

ENVISAT RADAR ALTIMETER and MICROWAVE RADIOMETER CROSS-CALIBRATION and VALIDATION PLAN

Prepared by:	J. Benveniste and the ENVISAT RA-2/MWR Cross-Calibration and Validation Team	
Checked by:	G. Levrini	
Approved by:	J. Louet	

*European Space Agency
Agence spatiale européenne*

ESRIN

Via Galileo Galilei - Casella Postale 64 - 00044 Frascati (Italy)
Tel. (39) 06 941801 - Fax (39) 06 94180280

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1**SCOPE**

This document is the detailed ENVISAT RA-2/MWR Cross-Calibration and Validation plan. The meaning of "detailed" is that this document is an expansion of the ENVISAT Cal/Val Plan relevant to RA-2/MWR Cross-Calibration and Validation.

It contains the cross-calibration and validation objectives and the methodology to reach these objectives. It describes the organisation set up to perform the work.

This document has been prepared by ESA and then reviewed and further refined by the members of the Cross-Calibration and Validation Team, hereafter CCVT.

This document does not consider the absolute calibration which is dealt with in the documentation produced within the Calibration Team.

2 EXECUTIVE SUMMARY

2.1 LIMINARY

The ENVISAT calibration and validation activity is organised in working teams with thematic responsibilities. This is documented in the ENVISAT Calibration and Validation Plan (ref. PO-PL-ESA-GS-1092). The instruments verification and the absolute calibration of range and σ_0 are tasks of the Calibration Team, coordinated by R. Francis and M. Roca. The relative calibration and product validation are the tasks of the RA-2/MWR Cross-Calibration and Validation Team (CCVT), coordinated by J. Benveniste. Orbit validation is the task of the Precise Orbit Determination Group, coordinated by P. Vincent and B. Duesman.

2.2 INTRODUCTION

With the dual frequency Radar Altimeter combined with the Microwave Radiometer for atmospheric correction, the laser retroreflector and the DORIS system for accurate orbit determination, the European Space Agency not only ensures continuity of the altimeter observations provided by ERS-1 and ERS-2, but improves significantly the radar altimeter data quality. At the end of the ENVISAT mission, there will be nearly two decades of precise altimetric observations. This will largely contribute to examine changes on interannual to decadal timescales of global and regional sea level, dynamic ocean circulation pattern, significant waveheight climatology, ice sheet elevation, which are key issues for climate change studies. The altimetric measurement time series, being produced from different altimetric missions, will need to be inter-calibrated, within a required precision for each parameter, in order to obtain a consistent multi-satellite data set.

Inter-calibration, or so-called cross-calibration, is the determination of relative biases between the measurements of different altimeters. Two altimetric systems are compared through their global geophysical data products. Due to the huge number of globally-distributed measurements processed, the relative calibration is significantly more precise than local absolute calibration. This is where lies the major quality of this technique to ensure consistency between two different but momentarily overlapping missions.

The cross-calibration performed with data taken during a limited overlap between two altimetric missions does not estimate long-term drifts but biases estimates performed on successive segments during the overlap can assess short term drifts. Even though both an absolute and a relative calibration experience will be carried out during the commissioning phase, there is also a need to have a long term drift estimating strategy. The permanent tide gauge network provide an estimation of drift which is complementary to the relative bias obtained from cross-calibration based on altimetry alone. The permanent tide gauges network is also necessary to cross-calibrate non overlapping missions.

The cross-calibration is done using the actual RA-2/MWR user data products as soon as they are available. Beyond the validation task to be performed, this ensures a thorough data product verification via actual intensive use of these products by a team of altimeter data experts.

The ENVISAT RA-2/MWR Cross-Calibration and Validation Team has been formed to cross-calibrate the RA-2 and MWR on ERS-2 and other simultaneously flying altimetric missions and validate the user level geophysical products. The details of the objectives, methodology, requirements, organisation and schedule are described hereafter in this document.

2.3 OBJECTIVES

ESA intends to perform both an absolute calibration for the range and sigma0 and a relative (against ERS-2) calibration for the three altimetric parameters, including wave height. The absolute calibration will provide a range reference point for the complete altimetric time series a decade after the absolute calibration of ERS-1 and a highly required sigma0 absolute calibration for the first time. The relative calibration will unify the ERS and ENVISAT data. A relative calibration between ERS-2 and ERS-1 was performed during for the commissioning phase of ERS-2. Due to the huge number of globally-distributed measurements processed, the relative calibration is significantly more precise than local absolute calibration, by a factor 5 to 10 [Letraon et al, 1998]. This is were lies the major quality of this technique, thus providing an efficient method to ensure consistency between two overlapping missions' data products, even though it does not provide an absolute calibration. Relative biases between ENVISAT and GEOSAT Follow On, TOPEX/POSEIDON or JASON will also be estimated. Relative calibration with ICESat/GLAS laser altimeter data are also being considered, but the difference in measurement principle may limit its usefulness and needs careful consideration.

2.3.1 Product Validation

The products to be validated are all the near real time and off-line products, see [Benveniste and Milagro-Perez, 2000] for details. The objective behind product validation is to authorise the distribution of validated products to all users within six months after launch. To best meet this objective, this post-development-validation activity should be performed by a team independent from the processor development. The validated data will be used for the cross-calibration activities: This will enhance the quality and thoroughness of the validation.

2.3.2 Algorithm Verification

The geophysical processing algorithms will undergo a post-launch verification on real data with the objective to assess algorithm performance, tune processing parameters and apply relevant calibration coefficients at the end of the commissioning phase. There is a special emphasis on verifying the impact of novel aspects of RA-2: S band channel data and impact on geophysical products of automatic tracking mode switching.

2.3.3 Core Objectives Summary

The core objectives of ESA for the ENVISAT RA-2 and MWR Cross-Calibration and Validation are the following:-

- geophysical processing algorithm verification: verify algorithms, tune processing parameters,
- validation of RA2/MWR near real time and off-line products: validate parameters in the geophysical data record and estimate their accuracy,

- relative calibration coefficients (bias and slope) with error estimates against ERS-2 and other altimetric missions of the three main measured parameters: range/height, wave height and sigma0/wind,
- validation of the absolute sigma0 (absolutely calibrated via transponder),
- absolute calibration of MWR geophysical algorithms against in-situ measurements of water vapor,
- relative calibration against ERS of MWR brightness temperatures and water vapor,
- long-term drifts detection preparation.

Each parameter needs to be cross-calibrated (for both RA-2 and MWR) within a specified accuracy, established in this document.

2.4 ORGANISATION

The cal/val activity is organised in working teams with thematic responsibilities. The RA-2 instrument verification and the absolute calibration of range and sigma0 are tasks of the Calibration Team. The relative calibration and product validation are the tasks of the RA-2/MWR Cross-Calibration and Validation Team (CCVT). The CCVT will liaise with the Precise Orbit Determination Team, due to the strong dependence of the range cross-calibration exercise on the validated orbit. The CCVT is further divided in thematic subgroups:-

- geophysical processing algorithm verification
- cross-calibration and validation of range
- cross-calibration and validation of wave height, sigma0/wind,
- MWR in-flight verification and geophysical calibration & validation.

The CCVT is composed of selected PIs and Co-Is, Expert Support Laboratories members, Instrument Processor Facility specialist and ESA Staff. Many scientific teams have proposed to contribute to the cal/val activity through the ENVISAT Announcement of Opportunity. AO proposals have been selected for their contribution to the core cal/val activity. The Team composition is detailed in this document. The CCVT is the author of this document.

2.5 CROSS-CALIBRATION and VALIDATION APPROACH

2.5.1 Algorithm Verification

Extensive validation of all RA-2 and MWR algorithms used in the ESA developed Ground Segment have been carried out before launch using both simulated and reconditioned data from other missions and by means of an algorithm review workshop, in June 1999 at ESA/ESRIN, composed of independent experts. Some aspects of the second generation Radar Altimeter are novel, thus effort will be dedicated to special evaluation and validation tasks, particularly involving the S band channel data and the automatic tracking mode switching:-

- dual frequency ionospheric correction validation, using the novel S band data.
- dual frequency rain flag validation, using the novel S band data.

- evaluation of the impact on geophysical applications of the novel automatic tracking mode switching.
- sea state bias preliminary estimation in both Ku and S band during commissioning phase, refined on a longer data set.

The strategy is to update algorithms, processing parameters and apply relevant calibration coefficients at the end of the commissioning phase with respect to the objectives.

2.5.2 Products Validation

The products to be validated are all the near real time and off-line products, see [Milagro-Perez and Benveniste, 2000] for details. The post-development product validation tasks will consists of:-

- Verify with real data the consistency of the product package (document, format and actual dataset: global valid data coverage, outliers, flag consistency...).
- Quantify the inherent validity and accuracy of range, wave height, wind speed, and geophysical corrections.
- Determine orbit error in the data products (via crossover analysis).
- Estimate time tag errors by minimization of crossover height differences.

The data will be used for the cross-calibration activities: This will enhance the quality and thoroughness of the validation.

2.5.3 ENVISAT MWR Calibration/Validation

The radiometer functioning will be promptly verified by monitoring temperature variation, gain variation and radiometric count range. The parameters to be calibrated are brightness temperatures of each channel, wet tropospheric altimeter path delay, water vapor and liquid water content. This will be done by:-

- comparison with ship-borne radiosondes (to mitigate slow accumulation of collocated data, preliminary comparison with space-borne water vapor measurements will be done),
- comparison with coincident simulated brightness temperature from ECMWF meteorological fields,
- comparison with other radiometers; e.g., comparison with ERS-2 MWR over the poles (small variability).
- comparison with GPS measurement of precipitable water vapour over specific regions (optional method to be investigated)

2.5.4 ENVISAT RA-2 Cross-Calibration

The RA-2 relative calibration approach is based on global comparison of ENVISAT and ERS data products, as well as TOPEX/POSEIDON, GEOSAT Follow-On, and/or JASON, and local differential observations on equipped (tide gauge, laser ranging) natural targets (e.g., the Channel), again using the products. The following methods are envisaged:

- (i) Cross-calibration of the RA-2 main geophysical parameters against ERS-2 (and/or TP, GFO, Jason), range, significant wave height and wind speed (σ_0):-

- global comparison at cross-overs and along the collinear tracks of millions of globally distributed data (significant error reduction), including cross-calibration of medium and low resolution tracking modes with the ERS-2 so-called "ice" mode.
- global statistical comparison against ERS-2, models, in-situ data.

(ii) Preparation of long-term drifts detection:-

- comparison of sea level heights monitored by RA-2 and by a global tide gauge network.

The output of these methods is the estimate of a bias plus its formal error. Drifts will be estimated on the long term.

Both the crossover method and the repeat track method have their own advantages. The advantage of the repeat track method, applicable only to satellites on the same orbit but providing many more data points for comparison, is its higher accuracy [Letraon et al., 1998]. Tide gauge networks are efficient at monitoring slow temporal drifts [Mitchum, 1998] [Cazenave, 1999].

2.5.5 Absolute Sigma0 Validation

The scientific utilisation of a calibrated sigma-0 is two-fold: improving the wind speed algorithm and retrieving the wave period. The Calibration Team using a transponder will calibrate the absolute sigma0. Its validation will be attempted by the CCVT, via the validation of geophysical models using sigma0 in both Ku and S bands and the development of an ENVISAT wind speed model.

2.5.6 Requirements on Mission Systems

To perform the relative calibration, a least one of the altimetric satellites –ERS-2, Topex/Poseidon, Geosat Follow On, Jason– should be producing valid data during the ENVISAT commissioning phase. For optimum results, there are requirements on the flying formation of the tandem ERS-2/ENVISAT. ENVISAT will fly a 35-day repeat orbit on the same ground track as ERS-2, 30 minutes ahead, thus not in the same orbital plane. The time-lag between satellites is required to be smaller than the decorrelation time of the fastest meteoceans signals. A time-lag of 30 minutes is highly satisfactory. To mitigate the cross-track geoid gradient, the requirement for the dual satellite cross-track distance was set to 200 meters for ERS-2/1 (the achievement was 100m or less) and to have simultaneous manoeuvres in order to minimise the losses in the dual data sets.

2.6 CONCLUSION of the EXECUTIVE SUMMARY

The objectives, methodology, requirements and organisation have been briefly described in this summary. A solid experience of relative calibration and validation has been acquired with the novel ERS-2/ERS-1 RA & MWR cross-calibration activities. The ENVISAT RA-2/MWR cross-calibration and validation activities are based on proven methodology. Experience to apply this methodology exist in various institutes, each of which have their own algorithms and methodology, experience, and areas of interest. The



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RA-2/MWR Cross-Calibration and Validation Team has been constituted with proposals from these institutes.

3 INTRODUCTION

With the dual frequency Radar Altimeter on ENVISAT, combined with the Microwave Radiometer for atmospheric correction and with the laser retroreflector and the DORIS system for accurate orbit determination, the European Space Agency not only ensures continuity of the altimeter observations provided by ERS-1 and ERS-2, but improves significantly the radar altimeter data quality. At the end of the ENVISAT mission, there will be nearly two decades of precise altimetric observations. This will largely contribute to examine changes on interannual to decadal timescales of:

- global and regional sea level,
- dynamic ocean circulation pattern,
- significant waveheight climatology,
- ice sheet elevation,

which are key issues for climate change studies.

The altimetric measurement time series, being produced from different altimetric missions, will need to be inter-calibrated, within a required precision, in order to obtain a consistent multi-satellite data set.

Inter-calibration, or so-called cross-calibration, is the determination of relative biases between the measurements of different altimeters. Absolute calibration is the comparison of the engineering measurement with an independent measurement (buoy, tide gauge) of the same parameter (range, sea-surface height, etc.). The absolute calibration will provide one reference point for the complete altimetric time series, a decade after the absolute calibration of ERS-1. Absolute calibration is not considered here. In relative calibration two altimetric systems are compared through their global geophysical data products. Due to the huge number of globally-distributed measurements processed, the relative calibration is significantly more precise than local absolute calibration. This is where lies the major quality of this technique to ensure consistency in two different but momentarily overlapping missions.

The cross-calibration performed with data taken during a limited overlap between two altimetric missions does not estimate long-term drifts, but bias estimates performed on successive segments during the overlap can assess short term drifts. Even though both an absolute and a relative calibration experience will be carried out during the commissioning phase, there is also a need to have a long term drift estimating strategy.

The permanent tide gauges network provide an estimation of drift (ref.) which is complementary to the relative bias obtained from cross-calibration based on altimetry alone. The permanent tide gauges network is also necessary to cross-calibrate missions in case they are non overlapping (ref.: Shum).

The cross-calibration is done using the actual RA-2/MWR user data products as soon as they are available. Beyond the validation task to be performed, this ensures a thorough data product verification via actual intensive use of these products by a team of altimeter data experts.

4 OBJECTIVES

4.1 Cross-Calibration and Validation Objectives

ESA intend to validate the data products and perform both an absolute calibration for the range and sigma0 and a relative (against ERS) calibration for the three altimetric parameters, including wave height. The absolute calibration will provide a range reference point for the complete altimetric time series a decade after the absolute calibration of ERS-1 (ref. E1 comm rep) and a highly required sigma0 absolute calibration for the first time. The relative calibration will unify the ERS and ENVISAT data. A relative calibration of ERS-2 and ERS-1 was performed during for the commissioning phase of ERS-2 (ref. E2 comm rep). Due to the huge number of globally-distributed measurements processed, the relative calibration is significantly more precise than local absolute calibration, by a factor 5 to 10 [Letraon et al., 1998]. This is where lies the major quality of this technique, providing an efficient and accurate method to ensure consistency between two overlapping missions' data products.

Merging data from all available altimetric missions has proved to drastically enhance the observational capabilities of any single altimetric mission. ESA will contribute to and facilitate efforts to estimate relative biases between all in-flight altimetric missions: tentatively ERS-2, TOPEX/POSEIDON, GEOSAT Follow On, JASON, ICESat, ENVISAT.

The core objectives of ESA for the ENVISAT RA-2 and MWR Cross-Calibration and Validation are the following:-

- Validation of RA2/MWR near real time and off-line geophysical products:
 - verify processing algorithms and validate parameters in the geophysical data record and estimate their associated accuracy;
 - the objective behind product validation is to authorise distribution of validated products to all users at the end of the commissioning phase.
- estimate relative calibration coefficients (e.g., bias + slope) with error estimates: relative calibration against ERS-2 and other altimetric missions of the three main measured parameters: range/height, significant wave height and sigma0/wind,
- validation of the absolute sigma0 (absolutely calibrated via transponder),
- absolute calibration of MWR geophysical algorithms against in-situ measurements of water vapor,
- relative calibration against ERS of MWR brightness temperatures and water vapor,
- long-term (entire mission duration) drifts detection preparation (during commissioning phase).

4.1.1 Accuracy Objectives

The accuracies to which the parameters need to be cross-calibrated (for both RA-2 and MWR) are given in Table 1. Drift is included for the long term drift monitoring activities established during commissioning phase and maintain throughout the mission.

Table 1

Cross-calibration objectives for RA-2 and MWR measurements, during the six month commissioning phase, against ERS-2 RA and MWR. The slope in windspeed and waveheight refers to the slope of a regression line when comparing RA-2 data to RA data.

PARAMETER	REL. BIAS	DRIFT	DYNAMIC RANGE
range/ sea-surface height	<1 cm	0.5 cm/year	
sigma-0 (Ku)	0.01 dB		- 5 to 20 dB
windspeed	2 cm/s	2 cm/s/year	3 to 20 m/s
windspeed slope	1%		
significant waveheight	1 cm	1 cm/year	1 to 10 m
significant waveheight slope	1%		
brightness temp (dual freq)	0.1 K	0.5 K/year	100 to 350 K
wet tropospheric correction	1.0 mm	1 mm/year	0 to 50 cm

To be precise, the numbers in the table are not a criteria to minimise the bias between ENVISAT and ERS-2, they are an objectives for the error on, for example, the cross-calibration bias (whatever the value of the bias). It is indeed assumed that ENVISAT data will be more precise than ERS-2 and the objective is to unify both time series with an estimate of the error.

Assume a 5 cm RMS precision for the instantaneous differences between ERS and ENVISAT. This depends on orbits errors and other sources of errors. Assume a 5000 km along-track decorrelation distance. This leads to 1750 degrees of freedom for a 35-day cycle (this order of magnitude can be deduced from the data themselves). this leads to an error estimate of about 1 mm for 1 cycle of data. This reflects a simple statistical computation. It does not account for unknown error sources (as it could be the case if, for example, SPTR jumps are not well corrected).

The formal error estimates in the case of both bias and drift estimation, with the assumption of 1 mm RMS error for an average over 35 days, with 6 months of data, give:

0.5 mm for the bias error

2.5 mm/year for the drift error.

To achieve the goal of 1 mm/year it would take about 1 year.

Another point is that most of the error will probably come from ERS-2 with a noisy or drifting reference data set (it will thus be an improvement to compare to other missions and a mean sea surface). In fact, we will probably reach a good level of precision for the intercalibration itself, but will remain the problem of the stability of the reference (ERS-2).

Thus a conservative objective of less than 1 cm precision for the range bias can be set for the commissioning phase, and typically 5 mm/year for the drift, keeping a goal of 1 mm/year precision for the entire mission. (J.Dorandeu, pers. comm.)

4.2 Algorithm Verification

Extensive verification of all RA-2 and MWR Algorithms used in the ESA developed Ground Segment have been carried out before launch:

- using simulated data,
- using reconditioned data (from other missions, e.g. ERS),
- using Flight Model instrument data (real instrument data).
- The selected algorithms have been peer-reviewed by independent experts and further discussed at a Products and Algorithm Review Workshop which took place in June 1999 at ESRIN.

A preliminary estimation of the sea state bias for the two RA-2 frequencies will be performed during commissioning phase. This parameter should be studied further during routine operations and refined on a longer data set.

In the absence of previous Radar Altimeter missions using S Band second channel, the validation plan of the algorithms relying on S band data (retracking, ionospheric correction, rain flag) are requiring actual in-flight S band data which will be available for the first time with RA-2.

The objective is to update algorithms, processing parameters and apply relevant calibration coefficients at the end of the commissioning phase with respect to the objectives. Special tasks linked with algorithm verification and validation are described in section 8.4. Further algorithms improvement is dealt with in section 16.

5 ORGANISATION

5.1 Working Teams

The cal/val activity is organised in working teams with thematic responsibilities.

The absolute calibration of range and sigma0 are the tasks of the CT, coordinated by R. Francis/M. Roca (ESA). This team is also in charge of instruments in-flight verification and level 1B algorithm verification.

The relative calibration and product validation are the tasks of the RA-2 /MWR CCVT, coordinated by J.Benveniste (ESA). The CCVT will liaise with the Precise Orbit Determination Validation Team, due to the strong dependence of the range cross-calibration exercise on the validated precise orbit determination.

The teams are further sub-divided in thematic subgroups. For CCVT:

- cross-cal and val of range/SSH, SWH, sigma0/wind
- absolute sigma0 validation, surface effects
- MWR Geophysical Calibration & Validation

The CCVT is composed of:

- Selected AO PIs and Co-Is,
- Selected scientists,
- Expert Support Laboratories members and Instrument Processor Facility specialist,
- ESA Staff.

Many scientific teams have proposed to contribute to the calibration and validation activity through the ENVISAT Announcement of Opportunity. AO proposals have been selected for their contribution to the core cal/val activity (see Table 2 on page 30).

5.2 Interaction

Reaching the objectives set out depends on several technical dependencies, which will be specified after the methodology has been described in the subsequent sections; see section 10 "Dependencies" on page 36.

In summary, there is a requirement of a validated orbit for the range cross-calibration and a requirement to close the range bias equation with ERS-1 absolute calibration, ERS-2/ERS-1 cross-calibration, ERS-2/ENVISAT cross-calibration and ENVISAT absolute calibration, within the compound error bar.

The CCVT coordinator will interact directly with the Calibration Team and the POD Validation Team coordinators. This means that there is a precise and timely information flow between the Teams. This is described in section 15 on page 85.

5.3 Reporting

The CCVT coordinator has the duty to report to the ENVISAT cal/val coordinator. Regular reporting will be composed of:-

- a first data (switch-on) report
- a preliminary report
- an interim report
- an end of commissioning phase report, including a validation report for all products
- a final report

All reports will be produced and peer-reviewed by the CCVT.

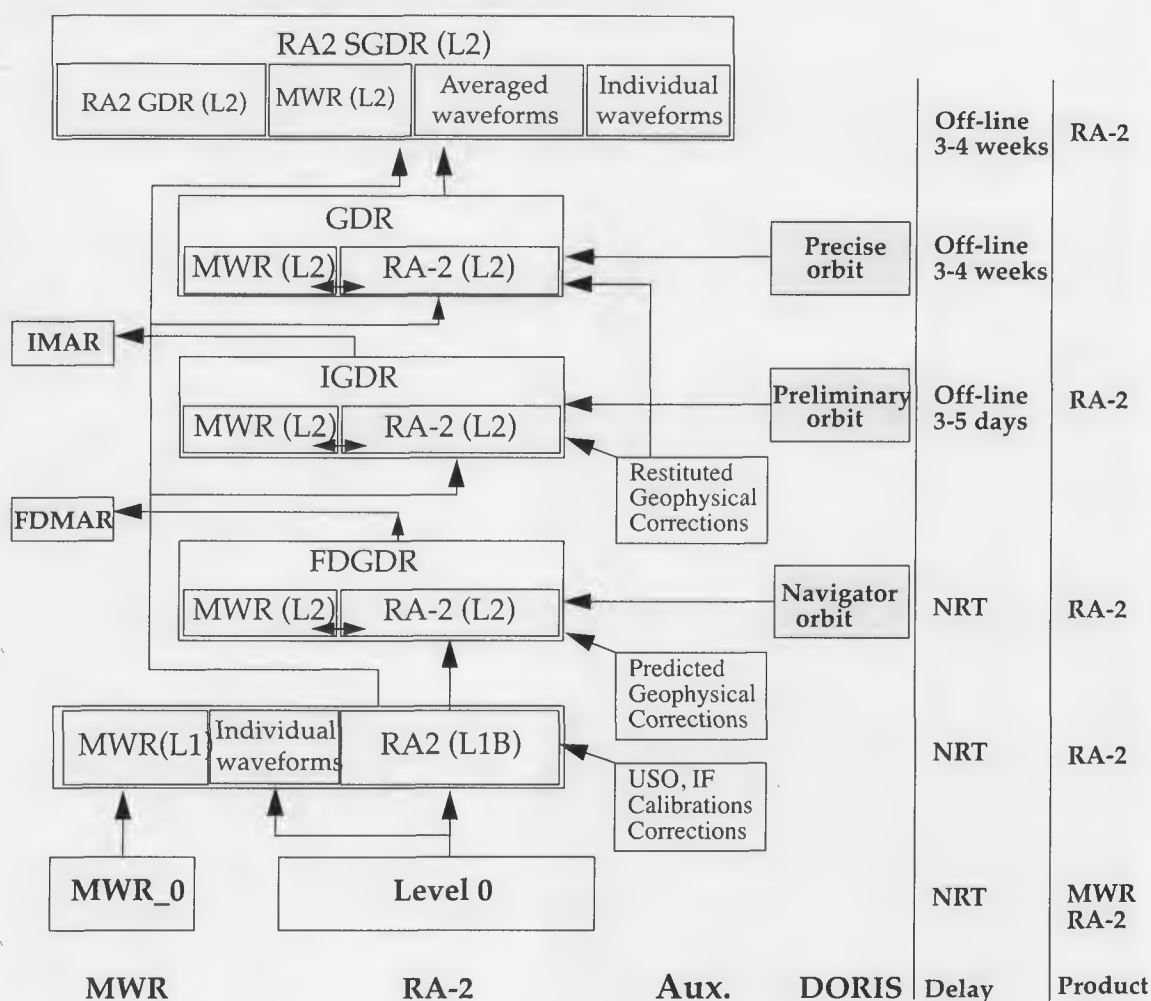
See section 15 on page 85 for the detailed reporting mechanics.

6 ALGORITHMS VERIFICATION AND PRODUCTS VALIDATION

The products to be validated are the near real time and off-line geophysical data records products. The algorithms to be verified by this Team are the geophysical (level 2) processing algorithms. This is the task of the Level 2 algorithm verification sub-group.

The RA-2 and MWR Products Tree is shown in figure 1. The figure shows the input/output integration among the different RA-2/MWR products and the relationship of the RA-2 processing chain with the MWR, as well as the availability of auxiliary data, including the DORIS products.

FIGURE 1 Structure of RA-2 and MWR Products Tree



An RA-2/MWR products and algorithms description is available in a brief guide for users [Benveniste and Milagro-Perez, 2000]. Full details will be found in the RA-2/MWR Products Handbook [ref.: PO-TN-ESR-RA-0050].

The required post-development verification and validation tasks on the RA-2/MWR NRT and off-line GDRs and the off-line SGDR products as well as the product documentation shall at least consists of:-

- Verify with real data the consistency of the product package (document, format and actual dataset: global valid data coverage, outliers, flag consistency...).
- Quantify the inherent validity and accuracy of range, wave height, wind speed, and geophysical corrections.
- Determine orbit error in the data products (via crossover analysis). Estimate time tag errors by minimization of crossover height differences.

Experience in this domain has been acquired with ERS-1 and ERS-2. For a detailed example of the validation activity and report refer to [Benveniste et al., 1997].

The data will be used for the cross-calibration activities: This will enhance the quality and thoroughness of the validation.

The geophysical algorithm verification and the products validation are detailed in the "RA-2/MWR Level 2 Algorithm Verification Plan", PO-PL-ESR-RA-0034, written by the RA-2/MWR Level 2 Algorithm Verification sub-group.

7 ENVISAT MWR CALIBRATION/VALIDATION

The main objective of the microwave radiometer (MWR) is the measurement of atmospheric humidity as supplementary information for tropospheric path correction of the radar altimeter signal, which is influenced both by the integrated atmospheric water vapour content and by liquid water. In addition, MWR measurement data are useful for the determination of surface emissivity and soil moisture over land, for surface energy budget, investigations to support atmospheric studies, and for ice characterisation.

The MWR instrument on board ENVISAT is a derivative of the radiometers used on the ERS-1 and ERS-2 satellites. It is a dual-channel nadir-pointing Dicke-type radiometer, operating at frequencies of 23.8 GHz and 36.5 GHz. With one feed horn for each frequency, the MWR points via an offset reflector at an angle close to nadir. The instrument configuration is chosen such that the 23.8 GHz channel is pointing in the forward direction, the 36.5 GHz channel in the backward direction with a footprint of about 20 km diameter for each beam.

The ENVISAT MWR has evolved from the instruments previously flown on ERS-1 and ERS-2. For ENVISAT, the design of the MWR had to be modified in some areas compared to its ERS predecessors to comply with the different platform and mission requirements. The structure is a new design using CFRP technology having the old deployable antenna replaced by non-deployable one fully integrated into the instrument structure. The design of the central electronics has been adapted to the revised internal and external interface requirements and change component status. The local oscillators feature a completely new design where the Gunn oscillators have been replaced by dielectric resonator oscillators.

The ENVISAT MWR sensor calibration and validation approach is built on a similar methodology as developed for ERS. The calibration exercise is based:

- 1) on systematic comparison between Envisat/MWR and ERS2 brightness temperatures over stable areas and
- 2) on the systematic comparison between Envisat/MWR measurements over ocean and simulations by a radiative transfer model over coincident meteorological fields from ECMWF.

Validation of the geophysical parameters is performed using comparison with in-situ measurements.

7.1 Verification: from L to L+6 months

Between Switch-on and Switch-on+~1month

After the launch of the satellite and the switch-on of the radiometer a couple of days later, only the instrument thermistors (internal temperatures), antenna, hot load and sky-horn counts and gain will be monitored at both frequencies 23.8 GHz and 36.5 GHz. The counts saturation and counts stability will be checked versus numbers of days in orbit.

Once the stability of these critical parameters (counts and gains) will be obtained, the brightness temperature of both chains shall be processed. For ERS2, the radiometer has been stable about 40 days after the switch-on.

During this stabilization phase, weekly reports will be delivered describing the instrument behaviour and evolution. After complete stabilization of the instrument, we will provide a technical report over radiometer working with survey of gains, counts and brightness temperatures since launch.

From radiometer stabilization to Launch+6months

The brightness temperatures provided by the Envisat MWR shall be then checked with respect of values obtained by ERS-2, which is flying over the same position that Envisat half an hour later. The direct comparison of brightness temperatures is allowed, as the respective instrument frequencies are exactly the same. It is therefore possible to do comparisons over areas with weak spatial and temporal variability. For a complete calibration of the instrument, we will check brightness temperatures:

- over sea: with a time delay of 30 minutes between Envisat and ERS2 passes, we make assumption that sea surface conditions (temperature and wind speed) and atmospheric parameters are the same and a direct comparison can be performed. Comparison over one complete orbit will be sufficient to detect strong discrepancies.
- over cold targets: the Antarctic plateau is very stable target with weak spatial and temporal variability. Comparison over this area allows detection of bias for low brightness temperatures (between 120 and 170K).
- over hot targets: selected areas are Amazonian forest and Saharan desert with corresponding brightness temperatures between 280 and 300K.

The green light for the use of the MWR wet tropospheric correction as part of the altimetric range geophysical corrections will be given through a MWR CVT defined flag, the Go-Ahead Flag (GAF). The GAF flag shall be initially determined by comparison with the ERS-2 Brightness Temperatures and then, as a second step, with the ERS-2 wet tropospheric correction. It is anyway clearly anticipated that at least one month shall be required after the instrument switch-on and before any use of valid and meaningful data, for the MWR sensor to stabilize in temperature.

In case of unavailability of the ERS2 radiometer for this calibration period, we propose:

- To compare Envisat/MWR brightness temperatures for both channels over Antarctic plateau with corresponding ERS2/MWR measurements at the same date of previous years. Furthermore, Antarctic is a very stable target, particularly during austral winter witch will correspond to this calibration period.
- To compare Envisat/MWR brightness temperatures with TMR or JMR measurements when available. In case of TMR, none of the frequencies are exactly the same, but using statistical comparison between ERS2/MWR and TMR or radiative transfer model, we will know with sufficient accuracy expected differences due to frequency differences (21 instead of 23.8 and 37 instead of 36.5 GHz). Comparison with JMR will be easier and more precise since one channel is exactly the same (23.8 GHz). These comparisons will be done either over stable targets (Greenland, less stable than the Antarctic plateau but nevertheless useful and above-mentioned hot areas) or at crossover points.

Results of these comparisons will be delivered in monthly reports between launch+1month and launch+6months. A final report over calibration and validation of the qualification phase will be delivered at the end of the verification phase.

During this verification period, we will also check the antenna pointing angles using measurements over coasts with simple coastal geometry (Maré Island off Nouvelle Caledonia Island). The brightness temperatures over land are roughly 100 Kelvin higher than over sea. The space and time between peaks observed for each brightness temperature give an information about the pointing angle. Note that this study needs a precise orbit determination.

7.2 Calibration-validation: from L+1month to L+1year

Then, the calibration itself will begin with a systematic comparison between measurements over ocean and simulations over coincident meteorological ECMWF fields. The most important improvements for this part of the validation regarding the ERS2 radiometer are:

- the use of the last version of the operational model at ECMWF with a better vertical resolution (60 levels instead of 31) and also a better horizontal resolution (T511 gaussian grid with a corresponding optimal resolution of 0.351 degree).
- the use of prediction at 12 hours, better compromise to have an impact of SSM/I assimilation for each latitude and a good balance in the precipitation's.
- an improved version of the UCL model with a better description of the surface and simultaneous simulation of backscattering coefficients in S and Ku bands.

The methodology is the following:

- Extraction of coincident pixels: temporal criteria are +/- 1 hour. Due to the new horizontal resolution in the ECMWF, we will maybe be less strict (+/- 30 minutes) to get a better consistency between measurements and simulations
- Filtering of cloudy pixels (use of a preliminary cloud liquid water algorithm and of the ATSR cloud flag) and meshes (elimination of cloudy model grid points)
- Statistical comparison of measurements in each mesh: average of all brightness temperatures falling in one mesh
- Analyses of the comparison for different situations (wet or dry atmosphere, low or strong wind speed) in terms of bias, correlation coefficient, standard deviation and coefficients of the regression line.

Other comparisons shall be performed with in-flight radiometers for the same set of ECMWF fields, with the following sensors, ERS-2 MWR, Topex/Poseidon TMR, Jason JMR, SSM/I, TMI and AMSR (when available). The global coherency of the results (same bias, or regression slope) shall allow the control of the sensor calibration.

These studies will be carried out in the first year of the mission. A report will be delivered at the end of the commissioning phase with the adjustment of the calibration coefficients. A final report on the in-flight calibration and preliminary validation will be delivered at launch+1year.

7.3 Products validation: from L+6months to L+2years

The Envisat MWR validation activities consist in validating the obtained geophysical products. This concerns the wet tropospheric correction for the Radar Altimeter and the surface wind speed. The most reliable method is the statistic comparison with in-situ measurements, i.e. with measurements performed by radiosoundings for water vapor and by ships and buoys for surface wind speed. This is not applicable to the cloud liquid water content for which no routine measurement is performed.

The statistic comparison with in-situ data requires more than one-year time to accumulate enough collocated data (about 1000 points per year). It is therefore considered as a long-term survey activity. To compensate for this slow data accumulation, preliminary comparisons shall be performed with space-borne measurements for water vapor content, wet tropospheric correction, cloud liquid water content and surface wind speed.

A report on the in-flight validation of geophysical parameters with in-situ measurements will be delivered at launch+2years.

7.4 Long term survey

The long-term survey activities shall rely in:

- The survey of the sensor principal internal parameters such as the different radiometric counts, the gain and residual term.
- The analysis of the brightness temperatures measured over specific areas with dry atmosphere and stable annual cycle. The favourite sites are the Sahara for the hot brightness temperatures and the Antarctic plateau for the cold ones. Over these regions, the idea is that any natural variation shall affect the two sensor channels in a similar way, allowing easily in this way to point out any drift on one particular channel. The cold ocean water locations will also be used, following Ruf's method developed for Topex/TMR
- The in-depth analysis of the raw data in case of anomaly detection.

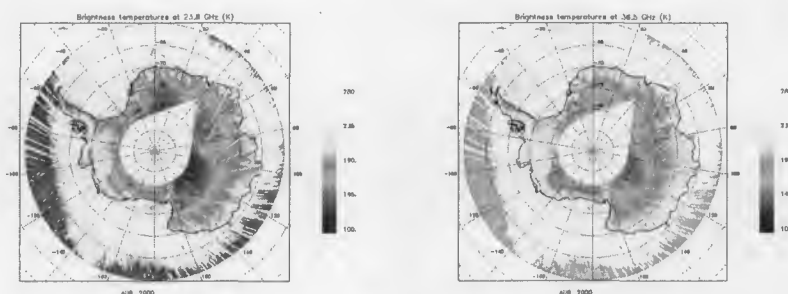


Figure 1: Maps of the ERS-2 MWR brightness temperatures over the Antarctic from August 2000. Over poles, the space and time cover is sufficient to draw maps of the brightness temperatures. Moreover, the atmospheric variability is weak, due to the very low water vapor content. Thus, the brightness temperatures are mainly representatives of surface emissivity and temperature variations, which slowly vary within the year. Consequently, the South Pole can be used as a stable target to survey the brightness temperature variations with time.

Monthly reports will be delivered by mail after the commissioning phase, and a final report at launch+2years will describe results of the validation and a first complete analyze of the long-term survey (internal stability, continuity with ERS2...). After that, the long term survey will be done routinely with a monthly control of the gain stability, and each year, a report with results over the long term survey over stable areas will be delivered.

7.5 Future improvements, new algorithms validation & implementation

The preparation of the ENVISAT MWR Commissioning Phase lead to the identification and elaboration of some new algorithms for the MWR Level 1B and level 2 processing chains. These improvements essentially cover the computation of the MWR Side Lobes contribution, proposed now as a bi-dimensional correction and a very promising and new generation Level 2 retrieval algorithm (neural network inversion). All these near-term algorithms improvements will be first validated during the Envisat MWR Commissioning Phase within the MWR CVT group before any implementation within the ESA ENVISAT processing chains.

8 ENVISAT RA-2 CROSS-CALIBRATION

8.1 Range

8.1.1 Absolute calibration

The absolute calibration of the range, in both Ku and S band, will be carried out during the commissioning phase using several sites located in the Mediterranean sea. The objectives, constraints and methods are fully described in the RA-2 In-Orbit Calibration Plan (Ref.: PO-PL-ESA-GS-0714). This task is the responsibility of the Calibration Team.

8.1.2 Relative calibration

The RA-2 relative calibration approach is based on the global comparison of ENVISAT and ERS data Products (GDRs), as well as TOPEX/POSEIDON, GEOSAT Follow On, and/or JASON, and local differential observations on equipped (tide gauge, SLR) natural targets (e.g., the Channel), again using the nominal GDR products.

The following methods will be used:

- comparison between Envisat and ERS collinear tracks,
- comparison between Envisat and ERS (and other radar altimeters) at crossover points,
- comparison of Mean Sea Surface models produced from ENVISAT and ERS, as well as models produced from other altimeters,
- comparison of sea level heights monitored by RA-2 and a tide gauge network.

The output of these methods is the estimate of a bias plus its formal error.

The advantage of the crossover method is that crossover lags are shorter and longer than the offset time between Envisat and ERS. With the collinearity method, the lag is always constant. The collinearity method, applicable only to satellites on the same orbit, provides many more data points for comparison and is thus more accurate. Tide gauge networks are efficient at monitoring slow temporal drifts.

8.2 SWH

Three methods are envisaged:

- comparison of ENVISAT SWH with models (e.g., WAM),
- comparison of ENVISAT SWH with buoys,
- comparison of ENVISAT SWH with ERS and/or TOPEX/POSEIDON, GEOSAT Follow On, JASON.

The output of these methods is the estimate of a bias plus its formal error.

8.3 Sigma Nought and Wind Speed

8.3.1 Relative calibration of sigma0 and wind speed

The validation of the sigma nought in S band and Ku band has the following objectives:

- To check the consistency of measurements at global level
- To verify the coherence with ERS.

The relative sigma nought calibration will be done in the framework of the relative calibration activities, by direct comparison of the Ku band data. The result will permit to use the same wind model of ERS for ENVISAT.

Three methods are envisaged:

- comparison of ENVISAT wind speeds with meteo models (e.g. ECMWF),
- comparison of ENVISAT wind speeds with buoys,
- comparison of global statistics of Envisat sigma nought with ERS and/or TOPEX/POSEIDON, GEOSAT Follow On, JASON.

The Ku and S band sigma0 will be examined globally, to ascertain the plausibility of both parameters over ocean.

The output of these methods is the estimate of a bias plus its formal error. A preliminary (using small amount of data) and a final sigma0 cross-calibration bias will be estimated and used to produce a significant wind speed.

8.3.2 Rain Flag

The sigma0 validation includes the validation of the rain flag algorithm, and the establishment of the related thresholds. The methodology is based on the different rain attenuation in the different bands. The rain flag and the rain attenuation correction will be closely examined against waveform distortion and available rain data (e.g. meteorological radars).

Over the oceans a close correspondence is found between the sigma0 values at Ku- and C-band, with departures from this mean relationship being principally due to rain within the altimetric footprint (see Quartly et al., 1996; Tournadre and Morland, 1997). A similar situation is expected for the sigma0s at Ku-band and S-band enabling us to define an altimetrically-derived rain flag, based on the observed attenuation of the signal.

Formally this test will be:

if $(\sigma_{0_Ku} - f(\sigma_{0_S}) < -g(\sigma_{0_S}))$ then rain_flag = .true.

otherwise rain_flag = .false.

where $f(.)$ and $g(.)$ are functions giving mean relationship and threshold respectively.

Points to note:

- 1) In this discussion, all σ_0 values have NOT been corrected for atmospheric attenuation
- 2) Mean relationship, $f(\cdot)$, and threshold, $g(\cdot)$, to be supplied as tables for ease of use.
- 3) When rain is present, σ_{0_Ku} will be less than $f(\sigma_{0_S})$. The above expression is written with threshold $g(\cdot)$ being positive for all values of σ_{0_S} .
- 4) Based on TOPEX experience, rain flag definition will probably not be reliable at very low wind speeds, so best extended to also include a test on σ_{0_S} being less than some threshold OR a test on radiometer-derived liquid water content.
- 5) It is envisaged that there be 3 versions of the tables:
 - i) Prior to launch — $f(\cdot)$ supplied from modelling by Chapron (IFREMER).
 - ii) After 2 weeks of operation — initial empirical relationship for $f(\cdot)$ and $g(\cdot)$ provided by Quartly (SOC).
 - iii) By end of commissioning phase — robust empirical tables for $f(\cdot)$ and $g(\cdot)$ provided jointly by Quartly (SOC) and Tournadre (IFREMER). Also a recommendation will be given as to whether a σ_{0_S} limit or radiometer-derived threshold be incorporated in the test.

The work will be carried out mainly by IFREMER (AO 600, AO 150) and SOC (AO 267).

8.3.3 Absolute σ_0 calibration

The σ_0 absolute calibration will be performed with a transponder. This activity belongs in the CT.

8.3.4 Absolute σ_0 validation

The scientific utilisation of a calibrated σ_0 is two-fold: improving the wind speed algorithm by determining a function $Wind = F(\sigma_0, \sigma_{0_s})$; and retrieving the wave period. The instrument calibration is the objective of the CT. The absolute σ_0 validation is an objective of the CCVT, via the validation of downstream models using σ_0 in both Ku and S bands. Due to the later availability of the absolute σ_0 , the full development, validation and implementation of a new ENVISAT wind speed model based on the absolute σ_0 is not an objective of the RA-2/MWR CCVT.

Finally, the absolute backscattering in the two bands (S and Ku) will be estimated with the Passive Calibration Method. Such method is based on the fact that in the determination of the absolute backscatter the basic unknown is the receiver response function and that the other parameters are sufficiently well known. Therefore the calibration method consists in determining such receiver response function (modelled as gain and offset) observing a set of natural targets with different brightness temperature. The brightness temperature of the targets can be determined with models (i.e. over ocean) or via observations made by other radiometers, appropriately converted to the RA-2 operating conditions.

The University of L'Aquila and the University of Rome will carry out the Passive Calibration Method. The CETP will provide assistance for the use of the on-board MWR.

8.3.5 Test for drift of σ_0

Check for consistency in scatter plot of simultaneous σ_0 measurements at Ku- and S-band. The form of the scatter plot should stay constant with time (i.e. no regional or seasonal signal), so any evolution of the mean relationship indicates changes in σ_0 calibration (see Quarty, 2000).

8.3.6 σ_0 monitoring using natural land targets

Use of time-constant backscatter land sites to provide identification of anomalies or drifts in σ_0 (Berry, 2000)

8.4 Special Tasks

8.4.1 Dual frequency ionospheric correction

The Level 2 Algorithm verification sub-group will validate the ionospheric correction. See "RA-2/MWR Level 2 Algorithm Verification Plan", PO-PL-ESR-RA-0034.

8.4.2 Ku and S Band Sea State Biases

The Level 2 Algorithm verification sub-group will validate both Sea State Biases. It is foreseen that an updated model, built from the first few cycles of RA-2 data, be established during the commissioning phase. See "RA-2/MWR Level 2 Algorithm Verification Plan", PO-PL-ESR-RA-0034.

8.4.3 RA-2 Performance and Cross Calibration with ERS RA Ice Mode

8.4.3.1 Impact of mode switching on geophysical products

The analysis of the in-flight performance, including tracking performance and mode switching behavior, will be done by the CT.

The impact of mode switching on the quality and usability of the geophysical products will be assessed within the CCVT.

8.4.3.2 Cross-calibration of Envisat range in medium and low resolution mode Vs ERS-2 Ice mode

Cross calibration of the Envisat altimeter elevation measurements with those from ERS-2 is critical in particular to ensure continuation of the ice sheet mass balance estimates. In addition comparisons of the sea surface height and ice freeboard estimates over the Arctic from Envisat and ERS-2 will ensure that time series of these parameters are consistent over the period of the two missions.

The method is to compare height estimates using both cross-over and collinear analysis of data acquired by Envisat in each of the three modes and by ERS-2 during the Envisat Cal/Val phase. The analysis will be carried out over a number of different ice surfaces and globally over the oceans in order to discriminate biases due to the differences in the ERS-2 and Envisat tracking and data recording systems. Once determined the results will be used to correct the ERS/Envisat estimates and ensure a consistent time series of the measurements.

8.5 Merging of results

More than one team will estimate cross-calibration biases using different methods. As mentioned in the description of the team constitution, this will ensure robustness of the results. The merging of the results from the different teams should be done with a formal error estimate.

8.6 Result Accuracy

To estimate the final result accuracy, there is a need to estimate the formal errors while the results are merged together. Here is a theoretical approach contributed by P. Challenor, that will need to be adjusted to the actual data. See also Stoffelen (1998).

Calculating errors from three or more data sources

If you have data from three or more sources looking at the same spatial and temporal scales, as long as the errors are statistically independent you can calculate an estimate of the mean square error that is independent of the errors in the other data sources. This means that, for example, we have two independent measurements of satellite height plus the altimeter we can derive an estimate of the altimeter error that is independent of the errors in the other two measurements. If there are four or more measurements it is possible to separate the bias and variance, with only three measurements this is not possible.

We begin by defining the signal and its error for each measurement.

We have

$$s_1 = h + e_1, \quad (1)$$

$$s_2 = h + e_2, \quad (2)$$

and

$$s_3 = h + e_3, \quad (3)$$

where s_1 , s_2 , s_3 are the measurements from the three independent sources; e_1 , e_2 , and e_3 are their associated errors, and h is the true signal. $E(e_1^2)$, $E(e_2^2)$ and $E(e_3^2)$ are the mean square errors (MSE) for the each measurement system respectively. We must note that we assume the use of expectation operators is well defined.

From (1-3) we have

$$E(s_1^2) = E(h^2) + 2E(e_1 \cdot h) + E(e_1^2), \quad (4)$$

$$E(s_2^2) = E(h^2) + 2E(e_2 \cdot h) + E(e_2^2), \quad (5)$$

and

$$E(s_3^2) = E(h^2) + 2E(e_3 \cdot h) + E(e_3^2), \quad (6)$$

$E(e_1^2)$, $E(e_2^2)$, and $E(e_3^2)$ are the unknowns which we are trying to determine.

The expected values of the cross-products are given by:

$$E(s_1 \cdot s_2) = E(h^2) + E(h \cdot e_1) + E(h \cdot e_2) + E(e_1 \cdot e_2), \quad (7)$$

$$E(s_1 \cdot s_3) = E(h^2) + E(h \cdot e_1) + E(h \cdot e_3) + E(e_1 \cdot e_3), \quad (8)$$

and

$$E(s_2 \cdot s_3) = E(h^2) + E(h \cdot e_2) + E(h \cdot e_3) + E(e_2 \cdot e_3). \quad (9)$$

The errors in the three measurement systems are statistically independent so all cross-product terms of the form $E(e_i \cdot e_j)$ ($i \neq j$) are zero. Using equations 8, 9, and 10 to eliminate the variance of the true value, h and its covariance with the error terms ($E(h^2)$, $E(h \cdot e_1)$,

$E(h.e2)$, and $E(h.e3)$), we find that the error variances can be now be written in terms that can be calculated:

$$E(e12) = E(s12) - E(s1.s2) + E(s2.s3) - E(s1.s3), \quad (10)$$

$$E(e22) = E(s22) - E(s1.s2) - E(s2.s3) + E(s1.s3), \quad (11)$$

and

$$E(e32) = E(s32) + E(s1.s2) - E(s2.s3) - E(s1.s3). \quad (12)$$

These equations give us formulae for the errors in each of the measurements systems that involve only terms we can calculate from the data. Thus it is possible to estimate the error in an altimeter without knowing the detailed error characteristics of the calibration data. For details of this method and an application see Tokmakian and Challenor (1999).

This approach will be discussed and refined during the commissioning phase.

9 SWITCH-ON AND "FIRST DATA" ACTIVITIES

9.1 Verification

Most of the switch-on activities will be performed in the RA-2 in flight verification Team and in the MWR cal/val Team.

The Level 2 Algorithm verification Team will inspect the first data as well (see "RA-2/MWR Level 2 Algorithm Verification Plan", PO-PL-ESR-RA-0034) for an immediate verification and geophysical validity of first data.

A "First Data" report will be drafted and delivered to the Envisat Project.

9.2 Promotion and outreach

Material for promotion and public release will need to be generated for Envisat Promotion purposes. Herebelow is a detail of the "First images" to be produced.

The oceanic/terrestrial/geophysical features that could be targeted as first RA2 images/products to be diffused, along with the specification on who is going to produce it and estimated time to completion of each item, are the following:

Switch-on

- **Wind speed:** A map (or a profile) with this geophysical parameter will be first produced at RA2 switch-on. This will be generated at ESRIN by plotting the RA2 wind speed values stored in the L2 products.
- **Wave height:** A map (or a profile) with this geophysical parameter will be first produced at RA2 switch-on as well. This will be generated at ESRIN by plotting the RA2 significant wave height values stored in the L2 products.
- **Sea level Anomalies Quick Look:** The corresponding map will be first produced at Launch date + 1 months. It will be done at ESRIN using information (altitude, range, mean sea surface) from the NRT Level 2 products.
- **MWR data:** a map of ERS-2 data + Envisat overlay at MWR switch-on, done by CETP.

L + 2 months

- **Ice sheet profile:** The corresponding map will be first produced at Launch date + 2 months. It will be done by ESRIN or MSSL.
- **Lake/river level:** The corresponding map will be first produced at Launch date + 2 months. It will be done by De Montfort University or GRGS.
- **Sea-ice thickness:** The corresponding map will be first produced at Launch date + 2 months. It will be done by MSSL.
- **Sea level Anomalies:** The corresponding map will be first produced at Launch date + 2 months. It will be done at ESRIN using information (altitude, range, mean sea surface) from the Level 2 products.

L + 6 months

- **Sea level anomalies time series (animation):** The corresponding maps and animation will be first produced at Launch date + 6 months. It will be done by ESRIN, DUT or CLS.
- **Eddy Kinetic Energy:** The corresponding map will be first produced at Launch date + 6 months and updated every week. It will be done by CLS.
- **Global wind speed:** The corresponding map will be first produced at Launch date + 6 months and updated every 6 months or cycle by cycle. It will be done at ESRIN.
- **Global wave height:** The corresponding map will be first produced at Launch date + 6 months and updated every week or cycle by cycle. It will be done at ESRIN.
- **Total water vapour:** The corresponding map will be first produced at Launch date + 6 months and updated every week. It will be done by CETP or ESRIN.
- **Total electron content in ionosphere:** The corresponding map will be first produced at Launch date + 6 months and updated every week or every cycle. It will be done at ESRIN for what concerns the electron content deriving from the dual frequency ionospheric correction, and at CLS/CNES in case of the electron content coming from DORIS.

L + 9 months

- **Global lake/river level variations:** The corresponding map will be first produced at Launch date + 9 months and updated every cycle. It will be done by De Montfort University or GRGS.

L + 18 months

- **Global gravity mapping:** The corresponding map will be first produced at Launch date + 18 months. It will be done by CLS.

Ad hoc

- **El Niño:** The corresponding map will be produced whenever it will happen. It will be done by ESRIN or DUT.

10**DEPENDENCIES**

In the process of reaching the objectives set out, looking carefully at the methodology described in the previous sections, there are several technical dependencies on items which may reside externally to the CCVT.

A number of issues listed below need to be addressed. Discussion and are to take place within the relevant Teams leading to decisive statements.

Switch-on

- Refer to the Switch-On and Data Acquisition Plan (PO-PL-ESA-SY-1027), in particular the RA-2 SODAP (PO-PL-DOR-RA-0213) and MWR SODAP (PO-PL-DOR-MR-0216)
- RA-2 and MWR should be switched-on as soon as possible after Launch, order of ten days.

RA-2 Instrument verification issues:

- When would be the on-board parameter sufficiently frozen to permit accumulation of a consistent data set? Refer to the RA-2 In-Flight Verification Plan (PO-PL-ESA-GS-1097) and the MWR calval section 7 on page 22.

Range

- IF: when is this file validated? use a pre-launch file or in-flight?
- USO: when is this file validated?
- SSB (SWH, WIND)
- Validated Orbit: when are the orbits validated? what do we do when the orbit has been reprocessed?
- Geophysical Corrections (including MWR wet tropospheric correction): can we include MWR wet at some point in time? should we?
- Verification of dual-frequency (Ku- and S-band) first order ionosphere removal algorithm.
- Verification of bias closure equation on ERS-1 abs cal, ERS-2/ERS-1 cross-cal, ERS-2/ENVISAT cross-cal, ENVISAT abs cal: need to get (early) preliminary values (before they are final) of absolute range bias and absolute sigma0 bias

Wind speed

- based on absolutely calibrated sigma0? This is not part of the CCVT objectives. see section 8.3 on page 28.

SWH

- IF: when is this file validated? use a pre-launch file or in-flight?

SSB

- SWH
- Wind speed
- SSB Model

Long term calibration monitoring

- Global tide gauge accessibility (A Cazenave, P. Woodworth, IOC/GLOSS-ALT)
- Capraia or other low-cost long-term site, e.g. Barcelona off-shore tower, Lake Erie or Gavdos island (TBD)

11

CONTRIBUTION BY PIs

Experience to apply the various cross-calibration and validation methods described hitherto exist in Europe and world-wide in various institutes, each of which having their own algorithms and methodology, experience, and research areas of interest. The methodology has been proved during the cross-calibration of ERS-2.

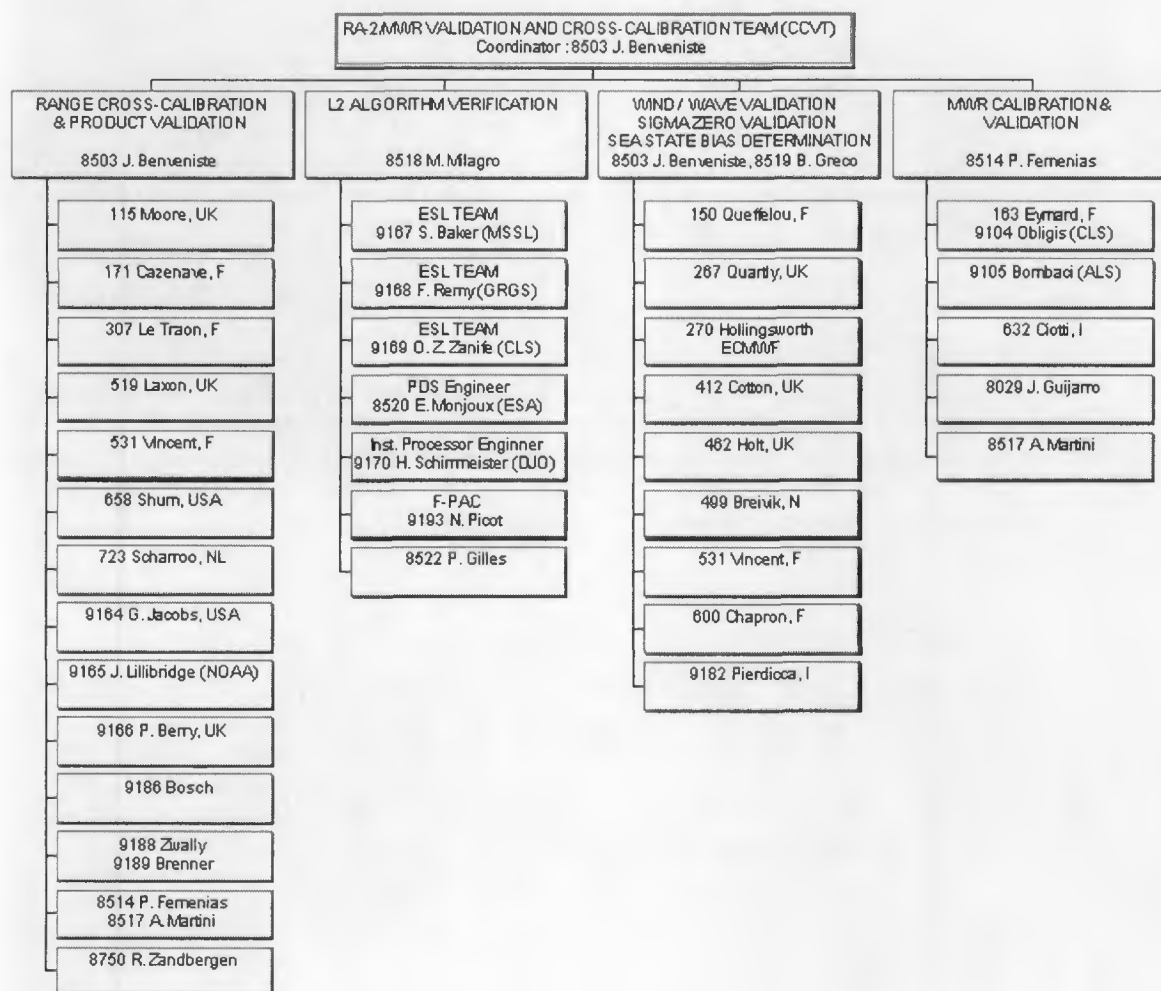
Based on the experience gained during the commissioning of ERS-2, taking into account the envisaged objectives described hereabove, a careful selection of contributions proposed via the ENVISAT Announcement of Opportunity was performed.

The PI of an AO that has been retained for the CCVT core activities is invited to join the Team along with the Co-Is which are involved in tasks relevant to the CCVT.

There may as well be contributions from other selected scientists.

The RA-2/MWR CCVT organigramme and membership is shown below.

The RA-2/MWR Cross-Calibration and Validation Team organigramme and membership



11.1 AO115, Moore, Newcastle U (UK)

AO 115; Philip Moore; University of Newcastle-upon-Tyne, UK; Long-term stability analysis of ENVISAT altimetry through cross-calibration and comparison against in-situ data with applications to global sea-level change.

Brief Tasks Summary:

Long-term monitoring of the ENVISAT altimeter relative bias will be undertaken. The analysis will use in situ tide gauge data, and dual satellite repeat pass and/or crossover analyses between ENVISAT and other concurrent satellites. If ENVISAT is the only operational altimeter tide gauge enhanced crossovers will be used to connect ENVISAT to earlier missions such as ERS-2 and TOPEX/Poseidon.

Present to launch:

Continuing monitoring of the altimetric bias of TOPEX/Poseidon using the global network of tide gauges and of ERS-2 through dual crossover analysis with T/P. The former permits the T/P altimetric drift to be removed from ERS-2. At some point our orbit determination software must be extended to accept ENVISAT including a macro-model of the satellite for surface forces.

Commissioning Phase:

Validation of the RA cannot be separated from orbital analysis and our efforts for the commissioning phase will include precise orbit determination from SLR and DORIS; estimation of the altimeter time tag bias from crossovers; investigation of the sea-state bias from crossovers and recovery of the ENVISAT relative altimeter bias from dual repeat pass and crossovers with concurrent altimeter satellites. The process will include validation of the ENVISAT altimeter product.

After Commissioning Phase

Long-term monitoring of the altimeter range stability will be undertaken by either comparison against in situ tide gauge data or by cross-calibration against T/P and JASON-1. The work will be extended to connect the ERS and ENVISAT missions to give a consistent time series for the total missions.

11.2 AO307/ESL*, Letraon, CLS (F)

Co-I: J. Dorandeu

ENVISAT GLOBAL STATISTICAL ANALYSIS

Brief task summary:

- ENVISAT altimeter system performance evaluation
- Altimeter measurement precise analysis, Time Tag bias estimation, noise level and spectrum determination
- Orbit precision evaluation, orbit error characterization
- Geophysical corrections quality assessment
- Sea Surface Height variability

11.3 AO723, Scharroo, Delft Univ of Technology (NL)

Co-Is: Pieter Visser, Marc Naeije, Ron Noomen, Ejo Schrama, Danny van Loon

Contribution to the absolute and relative calibration of the Envisat radar altimeter

Brief task summary:

Altimeter data products will be validated (data content, format, quality control, data flagging, editing). Fast-delivery and precise orbits will be delivered. Altimeter data and geophysical corrections of Envisat RA-2 and will be compared with data from other operational radar altimeters (of ERS-2, T/P, Jason and GFO) during the commissioning phase and beyond. Systematic, time-variant and geographically correlated differences are analysed using collinear track and crossover techniques.

Present to launch:

Algorithms will undergo critical review. In-house multi-satellite data base (RADS) will be prepared for the adoption of Envisat altimeter data. Build surface force model for Envisat in support of the precise orbit determination.

Commissioning Phase:

Level 2 GDRs will be acquired and stored in our multi-satellite data base. Fast-delivery and precise orbits will be computed on the basis of SLR, DORIS and altimeter data. These orbits will be delivered to the CCVT and will be compared against other available orbits to determine the consistency and quality of the various orbit products. In the first few weeks we will make a rapid validation of the altimeter products, including an assessment of the data format and consistency, global coverage, and the quality of measurements, corrections and flags. A suggestion for data screening will be provided. Throughout the commissioning phase available Envisat data will be compared against concurrent data from other satellites (ERS-2, T/P, GFO, Jason-1) using collinear track and crossover techniques in order to identify systematic, time-variant and geographically correlated differences between data produced by the various altimeters.

After commissioning phase:

At the end of the commissioning phase the calibration and validation results will be finalised and reported. Operational and precise orbits will remain to be delivered and updated. Long-term range and SWH stability will be monitored using the previously mentioned methods.

11.4 AO531, Vincent, CNES (F)

Range

The achievement of the verification activities occurs over two time frames. In the first phase a few months after launch, the operability and the good quality of the instrument measurements have to be proven so that users can rapidly trust the measurement system and begin to deal with science or operational objectives. To do so, local calibration and global verification approaches may be used during the first months of the mission. Then, because science and operational applications are more and more demanding in terms of system performance on a long term basis, the quality of the altimeter system has to be continuously re-assessed and data products permanently improved, after evaluation of all critical processing algorithms. Additionally, we will then perform a proper cross-calibration of all simultaneously orbiting systems and generate homogeneous products from them, so that data users may then benefit from the complementarity of all altimeter systems simultaneously flying.

Four tasks deal with the activities to be lead in the CCVT framework:

Task 1. Absolute range calibration of the ENVISAT altimeter system on a long term site

During last years, complementary altimetric missions have notably permitted to compare altimeter instruments: relative calibrations have been achieved with very successful results. However, problems discovered both in the algorithms and the instruments: SPTR and USO drift corrections for ERS, and the oscillator drift correction for TOPEX/POSEIDON reinforced the interest of regular absolute calibration campaigns to detect such problems in near-real time. Even if restricted to a single-point verification, well instrumented calibration sites are indeed quite useful in assessing the various components of the altimetric system, with the capability of measuring very accurately the environmental parameters interfering in the altimetric measurement: sea-state, sea level, troposphere and ionosphere effects, reference frame stability, etc.

Experiments will be carried out for the joint benefit of ENVISAT and Jason: sites under consideration are located in Corsica (France), Capraia (Italy) and Ibiza (Spain). Calibration campaigns to be performed during the commissioning phase of the mission will provide the basis for a long term Corsica-Capraia multi-satellite calibration area.

Such a task will naturally contribute in the RA2 CAL group activities; it will also contribute in the CCVT group work as it includes a multi-satellite approach.

Task 2. Global statistical validation of the ENVISAT altimeter system: data consistency

Assessment of the quality of the altimeter measurements, of the processing algorithms, of the effectiveness of the geophysical corrections, evaluation of the orbit accuracy, characterization of the long wavelength errors, of the noise of the instrument and of the wavenumber spectra of the sea-level measurements, may be performed through global statistical analysis (Le Traon et al., 1994). In order to check the whole data consistency, we will use the classical crossover and repeat-track techniques.

This task will be performed jointly with the CLS team that was selected as a PI in the frame of the ENVISAT Announcement of Opportunity.

Task 3. External checks of the ENVISAT altimeter system using tide gauges

Following the success of Mitchum's approach (1998), we propose to use a subset of the GLOSS tide gauge network and deal with the detailed analysis of local hydrodynamics at tide gauge sites, without considering the geodetic aspect of tying the tide gauge network to a stable terrestrial reference frame.

It is proposed to develop a modelling approach which will help to link the altimeter measurements obtained in the vicinity of the tide gauge sites, and the ones collected at the tide stations. This will be done on the basis of a 3D hydrodynamic ocean model, using a finite element approach to allow the refinement of the computational grid down to a few hundred meters at the tide gauge station. Regional models will be implemented at a number of stations selected for this long term cal-val application.

This task will be performed by the LEGOS co-investigators of the proposal.

Of course, results will be made available to geodesists for an integrated work to issue absolute sea-level time series, which is the objective of proposals like the one by A. Cazenave et al.

Task 4. Cross-calibration of simultaneously flying altimeters. Merging of all altimeter time series.

The first phase of the work will be to determine relative biases and drifts between range measurement of the different altimeters. Algorithm testing will have to be performed as it is now recognized that an accurate cross-calibration involves altimeter corrections as homogeneous as possible for all systems under consideration. Cross-calibration techniques will mainly follow previous works by Le Traon et al. (1996, for instance) and by Cazenave et al. at LEGOS.

We will then apply and improve the technique that was already used by the CLS team to generate homogeneous ERS-1/2 and T/P products distributed by AVISO. It is based on three major successive steps: * correct the orbit error for missions with the lowest accuracy, * extract sea-level anomalies using a common reference surface (the orbit patterns of all satellites are such that it will be difficult to jointly use classical mean profiles as a common reference; to deal with this problem, a high accuracy mean-sea surface that includes data from all altimeter satellites can be computed and used, taking care that the along-track accuracy is conserved by the computational process), * combine the data through a mapping method allowing to take into account the spectral characteristics of the different sources of error and of the oceanic signal (Le Traon et al, 1998, for instance).

This task will be performed jointly with the CLS team that was selected as a PI in the frame of the ENVISAT Announcement of Opportunity.

SWH

Validation of the ENVISAT RA2 wind/wave data and cross-calibration with wind/wave data from other altimeters will be performed jointly with Météo-France investigators.

It will be based on:

1. Classical global statistical analysis of the RA2 wind/wave data.
2. The comparison of RA2 wind/wave data to wind/wave data from other altimetric missions. This will be performed using simple statistical approaches, and/or crossover analysis as successfully used by Queffelec et al. (1998) to identify the long-term anomalous behaviour of significant waveheight as measured by the TOPEX A altimeter.
3. The use of a new high resolution regional wave model over the Mediterranean Sea (so-called "Aladin wave model"), as already completed by the Météo-France investigators at the time of ERS and TOPEX/POSEIDON using previous versions of wave models.

The anticipated results will be a global statistical characterization of RA2 wind/wave geophysical parameters, with respect to other altimeter measurements and wave models. Besides this validation work, it should be mentioned that Meteo-France intends to assimilate altimeter wave data from various missions (including ENVISAT) in their high resolution Med Sea wave model in order to improve both sea-state analysis and sea-state forecasts. This may also contribute to a longer term analysis of the RA2 waveheight error budget.

11.5 AO171/ESL*, Cazenave, LEGOS (F)

Title:

Calibration/Validation of the ENVISAT altimetry system by global in situ verification

Principal Investigators:

Anny Cazenave and Jean François Crétaux

LEGOS-CNES/GRGS, 18, Avenue Edouard Belin, 31401 Toulouse Cedex 4, France

Tel.: (33)5.61.33.29.22 ; Fax: (33)5.61.25.32.05 ; e-mail: anny.cazenave@cnes.fr

Co-Investigators:

M. Bergé-Nguyen, LEGOS-GRGS/CNES

K. Dominh, LEGOS-GRGS/CNES

V. Toumazou, LEGOS-GRGS/CNES

L. Soudarin, CLS

J.J.Valette, CLS

Brief task summary:

Sea level measurements derived from ENVISAT altimetry data will be compared to in situ tide gauge sea level on a global tide gauge network, including GLOSS sites complemented by a number sites for which sea level times series are available to us. At tide gauges sites collocated with space geodesy stations (GPS and/or DORIS), vertical crustal motions will be determined and removed to the tide gauge sea level measurements.

This investigation will allow external verification of the ENVISAT altimetry system through the detection of possible systematic errors and onboard instrumental drifts.

Present to launch

We will continue the on-going determination of vertical crustal motions using GPS and DORIS at a maximum number of tide gauge collocated sites; We will also continue promoting the extension of the DORIS network at tide gauges sites for the calibration of future altimetry systems (JASON-1 and ENVISAT).

Commissioning phase

We will accumulate global RA-2 level 2 GDRs, extract sea level data nearby the tide gauge sites, analyse simultaneously tide gauge measurements, correct the latter for vertical crustal motions, determine the sea level differences, compare the ENVISAT-derived sea level with Topex-Poseidon and JASON-1 sea level, interpret the results in terms of error budget of the ENVISAT altimetry system.

After commissioning phase

We will further collect all necessary data sets (ENVISAT, Topex-Poseidon and JASON-1 altimetry data, tide gauge data, DORIS and GPS data), update the calibration/validation results, prepare a validation report.

Construct sea level time series from ENVISAT altimetry data as well as by combining ENVISAT, Topex-Poseidon and JASON-1 data.

11.6 AO658, Shum, Ohio State University (USA)

Brief Tasks Summary

Cross-calibration tasks include:

- * Precise orbit verifications and assessment of orbit errors (geographically correlated and variable), altimeter time biases, sea state bias and timing accuracy of DORIS tracking system
- * Comparison between ERS-2, T/P, GFO and Jason for assessing accuracy of Envisat range, SWH, sigma0, wet troposphere and ionosphere delays
- * Tide gauge assessment of altimeter range drift
- * Great Lakes calibration site with vertical-positioned tide gauges using GPS. Verifications for ionosphere and wet troposphere delay verification
- * Tide gauge verification of instrument corrections (e.g. SPTR corrections for ERS-2 and ERS-1)

The RA-2 cross-calibration and instrument monitoring activities will occur during the commissioning phase and continue during the operational data span.

11.7 AO519/ESL*, Laxon, MSSL (UK)

AO519, Laxon, UCL, Wingham, Baker, Ice sheet, sea ice and polar ocean topography from spaceborne altimetry

Brief Tasks Summary:

Time series of land ice and sea ice elevation will be derived from RA-2 data and cross-calibrated with estimates from ERS-2. Anomalies will be investigated and offsets applied to ensure consistent time series across the two missions.

Present to Launch:

Develop capability to ingest and partition L1.5 RA-2 data and update orbits and corrections as required. Adapt processing software to handle RA-2 data.

Commissioning Phase:

Comparison of basin wide and regional ice sheet/sea ice elevation data over monthly time-scales. Identify any differences in elevation measurements/crossovers between the two missions. Investigate in detail any anomalies through detailed analysis of waveform data and relevant ancillary parameters.

After commissioning phase:

Continue cross comparison of elevations from the two missions for 12 months to identify any possible seasonal effects.

11.8 AO412, Cotton, SOS (UK)



Doc. ref.: PO-PL-ESR-RA-0005

Issue: 1.1

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PI, David Cotton (Satellite Observing Systems, UK)

CoIs, Peter Challenor (Southampton Oceanography Centre, UK), David Carter (Satellite Observing Systems, UK), Vladimir Karaev (Institute of Applied Physics, Nizhny Novgorod, RU)

A Co-ordinated Programme for Global Calibration/Validation of Altimeter Sea State Data

Brief Tasks Summary

Verifying performance of instrument, and validating wind/wave data, through assessment of ENVISAT FD wind/wave data Global and regional ENVISAT Distributions of sigma-0, Hs, U10) compared to those from ERS-2, JASON, GFO ENVISAT data co-located with buoy data and accuracy/reliability of ENVISAT data assessed Quality control and data flagging will also be verified

Present to Launch

Arrange access to buoy data. Acquire data formats and prepare analysis software

Commissioning Phase

Acquisition of global ENVISAT, ERS-2, TOPEX/JASON and Geosat Follow-On FD data. Acquisition of buoy data Verification of ENVISAT data format Verification of data flagging, quality control procedures. Generation and comparison of global and regional distribution functions of significant wave height, wind speed and sigma-0. Generation and analysis of co-located altimeter and buoy data sets. Generate recommendations of algorithm changes, calibration adjustments. Preliminary Report (launch + 3 months). Final Commissioning Report (launch + 6 months).

After Commissioning Phase

Continue collection of data. Generate and analyse co-located altimeter/buoy data sets. Update every six months to check for possible instrument drift. Investigate sea state dependencies on accuracy of altimeter wind/wave data. Develop improved wind speed algorithm. Further development of wave period algorithm

11.9 AO150, Queuffelou, IFREMER (F)

co-I: Bentamy, Chapron, Tournadre and Pouliquen, IFREMER

Title: Geophysical validation of ENVISAT RA-2 wind and wave products using crossovers with other in-flight satellite altimeters

Brief tasks summary

Wind and wave products of the ENVISAT radar altimeter will be compared with validated measurements from other satellite altimeters, at ground track crossovers, within a one hour time window. An optimistic view is that three altimeters at least could be in-flight during the ENVISAT commissioning phase: ERS-2, TOPEX-POSEIDON and/or its successor JASON, and GEOSAT follow-on (GFO). Statistical analysis of the collocated datasets, will allow to validate and, if needed, to calibrate the RA products. The resulting dataset will be useful for further studies, beyond the scope of the validation topic.

Rain flagging and rain products. The relationship between the Ku and S band backscatter coefficients will be defined and validated. This relation will be used to flag the RA samples affected by rain. The rain flag will be tested and validated by comparison with other rain flags and rain rate estimates from other satellite sources. Rain products (rain rate and rain cell diameter) will be defined and validated.

Present to launch

To continue the study of cross correlation between ERS-2 and TOPEX significant wave height and backscatter coefficient, in order to increase the present dataset (particularly for high wind and wave conditions), to detect eventual temporal trend measurements, and to get a reference cross-altimeter dataset at the ENVISAT launch time.

Adaptation to ENVISAT RA products of collocation methods and tools already developed for previous experiment with ERS, TOPEX, NSCAT or QUIKSCAT.

Definition of a Ku S band sigma naught relation using a theoretical model. Test of the method of rain product estimate for the TOPEX-POSEIDON archive. Definition of the rain flag operational mode.

Commissioning phase

Accumulation of data. First statistical results on wind and wave products comparisons. First preliminary results could be issued shortly (2 or 3 weeks) after the beginning of the commissioning phase according to the data availability.

Validation/calibration of the Ku/S band relation, especially control of the rms around this relation. Test of the rain flag. Test and validation of the rain products.

After commissioning phase

Above collocation procedures will be operated for long term monitoring. we will take advantage of the extended data base 1) to improve the analysis for extreme wind and wave conditions, and 2) to test the multi frequency concept applied to the combined effect of rain and wind stress on the backscatter.

11.10 AO462, Holt, UK Met (UK)

AO 462, Martin Holt, Jim Gunson, UK Met.Office

"Preparation for development of real-time global applications for ASAR and RA-2 wave observations."

Brief Tasks Summary

Establish communication links between ESA and UK Met. Office database. Comparison of near real-time RA-2 wave data with wave heights from collocated points in the UK Met.Office global wave model, and with ERS-2 data. Set up data processing methodology for AO 426. The above tasks will also be performed in tandem with the Envisat ASAR (ASA_WVS_1P) data product.

Present to launch

Communications and database teams prepare to acquire near real-time data. Apply tests of data processing to example datasets as provided by ESA.

Commissioning Phase

Extraction of global wave model height values collocated to RA-2 data points. Comparison of RA-2 data (low bit- rate, near real-time) with wave model values, and with ERS-2 observations. Compilation of statistics and assessment of relative performance of RA-2 with wave model and ERS-2. Report preliminary results to ESA as monthly summaries.

After Commissioning Phase

Global coverage of data comparisons in near real-time. Continue comparisons between RA-2, wave model and ERS-2, that will lead into AO 426.

11.11 AO499, Breivik, DNMI (N)

Brief Tasks Summary:

Temporal and spatial wave statistics from RA-2 data will be compared to statistics obtained from independent satellites and models. The project will also focus on extreme sea states.

Present to launch:

In-situ data delivery agreements. Overview of available wave data worldwide.

Commissioning Phase:

Accumulation of global RA-2 Level 2 GDRs, extraction of collocated data over buoys and coincidences with other satellite data and the model data. Preparation of preliminary validation report.

After Commissioning Phase:

Further collection of data with special emphasis on extreme sea states. Updates of calibration efforts on the Internet.

DNMI contribution will be regular evaluation reports on the performance of RA2 wave and wind data based on collocations with DNMI's operational weather and wave models and analysis. This is similar to what was done for ERS-1 and -2.

11.12 AO270, Hollingsworth, ECMWF (EU)

Wind/wave/range validation on NRT product:

- Quality assessment of the altimeter wind/wave product with height information and validation of the Model Wet tropo height correction in FDMAR (RA2_WWV_2P)
- Scatter plots of comparison between significant wave heights from RA2 on Envisat, from RA on ERS-1 or ERS-2, and from the ECMWF model
- Comparison of RA2, RA, and ECMWF collocation data around in-situ wave-height measurement buoys.
- Comparison of collocated range data from Envisat, ECMWF model and tidal gauges.
- Verification of the Envisat Sea Surface height product against ECMWF analysis of assimilated Sea Surface heights from ERS2 and Topex/Poseidon (on a best effort basis and conditional upon the successful implementation of the operational assimilation at ECMWF).

- Wind-speed scatter plots comparing ECMWF analysis with RA2
- Wave height histograms: WAM FG, WAM Analysis (after ingestion of ERS-2 data), ERS-2 data, RA2 data, and on an experimental basis: WAM analysis after ingestion of RA2 data.
- Comparison between total water vapour columns from MWR and collocated water vapour from the ECMWF model.

11.13 Bosch, DGFI/Fenoglio, Technical U. Darmstadt (D)

Global relative cross-calibration

The tandem operation of ERS-1 and ERS-2, the alternate operation of Topex and Poseidon and the comparison between ERS-1/2 and Topex/Poseidon have demonstrated that global relative cross calibration provides much higher precision than absolute calibration at a dedicated site. Therefore, dual satellite crossovers between Envisat and other altimeter satellites operating simultaneously (Jason-1, GFO) will be computed globally. To avoid errors due to sea surface variability only crossover events with nearly simultaneous overflights are considered. Crossovers will also be edited and/or weighted inverse proportional to the rms of the sea level, derived from previous altimeter missions. The time tag errors can also be estimated from crossover data. In case of a new tandem operation of ERS-2 and Envisat also collinear differences will be generated globally. Both, crossover and collinear differences will be fed into a common adjustment that provides error estimates and the complete covariance matrix for all parameters estimated simultaneously.

Relative comparison with tide gauge sea level records

At tide gauges the sea level and its variability is monitored relative to the land. Using estimates of the mean sea surface slopes from current and previous altimeter missions the instantaneous sea surface heights (ISSH) derived from altimetry can be extrapolated to the tide gauge location in order to compare the sea level time series with the tidal registrations. This type of comparison aims to monitor the long term stability of the altimeter systems as demonstrated e.g. by Mitchum for Topex/Poseidon. Comparisons during the (short) commissioning phase will not allow to significantly prove the system stability but they provide an independent tool to indicate system anomalies at an early stage. During the commissioning phase the comparisons will be performed with the WOCE tide gauge stations providing "fast delivery" data. Monitoring of the drift will be continued after the commissioning phase. For a long term monitoring additional tide gauges (in particular in the North Atlantic) will be used. At some of those sites continuous or episodic GPS measurement were already performed by DGFI. They allow to coordinate the stations within a geocentric reference frame (ITRF) and to estimate vertical crustal motions which have to be removed from the tide gauge registrations.

11.14 A0756, Dow/Zandbergen, ESA/ESOC

AO 756, Zandbergen, (Dow, Kuijper, Righetti) ESA/ESOC (EU)

Brief tasks summary

Measuring the Envisat RA-2 range bias relative to the range bias of other operational altimetry satellites (ERS-2, Jason, possibly Topex). The final value will be based on a weighted average of the values obtained with several different techniques, by the end of the commissioning phase. Global techniques include precise orbit determination with or without the use of the height measurements as tracking data and comparison with a reference sea surface model. Local techniques include the comparison of the same information over the Western Mediterranean Sea based on the short-arc orbits obtained in the absolute calibration campaign, and direct comparison of collinear tracks. These local techniques are expected to give the best results (or in fact can only be applied) for the relative bias between Envisat and ERS-2.

Present to launch: Validation of the software used for operational and precise orbit determination (POD). This software (Napeos) represents a new development based on our proven ERS software. Implementation of collinear tracks analysis. Validation of short-arc orbit determination. Consolidation/improvement of SLR station coordinates and consolidation of the physical models to be used in POD.

Commissioning Phase

Near-real-time orbit determination of ERS-2 and Envisat using operational tracking data (S-band) and high-precision models yielding a near-real-time monitoring of the RA2 absolute and relative bias, with medium accuracy (the accuracy cannot be easily predicted but will be established at the same time). Global POD for ERS-2 and Envisat with a delay of 5-10 days, resulting in a high-precision monitoring of the evolution of the relative range bias. Short-arc orbit determination over the Western Mediterranean for Envisat (as part of absolute range calibration activities) and ERS-2 (this will require a special effort by the ILRS to deliver a comparable number of ERS-2 passes over the Mediterranean). Comparison of the collinear passes. By the end of the commissioning phase, all orbits and products will be recomputed using the latest information (final EOP values, etc.) and global POD of Jason (or Topex) using all available tracking data (GPS, Doris, SLR) and the same POD software (Napeos) will be undertaken. The result will be published in a report covering the commissioning phase.

After Commissioning Phase

Routine operational orbit determination of ERS-2 and Envisat will continue, as will POD of ERS-2 and Envisat. The absolute and relative biases will be continually monitored and both the near-real-time medium-precision and the subsequent high-precision results will be made available via our internet pages. POD of Jason (or Topex) for continued relative range bias monitoring may be performed in piecemeal fashion or routinely, depending on available resources.

11.15 AO123, Lillibridge, NOAA(USA)

NOAA (J. Lillibridge): assimilate NRT Products in NOAA processing, provide report on data quality and timeliness (usability).

Brief tasks summary:

NOAA's Laboratory for Satellite Altimetry has been processing and analyzing fast-delivery altimeter data from ERS-1 and ERS-2 since 1992. In 1995 we established a processing system, in collaboration with the Delft University of Technology, which delivers daily Real-time Geophysical Data Record (RGDR) files with a latency of only 10 hours. In late 1998 several enhancements were made which dramatically improved the quality of the RGDR data: 1) the Delft orbits are now based on the DGM-E04 gravity model, which is specifically tuned to ERS; 2) a "feedback loop" between Delft and NOAA was implemented which feeds altimetric heights and crossovers into the orbit determination system; and 3) ESA's fast delivery system was upgraded to include the measured wet troposphere correction from the onboard MWR radiometer. These enhancements have brought the global rms variability of sea surface height down to the 15-20 cm range, consistent with residual radial orbit errors of 10 cm or less.

For the upcoming Envisat mission, NOAA's expertise in real-time processing makes it a prime candidate to evaluate the FDMAR/FDGDR as well as IMAR/IGDR products for the RA-2 altimeter / MWR radiometer instrument systems. By continuing the close working relationship we have with the orbit determination group at Delft, it will be possible to evaluate improvements to the DORIS navigator orbit (FDGDR) &/or preliminary DORIS orbit (IGDR) by utilizing the feedback system we've established between the orbit determination and altimetry. This work would include analysis of the geophysical corrections for the range measurements, and the algorithms utilized to make those corrections, in addition to critiquing the orbit quality.

NOAA can also contribute to the CCVT by performing cross-calibrations of the level-2 datasets between Envisat and Geosat Follow-On (GFO). GFO has been on-orbit since early 1998, but suffered a series of initial setbacks which have greatly prolonged its cal/val period. We expect routine data processing from GFO to begin in early 2001. NOAA's role in this U.S. Navy mission is to act as the primary distributor of the final high-quality datasets to non-military users, both foreign and national. The level-1b Sensor Data Records are acquired and archived at NOAA, and the level-2 Navy GDR datasets (NGDRs) will be upgraded by NOAA using the best available laser orbits and geophysical corrections. Crossover analyses between Envisat and GFO altimeter data will aid in the final calibration and validation of both systems.



Doc. ref.: PO-PL-ESR-RA-0005
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11.16 Jacobs, US Navy (USA)

Cross-Calibration and Verification of the ENVISAT Altimeter Products

Principal Investigator: Gregg A. Jacobs
Naval Research Laboratory, Code 7323
Stennis Space Center, MS 39529
Phone: (228) 688-4720 Fax: (228) 688-4759 e-mail: jacobs@nrlssc.navy.mil

Co investigators:

Charlie N. Barron, Naval Research Laboratory
Harley E. Hurlburt, Naval Research Laboratory
Scott Klingenberg, Naval Oceanographic Office
Doug May, Naval Oceanographic Office
Kirk Whitmer, Sverdrup Technologies
Ole Martin Smedstad, Planning Systems Incorporated

Brief tasks summary:

The Naval Research Laboratory (NRL) will evaluate the ENVISAT altimeter data set through the operational Altimeter Products System (ALPS) and the Modular Data Assimilation System (MODAS) to determine the accuracy and effectiveness for estimating ocean mesoscale features. Real time processing of the ENVISAT data will be made, and results will be made publicly available on a web site. The processing and presented analyses will include all variables on the Geophysical Data Records provided by the Cross Calibration and Validation Team (CCVT), orbit error correction analyses, and quality control analyses. For these analyses NRL will require the FDGDR, IGDR, and SGDR. The data will be evaluated between the different GDR versions as well as with other satellite data sets including JASON and GFO.

ALPS Monitoring

The ALPS system provides the real time processing of TOPEX/POSEIDON, ERS-2, and GFO altimeter data streams. The main objectives of ALPS are interpolation, quality control, and orbit error corrections. Because orbit solution errors are one of the largest contributors to real time altimeter data, an orbit error correction procedure has been implemented that removes a sinusoid from data composed of one full revolution of the altimeter satellite. The orbit solution error characteristics are expected to be quite different between the ENVISAT FDGDR, IGDR, and SGDR, and we intend to evaluate the orbit solution error level within each of these products. The amplitude of the orbit error corrections will be tracked and monitored daily within the ALPS system.

The data passes through additional quality control processing to identify and remove suspect measurements. If a measurement is found to be suspect at one point in the system, the datum is uniquely flagged so that the exact point within the system at which the datum became suspect may be determined. The flags are passed through the system to the final processed data. The processing and analysis will be set up for ENVISAT within the ALPS system. These results of the quality control will be provided daily on a web site. Any problems detected in the data sets should be quickly identified and notifications produced.

The ENVISAT products will be evaluated relative to one another and in comparison to other altimeter data sets. This has been ongoing for the T/P, ERS-2, and GFO data. In particular, we have been tracking crossover statistics between the data sets. The crossover analysis provides an evaluation of the sea surface height cross calibration between separate altimeter satellites. We will also perform an evaluation of the FDGDR, IGDR, and SGDR along the ENVISAT ground tracks. This will be done primarily to examine the orbit errors within each, though it is expected that dry troposphere corrections will also be significantly different. It is also possible that the wet troposphere and ionosphere corrections may change between the FDGDR and SGDR.

Data Assimilation

The processed and quality controlled ENVISAT data will be provided to the data assimilation systems for ocean environment estimation. The impact of the data on these systems will be examined through the expected reduction in forecast errors. There are two main systems into which the data will flow. The MODAS processing provides optimal interpolation (OI) of sea surface height anomaly from the reference time period (SSHA). The OI procedure incorporates expected length scales, time scales, and propagation speeds of mesoscale eddy features based on historical TOPEX/POSEIDON, ERS-1, ERS-2, and Geosat-ERM data. In addition to the interpolated field, the OI process provided an expected error based on the data error variance. The error variance depends on the sampling distribution. That is, the distance between repeat tracks, the repeat time, and the manner in which the tracks are sampled is taken into account when computing the analysis variance. It is possible to demonstrate the complementary ability of separate altimeter satellite data sets. We will examine the impact of the ENVISAT data on the expected errors within the OI. The altimeter data sets are also used in a global assimilative primitive equation ocean model. This model is presently running globally at 1/16° horizontal resolution and is assimilating T/P, ERS-2, and GFO altimeter data sets. The ENVISAT data will be included in the assimilation into the global model to evaluate its potential impact.

11.17 Berry, De Montfort U (UK)

Sigma0 drift monitoring, retracker verification and performance over land.

Principal Investigator: Professor P.A.M. Berry
De Montfort University
The Gateway
Leicester LE1 9BH, UK

DMU propose to tackle two areas of work: sigma0 cross-calibration and monitoring, and waveform analysis over land and comparison to the ocean ice and sea-ice retrackers in the products. DMU also proposes to assess the impact on continental applications of the resolution switching algorithm operation over land.

1) sigma0

DMU will investigate the behaviour of RA-2 sigma0 over the two primary land targets, and compare with ERS-2 and our modelled surface responses. The consistency of the measurements over time, will also be checked, as resources permit. Should ERS-2 fail prior to the ENVISAT launch, DMU will include cross-calibration of sigma0 (in the equivalent of ice mode, i.e. medium resolution mode) to their modelled surfaces to give a direct measurement.

2) Waveforms analysis

DMU will analyse the RA-2 Ku band waveform shapes over land, and compare with ERS-2 data, checking both for consistency with previous results and repeatability. DMU will investigate the behaviour of the resolution switching algorithm and evaluate its performance over land.

11.18 AO600, Chapron, IFREMER (F)

The activities mainly focus on the radar altimeter ocean surface backscatter properties that should make significant improvements in the use and accuracy of the ENVISAT RA-2/MWR instrument.

Our specific objectives will be to try to answer the following question: can improved algorithms (sea state bias, high resolution wind, rain or slick detection capability,...) be developed using physically-based reasonings and available other sources of information such as meteorological model outputs and/or other co-located remote sensor observations? The spatial and temporal complexities of the sea surface geometry do preclude the development of simple globally representative models, but we anticipate the answer will be positive.

Taking the sea state bias correction, the goal is to try to reduce the uncertainty in the electromagnetic range bias that corrupts any altimeter sea surface topography measurements. Our approach is to combine statistical and theoretical investigation to first examine closely the causes of present correction uncertainties. Today such an effort can take full advantage of the unprecedented accuracy and spatial coverage of nadir and off-nadir measurements at different frequency bands. This provides a magnified look at the physics, helping to better identify systematic anomalous behaviors and leading to develop possible alternative algorithms using other correlative inputs such as global wave or wind data.

Another primary thrust of the present project will certainly to fully exploit the wind/wave capabilities of the dual-frequency RA2 instrument. As already reported using global combination of existing altimeter and scatterometer data and wind residual examination, it exists strong evidence supporting a non-negligible sea state impact on the altimeter's inversion of wind speed. With precise altimeter/scatterometer collocations, it is possible to precisely document it and to propose improved corrections.

Finally, we will also focus on the critical impact of non-Gaussian statistics is its place in modifying the predicted occurrence of zero slope values which directly controls altimeter cross section measurements. The known modulation of short ocean waves by longer ones is a likely contributor to the radar altimeter's electromagnetic ranging bias but also to non-Gaussian statistics. A better identification of the statistical signature of these modulations from direct properly calibrated altimeter measurements should then help to better quantify their critical role in the total altimeter range bias, and subsequently develop strategies for improved corrections using either direct altimeter measurements or complementary sources of information. Airborne radar backscatter and optical observations generally affirms the importance of the non-Gaussian correction. Our specific objective will thus to show the implications and possible applications related to ocean radar interpretation and validation of the absolute sigma-naught calibration efforts.

11.19 AO267, Quarterly, SOC (UK)

AO267, Quarterly PI, SOC, Srokosz, Guymer and Watts Co-I, Accurate Rain Information from Envisat Sensors (ARIES)

Brief Task Summary:

- Determine mean σ_{Ku} — σ_S relationship
- Note any dependence on SWH
- Determine suitable thresholds for rain flag
- Check for instrument drift
- Global studies of precipitation patterns
- Case studies involving simultaneous AATSR and MERIS data.

Present to launch:

- Get and test code for handling Envisat IGDR format

Commissioning Phase:

- Provide initial empirical σ_{Ku} — σ_S relationship (within 2 weeks)
- Provide improved empirical σ_{Ku} — σ_S relationship

After Commissioning Phase

- Identify a number of case studies, using both altimetry and cloud parameters derived from AATSR and MERIS.

11.20 AO163, Eymard, CETP (F)

MWR calibration/validation. See section 7.

11.21 AO 632, Ciotti, U Aquila (I)

Peer review of MWR Cal/Val

Passive microwave calibration of sigma0.

11.22 Zwally, Brenner, GSFC (USA)

Perform verification and validation of the polar altimetry data received from ENVISAT during ENVISAT's calibration and validation phase. This work will have three objectives. The primary objective will be to verify and validate altimeter mode changes and retracking over the polar ice sheets and sea ice. One secondary objective will be to verify that the geodetic corrections are valid. Another secondary objective will be to determine the consistency between the ENVISAT processing and other radar altimetry missions. For this investigation we will require all polar altimetry data to include time, geodetic latitude and longitude, waveforms, range measurements, instrument range corrections, instrument mode status, instrument status, retracking corrections and associated flags, and geodetic range corrections.

Primary Objective

We will investigate altimeter mode switching over Greenland and Antarctica and the retracker performance of all retrackers present on the ENVISAT altimeter product. To accomplish this we propose performing the following studies.

Investigation of altimeter mode switching and affects on the measurement.

1.0 Plot all polar altimetry groundtracks of valid data over a continental mask and our best digital elevation map, DEM, colour coding what mode the altimeter is in to determine the general pattern of mode switching.

2.0 Compare coverage from 1.0 above with one 35-day repeat cycle of ERS data to affirm and quantify the extent of additional coverage conferred by mode changing in ENVISAT.

3.0 Plot several elevation profiles from both poles, starting where possible over ocean, traversing sea ice and then continuing onto and over the ice shelf, colour coding the altimeter mode to note if the mode changes are reasonable.

4.0 Plot waveforms and associated retracking parameters for several locations before, during and after mode changes to determine any problems in switching between modes and unexpected loss of data.

5.0 Perform 2.0 and 3.0 above for multiple repeat cycles if the data exists to check out consistency of performance over the same terrain.

Retracker Performance Validation

1.0 Calculate the GSFC V4 retracking correction for the data and create a data set with all the ENVISAT and GSFC retracking corrections, geodetic corrections, time, location, altimeter mode status, and uncorrected elevation in a format similar to our Ice Data Record, IDR, format for ERS-1.

2.0 Calculate crossovers for the above ENVISAT data set over both polar regions maintaining on each half of the record, the various retracker corrections, geodetic corrections, and altimeter mode status.

3.0 Calculate crossover statistics by type of surface (sea ice, ice sheet, ocean), altimeter mode, and retracker algorithm to determine how well the algorithms work under different surface characteristics and altimeter modes.

4.0 Calculate crossovers between the above ENVISAT data and ERS-1 or 2 data for a comparable season and time frame.

5.0 Calculate statistics of ERS/ENVISAT crossovers by type of surface (sea ice, ice sheet, ocean), altimeter mode, and retracker type to determine how consistent the algorithms are with the ones used for ERS and quantify any biases that may exist due to retracker differences, mode changes, or instrument problems.

6.0 Calculate and tabulate differences between the retracker algorithm results by type of surface and altimeter mode.

Secondary Objective

We will investigate the validity of the geodetic corrections. To accomplish this we propose performing the following studies.

We have models that the GSFC altimetry team is using for ERS, Geosat Follow On, GFO, and the Geoscience Laser Altimeter System (GLAS) for calculating the following corrections and geodetic parameters:

- Solid earth tides
- Load tides,
- Ocean tides
- Ionosphere
- Wet troposphere
- Dry troposphere
- Geoid

These corrections are dependent on the geodetic latitude, longitude, and except for the Geoid, time. We will calculate these corrections using our models and compare them with those available on the ENVISAT altimetry data. This will allow us to determine how consistent our models are with those used for ENVISAT and to determine any problems in the values of these parameters on the ENVISAT data products. We will present the results of this study in two ways. First we will plot histograms of the differences between the ENVISAT corrections and the GSFC models to determine the consistency of the corrections. Second we will plot the differences colour-coded on a ground track map to show if there is any geographic correlation.

Cross-calibration with GLAS will be investigated.

11.23 Pierdicca, University of Rome (I)

Passive Calibration of the RA2 Sigma0

To characterise the receiver in both S- and Ku-band using no-echo data acquired with a special Preset operation.

To determine the sigma0 calibration in both bands using the receiver characterisation and all other radar parameters needed, as measured during the RA2 on-ground characterisation

Present to launch:

- select the surfaces for the no-echo acquisitions, using TRMM, SSM/I and other radiometers' data. Those surfaces will be an input to the instrument activity planning
- prepare the emissivity models for the selected surfaces

During commissioning phase

- receive the no-echo processed data (proceed by the IECF)
- confirm their adequacy and quality, and in case provide feedback concerning the instrument setting
- analyse the no-echo data with the models and determine the calibration coefficients, the related error and the trend, if any

12 REQUIREMENTS

12.1 Flying Formation Configuration Requirements

To perform the relative calibration, a least one of the following satellites - ERS-2, TOPEX / POSEIDON, GEOSAT Follow On, JASON - should be producing valid data during the ENVISAT commissioning phase. For optimum results, there are requirements on the flying formation of the tandem ERS-2 / ENVISAT.

12.1.1 ENVISAT Repeat Orbit

The working assumption is that ENVISAT will fly a 35-day repeat orbit throughout its mission. ENVISAT will be placed on the same ground track as ERS-2, 30 minutes ahead of it (10:00 local time), thus not in the same orbital plane (7.5 deg between ENVISAT and ERS-2 orbital planes).

12.1.2 Time-lag

For the comparison between Envisat and ERS-2, a minimum separation of 30 minutes between satellites is required for decorrelation of the fastest meteoceans signals. For orbit phasing, the ENVISAT repeat orbit working assumption, section 12.1.1, is satisfactory. Thus, in addition to the crossovers technique, a comparison at collinear ground tracks with a very short time lag can be performed, a technique producing more precise results [Letraon et al. 1998].

12.1.3 Cross-track Distance

Looking at the ERS-2 commissioning experience, the requirement for the dual satellite cross-track distance was 200 meters. The rationale is to keep the influence of cross-track geoid gradient to a minimum. Another requirement was to have the manoeuvres on the two satellites synchronised (simultaneous).

The satellite command and control team at ESOC were able to drive the two ERS satellites within less than 100 meters during the commissioning phase and this efficiently contributed to the reduction of the cross-track gradient errors. This may be more difficult to achieve with ENVISAT due to its different thrusters, but should be retained as a goal to reach.

The requirements of the ERS-2/ENVISAT Tandem is to maximize the amount of simultaneous tandem data useable for cross-calibration, meanwhile keeping the dual cross-track distance between the two satellites to a minimum, always less than 2 km (twice each missions' deadband) and meanwhile satisfying the ± 1 km deadband mission requirement of both missions. The above requirements are no more than each mission's deadband requirement, but the message is that the cross-calibration results will benefit from a minimum dual crosstrack distance, as long as the health of ERS-2 is not jeopardized.

To perform the cross-calibration with ocean data and maximise the amount of simultaneous ocean data orbit manoeuvres should preferably occur over land, and possibly at or near beginning and end of each 35-day repeat cycles and over land.

Manoeuvres shall not, as far as possible, be performed during special operations of the payload, see section 12.2 on page 64.

12.2 Mission Operation Requirements

12.2.1 ENVISAT RA-2 Operation

RA-2 is required to operate in fixed mode during three 3 day periods which lie in the same phase (i.e. same 43 ground tracks) during each of the first three 35 day repeat cycles. This will provide information on the IF ripple bias which is likely to be the largest source of error in ice sheet elevation retrievals.

12.2.2 ERS RA Operation

ERS-2 RA should be commanded to operate in ocean mode over the US Great Lakes to support the tide gauge calibration site experiment.

To close a discussion that took place within the CCVTeam, it is stated that there are no specific requirements to operate ERS-2 in ice mode over oceans, nor to operate it in ocean mode on larger areas over land than the US great lakes.

12.2.3 ERS Mispointing

The gyroscopes on ERS-2 are the achille's heel of the mission and their use will be managed very carefully to maximise their lifetime. A zero-gyro mission has been developed and implemented.

The obvious requirement regarding mispointing is to have the best nadir pointing during the ENVISAT commissioning phase.

The impact of mispointing on the cross-cal accuracy will be assessed.

12.3 Data Requirements

Envisat RA-2/MWR Global Geophysical level data products (GDRs and SGDR) will be validated during the commissioning phase - as soon as they are available, i.e., after launch and switch-on. They will be used for the cross-calibration activities. If necessary, a further validation will be conducted in the post-commissioning phase, particularly when data sets of duration longer than the commissioning phase are required. The correspondence between ENVISAT and ERS data for cross-calibration is shown in the following table:

ENVISAT	ERS
FDGDR(FDMAR)	URA/OPR01,
IGDR(IMAR)	URA/OPR01,
GDR	URA/OPR01/OPR
SGDR	WAP01/WAP

(conditional to data latency)

The precise cross-Calibration should be applied to a dataset approaching final GDR-like quality. Even though the MWR will be calibrated separately, and therefore won't provide the wet tropo. correction for the height calibration, all other known high-precision corrections should be applied to the ENVISAT GDR. In addition, POE-class DORIS orbits should be utilized. The logical choice for the companion ERS-2 data would be the final OPR02, perhaps with enhanced Delft orbits...

12.3.1 ENVISAT Data

12.3.1.1 ENVISAT Data Products Description Overview

See [Benveniste and Milagro, 2000] or [Benveniste, 2000] for an overview of ENVISAT Altimetry products. See section 6 on page 20 for the product tree.

12.3.1.2 ENVISAT Data Requirement

The Envisat data requirement has been established and delivered to the ENVISAT Project early 2001. It is maintained in a separate spreadsheet document by the CCVT Data Circulation Coordinator.

12.3.1.3 Validated Orbit

Best available validated orbit will be used for the cross-calibration, including validated DORIS tracking and laser ranging data.

12.3.1.4 Wet Tropospheric Path Delay Correction

Model correction will be used until the ENVISAT MWR has been calibrated and validated. ECMWF model is present in the Altimetric products.

The ERS-2 MWR took 50 days to stabilise.

12.3.2 ERS Data

ERS-1 has ceased to function on 10 March 2000 after nine years of successful operation. Data from ERS-2 will be used for cross-calibration with ENVISAT.

The ERS-2 Radar Altimeter is a nadir-pointing pulse-limited radar designed to measure the echoes from the ocean and ice surface. It has two measurement modes, optimised for measurements over ocean and ice.

The ERS-2 Microwave Sounder is a nadir-viewing passive radiometer (two channels at 23.8 and 36.5 GHz) providing measurements of the total water content of the atmosphere within a 20 km footprint. The main purpose of the microwave radiometer is the

measurement of the tropospheric path delay for the altimeter through the measurements of the atmospheric integrated water vapour content and the estimate of the attenuation of the altimetric signal by the liquid water content of the clouds.

ESA distributes the fast delivery radar altimeter data (URA FD) from the ground station of Kiruna, Maspalomas, Gatineau and Prince Albert within three hours from sensing. At ESRIN/ISS these data are reformatted in BUFR data to be disseminated onto the GTS network for meteorological and near real time oceanographic applications. At D-PAF these data are received, collected and used for further processing to generate the Rapid Ocean Product Records (ROPR) and the Quick-Look Ocean Product Records (QLOPR) and to perform orbit determination. At F-PAF, the ERS transcription exabytes are received, archived and used to generate the RA products Ocean Intermediate Products (OIP) and the Ocean Product Records (OPR) and the MWR ones, Microwave Brightness Temperature products (MBT) and Vapour and Liquid water Content products (VLC). Identical transcription exabytes are also shipped to the UK-PAF for archive and for processing of the Waveform Products (WAP).

12.3.2.1 ERS Data Products Description Overview

The main characteristics of the ERS altimeter products are presented here below in tabular form.

12.3.2.1.1 URA FD: ERS-1/2 Radar Altimeter Fast Delivery Product

Identifier/Name	ERS.ALT.URA
Related document	ERS Ground Stations Products Specification, ER-IS-EPO-GS-0201, Issue 3/1, Dec 9, 1994
Data latency	Within 3 hours from sensing
Volume	~600Kbytes/orbit
Access/Medium	FTP server
Calibration	No external calibration added
Orbital information	Predicted orbit computed at ESOC
UTC/SBT correlation	Predicted file (PATM)

Note:

On Nov 30th 1998, the ALT.URA products have been enriched with the introduction of the:

1- Computation of the 1Hz Wet Tropospheric correction using time coincident ATSR Microwave Radiometer (MWR) measurement data.

2- Upgrade of the average Altimetric Range computation (least square fitting algorithm used to compute the 1Hz altimetric range value from the 20Hz elementary measurements). For more details see <http://earth.esa.int/12/4/eeo4.64>. The URA FD product is also delivered by the F-PAF in a CCSDS format (ALT.FDC).

12.3.2.1.2 URA BUFR data: ERS-1/2 Radar Altimeter Fast Delivery GTS Product

The features of this product are very close to the URA FD ones as described in the above chapter. The main difference between the two lies in the data format. The BUFR format is specified in R-1. Note that not all URA FD fields are represented in the BUFR data.

Note: BUFR format v.5 for ERS Fast Delivery Products has to be used as from January 17th 2000

12.3.2.1.3 ROPR: Rapid Ocean Product

Identifier/Name	ERS-2.ALT.ROPR
Related document	http://isis.dlr.de/guide/ERS-Alt.html
Data latency	Within 2 days from sensing
Volume	3 MByte/day (uncompressed)
Access/Medium	FTP server
Calibration	?
Orbital information	D-PAF rapid orbit (ERS-2.ORB.RPD)
UTC/SBT time correlation	Predicted file (PATM)

12.3.2.1.4 QLOPR: Quick-Look rapid Ocean Product

Identifier/Name	ERS-1/2.ALT.QLOPR
Related document	http://isis.dlr.de/guide/ERS-Alt.html

Data latency	Within 2 weeks from sensing
Volume	3 MByte/day (compressed)
Access/Medium	FTP server
Calibration	Venice external bias applied to the ERS-1 data. No cal. applied to ERS-2
Orbit information	D-PAF preliminary orbit (ERS-1/2.ORB.PRL)
UTC/SBT time correlation	Restituted file (PATN)

12.3.2.1.5 OPR: Ocean Product Records

Identifier/Name	ERS-2.ALT.OPR02
Related Document	Altimeter & Microwave radiometer ERS products - User Manual C2-MUT-A-01-IF, V2.2, 11/03/1996
Data latency	Within 2 months from sensing
Volume	350 Mbyte/cycle
Access/Medium	CD-ROM / Exabyte 8500
Calibration	No external calibration applied
Orbital information	D-PAF Precise orbit (ERS-2.ORB.PRC)
UTC/SBT time correlation	Restituted file (PATN)

12.3.2.1.6 WAP: Waveform Products

Identifier/Name	ERS-2.ALT.WAP
Related document	Altimeter Waveform Product ALT.WAP Compact User Guide, Issue 3.0, 15 June 1995, PF-UG-NRL-AL-0001

Data latency	10 weeks
Volume	
Access/Medium	Exabyte 8500
Calibration	No external correction applied
Orbital information	D-PAF Precise orbit (ERS-2.ORB.PRC)
UTC/SBT time correlation	Restituted file (PACC)

12.3.2.1.7 MBT & VLC MWR products

Identifier/Name	ERS-2.ALT.MBT (ERS-1 only) & ERS-2.ALT.VLC
Product Specification Document	Altimeter & Microwave radiometer ERS products - User Manual C2-MUT-A-01-IF, V2.2, 11/03/1996 Microwave Radiometer Products User Manual, C1-EX-MUT-A22-01-CN, Issue 1 Rev. 0, 26/12/91
Data latency	
Volume	
Access/Medium	Exabytes 8500
Orbital information	
UTC/SBT time correlation	Restituted file (PATN)

12.3.2.2 ERS Data Requirement

As agreed in plenary meeting #7, 14/12/01, cf. minutes 22/12/01, The CCVT will use, for cross-calibration estimates, a "standard" data set for OPPR and WAP. This "standard" sets will be specified in a separate technical note ("OPR AND WAP STANDARD PRODUCTS FOR CROSS-CALIBRATION WITH ENVISAT RA-2/MWR GDR", PO-TN-ESR-RA-0056).

The ERS data preparation for the CCVT is a timely opportunity to prototype the future "reprocessed" ERS-1 and ERS-2 data products. This is not an objective of the CCVT, but the CCVT may make recommendation on this matter.

ERS-2 WAP data is required within one month of acquisition during the Calibration Period. All geophysical corrections and orbits must be consistent between the two missions. A "WAP01" special product will be generated for the CCVT.

The ERS Products user requirement are maintained in a separate spreadsheet file.

12.3.2.3 Auxiliary files and extra corrections description

As a result of the ERS data quality control and Long Loop Sensor Performance Analysis activities, different corrections have been identified throughout the ERS mission for data improvement. These corrections, proposed to the user community to enhance the ERS Radar Altimeter data quality, have normally to be applied by the user.

Recent updates to this section consist of:

-The new SPTR correction has been finalised and a TN on the results and the validation is available (it has been uploaded in the CCVT web site):

The ERS SPTR200 Altimetric Range Correction: Results and Validation (ERE-TN-ADQ-GSO-6001)

The TN reports also on the range residual error after applying the correction as coming from the validation exercise.

-New results are available on the IF Filter Shape impact on the range. They come from an analysis of OPR reprocessed data.

-A document from CLS about the mispointing correction algorithm is available (it has been uploaded in the CCVT web site):

ERS-2 Radar Altimeter off Pointing impact study. Task-3 Mispointing correction algorithm (CLS/DOS/NT/99.219)

It reports on an algorithm to correct for the mispointing impact on the three geophysical parameters once the mispointing is known. The residual error after correction is also analysed. The mispointing correction procedure could follow the scheme hereafter reported:

1. PCS monitors operationally the mispointing value at the equator. One value every three days is retrieved in order to detect eventual variations in the overall mispointing behaviour.
2. As it has been done for Gyro 6 and Gyro 5, the orbital behaviour of Gyro 1 (which is now used operationally) can be retrieved.
3. Using the algorithm developed by CLS, once the mispointing is known, the correction for the three parameters can be calculated for each point along the orbit.

A short description of the ERS corrections is given here below.

12.3.2.3.1 USO drift correction

The USO correction has been originated to correct for the effects of the Radar Altimeter internal Ultra Stable Oscillator instability, the frequency of which is changing over time due to ageing effects. The timing variation has an impact on the Range parameter accuracy. To evaluate it, measurements of the USO clock frequency are performed every Tuesday. From these files, a correction to be applied to the Altimetric Range is calculated and made available by ESRIN/PCS. Actually three corrections are calculated depending on what level of data have to be corrected: URA, WAM or OPR. The typical time variation of all the USO clocks is a decreasing drift that then originates a drifting correction as reported in Fig. 1. It has to be noted that starting from November 21, 1998 the slope of the USO correction drift has changed from a value of 8.9 mm/year to 7.1 mm/year. At the moment, the absolute value of the correction is around 4 cm.

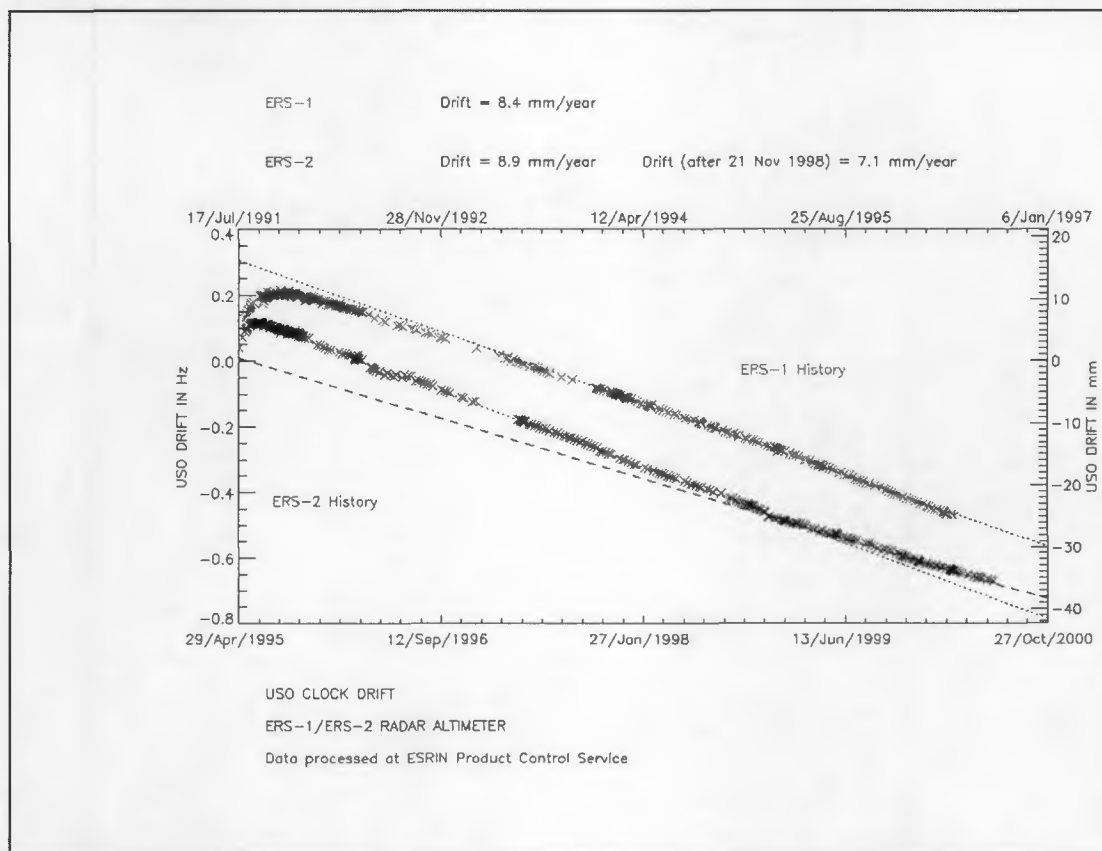


FIGURE 1 Ultra Stable Oscillator Frequency Drift and Relative Range correction

12.3.2.3.2 *SPTR correction*

The Scanning Point Target Response correction has been created to remedy for the asynchronous behaviour of the Radar Altimeter internal clock. The 80 MHz reference clock is implemented as hardware making use of four 20 MHz clocks whose phases are combined. Because of an asymmetry of these clocks, it happens that the time spans triggered by the overall clock may have different lengths and this causes a bias error on the Range measurements. The major problem is that the four clocks asymmetry does not remain stable over time but, because of temperature variations, changes after each instrument anomaly. In order to assess the value of the Range bias error, every day calibration measurements are performed when the satellite is flying over Tibet (before June 1999 it was every three days). These raw data, recorded when the instrument is in SPTR Mode, are processed and made available by ESRIN/PCS (<ftp://odisseo.esrin.esa.it/FTP/ers/auxdata/ra/>) in order to calculate the correction to be added to the Range. This correction is varying very much over time, presenting real jumps in correspondence to anomalous events. The values, as reported in Fig. 2, vary from -4 to 2 cm.

Recently a new SPTR algorithm has been developed and implemented, to take into account a number of instrumental characteristics not considered before as significant (IF filter correction, non perfect PTR Gaussian shape, etc.). Work is still on-going to finalise this new SPTR correction.

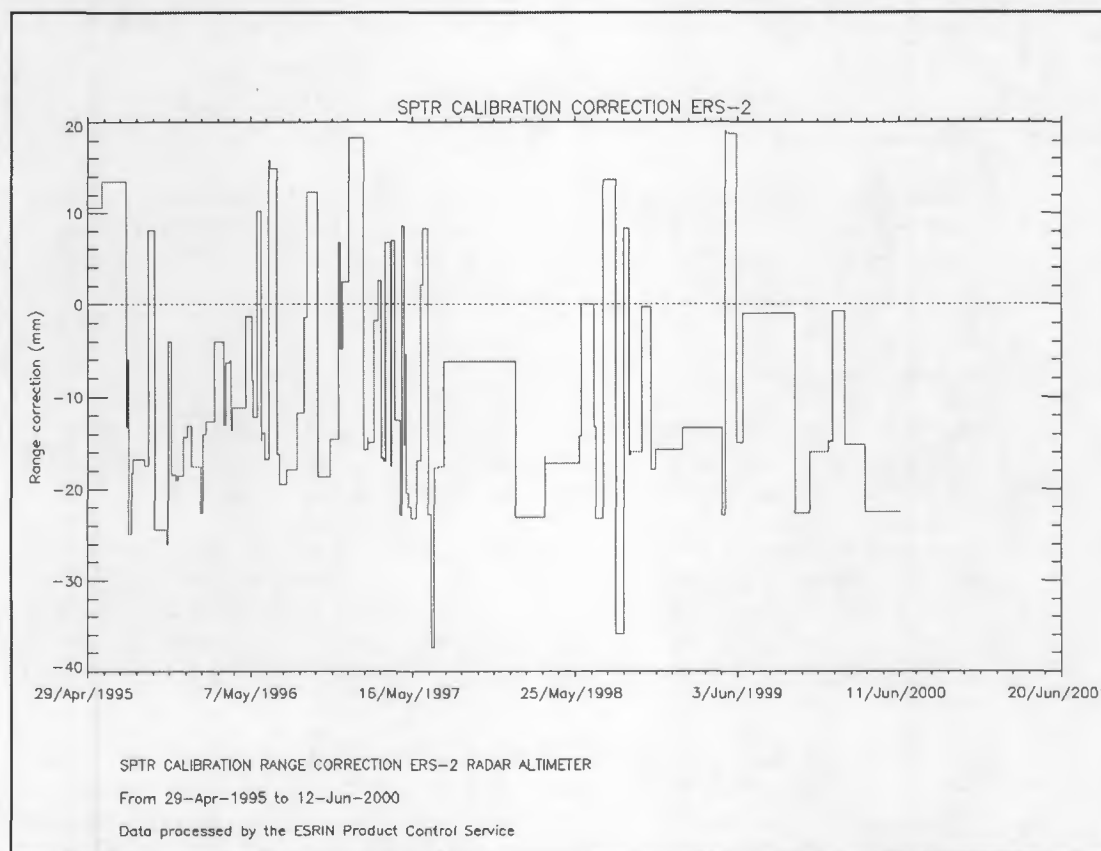


FIGURE 2 ERS-2 Scanning Point Target Response Range Correction

12.3.2.3.3 Wet tropospheric correction

The ERS-2 MWR 23.8 channel experienced a large gain fall on June 26th 1996. ERS-2 data comparisons before and after this date lead to the following corrections to be applied to the 23.6 channel Brightness Temperatures.

$$TB_{23.8} \text{ corrected} = 0.95238 TB_{23.8} + 16.25 \quad (1)$$

$$TB_{23.8} \text{ corrected} = 0.93 TB_{23.8} + 19.18 \quad (2)$$

Equation (1) is the proposed correction to be applied by the user to the OPR02 products. Equation (2) is the correction already applied to the 23.6 Channel Brightness Temperatures within the URA FD processing. For more information on these corrections, see R-2 & R-3.

12.3.2.3.4 *V3 OPR corrections*

Following the upgrade of the OPR processing chain from V3 to V6, several corrections have been proposed to correct the past V3 data. These corrections concern the altimeter range, the SSB and the Wet Tropospheric correction. See R-2 for detailed information.

12.3.2.3.5 *Absolute range calibration*

The ERS-2 Radar Altimeter has been cross-calibrated in 1995 against the ERS-1 Radar Altimeter. The output of the Commissioning Phase exercise showed that the difference in range between the two was a value non-significantly different from zero.

As a reminder, the ERS-1 altimeter absolute calibration has been carried out in 1991 and revealed a range bias equivalent to -41.5 ± 5.2 cm as referred in the 'Calibration of the ERS-1 Radar Altimeter' document (ER-RP-ESA-RA-0257). For information, the calibration values are not uniformly applied among the ERS RA products. It is therefore recommended to refer to the appropriate documentation. A recall is anyway given in the table here below.

It is also worth mentioning that the evaluation of one RA sensor calibration parameter (ϵ_{τ_g}), performed in laboratory prior to ERS-2 launch, proved to be different between ERS-1 and ERS-2 by 40.9 cm. This parameter corresponds to the delay within some parts of the radio frequency path, more precisely between the Front End Electronics (FEE) and the RA antenna and is not measured in flight. The values are equivalent to 27.07 ns for ERS-1 and 29.8 ns for ERS-2.

Considering the low reliability of the ERS-1 measurement done prior to its launch, it is realistic to consider the value 40.9 cm as the effective bias between ERS-2 and ERS-1 Radar Altimeters.

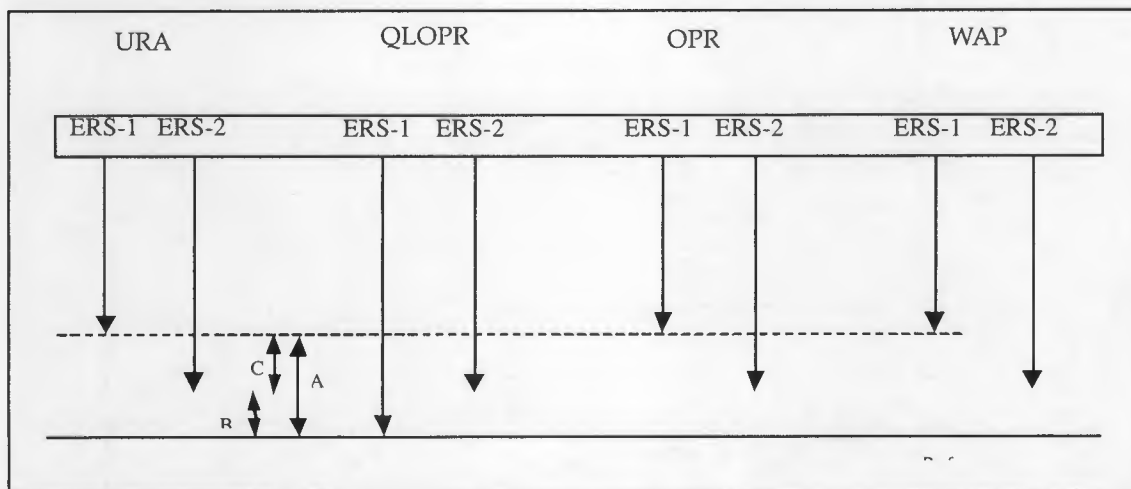


FIGURE 3 Representation of the different ERS Altimetric Ranges as read from the ESA Radar Altimeter products.

A represents the Venice Bias. $A = -41.5 \pm 5.2$ cm. (See R-4)

B represents a delta bias, being not significantly different from zero (result from the ERS-2 RA & MWR Commissioning Phase).

C represents the system bias (40.9 cm) (See R-5)

12.3.2.3.6 IF filter shape correction

It has been recently discovered that the ERS-2 and ERS-1 IF filter shapes had changed with time and that the use of the initial characterised IF filter shape within the ground processing had a significant and sufficient impact on the data to be considered as a new correction.

What has to be underlined is that not only the shape changes with time, but more important, the slope itself varies. Figure 4 depicts the significant difference between the IF Shape correction measured during the pre-launch in-vacuum tests and an in-flight one (on 27-Feb-2000); on the other hand it can be shown that the slope variation over the whole mission period is reasonably smooth (ref. R-6). The IF Filter changes have an effect on the shape of the received echo waveforms within the filter bank and consequently on the Sigma_0, Range and SWH when calculated by any retracking algorithm. In case a non-proper IF Filter Shape, which does not reflect the reality of the instrument, is used in the processing, errors are caused on the evaluated parameters. In order to assess those figures, a preliminary simulation has been performed by CLS showing an impact of few centimetres on the Range and of few decimals of dB on the Sigma_0 (ref. R-7). An internal study is on going to exactly quantify those numbers and propose an ERS-1 and ERS-2 IF filter shape correction.

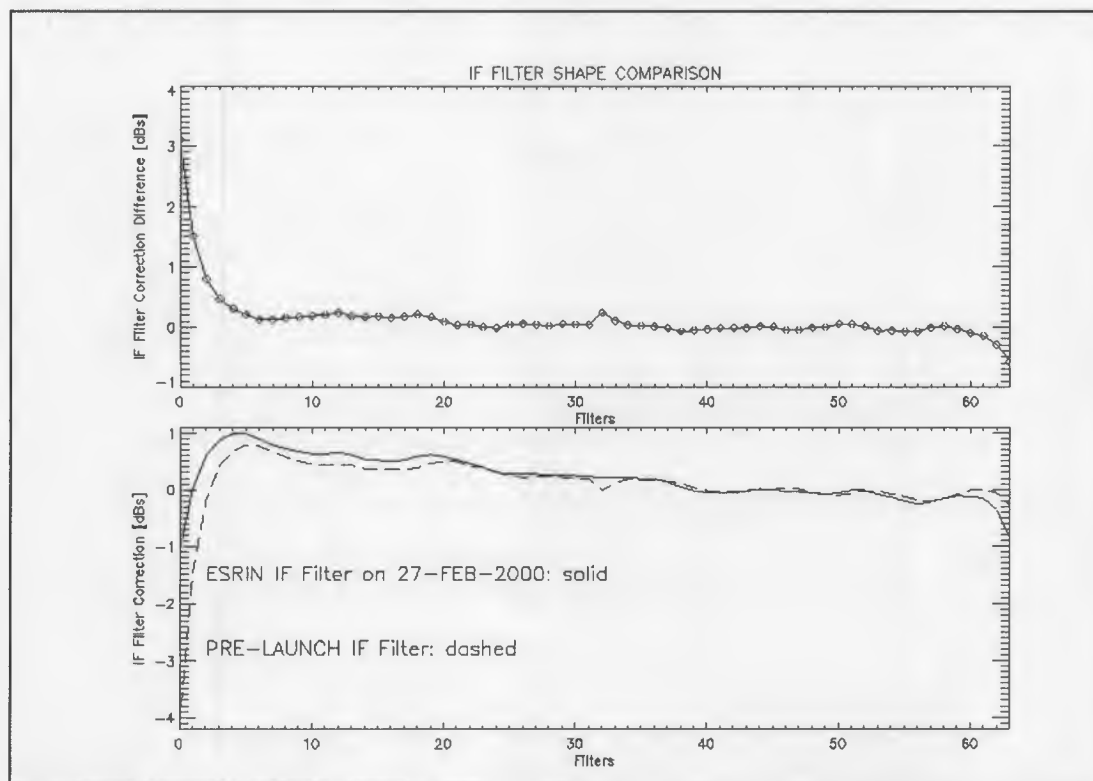


FIGURE 4 ERS-2 IF Filter Shape comparison between pre-Launch and in-flight results

12.3.2.3.7 Off-pointing angle correction

An Off-Nadir Pointing correction would be useful to compensate for a platform attitude that could cause the boresight of the Radar Altimeter antenna to point in a direction other than nadir. This would make the shape of the received echo within the filter bank to be distorted and consequently would originate errors in the estimation of the Range SWH and Sigma₀. As for the If Filter Shape correction, the Off-Nadir Pointing correction is, at the moment, not calculated operationally. This because the nadir pointing performance of the Radar Altimeter has degraded only recently, due to the shift to a mono-gyro attitude control scheme. Within ESRIN/PCS a study has been performed to assess a kind of "typical" mispointing behaviour along the orbit, before and after the mono-gyro attitude control software upload (ref. Fig 5). Since the mispointing values are in general lower than 0.1 deg and the algorithm is affected by a error which is growing exponentially when the mispointing value is decreasing, the absolute values might not be really meaningful; but a comparison will give useful results. With the help of the output of a simulation performed by CLS, the along orbit performance of the Sigma₀, SWH and Range due to mispointing has been evaluated, for both before and after the mono-gyro software upload. In summary they show that, due to the different pointing behaviour of the Radar Altimeter with one and three gyros piloting scheme, the parameters are, in average, affected as follows (ref. R-8):

Sigma_0 difference: 0.047 dB

Range difference: -0.12 cm

SWH difference: -0.5 cm

Even if the figures are very low and have been considered negligible for maintaining the operational performances of ERS-2, in order to avoid the above mentioned errors, the RA echo waveform should be corrected for the mispointing distortions before the parameters are retrieved. This in particular during the period between half January until half March, when the Sun-Blinding effect contributes to render the today's pointing system's performances much worst (ref. Fig. below).

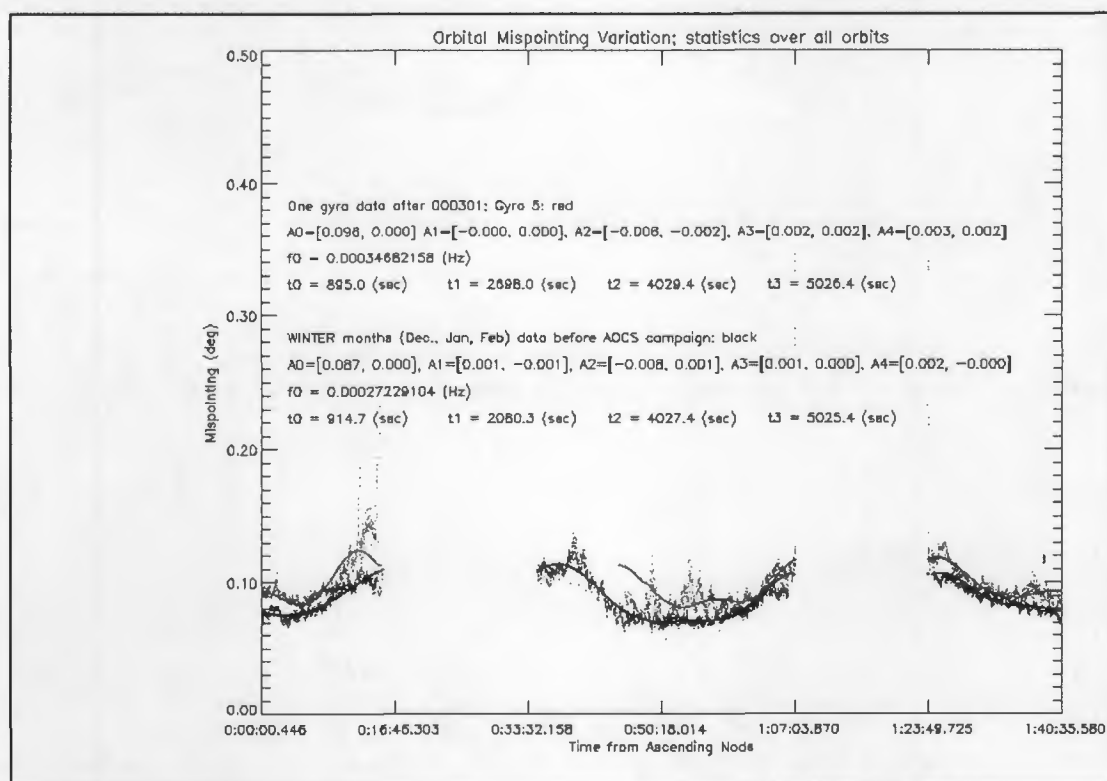


FIGURE 5

Around the orbit mispointing variation before and after mono-gyro software upload, no Sun-Blinding effect

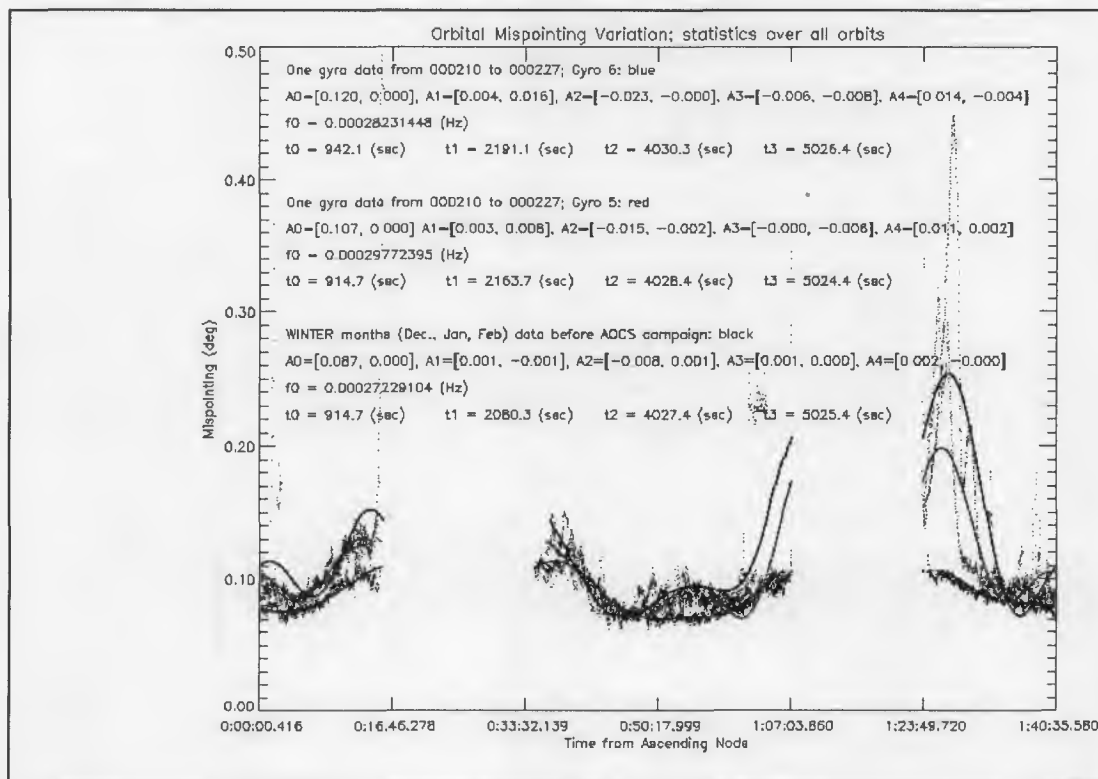


FIGURE 6 Around the orbit mispointing variation before and after mono-gyro software upload, Sun-Blinding effect

12.3.2.3.8 Time Tag Bias

For a while it is known that the time tags of ERS-1 and ERS-2 OPR altimeter data are early by at least a millisecond. In principle, this is no problem, were it not that in one millisecond the satellite changes altitude for up to 2.5 cm, such that it leads to an additional long-wavelength error in the derived sea level. The time tag error has to be corrected before orbit interpolation.

The time tag errors are on average 1.5 ms and 1.3 ms for ERS-1 and ERS-2 respectively, but they also include seasonal and geographical variations. Studies are under way to find the source and characterise the errors better.

12.3.2.4 ERS Ground Segment evolution

The ERS Ground Segment has been subjected to evolutions. Two important improvements related to the ERS RA & MWR data quality or availability are here below recalled:

- Optimisation of the ERS-2 Radar Altimeter acquisition mode: As of cycle 41 onwards (15 March 1999) the ice/ocean mode transitions will apply more closely to the ice or land boundaries and follow the coastline more precisely. See <http://earth.esa.int/12/4/eeo4.64>.
- On June 29 1999, the complete ERS-2 LBR Fast delivery data started to be delivered (increase of data volume of 7.7 %) following the installation of a new facility (DIS) at Prince Albert Ground Station.

12.3.2.5 ERS UTC/SBT time correlation file

Since recently the restituted UTC/SBT time correlation files (PATN files) have been put in free access on a server to the user community. These auxiliary files are available at the following ftp address:

<ftp://odisseo.esrin.esa.it/FTP/ers/auxdata/patn/>

12.3.3 Other altimetric data

Complementary altimetric missions are flying simultaneously. It is of major importance that these missions are mutually cross-calibrated. Data from Topex-Poseidon, GFO, Jason, and eventually ICESat will be compared to the ENVISAT data.

The GFO satellite altimeter is currently (January 2002) functional and supplying near real time data to the U.S. Navy and affiliated customers. The GPS receivers have not been functioning since the beginning of the mission. The use of both doppler and laser derived orbits, however, have enabled GFO to return both timely and high precision data. The satellite has been accepted by the Navy and is considered operational. The GFO sea surface height anomaly rms crossover value (10.4 cm) compares favourably with TOPEX/Poseidon (8.2 cm) and ERS-2 (14.7 cm). The GFO altimeter has also consistently been providing greater than 80% usable data, numbers that are equivalent to those for TOPEX/Poseidon.

The Jason-1 satellite has been launch on 7 December 2001 and has successfully passed its in-flight commissioning review on 6 february 2002.

ICESat, carrying the Geoscience Laser Altimeter System (GLAS), is planned for launch in 2002.

12.3.4 Other radiometric data

Data from SSM/I will be used to support MWR validation

ENVISAT AATSR and MERIS water vapour data will be compared to MWR.

12.3.5 In-situ data

In-situ data will be used to support RA2 and MWR validation, for instance: radiosondes, buoy, tide gauges. They will be provided by the CCVT members.

12.3.6 Model data

Model data will be used to support RA2 and MWR validation, for instance: significant waveheight, wind speed, simulated MWR brightness temperature, Sea level. They will be provided by the CCVT members.

12.3.7 SLR tracking

This requirement will be specified within the POD Validation Team.

The main requirement from the CCVT is to have access to orbits of the "precise" class, as soon as possible during the commissioning phase. So it may be stated here that an SLR intensive tracking campaign on ENVISAT is required for Envisat precise orbit solutions meanwhile DORIS is not validated. Of course SLR tracking is needed for DORIS calibration itself but this is to be dealt with in the POD team (ref.: POD plan doc).

Liaison with the POD Validation Team is required to efficiently deal with orbit related issues.

13 DATA PREPARATION AND CIRCULATION

13.1 ERS Data Preparation

As explained in section 12.3.2.2 on page 69 a "standard" OPR and WAP will be specified and used for Cross-Calibration purposes.

As agreed in plenary meeting #7, 14/12/01, cf. minutes 22/12/01, The CCVT members will produce "in-house" the "standard" data products strictly following the technical note "OPR AND WAP STANDARD PRODUCTS FOR CROSS-CALIBRATION WITH ENVISAT RA-2/MWR GDR", PO-TN-ESR-RA-0056.

Any variation from the standard, welcomed for assessment of sensitivity of the results, shall be precisely documented and published to the CCVT.

13.2 Auxiliary data preparation

The auxiliary data do not require special preparation other than routine generation.

13.3 Third party data preparation

Access and data processing are provided by Team members for all third party (non ESA)

13.4 Data circulation

Exchange of data and information is a primary need for the CCVT Members. Geographically distributed, PIs and Co-Is, need to retrieve relevant data, process it, evaluate results and submit reports to the CCVT. This is likely to originate a hefty circulation of data and information over a period of time, which is best achieved if organised with a common method.

The mechanism of data circulation and the detailed data requirements are described in a separate applicable document:

RA-2/MWR Data Circulation Plan, PO-PL-ESR-RA-0053.

13.4.1 Circulation mechanism - Web site

The different locations of CCVT team members, the duration of the CCVT works over time and the nature of the AOs contents which are expected to produce documentation as result, all lead to adopt the Internet as communication media. Its wide diffusion all over the world and the availability of broadly accepted standards and many powerful tools make it certainly suitable for CCVT data circulation needs.

Thus, CCVT data circulation may take place by means of the set up of a restricted-access Web server on the Internet that every CCVT member may access using a login and password. The Web server is located at ESRIN and is under the authority of the CCVT Coordinator. The Web server is maintained by the CCVT Webmaster, which takes care of building the web pages and organising information and documentation collection for publishing within the CCVTeam.

The Web server hosts all relevant information to the CCVT Members, makes them available for reading at any time, allows broadcast of notification to single or all PIs by use of E-mail, permits download of data and upload of PI reports. It also provides some search facility over the documentation pool and allows to have a view of the CCVT works at a glance.

Information that may be useful to exchange are as (at least) follows:

- Data availability / unavailability (provisional, actual) notification
- Data retrieval problem notification
- Report submission (weekly, preliminary, interim, final)
- Any information or document provided by the CCVT coordinator
- Any information or document provided by team members

The RA-2/MWR CCVT web site is reachable at the URL <http://styx.esrin.esa.it:8060>. The access is password protected.

14 SYSTEM REQUIREMENTS

The RA-2/MWR CCVT activity will depend on several ENVISAT, ERS and other ad hoc systems.

14.1 ENVISAT SYSTEMS

- USF
- IPF
- F-PAC
- IECF
- ESL reference processors

14.2 ERS SYSTEMS

14.2.1 ESRIN PCS RAT TOOL

This tool is operationally running and used to establish the quality of the Fast Delivery products as soon as they are available. The concept could be anyway applied to any kind of products.

It focuses on the extraction of information about the "bad" data quality rather than the "good" one. All the "bad" characteristics of the products (e.g. gaps, blanks, parameters out of range, etc.) are classified and automatically detected over every file as soon as it is available in PCS. A higher level process then assembles all the information recovered from every file and produces a report in HTML format. The report shows all the detected problems both in ASCII and graphic format (it displays over the world map their geographical location; very useful in order to detect eventual geographical correlation). The report can be produced at any time for a near real-time quality control and it is extendable with the view to identify new checks over different characteristics of the products. In relation to this, a detection of peaks in the range parameter could be advantageous while the range is for the moment, not controlled at all within the operational activities. All the problems; being identified as items and qualified with start and stop time, duration, geographical location, etc.; are stored in a database which is useful for evaluating statistics and performing long term analysis.

14.2.1.1 CYCLIC REPORT

The Cyclic Report describes the results of several ad hoc tools developed in house and dedicated to establish long term product and instrument performances. The subjects examined are: the Openloop Calibration behaviour (AGC and HTL), the tracking performances, the SPTR and USO corrections, the House Keeping parameter trends, the IF Filter Shape characteristics, the Off-Nadir pointing behaviour, and the fast delivery data (URA) overall performances.

Being the RA-2 instrument flying over ENVISAT not really different from the Radar Altimeter on ERS, it could be worthwhile to keep the same concept for the long term performances analysis. New investigation tools, dedicated to aspects that are not applicable at the moment, could be added.

14.2.1.2 ECMWF MONTHLY REPORT

The ECMWF Monthly Report is dedicated to the geophysical validation of the Fast Delivery Wind and SWH parameters by means of comparison with the models results and buoy measurements. The analysis performed are quite interesting especially because it represents the only operational information we have over these parameters under a geophysical point of view. The same kind of study and reporting would be very useful also within the ENVISAT project. I would suggest that the report would include more comments especially directed to people that do not have experience in meteorology.

14.2.1.3 CETP MONTHLY REPORT FOR THE MWR

The CETP Monthly Report includes gain trend analysis of the two channels in the instrument and brightness temperature analysis over the south pole which, being a stable target, enables to survey those parameters' variations over the years.

14.3 OTHER SYSTEMS

FRAPPE: Flexible Radar Altimeter Processor for performance evaluation. This is a workbench developed by MSSL for ESRIN's work on the ERS and ENVISAT data in a common environment. It has outgrown its original development to include additional data processing and visualisation. It is the system that today hosts the ESRIN implementation of the four ENVISAT reference processors.

EOGB: Earth Observation Graphics Bureau. This is a service in ESRIN to produce promotion material on which the CCVT will rely.

15 REPORTS GENERATION PROCESSES

15.1 Introduction

This section specifies the processes of report generation, delivery, distribution, archiving.

The RA-2/MWR CCVT coordinator has the duty to report to the ENVISAT cal/val coordinator (see section 5.3 on page 19). The reports to be produced shall reflect the activity of the CCVT and the results achieved. In turn, the CCVT members shall provide regular reports to the CCVT coordinator and participate in the peer-review of the other members reports as well as review of the integrated CCVT reports.

Unless otherwise specified, the reporting frequency shall be weekly during the first month of activity, monthly afterwards. These are brief reports summarising the activity, results so far, problems if any, and outlook. Further to these regular and brief reports, Two major reports shall be provided: an mid-term interim report and a final report.

All reports are made available to all members of the CCVTeam.

15.2 PIs reports

CCVT Members (PIs) shall provide an intermediate and a final report to the CCVT coordinator as output of their tasks. These reports are submitted for evaluation and discussion (peer review) by the CCVTeam. PIs also provide regular brief report as specified in the introduction of this section.

15.3 CCVT subgroups reports

From switch-on to switch-on + 1 months, the subgroup coordinators shall provide the CCVT coordinator with a weekly report summarising the activity, results, problems if any, and outlook. Afterward the reporting frequency will be reduced monthly.

15.4 Data circulation reports

The data circulation coordinator shall provide to the CCVT coordinator regular reporting on data availability/unavailability, data retrieval/circulation problem and measures taken to mitigate them, a provisional outlook on data availability. These reports shall be weekly at the initiation of each data flow and monthly after the first month.

15.5 Information exchange with RA-2 cal and POD calval teams

The CCVT coordinator will interact directly with the Calibration Team and the POD Validation Team coordinators. This means that there is a precise and timely information flow between the Teams. Information from RA-2 cal team and POD calval team will be provided regularly to the CCVTeam Coordinator. Particularly, a clear signal from the RA-2 Cal coordinator that the RA-2 in flight verification has been concluded and the science data is considered stable and a clear signal from the POD coordinator when the precise orbit can be used for cross-calibration purposes, shall be provided to the CCVTeam Coordinator.

Similarly, all reports produced within the CCVT shall be made available to the RA-2 cal and POD calval coordinators.

15.6 Reporting to the ENVISAT calval coordinator

See section 5.3 on page 19.

15.7 Information from the ENVISAT calval coordinator

The ENVISAT calval coordinator will provide to the CCVT Coordinator all information gathered at Mission level relevant to the RA-2/MWR CCVT.

15.8 Promotional outreach

Promotional material produced in ESRIN as well as contributed by the CCVT Members will be provided to support the ENVISAT Promotion campaign. See section 9.2 on page 34 for details on the promotional material envisaged.

15.9 Report format

Report documents format is defined to be PDF format (Adobe), as being a widely-spread standard convertible to other formats such as HTML for on-line publishing.

The PDF format also allows to easily set up a documentation pool including on-line visualisation and keyword search, based on the Acrobat plug-in for the browsers.

Special requirements regarding the generation of the PDF files will be followed, in particular in terms of font embedding and level of compression.

In case of any difficulty in exploiting the PDF format, the report sender will be requested to deliver the source word or presentation processor binary files.

For the generation of the interim and final report, the CCVT members will be asked to follow a specific layout and deliver the source file as well as the PDF files, for further processing to integrate the report.

15.10 Report delivery, distribution, archiving

Reports generated by CCVT members are collected by use of the upload feature included in the CCVT web site. The upload is performed using any standard web browser and requires CCVT members to provide relevant information along with the report, such as author, title, brief description.

Reports so identified are stored onto the CCVT web site as soon as they are uploaded, and made available subsequently for consultation and peer-review to the CCVT Members in a dedicated section of the web site.



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The publication of the reports and their organisation in a report catalogue is done by the Data Circulation coordinator under responsibility of the CCVT coordinator.

Standard browser search capabilities may be used to seek specific published reports by looking up for keywords, author name, title in the reports catalogue.

An historical archive of the web site report section is maintained to keep track of all versions of the reports. This archive is regularly backed-up.

The CCVT web site also keeps an archive of CCVT-wide e-mails exchanged on topics of interest to the whole CCVT. The e-mails archive may be browsed by date or by discussion thread in a specific web site section, and the body of each e-mail read at any time.

16**FINAL RECOMMENDATIONS**

The CCVT will be required to formulate further recommendations at the completion of the work.

- update of parameters in processors (application of calibration values)
- update of algorithms
- opportunity of reprocessing commissioning phase data
- new products and algorithms (e.g. SSH, SLA, X-overs, coastal zone data improvement)

17 OVERALL APPROACH

This section describes the logic of activities versus time.

17.1 Pre-Launch

Activities:

- Plan review and finalisation (if it is not in the plan, it doesn't exist!).
- Statement of Work for each PI
- Get prepared with data formats, computer resources, Products Read-Write sw
- access to Envisat data
- access to ERS-2 data
- access to 3rd party data
- Data/information access and circulation rehearsal

Specific actions:

Develop the ENVISAT and ERS-2 data requirement and deliver it to the ENVISAT and the ERS Projects (by 1/12/2000). Which data do we exactly need? how much (spatially)? for how long?

Requirements on the enhancing of ERS data shall be discussed within the CCVT. the organisation to (eventually) recondition data shall be described (cf. minutes of plenary meeting #7, 14/12/00)

17.2 Launch and switch on

Activities:

- "First data" verification
- "First data" promotion material production

17.3 During Commissioning Phase

Activities:

- RA-2 Level 2 Algorithm verification
- Products validation
- MWR calval
- RA-2 Cross-calibration
- interim report production

17.4 After Commissioning Phase

Activities:

- Final report production: drafting, review and finalisation
- production of recommendation for the routine phase
- production of recommendation for the reprocessing of commissioning phase data.

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SCHEDULE

The planned schedule is given here in tabular form here for direct readability. A Gantt chart version has been developed and is being used interactively for management.

date	Event
19/03/1997	Preliminary approach meeting
18/03/1998	Calibration workshop
01/04/1998	CCVT first internal meeting #1
31/05/1998	ENVISAT AO submission closing date
15/12/1998	ENVISAT AO selection
01/03/2000	CCVT internal meeting #2
24/03/2000	ENVISAT Cal/Val Organisation meeting
17/04/2000	CCVT internal meeting #3
06/06/2000	CCVT internal meeting #4
15/09/2000	CCVT internal meeting #5
10/11/2000	Delivery of Level 2 Products Read-Write SW to CCVT
13/10/2000	Delivery of CCVT plan issue 0.7 to CCVT
17/10/2000	CCVT first plenary meeting (#6)
14/12/2000	CCVT second plenary meeting (#7)
07/2001	Data circulation rehearsal
12/09/2001	CCVT third plenary meeting and Readiness Review
L	Launch
(L+1m)	First data report
(L+2m)	Preliminary report
(L+2m)	CCVT splinter meeting on products and algorithm verification
(L+3m)	Interim Report (prod val, l2 verif, prel x-cal)
(L+6m)	End comm ph Cross-cal and Val full report
(L+6m)	CCVT plenary meeting
(L+6m)	End Comm phase Workshop
(L+9m)	Validation Workshop (report+ presentation)
(L+10m)	Final RA-2/MWR CCVT meeting
L+12 Months	Final report on Cross-cal
(L+12m)	end of RA-2/MWR CCVT project

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ACRONYMS

ADA	Algorithms Definition and Accuracy
AGC	Automatic Gain Control
CCVT	Cross-Calibration and Validation Team
CT	Calibration Team
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DPM	Detailed Processing Model
DSD	Data Set Descriptor
ECMWF	European Centre for Medium-range Weather Forecasts
EOGB	Earth Observation Graphics Bureau
FDGDR	Fast-Delivery Geophysical Data Record
FRAPPE	Flexible Radar Altimeter Processor for Performance Evaluation
GDR	Geophysical Data Record
HTML	HyperText Mark-up Language
IECF	Calibration Facility
IF	Intermediate Frequency (auxiliary file)
IPF	Instrument Processing Facility
IGDR	Interim Geophysical Data Record
IODD	Input/Output Data Definition
IPF	Instrument Processing Facility
MAR	Marine Abridged Record (FDMAR, IMAR)
MCD	Measurement Confidence Data
MDS	Measurement Data Set
MPH	Main Product Header
MWR	Microwave Radiometer
NRT	Near Real Time
PCD	Product Confidence Data
PDF	Portable Document Format (Adobe)
PDS	Payload Data Segment (ground segment)
RT	Repeat Track
SGDR	Sensor Geophysical Data Record
SPH	Specific Product Header
SLA	Sea Level Anomaly
SPTR	Scanning Point Target Response (a range correction file based on -)
SSB	Sea State Bias
SSH	Sea Surface Height
SWH	Significant Wave Height
TBD	To Be Decided
TDS	Test Data Set
USF	User Service Facility
USO	Ultra Stable Oscillator
UTC	Universal Time Coordinated
WWW	World Wide Web
X-over	Cross-over point

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Maria Milagro
<Maria.Milagro@esa.int>
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1) J. Benveniste and CCVT, "Envisat RA2/MWR Cross-Calibration and Validation Plan", PO-PL-ESR-RA-0005, iss. 1.1, February 2002, ESA publication

2) M. Roca, "RA-2 In-flight Instrument calibration and Level 1b verification plan", PO-PL-ESA-GS-1097, iss. 2.a, December 2001, ESA publication

that are referred to in the RA2/MWR PH.

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