→ 2nd SMOS SCIENCE CONFERENCE

ABSTRACT BOOK

25–29 May 2015 | ESA–ESAC | Villafranca (Madrid), Spain

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Programme

Monday 25 May 2015

15:00	**Opening and welcome: news from SMOS** ***Susanne Mecklenburg, ESA/ESRIN (Italy)***
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15:30	SMOS after Five Years in Operations: From Tentative Research to Operational Applications *Kerr, Y.* *CESBIO (France)*
15:45	An Overview of New Insights from 5 Years of Salinity Data from SMOS Mission *Reul, N.* *IFREMER (France)*
16:00	Major achievements using SMOS over Cryosphere *Kaleschke, L.* *University of Hamburg (Germany)*
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17:05	Requirements from Operational NWP Agencies *Bauer, P.* *ECMWF (United Kingdom)*
17:25	Mission Concept SMOSOps *Martin-Neira, M.* *ESA/ ESTEC (The Netherlands)*
17:35	Mission Concept SMOSNEXT Kerr, Y. *CESBIO (France)*
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Tuesday 26 May 2015

Session 2 **Improvements to Level 1 and 2 retrieval algorithms - land and ocean**
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ESA/ESTEC (The Netherlands)

09:30 The SMOS Level2 Soil Moisture Algorithm. Principles and Future Trends
Kerr, Y. et al.
CESBIO (France)

10:00 The SMOS Level 2 ocean Salinity Algorithm. Principles and Future Trends
Font, J. (TBD)
Consejo Superior de Investigaciones Científicas (Spain)

10:30 Geolocation of RFI Sources with Sub-kilometric Accuracy from SMOS Interferometric Data
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10:50 Comparing the Impact of Different Bias Correction Techniques on SMOS Level 1 Brightness Temperature Maps Retrieval
Khazaal, A. et al.
CESBIO (France)

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Ocean Data Lab (France)

12:00 A Review of the Recent Improvements in the L-MEB Model (SMOS Mission) - Impact on the Accuracy of the Soil Moisture Retrievals
Wigneron, J. et al.
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Mahmoodi, A. et al.
CESBIO (France)

12:40 Retrieving SMOS Optical Depth of Forests: Interpretation of Results in Comparison with Available Data Bases of Height and Biomass
Ferrazzoli, P. et al.
Tor Vergata University, DICII (Italy)

13:00 SMOSHiLat: Microwave L-band Emissions of Organic-rich Soils in the Northern Cold Climate Zone in Support of the SMOS Mission
Bircher S. et al.
CESBIO (France)

13:20 **Lunch Break**

14:40 Nodal Sampling: An Advanced Image Reconstruction Scheme to Improve the Quality of SMOS Images
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BEC-ICM/CSIC (Spain)

15:00 Reducing Ascending/Descending Travel Direction Bias in SMOS Salinity Data
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National Oceanography Centre (United Kingdom)

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University of Liege (Belgium)

9:50 Spatial and Temporal Scales of SSS Variability from SMOS
Tzortzi, E. et al.
National Oceanography Centre (United Kingdom)

10:10 Persistence of Rainfall Imprint on SMOS Sea Surface Salinity
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Guimbard, S. et al.
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Brown, C. et al.
LOCEAN (France)

12:00 Estimation of Surface Ocean pH Exploiting SMOS Salinity Observations
Sabia, R. et al.
Telespazio-Vega UK Ltd for ESA (Italy)

12:20 A SMOS Optimal interpolation
Kolodziejczyk, N. et al.
Université Pierre et Marie Curie (France)

12:40 SMOS-MODE Overview
Portabella, M.
CSIC (Spain)

13:00 **SESSION SUMMARY & DISCUSSION**

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Kaminski, T. et al.
The Inversion Lab (Germany)

15:20 [Assimilating SMOS Observations to Improve Evaporation Estimates over Australia]
Miralles, D. et al.
VU Amsterdam / Ghent University (Netherlands/Belgium)

15:40 [An Approach of Monitoring Vegetation and Soil Moisture from SMOS]
Jiancheng, S. et al.
Institute of Remote Sensing and Digital Earth (China)

16:00 [Remotely Sensed Soil Moisture is Related to Forest Decline Occurrence]
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UPC/BEC (Spain)

16:20 [SMOS Based Global Soil State Product]
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Finnish Meteorological Institute (Finland)

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CESBIO (France)

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CNR (Italy)

10:00 SMOS Sea Ice Product: Operational Application and Validation
Kaleschke, L. et al.
University of Hamburg (Germany)

10:20 Investigating SMOS Data for Arctic Melt Ponds and Sea Ice Concentration Determination
Gabarro, C. et al.
BEC-ICM/CSIC (Spain)

10:40 Snow Melting Signature at L-band: Ground-based Measurements and SMOS Estimates over North America
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CNRS (France)

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11:30 Combined Use of Multifrequency Radiometry (L- to Ka-Band) for Enhanced Monitoring of Terrestrial Cryosphere Processes
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13:20 Assessing the Impacts of the Inclusion of SMOS Data into Environment Canada's Numerical Weather Prediction Systems

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Environment Canada (Canada)

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CESBIO (France)

15:00 New SMOS Level-4 Processor for Soil Moisture Disaggregation at 1km Resolution: Assessment of First Maps with In Situ Data
Molero, B. et al.
CESBIO (France)

15:20 Seasonal and Inter-annual Variability of SMOS Derived Soil Moisture and Ocean Salinity
Piles, M. et al.
Universitat Politècnica de Catalunya, IEEC/UPC and SMOS Barcelona Expert Center (Spain)

15:40 Different Soil Moisture Dynamics are Observed by SMOS and the South Fork In Situ Soil Moisture Network
Hornbuckle, B. et al.
Iowa State University (United States)

16:00 Validation of SMOS Level 3 Soil Moisture Data
Mialon, A. et al.
CESBIO (France)

16:20 SMOS L3 and L4 Dataset for the Monitoring of Extreme Hydrological Events
Al Bitar, A.
CESBIO (France)

16:40 Global SMOS Soil Moisture Retrievals Using the Land Parameter Retrieval Model
Van der Schalie, R. et al.
University of Amsterdam (The Netherlands)

17:00 **SESSION SUMMARY & DISCUSSION & COFFEE**
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Friday 29 May 2015

Session 7 **Synergistic use of SMOS measurements with other satellite/in situ data**
Chair: Yann Kerr, *Co-Chair: Susanne Mecklenburg*

09:30 Preliminary Study of Multi-year Ocean Salinity Trends with Merged SMOS and Aquarius Data.
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Earth and Space Research (United States)

10:00 Early Results from NASA Soil Moisture Active Passive Mission
Yueh, S. et al.
California Institute of Technology (United States)

10:30 Sea Surface Salinity Data Assimilation Improvement in a Global Ocean Forecasting System at 1/4° from SMOS and Aquarius Data
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CLS (France)

10:50 SMOS and SMAP Brightness Temperature Inter-Comparison and Calibration
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NASA (United States)

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11:40 Comparison of L-Band Radio Frequency Interference Seen by Aquarius and SMOS
Soldo, Y. et al.
NASA Goddard-GESTAR (United States)

12:00 An Overview of the SMOS+STORM Evolution Project: Measuring Surface Winds in Tropical and Extra-Tropical Storms with SMOS
Reul, N. et al.
IFREMER (France)

12:20 A Multi-dimensional Co-variance Model to Combine and Interpolate Sea Surface Salinity with Sea Surface Temperature
Buongiorno Nardelli, B. et al.
CNR (Italy)

12:40 **SESSION SUMMARY & DISCUSSION**

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TRANSFER TO AIRPORT

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University of Valencia. Earth Physics and Thermodynamics Department. Climatology from Satellites Group (Spain)

P02 Satellite Soil Moisture Validation in Romania
Diamandi, A. et al.
National Meteorological Administration (Romania)

P03 Soil Moisture Retrieval at Global Scale Using the SRP (Simplified Roughness Parameterization)
Fernandez-Moran, R. et al.
University of Valencia (Spain)

P04 Validation of Long-Term SMOS Soil Moisture Products Series Using Diverse Spatio-temporal Strategies and In Situ Networks in the Duero Basin (Spain)
González-Zamora, A. et al.
Universidad de Salamanca (Spain)

P05 Potential of Modelled vs. In Situ Data on SMOS L2 Soil Moisture Validation: a Case Study in Spain
Gumuzzio, A. et al.
Universidad de Salamanca (Spain)

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Köhler, J. et al.
University of Hamburg (Germany)

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Lanka, K. et al.
Indian Institute of Science (India)

P08 Characterisation of the Jucar River Basin Hydrological Climatology with ERA-Land Reanalysis. Consistency with In-Situ and SMOS Soil Moisture Products
Lopez-Baeza, E. et al.
University of Valencia.- Faculty of Physics (Spain)

P09 Soil Moisture in French Alpine Valley Using L-BAND Radiometer
Mialon, A. et al.
CESBIO CNRS (France)

P10 Why is SMOS Drier than the South Fork In Situ Soil Moisture Network?
Walker, V. et al.
Iowa State University (United States)

P11 Soil Moisture Remote Sensing with GNSS-R at the Valencia Anchor Station
Yin, C. et al.
Nanjing University of Information Sciece and Tecnology, Nanjing(China)

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LGGE (France)

P13 SMOS-based Snow Thickness Maps for Arctic Sea Ice: Comparison with Airborne Measurements
Maaß, N. et al.
University of Hamburg (Germany)

P14 The STSE Cryosmos Project: Exploiting the Potential of SMOS Data in Antarctica
Macelloni, G. et al.
CNR (Italy)

P15 Observations of Antarctic Icebergs Acquired with SMOS
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OBSEE (Poland)

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Fastopt (Germany)

P17 Quantitative and Qualitative Analysis of Coherence in Multi-temporal SAR Inferometry
Fakhri, F.
University of Turku (Finland)

P18 Comparison between AQUARIUS and SMOS Brightness Temperatures for the Period 2012-2014 Considering Similar Areas and According to Land Uses
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University of Valencia.- Faculty of Physics (Spain)

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Nigerian Meteorological Agency (Nigeria)

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Institut de Ciències del Mar – CSIC (Spain)

P21 Soil Surface Water Resources Assessment from SMOS L2 and In Situ Data for Poland
Lukowski, M. et al.
Institute of Agrophysics Polish Academy of Sciences (Poland)

P22 Global Maps of the Soil Roughness Effect Using L-band SMOS Data
Parrens, M. et al.
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P27 SMOS Assimilation into SURFEX Land Surface Model: Application to Crop Yield Estimate in West Africa
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LTHE (France)

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Universitat politècnica de Catalunya – UPC (Spain)

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CNRS (France)

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P31 SMOS Quality Control under IDEAS+ Framework
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Telespazio Vega UK (Spain)

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Tor Vergata University, DICII (Italy)

P33 Impact of SUN Glint on the SMOS Retrieved Brightness Temperature Maps for Five Years of Data
Khazaal, A. et al.
CESBIO (France)

P34 SMOS L1a to L1b Breadboard Developed at CESBIO via MATLAB (L1a2b)
Khazaal, A. et al.
CESBIO (France)

P35 SMOS Salinity Retrieval by Using Support Vector Regression with OTT Corrected Multi-angular Brightness Temperatures
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University of Ghent (Belgium)

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Telespazio Vega UK (Spain)

P37 Five Years of Ocean Salinity: How to Use the Data
Spurgeon, P. et al.
ARGANS (United Kingdom)

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Université Pierre et Marie Curie (France)

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INRA (France)

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IFREMER (France)

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Institute of Marine Sciences, CSIC (Spain)

Topic 9 **Synergistic Use of SMOS Measurements with other Satellite Derived and In-situ Data Over Land and Ocean, in Particular Aquarius and SMAP but also other Sensors**

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Al-Yaari, A. et al.
INRA (France)

P43 Downscaling of Soil Moisture Estimations at the Valencia Anchor Station Using Synergy of SMAP/SMOS Data
Ansari Amoli, A. et al.
Iranian Space Agency (Iran)

P44 Investigating the Potential of Satellite Salinity Measurements to Improve Tropical Cyclones Forecasting
Catany, R. et al.
University of Southampton (United Kingdom)

P45 Combining In-Situ and Satellite Observations to Better Estimate the Mixed Layer Salinity Budget in the Tropical Atlantic Ocean
Gaillard, F. et al.
LPO-IFREMER (France)

P46 Aquarius-derived Wind Speed as Auxiliary Constraint in SMOS Salinity Retrieval
Sabia, R. et al.
Telespazio-Vega UK Ltd for European Space Agency (ESA)

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Soloviev, A. et al.
Nova Southeastern University Oceanographic Center (United States)

Abstracts

MONDAY 25 MAY 2015
SESSION I :
SMOS – WHAT COMES NEXT? STATUS AND OUTLOOK
15:00 – 18:30

SMOS after Five Years in Operations: From Tentative Research to Operational Applications

Kerr, Y.[1]; Mecklenburg, S.[2]; Delwart, S.[2]; Wigneron, J.[3]; Ferrazzoli, P[4].; Hahne, A.[5]; Font, J.[6]; Reul, N.[7]; Boutin, J.[8]; Richaume, P.[1]; Mahmoodi, A.[1]
[1]CESBIO (France), [2]ESA/ESRIN (Italy), [3]INRA ISPA (France), [4]TUV (Italy), [5]ESA/ESTEC (The Netherlands), [6]ICM CSIC (Spain), [7]IFREMER (France), [8]LOCEAN (France)

The SMOS (Soil Moisture and Ocean Salinity) satellite was successfully launched in November 2009. This ESA led mission for Earth Observation is dedicated to provide soil moisture over continental surface (with an accuracy goal of 0.04 m3/m3) vegetation water content over land and ocean salinity [1-2]. These geophysical features are important as they control the energy balance between the surface and the atmosphere. Their knowledge at a global scale is of interest for climatic and weather researches in particular in improving models forecasts.

The purpose of this communication is to present the mission results after more than five years in orbit as well as some outstanding results already obtained. A special attention will be devoted to level 2 products and to the retrieval quality improvements from version 3 (at launch) to version 6 (release early 2015) of the algorithms. We will also show several operational products already emerging from this science driven mission after only 5 years in space.
The main products of the mission are of course soil moisture and Sea Surface salinity, but also vegetation opacity (directly related to water content) including forests, surface dielectric constant for level two but also brightness temperatures at the surface, strong winds, root zone soil moisture and RFI (radio frequency interferences) maps. From data several groups have started making new products several of them being either operational or on the verge of being such. We will show some of them or refer to related presentations. They include freeze defreeze (FMI), thin sea ice (Klimat Center Hamburg), near real time brightness temperatures and soon soil moisture (ECMWF), root zone soil moisture and drought indices (USDA and CESBIO). We are also working on more elaborate products such water fractions, flood risk indicator, Improved precipitation with use of assimilated SMOS data, etc..

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An Overview of New Insights from 5 Years of Salinity Data from SMOS Mission.

Reul, N.
IFREMER (France)

Measurements of salt held in surface seawater are becoming ever-more important for oceanographers and climatologists to gain a deeper understanding of ocean circulation and Earth's water cycle. ESA's SMOS mission is proving essential for this aim. Launched in 2009, SMOS has provided the longest continuous record (now ~5 years) of sea-surface salinity measurements from space. The salinity of surface seawater is controlled largely by the balance between evaporation and precipitation, but freshwater from rivers and the freezing and melting of ice also cause changes in concentrations. Along with temperature, salinity drives ocean circulation – the thermohaline circulation – which, in turn, plays a key role in the global climate. With a wealth of salinity data from SMOS now in hand complemented by measurements from the NASA–CONAE Aquarius satellite, which uses a different measuring technique. In this talk we shall provide an overview of how the SMOS mission – now celebrating five years in orbit – is providing detailed global measurements of ocean-surface salinity. An ensemble of key ocean processes for climate and biochemistry can now be determined and monitored for the first time from space using SMOS salinity data. This includes, for example, the detailed salinity structure of tropical instability waves along the equator and the salt exchanged across major oceanic current fronts through energetic ocean rings. Occurrences of large-scale salinity anomalies in the Pacific and Indian oceans related to El Niño, La Niña and the Indian Ocean climate are also well-evidenced in the five year-long data. In addition, the dispersal of freshwater into the ocean from the major large tropical rivers, namely the Amazon, Orinoco and Congo Rivers, their impact on tropical cyclone (TC) intensification and the oceanic imprints of the intense rainfall in the Trade Wind convergence zones and under TC can now be regularly monitored to better understand the variability of the oceanic part of the global water cycle. We will present how SMOS data, along with concurrent in situ Argo ocean-profile data, other satellite observations of sea-surface temperature, sea-surface height, surface-wind stress and ocean colour, are now providing new opportunities to investigate the surface and subsurface ocean mesoscale dynamics. The talk will tentatively illustrate how this type of data synergy is the key to unlock further scientific insight and increase our knowledge of the hydrologic cycle.

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TUESDAY 26 MAY 2015
SESSION II :
IMPROVEMENTS TO LEVEL I AND II RETRIEVAL ALGORITHMS – LAND AND OCEAN
09:30 – 15:45

SMOS Instrument Performance and Calibration after 5 Years in Orbit

Martin-Neira, M.[1]; Corbella, I.[2]; Torres, F.[2]; Duran, I.[2]; Duffo, N.[2]; Kainulainen, J.[3]; Oliva, R.[4]; Closa, J.[5]; Cabot, F.[6]; Khazaal, A.[6]; Anterrieu, E.[7]; Barbosa, J.[8]; Lopes, G.[8]; Tenerelli, J.[9]; Diez-Garcia, R.[10]; Fauste, J.[4]; Gonzalez, V.[11]; Turiel, A.[11]; Delwart, S.[12]; Crapolicchio, R.[12]; Suess, M.[1]
[1]ESA/ESTEC (The Netherlands), [2]Universitat Politècnica de Catalunya (Spain), [3]Harp Technologies Ltd. (Finland), [4]ESA/ESAC(Spain), [5]EADS-CASA Espacio (Spain), [6]CESBIO (France), [7]IRAP (France), [8]DEIMOS (Portugal), [9]Ocean Data Lab (France), [10]IDEAS (Spain), [11]SMOS Barcelona Expert Centre (Spain), [12]ESA/ESRIN (Italy)

ESA's Soil Moisture and Ocean Salinity (SMOS) mission has been in orbit for over 5 years, and its Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) in two dimensions keeps working well. The data for almost this whole period has been reprocessed with the new fully polarimetric version (v620) of the Level-1 processor which also includes refined calibration schema for the antenna losses.
The spatial tilt existing in the images produced with the previous version of the Level-1 processor, in the two main polarizations X and Y, has been considerably decreased, removing the negative trend at low incidence angles and reducing the overall standard deviation of the spatial ripples. The expected improvement in the third and fourth Stokes, after correcting the use of the cross-polar antenna patterns, has been confirmed.
In terms of bias, the new version of the Level-1 processor produces slightly warmer ocean images resulting in an increased average deviation with respect to the geophysical models. The portioning of this positive bias into instrumental and forward model contributions is not perfectly known. In any case, this bias does not compromise the accuracy of the sea surface salinity retrievals as the Ocean Target Transformation removes it. A problem which does persist in the new Level-1 data is the land-sea contamination, which has been tracked down to visibility amplitude calibration errors. Later versions of the processor will have this problem very much removed.
Regarding temporal variations, the long term drift exhibited by the previous processor version has been significantly mitigated thanks to a better calibration of the antenna losses and the use of only the most accurate Noise Injection Radiometer (NIR) out of the 3 units available in MIRAS. These improvements have also reduced the orbital and seasonal variations, although residual drifts still remain, in particular during October (which might be due to galactic glint) and the eclipse season.
The SMOS Calibration and Level-1 Processor team continues working on a simpler mode of operation of MIRAS, called ALL-LICEF.

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The SMOS Level2 Soil Moisture Algorithm. Principles and Future Trends

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The Soil Moisture and Ocean Salinity (SMOS) mission is ESA's (European Space Agency) second Earth Explorer Opportunity mission, launched in November 2009. It is a joint
programme between ESA CNES (Centre National d'Etudes Spatiales) and CDTI (Centro para el Desarrollo Tecnologico Industrial). SMOS carries a single payload, an L-Band 2D interferometric
radiometer in the 1400-1427 MHz protected band. The goal of the level 2 algorithm is to deliver global soil moisture maps with a desired accuracy of 0.04 m3/m3.
To reach this goal a retrieval algorithm was developed and implemented in the Ground segment which processes level 1 to level 2 data. In this context, a group of institutes prepared the soil moisture Algorithm Theoretical Basis document (ATBD) to be used to produce the operational algorithm.
The principle of the soil moisture retrieval algorithm is based on an iterative approach which aims at minimizing a cost function. The main component of the cost function is given by the sum of the squared weighted differences between measured and modelled brightness temperature (TB) data, for a variety of incidence angles. The algorithm finds the

best set of the parameters, e.g. soil moisture (SM) and vegetation characteristics, which drive the direct TB model and minimizes the cost function.
The end user Level 2 SM product contains soil moisture, vegetation opacity, and estimated dielectric constant of any surface, brightness temperatures computed at 42.5°, flags and quality indices, and other parameters of interest.
Based on recent study and analysis (see paper by JP Wigneron on LMEB, P Ferrazzoli on forest etc.. and results acquired since launch we have revisited the algorithm(flags, retrievals outputs, aux data). The goal of this presentation is to give an update on the algorithm changes and trends. Validation will be presented in other papers.

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The SMOS Level 2 Ocean Salinity Algorithm. Principles and Future Trends

Font, J.;
Consejo Superior de Investigaciones Científicas (Spain)

TBD

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Geolocation of RFI Sources with Sub-kilometric Accuracy from SMOS Interferometric Data

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[1]CNRS (France), [2]CESBIO (France)

Although MIRAS is operating in a protected band, the contamination of L1a data by man-made sources of radio-frequency interferences (RFIs) operating close to the L-band are frequently observed. Although the geolocation of such RFI sources has already been addressed, the accuracy is almost always kilometric (> 1 Km). This contribution is devoted to a major improvement brought to this problem by introducing an approach that performs the geolocation of such RFI sources with a sub-kilometric accuracy (< 1 Km).

RFI sources are modeled according to a parametric model where the location and the brightness temperature of the source at ground level are the key parameters. These parameters are optimized in a constrained iterative process where the visibilities corresponding to a given RFI source are computed with the actual modeling of the instrument and subtracted from the visibilities acquired by MIRAS. Since there is no guarantee that a given RFI source is found at the same ground location in all the snapshots, the average or the median location is retained.

The performances have been addressed with numerical simulations as well as with SMOS data contaminated by RFI. Among the many RFI sources affecting SMOS data worldwide, few of them have been geolocated. For most of them, ground coordinates have been provided by national spectrum management authorities of the corresponding country. For a very small number, these coordinates have been cross-checked with independent GPS measurements and/or accompanied with a ground truth or an evidence. This is the case of an RFI source in Ukraine as well as with another one in Germany.
In the first case, more than 1100 snapshots from 13 orbits passing close to the emitter in June 2011 have been processed in X and Y polarizations. The final accuracy on the location of this source is about 125 m.
The same processing has been performed over Germany, but over a longer period of time (6 months) because this RFI source turned out to be frequently switched off and often contaminated by other emitters. Nevertheless, the final accuracy on the location of this RFI source is about 140 m.

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Comparing the Impact of Different Bias Correction Techniques on SMOS Level 1 Brightness Temperature Maps Retrieval

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[1]CESBIO (France), [2]IRAP (France)

The two-dimensional L-band interferometer MIRAS (Microwave Imaging Radiometer by Aperture Synthesis) is the single payload of the SMOS (Soil Moisture and Ocean Salinity) space mission led by the European Space Agency and launched on November 2nd, 2009.
It has been showed that the problem of retrieving the radiometric temperature distribution of a scene under observation from interferometric data or visibilities is ill-posed and has to be regularized in order to provide a unique and stable solution. A band limited regularization approach has been proposed and implemented in the Level~1 processor of the SMOS Data Processing Ground Segment (DPGS). This approach aims to retrieve, from the

visibilities, the Fourier components of the brightness temperature map of the observed scene. Then, an inverse Fourier transform is applied in order to obtain the brightness temperature.

A systematic error or bias is observed in the retrieved maps due to a sharp frequency cutoff associated to the limited frequency coverage yielding the so-called Gibbs oscillations. Another kind of bias also appears in the reconstructed images coming from the contribution of the aliased regions to the visibilities. Indeed, due to the large spacing between the antennas of SMOS, the Shannon-Nyquist sampling criterion is not respect leading to an aliased region inside the reconstructed field of view.

To reduce this bias, it has been proposed and implemented in the DPGS, to remove from the visibilities the contribution of an artificial scene as close as possible to the observed one. From the differential visibilities, we reconstruct a differential brightness temperature distribution and the artificial scene is finally added back to the retrieved map.

Different techniques are applied for modeling and computing the artificial scene. For now, the approach adopted in the SMOS Level 1 operational data processor is a very simple one. It consists on the removal of a constant value over the entire Earth surface. This value is obtained from the three zero baselines measurements, provided by the three reference antennas of MIRAS, describing the average temperature of the observed scene.

In this work, we propose to test and compare other approaches for modeling and computing the artificial brightness temperature map. Indeed, the approach used for now in the DPGS is very simple while more complex, global and realistic approaches can be used. Also, the computation of the artificial scene in the DPGS depends only on the three zero-baselines visibilities while two of them are now discarded from the reconstruction due to calibration problems.

Two issues will be discussed in this work. The first one is concerned with the best methodology to calculate the artificial scene by comparing three configurations: (1) The artificial scene is calculated using the three zero baselines measurements. (2) The artificial scene is calculated using only one baseline measurement (the stable one). (3) The artificial scene is calculated using the entire (stable) baselines by applying a least square optimization problem that minimizes the difference between the measured and artificial contributions.

The second issue is concerned with the modeling of

other information to properly compute the microwave emission for a given target. Inaccurate information on land cover can lead to errors in modeled microwave emissions and hence wrong estimates of soil moisture and optical depth. The SMOS Level 2 processor uses a combination of external maps including ECOCLIMAP, ESRI's DCW, and ESA's GlobeCover to obtain the land cover data required in the modeling process. Although no suitable substitutes have been found to this date for these maps, they are thought to be out of date and not adequately representing the truth. NASA's SMAP mission, scheduled to be launched in January 2015, uses a modeling approach similar to SMOS to estimate soil moisture from passive L-band observations. Although some external maps are common in both missions, SMAP is planning to use MOIDS IGBP as the source for land cover. As the lives of the two missions are expected to overlap for some time in the future, it is expected that products from the two will be inter-compared to gain better insight into the performance of the methods as well as various input data used. Therefor there is high interest in comparing the choices of external data between the two missions.

In this presentation we examine differences between MODIS IGBP, based on the product developed by Broxton et al, and the current SMOS product based on ECOCLIMAP. In comparing two maps there are several issues that need to be addressed including different scales, resolutions, and taxonomies. Furthermore, the impact of MODIS IGBP on SMOS Level 2 products will be explored and results will be compared against the current SMOS products. In order to use MODIS IGBP in the SMOS processor one has to follow conventions set by the Level 2 processor. We present various issues involved in this process and decisions made to address them.

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A Look at the Brightness Temperatures from ESA's Reprocessing Campaign

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The European Space Agency's (ESA) SMOS (Soil Moisture and Ocean Salinity) satellite was launched in early November 2009 and has provided nearly five years of fully polarimetric brightness temperatures at L-band over a swath about 1000 km wide and over incidence angles ranging from nadir to about 60 deg. The single instrument on the satellite, MIRAS, consists of an array of 69 low-directivity antennas arranged in a Y-shape and a correlation unit which measures the cross-correlation between signals from pairs of these antennas. The so-called 'Level-1' Processor first transforms these cross-correlations into calibrated visibilities and then applies an image reconstruction algorithm to these visibilities to produce brightness temperature images. Owing to the spacing of the antennas, scene brightness far from boresight is aliased, and only the brightness temperatures over a portion of the field of view (FOV), the so-called extended alias-free field of view (EAF-FOV), are usable for scientific purposes.

In the second half of 2014 ESA initiated a reprocessing campaign, and a new set of brightness temperatures have been produced covering the period from January 2010 through February 2014. The reprocessing incorporates significant improvements in the calibration and image reconstruction methods, and in this presentation we will highlight the differences between brightness temperatures from the new and previous reprocessing campaigns, with a focus over the ocean.

Although the new reconstructed brightness temperatures exhibit smaller long and short term drift over the open ocean than those from the previous reprocessing campaign, the drift that remains is still significant for salinity retrieval. Yet a portion of the drift may arise from errors in the forward model used as the reference, and we will discuss the possible sources of the observed biases.

One feature that remains strongly apparent in the new brightness temperatures is the so-called 'land-sea contamination' bias, which refers to the large (several kelvin) biases in all four Stokes parameters up to about 1000 km from the coastlines. We will briefly discuss an empirical method recently developed to correct for this contamination, and we will demonstrate, through comparisons of retrieved salinity to in-situ salinity measurements (ARGO and ship TSG data) that this method can effectively remove this 'land contamination' bias without impacting the geophysical temporal and spatial structures in the surface salinity.

Another feature apparent in the new data is a large across-track bias in the first Stokes parameter in the EAF-FOV in the southern oceans towards the end of each year (but most apparent in December). We will show that the origin of this bias is sun glint, and we will briefly examine the possibility to correct for this glint using an empirically adjusted scattering model.

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A Review of the Recent Improvements in the L-MEB Model (SMOS Mission) - Impact on the Accuracy of the Soil Moisture Retrievals

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The L-MEB (L-band Microwave Emission of the Biosphere) is the forward model used in the operational SMOS algorithm to retrieve surface soil moisture (SM). This model is based on a well-known zero-order solution of the radiative transfer equations: the so called τ-ω model, L-MEB includes several parameterisations which were developed specifically to account for the multi-angular and bi-polarization capabilities of the SMOS brightness temperature (TB) observations in the retrieval process. A detailed description of the L-MEB model has been given in Wigneron et al. (2007). Since then, the model has been implemented in the SMOS algorithm which produced time series of the Level 2 (ESA) and Level 3 (CATDS) SM products, since the beginning of 2010. These SM products have been evaluated against numerical modelling products, in situ data from large SM networks included in the SMOS cal/val initiative and in a series of experimental campaigns based on field (SMOSREX, MELBEX, Upper Danube, etc.) or airborne measurements (NAFE-06, Australia; CAROLS, France; etc.). Eventually, numerical and physical models were used to develop new parameterizations of the soil roughness, soil permittivity, forests and low vegetation effects. Based on this very dense scientific activity some possible future improvements of the L-MEB model have been proposed. In a first step, this communication makes a quick review of the most significant recent results obtained in this field of research. In a second step, we present an illustration of the impact on the SM retrievals of using of a new parameterization of soil surface roughness in L-MEB which consists in combining both the roughness and vegetation effects in a single parameter (TR). The advantages of the SRP approach are twofold: firstly it not necessary to calibrate roughness effects (this is quite an open issue for large scale SMOS pixels) and secondly, the SRP method allows accounting for possible time changes in both the roughness characteristics and the vegetation optical depth. In this study, we present results of the evaluation of the SRP method against in situ measurements made within the SCAN network in 2011 in the USA. Even though first results are very encouraging, more studies evaluating the improvement in SM retrievals using the SRP method from the SMOS observations will be crucial to consolidate the novel retrieval method as a feasible option in the determination of SM at global scale.

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Retrieving SMOS Optical Depth of Forests: Interpretation of Results in Comparison with Available Data Bases of Height and Biomass

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SMOS algorithm retrieves both soil moisture and optical depth in vegetated areas. A correct estimate of optical depth is important for the reliability of soil moisture estimate. However, it can also be interesting for other applications, since several previous studies indicated that the optical depth contains information about vegetation water content (kg/m^2) for crops, and biomass (Mg/ha) for forests.

This work is focused on forests. A recent investigation compared Vegetation Optical Depth (VOD) retrieved by an L2 prototype algorithm with forest height derived by ICESAT GLAS Lidar (Simard et al, 2011), at global scale, showing a significant relationship between the two variables. For all forest pixels of the world, VOD retrievals were averaged among four days in February, May, July and November 2011, obtaining four different global maps. It was found that seasonal variations of forest VOD were very low on average.

As an extension of this work, values obtained in the different seasons were averaged, in order to filter noise. This seasonal average was carried out both with an “intersection” method, that considers pixels with retrieved VOD in all 4 seasons, and with a “union” method, based on all pixels with retrieved VOD in at least one season. The average VOD was compared with forest height estimated by GLAS, obtaining a linear (Pearson) correlation coefficient of 0.64 for a “union” seasonal average and of 0.77 for an “intersection” seasonal average. These results were influenced by the low data availability over Boreal forests due to RFI and snow cover, with the latter affecting the retrieval in February and partially in May. As a further investigation, only South American continent was considered, having several pixels mostly covered by forests, negligible snow effects, and low RFI. Additionally, forest biomass estimates of other data sets, such as the Tropical Forest Carbon Storage Map (Jet Propulsion Laboratory, JPL) and the Pantropical National Level Carbon Stock Dataset (Woods Hole Research Center, WHRC) are available. Using the “union” seasonal average the linear correlation coefficient was 0.73 between VOD and GLAS forest height and 0.69 with JPL biomass. For an “intersection” seasonal average, values increased to 0.79 and 0.72, respectively. Lower correlations were found with WHRC data base.

Further investigations are in progress. In particular, L2 prototype results are being compared with monthly averages of L3 data. Moreover, specific evaluations are in progress over selected forest areas in which local information about biomass and/or height is available.

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SMOSHiLat: Microwave L-band Emissions of Organic-rich Soils in the Northern Cold Climate Zone in Support of the SMOS Mission

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L-band microwave (1.4 GHz) brightness temperature (TB) observations of the Soil Moisture and Ocean Salinity (SMOS) satellite are used to retrieve global soil moisture data, taking advantage of the large difference between the dielectric constant of dry soil and water. The retrieval is based on the L-band Microwave Emission of the Biosphere (L-MEB) model using tuning parameters derived from study sites in dry and temperate climate zones. Thus, the aim of the SMOSHiLat project (ESA's STSE Changing Earth Science Network) is to improve our understanding of L-band emissions and supporting SMOS data quality in more northern climate zones covered by pronounced organic surface layers. A database is created including L-band TB and dielectric constant measurements of organic-rich soils, mainly from (1) Sodankylä, Finland (Finish Meteorological Institute), and (2) Gludsted, Denmark (HOBE). Additional organic samples are available from Islay, Scotland, and the West Siberian Plain, Russia.

The L-band dielectric constant measurements conducted at the IMS Laboratory (Bordeaux, France), show no distinct variability between a range of humus types encountered in the four regions. Due to the increased bound water fraction in porous organic material dielectric constants are consistently lower than measured in the underlying sandy mineral soils. Hence, one function was fitted through all organic soil moisture – dielectric constant couples, and tested in L-MEB by means of the tower-based ELBARA radiometer dataset acquired at the Research Center Jülich using Danish organic-rich soil. The derived relation proved satisfactory, and consequently, was implemented in the SMOS Soil Moisture Level 2 Prototype Processor (SML2PP). First runs were conducted over the Sodankylä test site and compared with retrieved soil moisture using the Dobson and Mironov dielectric mixing models. Results demonstrated significantly wetter retrieved soil moisture when using the organic fit function. This is in better agreement with an in situ surface soil moisture network average from measurements specifically calibrated for organic material and representative for prevailing land cover and soil types. Further test runs over other sites are planned in the near future.

In this presentation, the SMOSHiLat project will be presented with special focus on the SML2PP studies.

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Nodal Sampling: An Advanced Image Reconstruction Scheme to Improve the Quality of SMOS Images

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SMOS synthetic aperture radiometer provides large swath, good resolution snapshots of brightness temperatures on L-band using an appropriate inversion scheme based on the inversion of the G-matrix. However, due to the incomplete sampling of the measured visibilities at high spatial frequencies, sharp transitions in the SMOS brightness temperature scenes generate a Gibbs-like contamination ringing and spread sidelobes. This is the case of images affected by Radio-Frequency Interferences, the Sun, and even land/sea/ice transitions. These perturbations damage the quality of SMOS data, to the point of preventing the retrieval of valid estimates of sea surface salinity at some zones and times.

In this work we will present the last advances in the nodal sampling technique. This reconstruction method is based in oversampling images in such a way that the Fourier coefficients at known frequencies are preserved, then search for those subpixels for which the oscillatory perturbation cancels (zero-crossings) according to a given criterion (minimum Laplacian). A new sampling scheme has been introduced, based on allowing the zero-crossing points to lie slightly beyond the boundaries of the original pixel. This simple modification of the original nodal sampling leads to a dramatic decrease of error on ocean scenes. A comparison between the measured brightness temperatures and those obtained from modeled data lead to a reduction of 0.7 K with the previous version of the nodal sampling method and of almost 2 K with the new version, and practically attaining the minimum error for such comparisons.

In the talk we will present examples of maps of sea surface salinity obtained using the new technique, and also we will discuss the potentiality of this technique for soil moisture images on land.

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Reducing Ascending/Descending Travel Direction Bias in SMOS Salinity Data

Banks, C.; Srokosz, M.; Snaith, H.; Gommenginger, C.; Tzortzi, E.
National Oceanography Centre (United Kingdom)

SMOS has provided sea surface salinity (SSS) data for more than 5-years. However, it has been shown that the operational ESA Level 2 SSS data have significant spatially and temporally varying biases between measurements from ascending passes (SSSA; SMOS moving south to north at ~6 am local time) and measurements from descending passes (SSSD; SMOS moving southwards at ~6 pm). This paper will demonstrate how these variable biases can be reduced through the use of SSS anomalies.

This study used ESA SMOS Level 2 data from 2010 through 2013 to provide daily, one-degree by one-degree climatologies (separately for ascending and descending passes) using a moving window approach (in time and space). Salinity in each one-degree cell is based on all data not excluded after applying a number of quality control flags, from all four years for that cell plus data from those cells within 2º and ± 4 days. The daily, one-degree products can then be averaged to provide values of climatological SSS at lower spatial and/or temporal resolution – in this study daily, three-degree by three-degree.

These climatological products have been used to produce SSS daily, three-degree anomalies for both ascending and descending passes calculated by subtracting the climatology from the daily data (ANOMA and ANOMD) using the same quality control flags.

There is good general agreement between the SMOS climatology products and data from World Ocean Atlas 2013. However, there are significant differences at high latitudes, as well as in coastal and dynamic regions (given previous studies none of these results are unexpected). A number of regions have been chosen to study how the daily, area-averaged values of ANOMA minus ANOMD are lower than the values of SSSA minus SSSD.

For all regions, the seasonal cycle in ascending versus descending bias has been removed. In addition, both the average (mean and median), and the spread (standard deviation and range) of the differences between data from ascending passes and descending passes for the anomalies are reduced compared to those obtained using the original salinity values.

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EOF Analysis of SMOS Salinity Data in the North Atlantic Ocean: Detection and Removal of Non-physical Signals

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Empirical Orthogonal Functions (EOFs) allow to separate spatial and temporal patterns of variability in geophysical datasets. DINEOF (Data Interpolating EOFs) is a technique that allows to reconstruct missing data and remove noise by retaining only an optimal set of EOFs. A DINEOF analysis of Sea Surface Salinity (SSS) data from the Soil Moisture and Ocean Salinity (SMOS) is presented in this work. Part of the noise in the SMOS SSS data present some regularity in time and space, and it is therefore identified in the EOF modes. By selecting the EOF modes used for the reconstruction of missing data some of these noise sources can be effectively removed, resulting in a more accurate SSS field. A DINEOF analysis is presented for the surface salinity of the North Atlantic Ocean, and a preliminary study is also realised in the Mediterranean Sea. Outliers are detected and removed before the final DINEOF analysis, by examining the departure of individual pixels from the EOF basis retained by DINEOF. Results are compared to in situ data, in order to assess the gain obtained with the higher spatial and temporal resolution of the SMOS SSS data.

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Spatial and Temporal Scales of SSS Variability from SMOS

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Taking advantage of the different spatio-temporal coverage of satellite-derived sea surface salinity (SSS), SMOS observations are used for the first time in the analysis of the characteristic scales of SSS variations in space and time. The focus is on the Tropical/Subtropical Atlantic 30◦N-30◦S, which covers the dynamically different Evaporation-dominated Subtropics and Precipitation-dominated Tropics. For the spatial scales of SSS, the aim is to identify potential regions across the basin, where SSS varies concurrently in space on relatively short, i.e. subannual to interannual, time scales and are characterized by homogeneous SSS behaviour. Similarly, an initial insight is obtained into the persistence of coherent SSS changes in time, i.e. how quickly temporal SSS variations evolve over the different regions, by assessing temporal decorrelation lengths of SSS over the first 5 complete years (2010-2014) of SMOS data. The resulting scales are compared with those from other datasets, including Aquarius. An improved description and understanding of the spatio-temporal decorrelation length scales of SSS variations provides insights into the different controlling mechanisms acting on SSS in the region of interest, benefiting a wide range of oceanographic studies. Equally importantly, it provides valuable information on the correlation structure of the SSS that is necessary for its successful use in data assimilation into operational ocean models, which are becoming an increasingly powerful tool in oceanography.

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Persistence of Rainfall Imprint on SMOS Sea Surface Salinity

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The Soil Moisture and Ocean Salinity (SMOS) satellite mission monitors sea surface salinity (SSS) over the global ocean for more than 5 years. In previous studies, Boutin et al. (2014) have shown a clear freshening of SMOS SSS under rain cells of about -0.14pss/mm/hr at moderate wind speed (3-12m/s). This order of magnitude is compatible with in situ drifters observations taken at 45cm depth while SMOS SSS are at about 1cm depth and at a mean spatial resolution of 43km. Using Aquarius satellite SSS, Meissner and Wentz (2014) found a SSS decrease under rain cells of -0.12pss/mm/hr at 7 m/s wind speed, consistent with SMOS estimate considering the lower spatial resolution of Aquarius SSS (about 150km); Santos-Garcia et al. (2014) found an influence of the rain history preceding by a few hours the Aquarius measurement. In most cases, drifters observations also suggest that about half of the freshening observed locally disappears after one hour, likely because of mixing with surrounding waters. In this presentation, we will investigate the temporal and spatial evolution of SMOS SSS after a rain event. Rainfall information will be either derived from SSM/Is measurements (during periods when three SSM/Is satellites provide adequate sampling before and simultaneous to SMOS measurements) or from the NOAA CMORPH products. In order to separate instantaneous from historical effects, we distinguish two cases: 1) rainfall occurs at less than 30mn from SMOS observation but no rain occurred before; 2) rainfall occurred previous to SMOS observation (up to 3 hours before) but has stopped at least 30mn before SMOS acquisition. In addition to looking at the temporal evolution of SMOS SSS under the rain cell, since both vertical mixing and horizontal stirring may occur, we'll also investigate the spatial pattern of the fresh SSS region relative to the one of the rain cell.

Boutin et al. (2014), Sea surface salinity under rain cells: SMOS satellite and in situ drifters observations, JGR: Oceans, doi:10.1002/2014JC010070.

Meissner et al., Upper Ocean Salinity Stratification and Rain Freshening in the Tropics Observed From Aquarius, IGARSS 2014, Quebec City, Canada, July 2014.

Santos-Garcia et al. (2014), Investigation of rain effects on Aquarius Sea Surface Salinity measurements, JGR: Oceans, doi:10.1002/2014JC010137.

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Observational Evidences of the Large-Scale Tropical Cyclone Rainfall Impacts on the Upper Ocean Salinity

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Surface freshening and associated mixed-layer density changes due to rain storms were considered by Stommel (1993) as potential key regulator processes of the thermo-haline driven horizontal circulation of the upper ocean. The fate of the less buoyant large quantity of freshwater accumulated at the ocean surface in the wake of intense rain events during Tropical Cyclones (TC) stays however very poorly known. Quantitative estimates of the large-scale impacts of the TC accumulated rainfall on the oceanic mixed-layer salinity and density are lacking, in particular their characterization on intra-seasonal to inter-annual time scales. Rainfall in Tropical Cyclones (TC) is by essence episodic, relatively short-lived (0(3days)), spatially localized to bands spiralling around the storm center within relatively large spatial domains of 0(200-1000 km) where locally intense 0(>25 mm/h) downward freshwater flux to the upper ocean occur. Whether the imprints of these impacts can be detected using current satellite and in situ SSS observation systems is a question we attempt to answer in the present work. As local intense rain in TCs is very often associated with very high surface wind stresses and associated mixing, the large rain-induced ocean surface freshening expected during extreme events could be rapidly damped by vertical and horizontal diffusion and mixing in TC wakes, and therefore be difficult to detect from space.

To investigate if the TC season cumulated large scale signals might be nevertheless of detectable amplitude, the variability of both surface and mixed-layer salinity in all active TC areas are determined over the period 2010-2013 from the data of the Soil Moisture and Ocean Salinity and Aquarius satellite missions and from the ARGO float upper level data. Global and TC induced rainfall are first characterized using the Tropical Rainfall Measuring Mission (TRMM) satellite and TC track databases. TCs contributed between ~2-3% of the annual global rainfall during the 4-year period with regionally higher percentages reaching 10-15% on average in the subtropics. The northeastern tropical and western Pacific are nevertheless two specific and extended zones where TCs rain contributed as high as 70-90% and 40% of the annual falls, respectively.

Time series and maps of SSS and rain in these two relatively high TC rainfall oceanic areas are analyzed to potentially identify the TC-season induced freshening signals at the surface. ARGO float observations are used to corroborate the surface observations and quantify the freshwater input mixing in the upper ocean.

We clearly identify the rain storm induced freshening in large scale satellite SSS and in vertical in situ measurements. The implication of these new results for thermohaline circulation monitoring will be discussed.

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New Insights of PCO_2 Variability in the Tropical Eastern Pacific Ocean using SMOS SSS

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LOCEAN- Laboratoire d'Océanographie et du Climat: Expérimentations et approches numériques (France)

Complex oceanic circulation and air-sea interaction make the eastern tropical Pacific Ocean (ETPO) a highly variable source of CO_2 to the atmosphere. Although the scientific community have amassed 70,000 surface partial-pressure of carbon dioxide (pCO_2) datapoints measurements within the ETPO region over the past 25 years, the spatial and temporal resolution of this dataset is insufficient to fully quantify the seasonal to inter-annual variability of the region, a region where pCO_2 has been observed to fluctuate by >300 µatm.

Upwelling and rainfall events dominate surface physical and chemical characteristics of the ETPO, with both yielding unique signatures in sea surface temperature and salinity. Thus, we explore the potential of using a statistical description of pCO_2 within sea-surface salinity-temperature space. These SSS/SST relationships are based on in-situ SOCAT data collected within the ETPO. This statistical description is then applied to high resolution (0.25º) SMOS sea surface salinity and OSTIA sea surface temperature in order to compute estimate regional pCO_2. As a result, we are able to resolve pCO_2 at sufficiently high resolution to elucidate the influence various physical processes have on the pCO_2 of the surface ETPO.

Normalised (to 2014) oceanic pCO_2 between July 2010 and June 2014 within the entire ETPO was 41 µatm supersaturated with respect to 2014 atmospheric partial pressures. Values of pCO_2 within the ETPO were found to be broadly split between southeast and a northwest regions. The north west, central and South Equatorial Current regions were supersaturated, with wintertime wind jet driven upwelling found to be the first order control on pCO_2 values. This contrasts with the southeastern/ Gulf of Panama region, where heavy rainfall combined with rapid stratification of the upper water-column act to dilute dissolved inorganic carbon, and yield pCO_2 values undersaturated with respect to atmospheric partial pressures of CO_2.

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Estimation of Surface Ocean pH Exploiting SMOS Salinity Observations

Sabia, R.[1]; Fernández-Prieto, D.[2]; Shutler, J.[3]; Donlon, C.[4]; Land, P.[5]; Reul, N.[6]
[1]Telespazio-Vega UK Ltd for ESA (The Netherlands), [2]ESA/ESRIN (Italy), [3]University of Exeter (United Kingdom), [4]ESA/ESTEC (The Netherlands), [5]Plymouth Marine Laboratory (United Kingdom), [6]IFREMER (France)

The surface ocean currently absorbs approximately one third of the excess carbon dioxide (CO2) injected into the atmosphere from human fossil fuel burning and deforestation, mitigating the impact of global warming and climate change. However, this anthropogenic CO2 absorption by seawater determines a reduction of both ocean pH and the concentration of carbonate ion. The latter can also lead to a decrease in calcium carbonate saturation state, with potential implications for marine animals, especially calcifying organisms. The overall process is commonly referred to as Ocean Acidification (OA), and is nowadays gathering increasing attention as one of the major foci of climate-related research [1,2], having profound impact not only at scientific level, but also in its socio-economic dimension. Areas that have shown to be already particularly vulnerable to OA include upwelling regions, the oceans near the poles and coastal regions that receive freshwater discharges.

Growing international efforts are being devoted to develop a coordinated strategy for monitoring OA [3], with an eager need for global and frequent observations of OA-relevant parameters; however, the datasets acquired are currently mostly relevant to in-situ measurements, laboratory-controlled experiments and models simulations. Remote sensing technology can be integrated by providing synoptic and frequent OA-related observations, upscaling and extending in-situ carbonate chemistry measurements on different spatial/temporal scales; yet, the preliminary products developed so far are only regional, empirical or derived with a limited variety of satellite datasets [4,5].

Within this context, "Pathfinders-OA" is an ESA STSE project (led by Plymouth Marine Laboratory, UK) meant to exploit Earth Observation (EO) to monitor ocean acidification. This is being addressed by collecting relevant datasets and creating a large database of EO-in situ matchups, with the objective of developing and validating algorithms to retrieve OA parameters from space in 5 case-study regions (global ocean, Amazon plume, Barents sea, Greater Caribbean, Bay of Bengal).

Overall, the purpose of this study is to quantitatively and routinely estimate surface ocean pH by means of satellite observations, capitalizing on the recent advent of remotely-sensed salinity measurements [6]. The overarching objectives are to develop new algorithms and data processing strategies to

overcome the relative immaturity of OA satellite products currently available, and to produce a global, temporally evolving, quasi-operational suite of relevant satellite-derived data.
Specifically, this will be performed by exploiting the information content of Ocean Colour (OC) data, Sea Surface Temperature (SST), Wind Speed (WS) and Sea Surface Salinity (SSS) parameters (with an emphasis on the latter). A proper merging of these different satellites datasets will allow to compute at least two independent proxies among the seawater carbon dioxide system parameters: namely, the partial pressure of CO2 in surface seawater (pCO2); the total Dissolved Inorganic Carbon (DIC) and the total alkalinity (AT). Through the knowledge of these parameters, the final objective is to come up with the currently best educated guess of the surface ocean pH.
A preliminary effort in this sense was the estimation of monthly surface ocean pH maps for 2010 in the North Atlantic, using pCO2 data and computed AT derived from SMOS salinity measurements, with a preliminary estimation of the errors in pH due to inaccuracies in satellite SSS [7]. Currently, ongoing efforts aim at extending the temporal domain and the geographical analysis, including additional satellite datasets (especially OC-related) and the remaining carbonate system parameters, and performing different permutations (round-robin approach) in view of a systematic ocean pH sensitivity analysis. An overall validation plan is being devised to verify the consistency, accuracy and robustness of the satellite datasets produced, by quality-controlling the satellite products against in-situ measurements and modelling outputs.
The innovation of this study lies mainly in the effort of unifying fragmented remote sensing studies and generating a novel value-added satellite product: a global and frequent surface ocean pH “cartography”. This will foster the advancement of the embryonic phase of OA-related remote sensing and will aim at bridging the gap between the satellite and the process studies communities, benefiting from their cross-fertilization and feedback.

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A SMOS Optimal interpolation

Kolodziejczyk, N.[1]; Marchand, S.[2]; Martin, N.[3]; Vergely, J.[4]; Boutin, J.[2]; Yin, X.[2], Reverdin, G.[2], Sommer, A.[2]
[1]Université Pierre et Marie Curie (France), [2]LOCEAN-IPSL (France), [3]LOCEAN (France), [4]ACRI (France)

A method is presented for mapping sea surface salinity (SSS) from SMOS level-3 daily data in order to obtain less noisy and less biased SSS fields at length [O(75 km)] and time [O(1 week)] scales better than the ones reachable with in situ measurements. First, the SMOS L-3 daily field are corrected from coastal and latitudinal biases using an empirical method using Argo climatology (ISAS) over the 2010-2014 SMOS period. Residual seasonal biases and their lengthscales are estimated.
SSS is then estimated from the bias corrected data at a grid point using a method based on optimal interpolation (OI). Several large scales error correlation are tested, including the so-called long-wavelength errors, referred to as inter-dwell and ascending/descending biases. A trial SSS analysis is produced in the several regions of Atlantic ocean on a uniform grid with 0.25° resolution and a temporal resolution of one week, encompassing the period from 2010-2014.Validation using independent in situ data from thermosalinograph from ship of opportunity shows the benefit of SMOS OI mapping.

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SMOS-MODE Overview

Portabella, M.
CSIC (Spain)

TBD

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WEDNESDAY 27 MAY 2015
SESSION IV :
APPLICATIONS ADDRESSING CARBON

15:00 – 17:00

Constraining Terrestrial Carbon Fluxes by Assimilating the SMOS Soil Moisture Product into a Model of the Global Terrestrial Biosphere

Kaminski, T.[1]; Scholze, M.[2]; Blessing, S.[3]; Knorr, W.[2]; Vossbeck, M.[1]; Grant, J.[2]; Scipal, K.[4]
[1]The Inversion Lab (Germany), [2]Lund University (Sweden), [3]FastOpt (Germany), [4]ESA/ESTEC (The Netherlands)

Carbon dioxide (CO2) is the most important anthropogenic greenhouse gas contributing to about half of the total anthropogenic change in the Earth's radiation budget. And about half of the anthropogenic CO2 emissions stay in the atmosphere, the remainder is taken up by the biosphere. It is of paramount importance to understand CO2 sources and sinks and their spatio-temporal distribution. In the context of climate change this information is needed to improve the projections of future trends in carbon sinks and sources. In the present study we employ the Carbon Cycle Data Assimilation Systems to assimilate atmospheric CO2 flask samples with and without the SMOS L3 soil moisture product over two years into a process-based model of the terrestrial carbon cycle to constrain land surface CO2 exchange fluxes. We find that the assimilation of SMOS data improves the agreement with independent soil moisture data from ASCAT. Also the validation against in situ data provided by Fluxnet shows considerable improvement when SMOS data is assimilated jointly with CO2, compared to assimilating CO2 only. In both cases the assimilation also improves the fit of modelled atmospheric CO2 to the observations at flask sampling sites which have not been used in the assimilation. Reduction of uncertainty relative to the prior is generally high for both regional NEP and NPP and considerably higher than for assimilating CO2 only, which quantifies the added value of SMOS observations as a constraint on the terrestrial carbon cycle. The study demonstrates a high potential for a SMOS L4 carbon flux product.

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Assimilating SMOS Observations to Improve Evaporation Estimates over Australia

Miralles, D.[1]; Martens, B.[2]; Lievens, H.[2]; Fernández-Prieto, D.[3]; Verhoest, N.[2]
[1]VU Amsterdam / Ghent University (Belgium), [2]Ghent University (Belgium), [3]ESA/ESRIN (Italy)

INTRODUCTION
Terrestrial evaporation (ET) is an essential component of the climate system that links the water, energy and carbon cycles. Despite the crucial importance of ET for climate, it is still one of the most uncertain components of the (global) hydrological cycle. During the last decades, much effort has been put to develop and improve techniques for measuring the evaporative flux from the land surface in the field. However, these in situ techniques are prone to several errors and, more importantly, only provide relevant information at a very local scale. As a consequence, evaporative models have been designed to derive ET from large-scale multi-sensor satellite data.

METHOD
In this study, GLEAM (Global Land Evaporation – Amsterdam Methodology) is used to simulate evaporation fields over continental Australia. GLEAM consists of a set of simple equations driven by remotely-sensed observations in order to estimate the different components of ET (e.g., transpiration, interception loss, soil evaporation and sublimation). The methodology calculates a multiplicative evaporative stress factor that converts Priestley and Taylor's potential into actual evaporation. Unlike in other ET-dedicated global models, the stress factor in GLEAM is derived as a function of soil moisture (simulated using a precipitation-driven soil water balance model with microwave observations of soil moisture being assimilated) and observations of vegetation optical depth (VOD, retrieved from microwave remote sensing as well).

OBJECTIVE
This study investigates the merits of assimilating SMOS soil moisture (θobs) and VOD retrievals in GLEAM. The Level 3 SMOS θobs retrievals are assimilated into the soil water module of GLEAM using a simple Newtonian Nudging approach. Prior to the assimilation, θobs observations are rescaled to the climatology of the model using a standard CDF-matching approach. Several assimilation experiments are conducted to show the efficiency of

the assimilation scheme to improve ET estimates over continental Australia. Simulations are validated using both in-situ observations of soil moisture and ET-measurements from flux towers. The performance of the model run with assimilation of SMOS θobs and VOD is compared against an assimilation experiment using AMSR-E θobs and VOD.

PRELIMINARY RESULTS
Preliminary results in indicate that GLEAM estimates of ET and soil moisture (θ) dynamics are realistic over Australia, and that SMOS θobs have the potential to improve the model's performance at different spatial scales. On the other hand, AMSR-E θobs do not always improve model performance, potentially due to a wrong reproduction of seasonal dynamics.
Detailed results from this study will provide a better insight of the value of SMOS to increase understanding on the magnitude and dynamics of terrestrial ET over continental Australia and their dependency to soil water availability.

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An Approach of Monitoring Vegetation and Soil Moisture from SMOS

Jiancheng, S; Cui, Q.; Zhao, T.
Institute of Remote Sensing and Digital Earth (China)

Monitoring vegetation and soil moisture is important for the studies of the global water and carbon cycles. In this study, based on the commonly used zero-order radiative transfer model, we developed a two-step approach for retrieving vegetation optical depth (VOD) and soil moisture using only SMOS H-polarized multi-angular measurements. First, this was done by minimizing the soil signal and separating the vegetation signal from the multi-angular brightness temperature. The uniqueness of this approach is that the angular feature of soil emission is used and that the VOD is retrieved directly from the H-polarized multi-angular brightness temperature without any field correction or auxiliary soil or vegetation data. This approach is first validated by theoretical modeling and experimental data. The results demonstrate that VOD can be reliably estimated using this approach. The retrieved VOD is then compared with aboveground biomass, which shows strong correlation. Global mean VOD for the years of 2010 to 2011 generally shows a clear global pattern and corresponds well to the land cover types. The VOD of nine representative regions that are homogeneously covered with different vegetation types from 2010 to 2011 is compared with Normalized Difference Vegetation Index (NDVI). The results indicate that the VOD can generally reveal vegetation seasonal changes and can provide unique information for not only vegetation monitoring but also the vegetation correction for soil moisture estimation. Secondly, we have developed an algorithm for soil moisture estimation with the H-polarized multi-angular measurements also. A new parameterized soil emission model was developed. In this model, a surface roughness variable that considers the rms height, correlation length and correlation function shape was used. Validation using two soil moisture monitoring networks of Yanco Region and Little Washita watershed indicates that this algorithm performs well in surface soil moisture retrieval. Retrieved soil moisture agrees well with the in situ measurements with the RMSE of about 0.04 m3/m3.

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Remotely Sensed Soil Moisture is Related to Forest Decline Occurrence

Chaparro, D.; Vall-llossera, M.; Piles, M.; Portal, G.; Camps, A.; Pablos, M.; Pou, X.
Universitat Politècnica de Catalunya, IEEC/UPC and SMOS Barcelona Expert Centre (Spain)

INTRODUCTION
Forest decline episodes are linked to drought events and are expected to spread due to climate change [1]. Here, a forest decline survey is linked to remotely sensed soil moisture data, in order to analyse drought impact in forests.

METHODOLOGY
The impact of soil moisture on forest decline in NE Spain was studied in two ways:

A. Mean summer 2012 soil moisture calculated with SMOS L4 product (1 km resolution) [2] was used in a generalized linear model. Explanatory variables were: Mean SM, climatic precipitation, drought indices (SPI), anomaly of temperature and species. Forest decline, registered by DEBOSCAT project [3] after summer drought, was the response variable (0=unaffected, 1=affected). 2154 unaffected pixels and 1076 affected pixels were studied.

B. Soil moisture monthly anomalies:

B.1. Calculated with SMOS L4 product (1 km) as the difference between each studied month and the month mean for the years 2011-2014. SM anomalies were averaged in two categories (affected and unaffected) and then were plotted for the period June 2010 – August 2012.
B.2. Calculated using the same procedure with the ECV-SM data record (1978-2013; 25 km resolution) [4]obtained from SMMR, SSM/I, TMI, AMSR-E, WindSat and AMSR2 sensors (only passive datasets were used). Monthly anomalies were averaged in affected (n=11) and unaffected (n=12) categories and plotted (January 1979 – August 2012).

RESULTS
A. The model explained a 40% of forest decline occurrence. Mean SM explained a 5% of the model variability. Although other variables had a higher weight in the model, low SM clearly affected non-drought-adapted species as Fagus sylvatica and deciduous Quercus.

B. ECV SM anomalies on June/July 2012 presented differences between affected (-0.04 m3/m3) and unaffected (-0.09 m3/m3) pixels. Forest decline was not related to SMOS L4 anomalies.

Future work in SM anomalies will be presented at the conference.

REFERENCES
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SMOS Based Global Soil State Product

Rautiainen, K. [1]; Ikonen, J. [1]; Parkkinen, T.[1]; Schwank, M.[2]; Lemmetyinen, J. [1]; Pulliainen, J. [1]

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Finnish Meteorological Institute in co-operation with Gamma Remote Sensing has developed an algorithm for detecting seasonal soil state processes using L-band microwave radiometer observations from the MIRAS instrument on-board the ESA SMOS mission. The work has been performed during several ESA studies most importantly in the frame of STSE SMOS+ Innovation program. Currently, FMI and Gamma are validating the global soil state product using all available in situ observations (soil temperature and moisture) in the Northern Hemisphere together with relevant global products (ECMWF products, WMO synoptic measurements, land class and soil type databases). The work was initiated using observations form the SMOS tower-based reference radiometer ELBARA-II, located at the FMI Sodankylä test site since October 2009. The algorithm has been modified to accommodate CATDS daily gridded SMOS Level 1 brightness temperatures. Retrieval results of soil state have been validated against a frost depth observation network of the Finnish Environment Institute. The current parameterization of the retrieval is adapted for the boreal forest zone; further validation against in situ data acquired from different environmental conditions and geographic regions is required to extend the product for the whole Northern Hemisphere.

The soil state retrieval algorithm is based on defining freeze/thaw thresholds for the SMOS data. Firstly a frost factor (FF) value is calculated from the SMOS observations based on the difference between the V- and H-polarization signals. To standardize the method and enable automatic threshold detection, FF values are further normalized to relative values, which reach a maximum value of 100 in winter and minimum value of 0 in summer. The summer minimum and winter maximum values are experimentally determined for each observation grid cell. Additional auxiliary data is used to define the seasonal variation in each pixel. The end of the summer period can be estimated using WMO synoptic air temperature data interpolated over the Northern Hemisphere and the end of winter period using snow masks derived based on ESA DUE GlobSnow product. Both data are available in near real time, which is essential for the NRT soil state estimation. The product will be used especially for estimating the soil state changes; freezing and thawing. Both processes are of great interest and linked to climate change and carbon cycle studies.

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Surface Water Fraction over Tropical Area from SMOS Data

Al Bitar, A.
CESBIO (France)

Wetlands are a major component to the hydrological water cycle (Bullock & Acreman, 2003). Several wetland areas exhibit high seasonal behavior. Their extents are monitored using a variety of remote sensing techniques: optical (Mertes et al., 1993), thermal infrared, radar and microwave (Prigent, 2001). Still an accurate and continuous estimation of their dynamics at high temporal resolution is needed. On the other hand the effect of ponding and floods on the soil moisture from Soil Moisture and Ocean Salinity (SMOS) sattelite have been depicted in previous studies (Al Bitar et al., 2012, Jackson et al., 2012). In this work, we use SMOS brightness temperature (TB) data to deliver a new Surface Water Fraction (SWaF) product at 25km spatial resolution and 7days temporal resolution over tropical areas. L-band signal from SMOS is expected to be more sensitive to open water under dense vegetation compared to other commonly used microwave frequencies. Also, It presents the advantage of all weather capabilities compared to thermal and optical sensors. A simple algorithm based on main surface contributions like forest, water and soil is built from SMOS L3 TB data. It is applied on the Amazon and Congo basins which are characterized by dense vegetation and highly dynamic water surfaces. We show from time series analysis of TB and emissivity at different polarization and incidence angles that the signal measured by SMOS over these areas is highly sensitive to open water compared to the physical temperature. Also we show from TB seasonal percentile maps that the seasonal dynamics are related to the dynamics of wetlands. The new SMOS product is compared over the Rio Negro river to Jason-2 altimetric data delivered by the Hydroweb portal. This comparison is done over a flat area (slope of 1cm/1km) where the river water levels and the surface water extents are expected to be related. We find that the water fraction estimated by SMOS is highly correlated with water levels measured by Jason-2 ($R > 0.98$). We show also that this correlation decreases with the distance to the river. The dynamics of water surfaces are compared to the climatic regimes in Amazon and Congo basin. For the Amazon basin, the comparison shows that phase shift of three-months in the precipitation regime between the south and the north of the basin which is consistent with observed rainfall data. The results show the capabilities of the SMOS mission to deliver novice surface water fraction products.

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THURSDAY 28 MAY 2015
SESSION V :
APPLICATIONS ADDRESSING CRYOSPHERE

09:30 – 12:20

On the Analysis of Low Frequency Microwave Emission of the Ice Sheets

Macelloni, G.[1]; Brogioni, M.[1]; Yardim, C.[2]; Johnson, J.[2]; Aksoy, M.[2]; Bringer, A.[2], Jezek , K.[2]; Durand, M.[2]; Duan, Y.[2], Tan, S.[3]; Wang, T.[3]; Tsang, L.[3]; Drinkwater, M.[4]
[1]CNR (Italy), [2]Ohio State University (United States), [3]University of Michigan (United States), [4]ESA/ESTEC (The Netherlands)

Recent studies carried out mainly by Italian, French and American research groups were focused on explaining the emission mechanisms which take places in the ice sheets by using low frequency microwave radiometers (i.e. SMOS and Aquarius). In particular, by using experimental data and glaciological models it has been pointed out the good correlations between L-band Tb and the thickness and surface temperature of the Antarctic and Greenland Ice Sheets. Using electromagnetic models we are able to simulate the data and demonstrate that the SMOS measurements are mainly influenced by vertical temperature profile. In turn this is driven by surface temperature, ice sheet thickness, geothermal heat flux and accumulation rate. Theoretical investigation point out the influence of the layering in the upper part of the ice sheet on microwave emission. These results demonstrated that microwave radiometry offers the potential to remotely sense internal ice sheet temperatures. In particular theoretical results, were obtained using an e.m. model (the DMRT –ML), suggest that microwave radiometry at frequencies ~0.5 - ~ 2 GHz can probe sub-surface ice sheet emissions at depths up to a few km. Such a measurement is necessary in determining internal deformation and ice flow and then to improve ice sheet models which rely on temperature-dependent deformation rates within the body of the ice sheet. In order to test this concept an ultra-wideband “software defined” microwave radiometer (UWBRAD) is proposed. The radiometer will have 15x100MHz frequency channels occupying the 0.5-2GHz frequency band. The radiometer will measure microwave emission in circular polarization at nadir with a 1km spatial resolution and will have an NEDT in each channel of 1 K or better. The UWBRAD has been recently supported by the NASA Instrument Incubator Program, and is currently in development. Airborne deployment over borehole sites in Greenland is planned for 2016 to validate temperature measurement capabilities. A preliminary test is planned for Antarctic summer 2015-2016 when a prototype of the UWBRAD will be deployed at Concordia Base and compared to DOMEX-3 measurements. This latter is a microwave L-band radiometer installed for a long-term monitoring of the Antarctic plateau which was extensively used for calibration and validation of SMOS data.

****

SMOS Sea Ice Product: Operational Application and Validation

Kaleschke, L.[1]; Tian-Kunze, X.[1]; Maaß, N.[1]; Wernecke, A.[1]; Miernecki, M.[1]; Mueller, G.[1]; Fock, B.[1]; Gierisch, A.[1]; Schlünzen, K.[1]; Pohlmann, T.[1]; Dobrynin, M.[1]; Hendricks, S.[2]; Asseng, J.[2]; Kauker, F.[3]; Kaminski, T.[4]; Gerdes, R.[2]; Jochmann, P.[5]; Reimer, N.[5]; Holfort, J.[6]; Spreen, G.[7]; Gerland, S.[7]; King, J.[7]; Skou, N.[8]; Schmidl Søbjærg, S.[8]; Casal, T.[9]; Drusch, M.[9]; Beitsch, A.[1]
[1]University of Hamburg (Germany), [2]Alfred Wegener Institute for Polar and Marine Research (Germany), [3]O.A.Sys GmbH (Germany), [4]FastOpt GmbH (Germany), [5]HSVA Hamburgische Schiffbau-Versuchsanstalt GmbH (Germany), [6]Bundesamt für Seeschifffahrt und Hydrographie (Germany), [7]Norwegian Polar Institute (Norway), [8]DTU Space (Denmark), [9]ESA/ESTEC (The Netherlands)

The decline of Arctic sea ice raises increasing interest in Arctic shipping and the need for operational sea ice forecast systems. Sea ice thickness is one of the key parameters needed for the initialisation of forecast models. It can be derived from the freeboard conversion using altimetry (e.g. CryoSat-2) or from microwave radiometry at low frequencies. Both retrieval techniques are complementary because the freeboard method has a large relative uncertainty for thin ice while the radiometric approach is not sensitive for ice thicker than the penetration depth of the electromagnetic waves in the ice medium. This maximum ice thickness depends on the liquid brine concentration in the ice and thus on the ice salinity and temperature. At the SMOS frequency of 1.4 GHz the maximum thickness is about half a meter for homogenous level ice. An algorithm based on a combined thermodynamic and radiative transfer model which accounts for variations of ice temperature and ice salinity has been used for the continuous production of a SMOS-based sea ice thickness data product. Its validation so far was limited to a sparsely available ground truth and considerable uncertainties remained.

A forecast system for ship route optimisation has recently been developed and tested in an operational application during an extensive field campaign with the ice-strengthened research vessel Lance in the Barents Sea in March 2014. The ship cruise was complemented with coordinated measurements from a helicopter based on R/V Lance and the research aircraft Polar 5 operated from Longyearbyen airport, Spitsbergen. Sea ice thickness was measured using an electromagnetic induction (EM) system from the bow of R/V Lance and another EM-system towed below the helicopter. Polar 5 was equipped among others with the L-band radiometer EMIRAD2. An array of 15 ice drift buoys was deployed from an aircraft before the ship cruise to measure the ice movement. About 80 TerraSAR-X wide-swath mode images have been acquired for the main area of investigation. The experiment yielded a comprehensive data set allowing the evaluation of the operational forecast and route optimisation system as well as the SMOS-derived sea ice thickness product that has been used for the initialization of the forecast.

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Investigating SMOS Data for Arctic Melt Ponds and Sea Ice Concentration Determination

Gabarro, C.[1]; Pla-Resina, J.[1]; Elosegui, P.[2]; Martínez, J.[1]; González-Gambau, V.[1]; Portabella, M.[1]; Słomińska, E.[3]
[1]BEC-ICM/CSIC (Spain), [2]Haystack, MIT (United States), [3]OBSEE (Poland)

The Arctic Ocean is under profound transformation. Observations and model predictions show dramatic decline in sea ice extent and volume. Despite its importance, our understanding of the pacing of Arctic sea ice retreat is incomplete largely due to a paucity of observations.
Melt pond distribution is a key Arctic climate variable because they lower significantly the surface albedo relative to snow and also bare ice, hence have an important effect on the Earth's radiation balance. Ponds of melt water develop on the sea ice surface due to incoming shortwave radiation and above-freezing surface air temperatures. Nowadays, melt ponds are remotely detected using optical sensors only, hence observations are limited by cloud cover.
We will describe a novel, all-weather approach to melt pond detection over sea ice using SMOS brightness temperature data. The method uses physical emissivity models and exploits the multi-angular capability of SMOS to mitigate errors. The method employs a three-layer radiative transfer model (i.e., air, freshwater, and sea ice) to compute the emissivity of melt ponds at L-band (1.4 GHz) using the Fresnel reflection equations and the complex-valued dielectric constants of each of the three media. The low microwave frequency used by SMOS penetrates in the different media to a certain extent such that melt water and seawater signals can be differentiated. We will present preliminary results that compare theoretical models and SMOS data.
An algorithm to compute Arctic ice concentration using SMOS brightness temperature measurements from different polarization and incidence angles will also be presented. Despite its lower spatial resolution relative to SSMI or AMSR-E, ice concentration data products from SMOS can contribute to complement ongoing monitoring efforts in the Arctic Cryosphere.

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Snow Melting Signature at L-band: Ground-based Measurements and SMOS Estimates over North America

Pellarin, T.[1]; Mialon, A.[2]; Balsamo, G.[3]; Morin, S.[4]; Richaume, P.[2]; Kerr, Y.[2];
[1]CNRS (France), [2]CESBIO (France), [3]ECMWK (United Kingdom), [4]CNRM / Météo-France (France)

INTRODUCTION
Recent ground-based microwave measurements obtained in the Alps using an L-band radiometer located near Grenoble (France) have shown interesting brightness temperature (TB) behavior during snow melting periods. Conversely to dry snow conditions, the occurrence of wet snow in the afternoon leads to decrease the emission in H-pol while V-pol emission increases. This effect is not observed over dry snow where both polarizations increase in the afternoon. This specific behavior of

TBs can be observed at larger scale using SMOS measurements provided that ascending and descending SMOS orbits are observed during a single day. Thus, looking at the difference between morning and afternoon orbits at horizontal polarization can indicate locations where snow is melting.

METHOD

The first part of this study is based on three years of L-band passive microwave measurements obtained over grassland and forested areas in the Vercors region. The ESA radiometer (ELBARA-II) TB time-series are analyzed and compared against ground measurements as well as snow properties provided by a physical snow model (CROCUS from Météo-France). In a second step, SMOS H-pol TB difference maps are obtained over North America and compared to outputs of the ECMWF operational model.

RESULTS AND DISCUSSION

At the radiometer scale, snow melt periods can be easily detected. Verification of snow melting conditions can be done using 30-minute pictures of the footprint area taken from the radiometer location. At the regional scale, raw SMOS TBs for a given incidence angle generally provide imprecise snow liquid water maps. Much better results are obtained when using either synthetic TB derived from the best L-MEB simulation (fitted on SMOS measurements) or averaged SMOS TB over at least 3 days. Obtained maps are then compared to snow liquid water content maps from ECMWF.

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Combined Use of Multifrequency Radiometry (L- to Ka-Band) for Enhanced Monitoring of Terrestrial Cryosphere Processes

Lemmetyinen, J.[1]; Schwank, M.[2]; Derksen, C.[3]; Rautiainen, K.[1]; Toose, P.[3]; Roy, A.[4]; Santoro, M.[2]; Smolander, T.[1]; Wiesmann, A.[2]; Mätzler, C.[2]; Pulliainen, J.[1]; Fernandez, D.[5]

[1]Finnish Meteorological Institute (Finland), [2]GAMMA RS (Switzerland), [3]Environment Canada (Canada), [4]University of Sherbrooke (Canada), [5]ESA/ESRIN (Italy)

Recent studies have demonstrated the feasibility of L-band (1 – 2 GHz) radiometry for freeze/thaw monitoring of the surface soil layer [1, 2], which can be applied to multi-angular SMOS measurements. In addition to its relevance for e.g. terrestrial hydro climatology in northern regions, knowledge of surface freeze/thaw states can potentially improve the mapping of snow mass (snow water equivalent, SWE) by microwave radiometers at higher frequencies (19 and 37 GHz). State of the art SWE retrieval techniques [e.g. 3] are typically limited by static assumptions of the states on the snow density and the soil beneath.

L-band radiometry has the potential to provide information on snow density [4]. Conventionally considered as having minimal effect on microwave radiation at long wavelengths (such as L-band), dry snow nevertheless affects observed microwave signatures even at these wavelengths through changes in impedance matching between soil and the overlying media, as well as through the incidence angle at the soil interface that is affected by refraction within the snowpack. Theoretical studies show that a discernible effect in emitted microwave radiation is achieved with changing snow conditions [2]. Exploiting these effects, the multi-angular, dual-polarized SMOS observations have the potential to derive snow properties, such as the density of the lowest □10 cm of the snowpack. This in turn, would have the potential to improve SWE retrieval algorithms based on EO-data from other sensors (e.g. ESA GlobSnow).

A recently launched project within the STSE Pathfinders program addresses the above issues, including specific tests to address the possibility of retrieving the density of seasonal snow cover from SMOS observations. This presentation will provide an overview of radiometer measurements at forest and wetland sites in Sodankylä, Finland, and open cropland near Saskatoon, Canada. These measurements were used to evaluate the potential to retrieve dry snow density and ground permittivity from L-band brightness temperatures.

[1] K. Rautiainen et al., 2014. Detection of soil freezing from L-band passive microwave observations. Remote Sens. Environ.,147: 206–218.

[2] M. Schwank et al., 2014. Model for Microwave Emission of a Snow-Covered Ground with Focus on L Band. Remote Sens. Environ., 154: 180-191.

[3] M. Takala et al., 2011. Estimating northern hemisphere snow water equivalent for climate research through assimilation of space-borne

radiometer data and ground-based measurements. Remote Sens. Environ., 115: 3517–3529.

[4] M. Schwank et al. (Submitted 2014). Snow Density and Ground Permittivity Retrieved from L-Band Radiometry: A Synthetic Analysis. IEEE J. Selected Topics App. Earth Obs. Remote Sens.

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THURSDAY 28 MAY 2015
SESSION VI :
APPLICATIONS ADDRESSING HYDROSPHERE

12:20 – 17:30

Developing New Soil Moisture Datasets Using Neural Networks

Rodriguez-Fernandez, N.[1]*; Richaume, P.*[2]*; Kerr, Y.*[2]
[1]*CNRS (France),* [2]*CESBIO (France)*

This presentation will discuss the results of a number of projects that use statistical inversion approaches based on neural networks to retrieve soil moisture (SM) from SMOS brightness temperatures.

i) First, neural networks have been used to perform a multi-sensor soil moisture retrieval exploiting the synergies of SMOS, ASCAT and MODIS instruments. The SM reference dataset used for the supervised training has been taken from ECMWF HTESSEL model simulations. It will be shown that the addition of active microwaves improves the ability of the retrieval algorithm to capture the temporal variability of SM.

ii) Once trained, neural networks are very fast to apply Therefore, we have developed a neural network scheme to retrieve SM from SMOS data in near-real time (NRT). The neural network has been used to perform a global inversion of the SMOS operational algorithm. The characteristics of this new NRT SM dataset will be described and the performances evaluated against in situ measurements of SM.

iii) SM is an essential climate variable and creating long term SM datasets that are consistent along time is crucial for climate science. Traditional approaches to create long time series of SM consist in merging a posteriori SM datasets
created from different sensors observations using different retrieval algorithms. Here we will discuss an alternative way to derive a long term SM dataset which is consistent along time by construction. The method is based in optimizing different neural networks algorithms using different data as input as a function of time but using a common reference SM dataset for the supervised learning phase. The approach has been applied to AMSR-E and SMOS data to create a 11-year SM dataset. The results will be evaluated against time series of in situ measurements of SM and ECMWF ERA-Interim model data.

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Comparison between SMOS Brightness Temperature Observations and ECMWF ERA-Interim Based Brightness Temperature: Long Term Monitoring and Multi-year Global Analysis

De Rosnay, P.; Muñoz Sabater, J.; Dutra, E.; Albergel C.; Balsamo, G.; Boussetta, S.; Isaksen, L.
ECMWF (United Kingdom)

In this paper we analyse the reprocessed SMOS Near Real product for a more than 4-year period from January 2010 to March 2013. For the same period the European Centre for Medium-Range Weather Forecasts (ECMWF) produced a global L-band brightness temperature re-analysis at the SMOS resolution using the Community Microwave Emission Modelling Platform (CMEM). The L-band re-analysed product is based on the ECMWF land surface model forced by the ERA-Interim reanalysis and coupled to CMEM. The land surface model configuration is fixed to the current version of the operational Integrated Forecasting System, so it is consistent over the re-analysis period. The microwave model configuration was set-up to use the Wang and Schmugge dielectric model combined with the Wigneron vegetation opacity model and the simple Wigneron soil roughness parameterization as detailed in de Rosnay et al., ESA conference (2013) and as currently used for operational monitoring of SMOS data. Time series and anomalies of SMOS TB and ECMWF re-analysed TB are analysed and compared for the 4-year period of SMOS. Results are presented at global and regional scales using RMSE, bias, correlation and anomaly correlation metrics. The analysis is conducted at a range of time scale including daily, monthly, annual time scales and inter-annual time scales.

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Towards an Optimised Use of SMOS Data in the ECMWF Land Data Assimilation System

Muñoz Sabater, J.[1]; de Rosnay, P. [1]; Albergel, C. [1]; Balsamo, G. [1]; Isaksen, L. [1]; Boussetta, S. [1]; Drusch, M.[2]
[1]*ECMWF (United Kingdom),* [2]ESA/ESTEC (The Netherlands)

The European Centre for Medium-Range Weather

Forecasts (ECMWF) is consolidating a Land Data Assimilation System (LDAS) able to assimilate soil moisture information from passive microwave brightness temperatures. Weather forecasts can benefit from this update through a better initialisation of soil moisture prior to a forecast run.

This study shows the main results obtained from different experiments combining screen level variables (SLV) and SMOS brightness temperatures in the ECMWF LDAS. Firstly, three global scale assimilation experiments conducted during the summer month in the North Hemisphere (where evapotranspiration rates are higher, and therefore expecting a larger impact of SMOS data) quantify the added value of integrating SMOS data in the LDAS for the estimation of the soil water content. To this end, the soil moisture analyses are compared to all available in-situ observations belonging to the International Soil Moisture Network (ISMN). Both, the seasonal dynamic and the short term variability of the analysed soil moisture field are evaluated. Then, the impact in atmospheric variables, such as air temperature and air humidity, is also evaluated. Special emphasis is put in those areas where the assimilation of SMOS data is more promising. Secondly, short term experiments investigate the sensitivity of soil moisture forecasts and analysis to different model and SMOS brightness temperatures scenarios in the LDAS, with the objective of optimizing the use of SMOS data in the assimilation system. A range of data assimilation experiments using different configurations of the observation and model error representation are investigated and the results presented in this study.

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Assessing the Impacts of the Inclusion of SMOS Data into Environment Canada's Numerical Weather Prediction Systems

Carrera, M.; Charpentier, D.; Caron, J.; Belair, S.; Bilodeau, B.
Environment Canada (Canada)

SMOS brightness temperatures (TB) are assimilated in the Canadian Land Surface Data Assimilation System (CaLDAS) for the initialization of the soil moisture state. Several field scale studies have demonstrated that the inclusion of the SMOS (TB) data leads to increased skill in the simulation of soil moisture for both the superficial and root-zone layers. This study reports upon the impacts of the SMOS TB assimilation upon the prediction of near-surface variables in Environment Canada's Regional Deterministic Prediction System (RDPS). The RDPS, with 10 km grid spacing, is the principal forecast guidance used by Meteorological Service of Canada forecasters for forecasts in 1-2 day range over North America.

CaLDAS-SMOS will be run in offline mode assimilating SMOS TB data using the Ensemble Kalman Filtering (EnKF) methodology to generate soil moisture analyses for the 2014 warm season period. Short-range forecasts from the RDPS will be used as atmospheric forcing for CaLDAS-SMOS in offline mode. These CaLDAS-SMOS analyses of soil moisture will be compared with those produced by the current screen-level based data assimilation, currently in operations, using a series of in-situ networks over North America.

The impacts of the CaLDAS-SMOS soil moisture analyses upon Numerical Weather Prediction (NWP) forecasts will be assessed by performing a series of 48-h forecasts of the RDPS system using soil moisture initial conditions from the CaLDAS-SMOS system and those from the current screen-level system. Verifications will focus upon near-surface temperature, dew-point temperature and precipitation.

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Assimilation of SMOS Soil Moisture Products to Improve Streamflow Simulations on the Ouémé Catchment in Benin

Leroux, D.[1]; Pellarin, T.[1]; Vischel, T.[1]; Gascon, T.[1]; Kerr, Y.[2]
[1]LTHE (France), [2]CESBIO (France)

The Ouémé catchment is located in the central part of Benin in West Africa. Its climate, extremely dry in winter and heavy rains in summer, makes the water cycle a true challenge to model, especially for the water management in the agricultural areas.
DHSVM (Distributed Hydrology Soil Vegetation Model) is a physically based and distributed hydrological model that solves the energy and water balance at each time step. This model simulates the soil moisture at each soil layer, the snow quantity, the evapotranspiration, the runoff and the streamflow. It was used with an hourly time step at a 1 km resolution. Model parameters have been calibrated using 2005 in situ streamflow

measurements along with in situ precipitations. When using satellite precipitation observations, the streamflow simulations are no longer in agreement with in situ measurements.
The goal of this work is to assimilate the SMOS soil moisture product into the hydrological model DHSVM using a Kalman filter for a better constraint on the water cycle model when using satellite precipitation observations. First results tend to show an improvement of the simulated streamflow using the SMOS assimilation into DHSVM. SMOS acts on the system by adding or removing some water when satellite observations are either under or overestimating the precipitations.
The ESA's SMOS mission was launched in November 2009 and has been providing Soil Moisture and Ocean Salinity data for the last five years. Soil moisture products are available at a 25 km resolution with a 3-day global coverage (Level 3 data). Besides the choice of the assimilation method, the difference in spatial resolutions is also being taken care of by using an influence circle area.
Highlights are mainly put on the impacts of the assimilation on the soil moisture and on the streamflow. Furthermore, DHSVM also models the water table depth and a first attempt to estimate groundwater volume for the entire watershed is presented in this study.

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New SMOS Level-4 Processor for Soil Moisture Disaggregation at 1km Resolution: Assessment of First Maps with In Situ Data

Molero, B.[1]; Merlin, O.[1]; Malbeteau, Y.[1]; Al Bitar, A.[1]; Cabot, F.[1]; Stefan, V.[1]; Bacon, S.[1]; Kerr, Y.[1]; Rudiger, C.[2]
[1]CESBIO (France), [2]Monash University (Australia)

INTRODUCTION
Soil moisture is a water cycle variable controlling various land surface processes and as a consequence its knowledge is essential in meteorology, hydrology and agriculture. With this in mind, the SMOS (Soil Moisture and Ocean Salinity) mission emerges as a valuable tool for estimating soil moisture (SM) providing a mean resolution of 40 km. However, soil moisture information is needed at sub kilometric scales for applications such as hydrological modeling of small basins, drought prediction, crop monitoring, and water resource management. In order to overcome this spatial mismatch, a disaggregation algorithm called Disaggregation based on Physical And Theoretical scale Change (DisPATCh) was applied to SMOS Level 3 soil moisture retrievals to produce higher-resolution soil moisture maps over semi-arid regions (Merlin et al. 2012, 2013). Most recently, the DisPATCh prototype has been implemented as a Level 4 operational processor in the French data processing centre CATDS.

METHODS
The CATDS Level 4 Disaggregation processor (C4DIS) disaggregates soil moisture extracted from Level 3 CLF31A/D products to 1km resolution. It requires ancillary data that is retrieved from other satellite data services. For example, the datasets for land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) are obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) mission archives hosted on the NASA Land Processes Distributed Active Archive Center (LP DAAC). The C4DIS processor relies on a scalable architecture where the main processing algorithms are classified in modules. The DisPATCh prototype has been introduced in one of them and configured for a specific set of parameters (cloud-free threshold, output resolution, temporal window, etc.).

RESULTS AND DISCUSSION
This communication will present the first evaluation campaign of the Level4 disaggregated soil moisture product over different validation sites, specifically the Yanco area within the Murrumbidgee River catchment in south-eastern Australia, and the Little Washita and Walnut Gulch watersheds in the USA. Preliminary results for Australia show that the processor fulfills the specifications of DisPATCh and that the disaggregated soil moisture products can present considerable improvements in terms of correlation and bias (Malbeteau et al., 2015, in preparation). The evaluation of the products over other sites will serve as a preliminary assessment on the potentials and constraints of the new Level 4 disaggregated product and provide insight into variations in the product quality across different climatic and land cover zones.

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Seasonal and Inter-annual Variability of SMOS Derived Soil Moisture and Ocean Salinity

Piles, M.[1, 2]; Ballabrera, J.[2,3]; Muñoz-Sabater, J.[4]; Vall-llossera , M.[1,2]
[1]Universitat Politècnica de Catalunya, IEEC/UPC

(Spain), [2]SMOS Barcelona Expert Center (Spain), [3]Departament d'oceanografia física i Tecnològica and Institut de Ciències del Mar/CSIC (Spain), [4]European Center for Medium-Range Weather Forecasts (United Kingdom)

Even with barely five years of SMOS data available, it is already possible to provide insight about the temporal changes in surface soil moisture (SSM) and sea surface salinity (SSS), as well as their links with the Earth's water cycle and climate system [1]. This work focuses on the estimation of trends, cycles and anomalies in SSM and SSS time series. Their spatial coherence and relationships through precipitation are also analysed in this study. The analysis includes the determination of the variability at seasonal and inter-annual scales, focusing on four target regions representative of arid, semi-arid, sub-humid and humid climates across global land biomes. The correlation between temporal series of SSM and SSS anomalies with the North Atlantic Oscillation (NAO) and the El Niño/Southern Oscillation (ENSO) climate indices has been explored. Results show that, despite being yet a short data set, SMOS data provides coherent and reliable variability patterns at both seasonal and inter-annual scales.

[1] M. Piles, E. Martínez, J. Ballabrera, M. Vall-llossera, E. Olmedo, J. Martínez and J. Font, "Estimation of global soil moisture seasonal and inter-annual variability using SMOS satellite observations", Proc. RAQRS'IV, 2014.

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Different Soil Moisture Dynamics are Observed by SMOS and the South Fork In Situ Soil Moisture Network

Hornbuckle, B.[1]; Rondinelli, W.[2]; Patton, J.[3]; Cosh, M.[4]; Walker, V.[1]; Carr, B.[1]; Logsdon, S.[4]
[1]Iowa State University (United States), [2]USDA Agricultural Research Service (United States), [3]Oklahoma State University (United States), [4]USDA Agricultural Research Service (United States)

The SMOS mission is currently producing estimates of near-surface soil moisture, the water content of the first few cm of the soil surface, on a global scale. Several investigators have reported that SMOS soil moisture observations have a dry bias: SMOS soil moisture is lower than what is considered to be the "true" near-surface soil moisture, especially in agricultural areas.

Soil moisture as observed by sparse networks of in situ sensors are assumed to be the best source of "true" near-surface soil moisture and are hence used to validate satellite observations. For practical reasons the sensors that make up these networks must be buried at a depth below the soil surface. Some investigators have hypothesized that this unavoidable reality may be responsible for the dry bias. We compared observations of soil moisture from SMOS and from a network of in situ sensors installed in the watershed of the South Fork of the Iowa River in the Corn Belt of the United States to test this hypothesis.

We found that SMOS indeed has a dry bias of 0.05 to 0.07 m^3 m^-3 as compared to the South Fork network. We also found that the rate of soil drying after significant rainfall observed by SMOS is higher than the rate observed by the network. We conclude that SMOS and the network observe different layers of the soil: SMOS observes a layer of soil at the surface that is a few cm thick, while the network observes a deeper layer centered at the depth at which its in situ sensors are buried. These two layers have different soil moisture dynamics.

However, our conclusion does not explain the dry bias. We used both a land surface model that accounts for heat and moisture transport in the soil, and our own network of in situ sensors buried at two different depths in a 1 km^2 agricultural field, and found that, on average, these two soil layers have nearly identical soil moisture values. On the other hand, we found that the RMSE error in the relationship between the two soil layers is significant as compared to the 0.04 m^3 m^-3 standard for the SMOS mission. For the land surface model, which is appropriate for point-scale soil moisture, the RMSE error was close to 0.04 m^3 m^-3. For the in situ sensors in the field, the RMSE was 0.02 m^3 m^-3. As a result, much of the RMSE in the relationship between SMOS and network soil moisture may simply be due the fact that they observe different quantities of soil moisture.

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Validation of SMOS Level 3 Soil Moisture Data

Mialon, A.[1]; Al Bitar, A.[1]; Cabot, F.[1]; Bircher, S.[1]; Leroux, D.[1]; Parrens, M.[1]; Pellarin, T.[2]; Richaume, P.[1]; Rodriguez, N.[1]; Kerr, Y.[1]; Wigneron, J.[3]

[1]CESBIO (France), [2]LTHE (France), [3]INRA (France)

The SMOS ground segment “CATDS” (Centre Aval de Traitement des Données SMOS) has been delivering level 3 data, which are temporal aggregated products (1-day, 3-day, 10-day, monthly average). The retrieval is based on a modified version of ESA level 2 soil moisture processor to account for multi-orbit retrievals, correlated vegetation optical depth, projection on the EASE Grid.

The soil moisture retrieval has evolved and improved since its first version and major changes lead to reprocessing campaigns to obtain homogeneous time series, i.e. data done using one processor.

Three campaigns have been done so far at the CATDS and the last one, referred to as reprocessing RE03, uses the last calibrated brightness temperatures (version 620 for ESA level1C, version 280 for CATDS level3TB) and the last soil moisture processor (version 620 for EASE level 2 SM and version 280 for CATDS level 2 SM). The new set of products will be available in Spring 2015.

The validation of SMOS data (level 2 and 3) has been a constant activity since the beginning of the mission. It consists in evaluating the performances of these products by comparing them at various climate areas like for example in Australia, West Africa, Denmark, France, in the US. It is done for every release to insure that the new data are consistent and closer to in-situ observations, as for instance when it was decided to switch the dielectric constant model.

The aim of this communication is then to present data from the RE03 campaign and to discuss the changes and improvements of the new releases. A first analysis over a week (sept. 2013) shows that the new soil moisture values (RE03 version V280) are globally lower than the previous version by 0.01 m3/m3. This result is preliminary and the analysis will be extended to a longer time period.

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SMOS L3 and L4 Dataset for the Monitoring of Extreme Hydrological Events

Al Bitar, A.
CESBIO (France)

Soil moisture data from L-Band microwave presents a unique opportunity to enhance the monitoring of extreme events. Soil moisture state prior to heavy rain events conditions the infiltration capacity of the soil which plays a determining role in the initiation of flash floods. Also surface soil moisture from remote sensing is a very reliable proxy to root zone soil moisture (Crow et al. 2014), which is the primary variable to agricultural drought monitoring. It offers an essential component in the elaboration of an early warning system. In this work we present how SMOS soil moisture can be used to monitor extreme events. We first show how anomaly maps from latest SMOS L3 soil moisture and brightness temperatures data depicts extreme hydrological events during the last 4 years (since mission launch). We show maps for the Africa drought in 2011 and the Western US drought since 2012. We then present two operational L4 demonstration products from the SMOS mission: The SMOS Drought Index (Al Bitar et al. 2013) and SMOS Flood Risk Mapping. We show new validation results of the drought index product over India. The results show that even though India presents a challenging region for the use SMOS data due to RFI, the system can deliver early warning (1 month a head) for dry conditions. We show how a flood risk mapping using precipitation percentiles can be leveraged by SMOS soil moisture information. The flood risk maps in forecast mode (1 to 5 days) are compared to the Dartmouth Flood Observatory data in a-posteriorly (after event) mode. We show that the incorporation of SMOS soil moisture enhances systematically the flood risk forecast over the African and American continents (Delta R=0.2). We present perspectives in the enhancement of the spatial resolution of the current demonstration products through the use of high resolution data from Copernicus Sentinel-1 and Sentinel-2 missions and radar information from the SMAP mission.

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Global SMOS Soil Moisture Retrievals Using the Land Parameter Retrieval Model

Van der Schalie, R.[1]; de Jeu, R.[1]; Kerr, Y.[2]; Wigneron, J.[3]; Rodriguez-Fernandez, N.[2]; Al-Yaari, A.[3]; Drusch, M.[4]; Mecklenburg, S.[5]; Dolman, H.[1]
[1]University of Amsterdam (The Netherlands), [2]CESBIO (France), [3]INRA (France), [4]ESA/ESTEC (The Netherlands), [5]ESA/ESRIN (Italy)

INTRODUCTION

The Land Parameter Retrieval Model (LPRM) is a methodology that retrieves soil moisture from low frequency dual polarized microwave measurements and has been extensively tested on C-, X- and Ku-band frequencies. Its performance on L-band is tested here by using observations from the Soil Moisture and Ocean Salinity (SMOS) satellite. These observations have potential advantages compared to higher frequencies: a low sensitivity to cloud and vegetation contamination, an increased thermal sampling depth and a greater sensitivity to soil moisture fluctuations. These features make it desirable to add SMOS-derived soil moisture retrievals to the existing European Space Agency (ESA) long-term climatological soil moisture data record, to be harmonized with other passive microwave soil moisture estimates from the LPRM. This study is part of an ESA project (de Jeu et al., EGU2015, session CL 5.7).

METHOD
SMOS measures brightness temperature at a range of incidence angles, different incidence angles bins (42.5°, 47.5°, 52.5° and 57.5°) were combined and tested for both ascending and descending swaths. Two SMOS LPRM algorithm parameters, the single scattering albedo and roughness, were optimized against soil moisture from MERRA-Land, ERA-Interim/Land and AMSR-E LPRM over the period of July 2010 to December 2010. The SMOS LPRM soil moisture retrievals, using the optimized parameters, were then evaluated against the latest SMOS Level 3 (L3) soil moisture and a set of in situ networks over the period of July 2010 to December 2013.

RESULT
The optimization of the parameters against MERRA-Land, ERA-Interim/Land and AMSR-E LPRM resulted in a single scattering albedo of 0.12 and a roughness of up to 1.5 depending on soil moisture and incidence angle. The evaluation against SMOS L3 result in high correlations (>0.85) in many parts of the world, excluding dense forests and areas with high radio frequency interference.

DISCUSSION AND CONCLUSION
The optimization of the single scattering albedo and roughness showed no clear spatial dependency and therefore a single value could be used globally. The high correlations compared to SMOS L3 are in line with earlier findings when SMOS LPRM was compared to SMOS L3 over the OzNet sites in southeast Australia. This shows that SMOS LPRM optimized against MERRA-Land, ERA-Interim/Land and AMSR-E LPRM results in soil moisture retrievals very close to the SMOS L3 retrievals.

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FRIDAY 29 MAY 2015
SESSION VII :
SYNERGETIC USE OF SMOS MEASUREMENTS WITH OTHER SATELLITE/ IN SITU DATA
09:30 – 13:10

Preliminary Study of Multi-year Ocean Salinity Trends with Merged SMOS and Aquarius Data.

Lagerloef, G.; Kao, H.
Earth and Space Research (United States)

INTRODUCTION
An important scientific goal for satellite salinity observations is to document oceanic climate trends and their link to changes in the water cycle. This is a preliminary examination of multi-year sea surface salinity (SSS) trends from an extended merged analysis of SMOS and Aquarius data, years 2010-2014.

METHOD
Orthogonal mode analysis techniques will be evaluated to generate an extended 5-year inter-calibrated record covering the combined observing time of the two missions. The ~3-year overlap period will provide the basis of a predictor model that will yield a projection during the earlier years when SMOS-only data are available. The general method was originally developed to estimate ocean dynamic height from vertical ocean temperature profiles, and effectively removed systematic errors common to the conventional methods [1].
RESULTS
The analysis is in progress and no definitive results are yet available.

REFERENCES
[1] Lagerloef, G.S.E., 1994. An alternate method for estimating dynamic height from XBT profiles using empirical vertical modes. J. Phys. Oceanogr., 24, 205-213.

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Early Results from NASA Soil Moisture Active Passive Mission

Yueh, S. [1]; Entekhabi, D.[2]; Kellogg, K.[3]; Njoku, E.[3]; ONeill, P.[4]
[1]California Institute of Technology (United States),

[2]Massachusetts Institute of Technology (United States), [3]Jet Propulsion Laboratory (United States), [4]Goddard Space Flght Center (United States)

The NASA Soil Moisture Active Passive (SMAP) Mission was recommended as the one of the tier 1 missions in the National Research Council's Decadal Survey Report. The key science requirements for the SMAP mission are to provide accurate soil moisture and freeze/thaw classification for hydro-meteorology, hydro-climatology and carbon cycle studies. SMAP mission uses an L-band radar and an L-band radiometer for concurrent, coincident measurements integrated as a single observation system. The radiometer and radar share one common antenna reflector, which is a 6-m mesh deployable antenna. The antenna design is based on the offset parabola reflector design with one antenna feed to produce the antenna beam pointing at an incidence angle of about 40 degrees on the earth surface. The mesh antenna together with the feed will be positioned on a spinning assembly with a conical scanning rate of about 14 rotations per minute. The resulting swath width is about 1000 km, which will allow a global coverage every 3 days. The SMAP radiometer resolution is ~40 km, while the SMAP L-band radar provides backscatter measurements at higher resolution (~ 1 to 3 km).
The accuracy of the radar is limited for soil moisture sensing, however, by the higher sensitivity of radar to surface roughness and vegetation scattering. The significant advantage provided by SMAP is the concurrent L-band radar and radiometer measurement capability, so that the radar and radiometer measurements can be effectively combined to derive soil moisture estimates with intermediate accuracy and resolution (~9 km) that meet the SMAP science requirements.
The SMAP project went through design studies, development and test from 2008 to 2014, and the observatory is currently at the Vandenberg Air Force base for launch on January 29, 2015. SMAP will be launched on a Delta II launch vehicle, and will be placed into a polar sun synchronous orbit with a 685 km altitude. After launched into orbit, the first three months (Feb-April 2015) will be the commissioning phase for the observatory check out and final orbit adjustment. Following the commissioning phase will be one year of intensive calibration/validation activities for adjustment of calibration and algorithm parameters, including thresholds for radiometer frequency interference detection.
We have planned inter-calibration of SMAP and SMOS brightness temperatures and soil moisture by collocation over land and Antarctic. The in situ data from cal/val partners will also be used to assess the quality of SMAP products. The first release data of SMAP data will be the beta version of L1 radar and radiometer data in July 2015. The L2 soil moisture data will be released in October 2015 for beta version and April 2016 for validated version. This article will describe the results from the commissioning phase and early part of the intensive calibration/validation phase.

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Sea Surface Salinity Data Assimilation Improvement in a Global Ocean Forecasting System at 1/4° from SMOS and Aquarius Data

Tranchant, B.[1]; Greiner, E.[1]; Legalloudec, O.[2]; Letraon, P.[2]
[1]CLS (France), [2]Mercator Océan (France)

Improving the SSS data assimilation is a key issue to better understand the surface freshwater budget (evaporation, precipitation and runoff) in the ocean forecasting systems. It is also a key issue to better constraint various scales coming from different satellite data such as SMOS and Aquarius. Finally, it is a crucial information to fill the existing gaps in the current in-situ network.
Our previous SSS data assimilation studies have shown that removing the systematic bias was crucial. Now, the first important step is to estimate and remove the large scale bias with the ocean forecasting system. In this study, we use the bias correction method based on a 3D-Var method already used for correcting the model bias with in-situ data.
In this presentation, Mercator Ocean and CLS give an overview of dealing with the SSS issues within their operational and reanalysis frameworks.

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SMOS and SMAP Brightness Temperature Inter-Comparison and Calibration

Kim, E.[1]; Patel, H.[2]; Wu, A.[3]
[1]NASA (United States), [2]Emergent Space Technologies (United States), [3]ASRC (United States)

Due to their large sizes, both SMOS and SMAP use external targets in order to calibrate their respective level 1 brightness temperatures (TB). These external targets include cold space, the oceans, and

Antarctica. The radiometers in both missions have the same frequency, same polarizations, same incidence angle (one of many in the case of SMOS), similar swath widths, and so one. Yet, there are differences, too. The most significant difference is the use of interferometric imaging and reconstruction by SMOS, whereas SMAP uses a traditional real-aperture instrument. Other differences involve the exact nature of the two-point calibrations used. However, in the end, we demand that when the differences are taken into consideration, the two radiometers should yield the same TB when viewing the same targets. Because of the differences, the precise definition of "same target" can be important. This paper represents an early look at comparisons of SMOS and SMAP TBs, and includes a look at the effect of the precise definition of "same target" on such comparisons.

We used SMOS level 1 gridded data (TBs) and the SMAP level 1 TB product (regular and special products, ungridded) for our analyses. For simplicity, only V and H polarized TBs are considered at this time. For simple "simultaneous" match-ups, the data products from both missions are used in their native forms, and differences in footprint sizes and shapes are ignored. For the "global ocean" target, the extensive averaging required makes such differences between individual footprints negligible. The Antarctic "target" will actually be several targets of varying size and position to explore the effect of the precise choice of target parameters on the comparisons. Other potential targets such as the Amazon rainforest might be examined if time permits.

Comparison results will include basic statistics to quantify the level of similarity and the nature of differences.

Comparison results will be discussed, and a preliminary attempt will be made to attribute differences between SMOS TBs and SMAP TBs to the targets or to the instruments. The effects of the precise choice of target parameters will be discussed as well, and any overarching conclusions will be identified.

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Comparison of L-Band Radio Frequency Interference Seen by Aquarius and SMOS

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INTRODUCTION
Interference from man-made sources, Radio Frequency Interference (RFI), is an important consideration in remote sensing of soil moisture and ocean salinity. The radiometers on Aquarius and SMOS operate in the 1400-1427 MHz spectral band which is particularly suitable for making these measurement. Even though the band is protected for passive use only, RFI limits operation over important parts of the globe. Identifying and characterizing the sources of RFI is important for developing approaches for mitigation and as evidence to help remove the interference. This paper reports work comparing SMOS and Aquarius observations.

METHOD
In principle, the source of RFI should be the same for both instruments. However, the instruments employ very different technology, which effects the detection and therefor reporting of RFI. The first part of this work will review the algorithms used by Aquarius and SMOS to detect RFI and some of the instrumental differences affecting the sensitivity to RFI. The second part compares the observed RFI using both a nearly simultaneous look at a strong isolated RFI source and global averages. The comparison has been done in terms of RFI probabilities, which are a measure of the fraction of data lost to RFI, and therefor relate to the quality of geophysical variables retrievals. An attempt has been made to minimize the differences by presenting the data in a common format.

RESULTS
The global averages indicate that both systems see similar RFI, but differences exist in expected locations (e.g. France, due to differences in bandwidth) and unexpected locations (e.g. Japan). The comparison also shows that even when the same RFI sources are observed by both instruments, the intensity and spatial distribution of RFI probabilities can differ.

DISCUSSION AND CONCLUSION
SMOS and Aquarius employ different technology and have different instrument system parameters (such as bandwidth, field-of-view and antenna pattern). These differences impact the signal received and

also the algorithms available for detecting RFI. Although both radiometer systems essentially define RFI as a signal that exceeds the expected value by a pre-determined threshold, the two systems go about this in much different ways. The detected RFI is similar in general characteristics on a global scale but with important differences.

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An Overview of the SMOS+STORM Evolution Project: Measuring Surface Winds in Tropical and Extra-Tropical Storms with SMOS

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INTRODUCTION AND METHOD

The European Space Agency Soil Moisture and Ocean Salinity (SMOS) mission provides multi-angular L-band (electromagnetic frequency of 1.4 GHz) brightness temperature images of the Earth. Because upwelling radiation at 1.4 GHz is significantly less affected by rain and atmospheric effects than at higher microwave frequencies, the SMOS measurements offer unique opportunities to complement existing ocean satellite high wind observations in tropical cyclones and severe weather that are often erroneous in such conditions. The physical basis for surface wind speed retrievals in extreme weather from passive microwave radiometers involves emission from a rough, foam-covered sea surface. The sea state within tropical cyclones is complex and varies according to the storm sectors, but in the region where the wind speeds exceed tropical storm force (>17 m/s ~34 knots), breaking waves generate extensive foam patches and deep bubble layers. Foam patches are associated with high emissivity at microwave frequencies. The foam horizontal coverage and thickness extension as wind speed increases towards hurricane force and the associated emissivity increase are the basic principles for wind retrievals from radiometers. This information can be used as a means of remotely measuring surface wind speeds in hurricanes from airborne, or spaceborne, microwave radiometers. The Step Frequency Microwave Radiometer (SFMR) operating at C-band (4-8 GHz), which is the US/National Oceanic and Atmospheric Administration (NOAA)'s primary airborne sensor for measuring tropical cyclone surface wind speeds (Uhlhorn et al., 2003; 2007), is based on this principle.

The objective of the SMOS STORM project is to exploit the identified capability of SMOS satellite Brightness Temperatures acquired at L-band to monitor wind speed and whitecap statistical properties beneath Tropical Cyclones and severe Extra Tropical storms. Such new capability was demonstrated in 2012 by analysing SMOS data over the category 4 hurricane IGOR that developed in September 2010 [Reul et al. JGR, 2012].The SMOS sensor is closer to a true all-weather ocean wind sensor with the capability to provide quantitative and complementary surface wind information of great interest for operational hurricane intensity forecasts.

The methodology developed and validated on Igor was also successfully applied to several other important storms such as the Hurricane Sandy in 2012 and the Super Typhoon Hayian that devastated the Phillipines in 2013. These initial results showed great promise.

In this talk, we will present the status of the ESA project called SMOS+STORMS Evolution started in April 2014 for a period of 2 years which aim is to Demonstrate the performance, utility and impact of SMOS L-band measurements at high wind speeds over the ocean during Tropical and Extra-Tropical storm conditions.

RESULTS

Seven specific objectives to be addressed within the project are:

1Improve and consolidate our theoretical understanding of the L-band signal response and physical properties that can be inferred over the ocean during the passage of Tropical Cyclone (TC) and Extra-Tropical Cyclone (ETC) systems.

2)Consolidate, evolve, implement and validate the STSE SMOS+ STORM feasibility project Geophysical Model Function (GMF) and retrieval algorithm for high wind speed conditions.

3) Systematically produce and validate L-band SMOS high wind speed products with uncertainty estimates/flags for ETC and TC conditions over the entire SMOS Mission archive.

4)Develop, implement and validate new blended multi-mission oceanic wind speed products with uncertainty estimates incorporating SMOS+STORM Evolution L-Band measurements at high-wind speeds for TC and ETC events.

5)Generate a global database of TC and ETC events over the ocean surface and characterize each event using diverse Earth Observation and other observations in synergy.
6) Improve our understanding and parameterization of ocean-atmosphere coupling and mixed-layer dynamics for ETC and TC cases.
7) Demonstrate the utility, performance and impact of SMOS+ STORM Evolution products on TC and ETC prediction systems in the context of maritime applications.

The status of this work will be presented. In particular, we shall review:
1) Progresses to better understand the Geophysical Model Function to be used for SMOS High wind speed and foam layer properties (thickness & coverage) retrievals. These include sensitivity studies based on a Foam Emissivity model implemented at L-band and tested for numerous geophysical and observational dependencies (foam coverage, thickness, void fraction, SSS, SST, incidence angle, etc..).

2)The generation of a SMOS storm high wind first database completed over the full mission period archive (2010-2014) and covering all storm basins

3)TCs interceptions by SMOS over that period were selected and classified as function of the TC intensities on the Saffir Simpson Wind Scale. SMOS Brightness temperature (TB) from those intercepts were centered on the TC eyes, rotated with respect the track propagation direction and averaged over all realizations for each intensity scale. based on this analysis, we will demonstrate that SMOS Tb provide a clear direct measurement of the storm intensity over all the storm intensity scale range, outpassing scatterometer capabilities which measurements are limited to below Category 1.

4)Progresses on the merging of SMOS and AMSR-2 high wind database will be as well presented showing a high capability to improve the space/time coverage of the storm wind structures.

REFERENCE

Reul, N., J. Tenerelli, B. Chapron, D. Vandemark, Y. Quilfen, and Y. Kerr (2012), SMOS satellite L-band radiometer: A new capability for ocean surface remote sensing in hurricanes, J. Geophys. Res., 117, C02006, doi:10.1029/2011JC007474

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A Multi-dimensional Co-variance Model to Combine and Interpolate Sea Surface Salinity with Sea Surface Temperature

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Remote sensing provides accurate estimates of the Sea Surface Salinity only when averaging over sufficiently long space and time intervals. In order to provide mesoscale-resolving gap-free maps of SSS, new techniques thus need to be explored. Here, we combine SMOS data with Sea Surface Temperature and in situ salinity measurements through a multi-dimensional optimal interpolation algorithm. As shown in Buongiorno Nardelli (2012), this can be done by adopting a multi-dimensional covariance model defined by considering a thermal decorrelation term in addition to space-time decorrelation scales. This particular covariance model allows to give a higher weight to the SSS observations that lie on the isothermal of the interpolation point with respect to observations taken at the same temporal and spatial separation but characterized by different SST values. In the framework of ESA-OSMOSIS STSE project, this technique has been successfully used to combine SMOS L3 data with in situ ARGO measurements and satellite SST L4 data, obtaining daily SSS L4 data at ¼° resolution over the Southern Ocean.

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POSTER SESSIONS

Topic 1 - Calibration and Validation Activities Over Land, Ice, and Ocean

Poster 01

Analysis of the Soil Moisture Distribution over the Iberian Peninsula and South-West Area of Germany Using SURFEX Model Simulations, SMOS Products and In Situ Measurements

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Soil moisture is an important variable in agriculture, hydrology, meteorology and related disciplines. Despite its importance, it is complicated to obtain an appropriate representation of this variable, mainly because of its high temporal and spatial variability. SVAT (Soil-Vegetation-Atmosphere-Transfer) models can be used to simulate the temporal behaviour and spatial distribution of soil moisture in a given area.

SURFEX (SURFace EXternalisée) model developed at the Centre National de Recherches Météorologiques (CNRM) at Météo-France is used to simulate soil moisture at the Iberian Peninsula and, specifically, at the Valencia Anchor Station (VAS), SMOS validation site located east of the Iberian Peninsula. This site represents a reasonably homogeneous and mostly flat area of about 50x50 km2 with several distinguishable soil types and land covers.
The main cover type are vineyards (65%), followed by fruit (almond and olive) trees, shrubs, and pine forests, and a reduced number of small industrial and urban areas.

Simulated soil moisture and precipitation fields are compared with observations and with level-4 (~1 km), level-2 (~15 km) and level-3 (~25 km) soil moisture maps generated from SMOS over the Iberian Peninsula, the SMOS validation area (50 km x 50 km, eastern Spain) and selected stations, where in situ measurements are available covering different vegetation cover and soil types. Additionally, measurements from the ESA ELBARA-II L-band radiometer installed in the area to monitor SMOS validation conditions over a vineyard crop are also available. Furthermore, MODIS, LandSAF and SMOS products are also used to define realistic initial conditions for sensitivity simulations. The results of these simulations are investigated, compared among themselves and conclusions drawn.

Simulations of soil moisture have also been obtained for the stations network in Germany belonging to KIT (Karlsruhe Institute of Technology) in the framework of the Ribola Project (Räumlich integrierte Bodenfeuchtemessungen unter Verwendung von Radiofrequenzen im Langwellenbereich) where long time observations are available, allowing us to analyze the behavior of the simulation model and SMOS in two climatologically different areas (Spain-Germany) and to analyze soil moisture in both areas. Again, LandSAF and SMOS products are used to define realistic initial conditions for sensitivity simulations. The period of investigation covers the complete 2012 period for Spain and the complete 2014 period for Germany.

SURFEX simulations show a good relationship with in situ soil moisture measurements, thus allowing us to generate soil moisture maps throughout the area to be compared with SMOS soil moisture observations over those areas where in situ measurements are not available. We up-scaled all SMOS products to have the same spatial resolution as the simulations. With the aim to better analyzing the variability of soil moisture over the Iberian Peninsula we divided our study period according to hydrological year.

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Poster 02

Satellite Soil Moisture Validation in Romania

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Satellite soil moisture (SSM) products derived from space borne microwave data are looking promising for a wide range of applications (agro meteorology, hydrology, disaster management, etc.). An important step in the evaluation of SSM products is the validation with modelled, in-situ data or other satellite soil moisture products. SSM product validation with in-situ requires data from an adequate ground based soil moisture network.

Ground-based soil moisture observation networks are expensive to establish and operate but for the Romanian National Meteorological Service (NMA) the costs of adding soil moisture observations to its weather station network would be minimal since it is already owning and operating the infrastructure for data acquisition, transmission and management.

However, the density of the weather station network is generally not suitable for the validation soil moisture measurements. In order to increase the network density, NMA chose to build 30 mobile low-cost, easy to deploy soil moisture stations in addition to the deployment of soil moisture and temperature sensors at the 20 weather stations, representing The Romanian Soil Moisture & Temperature Observation Network (RSMN).

The soil moisture and temperature probes have been installed at the 20 selected weather stations and are fully operational since December 2014, while the prototype mobile station is undergoing intensive testing before the 30 stations will go in production. Although data collected only from the fixed part of RSMN would not allow a proper validation of satellite moisture products, a comparison of the soil moisture in-situ and satellite measurements has been deemed useful.

The comparison of sparse ground measurement data with coarse resolution pixel values can highlight the need for a more dense measurement network for proper validation of SSM. At the same time, it can serve as a reference when evaluating the complete RSMN.

Generally, the SMOS Level 2 product is overestimating the measured soil moisture with a few cases when the values are almost equal, but it is expected an improvement when data from the full-fledged RSMN will be available.

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Poster 03

Soil Moisture Retrieval at Global Scale Using the SRP (Simplified Roughness Parameterization)

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The estimation of soil moisture by SMOS is based on the relationship between the dielectric constant and the brightness temperature at L-band (~1.4 MHz). Furthermore, certain physical contributions which perturb the signal must be taken into account: soil and vegetation temperatures, texture and roughness, vegetation cover and litter.

The parameterization of roughness in the SMOS level 2 retrieval algorithm is based on four parameters (HR, QR, NRH and NRV) which are set as default contributions depending on a land classification.

As some studies have suggested, there is the possibility of combining soil roughness and vegetation contributions as a single parameter in the retrieval algorithm (method referred to as SRP, Simplified Roughness Parameterization). Classical retrieval approaches considers SM and TAU (vegetation optical depth) as retrieved parameters, while the SRP is based on the retrieval of SM and the new TR parameter combining TAU and soil roughness (TR = TAU + HR /2), besides the assumption of thermodynamic equilibrium at 6 am and 6 pm (ground and canopy temperature are equal). This method leads to an important simplification in the algorithm and allows accounting for time changes in the value of the roughness parameter HR.

In this study, the SRP was tested over the Valencia Anchor Station (VAS) with satisfactory results. Later, this method was analyzed against SM data measured over many in situ sites worldwide.

The use of SRP is a promising alternative for SM estimation at L-Band. This method implies that soil roughness parameter HR does no longer need to be calibrated since HR is retrieved simultaneously to vegetation optical depth.

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Poster 04

Validation of Long-Term SMOS Soil Moisture Products Series Using Diverse Spatio-temporal Strategies and In Situ Networks in the Duero Basin (Spain)

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The European Space Agency's Soil Moisture and Ocean Salinity (SMOS) Level 2 soil moisture and the new L3 product from the Barcelona Expert Center (BEC) were validated from January 2010 to June 2014 using two in situ networks in Spain: the Soil Moisture Measurement Stations Network of the University of Salamanca (REMEDHUS), which can be considered a small-scale network covering a 1300 km2 region, and the Inforiego network, which is a large-scale network (ITACyL, Castilla y León Region Government) that covers the main part of the Duero Basin (65000 km2). Comparisons of the temporal series using several strategies (total average, land use, and soil type) as well as using the collocated data at each location were performed. Additionally, spatial correlations were computed for each specific date. Finally, the Extended Triple Collocation (ETC) was used to compare satellite and in situ soil moisture measurements with soil moisture series simulated with the Soil Water Balance Model Green-Ampt (SWBM-GA).

The results of this work showed that SMOS estimates were consistent with in situ measurements in the time series comparisons, with high Pearson correlation coefficients (R) and Agreement Index (AI) for the total average, the land-use averages and the soil-texture averages. The results obtained at the Inforiego network showed slightly better results than REMEDHUS, which may be related to the larger scale of the former network. Moreover, the best results were obtained when all networks were jointly considered. In contrast, the spatial matching produced worse results for all the cases studied.

These results showed that the reprocessing of the L2 products (v5.51) improved the accuracy of the soil moisture retrievals making them suitable for developing new L3 products, such as the studied in this work. Additionally, the validation based on comparisons between small-scale/large-scale networks and satellite retrievals at a coarse resolution showed that temporal patterns of the soil moisture are better reproduced than the spatial ones.

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Poster 05

Potential of Modeled vs. In Situ Data on SMOS L2 Soil Moisture Validation: a Case Study in Spain

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The combined use of the information from ground observations, hydrological modeling and remote sensing could improve the soil moisture monitoring at large scales and through long periods. This work evaluated the capability of modeled vs in situ soil moisture measurements for the validation of the SMOS L2 soil moisture product (version 5.51) during four years (2010-2013). The long term in situ database was obtained from the Soil Moisture Measurement Stations Network of the University of Salamanca (REMEDHUS), located in north western Spain. For this study, soil moisture stations representative of different soil conditions in the REMEDHUS network were selected. The modeled time series were estimated at hourly rate in the study period (2010-2013) with the Soil Water Balance Model - Green-Ampt (SWBM-GA), using in situ measurements at the stations as a benchmark. The model was calibrated using a period of two years (2008-2009).

The comparisons were done both at point scale (one station vs its corresponding grid cell) and averaging all the stations within each grid cell. Systematic differences between SMOS series and the in situ and modeled series were reduced by using the normalization techniques of linear regression correction and Cumulative Distribution Function matching.

The results showed that the modeled series simulated accurately the inter- and intra-annual variability of the in situ soil moisture, providing satisfactory results for most of the studied stations. The dynamics of soil moisture throughout the study period was also well represented by the SMOS L2 series with good correlation with modeled time series, better than that obtained by the validation with in situ observations. However, some underestimation related to soil conditions, as well as peaks of overestimation, linked to rainfall events of the SMOS series were observed respect both the in situ and the modeled series. The normalization of the SMOS L2 data produced a notable improvement of the results, particularly, in the comparison between SMOS and modeled series, showing the capability of SWBM-GA modeled data to validate SMOS L2 soil moisture time series.

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Poster 06

Evaluation of Space Borne SSS Observations in Cold and Warm Ocean Regions: Study of Annual and Interannual Variabilities

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Spaceborne sea surface salinity (SSS) data by the European Space Agency's (ESA) "Soil Moisture and Ocean Salinity" (SMOS) and the National Aeronautical Space Agency's (NASA) "Aquarius/SAC-D" missions, are compared against in situ and model salinities obtained in the northern North Atlantic and Indian Ocean. In cold waters, SMOS SSS fields show a temperature-dependent negative SSS bias up to -2 g/kg for temperature classes below 5°C. Differences to independent ship-based thermosalinograph (TSG) data can be substantially reduced by a temperature-dependent bias correction inferred empirically as a relation between satellite and Argo data in the North Atlantic between 20°N and 80°N. Our method is confirmed by the similar comparison between independent TSG measurements and Aquarius fields, which were already corrected by a temperature-dependent bias correction by the Jet Propulsion Laboratory.
For both missions, retrieved spatial structures of SSS variability are in good agreement with those available from an eddy-resolving numerical simulation and from Argo data. Additionally, they show substantial salinity changes on monthly and seasonal time scales. Some fraction of the root-mean-square difference between in situ, and satellite data (approximately 0.9 g/kg) can be attributed to short-time scale ocean processes, notably at the Greenland shelf, and could represent associated sampling errors.
In contrast to the northern North Atlantic, the satellite retrieved salinities obtained in the warmer Indian Ocean are less affected by a temperature-dependent bias but land contamination and radio frequency interference (RFI) influence the near-shore data.
In the case of SMOS a complete 4-year-time-series and nearly 3 full years of Aquarius of processed salinity data are available. These series are rich in climatic events and both, SMOS and Aquarius are able to resolve interannual variability of salinity associated with the Indian Ocean Dipole mode.
We present a quality assessment of the satellite data and analyze the mechanisms responsible for these annual and interannual SSS anomalies.

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Poster 07

Validation of Satellite Soil Moisture Retrievals with Precipitation Data Using Copula Based Mutual Information Measure

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It has been deduced recently that mutual information can be used as an effective proxy to understand the relationship between soil moisture (SM) and rainfall (R) in general water balance setup (Tuttle & Salvucci, 2014, doi:10.1016/j.rse.2013.12.002). Based on this theory, in the current work, a new measure called copula mutual information (MI) is developed to compare the performance of two SM products derived from level 3 SMOS (CATDS) and AMSR-E (VUA) sensors using IMD rainfall data over India.
MI is a nonnegative scalar that quantifies mutual dependency between two random variables. Higher the value of MI, lesser would be the uncertainty in one variable explaining other or vice versa. In the current case, MI is used to quantify dependency between SM and R. Computation of MI involves joint and marginal pdfs of SM and R. Nonparametric copula theory is utilized to estimate joint pdf between SM and R which need respective marginal cdfs and a copula function. Marginal cdfs are estimated using nonparametric kernel density estimator and Clayton copula is used as copula function.
The method requires spatially and temporally concurrent information of R and SM datasets which is obtained by spatial resampling and filtering processes at 0.25 degrees resolution. MI is applied

separately to SMOS and AMSR-E datasets with IMD rainfall, grid wise and the SM product with greater MI is selected. It is observed that all most 95 % of 4632 grids have been computed with valid values of MI, the rest of the grids concluded with no result due to lack of data (in portions of snow fed regions). Of these grids it is observed that SMOS dataset has outperformed over AMSR-E product. Almost 65 % of grids have been selected with SMOS data and rest (~35 %) with AMSR-E product. It is observed that in SMOS product SM is retrieved with better accuracy in regions that exhibit moderate climatic conditions. At extreme climates of heavy rainfall and deserts, some of the regions are selected with AMSR-E data. Current analysis suggests the usage of SMOS SM product with confidence in most portions of India.
From the current work, it is determined that the proposed measure has ability to check the accuracy of satellite SM records with sole information of rainfall records. Hence, further attempts are being made to assimilate additionally the LULC, soil and elevation information to develop a deeper understanding on strengths and limitations of SM products.

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Poster 08

Characterisation of the Jucar River Basin Hydrological Climatology with ERA-Land Reanalysis. Consistency with In-Situ and SMOS Soil Moisture Products

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INTRODUCTION
A climatology over the Jucar River Basin within the period 1980-2012 has been carried out using soil moisture estimates from ERA-Interim/Land reanalysis (referred as ERA-Land). To study the validity of ERA-LAND reanalysis as a good climatological indicator, the consistency of the ERA-Land product with SMOS level-3 retrievals is evaluated. Previously, the quality of the SMOS level-3 product is validated at pixel scale using in-situ soil moisture measurements from the Valencia Anchor Station (VAS) network, for the period October 2011 to December 2013. In this study three different periods are distinguished according to the SMOS level-3 product generation (nominal or reprocessed mode) and the dielectric model (Dobson or Mironov). In addition, a quality control of in-situ data is conducted using precipitation measurements, as well as the operational soil moisture analysis from the European Centre for Medium-range Weather Forecast (ECMWF).

Given the good correlations found between in-situ data and SMOS L3 for the reprocessed and last periods and the low bias obtained for the latter, SMOS L3 can be used as a good quality observation to investigate the reliability of ERA-LAND soil moisture as a proxy variable to study the soil moisture climatology over all the Jucar River Basin.

METHODOLOGY AND RESULTS
A first comparison between SMOS L3 soil moisture and ERA-Land estimations was carried out at the ERA-Land pixel scale. Correlation coefficients vary depending on the pixel characteristics. In general, descending SMOS L3 products tend to be better correlated to ERA-Land estimations than ascending retrievals for periods 1 and 2. However, ascending orbit values are better correlated for period 3, although correlation differences between ascending and descending orbits are low.

Statistical results were also obtained for the comparison of averaged SMOS L3 soil moisture retrievals and ERA-Land estimations over the whole Jucar River Basin. The correlation coefficients are generally high. Similar R values are obtained for the ascending orbits, whereas for descending orbits a lower correlation value is observed in period 3. In general, ERA-Land estimations appear to be better correlated to SMOS L3 reprocessed data from period 1 for both ascending and descending orbits. Descending soil moisture retrievals show better correlation in periods 1 and 2, in contrast to ascending orbit retrievals. However, the correlation between SMOSL3 and ERA-Land products is higher for the ascending orbit rather than for the descending one in period 3.

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Poster 09

Soil Moisture in French Alpine Valley Using L-BAND Radiometer

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Since the launch of the satellite, a constant activity has been to compare SMOS derived soil moisture to in situ measurements to validate and improve the soil moisture retrieval. Many sites have been equipped with soil moisture probes and a few of them with L-Band radiometer placed on structures of ~10 m. height. The observed surfaces are homogeneous, i.e. one type of vegetation cover, whereas SMOS (~40km of resolution) observes more heterogeneous scenes, i.e. mix of different landscapes. Keeping this issue in mind, a new experimental site is proposed with the main objective to observe complex scenes to test the SMOS soil moisture retrieval.

The LEWIS radiometer (L-Band radiometer for Estimating Water in Soil) has been placed by a cliff in St Hilaire du Touvet (French Alps) since May 2014. Its position allows us to monitor a surface 800m down below in the valley du Grésivaudan which is flat, avoiding topographic effect. The instrument has a beam width of 13.6° which implies a field of view of several hundreds of meters, covering various landscapes (agricultural fields, forest, lake).
The instrument is equipped with 2 motors so that it moves in two directions (azimuth and elevation) and monitors regularly several areas of interest. It can also be pointed towards the deep sky for calibration.
In addition, soil moisture and temperatures probes are placed in different fields in the Valley and a pyrometer is installed with the radiometer to measure the skin temperature of the observed scene.

The first data confirm the consistency of Lewis measurements. The deep sky presents brightness temperatures of TBH = 5.4K et TBV = 4.3K, which is similar to what was observed at the SMOSREX site. This new site is planed to last 4 years to insure long time observations (L-band brightness temperatures and surface soil moisture) of heterogeneous scenes. Further works will also imply sun glint effect, snow detection and effect of urban areas.

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Poster 10

Why is SMOS Drier than the South Fork In Situ Soil Moisture Network?

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We find that SMOS retrieved soil moisture exhibits a dry bias and RMSE in excess of the mission accuracy goal in the Corn Belt of the Midwest United States. We discovered this dry bias using a network of 20 in situ sites established and maintained by the USDA ARS in the watershed of the South Fork of the Iowa River. In 2013, SMOS averaged 0.05 m3 m-3 less than the observed 5 cm soil moisture and the RMSE was 0.08 m3 m-3; in 2014 the bias increased to an average of 0.07 m3 m-3 and the RMSE was 0.09 m3 m-3. We have identified several possible explanations: underestimation of vegetation or soil surface roughness; inaccurate representation of soil or land surface type; undetected radio frequency interference (RFI); or the use of an incorrect surface temperature in the retrieval process.

We have begun our investigation by determining if SMOS is using a surface temperature that is too low and too noisy, resulting in a drier soil moisture that compensates for the error. Three SMOS Discrete Global Grid (DGG) pixel centers fall within the South Fork. We used a network-average of in situ soil temperature to calculate the effective ground temperature for the South Fork following the procedure for low vegetation described in the algorithm theoretical basis document (ATBD). In addition, we estimated vegetation temperature by using observations of air temperature at screen height in the South Fork and a relationship between air and vegetation temperature developed with long-term data from tower and in situ sensors in agricultural fields. We used a version of the radiative transfer model described in the ATBD adapted specifically for corn and soybeans to determine the sensitivity of retrieved soil moisture to surface temperature error.

Over the two-year period, the average SMOS minus South Fork effective ground temperature error was 0.58 K (RMSE 1.7 K). The sign of the error indicates that surface temperature cannot be the single source of the dry bias, but may in fact be producing a wetting effect. This effect is consistent with the differences between the two years: in 2014, when the dry bias was stronger, the temperature error was smaller (0.15 K) than in 2013 (1.0 K). The temperature error was noisy during both years; this may partially explain the noise seen in retrieved soil moisture. We will next explore the possibility that the dry bias is caused by contamination of low-level RFI and report our findings at the conference.

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Poster 11

Soil Moisture Remote Sensing with GNSS-R at the Valencia Anchor Station

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INTRODUCTION

In this paper, an experiment on soil moisture monitoring by Global Navigation Satellite System Reflected signals(GNSS-R) is introduced. L-band microwaves have very good advantages in soil moisture remote sensing, for being unaffected by clouds and the atmosphere, and for the ability to penetrate vegetation. During this experimental campaign, the ESA GNSS-R Oceanpal antenna was installed on the same tower as the ESA ELBARA-II passive microwave radiometer, so both measuring instruments had similar field of view. This experiment is fruitfully framed within the ESA - China Programme of Collaboration on GNSS-R

METHOD

The GNSS-R instrument has an up-looking antenna for receiving direct signals from satellites, and two down-looking antennas for receiving LHCP and RHCP reflected signals from the soil surface. In the first measurement stage, direct signals were acquired in channel 1, and LHCP signals were acquired in channel 2. In the second stage, direct signals were acquired in channel 2, and RHCP signals were acquired in channel 1. Thus we could collect data from 3 different antennas through 2 channels and, in addition, calibration could be performed to reduce the impact from differing channels. Reflectivity was measured, soil moisture could be retrivaled by L-MEB model considering the effect of vegetation optical thickness and soil roughness.

RESULTS

By contrasting GNSS-R and microwave radiometer data, a negative correlation existed between the reflectivity measured by GNSS-R and the brightness temperature measured by the radiometer. The two parameters represent reflection and absorption of the soil. Soil moisture retrieved by both L-band microwave remote sensing methods shows good agreement. In addition, correspondence with in-situ measurements and rainfall is also good.

DISCUSSION & CONCLUSION

This study uses data measured with Oceanpal GNSS-R system at the Valencia Anchor Station. Reference soil moisture estimations were obtained from ELBARA radiometer and in-situ measurements. The L-MEB model was simplified when applied to GNSS-R soil moisture retrival. By calculating the decay factor of soil roughness and vegetation, the results improved significantly.

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Topic 2 - Cryosphere Applications Over Land and Ocean

Poster 12

Using Brightness Temperature at L-Band to Investigate Antarctic Ice-sheet Temperature

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In recent years, a contrast is observed in Antarctica between warming of western part of ice-sheet and slightly cooling of eastern part. A dataset of well-calibrated monthly surface temperature would be highly valuable to investigate the Antarctic ice-sheet. The microwave radiometers offer a long record of observations irrespective of the cloudiness conditions. However, retrieving accurate physical temperature at a continental scale requires an emissivity with high accuracy (e.g. better than ~0.01, as this would correspond to 2~K). At high frequencies (e.g. SSM/I or AMSR-E), the emissivity varies spatially from 0.65 to 0.9 and are not well understood. But at lower frequency, the scattering is reduced and the emissivity is close to unity when the surface reflection effect vanishes (i.e. at V polarization near the Brewster angle of 50°). The spatial variation should be smaller and more predictable than at higher frequencies. Thus, the ESA's SMOS satellite operating at 1.4 GHz could improve the knowledge of the emissivity.

L-band emissivities are estimated with brightness temperatures (TB) at V polarization close to the Brewster angle in 2010 and 2011 from the SMOS level 3 product. The approach to derive emissivity is in Picard et al. (2009) and we have chosen to use the surface temperature from the ECMWF ERA-Interim reanalysis. Two different regions can be identified in Antarctica. The "wet zone" with cold TB, corresponds to areas subject to surface melting. Liquid water generates a rapid growth of the snow grains, which increases the scattering of microwave and explains low emissivities (0.66 to 0.85). However, some areas with low emissivities are not characterized by melt events and need further investigation. Thus, the wet zone is unfavourable for retrieving a reference temperature due to the large variations of emissivity and the value significantly lower than one. Second region, the "dry zone" with warmer TB, corresponds to the most of continent. TB is close to the physical temperature and the emissivity appears to be close to one. The expected high emissivity at L-band over the permanently snow-cover Antarctic ice-sheet is confirmed. However, several areas show emissivity no realistic compared to their known geographical features and estimation of emissivity need to be improved. For that, we propose to investigate emissivity by means of electromagnetic model.

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Poster 13

SMOS-based Snow Thickness Maps for Arctic Sea Ice: Comparison with Airborne Measurements

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The SMOS mission provides a daily coverage of the polar regions and its data have been used to retrieve thin sea ice thickness up to 0.5-1m. In addition, there has been an attempt to retrieve snow thickness over thick Arctic sea ice, which in turn may be useful for the ice thickness estimation based on freeboard measurements from lidar and radar altimetry. The retrieval of ice or snow parameters from SMOS measurements is based on an emission model that describes the 1.4 GHz brightness temperature of (snow-covered) sea ice as a function of the ice and snow thicknesses and the permittivities of these media, which are mainly determined by ice temperature and salinity and snow density, respectively.

In the first study on a potential SMOS snow thickness retrieval, these parameters were assumed to be constant in the emission model and a first SMOS-based snow thickness map was produced. The retrieved values were compared with airborne ice and snow thickness measurements taken during NASA's Operation IceBridge mission in spring 2012. Here, we show the results of a more elaborate approach to produce SMOS snow thickness maps, which takes into account available ice surface temperatures from MODIS (MODerate resolution Imaging Spectroradiometer) satellite images or from the IceBridge campaign itself, for example. Furthermore, the bulk ice and snow temperatures for the emission model are calculated differently from the given surface temperatures than was done before, following the results of a previous study that compared the emission model used in the SMOS retrieval with a more sophisticated L-band emission model.

As a first step we have produced (winter) snow thickness maps of the Arctic, from 3-day-averages up to monthly means, using the hitherto available SMOS data. We investigate the consistency between consecutive maps and examine whether regionally occurring increases in the retrieved snow thickness can be linked to precipitation events. Furthermore, we have expanded the comparison of SMOS and IceBridge snow thicknesses to the campaign data from 2011, 2012, and 2013. Although the agreements between the average SMOS and IceBridge snow thicknesses for the 2011 and 2013 data are lower than for the previously considered data only from 2012, the SMOS maps and the IceBridge measurements often agree as to where we find transitions from large-scale areas of very thin snow covers to areas predominantly covered by thicker snow layers.

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Poster 14

The STSE Cryosmos Project: Exploiting the Potential of SMOS Data in Antarctica

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In the past decade, because of the needs expressed by the scientific community, Space Agencies have devoted considerable efforts to develop low-frequency space-borne radiometers. The first mission in orbit is the ESA's SMOS was launched in 2009. The availability of a complete long-term time-series of calibrated brightness temperature data collected over the whole Earth led to investigate other research fields outside of the main mission objectives: the estimate of the soil moisture and sea surface salinity . In particular some activities were devoted to possible SMOS applications in the Cryosphere domain. In this regards promising results were obtained in the study of the sea ice and soil frozen. Due to the very low permittivity of dry snow at L-band (real part around 1.5-2, imaginary part 10-4), the penetration depth is very high (hundreds of meters) and the applicability of this frequency on terrestrial snow, which rarely overpasses a total depth of few meters, is limited. Nevertheless what is a limitation for a large part of the Globe constitutes a great opportunity for the regions where the snow depth is much higher: the Ice sheets and Ice shelves of Antarctica in particular. In order to investigate the potential of SMOS data in studying Antarctica a new project, CRYOSMOS funded by ESA as Support To Science Elements (STSE), was recently started. In this paper the scientific topics, which will be in depth analyzed along the project, will be presented. In particular it will be analyzed if the SMOS signature are related to the physical properties of Antarctica ice sheet and ice shelves. Observing the data over the continent it is possible to distinguish several main regions: the region of the ice shelves surrounding the continent, the region close to the coast which correspond to area where the snow could be wet along the year, the temperature is higher and the precipitations are more intense and frequents and the internal part where the ice sheet is always dry, the temperature is low and the precipitations scarce. Preliminary studies, aiming on interpreting these data, demonstrate that several factors concur to the observed Tb over the ice sheets like layering and sub-surface's characteristics, bedrock morphology, basal characteristics, temperature profile. An electromagnetic model which was recently developed highlight the influence of surface state on L-band brightness temperature and that surface processes resulting in density, grain size, wetness, etc. variations can be potentially identified from SMOS observation variations. Interesting spatial features are also observable on the ice shelves. The relationships between the ice sheet/ shelves properties will be in depth analyzed and theoretically validated in some particular places (e.g. the area of Dome-C where the Italian-French base of Concordia is located) by using electromagnetic models and ground based data or glaciological models.

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Poster 15

Observations of Antarctic Icebergs Acquired with SMOS

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Icebergs are large blocks of freshwater ice that break away from marine glaciers and floating ice shelves. In contrast to sea ice, they are composed of fresh water, exhibiting different structure and chemical composition. From the point of view of microwave observations, they pose a challenge for proper characteristics in terms of dielectric properties, penetration depth and emissivity.

This study provides a comprehensive summary of observations of massive icebergs monitored with SMOS for the last five years. SMOS resolution limits the region of interest to the southern hemisphere and allows to detect only free-floating large icebergs along coasts of Antarctica.

The study reports the analysis of angular characteristics of SMOS brightness temperature. Discussion emphasises how physical properties, such as size of every single iceberg or external conditions in the region where iceberg is spotted, affect derived shape of angular characteristics. Conducted analysis allows to examine iceberg breakup and documents gradual vanishing of tracked object, which is dragged towards the equator into warmer ocean waters. Comparison studies with targets such as multiyear ice in the Dome-C region, first-year ice or small oceanic islands comparable in terms of spatial dimensions (Heard Island and McDonald Islands (HIMI)) augment discussion.

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Topic 3 - Inter-Calibration and Comparison with other Sensors

Poster 16

Global-scale Error Analysis of the SMOS Soil Moisture Product through Validation Against Independent Information from an Active Mission and a Terrestrial Vegetation Model

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We present a triple collocation analysis of the daily SMOS level 3 soil moisture product covering the years 2010 and 2011. The method requires two further soil moisture data sets
with independent error characteristics. For this purpose we employ a soil moisture product derived from an active sensor (ASCAT) and soil moisture fields simulated by the Biosphere Energy Transfer Hydrology Model (BETHY).
The analysis is conducted on two global BETHY grids (2 by 2 degrees and 10 by 10 degrees). On the 2 by 2 degree grid SMOS errors range from less than 0.01 to 0.3 m^3/m^3 and the bias with respect to BETHY is below 0.4 m^3/m^3 for the vast majority of cells.
Using BETHY's map of plant functional types (PFTs) we find particularly high errors over grid cells dominated by PFTs with dense canopies as well as crops and wetlands.

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Poster 17

Quantitative and Qualitative Analysis of Coherence in Multi-temporal SAR Inferometry

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Coherence has become a valuable and common indicator of interpolating and manipulating many processes and studies of SAR Interferometry (InSAR). Land use and land cover varieties are considered the main vital influences and controllers of the coherence conduct. Nine interferometrics coherences are here generated and compared according to the differences in perpendicular ($B^{\perp}$) and temporal baselines using 14 C-band European Remote Sensing (ERS)-1/2 synthetic aperture radar SAR Single Look Complex (SLC) VV-polarization images acquired in ascending mode during 1995 – 1999 over the northern east of Thessaly plain. The result shows significant and remarkable impact of $B^{\perp}$ and temporal baseline on coherence which is ranged between 0.42 and 0.49. Also land use and land cover dynamics play imperative roles on the behavior of SAR inferometric coherence.

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Poster 18

Comparison between AQUARIUS and SMOS Brightness Temperatures for the Period 2012-2014 Considering Similar Areas and According to Land Uses

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Intercomparison between Aquarius and SMOS over land surfaces is more challenging than over ocean because land footprints are more heterogeneous. In spite of that, the exercise is worth at the primary level of brightness temperature (TB).

In this work we are comparing Aquarius and SMOS TBs obtained by considering similar areas and according to land uses. The area of study was an area in central Spain where we could get a significant number of matches between both instruments. The study period corresponded to 2012, 2013 and the first four months of 2014. SMOS data were obtained from CATDS level 3 and Aquarius' from PODAAC Aquarius.

Land uses were obtained from the Spanish SIOSE facility (Sistema de Informacion de Ocupacion del

Suelo en España) that uses a scale of 1:25.000 and polygon geometrical structure layer. SIOSE is based on panchromatic and multispectral 2.5 m resolution SPOT-5 images together with Landsat-5 images and orthophotos from the Spanish Nacional Plan of Aerial Orthophotography (PNOA).

SMOS ascending TBs were compared to inner-beam Aquarius descending half-orbit TBs coinciding over the study area at 06:00 h. The Aquarius inner beam has an incidence angle of 28,7º and SMOS data were considered for the 27,5º incidence angle. The Aquarius variable considered was rad_toa_X_nolc (TB at TOA with X pol and including Faraday's rotation correction). SMOS products corresponded to version 2.6x (data before 31st October 2013) and version 2.7x (data after 1st January 2014).

Intersections between both footprints have been analysed under both conditions of similar areas and according to land uses. For the latter, a linear combination of SMOS land uses has been obtained to match the larger Aquarius footprint. The results obtained permit to conclude that the land-uses approach gives better results. In both methods, also considering similar areas, the bias for H pol is notably reduced to 2 K.

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Topic 4 - Long-term Data Sets and ECVs Over Land and Ocean

Poster 19

Variability of Climatic Elements in Nigeria over Recent 100 Years

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Climatic variability is essential issue when dealing with the issue of climate change. Variability of some climate parameter helps to determine how variable the climatic condition of a region will behave. The most important of these climatic variables which help to determine climatic condition in an area are both the Temperature and Precipitation. This research deals with Long term climatic variability in Nigeria. Variables examined in this analysis include near-surface temperature, near surface minimum temperature, maximum temperature, relative humidity, vapour pressure, precipitation, wet-day frequency and cloud cover using data ranging between 1901-2010. Analyses were carried out and the following methods were used: - Regression and EOF analysis. Results show that the annual average, minimum and maximum near-surface temperature all gradually increases from 1901 to 2010. And they are in the same case in wet season and dry season. Minimum near-surface temperature, with its linear trends are significant for annual, wet season and dry season means. However, the diurnal temperature range decreases in the recent 100 years, implies that the minimum near-surface temperature has increased more than the maximum. Both precipitation and wet day frequency decline from the analysis, demonstrating that Nigeria has become dryer than before by the way of rainfall. Temperature and precipitation variability has become very high during these periods especially in the Northern areas. Areas which had excessive rainfall were confronted with flooding and other related issues while area that had less precipitation were all confronted with drought. More practical issues will be presented

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Topic 5 - Novel Data Products Using SMOS Data

Poster 20

Derivation and Experimental Exploitation of SMOS-based Surface Density Products

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A new set of surface density products at 1/4º of resolution and global scale have been developed at BEC. Those products are derived from the 3-day, 9-day, monthly and seasonal L3 SSS SMOS products, combined with Reynolds SST maps resampled at equivalent spatial and temporal resolutions. The density maps are produced using the new equation of state for seawater, the Thermodynamic Equation of Seawater - 2010 (TEOS-10), which replaces the EOS-80 as the official description of seawater and ice properties. Assessing the quality of the density products is not easy and requires an examination of connection between surface density and ocean dynamics. According to theory, horizontal velocities can be diagnosed from density anomalies under the appropriate environmental conditions. Hence, to assess the quality of our density products, we have derived surface velocities from density products using the Surface Quasi-Geostrophic (SQG) equations and compared the results with independent velocity estimations. To test the feasibility of this approach, we have focused on those density products that contain mesoscale features and SQG equations can be applied. Results have been compared with velocities derived from the altimeters on Jason-1/2 platforms.

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Poster 21

Soil Surface Water Resources Assessment from SMOS L2 and In Situ Data for Poland

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INTRODUCTION

The information about soil surface water resources is desired for scientific understanding the water circumference in global water cycle. The SWEX (Soil Water Equivalent indeX) was proposed for representing the surface soil water amount being in a relation to the surface Soil Moisture (SM) observed by SMOS in SMUDP2 on the depth corresponding to the radiometric Penetration Depth (PD). The SWEX concept is coupled to the need of the water retention for employing SMUDP2 in hydrology, in the measures of water mass (tons per square kilometre).

METHOD

The 2010-2014 SM data series from SMOS L2 and the SWEX_POLAND network were compared using i.a. Bland-Altman method, concordance correlation coefficient and total deviation index. Next, the PD was derived from dielectric constants defined for Nadir, being products of the retrievals performed under processing SMUDP2 with the version 551. PD values were defined on the base of the same attenuation level 1 Neper in the soil propagation media for a pixel, and under the assumption that the media fulfil lambertian conditions for the engaged radiation. Electromagnetically, it corresponds to the Kirchoff Approach and incoherent conditions under the thermodynamic equilibrium state of SMOS observations. The use of retrieved dielectric constants from SMUDP2 ensures that radiation transfer equations fulfil Fresnel conditions. Therefore, the sum of the emissivity and the absorptivity balances to the unity for Nadir, what allows on determining PD within 1 Neper of attenuation. The SWEX was obtained by multiplying SM by PD. The examination of SM, PD and SWEX spatial distributions for Central Europe was conducted using geostatistical methods. Those methods take into account not only values, but also the place space where they occur, introducing so-called "regionalized variable". For more detailed investigation 3 ROIs were chosen: Western Slovakia, Greater Poland and Polish part of Polesie.

RESULTS

All mentioned comparison methods confirmed a fair or moderate agreement of SMOS and in situ SM observations. Polesie had mean SM much bigger than Greater Poland, but the moistest was chosen region of Slovakia. PD values were in the range from 0.5 to about 11 lambda (21 cm) – from wet to dry conditions. Mean SWEX was identical for Polesie and Slovakia, which indicates that those two regions had similar water resources and bigger than Greater Poland, as was expected, because this region often suffers from agricultural droughts. The geostatistical examinations revealed that spatial dependences occurring in the SM distributions for the whole considered area were more or less 200 km. The exception was the driest of the studied days, when the spatial correlations of SM were not disturbed for a long time by any rainfall. Spatial correlation length on that day was about 400 km.

DISCUSSION & CONCLUSION

As it was already proven by many authors, SMOS SM data are reliable and indicate well the trends observed in situ. The proposed approach to estimate surface water resources stored in soil by introducing SWEX seems to be correct, but needs a lot of validation efforts to prove it.

The work was partially funded under the ELBARA_PD (Penetration Depth) project No.

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Poster 22

Global Maps of the Soil Roughness Effect Using L-band SMOS Data

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Since 2010, the Soil Moisture and Ocean Salinity (SMOS) satellite monitor soil moisture (SM) over land using passive L-band radiometry technique. At this frequency the signal depends on SM and vegetation but is significantly affected by surface soil roughness. Quantifying the surface soil roughness on ground surface emissivity is a key issue to improve the quality of passive microwave large-scale SM products.

The core of the SMOS algorithm permitting to provide SM operational data is the inversion of the L-band Microwave Emission of Biosphere (L-MEB) model that is the result of an extensive review of the current knowledge of the microwave emission. In this model, surface soil roughness is modeled with empirical parameters (Qr , Hr , Nrp , with p = H or V polarizations). These parameters had been estimated by numerous studies but only at local scale using in situ measurements or airborne campaigns. However, these local estimations are not representative at large scale and can lead to important errors in the SM retrievals.

In this study, a method has been developed to obtain the first global map of the roughness parameter, by combining the vegetation and soil roughness into one parameter, referred to as TR. SM and TR were retrieved globally using the SMOS L3 brightness temperature and the forward emission model L-MEB for 2011. The effect of vegetation and roughness can be separated in TR using the LAI MODIS data to account for the vegetation. This map could lead to improve soil moisture retrievals for present and future microwave remote sensing missions such as SMOS and the Soil Moisture Active Passive (SMAP).

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Poster 23

SMOS Measures Bottom Topography Under the Ice Cap in Antarctica

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During the preparations for SMOS it was considered what would actually be measured by a spaceborne L-band radiometer when passing over the vast ice cap of Antarctica. Excluding ice shelves and a rim along the border of Antarctica, i.e. considering the high elevation plateaus, the ice is generally very cold, never melting, and quite spatially uniform – and the penetration depth at L-band is large, many tens if not hundreds of meters. Thus it could be expected that the ice acts almost as a blackbody, and the brightness temperature would approach the mean annual temperature at any given location.

After the launch of SMOS it soon became clear that indeed the brightness temperature over large parts of Antarctica is quite uniform and stable. This led to the notion that especially the inner parts of the high plateau of East Antarctica might be used as an extended calibration site for SMOS but also as a reference target for inter-comparison of SMOS and other L-band space sensors like Aquarius and SMAP.

To be certain about the stability, tower based radiometer measurements have been carried out near the Concordia station in East Antarctica for years. To assess spatial homogeneity, an airborne campaign, DOMECair, was launched in 2013, and a 350 by 350 km area around Condcordia was sensed using an airborne L-band radiometer.

These airborne measurements revealed unexpected brightness temperature variations in cases approaching 10 K over a 100 km scale, and in an extreme case showing up to almost 1 K per km slope – over an area having a quite uniform temperature and surface elevation around 3000 m.

In a quest for an explanation, a map of the bedrock under the ice in the area was consulted. This map revealed a very mountainous bedrock with elevations from -1000 m to +500 m compared with sea level, i.e. an ice thickness variation of about 1500 m. Comparing a map of the measured brightness temperatures with the bedrock topography map reveals a striking correlation.

If the penetration depth at L-band is substantially greater than previously assumed, then varying ice thickness will influence the brightness temperature at the surface, since the physical temperature in the ice ranges from -55 °C near the surface but approaches some 0 °C near bedrock due to geothermal heat.

Numerical simulations using current values for the absorption coefficient of dry, Antarctic ice and realistic temperature profiles have been carried out, and they show that the surface brightness temperature is indeed modulated by around 6 K by the bottom topography variations of 1500 m.

Also SMOS imagery from the area reveal spatial variations – on a coarser scale of course. Some of these variations are due to bottom topography. Current research is investigating the correlation between SMOS imagery and bottom topography where it is known, with the aim of using SMOS data as indication of topography in areas not well mapped by radio echo sounding.

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Topic 6 - Operational Applications Using SMOS Data

Poster 24

Satellite Sea-Surface Salinity Data: Impact on Ocean Modeling

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Near-real-time satellite sea-surface salinity (SSS) data provide a new means for constraining ocean numerical circulation models, providing a critical independent component of surface density and upper ocean thermohaline circulation. Satellite SSS also provides an anchor for projecting satellite altimetry data into the ocean’s interior, facilitating improvements in data assimilation methods for modeling both mesoscale features and upper-ocean heat content. Impact studies using SSS data from the European Space Agency’s Soil Moisture – Ocean Salinity (SMOS) mission have been conducted using the computational core, the HYbrid Ocean Model (HYCOM), for the National Oceanographic and Atmospheric Administration’s (NOAA) operational Real-Time Ocean Forecast System (RTOFS). Comparisons between NOAA’s operational configuration, which uses an annual cycle of climatological monthly-mean values of SSS, and results using near-real-time satellite data are examined. The impact of how tightly the model is constrained to satellite observations is explored, both in terms of relaxation strength and satellite data update interval. The importance of assimilating near-real-time SSS will be demonstrated through the use of SMOS three-day global composite data sets in comparison to the use of monthly-mean values.

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Poster 25

Assimilation of SMOS Level 2 Soil Moisture Product in the Land Information System

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Retrievals from the Soil Moisture and Ocean Salinity (SMOS) satellite's Soil Moisture Level 2 User Data Product (SMUDP2) are assimilated into the Noah 3.2 land surface model within the NASA Land Information System (LIS). LIS is a software framework for running LSMs with a variety of meteorological forcing and fixed parameter data, and includes an Ensemble Kalman Filter data assimilation component. We have implemented the assimilation of SMOS soil moisture retrievals into an experimental near-real-time run at 3-km resolution over the south-eastern United States. The assimilation includes a bias correction using a vegetation type-dependent Cumulative Distribution Function (CDF)-matching method to ensure that the overall soil moisture climatology does not change in a mean sense. The experimental run is a real-time version of a LIS run that is produced at SPoRT operationally and utilized by National Weather Service partners for situational awareness for drought assessment and areal flood prediction. The model run is forced by North American Land Data Assimilation System-2 (NLDAS-2) analyses and Stage IV precipitation fields (a combination of radar and gauge data), and includes a daily update of Greenness Vegetation Fraction (GVF) from MODIS. We compare modeled soil moistures from a control run, the SMOS assimilation run, and an assimilation run with bias correction.. These fields are validated against in situ measurements from the North American Soil Moisture Database in order to assess the impact of both the SMOS data assimilation and the bias correction methodology.

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Poster 26

Improvements to the Use of Satellite Soil Moisture Measurements in an Operational Land Data Assimilation System

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The Met Office runs as a land data assimilation scheme, as part of the operational NWP suite, principally to provide an updated soil moisture analysis. Satellite estimates of near surface soil moisture are a critical observational dataset for this scheme. An important aspect of satellite usage is the conversion of the satellite retrieval to an equivalent value that represents the near surface soil moisture. In this poster we will examine the impact of updating this method of conversion for ASCAT via a new climatology generated from the latest version of the JULES land surface model, with updated soil parameters. SMOS level 2 data will be used as an independent assessment of the resulting soil moisture analyses. In addition future improvements to the land data assimilation scheme will be presented, such as plans to test the impact of SMOS data and improved treatment of observation errors.

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Poster 27

SMOS Assimilation into SURFEX Land Surface Model: Application to Crop Yield Estimate in West Africa

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INTRODUCTION
In West-Africa, land surface modelling (LSM) suffers from strong uncertainties related to the precipitation rate. The low density of the rain gauge network associated with almost no weather radar in this area imposes the use of satellite-based precipitation products which are known to be particularly inaccurate quantitatively. Consequently, LSM outputs exhibits some large discrepancies with in-situ soil moisture and associated fluxes. To improve land surface simulations, a solution lies in assimilating surface soil moisture estimates from the SMOS satellite. In a recent paper, Louvet et al. (2014) show that surface soil moisture simulated with a simple one-layer model (5 cm depth) can be strongly improved using SMOS measurements in West Africa. In the present paper, the methodology is applied to a more sophisticated land surface model (SURFEX from Meteo-France) in order to observe the benefit on both the root-zone soil moisture and the associated sensible and latent fluxes.

METHOD
SURFEX is a physical surface modelling platform designed to represent the surface processes exposed to an atmospheric forcing. The option ISBA-DIF allows a soil multi-layer simulation of a natural area. A first simulation is done at the West Africa scale (0.25° resolution) for the 2010-2013 period. Then, SMOS soil moisture product (L3SM) is assimilated into the SURFEX model using a Kalman filter scheme. Outputs of both simulations are compared together and assessed using in-situ data provided by the AMMA-CATCH observatory. Finally, an attempt to link soil moisture profiles with measured crop production is done in the Niamey region in Niger.

RESULTS & DISCUSSION
LSM results show some differences whether SMOS is used or not. Main differences concern the spatial distribution as well as the water infiltration depth. These two characteristics are closely linked to the crop production since the soil water content is the main limitation of the plant growth in this region. Crop measurements were obtained over 10 farms located in the Niamey region in Niger from 2005 to 2012. The mean production (8 years) is 690 kg/ha, and was equal to 765/381/506 kg/ha in 2010/2011/2012 respectively.
Most studies dedicated to crop monitoring are based on thermal infrared (e.g. MODIS) or rainfall measurements (e.g. CMORPH). Here, we focus on the soil water content which is the main limitation to crop production.

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Poster 28

SMOS and Long Term Soil Moisture Comparison. Study over the Iberian Peninsula

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INTRODUCTION
The SMOS mission is providing the first ever global observations of surface soil moisture (SSM) at L-band. With almost five years of mapping this variable, it is now possible to start analyzing SSM spatial and temporal variability along time. Also, for climate applications, it is important to account for SMOS SSM representativeness with respect to existing longer-term SSM data records. In this work, a study on the representativeness of SMOS SSM (2009-2014) over the Iberian Peninsula, with respect to the Essential Climate Variable (ECV) soil moisture data record created from passive data sets (1978 - 2013), and provided by the ESA-Climate Change Initiative. Moreover, different water deficit indexes are reviewed and calculated with both SMOS and ECV SSM data sets.

METHOD
SMOS data is obtained from the CP34-BEC data service [1]. The ECV SSM data set is obtained by merging SSM estimates from SMMR, SSM/I, TMI, AMSR-E, WindSat and AMSR2 sensors [2]. In both cases, SSM is provided in volumetric units [m3m-3] and with a spatial resolution of 25 km. As they are obtained using different retrieval algorithms and using sensors at different frequency bands, a matching technique is applied before comparison.
Due to the important impact of the soil moisture deficit over the Iberian Peninsula, the onset and duration of soil moisture deficit periods will be analyzed, both for ECV and SMOS time coverages. SSM anomalies and water deficit indexes will be used to characterize and compare drought periods for different regions on the peninsula. The prospect use of BEC fine-scale SSM data (1km) for enhanced spatial analysis [3].

DISCUSSIONS & CONCLUSION
Early results show that SMOS soil moisture estimates are (mostly) representative of soil moisture over the Iberian Peninsula, with some differences at specific areas. This comparison study, as well as results from the analysis of soil moisture trends and anomalies, will be presented at the conference.

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Topic 7 - SMOS Mission Status (Level 1 and 2 Data Quality, RFI, Evolution of Retrieval Algorithms)

Poster 29

Five Years of Early RFI Detection/Quantification with Tsys Signals Provided by the 69 LICEFs

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Although MIRAS is operating in a protected band, the contamination of L1a data by man-made sources of radio-frequency interferences (RFIs) operating close to the L-band are frequently observed. Contamination by RFI is an important issue since it propagates from measurements to reconstructed brightness temperature maps and then to higher level products. RFI should be detected as soon as possible in the processing pipeline, namely at the L1a level of the measurements provided by MIRAS.

The detection and quantification approach developed and implemented in L1 ground segment for processing the Tnir temperatures provided by the three NIR radiometers is adapted and extended to the processing of the 69 system temperatures Tsys provided by the LICEF. Contrary to Tnir values which are often saturated by strong RFI sources, Tsys values are not bounded. As a consequence, the reweighted least-square approach is more stable and the detection more robust. Moreover, statistics on the number of radiometers simultaneously affected by the RFI, or simultaneously suffering from a given excess of temperature, are now available. However, since the number of signals to process is larger, 69 instead of 3 per polarization, the processing time has also increased. This is not a strong bottleneck since the code is highly parallelizable.

The validation of the procedure has been performed with Tsys signals delivered by the 69 LICEF radiometers during the first five years of the mission. From the signal processing point of view, more than 99% of the millions of snapshots analyzed have been processed automatically, without any interruption of the pipeline, without requiring any interactive settings. From the scientific point of view, it turns out that more than 20% of them are corrupted by RFI with a brightness temperature excess larger than 3 times the expected standard deviation of such measurements that is not compatible with the scientific objectives of the mission. However, on the long term, it turns out that as soon as few RFI sources were switched off, a small decrease of this percentage is observed in both polarizations.

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Poster 30

Satellite Sea-Surface Salinity Data Consistency

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For operational applications of satellite sea-surface salinity (SSS) data, users need to understand the uncertainties, biases, trends, and dependencies of the data being used, as well as differences between primary sources. This information is particularly relevant to numerical modeling and the assimilation of SSS data for analysis and forecasting. Improvements to the European Space Agency's (ESA) Soil Moisture – Ocean Salinity (SMOS) mission and the joint United States and Argentine Aquarius/SAC-D mission data have begun to converge of retrieved SSS values, yet significant differences remain. Comparisons with in situ references suffer from the uncertainty introduced by near-surface processes that can produce actual differences between the skin SSS measured by satellites and the near-surface measured by in situ instruments. Triple point collocations (in situ, SMOS, Aquarius) and double differencing provide approaches for assessing satellite-to-satellite biases and trends. The latest versions of SMOS and Aquarius (Aquarius Data Processing System (ADPS) and Combine Active-Passive (CAP)) data are examined to characterize the data's uncertainty and differences between sources and how they relate to in situ values.

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Poster 31

SMOS Quality Control under IDEAS+ Framework

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Soil Moisture and Ocean Salinity (SMOS) is ESA's Earth Explorer mission, launched on the 2nd November 2009. With over 5 years in orbit, SMOS continues to provide insightful data to the scientific community. The SMOS payload, Microwave Imaging Radiometer by Aperture Synthesis (MIRAS), is an innovative instrument which remains under exhaustive qualitative and quantitative monitoring by the mission team.
Operational Quality Control (QC) of MIRAS instrument and data is carried out under the Instrument Data quality Evaluation and Analysis Service (IDEAS+) contract. IDEAS+ service layout, as it is applied to SMOS QC operations, is described in detail in this paper. A description of the QC activities and processes performed by IDEAS+ can be found here. In addition, for user reference, the paper describes the different types of information related to SMOS data quality and instrument health status available to users, and how they can be accessed.

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Poster 32

Retrieving SM under Forests: Quality Evaluation of L2 and L3 Results

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Retrieving Soil Moisture (SM) by SMOS in pixels covered by forests is a challenging task, since the sensitivity of measured brightness temperature TB to variations of this variable is reduced by the high attenuation produced by the canopy. For uniform and dense forests, the dynamic range of TB can be comparable with noise in the measurements. Moreover, the accuracy of the forward model can be critical, since errors in the albedo and the initial estimate of optical depth cannot be completely corrected by the iterative L2 algorithm. In spite of these problems, consistent efforts have been produced since SMOS launch, in order to improve accuracy of the algorithm and the quality of TB data. The new formulation of the forward model was included in a prototype L2 algorithm and in L3 data.

In this work, multitemporal SM retrieved by both L3 and prototype L2 algorithms are tested using available ground measurements. Tests span 2 years for L2 data and 3 years for L3 data. At first, ground measurements collected by US SCAN/SNOTEL network are considered. 15 nodes with a forest cover higher than 80% and 13 nodes with a forest cover in a range 30-50% are selected. Appropriate spatial averaging is applied, in order to get the best correspondence between SMOS pixel location and ground network nodes location, for both L2 and L3 grids. Information about brightness temperature, surface temperature and Snow Water Equivalent is provided for reference. Relevant statistical parameters (rmse, bias, correlation coefficient) are provided for each node and season.

Previous investigations found that the quality of the retrieval was dependent on climate. While several problems are observed at low temperatures, the performance of the algorithm is significantly improved for temperatures higher than 12 °C, where the rmse is lower than 0.1 m^3/m^3 for developed forests and 0.07 m^3/m^3 for mixed pixels with a forest cover of about 40%. It was also found that the fraction of successful retrievals decreases at low temperatures. This effect is observed particularly in some nodes located in the North West of the US, where snow cover is present almost half of one year. However, the influence of temperature is observed even in absence of snow. This effect, which can be due to soil or canopy effects, is investigated, also in comparisons with multiseasonal results collected over low vegetation pixels in similar climates.

Extension of the investigation to other forest sites in Finland and Australia is in progress.

In summary, this work demonstrates the achievement of important advances in retrieving SM under forests, which are useful both for next exploitation of SMOS and in view of SMAP and other future programs.

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Poster 33

Impact of SUN Glint on the SMOS Retrieved Brightness Temperature Maps for Five Years of Data

Khazaal, A.[1]; Tenerelli, J.[2]; Cabot, F.[1]
[1]CESBIO (France), [2]Ocean Data Lab (France)

The European Space Agency's (ESA) SMOS mission, launched on November 2nd, 2009, aims to retrieve global measurements of Soil Moisture and Ocean Salinity. The instrument used on board SMOS is a two-dimensional L-band interferometer MIRAS, equipped with 69 equally spaced antennas. The interferometric measurements, or complex visibilities provided by SMOS are obtained by cross-correlating the signals collected by each pairs of antennas with overlapping fields of view. These measurements are the input of the SMOS image reconstruction processor in order to retrieve the brightness temperature of the scenes under observation. It has been shown that the linear problem between the visibilities and the brightness temperature to retrieve is ill posed and need to be regularized to provide a unique and stable solution.

The complex visibilities are influenced by the scene brightness over the entire space surrounding the instrument. The objective of the image reconstruction procedure is to produce images that include only geophysical sources of brightness, at least over the so-called extended alias-free field of view. All other sources of brightness are referred to as "foreign sources". In an effort to achieve this objective, the contributions of these foreign sources to the visibilities are estimated and subtracted from the measured visibilities prior to the image reconstruction.

In this work, we will focus on one of these foreign sources, the sun radiation reflected on the sea surface or sun glint. Sun glint poses a particular problem for the reconstruction of brightness temperature images for two reasons. First of all, depending upon the roughness of the ocean surface, the sun glint may contribute to brightness temperature variations at spatial frequencies beyond those measured by the instrument. Secondly, the sun glint is mostly concentrated in the aliased part of the field of view, and so the glint may contribute to biases even in the alias-free part of the field of view. Here, we will investigate the impact of the sun glint on the quality of the retrieved images for the first five years of lifetime of the SMOS mission.

In this paper, we will compare first the model predicted sun glint with the glint derived from the SMOS data over the open ocean far from land. The scene brightness model over the ocean will be used to remove all contributions to the measured visibilities except that from the sun glint and this will allow the reconstruction of the specular lobe of the glint as derived from the measurements. These data will then be compared to the glint derived from the models.
Two important issues also arise when considering the impact of sun glint on the brightness temperature maps. First of all, when compared to a geophysical model over the open ocean, the alias-free and extended-alias-free averaged brightness temperatures exhibit drifts with both time of year and latitude. A portion of these biases may originate from both the direct effect of sun glint on the antenna temperatures and the indirect effect of the glint on the reconstructed image bias owing to the presence of the glint in the aliased part of the field of view. This paper will examine both of these effects using more than a 100 L1a orbits, covering the five first years of lifetime of SMOS (from 2010 to 2014) and the forward model mentioned above.

At the end, depending on the obtained results, conclusions will be made about the impact of sun glint correction on the quality of the retrieved images.

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Poster 34

SMOS L1a to L1b Breadboard Developed at CESBIO via MATLAB (L1a2b)

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Even after five years of the launch of SMOS, the level 1 operational processor (L1op) is still subject to several improvements and many changes have been implemented in the L1op due to recommendations from the Expert Support Laboratories (ESL) like CESBIO, IRAP, UPC and others.

To improve the quality of the data provided by the L1op, we have started at CESBIO and IRAP since 2011, the development and implementation of a MATLAB Breadboard (L1a2b) similar to what is implemented in the L1op (at that time, it was the L1pp: Level 1 processor prototype).

Our first motivation was to improve the image reconstruction chain by testing and comparing different approaches or algorithms for the reconstruction and the bias correction. Indeed, this breadboard alongside the MIRAS-Testing Software (MTS) developed at UPC, was used to cross-validate the L1op developed by DEIMOS. In its last version (v620), the L1op has adopted many recommendations due to tests conducted within the L1a2b. For example, the L1op uses now hexagonal grids in the image reconstruction as well as in the foreign sources correction module instead of a mix of hexagonal/Cartesian grids. Also, the sampling adopted now is the one used in the L1a2b. The most important contribution was the use of the Cross-polar antenna voltage patterns in the processing chain and now the SMOS reconstruction operators are generated by the L1a2b and delivered to ESA to be used in the L1op.

Other motivations for this work were the possibility of working on different problems related to the level 1 data processor and testing them using the L1a2b. In fact, the L1a2b is implemented using MATLAB and not C++ as the L1op. Therefore, it is much simpler to manipulate it in order to test different tools aiming to improve the quality of the level 1 data. Among these tools, we have two RFI detection methods, one based on the variation of the zero baselines, and the second on the evaluation of the kurtosis of each data set. Also, we have implemented a second tool that allows applying different bias correction techniques going from a very simple approach to a global one. A third tool was also generated using the L1a2b to assess the land/sea contamination along the coasts.

We should also indicate that the use of MATLAB instead of C++ is an advantage and not an inconvenient as we often think that MATLAB is too slow. In fact, the L1a2b is fully vectorized and as a consequence it is much faster than the L1op (30 min to process a single L1a orbit with the L1op compared to 4 minutes using the L1a2b).

In this work, we will present the basis of the L1a2b breadboard and its corresponding tools. We will also present our contributions to the L1op and compare both processors.

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Poster 35

SMOS Salinity Retrieval by Using Support Vector Regression with OTT Corrected Multi-angular Brightness Temperatures

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In November 2009 the European Space Agency's SMOS satellite was launched in order to enable, over ocean, satellite based estimations of Sea Surface Salinity (SSS) with a spatial and temporal coverage adequate for large scale oceanography [1].

For the retrieval of SSS, a maximum-likelihood Bayesian inversion scheme is applied under an iterative convergence loop [2], by comparing the multi-angular Brightness Temperatures (TBs) measured by SMOS with those gathered by a TB forward model, also taking into account constraints on Sea Surface Temperature (SST) and Wind Speed (WS).

In this study the potential of an alternative ε-insensitive Support Vector Regression (SVR) Salinity estimation is further examined as presented in [3,4], where the SVR training/testing has been performed using in situ SSS data from the ARGO network collected in limited test areas during several sample months. SMOS measurements, either the TBs or the emissivities, at a single incidence angle [3] or at several incidence angles [4] in both H and V polarisation, were used with the additional parameters SST and WS, and the performance of the SVR was evaluated considering different feature combinations. The estimated SVR salinity fields are in general well correlated with ARGO data, even if the SVR performance varies across different areas and along different months.

To further examine the potential of this approach we include basin-wide test areas over the Atlantic and Pacific Ocean ranging from -45° to +45° latitude. We systematically study the evolution of the SVR performances curve based on all feature permutations based on incidence angles, polarisations as well as the additional parameters SST and WS. Also we include the implementation of the OTT (Ocean Target Transformation) correction in order to improve results by reducing the instrumental bias.

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Poster 36

Verification of V6xx Baseline and Status of SMOS 2nd Full Mission Reprocessing – IDEAS+ QC

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The second full mission reprocessing of ESA's Earth Explorer mission, Soil Moisture and Ocean Salinity (SMOS) started in late 2014, covering the reprocessing of Level 1 and Level 2 products from January 2010 to about April 2015 This paper focuses on the process and results of On-Site Acceptance Testing (OSAT) for Level 1 and Level 2 Instrument Processing Facility (IPF) V6xx baseline, followed by Quality Control (QC) operations of the reprocessed products, which took place under Instrument Data quality Evaluation and Analysis Service (IDEAS+) contract.

With regards to OSAT, this paper presents a summary of the validation process that was followed for verification of V6xx Level 1 and Level 2 IPFs. The verification included exhaustive system and integration level testing in order to ensure that the quality of V6xx IPF met with the system and performance requirements.

Once the IPFs were verified, they were integrated in the reprocessing platform. Once the reprocessing started, the data was routinely monitored by IDEAS+ QC team for telemetry, calibration and scientific validation. The paper summarises the verification checks that were implemented by IDEAS+ team on reprocessed dataset.

A summary of results of analysis of reprocessed data is also presented here. Assessment of V6xx data and plots of QC results are included with an emphasis on the comparison against the previous baseline (V5xx).

Additional QC trends have been computed for the entire mission to evaluate the long-term stability for Level 1 (brightness temperature) and Level 2 (soil moisture and ocean salinity).
Finally, the paper also presents details of where the users can obtain information related to reprocessing and reprocessed dataset.

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Poster 37

Five Years of Ocean Salinity: How to Use the Data

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This poster will present a quality assessment of the new reprocessed Level 2 ocean salinity dataset, together with data selection and filtering techniques. How can users select the 'best' quality data? We will show methods that can be used to avoid contaminated or suspicious data, and show the impact on data quality.

Retrieved salinity quality depends on many factors, including proximity to land, sea surface conditions, position within the swath, contamination from external sources (sun, RFI, galactic radiation), Level 1 calibration, orbit direction, and other geophysical parameters. There are many flags and descriptors in the Level 2 products monitoring these factors: data selection methods require these to be used appropriately, depending on user requirements. Inappropriate data selection can result in erroneous data sets and invalid scientific results.

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Topic 8 - Status and Development of Level 3 and 4 Data Products

Poster 38

Empirical Salinity Bias Correction from Level 2 SMOS Data

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The SMOS sea surface salinities (SSS) are affected by biases coming from different unphysical contaminations such as the so-called land contamination, and latitudinal biases likely related to thermal effects on the antennas. These biases can reach more than 1 psu in some regions close to the coasts and show very strong spatial gradients according to the coast orientation and the position in the Field Of View (FOV). The zero order bias is the so-called Ocean Target Transformation (OTT) which is a correction applied at brightness temperature level. Here, we consider remaining SSS biases after OTT correction and we present an empirical way to correct them at salinity level.
This correction is empirically determined using the four years (2010-2014) of SMOS SSS and characterized according to the grid point position and the distance of the dwell-line to the satellite track. The biases for each dwell line relative to a reference dwell line are then estimated, with a least squares approach, and the combination of corrected SSS provide a salinity time series obtained from all the passes. These average salinities are known to within a constant (the bias of the reference dwell line) which is estimated using SSS climatology (ISAS v6.2 data) for each grid point and for the four years of observation.
Four year salinity monthly and weekly maps corrected from land contamination and latitudinal bias are presented. Independent validation, using in situ data from thermosalinograph from ship of opportunity is presented.

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Poster 39

Improvements of the Most Recent Reprocessed SMOS Soil Moisture Products

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INTRODUCTION
Soil Moisture and Ocean Salinity (SMOS) satellite has been providing soil moisture (SM) and ocean salinity (OS) retrievals at L-band for five years (2010-2014). During these five years, the SM retrieval algorithm,

the L-MEB (L-Band Microwave Emission of the Biosphere; (Wigneron et al., 2007)) model has been progressively improved and hence results in different versions of the SMOS SM products.

OBJECTIVE
This study aims at evaluating the last improvement in the SM products of the most recent SMOS level 3 (SMOSL3) reprocessing (SMOSL3_New, Processor V2.72) vs. the earlier versions (SMOSL3_Old, retrieval algorithm processors V2.45-48). The new SM product (V2.72) includes improvements, but not limited to, in (i) Level 1 brightness temperature reprocessing including a better detection of Radio Frequency interferences (RFI) and (ii) the L-MEB SM retrieval model such as replacing the Dobson dielectric model (Dobson et al., 1985) by the Mironov dielectric mixing model (Mironov et al., 2009).

METHOD
The SMOSL3_New and SMOSL3_Old versions were compared against SM-DAS-2 SM data assimilation system produced by the European Center for Medium range Weather Forecasting (ECMWF) forecast model at the global scale.

RESULTS
Correlation, bias, Root Mean Square Difference (RMSD) and unbiased RMSD (unbRMSD) were used as performance criteria in this study. First results show that the SMOS SM estimates have been improved: (i) SMOSL3_New was closer to SM-DAS-2 over most of the globe-with the exception of arid regions-in terms of bias, RMSD, and unbRMSD (ii) SMOSL3_New was closer to SM-DAS-2 over Europe and India but comparable with SMOSL3_Old over most of the rest of the globe in terms of correlations.

DISCUSSION & CONCLUSION
For instance, Fig. 1 shows the areas, in green, where SMOSL3_New has the lowest unbRMSD (66% of the considered pixels), and the areas, in red, where SMOSL3_Old has the lowest unbRMSD (34% of the considered pixels). The positive impact of introducing the improvements mentioned above in the new processing of SMOS datasets is clearly observed in the figure with the exception of deserts, particularly over sand dunes areas, where the Dobson model may be more accurate than the Mironov model. This study is in progress and will be extended using other existing satellites (ASCAT, AMSR-E, etc.) and in situ observations to precisely evaluate the improvements of the most recent SMOS soil moisture reprocessing.

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Poster 40

Presentation of the CATDS : Description of the SMOS L3/L4 Products Generation and Dissemination

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The CATDS (Centre Aval de Traitement des Données SMOS) is the French ground-segment facility in charge of the generation, calibration, archiving and dissemination of the SMOS science products level 3 and level 4. It processes Ocean Salinity (OS) and Soil Moisture (SM) products. CATDS is also providing services to users and scientists.

CATDS is split in two main types of components:
- a C-PDC (Production Centre) which routinely produces and disseminates L3 and L4 data from L1B and auxiliary data.
- 2 C-EC (Expertise Centre, 1 for SM, 1 for OS) which host the definition of algorithms, assess the quality of the products and provide specific information to users.

The C-PDC processing chain which generates SM and OS L3 data from L1B products is composed of several processors. Some of them are based on the ESA DPGS's prototypes. The main difference with level 2 processes is that DPGS processing is based on half an orbit, whereas C-PDC processing is based on several days of data.
One of the goal of the C-PDC L3 processors is to select correct input data and to reject the dubious ones. These L3 processors perform temporal analysis, time aggregations and spatial and temporal averages.

The L3 products generated and distributed are :
- 1 day, 3 day, 10 day and monthly maps of SM values
- 3 day maps of dielectric constant
- 1 day, 10 day and monthly maps of OS values
- 1 day maps of polarized TB at ground level

- 30 day maps of RFI probabilities

Generation and distribution of several L4 products should start in 2015 : locally available dis-aggregated SM fields, global root zone SM maps and drought indices, bias corrected OS. In parallel new products are being investigated for release at a later stage.

The C-PDC is operational since the middle of year 2011. A third reprocessing campaign is in progress based on the reprocessed L1B from DPGS.

A web site (www.catds.fr) describes the products and gives information related to the operational status.

Users can access the products either through FTP or through the Sipad, an interactive Web based tool which allows aggregations and sub-settings.

A single point of contact (support@catds.fr) operated by the production center allows users:

- To ask for the FTP credentials
- To give feedback about the products
- To obtain support either technical or scientifical on the products and their usage

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Poster 41

Products and Services in CP34-BEC

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The Barcelona Expert Center (BEC) was created in 2007 as a joint research venture partnered by the Technical University of Catalonia (UPC) and the Spanish Research Council (CSIC). BEC was created to provide support to the ESA SMOS mission as an Expert Support Laboratory, as well as developing new algorithms for processing SMOS data at higher levels.

The initial activities of BEC on SMOS were focused on calibration issues and the algorithms used to retrieve L2 salinity products; later on, designing higher level products was also included among the tasks of BEC. In January 2013, a new distribution service, called CP34-BEC, was started to replace the old CP34 (see http://cp34-bec.cmima.csic.es). The the new webpage is substantially improved, mainly to introduce changes in format and file types making them more accessible to final users, and also offering new algorithms, improving the quality of the products and also the visualization tools.

Catalogue of products:

Sea products

All Sea Surface Salinity (SSS) products are derived using the third roughness model [Guimbard et al., 2012], and are defined on a regular cylindric grid (0.25 degrees) with different time averaging (3-day, 9-day, monthly, seasonal, and annual). Three types of SSS products are served: Binned L3, OI L3 and fusion L4. Additionally, a new density L4 product is derived from each SSS product. Singularity exponents maps derived from daily OSTIA SST maps are also offered.

Land products:

Two different land products are distributed: Soil Moisture Level 3 products in an EASE-25km grid, with different averaging periods (1-day, 3-day, 9-day, monthly, seasonal, and annual) and Soil Moisture Level 4 products (restricted so far to the Iberian Peninsula at 1km spatial resolution; maps are obtained using the downscaling algorithm defined in [Piles et al., 2014])

Services:

BEC team offers a Singularity Analysis GUI, restricted to registered users (registration is free); see http://cp34-bec.cmima.csic.es/CP34GUIWeb/

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Topic 9 - Synergistic Use of SMOS Measurements with other Satellite Derived and In-situ Data Over Land and Ocean, in Particular Aquarius and SMAP but also other Sensors

Poster 42

Testing Simple Regression Equations to Derive Long-Term Global Soil Moisture Datasets from Satellite-based Brightness Temperature Observations

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INTRODUCTION

Passive microwave sensors offer the opportunity to retrieve surface SM (SSM) information from the measured brightness temperatures (TB) signals. Nevertheless, these microwave sensors provide individually SSM datasets which may not be consistent worldwide and across time. Therefore, the European Space Agency (ESA) established the Climate Change Initiative (CCI) project with a purpose to merge different observations acquired by several microwave sensors in an attempt to produce the most complete and consistent long-term time series of SSM over 1978-2010 as a first phase [1]. A new innovation in space technology, namely the SMOS (Soil Moisture and Ocean Salinity) SSM datasets has been providing multi-angular microwave TB observations at L-band [2] since 2010. SSM can be retrieved from the SMOS TB observations using several approaches such as a Radiative Transfer based model inversion (e.g. the ESA and CNES operational algorithms [2]), neural networks [3], and statistical regressions.

OBJECTIVE

The SMOS satellite being the first mission specifically designed to measure SSM from space, this study -an ESA-funded project- aims at studying the inclusion of SMOS SSM as reference for the long-term SSM datasets. Specifically, investigating the use of physically based multiple-linear regressions [4] to retrieve a global and long-term (e.g. 2003-2014) SSM record based on a combination of passive microwave remote sensing observations from the AMSR-E (2003 - 2011) and SMOS (2010 - 2014) sensors.

METHOD

The overlap measurement period (June 2010-Sept 2011) between AMSR-E and SMOS was used for calibration and validation. The coefficients of the regression equations were calibrated using AMSR-E TB and SMOS Level 3 (SMOSL3, V2.72) SSM (used here as a reference) over the Oct 2010 - Sept 2011 period while the rest of the overlap period (June – Sept 2010) was used for validation.

RESULTS

Based on the calibrated coefficients, global SSM maps were computed from the AMSR-E TB observations over the validation period (referred here to as AMSR-reg product). First results showed that the regression approach is very promising as it produces realistic SSM values from the AMSR-E TB product in terms of absolute values. Fig 1 displays a comparison between the temporal mean of the SMOSL3 and AMSR-reg SSM products over the validation period (June – Sept 2010). The global distributions of SSM and its spatial patterns are similar for both products with low values over arid and semi-arid regions, moderate values over India, the Sahel and the Eastern part of Australia. An overall mean of SSM of 0.129 m3/m3 and 0.128 m3/m3 was computed for SMOSL3 and AMSR-reg, respectively.

This study is in progress and further investigations will be directed to (i) evaluate the AMSR-reg SSM retrievals against land surface SSM simulations (e.g., MERRA-Land) and in situ observations over the period 2003-2009, at the global and local scales and (ii) investigate the temporal consistency of AMSR-reg (2003-2009) and SMOSL3 (2010-2014) SSM time series. Based on the results, the final goal of this study will be to merge the AMSR-reg (2003-2009) and SMOSL3 (2010-2014) SSM time series to produce a long term and consistent SSM product.

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Poster 43

Downscaling of Soil Moisture Estimations at the Valencia Anchor Station Using Synergy of SMAP/SMOS Data

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Soil moisture products from active sensors are not operationally available. Passive remote sensors return more accurate estimates, but their resolution is much coarser. One solution to overcome this problem is the synergy between radar and radiometric data by using disaggregation (downscaling) techniques.
Few studies have been conducted to merge high resolution radar and coarse resolution radiometer measurements in order to obtain an intermediate resolution product. In this paper we will present an algorithm using combined simulated SMAP radar and SMOS radiometer measurements for estimation of surface soil moisture. The goal is to combine the attributes of the radar and radiometer observations to estimate soil moisture at a resolution of 3 km.
The algorithm disaggregates the coarse resolution SMOS (15 km) radiometer brightness temperature product based on the spatial variation of the high resolution SMAP (3 km) radar backscatter. The disaggregation of the radiometer brightness temperature uses the radar backscatter spatial patterns within the radiometer footprint that are inferred from the radar measurements. For this reason the radar measurements within the radiometer footprint are scaled by parameters that are derived from the temporal fluctuations in the radar and radiometer measurements.

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Poster 44

Investigating the Potential of Satellite Salinity Measurements to Improve Tropical Cyclones Forecasting

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In this study, sea surface salinity (SSS) data from the NASA/CONAE Aquarius satellite are used to investigate salinity changes at the ocean surface induced by tropical cyclones. It is known that tropical cyclones in the North Atlantic (hurricanes) can induce upwelling of cold waters from below the thermocline (depths ~300 m) to the surface, leading to a detectable reduction in sea surface temperature (SST) of several degrees. This induced upwelling plays an important role in regulating the intensification of tropical cyclones. Here, the influence of salinity on the upwelling mechanism is explored and the potential of satellite SSS data to help improve tropical cyclone forecasts is assessed. Aquarius satellite SSS observations are combined with SST from GHRSST (Group of High Resolution Sea Surface Temperature) produced at the NOAA National Climatic Data Center (NCDC) and with output from the UK Met Office Forecasting Ocean Assimilation Model (FOAM). The FOAM system assimilates various satellite and in situ observations, including satellite SST and Argo temperature and salinity profiles. It is found that, in the case of Hurricane Katia in 2011, FOAM clearly captures the changes in SST induced by upwelling in the wake of the hurricane, but that SSS changes in FOAM differ from those observed by Aquarius. Since high wind speed and heavy rainfall are important sources of uncertainty on SSS measured from space, the impact of wind speed and rainfall on Aquarius SSS is assessed using additional satellite data.

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Poster 45

Combining In-Situ and Satellite Observations to Better Estimate the Mixed Layer Salinity Budget in the Tropical Atlantic Ocean

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Previous studies indicate that mixed layer salinity (MLS) budget estimated from a combination of surface currents, atmospheric fluxes and ARGO based salinity gridded products cannot be strictly closed, unless introducing a so-called 'residual' term. This residual term mostly accounts for unobserved small-scale structures, horizontal and vertical diffusion and measurement errors. By combining datasets now available from complementary observing systems based on in situ devices, a step toward the high wavenumber part of the spectrum can be made.
In this study we use in-situ observations from thermo-salinometers and drifting buoys collected in the tropical Atlantic during the 2011-2013 time period as they both provide locally high resolution

observations. They are compared in terms of absolute values and resolved scales to satellite derived products from SMOS and altimetry in order to detect areas where previously unresolved scales can potentially influence the MLS budget and later estimate their contribution.

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Poster 46

Aquarius-derived Wind Speed as Auxiliary Constraint in SMOS Salinity Retrieval

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With the recent advent of the ESA SMOS [1] and NASA/CONAE Aquarius [2] satellite missions, the remotely-sensed estimation of Sea Surface Salinity (SSS) has become possible with unprecedented details, providing a continuous stream of upper-layer salinity measurements adequate for large-scale oceanography and water cycle related studies.

Both satellites present different imaging features and technological challenges; namely, a distinctive difference between the two sensors is that Aquarius embarks an L-band scatterometer sensitive to the sea roughness (and therefore sea surface wind), which in turn modulates the brightness temperature measured by its L-band radiometer. The sea surface roughness correction is therefore optimized in Aquarius since the scatterometer and radiometer measurements are obtained simultaneously at every pixel or observation cell. In contrast, in SMOS, the roughness information is obtained from numerical weather prediction (NWP) model output, i.e., by spatially and temporally interpolating the European Centre for Medium-range Weather Forecasts (ECMWF) winds. This information is then ingested in the SMOS inversion scheme leading to the SSS retrieval. Within such a framework, the NWP model output errors will propagate into the SSS retrievals.

The objective of this study is to exploit the Aquarius-derived WS data to i) analyze their characteristics with respect to the auxiliary data currently used in SMOS, and ii) possibly improve the SMOS retrieval performances by ingesting Aquarius winds as auxiliary constraint in the SMOS retrieval.

The first step is to collocate SMOS and Aquarius overpasses over a year-long timeframe. Then, the wind retrieved by Aquarius is compared with both the ECMWF wind, which is used as a-priori information in the SMOS retrieval [3], and the SMOS retrieved wind itself, analyzing their differences and distribution. A constrained collocation criteria will be used to minimize collocation errors. Additionally, several other sources of validated wind speeds, such as the satellite scatterometers (ASCAT-A, ASCAT-B, Oceansat-2, RapidSCAT), could be used to analyze their distributions when compared to the L-band winds, as well as to study their impact on the SSS retrieval.

In a second step, a limited (collocated) set of Aquarius wind data will be directly ingested in the SMOS retrieval scheme as a-priori wind constraint. Ultimately, the objective is to compare these two SMOS SSS data obtained with the two different a-priori winds, and evaluate the errors in SSS that could be ascribed to the auxiliary WS source errors. If time allows, a similar analysis will be extended to other auxiliary data sources (i.e., scatterometer data).

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Poster 47

Freshwater Lenses in the Near-Surface Layer of the Ocean in the Western Equatorial Pacific Warm Pool

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In this work, we have analyzed the structure of freshwater lenses in the Western Equatorial Pacific based on observations during TOGA COARE and recent experiments. Convective rains produce lenses of freshened water in the upper layers of the ocean. These lenses are localized in space and typically involve both salinity and temperature anomalies. Substantial near-surface temperature anomalies can develop due to nighttime cooling and/or diurnal warming, because heat fluxes are effectively trapped within the lens by salinity stratification. Due to significant density anomalies, strong pressure gradients, which result in lateral spreading of freshwater lenses in the form resembling gravity currents. In order to understand dynamics of the freshwater lenses, we have conducted a series of numerical experiments using computational fluid dynamics tools. Available near-surface data from field experiments served as guidance for these numerical simulations. These 3D simulations help to elucidate relationship between the vertical mixing and horizontal advection of salinity under various environmental conditions, formation of the barrier layer and associated fronts, and potential impact of freshwater lenses on the Aquarius and SMOS satellite image formation.

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