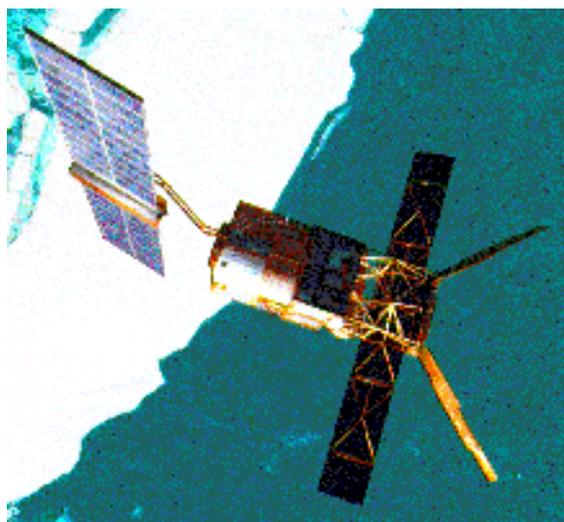


ERS-2 Wind Scatterometer Cyclic Report

from 8th January 2001 to 12nd February 2001
Cycle 60



Prepared by:

PCS team

ESRIN APP-ADQ

Inputs from:

F. Aidt
H. Hersbach

ESTEC TOS-EMS
ECMWF

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This report and its annex (ECMWF report) are available on PCS web:
<http://pcswww.esrin.esa.it>

1.0 Introduction and summary

The document includes a summary of the daily quality control made within the PCS and various sections describing the results of the investigations and studies of “open-problems” related to the Scatterometer. In each section results are shown from the beginning of the mission in order to see the evolution and to outline possible “seasonal” effects. An explanation for the major events which have impacted the performance since launch is given, and comments about the recent events which occurred during the last cycle are included.

This report covers the period from 8th January 2001 to 12nd February 2001 (cycle 60).

Mission events

- During the cycle 60 the ERS-2 satellite was affected by a large period of unavailability: from 17th January 2001 to 5th February 2001. On 17th January 2001 a failure of the Digital Earth Sensor (DES A-side) caused ERS-2 to enter in Safe-Mode and on 25th January 2001 gyro #1 also failed. During the period of Safe-Mode the spacecraft had drifted out of the nominal dead-band by some 30 Km. The nominal orbit was reached on 6th February 2001.
- For the remaining gyroscopes the number 4 cannot be used for mono-gyro piloting and the number 6 is very noisy and cannot be use reliability for piloting.
- In order to preserve the remaining gyroscopes and to continue the mission, since 6th February 2001, ERS-2 is operated in Extra Backup Mode (EBM) without gyros.
- The EBM is a coarse attitude control mode initially foreseen for spacecraft safety and not for data acquisition. Large Doppler shift, due to attitude biases, are found in the received Scatterometer echo. The actual ground processor doesn't foresee for any compensation of these frequency shifts and the Scatterometer products are not calibrated any more.
- A re-design of the Scatterometer data processor shall be performed to restore the initial data quality. In the mean time the distribution of the Scatterometer data to the users is temporarily suspended.

Calibration performance

- The position of the gamma nought histograms maxima computed over the rain forest had a large drop, up to 1 dB, due to EBM operations.
- The weekly gamma nought histogram's shape shows a good quality (a sharp peak) only for the first week of the cycle 60. For the third and fourth week no data were received (payload switch-off). The histograms for the second and fifth week are very noisy due to EBM operations.
- Four tracks over the rain forest has been selected to monitor the sigma nought time series (two ascending and two descending).The result for the cycle 60 is stable for the ascending track number 102 and 274 (acquired in mono-gyro) while for the descending tracks (number 453 and 496) it is clear the decrease of the signal due to EBM. The signal decrease is more important at far range. For the relative track 453 (acquired on 9th February 2001) the Aft beam shows a stable signal level. This means that the satellite attitude changed very quickly between the Fore beam sensing time and the Aft beam sensing time (roughly 100 s.) as shown in the gamma nought maps (see section 2.3.5).

- The antenna patterns, computed by PCS over a small area of the Brazilian rain forest for the cycle 60 show a bad quality. In particular the antenna profiles are not flat across the swath. The reason are: the small amount of available data and the EBM operations.
- The Transponders were working nominally during the first two calibration passes (mono-gyro operations) but no new gain constants have been computed yet. During the other calibration passes the instrument was switched-off.
- The ocean calibration monitoring (by ECMWF) for the cycle 60 (until 16th January 2001) shows that the bias level of the descending and ascending passes has been improved for all three beams. At the moment the reason of this remarkable result is not clear.
- The antenna temperature monitoring over the Brazilian rain forest confirms the increase of roughly 1 degree per year for the Mid and Fore antenna and roughly 2 degrees per year for the Aft antenna. The increase in the antennae temperature could be related with the degradation, during the years, of the antennae protection film.

Instrument performance

- During the cycle 60, on average, no power decrease was detected. The reason was the large period of instrument switch-off (17th January - 5th February 2001). As usual after a long period of instrument unavailability, when the AMI switches on again, the output power level is higher than its last value. This explains because, over the whole cycle, the averaged power decrease has been close to zero. A power increase could be scheduled by the end of April 2001, if the nominal trend (without new instrument unavailabilities) is confirmed.
- During the cycle 60 the Doppler frequency monitoring shows for the daily average of the CoG of the received spectrum an increase of roughly 1000 Hz for the Aft and Fore antenna and roughly 800 Hz for the mid antenna due to EBM operations.
- The evolution of the CoG of the received spectrum as function of the ascending node time, does not show a good agreement with the reference sinusoidal pattern. In particular the large fluctuation of the Doppler frequency around the orbit after 17th January 2001 is due to EBM operations. The amplitude of the variation during one orbit is roughly 3 KHz for the Mid beam and roughly 8 KHz for the Aft and Fore antennae (absolute values).
- The evolution of the standard deviation of the CoG of the received spectrum shows an increase of roughly 2500 Hz for the Fore and Aft antenna and roughly 1500 Hz for the Mid antenna.
- During cycle 60 the monitoring of the noise power shows a stable result.

Product performance

- During the cycle 60 the data coverage was of poor quality due to the large period of instrument unavailability.
- The number of valid nodes had a clear drop from 190000 per day to 9000 per day with EBM operations. The overall Scatterometer transfer function is not matched with the received echo (that is Doppler shifted by degraded satellite attitude). This fact caused the decrease of the signal to noise ratio and as consequence many nodes are discarded by the wind retrieval algorithm. Moreover the sigma nought are not calibrated, the distance to the cone is high (in particular for the nodes at far range) and the wind speed bias is around 1.5 m/s.

The following are the products performances from 8th January to 16th January 2001 (only mono-gyro operations).

- The wind speed bias (UWI -ECMWF Forecast) ranges from 0. to -0.1 m/s and the wind speed standard deviation is around 3.0 m/s. These values are within the nominal performances.
- The ambiguity removal algorithm was working fine for more than 90% of nodes. The wind direction deviation is within +/- 90 degrees for more than 93% of ambiguity removed nodes.
- ECMWF reports an average wind speed bias of -0.70 m/s (UWI-FGAT) and of -0.41 m/s (4D-Var-FGAT). The wind speed standard deviations are stable: 1.56 m/s (UWI-FGAT) and 1.64 (UWI-4D-Var). These results are comparable to the results from the previous cycle.
- The wind directional bias is close to zero (both UWI and 4D-Var products) and the direction standard deviations are ranging between 40 and 60 degrees (UWI) and between 15 and 25 degrees (4D-Var). These results are comparable to the results from the previous cycle.

2.0 Calibration Performances

The calibration performances are estimated using three types of target: a man made target (the transponder) and two natural targets (the rain forest and the ocean). This approach allow us to design the correct calibration using a punctual but accurate information from transponders and an extended but noisy information from rain forest and ocean for which the main component of the variance comes from the geophysical evolution of the natural target and from the backscattering models used. These aspects are in the calibration performance monitoring philosophy. The major goals of the calibration monitoring activities are the achievement of a “flat” antenna pattern profile and the assurance of a stable absolute calibration level.

2.1 Gain Constant over transponder

One gain constant is computed per transponder per beam from the actual and simulated two-dimensional echo power, which is given as a function of the orbit time and range time. This parameter clearly indicates the difference between “real instrument” and the mathematic model. In order to acquire data over the transponder the Scatterometer must be set into an appropriate operational mode that is defined as “Calibration”.

Table 1 shows the result of the calibration plan for cycle 60. The “Yes” in the EWIC column means that the raw data are available, “No” means that some problems caused a loss of data. The “On” in the transponder status column means that, from the raw data (EWIC), the transponders have been recognised as switched-on; “Off” that they were off. The “Yes” in the GC computed column means that a gain constant value has been retrieved, “No” means the opposite case.

As reported in Table 1 the transponders, during the cycle 60, worked as planned. No EWIC data were received from ESOC for the first calibration pass and for the second calibration pass the new gain constants have not been computed yet.

TABLE 1. Calibration Plan: Cycle 60

DATE	ORBIT (absolute)	ORBIT (relative)	Passage	Ground Station	EWIC (raw data)	AMI mode	Transponder Status	GC computed
010108	29915	1	A	KS	No	Calibration	On	No
010111	29958	44	A	MS	Yes	Calibration	On	No
010125	30151	237	D	KS	Yes	Off	n/a	n/a
010128	30194	280	D	KS	Yes	Off	n/a	n/a

Figure 1 and Figure 2 show the gain constants available since the beginning of the mission, the analysis is split for the different antenna elevation angle. From these figures it is clear that the gain constant measurements are stable (within +/-0.5 dB).

The plots in Figure 3 show the value of the Gain Constant for the three beams and for the ascending, descending and all passes. The plots show the average of all gain constants available since January 1996 (cycle 8) for each antenna elevation angle. The antenna patterns are flat but there is a clear shift of the level of the curves. On average, the mid beam is 0.3 dB higher than the aft one

and 0.5 dB higher than the fore one. For the descending passes the antenna pattern shows a slight negative slope from far range to near range.

Since September 1996, ESTEC has added a scaling factor to the gain constant in order to remove the bias among the three antennae. The gain constants were increased by 0.2 dB, -0.3 dB and 0.2 dB, for the fore, mid and aft beam respectively. The result is shown in Figure 4. The suggestion given by ESTEC has not been introduced into the ground processing because the antenna patterns computed over the rain forest do not show such bias (see Figure 5). So in the actual scenario, the differences among the antennae are considered as a bias due to the transponder themselves.

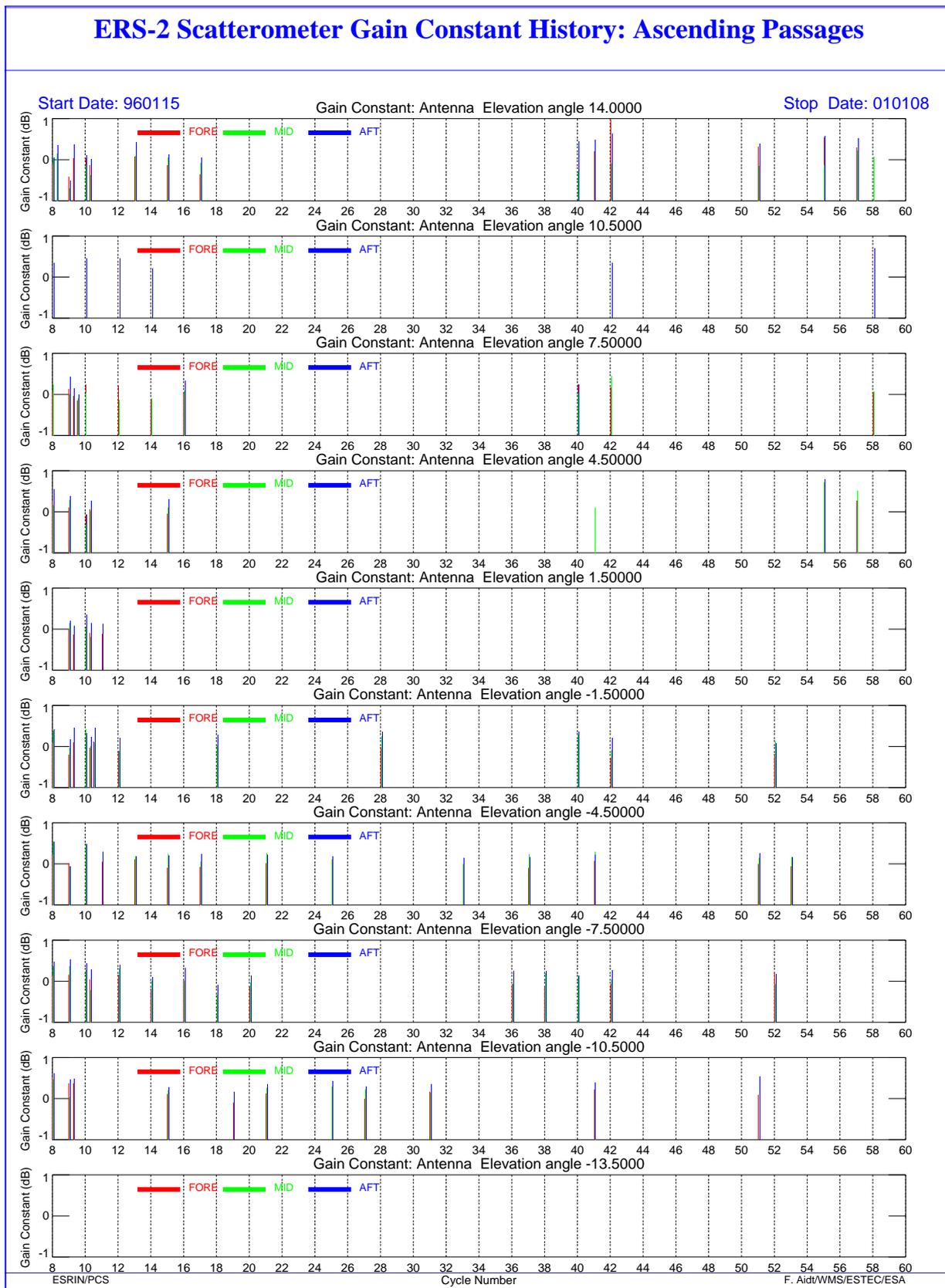


FIGURE 1. ERS-2 Scatterometer; gain Constant over transponder since the beginning of the mission (ascending passes).

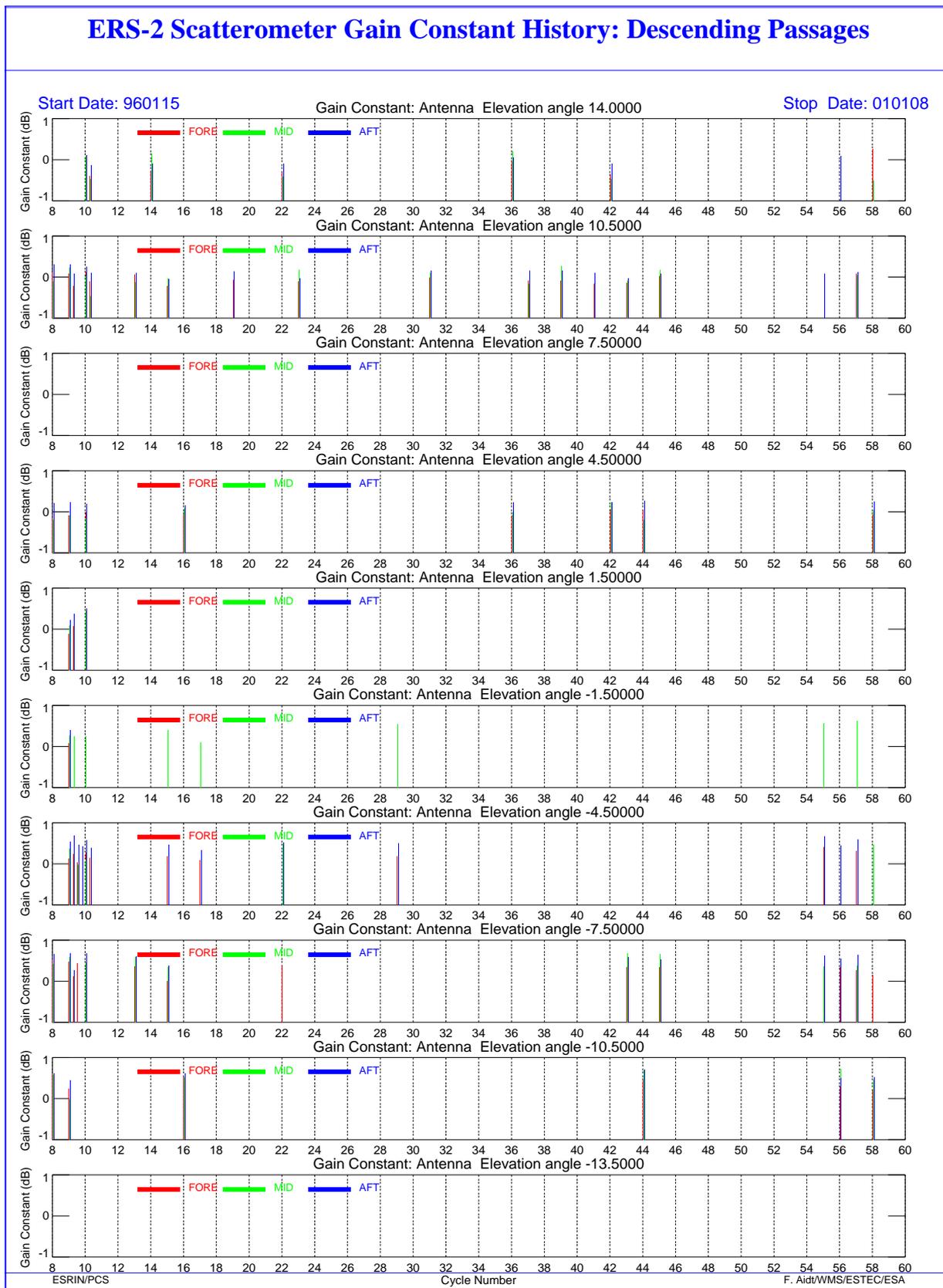


FIGURE 2. Scatterometer; gain Constant over transponder since the beginning of the mission (descending passes)

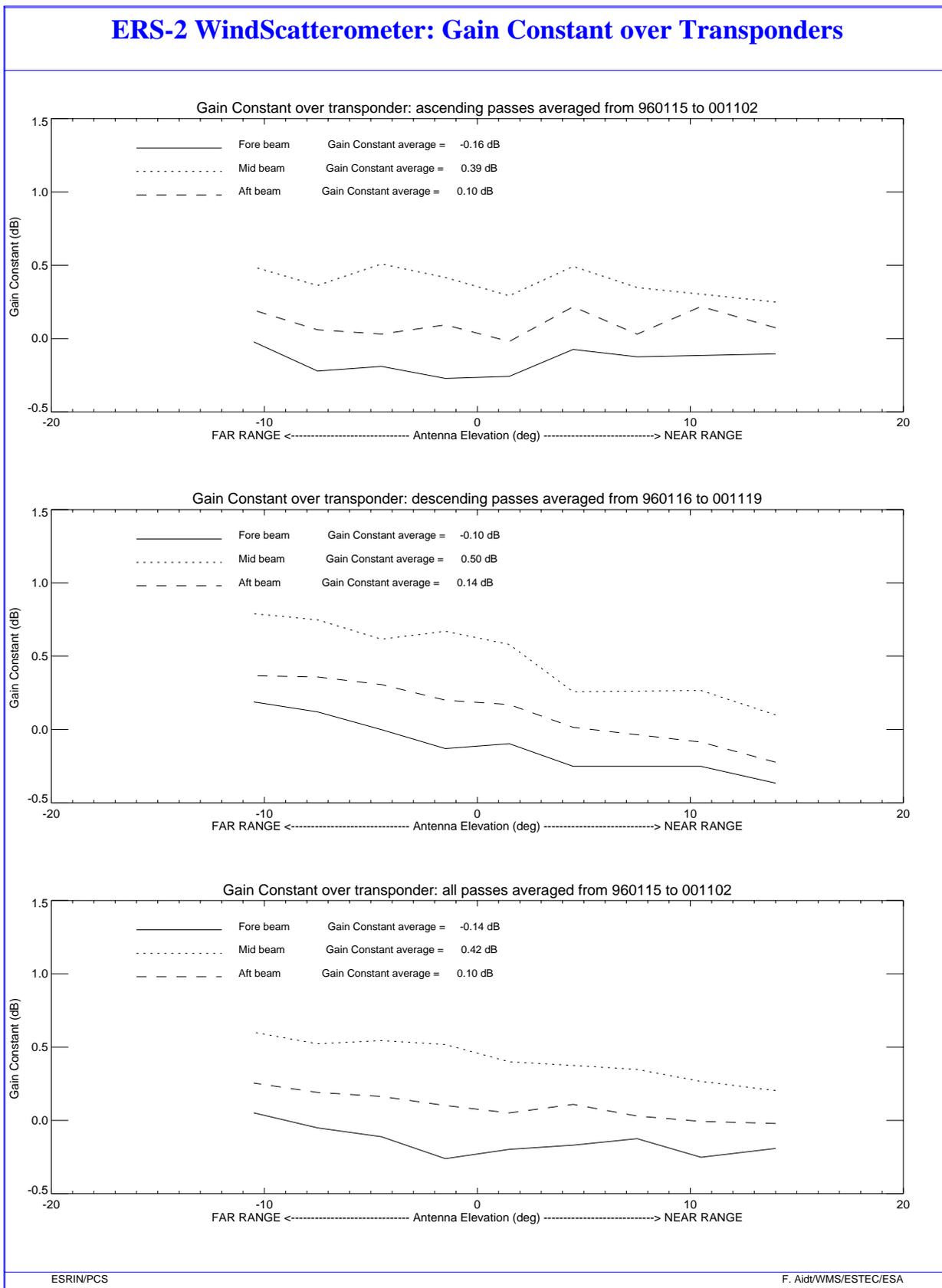


FIGURE 3. ERS-2 Scatterometer: gain constant over transponders. All data available since January 1996. Upper plot: ascending passes. Middle plot: descending passes. Lower plot: all passes.

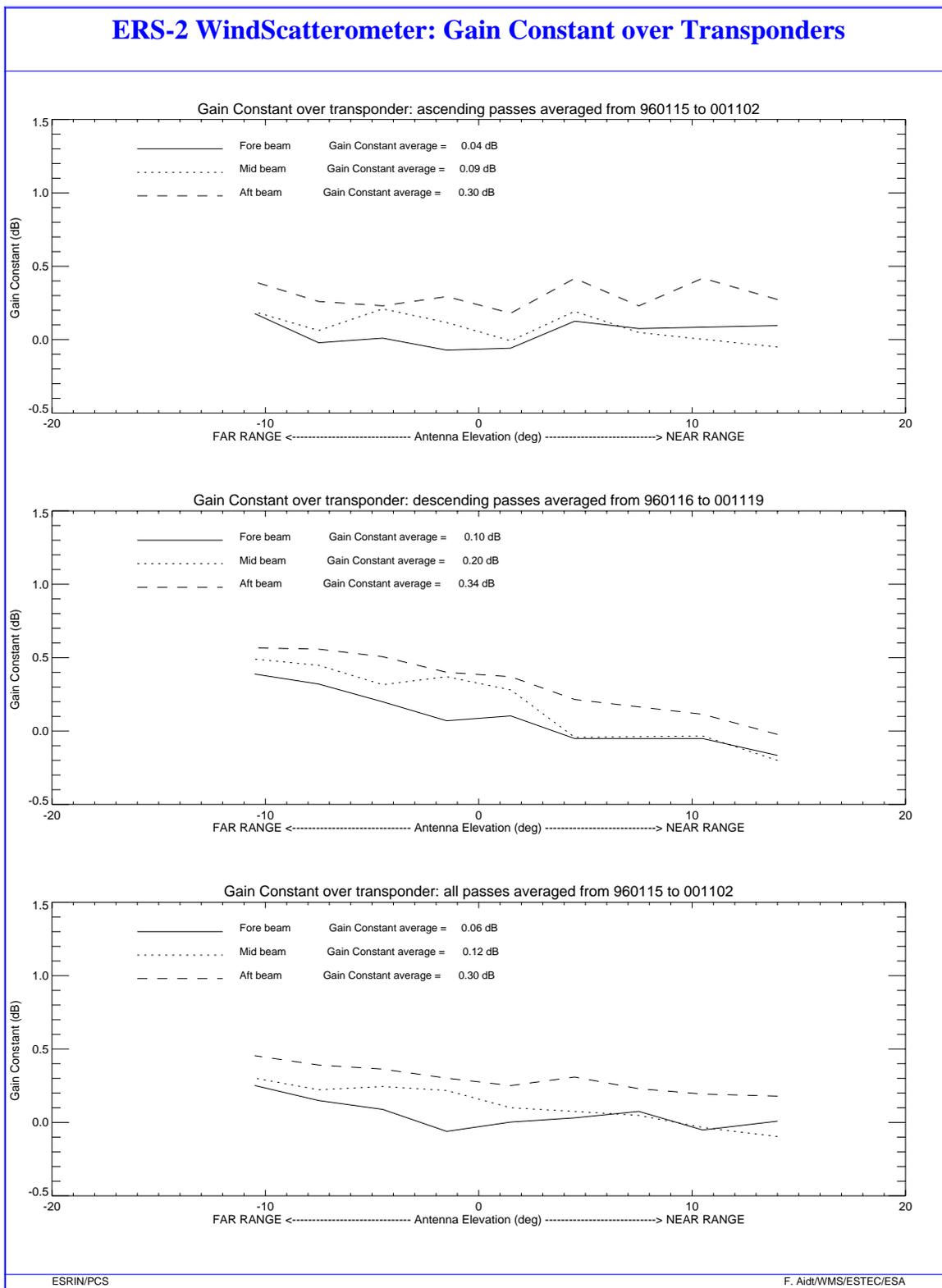


FIGURE 4. ERS-2 Scatterometer: gain constant over transponders plus a scaling factor. All data available since January 1996. Upper plot: ascending passes. Middle plot: descending passes. Lower plot: all passes.

2.2 Ocean Calibration

ECMWF performs the monitoring of ERS-2 sigma noughts over ocean (see the report in Annex).

The Scatterometer sigma noughts are compared with the ECMWF model first guess winds. The analysis is done for each incidence angle both ascending and descending passes. The result of the analysis are the antenna pattern biases.

The results are related only to the period 8th - 16th January 2001. In that period the amount of received data was stable and with good quality. Compared to the results of the previous cycle, the sigma nought bias level of the descending and ascending tracks has been improved for all three beams. At moment the reason of this remarkable result is not clear.

2.3 Gamma-nought over Brazilian rain forest

Although the transponders give accurate measurements of the antenna attenuation at particular points of the antenna pattern, they are not adequate for fine tuning across all incidence angles, as there are simply not enough samples. The tropical rain forest in South America has been used as a reference distributed target. The target at the working frequency (C-band) of ERS-2 Scatterometer acts as a very rough surface, and the transmitted signal is equally scattered in all directions (the target is assumed to follow the isotropic approximation). Consequently, for the angle of incidence used by ERS-2 Scatterometer, the normalised backscattering coefficient (sigma nought) will depend solely on the surface effectively seen by the instrument:

$$S^0 = S \cdot \cos \theta$$

With this hypothesis it is possible to define the following formula:

$$\gamma^0 = \frac{\sigma^0}{\cos \theta}$$

Using this relation, the gamma nought backscattering coefficient over the rain forest is independent of the incident angle, allowing the measurements from each of the three beams to be compared.

The test area used by the PCS is located between 2.5 degrees North and 5.0 degrees South in latitude and 60.5 degrees West and 70.0 degrees West in longitude.

The following paragraphs give a description of the activities carried out with this natural target.

2.3.1 Antenna pattern: Gamma-nought as a function of elevation angle

This analysis is normally carried out by ESTEC that has selected a larger region than the one used as test area within PCS. In this case the selected rain forest extends from 2.0 degrees South to 11.0 degrees South in latitude and 56.0 degrees West to 80 degrees West in longitude. A large area is selected in order to have a larger amount of measurements.

For cycle 60, the antenna patterns as function of the elevation angle have not been computed by ESTEC.

2.3.2 Antenna pattern: Gamma-nought as a function of incidence angle

Figure 5 shows the antenna patterns as a function of the incidence angle for cycle 60.

Due to the small amount of available data and EBM operations the antenna patterns show a bad quality. In particular the antenna profiles are not flat across the swath.

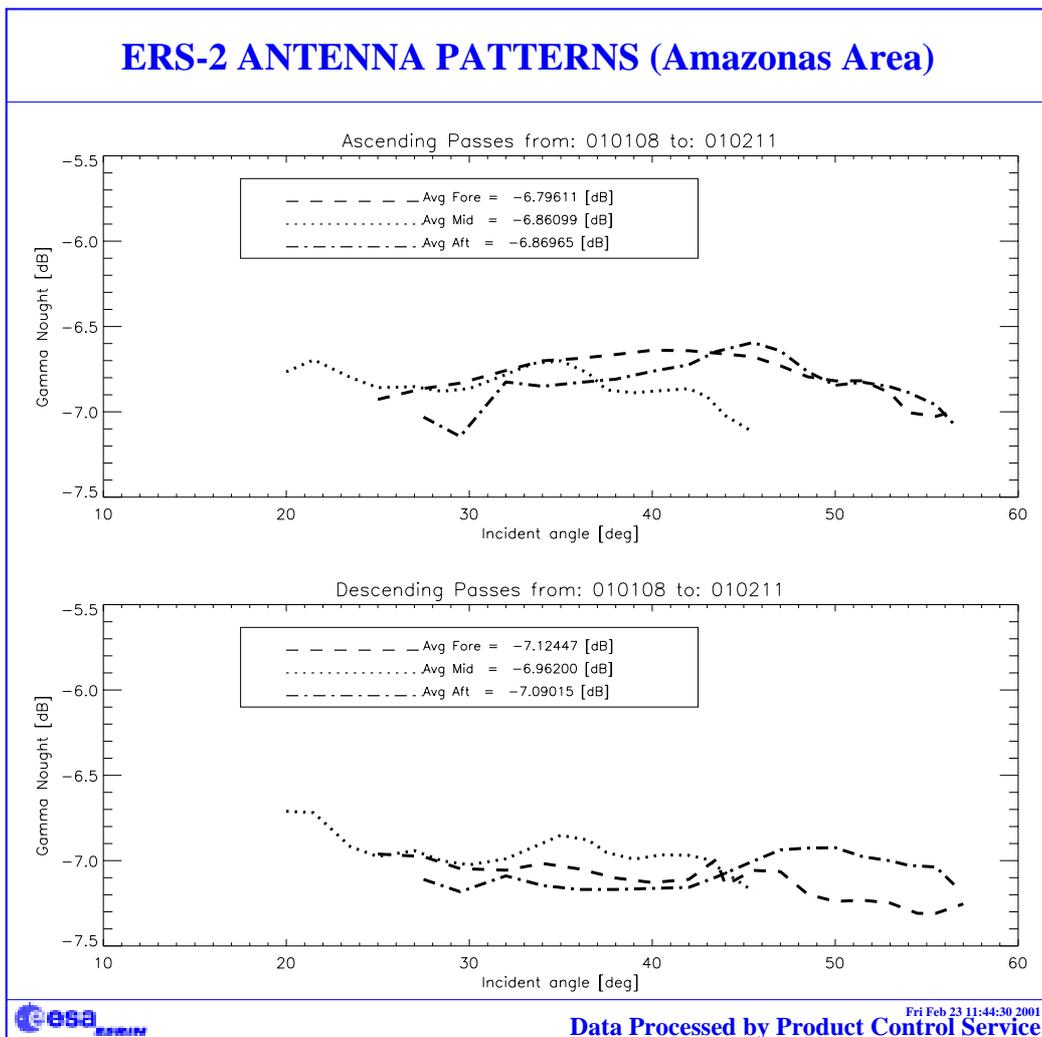


FIGURE 5. ERS-2 Scatterometer antenna patterns as function of the incidence angle: cycle 60.

2.3.3 Gamma nought histograms and peak position evolution

As the gamma nought is independent from the incidence angle, the histogram of gamma noughts over the rain forest is characterised by a sharp peak. The time-series of the peak position gives some information on the stability of the calibration. This parameter is computed by fitting the histogram with a normal distribution added to a second order polynomial:

$$F\langle x \rangle = A_0 \cdot \exp\left(-\frac{z^2}{2}\right) + A_3 + A_4 \cdot x + A_5 \cdot x^2$$

where:
$$z = \frac{x - A_1}{A_2}$$

The parameters are computed using a non linear least square method called “gradient expansion”. The position of the peak is given by the maximum of the function $F(x)$. The histograms are computed weekly (from Monday to Sunday) for each antenna individually (“Fore”, “Mid”, and “Aft”) and for ascending and descending passes with a bin size of 0.02 dB.

Figure 6 shows the evolution of the histograms peak position since January 1996. The step shown in March 1996 is due to the end of commissioning phase when a new Look Up Table was used in the ground stations for WSCATT FD-products generation. It is interesting to note the decrease of roughly 0.2 dB from August 1996 to June 1997. This is linked to the switch of the Scatterometer calibration subsystem from side A to side B on 6th of August. The redundancy of side A device caused a little change in the calibration that was corrected on 19th June 1997 with a new calibration LUT used in the ground processing.

Figure 7 shows the evolution of the peak position corrected with the new calibration set also for the period from August 1996 to June 1997. The plots in Figure 7 show that the calibration stability achieved over the rain forest is within 0.5 dB. A seasonal effect is also present in the peak position evolution for the three antennae.

After the 17th January 2001 the calibration level had a large drop, up to 1 dB in the peak position, due to EBM operation.

The EBM is a coarse attitude control mode that causes a large Doppler shift (see also section 3.1) in the received echo. In the ground processing that frequency shift is not compensated for and the Scatterometer data are not more calibrated. A re-design of the Scatterometer data processor shall be performed to restore the initial data quality.

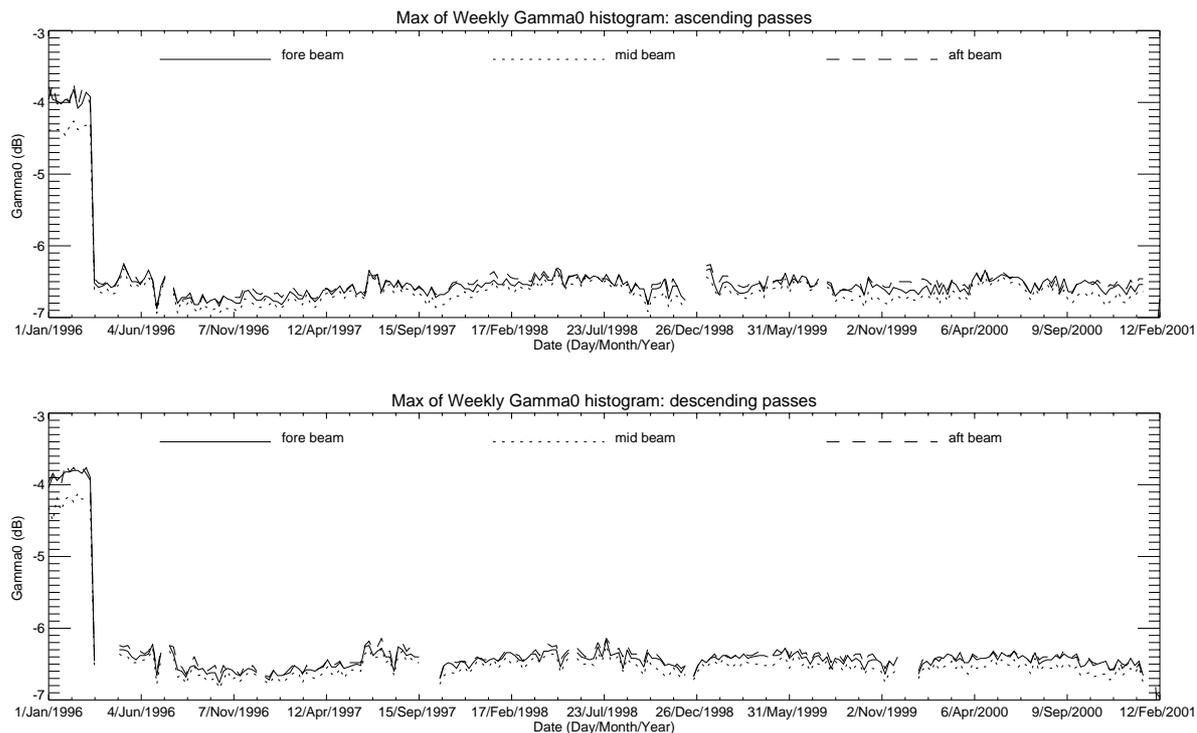


FIGURE 6. ERS-2 Scatterometer, gamma-nought histogram: weekly evolution of maximum position. From up to down: ascending passes, descending passes.

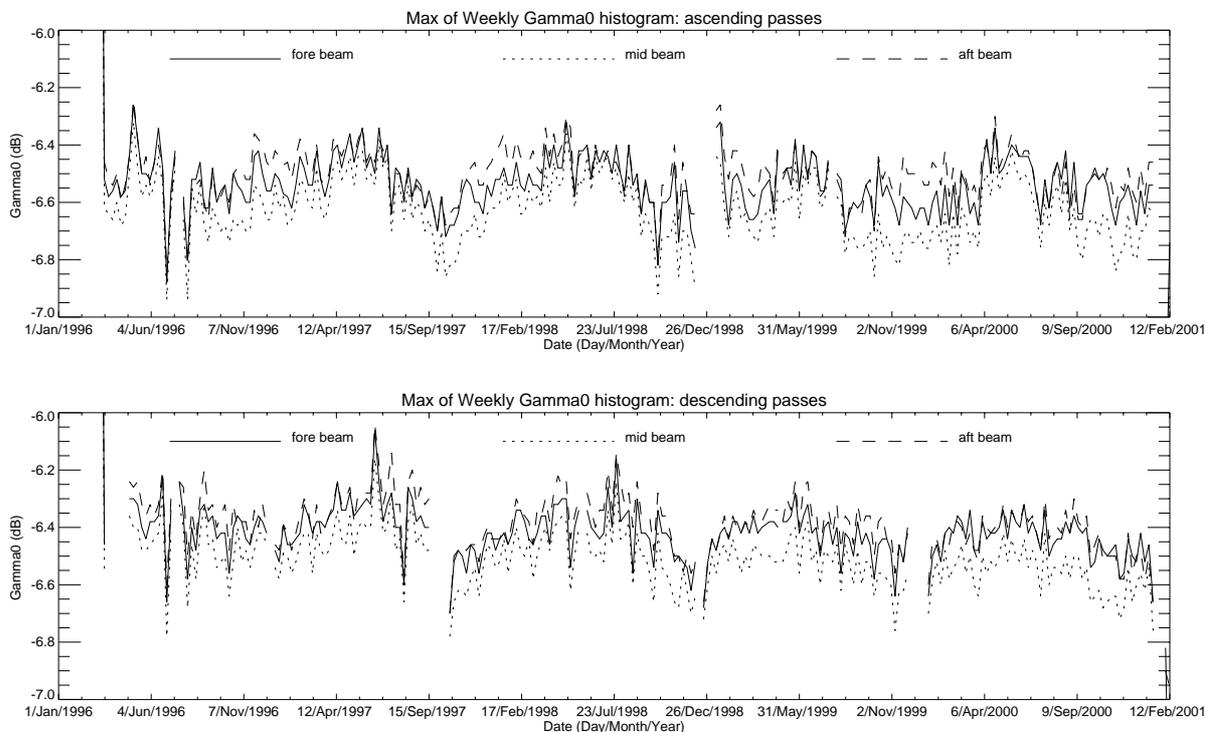


FIGURE 7. Gamma-nought histogram: weekly evolution of maximum position. Data from 6th of August 1996 to 19th June 1997 are corrected with the new calibration constant (+0.2dB). Upper plot: ascending passes. Lower plot: descending passes.

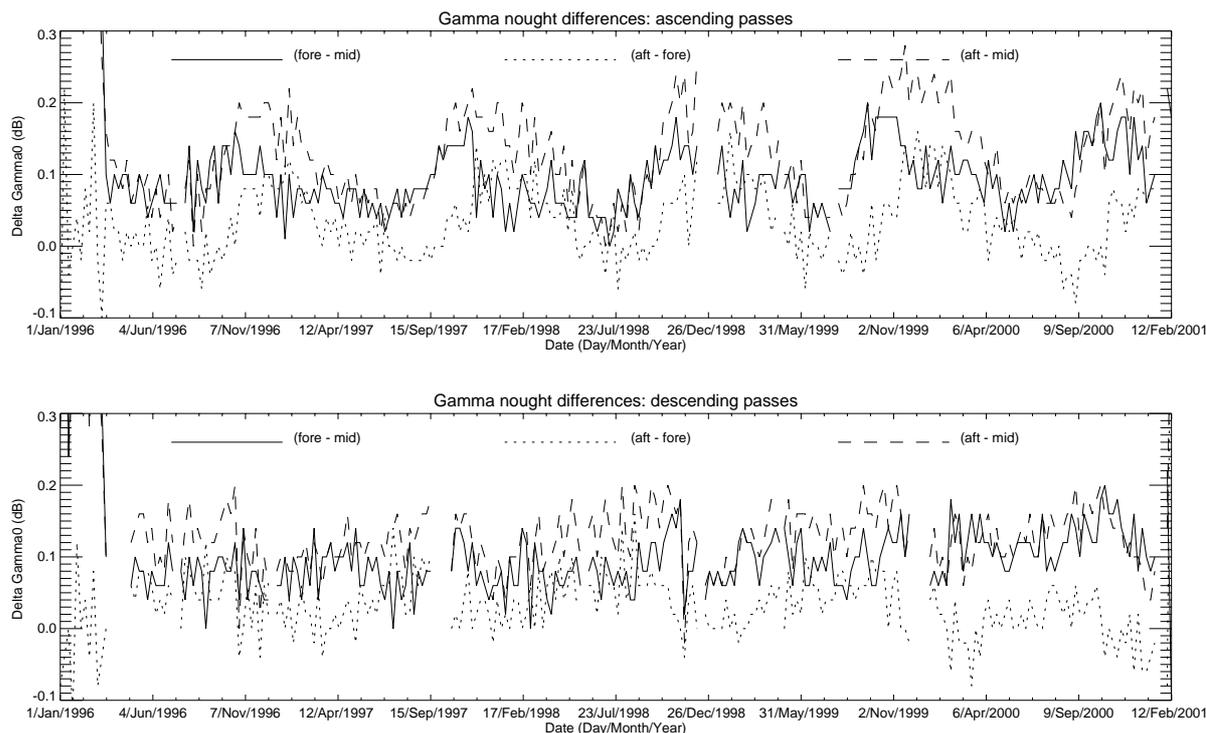


FIGURE 8. Inter-beam calibration, weekly differences of the maximum position since 1st January 1996. From up to down: ascending passes, descending passes.

For the inter-beam calibration, the results since 1996 are shown in Figure 8.

For the ascending passes, the differences in the signals have a seasonal behaviour. On average the differences are close to 0.1 dB during the summer and they are close to 0.2 dB during the winter. For the descending passes, the differences between the winter and the summer are less clear and the inter-beam calibration is around 0.1 dB (-0.03 dB for the aft-fore signal during the cycle 59).

A change around the end of year 1999 and the beginning of year 2000 is clearly present in the (aft-fore) difference signal as well as in the (aft-mid) signal. Investigations have been carried out in order to recognize which antenna has caused the change in the inter-beam calibration (see the report for the cycle 53). It can be noted that this evolution has mainly affected the Aft antenna with a mean decrease of roughly 0.05 dB in the signal. Because of the noise in the time series, it is also difficult to estimate if this evolution is related to mission or instrument events. The most relevant mission events were: the payload switch-off to face out the Leonid meteorite shower (November 1999), a series of AMI emergency switch down anomalies and the AOCS mono-gyro configuration (February 2000).

The mean and the standard deviation of the gamma-noughts are weekly computed directly using the Fast Delivery data. Figure 9 shows the evolution of the standard deviation since September 1996. The ascending passes show a gamma nought standard deviation higher than the descending ones. This can be explained because at ascending passes the test site appears less homogeneous; in particular for some areas near the rivers (see Figure 15). The last plot in Figure 9 shows the number of valid measurements used to compute the statistics. A reduction of the number of valid

observation since the beginning of 1999 can be seen. This is due to an increase of SAR images acquired over the Amazon rain forest.

The high values of the gamma nought standard deviations during the cycle 60 are due to data acquired in EBM (see section 3.1).

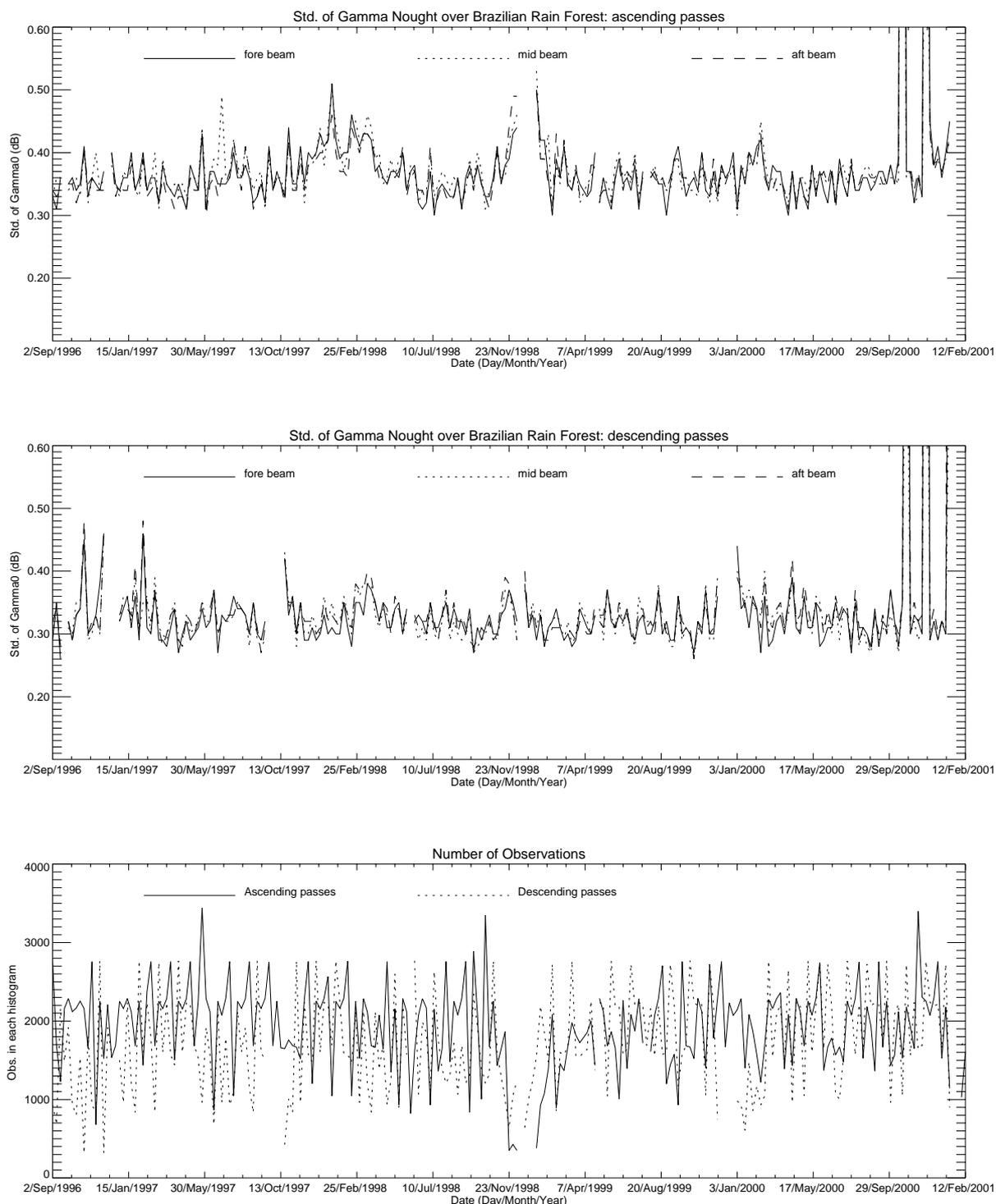


FIGURE 9. Gamma-nought histograms: weekly evolution of standard deviation. From up to down: ascending passes standard deviation, descending passes standard deviation, number of valid observations.

The Figures from 10 to 14 show the gamma nought histogram over the Brazilian rain forest throughout cycle 60.

The histograms for the cycle 60 show a good quality only for the first week of the cycle. Due to EBM operations the histograms for the other weeks show a very bad quality.

For the third and fourth week no data were received due to payload switch-off.

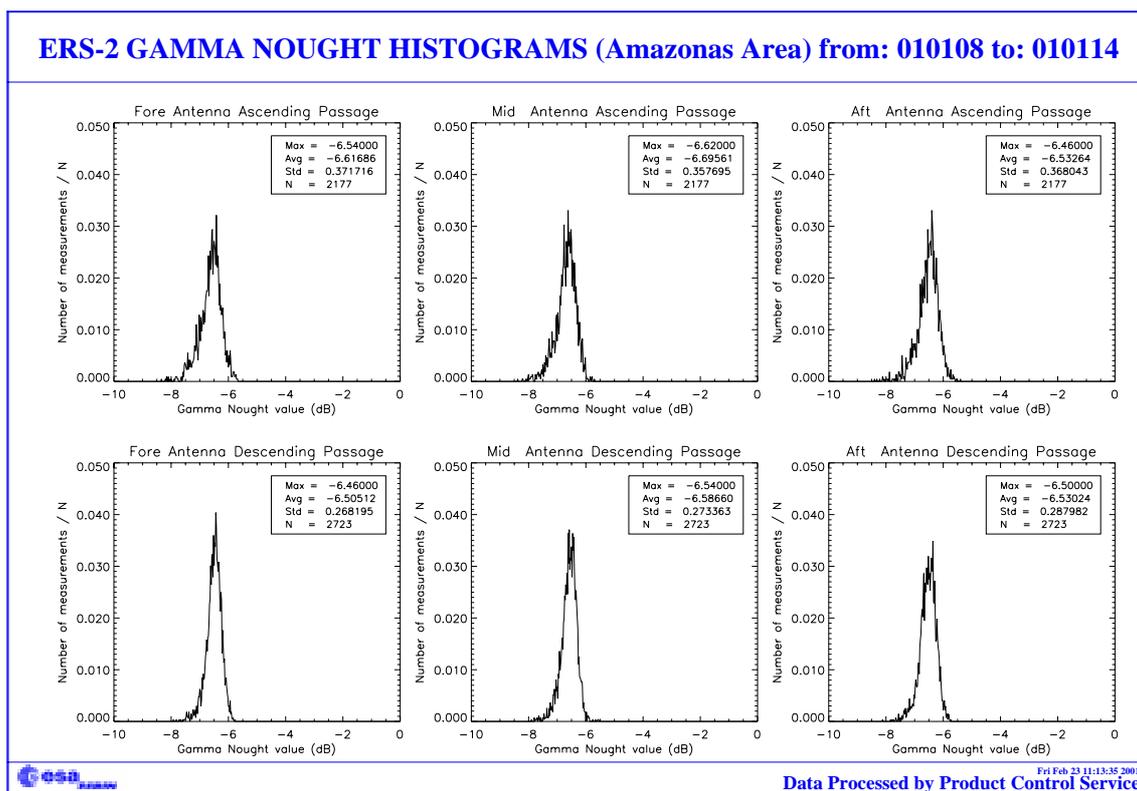


FIGURE 10. Gamma-nought histograms over Brazilian Rain forest: first week of the cycle 60.

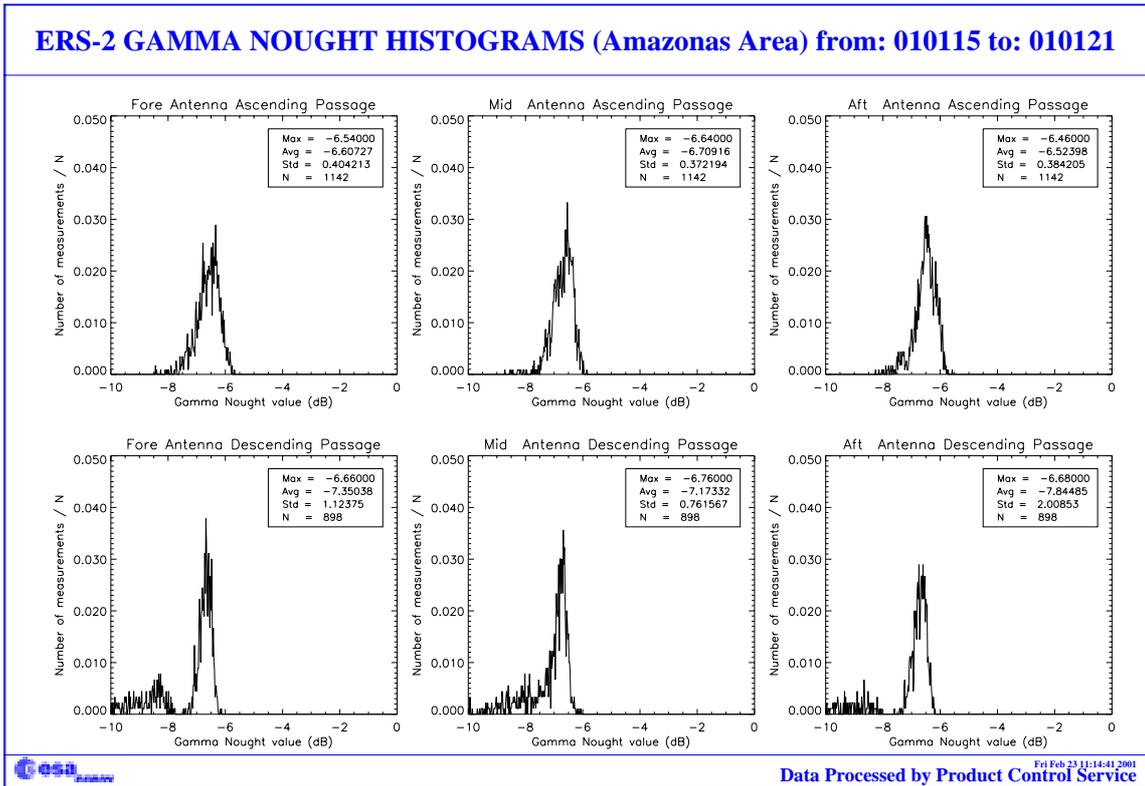


FIGURE 11. Gamma-nought histograms over Brazilian Rain forest: second week of the cycle 60.

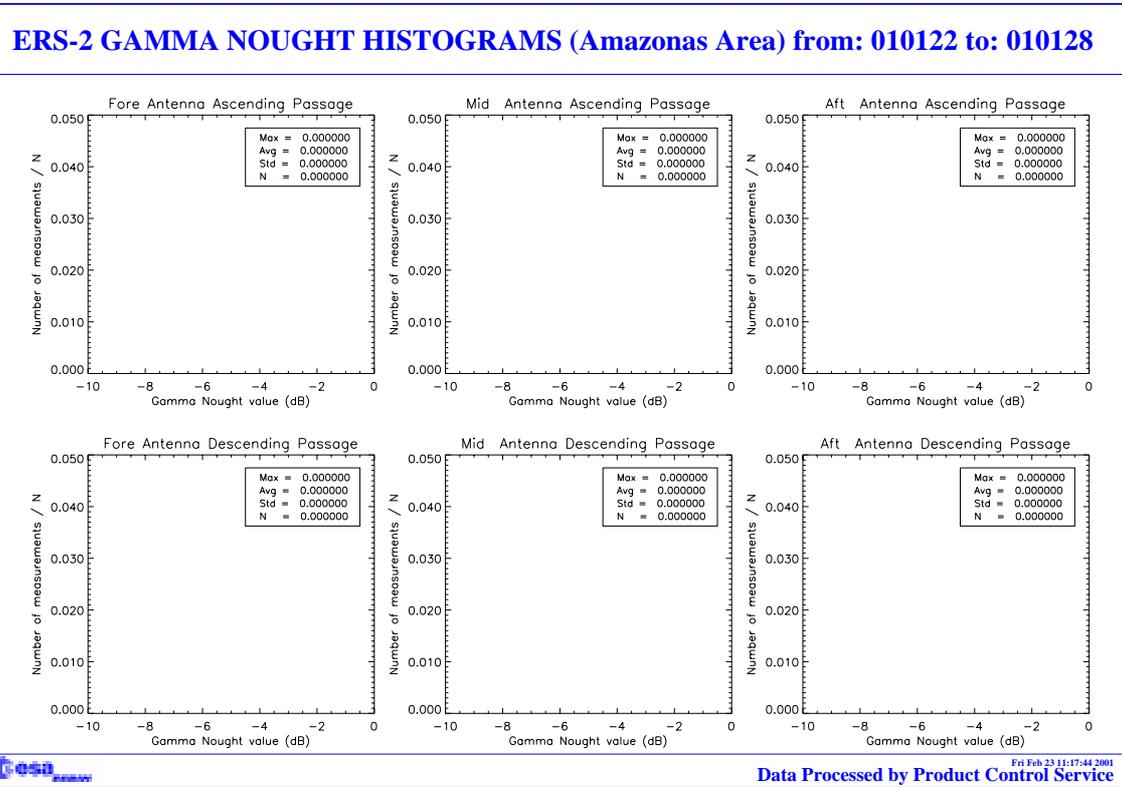


FIGURE 12. Gamma-nought histograms over Brazilian rain forest: third week of the cycle 60.

ERS-2 GAMMA NOUGHT HISTOGRAMS (Amazonas Area) from: 010129 to: 010204

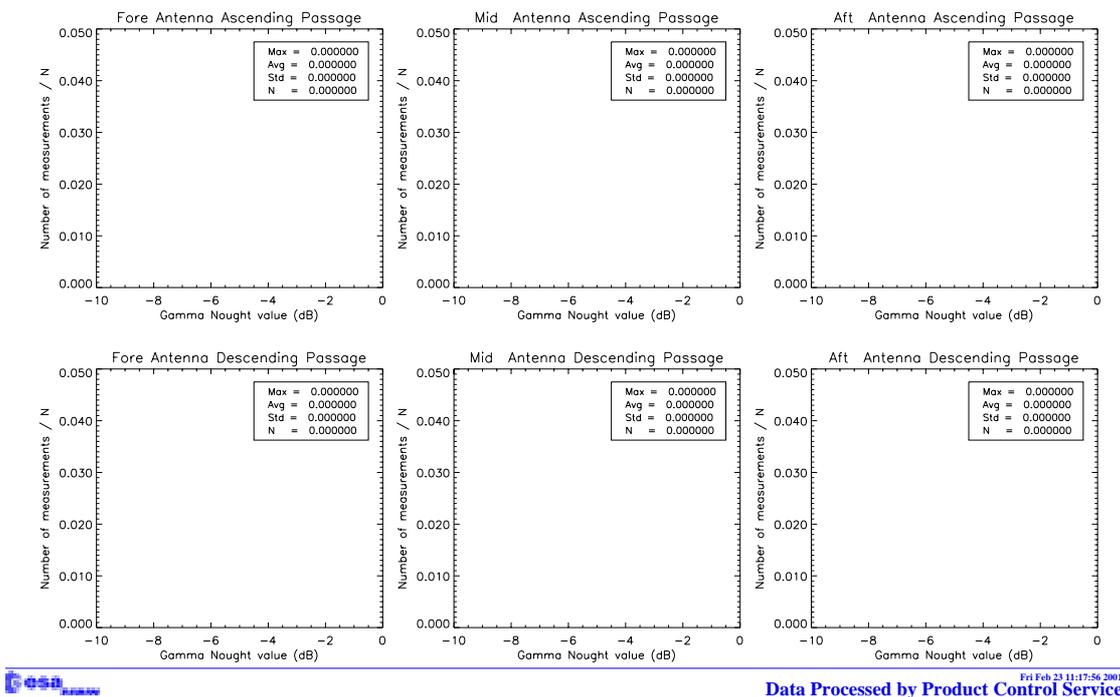


FIGURE 13. Gamma-nought histograms over Brazilian rain forest: fourth week of the cycle 60.

ERS-2 GAMMA NOUGHT HISTOGRAMS (Amazonas Area) from: 010205 to: 010211

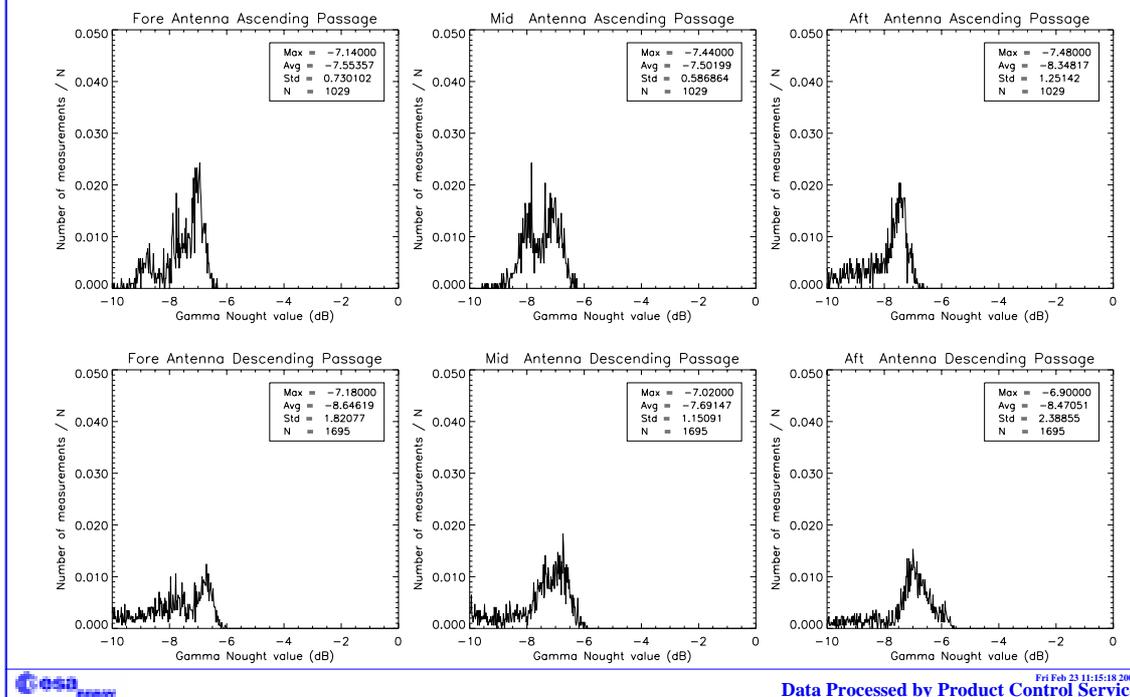


FIGURE 14. Gamma-nought histograms over Brazilian rain forest: fifth week of the cycle 60.

2.3.4 Gamma nought image of the reference area

The Figure 15 shows maps of the gamma nought over the Brazilian rain forest. This is the area where statistics are computed. Each map has a resolution of 0.5 degrees in latitude and 0.5 degrees in longitude, roughly this is the instrument resolution at the latitude of the test site. In each resolution cell falls the average of all the valid observations available during one cycle (35 days).

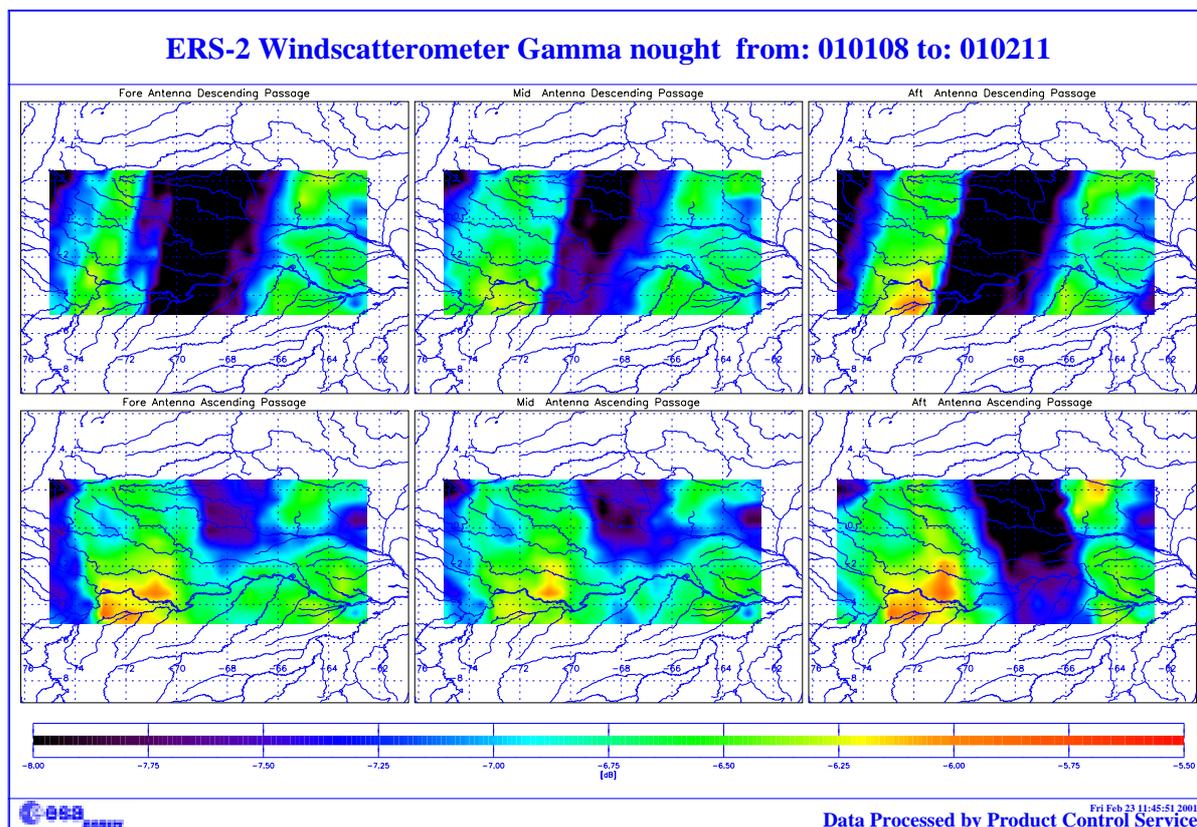


FIGURE 15. ERS-2 Scatterometer: gamma nought over the Brazilian rain forest cycle 60.

For the cycle 60 the large areas with low signal are due to data acquired in EBM.

2.3.5 Sigma nought evolution

The Figures 16 and 17 show the evolution of the sigma nought (mid beam) over the reference area. The analysis is done per orbit and per node and the scope is to evaluate the stability of the sigma nought for each incidence angle. The relative tracks chosen are those where the number of valid measurements for each node (across track) is greater than 20.

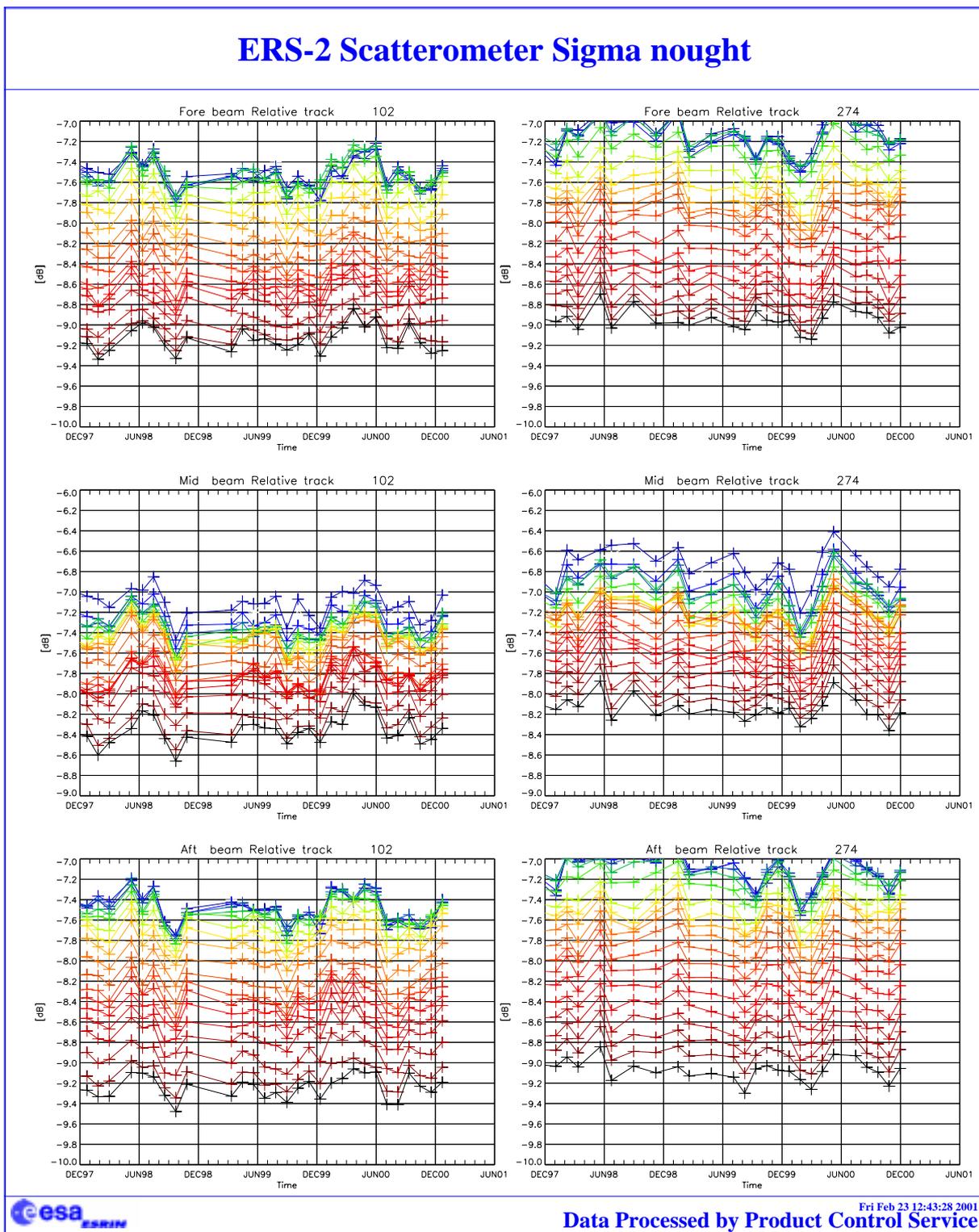


FIGURE 16. Sigma nought over the test area: ascending passes relative tracks 102 (left panels) and 274 (right panels); all nodes across the swath (since December 1997).

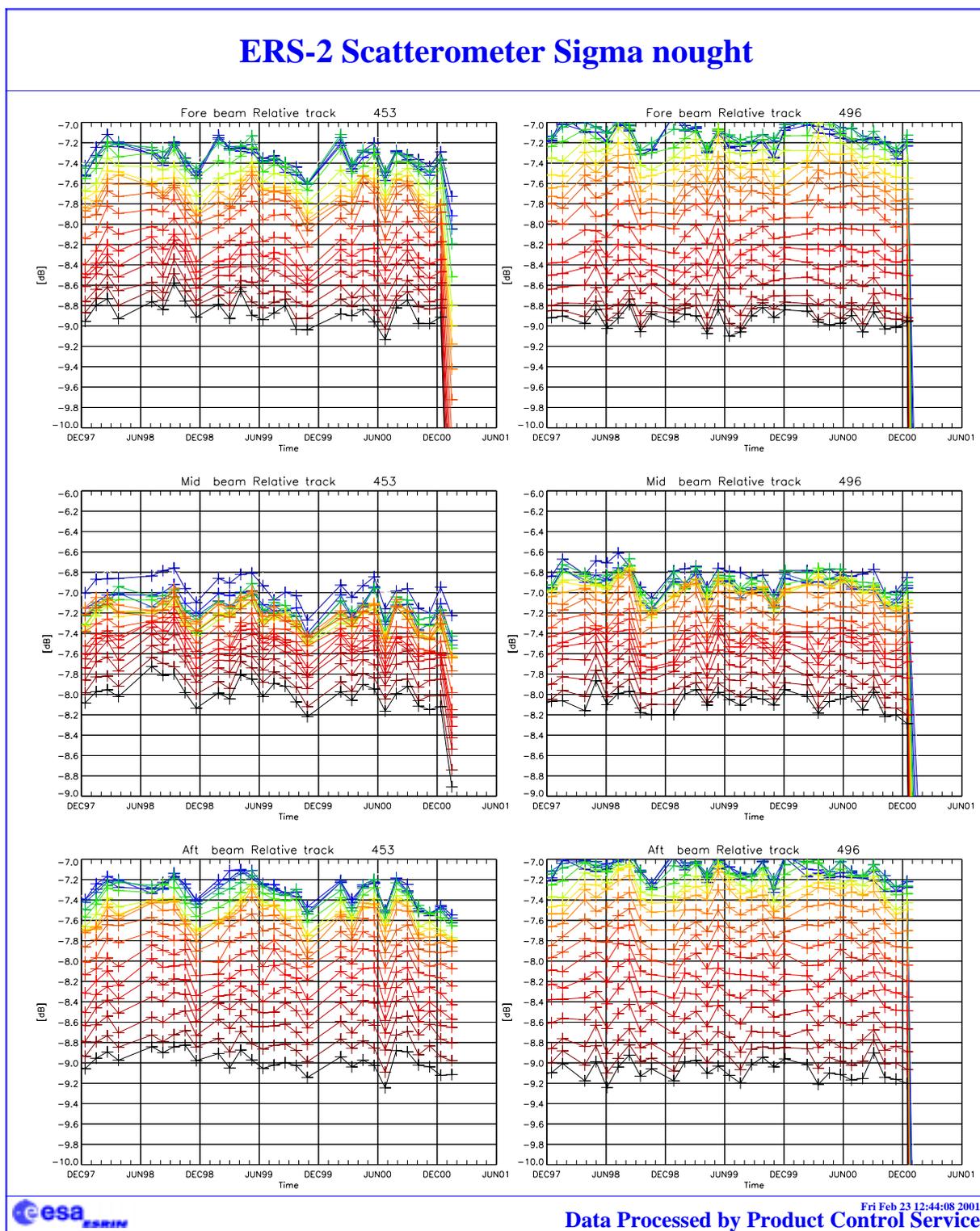
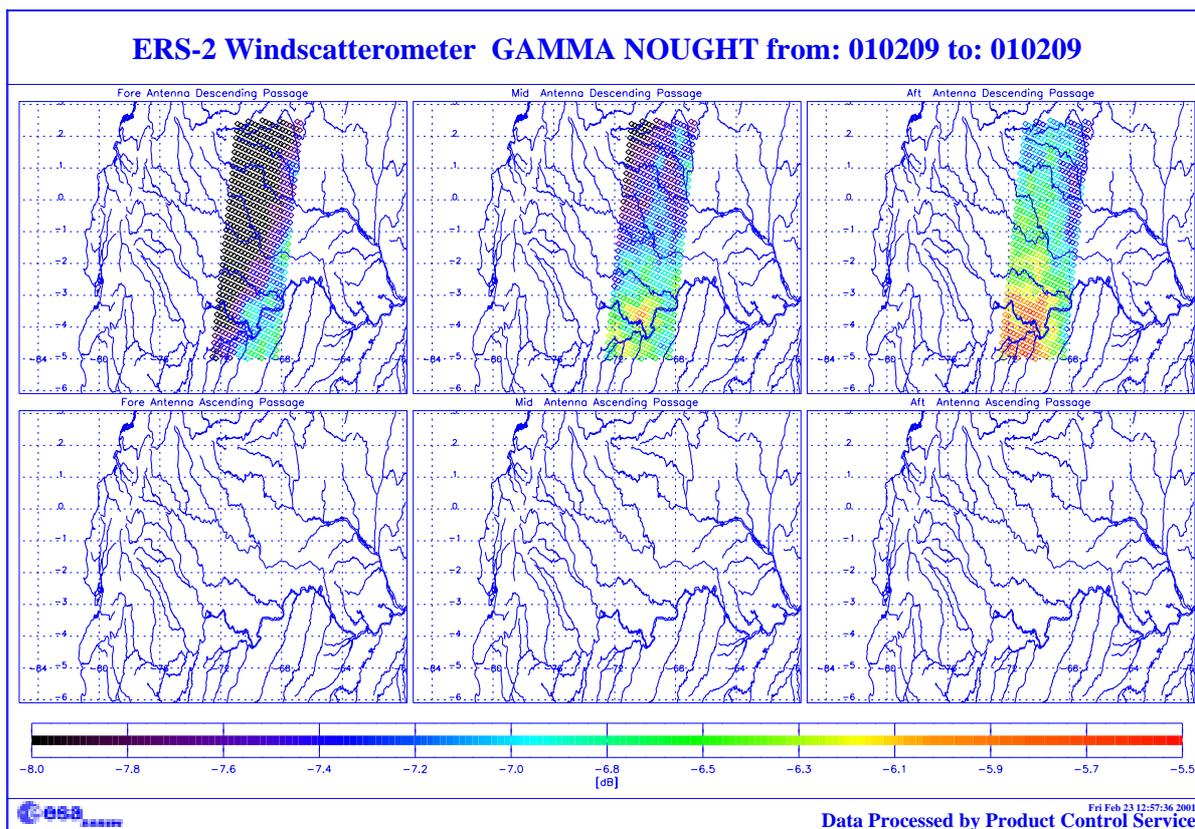


FIGURE 17. Sigma nought over the test area: descending passes relative tracks 453 (left panels) and 496 (right panels); all nodes across the swath (since December 1997).

The time series show a good correlation among the adjacent nodes (near and far range) and the stability, of the sigma nought, until 17th January 2001, ranges from 0.2 to 0.5 dB depending on the node.

The result of the monitoring for the cycle 60 is a very stable signal for the ascending track (acquired in mono-gyro) while for the descending tracks it is clear the decrease of the signal (data acquired in EBM). The signal decrease is more important at higher nodes (red and black coloured). For the relative track 453 (acquired on 9th February 2001) the aft beam signal shows a stable signal level. This means that the satellite attitude changed very quickly between the fore beam sensing time and the aft beam sensing time (roughly 100 s.) as shown below in the gamma nought maps.



ERS-2 Scatterometer Gamma Nought over the Rain Forest: descending track 9th February 2001.

2.3.6 Antenna temperature evolution over the Rain Forest

The monitoring of the antenna temperature over the Brazilian rain forest is performed by PCS. The antenna temperatures are retrieved from the satellite telemetry when the Scatterometer swath is over the test site and the instrument is active (AMI in wind only or wind/wave mode). The scope of this monitoring is to investigate a possible correlation between the antenna temperatures and the gamma-nought level. This correlation is not clear in the actual data because of the gamma nought variability over the selected area. A deep analysis is to be performed to better understand the facts.

The plots for the three beams and for the ascending, descending and all passes are presented in Figure 18. It is interesting to note that the annual variation is due to the earth inclination and that the antenna temperatures have an increase of roughly 1.0 degree per year in the case of the mid and fore antenna and 2 degrees per year for the aft antenna.

This temperature increase could be related to the degradation of the antennae protection film.

The result of the monitoring during the cycle 60 shows that the antenna temperature evolution is within the nominal range.

ERS-2 WindScatterometer: Antennas Temperature Evolution Over Rain Forest

Data available for descending passes : 987

Data available for ascending passes : 1094

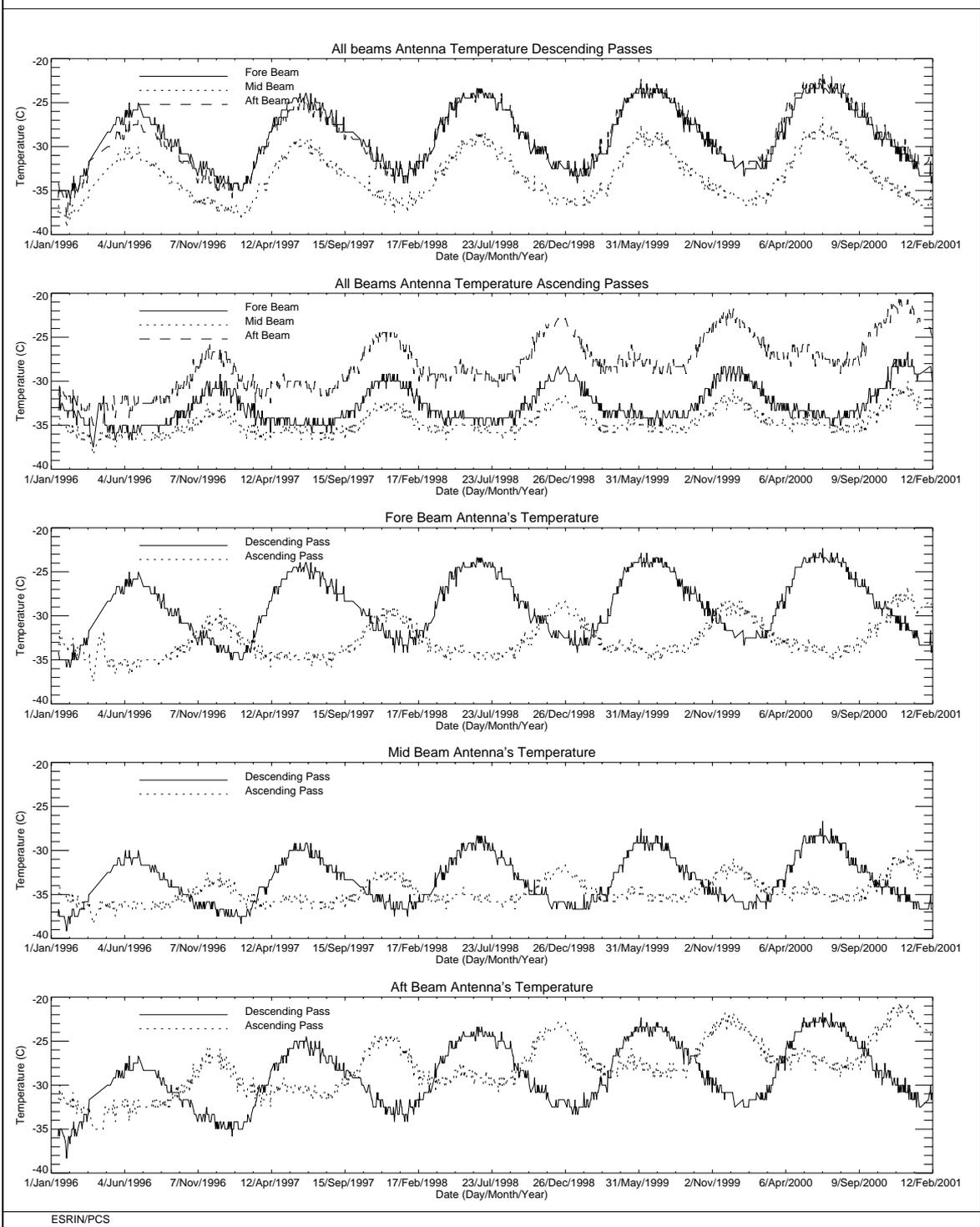


FIGURE 18. ERS-2 Scatterometer: evolution of the antenna temperatures over the Brazilian rain forest.

3.0 Instrument performance

The instrument status is checked by monitoring the following parameters:

- Centre of Gravity (CoG) and standard deviation of the received signal spectrum. This parameter is useful for the monitoring of the orbit stability, the performances of the doppler compensation filter, the behaviour of the yaw steering mode and the performances of the devices in charge for the satellite attitude (e.g. gyroscopes, Earth sensor, Sun sensor).
- Noise power I and Q channel.
- Internal calibration pulse power.

the latter is an important parameter to monitor the transmitter and receiver chain, the evolution of pulse generator, the High Power Amplifier (HPA), the Travelling Wave Tube (TWT) and the receiver.

These parameters are extracted daily from the UWI products and averaged. The evolution of each parameter is characterised by a least square line fit. The coefficients of the line fit are printed in each plot.

3.1 Centre of gravity and standard deviation of received power spectrum

The Figure 19 shows the evolution of the two parameters for each beam.

The tendency from the beginning of the mission to the operation with the new Attitude On-board Control System (AOCS) configuration (7th February 2000) is a clear and regular increase of the Centre of gravity (CoG) of received spectrum for the three antennae. An increase of roughly 200 Hz was observed at the end of the AOCS qualification period. After the AOCS commissioning phase this parameter further evolved.

The old AOCS configuration (one Digital Earth Sensor - DES, one Digital Sun Sensor - DSS and 3 gyros) is no more considered safe because 3 of the six gyros on-board are out of order or very noisy. The new attitude control configuration is designed to pilot the ERS-2 using only one gyro plus the DES and the DSS modules. Scope of this new configuration is to extend the satellite lifetime by using the available gyros one at the time.

For the new AOCS configuration, the gyro 5 was used until 7th October 2000 when it failed. From 10th October 2000 to 24th October 2000 was used the gyro 6 and this explains the decrease of roughly 100Hz in the CoG of the received spectrum. From 25th October 2000 to 17th January 2001 the gyro 1 was used to pilot the ERS-2 satellite.

On 17th January 2001 the AOCS was upgraded. The new configuration allows to pilot the satellite without gyroscopes. Unfortunately a failure of the Digital Earth Sensor (DES A-side) caused ERS-2 to enter in Safe-Mode on the same day. On 25th January 2001 gyro #1 also failed. During the period of safe mode the spacecraft had drifted out of the nominal deadband by some 30 Km. The nominal orbit was reached on 6th February 2001.

In order to preserve the remaining gyroscopes for further manoeuvres, ERS-2 will now be operated in Extra Backup Mode (EBM). The EBM is a coarse attitude control mode.

Until 17th January 2001 the evolution of the standard deviation of the CoG of the received spectrum was stable apart from the change occurred on 26th, October 1998. On October 26th, 1998 the standard deviation of the CoG had, on average, a decrease of roughly 100 Hz for the fore and aft antenna and of roughly 30Hz for the mid antenna. This change is linked with the increase of the transmitted power (see Section 3.3).

Other changes in the AOCS configuration are recognised in Figure 19. The two steps observed at the beginning of the plots of the CoG (see Figure 19) are due to a change in the pointing subsystem (DES reconfiguration) side B instead of side A after a depointing anomaly (see table 2 for the list of the all AOCS depointing anomaly occurred during the ERS-2 mission). The first change is from 24th, January 1996 to 14th, March 1996, the second one is from 14th February 1997 to 22nd April 1997. During these periods side B was switched on. It is important to note that during the first time a clear difference in the CoG of the received spectrum is present only for the Fore antenna (an increase of roughly 100 Hz) while during the second time the change has affected all the three antennae (roughly an increase of 200 Hz, 50 Hz and 50 Hz for the fore, mid and aft antenna respectively).

Table 2: ERS-2 Scatterometer AOCS depointing anomaly

From	To
24 th January 1996 9:10 a.m.	26 th January 1996 6:53 p.m.
14 th February 1997 1:25 a.m.	15 th February 1997 3:44 p.m.
3 rd June 1998 2:43 p.m.	6 th June 1998 12:47 a.m.
1 st September 1999 8:50 a.m.	2 nd September 1999 1:28 a.m.
7 th October 2000 4:38 p.m.	10 th October 2000 4:49 p.m.
24 th October 2000 4:05 p.m.	25 th October 2000 12:05 p.m.
17th January 2001	6th February 2001

The Figure 19 shows also when the satellite was operated in Fine Pointing Mode (FPM) in EBM mode or the on-board doppler compensation was missing. These events are related with the large peaks in the CoG of the received spectrum plots (fore and aft antenna) and are listed in Table 3.

Table 3: ERS-2 Scatterometer anomalies in the CoG fore and aft antenna

Date	Reason
26 th and 27 th September 1996	missing on-board doppler coefficient (after cal. DC converter test period)
6 th and 7 th June 1998	no Yaw Steering Mode (after depointing anomaly)
2 nd and 3 rd December 1998	missing on-board doppler coefficients (after AMI anomaly 228)
16 th and 17 th February 2000	Fine Pointing Mode (FPM) (due to AOCS mono-gyro qualification period)

Date	Reason
14 th April 2000	Fine Pointing Mode (FPM)
30 th May 2000	Fine Pointing Mode (FPM)
5 th July 2000	Fine Pointing Mode (FPM) after instrument switch-on
27 th September 2000	Fine Pointing Mode (FPM) to up-load AOCS software patch
2 nd November 2000	Fine Pointing Mode (FPM)
5 th and 6 th December 2000	Fine Pointing Mode (FPM) due to orbital manoeuvre
6th February 2001 onwards	Extra Backup Mode (EBM) coarse attitude control

The peaks shown in the plot of mid beam standard deviation of the CoG of the received spectrum are linked to the satellite manoeuvres and AOCS depointing anomaly.

During the cycle 60 the Doppler frequency monitoring shows for the daily average of the CoG of the received spectrum an increase of roughly 1000 Hz for the Aft and Fore antenna and roughly 800 Hz for the mid antenna (see Figure 20). The evolution of the Doppler frequency around the orbit is shown in figure 21 (Mid Antenna).

In Figure 21 is plotted, with different colours, the three days averaged CoG of the received spectrum (mid antenna) as time function from the ascending node (time = 0). Each unit of the X axis is 5 seconds from the ascending node while the Y axis is the frequency in Hz. The curves are obtained filtering the evolution of the CoG of the received spectrum throughout the orbit.

The large fluctuation of the Doppler frequency after 17th January 2001 are due to EBM operations. The amplitude of the variation during one orbit is greater than 1500 Hz (absolute value).

The evolution of the standard deviation of the CoG of the received spectrum shows an increase of roughly 2500 Hz for the Fore and Aft antenna and roughly 1500 Hz for the mid antenna (see Figure 20).

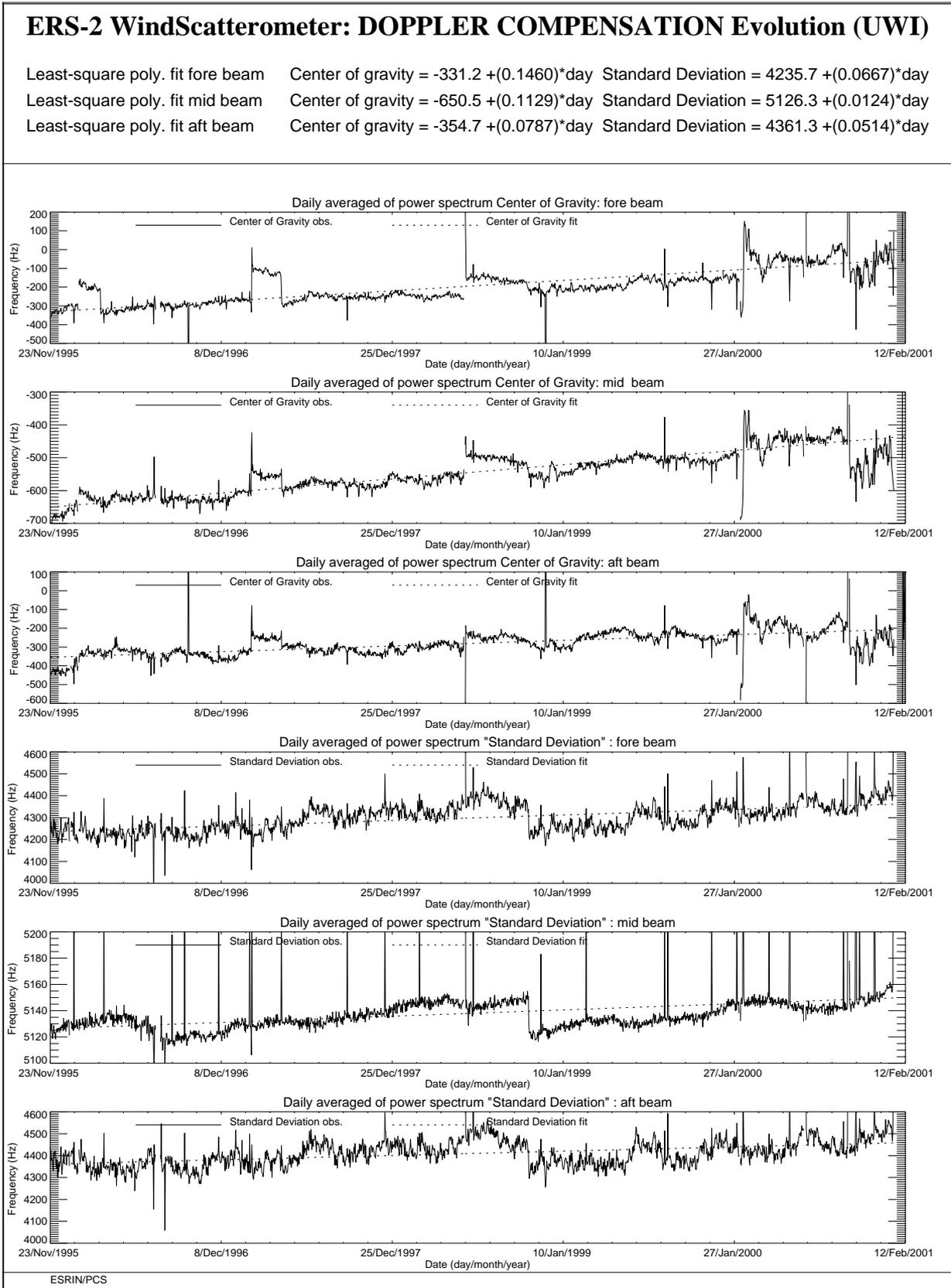


FIGURE 19. ERS-2 Scatterometer: Centre of Gravity and standard deviation of received power spectrum since the beginning of the mission.

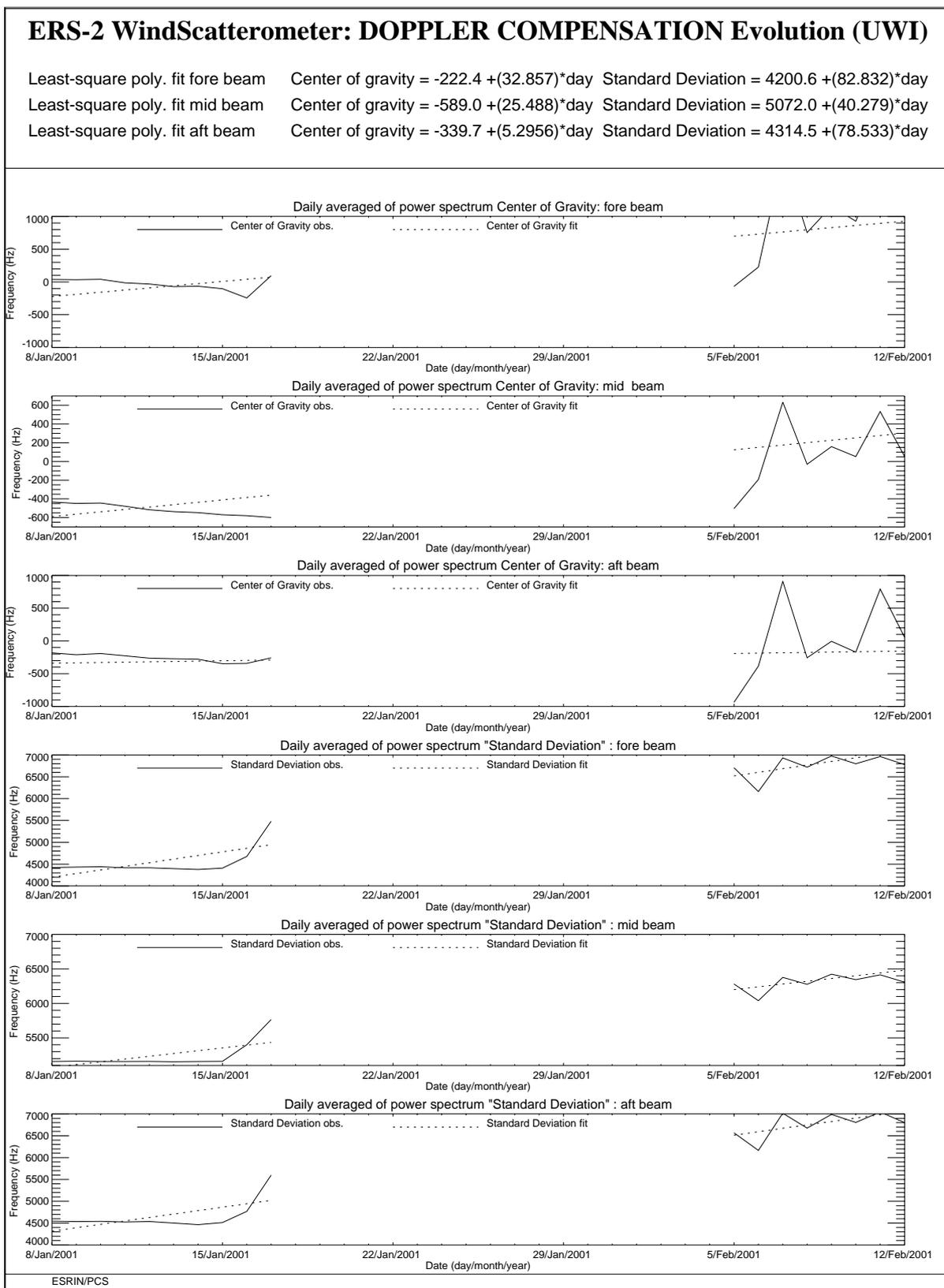


FIGURE 20. ERS-2 Scatterometer: Centre of Gravity and standard deviation of received power spectrum during the cycle 60.

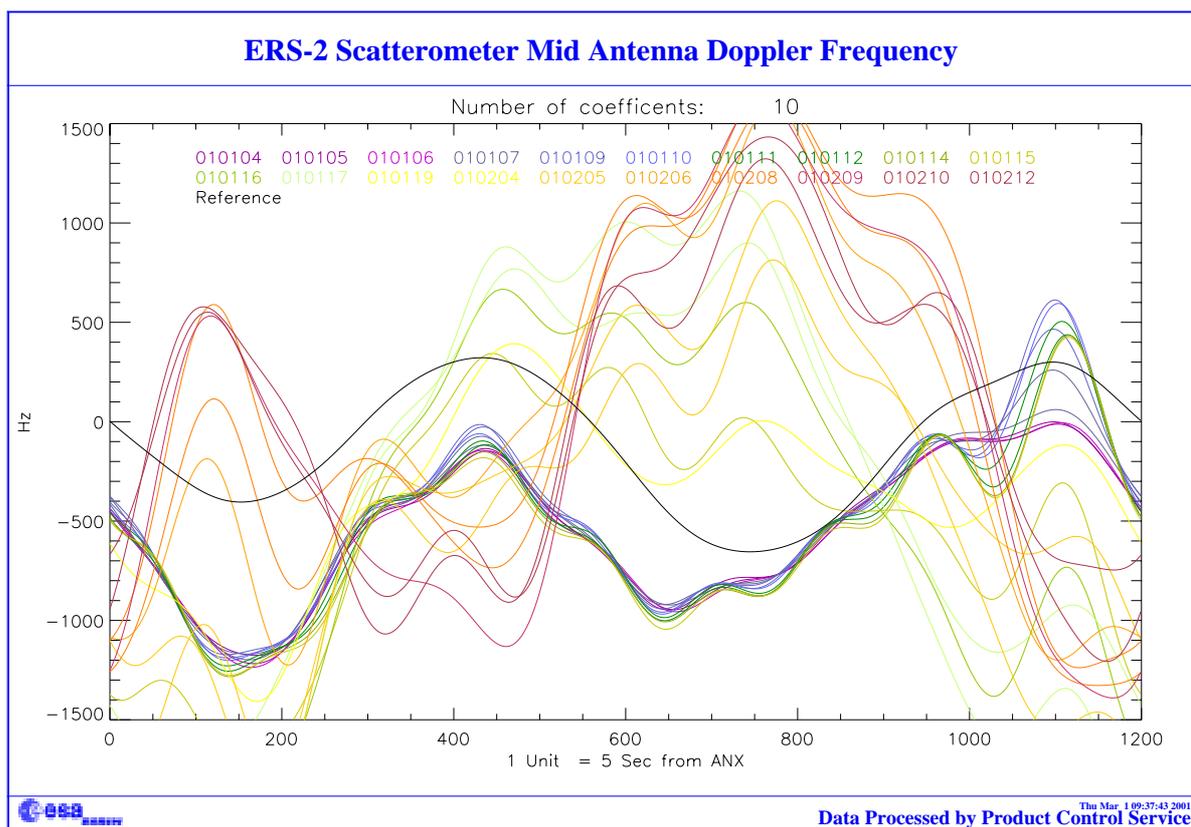


FIGURE 21. Low pass filtered evolution of the Mid beam CoG as function of ascending node time (1 unit 5 s.) Cycle 60.

3.2 Noise power level I and Q channel

The results of the monitoring are shown in Figure 22. The first set of three plots presents the noise power evolution for the I channel while the second set shows the Q channel. The noise level is less than 1 ADC Unit for the fore and aft signals and is negligible for the mid one. From the plots one can see that the noise level is more stable in the I channel than in the Q one. The PCS suspects that an explanation should be found in the different position of the receivers, in particular it seems that the Q one is closer to the ATSR-GOME electronics. A confirmation of this hypothesis has been asked to ESTEC.

Since 5th December 1997 some high peaks appear in the plots. These high values for the daily mean are due to the presence for these special days of a single UWI product with an unrealistic value in the noise power field of its Specific Product Header. The analysis of the raw data used to generate these products lead in all cases to the presence of one source packet with a corrupted value in the noise field stored into the source packet Secondary Header. Table 4 presents the list of the UWI products affected by a corrupted noise field and disseminated during cycle 60.

Table 4: UWI products with noise field corrupted (cycle 60)

Noise Field corrupted	Noise value (ADC Unit)	Acquisition Time
None	-	-

The reason why noise field corruption is beginning from 5th December 1997 is at present unknown. It is interesting to note that at the beginning of December 1997, we started to get as well the corruption of the Satellite Binary Times (SBTs) stored in the EWIC product. The impact in the fast delivery products was the production of blank products starting from the corrupted EWIC until the end of the scheduled stop time. A change in the ground station processing in March 1998 overcame this problem.

Since 9th August 1998 some periods with a clear instability in the noise power have been recognised. Table 5 gives the detailed list.

Table 5: ERS-2 Scatterometer instability in the noise power

From	To
9 th August 1998	26 th October 1998
29 th November 1998	6 th December 1998
23 rd December 1998	24 th December 1998
7 th June 1999	10 th June 1999
17 th August 1999	22 nd August 1999
8 th September 1999	9 th September 1999
3 rd October 1999	8 th October 1999
16 th October 1999	18 th October 1999
26 th October 1999	28 th October 1999

From	To
25 th December 1999	2 nd January 2000
10 th February 2000	11 th February 2000
19 th March 2000	26 th March 2000

To better understand the instability of the noise power the PCS has carried out investigations in the scatterometer raw data (EWIC) to compute the noise power with more resolution. The result is that for the orbits affected by the instability the noise power had a decrease of roughly 0.7 dB for the fore and aft signals and a decrease of roughly 0.6 dB in the mid beam case (see the report for the cycle 42).

The decrease of the noise power during the orbits affected by the instability is comparable with the decrease of the internal calibration level that occurred during the same orbits. The reason of this instability (linked to the AMI anomalies) is still under investigation. A plot that shows the correlation among the noise power, the internal calibration level and the AMI anomaly is reported in section 3.3.

Figure 23 shows the evolution of the noise power since 26th October when 2 dB were added to the transmitted power. The periods with the instability in the noise power are clear shown in the plots in particular for the fore and aft beam signals.

During cycle 60 the monitoring of the noise power shows a stable result.

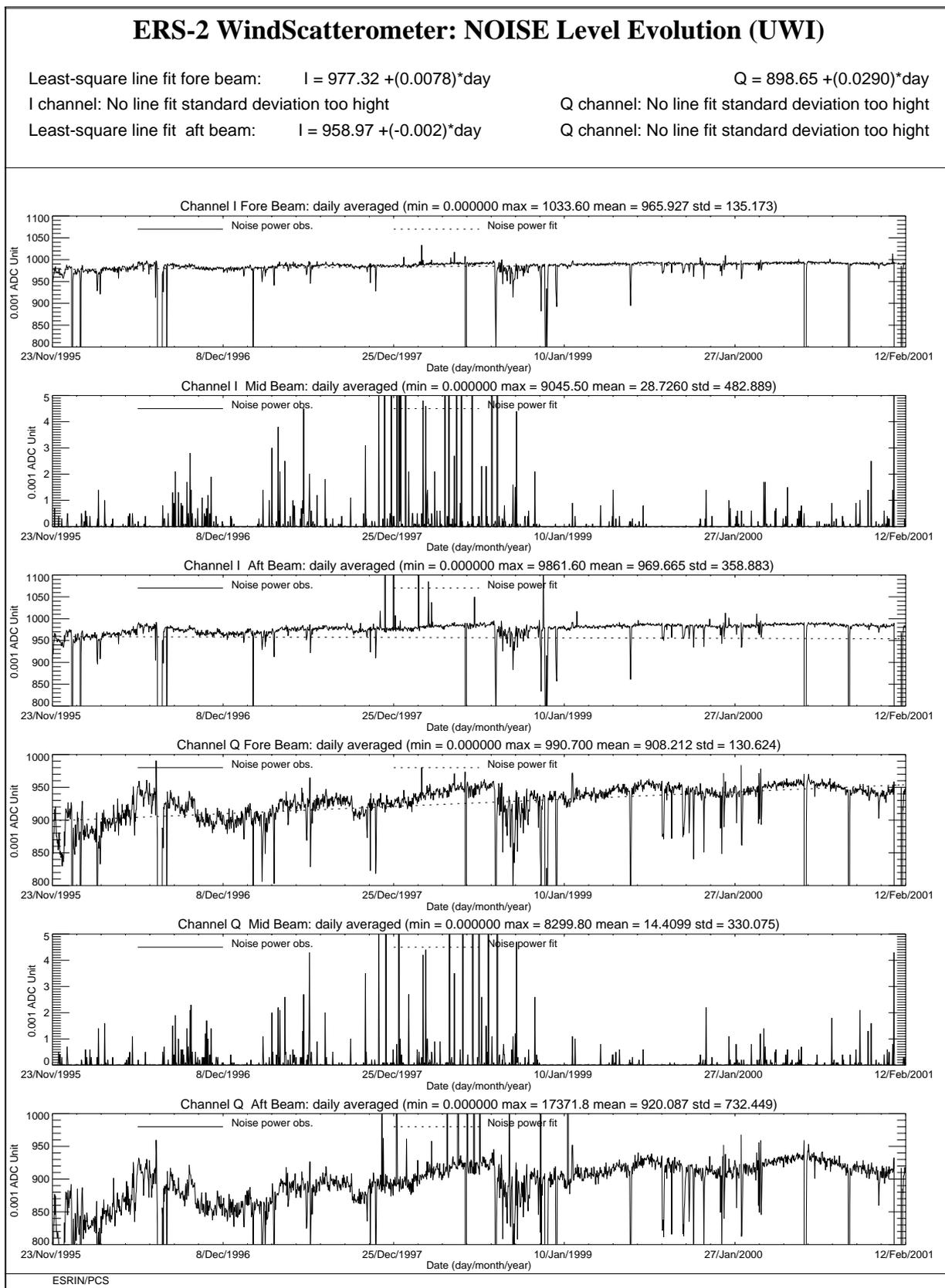


FIGURE 22. ERS-2 Scatterometer: noise power I and Q channel since the beginning of the mission.

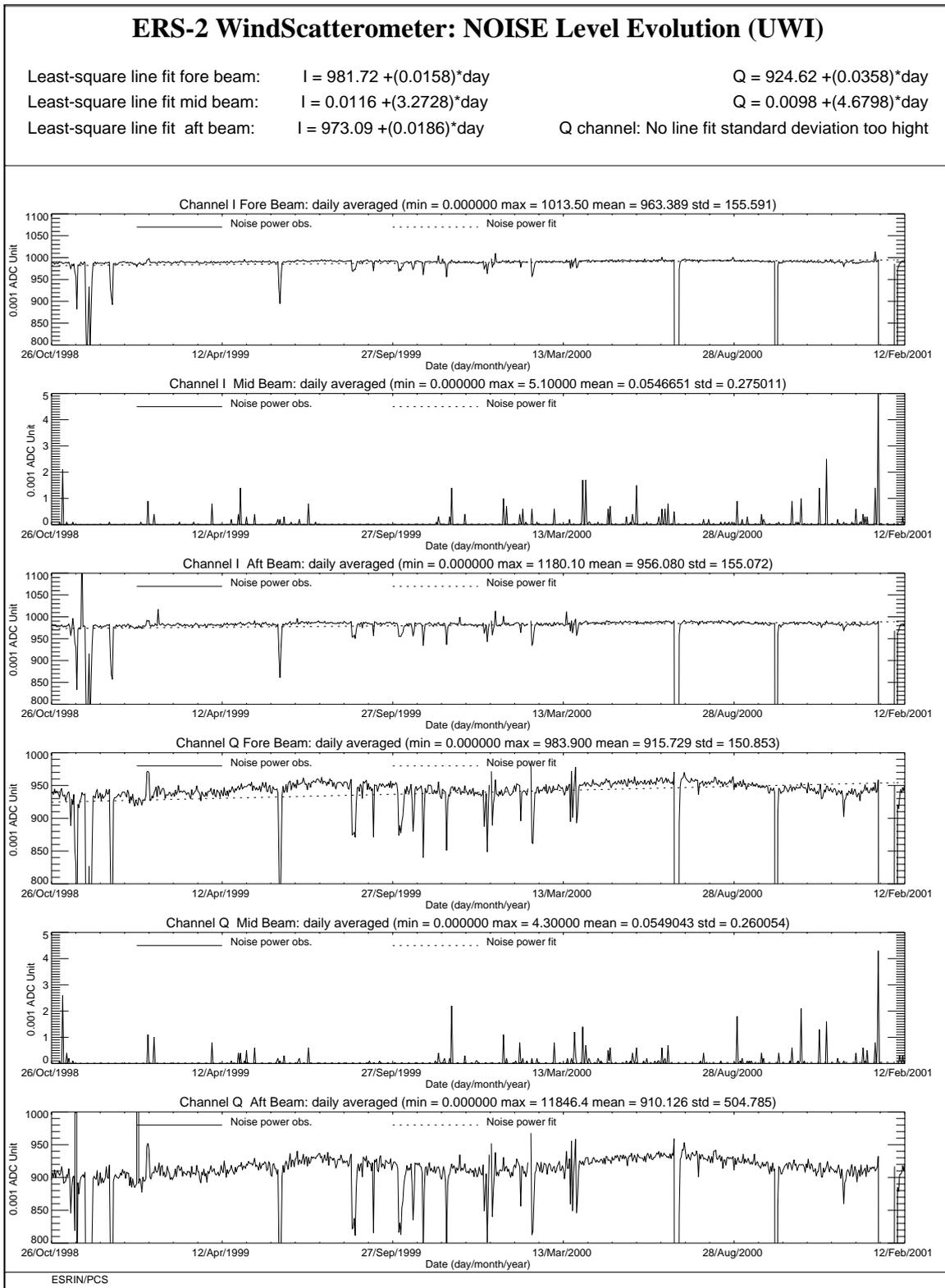


FIGURE 23. ERS-2 Scatterometer: noise power I and Q channel since 26th October 1998 when the transmitted power was increased by 2 dB.

3.3 Power level of internal calibration pulse

For the internal calibration level, the results, since the beginning of the mission, are shown in Figure 25.

The high value of the variance in the fore beam until August, 12th 1996 is due to the ground processing. In fact all the blank source packets ingested by the processor were recognized as Fore beam source packets with a default value for the internal calibration level. The default value was applicable for ERS-1 and therefore was not appropriate for ERS-2 data processing. On August 12th, 1996 a change in the ground processing LUT overcame the problem.

Since the beginning of the mission a power decrease is detected. The power decrease is regular and affects the AMI when it is working in wind-only mode, wind/wave mode and image mode indifferently.

The reason is that the TWT is not working in saturation, so that a variation in the input signal is visible in the output. The variability of the input signal can be two-fold: the evolution of the pulse generator or the tendency of the switches between the pulse generator and the TWT to reset themselves into a nominal position. These switches were set into an intermediate position in order to put into operation the scatterometer instrument (on 16th November 1995).

After the change of the calibration subsystem on August 6th, 1996 the decrease is more evident and it is estimated in 0.09 dB per cycle (0.0025 dB/day).

On 26th October 1998 (cycle 37) to compensate for this decrease, 2.0 dB were added to the Scatterometer transmitted power and this explains the large step shows in Figure 25 and Figure 24. After that day the power decrease is on average 0.08 dB per cycle (0.0022 dB/day).

It is important to point out the efficiency of the internal calibration for keeping the absolute calibration level stable. In fact, no important change is noted in the monitoring of the gamma-nought level over the Brazilian rain forest during the power decrease and after the increase of the transmitted power (see section 2.0).

Since 9th August 1998 the internal calibration level shows an instability. This instability is very well correlated with the fluctuations observed in the noise power as outlined in section 3.2.

Figure 24 shows the daily average of the internal calibration and the noise power from 1st August 1998 to 25th September 2000. In the figure are also reported the anomalies that affected the AMI and the platform (the triangles in the plot) and the days when the instability was very strong (asterisks in the plot).

From Figure 24 it seems that there is a clear correlation between the instability (noise and calibration level) and the AMI anomalies.

On 13th July 2000 an high peak (+3.5 dB) was detected in the transmitted power. This event has been investigated deeply by PCS and ESOC. The results of the analysis are reported in the technical note “ERS-2 Scatterometer: high peak in the calibration level” available in the PCS. The high transmitted power was obtained after an arc event which occurred inside the HPA. After that event the calibration level had an average increase of roughly 0.14 dB.

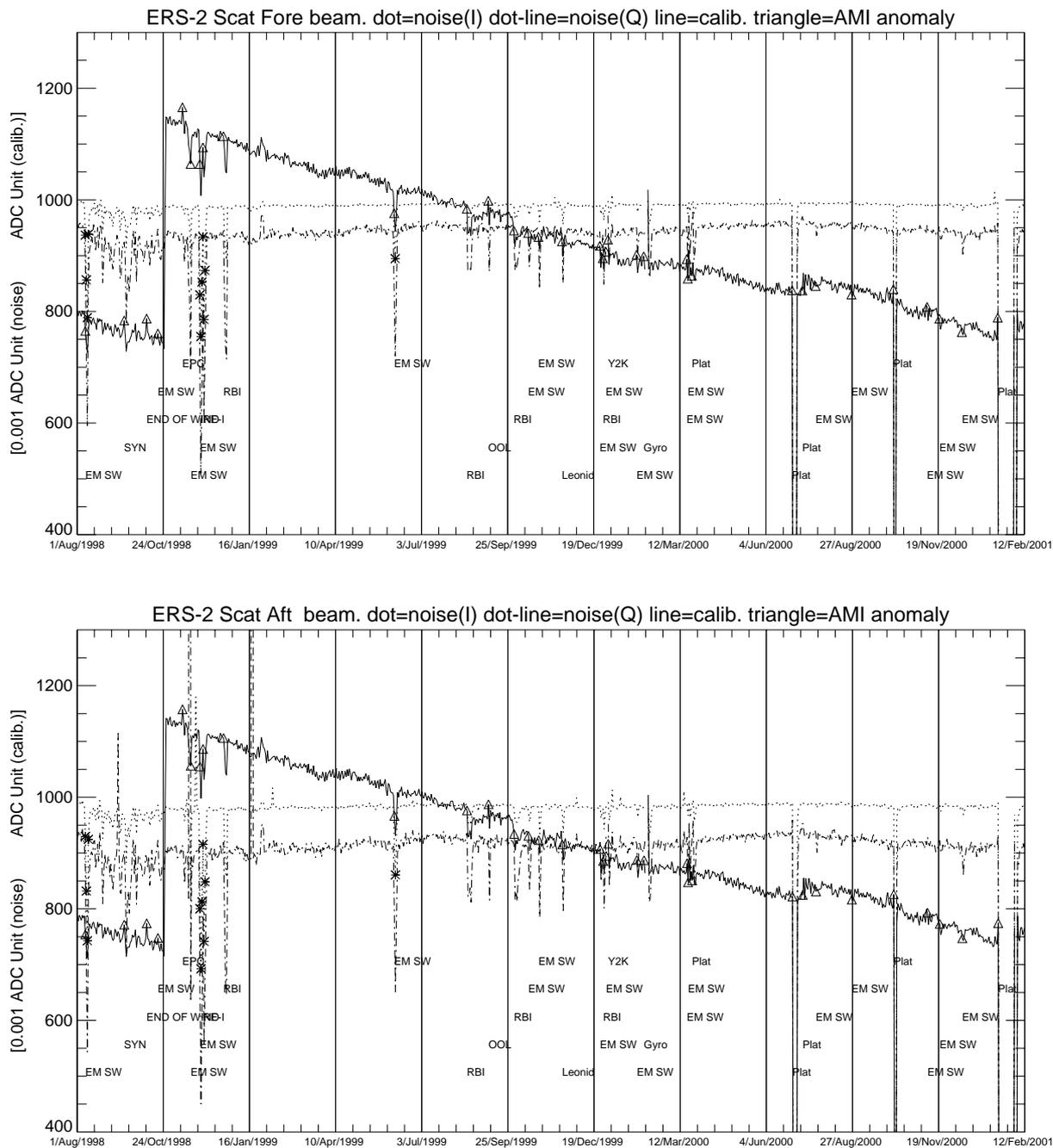
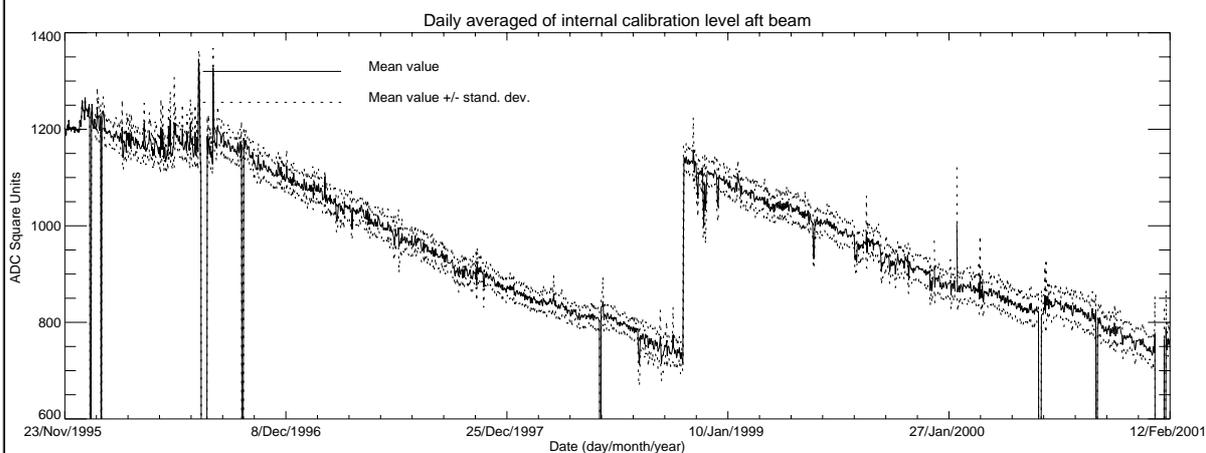
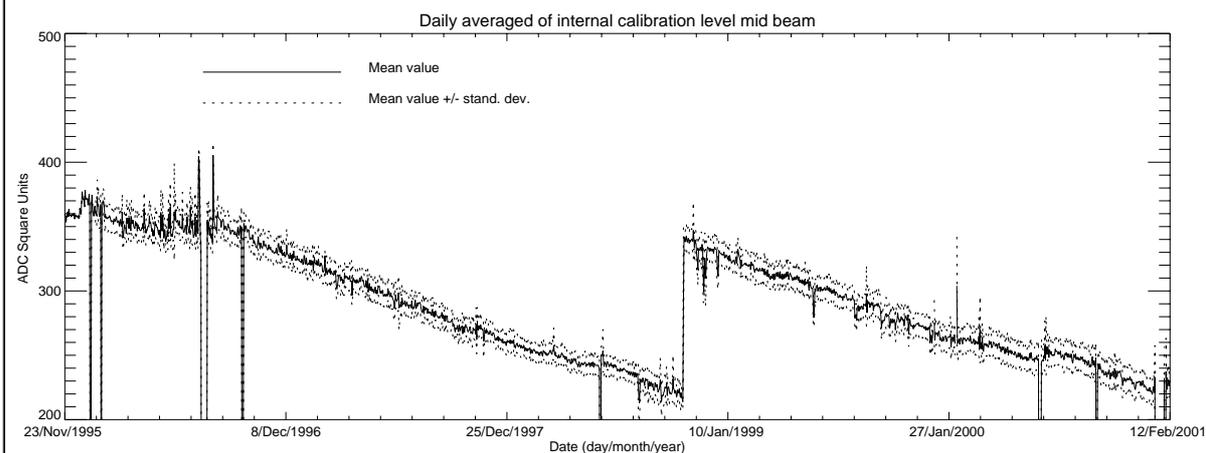
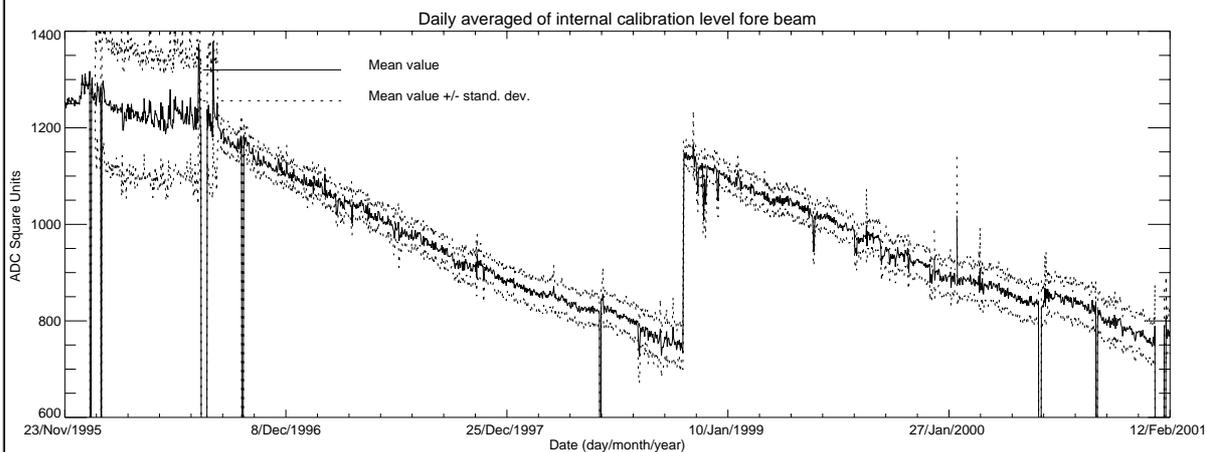


FIGURE 24. ERS-2 Scatterometer: noise power (I and Q channel) and internal calibration power evolution from 1st August 1998 to 17th July 2000. Upper panel Fore antenna, lower panel Aft antenna.

During the cycle 60, on average, no power decrease was detected. The reason was the large period of instrument switch-off (17th January - 5th February 2001). As usual after a long period of instrument unavailability, when the AMI switches on, the output power level is higher than its last value. This explains because, over the whole cycle, the averaged power decrease has been close to zero. If, during the next cycle, the nominal trend (without new instrument unavailability) is confirmed, a new power increase could be scheduled by the end of April 2001.

ERS-2 WindScatterometer: Internal CALIBRATION Level Evolution (UWI)

Least-square polynomial fit fore beam	gain (dB) per day -0.0002	$1001.01 + (-0.0416811) \cdot \text{day}$
Least-square polynomial fit mid beam	gain (dB) per day -0.0002	$293.766 + (-0.0114702) \cdot \text{day}$
Least-square polynomial fit aft beam	gain (dB) per day -0.0002	$983.999 + (-0.0410971) \cdot \text{day}$



ESRIN/PCS

FIGURE 25. ERS-2 Scatterometer: power of internal calibration pulse since the beginning of the mission.

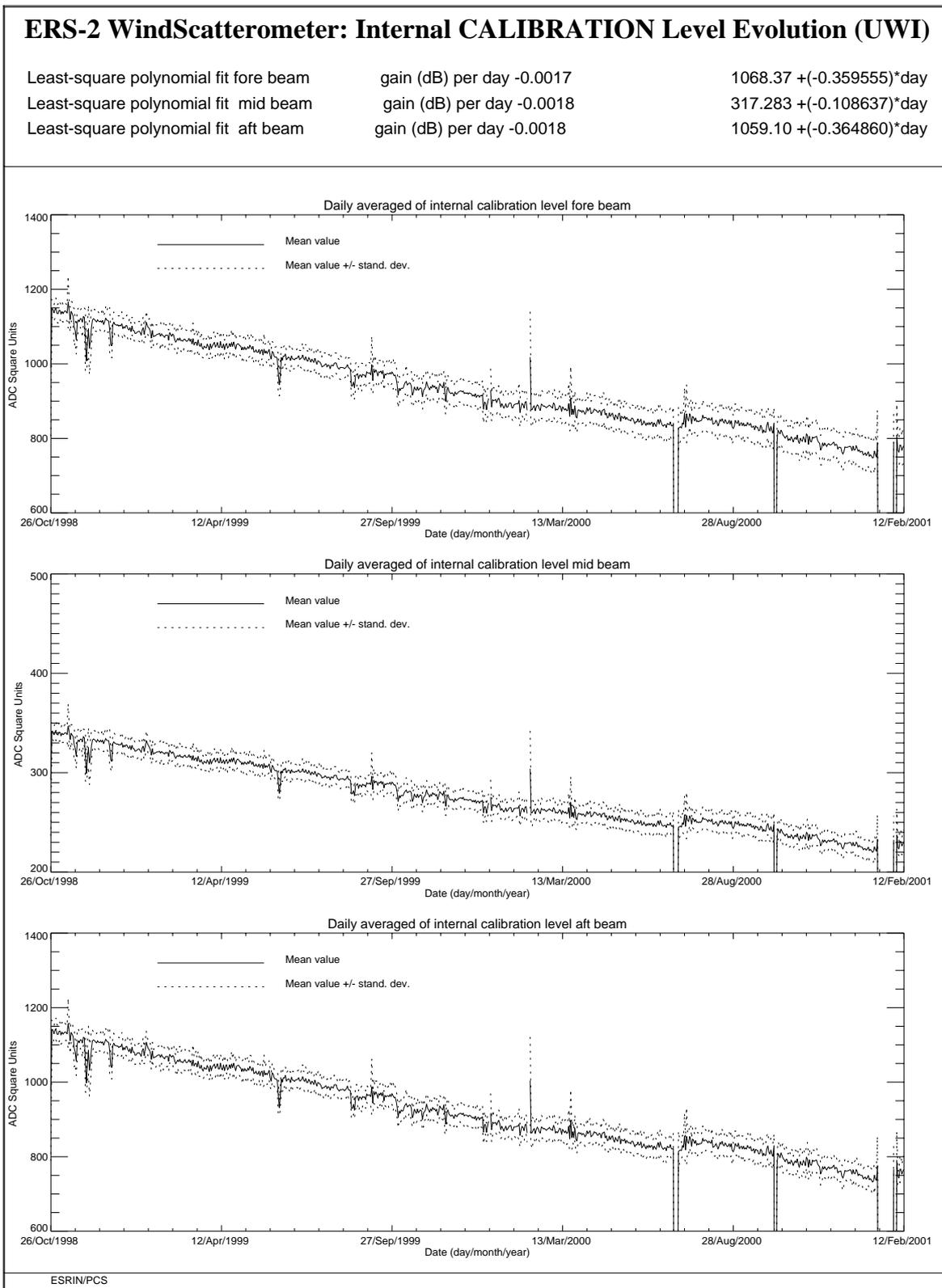


FIGURE 26. ERS-2 Scatterometer: power of internal calibration level since 26th October 1998 when the transmitted power was increased by 2.0 dB.

4.0 Products performance

One of the most important point in the monitoring of the products performance is their availability. The Scatterometer is a part of ERS payload and it is combined with a Synthetic Aperture Radar (SAR) into a single Active Microwave Instrument (AMI). The SAR users requirements and the constraints imposed by the on-board hardware (e.g. amount of data that can be recorded in the on-board tape) set rules in the mission operation plan.

The principal rules that affected the Scatterometer instruments are:

- over the Ocean the AMI is in wind/wave mode (scatterometer with small SAR imagettes acquired every 30 sec.) and the ATSR-2 is in low rate data mode.
- over the Land the AMI is in wind only mode (only scatterometer) and the ATSR-2 is in high rate mode. (Due to on board recorder capacity, ATSR-2 in high rate is not compatible with Sar wave imagette acquisitions.)

This strategy preserves the Ocean mission.

Moreover:

- the SAR images are planned as consequence of users' request.

These rules have an impact on the Scatterometer data availability as shown in Figure 27.

Each segment of the orbit has different colour depending on the instrument mode: brown for wind only mode, blue for wind-wave mode and green for image mode. The red and yellow colours correspond to gap modes (no data acquired). The major problems came from the orbit segments between Australia and Antarctic and between Africa and Antarctic where a lot of data are not acquired. A solution has been proposed by ESRIN. The new mission operation plan has not been accepted because it increase the number of AMI switches. As reported by ESTEC that increase has a negative impact in the instrument time life.

A new set of parameters in the Mission Plan Schedule (MPS) is operative from cycle 55 onwards. The new set allow the reduction of the gap mode when the AMI switches from wind/wave mode to wind_only mode. The reduction of the gap mode is up to 30 seconds and depends on the track.

For cycle 60 the percentage of the ERS-2 AMI activity is shown in table 6. The cycle 60 was characterized by a long period of instrument unavailability due to a failure in the AOCS. For that reason, in Figure 27, the AMI was switched off for some orbits and many orbits are also missing (due to all payload off).

Table 6: ERS-2 AMI activity (cycle 60)

AMI modes	ascending passes	descending passes
Wind and Wind-Wave	58.4%	56.0%
Image	0.8%	2.6%
Gap and others	40.8%	41.4%

The percentage of scatterometer activity is far from the nominal values. The reason was the long period of instrument unavailability.

Table 7 reports the major data lost due to the test periods and AMI or satellite anomalies occurred after August 6th, 1996 (before that day for many times data were not acquired due to the DC converter failure).

Table 7: ERS-2 Scatterometer mission major data lost after 6th, August 1996

Start date	Stop date	Reason
September 23 rd , 1996	September 26 th , 1996	ERS-2 switched off due to a test period
February 14 th , 1997	February 15 th , 1997	ERS-2 switched off due to a depointing anomaly
June 3 rd , 1998	June 6 th , 1998	ERS-2 switched off due to a depointing anomaly
November 17 th , 1998	November 18 th , 1998	ERS-2 switched off to face out Leonide meteo storm
September 22 nd , 1999	September 23 rd , 1999	ERS-2 switched off due to Year 2000 certification test
November 17 th , 1999	November 18 th , 1999	ERS-2 switched off to face out Leonide meteo storm
December 31 st , 1999	January 2 nd , 2000	ERS-2 switched off Y2K transition operation
February 7 th , 2000	February 9 th , 2000	ERS-2 switched off due to new AOCS s/w up-link
June 30 th , 2000	July 5 th , 2000	ERS-2 Payload switched-off after RA anomaly
July 10 th , 2000	July 11 th , 2000	ERS-2 Payload reconfiguration
October 7 th , 2000	October 10 th , 2000	ERS-2 Payload switched-off after AOCS anomaly
January 17 th , 2001	February 5 th , 2001	ERS-2 Payload switched-off due to AOCS anomaly

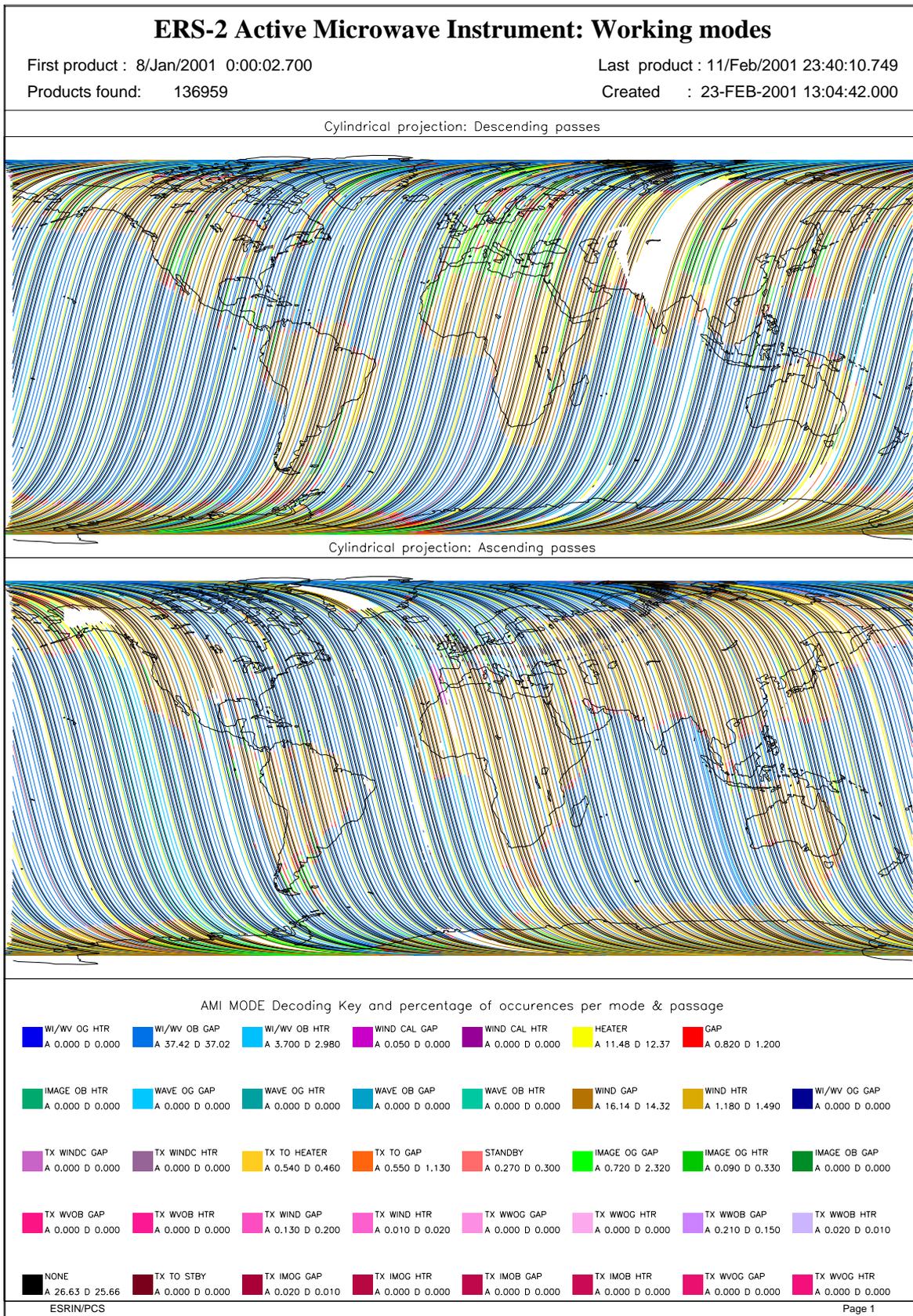


FIGURE 27. ERS-2 AMI activity during cycle 60.

The PCS carries out a quality control of the winds generated from the WSCATT data. The activity is split in two main areas: the first one includes a routine analysis of the fast Delivery Products disseminated to the users, the second one is focused on the improvement of the CMOD-4 (the operative ESA wind retrieval algorithm) for high wind speed (for more information see on the Web site <http://pcswwww.esrin.esa.it> the Cyclone Tracking home page). External contributions to this quality control come also from ECMWF and UK-Met Office.

The routine analysis is summarized in the plots of figure 28; from top to bottom:

- the monitoring of the valid sigma-nought triplets per day.
- the evolution of the wind direction quality. The ERS wind direction (for all nodes and only for those nodes where the ambiguity removal has worked properly) is compared with the ECMWF forecast. The plot shows the percentage of nodes for which the difference falls in the range -90.0, +90.0 degrees.
- the monitoring of the percentage of nodes whose ambiguity removal works successfully.
- the comparison of the wind speed deviation: (bias and standard deviation) with the ECMWF forecast.

The results since the beginning of the mission can be summarized (after August 6th, 1996 and apart from the events given in Table 7) as:

- a stable number of valid sigma-nought with a small increase after June 29th, 1999 due to the dissemination in fast delivery of the data acquired in the Prince Albert station.
- an accurate wind direction for roughly 93% of the nodes, a success in the ambiguity removal for more than 90.0% of the nodes.

The ERS-2 wind speed shows an absolute bias of roughly 0.5 m/s and a standard deviation that ranges from 2.5 m/s to 3.5 m/s with respect to the ECMWF forecast. The wind speed bias and its standard deviation have a seasonal pattern due to the different winds distribution between the winter and summer season.

It is important to note that only after the end of calibration phase (mid March 1996) the wind products have reached high quality.

Two important changes affect the speed bias plot: the first is on June 3rd, 1996 and it is due to the switch from ERS-1 to ERS-2 data assimilation in the meteorological model. The second change, which occurred at the beginning of September 1997, is due to the new monitoring and assimilation scheme in ECMWF algorithms (4D-Var).

Since 19th April 1999 two set of meteo-table (meteorological forecast centred at 00:00 and 12:00 of each day) are used in the ground processing. With this new strategy the data are processed using the 18 and 24 hours meteorological forecast instead of the 18, 24, 30 36 hours forecast. The data processed with the 18-24 hours tables instead of 30-36 hours tables have an increase in the number of ambiguity removed nodes but no important improvements are shown, on average, in the daily statistics.

Since 25th August 1999 a new LRDPF software (version 8500) is operative in the ground stations. With this upgrade the LRDPF is year 2000 compatible; no changes were introduced in the scatterometer data processing.

The mono-gyro AOCS configuration (see report for cycle 50) that was operative from 7th February 2000 to 17th January 2001 did not affect the wind data performance.

The new AOCS configuration (gyro-less EBM) has a very negative impact in the data quality.

The number of valid nodes has a clear drop from 190000 per day to 9000 per day. The overall Scatterometer transfer function is not matched with the received echo (Doppler shift in the received signal due to degraded satellite attitude) and this fact caused the decrease of the signal to noise ratio and as consequence many nodes are discarded by the wind retrieval algorithm. Moreover the sigma nought are not calibrated (the distance to the cone is high, in particular for the nodes at far range) and the wind speed bias is around 1.5 m/s.

The PCS quality control for cycle 60 are shown in Figure 29.

The following are the products performances until 17th January 2001.

The wind speed bias (UWI -ECMWF Forecast) ranges from 0. to -0.1 m/s and the wind speed standard deviation is around 3.0 m/s. These values are within the nominal performances.

The ambiguity removal algorithm was working fine for more than 90% of nodes. The wind direction deviation is within +/- 90 degrees for more than 93% of ambiguity removed nodes.

ECMWF reports (cycle 60) an average wind speed bias of -0.70 m/s (UWI-FGAT) and of -0.41 m/s (4D-Var-FGAT). The wind speed standard deviations are stable: 1.56 m/s (UWI-FGAT) and 1.64 (UWI-4D-Var). These results are comparable to the results from the previous cycle.

The wind directional bias is close to zero (both UWI and 4D-Var products) and the direction standard deviations are ranging between 40 and 60 degrees (UWI) and between 15 and 25 degrees (4D-Var). These results are comparable to the results from the previous cycle.

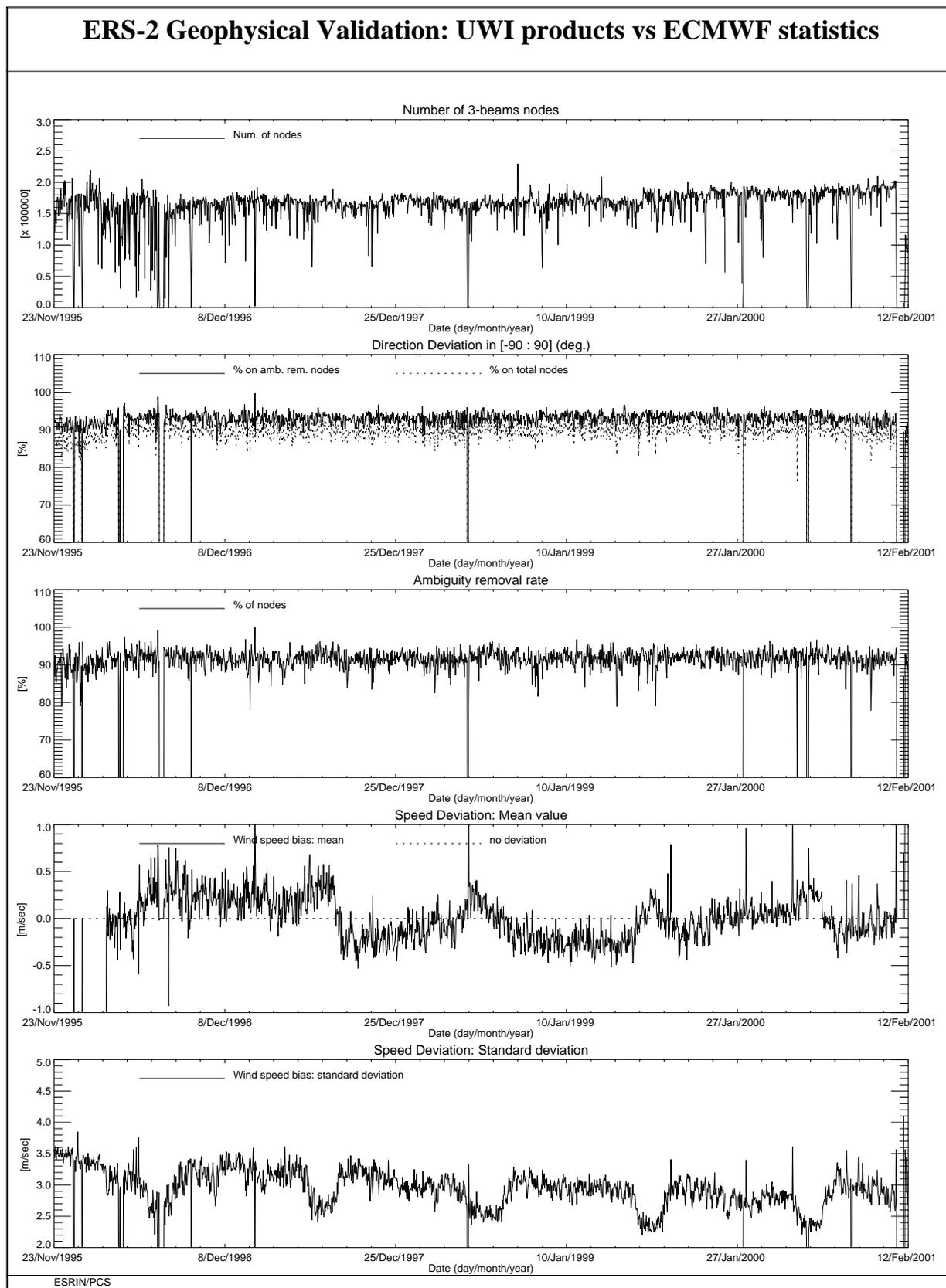


FIGURE 28. ERS-2 Scatterometer: wind products performance since the beginning of the mission.

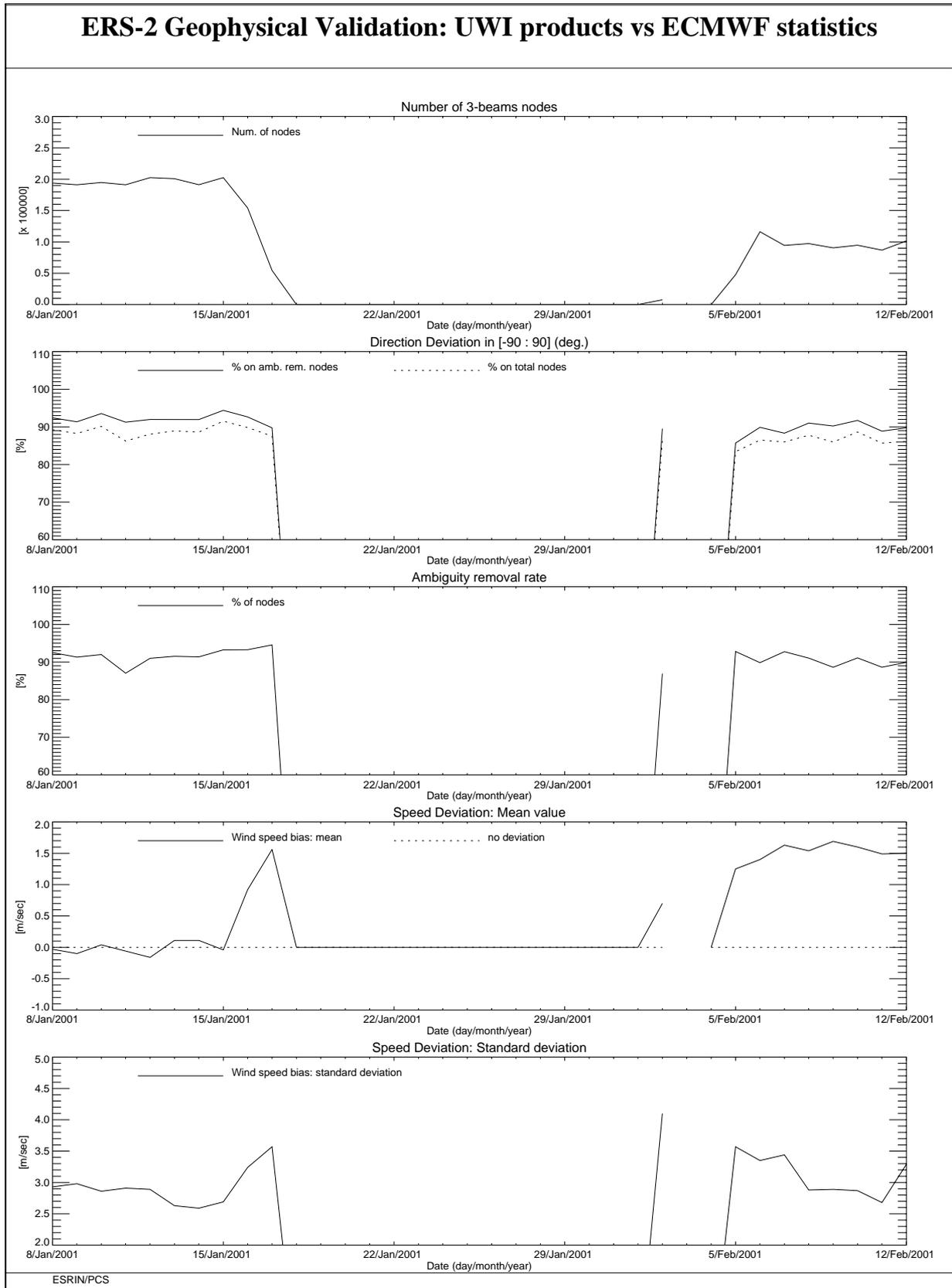


FIGURE 29. ERS-2 Scatterometer: wind products performance cycle 60.