Centre d'étude des **E**nvironnements **T**errestre et **P**lanétaires (CETP/IPSL/CNRS/UVSQ)
10-12 av de l'Europe, 78140 Vélizy France
Collecte **L**ocalisation **S**atellite
8-10 rue Hermès, 31526 Ramonville St-Agne, France

Report CETP/ERS2/MWR for 2001 – Long term survey of the ERS2/MWR

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Reports on activities performed in 2001 on the ERS2 / MWR survey

L. Eymard, E. Obligis, M. Dedieu, C. Marimont

1. Introduction

The statement of work for the long term survey of the ERS2 microwave radiometer (MWR) by CETP and CLS includes the following issues :

- continuous monitoring of the key instrumental parameters, to detect any anomaly ; detailed analysis of anomalies if observed, then update of the calibration ;
- long term analysis of the brightness temperatures over stable natural targets, to evaluate the instrument stability and quantify any drift.

Since the beginning of the contract in 1999, main activities in our team have concerned :

- First the transfer of the ERS2/MWR data processing on a new computer, devoted to this activity. Data from the Kiruna station are extracted from the ESRIN server (odisseo..esrin.esa.it) then automatically processed at CETP.
- Anomalies in the data (missing data, or telemetry format problems) have been identified and messages sent to ESRIN.
- At the end of every cycle, the gain plots are updated to append these data, and brightness temperatures are displayed over the South pole. These plots are then sent to ESA, accompanied by a short report by e-mail.
- In parallel to these routine activities, calibration / validation evaluations have been performed, by comparing measured brightness temperatures with simulated ones from ECMWF, and by comparing the tropospheric correction (or water vapour) with radiosonde data over oceans. Evaluation of new algorithm formulation has been performed on ERS2 data in preparation of ENVISAT.
- Finally, a preliminary study of the long term stability of ERS2/MWr has been achieved, using data from four land targets in Greenland and Antarctica (cold brightness temperatures), and in Sahara and Amazonia (hot temperatures). Despite the difficulty of separating natural and instrumental variations, a first evaluation of the MWR stability was given, and the formula proposed in 1996 to correct for the 23.8 GHz channel anomaly has been updated.

The following report summarizes the work performed in the framework of this contract in 2001. Part of this work has also contributed to preparation of the Envisat MWR calibration / validation activity, as mentioned above. For each activity, we will give the status, main steps and results.

2. Routine survey of the MWR

Since the launch of ERS2, only one major event has been noticed : the anomaly on the 23.8GHz channel which occurred in June, 1996. This anomaly is probably due to the failure of an amplifier, as the result is a decrease of the gain by a factor of about 10. Despite this problem, the sensitivity of the channel is still good enough, enabling to retrieve the tropospheric path correction with an accuracy similar to Topex/TMR. To use the standard algorithms, a linear correction was established, using data from the first year as reference. This work is described in the final report of the in-flight calibration / validation (Eymard and Boukabara, 1997).
The routine plots produced at the end of every 35 day cycle include the correction on the brightness temperature, but a simple multiplication by 10 for the gain. Figure 1 shows the gain since the anomaly in June, 1996, and a zoom on the last 10% data. The stability of the gain on the two channels is remarkable. Slight variations, which do not exceed a few %, can

be observed with time. Even when the instrument was switched off/on, the gain has come back close to each nominal value. Note that the gain of the 36.5 GHz presents a continuous, but very weak increase with time, due probably to the evolution of the receiver.
The brightness temperatures over Antarctica evidence the good quality of measurements : after correction of the anomaly, the 23.8 GHz channel works properly, and the two channels display the annual cycle of brightness temperatures around the pole. These plots are available on the web site of ESRIN, and Figure 2 gives an example, for two opposite seasons, at 23.8 GHz.

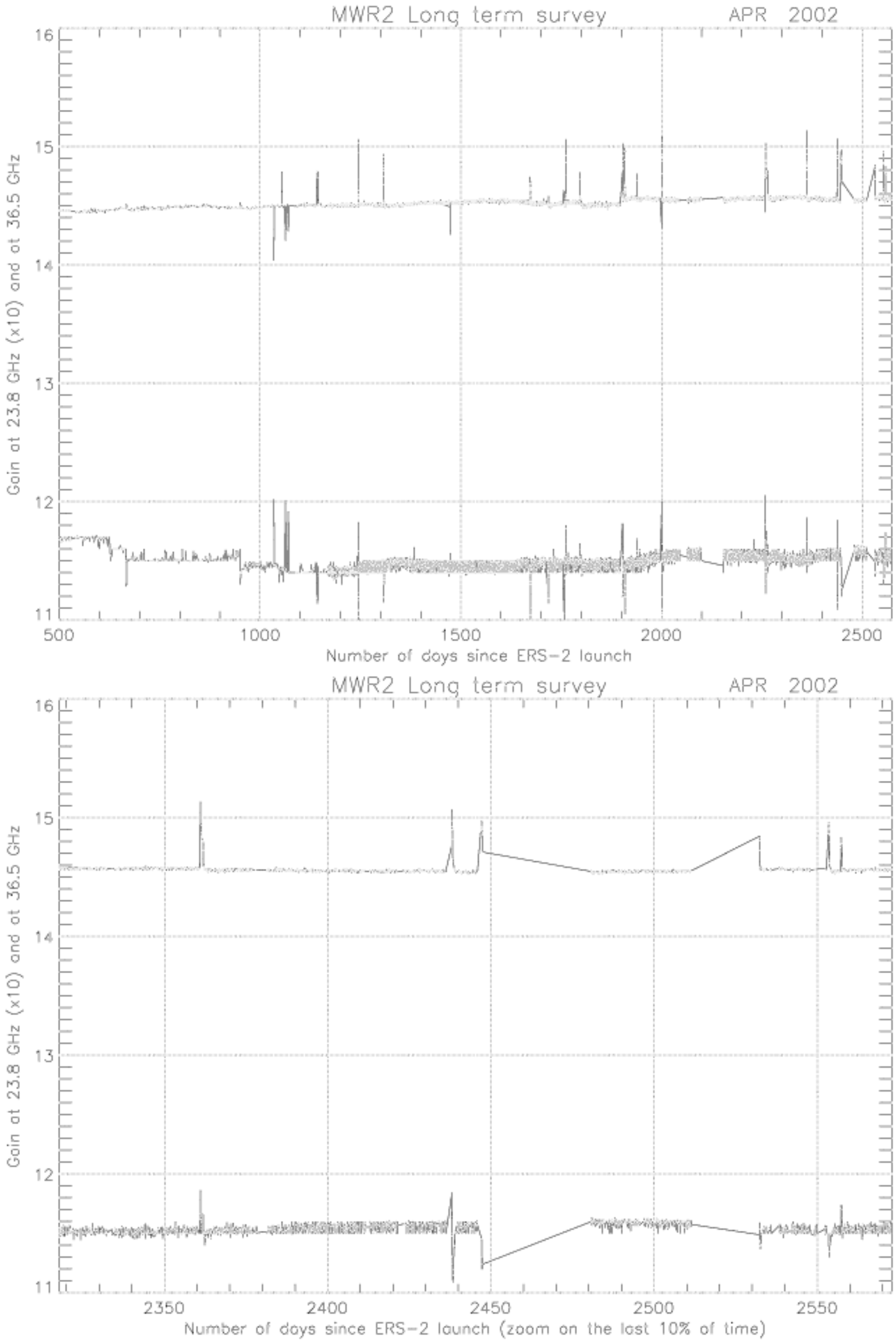

Figure1 : Plots of the MWR gain with time. Upper panel : all gain from June,1996 to April, 2002. Bottom panel : zoom on the last 10% data. The upper curve is for the 36.5 GHz channel, the lower for the 23.8 GHz channel (multiplied by 10).

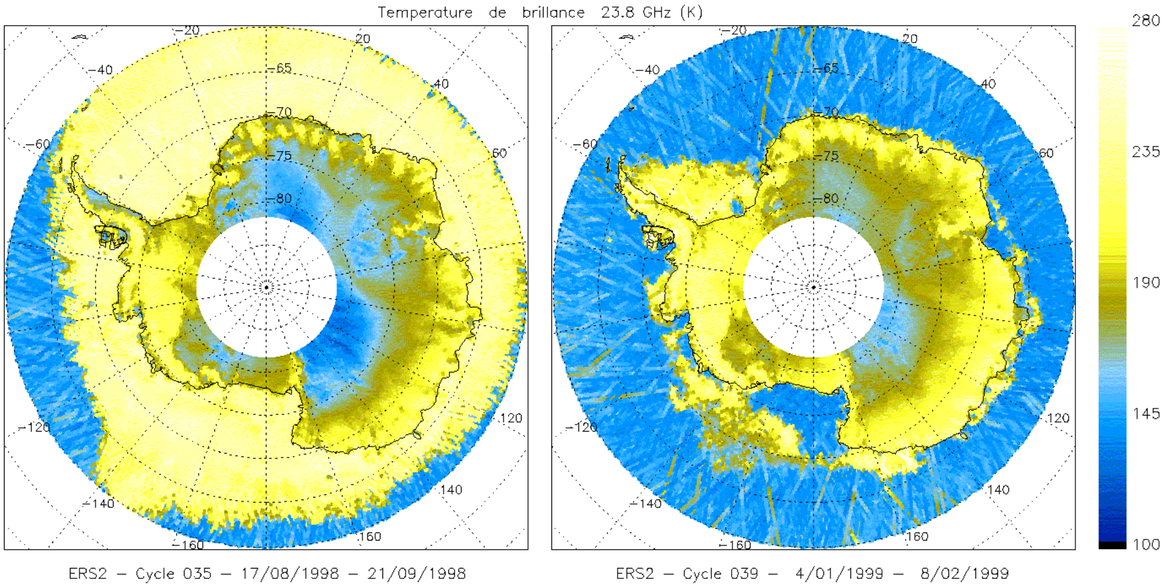

Figure 2 : Color display of the 23.8 GHz channel brightness temperatures around the South pole for two cycles at opposite seasons in 1998 / 1999. On the left, the sea ice covers a maximal area (yellow color, whereas the ocean appears in blue). On the right, in summer, ice is reduced to the continental zone. Note that the sea ice and coastal ice regions have high microwave emissivities (so high brightness temperature), and ocean and central Antarctica have low emissivities (and physical temperature, for the latter), leading to very small brightness temperatures

The processing chain used at CETP was derived from the ERS-1 data processing. Differences first concern the data level0 format, then the side lobe correction : for ERS-1, the method consisted of adding a signal representative of the far portion of the main lobe (below 3 dB) and those side lobes which are in view of the earth. This signal was estimated using radiative transfer simulations over oceans, and binned every 10° in latitude. For ERS-2, a study performed by Sid Boukabara in 1994 and summarized in the final report (Eymard and Boukabara, 1997) established that a better estimate is obtained by neglecting the far side lobes of the earth but taking the complete main lobe (diameter about 60 km).

The chain has worked properly most of the time, but a few problems with the telemetry have occurred (non readable data).

3. Calibration / validation and comparison with other radiometers

The major calibration / validation phase has been achieved in 1996 – 1997. The MWR data have been compared with simulations, in parallel with comparisons with other instruments : SSMI, Topex/TMR. The methodology is the following :

- selection of several ECMWF analyses (output fields containing temperature and humidity profiles, cloud amount, surface wind and temperature)
- co-location of satellite and model points, by averaging satellite data falling in given intervals (± 1 – 2 hours, ± 0.5 - 1°) within a model grid mesh
- simulation of the instrument brightness temperature and comparison with the measurement in clear (filtering out clouds using model cloud information and a liquid water algorithm on the radiometer).

In 1996 – 1997, we used Prigent's radiative transfer model, which was also used for deriving the retrieval algorithms. Comparisons were made with Topex/TMR and SSMI. For the last years, we have used the UCL model, after improvement by Boukabara (1997). Its advantage is a more sophisticated electromagnetic surface model, allowing us to simulate both the MWR and the altimeter measurements. A comparison has been performed in 1999 on several instruments : MWR, SSMI, TMR, and TRMM/TMI, and on the two altimeters (ERS2 and Topex). The results are presented in reports by Obligis and Eymard in 1999 and 2000.

In 2001, a new comparison was performed, using 4 analyses from the updated version of the ECMWF model (60 vertical levels, grid spacing close to 0.5°, instead of 30 levels, 1° spacing). Results were found consistent with previous ones (Figure 3).
For the calibration period of the Envisat radiometer, 4 analyses have been extracted for April and May 2002. Results are presented on figure 4. For the 23.8 GHz channel results are consistent with the ones of 2001 (similar slope and bias). For the 36.5 GHz, simulations performed over 2002 analyses seem lower (bias is now –1.6K instead of 2.2K). This is explainde by a change in the cloud / water parameterization in January, 2002, resulting in a increase of cloud liquid water in the model. As our simulations are performed in near clear air (a threshold is used to filter out clouds), the small remaining cloud water content has induced a higher bias on the 36.5 GHz channel.

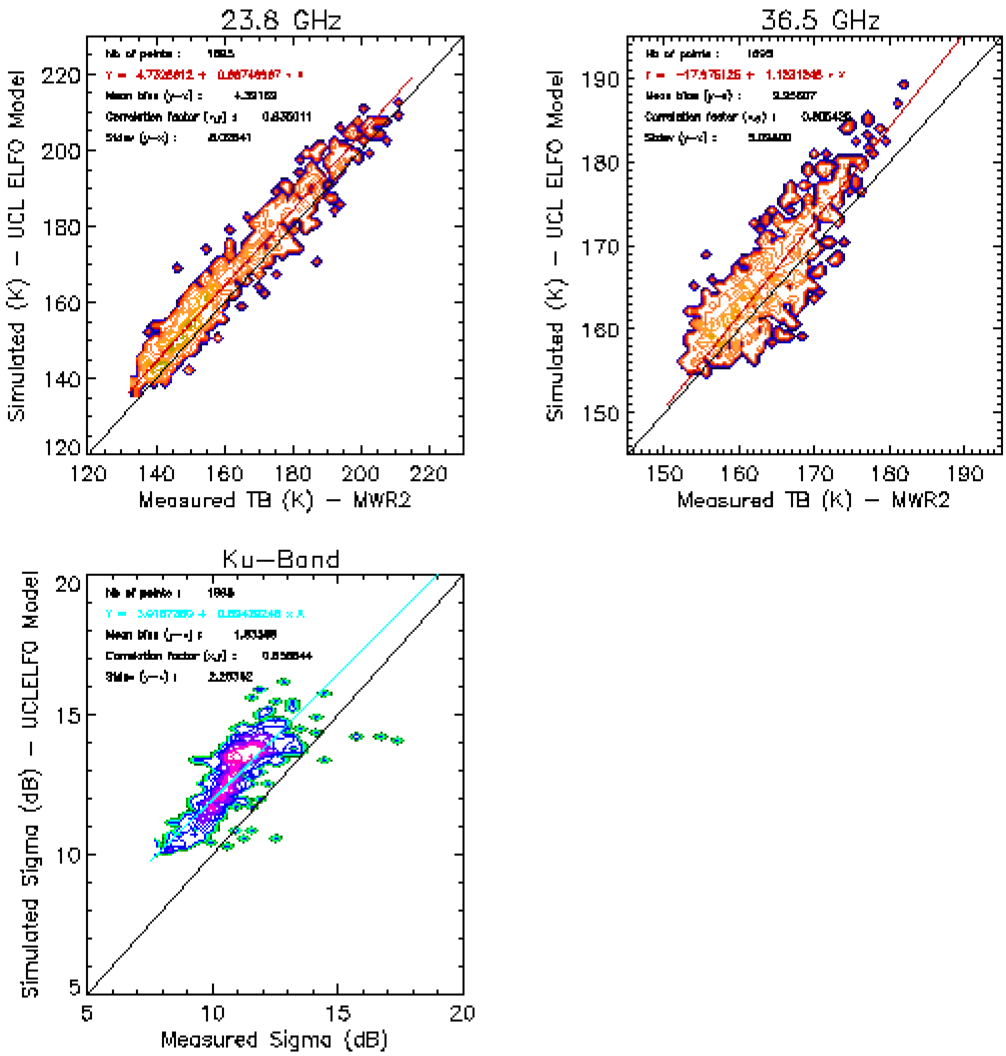

Figure 3 : comparisons between measurements and simulations by the UCL model with the Elfouhaily spectrum for 4 analyses in 2000-2001 (one per season).

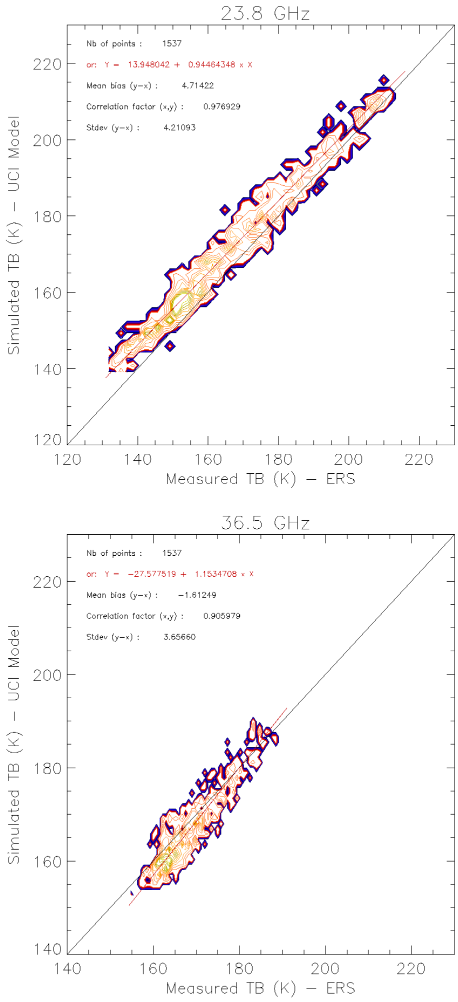

Figure 4 : comparisons between measurements and simulations by the UCL model with the Elfouhaily spectrum for 4 analyses in 2002. Measurements used for these comparisons are real time brightness temperatures calculated at CETP. This is why no comparison have been done for the backscattering coefficient.

Validation of an instrument as the MWR is difficult because of its field of view. The method we have applied since ERS-1 is to compare the tropospheric path corrections from the radiometer and calculated from measured vertical profiles over oceans. Then co-location within a given interval (+/-1 hour in time and +/-0.5 degree in space) is made before drawing the scatter plot. The Figure 5 shows the last results, obtained for a 6 years period (from launch to December 2000). Here the standard ERS-2 algorithm is directly applied to measurements (those of the 23.8 GHz channel corrected for the anomaly). The result is satisfactory : despite the anomaly, the retrieved tropospheric path correction is in agreement with the measured one. The mean bias is of 6 mm and a rms error of 1.67 cm (not corrected from the bias). But this value does not give an estimation of the absolute rms error of the wet tropospheric correction since it takes into account, error on the radiosounding measurement, error of colocalisation, atmospheric variability in one hour and 0.5 degree.

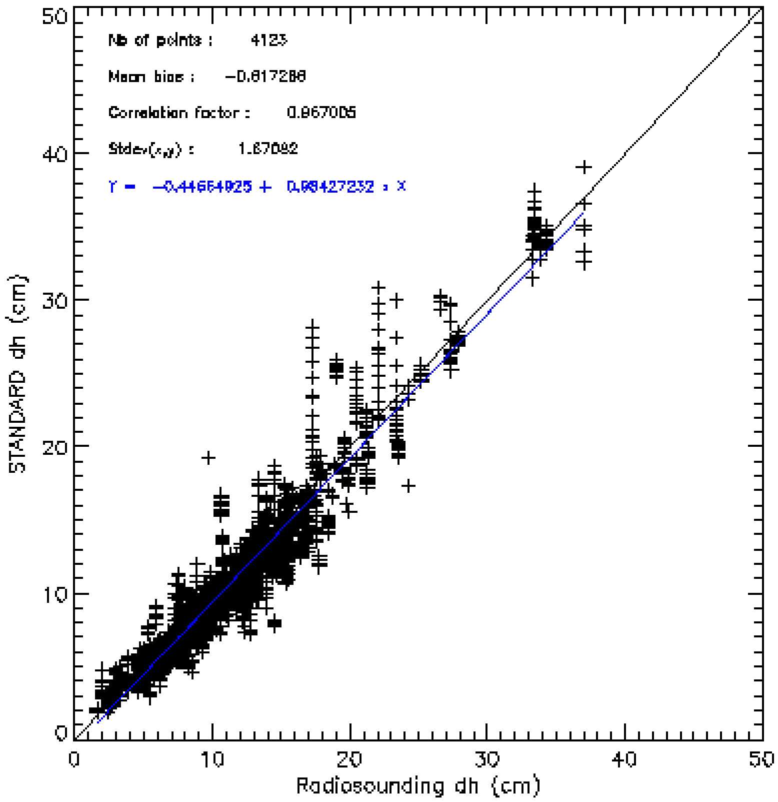

Figure 5: comparison between measured dh and dh retrieved by the OPR algorithm.

Finally, in the framework of the preparation to Envisat mission, a particular study has been conducted to take into account the contamination by the secondary lobes (important effect due to the big efficiency of the platform for the 23.8 GHz channel). In this context, we have checked, using particular tracks, that there is no significant signal due to a contamination by the secondary lobe on ERS2 brightness temperatures.

4. Long term survey

In 1999, a study was conducted both on TMR and MWR to evaluate the feasibility of using natural targets for long term survey. At the time of this study, some published results had been available, establishing a drift of the TMR 18 GHz channel with time. A correction to this drift was proposed by C. Ruf (Ruf, 2000) to correct for it, based on analysis of the coldest brightness temperatures over ocean.

We selected several areas over the globe, assumed to be as stable as possible. Except for the Antarctic plateau, they were chosen around nodes of both TMR and MWR. Results of this analysis was summarized in a report (Eymard and Obligis, 2000). The major results are the following :

- The Antarctica plateau appears a good location for long term survey, contrary to the Greenland glacier, because of ice melting in summer.
- Analysis of MWR brightness temperatures over this location, as well as over Sahara and Amazonia led us to slightly update the anomaly correction, the operational one underestimating high temperatures.
- The TMR drift could not be evidenced from Greenland analyses, because of the strong natural variation.

- The comparison between TMR and MWR near similar channels showed a similar calibration at low temperatures (over Greeland), but a large and unexplained difference at high temperature (Sahara and Amazonia). This could come from calibration procedures which do not account for the principle of these radiometers (Dicke radiometers) : any calibration correction should cancel when reaching the instrument internal temperature. Note for example that Ruf's proposed correction for the 18 GHz channel drift does not respect this requirement (same correction for all temperatures).

Although we could conclude that no significant drift could be detected on the MWR measurements, this study was however unsatisfactory, because the natural variation dominates the observations : the El Niño event in 1997 is so strong that all data over the globe for this year reflect its effect. In Ruf's study, this effect can be depicted as well. To overcome this limitation, a new study is being performed in 2002. First additional years will be processed (2000 to 2002) ; then a specific processing will be made to remove the annual cycle, and we will more accurately analyze the time variations of both radiometers. This task will be completed in September, 2002.

5. Final remarks and recommendations

The ERS-2/MWR has proven its good stability with time, and it provides good quality measurements. Our work on this instrument is consequently mainly a routine monitoring. The calibration / validation activity enters now in the ENVISAT framework, considering that no specific effort has to be made on ERS-2.
Nevertheless, the long term survey must be completed and more accurate, to possibly detect small drifts as the one which occurred on the TMR 18 GHz channel.

A point concerns the correction of the anomaly on the 23.8 GHz channel : the evaluation of the various corrections proposed since the failure in 1996 by comparing the first year and the next ones led us to conclude that the best one is the one proposed by CETP in 1997 : 0.93Tb +19.18, which is currently applied in the operational data processing. It results in a nearly perfect fit with the following years at medium – low temperatures (over the South Pole and Greenland), but a small bias is observed at the higher range of temperatures (Sahara and Amazonia). However, the brightness temperatures generally measures over the oceans are in the low – medium range, except in case of deep cloud.

The major question now is the following : is it necessary to update the calibration and algorithms of ERS-2 or not? The ENVISAT MWR2 will be calibrated, but as observed with ERS-1 and ERS-2, two instruments, although eventually identical, cannot be calibrated quite similarly. Our recent progresses on retrieval method (updated regression algorithm, and use of neural network) suggests that an update of the ERS-2 processing could be made, to keep the ERS-2 data comparable to Envisat ones. Arguments not to re-calibrate the ERS2/MWR are :
- the present processing does work properly, and the tropospheric path has been validated
- due to the anomaly on the 23.8 GHz channel, any calibration update will necessarily be artificial on this channel, which is the most important in the retrieval

Arguments to update the processing chain are :
- the ERS-2 retrieval algorithm was found to be biased at very low water vapour, and a new algorithm was developed for Envisat, to correct for this bias. It was tested on ERS2, so it will be easy to implement ;

- comparisons between ERS2 data and model simulations, which are the basis for calibration update, were already performed, to make possible applying the Envisat algorithms (either regression or neural algorithms).
- The ERS2/MWR processing cannot be considered as a reference to adjust the ENVISAT/MWR2 data processing, for the above reasons. It would be better optimizing the MWR2 in-flight calibration and retrieval, and update the ERS2 chain.

In conclusion, we recommend to update the ERS2 retrieval to benefit from the better retrieval methods developed for ENVISAT, which were already tested on ERS2. However, before implementing them, a detailed inter-comparison with ENVISAT must be performed and validation against radiosounding data is necessary to check the quality and reliability of the new retrieval in any situations, on both instruments. The final algorithms will be chosen in this analysis. For ERS2, it will result in a linear correction to apply on brightness temperatures, and a new algorithm. Note that the neural network algorithm will consist on a subroutine or function (several lines to code), whereas the new classical algorithm consists of a multilinear regression with an added linear correction for low temperatures.

Applicable documents and references :

Applicable documents :

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- E. Obligis and , analysis of Neural network retrieval algorithms for the ENVISAT/MWR . Report CLS/DOS/NT/01.37, September, 2001.

Reference :

Ruf, C.S., 2000: Detection of calibration drifts in spaceborne microwave radiometers using a vicarious cold reference. IEEE *Trans. Geosci. Remote Sens.*, 38(1), 44-52.