ERS-2 SCATTEROMETER CALIBRATION AND LONG LOOP PERFORMANCE SINCE LAUNCH

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This paper gives to the users of ERS-2 Scatterometer data a description of the evolution of instrument performances since it was switch on and operated for the first time on the 22nd November 1995.

A list of the major events since launch and a description of the instrument mode function is presented in order to give to users a feeling with the data availability.

The ERS-2 Scatterometer performance are described in term of calibration status, instrument status and products status. The results reported are gathered from the daily data quality control performed within ERS Product Control Service at ESRIN, the scatterometer transponder data processing at ESTEC, and from the geophysical monitoring activities executed at ECMWF.

1. INTRODUCTION

On the 21st April 1995, the second European Remote sensing Satellite, ERS-2 was launched from Kourou in French Guyana.

For already six month, a working Group had been setup in order to ensure proper Calibration of the instrument and Validation of the product before distribution to the users.

During the first attempt to switch on the instrument, it appears that an important anomaly in the Active Microwave Instrument (AMI), which combine the function of a Synthetic Aperture Radar (SAR) and a Wind Scatterometer, was preventing the instrument to work at the nominal power.

The scope of this document is, after a short description of the strategy proposed for Engineering Calibration and Geophysical Validation, and on the results achieved, to describe the evolution of the instrument and the actions taken in order to maintain the quality of the commissioning phase results for the all mission time life.

1.1 Calibration and Validation objectives

The objectives of the engineering calibration is to ensure the system response to be absolutely calibrated in terms of radar backscattering coefficient σ^0 over the range of incidence angles of the instrument.

An absolute radiometric calibration of 0.7 dB is needed to satisfy the geophysical data quality requirements in terms of wind speed and direction.

This is achieved using a combination of internal and external references. Two different types of external references are used, point targets (transponders) and distributed targets such as the tropical rain forest in South America.

The main objective of the ERS-2 scatterometer calibration was to provide the users with sigma nought equivalent to the ERS-1 one in order to ensure the continuity between the two instruments. It was assumed that, once the sigma nought are calibrated, that the wind processing and in particular the C-Band model used to compute the wind from the sigma nought was the same.

The initial setting was the one resulting from the on-ground characterisation data and the Scatterometer testing campaign. In particular, the output power was fixed because of the initial anomaly.

The commissioning phase activities were then limited to the following points:

- Set the on-board receiver gain
- Derive the antenna pattern correction for the three antennae from the rain forest and transponder echoes,
- Compute the antennae mispointing,

- Compute the calibration coefficients, and generate the associated Look_Up_Tables,
- Verify that the ERS-2 X-Band data are stable (monitoring of the Long Term Stability of the instrument),
- Compare the ERS-1 and ERS-2 response signal over rains forest and transponders,
- Validate the geophysical products.

Table 1. Satellite events

21st April 1995	ERS-2 Launch
26th January 1996	Attitude and Orbit Control System depointing anomaly.
14th February 1997	Gyroscope anomaly.

Table 2. Active Microwave Instrument events

1st May 1995	Switch-on of the AMI was attempted and failed due to activation of the receiver overload protection circuit.
	Reducing the RF drive level to the HPA. Output power reduction of 1.7 dB.
	AMI Image and Wave mode switch on.
	Attempt to operate in Wind mode failed.
16th November 1995	By use of an updated beam current command the input redundancy switch control circuit was set in an intermediate condition (Power split function).
15th - 25th July 1996	Scatterometer unavailability due to calibration DC converter switch off.
26th July 1996	Switch to Scatterometer electronics side B.
26th July to 5th August 1996	Scatterometer unavailability due to calibration DC converter switch off.
6th August 1996	Switch to calibration subsystem side B.
23rd September 1996	AMI Scatterometer test.
24th September 1996	Calibration DC converter test. Operation without calibration subsystem.
26th September 1996	No doppler information on board after the test.
31st October 1996	AMI Scatterometer test.

Table 3. Ground segment events related to scatterometer data

24th April 1995	Installation of SGI LRDPF version 6210.
3rd October 1995	SGI LRDPF version 6300 in operation at Maspalomas and Gatineau stations.
22nd November 1995	Wind mode was introduced as part of the nominal Mission Operation Plan.
15th January 1996	Start of the scatterometer commissioning phase.
19th March 1996	End of the scatterometer commissioning phase. Gain setting, final antenna pattern, new set of LUT in the ground stations.
16th April 1996	Wind scatterometer data distributed.
12nd August 1996	Update of the reference calibration pulse (new Look-Up-Table).
18th March 1997	Installation of SGI LRDPF version 7100.
June 1997	Updated of the value of internal calibration reference energy

1.2 Scope of the Long-Loop Scatterometer performance assessment

The scope of the Long-Loop Scatterometer performance assessment which is an important activity ran in the background, is twofold. The first objective is to maintain the quality of the results obtained during the commissioning phase, the second is to assess the evolution of the instrument quality due to ageing or to human action commanded from ground and to take all corrective actions necessary to restore the initial quality.

2. EVENTS SINCE LAUNCH

The events since launch can be grouped into three main categories.

1. Every thing linked to the satellite itself; these events are not related to the AMI or to the Ground processing, but do affect the data quality for a certain period of time. In this table we didn't include the orbit manoeuvres which are occurring roughly every month.
2. The instrument anomalies which generally affect the data for a short period (time needed for being alerted and to take the appropriate action). In few cases these anomalies are more difficult to overcome and the data quality could be slightly degraded until the definitive solution is implemented.
3. Ground segment events which are mostly installation of scatterometer data processing chain upgrades and Look-Up-Tables loading in the stations.

The following three tables are covering these three categories of events, starting with the satellite launch on the 21st April 1995 to the last Look-Up-Table update which should occur this week.

3. INSTRUMENT MODES: WIND ONLY AND WIND/WAVE

The scatterometer is part of ERS-2 payload and, the health of the AMI, its different mode of operation and the presence of other instruments on-board lead to some constraints. Some rules are also defined in the Mission Operation Plan.

These constraints and rules have consequences on the scatterometer data availability.

3.1 The constraints

The main constraints for the scatterometer is the SAR operations. As scatterometer and SAR images are two operation modes of the same instrument, their operations are mutually exclusive. This is well known.

On ERS-2, there is an other constraint of this kind which is less known. Because of the data rate, the on-board recorder cannot handle at the same time, both the ATSR-2 in High Rate mode (twice the data flow of the same instrument in Low Rate mode) and the AMI in Wind/Wave mode (i.e. wind measurements and one SAR imagette of roughly 6 x 6 km every 200 km).

Of course there are other constraints such as:

- 8 seconds (~ 53 km) are needed to switch from Wind Only to Wind/Wave or vice versa.
- The instrument is switched to Gap mode (no operation) if a Wind/Wave segment is less than 331.200 seconds (~ 2206 km).
- The instrument is switched to Gap mode (no operation) if a Wind Only segment is less than 321.000 seconds (~ 2138 km).

in order to avoid the Gap mode the following rules has been added

- If the AMI cannot switch because the segment is too short, less than 331.200 in Wind/Wave or less than 321.000 in Wind only, the instrument is switched in a default mode (which could be Wind/Wave or Wind Only).
- If two segments of the same mode are separated by less than 60 seconds (~ 400 km) the gap is filled by leaving the instrument in the same mode and these two segments are merged.

3.2 The rules from the Mission Operation Plan

In order to optimize the satellite potentiality and to satisfy all user communities, the following rule have been defined:

- The ATSR instrument is switched in High Rate mode over land, if it doesn't impact the ocean mission.

3.3 The consequences

To satisfy the ATSR community, the AMI is switched from Wind/Wave to Wind Only when the satellites crosses the coast line inland, and back to Wind/Wave when it is back over Ocean. This allows the switching of the ATSR to High Rate mode.

The first consequence is:

- Each time the AMI crosses the coast line, there is a gap in the data of 8 seconds (~53 km).

The main problem is between Antarctica and Australia or South America where the distance over the ocean is less than 2206 km. For example:

- Over Australia, the instrument is in Wind Only mode.
- When it crosses the coast line is tries to switch to Wind/Wave for a segment less than 331.200 seconds which is not allowed.
- Then it tries to switch in the default mode which today is also Wind/Wave, and therefore the switch is not allowed too.
- Then the instrument is switched in Gap mode.
- The merging doesn't work because the gap is bigger than 60 seconds.

A way to solve this problem would be to change the default mode from Wind/Wave to Wind Only. This moves the problem from over ocean, to over Australia which is less than 321.000 seconds long.

The only solution to avoid these gaps is to change the land mask over Antarctica in order to have an Antarctic Ocean larger than 2206 km.

4. INSTRUMENT LONG LOOP PERFORMANCES

The performance of the ERS-2 mission from the side of the Wind scatterometer instrument can be gathered in the following groups:

- Calibration Performances.
- Instrument Performances.
- Products Performances.

The results reported are a summary of the daily data quality control made in ESRIN / PCS, and of the external input given to ESRIN / PCS by ECMWF and ESTEC. This monitoring work has led to continuous upgrade of the instrument status and on the other side a good detection of the instrument problems.

4.1 Calibration Performances

The calibration performance are based on the use of two types of target: a man made target (the transponder) and a natural target (the rain forest). This approach allow us to design the correct calibration using a punctual but accurate information from transponders and an extended but noisy information from the Rain Forest for which the main component of the variance comes from the geophysical evolution of the natural target.

These aspects are both in the calibration performance monitoring philosophy. From the Transponders the Gain Constant is computed. This Gain Constant is simply found as the integral of simulated data (for a pass over a transponders) divided by the integral of the actual data acquired over the transponders. This parameter clearly means the difference from the “real instrument” to the mathematic model. The plots in figure 1 show the value of the Gain Constant compute since January 1996 for the three beams and for the ascending passes, descending passes and all passes.

The measurements are performed at fixed incidence angle and we have from 3 to 10 values for each angle. The plots show a good accuracy (within 0.5 dB) in the instrument calibration respect to the model. The antenna pattern for the three beams is, within 0.5 dB, flat in the across track direction.

For the relative level of the calibration across track gamma nought signal over Brazilian rain forest is shown in figure 2. The data are correspond to one week from 19 May to 25 May 1997. The actual level of the signal is in agreement with the ERS-1.

The stability of the calibration is shown in figure 3. The formulation used for the gamma nought takes in to account the incidence angle dependency so that the gamma nought is independent from the incidence angle for an isotropic target such as the rain forest and an histogram of gamma nought over the rain forest shall show a sharp peak. The plots in figure 3 is the time-series of the peak position for the three beams and for the ascending and descending passes. The small difference from ascending and descending passes (0.15 dB) could be related with the different status of the rain forest during the day such as humidity or leaves orientation: in fact the ascending passes are in the night while the descending ones are in the day.

The step shown in March 96 is due to the end of commissioning phase when a new LUT was installed in the ground station in order to correct the antenna pattern and to achieve the ERS-1 gamma nought level. The overall results is a calibration stability with an accuracy of 0.5 dB.

4.2 Instrument Performances

The instrument status is described by the monitoring of the following parameter: doppler compensation, internal calibration level, noise power level, normalised distance from sigma nought triplets measured to the theoretical model.

The doppler compensation evolution is shown in figure 4. The first set of three plots is relative to the daily mean value of centre of gravity of the signal spectrum for the three antennas, the second set is relative to daily mean standard deviation of the spectrum. The most interesting thing to note is the quick increase of the centre of the spectrum after the gyroscope anomaly occurred on 14th February 1997. The correction manoeuvre effectuated on 15th February 1997 doesn't restore the initial status and only with the manoeuvre of the 23rd April 1997 the doppler compensation returned to the nominal level. This problem allowed us to verify the impact of doppler compensation in the sigma nought and consequently in the wind estimation. During the period from 14th February to 23rd April 1997 a slight increase of sigma nought at low incident angle was detected. The impact in the wind retrieved was an improvement in the wind speed bias (difference between wind from ERS-2 and wind from model) at low incident angle as reported by ECMWF.

For the internal calibration level the evolution is shown in figure 5. The high value of the variance in the fore beam until 12nd August 1996 is due to ground processing. In fact all the blank source packets ingested by the processor were recognized as fore beam source packet 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. The 12th August, a change in the LUT 30 (EWS__STATIC) overcame the problem.

Since 6th August 1996 the internal calibration level shows a mean decrease of 0.1 dB per cycle. A special investigation has been performed on Windscatterometer raw data (EWIC product) in order to characterize the evolution. The major results are: the decrease noted in UWI products is confirmed from the EWIC data analysis. The decrease is the same for the I channel and the Q channel of the transmitter-received chain. The daily averaged echo power extracted from the EWIC data shows a decrease of received power correlated with the decrease of internal calibration level. The comparison of the figure 5 with the figure 3 shows the efficiency of the internal calibration: in fact during the period in which the transmitted power decrease, no effect is detected in the gamma nought over the rain forest.

A slight change in sigma nought (-0.2 dB) was noted to ECMWF since 6th August 1996 due to change of calibration subsystem on board ERS-2 after a high number of anomalies. This can also be noted in figure 3 where a small step in the signal from the rain forest around this date is obvious. This problem is solved with a new characterization in the model of calibration subsystem and with a new set of LUT’s. The

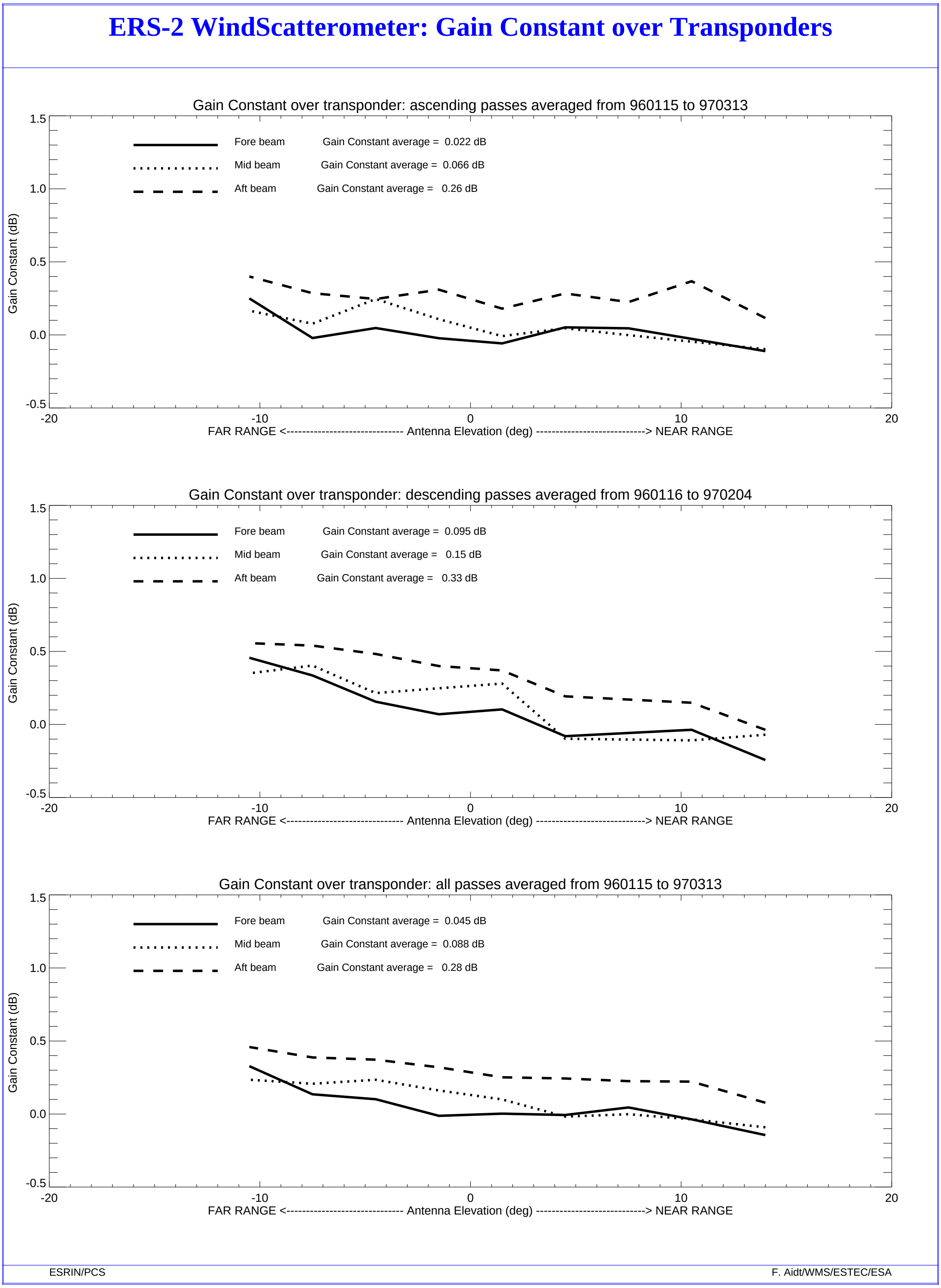

Figure 1. Across swath Gain constant as measured over the transponders. All passes averaged from January 1996 to March 1997.

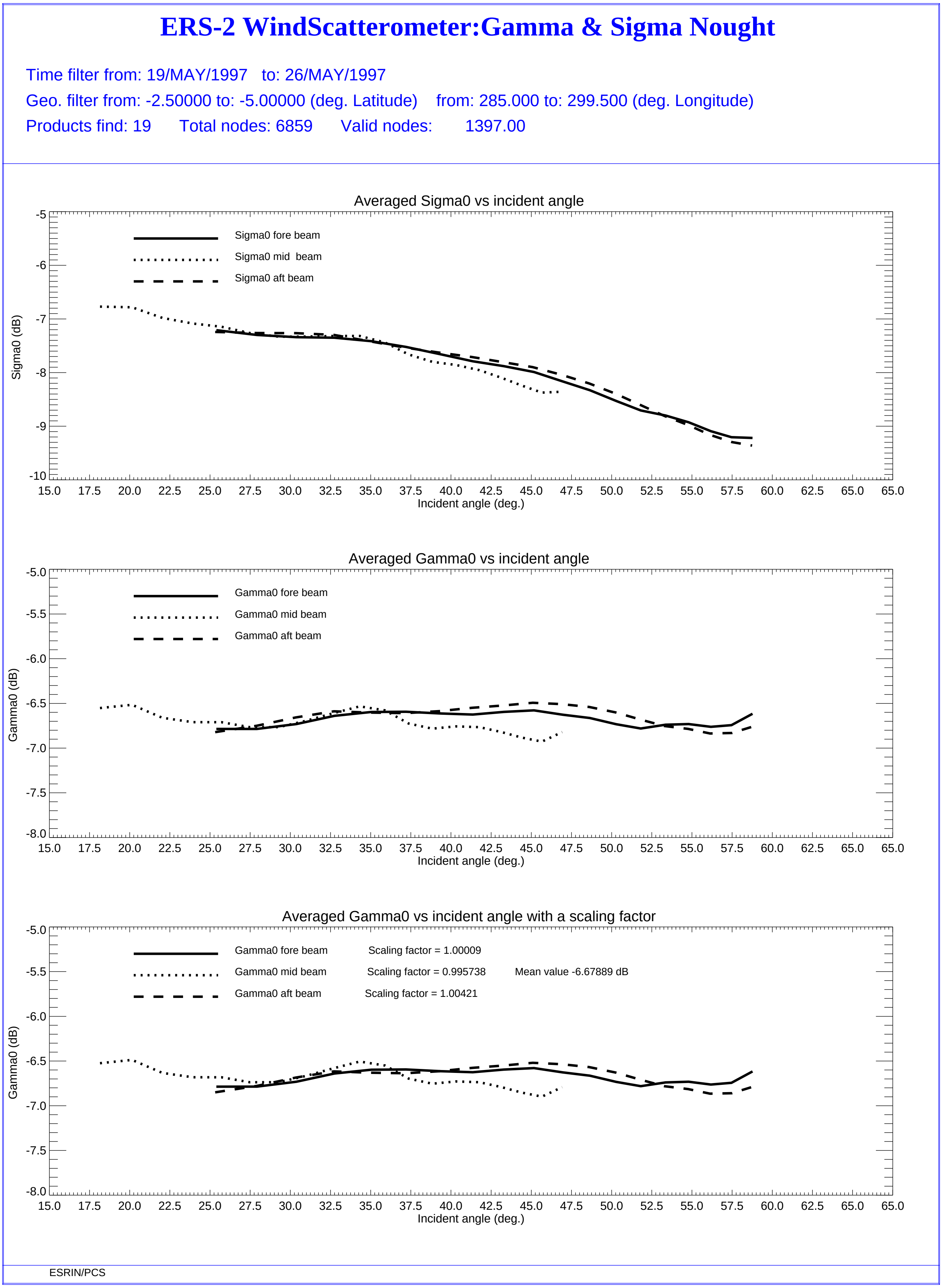

Figure 2. Across swath Antenna pattern as measured over the rain forest. Averaged over one week in May 1996 (19th to 26th).

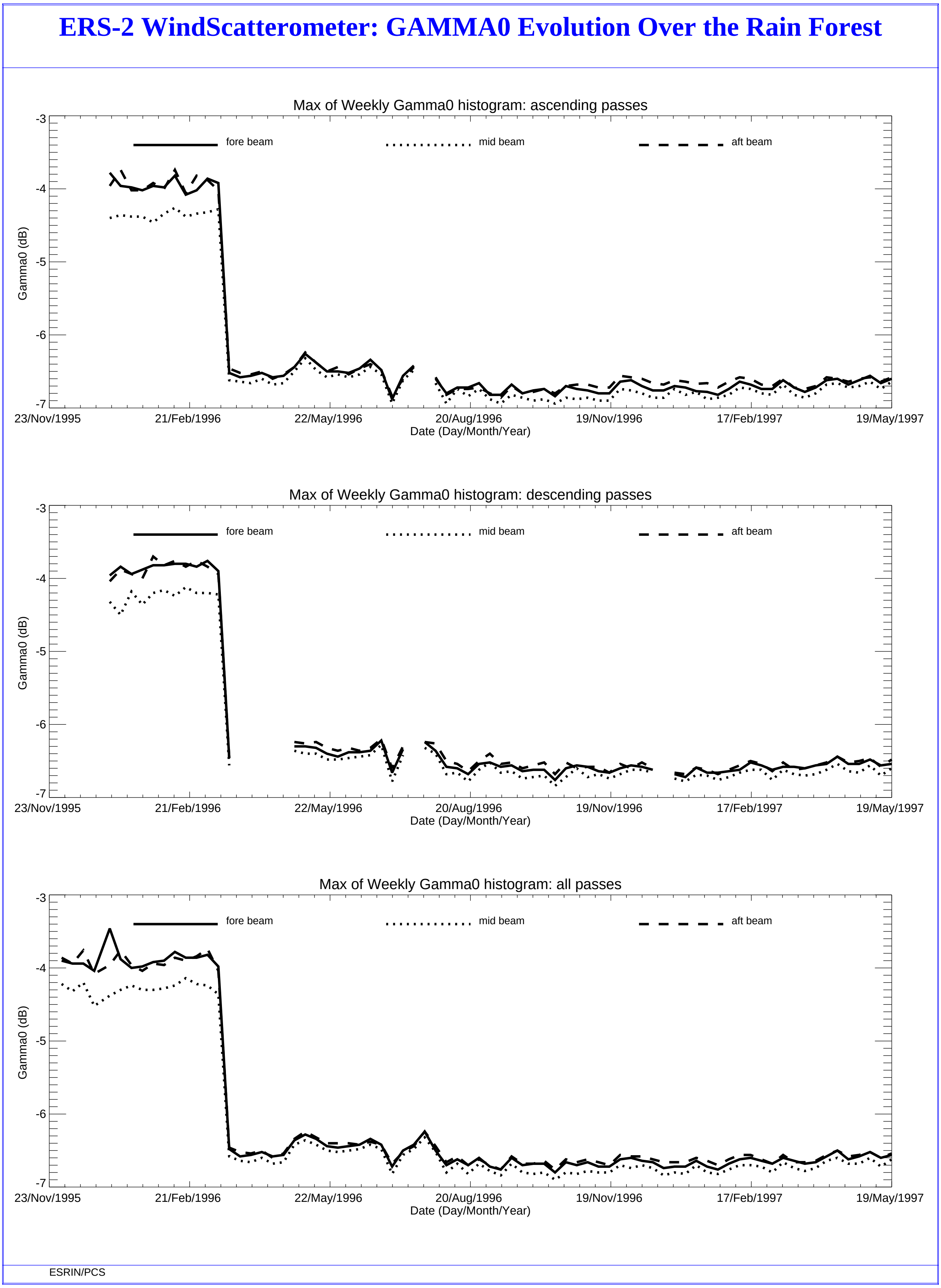

Figure 3. Gamma nought histogram peak position evolution since ERS-2 Scatterometer operation (November 1995 to May 1997).

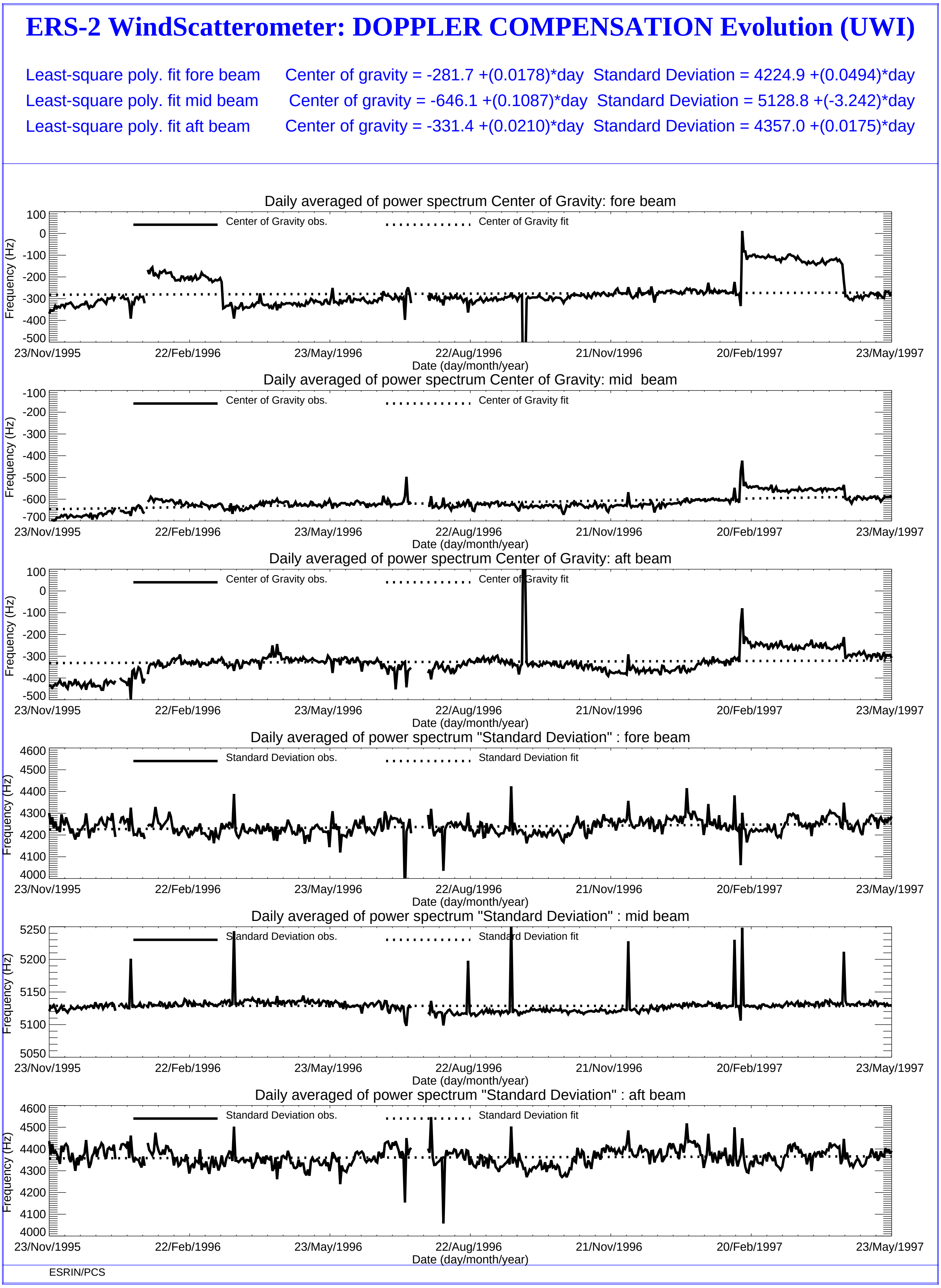

Figure 4. Doppler compensation (centre of gravity and standard deviation) evolution for the three scatterometer antennae (November 1995 to May 1997).

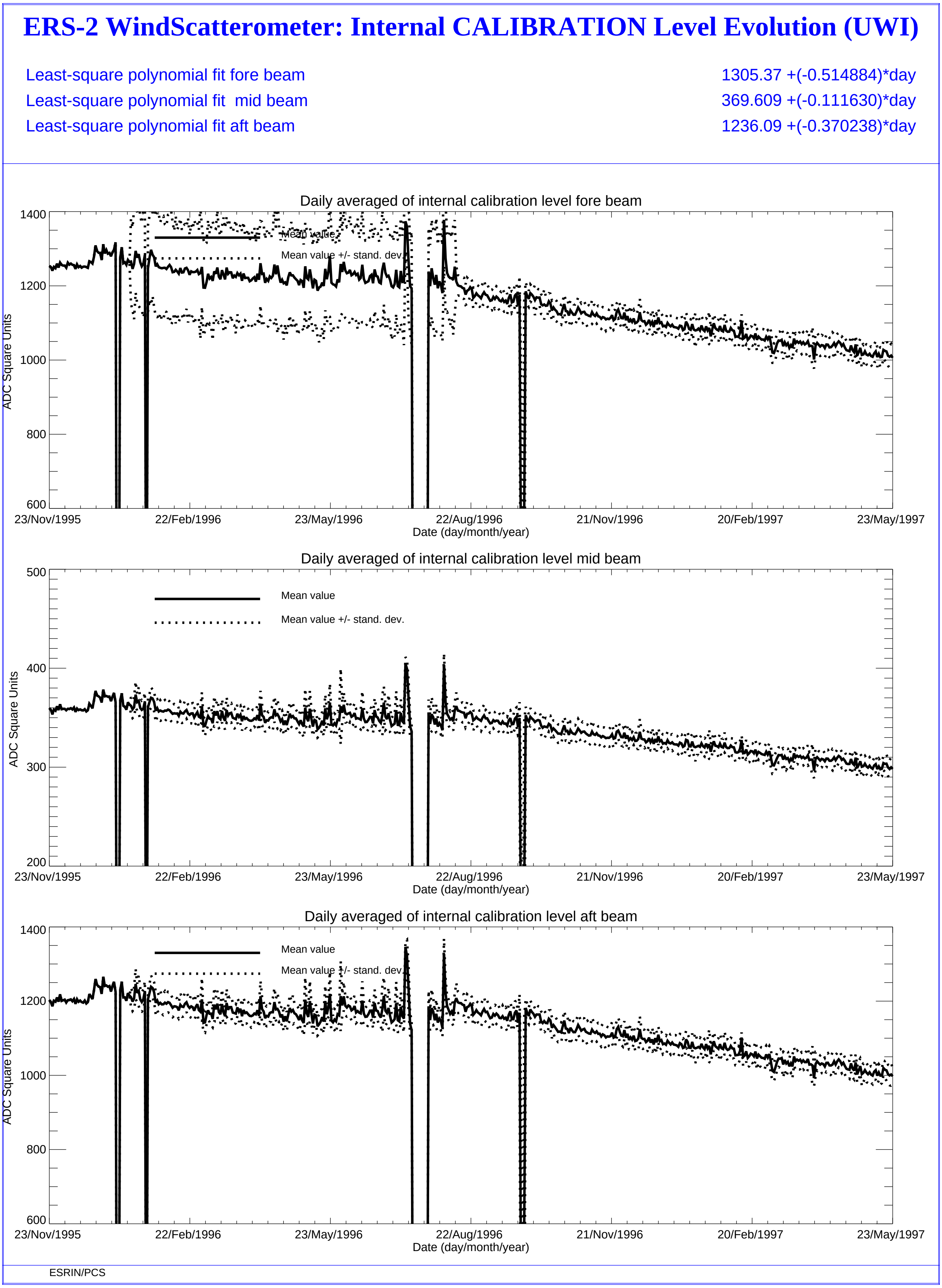

Figure 5. Internal Calibration level evolution for the three scatterometer antennae (November 1995 to May 1997).

ESRIN / PCS is now in charge for that activity. After an analysis made with the SSS (Scatterometer System Simulator and LUT generator), it was decided to change the calibration reference energy in the LUT 31 (EWS_DYNAMIC) in agreement with the results coming from the SSS. This change will be done in June 1997.

The figure 6 shows the evolution of the noise power level for the three beams and for the I channel (first three plots) and for the Q channel (last three plots). No special investigations are conducted for this parameter, but the result of the monitoring shows that the Q channel is slightly unstable compared with the I one.

4.3 Product performances

For the products status, the results are summarized in figure 7.

The first plot is the number of the valid sigma nought triplets used for the wind retrieval in each day. The behaviour of the plot is directly correlated with the total availability of the instrument and the ground processing. It has to be noted that since August 1996 the products availability is satisfactory apart a period when on-board tests were performed.

The second plot, compares the quality of wind direction retrieval in the range (-90, +90 deg.). The predictions and the wind derived from the Scatterometer are stable and similar.

On the third plot, it is shown that the percentage of nodes in which the ambiguity removal works successfully, is stable.

The fourth and fifth plot show the quality of wind speed retrieved: wind speed bias mean and standard deviation. The bias in wind speed of Scatterometer products compared with the ECMWF predictions is about 0.5 m/s. Note that only after the calibration activity the Scatterometer wind is suitable for science community. Since 3rd June 1996 an increase in wind bias is noted. This is due to the ERS-1 switch off. From that date onward the ECMWF predictions was using the ERS-2 Scatterometer data instead of ERS-1.

5. CONCLUSIONS

After the launch of ERS-2 on 21st April 1995 a serious anomaly causing the AMI instrument to shut down. The anomaly was resolved by setting the switch at the input to the HPA to an intermediate position and reducing the power output by a factor or two. This allowed to get wind data since November 1995.

At the end of the commissioning phase in March 1996 a new set of LUT was installed in the ground stations in order to characterize the new gain setting and antenna pattern.

Anomaly in calibration subsystem caused an instability in the Scatterometer availability until 6th August 1996 when calibration subsystem side A was dismissed.

The calibration performances have a good quality in term of flat across track signal and absolute level. The change in the calibration subsystem carried out slight increase in sigma nought (+ 0.2 dB). This problem shall be overcome with a new LUT that will be installed in the ground station in June 97. This new LUT has been successfully tested in ESRIN.

The instruments status is stable in term of doppler compensation and noise power level. A decrease of 0.1 dB per cycle (35 day) is noted for the internal calibration level.

A slight problem in the doppler compensation from February 1997 to April 1997allowed us to verify the effect in the sigma nought and in the wind. An increase of roughly 150Hz in the centre of the spectrum of the fore beam and roughly 100Hz for the other beams has carried out a small increase (+0.1 dB) in the sigma nought at low incidence angle and consequently a small change in wind retrieved at low incidence angle.

The availability of the Users Wind products (UWI) since 6th August 1996 is roughly of 0.16 Million of three beams Ocean nodes per day and is stable

The quality of the ERS-2 wind has a bias in wind speed of 0.5 m/s with respect to ECMWF predictions; -1.0 m/s with respect to FGAT analysis and -0.5 m/s with respect to PRESCAT wind retrieved by ECMWF from scatterometer sigma nought triplets.

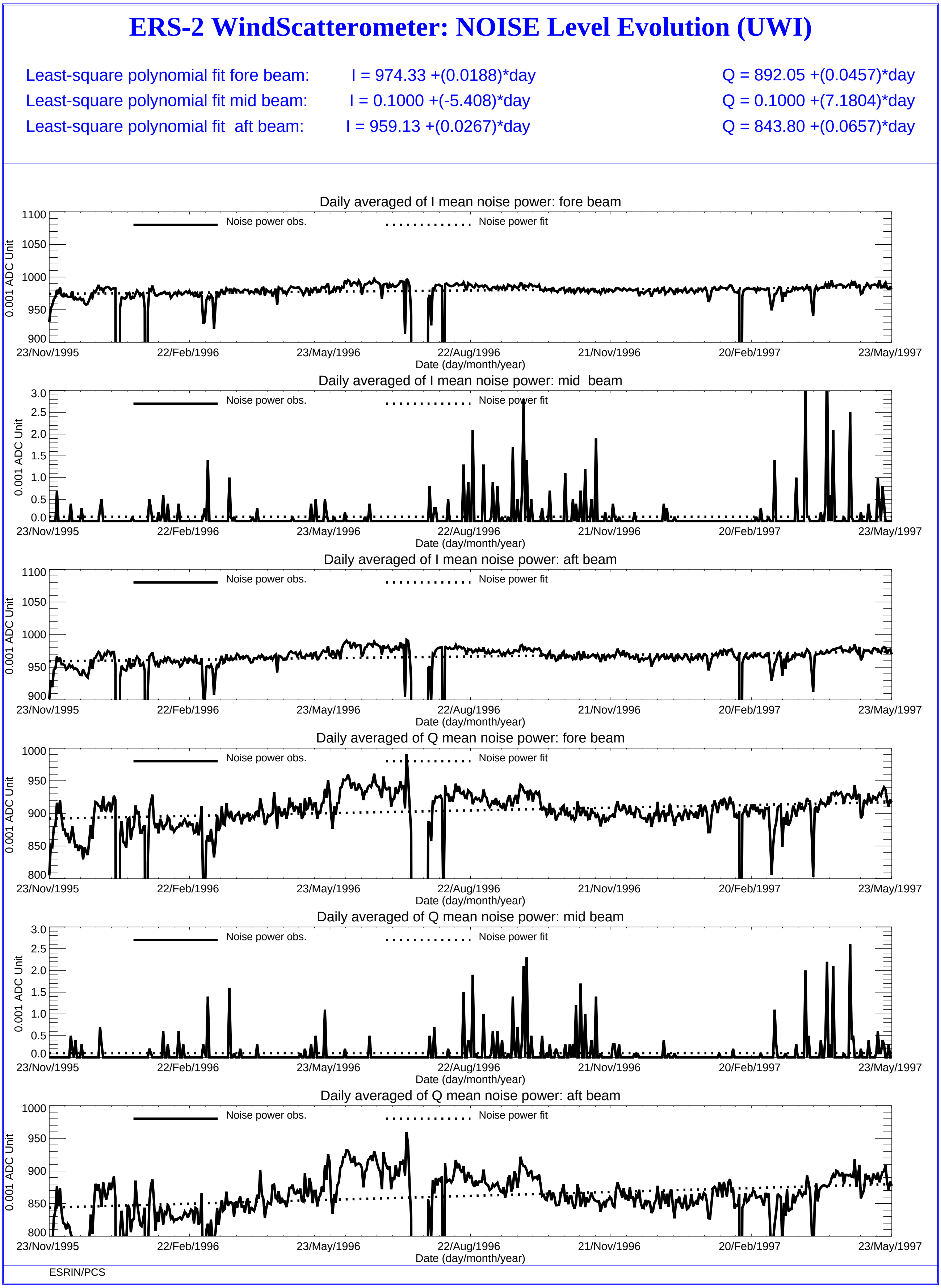

Figure 6. Noise level evolution for the three scatterometer antennae (November 1995 to May 1997).

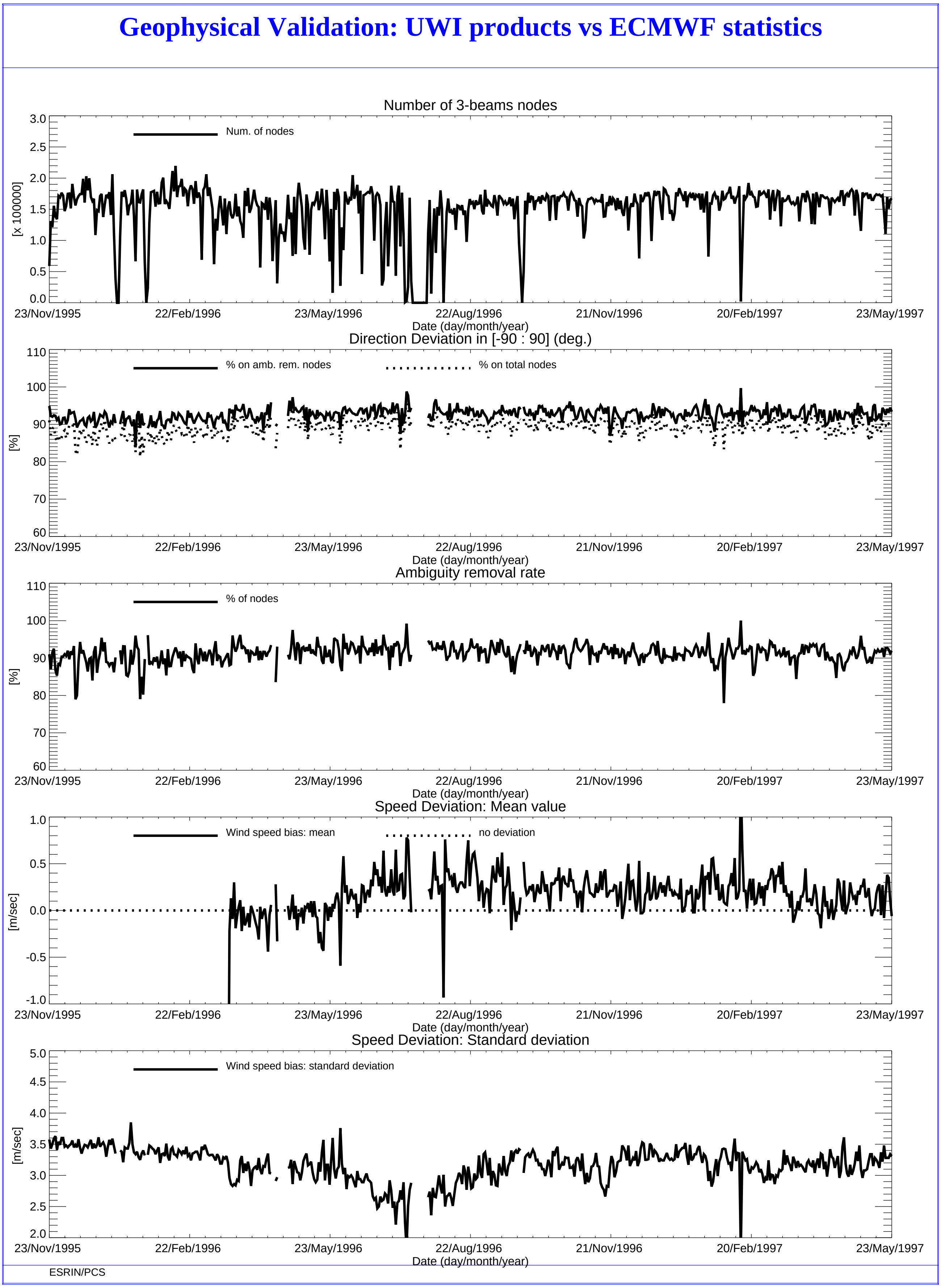

Figure 7. Number of valid measurement, Ambiguity removal performances and retrieved wind comparison with ECMWF forecasts (November 1995 to May 1997).