unique ability to shape and steer its radar beam over a 500 kilometre range. Users can have access to a variety of beam selections that can image swath from 35 kilometres to 500 kilometres with resolutions from 10 metres to 100 metres respectively. Incidence angles range from less than 20 degrees to more than 50 degrees.

Magagi–AO-3268

RADARSAT data are provided in the framework of Tiger Africa project (2005-2007).

Patel-AO-3284

The PI combines steep and shallow incidence angle RADARSAT SAR data for incorporating the effect of surface roughness and crop cover in mapping large area soil moisture. She proposes to validate data of SMOS by upscaling point measurement to the spatial soil moisture map with the help of multiparametric SAR data from RADARSAT SAR and ENVISAT ASAR (100x100 km) to a 4x4 matrix each of 25x25 km.

6.1.6.12 Comparison with Along Track Scanning Radiometer (ATSR)

The Advanced Along-Track Scanning Radiometer (AATSR) is one of the instruments on board ENVISAT (launched in may 2002). It is the most recent in a series of instruments designed primarily to measure Sea Surface Temperature (SST), following on from ATSR-1 and ATSR-2 on board ERS-1 and ERS-2. AATSR data have a resolution of 1 km at nadir and are derived from measurements of reflected and emitted radiation taken at the following wavelengths: 0.55 μm, 0.66 μm, 0.87 μm, 1.6 μm, 3.7 μm, 11 μm and 12 μm. Special features of the AATSR instrument include its use of a conical scan to give a dual-view of the Earth's surface, on-board calibration targets and use of mechanical coolers to maintain the thermal environment necessary for optimal operation of the infrared detectors.

Magagi–AO-3268

The vegetation fractional cover over semi-arid areas will be derived from the vegetation index MSAVI of Qi et al. (1994) computed from ATSR reflectance data corrected for the atmospheric effects using the algorithm 6S of Vermote et al. (1986).

Su-AO-3269 ???
Martins-AO-3934 ???
Walker-AO-3219 ???

6.1.7 SCIENTIFIC ISSUES

The scientific issues listed below have been identified as issues where investigation is needed in order to implement specific models into the retrieval algorithm or in order to better understand microwave emission from specific targets. The following list does not pretend to covert all types of surface but it includes issues where scientific community is particularly interested on.

6.1.7.1 Scaling Issues

DeJeu–AO-3238

Upscaling (e.g. upscaling from ground measurements to SMOS pixel size) has always been an issue in remote sensing research. Our research team has experience in the development of passive microwave retrieval methodologies at both satellite scale and field scale and we believe that using different L- and C-

band field experiments to derive a reliable and consistent emission model is the way to develop a state of the art emission model at satellite scale. The use of different field experiments gives us the opportunity to fully explore the performance of the emission model.

At the moment there are more than 300 FLUXNET sites and many of these sites have soil moisture information. Besides this network the consortium is familiar with other databases, including the global soil moisture data bank of Robock et al (2000), the ARS/USDA databases, and the Oklahoma Mesonet network. At the end we will use several of these databases to validate the microwave emission model. In addition, we will study the effect of footprint heterogeneity by using ancillary high resolution remote sensing products. We will use AATSR and MODIS land surface temperature data, MODIS and MERIS vegetation data and precipitation products (e.g. NEXRAD, AMSR-EOS, SSMI, TRMM) in combination with a land surface model to study the effects of internal variations of the important land surface parameters (i.e. soil moisture, vegetation temperature and vegetation characteristics) that drive the observed brightness temperature. Furthermore, such a study will also give information about the adequacy of the selected FLUXNET sites.

Mauser–AO-3236

The upscaling from ground measurements to SMOS pixel size will be achieved by use of a distributed land surface process model. The model results will be validated at the point scale and the SVAT model will be used to perform an upscaling of the soil moisture fields.

MartinezFernandez-AO-3230

Knowledge of the behaviour of soil moisture and its spatial and temporal distributions provides essential information for climate models and for estimations from remote sensing. For several decades, much attention has been on the spatial variability of the hydrological properties of soils but much less is known about its temporal variability. In recent years, there has been growing interest in analysing the temporal dynamics of the soil moisture content, above all since the publication of the paper by Vachaud et al. (1985). In this work, the authors introduced the concept of temporal stability as the invariable temporal association between spatial location and classic parametric statistical values of a given soil property. The authors demonstrated that certain sampling points are able to express the average behaviour of the whole study zone, whereas others are more characteristic of extreme values (dry or wet). Thus, the temporal stability of soil moisture is an evidence of the temporal persistence of the spatial structure. Different authors have analysed the temporal dynamics of different properties, with special attention to hydrological properties. Jaynes and Humsaker (1989) studied the temporal stability of infiltration and its application to irrigation. Van Pelt and Wierenaga (2001) analysed the temporal stability of the soil matric potential with a view to optimise sampling strategies. Study of the spatial and temporal variability of the soil moisture content has been addressed by several authors, with different aims and different spatial and temporal scales. Examples are Kachanoski and de Jong, 1988; Van Wesenbeeck and Kachanoski, 1988; Jaynes and Humsaker, 1989; Comegna and Basile, 1994; Famiglietti et al. 1998; Grayson and Western, 1998; Gómez-Plaza et al. 2000; Hupet and Vanclooster, 2002; Martínez-Fernández and Ceballos, 2003; Martínez-Fernández and Ceballos, 2005 .

The temporal instability of soil moisture may systematically introduce uncertainty in the data obtained with remote sensing. Amplification of the range of spatial and temporal scales in the analysis of the temporal stability of soil moisture may generate information that could contribute in reducing such uncertainty. As pointed out by Kachanoski and De Jong (1988), hydrological processes operate at different scales and hence the temporal stability of the spatial patterns is also a function of scale.

There has been some debate to know whether variability is greater during dry or during wet periods. Some authors have considered that there is greater stability in dry periods while others consider that variability is greater when the soil contains less moisture. This aspect will be studied in REMEDHUS using the data from the automatic soil moisture measuring stations.

Temporal stability was defined by Vachaud et al. (1985) as the invariable temporal association between spatial location and the classic parametric statistical values of a given soil property. For the analysis of the temporal stability of the soil moisture series, three statistical techniques will be used.

(i) Analysis of the accumulated probability function of the data corresponding to different observations. This aims to see whether a given point maintains its rank in the accumulated probability at different times in the sampling, above all for highly contrasted values of soil moisture.
(ii) The parametric test of relative differences, proposed by Vachaud et al. (1985) permits the graphic plotting of data in order to highlight the differences, in terms of temporal stability, between sampling points.
(iii) The standard deviation of the mean relative difference at each point, as an estimator of temporal variability.

Wagner–AO-3233

Scaling questions will mostly be addressed on the basis of the scaling layer produced from ENVISAT ASAR Global Monitoring (GM) data. This scaling layer is able to tell us how similar or dissimilar a 1 x 1 km^2 large region behaves in time compared to 25 x 25 km^2 large regions as provided by SMOS and ASCAT.

Friesen-AO-3280

In terms of ground truth campaigns collecting point samples for validation, the SMOS resolution is rather coarse. This resolution brings the need for large scale soil moisture information for calibration and validation purposes. Especially in West Africa, an extremely moisture limited region, soil water information plays a vital role in hydrologic and meteorologic modeling that aims towards an improvement of food security. Soil moisture fields obtained via remote sensing have to be validated with ground truth campaigns to provide useful moisture information.
Hydrotope analyses help to ensure statistical spatial validation and to improve sampling schemes for current and upcoming satellite data. In 2005 a first soil sampling ground campaign in the Volta Basin based on a hydrotope analysis was conducted.
Hydrotopes are landscape units with internally consistent hydrologic behavior such as upland areas, slopes and lowland or wetland areas. Earlier results by Flügel (1995) and Park (2001) rely on detailed datasets of elevation, soil type and properties, and land cover. The following hydrotope approach relies on detailed knowledge of local hydrologic processes, and globally available elevation and land cover datasets.
Based on extensive knowledge of the local hydrology of the Volta Basin, hydrotope maps delineating the most prominent hydrotopes within the sampling area are generated using elevation and land cover data.
Hydrotope analysis helps (i) minimizing sampling biases due to oversampling of hydrotope units, and (ii) minimizing the overall variance in sampling schemes.

Participating Teams:
Jackson–AO-3221
Martinez-Fernandez–AO-3230
Wagner–AO-3233
Mauser–AO-3236
Lopez-Baeza–AO-3252
Walker-AO-3219
deJeu–AO-3238
Grippa–AO-3257
Magagi–AO-3268
Su–AO-3269
Friesen–AO-3280
Patel–AO-3284

6.1.7.2 Mixed Pixel

Mauser–AO-3236

The analysis of the mixed pixel problem for the test area will be addressed by a) using simulated brightness temperature datasets for the test area and evaluate the capability to retrieve sub-pixel soil moisture information and b) investigating the potential of using ancillary satellite data to disaggregate soil moisture information. It is intended to combine the passive microwave data with active microwave data for this purpose.

Camps–AO-3254

The cal/val activity will consist in the development of high resolution brightness temperature models suitable to this region with a high spatial and temporal resolution in order to introduce them to the SMOS End-to-end Performance Simulator SEPS and then, to be able to reproduce accurate estimations of the brightness temperature that the sensor will observe, taking into account all the spatial averaging effects (synthetic beam formation, secondary lobes, etc), atmospheric contributions and cosmic and galactic noises. The obtained results with SEPS will be used in order to compare the measurements acquired by the sensor.

1) Acquirement of necessary auxiliary data to model the brightness temperature over the Catalonia region:
- Digital Elevation Model (DEM) of the area with a resolution of 30 x 30 m in order to model the effects of topography in the radiometric signal
- Classification of land uses obtained from CREAF (100 x 100 m)
- Maps of the soil moisture and surface temperature from hydrological models and climatology

The following effects will be taken into account: variation of local incidence angle, variation in atmospheric upwelling and downwelling contributions, atmospheric attenuation, and shadowing by the topography at high incidence angles.
2) Development in SEPS of a brightness temperature generator with high spatial and temporal (as high as possible) resolution with refined models of brightness temperature for the vegetation types of the area.
3) Comparison of the theoretical predictions with the simulator and SMOS level 1c measurements.

Participating Teams:
Mauser–AO-3236
Vanderborght–AO-3241
Lopez-Baeza–AO-3252
Camps–AO-3254
Pellarin–AO-3261
Su–AO-3269
Zribi–AO-3274
Hallikainen–AO-3281
Patel–AO-3284

6.1.7.3 Topography

Participating Teams:
Pellarin–AO-3261
Su–AO-3269
Zribi–AO-3274

6.1.7.4 Disaggregation

Camps–AO-3254

1) Development and implementation of algorithms devoted to pixel disaggregation techniques using the upgraded SMOS End-to-end Performance Simulator with the high spatial resolution brightness temperature generator and the in-situ and satellite data available from ENVISAT and other sensors (AVHRR IR, NDVI,

etc). At a first stage, it is intended to use multi-temporal amplitude SAR imagery information to get soil moisture changes at small scales (e.g. due to rain), and visible and IR imagery to get vegetation information. These informations will be both used in the mixed pixel study and in the disaggregation study. Other satellite information will be used to make the necessary atmospheric corrections.
2) The disaggregation techniques will be tested over an instrumented land site.

Participating Teams:
Walker–AO-3219
Lopez-Baeza–AO-3252
Camps–AO-3254
Grippa–AO-3257
Zribi–AO-3274

6.1.7.5 Impact of auxiliary data

Mauser–AO-3236

The impact of different surface characterizations on the surface parameter retrievals can be assessed, using information from the global database, used for the operational inversion of SMOS data and compare it against the much more detailed land surface information, being available for the Danube test site. A direct comparison of inversion results, obtained from both parameterizations will reveal the impact of the ancillary information quality on the retrieval within the specific test site.

Participating Teams:
Walker–AO-3219
Robock–AO-3227
Mauser–AO-3236
Grippa–AO-3257
Friesen–AO-3280

6.1.7.6 Forest

Participating Teams:
Vanderborght–AO-3241
Pellarin–AO-3261
Zribi–AO-3274
Hallikainen–AO-3281

6.1.7.7 Dew and Interception

Participating Teams: Hornbuckle–AO-3246

6.1.7.8 Agricultural Areas

Participating Teams: Magagi–AO-3268

6.1.8 SUMMARY OF CONTRIBUTIONS

There are 30 proposals involved in Soil Moisture.
These proposals include validation over a wide range of targets:

- Temperate low vegetation
- Temperate crop land
- Temperate deciduous forest

- Boreal coniferous forest (taiga)
- Vineyards and orchards
- Tropical irrigated agriculture
- Cold shrub/grass land (tundra)
- Semi arid shrub/grass land
- Tropical rain forest
- Savanna
- Maritime pines
- Desert

The following table summarises the activities for each proposal:

AO-#	PI	Country-PI	Sea/ Land	Comments	SM/OS/Tb	ERS envisat	other EO RS	airborne RS	camp aigns	netw orks	mod els	assimi lations
3168	Calvet	France	Land	SMOSMANIA	Tb and SM	no	no	no	no	yes	yes	yes
3211	Kaihotsu	Japan	Land	Mongolia	Tb and SM	no	yes	no	yes	yes	no	no
3219	Walker	Australia	Land	NAFE	Tb and SM	yes	no	yes	yes	yes	yes	yes
3221	Jackson	US	Land	SCAN	Tb and SM	no	yes	yes	yes	yes	yes	yes
3223	Singh	India	Land		SM	yes	yes	no	yes	yes	no	no
3227	Robock	US	Land		Tb and SM	no	no	no	no	yes	yes	yes
3230	MartinezFer	Spain	Land	REMEDHUS	SM	no	yes	no	no	yes	yes	no
3233	Wagner	Austria	Land	SMOSCAT	SM	no	yes	no	no	yes	no	no
3236	Mauser	Germany	Land	GLOWA-Danube	Tb and SM	yes	yes	no	yes	yes	yes	yes
3238	De Jeu	NL	Land	FLUXNET	Tb for SM	yes	yes	no	yes	yes	yes	yes
3241	Vanderborg	Germany	Land	TERENO	Tb and SM	no	yes	yes	yes	yes	yes	no
3246	Hornbuckle	US	Land	MidwestUS	Tb and SM	no	no	no	yes	yes	yes	no
3250	Paloscia	Italy	Land	ASTRA	Tb for SM	yes	yes	yes	yes	no	yes	no
3252	LopezBaeza	Spain	Land	VAS	Tb and SM	yes	no	no	yes	yes	yes	yes
3254	Camps	Spain	Both	CALIMAS	all	yes	no	yes	yes	no	yes	yes
3257	Grippa	France	Land	AMMA	Tb and SM	yes	no	no	yes	yes	yes	yes
3261	Pellarin	France	Land	S-Band-Mountain	Tb and SM	no	no	no	yes	no	no	no
3268	Magagi	Canada	Land		Tb and SM	yes	yes	no	yes	yes	yes	yes
3269	Su	NL	Land		Tb and SM	yes	yes	no	yes	yes	yes	yes
3273	Kim	US	Land		Tb for SM	no	no	yes	yes	no	yes	no
3274	Zribi	France	Both	CAROLS	all	yes	no	yes	yes	yes	yes	no
3275	Marczewski	PL	Land	SWEX	Tb and SM	yes	yes	no	yes	yes	yes	no
3279	Zhang	China	Land		Tb and SM	yes	yes	no	yes	no	yes	yes
3280	Friesen	NL	Land	GLOWA-Volta	Tb and SM	no	yes	no	yes	yes	yes	yes
3281	Hallikainen	Finland	Both		all	yes	yes	yes	yes	yes	no	no
3284	Patel	India	Land		Tb and SM	yes	yes	no	yes	no	no	no
3934	Martins	Brazil	Land		SM	yes	no	no	yes	yes	no	no
4682	Berry	UK	Land		Tb and SM	no	yes	no	yes	no	yes	no
6272	Skou	Denmark	Land	HOBE	Tb and SM	yes	yes	yes	yes	yes	yes	yes
6317	Escorihuela	Spain	Land	uyuni-salar	Tb	no	yes	no	no	no	yes	no

6.2 Ocean Validation Team

6.2.1 OCEAN VALIDATION OBJECTIVES

The SMOS Level 2 Ocean product consists in several sea surface salinities (SSS) computed by different methods, all of which must be considered tentative at the moment.

The aim of the validation exercise is to determine whether or not one method offers definite advantages over the others, and to establish the accuracy of the retrieval associated with each method.

It is assumed that the validation material will consist in in-situ measurements of salinity obtained by floating and fixed buoys, ship transects and dedicated campaigns as well as existing sea surface salinity climatology.

The collection of validation material at sea will not limit itself to sea surface salinity and temperature, but will also include the collection of information for the validation of the models used in the implementation of the level 2 retrieval algorithms, i.e. wind measurements, sea-state measurements, observation of slicks and foam, etc, to prepare future understanding of the physics of the retrieval of SSS.

The validation exercise will also evaluate the suitability of the SMOS level 2 products for assimilation into general circulation models of the ocean.

It is doubtful that a match-up strategy comparing level 2 products with in-situ measurements on a pixel per pixel basis will be successful and it is already foreseen that the construction of time and space averages of level 2 products will be needed. In order to insure coherence between the results of various validation teams, some rules specifying how the averaging should be performed should be established beforehand and accepted by the various validation teams.

The present SSS validation plan is structured in the following way:
The list of proposed campaigns to be executed, networks to be used, models to be used (and developed), assimilations to be performed, comparisons with other sensors, and scientific issues to be addressed, is given.

Each list includes a short description of sensors, models, etc, to be used and/or of the methods to be applied. It is intended to support the scientific community by providing visibility of the proposed activities from the different group and to encourage cross-fertilization and facilitate collaboration between these groups.

At this stage, the plan does not include any schedule or link between activities within the overall SMOS Calibration Validation and Retrieval Team. However, this is intended for a future release of the document.

6.2.2 CAMPAIGNS

The campaigns listed and described below are all these whose outputs have been identified as contribution to the objective of the ocean validation team. Although these campaigns will most probably cover a wider range of scientific issues than just SMOS validation, the short description provided below only covers the campaign's contribution to the ocean validation team objectives.

6.2.2.1 Campaign in the Gulf of Biscay

Zribi-AO-3274

Field campaigns will be carried out, combining airborne measurements with the French research aircraft ATR42, and in situ measurements. The project proposes to carry out a set of flights with the french research aircraft ATR42 and the microwave instruments mounted on-board (L-Band radiometer, C-Band scatterometer, L-Band GPS receivers). The IR radiometer and visible video camera of the aircraft operator will also be requested for the operation to document respectively, possible sea surface temperature gradients, and foam coverage. Flights will be devoted to remote sensing of the ocean surface, whereas in situ measurements from ships, buoys and floats will document the SST, SSS, wind and wave conditions.
The chosen geographic area is the Gulf of Biscay. The interest for this region is manifolds:
Transit time from Toulouse airport, where the ATR42 is based, will not be too long (refueling in Bordeaux or Brest may be necessary however).
Two operational meteo-oceanic buoys are operated in this region (Brittany and Gascogne buoys) by Météo-France and UKMetOffice. They will provide systematic measurements of SST, wind (speed and direction), waves (significant wave height and peak period). The PHAROS buoy operated by Meteo-France and CETMEF (48° 31' 42" N, 5° 49' 03" W) can also be used as a complement to provide the same parameters.

Ship measurements and drifter deployments can be organized from french coastal research vessels.
This region is characterized by a large range of variation of wind, wave, SST and SSS conditions. During the same flights, conditions at the Gascogne and Brittany buoys may be quite different in terms of wind speed, whereas they will be relatively similar in terms of SSS and SST. For the whole region, wind and SST conditions may vary significantly between storm and calm conditions (especially during spring and fall). Furthermore, far from the coast, it is expected to find homogeneous SSS conditions whereas near the coasts (and in particular at the outflow of the Garonne river, there are frequent SSS salinity gradients.
The proposed period will be a few months after the launch of SMOS, with two different periods, one focused on the SMOS brightness temperature calibration, and one focused on L-band emissivity modeling and SSS inversion.
Buoy measurements should be operational at:
Gascogne buoy (45.2°N, -5.0°W)
Brittany buoy (47.5°N, -8.5°W)
They will provide each hour, atmospheric parameters (pressure, wind, air temperature, humidity), and surface parameters (SST, wave height, wave peak period). Additional measurements of two-dimensional wave spectra are planned for another project. It will be tried to make these measurements available in 2008 during the CAROLS campaigns.
In addition, we requested ship operations by a coastal ship of the french national research fleet. Application has been sent (in April 2006) for the « Cote de la Manche » for a campaign in September and November 2007. Application for 2008 was sent in 2007. This ship cruise will provide SSS and SST along its track from thermosalinograph, and will also have the capability to deploy drifters like « SURFACT », SVP or other types of drifters, which are developed by CMM/Meteo-France and LOCEAN. These drifters will provide observations of SSS, SST at 30-50cm depth, and for some of them (SVP) wind speed using an acoustic system. It is also envisaged to equip the ship with the camera system already used during the WISE experiment, in order to document foam coverage.
SHOM will deploy a non-directional wave buoy in the Gulf of Biscay during 2008. We are in contact with F. Ardhuin (SHOM) in order to coordinate data acquisition with CAROLS ocean experiment.
In addition, discussions are under way to coordinate our campaign with ship measurements by the spanish team which will take place in the southern part of the Gulf of Biscay.

Camps-AO-3254

The airborne cruise COSMOS (campaign for validating the operation of SMOS), organised by ESA, would have been carried out from the 28th of March to the 3rd of July 2005. The objective was to collect long data series under different geo/biophysical, meteorological and oceanographic conditions in order to study pending problems related to the moisture and salinity determination and SMOS products validation. The aircraft would have been equipped with a L-band polarimetric radiometer (EMIRAD, manufactured by the Technical University of Denmark), a radar scatterometer and a thermal infrared radiometer. The main effort was the collection of land measurements, nevertheless several flights over the ocean were programmed, mainly in the Gulf of Biscay area. These flights would have focused on the wave and wind buoys located between 45ºN and 47.5ºN, which are serviced by the UK Met Office and MéteoFrance. An additional area extended to the South would have been sampled too. This second area coincides with the area where the Instituto Español de Oceanografía carries out a permanent observation program and has been considered suitable for the study of azimuthal and time short scale variability of observations in the L-band.
Unfortunately, the COSMOS campaign was cancelled. However, the sampling strategy that was foreseen could be repeated several times coinciding with the satellite passes during the calibration/validation SMOS phase (first 6 months after the satellite launch). This is a reason for considering the Cantabric Sea as a validation area.

6.2.2.2 Campaign in the North Sea

Stammer–AO-3241 ???

6.2.2.3 Campaign at the Great Barrier Reef

Heron–AO-3271

Field campaigns will be conducted in the Great Barrier Reef lagoon (GBR) where PLMR or the earlier Scanning Low Frequency Microwave Radiometer (SLFMR) have successfully mapped SSS in the past, and where suitable research assets and ocean features appear. The southern GBR is a new area of study and takes advantage of a monitoring network deployed for a Coral Bleaching Project 2006-2010 involving the University of Queensland, the Australian Institute of Marine Science, James Cook University and NOAA/NESDIS.

6.2.2.4 Campaign in the Gulf of Mexico

Burrage-AO-3229

Field campaigns will be conducted both in areas in which STARRS or the earlier Scanning Low Frequency Microwave Radiometer (SLFMR) have successfully mapped SSS in the past, and where suitable ocean features appear, and in new areas over open ocean, and in the vicinity of small offshore islands, that are yet to be identified. Areas being considered for STARRS deployment include the Gulf of Mexico for this project.

6.2.2.5 Campaign in the Mediterranean Sea

Camps–AO-3254

The Mediterranean Sea is not perfect for SMOS validation due to its oceanographic and geographical characteristics. It has a strong seasonal variability (mainly in the temperature field), and a strong mesoscale spatial variability. Nevertheless, the intense mesoscale dynamic and high salinity can provide a good scenario for checking the validity limit of level 2 SMOS products (spatial resolution 30-50 km and salinity resolution 1 psu). It is clear that level 3 products (100-200 km of spatial resolution and 0.1 psu of resolution in salinity) will be hardly useful for the Mediterranean Sea.

Zribi-AO-3274

It is possible to extend CAROLS activities to the Mediterranean Sea.

6.2.2.6 Campaign in the Canary Islands

Camps–AO-3254

The Canary Islands are located in the eastern basin of the North Atlantic Subtropical Gyre, one of the most suitable regions for SMOS data validation, since a low seasonal variability in temperature and salinity has historically been observed. To carry out SMOS validation, we will use both data from a fixed location (moored station) and from some other locations within the Subtropical Gyre. On the one hand, data from the fixed location will be available by means of a mooring west of La Palma island, where data will be recorded and supplied with the satellite link. On the other hand, data within the Subtropical Gyre will be acquired by a number (tentatively 15) of drifting buoys deployed in the region. Moreover, temperature and salinity data acquired by other research cruises in the region will also be used, as well as the outputs from numerical models.

6.2.2.7 Campaign in the Atlantic Ocean

Camps–AO-3254

In-situ oceanographic measurements will be collected on the Atlantic Ocean. For this purpose, surface water samples are being collected in the FICARAM sections from Gibraltar to Cartagena (South of Argentina). In 2006 – 2009, this section will be enlarged to the Antarctic, through the Drake pass. These transects are covered twice a year, during the spring (March – end of April) and the fall (October – end of November) by the "Las Palmas" vessel of the Spanish Army. The measured variables are temperature and salinity with a thermosalinometer SBE-45-MicroTSG, connected to the pCO2 system that also has oxygen and fluorescence sensors. This activity is supported by the EU project CARBOOCEAN.
In addition, since October 2005, continuous surface measurements of salinity, temperature (SBE 37-SI MicroCAT), chlorophyll, O_2 and CO_2 dissolved in water are being collected by MINAS (Multidisciplinary Iberian North Atlantic Station) CARIOCA buoy moored at 42º 58.3' N, 11º 02.3' W. This activity is supported by the Spanish Ministry of Science and Education MEC (National Project VACLAN) and the EU (Project CARBOOCEAN).

Gommenginger-AO-3265

The precise cruise plan for UK Natural Environemnt Research Council (NERC) research ships for 2007 onwards is still being defined, however a large UK oceanographic presence is planned in the Arctic and the North Atlantic during the International Polar Year campaigns (currently planned to take place between March 2007-March 2009). Another important source of in-situ measurements is expected through the continuation beyond 2008 of NOC's monitoring of the Atlantic Meridional Observing Circulation (MOC) at 26.5N project and its associated hydrographic sections and six-monthly or yearly recovery cruises.
The hydrographic and underway SSS data will consist of CTD casts and underway ship measurements from coincident NERC research cruises in the Atlantic Ocean.

6.2.2.8 Campaign in the Gulf of Cadiz

Navarro–AO-3266

Monthly cruises will be carried out in a coastal area of the Gulf shelf comprised between the Bay of Cadiz and the portuguese border, in the proximities of the Guadiana River mouth. During those campaigns sea surface salinity will be estimated with a CTD probe throughout the area with a sufficient sampling density to obtain a realistically detailed spatial picture of the region.

6.2.2.9 Campaign along the Uruguay Coast

Martinez-AO-3270

Field campaigns will be conducted where STARRS has successfully mapped SSS in the past, and where suitable research assets and ocean features appear in the Rio de la Plata South East continental margin of South America.

6.2.3 NETWORKS

The networks listed and described below are all these whose outputs have been identified as contribution to the objective of the ocean validation team. Although these networks will most probably cover a wider range of scientific issues than just SMOS validation, the short description provided below only covers the contribution to the ocean validation team objectives.

6.2.3.1 ARGO Floats Array

ARGO is an international program for the deployment of 3000 free drifting profiling floats, distributed over the global oceans, which measure the temperature and salinity in the upper 1000 to 2000 m of the ocean providing 100000 T/S profiles and reference velocity measurements per year. This allows continuous monitoring of the climate state of the ocean, with all data being relayed and made publicly available within

hours after collection. ARGO is an element of: Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), Climate Variability and Predictability Experiment (CLIVAR), and Global Ocean Data Assimilation Experiment (GODAE).

Participating Teams:
Stammer–AO-3241
Le Vine –AO-3259
Gommenginger–AO-3265
Gower–AO-3267
Gaillard–AO-3276
Poulain-AO-3244

6.2.3.2 Network in the North Sea

Permanent buoys and ships.
Participating Teams:
Stammer-AO-3241

6.2.3.3 Network in the Baltic Sea

Wave and seawater temperature information is provided by a permanent buoy at the sea salinity test site in the northern Baltic Proper and the Gulf of Finland. Frequent (5 to 10 days interval) salinity and temperature information is provided by commercial ships sailing between Helsinki and German harbours. Ocean data for the Arctic Sea test site are obtained from Norwegian stations.

Participating Teams:
Hallikainen–AO-3281

6.2.3.4 PIRATA and NOAA Weather Buoys

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA) is a multinational effort involving Brazil, France and the Unites States. It was conceived as a three-year pilot project (1997-2000) that extended the Pacific Ocean TAO (Tropical Atmosphere-Ocean) moored buoy array into the Atlantic Ocean. It provides time series of surface heat fluxes, surface and subsurface temperature and salinity in key regions of the tropical Atlantic Ocean. CLIVAR/Brazil is fully committed to support the enhancement of the PIRATA array.

Participating Teams:
Martínez–AO-3270
LeVine-AO-3259
Burrage-AO-3229

6.2.3.5 In-situ Data Network in the Great Barrier Reef

The southern Great Barrier Reef (GBR) is a new area of study which takes advantage of a monitoring network deployed for the Coral Bleaching Project 2006-2010 involving the University of Queensland, the Australian Institute of Marine Science, James Cook University and NOAA/NESDIS. A network of in-situ instruments monitors waves and currents as well as fixed vertical profiles of temperature.

Participating Teams:
Heron-AO-3271

6.2.3.6 Mediterranean Operational Oceanography Network

In the framework of national projects and the MFSTEP initiative, and follow-on operational programs organised within MOON (Mediterranean Operational Oceanography Network), autonomous profiling floats

(both APEX and PROVOR) are deployed throughout the Mediterranean Sea to measure temperature and salinity profiles and sub-surface currents. The floats cycle in the water column at 5-day intervals. The temperature/salinity measurements closest to the sea surface are at 4-6 m depth. The float population in the Mediterranean Sea currently includes more than 20 units distributed in most basins and plans are to maintain this number for the next few years.

Participating Teams:
Poulain–AO-3244

6.2.4 OCEAN MODELS

The models listed and described below have been identified for use by the ocean validation team. They will be used to compute either SSS (and perhaps any other SMOS product) to be compared with those derived by SMOS or brightness temperatures to be compared with those measured by SMOS. Although these models will most probably cover a wider range of scientific issues than simply SMOS validation, the short description provided below only covers the model's contribution to the ocean validation team objectives.

Camps–AO-3254
The model now in preparation at ICM for data assimilation of SMOS products is OPA, developed at LODYC Paris and presently used by MERCATOR. A realistic configuration of the model is being implemented as a regional simulation of the subtropical gyre of the North Atlantic Ocean with realistic forcing and boundary conditions. The initial conditions and open boundaries will be obtained from the operational MERCATOR ocean forecasting system and projected to the grid of our configuration. Surface forcing will be obtained from ECMWF, CMAP, and NCEP. Data assimilation will be used to reduce the errors of the salinity simulations, both in surface and subsurface. We plan to use the Singular Evolutive Extended Kalman (SEEK) filter to estimate the three-dimensional structure of the error covariance matrix from model outputs and observations. The assimilation of SMOS salinity observations will be carried out simultaneously to the assimilation of other variables. The relative importance of salinity observations will be estimated by comparing assimilation results with and without salinity. We will also focus on the development and implementation of an algorithm to assimilate salinity from surface drifters and ARGO floats. In a first step, we will use a pseudo-lagrangian approach, which estimates the eulerian velocities from two positions of the trajectory. The eulerian information will be assimilated using the SEEK filter. In a second step, we will implement a method based on Objective Analysis, that we will later combine with the covariance model used in the SEEK filter.
The validation in the Mediterranean Sea will be done in coordination with the MFSTEP-MedARGO proposal (3244, P.M. Poulain). The regional numerical model used is an OGCM at 1/8 x 1/8 degrees and 31 levels forced by ECMWF winds. Temperature (infrared imagery, XBT and floats), salinity (floats) and sea level anomaly (satellite altimeters) are assimilated and weekly nowcast and forecast produced.
For the Atlantic Ocean, we will use a diapycnal model (probably HYCOM, from RSMAS Miami) to produce analysed fields from the available in situ data (drifters, floats, CTD casts, moored buoys, ship transects), and then compare both to SMOS L2 products and L3 when available. The methodology will be developed during 2006-2007.

Zribi–AO-3274
Output of regional models (ROMS) will be used to characterize the surface properties (SST, SSS).

Burrage-AO-3229
Project performance will be assessed by ingestion of SMOS salinity products into the US Navy Modular Ocean Data Assimilation System, MODAS (www7320.nrlssc.navy.mil/modas/), and assimilation into global (Navy Coastal Ocean Model, NCOM) and regional (Intra America Seas, IAS) ocean circulation models. Success will be measured by identical experiment comparing models with and without SSS assimilation.

Stammer-AO-3241
The project will use all available SSS data available from eddy resolving models to test spatial gradients and to assess which spatial sampling of in-situ measurements is required for quantitative comparisons.

Poulain-AO-3244
The numerical model is the OPA (Ocean PArallelise) version 8.1 primitive equation model, in which the Navier-Stokes equations are used with the approximation of thin-shell, Boussinesq, hydrostatic and incompressible fluid. In the frame of MFSTEP, the code has been implemented in the Mediterranean at 1/16° x 1/16° horizontal resolution and 72 unevenly spaced vertical levels. The model domain is closed everywhere, also in the Atlantic part, the so-called Atlantic Box. The model equations consider an implicit free surface approximation to the primitive equations for oceanic fluids. The horizontal viscosity and diffusion, supposed to be the same for temperature and salinity tracers, are assumed to be bilaplacian with coefficients of and for viscosity and diffusion respectively. The vertical diffusion and viscosity terms have a variable value with the depth related to the value of the Richardson number. The vertical convective processes are parameterized using the enhanced vertical diffusion parameterization. The model salinity and temperature fields along the boundary of the Atlantic box are relaxed at all depth to the climatology. The coefficient of relaxation is bigger at the boundary of the box and exponentially decreases moving toward the inside of the box. The diffusion coefficient has been increased at the border of the Atlantic box area in order to add a sponge layer. At the Strait of Gibraltar, between 6.25° W and 5.125° W the viscosity is laplacian instead of bilaplacian as in the rest of the model domain. In the same geographical area the bottom friction drag coefficient is ten times bigger then in the other parts of the model. These two modifications are necessary to avoid a high transport at the Strait of Gibraltar. In order to maintain the total water budget of the model at each time step a water flux correction is done in the atlantic box. These parameterization imposes that the total water flux is equal zero at each time step but let run free the water flux in all the Mediterranean Basin preserving it's characteristic of concentration basin. The model is run with a time step of 600 s. The salt flux is given by a relaxation at the surface toward monthly mean climatological values given by MEDATLAS climatology. A sub-model computes air-sea fluxes of momentum and heat from 6h operational analysis atmospheric forcing in all the Mediterranean Basin.

Gommenginger-AO-3265
While the ship and ARGO data will give in-situ ground truth they will inevitably provide a limited calibration / validation dataset, due to the fact that the number of collocations will not be large. To circumvent this problem, near real-time output from the operational ocean model run within the UK National Centre for Ocean Forecasting (NCOF) could be used. NOC, ESSC and UKMO are all partners in NCOF (see http://www.noc.soton.ac.uk/NCOF/) and the team will have access to the Met Office global model output via the ESSC LAS/GODIVA server system, which includes SSS and SST. The NCOF models run at global (1 deg) and regional (1/9 deg) scales and assimilate data, including that from satellite observations and ARGO floats. Finally, the Met Office intends (subject to future funding) to provide a 1/20 deg global SST daily analysis (called OSTIA) as a baseline input to the SMOS retrieval process.
The approach to be adopted would be to collocate model-SMOS SSS measurements and statistically analyse these using techniques that have been developed for cal / val of other satellite datasets. The varying spatial resolution of output available from the NCOF models and their global coverage (including lower salinity coastal areas) will allow the SMOS SSS measurements to be calibrated and validated across a wide range of salinity values (note that the ship and ARGO data would be mainly from deep ocean where salinity variations are smaller).
By using the model the team would be able to do the cal / val not only based on spot collocations but also on larger scale averages. For example, for SMOS it is proposed to reduce the uncertainty in the measurements by averaging the SSS over scale of 1deg x 1deg and a month (roughly comparable to Levitus climatology) or 2deg x 2deg and 10 days (the GODAE requirement). Output from the NCOF models could be similarly averaged and a comparison made between the two SSS values to assess how much averaging improves the SMOS SSS product.
Taken together, these four components should allow a comprehensive assessment of the SMOS SSS measurements and provide a basis for improvements of the algorithms. As it is known that ocean models do not perfectly predict the ocean state (otherwise there would be no need for the SMOS mission!), the availability of in-situ data (ship, ARGO) will provide a check on the results obtained from the model-SMOS comparisons. In fact, it may be best to use triple collocations (ship-model-SMOS or ARGO-model-SMOS) to elucidate the differences between the three measurement types (as has been done for in-situ, model and

satellite wave height measurements previously).

Gower-AO-3267
With the experience and the knowledge the Virtual Centre for Ocean Surface Salinity (VCOSS) team has with ocean modeling of salinity patterns, the project will be able to look at whether the spatial variation and patterns depicted from the SMOS data are consistent with the patterns known from models using in-situ observations.

Gaillard-AO-3276
The surface in-situ data are obtained from diverse measuring tools (surface drifters, CTD, ARGO floats, thermosalinographs (TSG)) and cover a wide range of depths from 20cm to over 15m. A careful evaluation of potential errors in interpreting these data as SSS is required. The team proposes to model the upper T/S profile variability globally with an oceanic 1D model forced by ECMWF winds, ECMWF and satellite derived heat fluxes and by E-P estimates using satellite-derived precipitations. Then the TSG data are flagged when the model suggests large gradients in the upper layer.

6.2.5 ASSIMILATION

Data assimilation techniques are proposed for the validation of SMOS product in different ways. Data to assimilate and models used for assimilation have been identified for use by the ocean validation team. Although these models will most probably cover a wider range of scientific issues than simply SMOS validation, the short description provided below only covers the contribution to the ocean validation team objectives.

Camps–AO-3254
The SMOS mission has the potential to provide, for the first time, a continuous stream of global maps of salinity with a resolution suitable for the large-scale characterization of salinity variability. The largest amount of information retrieved from data is achieved when observations are combined with the output of numerical models using mathematical techniques known by the generic name of data assimilation. It should be noted that the range of variability of models and observations should be similar to ensure their adequate combination. However, the development of current ocean circulation models did not consider the actual assimilation of salinity observations, mainly because of the lack of existence of salinity observations. Instead, these models have been shown to be able to reasonably reproduce most of the observed variability of temperature and sea level, for more than ten years of continuous global monitoring. In some of these models, the time evolution of salinity is strongly constrained by adding relaxation terms into the salinity equation. Besides, there is a lack of consensus about the appropriate forcing terms relating the flow of mass across the sea-air interface and salinity. Boundary conditions and relaxation terms have a direct effect on the range of variability of salinity in numerical models.
In such a context, the study of the role that forcing and relaxation terms have in the variability range of the simulated salinity was proposed in MIDAS3, to compare it with the variability of available historical observations. After completing the proposed study, we expect to obtain a better understanding of the ability of the ocean models to simulate the range of variability found in salinity observations, and what parameters must be changed for the model to have a range of variability comparable to the observed one.
It is expected that at the beginning of the MIDAS4, the activities performed in ICM-CSIC under MIDAS3 will:

- Allow to build a working LINUX cluster, in which we will install, compile, and run the MOM3 ocean model (http://www.gfdl.noaa.gov/~smg/MOM/MOM.html). We will use two FORTRAN 90 compilers: a commercial one (requiring license), and the open-source G95 compiler (http://www.g95.org), still under development. We expect to allow a better portability of the model onto any related application by trying two compilers.
- Provide reference simulations with MOM3. The implementation and validation of the system will be done using a simplified configuration. The region selected for these simulations will include the subtropical gyre of the North Atlantic Ocean, near the Canary Islands region.
- Provide a post-processing system for the analysis of the outputs of the ocean simulations. We will create specific data analysis tools and a database of relevant historical observations, from the NODC global

database. With those observations, we will study the historical variability of temperature, salinity, sea level, and currents to compare it with the mode variability.

Built upon those results, the new specific activities to be done under MIDAS4 are:

a) Realistic configuration of the model. A realistic configuration of the model MOM3 will be implemented as a regional simulation of the subtropical gyre of the North Atlantic Ocean with realistic forcing and boundary conditions. The initial conditions and open boundaries will be obtained from the operational MERCATOR ocean forecasting system (http://www.mercator.eu.org/) and projected to the grid of our configuration. Surface forcing will be obtained from ECMWF, CMAP, and NCEP. The access to the MERCATOR data is guaranteed by the participation of this team in the project MERSEA (Marine Environment and Security for the European Area, AIP3-CT-2003-502885) and the access to all operational products provided by the project. The complexity and difficulties we will encounter during the implementation of the realistic configuration will be compensated by the experience acquired during the activities performed under MIDAS3.

b) Characterization of the salinity variability in the realistic simulation of the East Atlantic. We will estimate and analyze the covariance between salinity and the other variables of the model. First, we will compare the variance of salinity with the variance of the other variables. We will compare how well the variance of each variable of the model compares with the variance of the available observations. Next, we want to identify the time scale of the leading mode of variability in the region under study. Then, we will calculate the multivariate modes of variability using the Multivariate Empirical Orthogonal Functions (MEOF) using the same methods as in Ballabrera-Poy et al. (2001; 2002), and estimate the signal to noise ratios as in Ballabrera-Poy et al. (2003). These studies will allow the characterization of the leading modes of variability of surface salinity and the comparison with those of the other physical parameters of the region.

c) Study of the vertical variability of the upper ocean salinity. In this study, we will analyze the vertical profiles from the historical observations in our database constructed during MIDAS3 and the outputs of the model. Although our interest is the Eastern Atlantic, we will also study other regions with different regimes of evaporation and precipitation to generalize our findings. Our goal is to determine the vertical structure of the errors of the model and the relation between model output and the surface salinity retrieved by SMOS. We will also collaborate with Dr. J. Miller to continue the analysis of data from La Plata campaign, in which radiometric measures of salinity were collected simultaneously with in situ profiles (http://glaucus.fcien.edu.uy/pcmya/sacc/LaPlataW2003). The results of this section will be important for the subsequent data assimilation efforts because they will provide information about the error covariance matrix and they will allow building a relationship between model output and observations, i.e. the forward observation operator.

d) Data assimilation of buoys and SMOS products. The results of the previous tasks will provide the starting point for the development and implementation of the data assimilation algorithms to be used here. Data assimilation will be used to reduce the errors of the salinity simulations, both in surface and subsurface. We plan to use the Singular Evolutive Extended Kalman (SEEK) filter. Specifically, we will have to estimate the three-dimensional structure of the error covariance matrix from model outputs and observations. The assimilation of salinity observations will be carried out simultaneously to the assimilation of other variables. While waiting for the SMOS retrievals, we will use synthetic observations (generated by the model). To simulate salinity retrievals we will use the SMOS End-to-end Performance Simulator (SEPS) simulating the behaviour of the MIRAS instrument. The relative importance of salinity observations will be estimated by comparing assimilation results with and without salinity. We will also focus on the development and implementation of an algorithm to assimilate salinity from lagrangian floats, as the buoys and the ARGO floats (http://www.argo.ucsd.edu). The importance of developing methods for the assimilation of lagrangian trajectories increases with the role of such observation instruments in the global oceanic observing system. In a first step, we will use a pseudo-lagrangian approach, which estimates the eulerian velocities from two positions of the trajectory. The eulerian information will be assimilated using the SEEK filter. In a second step, we will implement the method described by Molcard et al. (2003) and Özgökmen et al. (2003), based on the Objective Analysis of Daley (1991). Finally, we will combine the covariance model used in the SEEK filter with the method of Molcard. We will also take into account the observations of the vertical structure of currents and hydrology provided by the mooring placed in the

region under study, and additional hydrographic samplings will be measured during maintenance operations.

The development of the data assimilation algorithms described here does not require real salinity observations (the data to be assimilated will be simulated from model outputs).

Poulain-AO-3244

Each week Mediterranean Sea data sets available for the two weeks (J0-14 to J0) before the starting day of forecast (J0) are assimilated. They include satellite data for the sea level anomaly, sea surface temperature, and in situ temperature profiles by VOS XBT observations and in situ temperature and salinity profiles by MEDARGO floats. The data assimilation scheme is the SOFA reduced order optimal interpolation scheme. The SST is assimilated using a relaxation term which corrects the surface heat flux. The other three data sets (SLA, XBT and ARGO) are assimilated using the background error correlation matrix (correlations among temperature, salinity, sea surface elevation and barotropic stream function errors). The assimilation is made using a daily cycle. In each analysis the model is run for 24 hours and the analysis is made at the end time of the model run (filter mode). The daily cycle starts two weeks before the forecast and creates 14 analyses. In order to produce background fields the model is forced by fluxes calculated from ECMWF analyses of the air temperature, humidity, winds and the cloud cover.

The co-variability of the SSS, sea surface temperature, and wind stress will be analyzed using the MFSTEP nowcast maps and the ECMWF products. This analysis will be first qualitative. In particular, regions with particular salinity and temperature signals and atmospheric forcing will be identified. In a second stage, PCA (or EOF) methods will be applied to the MFSTEP products to obtain a more quantitative statistical description of the Mediterranean salinity, and of its co-variability with temperature and winds. It is proposed to obtain collocated SMOS and in-situ MEDARGO data by using the MFSTEP model nowcasts in which the float data have been properly assimilated. The project will therefore use weekly MFSTEP nowcasts to cross-validate SMOS, both with level 2 (30-50 km resolution along-swath) and level 3 (gridded maps, monthly and 100 km resolution) data.

Gommenginger-AO-3265

While the ship and ARGO data will give in-situ ground truth they will inevitably provide a limited calibration / validation dataset, due to the fact that the number of collocations will not be large. To circumvent this problem, near real-time output from the operational ocean model run within the UK National Centre for Ocean Forecasting (NCOF) could be used. NOC, ESSC and UKMO are all partners in NCOF (see http://www.noc.soton.ac.uk/NCOF/) and the team will have access to the Met Office global model output via the ESSC LAS/GODIVA server system, which includes SSS and SST. The NCOF models run at global (1 deg) and regional (1/9 deg) scales and assimilate data, including that from satellite observations and ARGO floats. Finally, the Met Office intends (subject to future funding) to provide a 1/20 deg global SST daily analysis (called OSTIA) as a baseline input to the SMOS retrieval process.

Burrage-AO-3229

The high resolution SMOS products generated by correcting SMOS data for earth alias and mixed pixel effects in marginal seas and the coastal transition zone will be assimilated into the NRL MODAS data assimilation system, and into regional implementations of the US Navy NCOM numerical hydrodynamic model, including specifically the Intra-Americas Sea Nowcast Forecast System (IAS-NFS). However, it is a coastal ocean model emphasis, though global, that does not respect the "best state estimate" on a global basis. Indeed the proposal does not profess to estimate global benefit of SMOS SSS data assimilation.

6.2.6 COMPARISONS

Satellites already in operation provide in some cases information that could be used for validation of SMOS products by comparison. Although in most cases direct data comparison is not feasible, at least it will be possible to correlate outputs at large scale in order to get some sort of comparison. Data from other microwave sensors on other satellites could provide independent check for algorithm performance. They will also provide independent information on sea surface temperature, brightness temperature and radar

backscatter that could be used to determine accuracy of the SMOS brightness temperatures and the effects of temperature, waves, wind and roughness on the SMOS salinity retrievals.

6.2.6.1 Comparison with Advanced Microwave Scanning Radiometer (AMSR)

The EOS AMSR is a one of the six sensors aboard AQUA. AMSR-EOS is a passive microwave radiometer, modified from the Advanced Earth Observing Satellite-II (ADEOS-II) AMSR, designed and provided by JAXA. It observes atmospheric, land, oceanic, and cryospheric parameters, including precipitation, sea surface temperatures, ice concentrations, snow water equivalent, surface wetness, wind speed, atmospheric cloud water, and water vapor.

Participating Teams:
Stammer–AO-3241
Hallikainen–AO-3281

6.2.6.2 Comparison with Special Sensor Microwave Imager (SSMI)

The SSMI is a conically-scanning microwave radiometer with channels at 19, 22, 37 and 85 GHz. All measurements are obtained with dual polarization, except the 22GHz, which is only vertically polarized. The microwave images can "see" through most clouds. The SSMI sensors are located on the NOAA DMSP polar orbiting satellites.

Participating Teams:
Gaillard–AO-3276

6.2.6.3 Comparison with METOP ASCAT

Compared to the scatterometers on the ERS satellites, which view only a single swath, ASCAT will realise enhanced coverage from its use of dual swaths.
ASCAT's two sets of antennae provide two 550 kilometres wide swaths. Each swath is centred at an inclination of 36° to the left and right of the satellite ground track, resulting in a gap of about 650 km between the two swaths. This so-called gap, however, is observed during later obits, achieving almost global coverage in five days.
From MetOp's polar orbit 800 kilometres above the surface of the Earth, ASCAT makes the observations for each swath sequentially. Each point on the ground is viewed three times, first by the fore-beam, then the mid-beam and finally by the aft-beam. One cycle is completed for one swath before the cycle begins for the other swath. Each beam takes 35.4 milliseconds, totalling 0.21 seconds to complete one transmit-receive cycle for all the six antennae, i.e. both swaths.
In its nominal operation, the instrument will yield wind vector measurements in 50 km resolution cells. It will be able of measuring wind speeds in the range of 4-24 m/s, with an accuracy of 2 m/s or 10% and wind direction in the range of 0-360° with an accuracy of 20°.

Zribi–AO-3274

METOP/ASCAT observations will not coincide in time with SMOS observations but may coincide with part of the airborne observations. ASCAT will be used when they will coincide with airborne observations, with a strategy based on the joint validation of the direct modelling of radar cross-section σo and L-band Tb. The same electromagnetic model and sea surface description will be used to simulate both σo and Tb and then use this simulation for the inversion procedure.

Gaillard–AO-3276 ???

6.2.6.4 Comparison with Advanced Synthetic Aperture Radar (ASAR)

The Advanced Synthetic Aperture Radar (ASAR) onboard ENVISAT (launched in may 2002), operating at C-band, ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI. It features enhanced capability in terms of coverage, range of incidence angles, polarisation, and modes of operation. This enhanced capability is provided by significant differences in the instrument design: a full active array antenna equipped with distributed transmit/receive modules which provides distinct transmit and receive beams, a digital waveform generation for pulse "chirp" generation, a block adaptive quantisation scheme, and a ScanSAR mode of operation by beam scanning in elevation.

Zribi–AO-3274

ASAR observations will not coincide in time with SMOS tracks but may coincide with part of the airborne observations. ASAR data will be used when they will coincide with airborne observations, with a strategy based on the joint validation of the direct modelling of radar cross-section σ_0 and L-band Tb. Indeed, the same electromagnetic model and sea surface description will be used to simulate both σ_0 and Tb. At least two physical electromagnetic models (SSA-1, two-scale composite model) and three descriptions of the sea surface (Durden and Vesecky, 1985 Elfouhaily et al, 1997, Kudryavstev et al, 1999) are planned for the ATBD. An alternative electromagnetic model is under development at IFREMER and may be well appropriate to avoid some well-known limitations of the above-mentioned models. In order to better identify the best and most consistent options, the project proposes to test the results of these models against remote sensing observations collected during the field campaign, and using in situ data as ancillary information (SST, SSS, wind speed): Tb from CAROLS and SMOS, normalized radar cross-section σ_0 from STORM or ENVISAT/ASAR, bistatic coefficients from GPS receivers. As the same models can be used for active (radar) and passive (radiometric) observations and at different electromagnetic wavelengths (C-Band, L-Band), this combination will be used to better identify sources of deficiency of the models (foam, roughness, etc).

6.2.6.5 Comparison with STORM scatterometer

CETP has designed and developed a new airborne radar called STORM, which has a full polarimetric capability. STORM is derived from two previous versions of airborne radars developed at CETP, namely RESSAC (Hauser et al, JGR 1992) and RENE (Leloch-Duplex et al, Annales of Telecommunications, 1996). STORM is a real-aperture, C-Band system with a rotating antenna to explore in azimuth. It offers a polarization diversity, receiving the complex signal in amplitude and phase simultaneously in H and V polarizations, which makes it possible to analyze the radar cross-section in HH, VV, HV, and other cross-polarized terms related to the scattering matrix. The antenna are pointed towards the surface with a mean incidence angle of 20° and a 3-dB aperture of about 30° in elevation and 8° in azimuth. The backscattered signal is analyzed from nadir to about 35° along the look-direction in 1012 range gates every 1.53m.

Zribi-AO-3274

STORM is a radar airborne instrument that will provide under the flight track, the normalized radar cross-section at C-band, and as inverted products, the wind speed, wind direction and 2D spectrum of long waves. For SMOS inversion, at least two physical electromagnetic models (SSA-1, two-scale composite model) and three descriptions of the sea surface (Durden and Vesecky, 1985 Elfouhaily et al, 1997, Kudryavstev et al, 1999) are planned in the ATBD. An alternative electromagnetic model is under development at IFREMER and may be well appropriate to avoid some well-known limitations of the above-mentioned models. In order to better identify the best and most consistent options, the project proposes to test the results of these models against remote sensing observations collected during the field campaign, and using in situ data as ancillary information (SST, SSS, wind speed): Tb from CAROLS and SMOS, normalized radar cross-section σ_0 from STORM and eventually from ENVISAT/ASAR and ALOS/PALSAR, bistatic coefficients from GPS receivers. As the same models can be used for active (radar) and passive (radiometric) observations and at different electromagnetic wavelengths (C band, L band), this combination will be used to better identify sources of deficiency of the models (foam, roughness, etc).

6.2.6.6 Comparison with AQUARIUS

Starting in 2009, AQUARIUS mission will measure global SSS with unprecedented resolution. The science instruments will include a set of three radiometers that are sensitive to salinity (1.413 GHz; L-band) and a scatterometer that corrects for the ocean's surface roughness.

Participating Teams:
Stammer–AO-3241
Le Vine–AO-3259
Gower–AO-3267
Poulain-AO-3244

6.2.6.7 Comparison with ERS Scatterometer

The purpose of the Wind Scatterometer is to obtain information on wind speed and direction at the sea surface for incorporation into models, global statistics and climatological datasets. It operates by recording the change in radar reflectivity of the sea due to the perturbation of small ripples by the wind close to the surface. This is possible because the radar backscatter returned to the satellite is modified by wind-driven ripples on the ocean surface and, since the energy in these ripples increases with wind velocity, backscatter increases with wind velocity. It works at 5.3 GHz (C band) in VV polarisation.

Participating Teams:
Hallikainen–AO-3281
Gaillard–AO-3276

6.2.6.8 Comparison with QUIKSCAT SeaWinds

The SeaWinds scatterometer is a microwave radar designed specifically to measure ocean near-surface wind speed and direction. SeaWinds uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.4 GHz across broad regions on Earth's surface. The instrument collects data over ocean, land, and ice in a continuous, 1,800-kilometer-wide band, making approximately 400,000 measurements and covering 90% of Earth's surface in one day.

Participating Teams:
Hallikainen–AO-3281

6.2.6.9 Comparison with STARRS

Spatially-averaged ocean salinity values obtained from NRL Salinity, Temperature And Roughness Remote Scanner (STARRS) and the NRL Radsys software (after adaptation to the SMOS processing chain) in the marginal seas and coastal transition zone will be compared with corresponding results from MIRAS. The resulting comparisons will be used to make iterative improvements to the SMOS earth-aliased and land/ocean mixed pixel salinities obtained using the modified retrieval system.

Participating Teams:
Burrage–AO-3229
Martinez–AO-3270
Heron-AO-3271

6.2.7 SCIENTIFIC ISSUES

The scientific issues listed below are all these that have been identified as issues where investigation is needed in order to implement specific models into the retrieval algorithm or in order to better understand

microwave emission from specific targets. The following list does not pretend to cover all types of sea conditions but it includes issues where scientific community is particularly interested on over oceans.

6.2.7.1 Scaling Issues

Burrage-AO-3229

The project will acquire wave spectra from a drifting buoy in the wavelength range 1mm-1m, and will use these data to characterize the sea surface roughness field, by fitting empirical roughness models. The resulting models will be used to scale up the sea surface roughness experienced by the buoy to the scales of the STARRS (1 km) and SMOS (50 km) radiometer pixel size for use in rough surface emission and reflection corrections.

Gaillard–AO-3276

SST fields are one of the most important parameter in the inversion process. Using the results of the MEDSPIRATION project, high resolution SST fields will be produced, from regional to global scale. The SST variability within a SMOS pixel will then be analysed and the results compared to those of the analysis of the in-situ and model database. The associated errors in the SSS estimates will also be investigated.

6.2.7.2 Mixed Pixel

Burrage–AO-3229

Airborne surveys using the STARRS radiometer system will be conducted along and also parallel to, but separate from SMOS ground-tracks. These surveys will cross a sequence of about 3 (50 km) SMOS pixels covering ocean, coastal transition and land areas. The data will be analyzed to develop corrections for the effects of land/ocean mixed pixels on the SMOS salinity retrievals, with the aim of better utilizing SMOS ocean data near the coast.

Camps–AO-3254

The cal/val activity will consist in the development of high resolution brightness temperature models suitable to this region with a high spatial and temporal resolution in order to introduce them to the SMOS End-to-end Performance Simulator SEPS and then, to be able to reproduce accurate estimations of the brightness temperature that the sensor will observe, taking into account all the spatial averaging effects (synthetic beams, secondary lobes, etc), atmospheric contributions and cosmic and galactic noises. The obtained results with SEPS will be used in order to compare the measurements acquired by the sensor.

Martinez-AO-3270

The project will observe SMOS 'mixed pixels' directly using airborne radiometers, which, by virtue of design and low altitude, have higher spatial, and comparable radiometric, resolution to that of MIRAS. By sampling Tb over sea and land, and using known SMOS antenna patterns, the project will develop empirical models to mitigate land contamination. The results facilitate corrections for 'mixed pixels' and enable accurate delineation of MIRAS coverage. This will significantly improve the reliability and utility of SMOS salinity retrievals near the coasts.

6.2.7.3 Capillarity-Gravity

Burrage–AO-3229

In-situ measurements using the drifting or tethered NRL wave gauge buoy comprising a laser scanner and capacitive wire gauge capable of resolving wavelengths from 1mm to 1m will be obtained close to the SMOS

ground track during deployments in the Gulf of Mexico. The results will be used to characterize the spectra of those waves which are considered to be important for C and L-band roughness emission and bistatic scattering.

Zribi–AO-3274

According to the ATBD, different models describing the short capillary-gravity waves will be tested. These models will be used as input to simulate σ_0 and L-band Tb for the direct modelling and inversion procedure of SMOS and CAROLS observations.

6.2.7.4 Waves

Burrage–AO-3229

The spectra obtained using the techniques described above will be used in conjunction with spectra of longer wavelength (> 1m) observed by NDBC data buoys in the Gulf of Mexico. The combined spectra will be used to assess the performance of SMOS roughness (two-scale, SSA and empirical) models for use in surface salinity retrieval, and to characterize the differences in directional wavenumber/frequency spectra between waves sensed by C and L-band radiometers. The results will be used to determine the extent to which data from the STARRS C-band radiometer can be used to infer, and correct for, roughness-induced emission and reflection sensed by the STARRS L-band radiometer. If successful, an empirical roughness correction for L-band data using the C-band radiometer observations will be developed.

Zribi–AO-3274

Different models describing the longer waves will be tested. These models will be used as input to simulate σ_0 and L-band Tb for the direct modelling and inversion procedure of SMOS and CAROLS observations. Buoy and ship observations will be used to fix the input parameters (wind).

6.2.7.5 Swell

Burrage–AO-3229

The effects of swell on the SMOS two-scale and empirical roughness correction models will be evaluated based on the observational results obtained using the techniques described above.

Zribi–AO-3274

The models used can be combined with a model for swell (adding two spectra). Buoy, STORM and ENVISAT ASAR observations will be used to fix the input parameters (wave spectra of long waves).

6.2.7.6 Foam

Zribi–AO-3274

The different models proposed in the ATBD will be tested in the direct and inversion model of Tb. In addition, during the ship cruise, the team will carry out observations with a camera (same system as stereo-camera used during the WISE experiment) to estimate the foam coverage and its relation with wind speed, SST, salinity, and Tb. The team will also use a camera on board the aircraft, which will be used to estimate foam coverage in coincidence with Tb measurements.

Stammer–AO-3241

One of the most pressing issues in the development of retrieval algorithms for SSS measurements from SMOS is the problem of sea surface roughness, foam and slicks effects on brightness temperatures at 1.4 GHz. This impact will be studied over the entire span of antenna incidence angles of the SMOS instrument, using radiometer measurements from the FINO-1 platform located in the North Sea. For that purpose, a L-band and X-band radiometer from the ETH Zürich will be mounted on this platform and measurements of the emissivity and brighness temperature will be performed as a function of external parameters.

6.2.7.7 Sea Surface Temperature

Burrage–AO-3229

The possible use of STARRS C-band radiometer observations in conjunction with the coincident L-band radiometer data will be used to develop empirical models to derive SST simultaneous with wind-induced and non wind-related roughness parameters for use in correction STARRS L-band data. If successful, this model will obviate the current use of the STARRS IR radiometer for SST determination, and will effectively provide STARRS with an “all weather” capability for sensing ocean salinity.

Zribi–AO-3274

Measurements from the buoys, ships, drifters, and from outputs of regional models will be used as ancillary parameters to simulate and inverse Tb. Airborne observations from the IR airborne radiometer will be used as a complement to identify possible conditions of SST variations along the flight track.

6.2.7.8 Slicks

Zribi–AO-3274

ASAR data can be used to identify zones of slicks, although the observations will not be simultaneous to SMOS measurements.

Stammer–AO-3241

One of the most pressing issues in the development of retrieval algorithms for SSS measurements from SMOS is the problem of sea surface roughness, foam and slicks effects on brightness temperatures at 1.4 GHz. This impact will be studied over the entire span of antenna incidence angles of the SMOS instrument, using radiometer measurements from the FINO-1 platform located in the North Sea. For that purpose, a L-band and X-band radiometer from the ETH Zürich will be mounted on this platform and measurements of the emissivity and brighness temperature will be performed as a function of external parameters.

6.2.7.9 Coastal Zones & Islands

Burrage–AO-3229

The techniques described by Burrage under Scaling and Mixed Pixel subsections will be adapted to study the effects of islands, peninsulas, and the coastal transition zone on retrievals of ocean salinity by MIRAS. This will facilitate more accurate comparisons of SMOS with in-situ data obtained within coastal and island settings.

Zribi–AO-3274

Parts of the airborne measurements will be carried out over the Garonne outflow where important salinity gradients may occur especially during the spring season. The ship cruise will also document this region. The team will investigate the relation between salinity and airborne Tb. However, SMOS data will be too contaminated by the land contribution to use SMOS data for coastal application in this region.

6.2.7.10 Wind

Burrage–AO-3229

Wind data obtained from the NRL wave gauge buoy and NDBC data buoys will be used to determine the relationship between wind-induced roughness and emission and reflection for the STARRS and SMOS L-band radiometers. (See comments under previous subsections on Scaling, Mixed Pixel, Capillarity-Gravity, Waves and Swell.)

6.2.7.11 Sea Surface Roughness

Burrage–AO-3229

An attempt will be made to separate wind-induced and non-wind related sea surface roughness effects using the techniques described by Burrage under previous subsections concerning wind, waves and mixed pixels.

LeVine-AO-3259

Surface roughness is among the largest terms in the salinity retrieval error budget. The LeVine team will examine the SMOS data at the three Aquarius incidence angles (30°, 38°, 45°) for effects of roughness, and will test correction approaches that are being developed for the Aquarius (the primary Aquarius algorithm will be based on the scatterometer signal). This includes L-band radiometer-only algorithms using differences between V and H polarizations (especially at the large incidence angle) and using wind data from operational satellites and relationships such as developed during WISE.

6.2.8 SUMMARY OF CONTRIBUTIONS

There are 14 proposals involved in Ocean Salinity.

These proposals include validation over different seas and ocean locations around the globe:

- Antarctic (Gaillard)
- Arctic (Johannessen, Hallikainen)
- Atlantic (Johannessen, Camps)
- Baltic Sea (Hallikainen)
- Bay of Biscay (Zribi, Camps)
- Canada (Gower)
- Great Barrier Reef (Heron)
- Gulf of Mexico (Burrage)
- Mediterranean Sea (Poulain, Camps, Navarro)
- North Sea (Johannessen, Stammer)
- Pacific (Stammer, Gaillard)
- Uruguay Coast (Martinez)

The following table summarises the activities for each proposal:

AO-#	PI	Country-PI	Sea/ Land	Comments	SM/OS/Tb	ERS envisat	other EO RS	airborne RS	campa igns	networks	models	assimilati ons
3229	Burrage	US	Sea		Tb and OS	no	no	yes	yes	yes	yes	yes
3241	Stammer	Germany	Sea		Tb and OS	no	yes	no	yes	yes	yes	no
3244	Poulain	Italy	Sea	Med Sea	OS	no	no	no	no	yes	yes	yes
3254	Camps	Spain	Both	CALIMAS	all	yes	no	yes	yes	no	yes	yes
3259	Le Vine	US	Sea	AQUARIUS	Tb and OS	no	yes	no	no	yes	no	no
3265	Gommenginger	UK	Sea	Atlantic	Tb and OS	yes	yes	no	yes	yes	yes	yes

3266	Navarro	Spain	Sea		OS	yes	no	no	yes	no	no	no
3267	Gower	Canada	Sea		Tb and OS	no	no	no	no	yes	yes	no
3270	Martinez	Uruguay	Sea		Tb and OS	no	no	yes	yes	yes	no	no
3271	Heron	Australia	Sea		Tb and OS	no	no	yes	yes	yes	no	no
3274	Zribi	France	Both	CAROLS	all	yes	yes	yes	yes	yes	yes	no
3276	Gaillard	France	Sea	GLOSCAL	Tb and OS	yes	no	no	no	yes	yes	no
3281	Hallikainen	Finland	Both		all	yes	yes	yes	yes	yes	no	no
4488	Johannessen	Norway	Sea	atlantic40+	Tb and OS	yes	yes	no	no	yes	yes	no

6.3 Vicarious Calibration Team

6.3.1 VICARIOUS CALIBRATION OBJECTIVES

The role of the vicarious calibration team is to estimate the SMOS L1c calibration accuracy. Two approaches are envisaged:

1. To validate the L1c accuracy or estimate the calibration accuracy by comparing the TOA brightness temperature with those computed using stable natural targets such as:
    a. Snow over Dome-C in Antarctica
    b. Dense vegetation over tropical and boreal forests
    c. Ocean using the ARGO floats array and other buoys networks
    d. Desert over Takelimgan Sand Desert in China
    e. Salt over Uyuni Salar in South America

    The calibration will be validated using a number of independent methods and associated models. As the objective of the L1c validation is to estimate the accuracy (error bar) of the MIRAS calibration, the methods (and associated models) need not be linked (or compared) to the models used in the geophysical retrievals; any independent method can be used.

    Please note that it is the responsibility of the AO teams to determine the accuracy of their methods.
    The L1c product will be declared “validated” when all L1c measurements (with their error bars) will fall within the error bars associated with the different methods.

2. In the event that the SMOS calibration accuracy based on the engineering calibration approach is not of the quality required by the Level 2 retrieval algorithms, even if it is “validated” (see above), a calibration scale based on the model of natural targets will need to be developed.

    The calibration scale method will be derived from the methods developed for the validation of the L1c; however, the method output will not be a status “validated or not” but a radiometric scale which will be applied in the L1 processing to improve the calibration accuracy.

    Since the use of a calibration scale is mainly intended to improve the quality of the geophysical retrievals, the calibration scale method will need to be linked (compared) to the models used in the geophysical retrievals in order to guarantee coherence in the overall system approach.

The plan is structured in the following way:

1. Campaigns to be executed,
2. Networks to be used,
3. Models to be used (and developed),
4. Assimilations to be performed,
5. Comparisons with other sensors to be performed,
6. Technical and scientific issues to be addressed.

Each list will include a short description of sensors, models, etc, to be used and/or of the methods to be applied. It is intended to support the scientific community by providing visibility of the proposed activities from the different groups and to encourage cross-fertilization and collaboration between these groups.

At this stage, the plan does not include any schedule or link between activities within the overall SMOS Calibration Validation and Retrieval Team; however, this is intended for a future release of the document.

6.3.2 CAMPAIGNS

The campaigns listed and described below have been identified as contribution to the objective of the vicarious calibration team. Although these campaigns will most probably cover a wider range of scientific issues than just SMOS calibration, the short descriptions provided below only cover the campaigns contribution to the vicarious calibration team objectives.

6.3.2.1 Campaign over Takelimgan Sand Desert

This project proposes the use of Tazhong Station in Takelimgan Sand Desert as a vicarious calibration site. This site is well suited for cal/val activity because it is large, homogeneous, stable, well documented and relatively easy to access. The aims are:
1) Calibration of SMOS over Tazhong Station site in Takelimgan sand desert for short term. Field measurements, meteorological observation station records, aircraft experiment incorporated with satellite data such as MODIS, SAR, SSMI and AMSR-EOS will be assimilated to give ground truth data in purpose of calibration. L band (1.8GHz and 3.0GHz) may be used in aircraft or truck or tower to carry out synchronized measurement with SMOS during its commissionning phase. It will evaluate the sensors stability, radiometric accuracy, etc. The calibration report will be made shortly after the commissionning phase.
2) Calibration of SMOS over Takelimgan Sand Desert for long term. Statistical mean, minimum and maximum brightness temperatures over the desert and the Tazhong Station will be accumulated as well as meteorological records, field measurements during the SMOS operational period (3 years). Small drifts in absolute calibration and other long-term uncertainties will be studied and reported throughout the SMOS life cycle. The method is similar to the one reported by C. Ruf.
1. The purpose of the proposed campaign is to develop a direct physical model with parameters derived from in-situ measurements so that it can be used to evaluate stability, accuracy and sensitivity of the instrument MIRAS.
2. To equip automatic soil temperature sensors in different depth and different directions along the sand desert road to collect soil temperature profile information around Tazhong Station. Soil moisture profile, especially the deeper status should also be investigated.
3. To use truck mounted L band radiometer to observe emission of the sand in the three directions.
4. To use balloon borne L band radiometer to observe emission of the sand to be able to scale up from the ground measurements.

Participating Teams:
W. Zhang-AO-3279

6.3.2.2 Campaign at Dome C on the Antarctic Plateau

The data acquisiton plan uses an airborne L-band radiometer. The observations fall into temporal and spatial categories. Temporal stability can be evaluated with the Dome-C ground radiometer data (if available) or by using time series measurements from sequential aircraft radiometer flights. Data about spatial heterogeneity at L-band can be collected at ~50 m resolution over 50 km diameter area using the PLMR at moderately low altitude and very low cost. This is the same as the mode of operation for soil moisture field campaigns. Ken Borek Air has operated similar instruments on their Twin Otter aircraft in Antarctica and around the world for years. Borek provides aircraft resources to the US Antarctic Program. PI Ed Kim has visited Borek and determined that PLMR should be compatible with Twin Otters. In-situ ice pit sampling will be undertaken at distributed points within the footprints observed by the aircraft sensor.
Radiometric data from tower and snow mobile vehicle are collected at Dome-C together with snow data by the team of Paloscia.
The team of Walker is in consultation with the British Antarctic Survey, through Robert Gurney, and there is a possibility to perform some flights over Dome-C, in collaboration with PI Ed Kim.

Participating Teams:
S. Paloscia-AO-3250
E. Kim-AO-3273

6.3.2.3 Campaign over Large Dense Forest

To evaluate the spatial homogeneity of a dense forest, Kim's project proposes to fly the PLMR L-band radiometer to image areas of the size of a SMOS (or AQUARIUS) footprint (50-100 km diameter). Using this data plus the corresponding ground truth, this study will employ geostatistical and non-statistical techniques to quantify the variability.

The availability of AMSR-EOS data is open through the web. The comparison of SMOS data products with AMSR-EOS will be performed by Paloscia's team for selected forest areas in China and Russia already investigated with microwave passive and active sensors. Forests are relatively stable targets with an almost flat spectrum, and it is has been possible to deduce L-band emission from C-band measurements using some a-priori knowledge on the forest type and an existing model, which will be refined and further validated with airborne data.

Participating Teams:

S. Paloscia-AO-3250

E. Kim-AO-3273

6.3.2.4 Campaigns Involving Airborne Remote Sensor

Paloscia-3250----------

Forests are relatively stable targets with an almost flat spectrum, and it is has been possible to deduce L-band emission from C-band measurements using some a priori knowledge on the forest type and an existing model, which will be refined and further validated with airborne data. For this purpose, experimental campaigns with multi-frequency (L, C, X bands) airborne and ground based sensors are planned over several forests and fields in Tuscany, Italy. These investigations will contribute to understand instrument stability and calibration, as well as to assess the capability in estimating soil moisture at low incidence angle and woody biomass at high incidence.

Experimental campaigns with multi-frequency (L, C, X bands) airborne sensors were performed in Italy on selected forests and additional studies are planned in 2007-2008. Airborne and ground based data will be collected over forests in Italy in 2007 and used to validate forest model.

Kim-3273----------

L-band airborne radiometer measurements using Walker's PLMR instrument flying on a suitably equipped (e.g. Ken Borek Air) Twin Otter aircraft staged from a logistically suitable location near or at Dome-C or suitable forests. The data acquisiton plan using an airborne L-band radiometer is essentially the same for Dome-C and for forests. The observations fall into temporal and spatial categories.

Airborne field campaign plus ground truth collection during austral summer field season in Antarctica. Also, flights over dense forest areas in Australia, nearby tropical island areas, or the Amazon forest.

Martinez-3270----------

Field campaigns will be conducted where STARRS has successfully mapped SSS in the past, and where suitable research assets and ocean features appear in the Rio de la Plata South East continental margin of South America. Airborne instruments will if possible, comprise NRL Salinity Temperature And Roughness Remote Scanner, STARRS, V-polarisation radiometer system with L-, C- and IR-band modules and/or the Australian PLMR and SFMLR. These instruments will provide high-quality validation data and allow horizontal and vertical gradients of surface and sub-surface salinity and temperature to be accurately determined within the SMOS FOV during satellite overpass.

Burrage-3229----------

The primary airborne instrument will comprise Naval Research Laboratory (NRL) Salinity Temperature And Roughness Remote Scanner, STARRS, V-polarisation radiometer system with L-, C- and IR-band modules. Field campaigns will be conducted both in areas in which STARRS or the earlier Scanning Low Frequency Microwave Radiometer (SLFMR) have successfully mapped SSS in the past, and where suitable ocean features appear, and in new areas over open ocean, and in the vicinity of small offshore islands, that are yet to be identified. Areas being considered for STARRS deployment include the Gulf of Mexico and the Rio de la Plata/SE continental margin of South America.

Heron-3271----------

Field campaigns will be conducted in the Great Barrier Reef lagoon (GBR) where PLMR or the earlier Scanning Low Frequency Microwave Radiometer (SLFMR) have successfully mapped SSS in the past, and

where suitable research assets and ocean features appear. Airborne and in-situ data will be combined to validate SMOS Tb, SSS and SST under prevailing hydrographic and meteorological conditions. Surveys will be conducted along satellite ground tracks, to validate SST and SSS in marginal seas where complex wind/wave fields and nearby land will modify the radiometer response. Airborne instruments will comprise the new Australian-owned dual Polarimetric L-band Microwave Radiometer (PLMR) and an S60 high resolution thermal imager.

Camps-3254----------

ESA plans to fly SAMIRAS (Small Airborne MIRAS: demonstrator with 4 elements per arm) in summer 2006 with the HUT Skyvan aircraft to check its technical behavior. A logical follow-on is to test that SAMIRAS is able to meet the expected performances in image generation from measured visibilities and in extracting from them SM and OS values. If ESA covers the airplane costs, SAMIRAS can also be used simultaneously with SMOS pass over some validation areas and take advantage of the low flight to verify several aspects of the data processing.

Hallikainen-3281----------

The Helsinki University of Technology (HUT) airborne sensors, including the interferometric HUT-2D and a conventional radiometer are available for operational use in late 2006.

The HUT-2D instrument along with the HUT conventional L-band radiometer are employed under snow-free conditions to collect data, using appropriate polarisations and incidence angle range, for the three soil moisture test sites in southern Finland. These data are used to study in detail the effect of forests and mixed pixels. Occasionally, similar flights are carried out at the Sodankyla test site in northern Finland; these flights are combined with measurements at the Arctic Ocean test site. The effect of wind/waves and water temperature are examined in detail using HUT airborne sensors in the Gulf of Finland.

Participating Teams:

E. Kim-AO-3273
S. Paloscia-AO-3250
D. Burrage-AO-3229
M. Heron-AO-3271
C. Martinez-AO-3270
A. Camps-AO-3254
M. Hallikainen-AO-3281
J. Walker-AO-3219 in three river catchments of South-East Australia and in the Simpson Desert
Zribi-AO-3274 at Valencia Anchor Station, in South-West France and in the Gulf of Biscay
LopezBaeza-AO-3252 at the Valencia Anchor Site
Jackson-AO-3221 in the USA

6.3.3 NETWORKS

The networks listed and described below have been identified as contributing to the objective of the vicarious calibration team. Although these networks will most probably cover a wider range of scientific issues than just SMOS calibration, the short description provided below only covers the networks contribution to the vicarious calibration team objectives.

6.3.3.1 ARGO Floats Array

ARGO is an international program for the deployment of 3000 free drifting profiling floats, distributed over the global oceans, which measure the temperature and salinity in the upper 1000 m of the ocean providing 100000 T/S profiles and reference velocity measurements per year. This allows continuous monitoring of the climate state of the ocean, with all data being relayed and made publicly available within hours after collection. ARGO is an element of: Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), Climate Variability and Predictability Experiment (CLIVAR), and Global Ocean Data Assimilation Experiment (GODAE). See http://www.coriolis.eu.org/cdc/ftp_data_distribution.htm
Stammer will investigate global SMOS fields using ARGO data with surface drifters in place in the GINS sea and possibly in the western Pacific ocean.

Participating Teams:

D. Stammer-AO-3241
D. LeVine-AO-3259
C. Gommenginger-AO-3265
E. Gower-AO-3267
F. Gaillard-AO-3276
P.M. Poulain-AO-3244

6.3.3.2 Soil Moisture Measurement Network in Germany

Vanderborght and Mauser projects include direct comparison of soil moisture products with in-situ measurements available from measurement networks at several locations in Germany.

Participating Teams:
J. Vanderborght-AO-3241
W. Mauser-AO-3236

6.3.3.3 Soil Moisture Measurement Network in Finland

The Sodankyla NorSEN soil moisture test site will be equipped by 2007 with a number of permanent soil moisture sensors over a large area in order to provide continuous soil moisture information. The test site in southern Finland employs soil moisture measurements by the Geological Survey of Finland.

Participating Teams:
M. Hallikainen-AO-3281

6.3.3.4 Global Soil Moisture Data Bank

The Global Soil Moisture Data Bank (GSMDB, Robock et al. 2000) currently provides 10-daily root zone soil moisture measurements from a few tens observation sites spread over Ukraine, Russia, Mongolia, China and India.

Participating Teams:
J. Vanderborght-AO-3241
A. Robock-AO-3227

6.3.3.5 PIRATA and NOAA Weather Buoys

The Pilot Research Moored Array in the Tropical Atlantic is a project designed by a group of scientists involved in CLIVAR, and is implemented by the group through multinational cooperation. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic ocean that are relevant to regional climate variability on seasonal, interannual and longer time scales.
PIRATA will be supplemented by NOAA weather buoys (www.ndbc.noaa.gov).
NOAA's Tropical Moored Buoy (TMB) projects consist of the Tropical Atmosphere Ocean (TAO) / Triangle Trans-Ocean Buoy Network (TRITON) (TAO/TRITON) array, with stations operated by NOAA's Office of Atmospheric Research (OAR) Pacific Marine Environmental Laboratory (PMEL) and Japan, respectively, and the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) array, with stations operated by PMEL, Brazil, and France. TAO is also an element of TOGA programme.

Participating Teams:
C. Martinez-AO-3270
D. Burrage-AO-3229
D. Levine-AO-3259

6.3.3.6 In-situ Data Network in the Great Barrier Reef

The southern Great Barrier Reef (GBR) is a new area of study which takes advantage of a monitoring network deployed for the Coral Bleaching Project 2006-2010 involving the University of Queensland, the Australian Institute of Marine Science, James Cook University and NOAA/NESDIS. A network of in-situ instruments monitores waves and currents as well as fixed vertical profiles of temperature.

Participating Teams:
M. Heron-AO-3271

6.3.4 MODELS AND ASSIMILATION

The models listed and described below have been identified for use by the vicarious calibration team. They will be used to compute TOA brightness temperatures to be compared with those measured by SMOS.
Two families of models have been identified:

1. Independent model not related to any SMOS geophysical retrieval algorithms
2. Model related or comparable with those used in the SMOS geophysical retrieval algorithms

Although these models will most probably cover a wider range of scientific issues than simply SMOS calibration, the short description provided below only covers the model's contribution to the vicarious calibration team objectives.

6.3.4.1 ECMWF Operational Weather Forecast System

The system will use the two-scale emission model from the Universite Catholique de Louvain.

Participating Teams:
ECMWF-AO-3262

6.3.4.2 Snow Model

Kim: forward radiative transfer model of Dome-C.
Paloscia: multilayer coherent physical model. The model used to simulate the brightness temperature of snow pack in Dome-C will be a coherent multilayer model, based on the strong fluctuation theory and wave approach.

Participating Teams:
S. Paloscia-AO-3250
E. Kim-AO-3273

6.3.4.3 Forest Model

Kim: forward radiative transfer model of dense forest.
Paloscia: discrete element radiative transfer model. Simulations of emission from forests will be performed using a first order discrete element radiative transfer model, which describes a forest as a two-layer medium (trunks and crowns) over a rough interface (soil).

Participating Teams:
S. Paloscia-AO-3250
E. Kim-AO-3273

6.3.4.4 Ice Emissivity Model MEMLSI

The sea ice version of the Microwave Emission Model of Layered Snowpacks (MEMLS, Wiesmann and Mätzler 1999) is a multiple-scattering model allowing many layers in order to simulate snow cover emission including most of the known physical effects. MEMLS was extended with a sea ice module, this extension is described in Tonboe et al. (2006). MEMLS is based on a six-flux radiative-transfer theory, using a correction function approach to quantify snow structure, including multiple scattering both for stratification and snow grains.

Participating Teams:
D. Stammer-AO-3241

6.3.4.5 Navy Coastal Ocean Model and Modular Ocean Data Assimilation System

SMOS salinity products will be ingested into the US Navy MODAS (www7320.nrlssc.navy.mil/modas/) and assimilated into the global NCOM and the regional (Intra America Seas, IAS) ocean circulation models. Success will be measured by identical experiment comparing models with and without SSS assimilation. However, it is a coastal ocean model emphasis, though global, that does not respect the "best state estimate" on a global basis. Indeed the proposal does not profess to estimate global benefit of SMOS SSS data assimilation.

Participating Teams:
D. Burrage-AO-3229

6.3.5 COMPARISONS

6.3.5.1 Comparison with Advanced Microwave Scanning Radiometer (AMSR)

The EOS AMSR is a one of the six sensors aboard AQUA. AMSR-EOS is a passive microwave radiometer, modified from the Advanced Earth Observing Satellite-II (ADEOS-II) AMSR, designed and provided by JAXA. It observes atmospheric, land, oceanic, and cryospheric parameters, including precipitation, sea surface temperatures, ice concentrations, snow water equivalent, surface wetness, wind speed, atmospheric cloud water, and water vapor.

The calibration method for short term and long term from Zhang team will include simulation model and its parameterization, and statistic results of SMMR and AMSR-EOS C-band brightness temperature over the Takelimgan Desert.

Participating Teams:

ECMWF-AO-3262
D. Stammer-AO-3241
W. Zhang-AO-3279
S. Paloscia-AO-3250
D. LeVine-AO-3259
M. Hallikainen-AO-3281
DeJeu-AO-3238
Grippa-AO-3257
Friesen-AO-3280
Kaihotsu-AO-3211
Jackson-AO-3221
Magagi-AO-3268
Escorihuela-AO-6317

6.3.5.2 Comparison with Special Sensor Microwave Imager (SSMI)

The SSMI is a conically-scanning microwave radiometer with channels at 19, 22, 37 and 85 GHz. All measurements are obtained with dual polarization, except the 22GHz, which is only vertically polarized. The microwave images can "see" through most clouds. The SSMI sensors are located on the NOAA DMSP polar orbiting satellites.

Participating Teams:

ECMWF-AO-3262
D. Stammer-AO-3241
D. LeVine-AO-3259
W. Zhang-AO-3279
F. Gaillard-AO-3276
S. Paloscia-AO-3250
Magagi-AO-3268
Singh-AO-3223
Su-AO-3269

6.3.5.3 Comparison with Tropical Microwave Imager (TMI)

TMI is a passive microwave sensor designed to provide quantitative rainfall information over a wide swath under the TRMM satellite. By carefully measuring the small amounts of microwave energy emitted by the Earth and its atmosphere, TMI is able to quantify the water vapor, the cloud water, and the rainfall intensity in the atmosphere. It is a relatively small instrument that consumes little power. This, combined with the wide swath and the good, quantitative information regarding rainfall make TMI the "workhorse" of the rain-measuring package on the NASA Tropical Rainfall Measuring Mission launched in 1997.

Participating Teams:

ECMWF-AO-3262
D. Stammer-AO-3241
DeJeu-AO-3238
Su-AO-3269
Singh-AO-3223

6.3.5.4 Comparison with Advanced Synthetic Aperture Radar (ASAR)

The Advanced Synthetic Aperture Radar (ASAR) onboard ENVISAT (launched in may 2002), operating at C-band, ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI. It features enhanced capability in terms of coverage, range of incidence angles, polarisation, and modes of operation. This enhanced capability is provided by significant differences in the instrument design: a full active array antenna equipped with distributed transmit/receive modules which provides distinct transmit and receive beams, a digital waveform generation for pulse "chirp" generation, a block adaptive quantisation scheme, and a ScanSAR mode of operation by beam scanning in elevation.

Participating Teams:

D. Stammer-AO-3241
W. Zhang-AO-3279
S. Paloscia-AO-3250
W. Marczewski-AO-3275
M. Hallikainen-AO-3281
A. Camps-AO-3254
J. Walker-AO-3219
Martins-AO-3934
Patel-AO-3284
Su-AO-3269
Magagi-AO-3268
Grippa-AO-3257
Singh-AO-3223
Zribi-AO-3274
Gommenginger-AO-3265
LopezBaeza-AO-3252
Mauser-AO-3236

6.3.5.5 Comparison with Scanning Multichannel Microwave Radiometer (SMMR)

SMMR on SEASAT was a multispectral, dual-polarization microwave radiometer observing at the following frequencies: 6.6 GHz (45.4 mm), 10.7 GHz (28 mm), 18.0 GHz (16.6 mm), 21.0 GHz (14.2 mm), and 37.0 GHz (8.1 mm). Six Dicke-type radiometers were utilized. Those operating at the four longest wavelengths measured alternate polarizations during successive scans of the antenna; the others operated continuously for each polarization. The antenna was a parabolic reflector offset from the nadir by 42º. Motion of the antenna reflector provided observations from within a conical volume along the ground track of the spacecraft. SMMR had a swath width of about 600 km and the spatial resolution ranged from about 22 km at 37 GHz to about 100 km at 6.6 GHz. The absolute accuracy of sea surface temperature obtained was 2 K with a relative accuracy of 0.5 K. The accuracy of the wind speed measurements was 2 m/s for winds ranging from 7 to about 50 m/s. On NIMBUS-7, microwave brightness temperatures were observed with a 10-channel (five-frequency dual polarized) scanning radiometer operating at frequencies of 37 (0.81 cm), 21 (1.42 cm), 18 (1.66 cm), 10.69 (2.8 cm), and 6.6 (4.54 cm) GHz.

Participating Teams:

D. Stammer-AO-3241
W. Zhang-AO-3279
DeJeu-AO-3238

6.3.5.6 Comparison with Advanced Very High Resolution Radiometer (AVHRR)

The AVHRR is a radiation-detection imager that can be used for remotely determining cloud cover and surface temperature. The term surface can mean the surface of the Earth, the upper surface of clouds, or the surface of a body of water. This scanning radiometer uses 6 detectors that collect different bands of radiation wavelengths.

The first AVHRR was a 4-channel radiometer, first carried on TIROS-N (launched in October 1978). This was subsequently improved to a 5-channel instrument (AVHRR/2) that was initially carried on NOAA-7 (launched

in June 1981). The latest instrument version is AVHRR/3, with 6 channels, first carried on NOAA-15 launched in May 1998.

Participating Teams:
D. Stammer-AO-3241
D. Burrage-AO-3229
W. Marczewski-AO-3275
A. Camps-AO-3254
Mauser-AO-3236
Singh-AO-3223

6.3.5.7 Comparison with AQUARIUS

AQUARIUS mission will measure global SSS with unprecedented resolution. The science instruments will include a set of three radiometers that are sensitive to salinity (1.413 GHz; L-band) and a scatterometer that corrects for the ocean's surface roughness.

Participating Teams:
D. LeVine-AO-3259
D. Stammer-AO-3241
E. Kim-AO-3273

6.3.5.8 Comparison with Shuttle Radar Topography Mission (SRTM)

The SRTM obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000.

Participating Teams:
S. Paloscia-AO-3250

6.3.5.9 Comparison with Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes from south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands. The data will improve the understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change.

Participating Institutes:
W. Zhang-AO-3279
W. Marczewski-AO-3275
Friesen-AO-3280
DeJeu-AO-3238

6.3.5.10 Comparison with Medium Resolution Imaging Spectrometer (MERIS)

MERIS, onboard ENVISAT (launched in may 2002), is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range. Fifteen spectral bands can be selected by ground command, each of which has a programmable width and a programmable location in the 390 nm to 1040 nm spectral range.

The instrument scans the Earth's surface by the so called "push-broom" method. Linear CCD arrays provide spatial sampling in the across-track direction, while the satellite's motion provides scanning in the along-track direction.

MERIS is designed so that it can acquire data over the Earth whenever illumination conditions are suitable. The instrument's 68.5° field of view around nadir covers a swath width of 1150 km. This wide field of view is shared between five identical optical modules arranged in a fan shape configuration.

Participating Teams:
D. Stammer-AO-3241
A. Camps-AO-3254

F. Gaillard-AO-3276
W. Marczewski-AO-3275
J. Walker-AO-3219
DeJeu-AO-3238
Singh-AO-3223
Grippa-AO-3257
Su-AO-3269
LopezBaeza-AO-3252
Navarro-AO-3266
Zribi-AO-3274

6.3.5.11 Use of Radar Altimeter (RA)

RA, onboard ENVISAT (launched in march 2002), is an instrument for determining the two-way delay of the radar echo from the Earth's surface to a very high precision: less than a nanosecond. It also measures the power and the shape of the reflected radar pulses.
It is a nadir-looking pulse-limited radar altimeter based on the heritage of ERS RA functioning at the main nominal frequency of 13.575 GHz (Ku Band), which has been selected as a good compromise between the affordable antenna dimension that provides the necessary gain and the relatively low attenuation which experience the signals propagating through the troposphere.

Participating Teams:
D. Stammer-AO-3241
F. Gaillard-AO-3276
A. Camps-AO-3254

6.3.5.12 Comparison with Along Track Scanning Radiometer (ATSR)

The Advanced Along-Track Scanning Radiometer (AATSR) is one of the instruments on board ENVISAT (launched in may 2002). It is the most recent in a series of instruments designed primarily to measure Sea Surface Temperature (SST), following on from ATSR-1 and ATSR-2 on board ERS-1 and ERS-2. AATSR data have a resolution of 1 km at nadir and are derived from measurements of reflected and emitted radiation taken at the following wavelengths: 0.55 μm, 0.66 μm, 0.87 μm, 1.6 μm, 3.7 μm, 11 μm and 12 μm.
Special features of the AATSR instrument include its use of a conical scan to give a dual-view of the Earth's surface, on-board calibration targets and use of mechanical coolers to maintain the thermal environment necessary for optimal operation of the infrared detectors.

Participating Teams:
A. Camps-AO-3254
W. Marczewski-AO-3275
J. Walker-AO-3219
Magagi-AO-3268
Su-AO-3269
Martins-AO-3934

6.3.5.13 Comparison with Phased Array L-band Synthetic Aperture Radar (PALSAR)

PALSAR, onboard ALOS, is an active microwave sensor using L-band frequency for cloud-free and day-and-night land observation, and provides higher performance than the JERS SAR. The fine resolution mode is a conventional one. Other modes include the ScanSAR mode, allowing to acquire a 250 to 350 km width (depending on the number of scans) of SAR images at the expense of spatial resolution. This is three to five times wider swath than conventional SAR images.
Thomas Jackson is PALSAR Hydrology PI.
Wolfgang Wagner is PALSAR Hydrology PI.
Nicolas Floury (ESA) is PALSAR Hydrology PI.
Mark Drinkwater (ESA) is PALSAR Ocean PI.

Participating Teams:
M. Hallikainen-AO-3281
Kaihotsu-AO-3211

Mauser-AO-3236

6.3.5.14 Comparison with ERS Scatterometer

The purpose of the Wind Scatterometer is to obtain information on wind speed and direction at the sea surface for incorporation into models, global statistics and climatological datasets. It operates by recording the change in radar reflectivity of the sea due to the perturbation of small ripples by the wind close to the surface. This is possible because the radar backscatter returned to the satellite is modified by wind-driven ripples on the ocean surface and, since the energy in these ripples increases with wind velocity, backscatter increases with wind velocity. It works at 5.3 GHz (C band) in VV polarisation.

Participating Teams:

S. Paloscia-AO-3250
M. Hallikainen-AO-3281
Su-AO-3269

6.3.5.15 Comparison with QUIKSCAT SeaWinds

The SeaWinds scatterometer is a microwave radar designed specifically to measure ocean near-surface wind speed and direction. SeaWinds uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.4 GHz across broad regions on Earth's surface. The instrument collects data over ocean, land, and ice in a continuous, 1,800-kilometer-wide band, making approximately 400,000 measurements and covering 90% of Earth's surface in one day.

Participating Teams:

M. Hallikainen-AO-3281

6.3.6 TECHNICAL AND SCIENTIFIC ISSUES

6.3.6.1 Instrument Calibration

6.3.6.1.1 Light Cost Effective Front End (LICEF)

There are 69 antenna elements, called LICEF receivers, which are equally distributed over the three arms and the central structure. Each LICEF is an antenna-received integrated unit that measures the radiation emitted from the Earth at L-band. The acquired signal is then transmitted to a central correlator unit, which performs interferometry cross-correlations of the signals between all possible combinations of receiver pairs. The principal coefficients which are used in the model of the instrument are the scattering parameters, coefficients characterising the LICEF and the diagrams of each antenna. The good calibration of the instrument depends on the good knowledge of these coefficients and also of the good functioning of the instrument itself.

The LICEF physical temperature STD is a product of the level 1b.

The 72 LICEF health statuses and the 69 LICEF physical temperatures are products of the level 1a.

Participating Teams:

E. Anterrieu-AO-3260

6.3.6.1.2 Noise Injection Radiometer (NIR)

One source of bias is the instrumental inaccuracies in the NIR used to measure the antenna temperature (average value of the scene). These errors are: thermal noise (~0.2K), offset and linearity errors. The basic calibration operation consists of calibrating the reference on-board radiometers, which are 3 NIR. This operation implies the use of 2 (hot and cold) sources. The hot source is an on-board noise diode; the cold source is the sky. Hot calibration is performed at regular intervals during the flight, with a typical periodicity of one to ten sequences within each orbit. Cold calibration, which implies a manoeuvre, is performed along one orbit every 4 weeks.

NIR brightness temperatures in H and V polarisations, NIR modes and errors and NIR calibrated gain and offset are products of the level 1a.

Participating Teams:

M. Hallikainen-AO-3281

6.3.6.1.3 On-board Calibration System (CAS)

Concerning the interferometer, the on-board calibration system supplies most of necessary information for subsystems included in the on-board calibration loop. Calibration sequences are performed at regular

intervals during the flight (see above for NIR). Again, the influence of thermal variations along the orbit deserves particular consideration.

Participating Teams:
M. Hallikainen-AO-3281

6.3.6.1.4 Power Measurement System (PMS)

The PMS voltage, gain and offset are products of the level 1a.

Participating Teams:
A. Camps-AO-3254

6.3.6.2 Instrument Stability

The science issues involve very small, long-term trends. The calibration and stability requirements on the instrument are therefore severe.

Participating Teams:
E. Anterrieu-AO-3260
A. Camps-AO-3254
M. Hallikainen-AO-3281
D. LeVine-AO-3259
S. Paloscia-AO-3250

6.3.6.3 Earth Aliases

The question of earth alias influence is complex for MIRAS with its suboptimal antenna element spacing. Theoretical prediction of these aliases is feasible, but in-situ measurements accounting for actual coastal configuration and land emission are needed to validate them.
Burrage work on the earth aliases will be concentrated on the impact and amelioration or rectification of coastal brightness temperature signals.

Participating Teams:
D. Burrage-AO-3229
M. Heron-AO-3271
C. Martinez-AO-3270

6.3.6.4 Image Reconstruction

SMOS sensor configuration presents several particularities that determine Level 1C products characteristics: the same pixel is observed under different views at different incidence angles, with varying spatial resolution, radiometric accuracy and sensitivity, and different polarization modes can be operated implying different accuracies and spatio-temporal characteristics for the reconstructed brightness temperature fields. In addition to the random noise errors, the image reconstruction process induces other radiometric errors (radiometric biases) that impact the retrieval accuracy.
The brightness temperature calibration and the visibility calibration will depend, among other things, on an accurate knowledge of the state of the instrument and the image reconstruction method applied. In theory, the reconstruction algorithm allows estimating the instrumental coefficients. It is useful to check if the residues show signatures of a poor estimate of the instrumental coefficients. In this case, it should be possible to tune the reconstruction algorithm under constraints in the most suitable possible way (e.g. weighting the constraints).

Participating Teams:
E. Anterrieu-AO-3260
A. Camps-AO-3254

6.3.6.5 Sun Glint and Direct Sun

The sun is an extremely strong radiation source at L band, exhibiting a time-dependent blackbody temperature that ranges between 100000 K and 10 million K, depending on the solar activity, and the next solar maximum is expected in 2010, that is 2 years after SMOS launch.
Two distinct mechanisms may contribute to the solar radiation intercepted by a radiometer antenna: one is the reflection of sun radiations by the earth-surface (sunglitter effects) and the other is the direct leakage into the antenna. Modeling is used for the reflected contamination while direct contamination is addressed by the level 1 processor.
It was shown that the centre of the sun's glitter pattern will never be located in the area of SMOS field of view. However the expected range of surface wind speeds (zero wind is very rare) will cause the sun's glitter pattern to spread within the alias free field of view which might contamine the useful measured signals.

Sun-glitter effects might be modelled using approximate scattering models to compute the forward scattering of the sun radiations from the rough water surface. Sun glitter does not occur frequently in practice. However, when it does, this phenomenon may have severe effects on the brightness temperature signals measured by spaceborne L- band radiometers.
The subtraction of known sources (sun, moon, sky, galaxy...) can generate biases on the whole of a snapshot if a significant error is present on the external data (sun intensity, ocean reflectivity, etc). With regard to the subtraction of the sun glint, one can expect significant error due to the fact that the contribution of the sun glint depends on the roughness parameters of the sea surface which are known with a large error. Various models of sun glint could be tested in order to understand the incidence of the model choice on the reconstruction.
External data from radiotelescope on the sun and the moon needed ?

Participating Teams:
A. Camps-AO-3254
E. Anterrieu-AO-3260
M. Heron-AO-3271

6.3.6.6 Galactic Noise and Cosmic Background

At L band, radiation from celestial sources is strong and spatially variable; associated corrections needed to interpret L-band radiometric measurements have been thoroughly described by Le Vine and Abraham (2004). Radiation originates from three types of sources. The hydrogen line emission corresponds to a hyperfine atomic transition in neutral hydrogen: the radiation is maximum around the plane of the galaxy, most of the time less than 2 K. The cosmic background is a remnant signal of the origin of the universe and is almost constant in space and time (2.7 K). In addition to the almost constant cosmic background, a very variable (in space) continuum radiation (up to more than 10 K) is due to emissions from discrete radiosources.
As in the case of atmospheric emission, the cosmic background adds a contribution to the radiometric temperature that depends on the incidence angle linked to the reflection of the signal. The two other types of sources add a signal that varies according to the incidence and azimuth angles of the measurement.
Burrage will work on the galactic noise focusing on the relative performance of different roughness correction models.

Participating Teams:
D. Burrage-AO-3229
M. Heron-AO-3271
C. Martinez-AO-3270

6.3.6.7 Geolocation Biases

The impact of misregistration of SMOS products is such that a 1 km shift in the level 1C products can lead to a 2.3% error in soil moisture estimation at level 2. Since this effect is incompatible with the mission requirements, an accurate estimation of localisation biases is needed. This is specially true since, when compiling localisation error budget, it becomes obvious that the major contributors to this budget are biases, not expected to evolve once in orbit, but introduced at launch and arms deployment times. The measurement of biases with such a high accuracy, based on images of rather modest resolution, is by itself challenging, but the maturity of correlation techniques, developped for other earth observation needs, makes it feasible.

Participating Teams:
F. Cabot-AO-3282

6.3.6.8 Total Electron Content (TEC) and Faraday Rotation

The total electron content (TEC) of the ionosphere induces a frequency dependent effect leading to the polarisation rotation (also called Faraday rotation). The TEC varies with solar activity, time of day and year and latitude. The Faraday rotation is due to the effect of ionospheric electrons on the propagation of electromagnetic waves.
The capability to observe dual polarisation is required to significantly improve the retrieval. In addition, dual polarization capability may prove useful for removing Faraday rotation effects. Finally, dual polarized signals are required to correct unavoidable polarisation leakage effects.
The TEC magnitude, the International Geomagnetic Reference Field (IGRF) vector and the Faraday rotation angle are products of the level 1c.

Participating Teams:

D. LeVine-AO-3259

6.3.6.9 Ruf Method

C. Ruf has developed a method using the lower brightness temperatures over ocean. The survey of the colder part of the brightness temperature histograms makes it possible to detect very weak drift.

Participating Teams:

D. LeVine-AO-3259
F. Gaillard-AO-3276
M. Hallikainen-AO-3281
W. Zhang-AO-3279

6.3.6.10 Radio-Frequency Interference (RFI) Map

For every pixel, there shall be an RFI flag defined in a specific auxiliary file. This will be translated directly into a flag for RFI effect within the L1c products. No estimation of extraneous sources shall be made by comparing values retrieved in consecutive snapshots in the L1PP. Identification of RFI sources shall be done at L2 by spatial and temporal data analysis. The L1PP shall simply mark the pixels already identified for an easier discarding by L2.

Raw SMOS correlator and NIR signals will be examined for evidence of RFI and techniques for compensating for RFI will be applied when there is a problem. Within the AQUARIUS team, there is a significant experience dealing with RFI at L-band in synthetic aperture radiometers (i.e. Le Vine with the synthetic aperture radiometer ESTAR).

Participating Teams:

D. Le Vine-AO-3259
D. Stammer-AO-3241

6.3.6.11 Atmospheric Brightness Temperature and Attenuation

All goals shall be met in the presence of atmospheric effects, including oxygen and water vapour absorption. Corrections for such perturbations shall be included in the ground segment processor, as needed.

The method for computing gazeous radiative contributions has to be selected in such a way that the resulting error on upwelling brightness temperatures due to approximating the effect of physical atmospheric properties (pressure, temperature, water vapor concentration) never exceeds 0.05 K for SMOS operating conditions. It is expected that this goal is compatible with computing power/time requirements. Then, the major error source will be due to estimates of absorption cross sections, which in turn reflect the uncertainty on spectroscopic measurements. This uncertainty is estimated around 5%.

Since the uncertainty on absorption cross sections cannot be overcome, the resulting error will have to be corrected within the overall SMOS validation process. However, the variation with incidence angle offers a possibility to discriminate among other effects.

Assuming one succeeds in determining correctly the absorption cross sections, the resulting uncertainty would be permanently eliminated.

In case a simplified algorithm is applied, care must be applied, based on considering a representative sample of experimental atmospheric data or analyses, in order to ensure that either tables or empirical laws cover the whole ranges of physical situations.

Assumptions are related to laboratory knowledge of spectral properties of atmospheric gases. Limitations concern the presence of liquid (cloud or rain) water in the atmosphere, for which a flagging approach is suggested rather than a correction.

Stammer project will estimate geophysical parameters and atmospheric corrections through radiometric measurements from a tower in the North Sea.

Participating Teams:

D. Stammer-AO-3241

6.3.6.12 Global Monitoring of Level 1C Brightness Temperature

SMOS level 1C brightness temperatures will be introduced in ECMWF Integrated Forecast System (IFS). The observations will be archived in the operational database in BUFR (Binary Universal Form for the Representation of meteorological data) format. For the monitoring over ocean areas, radiative transfer calculations at L-band will be performed using the parameterized version of the two-scale emission model from the Université Catholique de Louvain (UCL). Modelled brightness temperatures will be based on analysed atmospheric fields including 10m wind speed, sea surface temperature and salinity. The computations will be carried out for horizontal and vertical polarizations at 0° and 50° zenith angle.

Systematic differences, such as drifts and biases, will be analysed from the departure statistics for individual areas of the globe. In addition, SMOS departure statistics will be compared with departure statistics obtained for other operational passive microwave imagers, e.g. AMSR, TMI, or SSMI.
Over land, brightness temperatures will be archived and compared with modelled soil moisture fields. Time series and cumulative distribution functions (CDF) will be produced for individual model grid boxes and selected areas of the globe. The shape of the CDF characterizes the potential accuracy of a SMOS derived soil moisture product.

Participating Teams:
ECMWF-AO-3262

6.3.6.13 Uyuni Salar

The Salar de Uyuni is a large and radiometrically homogeneous area. Its extent is several SMOS pixels and its emissivity is high and rather homogeneous except when flooded (about 3 months per year). It is located in a rather uninhabited area where no RFI is to be expected. Therefore it provides a perfect calibration site for SMOS Tb.

Participating Teams:
M.J. Escorihuela-AO-6317

6.3.7 SUMMARY OF CONTRIBUTIONS

The following teams are part of the vicarious calibration plan:

Anterrieu-AO-3260 (LICEF, image reconstruction, sun glint, instrument stability)
Burrage-AO-3229 (earth aliases, galactic noise)
Cabot-AO-3282 (geolocation)
Camps-AO-3254 (PMS, image reconstruction, sun glint, instrument stability)
ECMWF-AO-3262 (global brightness temperature)
Gaillard-AO-3276 (ruf method)
Hallikainen-AO-3281 (NIR, CAS, ruf method, instrument stability)
Heron-AO-3271 (earth aliases, galactic noise, sun glint)
Kim-AO-3273 (Dome-C, dense forest)
LeVine-AO-3259 (faraday rotation, ruf method, RFI map, instrument stability)
Martinez-AO-3270 (earth aliases, galactic noise)
Paloscia-AO-3250 (Dome-C, dense forest, instrument stability)
Stammer-AO-3241 (RFI map, atmospheric attenuation)
Zhang-AO-3279 (ruf method, takelingam desert)
Walker-AO-3219 (dense forest, simpson desert)
Escorihuela-AO-6317 (uyuni salar)

Linked Projects *(calibration teams are in italic):*

----------airborne radiometer (OS)
Heron-3271 mal.heron@jcu.edu.au
Martinez-3270 carmar@glaucus.fcien.edu.uy
Burrage-3229 burrage@nrlssc.navy.mil

----------France & Spain
Camps-3254 camps@tsc.upc.edu
Zribi-3274 mehrez.zribi@cetp.ipsl.fr
Calvet-3168 jean-christophe.calvet@meteo.fr
Cabot-3282 francois.cabot@cnes.fr
Pellarin-3261 thierry.pellarin@hmg.inpg.fr
Anterrieu-3260 eric.anterrieu@ast.obs-mip.fr
Gaillard-3276 fabienne.gaillard@ifremer.fr
Poulain-3244 ppoulain@ogs.trieste.it

LopezBaeza-3252 ernesto.lopez@uv.es
MartinezFernandez-3230 jmf@usal.es

----------Dome C (TB)
Kim-3273 ed.kim@nasa.gov
Paloscia-3250 s.paloscia@ifac.cnr.it

----------GLOWA (SM)
Friesen-3280 j.friesen@tudelft.nl
Mauser-3236 w.mauser@iggf.geo.uni-muenchen.de

----------AMMA (SM)
Friesen-3280 j.friesen@tudelft.nl
Zribi-3274 mehrez.zribi@cetp.ipsl.fr
Grippa-3257 manuela.grippa @cesbio.cnes.fr
Magagi-3268 ramata.magagi@usherbrooke.ca

----------REMEDHUS (SM)
MartinezFernandez-3230 jmf@usal.es
Wagner-3233 ww@ipf.tuwien.ac.at
Camps-3254 camps@tsc.upc.edu

----------SMOSMANIA (SM)
Zribi-3274 mehrez.zribi@cetp.ipsl.fr
Calvet-3168 jean-christophe.calvet@meteo.fr

7 DATA DISTRIBUTION PLAN

Responsible:

- The data distribution team will be lead by N. Wright (ESA/ESRIN).

Objectives:

- To distribute all data needed by users within the frame of the calibration validation and retrieval plan execution. It will describe the method how users, PI & collaborators, the development and VRT teams will access data and identify the different distribution methods that will be used to provide the required service.

Inputs:

- Calibration Plan
- Validation Coordination Plan
- Campaign Coordination Plan
- L1 Product Maintenance Plan
- L2 Product Maintenance Plan

Outputs:

- Requested data products
- Data distribution reports
- Happy users

The AO PI are requested to provide clearly their data needs, in terms of spatial coverage (complete coverage of the globe or geographic areas defined by corner coordinates) and in terms of ESA sensor data. Please note that the procurement of non-ESA data needed by the AO teams remain the responsibility of the AO PI. Media (ie CD or DVD) will only be used for large volume requests. The Ground Segment at ESAC will have the capacity to distribute data electronically during the commissioning phase but not for "all products, to all users, at all times". "Some products to some PI every day" would be a reasonable description. The ESAC team will be given all PI requests and will make that compatible with the bandwidth at ESAC.
The Long Term Archive (LTA) at Kiruna will have the capacity to distribute much more data electronically during the commissioning phase to PI. The LTA data are available, by default, 2-4 days after the ESAC data.
An alternative has been discussed with Brockman Consult (Germany), where the idea is to reuse the infrastructure developed for MERIS by Brockman Consult (i.e. MERCI) and extend it to SMOS. The MERCI development has now been upgraded to the status of Cal/Val Portal, and therefore, as its name suggests, could be used for SMOS. The Cal/Val portal should be upgraded to support SMOS Cal/Val and should be available for the SMOS commissioning phase (http://calvalportal.ceos.org user:esa pswd:envisat).
Now, the integration of SMOS in the Cal/Val portal is part of the evolution that started in 2007. The completion is foreseen for 2008. Therefore, the portal should be ready for the SMOS commissioning phase. It will include an adaptation of BEAM, the reader toolbox for MERIS and AATSR products. The new BEAM4.0 architecture will be able to handle and analyse some SMOS data products. As before, BEAM will remain user driven, flexible, open source and platform independent.
ESAC will distribute about 150 Gbytes per day and the LTA about 800 Gbytes per day electronically to users (Cal/Val or Science PIs). All other distribution needs will have to be addressed by media. For each processing centre, there will be a maximum number of media that can be generated and distributed per day (probably between 20 and 100).
It is clear that 950 Gbytes/day is not sufficient to fulfil all the Cal/Val or Science PIs requests. The priority for the moment is clearly the Cal/Val PIs. It is then necessary to take the requests and allocate them to the various possibilities:
1) electronically from ESAC
2) media from ESAC
3) electronically from LTA
4) media from LTA

L1C should be systematically available 4 months after launch and L2 after 5 months if all goes well. ESAC will push the data to the Cal/Val portal and from there the users can pick them up. Alternatively ESAC or the LTA can push the data to the users directly but the portal is the preferred route.
The overall distribution will have to be managed as there will be more requests than available bandwidth. The management head should eventually be involved in trying to sort out the priorities.
The data will be put on a password protected FTP server and each PI will be informed of any new products by an electronic mail. Note that the mail will only be sent to the PI, not to all the team.

Electronic distribution takes place after production on a priority basis. It should happen within a few hours of production in the worst case for the normal user but it will be quite variable because the network links are shared.
ECMWF is a special case where they should get their BUFR product within three hours of production. NRT delivery is intended for ECMWF and no one else. However, other interested third parties might also get it without any guarantee. This NRT service should allow someone to assess the utility of the NRT data for their application. If they then decide that the delivery time needs to be improved for their application, ESA will investigate technical and financial alternatives to improve the service. It is clear to everyone that ECMWF gets special treatment because they are making a financial commitment to ESA related to SMOS i.e. it does not come for free.
Media distribution is up to a week from sensing.

The estimated size of the data set record in the SMOS products (half-orbit) are:
L1A (MIR_SC_D1A dual pol) : 41891 bytes (in one product 1350 snapshots x 2 polarizations are expected) total size of the product: ~108 MB
L1A (MIR_SC_F1A full pol) : 41891 bytes (in one product 1350 snapshots x 4 polarization are expected) total size of the product: ~215 MB
L1B (MIR_SC_D1B dual pol) : 22515 bytes (in one product 1350 snapshots x 2 polarization are expected) total size of the product: ~56 MB
L1B (MIR_SC_F1B full pol) : 22515 bytes (in one product 1350 snapshots x 4 polarization are expected) total size of the product: ~116 MB
L1C (MIR_SCSD1C (sea)/MIR_SCLD1C (land) dual pol) : total size of the product: ~300 MB
It is composed of two data sets:
- 24 bytes (in one product 4800 points x 1350 snapshots x 2 polarizations are expected)
- 161 bytes (in one product 1350 snapshots x 2 polarizations are expected)
L1C (MIR_SCSF1C (sea)/MIR_SCLF1C (land) full pol) : total size of the product: ~520 MB
It is composed of two data sets:
- 24 bytes (in one product 4800 points x 1350 snapshots x 2 polarizations are expected)
- 161 bytes (in one product 1350 snapshots x 2 polarizations are expected)
L2 Ocean Salinity: total product size: ~13 MB
174 bytes per data set record (around 80000 grid points are expected in average for each product)
L2 Soil Moisture: total product size: ~14 MB
174 bytes per data set record (around 80000 grid points are expected in average for each product)

7.1 SMOS Cal/Val Data Support

Requirements

1. Support for SMOS products implemented into the CalValPortal software. This enables the product-registration software to ingest and analyse the SMOS data products.
2. Analyse and implement an imaging concept for SMOS data.
3. Define an appropriate set of calibration sites and implement them into the CalValPortal.

4. Analyse and eventually extend the already implemented means to generate subsets of data products. It shall be discussed with the SMOS calibration team whether the current subset format responds to their needs.
5. Gather in-situ data over the calibration sites covering the parameters needed for the calibration exercise.

It has to be clarified by which methods the SMOS data will be available for the CalValPortal during the commissioning phase. It is expected that the first datasets will not be distributed using standard ESA interfaces (rolling archive, EOLI).
The same question arises in connection with the in-situ datasets. It has to be clarified where these datasets shall originate, in which format the data is stored and analysed, how the datasets fit into the current concept of in-situ data storage.

Brockmann Consult (BC) Solution

The target for the SMOS Calibration support is to have a full support for the sensor implemented in the CalVal Portal. This includes full support for the data products in the CalValPortal web-application, full support for in-situ measurements in the CalValPortal and support for SMOS products in BEAM/VISAT as analysis tool.

As a basis for this, BC will implement a reader for SMOS products in BEAM to be able to extract the required metadata stored in the CalVal database. Additionally, the product quality can be checked and corrupted products or products not following the file specification can be detected and marked as corrupted.
As the SMOS products are not stored as regular gridded datasets, an adapter must be implemented to bring the product data to this format, adding “no-data” pixels to form a rectangular raster containing the measurement data. Based on this raster, quicklook and thumbnail images can be generated.
An additional benefit is that the SMOS CalVal users can use BEAM as a tool for data analysis.
It has to be investigated if a subset of the data in native format is needed and can be implemented with an appropriate effort. As a fallback Brockmann Consult suggest to omit subsetting in native format and allow subsets in ASCII format.
Available SMOS data products:

Product	Description	Support
SMOS L0	Source Packets with added Earth Explorer product headers, chronologically sorted by Source Packet type.	no
SMOS L1a	Reformatted and calibrated observation and housekeeping data, physically consolidated in pole-to-pole time-based segments.	To be clarified if technically possible with appropriate effort.
SMOS L1b	Image reconstructed SMOS observation measurements; consist of geolocated vectors of Brightness Temperatures in the antenna polarisation reference frame.	To be clarified if technically possible with appropriate effort.
SMOS L1c	Reprocessed Level 1b, which are geographically sorted, that is swath-based maps of Brightness Temperature.	Yes
SMOS L2	Soil Moisture swath-based maps and Ocean Salinity swath-based maps.	Yes

To ensure a complete coverage of SMOS data over the dedicated test sites, a data distribution mechanism for SMOS data has to be defined. Ideally, this shall be implemented by an online access to the ESA catalogue. As it is expected that this access will not be possible during the commissioning phase, other means of data access have to be defined.
Special calibration sites have to be defined in addition to the ones already covered by the CalValPortal. These sites shall be added to the CalValPortal.

The data format of in-situ measurements needed for the sensor calibration has to be clarified. It depends on the data format and the needs of the scientists whether the database structure needs to be adapted. It is expected that the data can be handled with the current database structure.
Experiences with the current implementation of the CalValPortal show that the main issue lies in retrieving in-situ measurements from the scientists. A campaign should be started to retrieve datasets from all SMOS PI to make their datasets available to the CalValPortal.
A sensor description shall be added to the CalValPortal containing all information needed to understand the SMOS sensor.
Dynamic auxiliary data are ECMWF and MODIS-LAI. These need to be made available to the PI along with the L1c in order to process to L2 with the prototypes.

A working version 0.5 of the SMOS box was ready for delivery by 10 December 2008. A small hand-over meeting with some potential SMOS box users was organized to introduce and demonstrate the software and to enter into a dialogue with this small user group to assess the current software features and to sketch a way for future development (carsten.brockmann@brockmann-consult.de).

1. Short and general introduction to BEAM concepts and VISAT GUI
2. Representation of SMOS L1C, L2 data in BEAM
3. Discussion of SMOS data product content in BEAM
4. Discussion of applicability of relevant VISAT tools to SMOS data
5. Discussion of dedicated SMOS box features
6. Explanation of SMOS format, its generation and maintenance

During the commissioning phase, each cal/val PI will be able to download all acquisitions of SMOS from the FTP server (141.4.215.16). All data intersecting one of its sites will be directly copied into its FTP home directory. These datasets will be available for a certain period of time, then they will be removed. Additionally, the cal/val PI will be able to access the complete backlog archive containing all products from Level-0 to Level-2 and the auxiliary data.
During Spring 2009, ESA and Brockmann Consult performed some end-to-end tests of the data distribution system. During these tests, the PI may receive mail notifications about data availability. This is a good opportunity to also test its account and download some of the test data.

Version 1.0 of the SMOS-Box is available (29 june 2009) for download from the BEAM website at http://www.brockmann-consult.de/cms/web/beam/software
In addition, updated test data are available for download at ftp 141.4.215.16. Please login as 'smosbox' with smos4u in order to fetch the data. Also note that the SMOS-Box wiki is now public.
http://www.brockmann-consult.de/beam-wiki/display/SBOX/SMOS+Toolbox+for+BEAM

Version 1.0 of the BEAM SMOS-Box is an add-on to BEAM 4.6 and requires that BEAM 4.6 is installed. The SMOS-Box is capable of reading SMOS data products complying with Schemas Release 2009-06-02_v04-03-09.

Ocean Data for Validation

IFREMER creates a list every day of available ARGO floats locations and times.
AQUARIUS is putting together a system of extraction with NASA, where they feed the SeaBASS database and Gene Feldman does the extraction and formatting for AQUARIUS validation plan. The problem now is to decide which in-situ data and what format should be prepared for the SMOS OS PI.

The CATDS (Centre Aval de Traitement des Données SMOS) team will receive the SMOS level 2 products at IFREMER within the frame of the CATDS project. Therefore, they will do the match-up between in-situ data and SMOS level 2 products coming out of the processing chains from both ESA and the CATDS. In this context, IFREMER/CATDS is willing and pleased to deliver the future SMOS L2 products/in-situ global Match-up DataBase (MDB) to all the user community through (likely) an open web access portal.

Things to be checked :
(i) that this is OK with CNES. But, a-priori, since the CATDS team conceived the MDB processing chain and will implement and run the match-up exercise internally at IFREMER (this MDB chain will run offline of the CATDS industrial processing chain), it should not be associated with any industrial propriety problems from CNES.
(ii) that the date at which the SMOS L2 products will arrive at IFREMER from the CNES distribution is OK so that the match-ups will be in a position to be distributed to the community during commissioning phase. If the CNES distribution is only started after commissioning phase, then maybe ESA will have to give IFREMER a dedicated access to the L2 products sooner than to CNES.

Available SSS and SST Databases

SMOS OS validation PI should make sure that they upload their in-situ datasets (when they have any) on at least one of these databases, preferably on the CalValPortal of CEOS, and inform catherine.bouzinac@esa.int.

http://calvalportal.ceos.org/
The Committee on Earth Observation Satellites (CEOS) is providing information and data for Calibration (Cal) and Validation (Val) of Earth Observation (EO) data through this portal. This portal shall support worldwide activities on calibration and validation, and specifically ensure that sensor intercalibration is favoured in a standardised way. The overall goal is to increase measurement accuracy of all the sensors which will be supported by this system, so that the GMES (Global Monitoring for Environment Security) programme can be served with the best information products available.

http://seabass.gsfc.nasa.gov/
Archived data include measurements of apparent and inherent optical properties, phytoplankton pigment concentrations, and other related oceanographic and atmospheric data, such as water temperature, salinity, stimulated fluorescence, and aerosol optical thickness. Data are collected using a number of different instrument packages, such as profilers, buoys, and hand-held instruments, and manufacturers on a variety of platforms, including ships and moorings. SeaBASS (Sea Biooptical Archive and Storage System) includes data from over 1,500 field campaigns, collected by over 80 contributors from 55 institutions in 14 countries. The architecture of SeaBASS consists of three tiers: geophysical data and metadata recorded in digital text files that adhere to the American Standard Code for Information Interchange (ASCII) format; a directory tree structure residing on a dedicated server at NASA Goddard Space Flight Center for storage of the data files; and, a relational database management system (RDBMS), built using the SQL Server product from Sybase, Inc., used to catalog and distribute the data and files. Through the use of online search engines that interface with the RDBMS, the full biooptical data set is queriable and available to authorized users via the World Wide Web at this site.
Data are released to the public once they have passed a series of quality control procedures. Data collected prior to 1 January 2000 have been released to the NOAA National Oceanographic Data Center for inclusion in their archive.

http://www.coriolis.eu.org/
A system for operational oceanography is available in France (MERCATOR) to monitor and forecast the ocean behavior. It is composed of three projects:
Sea-surface observation using satellite sensors,
In-situ measurements from ships, moored or drifting autonomous systems,
Assimilation of in-situ and satellite data in an ocean circulation model.
Coriolis contributes to the in-situ part of this system, with the objective of developing continuous, automatic, and permanent observation networks. The data collected enable water properties to be mapped, such as temperature and salinity.

http://www.ifremer.fr/gosud/

The main objective of GOSUD (Global Ocean Surface Underway Data Pilot Project) is to collect, process, archive and disseminate in real time and delayed mode, sea surface salinity and other variables collected underway, by research and opportunity ships.

http://seaboard.ndbc.noaa.gov/
The National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC), a part of the National Weather Service (NWS) designs, develops, operates, and maintains a network of data collecting buoys and coastal stations.

http://www.medspiration.org/
The GHRSST (Global High Resolution SST) Match-up Database (MDB) of colocated satellite and in-situ SST is a service of Medspiration project funded by ESA. It is required by GHRSST for quality control of satellite SST datasets, in particular for deriving or verifying SSES using in-situ SST observations from ships, buoys and profiling floats. Such observations provide a reliable independent reference data set that must be matched in space and time to satellite observations.
Although several independent MDB systems have previously been created by agencies responsible for particular SST products, their formats are diverse, their in-situ data sources may be different, and they do not share uniform quality control and spatial/temporal match-up criteria. These important differences make it difficult to compare MDB analyses of different SST products with each other. The GHRSST-MDB is intended to remedy this. It is a new multi-sensor SST MDB being developed at the IFREMER centre in Brest, France by integrating in-situ data held within the Coriolis system (responsible for the collection and archive of global in-situ oceanographic data, http://www.coriolis.eu.org) and an archive of GHRSST data products, both hosted by IFREMER.

http://www.nodc.noaa.gov/
http://www.bodc.ac.uk/
http://www.oceannet.org/
http://www.ferrybox.org
http://www.seprise.eu/
http://www.ioc-goos.org/

7.2 SMOS Tools

A common repository for all tools is the FTP server at ESAC : ftp://anonymous@193.146.123.163

SMOS Data Viewer
http://213.170.46.150/smos/software/SMOSView/
ftp://193.146.123.163/smos/software/SMOSView/
ftp://ftp.smos.esa.int/from_esa/SDV
INDRA Antonio Martínez Lobo amlobo@indra.es
poligono industrial 1
San Fernando de Henares
28830 Madrid
Tel: +34 916 269 000
Deimos Portugal is now looking after the SMOS Data Viewer:
http://www.smos.com.pt/project_tools_visualization.html
nuno.almeida@deimos.com.pt
Deimos Engenharia
Av. D. João II, Lote 1.17
Torre Zen, 10º, 1998-023 Lisboa
Tel: +351 21 893 3010
Example of exported IDL code from SDV (SMOS L1c Dual Product). It is the structure of one measurement.

```
Flags$0_t = { BitFields$0:0L }
```

```
tem$85_t = {  Flags$0:Flags$0_t  ,  BT_Value$1:0.0  ,
Pixel_Radiometric_Accuracy$2:0L  ,  Incidence_Angle$3:0L  ,  Azimuth_Angle$4:0L
,  Faraday_Rotation_Angle$5:0L  ,  Geometric_Rotation_Angle$6:0L  ,
Snapshot_ID_of_Pixel$7:0LL  ,  Footprint_Axis1$8:0L  ,  Footprint_Axis2$9:0L }
```

Land Cover Tool
ftp://smosiatlt:smosgmv@ftp.gmv.es
José Antonio Barba Milanés
GMV,S.A.
Isaac Newton, 11
P.T.M. Tres Cantos
E-28760 Madrid
Tel. +34 91 807 21 45
www.gmv.com

SMOS Level 2 Processor for Sea Surface Salinity and SMOS L1C/L2OS data analyser tool
ACRI-ST
260, rte du Pin Montard BP 234
06904 SOPHIA ANTIPOLIS Cedex FRANCE
tel: +33 (0)4 92 96 29 06

SMOS Level 2 Processor for Soil Moisture
Ali Mahmoodi
Array Systems Computing Inc.
www.array.ca ali@array.ca
Tel: 416 736 0900 Ext. 232

SMOS Level 1 Processor Prototype
Visualisation Tool
SEPS Ground Segment
http://www.smos.com.pt/project_tools.html
SEPS Ground Segment (SEPS-GS) is an evolution of the SMOS End-to-end Performance Simulator (SEPS) used by L1PP team to simulate the MIRAS instrument and to generate Level 0 data. SEPS was initially developed by UPC, GMV and EADS CASA in order to help the scientific community to assess the performance of the SMOS mission. SEPS-GS is an evolution of SEPS v4.0.1 focused mainly on the generation of L0 products that can be directly ingested by the L1PP.
L1PP 2.1 - Launch version, with all baseline algorithms implemented
L1PP 3.1 - Commissioning version, with extra configuration options and algorithms
The test scenarios provided on the webpage are not backward compatible. This means that to run L1PP 3.1, the 3.1 scenarios must be used and to run L1PP 2.1, the 2.0 scenarios must used. Both are available online and the configurations are equivalent.
Antonio Gutiérrez Peña
Ground Segment Systems
antonio.gutierrez@deimos.com.pt
DEIMOS ENGENHARIA
Av. D. João II, Lote 1.17
Torre Zen, 10º, 1998-023 Lisboa
Tel: +351 21 893 3013

Soil Moisture Retrieval Software (version 3)
This software runs on Windows XP, Windows 2000 and UNIX-LINUX (excepted Brightness Temperature Generator module) operating systems. SRSv3 uses Earth Explorer CFI version 2.2.2 for orbital computations. Libraries can be obtained from http://eop-cfi.esa.int.
It deals with inversion of soil moisture only. One objective of the study extension concerning the software is that it shall be opened to any forward model, be opened to standard data formats, provide the user with more

help, check data for consistency before processing, and account for SMOS baseline design at the end of phase B.
It has been upgraded to deal with the synergetic use of optical and SAR observations to improve the soil moisture retrieval accuracy. Moreover, to benefit from biogeophysical variables at high resolution to increase estimations of surface soil moisture, a second inverse module called “disaggregation” has been implemented. Modifications in input reading have been done in order to let the user able to use off-line brightness temperature as surface reference.
Vincent Rivalland
Noveltis, 31520 Ramonville, France
Tel: +33 562 88 11 11
ftp.noveltis.fr
vincent.rivalland@noveltis.fr

Brightness Temperature Propagation Tool
CLS

Level 1 Data Comparison Tool
ftp://193.146.123.163/smos/software/SCoT/SUV_1.0/
In that folder there is:
the software (including a matlab virtual machine for Linux so no need to purchase any licence),
the documentation and a test data set to use the tool and do some comparison exercise.
The tool aims to support the validation teams to compare the L1 data generated under different version, configuration or calibration set up of the L1 processor prototype.

DPGS Comparison Tool

http://213.170.46.150/smos/software/DPGS Comparison Tool/
ftp://193.146.123.163/smos/software/DPGS_Comparison_Tool/
The DPGS Comparison Tool is a program to compare Science SMOS products in Earth Explorer format. It is mainly used by the developers of the SMOS components but it is designed and presented as a public program, for Linux or Windows XP.

INDRA Antonio Martínez Lobo amlobo@indra.es
poligono industrial 1
San Fernando de Henares
28830 Madrid
Tel: +34 916 269 000

DPGS Product Converter

http://213.170.46.150/smos/software/ProductConverter/
ftp://193.146.123.163/smos/software/Product_Converter/
The main function of the DPGS Converter is to provide the DPGS with a tested mechanism to convert SMOS prototype products to SMOS operational products. The use of the DPGS Converter is not restricted to the development of the DPGS and its subsystems, but it is a public software, freely available to those users interested in converting SMOS products, on Windows XP.

INDRA Antonio Martínez Lobo amlobo@indra.es
poligono industrial 1
San Fernando de Henares
28830 Madrid
Tel: +34 916 269 000

DPGS XML Read Write API

ftp://193.146.123.163/smos/software/XML_RW_API
http://213.170.46.150/smos/software/XML_RW_API/
Application Programming Interface for Linux or Windows XP.
INDRA Antonio Martínez Lobo amlobo@indra.es
poligono industrial 1
San Fernando de Henares
28830 Madrid
Tel: +34 916 269 000
C++ R/W library developed by INDRA. The library is using product schema description so if you build your operational SW with this library it will be robust in case the product format is modified. Moreover the library will be a SW component maintained during the SMOS mission.
The R/W API is available on the ESAC FTP server 193.146.123.163 (anonymous login) under smos/software/XML_RW_API. The last version is v04-01-05. The products schemas are available on the same server under smos/schemas/. The last version is v04-02-00.

SMOS End-to-End Performance Simulator
http://www.smos.esa.int/SEPS/
Adriano Camps
UPC, Barcelona, Spain
Tel: +34 934054153
camps@tsc.upc.edu

SMOS interactive analysis tool (converter of auxiliary data to KML or KMZ format)
The last version of the SMOS Interactive Analysis Tools is 1.2.
ftp://smosiatlt:smosgmv@ftp.gmv.es/SMOSLCT_V1.2_FINAL_VERSION/

SMOS Global Mapping Tool (GMV)
Available on the following FTP server at ESAC:
ftp://193.146.123.163/smos/software/GMT/GMT_2.4/
The Software User Manual (SUM) and the Interface Control Document (ICD) also are provided there.
The directory "GMT-config-examples" contains examples of configuration file in order to generate some default maps.

SMOS preprocessed ADF (VTEC, ECMWF, LAI)
ftp://193.146.123.162/from_ESAC
https://eoa-ke.eo.esa.int/smos

8 ANNEXES

8.1 Calibration Plan

Responsible:

- Calibration Team lead by M. Brown

Objectives:

- To generate all the necessary Look Up Tables (LUT) needed by the L1 processor in order for the L1 Development Team to fully verify the L1 processing.
- To develop all evaluation methods needed to verify that L1 products are of sufficiently high quality to meet the System Requirements of SMOS, as well as the needs of the L2 processing to meet the System and Mission Requirements of SMOS.
- To support the Validation and Retrieval Coordination Team with the analysis of the Vicarious Calibration Activities.

Inputs:

- On-ground characterization database results and test definitions,
- On-orbit observation and calibration L0 products and associated telemetry, requested by the Calibration Plan,
- Feedback from the Coordination Team regarding results of validation and vicarious calibration activities.

Outputs:

- Calibrated L1 products,
- Commissioning Phase report.

8.2 Calibration Issues

(P. Walteufel, Y. Kerr, J. Boutin and C. Ruf, 23 march 2001)

8.2.1 WHAT IS CALIBRATION ?

In general terms, the purpose of calibration is to define a relationship, for a set of measured parameters Pj, between "uncalibrated" values Pj and "calibrated" values P'j deemed to be the best estimates for actual values : [P'j,...] = Fj ([Pj,...]). The Fj relationships might be simply defined as a sequence of [P'j,...,Pj,...] vectors throughout the whole ranges considered for the measurements. Most of the time however, analytic forms stipulated by parameters Km can be assumed for the Fj; then, the purpose of calibration is to determine the optimal Km for a set of functions: [P'j,...] = Fj ([Pj,...],Km...); Often, there is a single measured quantity P ; often again, F(P) is a linear function ; in which case two Km parameters only (i.e. K0, K1) are needed. Total Power Radiometry (TPR) measurements offer a convenient (and relevant) illustration. Looking at this example however, one sees there are actually two ways to approach the calibration problem:
One way is based on an approximate instrument model; then, assuming that a quadratic detection law holds over the relevant range, a linear response curve actually results, with parameters (K0, K1) having well identified physical meanings, related to the noise figure and to the gain of the measuring device.
Another way is to ignore any physical model and to assume that anyway, in a restricted range, the response curve can be assumed to be linear.
In the case of a TPR, the distinction is not immediately apparent, since the basic operation of this device is so simple (even though operating it correctly may require enormous care...). When using for example a couple of well known sources ("hot" and "cold" loads) in order to carry out an internal calibration, we actually consider the radiometer to be a "black box" with a linear response; at the same time, we are aware that the meaningful instrument parameters, input noise and gain, will be provided by the calibration measurements. However, in the case of interferometry, we shall have to keep this distinction in mind later on.
Losing hardly any generality, the "uncalibrated" data itself can be elaborated in such a way that P' does not differ much from P. This can be achieved by using, in order to compute P, approximate calibration data. Then

the calibration formula reads: P' = K0 P + K1, where K0 is close to unity and K1 << P over the relevant range of P values.

8.2.2 CALIBRATION VERSUS VALIDATION

Let us consider the whole SMOS mission as aimed at providing measured values of physical quantities for various levels of elaboration. In our case, typical levels are: visibility functions, brightness temperatures TB, surface parameters such as soil moisture.
There are two ways of using external data available in addition to those provided by the instrument: either such external data are entered in the processing of SMOS data, or they are not.
In the first case, one can speak of calibration data. For instance sea surface salinity of a well-known area is used to infer drifts of the instrument.
In the second case, it may happen that external data are used for checking the consistency between those data and data provided by SMOS. One would speak then of validation.
Therefore the distinction between calibration and validation does not depend on the nature of the data (their level of elaboration), but only on the purpose to which they are used. It can only be expected that calibration is carried out continuously while validation will be more based on time limited experiments. Actually cal and val data may have exactly the same nature: assuming for example a set of TB, there is nothing to forbid to select half of this set for calibration purpose and then use the other half for validation.
In what follows, data are considered to be used for calibration purposes. But there is no difference, until one decides how to use them.

8.2.3 INTERFEROMETRIC MEASUREMENTS AND RECONSTRUCTION

The SMOS basic sensor consists of many dozens of dual polarization radiometers. Antenna properties and receiver characteristics are made as identical as possible.
The signals yielded by those radiometers are used to compute time integrated, one-bit correlation products, which are telemetered down to Earth. From those, visibility functions are extracted; then the reconstruction yields a map of "normalized" TB Mxi(Oi), Myi(Oi) on the antenna ports X and Y, for every solid angle direction (Oi) .
The reconstruction operator is basically a 2D inverse Fourier transform. However it is actually hugely complicated because it is necessary to account for intrument parameters which are specific of each receiving channel and each couple of receiving channels (baselines). In addition, a fringe washing correcting function (due to the finite instrument bandwidth) has to be introduced.
For the reconstruction, five approaches have been mentioned to the SMOS SAG: direct method, using phase/amplitude closure relationships, using external point sources, "clean" algorithm, "maximum entropy" method. For all five methods, the accuracy is yet to be assessed especially with respect to realistic magnitudes and distribution.
Most probably a combination of methods will have to be used. This is all the more true since, in this list, two kinds of issues are actually considered together: one is the numerical method for dealing with the reconstruction (i.e. inverting the visibilities/normalised TB relationship); the other one is measuring, or setting constraints upon, the parameters which are necessary to specify the reconstruction operator. The second range of considerations is close to calibration issues.

8.2.4 TOTAL POWER MEASUREMENT AND BRIGHTNESS TEMPERATURE MAPPING

In addition to the interferometer, several (one plus redundancies) total power radiometers (TPR) on board SMOS will provide total power measurements, i.e. quantitative measurements of TB integrated over the whole antenna pattern. That is, one obtains, as the (processed) output of one receiver, say for antenna port X, estimates of the brightness temperature <Tx> integrated over the antenna pattern.
For every direction Oj within the solid angle, the temperature values on the antenna port are obtained by multiplying the M fields (normalised TB) by TPR data:
Txj(Oj) = <Tx> x Mxj(Oj)

8.2.5 THE NEED FOR CALIBRATION

The parameters involved in the reconstruction process are many; they include sets of gain pattern coefficients. They involve many error sources: linked either to the channel (channel errors) or to the pairs of

channels used to build the correlation products (baseline errors). Moreover all these physical parameters of the SMOS instrument are intermingled in the reconstruction process.
If the response function was perfectly known, and the values of parameters entering it were also perfectly known and stable, there would be no calibration problems. Such problems are likely to arise because:
1. The response function may not be perfectly known;
2. The parameters are not perfectly measured before the flight;
3. These parameters vary during the flight.
The theoretical problems associated with 2D radiometric interferometry have been investigated in depth; therefore there is no reason to believe that we shall not know correctly the instrument response function. Specifications before flight measurements are addressed during the industrial Phase A. This leaves us with the 3rd issue.
Without going into any detail, one can think of four reasons why the instrument parameters vary throughout the flight:
1. Random fluctuations;
2. Slow drifts due to aging;
3. Sharp variations due to events (failures, energetic particles, ...)
4. Systematic variations.
One is not too much concerned with random fluctuations on time scales shorter than the elementary integration time (for SMOS, circa 3 seconds), because they merge with other source of random errors and hopefully can be averaged out as well. One is, on the contrary, very much concerned with fluctuations on time scales ranging from this limit to the time interval between calibration operations, and this is where short-term stability requirements will have to be detailed. Still, by definition, calibration is unable to deal with such fluctuations.
The calibration, now, should correct for other errors. In this respect, it is worth stressing the possibility (case 4) of systematic variations on various time scales, due to the fact that the structure might undergo mechanical oscillations, and that thermal and mechanical constraints are likely to vary in a systematic way along the orbit, or with time of year, etc.

8.2.6 SMOS ON-BOARD CALIBRATION

Several calibration subsystems are considered for the SMOS interferometer. They involve noise injection (either correlated or uncorrelated) and are meant to measure phase and modulus imbalances as well as offsets in the receivers. A careful calibration subsystem is expected to be present for TPR.
This being said, the on-board calibration subsystems have short comings, basically in 3 areas :
1. It is not warranted that on-board calibration will reach the accuracy required for ocean measurements. Most of the figures quoted in the MIRAS pilot project are in the range of 0.5 K to 1 K, whereas the ocean requirements for accuracy are better than 0.1 K.
2. Parts of the instrument are outside the calibration loops. Specifically, this lies in front of the calibration switch and includes the antenna characteristics and mismatch, as well as the consequence of coupling effects.
3. There may be a lack of reliability in the calibration subsystems themselves: this was illustrated in a recent analysis by C. Ruf concerning the apparent drift of one of the channels of the TOPEX radiometer.
These reasons, at least for items 2 & 3, are not SMOS specific at all, and they are acknowledged. For item 2, it is hoped either that the design will reduce error sources to negligible levels or that before flight measurements will keep their reliability throughout the flight.
All in all, however, this accounts for the need of external calibration.

8.2.7 SPECIFIC SMOS DIFFICULTIES

What is SMOS specific is:
1. Radiating elements used in the mission have a wide antenna pattern. The (copolar) pattern is about 70° for the half power gain, which would correspond to a typical size of about 1000 km for a 3 dB contour on the Earth surface when nadir looking. Actually, since the antenna axis will be tilted, the area seen by the radiometer will be much larger than that and might even extend (along track) up to the horizon line and beyond it into the sky. Moreover about half of the main beam integrated gain lies outside the 3 dB contour.
2. The instrument response function is enormously complex.

3. The accuracy requirements are very severe, at least for the measurements over the ocean, which correspond to the cold side of the TB bracket (60-150 K); for the warm side (150-300 K), requirements are less stringent.

8.2.8 TOTAL POWER RADIOMETRY (TPR) CALIBRATION ON EARTH TARGETS

Due to the wide antenna pattern of SMOS antennas (see above), there seems to be no hope to obtain ground truth data allowing to compute a <TB> that might be compared accurately to the TPR measurements. Another possibility is to use statistical methods similar to those developed by C. Ruf for the TOPEX radiometer.
Should one select homogeneous zones as much as possible (large ocean area with no islands) ?
The selection will be made naturally by looking at the lower end of the TB histogram.
In any case, one should keep in mind the Faraday rotation issue (hence prefer the morning orbit, as a minimum).
Problem of the hot source : is there a hope to use the upper end of the TB histogram ? That might correspond to zones dominated by thick forests. However, assimilating thick forests to blackbodies is not proven (see work by Catherine Prigent (2001) over the Amazon Basin).
Possibly for the hot source, the accuracy of internal calibration for the TPR might be adequate.

8.3 L1 Product Maintenance Plan

Responsible:

- L1 Development Team lead by A. Gutierrez (DEIMOS Portugal) under ESA contract.

Objectives:

- To verify the proper functioning of the L1 processor with on-orbit instrument data.
- To support the execution of the calibration.
- To support the L2 Development Team to establish a L1 processor configuration status for which the results are deemed of sufficient quality by the Validation and Retrieval Coordination Team.
- To support the Validation and Retrieval Coordination Team with the analysis of the Vicarious Calibration Activities.

Inputs:

- Calibration Plan
- Validation and Retrieval Coordination Plan
- Campaign Implementation Plan
- Algorithm Validation Report

Outputs:

- Calibrated L1 products
- Commissioning Phase report

Proposed minimum content:

- Instrument / Spacecraft configuration
- “Dual Pol” mode processing verification
- “Full Pol” mode processing verification
- NIR & uncorrelated NIR mode processing verification
- Deep sky mode processing verification
- Non-Nominal Processing configuration
- “Strip Adaptive” processing
- “Apodization Window” optimization
- L1 Product Improvement

- Algorithm update as a consequence of Verification activities
- Algorithm update as a consequence of Validation activities
- Algorithm update as a consequence of improved scientific knowledge

Issue date: The detailed plan will be available 2 or 3 months before launch.

8.4 L2 Product Maintenance Plan

Responsible:

- L2 Soil Moisture Development Team lead by A. Mahmoodi (ARRAY) under ESA contract.
- L2 Ocean Salinity Development Team lead by P. Spurgeon (ARGANS) under ESA contract.

Objectives:

- To verify that the geophysical product generated by of the L2 processor with on-orbit instrument data are within the allowed natural variability
- To support the execution of the validation activities
- To support the Calibration and Validation and Retrieval Coordination Team establish a L1 processor configuration status for which the results are deemed of sufficient quality

Inputs:

- Calibration Plan
- Validation and Retrieval Coordination Plan
- Campaign Implementation Plan
- Algorithm Validation Report (SM & OS)

Outputs:

- Calibrated L2 products
- Commissioning Phase report

Proposed minimum content:

- Instrument / Spacecraft configuration
- “Dual Pol” mode processing verification
- “Full Pol” mode processing verification
- Non-Nominal Processing configuration
- “Strip Adaptive” processing
- “Apodization Window” optimization
- L2 Product Verification
- Geophysical parameters
- Topographic constraints, Precipitation, Atmospheric conditions, wetlands and flooding, snow and snow melt, frozen surfaces, etc.

- L2 Product Improvement
- Algorithm update as a consequence of Verification activities
- Algorithm update as a consequence of Validation activities
- Algorithm update as a consequence of improved scientific knowledge

Issue date: The detailed plan will be available 2 or 3 months before launch.

8.5 Definitions

The following definitions are systematically used within this document and all the derived documents.

- **Calibration**

Definition: The process of quantitatively defining the system response to known, controlled signal inputs. In other words, the calibration enables to transform engineering units (volts) into absolute physical quantities at the entrance of the instrument (brightness temperatures).
Notes: Here is the CEOS definition:

1. "System response" includes both instrument and processing.
2. This process stops at level 1 data products, as in higher level processing system-external information is used.
3. The result of the process is applied routinely to the raw measurements, i.e. there is no active decision process required.

Calibration coefficients could be improved as a result of the analysis of the quality of the geophysical products.

- **Vicarious Calibration**

Definition: The process of quantitatively defining the system response to signal inputs coming from a stable and / or known natural target, and thus relying in most cases on some models (atmospheric contribution, target emission or spatial extrapolation of ground measurements, etc).
Notes:

1. The natural target can be a celestial body (sun, moon, sky) or an extended, homogeneous, and known area on the Earth (Dome C, rainforest, desert, etc) or a test site with adequate sampling strategy.
2. However, in most cases, the term calibration is not appropriate, as the result is not routinely applied to the raw measurements. In such cases, one would better talk about "vicarious validation" (see below).

- **Validation**

Definition: The process of assessing by independent means (usually ground truth) the quality of the geophysical data products derived from the system output.
Notes: Here is the CEOS definition:

1. The statement "valid" holds within the error bars of the system and the "independent means".
2. The (lack of) time coincidence of the measurements has to be considered.
3. The (possible, probable) difference in validity scale of the system output and the independent means has to be considered. (Scale between extended sensor FOV and point measurements on ground, in particular.)
4. Validation can be applied in principle to all levels of data products. In reality, the vast majority will be at level 2 (geophysical products).
5. The validation has to consider the impact (additional error, scale difference, etc) of external auxiliary data used in the processing (e.g. sea surface temperature, land surface temperature, etc).
6. A data set acquired for the purpose of validation can in principle also be applied for calibration.

- **Verification**

Definition: The process of providing confirmation, through the provision of objective evidence, that specified requirements have been fulfilled.
Note: Because of the limitations outlined under the definition of validation, the verification has to be understood as being limited to functional requirements ("Does the output make sense?") and not quantitative!

- **Monitoring**

Definition: The process of following the system output over time.

Notes:

1. For this process, it is not necessary to know / establish the absolute system response to a given target.
2. Monitoring can happen at a variety of time scales: short term (e.g. to detect external radiofrequency interference), medium term (e.g. to establish changes of the system output at the orbital frequency), or long term (over years, to establish seasonal / long term drifts).
3. Monitoring requires the availability of conditions / targets which are stable for all the scales up to the respective time scales.

- **Characterisation**

Definition: The process of establishing quantitative correlations between changes in the system output, or specific elements of it, and changes of the environment in which the system, or specific elements of it, operate.
Note: In most cases, the result of the characterisation process will be used in the system calibration.

- **Comparison**

Definition: The process of quantitative comparison of system outputs from different systems over similar targets.
Notes:

1. This term is specifically used for the outputs from different satellite sensors, with all different specific technical implementations (orbit, sensor field of view, sensitivities and frequencies) and operating principles (active / passive, real / synthetic apertures).
2. Obviously, all satellite sensors have the common problems of calibration and validation, with none of them being *a priori* better or worse.

- **Retrieval**

Definition: The process of deriving quantitative geophysical variables from remote sensing data with associate error bars.
Note: The term is loosely used to describe the process of developing level 2 algorithms of good quality.

8.6 Methods For SMOS Calibration And Validation

Y. Kerr, Ph. Waldteufel, November 2007

INTRODUCTION
By request of the SMOS Science Advisory Group in October 2007, a set of requirements needed to be formulated such that the flight campaigns could be efficiently planned. In particular, the requirements for validation of land surface products and the question of which products should be validated and to what extent, needed to be described. This relates also to the use of airborne interferometric radiometers in contrast with the already available data from conventional radiometers.
The first item discussed is to clearly separate calibration and validation activities (using CEOS definitions).

CALIBRATION
Calibration focuses on assessing all sources of biases on the reconstructed brightness temperatures (level 1) after carrying out internal and sky calibration operations.

8.6.1 "DIRECT" CALIBRATION

The first step is internal calibration and this is considered as extensively covered by the on-board in-orbit calibration plan. After this, the goal would then be to compare brightness temperatures of a known target (either known (galaxy background) or measured (radiometer)) and SMOS. However it is expected that some

"vicarious calibration" will also be necessary to ensure that a) "high temperature point" is achievable, b) potential drifts are monitored.
Issues:

- this should avoid the use of any model (otherwise it is a validation exercise)
- the specificities of SMOS and the fact that the first item to be calibrated is the NIR

So the focus should be on assessing the sources of bias by comparing the reconstructed brightness temperatures (level 1) after carrying out internal and sky calibration operations, to surface values.

This requires surfaces which are as homogeneous, stable and known as possible. The only proper way found yet to achieve this goal is to make full use of the buoys network (ARGO and the like). The suggested method relies on using a network of buoys on selected (steady and low wind) areas, but requires a radiative transfer ocean model.

It may be noted that for monitoring purposes, the averaged Tb over a (very) large area in the southern pacific ocean should provide useful information for drift monitoring as demonstrated with SMMR.

Obviously no aircraft operation can provide useful info for the calibration aspects.

8.6.2 "RUF" METHOD FOR VICARIOUS CALIBRATION

The most promising vicarious method is the one elaborated by C. Ruf and proposed in several Cal Val projects. The advantage of the method is that it extrapolates measurements to the "limit" value (hence the true sense of vicarious) and relies on fairly robust assumptions (climatological stability over SMOS lifetime). As the approach is almost costless and apparently accurate to a tenth of a Kelvin, it is compulsory to at least test it extensively and probably to adapt it.

No aircraft operation is needed there.

8.6.3 STABLE TARGETS FOR VICARIOUS CALIBRATION

The first stable target area to come to mind is the ocean. A suitable area can probably be identified but some work is requested there.

The Dome C has been suggested on several occasions and recent work shows that it is a potentially interesting target as the Tb are expected to be very stable (less than 0.2 K). The only concerns are related to the accurate validity of the stability (fairly probable) and the spatial variations. For this last point an aircraft survey might be interesting if carefully planned. The US and Australia are intending to perform such a survey and it is worth waiting for their results (and supporting their proposal).

Some other targets have been suggested, deserts, rain forests but none can be safely assumed to be stable with time except maybe very high altitude flat rocky plateaux.

Given the high uncertainty of stability, it is not worth investing flight time to cover such targets.

<u>Suggested methods:</u>

- network of buoys on selected (steady and weak wind) areas, using radiative ocean model. Why ?

- Very high expected sensitivity (better than 0.1 K)
- Consistency with buoys requested for assimilation

- vicarious method derived from Chris Ruf method for ERS Why ?

- Based on robust hypothesis (stability over SMOS lifetime)
- Cost free and feasible at any time

- Expectation for 0.1 K accuracy

- **Ice sheet** Dome C control Why ?

- Upward Tb expected very stable (within 0.1 to 0.2 K)

- Some averaging needed

- **rain forest** control Why ?

- Expectation of blackbody radiation in some areas

VALIDATION
Validation focuses on assessing correctness of retrieved geophysical quantities (SM, OS). Therefore ground truth measurements have to be compared to values retrieved (L2) from SMOS data. Actually, successful validation of SMOS L2 should amount to validating radiative models.
Validation is the process of assessing the validity of the product. In some cases, it can apply to Tb but here it will only cover SSS and soil moisture. So the goal is to assess how valid the product is, and this is where it becomes complicated as ground measurements enter the equation rather abruptly (what is the pseudotruth).

The issues are as follows:

- Necessity to have valid ground measurements (what is SM or SSS)
- Necessity to have representative ground measurements
  - Heterogeneity (highly variable composition of observed land scenes)
  - Scaling issues (point measurements versus 40 km size SMOS pixel)
  - Temporal validity
  - Knowledge of the surface over a 40km x 40km square (or rather a varying ellipse)
  - Necessity to explore a number of representative areas
  - Spatial average of point measurements
- Possible additional Tb biases depending on location in FOV

Moreover it must be acknowledged that there are some doubts or weaknesses for ignorance on the radiative transfer (RT) models for various surfaces so good validation will probably start by a verification of the radiative transfer codes.

This part is where aircraft campaigns can help providing some answers and verifications.

The main goals of such an airborne campaign would be:

- Over the dedicated cal/val sites
  - Check representation of point measurements
  - Validate average of ponctual SM to areal SM with models
  - Provide some area of integrated SM/SSS measurements to a SMOS pixel

- During transfers
  - Check signal and RT models for specific surfaces if needed

- Over all the surfaces
  - Separate scale effects from those of RT models
  - Provide data for empirical test relationships
  - Check perturbing factors

Aircraft campaigns should fulfil the above !

PS: Additional interest before launch is to test interferometric measurements and related algorithms up to level 2! Possibly full polarisation data should be useful too!

8.7 AO Proposals Overview

AO #	PI	Country -PI	Sea/ Land	Comments	SM/OS/Tb	ERS envisat	other EORS	airborne RS	campaigns	networks	models	assimilations
3168	Calvet	France	Land	SMOSMANIA	Tb and SM	no	no	no	no	yes	yes	yes
3211	Kaihotsu	Japan	Land	Mongolia	Tb and SM	no	yes	no	yes	yes	no	no
3219	Walker	Australia	Land	NAFE	Tb and SM	yes	no	yes	yes	yes	yes	yes
3221	Jackson	US	Land	SCAN	Tb and SM	no	yes	yes	yes	yes	yes	yes
3223	Singh	India	Land	missing	SM	yes	yes	no	yes	yes	no	no
3227	Robock	US	Land		Tb and SM	no	no	no	no	yes	yes	yes
3229	Burrage	US	Sea		Tb and OS	no	no	yes	yes	yes	yes	yes
3230	MartinezFer	Spain	Land	REMEDHUS	SM	no	yes	no	no	yes	yes	no
3233	Wagner	Austria	Land	SMOSCAT	SM	no	yes	no	no	yes	no	no
3236	Mauser	Germany	Land	GLOWA-Danube	Tb and SM	yes	yes	no	yes	yes	yes	yes
3238	De Jeu	NL	Land	FLUXNET	Tb for SM	yes	yes	no	yes	yes	yes	yes
3241	Stammer	Germany	Sea		Tb and OS	no	yes	no	yes	yes	yes	no
3241	Vanderbogh	Germany	Land	TERENO	Tb and SM	no	yes	yes	yes	yes	yes	no
3244	Poulain	Italy	Sea	Med Sea	OS	no	no	no	no	yes	yes	yes
3246	Hornbuckle	US	Land	MidwestUS	Tb and SM	no	no	no	yes	yes	yes	no
3250	Paloscia	Italy	Land	ASTRA	Tb for SM	yes	yes	yes	yes	no	yes	no
3252	LopezBaeza	Spain	Land	VAS	Tb and SM	yes	no	no	yes	yes	yes	yes
3254	Camps	Spain	Both	CALIMAS	all	yes	no	yes	yes	no	yes	yes
3257	Grippa	France	Land	AMMA	Tb and SM	yes	no	no	yes	yes	yes	yes
3259	Le Vine	US	Sea	AQUARIUS	Tb and OS	no	yes	no	no	yes	no	no
3260	Anterrieu	France	Global	reconstruction	Tb	no	no	no	no	no	no	no
3261	Pellarin	France	Land	S-Band-Mountain	Tb and SM	no	no	no	yes	no	no	no
3262	ECMWF	ECMWF	Global	ECMWF	Tb	no	yes	no	no	no	yes	no
3265	Gommengin	UK	Sea	Atlantic	Tb and OS	yes	yes	no	yes	yes	yes	yes
3266	Navarro	Spain	Sea		OS	yes	no	no	yes	no	no	no
3267	Gower	Canada	Sea		Tb and OS	no	no	no	no	yes	yes	no
3268	Magagi	Canada	Land		Tb and SM	yes	yes	no	yes	yes	yes	yes
3269	Su	NL	Land		Tb and SM	yes	yes	no	yes	yes	yes	yes
3270	Martinez	Uruguay	Sea		Tb and OS	no	no	yes	yes	yes	no	no
3271	Heron	Australia	Sea		Tb and OS	no	no	yes	yes	yes	no	no
3273	Kim	US	Land	vic-cal	Tb for SM	no	no	yes	yes	no	yes	no
3274	Zribi	France	Both	CAROLS	all	yes	yes	yes	yes	yes	yes	no
3275	Marczewski	PL	Land	SWEX	Tb and SM	yes	yes	no	yes	yes	yes	no
3276	Gaillard	France	Sea	GLOSCAL	Tb and OS	yes	no	no	no	yes	yes	no
3279	Zhang	China	Land	desert	Tb and SM	yes	yes	no	yes	no	yes	yes
3280	Friesen	NL	Land	GLOWA-Volta	Tb and SM	no	yes	no	yes	yes	yes	yes
3281	Hallikainen	Finland	Both		all	yes	yes	yes	yes	yes	no	no
3282	Cabot	France	Global	geolocation	other	no	no	no	no	no	no	no
3284	Patel	India	Land		Tb and SM	yes	yes	no	yes	no	no	no
3934	Martins	Brazil	Land	Caatinga	SM	yes	no	no	yes	yes	no	no
4488	Johannesse	Norway	Sea	atlantic40+	Tb and OS	yes	yes	no	no	yes	yes	no
4682	Berry	UK	Land		Tb and SM	no	yes	no	yes	no	yes	no
6317	Escorihuela	Spain	Land	uyuni-salar	Tb	no	yes	no	no	no	yes	no
6272	Skou	Denmark	Land	HOBE	Tb and SM	yes	yes	yes	yes	yes	yes	yes
6862	Bahamon	Spain	Sea	Blanes	OS	yes	no	no	yes	no	yes	yes
6945	Schwank	CH	Land	ELBARA	Tb	yes	no	yes	yes	no	yes	no
6995	Wigneron	France	Land	Landes	Tb and SM	no	no	yes	yes	yes	yes	no
7025	Mironov	Russia	Land	Siberia	Tb and SM	yes	no	yes	yes	yes	yes	no

8.8 AO PI Mailing List

3259 David Le Vine (PI) NASA david.m.levine@nasa.gov
3276 Fabienne Gaillard (PI) IFREMER fabienne.gaillard@ifremer.fr
3265 Christine Gommenginger (PI) NOC cg1@noc.soton.ac.uk
3267 Jim Gower (PI) Institute of Ocean Sciences jim.gower@dfo-mpo.gc.ca
3229 Derek Burrage (PI) Naval Research Lab. burrage@nrlssc.navy.mil
3241 Detlef Stammer (PI) University Hamburg detlef.stammer@zmaw.de
3241 Jan Vanderborght (PI) Agrosphere Institute j.vanderborght@fz-juelich.de
3281 Martti Hallikainen (PI) Helsinki University of Technology martti.hallikainen@tkk.fi
3270 Carlos Martínez (PI) Universidad Republica carmar@glaucus.fcien.edu.uy
3244 Pierre-Marie Poulain (PI) Istituto Nazionale di Oceanografia ppoulain@ogs.trieste.it
3274 Mehrez Zribi (PI) CNRS/IPSL/CETP mehrez.zribi@ird.fr
3254 Adriano Camps (PI) Universitat Politecnica de Catalunya camps@tsc.upc.edu
3271 Malcolm Heron (PI) James Cook University mal.heron@jcu.edu.au
3266 Gabriel Navarro (PI) Instituto de Ciencias Marinas de Andalucia CSIC gabriel.navarro@uca.es
3238 Richard de Jeu (PI) Vrije Universiteit Amsterdam richard.de.jeu@falw.vu.nl
3233 Wolfgang Wagner (PI) Vienna University of Technology ww@ipf.tuwien.ac.at
3236 Wolfram Mauser (PI) University of Munich w.mauser@iggf.geo.uni-muenchen.de
3268 Ramata Magagi (PI) University of Sherbrooke ramata.magagi@usherbrooke.ca
3269 Bob Su (PI) IIGISEO b_su@itc.nl
3227 Alan Robock (PI) Rutgers University robock@envsci.rutgers.edu
3221 Thomas Jackson (PI) USDA tjackson@hydrolab.arsusda.gov
3246 Brian Hornbuckle (PI) Iowa State University bkh@iastate.edu
3219 Jeffrey Walker (PI) University of Melbourne j.walker@unimelb.edu.au
3279 Weiguo Zhang (PI) CSSAR wgzhang@nmrs.ac.cn
3168 Jean-Christophe Calvet (PI) Meteo-France/CNRM jean-christophe.calvet@meteo.fr
3261 Thierry Pellarin (PI) LTHE thierry.pellarin@hmg.inpg.fr
3223 Ramesh Singh (PI) Indian Institute of Technology ramesh@iitk.ac.in
3284 Parul Patel (PI) ISRO parul@sac.isro.gov.in
3211 Ichirow Kaihotsu (PI) Hiroshima University kaihotu@hiroshima-u.ac.jp
3275 Wojciech Marczewski (PI) Space Research Centre wmar@cbk.waw.pl
3257 Manuela Grippa (PI) CESBIO manuela.grippa@cesbio.cnes.fr
3230 Jose Martinez-Fernandez (PI) University of Salamanca jmf@usal.es
3252 Ernesto Lopez-Baeza (PI) University of Valencia ernesto.lopez@uv.es
3280 Jan Friesen (PI) Technical University of Delft j.friesen@tudelft.nl
3282 Fancois Cabot (PI) CNES francois.cabot@cnes.fr
3260 Eric Anterrieu (PI) Observatoire Midi-Pyrenees eric.anterrieu@ast.obs-mip.fr
3250 Simonetta Paloscia (PI) IFAC-CNR S.Paloscia@ifac.cnr.it
3273 Edward Kim (PI) NASA GSFC ed.kim@nasa.gov
3262 Patricia Rosnay (PI) European Centre for Medium-Range Weather Forecast patricia.rosnay@ecmwf.int
3934 Eduardo Martins (PI) FUNCEME, Fortaleza, Brazil, esm9@secrel.com.br
4488 Johnny Johannessen (PI) NERSC, Norway, johnny.johannessen@nersc.no
4682 Philippa Berry (PI) EAPRS, UK, pamb@dmu.ac.uk
6272 Niels Skou (PI) Technical University of Denmark ns@space.dtu.dk
6317 Maria-Jose Escorihuela (PI) IsardSat, Spain, mj.escorihuela@isardsat.cat
6862 Nixon Bahamon (PI) CEAB, Spain, bahamon@ceab.csic.es
6945 Mike Schwank (PI) WSL, Switzerland, mike.schwank@wsl.ch
6995 Jean-Pierre Wigneron (PI), INRA, France, wigneron@bordeaux.inra.fr
7025 Valery Mironov (PI) Russia, rsdvm@ksc.krasn.ru

8.9 Other Participants (non-PI) Mailing List

Gary Lagerloef ESR lagerloef@esr.org
Bertrand Chapron IFREMER/LOS bertrand.chapron@ifremer.fr
Nicolas Reul IFREMER/LOS nicolas.reul@ifremer.fr
Jean Tournadre IFREMER/LOS jean.tournadre@ifremer.fr
Jerome Gourion IFREMER jerome.gourion@ifremer.fr
Jean-Francois Piolle IFREMER/LOS jean.francois.piolle@ifremer.fr
Christine Coatanoan IFREMER/SISMER christine.coatanoan@ifremer.fr
Gilles Reverdin IPSL/LOCEAN reverdin@lodyc.jussieu.fr
Jerome Vialard IPSL/LOCEAN vialard@lodyc.jussieu.fr
Sylvie Thiria IPSL/LOCEAN thiria@lodyc.jussieu.fr
Michel Crepon IPSL/LOCEAN crepon@lodyc.jussieu.fr
Jacqueline Boutin IPSL/LOCEAN jacqueline.boutin@locean-ipsl.upmc.fr
Philippe Waldteufel IPSL/SA philippe.waldteufel@aerov.jussieu.fr
Gerard Caudal IPSL/CETP gerard.caudal@cetp.ipsl.fr
Cecile Mallet IPSL/CETP cecile.mallet@cetp.ipsl.fr
Pierre Blouch Meteo-France/CNRM pierre.blouch@meteo.fr
Thierry Delcroix LEGOS thierry.delcroix@cnes.fr
Estelle Obligis CLS obligis@cls.fr
Christine Boone CLS boone@cls.fr
Sylvie Labroue CLS labroue@cls.fr
Joël Dorandeu CLS joël.dorandeu@cls.fr
Gilles Larnicol CLS gilles.larnicol@cls.fr
Jean-Luc Vergely ACRI JeanLuc.Vergely@aerov.jussieu.fr
Emmanuel Dinnat NASA/GSFC emmanueldinnat@yahoo.fr
Meric Srokosz NOC mas@noc.soton.ac.uk
Helen Snaith NOC hms@noc.soton.ac.uk
Peter Challenor NOC pc@noc.soton.ac.uk
Brenda Topliss Bedford Institute of Oceanography toplissb@mar.dfo-mpo.gc.ca
Irene Rubinstein York University rubin@yorku.ca
Youyu Lu Bedford Institute of Oceanography LuY@mar.dfo-mpo.gc.ca
Jim Helbig Northwest Atlantic Fisheries Centre helbigj@dfo-mpo.gc.ca
Paul Hwang Naval Research Lab. phwang@nrlssc.navy.mil
Stephan Howden University of Southern Mississippi stephan.howden@usm.edu
Jerry Miller ONRG jmiller@onrglobal.navy.mil
William Teague Naval Research Lab. teague@nrlssc.navy.mil
Joel Wesson Naval Research Lab. wesson@nrlssc.navy.mil
Gerd Becker BSH gerd.becker@bsh.de
Georg Heygster University of Bremen heygster@uni-bremen.de
Kurt Roth University of Heidelberg kurt.roth@iup.uni-heidelberg.de
Clemens Simmer University Bonn csimmer@uni-bonn.de
Bertel Vehvilainen Finnish Environment Institute bertel.vehvilainen@ymparisto.fi
Pekka Alenius Finnish Institute of Marine Research pekka.alenius@fimr.fi
Kimmo Kahma Finnish Institute of Marine Research kimmo.kahma@fimr.fi
Mauricio Mata Univ. Fed. Rio Grande mauricio.mata@furg.br
Alberto Piola Universidad de Buenos Aires apiola@hidro.gov.ar
Jordi Font Instituto de Ciencias del Mar CSIC jfont@icm.csic.es
Srdjan Dobricic INGV dobricic@bo.ingv.it
Andre Chanzy Institut National de Recherche Agronomique andre.chanzy@avignon.inra.fr
Monique Dechambre CNRS/IPSL/CETP Monique.Dechambre@cetp.ipsl.fr
Jean-Yves Delahaye CNRS/IPSL/CETP jean-yves.delahaye@cetp.ipsl.fr
Daniele Hauser CNRS/IPSL/CETP daniele.hauser@cetp.ipsl.fr
Yann Kerr CNES/CNRS/CESBIO yann.kerr@cesbio.cnes.fr
Catherine Ottle CNRS/IPSL/CETP catherine.ottle@cetp.ipsl.fr
Jean-Pierre Wigneron Institut National de Recherche Agronomique wigneron@bordeaux.inra.fr

Ignasi Corbella Universitat Politecnica de Catalunya corbella@tsc.upc.edu
Merce Vallossera Universitat Politecnica de Catalunya merce@tsc.upc.edu
Jordi Mallorqui Universitat Politecnica de Catalunya mallorqu@tsc.upc.edu
Emilio Garcia Instituto de Ciencias del Mar CSIC emilio@icm.csic.es
Alonso Hernandez-Guerra Universidad Las Palmas ahernandez@dfis.ulpgc.es
Marcos Portabella Koninklijk Nederlands Meteorologisch Instituut (WM/RW) portabel@knmi.nl
Alicia Lavin Instituto de Oceanografia Santander alicia.lavin@st.ieo.es
Antoni Rius Institut d'Estudis Espacials de Catalunya rius@ieec.uab.es
Aida Fernandez-Rios Instituto de Investigaciones Marinas CSIC aida@iim.csic.es
Peter Ridd James Cook University peter.ridd@jcu.edu.au
Arnstein Prytz James Cook University arnstein.prytz@jcu.edu.au
Jorg Hacker Flinders University jorg.hacker@flinders.edu.au
Javier Ruiz Instituto de Ciencias Marinas de Andalucia javier.ruiz@uca.es
Jesus Gomez National Oceanographic Centre jxge@noc.soton.ac.uk
Miguel Bruno University of Cadiz miguel.bruno@uca.es
Fidel Echevarria University of Cadiz fidel.echevarria@uca.es
Laura Prieto Instituto de Ciencias Marinas de Andalucia laura.prieto@uca.es
Emma Huertas Instituto de Ciencias Marinas de Andalucia emma.huertas@icman.csic.es
Agueda Vazquez University of Cadiz agueda.vazquez@uca.es
A.J. Dolman Vrije Universiteit Amsterdam han.dolman@geo.falw.vu.nl
Manfred Owe, NASA Goddard Space Flight Center, USA, owe@hsb.gsfc.nasa.gov
Thomas Holmes, Vrije Universiteit Amsterdam, Netherlands, thomas.holmes@falw.vu.nl
Guido van der Werf, Vrije Universiteit Amsterdam, Netherlands, guido.van.der.werf@falw.vu.nl
Jennifer Grant, Vrije Universiteit Amsterdam, Netherlands, jennifer.grant@falw.vu.nl
Michiel van der Molen, Vrije Universiteit Amsterdam, michiel.van.der.molen@falw.vu.nl
Antoon Meesters, Vrije Universiteit Amsterdam, Netherlands, antoon.meesters@falw.vu.nl
Riccardo Valentini, Universita di Tuscia, Italy, rik@unitus.it
Heike Bach VISTA GmbH bach@vista-geo.de
Karsten Schulz, Centre for Environmental Research, Leipzig, Germany, karsten.schulz@ufz.de
Robert Leconte Ecole de Technologie Superieure rleconte@ctn.etsmtl.ca
Kalifa Goíta University of Sherbrooke kalifa.goita@usherbrooke.ca
Stephane Belair Meteorological Service of Canada stephane.belair@ec.gc.ca
Anne Smith, Agriculture and Food of Canada, Lethbridge, Canada, smitha@agr.gc.ca
Aaron Berg, University of Guelph, Canada, aberg@uoguelph.ca
Anne Walker, Environment of Canada, Toronto, Canada, anne.walker@ec.gc.ca
Yaoming Ma, Institute of Tibetan Plateau Research, Beijing, China, ymma@itpcas.ac.cn
Yanbo He, National Meteorological Center, Beijing, China, yanbohe@cma.gov.cn
Qinhuo Liu, Institute of Remote Sensing Applications, Beijing, China, qhliu@irsa.ac.cn
Qiang Yu, Institute of Geographical Sciences, yuq@igsnrr.ac.cn
Li Wan, China University of Geoscience, Beijing, China, wanli@cugb.edu.cn
Jun Wen, Cold and Arid Regions Environmental Research Institute jwen@lzb.ac.cn
Haibin Li, Rutgers University, New Brunswick, New Jersey, USA, hli@envsci.rutgers.edu
Erdenetsetseg Divaa, Institute Meteorology Hydrology, Ulaanbaatar, edivaa@yahoo.com
Konstantin Vinnikov, University of Maryland, College Park, MD, USA, kostya@atmos.umd.edu
Suxia Liu, IGSNRR, CAS, Beijing, China, liusx@igsnrr.ac.cn
Xingguo Mo, IGSNRR, CAS, Beijing, China, moxg@igsnrr.ac.cn
Randal Koster, Goddard Space Flight Center, NASA, randy.koster@nasa.gov
Rolf Reichle, Goddard Space Flight Center, NASA, Greenbelt, MD, USA, rolf.reichle@nasa.gov
Christa Peters-Lidard, GSFC NASA, Greenbelt, MD, USA, christa.peters@nasa.gov
Jeffrey Basara, University of Oklahoma, Norman, USA, jbasara@ou.edu
Irina Trofimova, Institute of Telecommunications, Ukraine, pops_tr@i.com.ua
Tatiana Adamenko, Ukrainian Hydrometeorological Centre, adamenko@ukrweather.kiev.ua
Anatoliy Prokopenko, Ukrainian Hydrometeorological Centre, prokopenko@ukrweather.kiev.ua
Robert Scott, Illinois State Water Survey, Champaign, USA, rwscott1@uiuc.edu

Dara Entekhabi MIT darae@mit.edu
Eni G. Njoku NASA JPL eni.g.njoku@jpl.nasa.gov
Peggy ONeill NASA GSFC peggy.e.oneill@nasa.gov
Ana Barros, Duke University, USA, barros@duke.edu
David Bosch, Agricultural Research Service, Georgia, USA, dbosch@tifton.usda.gov
Michael Cosh, Agricultural Research Service, USA, mcosh@hydrolab.arsusda.gov
Wade Crow, Agricultural Research Service, USA, wcrow@hydrolab.arsusda.gov
Randy Koster, NASA Goddard Space Flight Center, USA, koster@janus.gsfc.nasa.gov
Venkat Lakshmi, University of South Carolina, USA, vlakshmi@geol.sc.edu
Susan Moran, Agricultural Research Service, Arizona, USA, smoran@tucson.ars.ag.gov
John Prueger, Agricultural Research Service, Iowa, USA, prueger@nstl.gov
Garry Schaefer, Agricultural Research Service, Oregon, USA, garry.schaefer@por.usda.gov
Mark Seyfried, Agricultural Research Service, Idaho, USA, mseyfrie@nwrc.ars.usda.gov
Patrick Starks, Agricultural Research Service, Oklahoma, USA, patrick.starks@ars.usda.gov
Eric Wood, Princeton University, New Jersey, USA, efwood@princeton.edu
Gene Takle Iowa State University gstakle@iastate.edu
Mark Gleason Iowa State University mgleason@iastate.edu
Elwynn Taylor Iowa State University setaylor@iastate.edu
Moti Segal Iowa State University segal@iastate.edu
Martha Anderson USDA manderson@hydrolab.arsusda.gov
John Prueger USDA prueger@nstl.gov
Rick Cruse Iowa State University rmc@iastate.edu
Gilles Boulet CESBIO gilles.boulet@cesbio.cnes.fr
Shou Ban, CSSAR, Beijing, China, ban@nmrs.ac.cn
Jingye Yan, CSSAR, Beijing, China, yjy@nmrs.ac.cn
Hao Liu, CSSAR, Beijing, China, liu_how@nmrs.ac.cn
Guicai Li, Chinese Satellite Meteorology Centre, guicai.li@nsmc.cma.gov.cn
Xunying Wu, Chinese Meteorological Administration, wuxy@cma.gov.cn
Franþois Bouyssel METEO-FRANCE/CNRM francois.bouyssel@meteo.fr
Joel Noilhan METEO-FRANCE/CNRM joel.noilhan@meteo.fr
Jean-Martiel Cohard LTHE jean-martial.cohard@hmg.inpg.fr
Jean-Paul Laurent LTHE jean-paul.laurent@hmg.inpg.fr
Bernard Mercier LTHE bernard.mercier@hmg.inpg.fr
Kamlesh Tiwari Indian Institute of Technology kamlesh.narayan.tiwari@iitkgp.ac.in
A.M. Jha ISRO am_jha@sac.isro.gov.in
Toshio Koike University of Tokyo tkoike@nagaokaut.ac.jp
Keiji Imaoka EO Research & Applications Center JAXA imaoka.keiji@jaxa.jp
Takeo Tadono EO Research & Applications Center JAXA tadono.takeo@jaxa.jp
Akihiko Kondoh, Chiba University, Chiba, Japan, kondoh@faculty.chiba-u.jp
Atsushi Higuchi, Chiba University, Chiba, Japan, higu@faculty.chiba-u.jp
K. Dabrowska, Institute of Geodesy and Cartography, katarzyna.dabrowska-zielinska@igik.edu.pl
Boguslaw Usowicz, Institute of Agrophysics, Lublin, Poland, usowicz@demeter.ipan.lublin.pl
Leszek Labedzki, Institute of Grassland Farming, IMUZ, Bydgoszcz, Poland, labl@poczta.onet.pl
Witold Bochenek, Institute of Geography, IGiPZ, Szymbark, Poland, igszymbark@poczta.onet.pl
Roman Schreiber, Space Research Centre, Torun, Poland, schreibe@ncac.torun.pl
Jan Polcher IPSL/LMD jan.polcher@lmd.jussieu.fr
Thierry Lebel LTHE thierry.lebel@hmg.inpg.fr
Carmen Antolin University of Valencia m.carmen.antolin@uv.es
Teodoro Estrela Jucar River Basin Confederation teodoro.estrela@chj.mma.es
Aranzazu Fidalgo Jucar River Basin Confederation afidalgo@chj.mma.es
Beatriz Martinez University of Valencia beatriz.martinez@uv.es
Cristina Millan University of Valencia cristina.millan@uv.es
Beatriz Navascues Instituto Nacional de Meteologia b.navascues@inm.es
Ernesto Rodriguez Instituto Nacional de Meteologia e.rodriguez@inm.es

Krystyna Stankiewicz Institute of Geodesy and Cartography krystyna.stankiewicz@igik.edu.pl
Nick van de Giesen Technical University Delft n.c.vandegiesen@tudelft.nl
Tammo Steenhuis Cornell University tss1@cornell.edu
Markus Peichl DLR markus.peichl@dlr.de
Giovanni Macelloni IFAC-CNR g.macelloni@ifac.cnr.it
Paolo Pampaloni IFAC-CNR p.pampaloni@ifac.cnr.it
Emanuele Santi IFAC-CNR e.santi@ifac.cnr.it
Marco Tedesco NASA GSFC mtedesco@umbc.edu
Peter Bauer, ECMWF, pbauer@ecmwf.int
John Hodkinson, ECMWF, Reading, UK, jhodkinson@ecmwf.int
Milan Dragosavac, ECMWF, Reading, UK, mdragosavac@ecmwf.int
Drasko Vasiljevic, ECMWF, Reading, UK, dvasiljevic@ecmwf.int
Dirceu Reis, FUNCEME, Fortaleza, Brazil, dirceu@funceme.br
Fritz Teixeira, FUNCEME, Fortaleza, Brazil, fritz@funceme.br
Alexandre Costa, FUNCEME, Fortaleza, Brazil, alex@funceme.br
Humberto Barbosa, FUNCEME, Fortaleza, Brazil, barbosa@funceme.br
Alexander Loew, Hamburg University, Germany, alexander.loew@zmaw.de
Antje Tittebrand, Hamburg University, Germany, antje.tittebrand@zmaw.de
Andreas Colliander, JPL, andreas.colliander@jpl.nasa.gov
Bruno Picard, CLS, France, bruno.picard@cls.fr
Brian Ward, National University of Ireland, bward@nuigalway.ie
Claire Gruhier, CESBIO, France, claire.gruhier@cesbio.cnes.fr
Florian Schlenz, University of Munich, Germany, f.schlenz@iggf.geo.uni-muenchen.de
Paolo Ferrazzoli, University of Roma, Italy, ferrazzoli@disp.uniroma2.it
Ingo Voelksch, WSL, Switzerland, ingo.voelksch@wsl.ch
Joaquin Munoz, ECMWF, joaquin.munoz@ecmwf.int
Marco Carrera, Environment Canada, Dorval, QC, Canada, marco.carrera@ec.gc.ca
Mike Schwank, WSL, Switzerland, mike.schwank@wsl.ch
Pablo Punal, Universidad de Valencia, Spain, pablo.punal@uv.es
Philippe Richaume, CESBIO, France, philippe.richaume@cesbio.cnes.fr
Stephanie King, Institute of Ocean Sciences, Canada, stephanie.king@dfo-mpo.gc.ca
Simone Bircher, Danish Technical University, Denmark, subi@space.dtu.dk
Sonia Zine, IFREMER, France, sonia.zine@ifremer.fr
Marco Talone, ICM-CSIC, Barcelona, Spain, talone@icm.csic.es
Jan Balling, Danish Technical University, Denmark, jeb@space.dtu.dk
Heye Bogena, Agrosphere Institute, Juelich, Germany, h.bogena@fz-juelich.de
Estec Cardellach, IEEC, Spain, estel@ieec.uab.es
Johanna Dallamico, University of Munich, Germany, j.dallamico@iggf.geo.uni-muenchen.de
Carolina Gabarro, ICM-CSIC, Barcelona, Spain, cgabarro@icm.csic.es
Claire Henocq, IPSL, France, claire.henocq@locean-ipsl.upmc.fr
Juha Kainulainen, TKK, Helsinki, Finland, juha.kainulainen@tkk.fi
P.Y. Le Traon, IFREMER, France, pierre.yves.le.traon@ifremer.fr
Christian Matzler, University of Bern, Switzerland, matzler@iap.unibe.ch
Carsten Montzka, Agrosphere Institute, Juelich, Germany, c.montzka@fz-juelich.de
Kimmo Rautiainen, TKK, Helsinki, Finland, kimmo.rautiainen@tkk.fi
Kauzar Saleh, University of Cambridge, UK, kauzar.saleh@geog.cam.ac.uk
Joseph Tenerelli, BOOST, France, joseph.tenerelli@boost-technologies.com
Rasmus Tonboe, Danish Meteorological Institute, Denmark, rtt@dmi.dk
Lars Kaleschke, University of Hamburg, Germany, lars.kaleschke@zmaw.de
Jouni Pulliainen, Finnish Meteorological Institute, Finland, jouni.pulliainen@fmi.fi
Olivier Merlin, CESBIO, France, olivier.merlin@cesbio.cnes.fr
Franz Conen, University of Basel, Switzerland, franz.conen@unibas.ch
Laura Dente, ITC, Netherlands, dente@itc.nl
Arnold Gordon, LDEO, NY, USA, agordon@ldeo.columbia.edu

Istvan Heiler, FIMR, Finland, istvan.heiler@fimr.fi
Maciek Lubczynski, ITC, Netherlands, lubczynski@itc.nl
Catherine Prigent, Observatoire Paris-Meudon, France, catherine.prigent@obspm.fr
Ulrich Stoehlker, BfS, Germany, ustoehlker@bfs.de
Juha Lemmetyinen, Finnish Meteorological Institute, Finland, juha.lemmetyinen@fmi.fi