AATSR
Validation Implementation Plan

Version 4: Ongoing Validation

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1 INTRODUCTION

1.1 Background

The Advanced Along-Track Scanning Radiometer (AATSR) was launched on Envisat in March 2002. The AATSR instrument is designed to make precise and accurate global Sea-Surface Temperature (SST) measurements, which when added to the large data set collected from its predecessors, ATSR-1 and ATSR-2, will provide a long term record of SST data (> 15 years) that can be used for independent monitoring and detecting of climate change. Validation of AATSR is defined as the assessment by independent means of the quality of AATSR data products. Over sea, the primary product of AATSR is SST. Over land, because of the developmental nature of potential land products, namely Land Surface Temperature (LST) and Normalised Difference Vegetation Index (NDVI), the primary product for validation purposes is considered to be top-of-atmosphere (TOA) visible and near infrared reflectances and thermal brightness temperatures.

1.2 Scope of this 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 Science Advisory Group (SAG).

Part 3 of the AATSR validation plan (AD12) is the Validation Implementation Plan (VIP). Version 1 to 3 of the VIP describe in detail the activities that were performed to validate the AATSR data products up to and including the MERIS and AATSR validation team (MAVT) workshop, which was held in October 2003. This document is Version 4 of the AATSR VIP and describes ongoing validation activities after the MAVT workshop during the Envisat data exploitation phase.

1.3 Current status of AATSR validation

The AATSR validation programme has successfully completed the initial validation phase. The results of the programme, which were presented at the MAVT workshop, have been able to demonstrate that:

1. The AATSR instrument is currently meeting its scientific objectives of determining global SST to an accuracy of 0.3 K (one sigma).
2. The AATSR SST product is currently of sufficient quality that it can be released unconditionally to the public.
3. Further validation investigations are essential to future data exploitation, particularly in the establishment of climate trends in SST at both global and regional scales.

The results of the programme have shown that the ATSR series of instruments continues to be the world leader in delivering accurate measurements of SST, which is a key climate variable. This is in part due to the expertise of the AASTR team as well as the design and quality of the instrument.

2 SCIENTIFIC PRIORITIES FOR AATSR

2.1 Primary Scientific Priority

The scientific priorities for AATSR are detailed in several documents, notably the AATSR Science Requirements [AD4] and the AATSR Science Exploitation Plan [AD13].

The primary priority is to determine the ultimate accuracy of AATSR SST, globally and regionally, for climate change detection.

The AATSR scientific requirements specify that AATSR's SST values achieve an absolute accuracy of better than ±0.5 K, with ±0.3 K (one sigma) adopted by the project as the target accuracy. This level of accuracy would allow reasonably accurate calculations of ocean-atmosphere heat transfer and reasonably effective accurate tracking of major SST anomalies such as El Niño, which are typically of 3 to 4 K in magnitude.

In detecting climate change from long time-series of data, the main scientific problem is that of discriminating between seasonal variability and long-term trends. A number of analytic techniques are available to facilitate the characterisation of seasonal variability, thus a major area of research from AATSR data will be that of variability of the ocean-atmosphere system, including manifestations of large-scale SST anomalies such as El Niño, which can perturb a global time-series. Overall, the scientific priority must be to generate and examine time-series of (A)ATSR in order to quantify and to separate seasonal variability and long-term trends in the (A)ATSR record of global SST. New AATSR products, such as LST, NDVI, clouds or aerosols, represent key indicators of the climate system that have the potential to be fully incorporated into future climate prediction models.

Therefore, the central aims of the next phase of the validation programme are to:

1. Monitor instrument drift in order to be able to determine global trends of sea surface temperature over time with as high a confidence as possible (0.1 K per decade knowledge of instrument drift required) [*Trends*]
2. Perform regional validation of AATSR SST so that it will be possible to derive regional patterns of climate change in order to improve both knowledge of their contributions to global trends and to improve "fingerprinting" of climate change [*Fingerprinting*]
3. Support on-going activities connected with validation of new AATSR products that are required by users investigating climate change phenomena [*New products*]

2.2 Justification for ongoing SST validation

The primary objective of validation is to ensure that the geophysical data products generated from AATSR data meet the accuracy specified in the scientific requirements and, as a secondary objective, to determine the ultimate accuracy of AATSR under favourable geophysical conditions. In an ideal case, validation might be a systematic and mechanistic procedure of low scientific significance. Actually, on account of the great complexity of the ocean-atmosphere system a carefully targeted validation programme is essential to achieving the scientific goals of the mission. Moreover, the task of quantifying global change makes the highest demands on the accuracy and stability of the measuring system. It can be convincingly argued that, in the case of a sensor such as AATSR, the validation programme should be considered to be an intrinsic element of the scientific exploitation programme. The reason for this is that, in order to rectify potential shortcomings in the data retrieval schemes, it is necessary to obtain more information about, or a better understanding of, the prevailing geophysical conditions.

Furthermore, an important objective of AATSR is to establish continuity of the high-precision record of global sea-surface temperature (SST) initiated by the ATSR-1 sensor in 1991 and continued from April 1995 by ATSR-2. The AATSR sensor is expected to extend the data-set for at least five years, thereby providing a 15-year data set (through June 2006) for quantitative investigation of global climate change. Two additional scientific priorities immediately emerge from this. First, there is a need to ensure that the data from all three instruments are processed in such a way as to achieve the highest levels of possible accuracy and secondly, there is a need to ensure that long-term stability of the data products is achieved.

2.2.1 Long term trend analysis

For the accurate detection of global change in the SST fields, the requirements are more stringent, raising a number of questions concerning the consistency of the data, which must be addressed by the validation programme.

First, there is a requirement for great stability and freedom from drift. A paper by Allen et al [RD1] showed that given the expectations at the time for anthropogenic changes in average global SST, an instrument drift of the order of better than 0.1 K per decade is desirable for the most efficient detection of global change. This is at the limit of what can be meaningfully measured. Therefore there is a need for regular checking of AATSR's SST accuracy, to the highest level of precision.

Secondly, although AATSR is generally meeting the Defra specifications, it is also the case that, within the specified accuracy of 0.3 K, there are variations of accuracy from region to region. Regions that are difficult, as shown by regional analyses, include the tropical and southern Atlantic and northern Indian oceans, where there are often high concentrations of low altitude aerosols, the tropics in general where there are heavy loads of water vapour and the Southern Ocean where correlative data are extremely sparse. Also, it is clear from the data that there are latitude dependent effects in the current retrieval scheme which possibly have their roots in shortcomings in our knowledge of radiative transfer.

Therefore, long-term trend analysis of the AATSR instrument performance on both global and regional scales is an essential part of the ongoing validation programme.

2.2.2 Regional fingerprinting

Change in global SST is not only detected by monitoring global averages, it can also be detected, perhaps more rapidly than is the case with global averages, by inspecting patterns such as gradients across ocean basins or differences between ocean basins. Such techniques demand high accuracy and precision, such as only AATSR has the potential to achieve, in the region of 0.1 to 0.2 K. Obviously, it is crucial to the fingerprinting approach that not only does AATSR achieve that level of accuracy, but that it does so consistently across the entire principal regions of the global oceans. For this reason, a need is foreseen to carry out targeted campaigns using autonomous systems complemented by occasional high-precision 'point' samples, throughout the AATSR mission.

If SST is to be used as a true indicator of climate change, it is important that regional ocean processes that have a strong SST signature are well understood. In particular the natural variability associated with such processes needs to be quantified. Major processes with the potential to perturb the global SST signature include El Niño, the Somali upwelling, the Gulf Stream and the Kuroshio and Agoulhas currents. Research into the behaviour of such phenomena, particularly with respect to quantifying their intensity and geographical extent, should receive high priority. A highly relevant scientific question concerns the relationship between global SST and heat content of the oceans, in particular, as the oceans warm, whether it is appropriate to assume that the relationship between SST and heat content remains constant. Intuitively, increased heat input to the oceans should lead to increased vertical mixing and a changed relationship between SST and heat content. It is important for the results of the AATSR validation programme to feed into this important area of scientific research.

2.2.3 New AATSR products

The current limitations to the data almost invariably have their roots in shortcomings to our knowledge and understanding of the atmosphere. For example, there are currently small systematic latitude-dependent errors in SST values that have their roots to some extent in limitations to knowledge of infrared molecular absorption in the atmosphere. Other problems arise on account of the presence of aerosols in the atmosphere. The unambiguous identification of clouds in the data, especially over land, still has limitations and the sophisticated cloud identification routine already in place could still have room for further development. The task of relating validation results to our understanding of the radiative properties of the natural system is certainly a scientific one and the ultimate benefit will be in improved accuracy and credibility of the AATSR contribution to the climate record.

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3 THE AATSR INSTRUMENT

3.1 Instrument Overview

A description of the unique functionality of the AATSR instrument can be found in [RD2]. The data collected from the instrument is processed as part of the Envisat ground segment to Level 1b (calibrated, geo-located radiances) and Level 2 (geophysical products).

3.2 Calibration

AATSR is a self-calibrating instrument. It has an on-board calibration system, which involves the use of two specially designed and highly stable blackbody reference targets (for the thermal channels), and a diffusely reflecting target that is illuminated once per orbit (for the visible and NIR channels). Furthermore the instrument calibration was verified in ground tests. A number of activities were carried out post-launch to check and characterise the AATSR sensor. These are described in detail in the AATSR Commissioning Report [AD14]. The AATSR commissioning phase was completed on 16th September 2002. Additional information on instrument calibration can be found in Section 5, under vicarious validation activities.

3.3 AATSR Data Products

Table 3-1 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	Level 1b	• 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	Level 2 Gridded	• Full resolution nadir-only and dual-view SST over sea • Full resolution Land Surface Temperature (LST) and Normalised Difference Vegetation Index (NDVI) over land • Product quality data, geolocation data and solar angles
ATS_AR__2P	Level 2 Spatially averaged	• 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 3-1: Summary of AATSR data products

AATSR was designed primarily to measure precise and accurate sea surface temperature. The main aim of the validation programme is, therefore, to assess whether this is being achieved through validation of the Level 2 ATS_NR_2P, ATS_AR_2P and Meteo products. 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 is being carried out using land and cloud targets. An AATSR LST retrieval is now included in the operational processor and validation of this product will be required.

3.4 Algorithm Verification

The term 'algorithm verification' is used to describe the process of verifying that the software implementing the AATSR algorithms in the AATSR Operational Processor (OP) is working correctly. The SAG is responsible for the scientific correctness of the algorithms in the first place and for any improvements to them in the future.

Detailed algorithm verification of the processors used to produce the Level 1b and Level 2 products has been performed since the launch of Envisat. The process of algorithm verification will be carried out throughout the lifetime of the AATSR instrument for long-term product assurance. Algorithm verification is led by Andrew Birks of the Rutherford Appleton Laboratory, under an Expert Support Laboratory (ESL) contract to ESA. Contact details are:

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3.4.1 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 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:

- The Main Product Header (MPH) is present and has the expected size;
- The Secondary Product Header (SPH) is present and has the expected size;
- All Annotation Data Sets (ADS) and Measurement Data Sets (MDS) types as specified in the Input/Output Data Definition (IODD) are present;
- The SPH contains one Data Set Descriptor (DSD) corresponding to each data set present;
- The SPH contains all required reference and spare DSDs;
- The total product size is consistent with the sum of its component data sets, as defined by the DSDs;
- The specified MPH field contents have realistic magnitudes;
- The 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.

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 compare all quantities (e.g. cloud flags).

More specific details of the tests used for the different products are given in Table 3-2

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 3-2: Algorithm Verification Tests[1]

3.4.2 Progress to date

Most of the algorithm verification tasks were completed in the initial validation phase. The results are described in [RD5 and RD6]

3.4.3 Activities for Ongoing Analysis

A subset of algorithm verification tasks will be repeated regularly throughout Phase E for long term product quality monitoring. These tasks are currently being defined as part of the long term algorithm verification plan.

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

4 AATSR VALIDATION ORGANISATION

4.1 The MERIS and AATSR Validation Team (MAVT)

The MAVT is the combined MERIS and AATSR validation team organised by ESA, which provides a common validation programme infrastructure for these two similar instruments. Pascal Lecomte (ESA ESRIN) is currently responsible for the entire Envisat validation programme. Validation of AATSR data is done as part of MAVT, and is coordinated by Evert Attema (ESA ESTEC) and Paul Snoeij (ESA ESTEC). The current members of the MAVT are listed in Table 4-1.

Name	Function
Evert Attema	MAVT validation coordination
Paul Snoeij	Validation engineer; supporting Evert Attema
Gary Corlett	MAVT subgroup leader: AALV: AATSR Land Validation and AASTV: AATSR Sea Surface Temperature Validation
Philippe Goryl	MAVT subgroup leader: MCWP: Meris Clouds and Water Vapour
Mike Rast	MAVT subgroup leader: MVPAC: Meris Vegetation Product and Atmospheric Correction
Jean-Paul Huot	MAVT subgroup leader: MWPV: Meris Water Product Validation

Table 4-1: Current composition of the MAVT during the ongoing validation phase

4.2 Validation management

The AATSR validation programme necessarily involves a number of different organisations. Of primary importance is the Principal Investigator (PI) for the AATSR and also ESA, particularly through the MAVT and the Quality Working Group (QWG).

The AATSR Quality Working Group is the key link between the validation programme for the AATSR products and the entities implementing any required changes to the ESA operational processing scheme. The current members of the QWG are given in Table 4-2.

Organisation	Name	Function
Defra	Cathy Johnson Sophia Oliver Hugh Kelliher (Space ConneXions)	Instrument Provider
ESA	Pascal Lecomte Philipe Goryl Paul Snoeij Gareth Davies (Vega)	Space craft operations & operational data products
University of Leicester	David Llewellyn-Jones Gary Corlett	Principal investigator & validation Scientist
RAL	Chris Mutlow Andrew Birks Jack Abolins Dave Smith	In flight performance, algorithm definition and verification & calibration

Table 4-2: Current membership of the AATSR QWG

The SAG is chaired by the PI and is responsible for generating, maintaining and improving existing scientific algorithms for the generation of the scientific data products from the AATSR measurement data. The results from the validation programme feed into the maintenance and improvement process for the existing algorithms.

A schematic diagram showing the key management parties involved in the validation programme is given in Figure 4-1. Interaction with users in the form of provision of information and feedback of user priorities/results is an important part of the overall scheme.

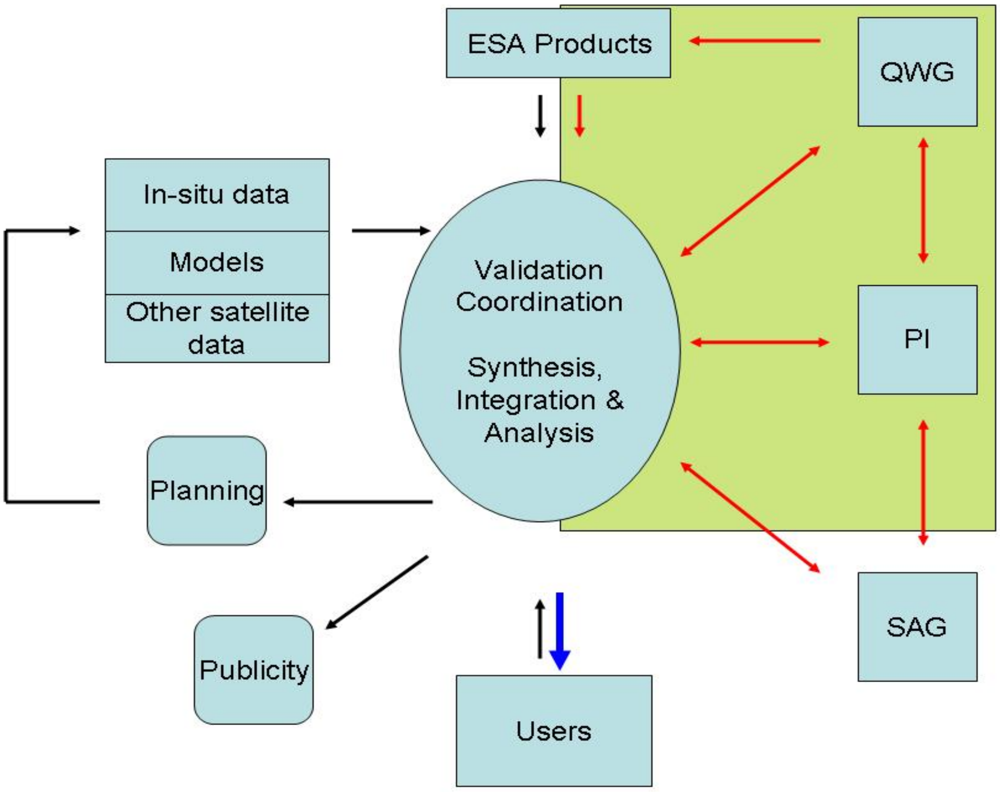

Figure 4-1: Key management parties involved in the validation of AATSR. The interfaces covered by the box on the right hand side of the figure represent the primary validation loop. Note that several of the links are two-way, particularly with respect to the user community for AATSR data.

The resulting operating structure for the validation programme is shown in Figure 4-2. The primary responsibility of the validation scientist is to act as a central co-ordination point for the AATSR validation programme on behalf of Defra, via its management interface of the Data Exploitation Contractor (DEC), Space ConneXions Ltd. Included in Figure 4-2 is a direct link to the Flight Operations Support (FOS) team covering the interface between mission management and validation activities.

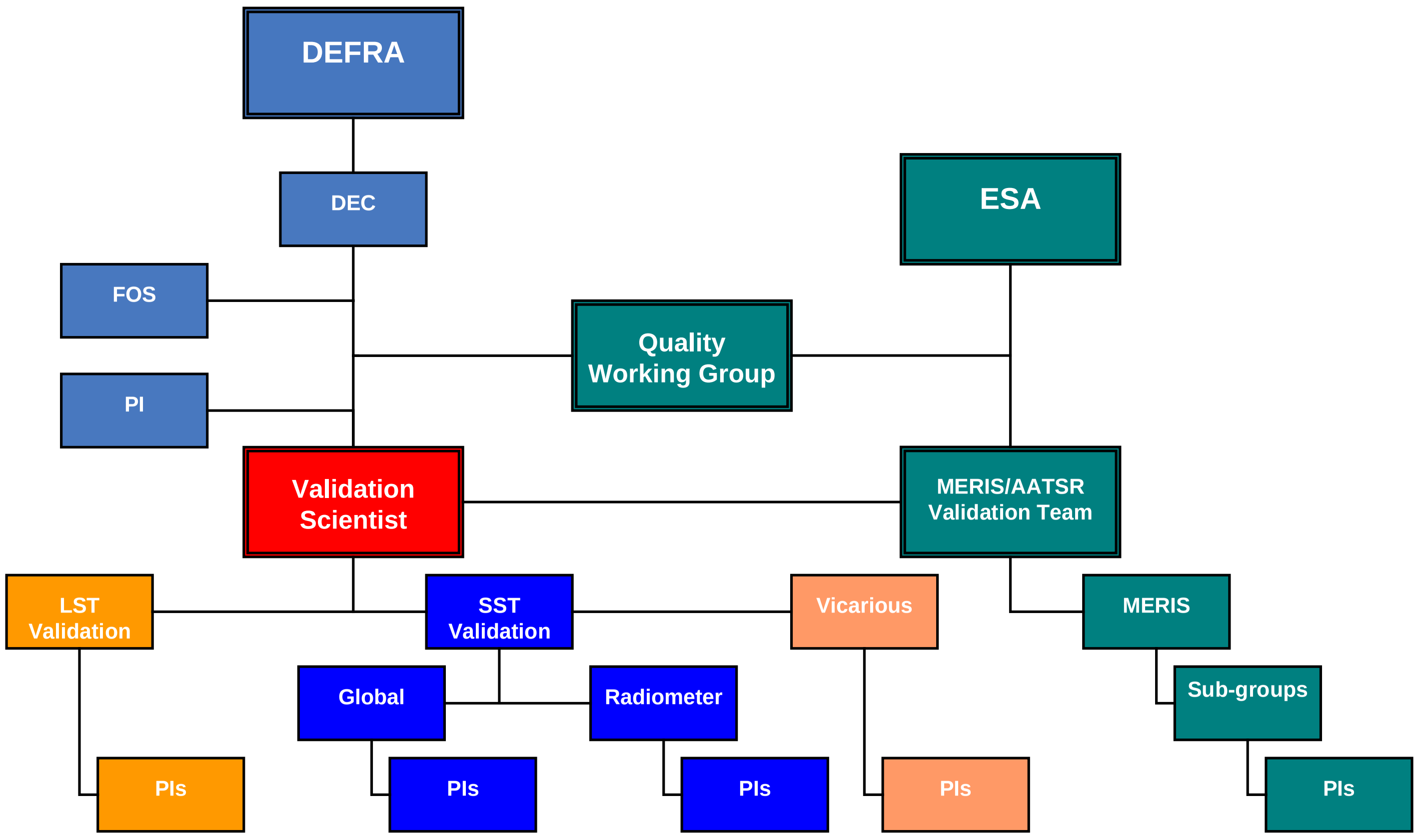

Figure 4-2: Schematic diagram showing the operating structure and communication interfaces from the validation scientist to all other relevant parties.

4.3 The role of the Validation Scientist (VS)

The VS is the key link between the validation investigators and instrument provider. The VS maintains close contact with the AATSR FOS team and provides investigators with timely information about the instrument performance and availability. The validation investigators provide their results and feedback on instrument performance to the VS who is then responsible for coordinating the results and feedback and reporting it to Defra, ESA and the PI. The VS requires regular updates (at least monthly) from the validation investigators in order to ensure that any data quality issues are highlighted and dealt with accordingly.

A flow diagram, showing the decision making process, involving the PI and the QWG, is shown in Figure 4-3. Only the QWG can agree changes to the ESA operational processor.

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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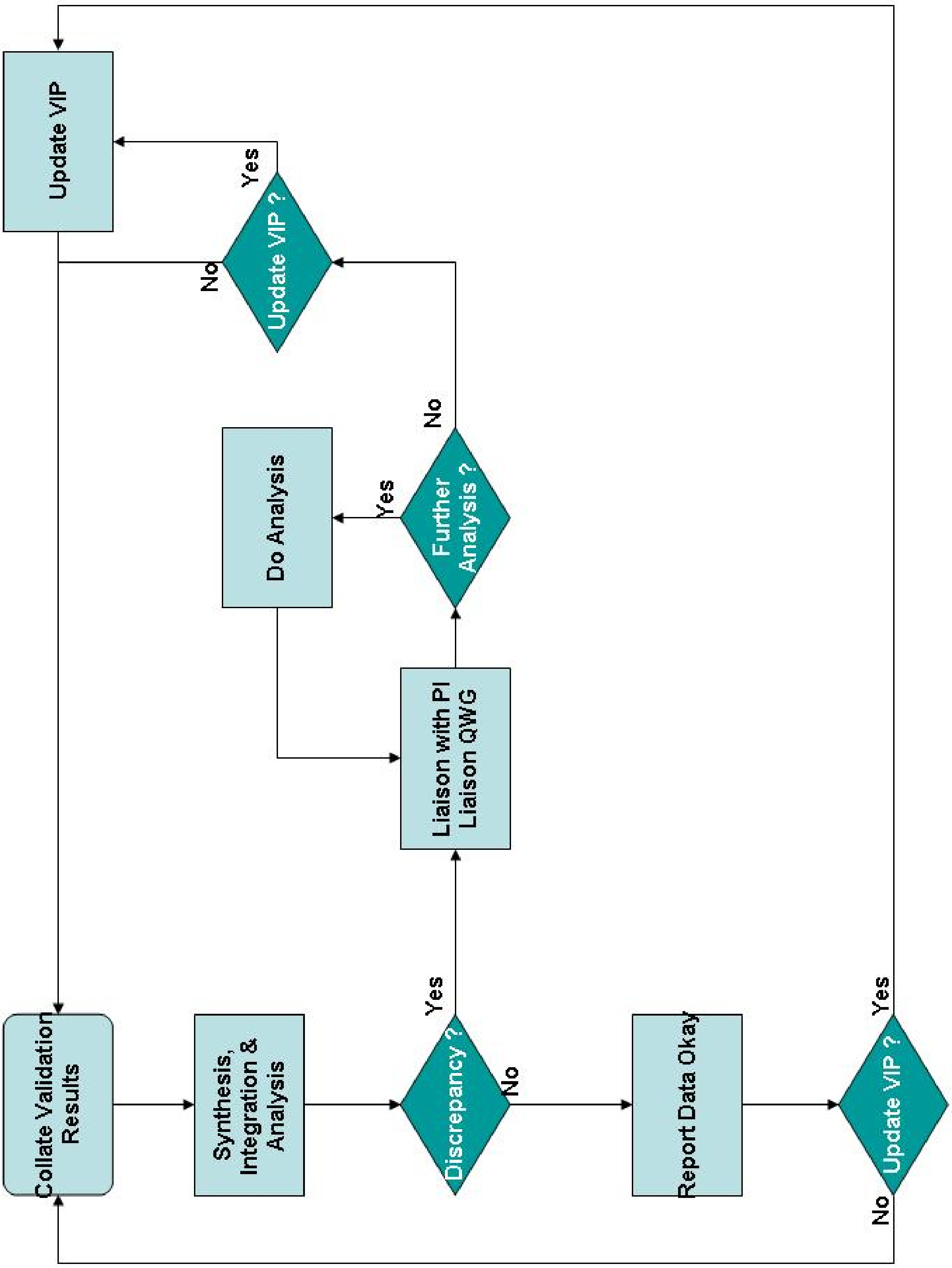

Figure 4-3: The validation decision making process

4.4 The validation principal investigators

The current AATSR validation team, including an indication of which validation priority each investigator addresses, is given in

Table 4-3.

Product Validated	Validation Priority	Name	Institute	ESA AO No.	Status
Level 2 SST[(a)]	Trends Fingerprinting	Saunders, Roger O'Carroll, Anne Watts, James	UKMO	Pending	Active
Level 2 SST[(a)]	Trends Fingerprinting	Remedios, John Corlett, Gary Noyes, Elizabeth	Uni. Leicester	N/A	Active
Level 2 SST[(b)]	Trends Fingerprinting	Barton, Ian	CSIRO	Pending	Active
Level 2 SST[(b)]	Trends Fingerprinting	Minnett, Peter[(c)]	Uni. Miami	590	Active
Level 2 SST[(b)]	Fingerprinting	Nightingale, Tim[)]	RAL	552	Active
Level 2 SST[(b)]	Fingerprinting Trends	Robinson, Ian Donlon, Craig	Uni. Southampton UKMO	Pending	Active
Level 1b reflectance	Trends	Hagolle, Olivier	CNES	119	Active
Level 1b reflectance	Trends	Kerridge, Brian	RAL	Pending	New
Level 1b reflectance	Fingerprinting	Nieke, Jens	NASDA/DLR	Pending	New
Level 1b reflectance	New Products	Poulsen, Caroline	RAL	501	Active
Level 1b reflectance	Trends	Smith, Dave	RAL	410	Active
Level 1b IR	Trends	Hook, Simon	NASA-JPL	Pending	Active
LST	New Products	Coll, Cesar	Uni. Valencia	Pending	Active
LST	New Products	Hook, Simon	NASA-JPL	Pending	Active
LST	New Products	Prata, Fred	CSIRO	Pending	Active
LST	New Products	Sobrino, Jose	Uni. Valencia	Pending	Active
LST	New Products	Stoeve, Julienne	Colorado State	Pending	Active

(a) Level 2 spatially averaged product validation (ATS_AR__2P)
(b) Level 2 gridded SST product validation (ATS_NR__2P)
(c) Data provided by the University of Miami and analysed at the University of Leicester

Table 4-3: Composition of the AATSR validation team

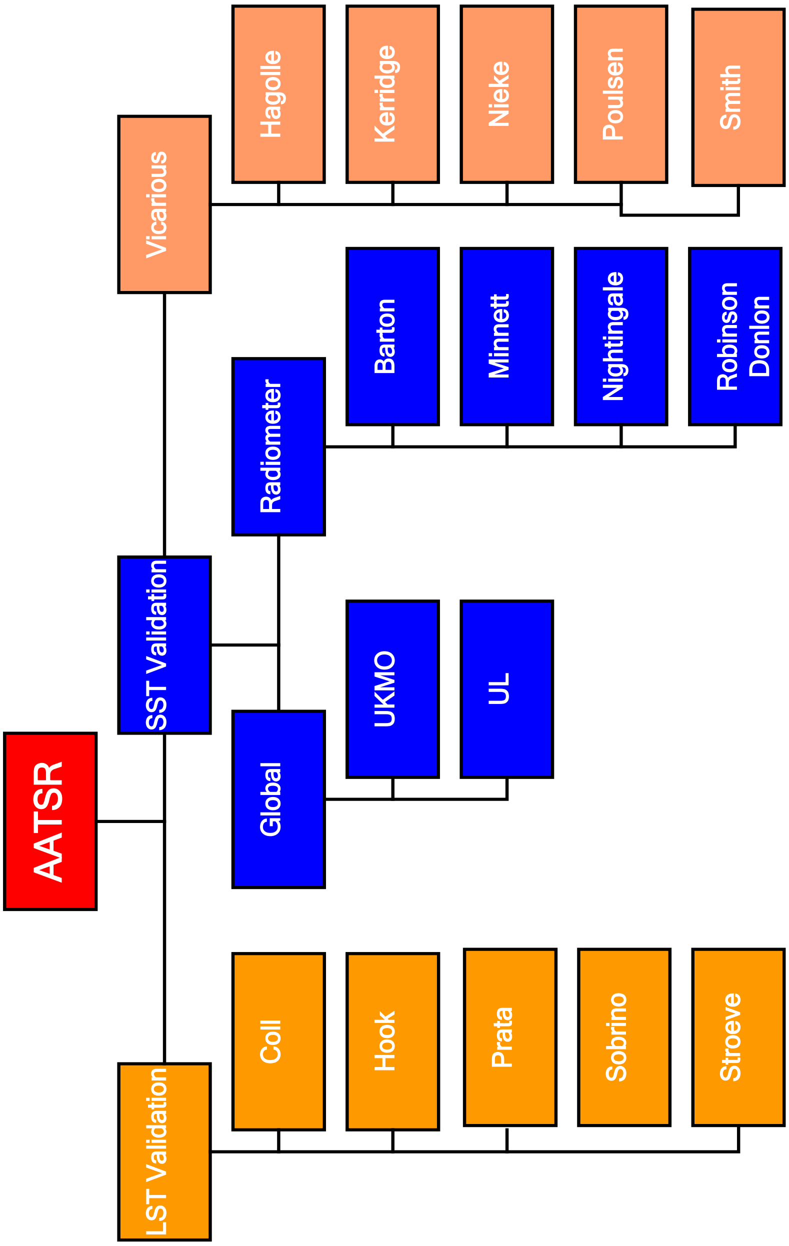

Figure 4-4: Schematic diagram detailing the make-up of the validation data providers.

Further details of the work done by individual validation team members can be found in the Appendix.

5 ONGOING VALIDATION OF AATSR SST PRODUCTS

5.1 Requirements for ongoing SST validation

The validation activities undertaken to date have shown that the AATSR instrument is meeting the Defra specification of determining global SST to an accuracy of 0.3 K (one sigma), which is the primary product for the AATSR mission. The validation programme has so far concentrated on the initial validation period (end of commissioning to December 2002) although several *in situ* match-ups from the DAR011 and M-AERI radiometers and also the UKMO buoy comparison results have extended beyond that period. A complete review of the initial validation activities carried out so far was carried out at the MAVT workshop in October 2003, which was able to recommend release of the AATSR SST product for use scientifically [RD4]. The conclusions from the workshop most relevant to the ongoing validation of AATSR are those identifying the areas where additional analyses are necessary.

Two aspects of the initial validation programme were highlighted for further work:

a) There are a number of regions of the world where comparisons with other datasets reveal discrepancies and where AATSR measurements must be carefully validated. These potential variations in accuracy are a function of season and year (i.e. dependent on sea surface and atmospheric parameters such as water vapour, aerosol and cloud) and hence the validation must be performed over long timescales, covering several seasons and years.

b) Available precision measurements from *in situ* radiometers cover a narrow range of sea surface temperatures and atmosphere conditions. Further measurements are required to increase the statistical significance of the data and possibilities for extending the range of conditions that can be measured should be explored.

At the MAVT workshop, it was also agreed that the AATSR validation programme needed to be extended considerably further in order to meet the requirements of users in three areas 1) long-term trends, 2) regional fingerprinting and 3) additional AATSR products that are required by users investigating climate change phenomena.

The ongoing AATSR validation programme aims to meet these requirements by adopting a strategic approach that combines analyses of regional/global datasets with precision validation against autonomous measurements systems and targeted *in situ* radiometer deployments. The results from each of these areas will be used to refine the validation programme as it continues and develops.

5.2 Strategy for ongoing SST validation

The validation of AATSR SST products is the primary requirement for the validation programme. The strategy adopted for the validation programme aims to meet user requirements for SST, as identified in the scientific priorities for AATSR, through a balanced and cost-effective programme. It incorporates information from satellite data and buoy analyses together with data from regular and campaign cruises of precision *in situ* radiometers.

Truly independent validation necessarily requires deployment of precision radiometers but this must be balanced by cost, feasibility, and the visions of cooperating international agencies. Therefore the overall methodology incorporates the following three aspects which need to be covered:

1) Regular measurements in good locations for precision validation of AATSR to improve statistics and to characterise SST accuracy and instrument drift

2) Regular cruises in regimes with differing geophysical characteristics to establish the performance of AATSR over a range of SST conditions and atmospheric humidities
3) Campaign cruises to selected regions of importance to AATSR validation

The plans that are being implemented in the ongoing phase of AATSR validation, balance results from the initial validation activities, expected future discoveries and planned international campaigns to meet the above requirements within a feasible programme. In the ongoing validation phase, it is envisaged that the DAR011 and M-AERI radiometers operated by Dr. Barton and Dr. Minnett, which have been operating consistently for a number of years in particular regions, will provide a long term context for monitoring AATSR performance. Comparisons over a range of SST conditions and atmospheric humidities will be provided by long-term operations of the ISAR radiometer within the Bay of Biscay. Finally, targeted regions of importance will be covered by operations of the SISTeR radiometer, campaigns of DAR011 and M-AERI and by the M/V Falstaff ISAR if available.

As a specific example, the mechanism for cruise planning under Defra/ESA funded validation projects is presented in Figure 5-1, with connections shown to the UL and UKMO regional analyses. Note that the decision making process must consider the cost and feasibility of a cruise opportunity, taking into account the campaign logistics, and financial budgets from Defra and ESA.

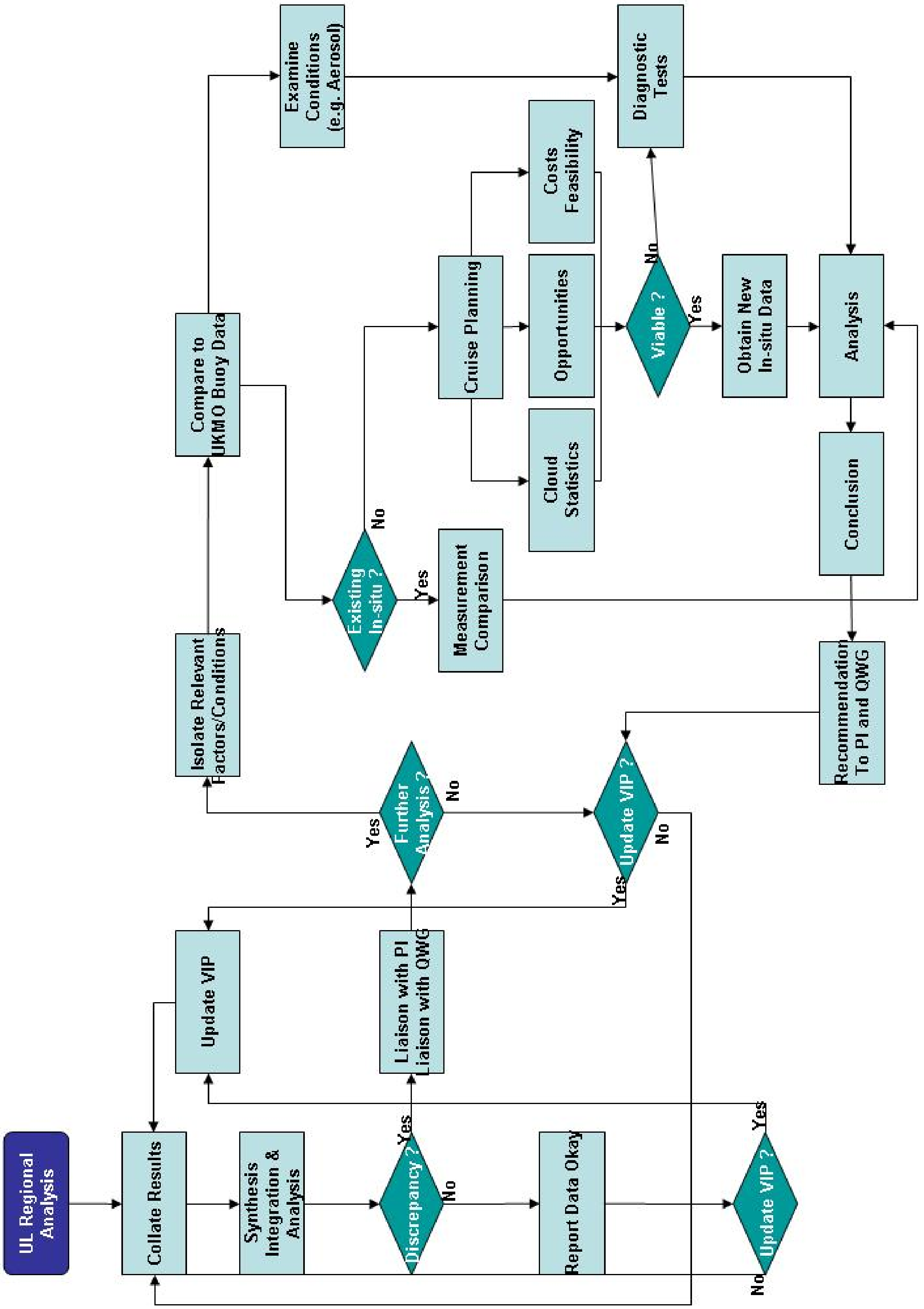

Figure 5-1: Mechanism for Defra/ESA cruise planning based on UL and UKMO regional analysis

5.3 Implementation for ongoing SST validation

5.3.1 Validation priorities

The essential elements of the next phase of validation are the following, which can be regarded as specific priorities, or key aspects that need to be addressed for continued validation of AATSR SST:

- Global and regional analyses against buoy data and SST operational analysis fields over seasons and years [Trends]
- Global and regional comparisons with other satellite datasets and ECMWF analyses over seasons and years [Trends, Fingerprinting]
- Analysis of AATSR regional SST comparisons and AATSR cloud flagging for campaign planning [Fingerprinting]
- Internal diagnostic validation tests of AATSR SST datasets [Trends, Fingerprinting]
- Deployment of the ISAR autonomous precision radiometer in the Bay of Biscay to improve statistics of validation comparison, perform validation over a range of atmospheric conditions, and to provide long-term monitoring [Trends, Fingerprinting]
- Deployment of the SISTeR radiometer on opportunity cruises to targeted areas [Fingerprinting]
- Continued exploitation of validation team experiments to improve the statistical significance of the collected validation data and to maintain long term monitoring of instrument performance such as continued M-AERI operation in the Caribbean [Trends, Fingerprinting]
- Opportunistic opportunities for data collection such as the M-AERI operation on the NOAA Ship Ronald H Brown, the RNZNS Hinau and the R/V Tangaroa. [Fingerprinting]
- The introduction of new validation data sources such as the aircraft based AIRES instrument, operated by the UKMO. [Fingerprinting]

Note: The descriptors [Trends] and [Fingerprinting] included at the end of each of the bullet points listed above are used to indicate which of the two SST scientific priorities, stated in Section 2, is being addressed by each of the above elements proposed for the next validation phase.

The next two sections, 5.3.2 & 5.3.3 describe detailed work plans for the analyses under the headings of global/regional SST fields and high precision radiometers.

5.3.2 Detailed work plan for Analysis of Global and Regional SST Fields

This section details progress to date, activities for ongoing validation and their benefits, in the validation of global and regional SST fields.

5.3.2.1 Progress to date

Two types of analysis have been performed to date, by the UK Meteorological Office (UKMO) and by the University of Leicester (UL). The UKMO derive bulk SST from the AATSR observed skin SST, using surface wind and fluxes of heat and momentum from operational global NWP analyses. A skin to bulk correction is applied to the near real-time AST product. They have performed daily processing of the METEO product and used the results to make comparisons made on a global scale with SST analysis fields and *in situ* buoy data. From approximately 140 match-ups per week through the 13-month period, statistics show that the AATSR skin SST is within ± 0.3 K of the buoy SST, with only five exceptions. The mean difference between AATSR SST and buoy SSTs for approximately 6700 match-ups (excluding 5 outliers) was 0.05 K with a standard deviation of 0.41 K. With just the night time match-ups, the mean was 0.07 K with a standard deviation of 0.35 K. At night a bias of between -0.1 and -0.2 K, with AATSR reading cooler, is expected with the improved atmospheric correction resulting from the inclusion of the 3.7 µm channel into the retrieval scheme. Such a difference is observed between the two data sets.

However, it should be noted that the estimates of the ocean's skin temperature derived from AATSR measurement data show marginally better agreement with the buoy data (bulk SST) than does the Met Office estimates of bulk SST from AATSR data. This suggests that the AATSR SST product is possibly still sub-optimum as there is no observed difference owing to the skin effect (a difference of 0.2 K between bulk and skin SST values is expected). Further investigation and observations are required to establish whether the difference is in the AATSR data or the bulk data.

The comparison of AATSR with buoy data can be used to identify systematic errors or serious regional anomalies as it provides what are really gross error estimates. In addition, it can be used to relate the performance of AATSR to the well established standard of bulk SSTs that end users are familiar with.

The spatially averaged AATSR SST product has been compared with SST data from other sensors such as AVHRR, MODIS, TMI and also ECMWF reanalysis fields for September 2002. Comparisons of global monthly mean data are made at half-degree resolution. Before definite conclusions can be drawn about the accuracy of AATSR, more results are needed and the accuracy of these other datasets must be investigated. However, similar analysis performed with ATSR-2 and AVHRR data show that the differences are correlated with tropospheric aerosol loading derived from the NASA TOMS instrument. This aerosol is unaccounted for by AVHRR but the analysis indicates the truly unique advantage of the ATSR series in applying a valid atmospheric correction from the dual-view operation. Nonetheless, these highly significant results require further work to demonstrate that AATSR is correcting for all of the aerosol effects. Further details of analysis are given in [RD3 and RD4].

Overall, areas identified for further investigation so far from the regional analyses include the Indian Ocean, the tropical Atlantic Ocean, the northern Pacific Ocean and the Sea of Japan. The guiding criterion has been the magnitude of discrepancies between AATSR and other sensors/analyses. However, these do not necessarily indicate a problem with AATSR since AATSR should be less sensitive to many atmospheric factors for example. The information that arises from the regional analysis therefore characterises the discrepancy rather than identify gaps in knowledge. It is also important to note that the regions identified may not be affected by the same factors since atmospheric states, sea surface conditions and instrument performance can all play a role. The mechanism by which the results of the regional analyses are carried forward has been explained in Figure 5-1.

5.3.2.2 Activities for ongoing analysis

The following activities are proposed during the ongoing analysis:

1) Global analysis of the spatially averaged SST product by comparison with buoy networks and operational analysis fields. The UKMO have confirmed their commitment to the project through the ongoing analysis.

2) UL will continue to perform regular comparisons and diagnoses of AATSR global data fields with similar global fields from other sources e.g. AVHRR, MODIS, TMI and ECMWF. A key aim will be to identify and categorise regions of variability in the inter-comparisons and identify magnitude of the deviation, time dependence (e.g. seasonality) and geophysical regimes that lead to the differences.
3) Further diagnostic analysis of results already obtained, especially with respect to regional and seasonal variations in performance of AATSR will be carried out by both the UKMO and UL.
4) The regional results from comparisons of global fields will be extended to define priorities for field campaigns by examination of a) SST differences between AATSR and other sensors b) understandings of the effects through correlations with geophysical variables c) investigations of cloud cover climatology.
5) Global field comparisons will also be extended to internal diagnostic tests that simply look at the AATSR itself by comparing month on month and year on year to look for anomalies. The tests will also include comparing the 30 arcmin spatially averaged product to an averaged product produced from the gridded product.

5.3.2.3 Benefits

Many of the early errors in SSTs produced from ATSR 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 has the advantage that it can be carried out at a global scale and without field data collection campaigns. With the increasing emphasis on regional climate change detection and attribution, the importance of global field characterisation has become pressing and is now a key part of the AATSR validation plan. Internal diagnostic tests of the global AATSR dataset are a significant aspect of this work. In addition, the results from the new regional comparisons will be used to direct possible targeted opportunities for deployment of the precision radiometers. This type of analysis is essential for the ongoing validation of AATSR.

5.3.3 Detailed work plan for high precision validation of point-to-point SST values

This section details progress to date, activities for ongoing validation and their benefits, in the point-to-point validation using precision in situ infrared radiometers. The importance of the *in situ* precision radiometers has already been emphasised. The essential aspect of these radiometers is that they provide the only objective direct validation of AATSR SST since they measure the same quantity precisely in a well-known and characterised location. Further deployment of the radiometers will therefore continue to be important in performing two functions (a) continued characterisation of instrument performance to ensure long term drifts of AATSR SST are accurately known (b) increased numbers of observations to improve the statistical significance of the observations. In addition, it is highly desirable for the radiometers to provide results over a range of sea surface and atmospheric conditions. The highest data return for minimum cost is clearly provided by autonomous precision radiometers but flexibility in deployment is desirable.

5.3.3.1 Progress to date

To date, the ISAR and SISTeR radiometers have been successfully deployed on several ocean-going vessels. The ISAR instrument has been operating autonomously for a period of several weeks in June and July 2002 on the M/V's Val de Loire and Pride of Bilbao, operating between Southampton and Bilbao in Northern Spain. The SISTeR instrument operated on the SCIPIO cruise around the Western Indian Ocean during July 2002. Further details of the analyses are given in [RD3 and RD4].

To date, two valid match-ups have been returned from the ISAR cruises so far. It should be noted that these two points have a much greater significance that one might expect, owing to the absolute value of the compared SST measurements. All but the two ISAR match-ups provided to date from the entire point-to-point activities performed so far cover a small range of absolute SST values between 297 K and 299 K. The ISAR comparison at around 285 K is therefore vital in showing the validity of AATSR over a range of SST values.

The SISTeR radiometer was deployed on the NERC research ship the RRS Charles Darwin for the SCIPIO cruise through the Western Indian Ocean. In the course of the cruise, the ship achieved a total of 17 underpasses of the ENVISAT and ERS2 (for ATSR-2 validation) satellites; the satellites travel in tandem in the same orbit approximately 30 minutes apart. Of these 17 overpasses, 4 were successful *i.e.* the wind and sea-state were acceptable, the sky was clear and the radiometer and the satellite were functioning correctly. Only one overpass was lost on account of a satellite malfunction; the other lost overpasses were due to inclement weather. This number of successful overpasses was lower than expected on account of the fact that the measurement campaign was delayed beyond the time of optimum predicted cloud-free views. Nevertheless, this number of successful overpasses is greater than that achieved in any previous SISTeR cruise and vindicated the planning procedures used in this project and future projects, which involved investigation of cloud climatology to select the region and, subsequently, the opportunity to influence the cruise–track to maximise the opportunities for overpasses.

Further to the analyses above, the University of Leicester has been analysing validation data from the autonomous M-AERI instrument onboard a Royal Caribbean cruise ship. The analysis of match-ups from September 2002 to February 2003 is complete and offers 12 points of comparison.

Other autonomous and targeted precision radiometer measurements are provided by the University of Miami and by CSIRO in Australia. Validation of the data provided by the University of Miami is performed by UL. The quality of data from Dr. Barton at CSIRO has been excellent and was the first to show the accuracy of AATSR through comparison with a radiometer. To date, twenty-four definite match-ups have been observed from both Miami and CSIRO data, with twelve others awaiting qualification before being submitted to the validation scientist for inclusion in the overall summary. Details of the match-ups are given in [RD3 and RD4].

5.3.3.2 Activities for ongoing analysis

UL will continue to analyse data from the M-AERI instrument on the Royal Caribbean cruise ship. In addition, UL will seek closer liaison with Dr. Minnett and will seek to obtain data from other targeted M-AERI deployments. No control over the location of the data is possible as this is decided by instrument operation considerations and the data providers who provide the funding for the validation campaign. However, the Validation Scientist will continue to represent AATSR considerations to Dr. Minnett, who has confirmed that the operation of the M-AERI onboard the Caribbean cruise liner will continue for a period covering the duration of this phase of AATSR validation. In addition, he has confirmed the following opportunity cruises for which M-AERI data will be provided to UL for analysis:

- NOAA Ship Ronald H Brown - Feb 12 to March 29, 2004 - Charleston, Barbados, Cape Verde, Canary Is, Puerto Rico.
- RNZNS Hinau - March 1- 5, 2004 - off Auckland, NZ
- R/V Tangaroa - March 18 - April 16, 2004 - Wellington, to area SE of the South Island of NZ, back to Wellington.

It should be recognised that no influence can be placed on where these cruises go, only to accept that the data will benefit the overall validation programme since the cruises are guided by similar scientific principles, the outcomes of discussions at MAVT workshops, and by practical considerations governed by funding bodies.

The use of ISAR data in the ongoing activities is foreseen through several opportunities. The Southampton Oceanographic Centre (SOC) would continue to operate their ISAR onboard the Pride of Bilbao ferry, operating up and down the Bay of Biscay. Such operations are the most efficient and cost effective ways of deploying the ISAR and provide a means of monitoring AATSR over a longer time period. Also, SOC believe that the Bay of Biscay has a good range of environments for validation over a long period of time.

Occasional high precision measurements by the SISTeR radiometer, again in areas shown to exhibit anomalous behaviour and, of course, where cruise opportunities can be secured, will be led by RAL. Two options will be pursued for finding SISTeR opportunities, requiring a careful trade-off of cost against return. First, the fact that SISTeR has already been deployed on two NERC vessels, the RSS Charles Darwin and the RRS James Clark Ross is important. Cruise opportunities on either of these two vessels will result in lower deployment costs. Secondly, opportunities will arise for deployment on other vessels that will have higher deployment costs associated with the initial negotiations and planning to install the instrument on a new vessel.

Dr. Barton is currently in the process of confirming his *in situ* programme for the next two years. The expectation is that regular cruises will continue as before.

5.3.3.3 Benefits

The validation of the point-to-point SST values is essential is ensuring AATSR is meeting its stringent accuracy requirements for monitoring climate change. To do this, high precision measurements covering a range of absolute SST values across a broad range of environments are necessary. The activities described above will benefit this activity, as they are the first steps taken to date to maximise the data return by directing and targeting the required validation activities

6 ONGOING VALIDATION OF LEVEL 1B REFLECTANCES

6.1 Overview

The level 1b thermal channels (3.7μm, 11μm and 12μm) will be validated inherently through the validation of the level 2 SST product (Section 5) and the land surface temperature product (Section 7). Validation of the visible/near infrared channels (0.55μm, 0.67μm, 0.87μm and 1.6μm) 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.

6.2 Visible and near infrared reflectance validation against stable surface locations

Several validation PI's, Dave Smith from RAL, Fred Prata from CSIRO and Olivier Hagolle from CNES, are comparing AATSR and MERIS top-of-atmosphere radiances for a range of desert regions and Greenland ice, and monitoring 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. 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. Further details of the analyses are given in [RD3 and RD4].

Outputs from the work include:

- Time series of uncorrected top-of-atmosphere reflectances
- Calibration drift correction values
- Reflectances corrected for atmospheric absorption (not aerosols)
- Intercomparisons with MERIS and ATSR-2 reflectances

6.2.1 Progress to date

Full details of the work carried out to date can be found in RD3 and RD4. The results presented from the analysis by Dave Smith over both the desert and ice calibration targets show that all AATSR visible channels measure reflectances higher than those measured by ATSR-2 and that AATSR is in good agreement with the corresponding MERIS channels; combining these results shows that MERIS is also measuring significantly higher than ATSR-2

All measurements obtained so far show the following ratios:

- **R_{AATSR}/R_{ATSR-2}**
  - 0.56μm 1.132
  - 0.67μm 1.088
  - 0.56μm 1.081
- **R_{AATSR}/R_{MERIS}**
  - 0.56μm 1.041

  - 0.67µm 1.001
  - 0.56µm 1.037

- **R_{MERIS}/R_{ATSR-2}**
- 0.56µm 1.087
- 0.67µm 1.086
- 0.56µm 1.042

If MERIS and AATSR measurements were significantly different from each other as well as ATSR-2, it would suggest that the basic radiometric calibrations were incorrect. However, the results show that MERIS and AATSR calibrations appear to be in agreement with each other, but are both measuring significantly higher than ATSR-2 and a range of other satellite sensors. Errors in the pre-launch calibrations of AATSR and MERIS remain a possibility, but since both instruments were calibrated independently at different institutions, systematic errors of the same magnitude and bias would be unlikely.

6.2.2 Activities for ongoing analysis

The main activities for ongoing analysis are to continue the current work plan in order to establish why AATSR and MERIS appear to agree to each other but not to other sensors. Proposed activities include:

- Produce long term trends over desert targets to establish calibration drift.
- Compare calibration drifts of AATSR and MERIS
- Investigate 1.6µm calibration
- Work on atmospheric corrections
- Extend range of comparisons to include other instruments

In addition, other explanations for the observed differences exist that should be investigated, including:

- Errors introduced during data processing.
- Assumptions about the calibration sites.
- Assumptions about the calibrations of other sensors.
- Out of band spectral leakage.

6.2.3 Intercomparison of AATSR visible and near infrared reflectances against other satellite sensors

An evolving area of AATSR vicarious validation is the intercomparison of normalised visible and near infrared reflectance measures by AATSR with similar data from other satellite sensors including ATSR-2, MERIS, SeaWifs, GOME, SCIAMCHY, Polder, ANHRR, MISR, SPOT and VEGTATION. The work is carried out by Dave Smith from RAL, Olivier Hagolle from CNES and Brian Kerridge from RAL. Further details of the analyses are given in RD3 and RD4.

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 smallest of either the AATSR pixel or the third-party ground pixel is averaged over the entire larger pixel. The normalised radiances over each pixel is then convoluted with the instrument response functions of AATSR. For the comparison, a partly cloudy scene over the ocean will be preferred, such that a large dynamic range is covered. The inhomogeneity of the scene also allows confirmation of the positioning and geolocation of the instruments.

6.3 Visible and near infrared reflectance validation against Arctic Stratus and Tropical CumuloNimbus clouds

Caroline Poulsen 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).

Two methods of calibrating AATSR data are used. In the first method, Arctic stratus clouds are used to absolutely calibrate 0.55, 0.67 and 0.87 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 μm 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.

6.3.1 Progress to date

Further details of analysis are given in [RD3 and RD4]. In summary, Caroline Poulsen from RAL has tested the absolute calibration of AATSR using Arctic stratus clouds and also an intercomparison of AATSR (and MERIS) spectral channels against tropical convective clouds. The conclusions are that:

1) For absolute
   a) There is a slight positive bias of ~ 2-3% across the AATSR reflectance channels.
   b) No significant sensitivity to ozone or aerosols
   c) Calibration is sensitive to molecular scattering (0.55 and 0.67) channels.
   d) Results are sensitive to cloud top height
2) Inter channel calibration
   a) MERIS and AATSR well spectrally inter-calibrated with observed differences of 2-5%, similar to the results presented by Dave Smith

6.3.2 Activities for ongoing analysis

The current results from the validation using cloud targets are very promising. They show similar conclusions to the validation against desert sites in that AATSR and MERIS show good agreement to each other. The work is done on a best efforts basis and it is expected that ongoing activities in this area will follow the same work plan as before.

7 ONGOING VALIDATION OF OTHER AATSR PRODUCTS

7.1 Land Surface Products

As land constitutes only about one-fifth of the global surface and the heat capacity of land masses is significantly lower than that of the oceans, the properties of the land surfaces have, understandably, tended to receive lower priorities when investigating global climatic processes. However, the large inhomogeneity of land surfaces, notably their albedos, temperatures and transpiration properties means that, as climate models become more and more precise, there will be a great need for better information about the radiative properties of land surfaces. The AATSR can provide high quality data on Land Surface Temperature (LST) and on the reflective visible and emitted infrared properties of the land surface, which can produce a state-of-the-art vegetation index product that will provide information on vegetation dynamics.

7.1.1 Land Surface Temperature

The AATSR LST product has recently been installed into the operational Level 2 processor. Initially, the product was only produced using an add-on to the prototype processor (by Andrew Birks at RAL) in order for a through product evaluation phase to be carried out. Currently, there are three variants of the LST algorithm being validated. These are:

1. LST products produced using the prototype processor at RAL
2. LST products produced using a processor at CSIRO (Fred Prata)
3. LST products produced using a processor at NASA-JPL (Simon Hook)

The work done so far has involved comparisons against ground based *in situ* data across several sites in Europe, the USA and Australia. Validation at these sites has shown that the regression algorithm used in the LST processor is working well and comparisons with data from the National Center for Environmental Prediction (NCEP) network suggest that the global coefficients employed in the algorithm are delivering surface temperatures within ±2 K over a range of 240 – 300 K. Some individual *in situ* comparisons show differences greater than ±2 K and are attributed to unoptimised coefficients for particular surface environments. Some intercomparisons with MODIS data have been performed and show a lower bias for AATSR but similar standard deviations. The analysis carried out so far has shown several anomalous features including 1) differences between the CSIRO and RAL retrievals 2) certain land sites being classified as ocean and 3) problems with the cloud flagging over land. Further details of the analyses are given in RD3 and RD4.

One unusual instance of the LST retrieval is a lake surface temperature retrieval. Although the lake surface is obviosuly water, the standard SST retrieval scheme cannot be applied owing to topographical effects. One of the main validations sites of the LST algorithm has bene Lake Tahoe, which crosses the California/Nevada border in the western USA. Simon Hook from NASA-JPL has validated over one year of AATSR LST values, prodcued using his own processor. Over this time he observed a bias of 0.05 K between the AATSR data and the *in situ* data, whereas similar analysis for MODIS data showed a higher bias of 0.19 K.

The ongoing activites in this area will be to continue the fine work that has been started by all the LST valdiation team. The team currently consists of:

- Fred Prata (CSIRO)
- Simon Hook (NASA-JPL)

- Jose Sobrino (University of Valencia)
- Cesar Coll (University of Valencia)
- Julienne Stroeve (Colorado State University)

Specific taks to be investigated will include:

- Differences between the implementations
- Cloud flagging over land
- Covering all possible land surface types (10 out of 14 have been validated to date)
- More comparisons with MODIS and other sensors

7.2 Clouds and aerosols

Clouds and aerosols are an important consideration in AATSR retrievals of SST with requirements for cloud masking and for the correction of aerosol and thin cloud contributions to the observed brightness temperatures. Understanding of these effects is therefore an important consideration for SST retrieval.

The climatic importance of clouds and aerosols in moderating or amplifying radiative forcing is generally accepted. It is also generally accepted that our knowledge of cloud dynamic and radiative properties falls well short of that required by modern climate analyses and prediction schemes. Moreover, both clouds and aerosols feature strongly in AATSR data. Once the practical priority of identifying the presence of clouds in order to retrieve surface temperature has been satisfied there is much scope for using AATSR's multi-angle multi-wavelength viewing geometry to characterise and investigate the properties of clouds.

The sources of aerosols are diverse, ranging from large-scale natural events such as volcanic eruptions to desert storms, biomass burning and anthropogenic sources associated with industrial pollution and agriculture. The AATSR, on account of its unique dual angle viewing geometry, is especially sensitive to atmospheric aerosol and there is great potential for using AATSR data, generally in combination with data from other sources, to examine and quantify the radiative properties of atmospheric aerosols.

There are currently no plans to develop cloud or aerosol products.

8 REFERENCES

8.1 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	UNKNOWN	MERIS Cal/Val Implementation Plan
AD9	deleted	
AD10	PO-PL-ESA-GS-1092	Envisat Calibration and Validation Plan
AD11	PO-TN-RAL-GS-10099	AATSR Algorithm Verification Plan
AD12	PO-PL-GAD-AT-005 (3)	AATSR Validation Implementation Plan
AD13	UL-SEP-P01	AATSR Science Exploitation Plan
AD14	PO-RP-RAL-AT-0511	AATSR Commissioning Report

Table 8-1: List of Applicable Documents

8.2 Reference documents

RD1	M.R. Allen, C.T. Mutlow, G.M.C. Blumberg, J.R. Christy, R.T. McNider and D.T. Llewellyn-Jones, "Global change detection," *Nature*, **370**, pp. 24-25, 1994
RD2	D. Llewellyn-Jones, M.C. Edwards, C.T. Mutlow, A.R. Birks, I.J. Barton and H.Tait, "AATSR: Global-Change and surface-Temperature Measurements from Envisat," *ESA Bulletin*, 105, pp. 10-21, 2001.
RD3	Proceedings of the Envisat Validation Workshop, 9-13 December 2002, ESA-Esrin, Frascati, Italy, http://www.envisat.esa.int/pub/ESA_DOC/envisat_val_1202/proceedings/
RD4	Proceedings of the MAVT Workshop, 20-24 October 2003, ESA-Esrin, Frascati, Italy, to be published
RD5	Birks, A.R., 2002, Algorithm verification for AATSR. ESA special publication 520 (written for the Envisat Calibration Review)
RD6	Birks, A.R., 2003, Algorithm Verification for AATSR: Level 2 Verification. ESA special Publications 531 (written for the Envisat Validation Workshop)

Table 8-2: List of Reference Documents

9 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 for 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
IODD	Input/Output Data Definition
ISAR	Infrared Sea surface skin temperature Autonomous Radiometer
JRC	Joint Research Centre
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 Center 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
VIP	Validation Implementation Plan
VS	Validation Scientist