PRELIMINARY REPORT ON LONG TERM STABILITY OF ERS2/MWR OVER CONTINENTAL AREAS

L. Eymard (CETP/IPSL/CNRS), E. Obligis (CLS)

1. Introduction:

The control of key instrumental parameters has been performed routinely since the ERS2 launch. It consists in a survey of the radiometric counts of the hot and cold calibration measurements, and of the resulting gain. No significant variation could be evidenced since the 23.8 GHz anomaly which occurred on 26 June 1996. However, it is not a complete control of the brightness temperature. Comparison of the operational measurements with simulations, as done during the in-flight calibration phase is a useful tool, but ECMWF does not guarantee that the meteorological fields will be statistically equivalent over a several year duration, because humidity is the quantity with the greatest uncertainty in the prediction model (due to assimilation/analysis procedure, to the cloud scheme, among others). Moreover, the direct radiative transfer model is not perfect. For these reasons, recalling that the absolute instrument calibration is estimated to within 2-3 K, additional methods to control the radiometer drift must be tested.
In case of polar orbits, a direct comparison can be achieved over poles, where the atmosphere variability is much less than over open oceans, and the annual cycle is quite stable. A preliminary test was performed on ERS1 data by Bernard et al, 1993. The use of measurements over warm targets (Sahara, Amazonia) could complement the analysis for high brightness temperatures. On these continental regions, we expect that any natural variation should affect all channels in a near-similar way and the drift on one particular channel could thus be easily pointed out. We have therefore undertaken to analyze the time evolution of the ERS2/MWR data over the Antarctic plateau, and to compare its behaviour with the one of Topex/TMR over three common areas : Greenland glacier, Saharian desert and Amazonian forest.

The method used is the following, for the two instruments :

- selection of the spatially less variable areas over one year (small area, but at least two orbits overpasses)
- computation of the mean Tb and standard deviation over each orbit segment overpassing the area, in order to build a time series
- analysis of the time variations (annual and diurnal cycles)
- selection of the most stable data using statistical criteria.

As we used VLC products provided by CERSAT, in order to have the global operational data set, the 23.8 GHz channel was not corrected from the 26 June 1996 strong anomaly. We applied the brightness temperature correction developed by Eymard and Boukabara, 1997 (final report, ERS-2/MWR calibration-validation), and compared it to the correction proposed in CERSAT accompanying documents.

2. ERS2/MWR long term analysis over the Antarctic plateau

Over the Antarctic plateau, the brightness temperatures range within 120 and 170K during the annual cycle. After displaying the brightness temperature maps for each cycle over one year, we selected a very cold area, of location:(81.3 81S ; 116 116E). The brightness temperatures present a higher variability during austral summer than during winter. It is due to the solar

heating, which progressively penetrates the ice, inducing a time shift between the two channels, and to the meteorological variations, greater during summer (snow fall, wind, etc...). We therefore selected only the colder temperatures period observed in winter. An additional selection criterium is the minimum horizontal variability over each individual orbit segment. Then we computed the difference Tb36.5 - Tb23.8.
The result is the following : mean bias : 7.6K; trend over the four winters : 0.23K
The relative stability of the two channels seems therefore very good.

3. Comparison TMR / MWR

The three areas selected are: Greenland (65 66N; 47.5 46W), Sahara (19 21N; 6.5 4.5W), Amazonia (6.5 4S;67.5 65.5W). In this analysis, we do not discuss the question of the 18 GHz drift, suggested by several studies.

the previous method has been applied, but with the following adaptations:
Greenland: Interpolation of TMR and MWR data on the four successive winters, after selection of the lowest values (same method as over Antarctica); Check of consistency of the interpolated data set, with respect to the initial data for each instrument.

Sahara: Interpolation on the whole period. In spite of the diurnal cycle (difference between day and night) clearly seen on ERS data, due to its fixed overpass times, no filtering was applied because of the Topex time drift within the cycle.

Amazonia: A similar data processing was applied. Again a diurnal cycle is detected on ERS data (convection during late afternoon?), but not accounted for.

The comparison results are summarized in table 1 (in red, the Topex/ERS direct comparisons):

AMAZONIA	**Bias (K)**	**sd dev. (K)**	**trend (K)**
T 21- T18	-1.1	0.5	0.1
T 37- T18	-1.2	0.8	0.4
T23.8-T21	6.8	2.5	-0.5
T36.5-T23.8	6.4	1.0	1.1
T37-T21	-0.1	0.6	0.3
T37-T36.5	-13.3	2.9	-0.4
SAHARA			
T 21- T18	-1.2	0.6	-0.3
T 37- T18	0.0	1.3	-1.3
T23.8-T21	6.6	2.5	-2.1
T36.5-T23.8	7.3	0.9	0.2
T37-T21	1.2	0.9	-1.0
T37-T36.5	-12.8	2.6	0.9
GREENLAND			

T 21- T18	4.9	1.8	1.4
T 37- T18	21.2	4.1	-1.5
T23.8-T21	1.1	3.6	0.3
T36.5-T23.8	16.6	3.8	-2.4
T37-T21	16.2	3.6	-3.0
T37-T36.5	-1.5	4.2	-0.9

Table 1 : comparison TMR / MWR over selected areas of Amazonia, Sahara and Greenland.

4. Impact of the choice of the 23.8 GHz anomaly correction :

The above table shows some differences between the behaviours of TMR and the MWR, in term of bias and trend. The bias will be discussed in the next section.

The direct comparison between the closest frequencies (23.8 - 21; 37-36.5) leads to the following comments:

- the trend of the difference 23.8-21 is small over Amazonia and Greenland (respectively -0.5 and 0.3K), but is greater over Sahara (-2.1K);
- the trend of the difference 37-36.5 is less than 1K over the three zones (-0.4, 0.9, -0.9 over Amazonia, Sahara and Greenland, respectively).

Part of these discrepancy can be explained by the different sampling of the two satellites : although the selected areas are small, the two satellites do not overpass exactly the same place, as shows the rather large standard deviation in all cases.

An alternative method to compare the two instruments is to consider the differences 36.5-23.8 and 37-21: due to the frequency proximity, similar results can be expected over continental areas in term of trend. We find in the three cases a value greater for ERS than Topex (1.1 / 0.3 over Amazonia, 0.2/-1. over Sahara and -2.4/-3. over Greenland. So the question which arises is the following : is this difference due to natural change in the surface emissivity with frequency, or is it due to a calibration problem? In the case of TMR, none of the studies performed to analyze the path delay drift could evidence a problem with the 21 and 37 GHz channels. We must therefore check the sensitivity to the MWR 23.8 GHz anomaly correction, recalling that is based on comparisons between data obtained during the first year, and just after the gain failure. The correction proposed by Eymard and Boukabara was obtained by comparing data over the two polar areas, in order to have a wide range of values. The one proposed in the CERSAT documents was obtained through TMR/MWR cross-orbit point comparisons. They are slightly different :

- CETP correction : 0.93Tb +19.18
- CERSAT correction : 0.9524Tb+ 16.25

The table 2 shows the characteristics of the corrections, including also another one, which is a preliminary correction obtained by Boukabara using a smaller data set (0.94Tb+17.41). We note hereafter CETP the first correction, CERSAT the second one, and SAB1 the last one.

	Change for 100K	change for 300K	balance temperature
CETP	112.2	298.2	274.0
CERSAT	111.3	301.3	341.4
SAB1	111.4	299.4	290.2

Table 2 : Main differences between the three corrections tested. The balance temperature is the temperature at which there is no change in the brightness temperature.

Using the three corrections over the four areas, we obtain the trends summarized in the table 3 for the 36.5-23.8 GHz difference and in table 4 the corresponding comparisons with TMR (23.8-21).

	GREENLAND	SAHARA	AMAZONIA	ANTARCTICA
CETP	-2.4	0.2	-0.3	0.2
CERSAT	-0.9	-3.7	-2.9	0.7
SAB1	-2.5	-1.1	-0.3	0.9
TMR (37-21)	-3.	-1.	0.3	

Table 3 : Difference 36.5-23.8 GHz over the various areas using the three corrections. The TMR corresponding difference 37-21 is given for comparison.

	GREENLAND	SAHARA	AMAZONIA
CETP	0.3	-2.1	-0.5
CERSAT	0.1	1.8	3.6
SAB1	0.4	-0.8	0.9
TMR (21-18)	1.4	-0.3	0.1

Table 4 : Difference 23.8-21 GHz over the various areas using the three corrections. The TMR difference 21-18 is given for comparison.

From their characteristics (table 2), the three correction lead to very different behaviours at low and high temperatures: over Antarctica, their difference is small, and there is no evidence that one correction is better than the others (when considering another area, slightly warmer, a clear trend is observed on the 36.5-23.8 GHz, close to 1.8 K for all corrections). However, if we admit that the TMR 37-21 GHz difference is a reference, the CERSAT correction strongly differs from the others and from TMR, whereas the two others lead to closer results, except over Sahara. The difference can be explained by their opposite change at high temperature : the CERSAT correction increases the brightness temperature, whereas the two others decrease it at 300K.

The last column in the table 2 gives an additional criterium : because the MWR is a Dicke radiometer, the radiometric count (from which the brightness temperature is derived) falls to nearly zero when the observed temperature is equal to the internal temperature (assuming the instrument is isothermal). Thus no correction has to be applied for such temperature, whatever be the cause of the anomaly. The CERSAT correction leads to a no-change temperature of 341K, which is much higher than the mean temperature measured within the radiometer (around 288K). On the contrary, the CETP correction gives a balance temperature too low, contrary to the SAB1 correction. The reason for this difference between the two corrections developed at CETP lies in the comparison points selection: in the Eymard and Boukabara report (figure 21), the 23.8 GHz temperatures are compared before and after the anomaly. A group of points deviating from the main group, induces a small decrease of the slope of the regression line, which does not superimpose on the center of the high temperature data set (in red color).

Thus none of the above corrections is fully satisfactory. On bases of the previous discussions, we have tested an empirical correction, using the following assumptions:

- at low temperatures (say close to 100 K), the correction should be close to all three (between 111.3 and 112.5K)
- the balance temperature should be about 280 - 290K.

With these constraints, we tested three corrections : 0.9325Tb+19.25; 0.9335Tb+19.15; 0.936Tb+18.38. The comparison results, given in table 5, do not significantly differ from each other.

	GREENLAND	SAHARA	AMAZONIA	ANTARCTICA
36.5-23.8	-2.2	-0.9	0.	0.
23.8-21	0.1	-1.	0.6	

Table 5: Mean results of the three new corrections over the four areas.

These results are also confirmed by using another selection method over every area (taking the 30 lower values). After testing various corrections, we note that it is impossible to get a similar agreement with TMR over all areas. In particular, none of the corrections satisfactory fits for the Sahara area. On this area, the number of Topex and ERS overpassing orbits is small, and they do not sufficiently coincide to prevent from a physical discrepancy. Over Amazonia, the rain forest gives a noisy signal, but rather homogeneous, and over Greenland, there are many TMR orbit segments (northern latitude of Topex), ensuring a better overpassing of ERS tracks.
In conclusion, the CETP correction provides rather good comparison results with TMR, but a fine analysis of this correction makes us suspect that the slope of the correction should be slightly greater. It is however consistent with TMR over Greenland, and differs only slightly over warm areas (less than 1K trend with respect to TMR), so it can be used with confidence in most of the oceanic conditions. The CERSAT correction induces an excess change of high temperature (by more than 2.5K), which could lead to biases in the path delay retrieval in high water vapour / cloudy conditions, as well as in low temperature conditions (2K difference in the trend over Greenland), as seen in Table 3.

4. Analysis of the TMR-MWR difference :

In the following, we use the CETP correction, and the last proposed new correction for comparison (in parenthesis). The comparison TMR/MWR over Greenland shows :
- a similar behaviour of the differences 36.5-23.8 and 37-21 GHz channels (respective trends -2.2 (-2.3) and -3.K)
- a small mean bias at corresponding frequencies (23.8-21 and 37-36.5) (0.3 (1.1) and -1.5K, respectively), so within the absolute calibration error of both instruments.

Comparisons over Sahara and Amazonia lead to different conclusions. Despite the rather large scatter due to the different sampling of the diurnal cycle between both intruments, the mean biases are consistent over the two areas:

T23.8-T21 : 6.8K (7.5)
T37-T36.5 : -13K

The mean differences within each instrument are also consistent over the two areas, but very different from each other:

T36.5-T23.8 : 6.4 (7.5) K over Amazonia, 7.3 (7.3)K over sahara
T37-T21 : -0.1K over Amazonia, 1.2K over Sahara

Thus the TMR and the MWR strongly differ over warm surfaces, whereas the surface emissivity cannot differ so much (in particular for channels 36.5 and 37 GHz). This difference is therefore certainly due to calibration problems.

As both radiometers are based on the same principle of Dicke switching, for temperatures close to the internal temperature (about 290 K), the calibration errors are minimized, whereas the largest errors are expected at low temperatures. We find the opposite when comparing TMR and the MWR over Greeland (low temperatures) and warm areas. A possible explanation is that the in-flight calibration adjustment was not kept consistent with the on-ground measurements (correction applied to the brightness temperatures, instead of change on some transmission coefficient in the radiometer transfer function). Looking at the MWR in-flight calibration (figure 7 in the final report), the effect of the calibration correction at high temperature can be estimated, using the regression line between simulations and measurements : for a brightness temperature of 300K, the simulated temperature would be respectively 288 and 293K at 23.8 and 36.5 GHz before calibration correction (panels b) and 295 and 294K, respectively after re-calibration (panels c). There is therefore a 7K difference on the 23.8GHz channel before and after in-flight calibration, which could explain the discrepancy with the 21GHz channel of TMR. For the 36.5 GHz channel, the in-flight calibration did not induce any significant change at high temperature, so it will be necessary to check the TMR calibration as well.

6. Conclusion

The Antarctica plateau appears as a good natural target to check the long term stability of radiometers (very low winter temperatures). Results for the ERS2/MWR suggest a very good stability, despite the instrumental problem of the 23.8 GHz channel in June 1996.
The choice of the 23.8 GHz channel correction was tested by comparing the CERSAT formula and the one proposed by Eymard and Boukabara in 1997 through a direct comparison of ERS2 data sets before and after the anomaly occurrence. However, this correction slightly underestimates high temperatures, and an optimal correction can be found by considering the MWR / TMR trend, in addition to a better selection of the ERS1/ERS2 comparison points.
Finally, the strong difference between the TMR and MWR brightness temperature is probably due to the in-flight calibration procedure. The difference between the MWR 23.8 and TMR 21 GHz channels can be explained by a default in the MWR calibration, and a similar analysis of the TMR in flight calibration should be performed to complete these results.