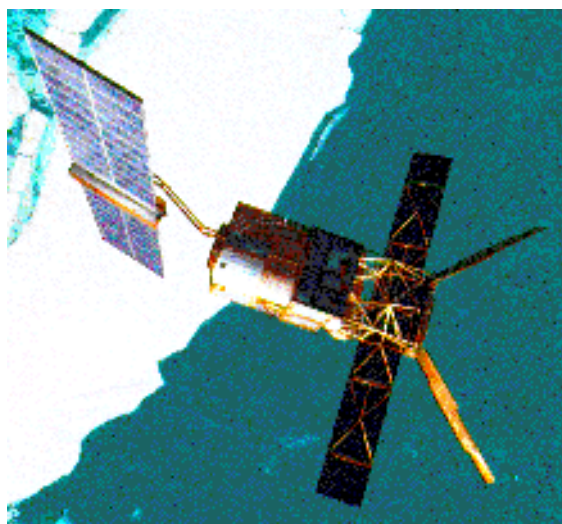


ERS-2 Wind Scatterometer Cyclic Report

from 29th December 2003 to 2nd February 2004
Cycle 91



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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 29th December 2003 to 2nd February 2004 (cycle 91) and includes the results of the monitoring activity performed by ESRIN and ECMWF.

Mission events

- Since 15th January 2004 Scatterometer data from West Freugh (UK) station are disseminated on GTS network. This new ground station improves the data coverage of the North Atlantic filling the gap present in the wind data disseminated during the previous cycle 90.
- The ERS-2 satellite was piloted in ZGM throughout the cycle 91.
- During the cycle 91 the AMI instrument was operated in wind-wave mode along all orbits and the short term yaw control activity was carried out following the nominal plan.
- During cycle 91 ESACA processor worked nominally without faults.

Yaw performance

- The result of the yaw monitoring for cycle 91 is a mean yaw error angle within the expected nominal range (+/- 2 degrees) for most of the orbits. On 10th, 12th and 26th January 2004 many orbits had a bad quality yaw performances due to strong degraded satellite attitude. There was no increase of solar activity during those days. The combined kp and yaw-error flag was set for these cases allowing the users to reject low quality measurements.

Calibration performance

- Calibration data from Transponder are regularly acquired and archived for re-processing. The CALPROC processor is not able to produce accurate gain constant with the actual degraded satellite attitude. For that reason ESRIN had initiated the TOSCA (Tool for Scatterometer Calibration) project to re-design the calibration processor and re-compute valid gain constants coefficients.
- Due to the regional mission scenario the calibration performances over the Brazilian rain forest are not available because that area is not covered by the ESA ground station. The chance to install a new station to cover the calibration site is under investigation as well as the possibility to use stable ice area in Greenland to monitor the instrument calibration.
- The Ocean Calibration monitoring is still performed by ECMWF. Compared to cycle 90, bias levels were nearly unchanged. The situation is slightly better than that for nominal data in 2000.

Instrument performance

- During the cycle 91 the mean power decrease has been 0.1 dB per cycle. This value confirms the trend detected since the beginning of the mission.

- The noise power level was within the nominal value. The daily average value is around 1.7 ADC unit (I) and 1.5 ADC unit (Q) for the Fore and Aft beam and it is not measurable for the Mid beam.
- The Doppler compensation performances were stable during the cycle 91 and that fact indicates the effectiveness of ESACA processor to compensate for satellite attitude changes. The CoG of the compensated spectrum is very close to zero and its standard deviation was around 1600 Hz for the Fore and Aft antenna and around 2700 Hz for the Mid antenna.

Product performance

- During cycle 91, data was regularly disseminated throughout the GTS network. Data was received at ECMWF between 21:02 UTC 29 December 2003 and 20:59 UTC 2 February 2004 and for all 6-hourly batches.
- Currently the performances of ESACA winds are affected by Land contamination. Around coastal zones many Sea nodes have a strong contribution of Land backscattering and the retrieved wind is not correct. An optimization of the Land/Sea flag in the ground processing is under implementation. A 5% of land contamination (a node is flagged as Sea if it contains less than 5% of echoes samples acquired over land) has been agreed with the users during the 25th Ascot SAG.
- The PCS has upgraded its own wind monitoring scheme. The Land contamination has been removed by using a refined Land/Sea mask. Also the ice contamination has been removed with a simple geographical filter. With these new settings the PCS statistics are very similar to the ones reported by ECMWF. The wind speed bias (UWI vs 18 or 24 hour forecast) is roughly 0.5 m/s and the speed bias standard deviation is around 2 m/s.
- Compared to cycle 90, the agreement with ECMWF first-guess (FGAT) fields worsened. Relative bias levels became more negative (from -0.51 m/s to -0.61 m/s), and scatter has again increased (from 1.65 m/s to 1.71 m/s). Part of this deterioration is caused by seasonal variations for the regional data set. However, the less optimal results appear to be concentrated in a relatively small area south-west of the previously existing data-void area in the North Atlantic. Also, the degradation was largest in the near range, while the relative standard deviation was nearly unaltered in the far range. The quality of both the UWI and de-aliased CMOD4 wind direction was stable. Compared to nominal data in 2000, bias levels for both backscatter and wind speed are more optimal. Standard deviations of wind speed are less optimal to those for 2000. A fair comparison, however, cannot be made due to large differences in data coverage.
- The ERS-2 scatterometer data was not used in the 4D-Var data assimilation system at ECMWF. However, it is being processed passively in the operational suite and assimilated actively (on the basis of CMOD5) in the experimental suite that is scheduled to become operational within a few months.

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 in an appropriate operational mode defined as “Calibration Mode”.

Since January 2001 with the operations in Zero Gyro Mode (ZGM) the satellite attitude is not stable as it was in the nominal Yaw Steering Mode (YSM). In particular there is a non-predictable variation of the yaw error angle along the orbit. For that reason the gain constant data computed by the CALPROC processor, that assumes a stable orbit, are meaningless and a new calibration processor is under development. In the mean time, data from the Transponder are still acquired and archived for future re-processing. The reprocessed gain constants will be provided in this section when available.

For the gain constant computed during the nominal YSM please refer to the Scatterometer cyclic report - cycle 60 -

2.2 Ocean Calibration

The Scatterometer sigma noughts were compared with the ECMWF model first guess winds. The result is shown in Figure 1 as the ratio of $\langle \sigma_0^{0.625} \rangle / \langle \text{CMOD4}(\text{First Guess})^{0.625} \rangle$ converted in dB for the for beam (solid line), mid beam (dashed line) and aft beam (dotted line), as a function of incidence angle for descending and ascending tracks. The thin lines indicate the error bars on the estimated mean. First-guess winds are based on the in time closest (+3h, +6h, +9h, or +12h) T511 forecast field, and are bilinearly interpolated in space.

The average sigma0 bias levels (compared to simulated sigma0's based on ECMWF model first-guess winds) stratified with respect to antenna beam, ascending or descending track and as function of incidence angle (i.e. across-node number) is displayed in Figure 1. Compared to cycle 90, bias levels were nearly unchanged. The situation is slightly better than that for nominal data in 2000 (see the same figure of the ECMWF cyclic reports for cycle 48 to 59).

The dependency of the bias as function of incidence angle is small, and most negative in the near range. Internode differences are slightly smaller than for the nominal period. Bias levels are in between 0.0 and -0.5 dB.

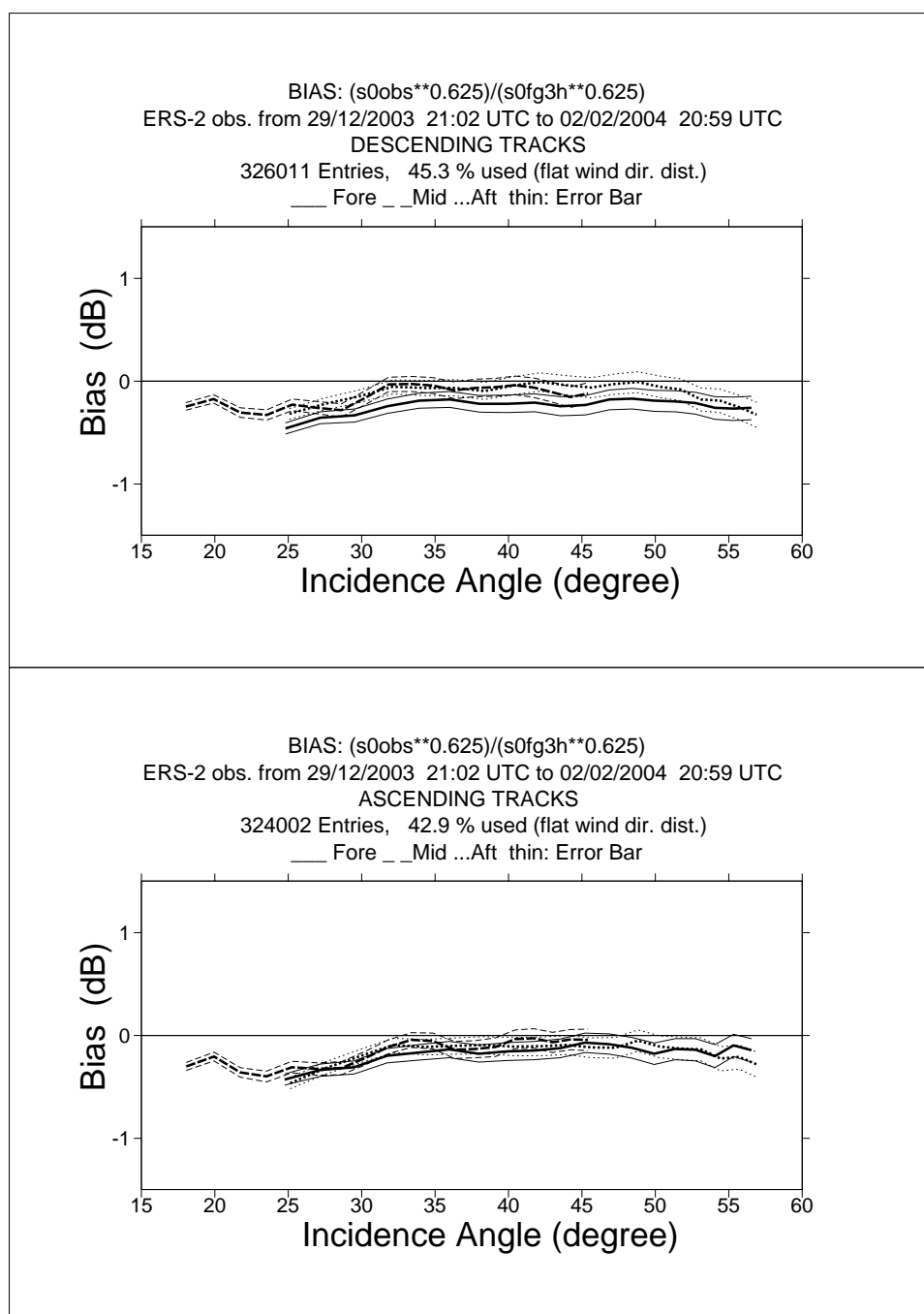


FIGURE 1. ERS-2 Scatterometer Ocean Calibration cycle 91. Ratio of $\langle \sigma_0^{0.625} \rangle / \langle \text{CMOD4}(\text{First Guess})^{0.625} \rangle$ converted in dB for the fore beam (solid line), mid beam (dashed line) and aft beam (dotted line), as a function of incidence angle for descending and ascending tracks. The thin lines indicate the error bars on the estimated mean. First-guess winds are based on the in time closest (+3h, +6h, +9h, or +12h) T511 forecast field, and are bilinearly interpolated in space.

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. That area is actually not covered by the Regional mission scenario (since cycle 86 onwards) and therefore the calibration monitoring activity over the Brazilian rain forest is suspended because no data are available.

The chance to continue the monitoring activity with a new receiving station covering the Brazilian rain forest is under investigation. The following paragraphs will report on the results when data will be available.

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

Due to the regional mission scenario data over the Brazilian rain forest are not available and the, the antenna patterns in function of the elevation angle have not been computed.

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

Due to the regional mission scenario data over the Brazilian rain forest are not available and the, the antenna patterns in function of the incidence angle have not been computed

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.

Due to the regional mission scenario data over the Brazilian rain forest are not available and the, the histograms have not been computed.

For the time series since the beginning of the mission please refer to the Scatterometer cyclic report cycle 86.

2.3.4 Gamma nought image of the reference area

Due to the regional mission scenario data over the Brazilian rain forest are not available and the, the histograms have not been computed

2.3.5 Sigma nought evolution

Due to the regional mission scenario data over the Brazilian rain forest are not available and the, the sigma nought evolution have not been computed

For the time series since the beginning of the mission please refer to the Scatterometer cyclic report cycle 86.

2.3.6 Antenna temperature evolution over the Rain Forest

Due to the regional mission scenario data over the Brazilian rain forest are not available.

For the time series since the beginning of the mission please refer to the Scatterometer cyclic report cycle 86.

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 2 shows the evolution of the two parameters for each beam for the long term monitor and Figure 3 shows the same for the cycle 91

The tendency from the beginning of the mission to the operation with the new Mono Gyro (MGM) Attitude On-board Control System (AOCS) configuration (7th February 2000) is a clear and regular small 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 MGM qualification period. After the AOCS commissioning phase this parameter further evolved.

The nominal 3-gyroes AOCS configuration (plus one Digital Earth Sensor - DES, and one Digital Sun Sensor - DSS and backups) was no more considered safe because 3 of the six gyros on-board were out of order or very noisy. The MGM configuration was designed to pilot the ERS-2 using only one gyro plus the DES and the DSS modules. Scope of ZGM configuration was to extend the satellite lifetime by using the available gyros one at the time.

With MGM configuration, the gyro 5 was used until 7th October 2000 when it failed. From 10th October 2000 to 24th October 2000 the gyro 6 was used. 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 gyroscope for further manoeuvres, ERS-2 will now being operated in Extra Backup Mode (EBM). The EBM is a coarse attitude control mode. An upgrade of

EBM has been performed on 30th March 2001. The aim of the upgrade was to introduce the Yaw steering law inside the piloting function. The new configuration has been renamed as EBM-YSM.

Since 7th June 2001 a new AOCS configuration is active on board. The purpose of the Zero Gyro Mode (ZGM) is to improve the yaw performances without use of gyroscope.

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).

Others changes in the AOCS configuration are recognised in Figure 2. The two steps observed at the beginning of the plots of the CoG (see Figure 2) are due to a change in the pointing subsystem (DES reconfiguration) side B instead of side A after a depointing anomaly (see table 1 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 1: 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.
17 th January 2001	6 th February 2001

The Figure 2 shows also when the satellite was operated in Fine Pointing Mode (FPM) in EBM, ZGM 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 2.

Table 2: 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)

Date	Reason
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)
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
6 th February - 30 th March 2001	Extra Backup Mode (EBM) coarse attitude control
30 th March 2001- 7 th June 2001	EBM-YSM gyro-less yaw steering mode
7 th June 2001 - onwards	ZGM commissioning phase

The peaks (before February 2001) 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.

Since February 2003 (with the beta version of ESACA processor) the evolution of the Doppler compensation was stable. This because ESACA takes into account the real acquisition geometry and therefore is able to compensate for the received signal. The CoG is very close to zero and the standard deviation was reduced a lot: it was around 1800 Hz for Fore and Aft beam and around 2800 Hz for the mid beam.

During the cycle 91 the Doppler compensation evolution was stable (see Figure 3) apart from the small peak in the standard deviation of the received spectrum on day 26th January 2004 due to a strong degraded satellite attitude.

ERS-2 WindScatterometer: DOPPLER COMPENSATION Evolution (UWI)

Least-square poly. fit fore beam	Center of gravity = $-132.1 + (0.0752) \cdot \text{day}$	Standard Deviation = $4249.9 + (0.0467) \cdot \text{day}$
Least-square poly. fit mid beam	Center of gravity = $-783.3 + (0.3100) \cdot \text{day}$	Standard Deviation = $5107.8 + (0.0376) \cdot \text{day}$
Least-square poly. fit aft beam	Center of gravity = $-400.2 + (0.1845) \cdot \text{day}$	Standard Deviation = $4371.2 + (0.0372) \cdot \text{day}$

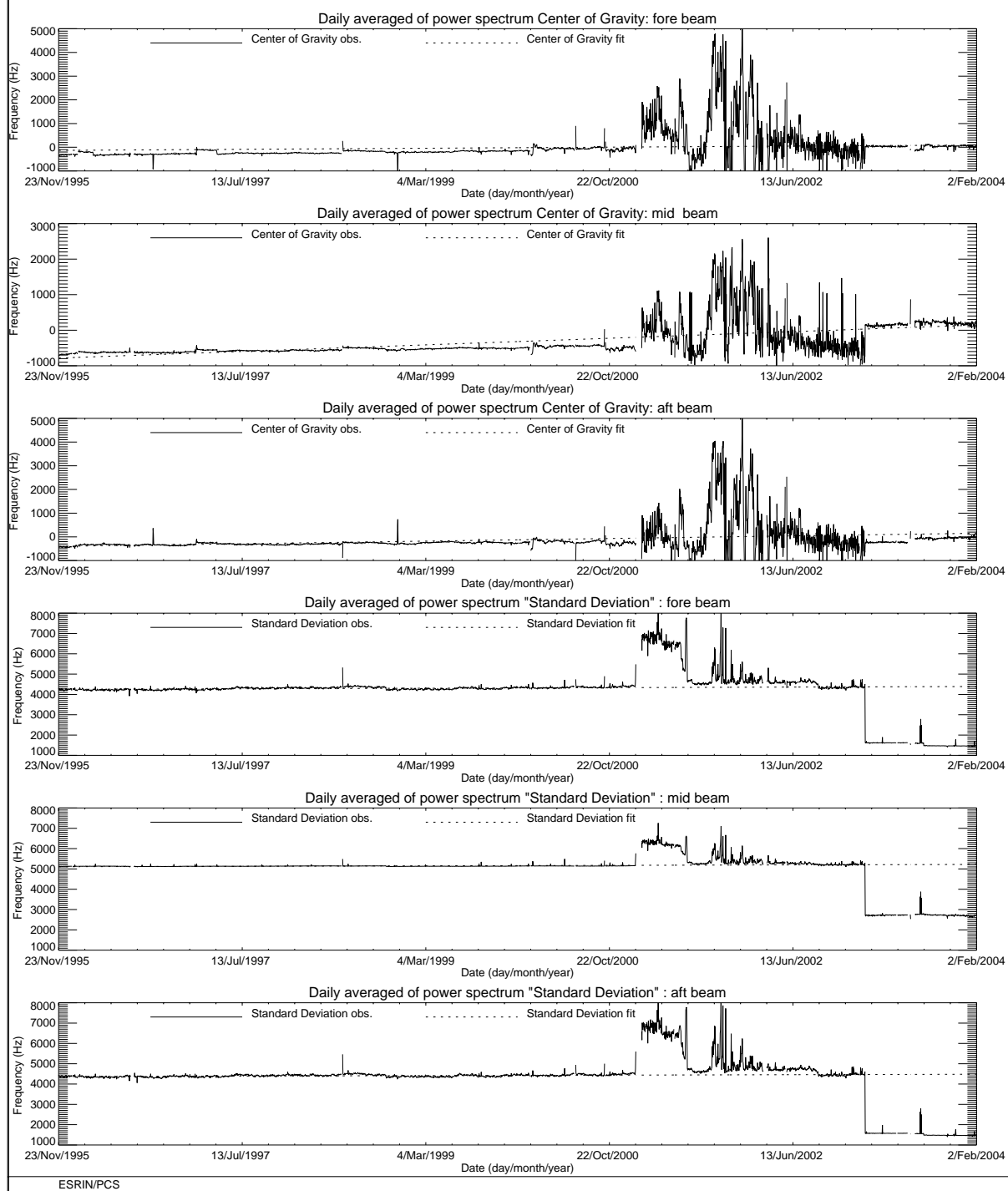


FIGURE 2. ERS-2 Scatterometer: Centre of Gravity and standard deviation of received power spectrum since the beginning of the mission.

ERS-2 WindScatterometer: DOPPLER COMPENSATION Evolution (UWI)

Least-square poly. fit fore beam Center of gravity = $37.135 + (-0.038) \cdot \text{day}$ Standard Deviation = $1460.6 + (-0.062) \cdot \text{day}$
 Least-square poly. fit mid beam Center of gravity = $172.71 + (-0.355) \cdot \text{day}$ Standard Deviation = $2675.7 + (0.2930) \cdot \text{day}$
 Least-square poly. fit aft beam Center of gravity = $-37.52 + (1.1951) \cdot \text{day}$ Standard Deviation = $1466.2 + (0.0053) \cdot \text{day}$

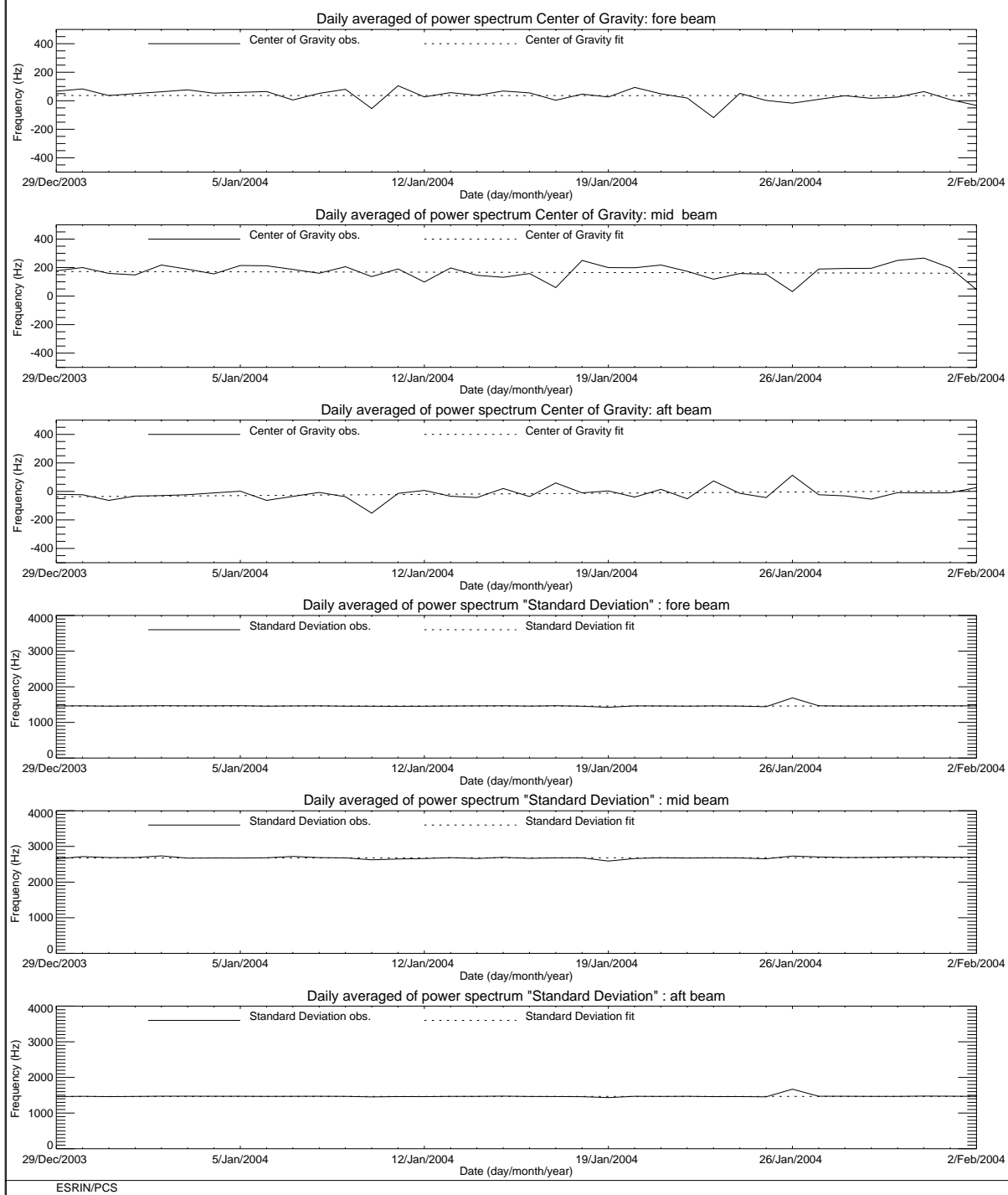


FIGURE 3. ERS-2 Scatterometer: Centre of Gravity and standard deviation of received power spectrum during the cycle 91.

3.2 Noise power level I and Q channel

The results of the monitoring are shown in Figure 4 (long-term) and Figure 5 (cycle 91). The first set of three plots presents the noise power evolution for the I channel while the second set shows the Q channel. From the plots one can see that the noise level is more stable in the I channel than in the Q one. The I and Q receivers are inside the same box and any external interference should affect both channel. The fact that the receivers are closer to the ATSR-GOMNE electronics could have some impact but there is no clear explanation on that behaviour.

From 5th December 1997 until November 1998 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. The reason why noise field corruption is beginning from 5th December 1997 and last until November 1998 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 until March 2000 some periods with a clear instability in the noise power have been recognised. Table 3 gives the detailed list.

Table 3: 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
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.

The noise power decrease noted on 6th June 2001 is related with continuous wave operation around the orbit. The reduction of the noise is an artifact due to on-board data processing. In fact all noise samples taken during 32 FMA sequence are squared and averaged over 896 samples. In wind-wave mode 2 FMA sequences are missing (to acquire SAR imagerie) but the average is still computed over 896 samples (see ER-SS-MSS-AM-0700 sheet 167).

On 28th February 2003 the Scatterometer receiver gain has been increased by 3 dB to increase the usage of the on-board ADC converter. This explains the increase of the noise for the Fore and Aft beam channel. For the mid beam channel the noise still remains not measurable.

The evolution of the noise power during the cycle 91 was stable (see Figure 5). The daily average for the Fore and Aft beam noise is around 1.7 ADC and for the Mid beam the noise is not measurable.

ERS-2 WindScatterometer: NOISE Level Evolution (UWI)

Least-square line fit fore beam: $I = 863.64 + (0.1274) \cdot \text{day}$

$Q = 812.81 + (0.1145) \cdot \text{day}$

I channel: No line fit standard deviation too high

Q channel: No line fit standard deviation too high

Least-square line fit aft beam: $I = 840.81 + (0.1247) \cdot \text{day}$

Q channel: No line fit standard deviation too high

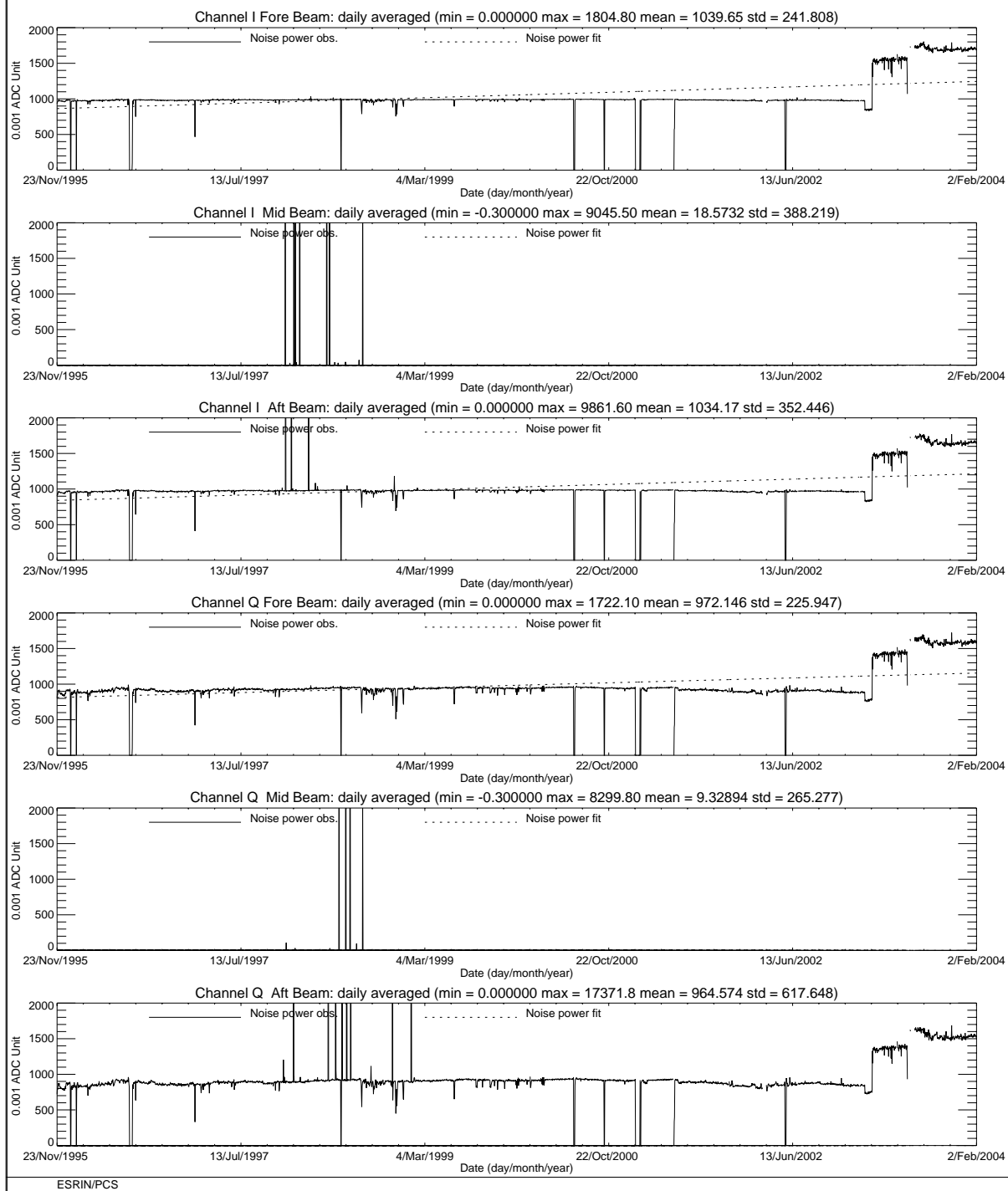


FIGURE 4. ERS-2 Scatterometer: noise power I and Q channel since the beginning of the mission.

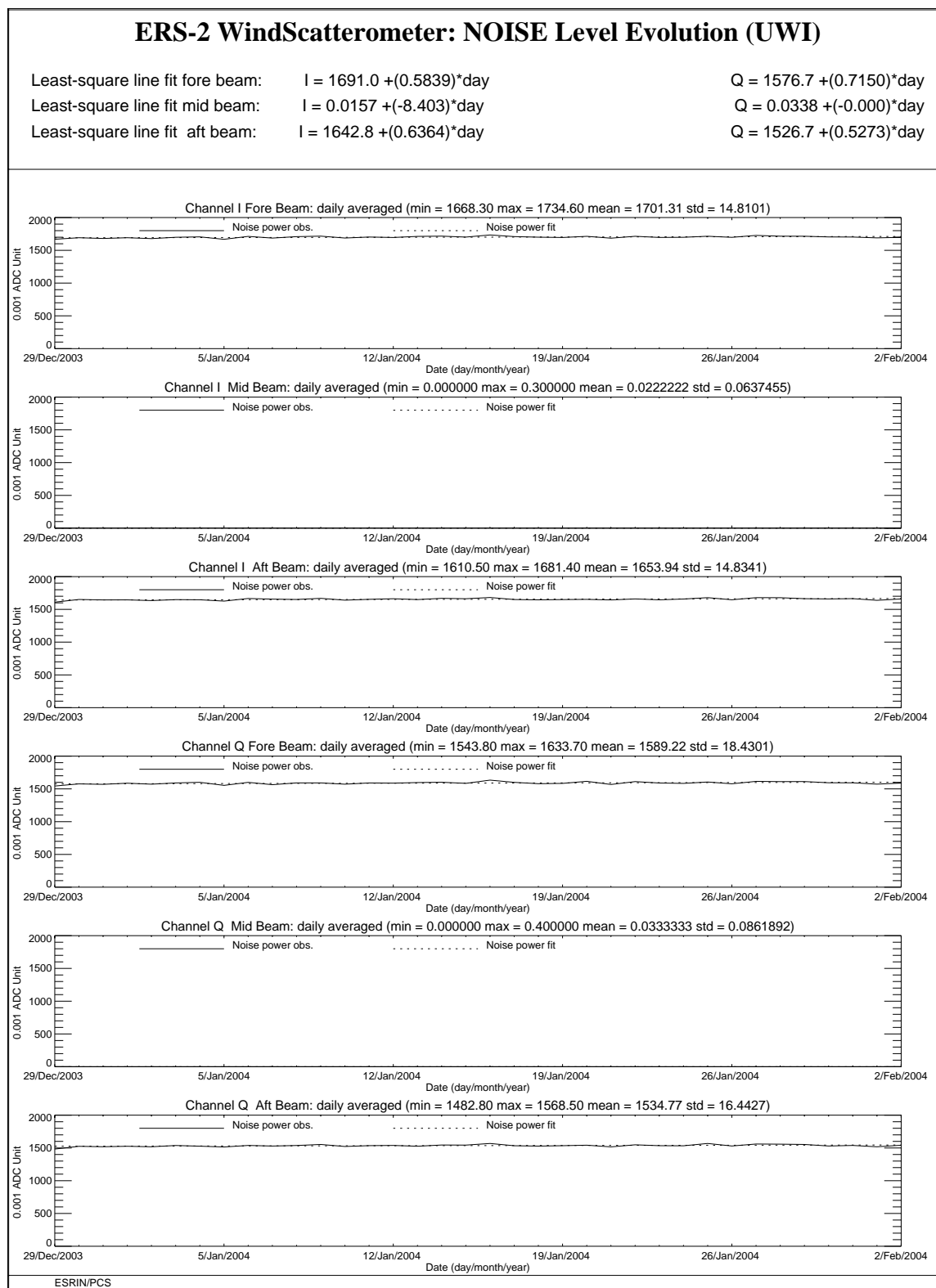


FIGURE 5. ERS-2 Scatterometer: noise power I and Q channel for cycle 91.

3.3 Power level of internal calibration pulse

For the internal calibration level, the results are shown in Figure 6 (long-term) and Figure 7 (cycle 91).

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 average power decrease is around 0.08 dB per cycle (0.0022 dB/day) and is more clear after August, 6th 1996 when the calibration subsystem has been changed.

The reason of the power decrease is because 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).

To compensate for this decrease, on 26th October 1998 (cycle 37) 2.0 dB were added to the Scatterometer transmitted power and on 4th September 2002 (cycle 77) were added 3.0 dB. On 28th February 2003 (cycle 82) the Scatterometer receiver gain was increased by 3 dB to improve the usage of the on-board ADC converter. These events are clearly displayed by the large steps shows in Figure 6.

Since 9th August 1998 until March 2000 the internal calibration level shows an instability after an AMI or platform anomaly (see reports from cycle 35 to cycle 52). This instability is very well correlated with the fluctuations observed in the noise power.

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 detected after an arcing event which occurred inside the HPA. After that event the transmitted power had an average increase of roughly 0.14 dB.

During the cycle 91 the mean power decrease has been 0.10dB per cycle. That value is within the trend detected since the beginning of the mission.

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

Least-square polynomial fit fore beam	gain (dB) per day	0.0000	$977.207 + (0.00920904) \cdot \text{day}$
Least-square polynomial fit mid beam	gain (dB) per day	0.0001	$287.264 + (0.00345249) \cdot \text{day}$
Least-square polynomial fit aft beam	gain (dB) per day	0.0001	$959.497 + (0.0116868) \cdot \text{day}$

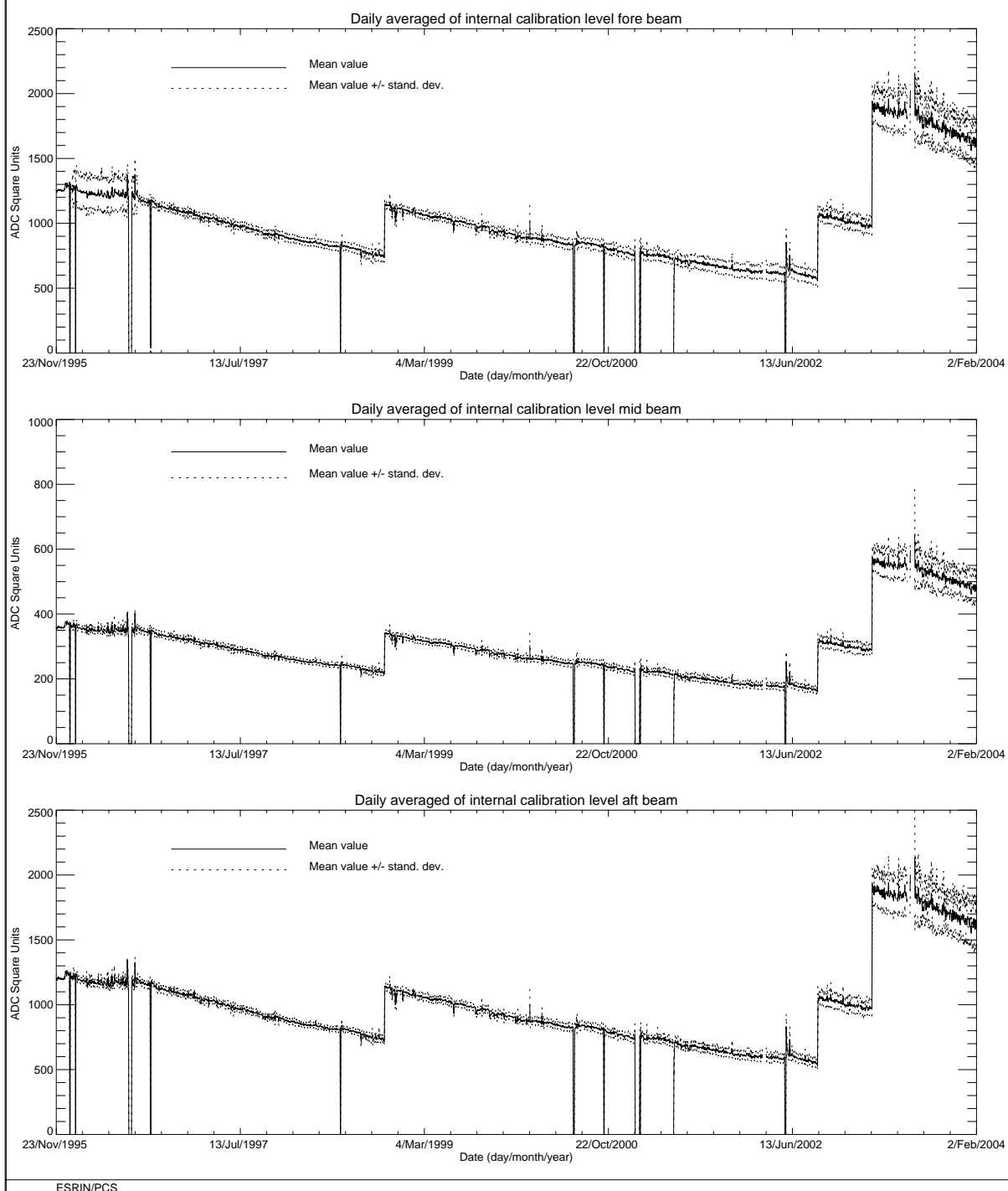


FIGURE 6. ERS-2 Scatterometer: power of internal calibration pulse since the beginning of the mission.

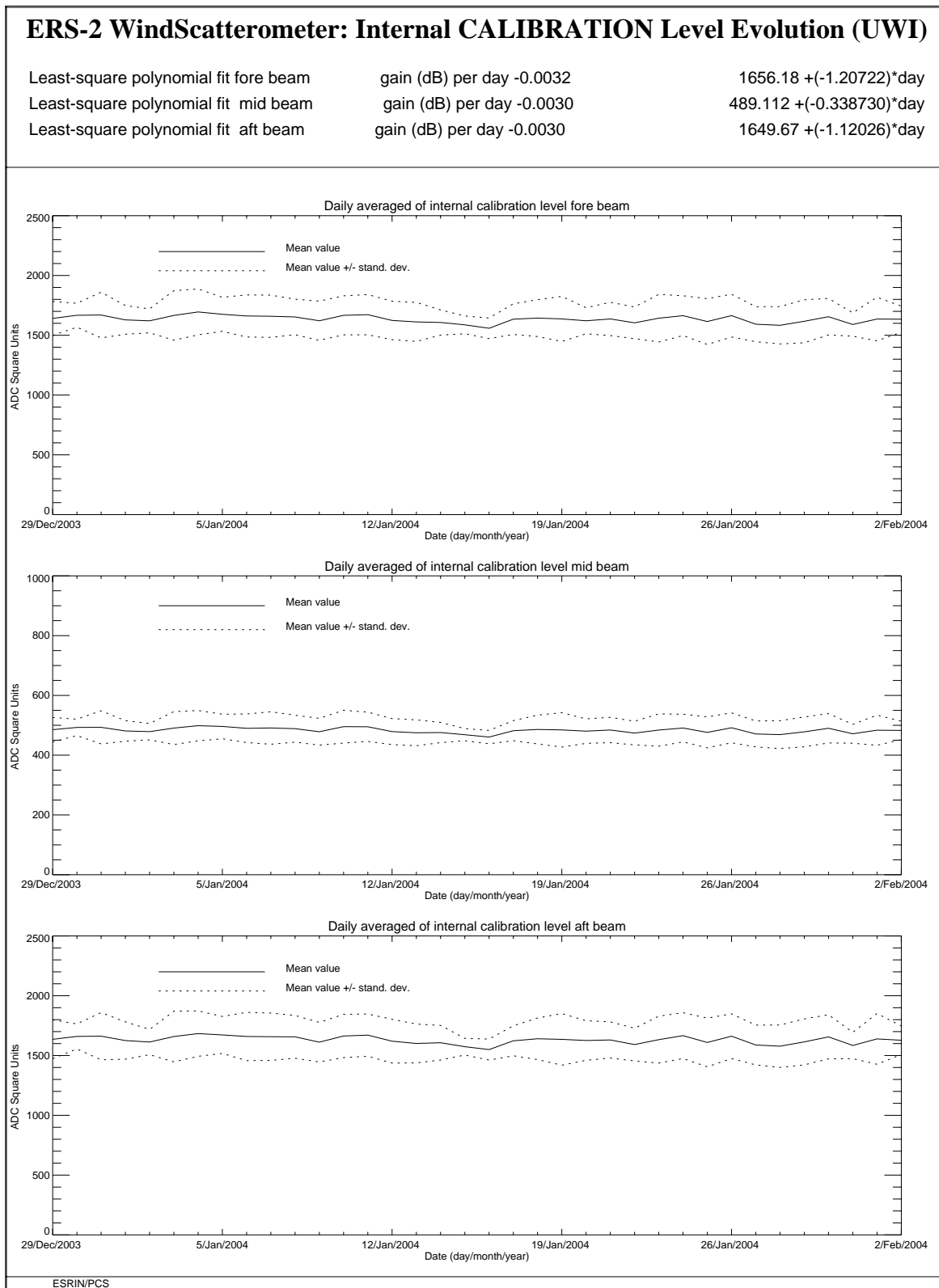


FIGURE 7. ERS-2 Scatterometer: power of internal calibration level cycle 91.

4.0 Products performance

The PCS carries out a quality control of the winds generated from the WSCATT data. External contributions to this quality control (from ECMWF) are also reported in this chapter.

4.1 Products availability

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 imagerettes 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 imagerette 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.

Since July 16th 2003 the ERS-2 Low Rate mission is continued within only the visibility of ESA ground stations over Europe, North Atlantic, the Arctic and western North America. The reason was the failure of both on-board tape recorders.

In order to maximize the data coverage, since September 7th 2003 the ground station in Maspalomas, Gatineau and Prince Albert are acquiring and processing data for all the ERS-2 satellite passes within the station visibility (apart from passes for which other satellites have an higher priority). To further increase the wind coverage of the North Atlantic area, since December 8th, 2003 is operative a new ground Station in West Freugh (UK) and data from this new station are available to the user since mid January 2004. Due to its location, the West Freugh acquisitions have some overlap with those from three other ESA stations, Kiruna, Gatineau or Maspalomas. The station overlap depends on the relative orbit of the satellite. Consequentially, overlapping wind scatterometer LBR data may be included in two products. Since the two products are generated at different ground stations the overlap may not be completely precise, with a displacement up to 12 Km and slight differences in the wind data itself.

Figure 8 shows the AMI operational modes for cycle 91. 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). Due to ZGM commissioning phase the AMI was operated in wind-wave mode through-

out the orbits. For cycle 91 the percentage of the ERS-2 AMI activity is shown in table 4. The values are in the nominal range.

Table 4: ERS-2 AMI activity (cycle91)

AMI modes	ascending passes	descending passes
Wind and Wind-Wave	95.13%	82.72%
Image	2.96%	14.63%
Gap and others	1.91%	3.65%

Table 5 reports the major data lost due to the test periods, AMI and satellite anomalies or ground segment anomalies occurred after 6th August, 1996 (before that day for many times data were not acquired due to the DC converter failure).

Table 5: 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
May 22 nd , 2001	May 24 th , 2001	ERS-2 Payload switched-off due to platform anomaly
May 25 th , 2001	May 25 th , 2001	AMI switched-off due thermal analysis
November 17 th , 2001	November 18 th , 2001	ERS-2 switched off to face out Leonide meteo storm
November 27 th , 2001	November 28 th , 2001	ERS-2 payload off due to 1Gyro Coarse Mode commissioning
March 8 th , 2002	March 20 th , 2002	ERS-2 payload unavailability after RA anomaly
May 19 th , 2002	May 24 th , 2002	AMI switched-off due to arc events
May 24 th , 2002	May 28 th , 2002	AMI partially switched-off due to arc events
May 31 st , 2002	June 3 rd , 2002	Gatineau orbits partially acquired due to antenna problem
June 4 th , 2002	June 5 th , 2002	AMI partially switched-off due to arc events
July 25 th , 2002	July 25 th , 2002	AMI switched off HPA voltage too low

Start date	Stop date	Reason
September 11 th , 2002	September 11 th , 2002	AMI switched off macrocommand transfer error
November 17 th , 2002	November 18 th , 2002	ERS-2 switched off to face out Leonide meteo storm
December 9 th , 2002	December 10 th , 2002	IDHT anomaly no data recorded on board
December 20 th , 2002	December 20 th , 2002	IDHT anomaly no data recorded on board
January 14 th , 2003	January 14 th , 2003	IDHT anomaly no data recorded on board
16 th May 2003	19 th May 2003	AMI off due to bus reconfiguration
June 22 nd , 2003	July 16 th , 2003	IDHT recorders test no data acquired
July 16 th , 2003	onwards	Data available only within the visibility of ESA ground station

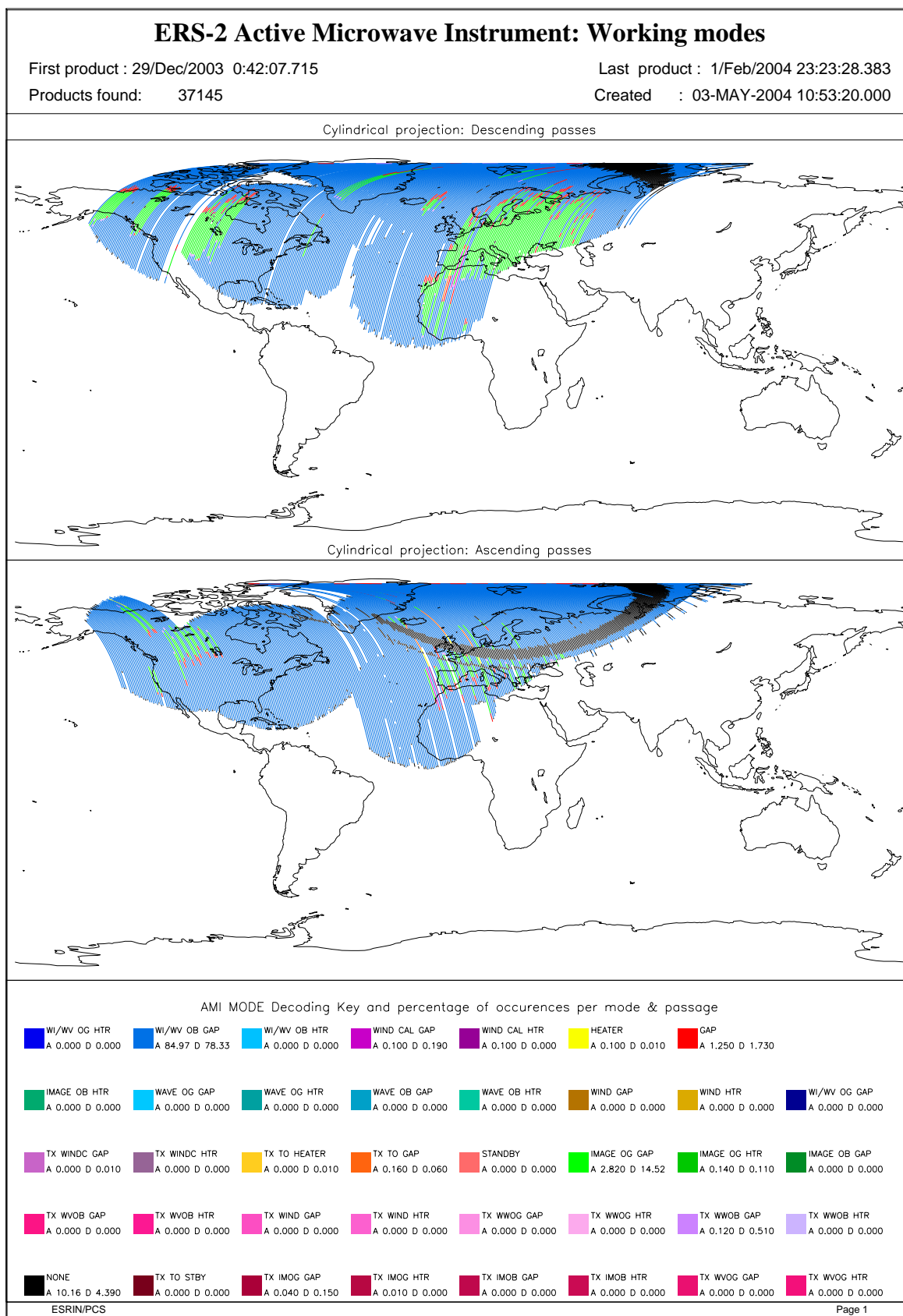


FIGURE 8. ERS-2 AMI activity during cycle 91.

4.2 PCS Geophysical Monitoring

The routine analysis is summarized in the plots of figure 9; 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 August 6th, 1996 until the beginning of the operation with the Zero Gyro Mode (ZGM) in January 2001 can be summarized as:

- High quality wind products has been distributed since Mid March 1996 (end of calibration and validation phase)
- The number of valid sigma-nought distributed per day was almost stable with a small increase after June 29th, 1999 due to the dissemination in fast delivery of the data acquired in the Prince Albert station.
- The wind direction is very accurate for roughly 93% of the nodes, the ambiguity removal processing successfully worked for more than 90.0% of the nodes.
- The UWI 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.
- Two important changes affect the speed bias plot.
- the first is on June 3rd, 1996 due to the switch from ERS-1 to ERS-2 data assimilation in the meteorological model.
- the second 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. This allowed the processing of wind data with 18 and 24 hours meteorological forecast instead of the 18, 24, 30 36 hours forecast. The comparison between data processed with the 18-24 hours forecast instead of 30-36 hours forecast shown an increase in the number of ambiguity removed nodes with a neutral impact in the daily statistics.
- 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.

During the Zero Gyro Mode (ZGM) phase the dissemination of the fast delivery scatterometer data to the users has been interrupted on 17th January 2001 due to degraded quality in sigma noughts and winds. The satellite attitude in ZGM is slightly degraded and the “old” ground processor was not able to produce calibrated data anymore. For that reason a re-design of the entire

ground processing has been carried out and since August 21st 2003 the new processor named ERS Scatterometer Attitude Corrected Algorithm (ESACA) is operative in all the ESA ground station and data was redistributed to the user.

Although for a long period data was not distributed, the PCS has monitored the data quality (as shown in Figure 9) and the results during that period can be summarized as:

At the beginning of the ZGM (January 2001 - end July 2001) the number of valid nodes has a clear drop from 190000 per day to 9000 per day. This because the satellite attitude was strong degraded and the received signal had a very high Kp figure (in particular for the far range nodes). For the valid nodes, due to no calibrated sigma nought, the quality of the wind was very poor, the distance from the cone was high and the wind speed bias was above 1.5 m/s.

At the end of July 2001 the ZGM has been tuned and the satellite attitude had an improvement. This explain the increase of the number of valid nodes (returned around the nominal level) and the improvements in the wind speed bias (around 0.5 m/s).

On 4th February 2003, a beta version of the new ESACA processor has been put in operation in Kiruna for validation and the monitoring of the data quality has been done only for the new ESACA data. The number of valid nodes slight decreased because Kiruna station process only 9 of 14 orbits per day. The wind speed direction deviation had a clear improvement because ESACA implements a new ambiguity removal algorithm (MSC) and the ambiguity removal rate is now stable at 100% (the MSC is able to remove ambiguity for all the nodes). The wind speed bias had a clear drop from 0.5 to -0.5 m/s. That value is closer to the nominal one (around -0.2 m/s). As reported in the previous cyclic reports the beta version of ESACA had some calibration problem for the near range nodes and this explains why the data quality does not match exactly the one obtained in the nominal YSM. That problem has been overcome with the final release of the ESACA processor put into operation on August 21st 2003.

On June 22nd the failure of the on-board tape recorder discontinued the ERS global mission (see section 4.1) and this explains the low number of valid nodes available after that day.

Currently the performances of ESACA winds are affected by land contamination. Around costal zones many Sea nodes have a strong contribution of Land backscattering and the retrieved wind is not correct. An optimization of the Land/Sea flag in the ground processing is under implementation.

In the statistics computed by PCS on the fast delivered winds the Land contamination has been removed by using a refined Land/Sea mask. Also the ice contamination has been removed with a simple geographical filter. With these new setting the PCS statistics are very similar to the ones reported by ECMWF. The wind speed bias (UWI vs 18 or 24 hour forecast) is roughly 0.5 m/s and the speed bias standard deviation is around 2 m/s.

The wind direction deviation shows a good performance: more than 98% of the nodes has a direction deviation within [+90;-90] degrees.

Performances of ESACA winds computed by ECMWF are given in section 4.3.

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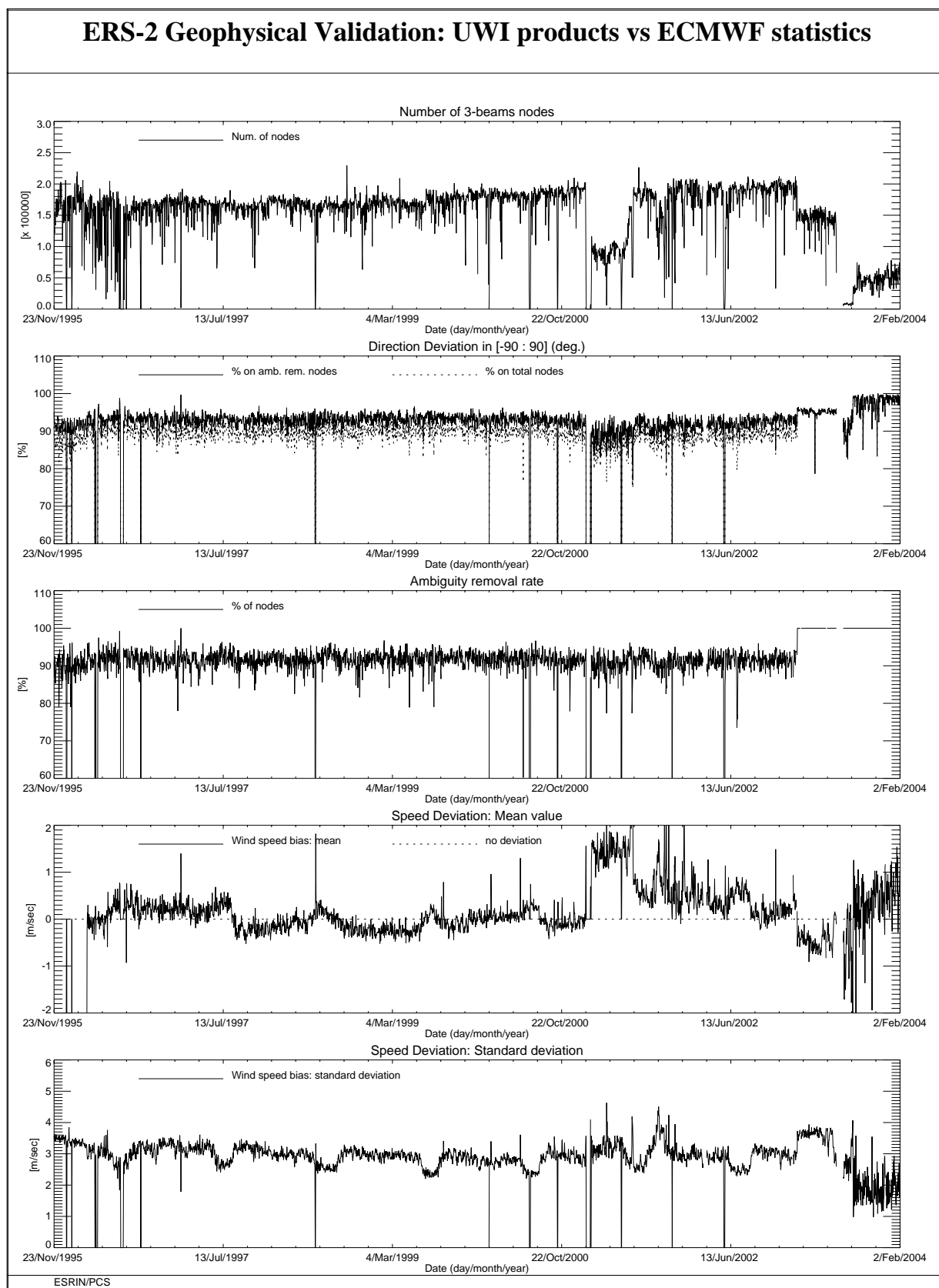


FIGURE 9. ERS-2 Scatterometer: wind products performance since the beginning of the mission.

4.3 ECMWF Geophysical Monitoring

On 21 August 2003, the world-wide dissemination of ERS-2 data was restarted. Due to a failure of both on-board LBR tape recorders two months earlier, only data is being received for data within the visibility range of a ground station. In practice this limits coverage to the North-Atlantic, part of the Mediterranean, the Gulf of Mexico, and to a small part of the Pacific north-west from the US and Canada (see Figure 10). Since 8th December 2003, a new ground station became operational at West Freugh (Scotland, UK), filling the gap in data coverage over the North-Atlantic. However, at ECMWF, data for this station was only received from 23:47 UTC 15 January 2004 onwards. Its area of coverage, with the exception of the previously existing gap, is now reported by more than one ground station, which leads to a duplication in dissemination. Locations of vector wind cells between stations can differ up to 12km. The UWI winds are mostly almost identical, however, the result of the de-aliasing is occasionally not equal, resulting in anti-parallel winds (Note from ESRIN: for each node the ambiguity removal is performed taking into account a large area of influence around the node. It happens that for the same node the area of influence differs from one station to other due to the data acquisition strategy. Differences in the area of influence explains the result reported by ECMWF. ESRIN is investigating the possibility to centralize the Scatterometer data processing in order to remove dissemination of duplicated winds

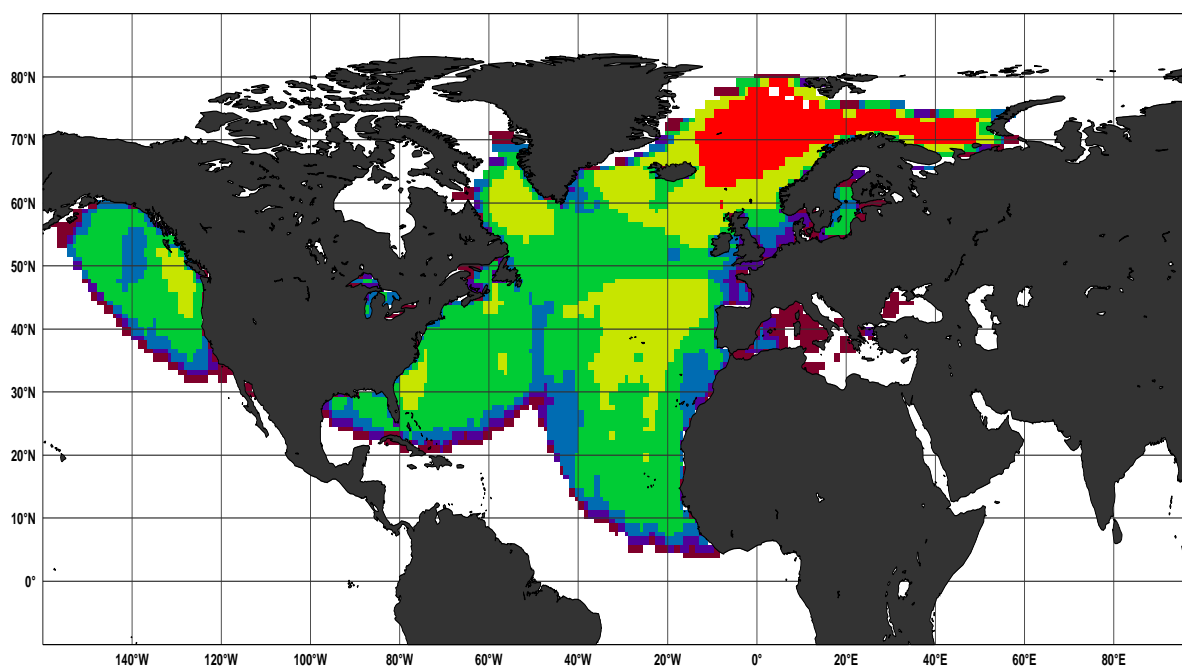


FIGURE 10. Average number of observations per 12H and per 125km grid box for UWI winds that passed the UWI flags QC and a check on the collocated ECMWF land and sea-ice mask.

The quality of the UWI product was monitored at ECMWF for cycle 91. Results were compared to those obtained from the previous cycle, as well for data received during the nominal period in 2000 (up to cycle 59). The ERS-2 scatterometer data was not used in the 4D-Var data assimilation system at ECMWF. However, it is being processed passively in the operational suite and assimilated actively (on the basis of CMOD5) in the experimental suite that is scheduled to become operational in one month. During cycle 91, data was received between 21:02 UTC 29 December 2003 and 20:59 UTC 2 February 2004 and for all 6-hourly batches. However, for the batches

around 06 UTC 10 January 2004 only 6 observations were received, and for 06 UTC 26 January 2004 all 464 observations were rejected by the ESA quality control flag. Mostly, the asymmetry between fore and aft incidence angles was within bounds (3 degrees). Peaks up to 7 degrees occurred for 12 UTC 10 January, 12 UTC 19 January and between 12 UTC 25 January and 00 UTC 26 January 2004. The combined kp and yaw-error flag was set for these cases. Although there was some solar activity during cycle 91, no magnetic storms occurred around these periods of large errors in attitude. Compared to cycle 90, the agreement with ECMWF first-guess (FGAT) fields worsened. Relative bias levels became more negative (from -0.51 m/s to -0.61 m/s), and scatter has again increased (from 1.65 m/s to 1.71 m/s). Part of this deterioration is caused by seasonal variations for the regional data set. However, the less optimal results appear to be concentrated in a relatively small area south-west of the previously existing data-void area in the North Atlantic. Also, the degradation was largest in the near range, while the relative standard deviation was nearly unaltered in the far range. The quality of both the UWI and de-aliased CMOD4 wind direction was stable. Compared to nominal data in 2000, bias levels for both backscatter and wind speed are more optimal. Standard deviations of wind speed are less optimal to those for 2000. A fair comparison, however, cannot be made due to large differences in data coverage.

The ECMWF assimilation system was not changed during cycle 91.

4.3.1 Distance to cone history

The distance to the cone history is shown in Figure 11.

Curves are based on data that passed all QC, including the test on the kp-yaw flag, however subject to the land and sea-ice check at ECMWF (see cyclic report 88 for details). Time series are very (due to lack of statistics) noisy, especially for the first nodes. This makes it difficult to identify peaks that might indicate a low data quality. Most spikes are a result from low data volumes. The volatile behaviour on 25 January 2004 arises from the rejection of almost all data by the combined kp-yaw flag. Compared to cycle 90, average levels have decreased from 1.23 to 1.17 and are now about 7% higher than for nominal data.

4.3.2 UWI minus First-Guess history

In Figure 12, the UWI minus ECMWF first-guess wind-speed history is plotted. The history plot shows many peaks. Similar results apply for the history of de-aliased CMOD4 winds versus FGAT. Most peaks are a result of low data volume. Others indicate a real discrepancy between UWI and ECMWF winds.

Average bias levels and standard deviations of UWI winds relative to FGAT winds are displayed in Table 6.

Table 6: Biases and standard deviation of ERS-2 versus ECMWF FGAT winds in m/s for speed and degrees for direction

	Cycle 90 UWI	Cycle 90 CMOD-4	Cycle 91 UWI	Cycle 91 CMOD-4
speed stdev	1.65	1.63	1.71	1.70
node 1-2	1.63	1.58	1.78	1.73

Table 6: Biases and standard deviation of ERS-2 versus ECMWF FGAT winds in m/s for speed and degrees for direction

	Cycle 90 UWI	Cycle 90 CMOD-4	Cycle 91 UWI	Cycle 91 CMOD-4
node 3-4	1.56	1.54	1.66	1.65
node 5-7	1.56	1.56	1.64	1.63
node 8-10	1.60	1.59	1.68	1.67
node 11-14	1.61	1.61	1.70	1.70
node 15-19	1.68	1.68	1.69	1.69
speed bias	-0.51	-0.49	-0.61	-0.59
node 1-2	-1.21	-1.16	-1.25	-1.20
node 3-4	-0.89	-0.81	-0.93	-0.86
node 5-7	-0.56	-0.52	-0.64	-0.61
node 8-10	-0.32	-0.31	-0.44	-0.43
node 11-14	-0.28	-0.28	-0.38	-0.37
node 15-19	-0.24	-0.23	-0.39	-0.39
direction stdev	29.3	19.8	28.9	19.6
direction bias	-3.3	-2.9	-2.8	-2.9

From this it is seen that the bias of both the UWI and CMOD4 product have been reduced by 0.04 m/s. However, internode differences have, again, become larger, being most negative in the near range. The average bias level is better than for nominal data in 2000 (UWI: -0.61 m/s now, was -0.79 m/s for cycle 59).

The standard deviation of UWI winds compared to cycle 90 has worsened as well (1.71 m/s, was 1.65 m/s). The increase is largest in the near range (0.15 m/s) and only 0.01 m/s at the highest nodes. This reverses the internode dependency completely; performance is now worst in the near range, instead of in the far range for cycle 90.

For cycle 91 the (UWI - model) direction standard deviations were ranging between 20 and 40 degrees. Sharp peaks are the result of low data volumes. For de-aliased CMOD4 winds values between 20 and 30 degrees are most common. With respect to cycle 90, the average standard deviation (see Table 6) of the UWI wind direction was slightly lower (28.9 degrees, was 29.3 degrees). The same applies for de-aliased CMOD4 winds (19.6 degrees, was 19.8 degrees). Bias levels in wind direction were also very similar (-3.3 degrees, was -2.3 degrees for UWI; -2.9 degrees unaltered for CMOD4).

4.3.3 Scatter plots

Scatterplots of model 10 m first-guess winds versus ERS-2 winds are displayed in Figures 16 to 18. Values of standard deviations and biases are slightly different from those displayed in Table 6. Reason for this is that, for plotting purposes, the in 0.5 m/s resolution ERS-2 winds have been slightly perturbed (increases scatter with 0.02 m/s), and that zero wind-speed ERS-2 winds have

been excluded (decreases scatter with about 0.05 m/s). The scatterplot of UWI wind speed versus FGAT (Figure 16) is very similar to that for (at ECMWF inverted) de-aliased CMOD4 winds (Figure 18). It confirms that the ESACA inversion scheme is working properly.

The enhanced standard deviation with respect to cycle 90 (1.72 m/s, was 1.61 m/s), seems to arise from slightly more collocations between low UWI and strong FGAT winds. Winds derived on the basis of CMOD5 are displayed in Figure 19. The bias compared to FGAT winds remains small for all wind domains (on average -0.01 m/s, was 0.06 m/s) The relative standard deviation is lower than for CMOD4 winds (1.69 m/s versus 1.72 m/s).

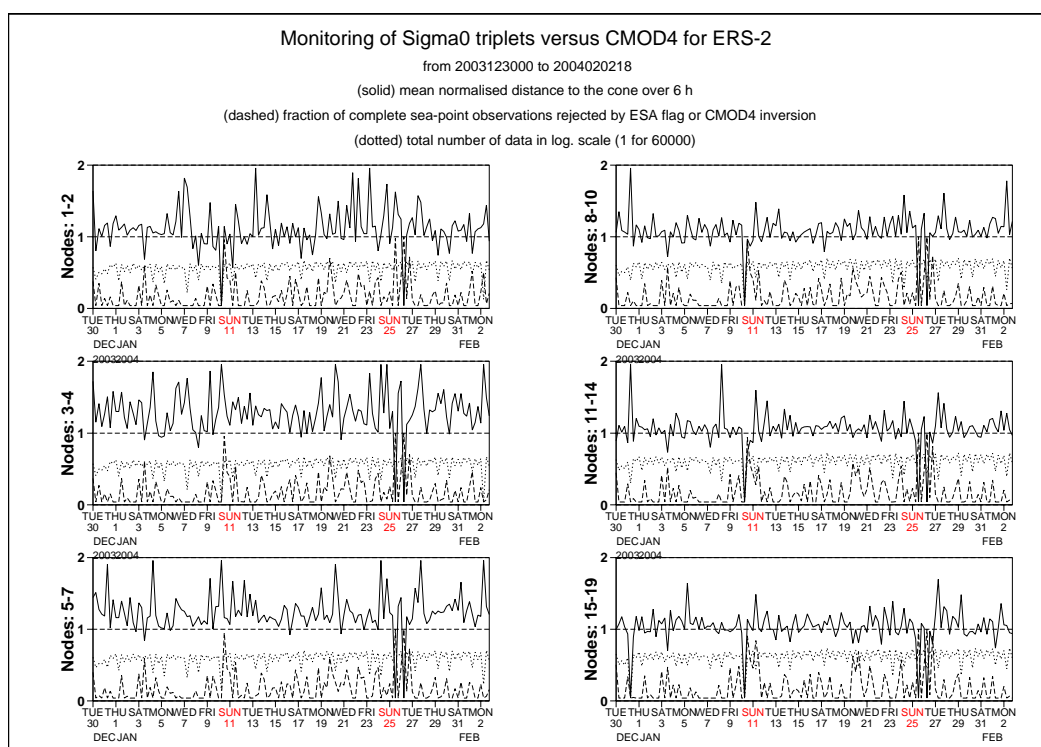


FIGURE 11. Mean normalised distance to the cone computed every 6 hours for nodes 1-2, 3-4, 5-7, 8-10, 11-14 and 15-19 (solid curve close to 1 when no instrumental problems are present). The dotted curve shows the number of incoming triplets in logarithmic scale (1 corresponds to 60,000 triplets) and the dashed one indicates the fraction of complete sea-located triplets rejected by the ESA flag, or by the wind inversion algorithm (0: all data kept, 1: no data kept). Cycle 91

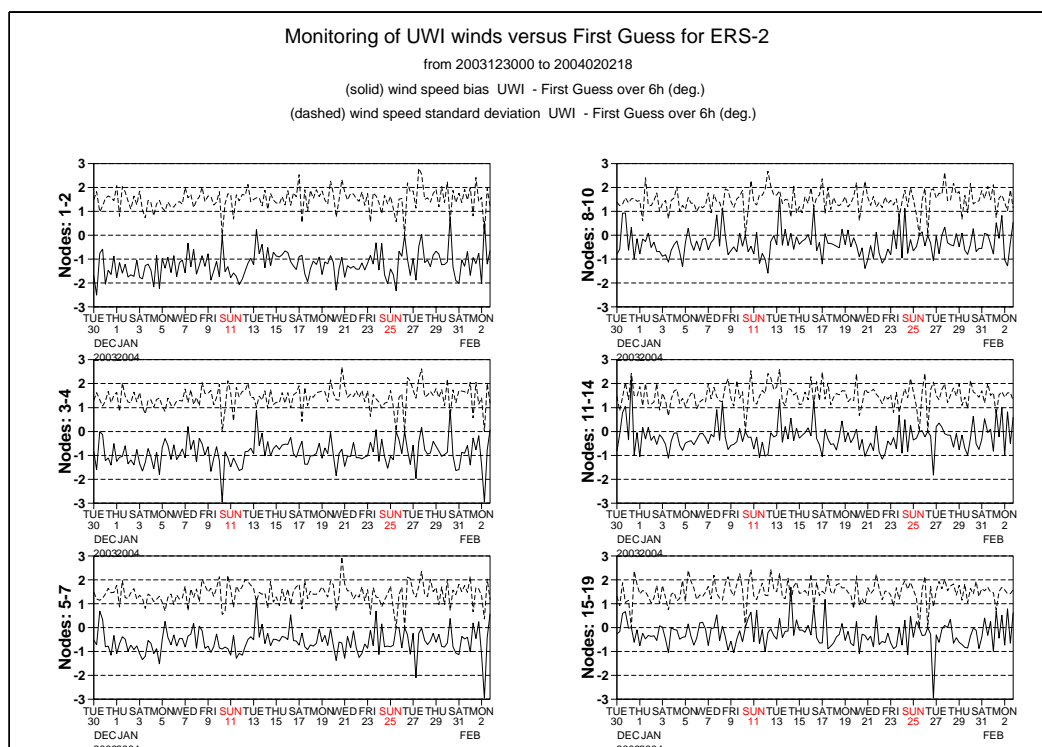


FIGURE 12. Mean (solid line) and standard deviation (dashed line) of the wind speed difference UWI - first guess for the data retained by the quality control.Cycle 91

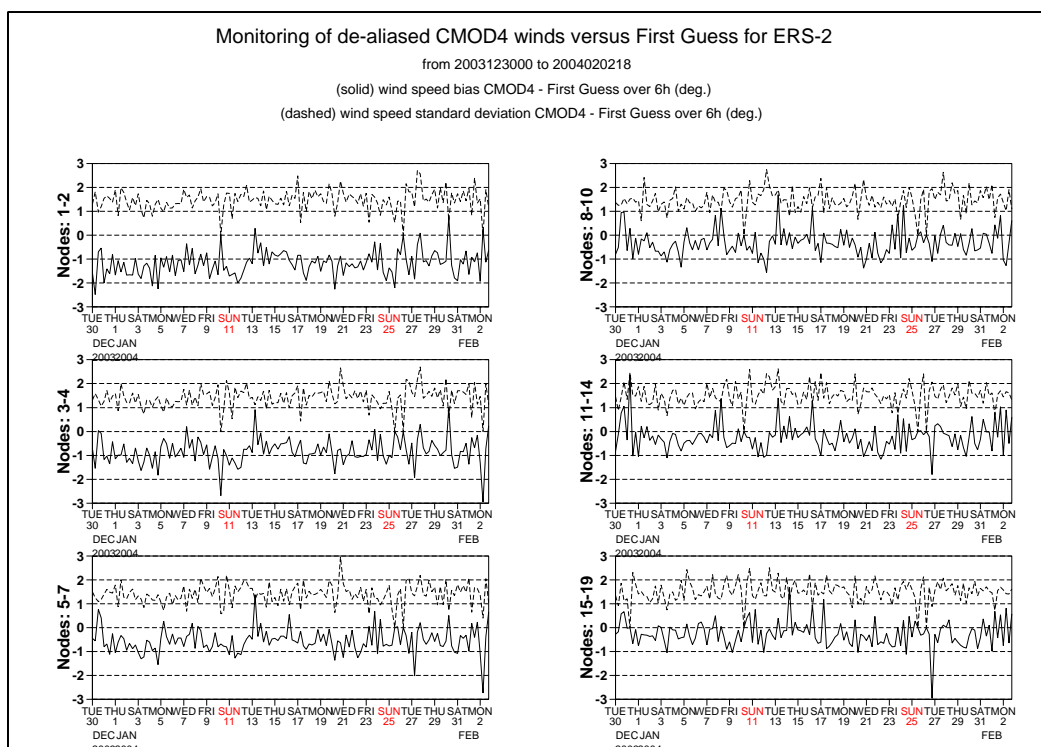


FIGURE 13. Same as Fig.12, but for the de-aliased CMOD-4 wind. Statistics are computed only for wind speeds higher than 4 m/s.Cycle 91

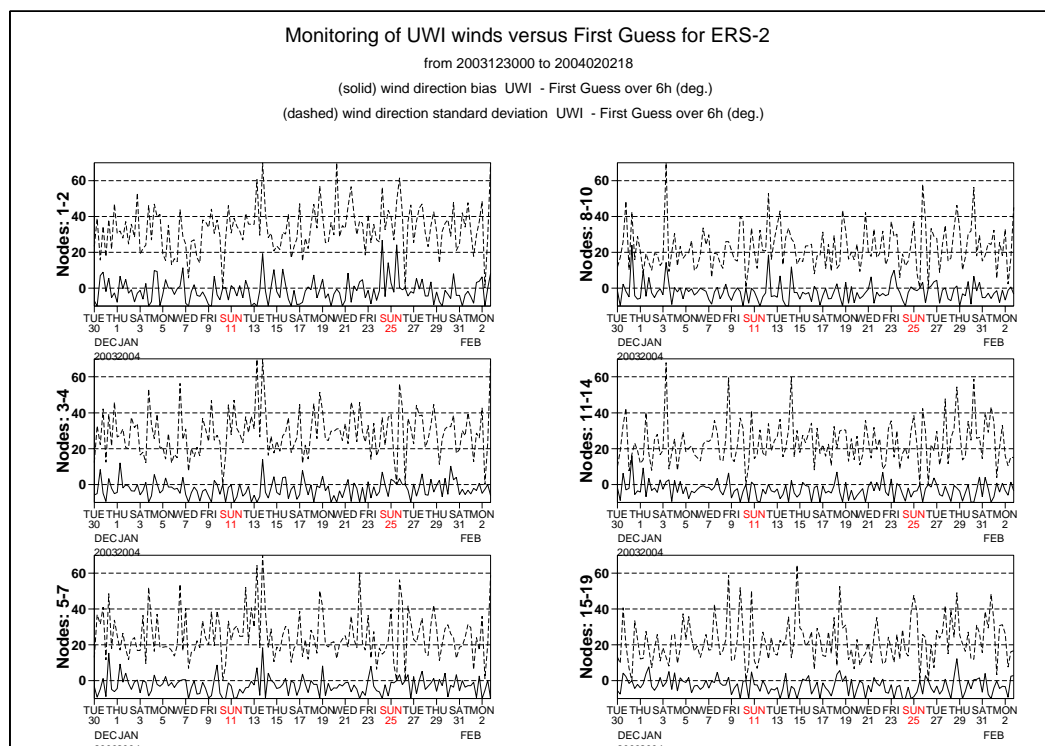


FIGURE 14. Same as Fig. 12 but for wind direction. Cycle 91.

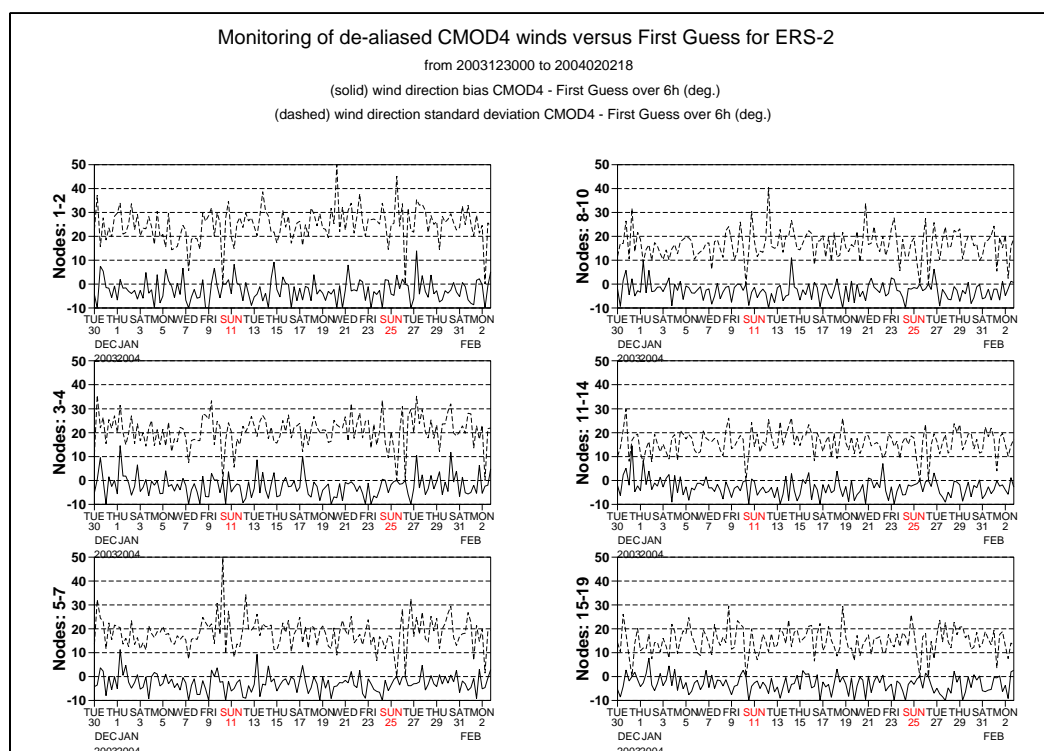


FIGURE 15. Same as Fig. 13 but for wind direction. Cycle 91.

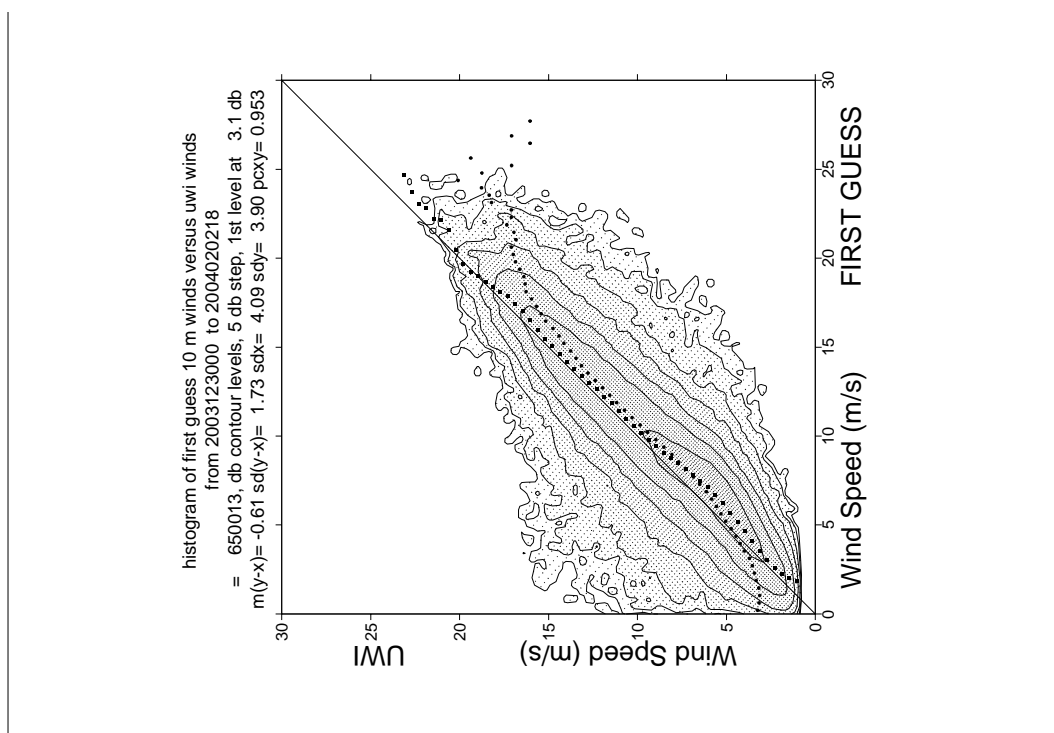


FIGURE 16. Two-dimensional histogram of first guess and UWI wind speeds, for the data kept by the quality control. Circles denote the mean values in the y-direction, and squares those in the x-direction. Cycle 91

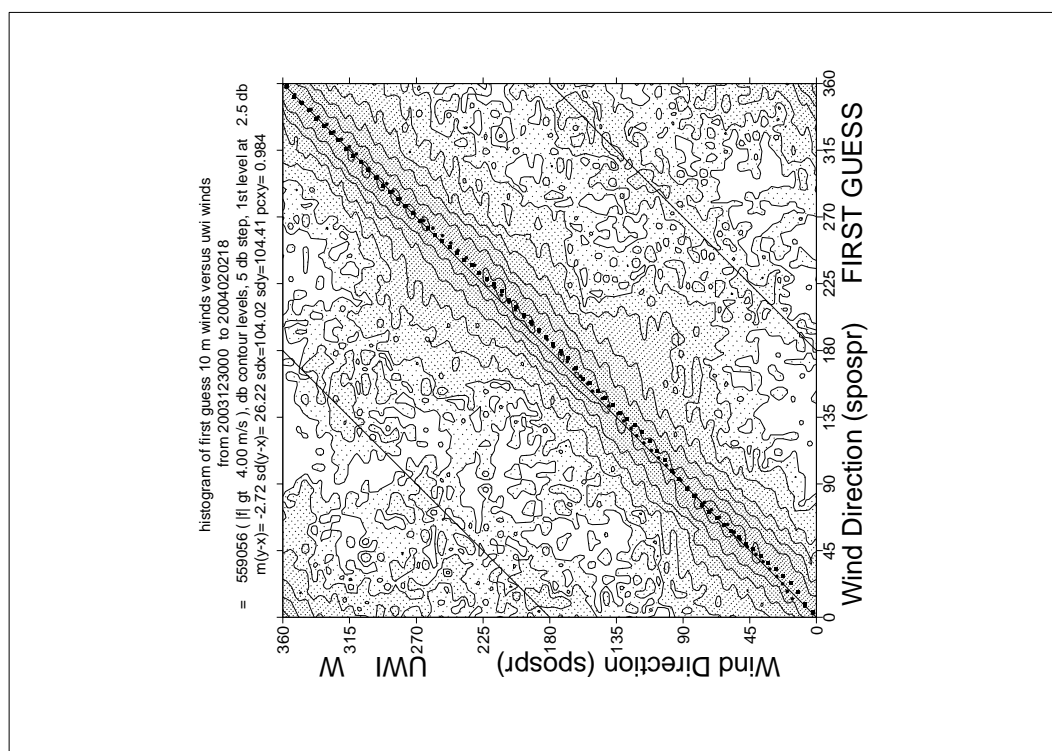


FIGURE 17. Same as Fig. 17, but for wind direction. Only wind speeds higher than 4m/s are taken into account. Cycle 91.

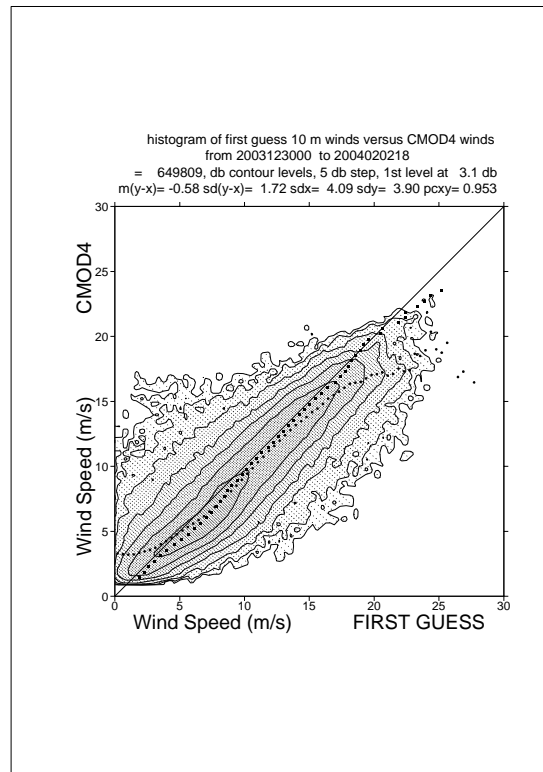


FIGURE 18. Same as Figure 16 but for de-aliased CMOD-4 winds. Cycle 91

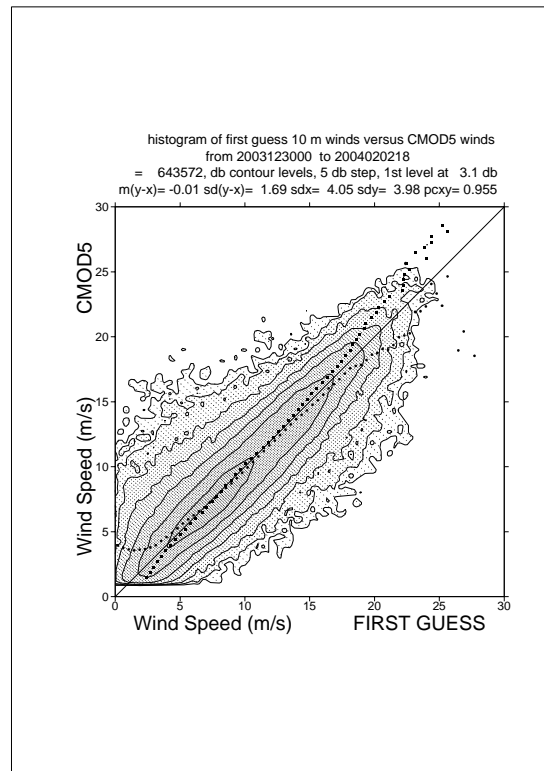


FIGURE 19. Same as Figure 16 but for de-aliased CMOD-5 winds. Cycle 91

5.0 Yaw error angle estimation

The yaw error angle estimation is computed on-ground by the ESACA processors. The full set of results of the yaw processing is stored in an internal ESA product named HEY (Helpful ESA Yaw) disseminated from the ground station to ESRIN. The estimation of the yaw error angle is based on the Doppler shift measured on the received echo. That estimation can be done with a good accuracy only for small yaw error angle (in the range between ± 4 deg.). Above that range, due to high Doppler frequency shift the signal spectrum is outside the receiver bandwidth and the yaw estimation is strongly degraded. Details regarding the yaw processing can be found on the following document (chapter 9): <http://earth.esa.int/pcs/ers/scatt/articles/soamain-030521.pdf>

The yaw error angle estimation aims to compute the correct acquisition geometry for the three Scatterometer antenna throughout the entire orbit. The Yaw error angle information is used in the radar equation to derive the calibrated backscattering (sigma nought) from the Earth surface and to select the echo samples associated to one node. In ESACA the definition of the node position is as the one adopted in the old processor (for details see: http://earth.esa.int/pcs/ers/scatt/articles/scatt_work98_processing.pdf). In such way the distance between the nodes (both along and across track) is kept constant (25 Km) and what is changing in function of the yaw error angle is the number of echo samples that contributes to the node calculation and the incidence angle of the measurement. This is why the three scatterometer antennae could see the node with a different geometry due to an arbitrary variation of the yaw angle along track. The number of samples that actually contributes to a node and the yaw flag can be retrieved from the UWI Data Set Record (DSR) product. For that reason the definition of few fields in the UWI product has been updated. For details see the Scatterometer cyclic report - cycle 90 -.

The figure 20 shows for each orbit the average doppler frequency shift (first 3 plots Fore Mid and Aft antenna), the minimum, maximum and mean yaw (fourth plot), the yaw standard deviation (fifth plot) and the percentage of source packets acquired with a yaw error angle outside the range ± 2 degrees (sixth plot).

The result of the yaw monitoring for cycle 91 is a mean yaw error angle within the expected nominal range (± 2 degrees) for most of the orbit. On 10th, 12th and 26th January 2004 many orbits had a bad quality yaw performances due to strongly degraded satellite attitude. There was no increase of solar activity during those days.

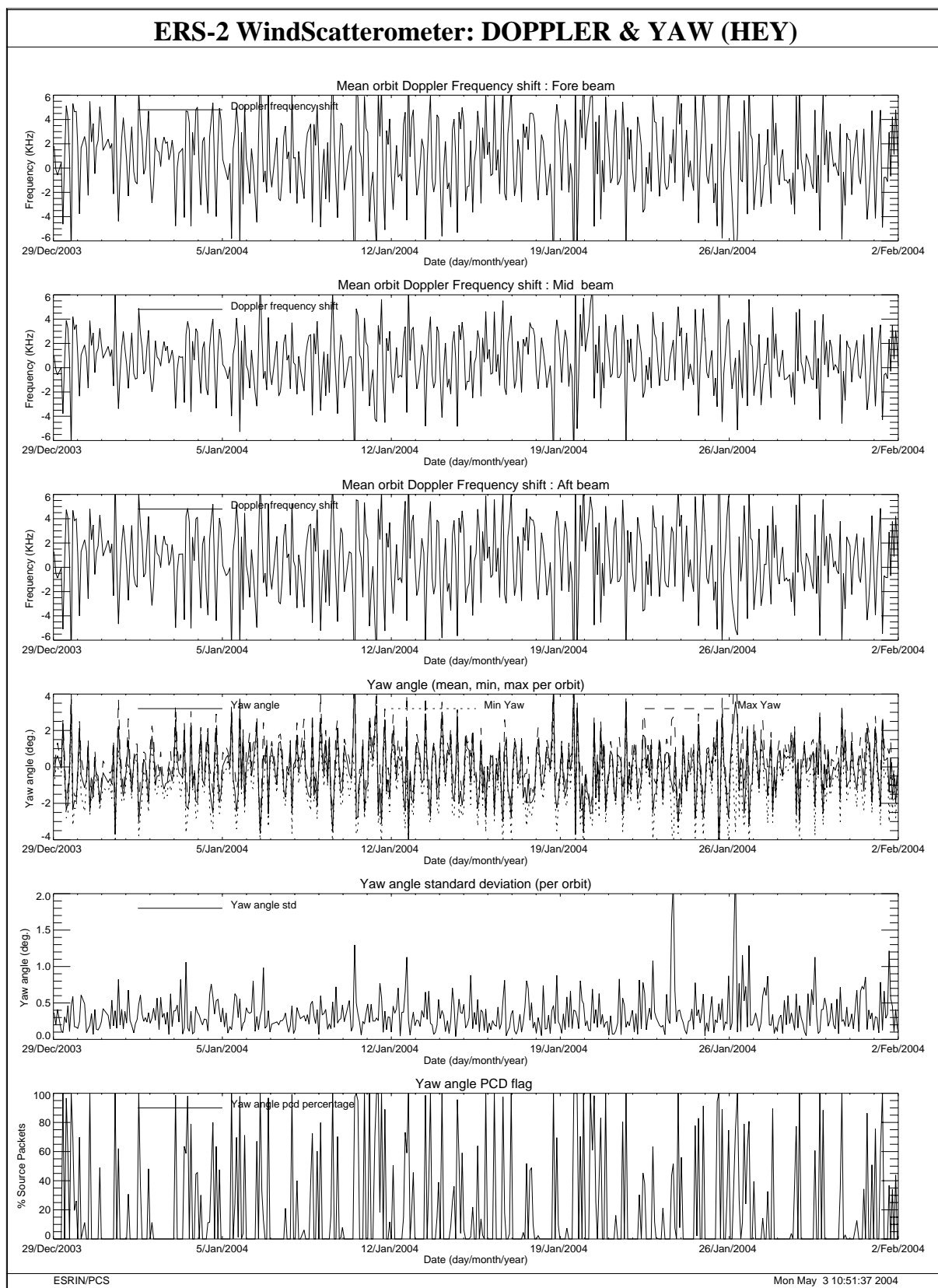


FIGURE 20. Doppler frequency shift and Yaw angle monitoring for cycle 91.

