Monitoring statistics of the ERS-2 scatterometer for ESA

cycle 83

(Project Ref. 15988/02/I-LG)

Hans Hersbach
European Centre for Medium-Range Weather Forecasts,
Shinfield Park, Reading, RG2 9AX, England
Tel: (+44 118) 9499476, e-mail: dal@ecmwf.int

June 12, 2003

1 Introduction

From 12 December 2001 onwards, ESRIN redistributes ERS-2 scatterometer data to a selected group of users. On 4 February 2003, a new processor, ESACA, was introduced. It is an upgrade of the existing LRDPF and includes new scatterometer processing algorithms that anticipate errors in the satellites yaw attitude control. It was installed for Kiruna station only and is currently running in test phase. The quality of this experimental product was monitored at ECMWF for cycle 83. This scatterometer data was not used in the 4D-Var data assimilation system at ECMWF.

For cycles 81 and 82, monitoring of ESACA data had revealed three imperfections. Firstly, there appeared to be an error in the BUFR encoding of k_p. This gave rise to large numbers of erroneously high k_p values. Since the high-k_p data was shown (see previous report) to be of good quality, the quality control check on k_p was, like for cycle 82, disabled.

Secondly, it was shown that UWI winds are not in line with (at ECMWF inverted) CMOD4 winds anymore, the latter being of considerably higher quality. Especially for strong winds, the UWI winds have a larger random error w.r.t. ECMWF FGAT winds than CMOD4 winds have.

Finally, backscatter levels of the near-range fore and aft beams were found to be biased low compared to the corresponding level of the mid beam, which led to large negative UWI wind-speed biases ($\sim$ -1.5 m/s).

During cycle 83, at ESRIN one was able to remedy the first two imperfections. However, the appropriate updates of the ESACA processor have not yet been implemented for Kiruna station.

During cycle 83, data was received between 21:08 UTC 24 March and 20:59 UTC 28 April 2003. Due to the reception of data from Kiruna station only, for most days in cycle 83, no data was received for the 6-hourly data periods centered around 00 UTC. In case data was received for 00 UTC, data volumes were low. Occasionally low volumes for 18 UTC and 6 UTC can also be attributed to the lack of data from the other stations. Besides these daily data gaps, no interruptions in data reception were observed.

Time series for the asymmetry between the incidence angles of the fore and aft beam (related to yaw attitude errors), show several peaks (from 3 up to 7 degrees), the largest occurring at 18 UTC 1 April 2003. For that date, a peak in the distance to cone history was observed as well, and UWI winds were found to be far too weak. The peak was not accompanied by a sign for anomalous solar activity.

Besides the anomaly at 18 UTC 1 April 2003, the potential quality of the wind product is high. A small transition towards improved performance of both UWI winds and de-aliased CMOD4 winds occurred around 30 March 2003. The average quality of the UWI wind speed was for cycle 83 somewhat higher than for data received during cycle 82. However, the quality of UWI wind direction was lower. This trend was not found for de-aliased CMOD4 winds, which indicates that the potential quality in wind direction was unaltered.

The ECMWF assimilation system was not changed during cycle 83.

2 ERS-2 statistics from 24 March to 28 April 2003

2.1 Sigma0 bias levels

The average sigma0 bias levels (compared to simulated sigma0's based on ECMWF model first-guess winds, see Figure 1) showed the following evolution w.r.t. corresponding levels for data received during cycle 82. In general, bias levels have become less negative (0 - 0.15 dB) for all tracks, beams and incidence angles. The reduction was not uniform. As a result the following picture (see Figure 1) emerges. Bias levels are between 0.2 and 1.1 dB too low. Levels are rather uniform, with a slight improvement with respect to cycle 82. Inter-beam differences have somewhat increased for the mid-angle range of the descending tracks. The large negative bias for the fore and aft beam in the near range is still evident. Although, the bias for the mid beam of the ascending tracks has improved somewhat.

2.2 Incidence angles

For ESACA, across node binning is, like the old processor, retained on a 25km mesh. From simple geometrical arguments it follows that variations in yaw attitude will lead to asymmetries between the incidence angles of the fore and aft beam. Indeed, this has been observed. Figure 2 gives a time evolution of this asymmetry, showing the rapid variations, which are typical for yaw attitude errors. Several peaks are observed, the largest occurring around 20 UTC 1 April 2003, i.e., near the end of the daily data batch received from Kiruna station.

2.3 Distance to cone history

The distance to the cone history is shown in Figure 3. Most of the peaks are due to low data volumes that now occur on a daily basis. The peaks at 18 UTC 1 April, 6 UTC 6 April, 18 UTC 15 April, and 18 UTC 20 April 2003 are not connected to a low data volume. Only for the first peak, the quality of the UWI winds was low (see next subsection). In contrast to what was observed for data retrieved from the old processor (cycle 81 and before) these peaks are most pronounced at low incidence angles.

For low and high incidence angles, the cone distance is on average on its normalized levels, and slightly too high for mid-range nodes. Averaged over all data (see top panel of Figure 8), the cone distance is about 5% below the average for cycle 69 (December 2000), i.e., the last cycle in nominal mode.

2.4 UWI minus First-Guess wind history

In Figure 4, the UWI minus ECMWF first-guess wind-speed history is plotted.

Besides peaks induced by the daily data gaps, the wind-bias and the standard deviation history shows a large peak for 18 UTC 1 April 2003. This peak, which is most pronounced at lower nodes, was also observed in the distance to cone and (fore - aft) incidence angle history. For this period, far too weak UWI winds are found, and for several patches, the wind direction looks unrelated to the FGAT wind direction. Two examples are shown in Figure 9.

In the top panel of Figure 10, all locations are plotted for which UWI winds were more than 8 m/s weaker than the FGAT winds. The low-quality data described above is clearly seen as the track running from the southern Indian ocean till the Barents sea.

Around 30 March 2003 (see Figure 4), a transition towards improved performance occurred. The standard deviation of the UWI versus FGAT winds decreases somewhat, and corresponding bias levels become less negative as well. A similar behavior is observed for de-aliased CMOD4 winds (see Figure 6).

Average bias levels and standard deviations of UWI winds relative to FGAT winds are displayed in Table 1. From this it is seen that, compared to cycle 82, the average bias level is reduced by 0.05 m/s. The large negative wind bias for the lower nodes (-1.55 m/s, was -1.56 m/s) is a result of the large negative biases in sigma0 levels (see Figure 1). Standard deviations have been slightly reduced (average 1.60 m/s, was 1.62 m/s).

Like for ESACA data received for cycle 82, the at ECMWF inverted CMOD4 winds do not match the UWI winds. The quality of these CMOD4 winds is considerably higher than that of the UWI winds (standard deviation of 1.46 m/s versus 1.60 m/s). Best results are obtained for CMOD5 (shown below).

For cycle 83 the (scatterometer - model) direction standard deviations were ranging between 20 and 40 degrees (Figure 5). For de-aliased CMOD4 winds values between 20 and 30 degrees are most common. On average (see Table 1), the quality in wind direction is lower to that for data received during cycle 82.

	cycle 82		cycle 83	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.62	1.48	1.60	1.46
node 1-2	1.60	1.55	1.60	1.54
node 3-4	1.49	1.46	1.49	1.45
node 5-7	1.53	1.44	1.52	1.42
node 8-10	1.60	1.43	1.59	1.41
node 11-14	1.61	1.43	1.60	1.40
node 15-19	1.62	1.46	1.58	1.41
speed BIAS	-0.80	-0.85	-0.75	-0.81
node 1-2	-1.56	-1.61	-1.55	-1.60
node 3-4	-1.16	-1.16	-1.13	-1.14
node 5-7	-0.83	-0.82	-0.79	-0.79
node 8-10	-0.61	-0.64	-0.55	-0.59
node 11-14	-0.57	-0.64	-0.51	-0.61
node 15-19	-0.64	-0.72	-0.58	-0.68
direction STDV	28.3	19.0	33.9	18.9

Table 1: Biases and standard deviation of ERS-2 versus ECMWF FGAT winds in m/s for speed and degrees for direction

An evolution of average performance since December 2001 is shown in Figure 8. It clearly shows the gradual improvements achieved during 2002, and the jump in performance since the introduction of ESACA.

2.5 Scatter plots

Scatterplots of model 10 m first-guess winds versus ERS-2 winds are displayed in Figures 11 to 14. Values of standard deviations and biases are slightly different from those displayed in Table 1. 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). These scatterplots elucidate the trends described in the previous subsection. Like for cycle 82, the quality of the CMOD4 winds (Figure 13) is higher than that of the UWI winds (Figure 11). This seems to be especially true for strong winds. Values of standard deviations are slightly lower to those for cycle 82.

The average bias of the UWI wind direction is small (0.7 degrees, was 1.0 degrees for cycle 82), and its standard deviation has increased substantially (32.1 degrees, was 25.8). This negative trend was not observed for the de-aliased CMOD4 winds, which indicates that the new ambiguity removal algorithm performed less optimal.

There was a number collocations of low UWI winds and high ECMWF FGAT winds (Figure 11). They mainly originate from the low-quality patch around 20 UTC 1 April 2003 (see previous subsection). The asymmetry in the fore and aft incidence angles was large for these data, indicating a large error in the platform yaw attitude. In case a threshold on yaw error would have been included in the quality control, this erroneous data would have been disregarded. Many of these collocations are also present for de-aliased CMOD4 winds (see Figure 13), however, most are absent for de-aliased CMOD5 winds (see Figure 14, and also the lower panel of Figure 10). Apparently, for CMOD5, the inversion algorithm is not able to generate a wind product from the underlying low-quality backscatter triplets, which, in principle, favors this model function.

Winds derived on the basis of CMOD5 are displayed in Figure 13. Compared to cycle 82, both the bias level (-0.53 m/s, was -0.57 m/s) and the standard deviation (1.45 m/s, was 1.48 m/s) have improved. CMOD5 winds are of higher quality than the CMOD4 and UWI winds. Although CMOD5 winds are too low (induced by too low backscatter levels, see Figure 1), the random error of CMOD5 winds w.r.t. FGAT winds is lower than it used to be for UWI winds during the nominal period (i.e., before January 2001).

Figure Captions

Figure 1: Ratio of $< \sigma_0^{0.625} > / <$ CMOD4(FirstGuess)$^{0.625} >$ 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.

Figure 2: Time series of the difference in incidence angle between the fore and aft beam.

Figure 3: Mean normalized 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).

Figure 4: Mean (solid line) and standard deviation (dashed line) of the wind speed difference UWI - first guess for the data retained by the quality control.

Figure 5: Same as Fig. 4, but for the wind direction difference. Statistics are computed only for wind speeds higher than 4 m/s.

Figures 6 and 7: Same as Fig. 5 and 6 respectively, but for the de-aliased CMOD4 data.

Figure 8: Evolution of the performance of the ERS-2 scatterometer in ZGM averaged over 5-weekly cycles from 12 December 2001 (first data received, cycle 69) to 28 April 2003 (end cycle 83) for the UWI product (solid, star) and de-aliased winds based on CMOD4 (dashed, diamond). Dotted lines represent values for cycle 59 (5 December 2000 to 17 January 2001), i.e. the last stable cycle of the nominal period. From top to bottom panel are shown the normalized distance to the cone (CMOD4 only) the standard deviation of the wind speed compared to FGAT winds, the corresponding bias (for UWI winds the extreme inter-node averages are shown as well), and the standard deviation of wind direction compared to FGAT.

Figure 9: UWI wind vectors (red) and collocated FGAT wind vectors (blue) for 1 April 2003 in the Barents Sea (top panel) and Southern Indian Ocean (lower panel)

Figure 10: Locations of data during cycle 83 for which UWI winds (top panel), respectively CMOD5 winds (lower panel) are more than 8 m/s weaker than the collocated FGAT winds.

Figure 11: Two-dimensional histogram of first guess and UWI wind speeds, for the data kept by the quality control, however, disregarding the level of k_p. Circles denote the mean values in the y-direction, and squares those in the x-direction.

Figure 12: Same as Fig. 11, but for wind direction. Only wind speeds higher than 4m/s are taken into account.

Figure 13: Same as Fig. 11, but for de-aliased CMOD4 winds.

Figure 14: Same as Fig. 11, but for de-aliased CMOD5 winds.

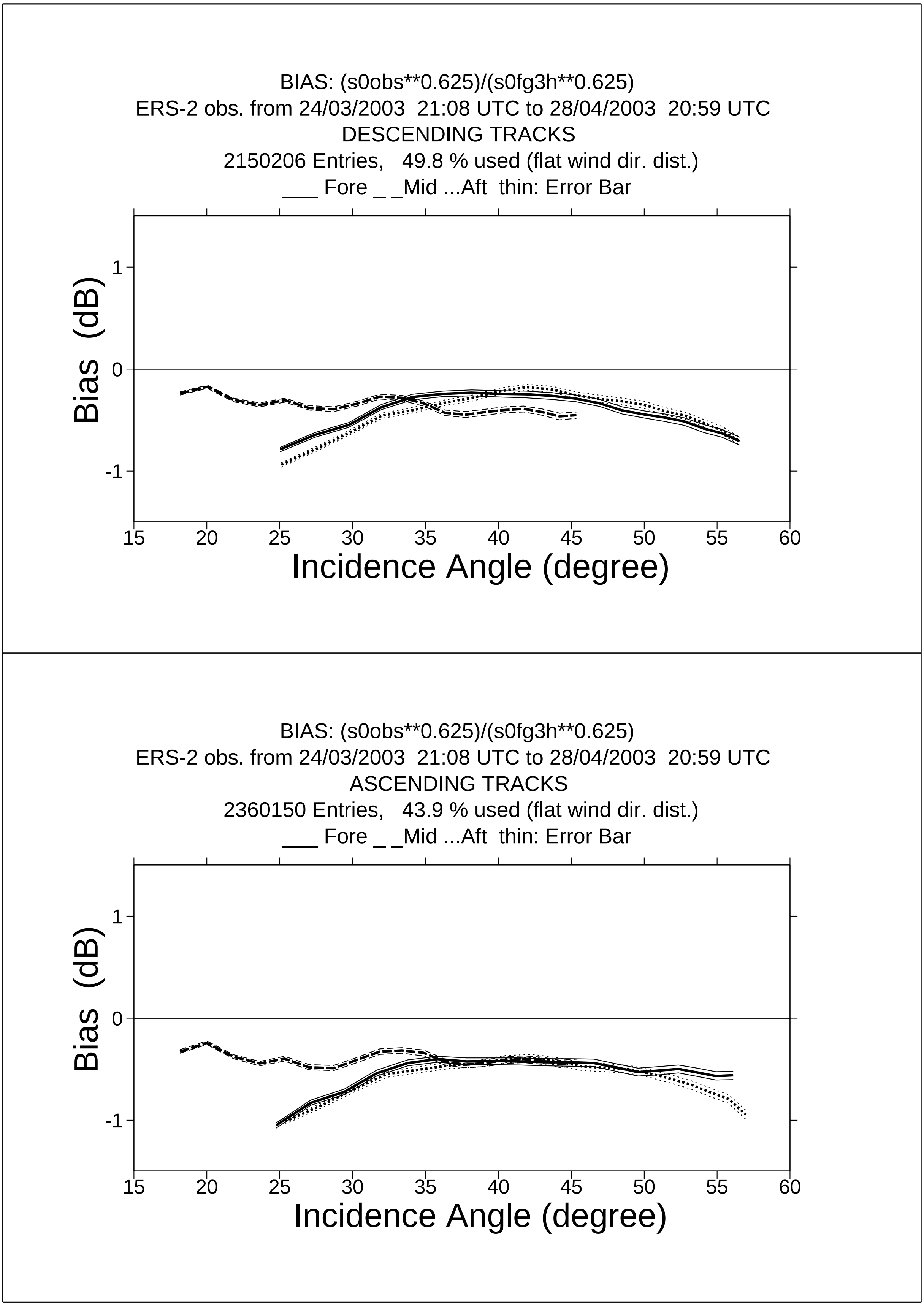

BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 24/03/2003 21:08 UTC to 28/04/2003 20:59 UTC
DESCENDING TRACKS
2150206 Entries, 49.8 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)
BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 24/03/2003 21:08 UTC to 28/04/2003 20:59 UTC
ASCENDING TRACKS
2360150 Entries, 43.9 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)

Figure 1

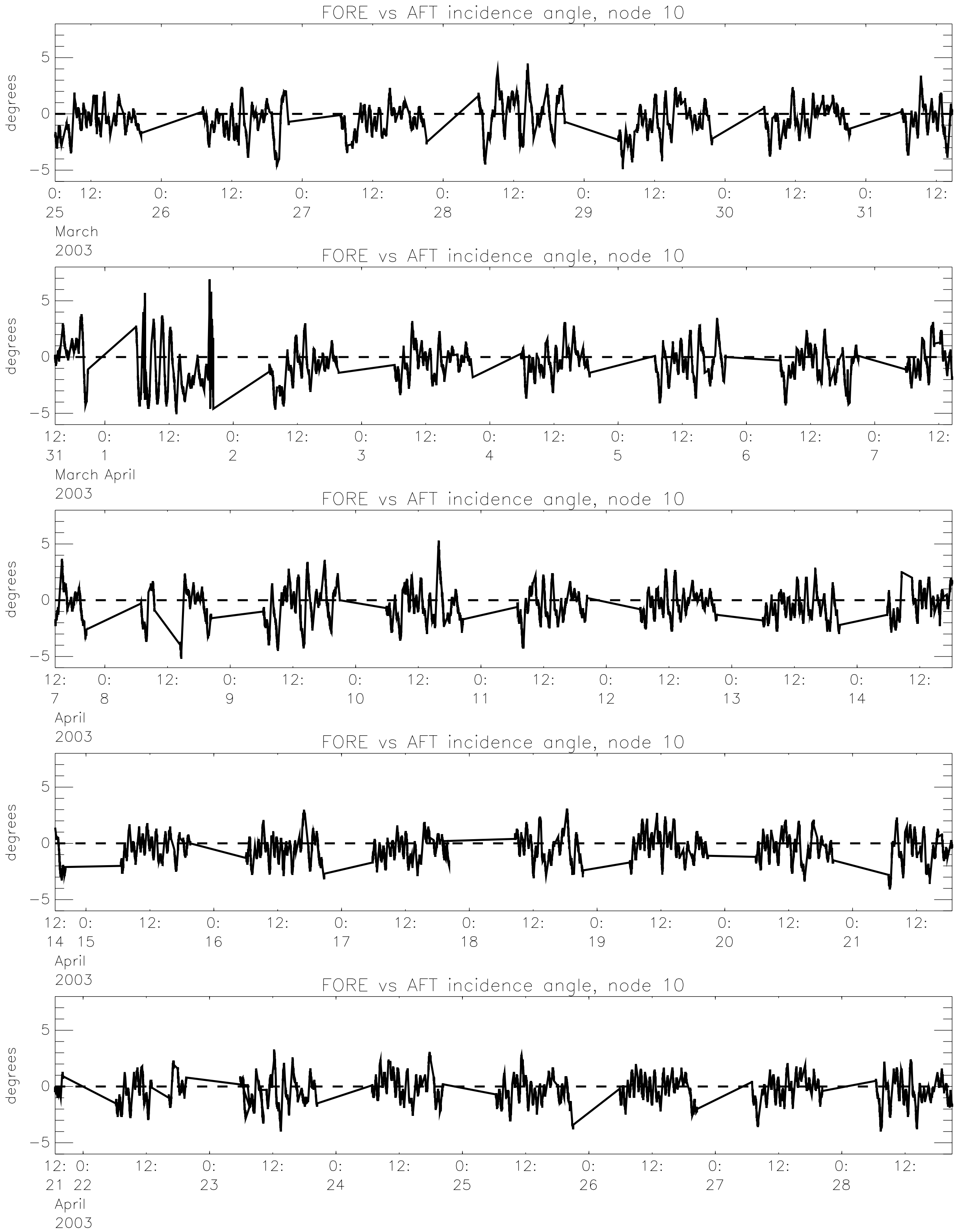

FORE vs AFT incidence angle, node 10
degrees
5
0
−5
0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12:
25 26 27 28 29 30 31
March
2003
FORE vs AFT incidence angle, node 10
degrees
5
0
−5
12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12:
31 1 2 3 4 5 6 7
March April
2003
FORE vs AFT incidence angle, node 10
degrees
5
0
−5
12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12:
7 8 9 10 11 12 13 14
April
2003
FORE vs AFT incidence angle, node 10
degrees
5
0
−5
12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12:
14 15 16 17 18 19 20 21
April
2003
FORE vs AFT incidence angle, node 10
degrees
5
0
−5
12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12: 0: 12:
21 22 23 24 25 26 27 28
April
2003

Figure 2

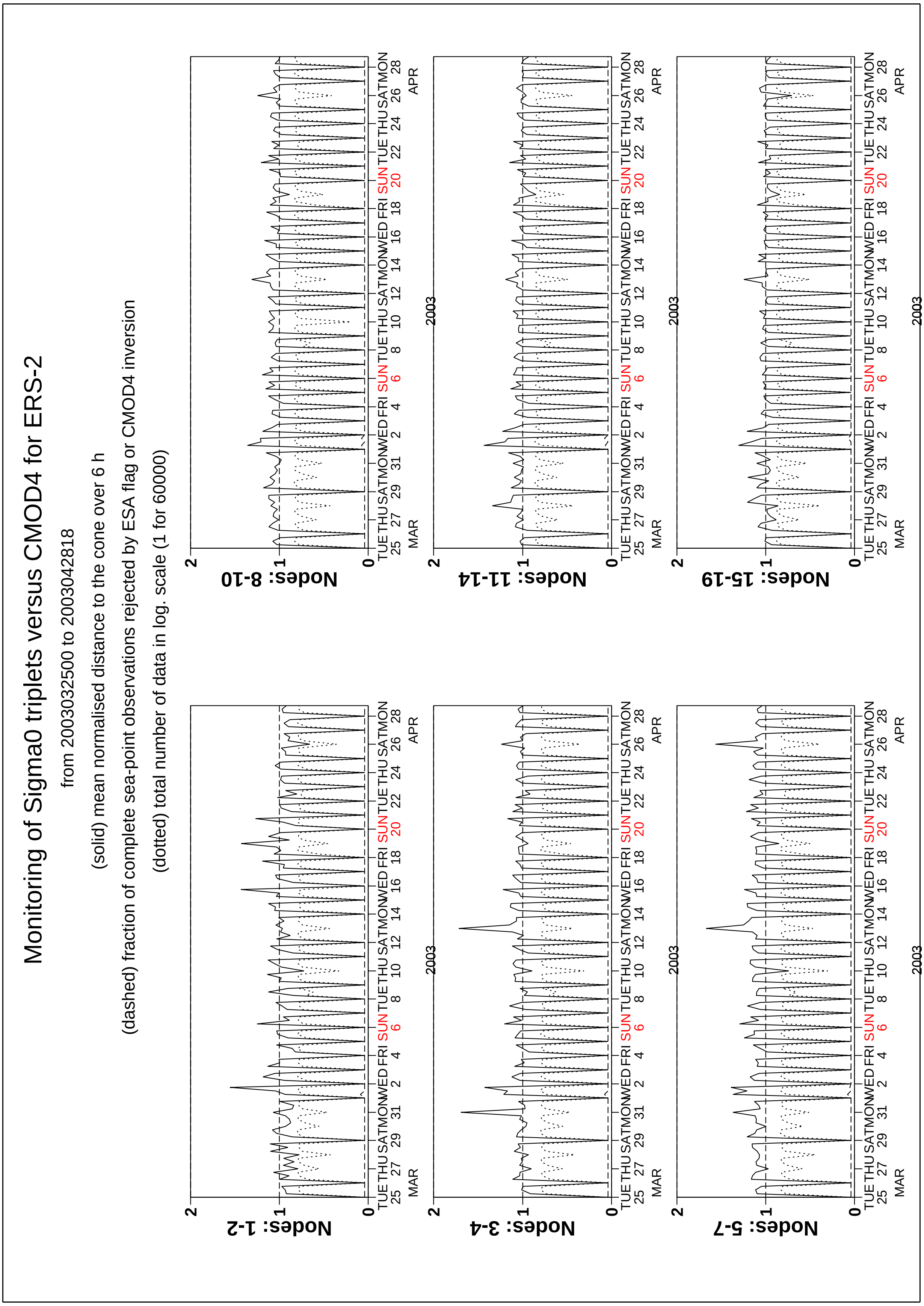
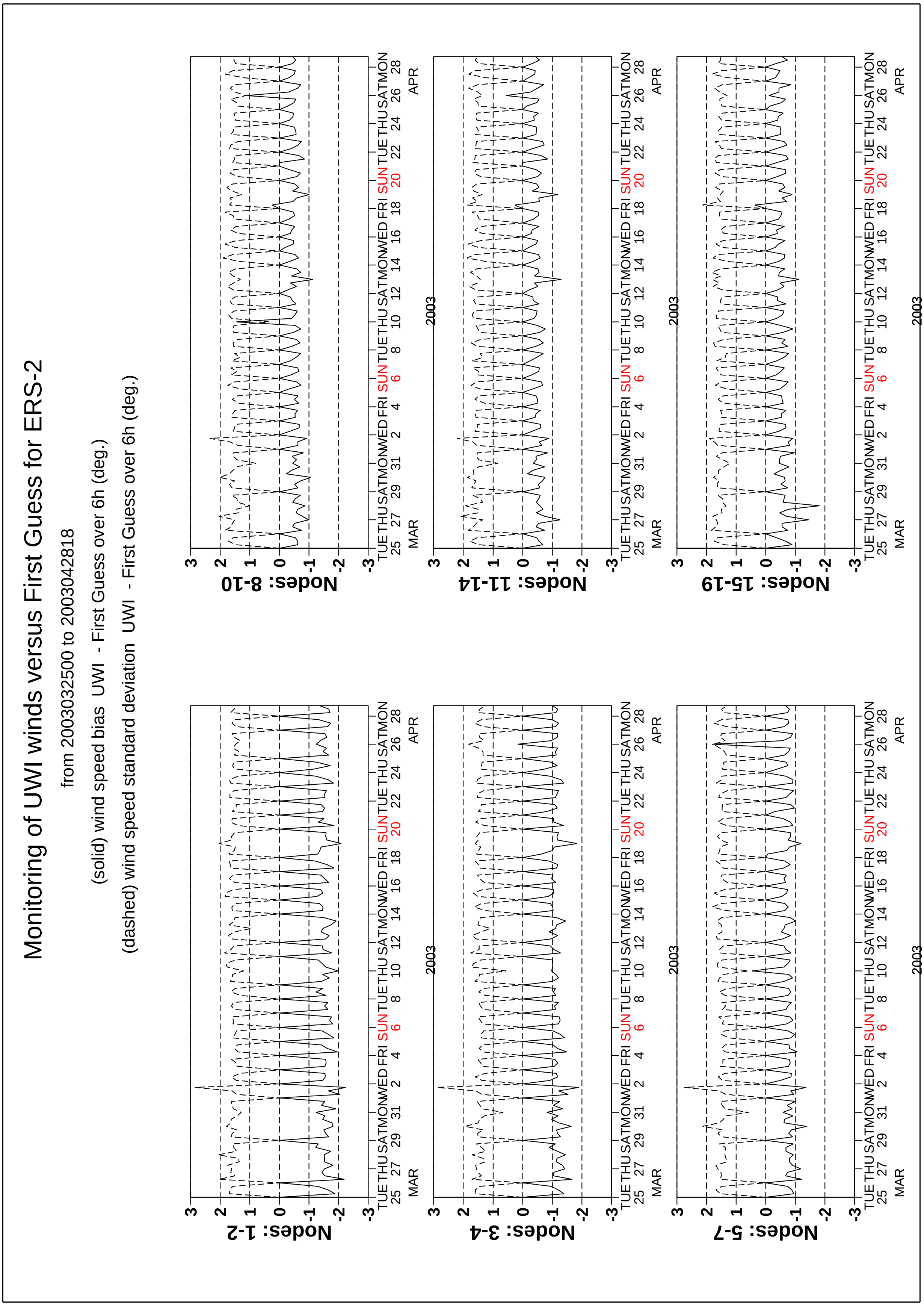
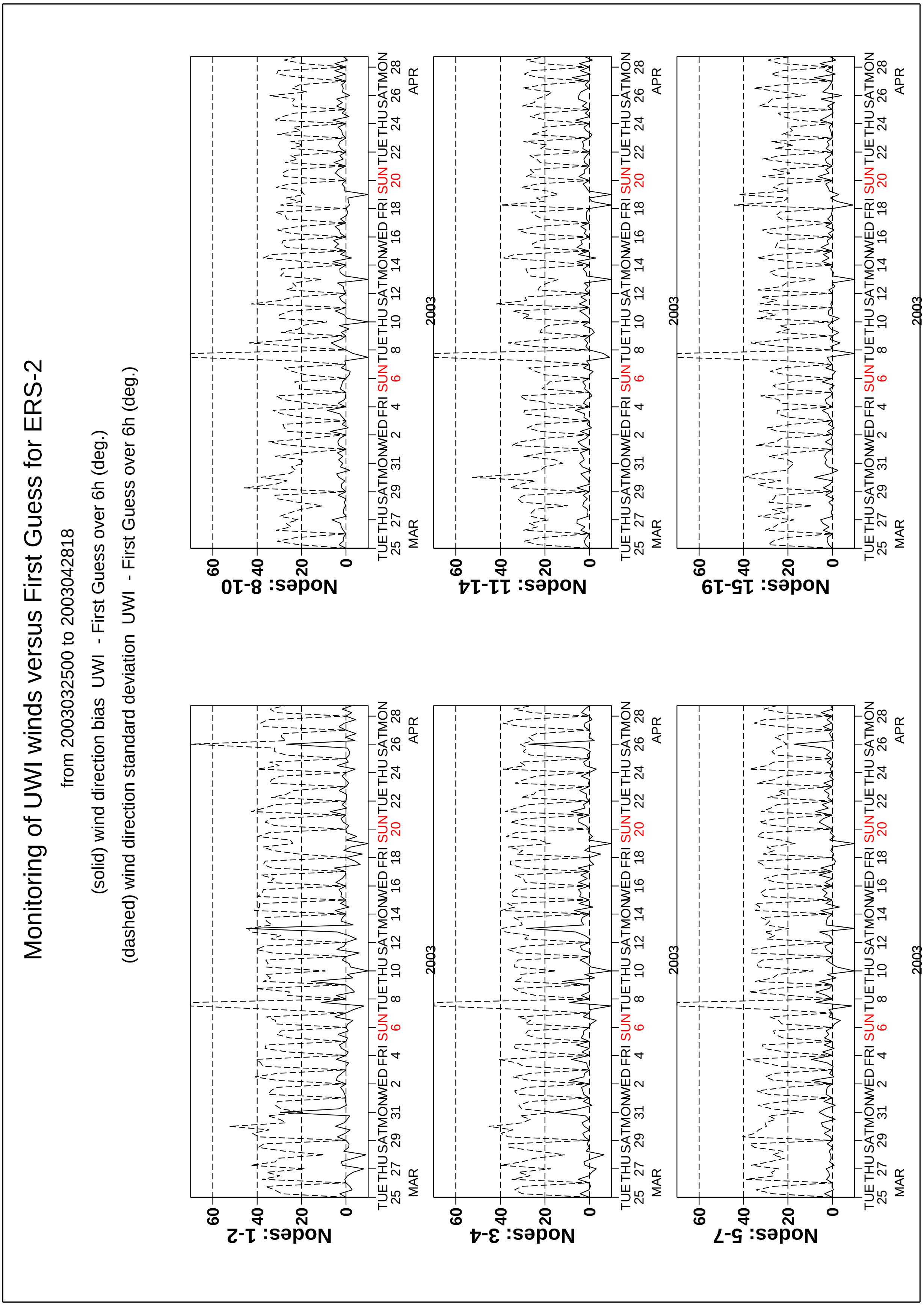

Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2003032500 to 2003042818
(solid) mean normalised distance to the cone over 6 h
(dashed) fraction of complete sea-point observations rejected by ESA flag or CMOD4 inversion
(dotted) total number of data in log. scale (1 for 60000)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
MAR
APR
2003

Figure 3



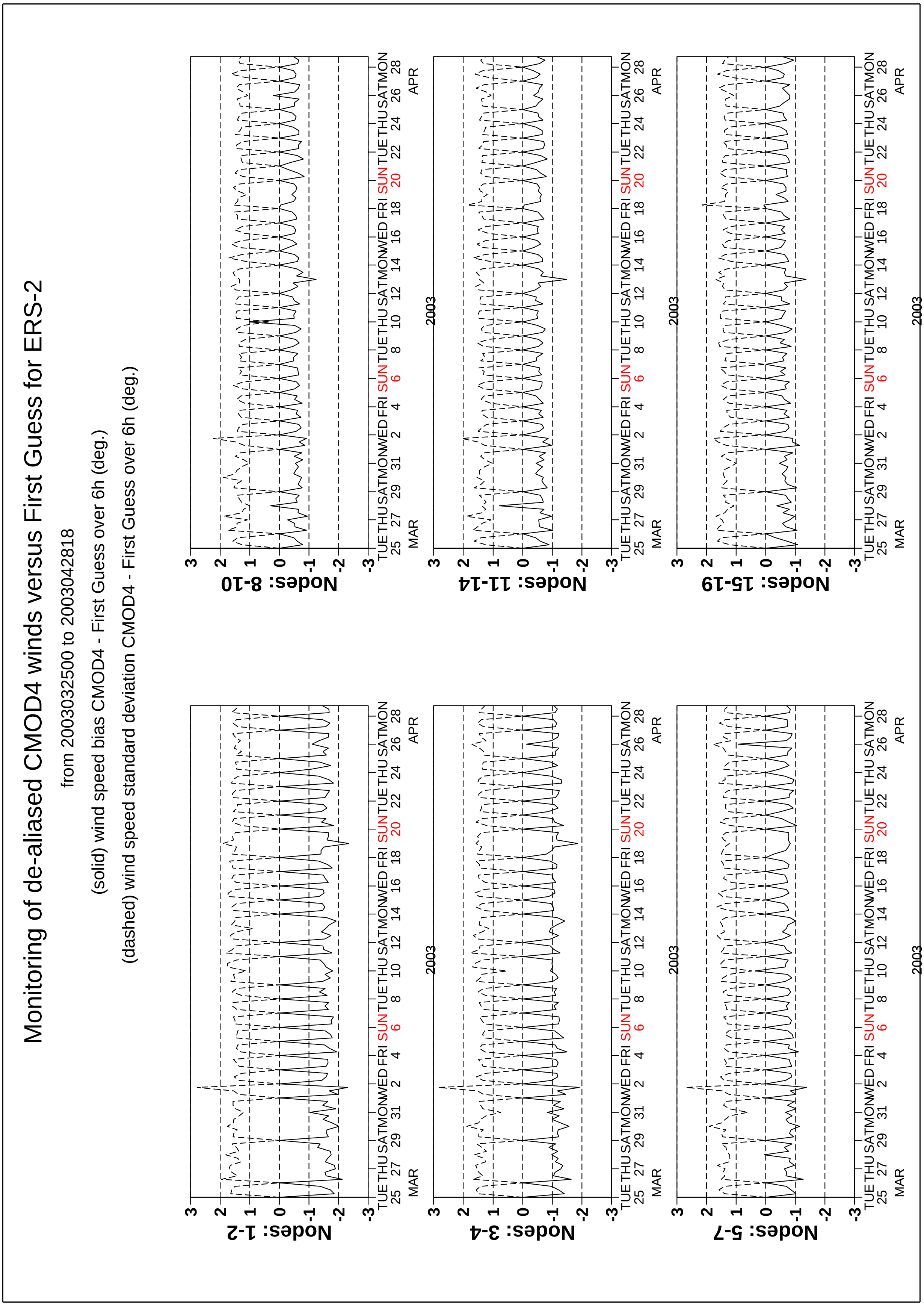
Monitoring of UWI winds versus First Guess for ERS-2
from 2003032500 to 2003042818
(solid) wind speed bias UWI - First Guess over 6h (deg.)
(dashed) wind speed standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
MAR
APR
2003

Figure 4



Monitoring of UWI winds versus First Guess for ERS-2
from 2003032500 to 2003042818
(solid) wind direction bias UWI - First Guess over 6h (deg.)
(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19

Figure 5



Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003032500 to 2003042818
(solid) wind speed bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind speed standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
MAR
APR
2003

Figure 6

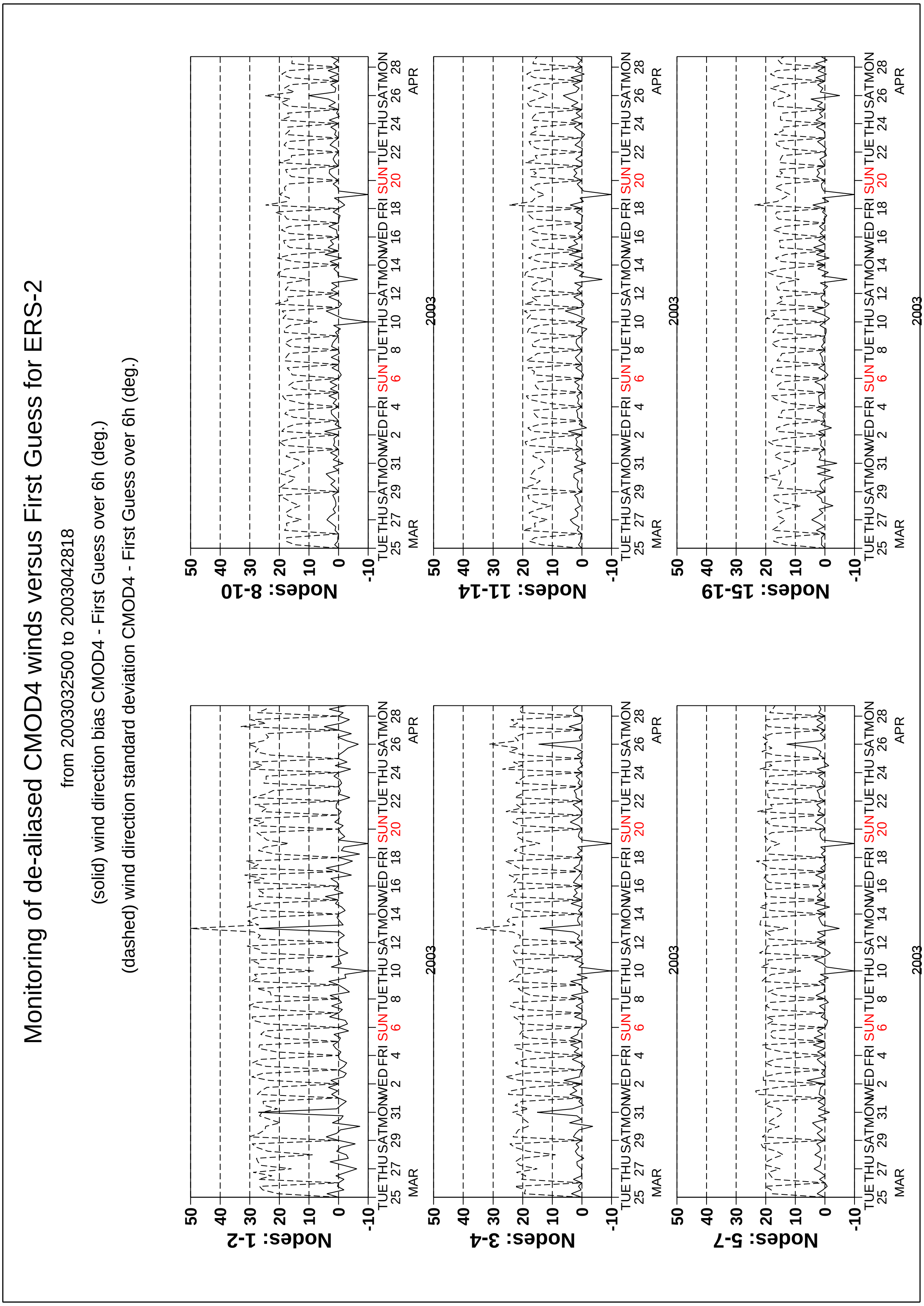

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003032500 to 2003042818
(solid) wind direction bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind direction standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
MAR
APR
2003

Figure 7

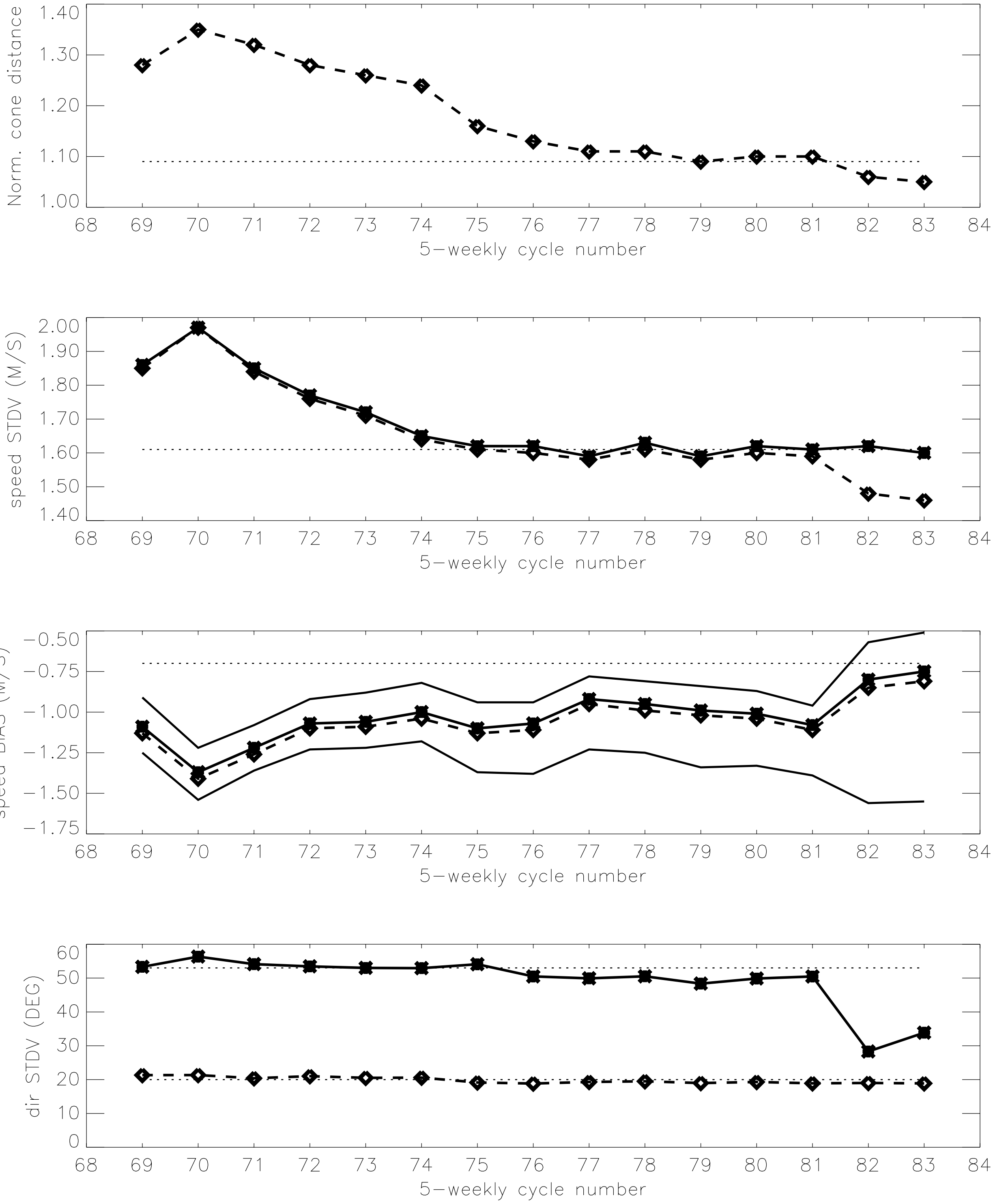
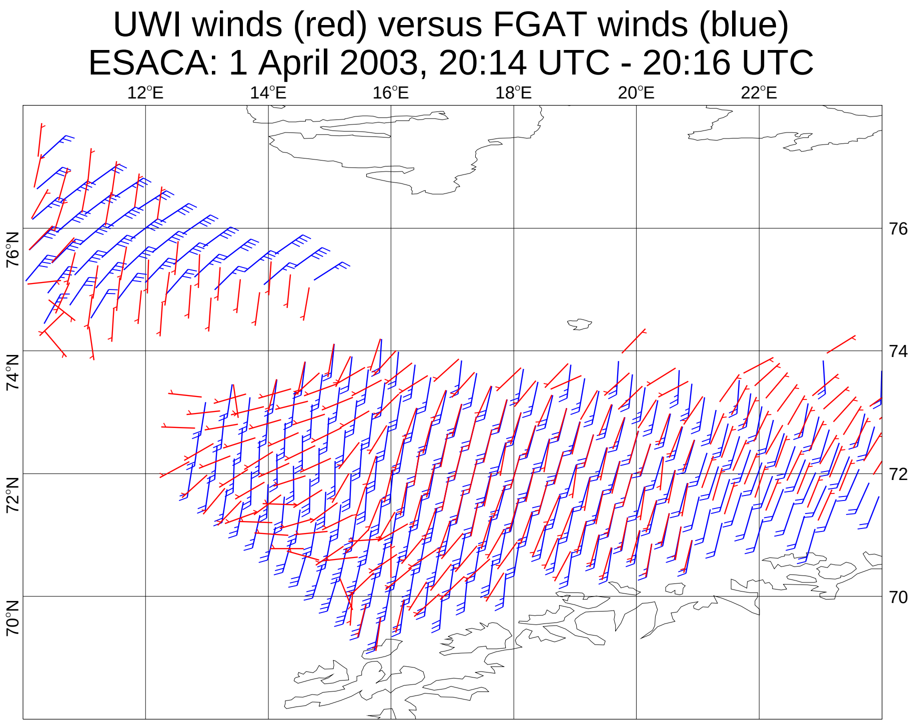

Norm. cone distance
1.40
1.30
1.20
1.10
1.00
68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84
5−weekly cycle number
speed STDV (M/S)
2.00
1.90
1.80
1.70
1.60
1.50
1.40
5−weekly cycle number
speed BIAS (M/S)
−0.50
−0.75
−1.00
−1.25
−1.50
−1.75
5−weekly cycle number
dir STDV (DEG)
60
50
40
30
20
10
0
5−weekly cycle number

Figure 8


UWI winds (red) versus FGAT winds (blue)
ESACA: 1 April 2003, 20:14 UTC - 20:16 UTC
12°E
14°E
16°E
18°E
20°E
22°E
76°N
74°N
72°N
70°N
76
74
72
70

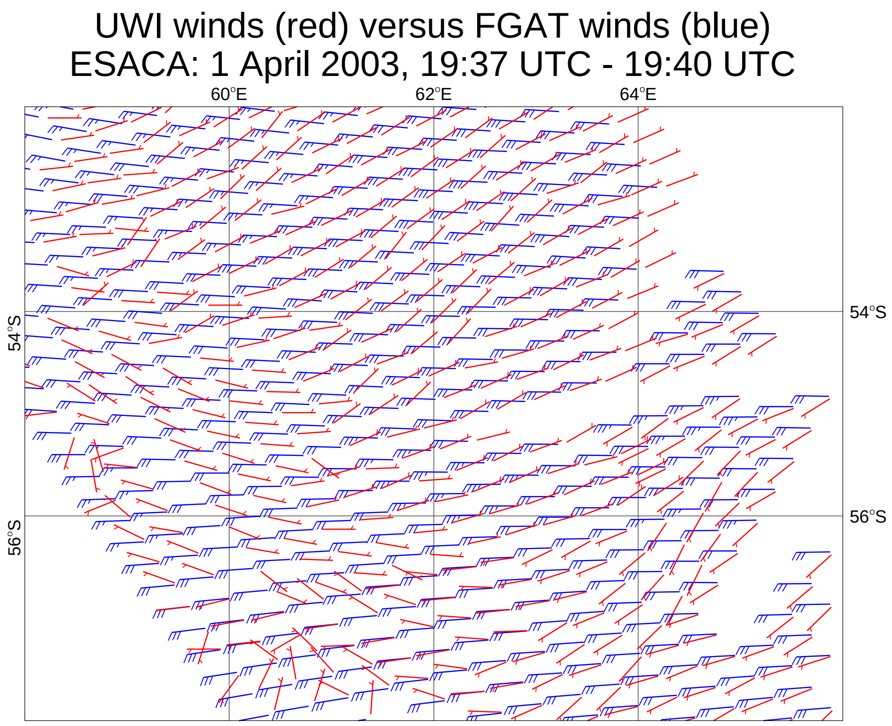
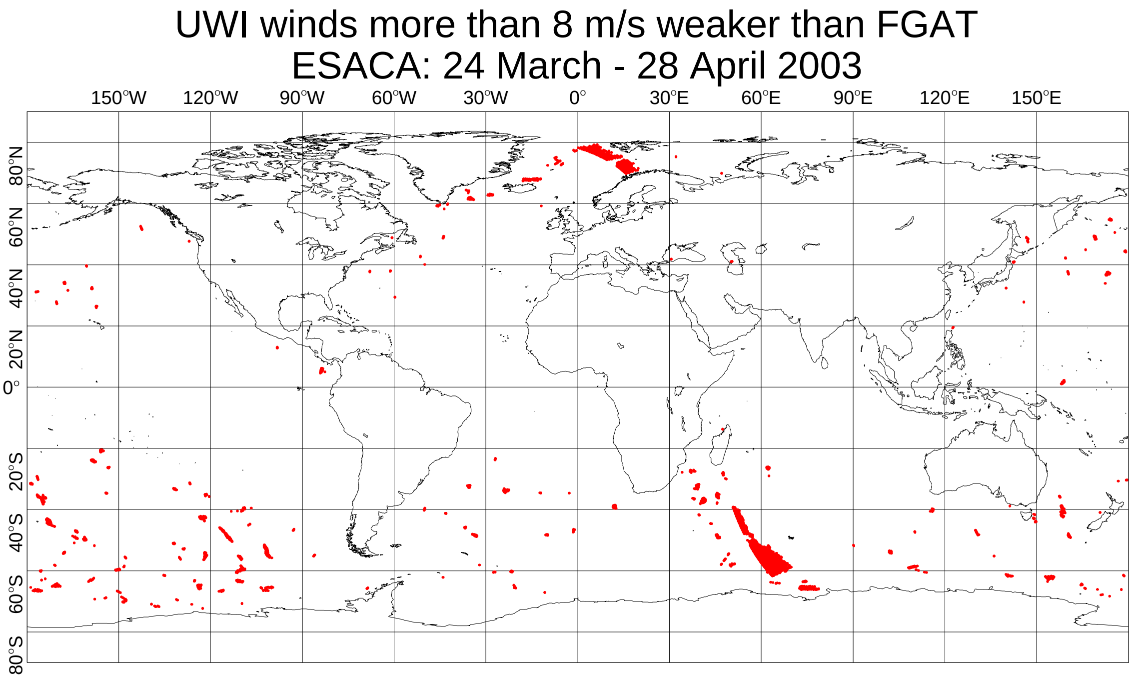

UWI winds (red) versus FGAT winds (blue)
ESACA: 1 April 2003, 19:37 UTC - 19:40 UTC
60°E
62°E
64°E
54°S
56°S
54°S
56°S

Figure 9


UWI winds more than 8 m/s weaker than FGAT
ESACA: 24 March - 28 April 2003
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S

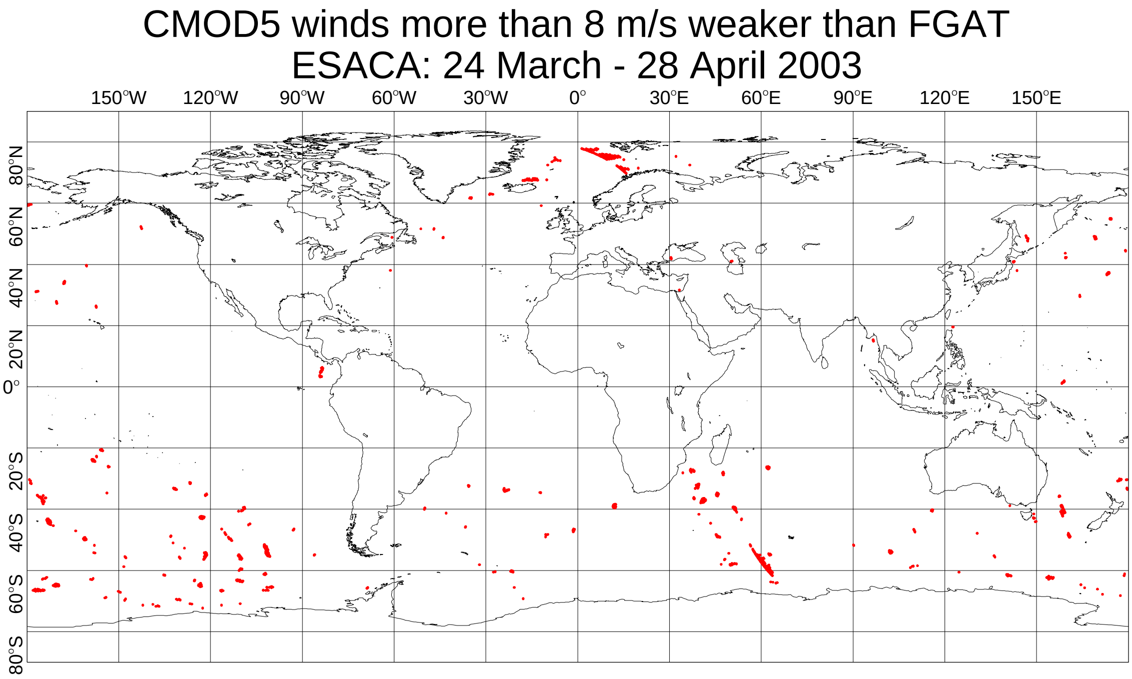

CMOD5 winds more than 8 m/s weaker than FGAT
ESACA: 24 March - 28 April 2003
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S

Figure 10

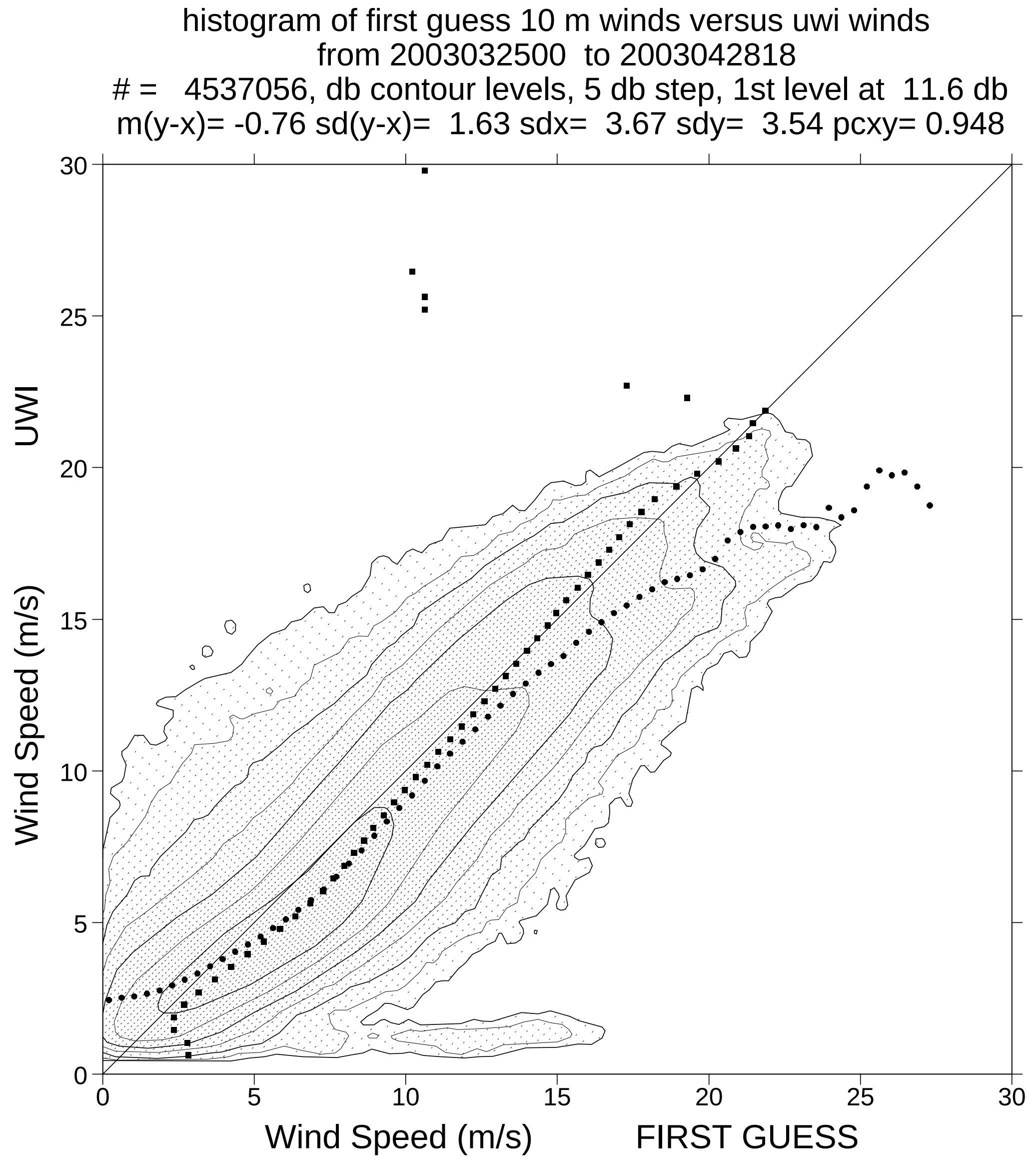
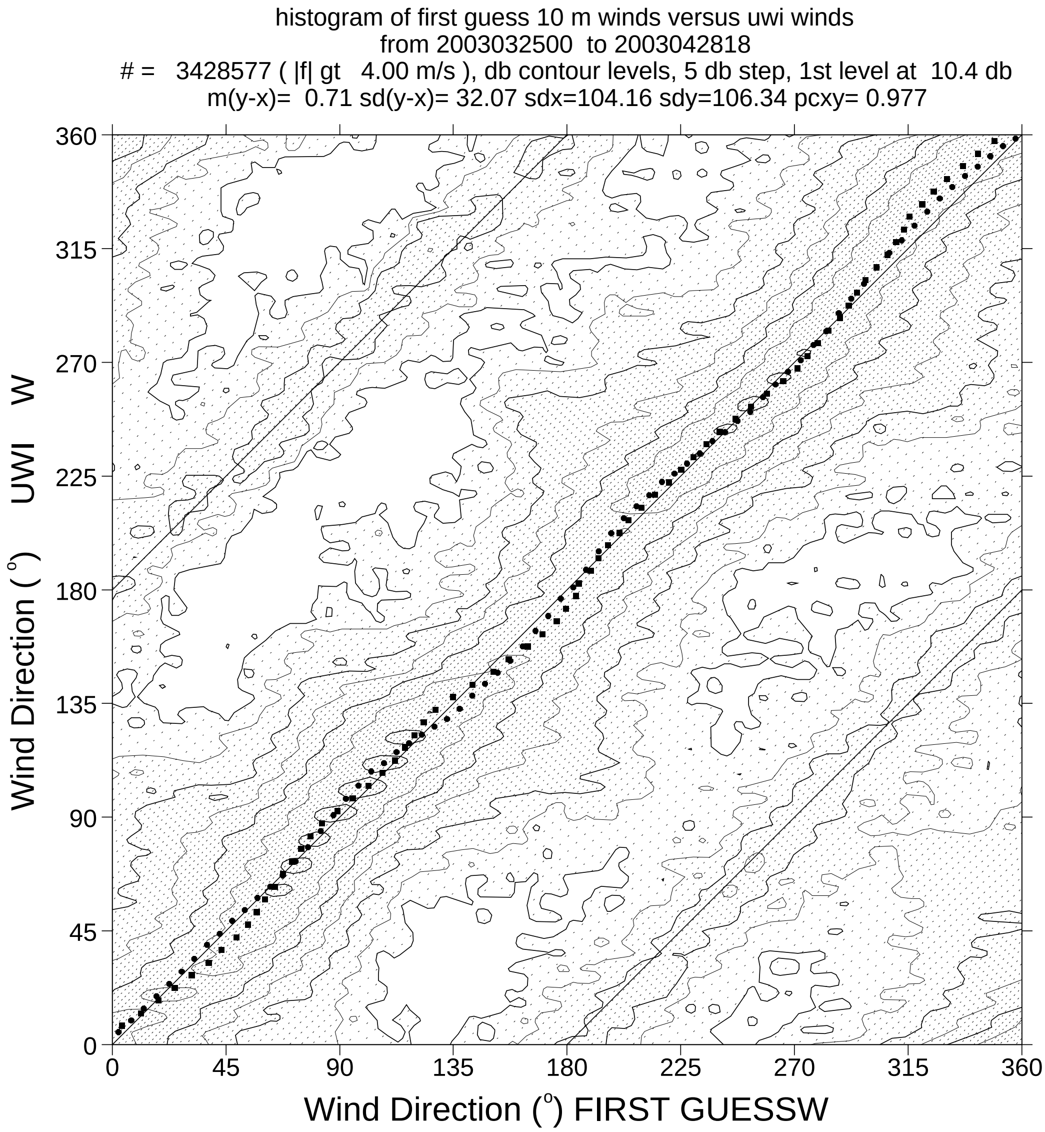

histogram of first guess 10 m winds versus uwi winds
from 2003032500 to 2003042818
= 4537056, db contour levels, 5 db step, 1st level at 11.6 db
m(y-x)= -0.76 sd(y-x)= 1.63 sdx= 3.67 sdy= 3.54 pcxy= 0.948
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 11



histogram of first guess 10 m winds versus uwi winds
from 2003032500 to 2003042818
= 3428577 (|f| gt 4.00 m/s), db contour levels, 5 db step, 1st level at 10.4 db
m(y-x)= 0.71 sd(y-x)= 32.07 sdx=104.16 sdy=106.34 pcxy= 0.977
Wind Direction (o) UWI W
Wind Direction (o) FIRST GUESSW
0
45
90
135
180
225
270
315
360

Figure 12

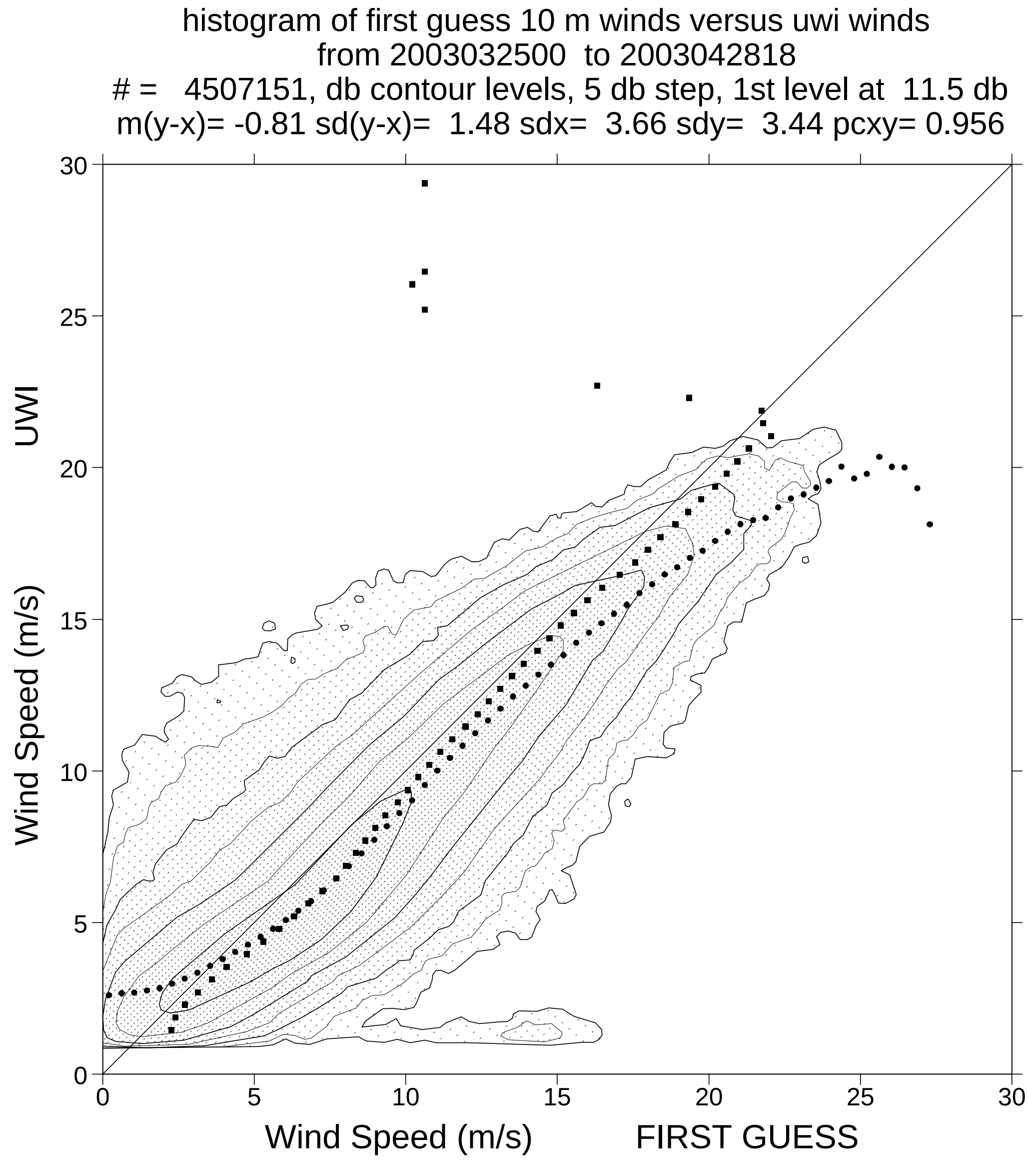

histogram of first guess 10 m winds versus uwi winds
from 2003032500 to 2003042818
= 4507151, db contour levels, 5 db step, 1st level at 11.5 db
m(y-x)= -0.81 sd(y-x)= 1.48 sdx= 3.66 sdy= 3.44 pcxy= 0.956
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 13

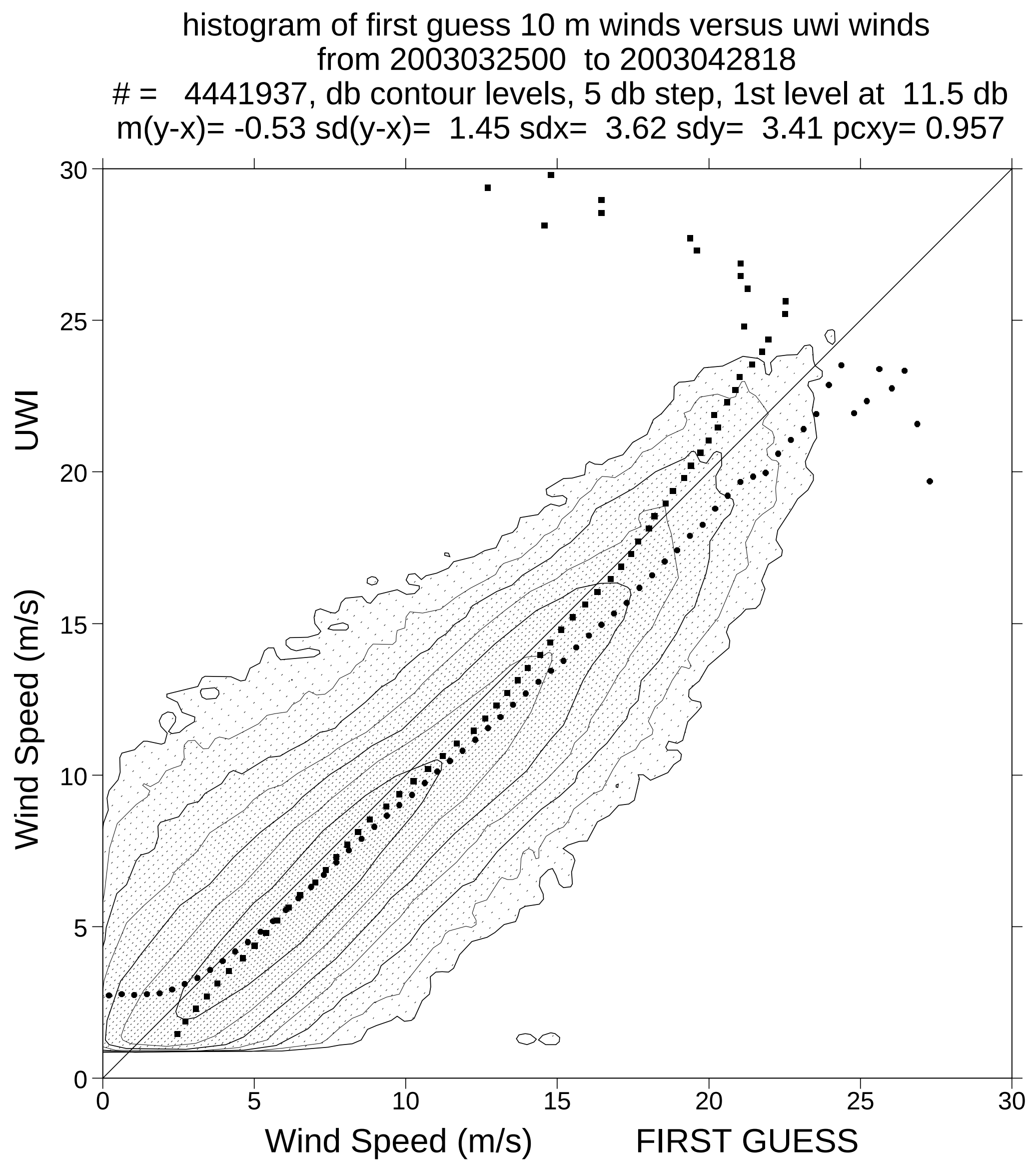

histogram of first guess 10 m winds versus uwi winds
from 2003032500 to 2003042818
= 4441937, db contour levels, 5 db step, 1st level at 11.5 db
m(y-x)= -0.53 sd(y-x)= 1.45 sdx= 3.62 sdy= 3.41 pcxy= 0.957
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 14