AATSR Validation Implementation Plan

PO-PL-GAD-AT-005 (3): Version 2.1

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Document Change Record

Issue	Date	Affected Pages	Details
1.0	April 2001		Version 1
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Contents

1 Scope of document

The AATSR validation plan is made up of three parts. The first part, validation principles and definitions (AD1), gives an overview of the AATSR validation programme and sets out the principles behind it. The second part, the AATSR measurement protocol (AD2) discusses the measurements needed for validation, and recommends the instrumentation and procedures that should be used. Both of these documents have been written with the help of the AATSR SAG.

This document forms part 3 of the AATSR validation plan, and describes in detail the activities that will be performed to validate the AATSR data products.

The validation implementation plan includes details of:

- The AATSR data products.
- Validation organisation.
- Validation activities that will make up the core validation programme, including the names of Principal investigators, instrumentation that will be used, geographical location and planned activities.
- The schedule of validation activities.
- The validation loop, describing what happens to the validation data once it has been collected.
- Longer term validation activities.

2 Applicable Documents

AD1	PO-PL-GAD-AT-005 (1)	AATSR Validation Principles and Definitions
AD2	PO-PL-GAD-AT-005 (2)	AATSR Validation Measurement Protocol
AD3	PO-PL-RAL-AT-0501	AATSR Commissioning Plan
AD4	PO-RS-GAD-AT-0001	AATSR Science Requirements
AD5	PO-TR-RAL-AT-0024	AATSR Infra-red radiometric calibration report – Issue 1
AD6	PO-TR-RAL-AT-0023	AATSR Visible radiometric calibration report – Issue 2
AD7	PO-PL-GAD-AT-0006	AATSR Ground Segment Development Plan
AD8		MERIS Cal/Val Implementation Plan
AD9	SVDS-02	SCIAMACHY Validation Handbook
AD10	PO-PL-ESA-GS-1092	Envisat Calibration and Validation Plan
AD11	PO-TN-RAL-GS-10099	AATSR Algorithm Verification Plan

3 Acronyms

AATSR	Advanced Along Track Scanning Radiometer
ADS	Annotation Data Set
AIMS	Australian Institute of Marine Science
A/O	Announcement of Opportunity
ASTER	Advanced Space borne Thermal Emission and Reflection radiometer
ATBD	Algorithm Theoretical Basis Document
ATSR-2	Along Track Scanning Radiometer 2
AVHRR	Advanced Very High Resolution Radiometer
AWS	Automatic Weather Station
BADC	British Atmospheric Data Centre
BB	Black Body
BT	Brightness Temperature
Cb	CumuloNimbus
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEFRA	Department of the Environment, Food and Rural Affairs
DSD	Data Set Descriptor
ESA	European Space Agency
EOS	Earth Observation Science
FOS	Flight Operations Support
GBR	Great Barrier Reef
GPS	Global Positioning System
ISAR	Infrared Sea surface skin temperature Autonomous Radiometer
JRC	Joint Research Centre
L	Launch
LST	Land Surface Temperature
M-AERI	Marine Atmosphere Emitted radiance Interferometer
MAVT	MERIS and AATSR Validation Team
MDS	Measurement Data Set
MODIS	Moderate Resolution Imaging Spectroradiometer
MPH	Main Product Header
NCEP	National Centre for Environmental Prediction
NERC	Natural Environment Research Council
NDVI	Normalised Difference Vegetation Index
NWP	National Weather Prediction
OP	Operational Processor
PDS	Payload Data Segment
PI	Principal Investigator
PP	Prototype Processor
RAL	Rutherford Appleton Laboratory
SAG	Science Advisory Group
SCIPIO	Satellite Calibration and Interior Physics in the Indian Ocean
SISTeR	Scanning Infrared Sea Surface Temperature Radiometer
SODAP	Switch On and Data Acquisition
SPH	Specific Product Header
SST	Sea Surface Temperature
TOA	Top Of Atmosphere
VDP	Validation Data Provider
VS	Validation Scientist

4 Validation requirements

The main objectives of the AATSR validation programme are to assess whether the AATSR instrument is returning global skin SST measurements and visible channel reflectances, which meet the scientific requirements of the mission in terms of accuracy. To meet these objectives, a number of validation activities will be carried out. Some of these are designated "core" activities, and are considered central to the validation programme. Other additional activities will be important for adding information and enhancing the core assessment made.

Validation can be considered in two phases: an initial validation period from launch (L) up until the validation workshop at L + 9 months, and ongoing validation during the remainder of the mission. These phases are described here.

4.1 Initial Validation

The first six months of the mission are known as the commissioning phase of the satellite. During this period, every instrument on the platform is switched on, data acquisition begins, and preliminary validation is carried out to assess the quality of the data received. As detailed in AD10, at the end of the commissioning phase, Level 1b data products are distributed to all users. Level 2 products are distributed to science AO PI's. At L + 9 months, a validation workshop will be held by ESA. This workshop will mark the end of the initial validation phase and the point at which all data become available to all users.

During the initial validation phase, the validation team will be considering the question; does the instrument meet its specifications? More specifically, the objectives are:

?? To determine whether the AATSR instrument is returning an acceptable global skin SST (±0.3 K, as defined in AD4).

?? To make an initial assessment of the quality of the AATSR SST data products, in a limited number of sites and seasons. Making timely use of any tandem ATSR-2/AATSR mission, this should include the determination of any bias difference between the measurements made by AATSR and those made by ATSR-2.

?? To assess the accuracy of the AATSR data retrieved over land (as defined in AD4). Eventually this will include both the reflectance values returned by the visible channels and the temperatures retrieved from the thermal channels.

Sections 9 and 10 detail the validation activities that will be carried out to meet these objectives. Initial validation includes core and non-core validation activities.

4.2 Ongoing Validation

After the validation workshop, validation activities will continue. During the mission as a whole, the upper limits of achievable accuracy of the AATSR will be assessed. Specifically the aims of the on-going validation programme are:

?? To make a detailed assessment of the quality of the AATSR SST data products in an increasing number of sites and seasons.

?? To monitor the quality of the AATSR data products over the duration of the mission (for example, to investigate the success of the SST retrievals in varying conditions such as periods of high aerosol contamination following a volcanic eruption). This is essential for ensuring continuity of the climate record.

?? To validate new AATSR products. Ongoing validation will seek to validate new products as they are developed and made operational.

Ongoing validation is described in Section 16. Core and non-core activities are included.

5 AATSR Data Products

Table 5-1 summarises the AATSR Data products. After reception on the ground, the raw data are converted into a Level 0 product. This consists of a chronological sequence of records, each containing a single instrument source packet, and with each source packet representing one instrument scan. Level 0 data are processed to give, firstly, the Level 1b and then the Level 2 product. Level 0 data are not routinely available to users.

Product ID	Name	Description
ATS_NL__0P	Level 0 Product	?? Instrument source packet data
ATS_TOA_1P	GBTR	?? Full resolution top of atmosphere BT/reflectance for all channels and both views. ?? Product quality data, geolocation data, solar angles and visible calibration coefficients
ATS_NR__2P	GST	?? Full resolution nadir-only and dual-view SST over sea ?? Full resolution 11 ?m, BT and Normalised Difference Vegetation Index (NDVI) over land ?? Product quality data, geolocation data and solar angles
ATS_AR__2P	AST	?? Spatially averaged ocean, land and cloud parameters ?? Spatially averaged top of atmosphere BT/reflectance
ATS_MET_2P	Meteo Product	?? SST and averaged BT for all clear sea pixels, 10 arc min cell, for Meteo users
ATS_AST_BP	Browse Product	?? 3 band colour composite browse image derived from L1b product. 4 km x 4 km sampling.

Table 5-1: Summary of AATSR data products

AATSR was designed primarily to measure sea surface temperature, precisely and accurately. The main aim of the validation programme is, therefore, to assess whether this is being achieved through validation of the Level 2 products. The ATS_NR_2P GST product contains full resolution nadir-only and dual view SST measurements over sea, whilst the ATS_AR_2P AST product contains ocean parameters that have been spatially averaged (over 50 and 17 km^2 grid cells, or half degree and 10 arcmin cells). The core validation activities will assess whether the SST measurements given in these Level 2 products are being measured to the accuracy and precision expected from the instrument design. Examination of the BT's in the Level 1b product will be an inherent part of this process.

Validation of the visible channels in the Level 1b product is also important, and will be carried out over land and cloud. The vicarious validation work of Smith (Section 10.1.1) is seen as essential to the validation programme and designated a core activity. Also over land, an AATSR LST retrieval is currently being prototyped for inclusion in the Level 2 products. This prototype will be validated during the commissioning phase of Envisat, before a decision is made as to whether to produce it operationally.

The Meteo product (ATS_MET_2P) is an extraction from the AST product, designed for use by meteorological users in near real time. It will be validated by the Hadley Centre as part of their validation activities.

The browse product is intended to provide 3 band colour composite, quick-look images at coarse resolution. Derived from the L1b product, it is not covered specifically by validation activities.

6 AATSR Validation Organisation

As AATSR is an Announcement of Opportunity Instrument, the DEFRA is responsible for its calibration and validation throughout the mission. As part of this responsibility, an AATSR validation scientist (VS) has been appointed. The role of the VS is to ensure that the objectives outlined in Section 4 are achieved. The VS will coordinate and manage a validation programme for AATSR, ensuring validation data are collected and analysed in a timely manner. The VS will act as a single point of contact for reporting the progress/results of the validation programme on behalf of the AATSR team and DEFRA. The validation activities that will be carried out are outlined in Sections 9 and 10, whilst information on what happens to the validation data once collected, is given when the Validation Loop is discussed in Section 15.

The AATSR VS is based at the Space Research Centre, University of Leicester, and works directly alongside the instrument PI, Professor David Llewellyn-Jones.

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6.1 The MERIS and AATSR Validation Team (MAVT)

In order to coordinate and manage the cal/val activities of the Envisat instrument, ESA have set up calibration and validation teams for the different payload instruments (see Figure 6.1-1). Guido Levrini of ESA ESTEC coordinates the cal/val programme as a whole.

AATSR has a calibration team (Figure 6.1-2), which focuses on the engineering aspects of the instrument commissioning and the verification of the data processing software. For validation, AATSR joins with MERIS to form the MAVT, the MERIS and AATSR Validation Team (Figure 6.1-3). In some instances, MERIS and AATSR carry out similar validation measurements, and integration with the MERIS team is useful in that it ensures that AATSR validation activities are firmly integrated into the Envisat validation team. The MAVT is co-ordinated by Evert Attema at ESA ESTEC, helped by Paul Snoeij. Within the MAVT structure, AATSR activities are co-ordinated by the VS. Names listed in each column represent PI's that will be carrying out validation activities. In addition, a number of ESA observers are listed (P.Regner, P.Goryl, and H.Tait).

To aid administration and organisation within ESA, every validation activity is assigned a number. These numbers are 3 digits if the activity is an original AO response, or 4 digits if the activity is additional to the AO response. These numbers have been retained in this document for administrative purposes.

Information for the AATSR validation team is disseminated by the VS via the AATSR validation website, found at http://www.leos.le.ac.uk/aatsr/

It should be noted Figures 6.1-1 to 6.1-3 are applicable for the commissioning phase only.

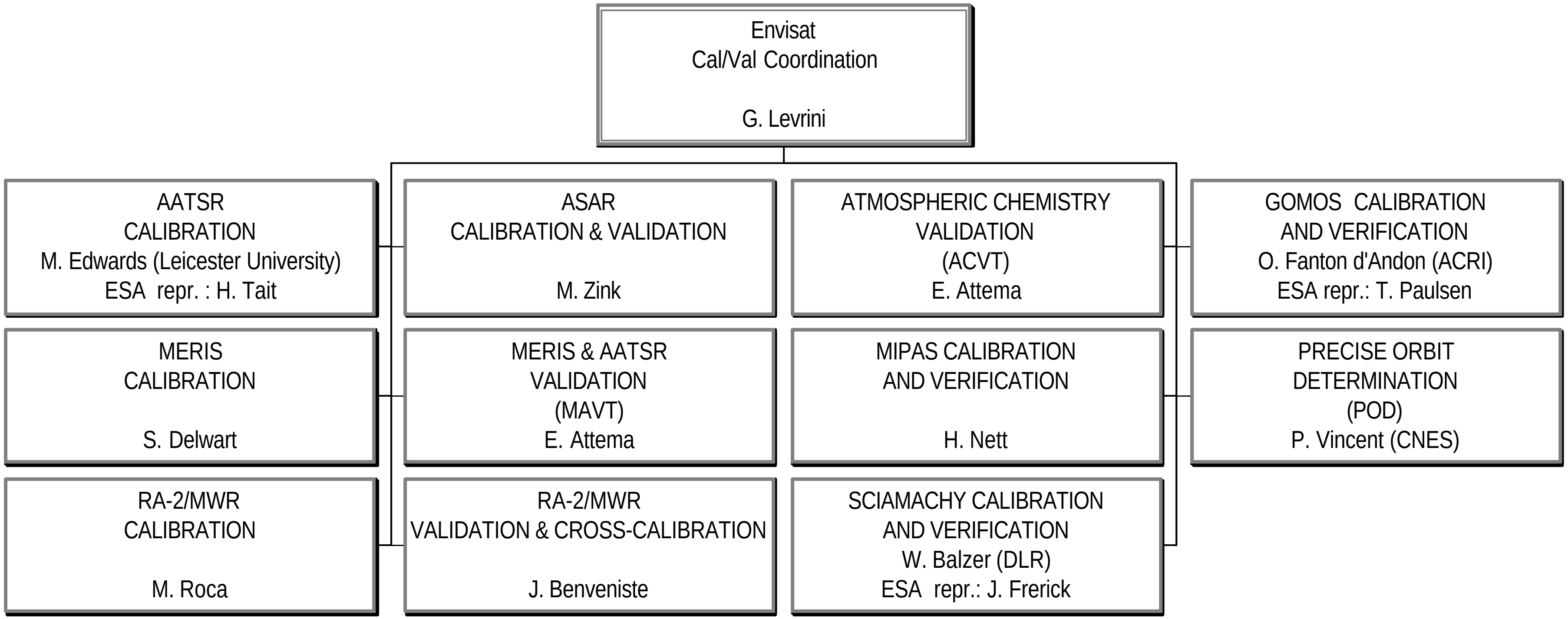

Figure 6.1-1 Organisation of the Envisat Cal/Val Programme

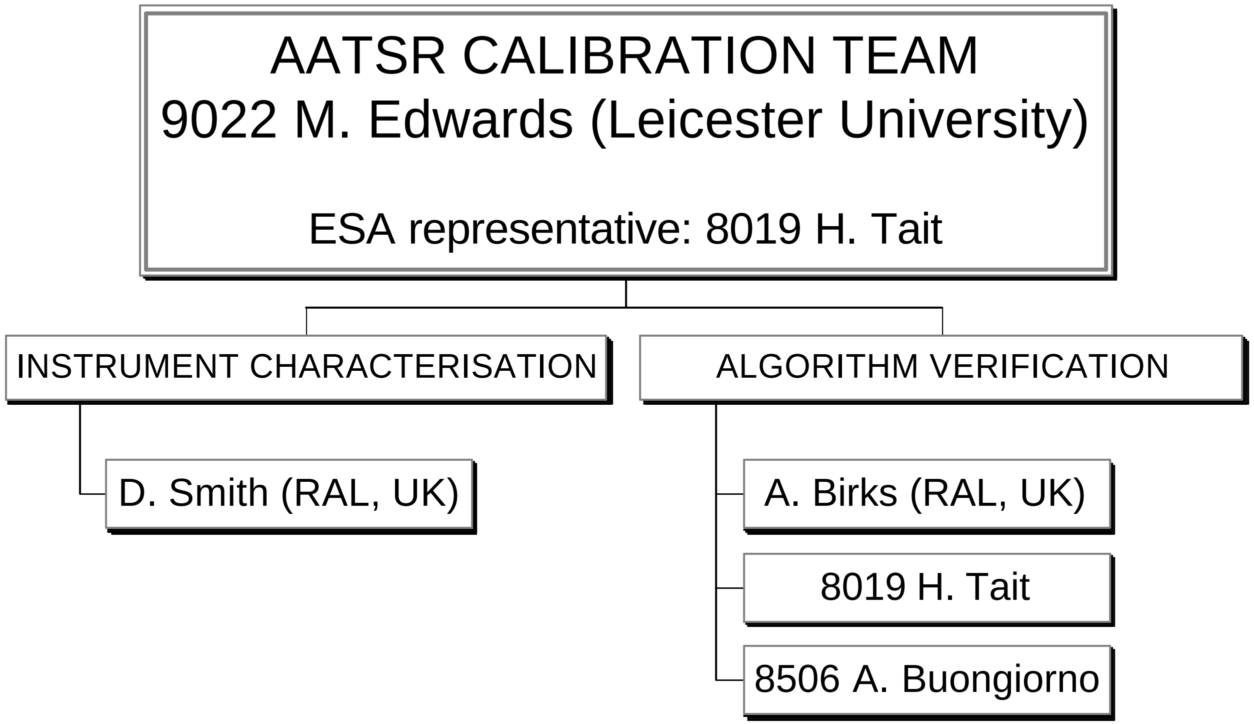

Figure 6.1-2 Organisation of the AATSR Calibration Team

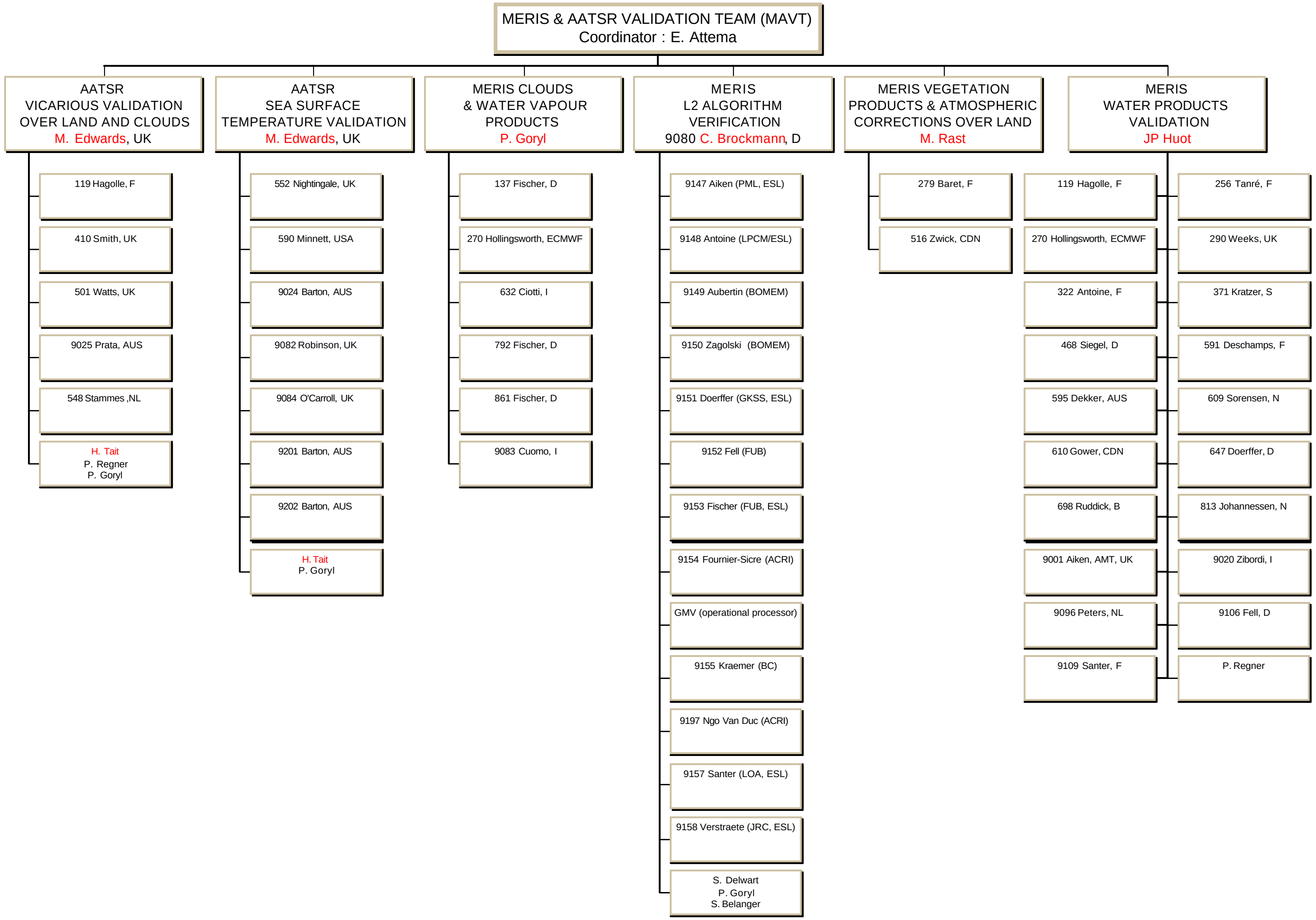

Figure 6.1-3: Organisation of the MERIS and AATSR Validation Team

7 Calibration

Most of the instruments on board Envisat require a series of activities post-launch to calibrate the instrument. AATSR is slightly different in that it is self-calibrating. It has an on-board calibration system, which involves, for the thermal channels, the use of two specially designed and highly stable black-body reference targets, and, for the visible and near infra-red channels, a diffusely reflecting target that is illuminated once per orbit (for more information on AATSR calibration, see AD5 and AD6). As such, calibration of the instrument after launch is not required.

However, as indicated in Figure 6.1-2, there will be specific activities to check and characterize the instrument post-launch. These activities should be completed before validation starts, and are detailed in AD4. The majority of these activities will be carried out during the AATSR SODAP in the first few weeks of the mission, although some will continue further into the commissioning phase after validation has started. At the end of the SODAP, there will also be some algorithm verification activities where data processing algorithms are verified and fine-tuned. These are discussed in Section 8.

The vicarious calibration of the visible channels, where visible channel data from AATSR are compared with data from other instruments, can be classified as either calibration or validation. Within the AATSR validation programme, vicarious cal/val is treated under the title of validation, and is described in Section 10.1.

8 Algorithm verification

Algorithm verification is being conducted by Andrew Birks of the Rutherford Appleton Laboratory, under an Expert Support Laboratory (ESL) contract to ESA.

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8.1 Methodology

Algorithm verification is distinct from instrument commissioning (as described in AD3). Applying to all processed AATSR products, specific objectives of the activity include:

- To verify that the algorithms used by the AATSR Operational Processor (OP) work correctly when presented with AATSR data.
- To verify that the AATSR products are being correctly generated.
- To verify, and if necessary regenerate, auxiliary data files used by the AATSR OP.

It will encompass a variety of different tests including:

Format Verification

Done independently for each product type, it will be verified that:

- MPH is present and has the expected size;
- SPH is present and has the expected size;
- All ADS and MDS types as specified in the IODD are present;
- SPH contains one DSD corresponding to each data set present;
- SPH contains all required reference and spare DSDs;
- Total product size is consistent with the sum of its component data sets, as defined by the Data Set Descriptors;
- Specified MPH field contents have realistic magnitudes;
- Specified SPH field contents have realistic magnitudes.

Content Verification

The contents of the products will be verified. This will include checking the annotation data sets, geolocation and regridding, radiometric checks, and cloud flagging.

More specific details of the tests used for the different products are given in Table 8-1.

Data from AATSR will be compared to ATSR-2, if possible. Time differences between the two instruments will mean that it will not be possible to check all quantities using this method (e.g. cloud flags).

Product	Test Case #	Test
Level 1b	1	GBTR Format verification
	2	ADS #7 (VISCAL) verification
	3	ADS #3 (Pixel Latitude/Longitude) verification
	4	ADS #4 (scan pixel x and y) verification
	5	Solar and viewing angle verification
	6	Scan and pixel number verification
	7	Image plane consistency
	8	Product confidence words
	9	Land/sea flags
	10	Cloud flags
	11	SQUADS verification
	15	GBTR comparison with ATSR-2 data
Browse	12	Browse product format verification
	13	Browse product ADS
	14	Browse product inspection
Level 2 & METEO	21	GSST Format verification
	22	Level 2 ADS
	23	Level 2 Image data
	24	Level 2 SQUADS verification
	25	AST format verification
	26	AST datasets
	27	ABT datasets
	28	METEO product format verification
	29	METEO product dataset
	30	Level 2 image comparison with ATSR-2 data

Table 8-1: Algorithm Verification Tests[1]

The following level 1 processes cannot be verified directly by inspection of the products:

- Telemetry data unpacking
- Infrared calibration coefficients
- Interpolation of image pixel geolocation

To address these issues, specific breakpoints will be requested in the OP. Additional breakpoints may also be requested if higher level tests show a problem requiring more detailed investigation.

A more detailed description of algorithm verification activities can be found in the AATSR Algorithm Verification Plan (AD 11). This document gives details of test objectives, test data, test procedures, test tools, expected test results or pass/fail criteria, and suggestions for corrective action in case of test failure (e.g. detailed breakpoint analysis).

8.2 Reporting

The results of algorithm verification will be reported to ESA on a monthly basis throughout the period of algorithm verification activities. These reports will also be sent to the VS. A. Birks will participate in the validation loop as required.

[1] These tests may change slightly as algorithm verification test cases continue to evolve.

8.3 Schedule

Work on algorithm verification will start immediately after the end of the AATSR SODAP. The results of algorithm verification will feed back into upgrades of the AATSR processing chain at the end of the Commissioning Phase. The target for completion of L1b algorithm verification is L+4 months. L2 algorithm verification should be completed by L+6 months.

At a number of points prior to launch, L0 data obtained directly from the AATSR instrument will be made available. Algorithm verification will include examination of the format of this Level 0 data to ensure that it is consistent with that expected by the data processing system. These data will be further tested by processing through the PP, in such cases where instrument and auxiliary file configurations allow.

9 Validation of Level 2 SST Products

As already discussed, AATSR was designed to measure SST, precisely and accurately. The main aim of the validation programme, therefore, is to assess whether this is being achieved through validation of the Level 2 Gridded Surface Temperature Product, and the Spatially Averaged Surface Temperature Product.

The validation of SST can be done at three different levels.

?? Early indication of gross errors in AST
?? Spot values for gridded data, taken using autonomous instrumentation
?? Precision measurements

Measurements taken under these three headings vary in their frequency, global distribution and accuracy. They are all necessary, and considered "core" validation activities. Figure 9-1 details the PI's leading different projects involved in the three levels of SST validation. Ian Barton of CSIRO is listed several times as he will act as the contact point for all Australian projects. The administrative number of the activity is also listed.

PI's involved in validating SST will validate the SST products, GST and AST. Many have also requested the Level 1b products containing TOA brightness temperatures/reflectance. This will give them the values from which SST has been calculated, and allow assessment of surface conditions and the SST retrieval. The Level 1b product is provided to PI's for anomaly investigations, rather than the derivation and application of new SST retrievals.

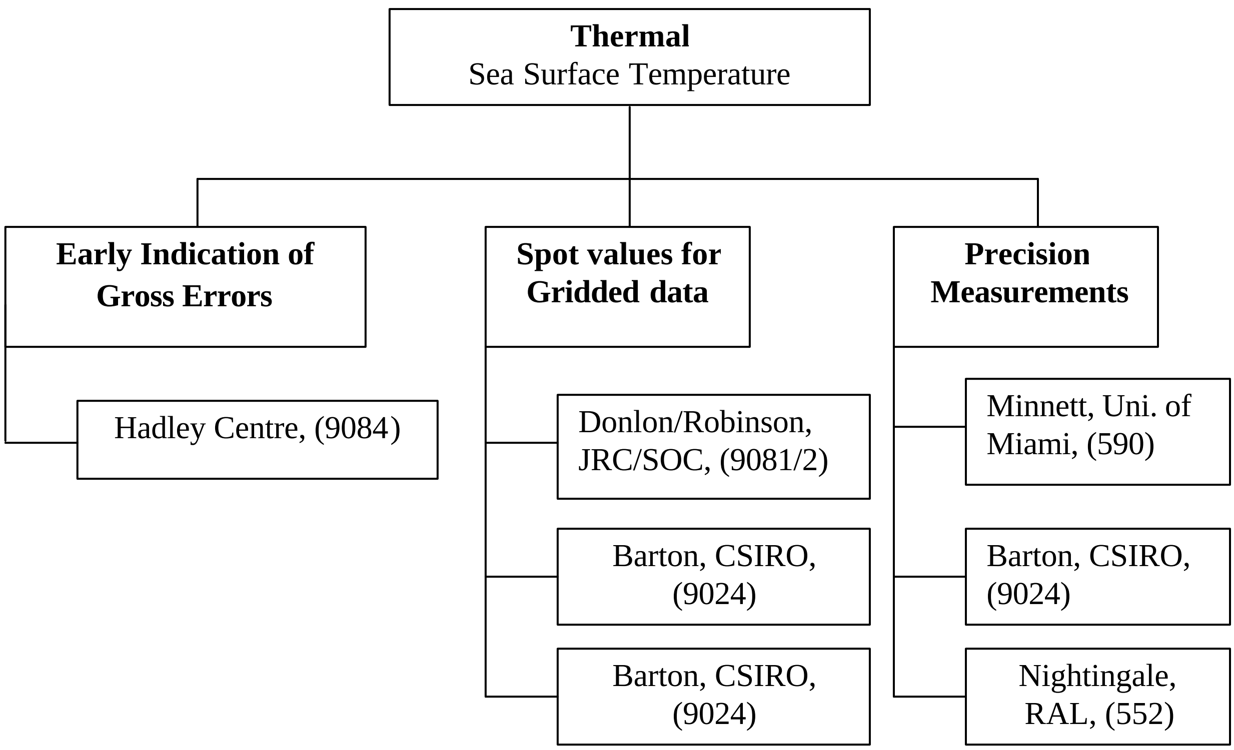

Figure 9-1: Levels of Validation for validating AATSR SST data products, and the PI's involved in each activity.

9.1 Level 1: Global Buoy Comparison including early indication of gross errors in AST data

Many of the early errors in SSTs produced from ATSR-1 and ATSR-2 data were detected using systematic comparisons with buoy data and SST analysis fields. This is a good method of detecting gross errors in SST at an early stage, and is advantageous in that it can be carried out at a global scale and without field data collection campaigns.

9.1.1 Derivation of bulk SST from AATSR SST, and comparison to model SST's and buoy data, Met Office/Hadley Centre (9084)

The Met Office will derive bulk SSTs from the skin SSTs. They will use the METEO product, a near real time subset product of the AST containing SST and averaged BT for all clear sea pixels. The METEO product is provided to the Met services in BUFR format.

The key staff involved in this activity are:

Principal Investigator (Contact): Roger Saunders
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Roles:

- Roger Saunders acts as the project manager and is the main point of contact.
- Anne O'Carroll
    - Code development and testing of NRT (A)ATSR processor
    - AATSR Validation (MET Office datasets, NILU, monthly reports)
- Lisa Horrocks
    - Inclusion of thermocline model into NRT (A)ATSR processor
    - Studies into skin effect modelling
    - AATSR validation (BUOYS)

In addition, a new member of staff will be joining the Met Office in the summer 2002, to work on the AATSR level 1b archive. Nick Rayner at the Hadley Centre will be utilising the AATSR bulk SST's in the Met Office HadiSST analysis.

9.1.1.1 Methodology

The Met Office will derive bulk SST from the AATSR observed skin SST, using surface wind and fluxes of heat and momentum from operational global NWP analyses. The skin to bulk correction will be applied to the near real time AST product.

It is planned, after careful monitoring, to assimilate the derived bulk SSTs into the new HadISST analysis scheme, along with in situ data, using Laplacian techniques and optimal interpolation, similar to the way in which AVHRR MCSSTs are assimilated. The HadISST analyses are globally complete SST and sea-ice monthly fields at 1? spatial resolution, available one month behind time.

The steps of the processing chain are:

1. Retrieve and decode AATSR near-real-time BUFR data
2. Compute skin SST's (10' ? 10') from brightness temperatures
3. Combine (10' ? 10') AST data into 0.5? ? 0.5? data (if required)
4. Retrieve and interpolate (in space and time) the fluxes to drive the models of the skin effect and diurnal thermocline, and other fields required for quality control. This can be done over the full instrument swath.
5. Quality control incoming AATSR AST data.
6. Calculate value of delta-T (skin) from parameterisation of skin effect using model fluxes.
7. Calculate value of delta-T (sub-skin to 1m depth) from model of diurnal thermocline, using history of fluxes to set a diurnal thermocline flag if computations show a significant thermocline is likely.
8. Quality control output of skin and thermocline models.
9. Write out record of bulk SST, skin SST, latitude, longitude, time, across-track distance, delta-T's, quality control information, heat fluxes, brightness temperatures.
10. Retrieve buoy data and match in space and time with AATSR data. Produce NRT matchup file.
11. Retrieve offline buoy data (e.g. TOA array) and match with AATSR swath. Produce offline matchup file.

In addition to processing AATSR data in near real time, the same chain can also be used for processing ATSR-1/2 data, offline. The flexibility of using fluxes from an NWP model other than the Met Office's will be included (e.g. ECMWF reanalysis fields).

The METEO product provides the Met Office with both SST values and spatially averaged brightness temperatures (BT) for all clear sea pixels, in 10 arc minute cells. The processing and data analysis system set up by the Met Office is designed to be totally flexible. It takes the AATSR BT values, applies SST coefficients and thus generates SST values. Whilst the Met Office may generate and test new coefficients, they confirm that for validation purposes, the 'official' SST coefficients will be used.

The Met Office will also be carrying out cross comparisons between ATSR-2 and AATSR. The methodology for this is still TBD.

9.1.1.2 Validation results and deliverables

Results from validation activities at the Met Office will be available in different ways. On the Met Office website, there will be:

?? Daily maps showing bulk/skin SST, skin delta T, thermocline, NWP fluxes and error estimations.

?? Every 5 days: Time series of regional/global means (and standard deviations) of the difference between AATSR SSTs (both skin and bulk), and the MohSST pentads (in situ observations at 5? spatial resolution). The purpose of this comparison at the pentad resolution is to highlight sudden gross changes in the instrument performance.

?? Every 5 days and monthly: Global maps of the differences between AATSR SST's and the MohSST pentads (as above).

?? Monthly: Monthly mean maps of the bias/standard deviation of the difference between AATSR skin/bulk SST's and HadISST (an SST dataset compiled from in-situ and AVHRR data, at 1? spatial resolution). This will be a much finer comparison than the weekly checks, and will detect not only instrument problems but also levels of accuracy and any regional anomalies. Statistics will be compiled with a lag of one month since the preliminary NRT HadiSST datasets need to be compiled by the Hadley Centre first.

?? Monthly: Match-up datasets of skin/bulk SST's and drifting/fixed buoy SST's. A subset of these buoy matchups will be uploaded every month to the NILU database.

?? Monthly: Summary reports outlining validation activities and significant results.

9.1.1.3 Geographical Location

The Met Office will validate AATSR data over the oceans on a global scale subject to availability of global data from the satellite (i.e. no blind orbits), and the inevitable limitations of using in situ observations.

9.1.1.4 Data Requirements

?? The Hadley Centre requires the ENVISAT AATSR Meteo Product (ATS_MET_2P) in Near Real Time (within 24 hours of measurement time).

?? All orbits are required.

?? Orbits will be FTP'd from ESA.

9.1.1.5 Schedule

The Hadley Centre will work to the overall schedule outlined in Section 14. Up until launch, work will be carried out coding and updating the Met. Office AATSR Near-Real Time processor. The processor will receive cloud-cleared AATSR ABT data, calculate the skin SST, and apply the skin effect and diurnal thermocline models to estimate bulk SST.

9.2 Level 2: Spot values for validating GST data

Validation will also take place using autonomous measurements from instruments on board ships of opportunity. These will provide spot values for validating SST gridded data (GST).

9.2.1 Infrared Sea surface skin temperature Autonomous Radiometer (ISAR5C) system (9082)

One of the instruments that will be used for Level 2 validation is the ISAR5C, designed by Dr Craig Donlon of JRC, and developed in conjunction with Southampton University.

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Co-Investigators:

Mike Reynolds, BNL
Dr Tim Nightingale, RAL

9.2.1.1 Instrumentation

ISAR5C is a precision, autonomous, self-calibrating infrared radiometer, capable of measuring in situ sea surface temperature (SSST) accurate to ? 0.1K rmse, as demonstrated at the recent CEOS-RSMAS radiometer intercalibration exercise (see Figure 9.2.1.1-1). The ISAR5C radiometer uses two precision calibration black body (BB) cavities to maintain the radiance calibration of a solid state infrared detector having a spectral window of 9.6-11.5? m. All ISAR5C target views are made using a single route optical path via a protective scan drum arrangement that allows the target view to be accurately positioned over a range of 180?. The BB apertures are completely sealed from direct water ingress using a patent pending shutter mechanism triggered by an optical rain sensor that completely seals the ISAR5C from the external environment. This is important in order to protect the instrument on deployments of up to 3 months. The high quality rain sensor is also used to determine the position of the ISAR5C in relation to recent rain events where cooler freshwater would be expected at the sea surface, further complicating the relationship between the SST at depth and that observed by AATSR.

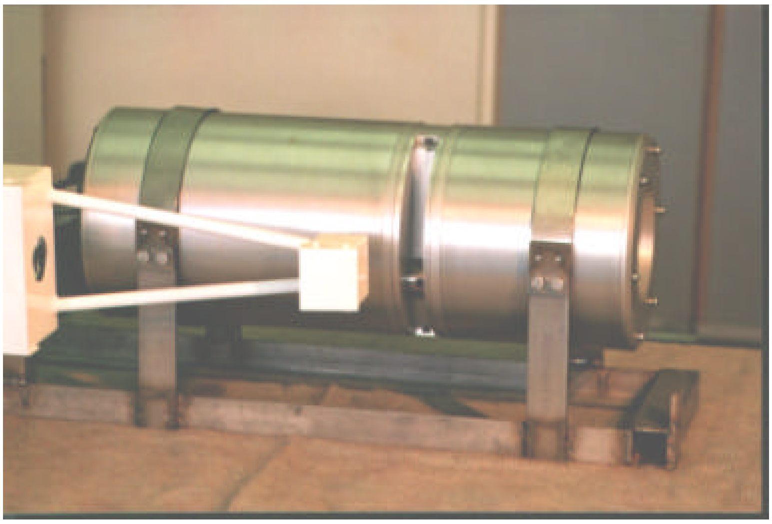

Figure 9.2.1.1-1 The Infrared Autonomous SST Radiometer (ISAR5C) shown together with the optical rain gauge in place. The rain gauge is used to control the opening/closing of a shutter system that seals the instrument from rain and sea spray during bad weather. The shutter is open in this picture revealing the small viewing aperture and scan drum assembly.

The ISAR5C system has been designed from the outset to provide a total solution to the needs of satellite validation work. It has a dedicated fully configurable RS-485 port that can be used to connect other sensors required to place the radiometer measurements into an ocean-atmosphere context. For the validation of AATSR, the ISAR5C system has been configured to log solar radiation, air temperature and humidity. Additional supporting data collected independently of the ISAR5C system include bulk SST determined from a SBE-48 hull mounted (internal) sensor and wind vectors from a Gill Windmaster 3 axis sonic anenometer. The maximum deployment of an ISAR5C instrument is 3 months although experience suggests that the ISAR5C, like any other oceanographic instrument, should be thoroughly checked at 1-month intervals for problems.

9.2.1.2 Methodology

For validation during the commissioning phase, ISAR5C will be installed on a Brittany Ferry, the Val De Loire. Two instruments will be used in tandem, one deployed on the Ferry and the second returned to the laboratory for service, maintenance and re-calibration.

In situ data

- As the Ferry continues normal operating duties, ISAR5C will provide measurements of SST at 3-minute intervals. The SST data will be derived as an integrated average over a 1 minute period and include full correction for sky reflections at the sea surface, calibration and ancillary engineering data.
- An automatic CDWR backup of each day's data will be made every night. Complete data download will depend on access to the ship and may incur a delay of up to 3 months depending on vessel operations.
- The quality of the data will be maintained via mandatory pre and post deployment calibrations (using a CASOTS-BB and a NIST standards traceable thermistor, maintained at SOC specifically for this purpose), and by periodic cross deployment with the SISTeR

instrument. Each ISAR5C will undergo a complete service and parts replacement according to a maintenance schedule following every deployment.

Co-location with AATSR data

- AATSR data will be extracted and ship track will be overlain.
- All AATSR data within ± 1 hour of ship position and within ± 25km will be automatically extracted.
- A detailed analysis of contemporaneous ship and AATSR data will be performed on a case-by-case basis at the highest spatial and temporal resolution possible, taking into consideration all available data (e.g. visual observations, other satellite data (RA2), ship logs etc).
- The matchup data and monthly reports will be sent to the VS, and will enter the validation loop. Correlative measurements will be entered into the NILU database.

9.2.1.3 Geographical Location

During the commissioning phase, the ISAR5C will be installed on the Val De Loire, a Brittany Ferry (Figure 9.2.1.3-1). The Ferry has different routes seasonally. These are listed, together with the ferry times, in Table 9.2.1.3-1. The routes are shown in Figure 9.2.1.3-2.

Although testing of the system on the ferry will have taken place, at the time of Envisat launch, the Val de Loire Ferry will be port for a refit. The refit will be complete on 10th March. ISAR5C will then be installed and the commissioning phase deployment will begin.

Winter Schedule	**Summer Schedule**
November 11th to February 11th	**March 11th to November 11th**
Portsmouth <> Caen	**Plymouth <> Santander**
<< Mon 16:30 – Mon 21:20	>> Mon 08:30 – Tues 09:00
>> Mon 23:15 – Tues 6:30	<< Tues 11:00 – Wed 09:00
<< Tues 08:00 – Tues 13:00	>> Wed 12:00 – Thu 12:30
>> Tues 14:30 – Tues 21:30	<< Thu 14:30 – Fri 12:30
<< Tues 23:15 – Wed 06:00	
>>Wed 07:45 – Wed 14:45	**Plymouth > Roscoff**
<<Wed 16:30 – Wed 21:30	>> Fri 14:30 – Fri 21:30
>>Wed 23:15 – Thu 06:15	
<< Thu 08:00 – Thu 13:00	**Roscoff <> Cork**
>> Thu 14:30 – Thu 21:30	>> Fri 23:30 – Sat 13:00
<< Thu 23:15 – Fri 06:00	<< Sat 15:30 – Sun 08:00
>> Fri 07:45 – Fri 14:45	
<< Fri 16:30 – Fri 21:30	**Roscoff >> Plymouth**
>> Fri 23:15 – Sat 07:30	<< Sun 12:00 – Sun 17:00
<< Sat 13:30 – Sat 16:30	
>> Sat 23:15 – Sun 08:00	
<< Sun 23:15 – Mon 07:30	

Table 9.2.1.3-1 Schedule of the Val De Loire

Figure 9.1.3.2-1: The ISAR5C instrument is installed on the Brittany Ferry, the Val de Loire.

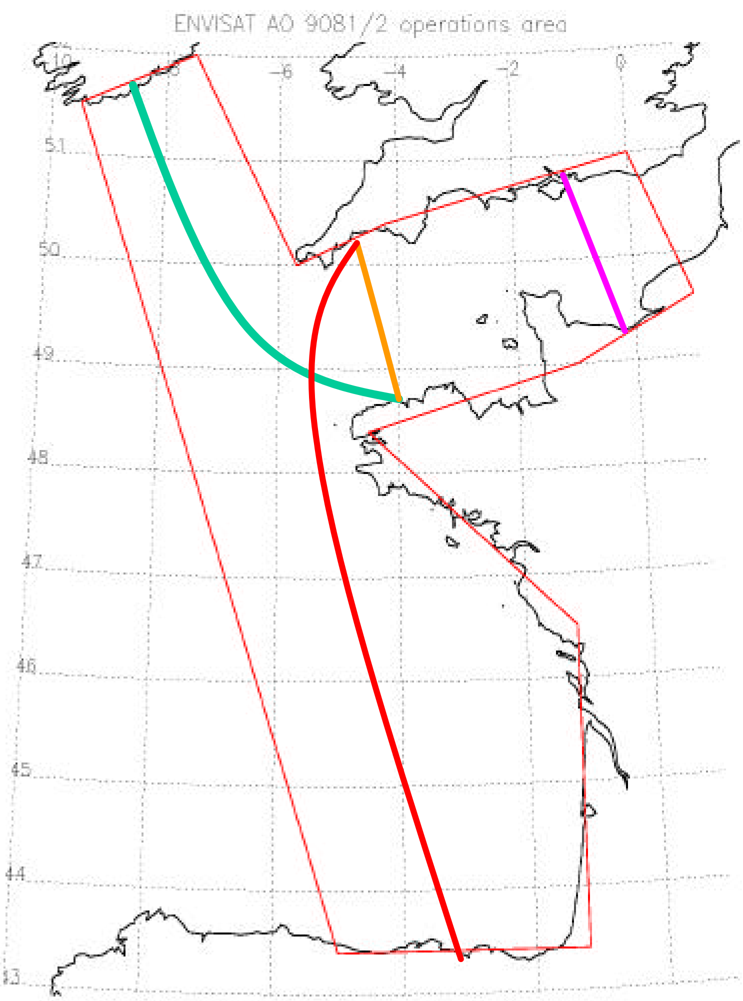

Figure 9.2.1.3-2: Routes of the Val De Loire Brittany Ferry, which will carry the ISAR5C instrument to make measurements of SSS for AATSR validation

The polygon is defined by the coordinates:

51N, 0W
49.6N, 1E
49N, 1W
48.4N, 4.5W
46.5N, 1.2W
43.4N, 1.2W
43.4N, 5W
51.5N, 9.5W
52N, 7.5W
50N, 5.7W
50.4N, 4.2W
51N, 0W

While deployments during the commissioning phase will focus on the area covered by the Brittany Ferries, negotiations will continue with ferry companies/merchant ships operating over a wider geographical coverage for post-commissioning phase deployments. It will be a priority to ensure these passages include a broad range of atmospheric and oceanic conditions although the constraints of ship and passage availability may preclude optimal passage routes. Ideally these should operate from Southampton or Portsmouth facilitating access to the ship, and call to places where project contacts are available to provide maintenance and support to the ISAR5C system. Final discussions with Wallenius Lines to use the M/V Walstaff on a regular passage between Europe and the United States are nearing completion and in collaboration with the US coPI, at least one ISAR5C instrument is expected to operate on this route before the end of 2002. Target calls include Miami, USA (University of Miami, RSMAS, Dr. P. Minnett), Seattle, USA, (University of Washington, APL, Dr. A. Jessup), Hobart, Tasmania (CSIRO, Dr. I. Barton).

Post-commissioning, it may be possible to operate both ISAR5C's simultaneously on separate ferries although there is a risk that both ISAR5C's sustaining damaged due to extreme weather resulting in no validation data being available for as repair or replacement is undertaken.

9.2.1.4 Pre-launch ISAR5C Activities

Table 9.2.1.4-1 details key ISAR5C activities in the two years prior to Envisat launch.

Key ISAR5C Activity	Date
ISAR5C-1 prototype built	Jan 2000
ISAR5C-1 successfully completed a 4 week shore side test at SOC	October 2000
Revised ISAR5C version 5C design released	May 2001
Prototype operational software completed	April 2001
ISAR5C-1 participated in the Miami radiometer intercomparison	May 2001
ISAR5C-2 commissioned	July 2001
New ISAR5C electronics design	August 2001
Purchase of equipment commenced	September 2001
Revised ISAR5C operational software	November 2001
ISAR5C-1 installed on the Val de Loire Ferry	January 2002

Table 9.2.1.4-1: Key ISAR5C activity pre-launch

9.2.1.5 Data Requirements

- The following AATSR data products are required:
  ATS_TOA_1P
  ATS_NR_2P
  ATS_AR_2P
- Additional data products needed are:
  RA-2_WWV_2P products
  RA2_GDR_2P products
- Data needed are offline.

Address to where data should be sent

Professor Ian Robinson
Address as above

Dr Craig Donlon
Address as above

9.2.1.6 ISAR5C Schedule

Robinson/Donlon will work to the overall schedule outlined in Section 14. In terms of the two ISAR5C instruments, the draft schedule is as detailed in Table 9.2.1.7-1:

Date (2002)	Draft Schedule
27 January	Pre-deployment ISAR5C-01 calibration
Jan-February	ISAR5C-01 shakedown deployment on Portsmouth-Caen route (ATSR-2).
10 February	VDL into refit until Mar10; new route Santander-Plymouth-Roscoff-Cork
11 February	Post deployment calibration of ISAR5C-1 and shakedown assessment
1 March	ENVISAT launch (L+0)
3-10 March	ISAR5C-02/3 integration and calibration workshop @ SOC
11 March	Start of commissioning phase 1 deployment only ATSR-2 data available
1 May	Pre cruise calibration of ISAR5C-2
11 May	ISAR5C-1 replaced by ISAR5C-2.
12 May	Post cruise calibration of ISAR5C-1 which then begins refurbishment
1 July	Pre cruise calibration of ISAR5C-1
11 July	ISAR5C-2 replaced by ISAR5C-1
12 July	Post cruise calibration of ISAR5C-2 which then begins refurbishment
1 August	Completion of commissioning phase 1 deployment; start of phase 2 (L+6)
1 September	Pre cruise calibration of ISAR5C-2.
11 September	ISAR5C-1 replaced by ISAR5C-2
12 September	Post cruise calibration of ISAR5C-1 which then begins refurbishment
20 September	Completion of commissioning phase 1 data analysis
1 November	Pre cruise calibration of ISAR5C-2
11 November	ISAR5C-1 replaced by ISAR5C-2
12 November	Post cruise calibration of ISAR5C-1 which then begins refurbishment
December	Final report, and presentation of results at validation workshop

Table 9.2.1.7-1 Draft schedule for ISAR5C-1 and ISAR5C-2 activities

9.2.2 The Rottnest Island Ferry in Perth, Barton (9024)

Validation measurements are being collected by an infrared radiometer fitted to a passenger ferry that operates on a daily basis between the Perth coast and Rottnest Island, 25km offshore.

Principal Investigator: Dr Ian Barton
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Co-Investigator: Mr Alan Pearce
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PO Box 20, North Beach
Western Australia WA 6020
Alan.Pearce@csiro.au

9.2.2.1 Instrumentation

The Rottnest Island passenger ferry carries a TASCO infrared radiometer (HORIBA IT-340), which is housed in a well-sealed tube located in a semi-protected area near the bridge of the ferry, as well as a PRT sensor in the engine intake system for "bulk" temperature measurements. As the ferry makes the 25 km return trip between Hillarys Marina and Rottnest Island, both the TASCO and the PRT temperatures are recorded together with date/time and a GPS position. A second infrared radiometer has been installed at the CSIRO laboratories near the coast to sense the downwelling sky radiance and thereby allow for the reflected sky radiance correction.

Data are automatically logged onto a datalogger at 10-second intervals and are downloaded onto computer on a weekly to fortnightly basis. From time-to-time, the objective lens of the radiometer requires replacement due to salt corrosion. The infrared radiometers are calibrated against an accurate portable black body at about monthly intervals, and the bulk temperature device is calibrated against a standard thermometer. At times when the conditions are not suitable, the radiometer system can be covered to avoid excess spray. The facility will shortly be upgraded to overcome some of the operational problems, which have been experienced. Wind measurements are also available from shore weather stations at Hillarys Marina and Rottnest Island.

9.2.2.2 Methodology

1. **Instrument installation:** The TASCO radiometer is fitted to the Rottnest Island passenger ferry SeaFlyte, with a clear beam view of the sea. It samples in the 8 to 12 µm range.
2. **Validation Data Collection:** The ferry travels daily between Hillarys Marina and Rottnest Island (32°S), with different schedules in summer and winter. On a typical daily schedule, the ferry departs at 0900 and 1430 daily, with a travel time to the Island of 40 minutes. On the transect, the datalogger records both TASCO and PRT measurements at 10-second intervals, and after downloading, 1-km averages are computed along the track.

3 **Data Download:** Once a week or fortnight, the instrumentation is checked and maintained, and data are downloaded.
4 **Satellite data ordering and collection:** Co-incident AATSR will be received
5 **In situ/satellite data matchups:** High resolution (1km) AATSR data contemporaneous with valid TASCO data are required to perform a satisfactory validation study. Matchups between SST measurements collected by the TASCO and cloud free AATSR imagery will be made at Marmion. These data will be emailed to the validation scientist, and will enter the 'validation loop'. Validation reports will be sent to the VS on a monthly basis.

9.2.2.3 Geographical Location

Validation measurements will be collected in Perth, Australia, along the Hillarys - Rottnest Island transect (25 km). Only daytime data will be collected. This is located at 31.8° S, 115.8°E to 32.0°S, 115.5°E. Figure 9.2.2.3-1 shows a map of the transect along which validation data will be collected.

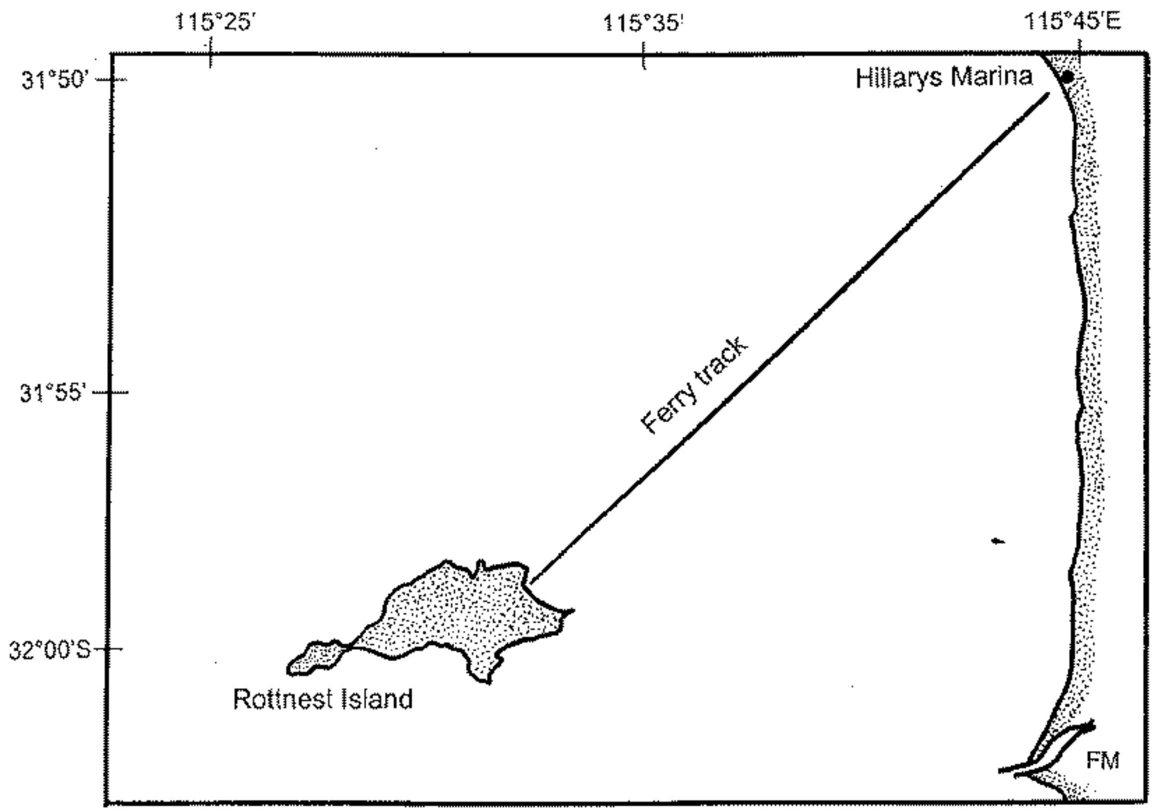

Figure 9.2.2.3-1 Ferry transect along which validation data will be collected with the TASCO radiometer

9.2.2.4 Planned Validation Activities

Following upgrades, the TASCO radiometer will be re-installed at the end of February 2002. It will remain on the Rottnest Island Ferry throughout the commissioning phase.

9.2.2.5 Data requirements

?? The following AATSR data products are required:

ATS_TOA_1P
ATS_NR_2P

- Data volume: 512 x 512 scenes of ATS_TOA_1P and ATS_NR_2P for every daytime pass over the ferry transect.
- Data needed are offline.

Address to where data should be sent

Dr Ian Barton
CSIRO Marine Research
Castray Esplanade
Hobart, Tasmania 7000
Ian.Barton@csiro.au

9.2.2.6 Interfaces

The PI will interface with a number of parties.

Interfaces	With whom	Reason	Timing
1	Validation Scientist	?? Help with NILU submission ?? Send validation results (in situ/satellite data matchups) ?? Participation in Data Quality Group	As required. Monthly As required
2	ESA	?? Order and receive AATSR Data	
3	NILU	?? Weekly uploads of ferry data, approx. 50 Kbytes.	Weekly

9.2.2.7 Schedule

Validation data collection on board the Rottnest Island Ferry will follow the overall validation schedule described in Section 14.

9.2.3 The wave-piercing ferry in Townsville, Barton (9201)

Validation measurements will be collected using an infrared radiometer fitted on a wave-piercing catamaran ferry.

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Co-Investigator: Dr William Skirving
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9.2.3.1 Instrumentation

An infrared radiometer system, based on an Everest radiometer, has been developed by the Australian Institute of Marine Science (AIMS). It has in-built black body targets, and is installed on the Island Pearl Ferry[2] (see Figure 9.2.3.1-1), which operates between Townsville and Kelso reef on the Great Barrier Reef. The ship design allows an almost vertical view of the sea surface which is undisturbed by the ferry's wake. A view of 30 degrees to the vertical is used to ensure that reflections from the ship do not contaminate the reflected sky radiance. The ferry also carries a bulk temperature measuring system, and surrounding buoys provide measures of air and sea temperature, wind and solar radiance every 30 minutes. Currently, the sky radiance is calculated using an atmospheric transmission model with radiosonde data from Townsville airport, which is close to the coast. Radiosondes are launched at approximately 0900 local time daily.

[2] In early 2002, the radiometer was transferred from the Pure Pleasure Ferry to the Island Pearl ferry. The Island Pearl is a catamaran ferry following a similar route to the Pure Pleasure.

Figure 9.2.3.1-1: A catamaran similar to the Island Pearl that will operate between Townsville and the Kelso Reef, carrying an infrared radiometer designed to collect measurements for the calculation of sea surface temperature.

Figure 9.3.2.1-2: The Everest Radiometer fitted to the bow of a catamaran operating from Townsville to the Great Barrier Reef.

9.2.3.2 Methodology

1. **Instrument installation:** The Everest radiometer is fitted to the bow of the Island Pearl Ferry.
2. **Validation Data Collection:** The Ferry travels from Townsville to Kelso Reef, a distance of 90 km at between 9.00 and 11 am every day, 5 or 6 days a week. On the transect, the radiometer records measurements at 8-14? m wavelengths, at single

waveband intervals. The system averages over one minute. A bulk SST measurement, a pyrgeometer output and local radiosondes give an emissivity correction.

3. **Data Download:** Once a week, the instrumentation is checked and maintained, and data are downloaded daily.
4. **Satellite data ordering and collection:** Coincident AATSR data will be obtained.
5. **In situ/satellite data matchups:** High resolution (1km) AATSR data contemporaneous with valid Everest data are required to perform a satisfactory validation study. Matchups between in situ SST measurements and cloud free AATSR imagery will be made at AIMS. These data will be e-mailed to the validation scientist, and will enter the 'validation loop'. Validation reports will be sent to the VS on a monthly basis.

9.2.3.3 Geographical Location

Validation measurements will be collected on a 90km transect between the Australian coast at Townsville and the Great Barrier Reef. This is at 19.2 S to 18.5 S along 147.0 E. During the austral winter months, this area has an extremely low level of cloud cover, which will ensure that many data coincidences between ship and satellite data occur.

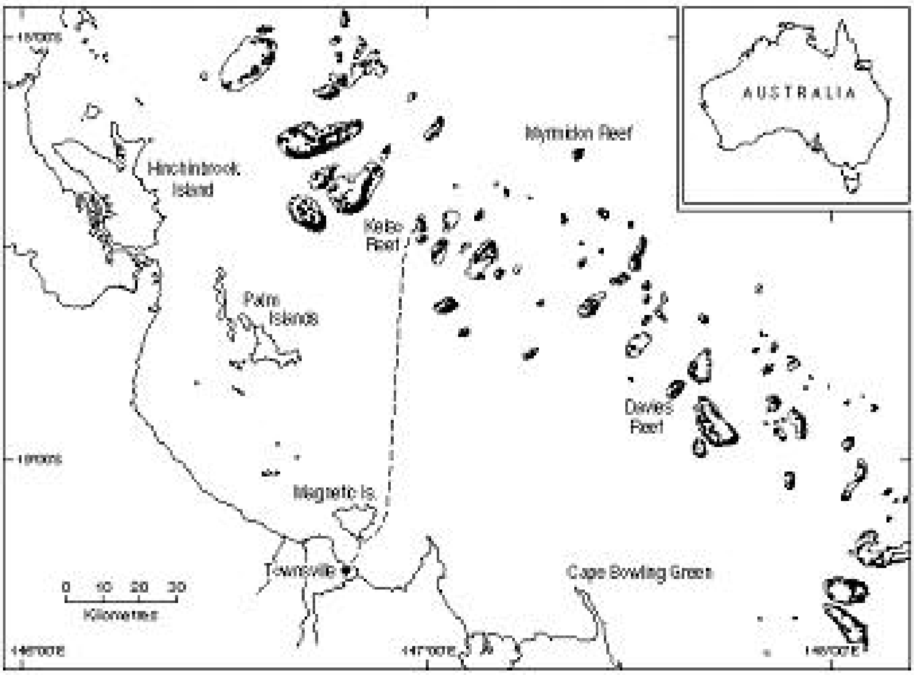

Figure 9.2.3.3-1 Location of the validation activities operating from Townsville to the Great Barrier Reef.

9.2.3.4 Planned validation Activities

Data from the Everest radiometer are already being collected and used for the validation of SST measurements from ATSR-2. This activity will continue with AATSR on ENVISAT.

Previously installed on the Pure Pleasure Ferry, the radiometer will be installed on a new ferry, the Island Pearl, following upgrades at the end of February 2002. This ferry follows the same route as the Pure Pleasure ferry, and has a wake that stays close to the side of the ferry enabling a good clear view of the water.

9.2.3.5 Data requirements

- The following AATSR data products are required:
  ATS_TOA_1P
  ATS_NR_2P
- Data volume: 512 x 512 scenes of ATS_TOA_1P and ATS_NR_2P for every daytime pass over the ferry transect.
- Data needed are offline.

Address to where data should be sent

Dr Ian Barton
CSIRO Marine Research
Castray Esplanade
Hobart, Tasmania 7000

9.2.3.6 Interfaces

The PI will interface with a number of parties.

Interfaces	With whom	Reason	Timing
1	Validation Scientist	?? Help with NILU submission ?? Send validation results (in situ/satellite data matchups) ?? Participation in Data Quality Group	As required. Monthly As required
2	ESA	?? Order AATSR Data ?? Receive AATSR Data	
3	NILU	?? Weekly uploads of ferry data, approx. 50 Kbytes. ?? Downloads of data from other validation exercises.	Weekly As required

9.2.3.7 Schedule

Validation data collection from Townsville will follow the overall validation schedule described in Section 14.

9.3 Level 3: Precision Measurements for validating GST data

On the third level, validation will take place using radiometers specifically designed to take measurements of a high precision. These instruments are generally not autonomous and as a consequence, provide fewer data points and a limited coverage. Data, however, are very accurate, and supplements information given from Level 1 and Level 2 validation activities.

9.3.1 SISTeR, Nightingale (552)

SISTeR is a precision radiometer developed by Dr Tim Nightingale of RAL. It has been used for the validation of ATSR and ATSR-2 data, and will be involved in making measurements for validating AATSR. For more information on SISTeR, see http://www.atsr.rl.ac.uk/validation/, and the references listed below.

Principal Investigator: Dr Tim Nightingale
Space Science and Technology Department
Rutherford Appleton Laboratory
Chilton, Didcot
Oxon, OX11 0QX
T.J.Nightingale@rl.ac.uk

Co-Investigators: Dr Chris Mutlow, RAL
Dr Marianne Edwards, University of Leicester
Dr Craig Donlon, JRC

9.3.1.1 Instrumentation

The Scanning Infrared Sea surface Temperature Radiometer, SISTeR, is a compact and flexible, self-calibrating radiometer, specifically designed for research in a maritime environment. It measures approximately 20 x 20 x 40 cm, and weighs about 20kg. SISTeR is shown in Figure 8.3.1.1-1.

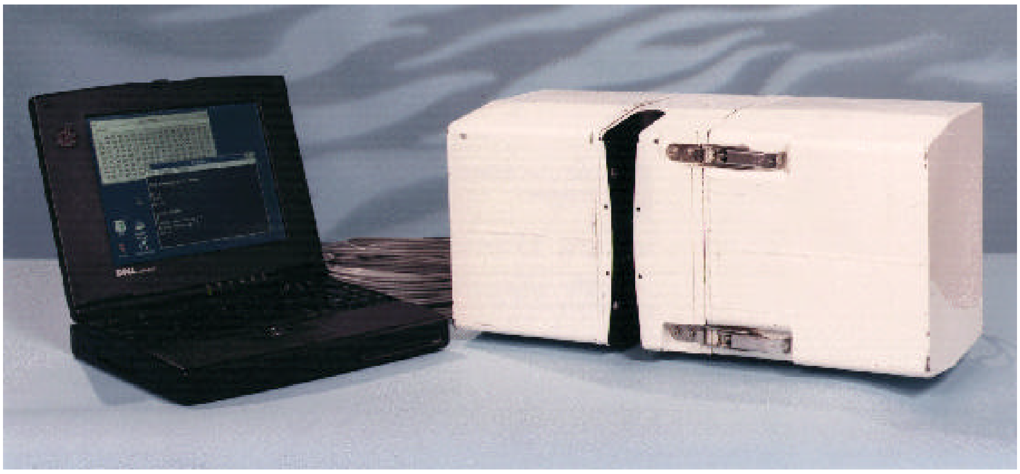

Figure 9.3.1.1-1: The SISTeR radiometer and supporting equipment (taken from http://www.atsr.rl.ac.uk/validation/sister/sis_inst/)

The instrument is divided into three compartments containing the fore-optics, the scan mirror and reference black bodies, a small format PC with signal processing and control electronics. The fore-optics compartment contains a DLATGS pyroelectric detector and preamplifier, mounted onto an assembly containing a concentric 6-position filter wheel and a black rotating chopper. The filter wheel contains three narrow-band filters centred at 3.7µm, 10.8µm and 12.0µm, matching those in the ATSR instruments. The beam is chopped at 100Hz, a compromise between the optimum noise performance of the detector and a fast filter response in the signal processing chain. The main optical element is an ellipsoid mirror, by which the detector can view a 45° scan mirror through an anti-reflection coated ZnSe window.

All external radiance measurements are calibrated using two internal black bodies, operated at ambient temperature and at a programmable increment (typically 10 K) above ambient temperature. Each black body contains an embedded rhodium iron thermometer and is calibrated complete against a standard thermometer. External views can be programmed in fine increments at angles in a range spanning 180? from nadir to zenith.

9.3.1.2 Methodology

1. **Instrument development and testing:** SISTeR has been used on a number of validation campaigns already, collecting validation data points for the ATSR-2 instrument. Between deployments, the instrument undergoes extensive cleaning and maintenance, and calibration activities.

2. **Organisation of cruises/negotiation with ships-of-opportunity:** Negotiations with ships-of-opportunity take place, making use of both pre-existing contacts and new opportunities. Cruise availability and the participation of SISTeR are confirmed. Ancillary instruments that will be needed are identified, and acquired (by purchase, loan or hire).

3. **Instrument packing and shipping:** SISTeR is packed and arranged for shipping, with all required documentation, at times and places agreed with the cruise operator.

4. **Installation:** The SISTeR is generally mounted as far forward and as high as possible on the host ship, so that it is clear of "green water" and spray, and can view undisturbed water forward of the bow wave. Where possible, the viewing angle to the sea is kept within the range 15° - 40° from nadir. The instrument also requires a clear view to the sky at the complementary angle from zenith.

   The SISTeR is equipped with a quick release mount and is provided with a small turret, to which a mating bracket is attached. The turret should be mounted on a horizontal surface with a pattern of eight holes. A small horizontal platform, with the pattern pre-drilled, is also available and can be attached to handrails with U-bolts.

   The SISTeR requires 24V DC power and serial data connections. Instrument data are logged remotely on a laptop PC. Waterproof power supplies, serial modems and cable sets are available for runs of 100m or more with terminations for a variety of mains outlets.

5. **In situ data collection:** The SISTeR makes continuous measurements throughout the cruise, unless severe weather prevents data collection (in this instance, the instrument is covered to protect it). Typically, SISTeR radiances are sampled every 0.8s with the 10.8µm filter. Skin SSTs are calculated from the upwelling ocean radiance samples, corrected for a small, reflected sky radiance term with the complementary sky samples. Over a flat sea surface and for a narrow filter function, the upwelling radiance can be approximated closely as

$$R\_up = B(SST) + (1 - e)\, R\_down$$

where R_*up* and R_*down* are the upwelling sea and complimentary downwelling sky radiances, e is the emissivity of the sea surface and B(T) is the Planck function, each integrated over the instrumental filter function and field of view. R_*up* and R_*down* are measured directly by the SISTeR, and so the term B(SST) and hence the skin SST can be retrieved from these. The data are analysed on board and are available at the end of the cruise for comparison to satellite data. If urgently required, small amounts of data can usually be supplied whilst at sea. Supporting measurements of local meteorological parameters, bulk sea surface temperature and balloon-sonde profiles of atmospheric state will provide a valuable context for the skin SST data.

SISTeR Operation: All aspects of the SISTeR instrument, fom the scan mirror position to the detector signal are accessible through variables defined in a C library. Control programs of arbitrary complexity can be written, but generally just a few lines of code are needed to define a scan sequence. When a control program is running, the complete instrument state is transmitted over a serial link to a laptop ground station after every measurement. All SISTeR measurement sequences contain repeated measurements of its two internal black bodies. In addition, to calculate the skin SST, the SISTeR is programmed to make measurements both of upwelling radiances from the sea surface and complementary downwelling sky radiances.

In the SISTeR longwave channels, the measured noise temperature for a 1 second sample at typical SSTs is less than 30mK. Measurements of an external CASOTS black body before, during and after a typical one-month validation campaign showed that the SISTeR calibration remained repeatable to better than 20mK, even though the scan mirror finish had deteriorated noticeably over the same period.

6. **Satellite data ordering and collection:** AATSR data will be ordered via the data co-ordinators.
7. **In Situ/satellite data matchups:** High resolution AATSR data contemporaneous with valid SISTeR data are required to perform a satisfactory validation study. Matchups between SST measurements collected in situ and cloud-free AATSR data will be made by Tim Nightingale at RAL.

9.3.1.3 Geographical Location

Ideally, SISTeR will collect data on a global scale. Precise location will depend on the cruises that can be undertaken, and the availability of funding and berths.

The SCIPIO cruise will operate in the West Indian Ocean in the geographical location:
Latitude 0-25? S
Longitude 50-70? E

9.3.1.4 Planned Validation Activities

The SCIPIO (Satellite Calibration and Interior Physics in the Indian Ocean) cruise will take place from 31st May to 11th July 2002. It will consist of 2 legs – from the Seychelles to Mauritius, and then a round trip from Mauritius. The nominal location of the cruise is shown in Figure 9.3.1.4-1.

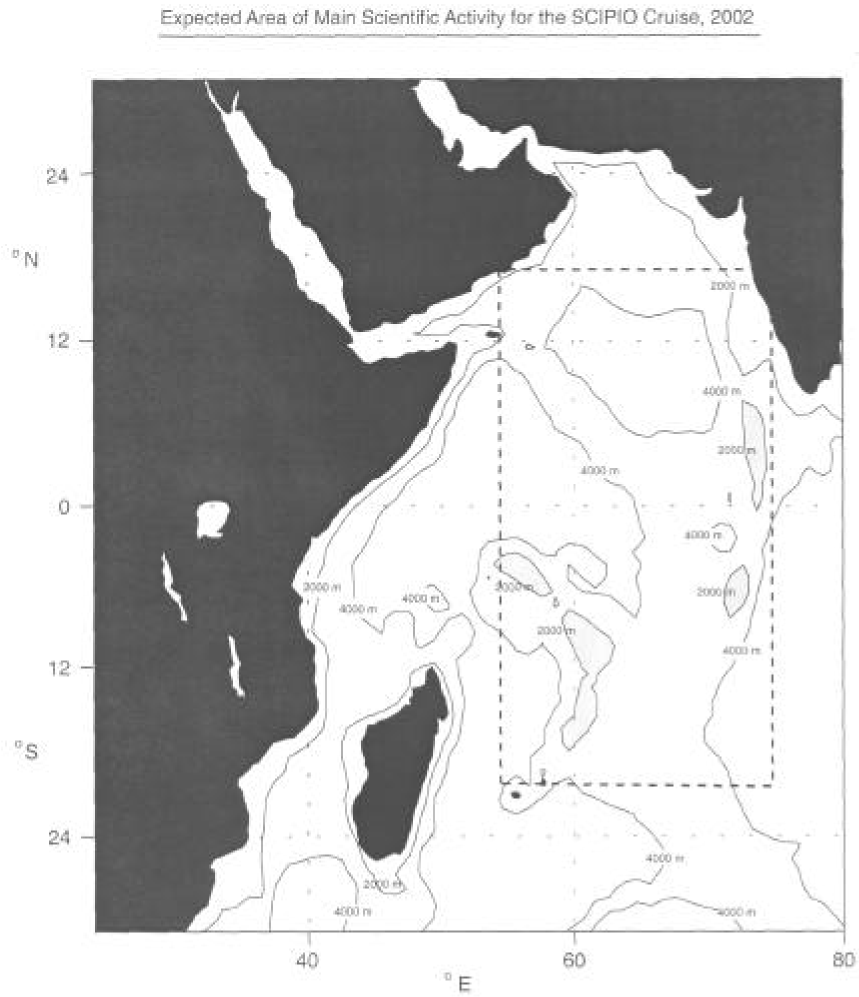

Figure 9.3.1.4-1 Nominal location of the SCIPIO cruise

A berth has been secured on the SCIPIO cruise for Tim Nightingale, and funding has been obtained through a NERC Enabling Grant.

9.3.1.5 Data Requirements

- The following AATSR data products are required:
  - ATS_TOA_1P
  - ATS_NR_2P
  - ATS_AR_2P
- No requirement for NRT data

Address to where data should be sent: Dr Tim Nightingale
Rutherford Appleton Laboratory
Chilton
Didcot
OX11 0QX

9.3.1.6 Interfaces

The PI will interface with a number of parties:

Interfaces	With whom	Reason	Timing
1	Validation Scientist	?? Help with cruise planning, instrument installation and running, data acquisition. ?? Help with NILU submission ?? Send validation results (in situ/satellite data matchups) ?? Participation in Data Quality Group	As required Monthly As required
2	ESA	?? Order and receive AATSR Data	As necessary < 3 weeks, post data take
3	NILU	?? Upload SISTeR data, meteorological data, balloon-sondes, bulk temperature data ?? Download additional wind speed data	Post-cruise

9.3.1.7 Schedule

The work will fit into the overall schedule outlined in Section 14.

9.3.1.8 References

C.J. Donlon, T. Nightingale, L. Fielder, G. Fisher, D. Baldwin and I.S. Robinson 1999: The calibration and intercalibration of sea-going infrared radiometer systems using a low cost blackbody cavity, *J. Atmos. Oceanic Technol.*, **16**, 1183-1197.

C.J. Donlon and T.J. Nightingale, 2000: Effect of atmospheric radiance errors in radiometric sea-surface skin temperature measurements. *Applied Optics*, **39**, 2387-2392.

9.3.2 M-AERI, Minnett (590)

Global Validation of AATSR SST's will be validated using precision measurements taken with the M-AERI, as described in A/O proposal 590. In addition to AATSR, the M-AERI has been used to validate AVHRR, MODIS, TRMM, ATSR-2 and AIRS. The work is funded by NASA and performed on a best efforts basis for AATSR.

Principal Investigator: Dr Peter Minnett
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Meteorology and Physical Oceanography
University of Miami
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pminnett@rsmas.miami.edu

Co-Investigators: Dr Craig Donlon, JRC
Dr Bill Emery, University of Colorado
Dr Simon Hook, NASA JPL
Dr Andy Jessup, University of Washington
Dr Frank Palluconi, JPL
Dr Goshka Szczodrak, RSMAS-MPO
Dr Gary Wick, NOAA

9.3.2.1 Instrumentation

The primary instrument that will be used to collect validation measurements is the M-AERI (Marine Atmosphere Emitted radiance Interferometer). The M-AERI is a robust, accurate, self-calibrating, sea-going Fourier-transform interferometric infrared spectroradiometer that is deployed on marine platforms to measure the emission spectra from the sea surface and marine atmosphere (Minnett *et al.* 2001). The environmental variables derived from the spectra include the surface skin temperature of the ocean, air temperature and surface emissivity. Use of the M-AERI for the validation of satellite-derived surface temperature fields, and the study of the physics of the skin layer has been extensive. The instrument has been deployed on numerous research cruises. In January 2000, it could be reported that on no occasion had data collection been terminated by an instrument failure (Minnett *et al.*, 2001). Other radiometers, operated by some of the Co-Investigators, will provide data in a similar fashion to the M-AERI. While not providing the spectral information available from the M-AERI, these instruments make measurements in spectral intervals defined by filters that correspond to the window channels of the AATSR. These radiometers are also well calibrated to provide accurate skin SST from ships.

The key instrument parameters of the M-AERI system are given in Table 9.3.2.1.

Scan Time	1 second in each direction
Spectral Coverage	5.5-18.2?m, 550-1800 cm^{-1} 3.3-5.5?m, 1800-3000 cm^{-1}
Spectral Sampling	0.48 cm^{-1}
Instrument field-of-view	45 mrad (full angle)
Dimensions	116 cm L x 71 cm W x 76 cm H
Mass (sensor)	93 Kg
Power (system)	1 kW maximum (approx.)

Table 9.3.2.1 Key instrument parameters of the M-AERI system

The M-AERI operates in the range of infrared wavelengths from 3 to 18 ?m, measuring spectra with a resolution of 0.5 cm^{-1}. Two infrared detectors are used to achieve this spectral range, and these are cooled to 78K by a Stirling cycle mechanical cooler to reduce the noise equivalent temperature different to levels well below 0.1K. The M-AERI includes two internal black body cavities for accurate real-time calibration. A scan mirror directs the field of view from the interferometer to either of the black body targets to the environment from nadir to zenith. The mirror is programmed to step through a pre-selected range of angles, viewing either the atmosphere or the sea surface. The interferometer integrates measurements over a pre-selected time interval, usually a few tens of seconds, to obtain a satisfactory signal to noise ratio, and a typical cycle of measurements (two view angles to the atmosphere, one to the ocean, and calibration measurements) takes about 5 minutes. Pitch and roll sensors on the M-AERI mean the influence of the ship's motion on the measurements can be determined.

Instrument Operation: The M-AERI runs continuously under computer control, except for a brief period at midnight UTC when the computer reboots and undertakes some housekeeping tasks. This ensures that there is enough disk space for the new day's data. In the event of a shortage in disk space, the system will automatically delete the oldest day's data. It is thus important that an operator saves data to CD or tape on a regular basis to prevent data loss. Some data loss will occur in the event of heavy rain or sea spray. The mirror must remain clean and dry in order for the M-AERI to provide the required measurements. A rain sensor ensures that the mirror is moved into a 'safe' position in the event of light rain and spray. During heavy rain, the M-AERI is covered for protection.

Data Flow: In addition to interferometer data, a comprehensive set of housekeeping data are collected from the blackbody subsystem, the mirror controller, the environmental monitors (temperature, humidity, pressure and precipitation), a global positioning system location and an inclinometer. The housekeeping data are sampled (200 average sample) and recorded at 5-second intervals. These are invaluable for validation and data analysis.

9.3.2.2 Methodology

In the following discussion, the operational methodology given here for the M-AERI, will be applied, where appropriate, to the radiometer deployments organized by the Co-Investigators.

1. **Instrument development and testing**: the M-AERI has now been used on a number of data collection exercises, and is considered proven in its ability to measure SST to an accuracy of <0.1K. Periodically the M-AERI is brought together with similar instruments, such as those of the Co-Investigators and the SISTeR (UK) and the DAR011 (Australia), for cross-comparisons and calibration checks against reference black body targets.

 i. **Intercalibration at Miami, 1998**: One such inter-comparison took place in the form of a workshop, held at RSMAS in March 1998. The purpose of the workshop was to provide a framework in which investigators using infrared radiometers, spectrometers and imaging devices could come together to compare instruments, calibration targets and measurement protocols. This would ensure consistent and accurate datasets for future use in validating infrared retrievals of surface temperature over land and sea.

An instrument platform to support remote sensing and meteorological instruments was constructed on the roof of the marine science centre at RSMAS. A 15m high meteorological tower next to the instrument platform provided data on wind speed and direction, air temperature and humidity, downwelling long and short wave radiation. Floats in the water in front of the building provided a near surface in situ surface temperature. Instruments were compared to each other and to internationally recognised black body calibration targets.

Results of the 1998 inter-comparison workshop can be found at http://www.rsmas.miami.edu/ir and has been reported by Kannenberg and Palluconi, 1998 (Kannenberg, R., and F. Palluconi, Joint Rosenstiel School of Marine and Atmospheric Science (RSMAS) Committee on Earth Observation Satellites (CEOS) Validation Workshop, The Earth Observer, 10 (3), 38-42, 1998; http://eospso.gsfc.nasa.gov/eos_observ/5_6_98/may_jun98.html). Comparing M-AERI to a blackbody maintained by the National Institute of Standards and Technology, for example, an error analysis indicated that the absolute accuracy of M-AERI sea surface skin temperatures does indeed meet or exceed the design goal of 0.1C absolute accuracy (Minnett *et al*., 2001).

ii. **Intercalibration at Miami, 2001.** A second international infrared radiometry workshop and inter-comparison took place at the Rosenstiel School of Marine and Atmospheric Science, University of Miami, from May 28 to June 1, 2001. The workshop was coordinated by Dr Peter Minnett of RSMAS and Dr Ian Barton of CSIRO, and aimed to compare radiometers using measurements of SST taken on a short cruise of the R/V Walton Smith, and calibrate radiometers against a NIST-certified blackbody calibration target.

Six different makes of radiometers were calibrated against the NIST standard Black Body in the laboratory and seven radiometers were mounted on the RV Walton Smith (a research ship owned by the University of Miami) for an intercomparison under sea-going conditions. Radiometers tested both in the laboratory and on the Walton-Smith included the ISAR5C, DAR011, SISTeR and the M-AERI (ship only). Figure 9.3.2.2-1 shows the radiometers mounted on the ship.

Figure 9.3.2.2-1 View from above of the radiometers mounted on the R/V Walton-Smith. From fore to aft, they are the SISTeR, ISAR5C (hidden), CIRMS, M-AERI and DAR011

A report of the workshop can be found in:
Minnett, P. and Barton, I., 2001, 'The second international infrared radiometer calibration and inter-comparison'. Report to ESA.

A scientific paper giving a more detailed analysis is in preparation, and should be available early 2002.

Table 9.3.2.2-1 is a summary showing preliminary results of comparing radiometers. It shows small differences and confirms the suitability of all radiometers for SST validation.

Radiometer pair	Mean of difference (K)	Standard deviation of difference (K)	No. of points
MAE-ISA	0.002	0.135	80
MAE-SIS	0.046	0.066	144
MAE-DAR	-0.008	0.076	149
ISA-SIS	0.038	0.101	79
ISR-DAR	0.007	0.114	80
SIS-DAR	-0.053	0.074	144
TAS-SIS	-0.001	0.157	24
TAS-DAR	-0.054	0.163	23

Source: The second international infrared radiometer calibration and inter-comparison, Report to ESA by Peter Minnett and Ian Barton, 28th September 2001.

Table 9.3.2.2-1: Means and standard deviations of the differences between pairs of radiometers for the entire cruise period, at the Miami intercomparison.

2. **Organisation of Cruises/ Negotiation with ferries/ships-of-opportunity.** RSMAS has 3 M-AERI instruments that will be used for AATSR validation (given the availability of funding). Specific details of campaigns are mentioned in Section 9.3.2.4. Recent negotiations have led to the installation of a M-AERI on the Royal Caribbean cruise ship,

the 'Explorer of the Seas', in October 2000. Continuing negotiation and international liaison has enabled participation in cruises worldwide in the past, and this will continue into 2002.

3. **Installation.** Once negotiations are completed, the M-AERI is installed on the vessel.

4. **In Situ Data Collection.** As the vessel continues normal operating duties, the M-AERI makes measurements as described above. On shorter cruises such as the weekly cruise of the Explorer of the Seas, the instrument can be left to run almost autonomously, with little technical assistance needed. Data are downloaded on a weekly basis as the boat comes into port in Miami. On longer cruises, a dedicated technician/scientist accompanies the instrument on the cruise, maintaining it and ensuring data are collected.

   Interferometer and housekeeping data are collected together. The merged data stream is recorded in a customized data format (DMW, developed at the University of Wisconsin). After creation of the DMW format data files, a sequence of FORTRAN language modules are executed. 5 processing steps are performed on the raw data.

   ?? A correction for detector nonlinearity is applied to the longwave band.
   ?? The forward and backward Michelson scans for each of the longwave and shortwave bands are calibrated individually.
   ?? The forward and backward scans are averaged for each band.
   ?? A finite field of view correction is applied to each calibrated spectrum.
   ?? The spectra are resampled to a standard wave-number scale common to all M-AERI systems.

5. **Satellite data ordering and collection:** AATSR will be ordered in advance, depending on the geographic and temporal location of M-AERI and filter radiometers.

6. **In situ/satellite data matchups:** High resolution (1km) AATSR data contemporaneous with valid M-AERI and radiometer data are required to perform a satisfactory validation study. Matchups between SST measurements collected by M-AERI and cloud free AATSR imagery will be made at RSMAS. Similar measurements made by the Co-Investigators will be collated at RSMAS. These data will be e-mailed to the VS, who will be responsible for their analysis and for feeding them into the 'validation loop'. Validation reports will be sent to the VS on a monthly basis.

   Given limitations of available personnel at RSMAS to perform the in situ/satellite measurements, this work will be performed with help, where possible, from personnel at Leicester University.

9.3.2.3 Geographical Location

Ideally, M-AERI and other instruments will validate SST measurements from AATSR on a global scale. Particular attention will be paid to capturing the full range of atmospheric variability from the polar to equatorial zones. For the ocean, emphasis will be placed on deployments on long trans-oceanic quasi-meridional sections in the Pacific and Atlantic Oceans, and targeted campaigns in regions of known 'difficult' conditions, such as the outflow of continental aerosols.

As explained in Section 9.3.2.4, at the present time, possible validation activities include validation data collection in the East Caribbean, Pacific and Arabian Seas.

9.3.2.4 Planned Validation Activities and Specific Cruises

There are three M-AERI instruments potentially available for deployment.

?? **Royal Caribbean Cruise Line Ship**

One of the M-AERI instruments is deployed on board the Royal Caribbean 'Explorer of the Seas' Cruise ship. This ship makes a 7-day cruise round the Caribbean, docking in Miami every Saturday. A weekly changeover of passengers allows scientists to download data and maintain the instrument. The M-AERI was installed on the ship in November 2000, and the collection of sea surface temperature measurements is underway. Experience throughout the pre-launch period should ensure the successful collection of validation points throughout the commissioning and post-commissioning phases. For more details see http://www.rsmas.miami.edu/rccl/.

Two cruise tracks are undertaken by the 'Explorer of the Seas', an Eastern Caribbean Circuit (begun November 2000) and a Western Caribbean circuit (to begin Spring 2002). These are shown in Figures 9.3.2.4-1 and 9.3.2.4-2. For the Eastern Circuit, the Liner sails a weekly seven-night eastern Caribbean itinerary from Miami, down to Haiti, Puerto Rico, US Virgin Islands, Nassau in the Bahamas and back across the Gulf Stream.

From April 13th 2002, the Royal Caribbean Cruise ship will sail in alternate weeks, the Eastern Caribbean Circuit, followed by the Western Caribbean Circuit.

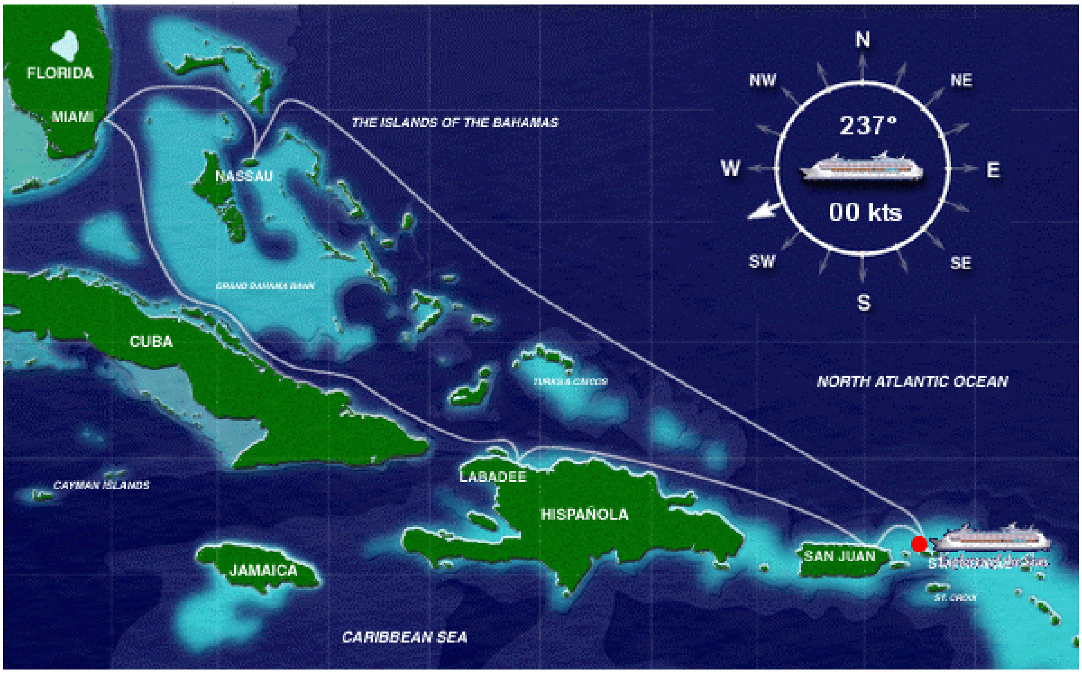

Figure 9.3.2.4-1 Eastern Caribbean Circuit of the Royal Caribbean 'Explorer of the Seas' Liner, carrying a M-AERI making measurements of SST
(Source of image: http://www.rsmas.miami.edu/rccl/obs/ex-rt-obs.pl)

Figure 9.3.2.4-2: Western Caribbean Circuit of the Royal Caribbean 'Explorer of the Seas' Liner, carrying a M-AERI making measurements of SST

Although the ship is at sea every night and two days a week, 52 weeks a year, the expected number of matchups with AATSR data are only 15-25.

?? **Research Vessels/Ships of opportunity**

The other two M-AERI instruments will be deployed episodically on research vessels and ships of opportunity throughout the commissioning and post-commissioning phases of ENVISAT. Past deployments of M-AERI instruments are shown in Figure 9.3.2.4-3.

Planned deployments are shown in Table 9.3.2.4-1.

Ship	Geographic Location			Dates
	Area	Latitude Range	Longitude Range	
Polar Star	Western Pacific Callao (Peru) to Seattle	13 S – 48 N	77 – 123 W	19/03/02–18/04/02
TBC	Mediterranean	TBC	TBC	September 2002
TBC	Seattle to Sydney	TBC	TBC	November 2002

Table 9.3.2.4-1: Deployments for validation of the M-AERI instruments

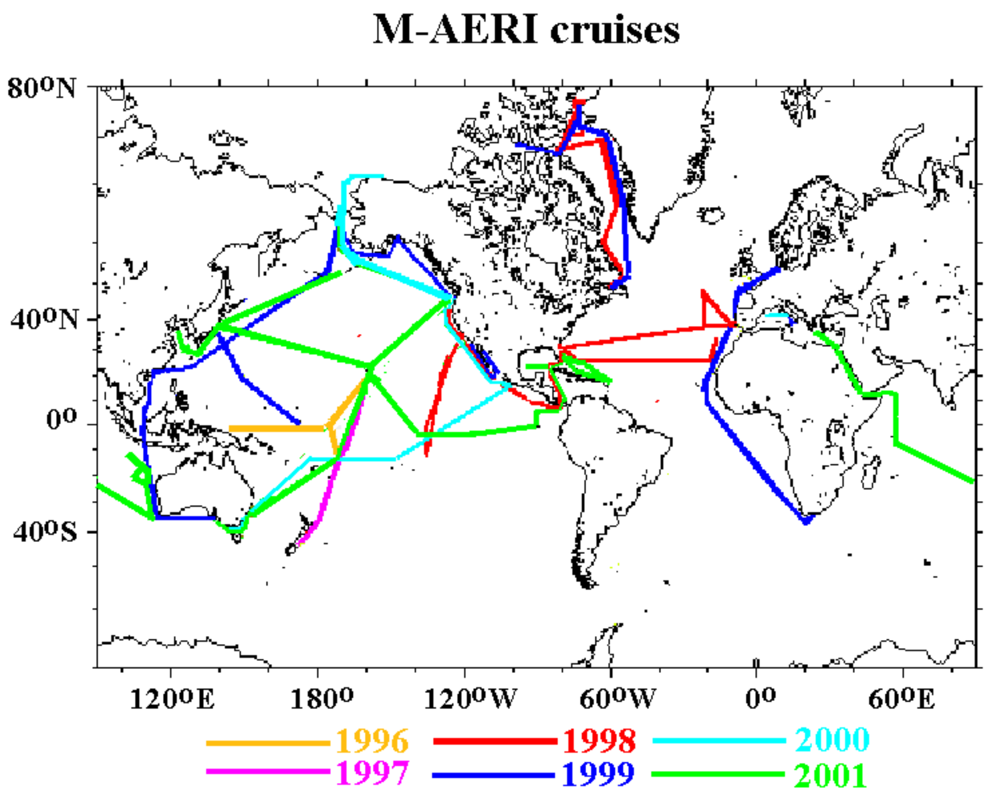

Figure 9.3.2.4-3: Schematic representation of the past cruises for the University of Miami's M-AERI systems

9.3.2.5 Data Requirements

?? The following data products are required:
    ATS_TOA_1P full resolution or ATS_NR_2P full resolution
    512 x 512 scenes coincident with ship tracks

?? Data needed is offline, just after validation cruises. Some data (that covering the Royal Caribbean cruise track) is required continuously. No Near-Real-Time data are required.

?? Primarily scenes products located over the ships are required. Additionally full orbits of data for comparison with AVHRR Pathfinder and MODIS are needed.

Address to where data should be sent:

Dr Peter Minnett
Rosenstiel School of Marine and Atmospheric Science
Meteorology and Physical Oceanography
University of Miami
4600 Rickenbacker Causeway, Miami 33149
pminnett@rsmas.miami.edu

9.3.2.6 Interfaces

The PI will interface with a number of parties.

Interfaces	With whom	Reason	Timing
1	Validation Scientist	Help with cruise planning, instrument installation and running, data acquisition. Help with NILU submission Send validation results (in situ/satellite data matchups) Participation in Data Quality Group	As required Monthly As required
2	ESA	Order and Receive AATSR Data	As necessary
3	NILU	Upload one small file per day per M-AERI instrument when operating. Download other cruise validation data (i.e from SISTeR, ISAR5C, DAR011).	TBC As required

9.3.2.7 Schedule

Validation data collection using the M-AERI will follow the schedule outlined in Section 14.

9.3.3 DAR011, Barton (9202)

Validation activities from Hobart are being conducted by Dr Ian Barton, CSIRO. A precision radiometer, the DAR011, will be operated on board research ships-of-opportunity, such as the RV Franklin.

Principal Investigator:

Dr Ian Barton
CSIRO Marine Research
Castray Esplanade
Hobart, Tasmania 7000
Ian.Barton@csiro.au

9.3.3.1 Instrumentation

The instrument being used for validation measurements is the DAR 011 radiometer, built by CSIRO (see Figure 9.3.3.1-1). This instrument benefits from a long heritage and performs extremely well. Bulk temperature is obtained from a well-calibrated thermosalinograph, which operates continuously. Full meteorological data are available including radiosonde launches at satellite overpass times when the skies are free of clouds.

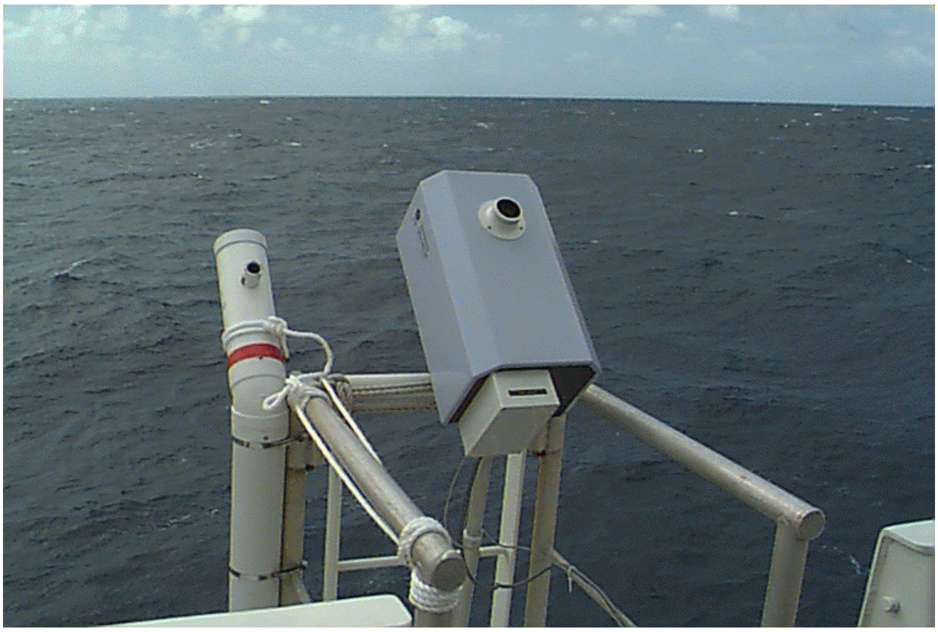

Figure 9.3.3.1-1: The DAR011 radiometer, mounted on the RV Franklin, used for validation activities based in Hobart. (Photograph from CSIRO)

9.3.3.2 Methodology

1. **Instrument development and testing**: the DAR011 has now been used on a number of data collection exercises. It was involved in the intercalibration exercise in Miami in 1998 and 2001.

2. **Organisation of Cruises/ Negotiation with ferries/ships-of-opportunity.** The Research Vessel, the Franklin, operates in Australian waters. It has a full complement of

oceanographic and meteorological instrumentation that provides the supporting marine and atmospheric data needed for analysis. The frequency of cruises is determined by berth availability, ship schedule and funds to cover travel, ship time and at-sea allowances.

3. **Installation.** Once negotiations are completed, the DAR011 is installed on the vessel.

4. **In Situ Data Collection.** The DAR011 makes continuous measurements throughout the cruise. Radiosondes are launched as satellite overpass times when the sky is free of clouds. The radiometer views the sky on a regular basis to ensure that an accurate correction can be applied to account for the non-unity emissivity of the sea surface. The data are analysed on board and are available at the end of the cruise for comparison to satellite data. If required urgently, small amounts of data can be usually supplied via the internet whilst at sea.

5. **Satellite data ordering and collection:** AATSR will be ordered from the ESA User Services Facility in advance, depending on the geographic and temporal location of DAR011 instrument.

6. **In situ/satellite data matchups:** High resolution (1km) AATSR data contemporaneous with valid DAR011 data are required to perform a satisfactory validation study. Matchups between SST measurements collected in situ and cloud free AATSR imagery will be made at CSIRO, Hobart. These data will be e-mailed to the validation scientist, and will enter the 'validation loop'. After the AATSR SODAP and during the commissioning phase (2-6 months after launch), validation reports will be sent to the VS on a monthly basis.

9.3.3.3 Geographical Location

Cruises usually occur in Australian waters - but on occasion, data will be collected from areas some distance from Australia. Cruises will be targeted that promise a high probability of clear skies, typically cruises in tropical waters during the months of June to October, when the monsoon activity is north of the equator and clear skies are frequent. Following launch of ENVISAT, it is anticipated that there would be three to six two-week cruises per year. Prior to launch, the instruments and data collection techniques will be tested through one or two shorter cruises per year.

9.3.3.4 Planned Validation Activities

Three cruises of the RV, the Franklin had been planned for the latter half of 2001, but with the new Envisat launch date of March 2002, all these validation data collection opportunities are now too early.

The DAR011 will be operated on a cruise on the Lady Basten in conjunction with AIMS. This cruise will take place in the Great Barrier Reef area near Townsville (exact cruise track TBC). This cruise will take place in June 2002 (exact dates TBC).

There is also the possibility to take part in a cruise in the last two weeks of May 2002. This will also take place in the Great Barrier Reef area (exact dates and cruise track TBC).

CSIRO are in the process of transferring operations from the Franklin to the Southern Surveyor. This ship will not be ready before September 2002.

9.3.3.5 Data Requirements

?? The following AATSR data products are required:
ATS_TOA_1P
ATS_NR_2P

?? Data volume: 512 x 512 scenes of ATS_TOA_1P and ATS_NR_2P of all passes covering the ship tracks: 6-10 weeks of operation anticipated per year.

?? Data needed are offline.

Address to where data should be sent

Dr Ian Barton
CSIRO Marine Research
Castray Esplanade
Hobart, Tasmania 7000

9.3.3.6 Interfaces

The PI will interface with a number of parties.

Interfaces	With whom	Reason	Timing
1	Validation Scientist	?? Help with NILU submission ?? Send validation results (in situ/satellite data matchups) ?? Participation in Data Quality Group	As required Monthly As required
2	ESA	?? Order AATSR Data ?? Receive AATSR Data	As necessary
3	NILU	?? 2 Mbytes of data submitted at the end of every cruise. ?? Download of wind data for research vessel track.	At the end of every cruise

9.3.3.7 Schedule

The validation activities from Hobart will follow the overall validation schedule outlined in Section 14.

10 Validation of the Level 1b GBTR product, AATSR visible/near infrared data

The level 1b thermal channels (3.7? m, 11? m and 12? m) will be validated inherently through the validation of the level 2 SST product (Section 9) and the land surface temperature product (Section 11). Validation of the visible/near infrared channels (0.55? m, 0.67? m, 0.87? m and 1.6? m) will be carried out over land and cloud. This is done in two ways, through vicarious validation and through the collection of ground measurements taken during field campaigns.

Figure 10-1 gives the names of PI's leading different project involved in the validation of visible/near infrared channels, together with their project ID number. The work by Smith and Prata is considered core validation. The work of Stammes, Hagolle and Watts is being carried out primarily for the validation of other instruments (for SCIAMACHY and MERIS). It is not considered core AATSR validation activities, although data from these activities will be useful for initial AATSR validation and their work is included here.

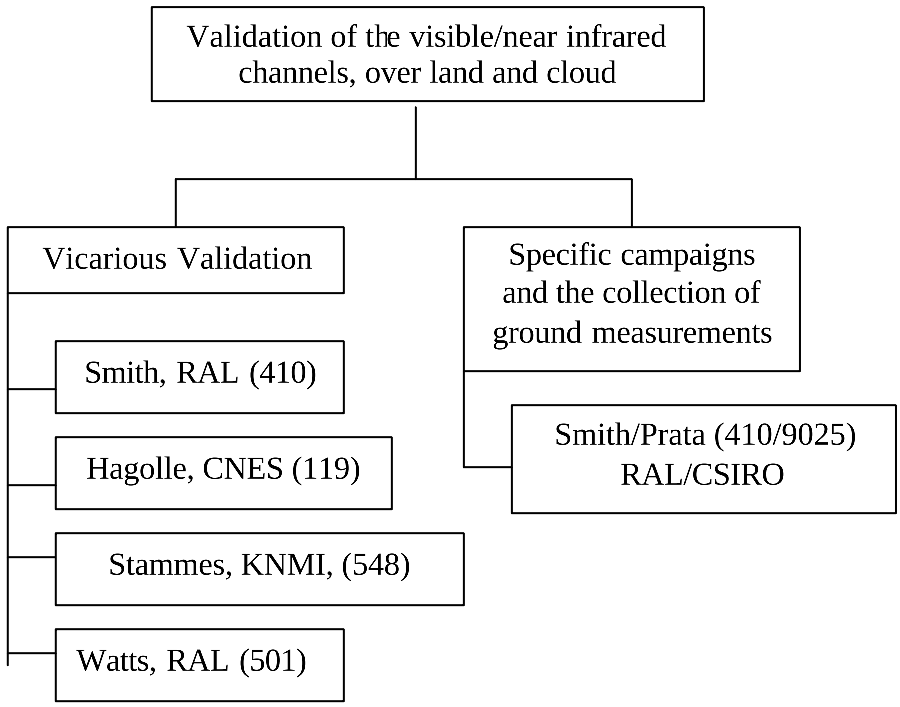

Figure 10-1: PI's involved in validation of the AATSR visible/near infrared channels

10.1 Vicarious Validation

Vicarious validation compares top-of-atmosphere (TOA) radiances from AATSR to TOA measurements from similar sensors. At the present time, there are four projects that will do vicarious validation for AATSR, over stable land sites and over cloud.

10.1.1 Vicarious Inter-Calibration of AATSR and MERIS using terrestrial targets, Smith (410)

Principal Investigator: Dr David Smith
Rutherford Appleton Laboratory
CCLRC, Chilton
Didcot, Oxfordshire
OX11 0QX

Co-Investigators: Dr Chris Mutlow, RAL
Dr Carina van Eijk, Institute of Applied Physics
Dr Fred Prata, CSIRO Atmospheric Research

10.1.1.1 Methodology

Smith will compare AATSR- and MERIS top-of-atmosphere radiances for a range of desert regions and Greenland ice, and monitor the long-term stability of the instruments. This will lead to a robust characterisation of the in-orbit performance of the instruments and the on-board calibrators. Using similar channels on AATSR and MERIS enables direct comparisons of the instrument calibrations to be made, Figure 10.1.1.1-1. The measurements will be particularly useful to check for any across track variations in the calibration of MERIS. The results will also be compared against the existing ATSR-2 data for the same scenes. In-situ measurements provided by CSIRO over Australian sites will validate the top-of-atmosphere measurements (see Section 10.2.1).

Outputs from the work include:
?? Time series of uncorrected top-of-atmosphere reflectances.
?? Calibration drift corrections.
?? Reflectances corrected for atmospheric absorption (not aerosols).
?? Intercomparisons with MERIS and ATSR-2 reflectances.

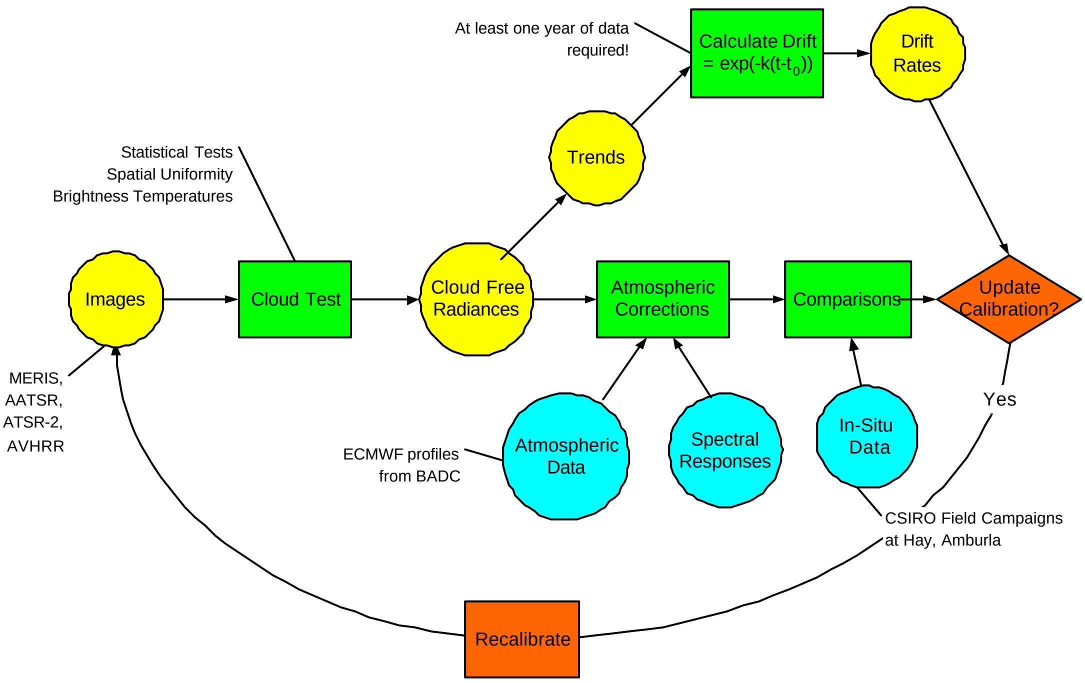

Figure 10.1.1.1-1: Intercomparison scheme for AATSR, ATSR-2 and MERIS.

10.1.1.2 Geographic Locations

Table 10.1.1.2-1 gives the latitudes and longitudes of the main regions to be studied. These include the CNES sites listed in Table 10.1.2.3-1. Other sites may also be required as the investigation progresses.

Site Name	Lat centre (°)	Long centre (°)	Lat_min	Lat_max	Long_min	Long_max
Arabia1	18.88	46.76	18.38	19.38	46.26	47.26
Arabia2	20.13	50.96	19.63	20.63	50.46	51.46
Arabia3	28.92	43.73	28.42	29.42	43.23	44.23
Sudan1	21.74	28.22	21.24	22.24	27.72	28.72
Niger1	19.67	9.81	19.17	20.17	9.31	10.31
Niger2	21.37	10.59	20.87	21.87	10.09	11.09
Niger3	21.57	7.96	21.07	22.07	7.46	8.46
Egypt1	27.12	26.1	26.62	27.62	25.6	26.6
Libya1	24.42	13.35	23.92	24.92	12.85	13.85
Libya2	25.05	20.48	24.55	25.55	19.98	20.98
Libya3	23.15	23.1	22.65	23.65	22.6	23.6
Libya4	28.55	23.39	28.05	29.05	22.89	23.89
Algeria1	23.8	-0.4	23.3	24.3	-0.9	0.1
Algeria2	26.09	-1.38	25.59	26.59	-1.88	-0.88
Algeria3	30.32	7.66	29.82	30.82	7.16	8.16
Algeria4	30.04	5.59	29.54	30.54	5.09	6.09
Algeria5	31.02	2.23	30.52	31.52	1.73	2.73
Mali1	19.12	-4.85	18.62	19.62	-5.35	-4.35
Mauritania1	19.4	-9.3	18.9	19.9	-9.8	-8.8
Mauritania2	20.85	-8.78	20.35	21.35	-9.28	-8.28
Libyan Desert	22	28.5	21	23	28	29
Dunhuang	40.095	94.155	40.02	40.17	94.01	94.3
Sonora	31.8	-113.86	31.54	32.06	-114.18	-113.54
Hay	-34.382	145.292	-34.632	-34.132	145.042	145.542
Amburla	-23.285	133.119	-23.535	-23.035	132.869	133.369
Thangoo	-18.1	122.26	-18.35	-17.85	122.01	122.51
Greenland	73.75	-40	(point and radius of 488 km)			

Table 10.1.1.2-1 Geographic Location of the sites used for Vicarious Validation

10.1.1.3 Data Requirements

The following data are required:

- AATSR level 1b (GBTR) images for selected calibration sites over the whole mission
    - All channels (3.7? m, 11? m, 12? m, 1600nm, 870nm, 660nm, 555nm)
- MERIS level 1b radiances for selected calibration sites over the whole mission
    - 520, 560, 620, 665, 681, 865, 890 nm channels
    - Desert reflectances obtained using the METRIC tool
- ATSR-2 GBT images containing all channels (Smith already has a complete time series for selected sites).
- ECMWF atmospheric profiles from BADC
- In situ measurements from CSIRO (see Section 10.2.1)

10.1.1.4 Interfaces

The PI will send validation reports to the VS on a monthly basis. Results will also be exchanged with CNES (Section 10.1.2).

10.1.1.5 Schedule

The vicarious validation work of Smith will follow the overall validation schedule outlined in Section 14.

10.1.2 Validation of MERIS calibration using natural targets, Hagolle (119)

A limited amount of vicarious calibration of the AATSR visible channels will be undertaken as part of the MERIS calibration activities. The primary aim of this activity is to validate and monitor the absolute calibration of MERIS using a variety of natural targets, including stable desert sites. However, over desert sites, it is also possible to conduct vicarious calibration of the AATSR visible channels and perform cross calibration between MERIS, AATSR and other sensors.

Details of the MERIS calibration exercise using natural targets are contained in AD8 (the MERIS Cal/Val Implementation Plan). The AATSR aspects of this work are described here. It is important to note that this work is not central to CNES' activities and is only designed to compliment the MERIS calibration. Therefore it is a lower priority task for CNES and will be performed on a best efforts basis.

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Xavier Briottet, ONERA
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Francois Cabot, CNES
A Meygret, CNES
T.Tremas, CNES
M. Dinguirard, ONERA
A. Lifermann, CESBIO
O. Hautecoeur, CESBIO
F.M. Breon, CEA

10.1.2.1 Instrumentation

This method uses the characterisation of the properties of 20 desert sites that was obtained with POLDER 1 instrument. Given the very good stability with time of these sites, no in-situ measurement is needed for this method. Measurement protocols are not applicable for this work.

10.1.2.2 Methodology

Twenty desert sites in North Africa and Arabia have been selected for their spatial uniformity and temporal stability, using Meteosat data. The sites are quite lambertian and the directional variations of their reflectance has been monitored using POLDER data. Since POLDER data makes a very complete sampling of the directional conditions, it is nearly always possible to find a POLDER acquisition with solar and viewing angles very close to the angles of any sensor measurement. POLDER can thus be used as a transfer radiometer to make cross calibrations between sensors, even if they do not have the same scanning geometry.

The main error sources are the aerosols and the variation of the site reflectance: aerosols can modify the top of atmosphere reflectance of the desert sites, but it is expected that after averaging a lot of measurements, the aerosol effect will mainly affect the results as a noise and not as a bias. The cross-calibration results could also be affected by long term variations of the desert sites reflectance, but averaging the results for 20 desert sites reduces the eventual variations. Since 1996, CNES has been collecting desert sites data from many sensors. These data are gathered in an ORACLE database: for the moment, the available data are:

SeaWiFS, AVHRR (NOAA14,15,16)
MODIS, MISR
POLDER 1, SPOT 1,2,3,4, VGT,

The desert sites can be used in the following ways:

- To compare the absolute calibration of AATSR with the calibration of MERIS and other sensors
- To check the stability of the instrument calibration as a function on time.

10.1.2.3 Geographic Locations

The desert sites are given in Table 10.1.2.3-1.

Site Name	Lat centre (°)	Long centre (°)	Lat_min	Lat_max	Long_min	Long_max
Arabia1	18.88	46.76	18.38	19.38	46.26	47.26
Arabia2	20.13	50.96	19.63	20.63	50.46	51.46
Arabia3	28.92	43.73	28.42	29.42	43.23	44.23
Sudan1	21.74	28.22	21.24	22.24	27.72	28.72
Niger1	19.67	9.81	19.17	20.17	9.31	10.31
Niger2	21.37	10.59	20.87	21.87	10.09	11.09
Niger3	21.57	7.96	21.07	22.07	7.46	8.46
Egypt1	27.12	26.1	26.62	27.62	25.6	26.6
Libya1	24.42	13.35	23.92	24.92	12.85	13.85
Libya2	25.05	20.48	24.55	25.55	19.98	20.98
Libya3	23.15	23.1	22.65	23.65	22.6	23.6
Libya4	28.55	23.39	28.05	29.05	22.89	23.89
Algeria1	23.8	-0.4	23.3	24.3	-0.9	0.1
Algeria2	26.09	-1.38	25.59	26.59	-1.88	-0.88
Algeria3	30.32	7.66	29.82	30.82	7.16	8.16
Algeria4	30.04	5.59	29.54	30.54	5.09	6.09
Algeria5	31.02	2.23	30.52	31.52	1.73	2.73
Mali1	19.12	-4.85	18.62	19.62	-5.35	-4.35
Mauritania1	19.4	-9.3	18.9	19.9	-9.8	-8.8
Mauritania2	20.85	-8.78	20.35	21.35	-9.28	-8.28

Table 10.1.2.3-1 Desert Sites used for vicarious validation by Hagolle (119)

10.1.2.4 Data Requirements

Systematic use of every AATSR Level 1b ATS_TOA_1P product acquired over these sites

The default method of obtaining AATSR data for this work will be via the ENVISAT USF. PERL scripts provided by the USF will be used to set up a standing order for 512x512 km scenes over each site and to regularly download these products. The extraction of the suitable calibration points from the AATSR products will be performed manually by CNES.

Under AO 410, RAL will also be requesting data over certain desert sites and performing a similar extraction of relevant pixels (see Section 10.1.1). For those sites, which coincide between the two projects, there will be an exchange of MERIS and AATSR extractions between RAL and CNES.

10.1.2.5 Interfaces

The activities of CNES are administered by the MERIS team coordinator, Steven Delwart. Results reports will be sent to him and copied to the AATSR VS. There are no plans for CNES to upload data to or download data from NILU. Where AATSR results are reported at ENVISAT events such as the Commissioning Review and the Validation Workshop, they shall be covered under the general reporting for MERIS.

10.1.2.6 Schedule

The work of Hagolle at CNES will follow the overall validation schedule detailed in Section 14.

10.1.3 Intercomparison of AATSR with MERIS and SCIAMACHY, Stammes (548)

The work outlined in AO 548 is primarily concerned with the validation of SCIAMACHY Level 2 products, namely, polarization, radiances, cloud and aerosols. It also, however, involves the use of MERIS and AATSR data for inter-comparison with SCIAMACHY data, and is included here for completeness. A more detailed description of the work can be found in the SCIAMACHY validation handbook (AD9).

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Co-Investigators:

W.H. Knapp, KNMI
Martin de Graaf, KNMI
llse Aben, Space Research Organisation Netherlands
Cristine Tanzi, SRON

10.1.3.1 Methodology

The SCIAMACHY instrument measures the Earth's radiance between 240-1750nm, 1940-2040nm and 2265-2380nm. The spectral resolution is wavelength dependent, varying between 0.2 and 1.5nm. The measurements are performed in an alternating limb nadir mode such that an atmospheric volume is first observed in limb, and after 435 seconds, observed in nadir view. Solar and lunar occultation measurements are performed when possible. For radiometric calibration, an internal white light source can be observed as well as the sun and the moon. The default swath width of SCIAMACHY is 960km.

This work will compare normalised radiances of SCIAMACHY acquired in nadir mode to those of AATSR and MERIS. The normalised radiance is proportional to the ratio of the Earth's reflected radiance to the solar irradiance perpendicular to the solar beam. To this end, the AATSR and MERIS pixels will be collocated with the SCIAMACHY ground pixel, and averaged over the SCIAMACHY ground pixel. The SCIAMACHY normalised radiances will be convoluted with the instrument response functions of AATSR and MERIS. For the comparison, a partly cloudy scene over the ocean will be used, such that a large dynamic range is covered. The inhomogeneity of the scene allows confirmation of the positioning and geolocation of the instruments. A similar approach was successfully applied to GOME and ATSR-2 data (Koelemeijer *et al.*, 1998).

To assess SCIAMACHY degradation during its lifetime, SCIAMACHY normalised radiances acquired over a number of Saharan sites will be analysed (in conjunction with Hagolle, AO 119).

A second objective of this activity is cloud validation. The SCIAMACHY level 2 cloud products will consist of cloud cover fraction, cloud optical thickness, and cloud top pressure.

These cloud properties will be compared to cloud properties derived from MERIS and AATSR data. Cloud top pressure retrieval from SCIAMACHY employs the oxygen A-band, i.e. similar as MERIS. AATSR cloud top pressures will be derived by converting cloud top temperatures to pressures using atmospheric temperature profiles from the European Centre for Medium-range Weather Forecasts (ECMWF) model. A similar comparison was performed regarding effective cloud fractions and cloud top pressures derived from GOME and ATSR-2 [Koelemeijer and Stammes, 1999; Koelemeijer *et al.*, 2000].

10.1.3.2 Geographic Location

Sites cannot be predefined.

10.1.3.3 Data Requirements

- The following AATSR data products are required:
  ATS_TOA_1P
- Data volume: half orbit ATS_TOA_1P on request, and 512 x 512 scenes of ATS_TOA_1P over desert sites.
- Timing: < 3 weeks delivery after data take.

Address to where data should be sent:

Piet Stammes
Address, as above.

10.1.3.4 Interfaces

Stammes will send monthly validation reports to the SCIAMACHY coordinator. These will be copied to the AATSR VS.

10.1.3.5 Schedule

Stammes will follow the overall validation schedule outlined in Section 14.

10.1.3.6 References

Koelemeijer, R.B.A., Stammes, P., and Watts, P.D., 1998, Comparison of visible calibrations of GOME and ATSR-2, *Remote Sensing Environment*, 63, pp 279-288

Koelemeijer, R.B.A., and Stammes, P., 1999, Validation of global ozone monitoring experiment cloud parameters using oxygen A-band measurements from the Global Ozone Monitoring Experiment, *J.Geophy.Res.*, 104, 18, pp 801-814

Koelemeijer, R.B.A., Stammes, P., Hovemnier, J.W., and de Haah, J.F., 2000, A fast method for retrieval of cloud parameters using oxygen A-band measurements from the Global Ozone Monitoring Experiment, in press.

10.1.4 MERIS/AATSR calibration using Arctic Stratus and Tropical CumuloNimbus clouds, Watts (501)

Philip Watts of RAL will provide calibration of the reflectance channels of the AATSR and MERIS instruments using cloud targets. Two methods and corresponding cloud types are utilised in conjunction with a multiple scattering plane parallel cloud model and NWP data to aid definition of atmospheric conditions.

This work is funded by ESA as an activity for MERIS, and hence calibration of the MERIS instrument is the main priority. Calibration of AATSR reflectance channels will also take place however. The work is described in AD8 (the MERIS Cal/Val implementation plan). The work is funded for launch + 1 year.

Principal Investigator:

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Co-Investigators:

Caroline Poulsen, RAL
Carsten Brockmann, Brockmann Consult
David Smith, RAL
A.J.Baran, Met. Office

10.1.4.1 Methodology

Two methods of calibrating AATSR data are used.

In the first method, Arctic stratus clouds are used to absolutely calibrate 0.55, 0.67, 0.87 and 1.6?m AATSR channels, using a comparison of nadir and along track reflectances and knowledge of the bi-directional reflectance distribution function.

In the second method, deep convection clouds in the tropical regions are used to intercalibrate the 0.55, 0.67, and 0.87 ?m channels by comparison of nadir view data and correction for residual above-cloud atmospheric effect. The target reflectance is more or less insensitive to the underlying surface or overlying atmosphere when a very deep cloud over ocean is observed. Radiative transfer models provide an estimate of the ratio between expected reflectances at non-absorbing wavelengths.

For both methods, the following analysis steps are needed:

a) Selection of suitable target areas within the imagery

For the arctic stratus method, a suitable target is one that conforms closely to the plane-parallel model, is water cloud, contains a range of optical depths around t = 4, overlies blue water ocean and does not include strong sunlight geometry. These requirements are identified through both automated and non-automated methods.

For tropical deep convection, a suitable target is optically thick and geometrically deep, covers a large area, is illuminated at high solar angles, and lies over the ocean. Again automated and non-automated methods are used.

b) Prediction of the expected reflectance ratios (along track/nadir in stratus case, channel to channel in the tropical Cb case)

For both methods, expected reflectance ratios are calculated using a fast cloud-atmosphere-surface radiative transfer model developed for cloud parameter inversion as part of a study for SEVIRI.

c) Generation of calibration factors by comparison to measured ratios, and quality control of analysis fit.

10.1.4.2 Geographic Location

Using clouds as calibration targets mean that is hard to specify data over a specific geographic area. The presence and location of clouds is highly variable. To achieve a reasonable number of targets in a given time period, a large area must be defined.

The MERIS Calibration plan details a strategy for defining the geographic location needed. In summary, the single best search region for the arctic stratus clouds is the North Atlantic/North Norway region. For tropical deep convection clouds, the most useful areas are the Western Pacific and the Eastern Indian Ocean, with the convection moving seasonally with the intertropical convergence zone.

10.1.4.3 Data Requirements

?? The following AATSR data products are required: ATS_TOA_1P.
?? AATSR and MERIS data over cloudy scenes are required. Brockmann Consult will regularly screen full MERIS child data for suitable targets. BC will then send the selected data to Watts, deleting the other data that are not required. Corresponding AATSR data will have to be ordered by the AO team from the AATSR coordinators (HT and MCE).

10.1.4.4 Interfaces

Under contract to ESA, the MERIS team coordinator administers this activity. Monthly reports and results sent to the MERIS team coordinator will also be copied to the AATSR VS. Brockmann Consult will make pre-selection of scenes.

10.1.4.5 Schedule

A draft schedule for this activity is shown in Figure 10.1.4.5-1.

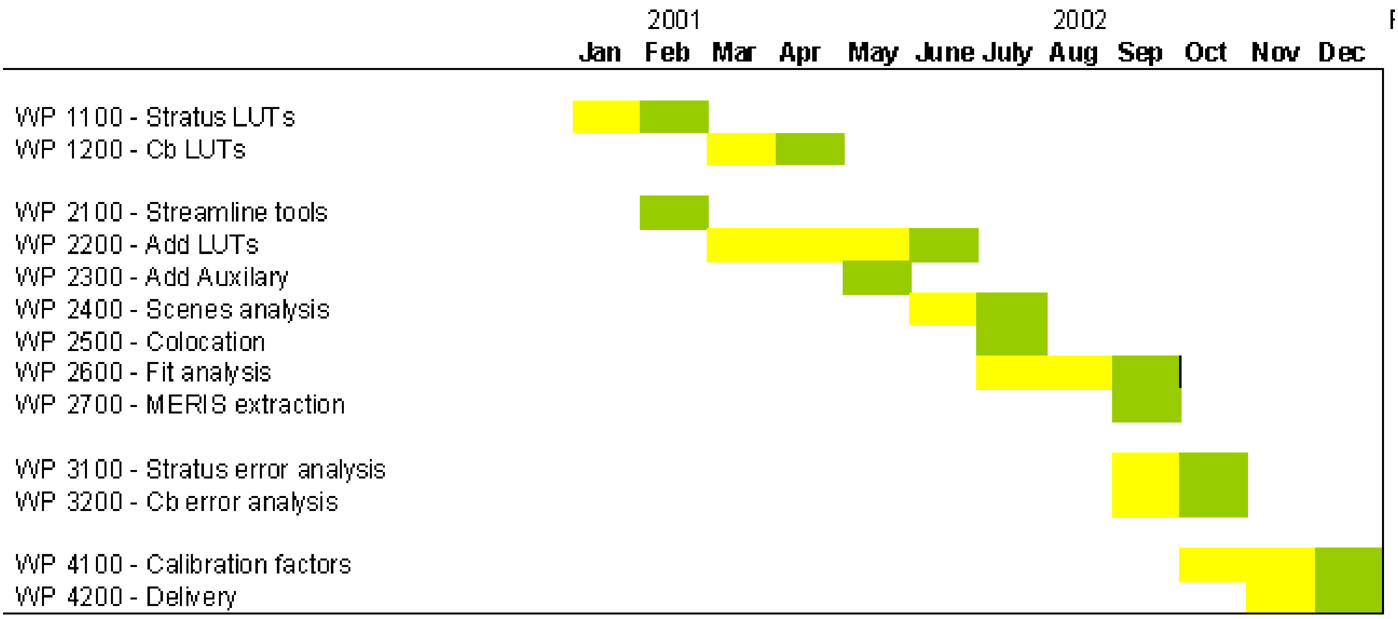

Figure 10.1.4.5-1: Schedule of activity 501; the inter and absolute calibration of AATSR/MERIS reflectance channels using cloud

10.2 Specific Campaigns and the collection of ground measurements

In addition to the validation of the visible and near-infrared channels using vicarious methods, these channels can also be validated over land using dedicated field campaigns and the collection of ground measurements.

10.2.1 Ground data collection in Australia, Prata (9025)

Fred Prata of CSIRO has been undertaking radiometric measurements over land for a number of years, at three sites in Australia – Thangoo, Amburla and Hay. These three sites represent different environmental conditions and land cover types. Continuing work with ATSR and ATSR-2, ground measurements taken at sites in Australia will be compared with data from AATSR. Prata is named as a co-investigator on the proposal by Smith (410), and will work in collaboration with him. He is also involved in validation of the land surface temperature product (Section 11).

Principal Investigator:	Dr Fred Prata CSIRO Atmospheric Research PMB 1 Aspendale Vic. 3195 Australia
Co-Investigators:	Dr David Smith, RAL.

10.2.1.1 Instrumentation

A number of instruments will be used including ground-based spectrometers, sun photometers, radiosonde equipment and aircraft mounted spectrometers.

10.2.1.2 Methodology

Validation conducted by Prata will take the form of specific campaigns and long term monitoring. The validation methodology will be similar to that used for the ATSR-2 Atmospheric Correction Experiment (ACEX). The surface measurements and atmospheric data collected at the satellite overpass time were fed into a radiative transfer code (MODTRAN 3B) and TOA reflectances calculated for comparison with the ATSR-2 reflectances. The accuracy of this method of validation was limited by the spatial sampling of the ground-based reflectances. During the AATSR validation, the sampling problem will be overcome by the use of spectrometers flown aboard aircraft.

The first validation campaign will take place shortly after ENVISAT launch during the AATSR commissioning phase. The exact timing of the campaign will depend on selection of optimum weather conditions. Within 6 months, a second campaign will take place to establish the reproducibility of the validation results and to check on the stability and performance of the AATSR onboard calibration system. It is likely that these campaigns will take place at the Hay site, but consideration will be given to conducting the campaigns at Amburla.

The Amburla site is well suited to validation because of its homogeneity, stability and because it is an instrumented site. The most important aspect of validation at this site will be the ability to determine the site's spectral reflectance stability. For this purpose upwelling spectral irradiances should be monitored at the site. Overflights of the site using a video camera system approximately once per month are desirable. The spectral BRDF of the site should be measured at least once, from the air if funding permits, during the monitoring period.

10.2.1.3 Geographical Location

Validation work will be carried out at three locations in Australia – Uardry, Amburla and Thangoo. These are summarised in Table 10.2.1.3-1.

Field Site	Longitude (E)	Latitude (S)	Height (m)	Climate	Surface type
Uardry	145.304	-34.392	110	Temperate	Grassland
Amburla	133.119	-23.385	626	Semi-arid	Bare Soil
Thangoo	122.352	-18.179	60	Tropical	Savanna

Table 10.2.1.3-1 List of the 3 Australian sites, their locations and character

The sites are all instrumented differently. They are all within 200km of a radiosonde site and measure the upward and downward components of the short-wave and long-wave radiation field. Some sites have optical depth measurements.

?? Uardy

Hay plains, New South Wales, Australia

Uardry is a semi-arid grasslands site located on the vast Hay plains some 50 kilometres east of the township of Hay. The site and surrounding region are dry land grazing properties (mainly sheep) characterised by large treeless expanses of natural vegetation located on extremely flat and homogeneous natural terrain. The overlying atmosphere is characterised by a semi-arid climate with low amounts of water vapour and aerosols. Regular winter/spring rainfall provide seasonal vegetative growth. The site has moderate column amounts of water vapour (typically 10 to 30 kg m^{-1}) and aerosol optical depth (typically 0.03 at 0.5 micron). Instruments monitor continuously at several points the surface radiation budget components (broadband shortwave and longwave fluxes, downwelling and upwelling), meteorological parameters, and in clear daytime skies the aerosol optical depth, column ozone and water vapour amounts.

?? Amburla

Tanami Desert, Northern Territory, Australia

Amburla is an arid desert site located on a long flat plain (approximately 30 km x 12 km) characterised by a red soil with a sparse cover of Mitchell grass. The site, which is located 100 kilometres northwest of Alice Springs, is used for cattle and camel grazing. Ephemeral vegetative growth following heavy tropical thunderstorm activity or slow-moving rainband activity, may be significant but is uncommon. The site has moderate column amounts of water vapour (typically 5 to 40 kg m^{-1}) and aerosol optical depth (typically 0.03 at 0.5 micron). The site is instrumented to continuously monitor at several points the surface radiation budget components (broadband shortwave and longwave fluxes, downwelling and upwelling) and meteorological parameters.

?? Thangoo

Thangoo is uniform over an area of at least 3 km x 3 km and characterised by a hot and humid monsoonal summer climate, a warm to hot and relatively dry winter climate, and significant aerosol loading in spring and early summer due to large uncontrolled bushfires. A location at the southern extent of the ITCZ (inter- tropical convergence zone) is planned to minimise monsoonal activity (cloud) and maximise the summer day-to-day atmospheric variability (aerosol and water vapour). Continuous monitoring at several points will include the surface radiation budget components (broadband shortwave and longwave fluxes, downwelling and upwelling), meteorological parameters, and in clear daytime skies, the aerosol optical depth, column ozone and water vapour amounts.

10.2.1.4 Planned Validation Activities

Measurements are being undertaken at the three validation sites on a continuous basis. During the commissioning phase, validation reports will be made available on a monthly basis. It is hoped that dedicated campaigns will be undertaken to complement the continuous measurements.

10.2.1.5 Data Requirements

?? The following AATSR data products are required:
ATS_TOA_1P
?? Transfer of products via ftp.
?? The data needed are offline.

Address to where data should be sent:

Dr Fred Prata
Address as above.

10.2.1.6 Interfaces

TBD

10.2.1.7 Schedule

The work of Prata will fit into the schedule of Smith (Section 10.1.1), and the overall validation schedule outlined in Section 14.

11 Land Surface Temperature Prototype Product

The L2 GST product, currently produced by the ENVISAT payload data segment, does not contain a Land Surface Temperature retrieval. It has a placeholder for such a value over land but at the current time, this field contains the 11 ?m brightness temperature over land.

CSIRO have proposed an AATSR LST retrieval, and during the ENVISAT Commissioning Phase, this retrieval is to be tested in the AATSR Prototype Processor. Following an initial evaluation of the prototype retrieval, a decision will be taken whether or not to add the retrieval to the Operational Processor used in the ENVISAT payload data segment.

RAL, under contract to ESA, will be responsible for implementing the algorithm within the PP, with assistance from CSIRO. It is hoped that the prototype product will be available at Launch, or by the end of the AATSR SODAP at L+2 months at the latest.

CSIRO will be responsible for providing an initial assessment of the algorithm's performance, over Australian sites. Other experts working in this field have been invited to review the results of the algorithm and contribute validation results to increase the number of geographical areas covered by this initial evaluation. Fred Prata (as lead scientist for AATSR LST retrieval) and Marianne Edwards (as AATSR Validation Scientist) will jointly co-ordinate the activities of this group, and will be responsible for reporting results back to ESA and DEFRA at the ENVISAT Validation Workshop at L+9 months.

It should be noted that at present, there will be no spatially averaged LST retrieval. This will be considered once the retrieval in the 1 km product has been optimised.

Members of the land surface validation team are:

- Fred Prata, CSIRO
- Jose Sobrino, University of Valencia
- Simon Hook, JPL
- Julienne Stroeve, University of Colorado
- Cesar Coll, University of Valencia

Data requirements and distribution

During the commissioning phase, the prototype LST product will be produced at RAL and distributed to team members via an ftp server. The exact mechanism for this data dissemination is TBD.

Interfaces

The AATSR VS will coordinate the LST validation team in conjunction with Dr Fred Prata. Team members will receive data from RAL, and send validation results back to the VS. The VS will then laise with Dr Prata.

Schedule

All team members will follow the schedule given in Section 14.

11.1 Land Surface Temperature validation projects

11.1.1 LST product validation over sites in Australia

Dr Fred Prata, the author of the LST ATBD will conduct LST product validation over sites in the Australia (the same sites as used for validation of the visible and near infrared wavelengths, as discussed in Section 10.2.1).

Principal Investigator: Dr Fred Prata
CSIRO Atmospheric Research
PMB 1 Aspendale
Vic. 3195
Australia

11.1.1.1 Methodology

The details described here are taken from:
Prata, A, 2000 The proposed global land surface temperature product for Envisat's AATSR: Scientific basis, algorithm description and validation protocol, in Proceedings of the ERS-Envisat Symposium 'Looking down to Earth in the New Millennium' Gotherburg 16-20th October 2001.

The ideal method for obtaining an independent validation dataset is to use two multi-channel radiometers with AATSR pass-bands from an aircraft and from the ground. The measurements should be made as close as possible to the overpass time of AATSR and ancillary data relating to atmospheric profiles and emissivity measurements must be collected. The target validation site must be uniform at scales of hundreds of meters to several kilometres. The sky must be clear during the measurement period and the aerosol content of the atmosphere must be low.

Given that it is unlikely that this ideal measurement protocol will be met on many occasions, 3 alternative strategies will be used:
i. Gathering large amounts of less accurate near-simultaneous temperature measurements at well chosen sites.
ii. Using numerical model temperature simulations from high resolution mesoscale models.
iii. Comparison of the AATSR LST product with MODIS, AVHRR and GLI LST products.

The first strategy has been implemented using the Australian validation sites shown in Table 10.2.1.3-1. The data from these sites consist of contact temperature measurements and radiometric measurements. The contact temperatures are representative of satellite measurements although biases exist under certain atmospheric and surface conditions. The radiometer data also show a strong correlation with the satellite data, but these measurements must be emissivity corrected prior to comparison with the AATSR LST product.

Currently there are 3 radiometers operating at the Thangoo site, 4 at Uardry and 1 at Amburla. The validation data set will consist of:
- 30 minute time-series of 2 minute temperature averages and standard deviations, centred on the time of the overpass. The temperatures will consist of spatially averaged contact measurements over an area of approximately 1 * 1 km^2. The number of sensors used in the spatial average will vary.

?? 30 minute time series of radiometer measurements (average and standard deviations). Appropriate for the nadir and forward views of AATSR.
?? Radiosonde profiles of temperature and moisture made at the nearest upper-air station to the site.
?? 30 minute time series of upward and downward longwave and shortwave flux density measurements.
?? 30 minute time series of aerosol optical depths at 0.55, 0.67 and 0.87 ? m obtained from multi-filter rotating shadowband radiometers.
?? Library spectral emissivity profile measurements made at each site. Only one dataset per site it envisaged, but this may be expanded to several seasonal datasets as resources permit.
?? Standard surface meteorological data (air temperature, wind-speed, humidity and surface pressure) at each site as 30-minute time-series centred on the overpass.

The dataset required for the mesoscale model will depend on the exact details of the model employed. A minimum dataset might comprise:
?? Surface temperature. This must be as close to the surface as possible without being below the ground. The lowest vertical level in the atmosphere will not be appropriate. Inversion of the Stefan-Boltzmann flux density to get a radiative transfer temperature would be acceptable to use.
?? Vertical profiles of temperature and moisture.
?? Description of surface character
?? Model estimate of degrees of cloudiness
?? Description of model grid size, integration step size and vertical resolution

Comparisons with products from other satellites can only be done when the measurements are nearly simultaneous. The kind of information required for this validation include:
?? 11 and 12 ? m TOA brightness temperatures at the site.
?? Pixel-by-pixel LST at a minimum of 5 x 5 pixels, centred on the pixel closest to the site.
?? Pixel-by-pixel spectral emissivity retrievals (if available) at a minimum of 5 x 5 pixels, centred on the pixel closest to the site.
?? Satellite data and time of acquisition of collocated pixel.
?? Satellite view zenith and azimuth angles of collocated pixel for daytime data, sun zenith and azimuth angles.
?? Satellite measure of cloudiness. This cloud be a cloud flag, a confidence flag or for daytime data reflectance, values in the shortwave channel of the sensor being used.
?? Description of the theoretical basis for the LST product.

11.1.1.2 Geographical location

The geographical location of validation sites are given in Table 10.2.1.3-1.

11.1.1.3 Data Requirements

The AATSR LST prototype product over selected sites.

In addition to AATS LST product data over the 3 Australian sites, data over other sites will also be needed for quality control and global validation. Key areas for global validation include:

1. Snow and ice covered surfaces

2. Boreal forest
3. Tropical forest
4. Mid-latitude agricultural land
5. Desert
6. Mixed, close-canopy forest
7. Steppe

Approximately 40 clear-sky AATSR data products (20 ascending, 20 descending) from these regions and the Australian sites are required. Table 11.4.1.3-1 gives details of the geographic locations of the sites chosen.

Area	Description	Longitude	Latitude
		+ = E, - = W	+ = N, - = S
1	Greenland	-40	+74
2	Canada	-105	+54
3	Borneo	+113	-1.5
4	Spain	-1	+39
5	Sahara	0	+30
6	Siberia	+114	+68
7	Kamchatka	+158	+56

Table 11.4.1.3-1 AATSR product requirements for global quality control

11.1.2 LST product validation over the Barrax test site

Land surface temperature validation will be carried out using the Barrax test site. This is a 100 km^2 agricultural area in the Albacete county (Castilla La Manche), which has been used for many national and international studies. The main crops in the area are wheat, barley, corn and alfafa.

Principal Investigator Dr José A.Sobrino
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46100, Burjassot
Spain

11.1.2.1 Methodology

1. A series of temperature measurements are taken of the surface using a CIMEL radiometer, to obtain radiometric temperature of the surface (Tr). This has wavebands in the 11 and 12 ? m wavelengths.
2. Surface emissivity is derived though a series of emissivity transects using the box method (?).
3. Using the CIMEL radiometer, effective atmospheric temperature is derived (Ta).
4. Using Tr, ? and Ta, the in situ Land surface temperature is obtained. This is then compared to the LST obtained from AATSR using the proposed algorithms

Measurements can be made at the site throughout the year.

11.1.2.2 Geographical Location

Validation will be done at the Barrax test site, located at 39? 03' N, 2? 05'W. This is an agricultural site, 28km from the city of Albacete. The site is defined by the coordinates:

39? 01' N, -2? 05' W
39? 07' N, -2? 05' W
39? 03' N, -2? 00' W
39? 03' N, -2? 11' W

11.1.2.3 Data Requirements

?? The AATSR LST prototype product.

11.1.2.4 References

Sobrino, J.A., Reillo, S., Cuenca, J., and Prata, A.J., Surface temperature from ATSR-2 data: Algorithms and validation. ERS-ENVISAT Symposium, Gothenburg, 16-20th October 2000

Sobrino, J.A., Soria, G, and Prata, A.J., Surface Temperature from ATSR-2 data: Algorithms and Validation. Journal of Geophysical Research (submitted)

11.1.3 LST product validation over the Greenland ice sheet

Land surface temperature validation will be carried out around the Greenland ice sheet.

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11.1.3.1 Methodology

Automatic weather stations are situated around the Greenland Ice Sheet. These collect a number of data including:

- Air temperature
- Wind speed
- Wind direction
- Humidity
- Pressure accumulation rate at high temporal resolution to identify individual storms
- Surface radiation balance in visible and infrared wavelengths
- Sensible and latent heat fluxes
- Snow pack conductive heat fluxes

Hourly average data are transmitted via a satellite link (GOES or ARGOS) to the University of Colorado throughout the year. In addition, measurements are stored in solid state memory. The system is powered with two 100 Ah batteries, charged by a 10 or 20 W solar panel. The satellite data-link is powered by two separate 100 Ah batteries connected to a 20 W solar panel. This set-up guarantees continuous data recordings and storage, even in the case of satellite transmission failure. The expected lifetime of the instrumentation is 5 years.

Data at some sites have been available since 1992 and data collection continues. In 2001, three more stations were installed in the ablation region of the ice sheet. At these sites, skin temperature is not measured. However, profiles of air temperature and temperature in the snow pack may provide the opportunity to derive the skin temperature. Alternatively, net solar radiation and net radiation information together with modelled incoming longwave radiation could be used to estimate the surface temperature. This may however, lead to large errors though since the errors for the individual instruments could translate into large errors in the outgoing LW radiation at the surface.

Figure 11.4.3.1-1 shows one of the Greenland AWS.

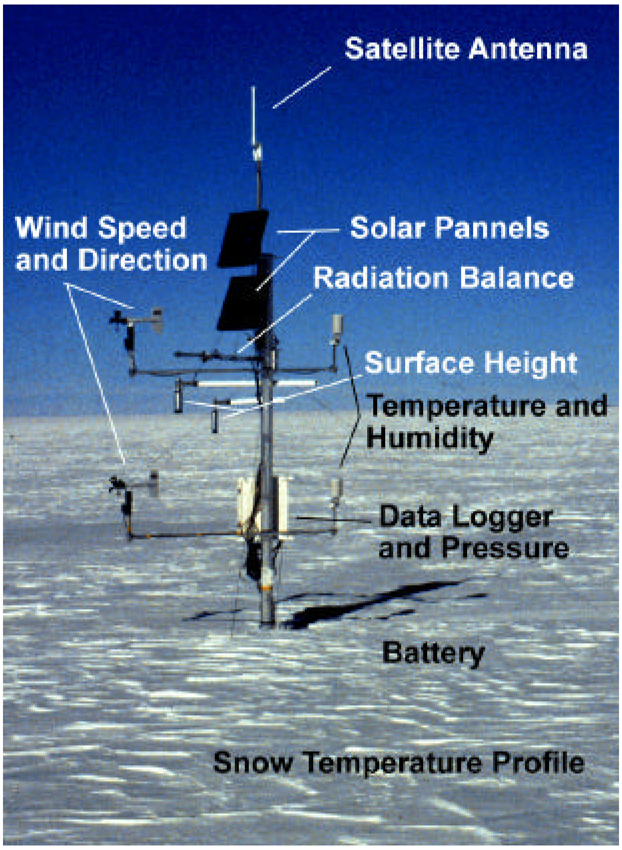


Figure 11.4.3.1-1 Automatic Weather Station situated in Greenland
(Source of Photo: http://cires.colorado.edu/steffen/gc-net/gc-net.html)

11.1.3.2 Geographical Location

Figure 11.4.3.2-1 shows the location of automatic weather stations over Greenland. The location in Lat/Long is provided in Table 11.4.3.2-1.

	Latitude	Longitude		Latitude	Longitude
1	69.57317	49.29517	10	66.00055	44.50139
2	69.8819	46.97358	11	63.14889	44.81667
3	73.8333	49.49528	12	75	29.99972
4	77.1433	61.095	13	69.91333	46.85472
5	78.5266	56.8305	14	75.09975	42.33256
6	72.57944	38.50417	15	66.47944	42.50027
7	78.01677	33.99387	16	69.69942	33.00058
8	66.48096	46.27995	17	69.417	50.124
9	69.49835	49.68156	18	65.75845	39.60177

Table 11.4.3.2-1: Location of the automatic weather stations in Greenland

11.1.3.3 Data Requirements

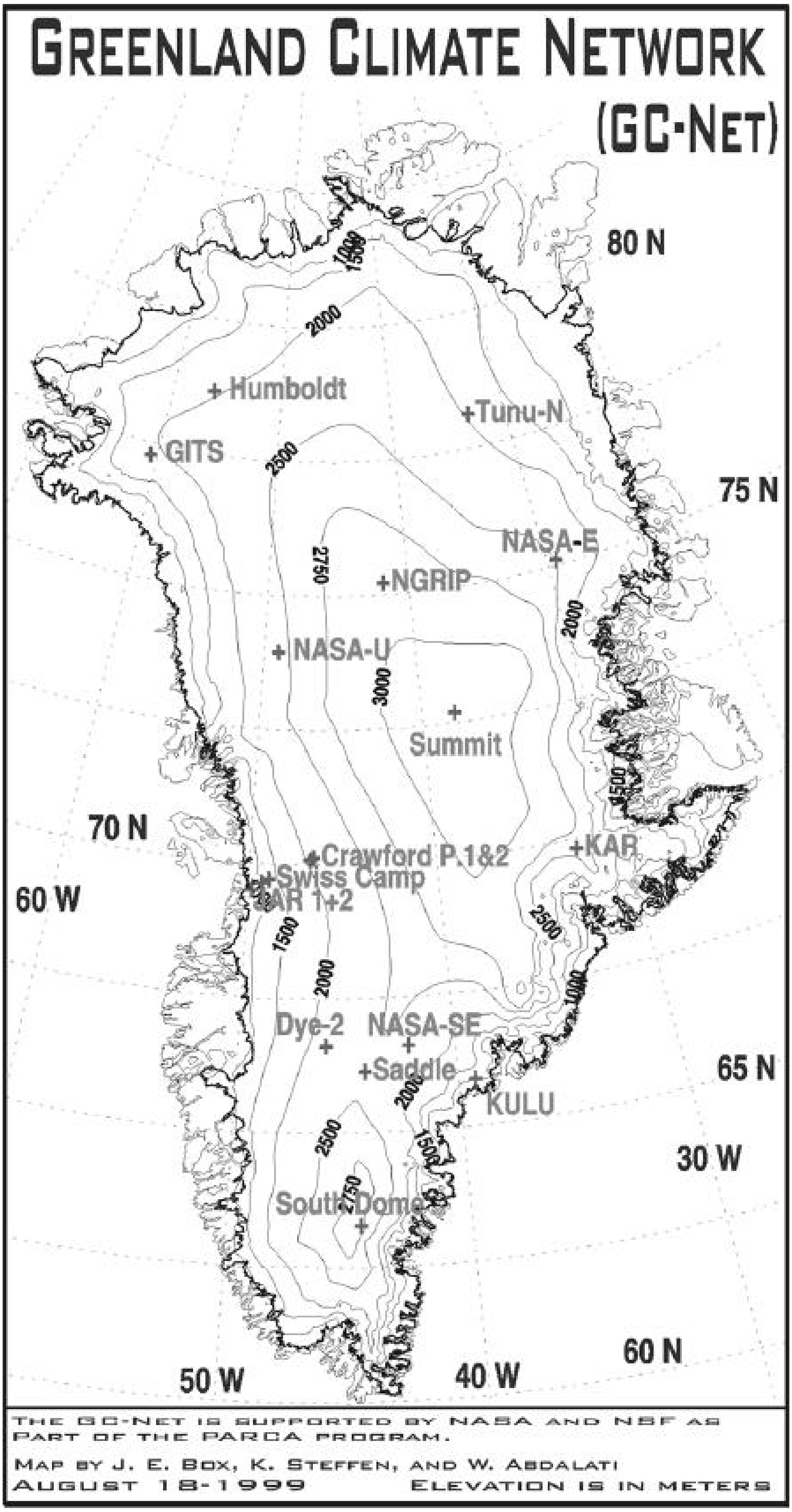


Figure 11.4.3.2-1: Location of Automatic Weather Stations over Greenland
(Source of Image: http://cires.colorado.edu/steffen/gc-net/gc-net.html)

11.1.4 LST product validation in Valencia

Dr Cesar Coll will carry out LST validation at a site near Valencia.

Principal Investigator: Dr Cesar Coll
Dept. of thermodynamics, Faculty of Physics
University of Valencia
Dr Moliner, 50
46100-Burjassot (Valencia)
Spain

11.1.4.1 Methodology

The validation site is within a large area of rice fields, located a few kilometres south of Valencia City. The area is completely flat and surrounds the Albufera Lagoon. The size of the area is 3 km * 3km. The most ideal time for validation is June to September when the rice crops have full growth and attain nearly full cover. Daily visits can be made to the field site depending on weather conditions and staff availability.

Temperatures will be measured using two Everest and one CIMEL (4 bands) radiometers, along prefixed transects covering one square of 1km by 1km. Measurements will be made ±1 hour around AATSR overpass time. Measurements will include:

?? Radiometric temperatures at selected points along transects, and time of measurement.
?? Atmospheric downwelling radiances.
?? Emissivity of plants and underlying soil (CIMEL bands at 11 and 12 ? m).
?? Air temperature and humidity at surface level.
?? Local radiosonde measurements for one or two days. The Spanish meteorological office launches radiosondes at 00 and 12 hr. The nearest measurements are Palma de Mallorca, Barcelona and Murcia.

11.1.4.2 Geographical Location

Figure 11.4.4.2-1 shows a false colour ASTER image of the study area (taken June 30th 2000). The study area appears red in the bottom right of the image around the lagoon.

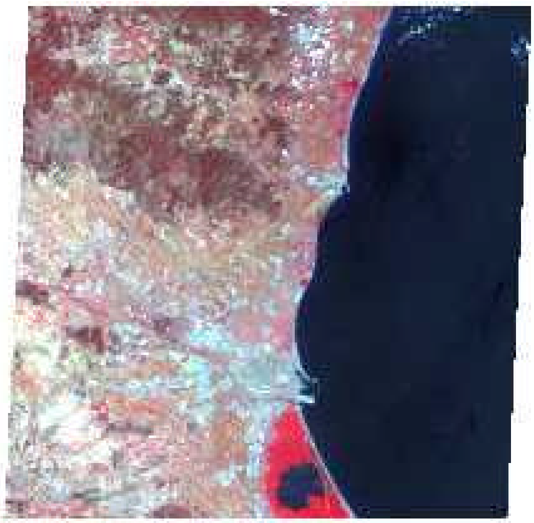


Figure 11.4.4.2-1 ASTER image of the Valencia study area (30th June 2000)

The coordinates of the study area are:

0? 21’ 40 W

39? 22’ 40 N

11.1.4.3 Data Requirements

TBD

11.1.5 LST product validation at Lake Tahoe

Dr Simon Hook will carry out LST product validation at Lake Tahoe, a large lake situated in a granite graben near the crest of the Sierra Nevada Mountains on the California - Nevada border

Principal Investigator: Dr Simon Hook
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109
(818) 354-4321

11.1.5.1 Instrumentation

In order to validate mid (3-5 µm) and thermal infrared (8-14 µm) data from airborne and spaceborne instruments in-flight, the Jet Propulsion Laboratory (JPL) and University of California at Davis (UCD) are currently maintaining four surface sampling stations on Lake Tahoe (Hook et al. 1999, 2000, 2001). The four stations are referred to as TR1, TR2, TR3 and TR4 (Figure 11.1.5.1-1). Each raft/buoy has a custom-built self-calibrating radiometer and several temperature loggers. The sensor end of each of the loggers is mounted ~2 cm beneath the surface on a floating support that trails behind each raft (Figure 11.1.5.1-2). The radiometers are near-nulling and self calibrating. They are accurate to ? 0.1 K. NIST traceability is provided by laboratory calibration of the radiometer against the JPL cone blackbody that was traced to NIST using their transfer radiometer. The temperature loggers are calibrated in a NIST-traceable water bath. Each raft contains a data logger with dial-up cellular telephone access. The data logger receives data from the radiometer and 4 temperature sensors mounted on the support trailing each raft. The data are automatically downloaded daily via cellular telephone modem to JPL allowing near real-time monitoring. The other static temperature loggers are included for redundancy and downloaded approximately every two months under normal operations. A full set of measurements is made every 2 minutes. However, the units can be remotely re-programmed if a different sampling interval is desired. Meteorological stations (wind speed, wind direction, relative humidity, air temperature and net radiation) are also included on TR1, TR3 and TR4 (Figure 11.4.5.1-2). A similar meteorological station will be added to TR2 in the near future.

Both JPL and UCD maintain additional equipment at the US Coast Guard station that provides atmospheric information (Figures 11.1.5.1-1 and 11.1.5.1-3). This includes a full meteorological station (wind speed, wind direction, relative humidity), full radiation station (long and shortwave radiation up and down), a shadow band radiometer and an all sky camera. The shadow band radiometer provides information on total water vapour and aerosol optical depth.

Measurements of algal growth rate using 14C, nutrients (N, P), chlorophyll, phytoplankton, zooplankton, light, temperature and secchi disk transparency are also made tri-monthly at the Index station and monthly samples for all constituents except algal growth and light are made at the Mid-lake station. Many samples are taken annually around the Tahoe Basin to examine stream chemistry and snow and atmospheric deposition constituents.

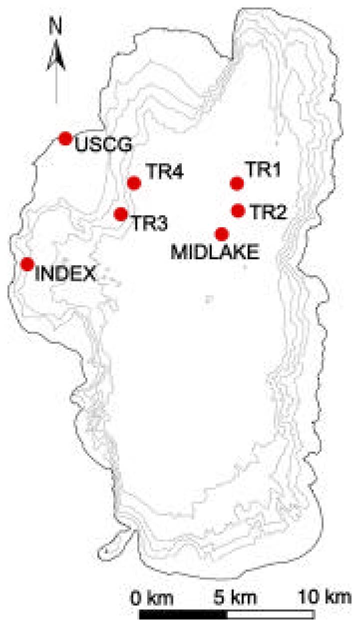


Figure 11.1.5.1-1. Bathymetric map of Lake Tahoe with a contour interval of 100 m. The 4 NASA rafts are labelled TR1, TR2, TR3 and TR4. Also shown is the US Coast Guard station (USCG), Midlake and Index stations. A variety of atmospheric measurements are made at the USCG and a variety of water properties are measured at the Midlake and Index stations.

Figure 11.1.5.1-2. Surface monitoring station at TR1. The station measures the radiometric skin temperature, bulk temperature, wind direction (magnetic) and speed, relative humidity, air temperature and net radiation.

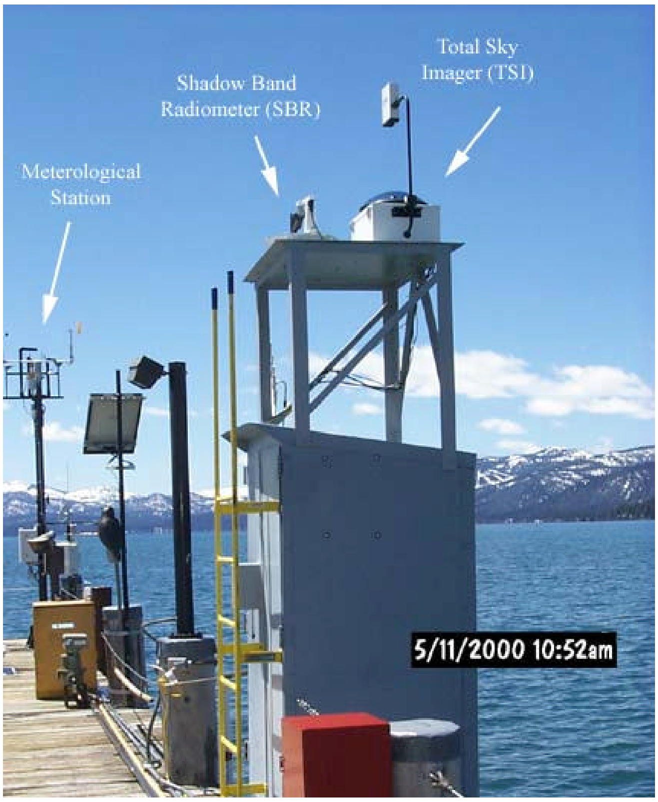


Figure 11.1.5.1-3. Yankee Total Sky Imager (TSI) and Yankee Multi Filter Rotating Shadowband Radiometer (MFRSR) located above the gauging station on the US Coast Guard Pier. A full meteorological station is also located on the pier and maintained by UCD.

11.1.5.2 Methodology

The strategy adopted to validate the mid and thermal infrared data and products from airborne and spaceborne instruments was to first validate the radiance at sensor data and then validate the derived surface products (radiance, temperature, emissivity). In the AATSR study, the radiance at sensor product will be validated followed by the land surface temperature product. A key feature of the Lake Tahoe validation site is that measurements are made continuously. This allows us to validate all clear overpasses provided suitable tools exist for extracting the infrared data.

Radiance at Sensor Product – ATS_TOA_1P GBTR

The procedure for validating the radiance at sensor product is summarized as the follows:

- Obtain the interpolated NCEP atmospheric profile for the time of the overpass.
- Correct the surface radiometric measurements to surface skin temperature.
- Calculate the average bulk temperature for each raft.
- Calculate the skin effect (difference between the average bulk and skin temperature).
- Determine the skin temperature for rafts with bulk temperature values only.
- Propagate the surface skin temperature to at-sensor radiance using the radiative transfer model (MODTRAN 3.5) driven by the atmospheric profile.
- Convolve the modelled at-sensor radiance with the system response functions for the satellite radiometer.

- Extract the satellite radiometer at-sensor radiance values over each of the rafts. For AATSR a 3x3 km area (3x3 pixels) will be extracted. The area extracted is centred on the location of each raft, which was determined by differential GPS.
- Calculate the average difference between the predicted and satellite measured values.
- Assess the accuracy of product over time.

Step (1) – Obtain the interpolated NCEP atmospheric profile for the time of the overpass

Atmospheric profiles are obtained from the National Centre for Environmental Prediction (NCEP). The NCEP produces global model values on a 1-degree by 1-degree grid at 6 hr intervals. Lake Tahoe is centred on 39 N, 120 W and the grid value for this point is utilized. The NCEP data are interpolated to the overpass time.

Step (2) – Correct the surface radiometric measurements to surface skin temperature

The radiometers measure the radiative temperature of the skin of the lake over the 7.8-13.6 μm wavelength region and in order to obtain the skin (kinetic) temperature it is necessary to correct the data for any atmospheric and emissivity effects. The skin temperature is derived by correcting for surface emissivity and subtracting the sky radiance reflected by the surface into the path of the radiometer:

$$L_{obs} = \int_{\lambda} R(\lambda)\left\{ L_{path}(\lambda) + \tau(\lambda)\varepsilon(\lambda)L_{BB}(T,\lambda) + \tau(\lambda)(1-\varepsilon(\lambda))\frac{I_{sky}(\lambda)}{\pi} \right\} d\lambda \qquad \text{Equation 1}$$

Where:

L_{obs} = *observed radiance at sensor*

L_{BB} = *blackbody radiance (Planck function)*

L_{path} = *emitted radiance from surface – sensor path*

I_{sky} = *total downwelling irradiance upon the surface*

λ = *wavelength*

T = *temperature*

τ = *surface – sensor path tranmittance*

ε = *surface emissivity*

R = *Normalized system spectral response function*

The path transmittance, path radiance, and downwelling irradiance terms are obtained from a radiative transfer model (MODTRAN 3.5) driven by a supplied atmospheric profile obtained in Step (1). The emissivity of the water was obtained from the ASTER spectral library. The emissivity of water has been shown to change with view angle and wind speed. Currently these affects are not accounted for, however, modelled values of the emissivity variation of water with wind speed and view angle were obtained recently and will be incorporated into future analyses. With all terms of Equation 1 determined, the equation is solved for temperature by iteration. It should be noted the path transmittance terms and path radiance terms are for the 1m of air between the water surface and the radiometer. For a high altitude site with a dry atmosphere these terms are close to 1 and 0 respectively.

Step (3) Calculate the average bulk temperature for each raft

The bulk temperature is measured approximately 2 cm beneath the surface by several different types of temperature sensors. Initially, the temperature trace of each logger over time is examined to make sure the logger is reading correctly. This is necessary because the cables from the loggers occasionally develop leaks causing the temperature values to drift. The data from any suspect loggers are discarded and the two temperature values closest to the overpass time, for a given logger, are linearly interpolated to the acquisition time of the nadir pixel. The mean and standard deviation of the interpolated values for each raft is then calculated. Since the measurements are normally made every 2 minutes with a maximum of every 5 minutes the interpolation time is typically less than 2 minutes.

Step (4) Calculate the skin effect

The skin effect is calculated as the bulk temperature minus the skin temperature. The skin effect is typically less during the day than at night. The smaller skin effect observed in the daytime is attributed primarily to strong solar heating coupled with low wind speeds. However, other factors are important such as the difference between the air and water temperature. Figure 11.1.5.1-4 shows a plot of some recent field data acquired over Lake Tahoe at the TR3 station on June 7th 2001. These data were derived using the Mk III near-nulling radiometer and include simultaneous meteorological data. These data are from a calm day; notice that as the solar elevation increases (1600 GMT, 0800 PST), the bulk and skin temperature both increase, with the skin temperature increasing more rapidly and surpassing the bulk temperature until the early afternoon. In the early afternoon the wind increases, resulting in a reduction in the skin and bulk temperatures (shown by a double arrow on Figure 11.1.5.1- 4). The morning increase in the bulk temperatures is also associated with an increase in the standard deviation of the bulk temperature measurements (not shown). The standard deviation of the bulk temperatures also decreases in the early afternoon as the wind increases due to greater mixing. In the late afternoon the wind speed decreases and a skin/bulk differential is established which remains fairly constant throughout the night. As the wind speed increases in the early afternoon, so does the air temperature as warm air from the adjacent land is blown over the lake. Days characterized by low wind speeds and strong solar heating occur predominantly in the spring and fall. These data illustrate the importance of measuring the skin (what the satellite measures) rather than bulk temperature which could be different by as much as ± 0.5 K.

Step (5) Determine the skin temperature for rafts with bulk temperature values only

In some cases, the radiometric temperature is not available at a given overpass or for a particular raft on a given overpass. If no radiometric temperatures are available from any of the rafts, the radiometric temperature is estimated by adding the average difference for all the overpasses to the bulk temperature at each raft. If radiometric temperatures are available at some of the rafts then the average difference of the available radiometric temperatures is calculated and added to the bulk temperatures of the rafts that have bulk measurements but no radiometric measurements to estimate the radiometric temperature at that raft.

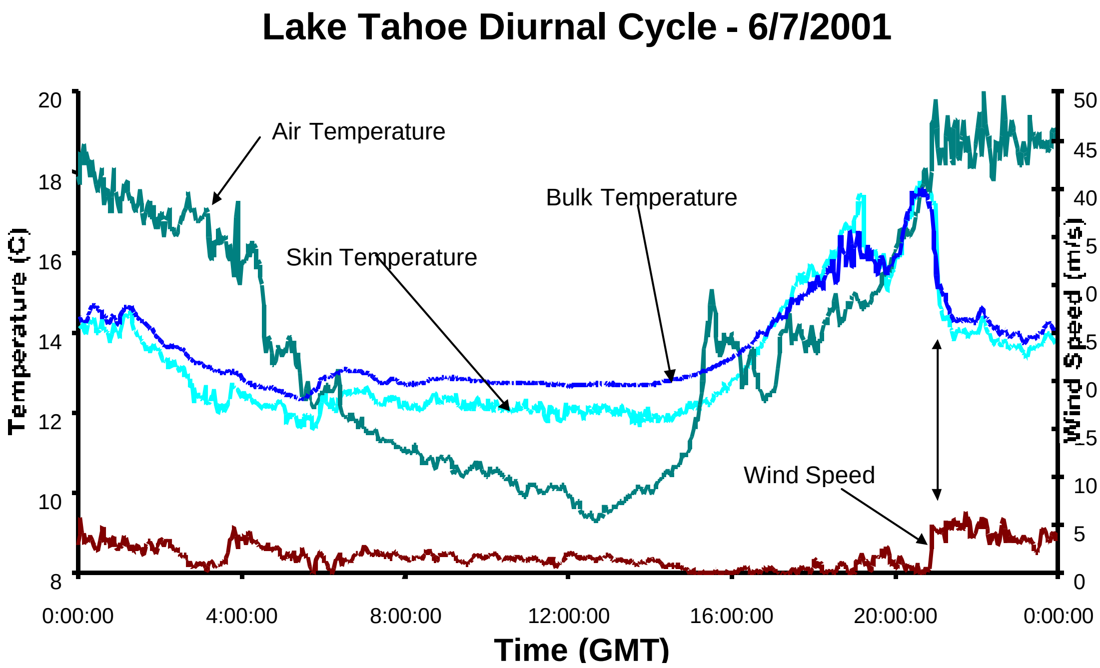


Figure 11.1.5.1-4. Variations in the bulk-, skin-, air-temperatures and wind speed on June 7, 2001 at L. Tahoe.

Step (6) Propagate the surface skin temperature to at-sensor radiance

The at-sensor radiance is calculated using a radiative transfer code (MODTRAN 3.5) driven by the interpolated NCEP profile obtained in Step (1) and the derived surface skin temperature and emissivity of water.

Step (7) Convolve the modeled at-sensor radiance with the system response functions for the satellite radiometer

The high-resolution at-sensor radiance spectrum obtained in Step (6) is convolved to the sensor system response. This step necessitates that the AATSR project provide the sensor system response for the AATSR channels.

Step (8) Extract the satellite radiometer at-sensor radiance values over each of the rafts

For AATSR data a 3x3 km area (3x3 pixels) will be extracted. The area extracted is centred on the location of each raft, which has been determined by differential GPS

Step (9) Calculate the average difference between the predicted and satellite measured values

For each overpass day there are typically 4 validation points (1 per raft). For each of these points the difference between the predicted (derived from ground measurement) and the satellite-measured values is calculated. These 4 values are then averaged to obtain an average difference between the predicted and measured values for a given overpass day.

Step (10) Assess the accuracy of product over time

This involves determining the average uncertainty between the measured and predicted radiances over time.

Land Surface Temperature Prototype Product: Temperature

The procedure for validating the surface temperature product is summarized as:

- Obtain the interpolated NCEP atmospheric profile for the time of the overpass.
- Correct the surface radiometric measurements to surface skin temperature.
- Calculate the average bulk temperature for each raft.
- Calculate the skin effect (difference between the average bulk and skin temperature).
- Determine the skin temperature for rafts with bulk temperature values only
- Extract the satellite derived surface temperature values over each of the rafts. For the AATSR data a 3x3 km area (3x3 pixels) will be extracted. The area extracted is centred on the location of each raft, which was determined by differential GPS.
- Calculate the average difference between the predicted (derived from satellite) and ground measured values. Note the predicted values are now those derived from the satellite.
- Assess the accuracy of product over time.

A detailed description of these steps is provided in the validation procedure for the at-sensor radiance product, where appropriate.

Land Surface Temperature Prototype Product: Emissivity

The procedure for validating the surface emissivity product is summarized as:

- Extract the satellite derived surface emissivity values over each of the rafts. For the AATSR data a 3x3 km area (3x3 pixels) will be extracted. The area extracted was centered on the location of each raft, which was determined by differential GPS.
- Convolve a laboratory spectrum of emissivity to the system response function of the instrument. For water the emissivity spectrum is well known when nadir-viewed.
- Calculate the average difference between the predicted (derived from satellite) and ground measured values. Note the predicted values are now those derived from the satellite.
- Assess the accuracy of product over time.

11.1.5.3 Geographic Location

Lake Tahoe is a large lake centered on 39 N 120 W on the California-Nevada border. The level of Lake Tahoe is approximately 1898 m above MSL. It is roughly oval in shape with a N-S major axis (33 km long, 18 km wide), and has a surface area of 500 km^2 (Figure 11.1.5.1-1). The land portion of the watershed has an area of 800 km^2. Lake Tahoe is considered a deep lake; it is the 11^{th} deepest lake in the world, with an average depth of 330 m, maximum depth of 499 m, and a total volume of 156 km^3. The surface layer of Lake Tahoe deepens during the fall and winter. Complete vertical mixing only occurs every few years. Due to its large thermal mass, Lake Tahoe does not freeze in winter. There are approximately 63 streams flowing into the lake and only one river flowing out of the lake. Lake Tahoe is renowned for its high water clarity. However, the water clarity has been steadily declining from a maximum secchi depth of 35 m in the sixties to its current value of ~20 m. Research by UC Davis (Jassby et al. 1999; Paerl et al. 1975) has identified that the decline is in part due to increased algal growth facilitated by an increase in the amount of nitrogen and phosphorus entering the lake and, in part, due to accumulation of small suspended inorganic particulates derived from accelerated basin-wide erosion and atmospheric inputs.

11.1.5.4 Planned validation Activities

Measurements at the Tahoe site are made every 2 minutes on a continuous basis. In addition there are periodic validation campaigns when supplemental measurements are made, e.g. aircraft data. It is assumed no additional coordination will be required for these campaigns since the equipment is "always on" and AATSR data will always be acquired over the site.

11.1.5.5 Data requirements

- The following AATSR data products are required:
  ATS_TOA_1P
  Land Surface Temperature Prototype Product
- Data volume: 512 x 512 scenes of ATS_TOA_1P and Land Surface Temperature Prototype Product for every overpass over the site (day AND night).
- Data needed are offline.

Address to where data should be sent

Dr Simon J. Hook
Mail Stop 183-501
Jet Propulsion Laboratory
Pasadena, CA, USA 91109

11.1.5.6 Interfaces

The PI will interface with a number of parties.

Interfaces	With whom	Reason	Timing
1	Validation Scientist (ME)	• Help with access to Prototype Surface Temperature Product.	As required.
2	ESA (HT)	• Order AATSR Data • Receive AATSR Data	
3	CSIRO Fred Prata	• Prata has supplied text file extractions over ATSR2 data over targets (buoys). It is assumed these extractions will continue for AATSR in order to facilitate a timely turnaround of results	Weekly

11.1.5.7 Schedule

Validation data will be acquired on a near continuous basis. It is assumed AATSR data will be acquired over the site for the duration of the AATSR mission and data will continue to be provided beyond the commissioning phase.

References

http://shookweb.jpl.nasa.gov/validation
http://modis-land.gsfc.nasa.gov/val/
http://blt.wr.usgs.gov/

Hook, S. J., Prata, A. R. and S. G. Schladow, 1999. Interim Status Report. Available from: http://eospso.gsfc.nasa.gov/validation/terraval.html.

Hook, S. J., Prata, A. R. and S. G. Schladow, 2000. Interim Status Report. Available from: http://eospso.gsfc.nasa.gov/validation/terraval.html.

Hook, S. J., Prata, A. R. and S. G. Schladow, 2001. Interim Status Report. Available from: http://eospso.gsfc.nasa.gov/validation/terraval.html.

Jassby, A. D., Goldman, C. R., Reuter, J. E. and R. C. Richards, 1999. Origins and scale dependance of temporal variability in the transparency of Lake Tahoe, California-Nevada. *Limnology and Oceanography*, vol. 44, pp. 282-294.

Paerl, H. W., Richards, R. C., Leonard, R. L. and C. R. Goldman, 1975. Seasonal nitrate cycling as evidence for complete vertical mixing in Lake Tahoe, California-Nevada. *Limnology and Oceanography*, vol. 20, pp. 1-8.

12 Summary of validation activities during the commissioning phase

Sections 9 to 11 outline the different validation activities that will take place during the commissioning phase of Envisat. These are summarised in Table 12-1 in relation to validation of the different products.

Product ID	Name	Description	Validation	PI
ATS_NL__0P	Level 0 Product	?? Instrument source packet data	No	
ATS_TOA_1P	GBTR	?? Full resolution top of atmosphere BT/reflectance for all channels and both views.	0.55?m, 0.67 ?m, 0.87 ?m and 1.6 ?m over land and cloud	Smith Hagolle Stammes Watts Prata
			3.7?m, 11?m, 12?m – inherent through validation of SST level 2 products, and LST product	
		?? Product quality data, geolocation data, solar angles and visible calibration coefficients	Specific validation through algorithm verification activity. Inherently validated though validation of other products	Birks
ATS_NR__2P	GST	?? Full resolution nadir-only and dual-view SST over sea	Yes	Robinson/Donlon Barton Minnett Nightingale
		?? Full resolution 11 ?m BT and Normalised Difference Vegetation Index (NDVI) over land	NDVI not validated Prototype LST product to replace 11?m BT	Prata Sobrino Stroeve Coll Hook
		?? Product quality data, geolocation data and solar angles	Specific validation through algorithm verification activity. Inherently validated through validation of other products	Birks
ATS_AR__2P	AST	?? Spatially averaged ocean, land and cloud parameters	Yes	Robinson/Donlon Barton Minnett Nightingale
		?? Spatially averaged top of atmosphere BT/reflectance	Inherently validated through validation of other products.	
ATS_MET_2P	Meteo Product	?? SST and averaged BT for all clear sea pixels, 10 arc min cell, for Meteo users	Yes	UK Met Office
ATS_AST_BP	Browse Product	?? 3 band colour composite browse image derived from L1b product. 4 km x 4 km sampling.	Not officially validated, but the product will be examined, and the LUT reviewed as part of the algorithm verification work.	Birks

Table 5-1: Validation of AATSR data products

13 AATSR Data Requirements and Distribution

13.1 Data Requirements

In order to ascertain satellite data requirements during the commissioning phase, and the logistics of data distribution and circulation, Hannah Tait (ESA ESTEC) has compiled a spreadsheet of validation data requirements. This spreadsheet is primarily to aid ESA in planning, and is constantly evolving and changing as plans develop and requirements change. A copy of the spreadsheet can be obtained directly from Hannah Tait, and she should be notified of any additions or modifications to the current estimates.

Contact details:

Hannah Tait
ESA ESTEC
Keplerlaan 1,
Postbus 229
2200 AG Noordwijk
The Netherlands
Tel: +31 71 565 5918
Hannah.Tait@esa.int

13.2 Data Distribution

Full details of AATSR data distribution to Envisat Cal/Val PI's during the commissioning phase can be found in the technical note PO-TN-ESA-GS-1227, written by Hannah Tait (HT). To summarise:

?? In general, ca/val PI's will have access to AATSR data from L + 3 months, after the instrument SODAP and one month of algorithm verification. Earlier access will be considered on a case-by-case basis.

?? NRT products will be generated from unconsolidated Level 0 data, within 3 hours of acquisition. Off-line products will be generated 2-3 weeks after acquisition. All AATSR cal/val PI's (with the exception of the UKMO using the Meteo product) will be provided with off-line products during the commissioning phase.

?? Level 1b data (ATS_TOA_1P product): 512 * 512 scenes

During the commissioning phase, level 1b data will be ordered via AATSR coordinators (HT and ME). There will be no systematic distribution.

Data requests for PI's with long-term pre-defined site locations (a fixed buoy or field site monitored over months or years) will be pre-programmed into the PDS before launch by ESA, for systematic delivery whenever an overpass crosses the site.

Short term requirements and/or requirements over sites yet to be determined will be entered into the USF on an as-needed basis by HT. PI's should inform HT of their requirements.

Level 1b data will be available in 512 x 512 km scenes, to download from the UK-PAC by FTP. PI's are responsible for downloading data from the FTP site. Overpass data used to generate the order will be supplied in order to identify the product for download (orbit number and start/stop time will be in the product filename).

PI's validating SST are expected to use mostly L2 data, with L1b only used for anomaly investigations. If PI's are generating their own SST data from L1b data, the 'official' SST coefficients, as used by ESA should be used.

?? Level 2 data (ATS_NR_2P and ATSR_AR_2P)

Level 2 data will be generated at the UK-PAC.

The 14 orbits of off-line L2 data generated each day will be written onto CD. This master CD will be copied and routinely distributed to a mailing list of users once per day, every day. PI's will therefore receive 3 CD's a day throughout the commissioning phase. ESA will help PI's identify the correct orbit number of the data they require from the CD, with information being provided in the form of overpass tables. Alternatively, ESOV can be used. The orbit number of a product will appear in the product name. One product represents one whole orbit. Once extracted, the product can be read into EnviView. A tool (PdsPixels) will be provided with EnviView to aid PI's in extracting the pixels of interest.

?? The Meteo product

The Meteo product will be available to the UKMO from L + 3 onwards.

It can be ftp'ed from Kiruna within 3 hours, available in both PDS and BUFR format.

The 4 blind orbits are available within one day.

?? Special cases:

AO 501: Watts et al

This AO requires AATSR and MERIS data over cloudy scenes. Brockmann Consult will regularly screen full MERIS child data for suitable targets. BC will then send the selected data to Watts, deleting the other data that are not required. Corresponding AATSR data will have to be ordered by the AO team from the AATSR coordinators (HT and MCE).

AO 552: Robinson/Donlon

This AO requires RA-2 data. This will be sent to Donlon on CD.

AO 410/119: Smith/Hagolle

These AO's use the same sites, for MERIS and AATSR. The MERIS data will be extracted by the METRICS tool, running on the IECF.

14 Schedule for validation activities

In terms of a schedule for validation activities, there are a number of important milestones that affect all validation activities. This section describes events, which are applicable to all activities. Milestones specific to any one activity have been included in the section relevant to that activity.

Figure 14-1 gives the current provisional schedule for activities relevant to validation, from launch until the end of December 2002. The transition phase referred to in the schedule denotes the handover from ESTEC to ESRIN at the end of the commissioning phase. Important milestones and key dates are listed in Table 14-1. These dates should be seen as provisional, subject to events and successful operations.

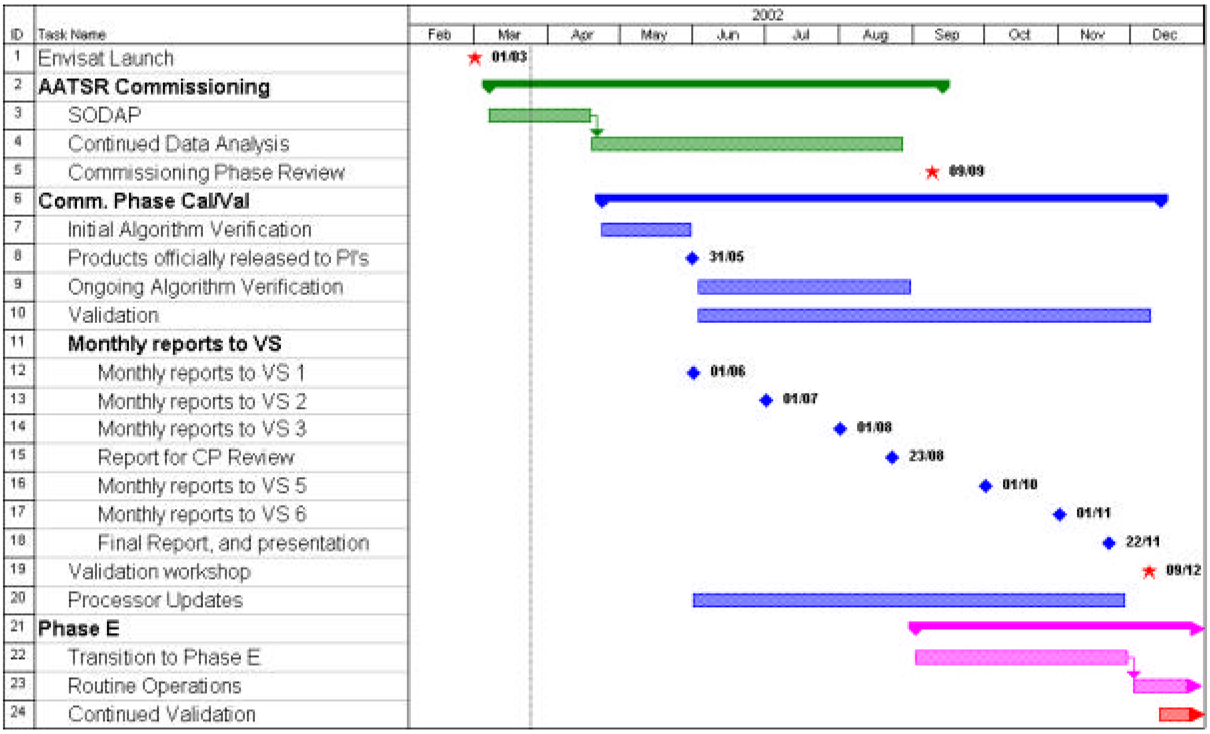


Figure 14-1: Schedule for activities during the commissioning phase

Phase	Milestone	Approx. Timing	Approximate Dates
Launch		L	1 March
AATSR Commissioning			
	SODAP	L to L + 2 m	7 March to 21 April
	Data Analysis	L + 2 to L + 6	22 April to 30 August
	Commissioning Phase Review	L + 6	9-13 Sept or 30 Sept to 4 Oct (ESTEC)
Validation			
	Initial algorithm verification	L + 2 to L + 3	23 April to 31 May
	Products released to PI's	L + 3	31 May
	Ongoing algorithm verification	L + 3 to L + 6	3 June to 30 August
	Validation	L + 3 to L + 9	3 June to 29 November
	Validation workshop	L + 9	9-13 December
	L1b processor update	L + 3 to L + 9	
Phase E (ESRIN)			
	Transition to Phase E	L + 6 to L + 9	
	Routine Operations	L + 9	

Table 14-1: Important milestones and key dates during the commissioning phase

AATSR Commissioning
Instrument commissioning is described in detail in AD3. Taking place in the first six months after launch, the instrument is switched on, checked out and optimised. It is then configured for nominal operations.

Figure 14-2 gives a provisional schedule for activities during the SODAP, indicating when poor, useable and good quality AATSR data will be available. From this schedule, it can be seen that some data which could be used for validation, may be produced before the 'official' data availability date of L + 3 months. If good data are available and PI's require data from this earlier period, backordering of data will take place. This will be considered on a case-by-case basis. As with the dates given in Figure and Table 14-1, the schedule provided in Figure 14-2 is provisional only, assuming success at all stages.

The commissioning phase will be completed by holding a Commissioning Phase Review at L + 6 months. This will be held at ESA ESTEC, and will provide the first opportunity to report early results of validation.

Validation
The formal period of validation will take place from L + 3 months until L + 9 months, although as discussed above, some validation may take place before this time. PI's will report to the VS on a regular basis during this time (see Section 15.1). This phase of validation will end with a validation workshop at L + 9 months.

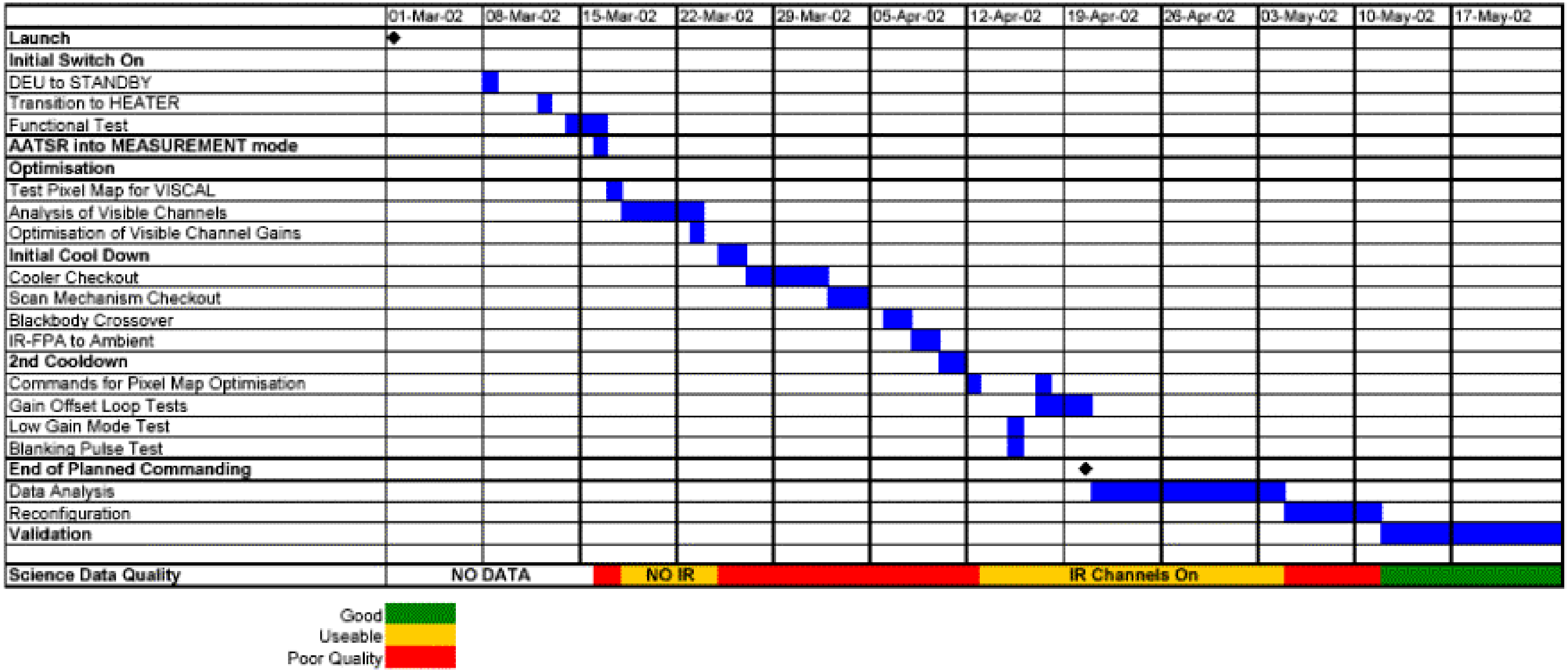


Figure 14-2: Schedule of activities during the SODAP

15 The Validation Loop

During the commissioning phase, and up until the validation workshop at L + 9 months, it is important that validation results are reported and acted on, quickly and effectively. The validation loop in Figure 15-1 has been produced to illustrate the mechanism by which this will occur[3]. It describes what happens to the validation data once collected.

1. Following ENVISAT Launch, and the AATSR Switch On and Data Acquisition Phase (SODAP), AATSR data will become available to AATSR validation data providers (VDP's). VDP's will inform the Validation Scientist (VS) of any planned campaigns, and the VS will ensure that the Flight Operations Support team are aware of these campaigns in their planning. This will ensure that the data will be collected at that time, if this is possible, or that the VDP is informed in advance of the non-availability of the instrument. VDP's will order and receive AATSR data, collect in situ measurements and perform in situ/satellite matchups. VDP's will submit validation data to the NILU database.

2. Following the SODAP, for the remainder of the Commissioning Phase, once a month, VDP's will send the VS information files containing the in situ/satellite matchups plus any analysis/comments they have. If validation data are unavailable on a monthly basis, the VDP's will still send a short report detailing progress, and expectation of the timing of results (see Section 15-1).

3. During commissioning, ESA will perform algorithm verification, and will report results to the VS. The VS will report results of the algorithm verification to the VDP's.

4. The VS will coordinate validation activities, collating all the results received, and analysing them. If the validation data reveal anomalies and errors, the VS will investigate possible sources of error, by asking VDP's to check their data, and seeking advice from the PP team, the FOS team and the PDS team. If thought necessary, investigations by the various specialist teams may take place at this stage on a limited scale. In this way, a basic level of quality assurance will be applied.

5. The VS will produce monthly validation reports, which will be sent to members of the DQG. The DQG will be an ad hoc group, convened by the VS as required (i.e. whenever there is a significant input of validation results). It will communicate via email and meet as necessary, as part of an FOS or AATSR SAG meeting, or as an AATSR validation team meeting. Depending on the validation report under review, a meeting of the DQG will involve appropriate people – namely the PI, the Project Scientist, the VS and the FOS manager, and validation PI's as necessary. DEFRA, ESA, and NERC will have full visibility of the group and can attend meetings, if desired.

6. The DQG will review the validation results, and decide what, if any, further action is needed. They may authorise further investigations (into the validation data collected, the data processing chain, the instrument etc). The VS will coordinate any further investigations, and report back to the DQG.

[3] 25/03/02 Following the re-organisation of review groups by DEFRA, the validation loop is currently under review.

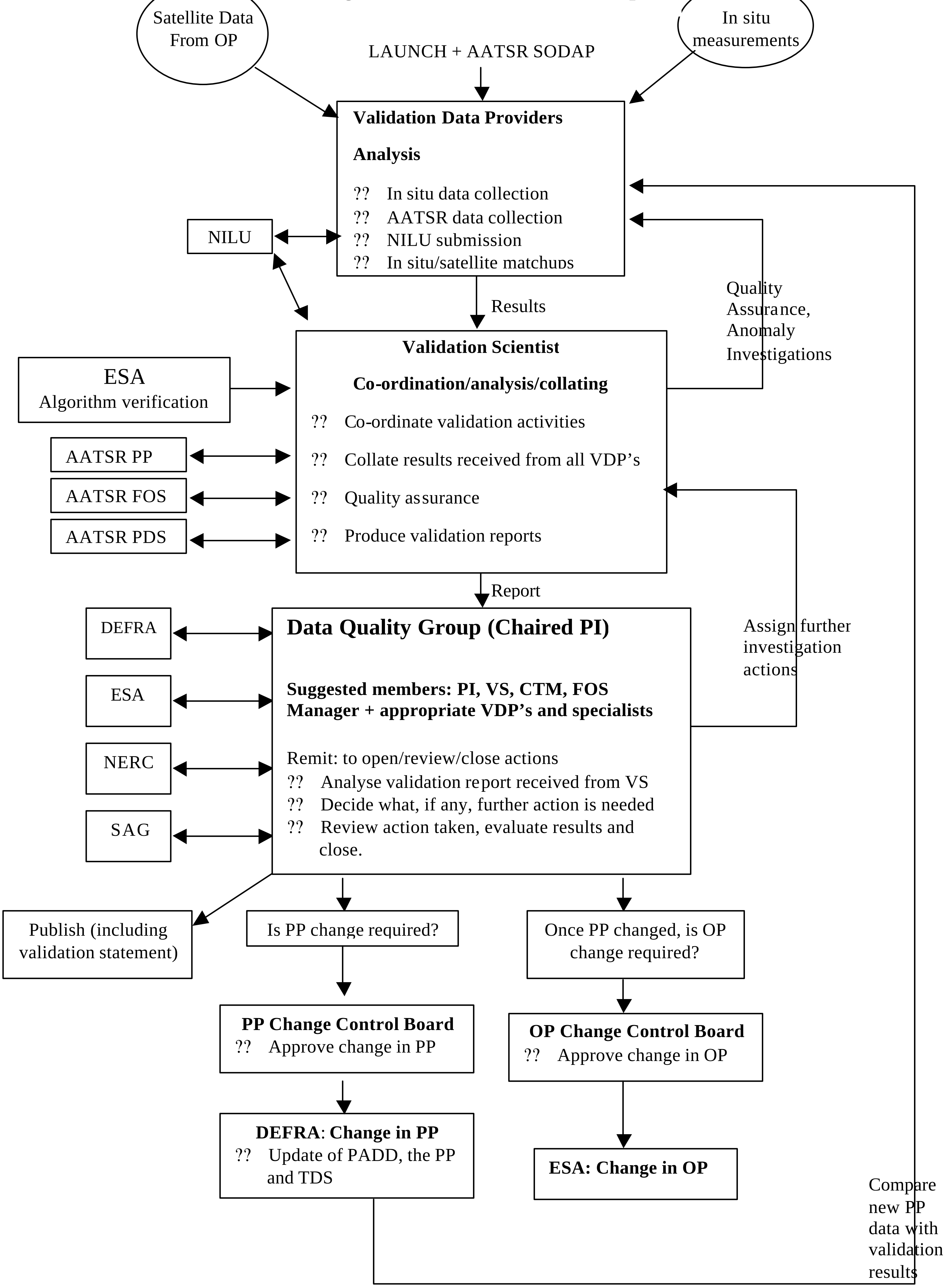
7. If a change to the data processing is recommended by the DQG, this change will first be tested with the PP. If results of the test confirm that a change in the operational system is needed, recommendations to permanently change the PP are passed to DEFRA. A Change Control Board (ESA, DEFRA, PI, SAG) meets to approve the change. If a change is approved, DEFRA updates the PADD, the PP and the TDS. New data from the PP are provided to the VDP's, and tested against validation results.

8. Following successful testing, a change in the OP is made, and the validation loop begins again.

9. Statements about the status of validation activities will be made by the DQG on a regular basis and published on the AATSR validation website.

10. Following the commissioning phase, the validation loop will continue, although it is envisaged that meetings of the DQG will be held less frequently.

Figure 15-1 The Validation Loop



15.1 Reporting

As described in the validation loop, VDP's will report to the VS on a monthly basis. Provisional dates for these reports are given in Figure 14.1. In order to minimise paperwork and ease interpretation of reports, a reporting template will be provided for VDP's, made available in word and pdf form on the AATSR validation website (http://www.leos.le.ac.uk/aatsr). In addition to monthly reporting, VDP's are encouraged to use this form to report anomaly or result information at any other time. The form should be returned to the VS.

A longer reporting template will be provided for reporting results for the commissioning phase review and validation workshop. For these two events, longer reports giving more detail are required.

Having received and collated reports, the VS will report to appropriate parties as shown in the validation loop. VDP's will be kept informed of progress and results through monthly emails and the AATSR validation website. It is hoped that validation results can be discussed within the team using the discussion forum on the website.

In addition, VDP's are expected to submit correlative data to the NILU database, following the metadata guidelines provided by NILU.

16 Future Validation Activities

As described in Section 4, the objectives of the AATSR validation programme are extended post-commissioning to include:

?? Validate AATSR SST products in an increasing number of sites and seasons.
?? Monitor long-term data product quality.
?? Validate new products.

Many of the activities detailed as initial validation activities will continue, whilst additional activities will be conducted by the wider scientific community.

Continuation of Commissioning Phase Activities

Table 17.1-1 gives an indication of the continuation of commissioning phase activities after the validation workshop at L + 9 months. Year 2 and 3 represents one and two years from L + 9 months respectively.

ID No.	Activity	Post-commissioning
9084	Global buoy comparison, including early indication of gross errors.	Continuation of activities throughout years 2 and 3.
9081/2	Robinson/Donlon: ISAR5C	Continuation of activities throughout years 2 and 3, pending availability of funding. Deployment of ISAR5C 1 and 2 in more geographic locations. (TBC)
9024	Barton: Rottnest Island Ferry, Perth	Continuation in years 2 and 3, pending availability of personnel and funding (TBC).
9024	Barton: Pure Pleasure Ferry, Townsville	Continuation in years 2 and 3, pending availability of personnel and funding (TBC).
590	Minnett: M-AERI	Continuation in years 2 and 3, pending availability of cruises and funding (TBC)
9024	Barton: DAR011	Continuation in years 2 and 3, pending availability of funding, cruises and berths (TBC)
410	Smith: Vicarious inter-calibration of AATSR and MERIS using terrestrial targets	Long term monitoring of desert sites, pending availability of funding. (TBC)
501	Watts	Activity continuing to L + 1 year
9025	Prata	Planned continuation of field data collection, pending availability of funding (TBC)

Table 17.1-1 Continuation of initial validation activities, post the validation workshop at L + 9 months.

Additional validation activities

Table 17.2-1 lists ESA A/O proposals that have been categorised as ‘Science’ proposals, and which include validation work. These PI’s will receive data when it is released for general use at the end of the commissioning phase. (NB Some listed projects use AATSR data, but only as a means of validating data from MERIS. Nevertheless, these may make interesting contributions and have been included here for completeness).

Validation Activity, AO Project No.	Parameter investigated (in relation to AATSR)
889 (Rao)	SST using in-situ ship and buoy data
656 (Kwarteng)	Atmospheric Aerosol
647 (Doerffer)	SST
247 (Matzler)	Surface Temperature, Atmospheric Parameters
595 (Parslow)	SST
861 (Fischer)	Cloud optical thickness, and cloud albedo
609 (Sorensen)	Atmospheric parameters
864 (North)	Aerosol Opacity and land surface bi-directional reflectance

Table 17.2-1: Additional post-commissioning validation projects, not included in the core validation programme

In addition to these AO science proposals, it is hoped that validation data will come from the wider scientific community. Initial contact has already been made with several groups with a view to future collaboration regarding validation work.

New Products

A number of new products are being discussed for AATSR data. If new products are developed, validation will be carried out post-commissioning to validate the parameters derived.

As described in Section 11, an AATSR land surface temperature product is being prototyped for inclusion in the L2 products. Following successful validation during the commissioning phase, a decision will be taken as to whether to make this product operational.

17 Development of the AATSR Validation Implementation Plan

The AATSR Validation Implementation Plan is a working document, and will continue to evolve throughout the mission. Versions 1 and 2 of the plan deal specifically with validation activities during the commissioning phase. It is envisaged towards the end of the commissioning phase, Version 3 will be issued providing more information on validation activities that will continue into Envisat Phase E, the Exploitation phase.