Monitoring statistics of the ERS-2 scatterometer for ESA

cycle 85

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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 85. This scatterometer data was not used in the 4D-Var data assimilation system at ECMWF.

On 22 June 2003, the Low Bit Rate recorder on-board ERS-2 failed. Investigations revealed that this device cannot be recovered. The satellites second recorder is also not in working order, which means that recording capabilities will be permanently unavailable. The ERS-2 Low Rate mission is being continued over the visibility area of ESA ground stations, which will limit coverage to the North Atlantic.

During cycle 85, data was received between 21:05 UTC 2 June and 07:14 UTC 2 July 2003. Due to the reception of data from Kiruna station only, for most days in cycle 85, 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. Since the on-board failure on 22 June 2003, only three batches of (low volume) data have been received, i.e., on 12 UTC 24 June 2003, on 18 UTC 01 July 2003, and on 6 UTC 02 July 2003, containing 0.5%, 3%, respectively 0.01% of typical data volumes. These data were all located between 60N and 80N.

Time series for the asymmetry between the incidence angles of the fore and aft beam (related to yaw attitude errors), show several peaks, with amplitudes from 3 up to 5 degrees. No clear signals for enhanced solar activity were observed.

For cycle 85, the potential quality of the wind product is high and stable. Only small patches of suspected poor quality data were observed.

Compared to FGAT winds, the random error of the UWI wind speed was for cycle 85 slightly lower than that for data received during cycle 84. Bias levels became somewhat less negative. The quality of the UWI wind direction was somewhat better to that for data received during cycle 84.

2 ERS-2 statistics from 2 June to 7 July 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 84. For descending tracks, bias levels where nearly unchanged for all beams and incidence angles. For ascending tracks bias levels have become approximately 0.1 dB more negative at low and high incidence angles. Levels in the mid range were more stable. This trend applied to all three beams. As a result the following picture (see Figure 1) emerges. Bias levels are between 0.3 and 1.2 dB too low. With the exception of the fore and aft beam at low incidence angles, levels are rather uniform. Compared to cycle 84, inter-beam differences are unchanged. The large negative bias for the fore and aft beam in the near range is evident.

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 rapid variations, which are typical for yaw attitude errors. Several peaks are observed, the largest occurring around 7 UTC 8 June 2003.

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 6 UTC 8 June 2003 (all nodes) and at 6 UTC 7 June 2003, 6 UTC 9 June 2003, 6 UTC and 12 UTC 14 June 2003 and at 12 UTC 19 June 2003 (all only at lower nodes) are not connected to a low data volume. Only for the peak at 6 UTC 8 June 2003 the quality of the UWI winds was slightly lower than average (lower nodes only, see Figure 4). It coincides with the peak in yaw error.

	cycle 84		cycle 85	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.60	1.45	1.59	1.44
node 1-2	1.56	1.51	1.50	1.46
node 3-4	1.46	1.42	1.40	1.38
node 5-7	1.51	1.39	1.49	1.37
node 8-10	1.59	1.39	1.60	1.39
node 11-14	1.61	1.39	1.61	1.40
node 15-19	1.60	1.41	1.58	1.41
speed BIAS	-0.82	-0.87	-0.80	-0.84
node 1-2	-1.64	-1.70	-1.63	-1.69
node 3-4	-1.21	-1.22	-1.19	-1.20
node 5-7	-0.85	-0.85	-0.82	-0.82
node 8-10	-0.60	-0.64	-0.57	-0.60
node 11-14	-0.57	-0.66	-0.54	-0.60
node 15-19	-0.64	-0.73	-0.62	-0.69
direction STDV	27.1	18.6	25.9	18.6

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

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 9), the cone distance is about 5% below the average for cycle 69 (December 2000), i.e., the last cycle in nominal mode.

The large peaks for 12 UTC 24 June 2003, 18 UTC 1 July 2003 and 6 UTC 02 July 2003, i.e., the batches of data received after the recorder failure, are probably due to insufficient statistics. All winds within these batches were observed for latitudes between 60N and 80N (see Figure 8).

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 does not show large peaks. Some small peaks in enhanced standard deviation are observed for 6 UTC 8 June 2003 (near range) and 6 UTC 18 June 2003 (mid range). The large peaks for data received after 22 June 2003 (for locations see Figure 8) are probably the result of low date volumes.

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 84, the average bias level has become slightly less negative (-0.80 m/s, was -0.82 m/s). In specific, the large wind bias at the lower nodes was slightly reduced (-1.63 m/s, was -1.64 m/s). Standard deviation has slightly decreased as well (average 1.59 m/s, was 1.60 m/s).

Like for ESACA data received for cycle 84, 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 1.44 m/s versus 1.59 m/s). Best results are obtained for CMOD5 (shown below).

For cycle 85 the (scatterometer - model) direction standard deviations were ranging between 20 and 40 degrees (Figure 5). Sharp peaks are the result of low data volumes. For de-aliased CMOD4 winds values between 20 and 30 degrees are most common. On average (see Table 1), the quality of the UWI wind direction is higher than that for data received during cycle 84 (25.9 degrees, was 27.1 degrees, see also lower panel of Figure 9). The quality of the de-aliased CMOD4 wind direction is stable.

In Figure 10 all locations are plotted for which UWI winds were more than 8 m/s weaker than the FGAT winds. Taking into account the smaller data volume due to the lack of data since 22 June 2003, the number of such collocations and their rather point-wise distribution is comparable to that for cycle 84. There are no clear signs for instrument anomalies (such as occurred for cycle 83, and for cycles before the introduction of the ESACA processor), in which case large parts of tracks would appear in Figure 10. This plot does not contain data for the period around 6 UTC 8 June 2003, i.e., when both a peak in the incidence-angle difference and (UWI-FGAT) time series were observed. Apparently the misfit in winds is the result of a smaller difference over a relatively large area.

For two cases from Figure 10, wind fields are shown in Figure 11. In the top panel (near Solomon Islands) the large local difference in wind speed between UWI and FGAT winds is the result of a strange patch of UWI winds. In the lower panels of Figure 11 (South-Atlantic), main differences might be caused by a misplacement of a front. However, the patch of UWI winds near 32S and 17W, looks erroneous. So for both cases part of the large deviations of UWI winds from FGAT may result from an instrument anomaly.

2.5 Scatter plots

Scatterplots of model 10 m first-guess winds versus ERS-2 winds are displayed in Figures 12 to 15. 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 84, the quality of the CMOD4 winds (Figure 14) is higher than that of the UWI winds (Figure 12). This seems to be especially true for strong winds. Values of standard deviations are slightly lower to those for cycle 84.

The average bias of the UWI wind direction (Figure 13) is small (0.5 degrees, was 0.6). Its standard deviation has decreased somewhat (23.6 degrees, was 25.0) w.r.t. cycle 84.

There were few collocations of low UWI winds and high ECMWF FGAT winds (Figure 12). These usually originate from large errors in yaw attitude control.

Winds derived on the basis of CMOD5 are displayed in Figure 14. Compared to cycle 84, the bias level has become slightly less negative (-0.56 m/s, was -0.58 m/s) and the standard deviation improved somewhat as well (1.44 m/s, was 1.46 m/s). CMOD5 winds are of higher quality than the CMOD4 (Figure 14) and UWI winds (Figure 12). Although CMOD5 winds are too weak (induced by too low backscatter levels, see Figure 1), the random error of CMOD5 winds w.r.t. FGAT winds is lower than it was 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 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.

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 ESA flags, 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: Locations of UWI winds received after the on-board failure of 22 June 2003.

Figure 9: Evolution of the performance of the ERS-2 scatterometer averaged over 5-weekly cycles from 12 December 2001 (cycle 69) to 7 July 2003 (end cycle 85) 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 10: Locations of data during cycle 85 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: UWI or CMOD5 wind vectors (red) and collocated FGAT wind vectors (blue) near the Solomon Islands for 5 June 2003 (top panel) and in the South-Atlantic for 13 June 2003 (lower panels).

Figure 12: 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 13: Same as Fig. 12, but for wind direction. Only wind speeds higher than 4m/s are taken into account.

Figure 14: Same as Fig. 12, but for de-aliased CMOD4 winds.

Figure 15: Same as Fig. 12, but for de-aliased CMOD5 winds.

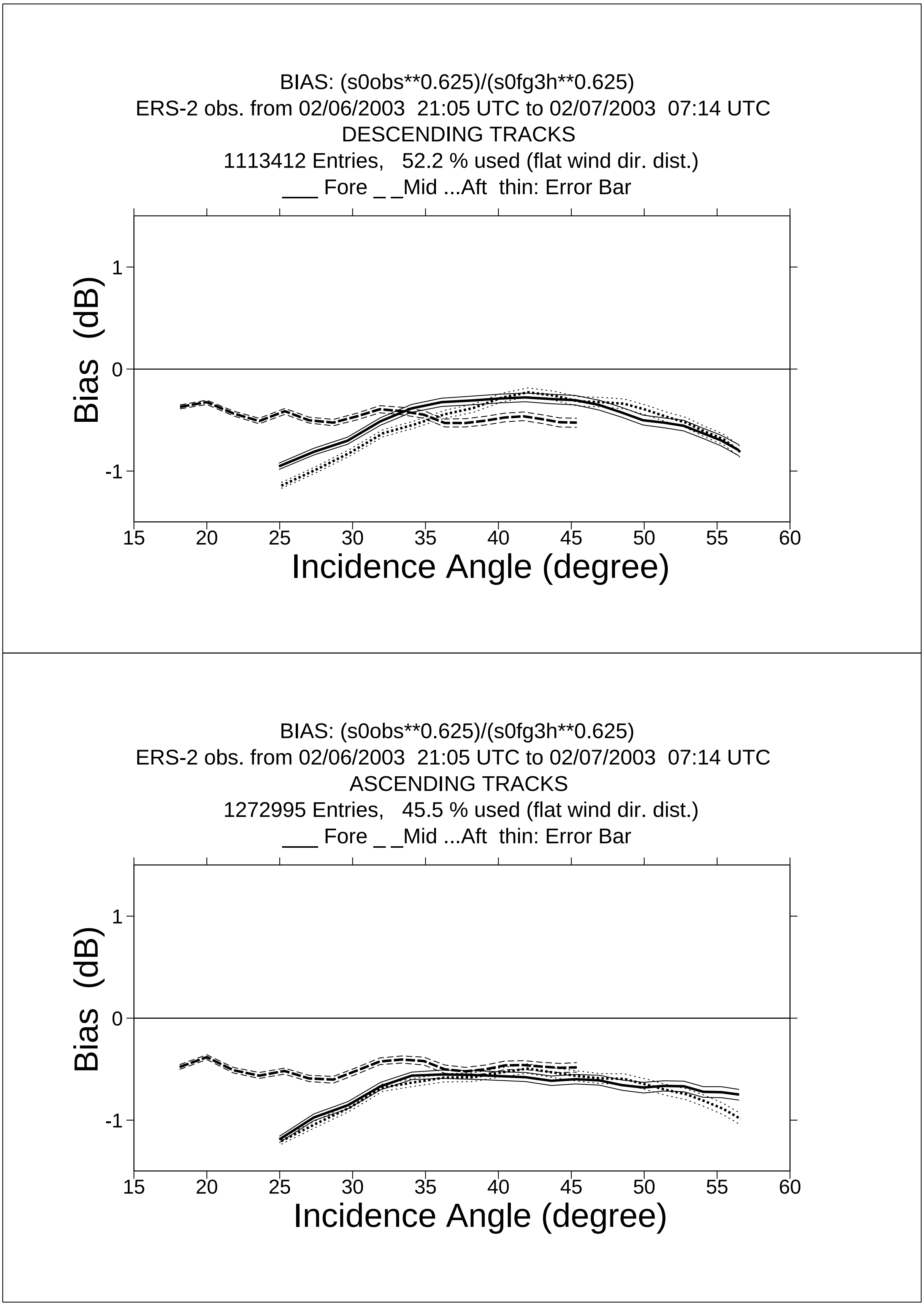

BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 02/06/2003 21:05 UTC to 02/07/2003 07:14 UTC
DESCENDING TRACKS
1113412 Entries, 52.2 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)
BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 02/06/2003 21:05 UTC to 02/07/2003 07:14 UTC
ASCENDING TRACKS
1272995 Entries, 45.5 % 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

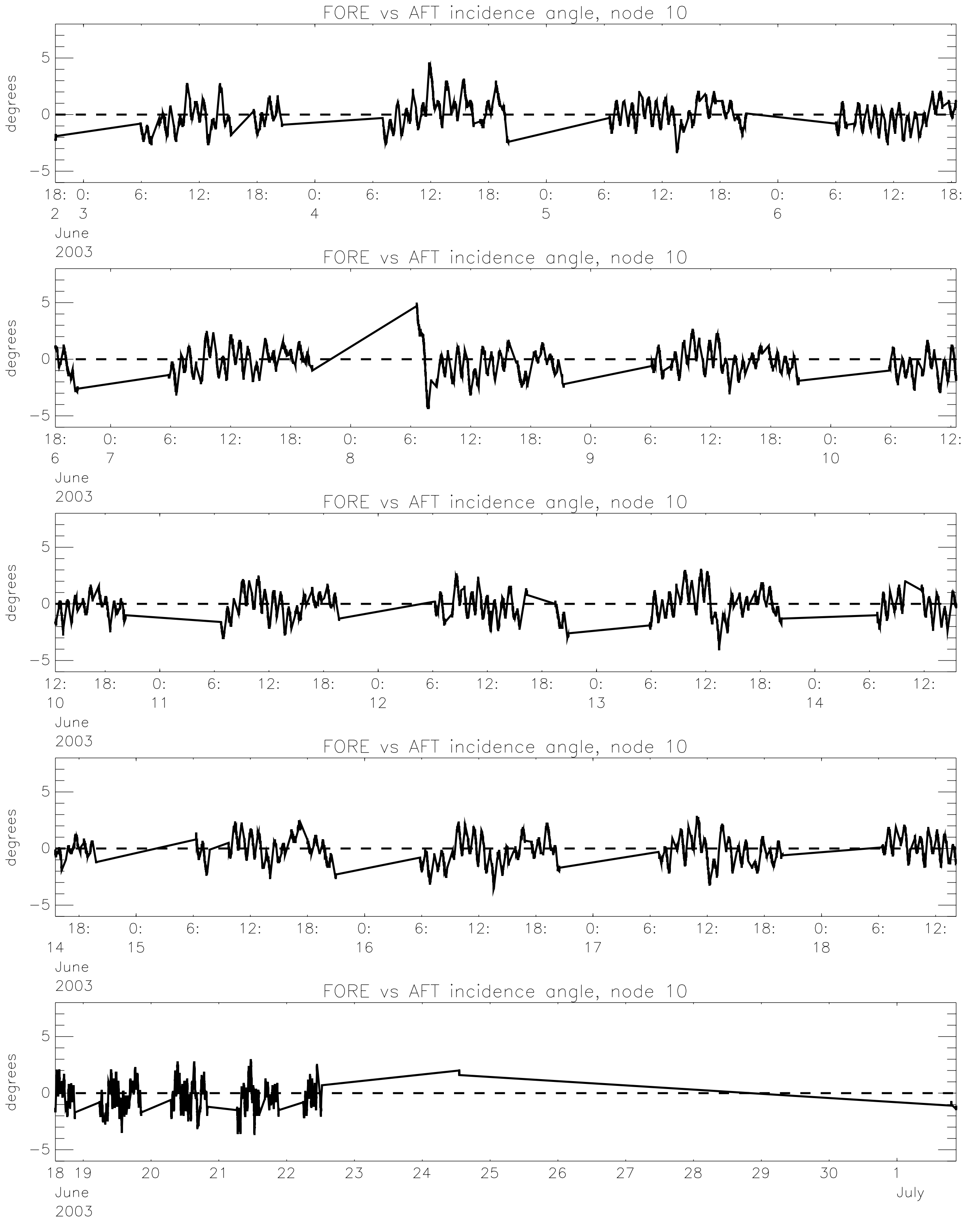


Figure 2

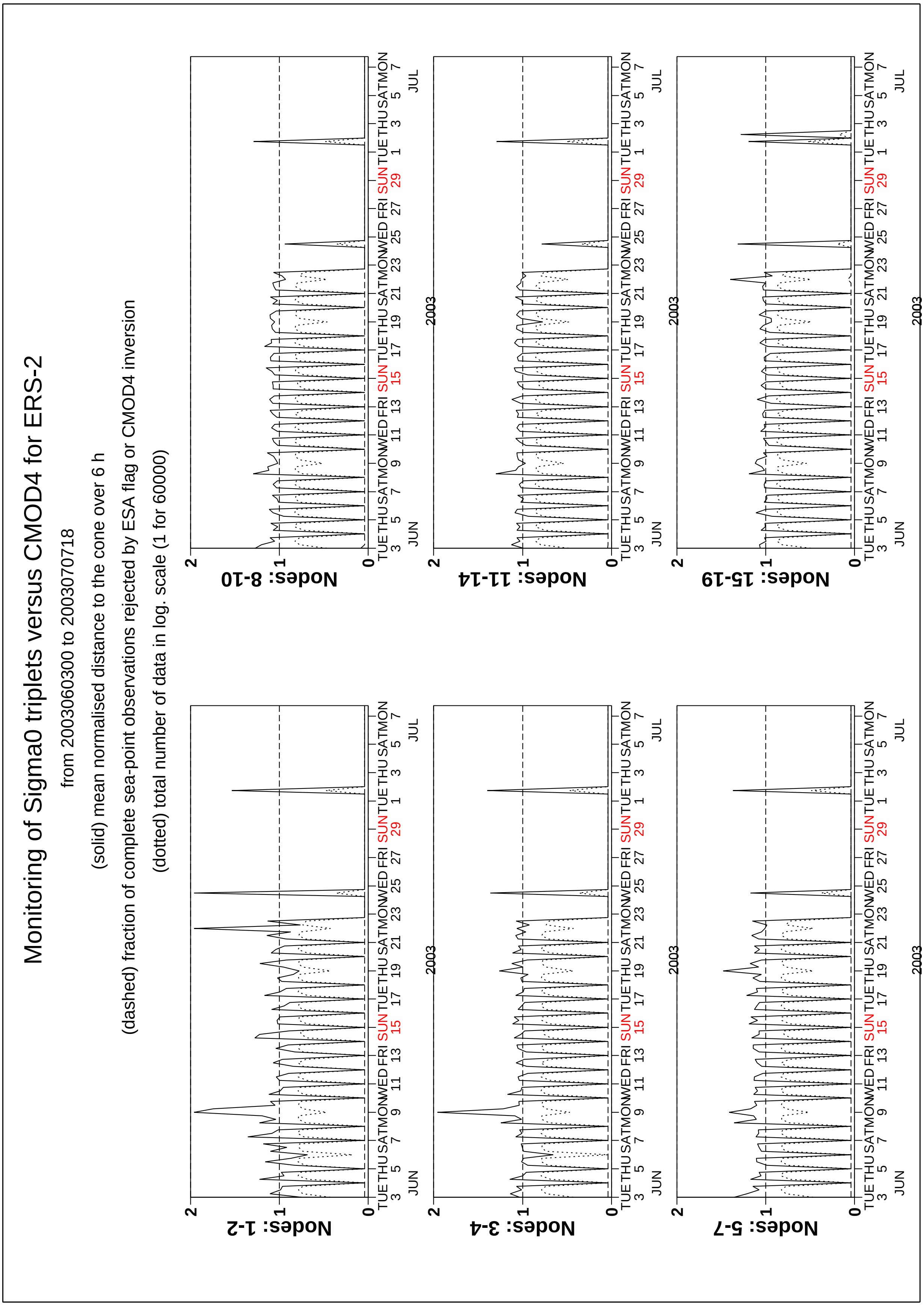
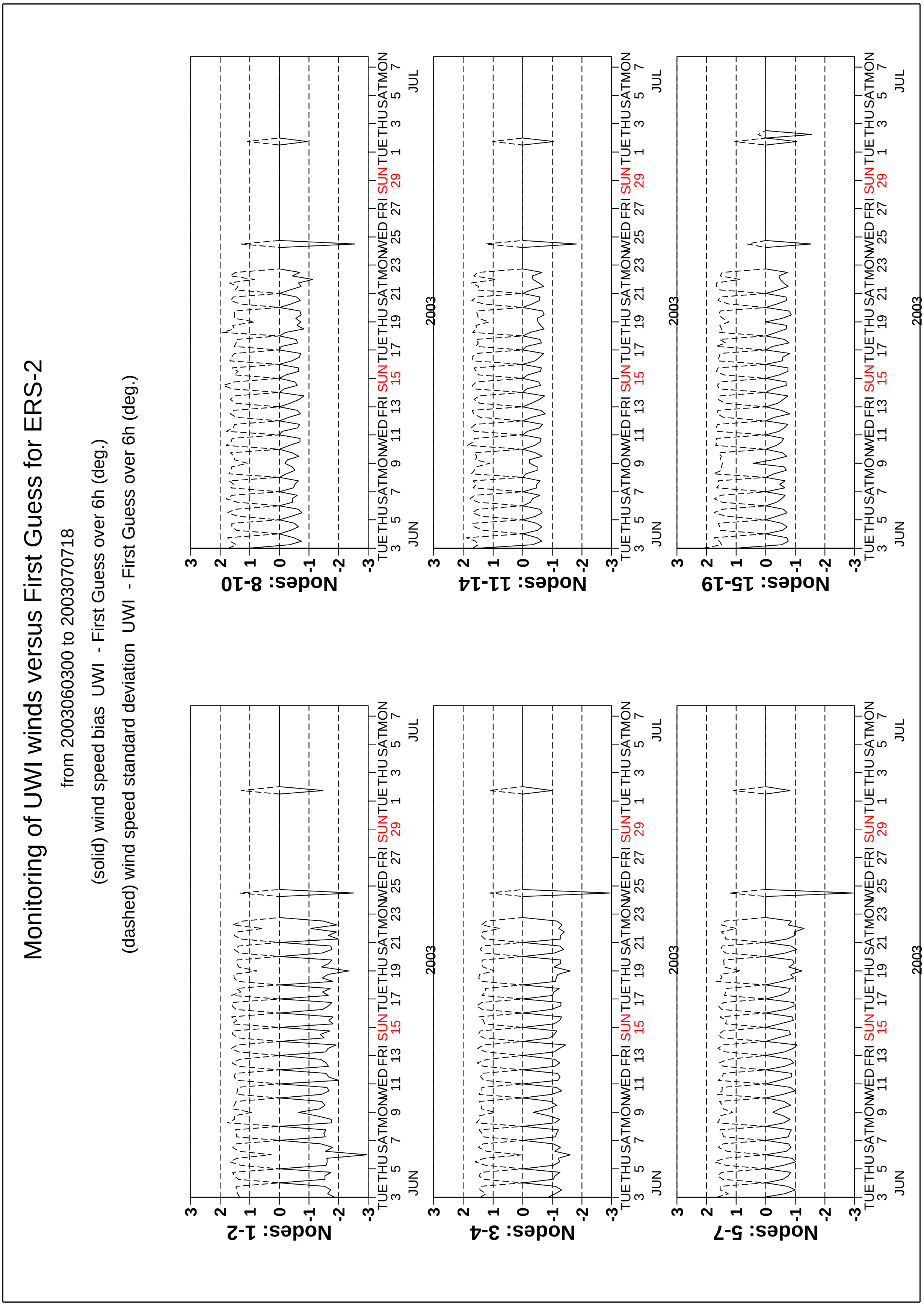
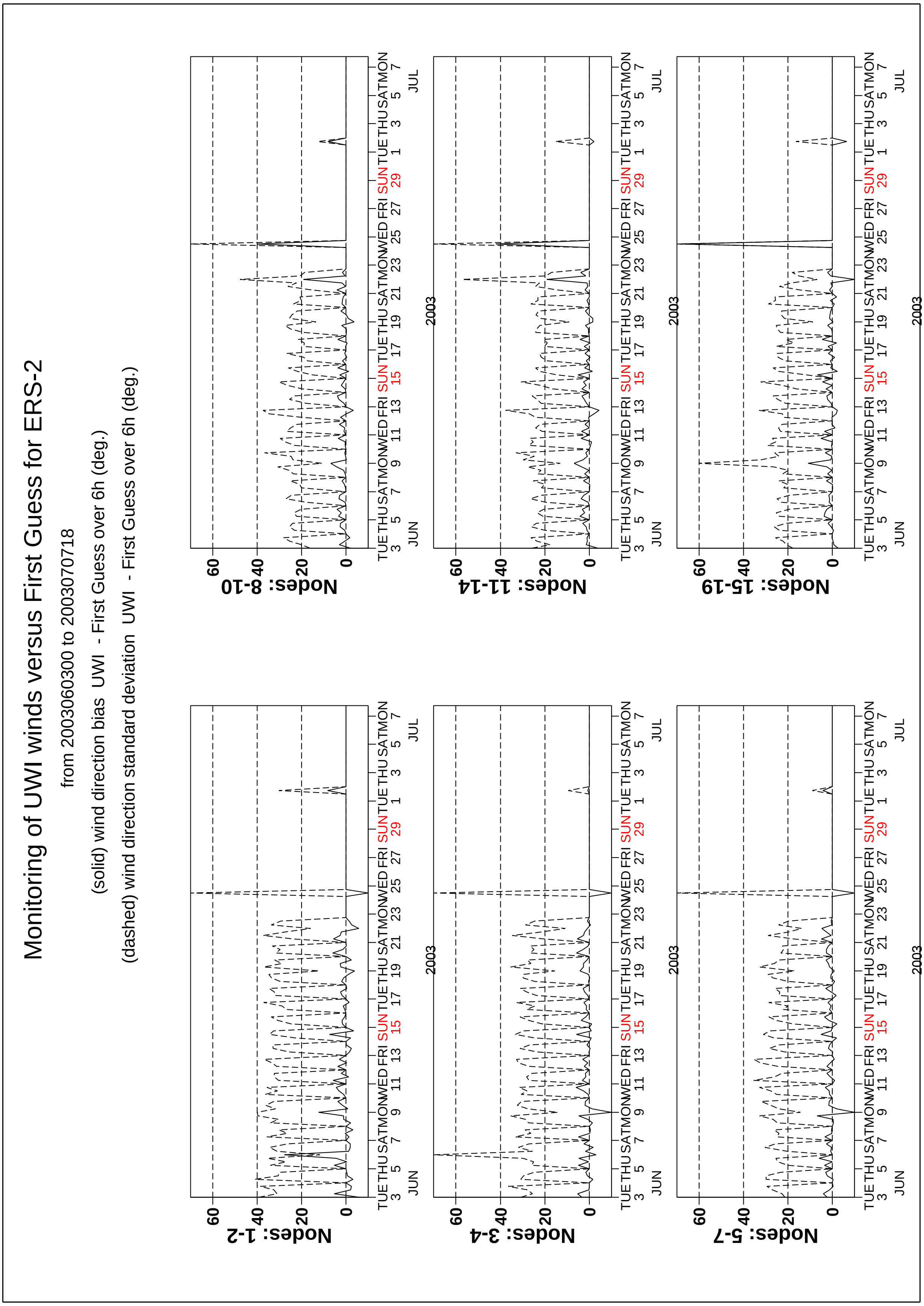

Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2003060300 to 2003070718
(solid) mean normalised distance to the cone over 6 h
(dashed) fraction of complete sea-point observations rejected by ESA flag or CMOD4 inversion
(dotted) total number of data in log. scale (1 for 60000)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
JUN
JUL
2003

Figure 3



Monitoring of UWI winds versus First Guess for ERS-2
from 2003060300 to 2003070718
(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
JUN
JUL
2003

Figure 4



Monitoring of UWI winds versus First Guess for ERS-2
from 2003060300 to 2003070718
(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: 8-10
Nodes: 3-4
Nodes: 11-14
Nodes: 5-7
Nodes: 15-19

Figure 5

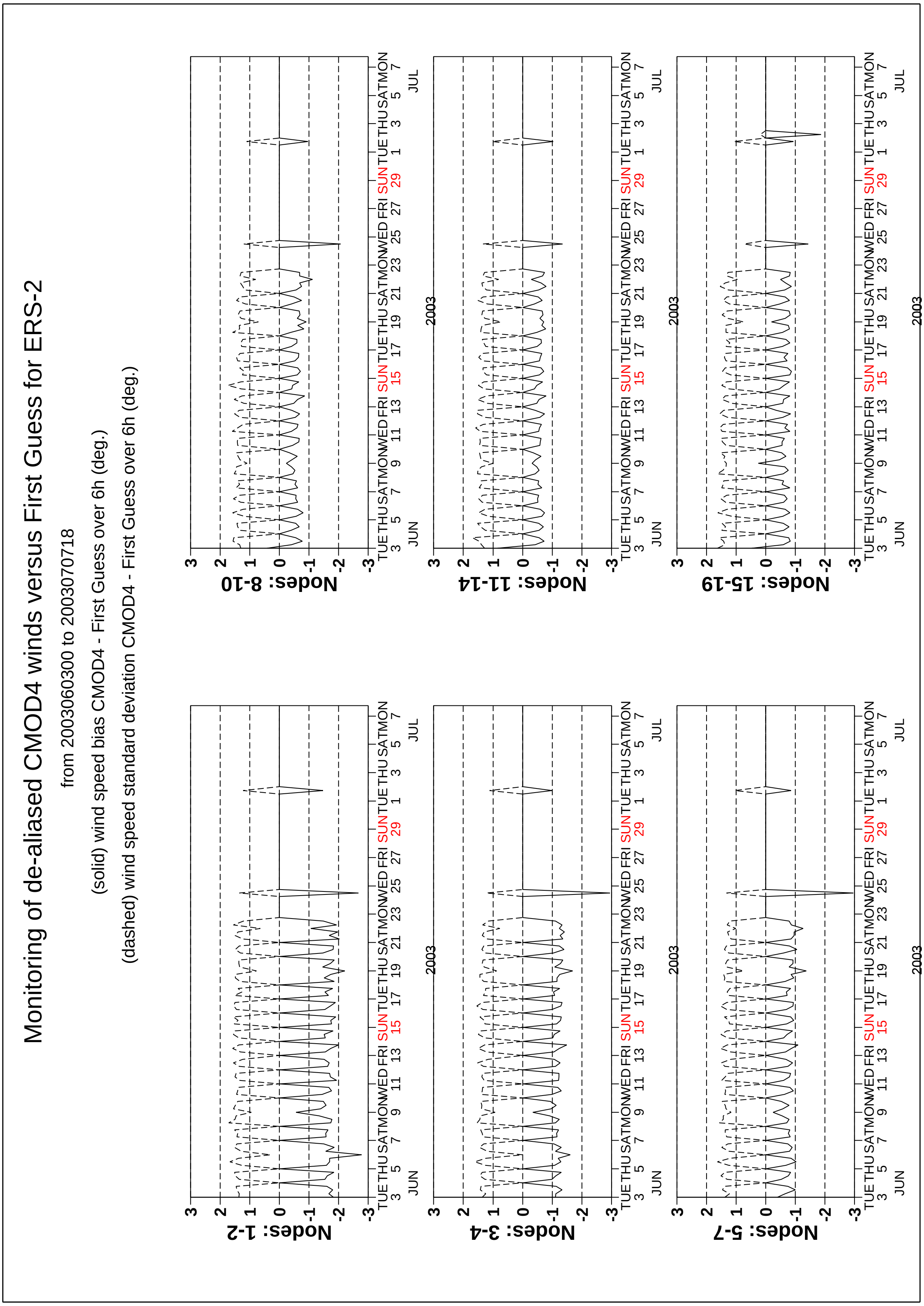

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003060300 to 2003070718
(solid) wind speed bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind speed standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
2003
JUN
JUL

Figure 6

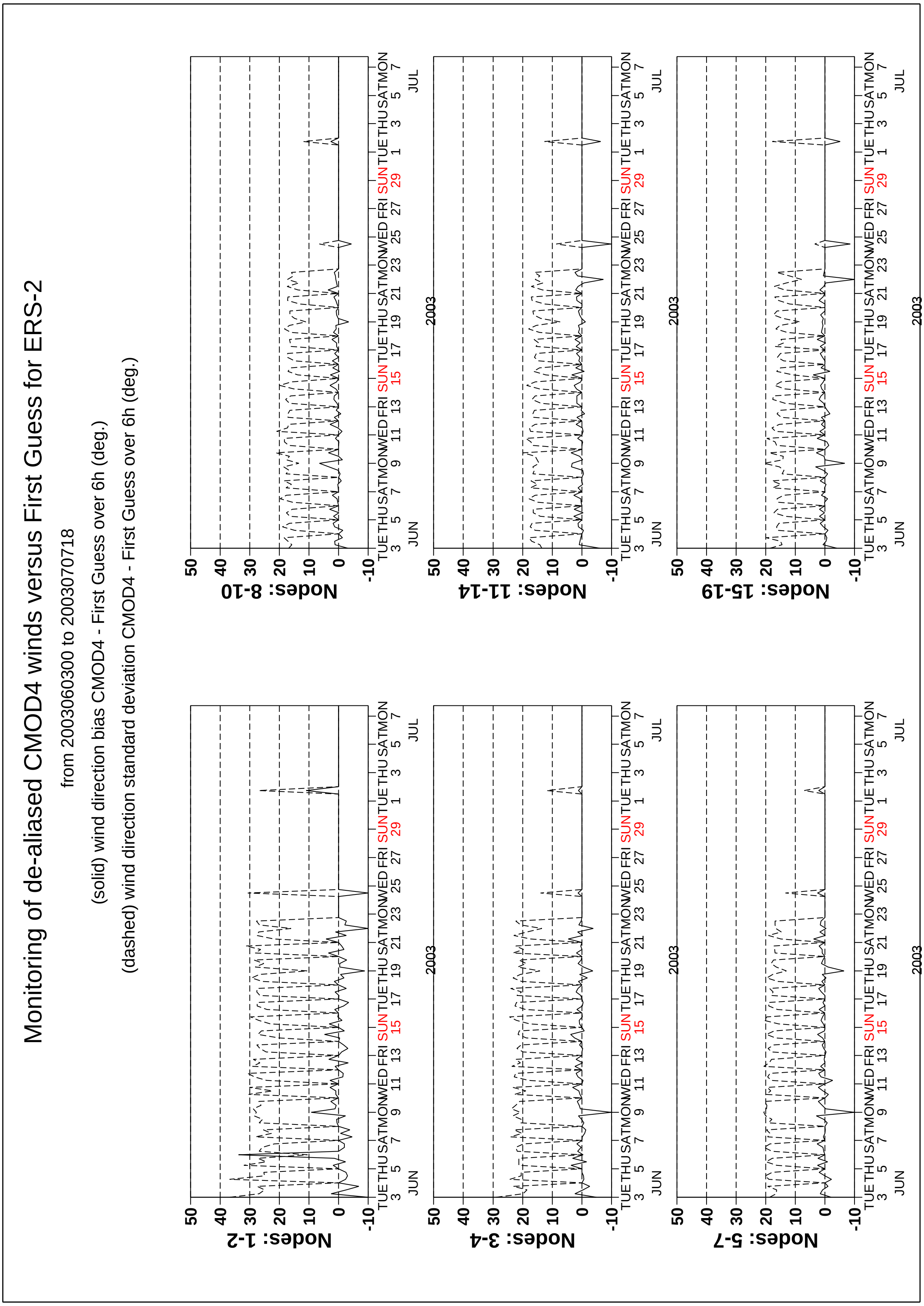

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003060300 to 2003070718
(solid) wind direction bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind direction standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
JUN
JUL
2003

Figure 7

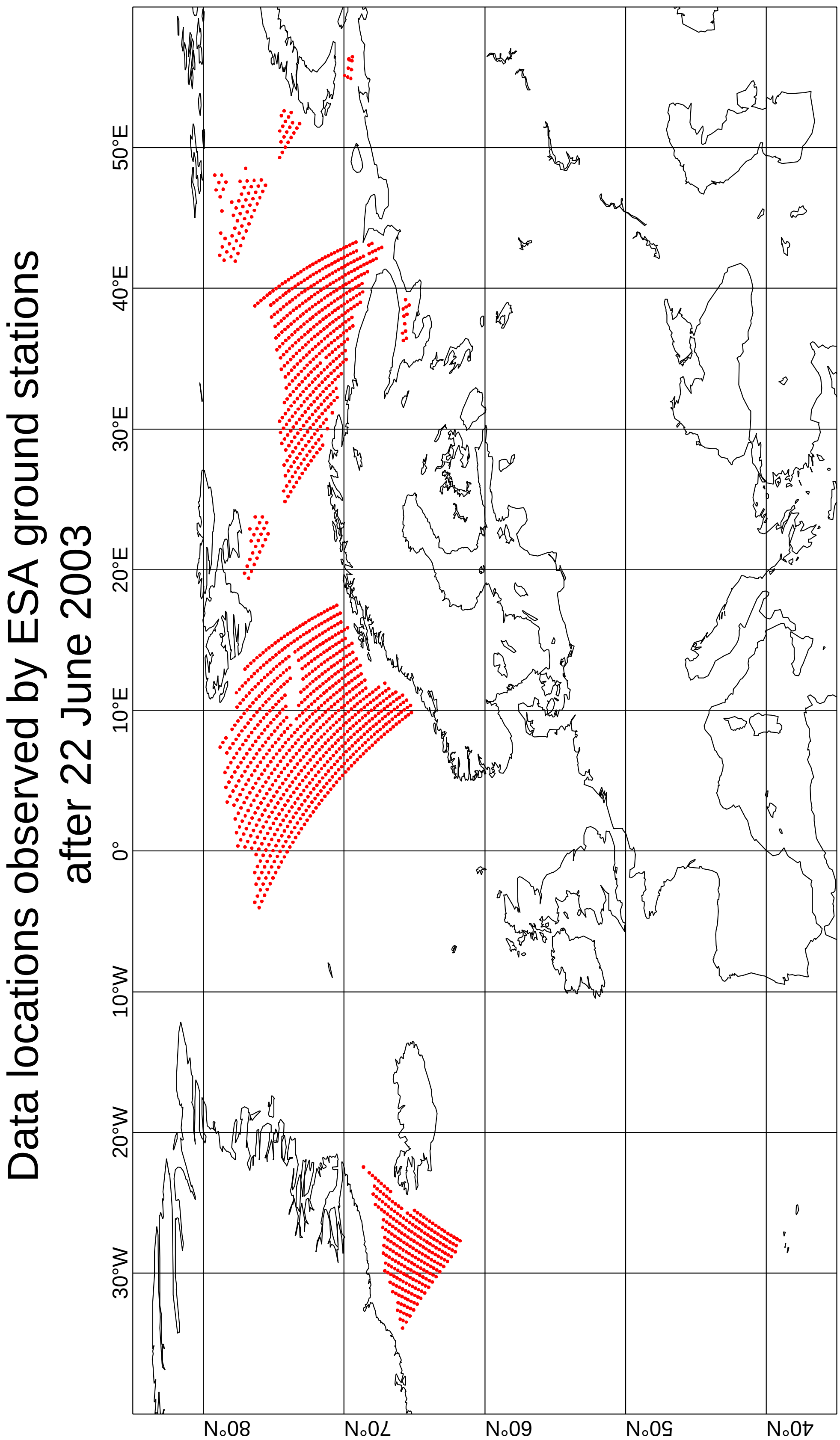

Data locations observed by ESA ground stations
after 22 June 2003
50°E
40°E
30°E
20°E
10°E
0°
10°W
20°W
30°W
80°N
70°N
60°N
50°N
40°N

Figure 8

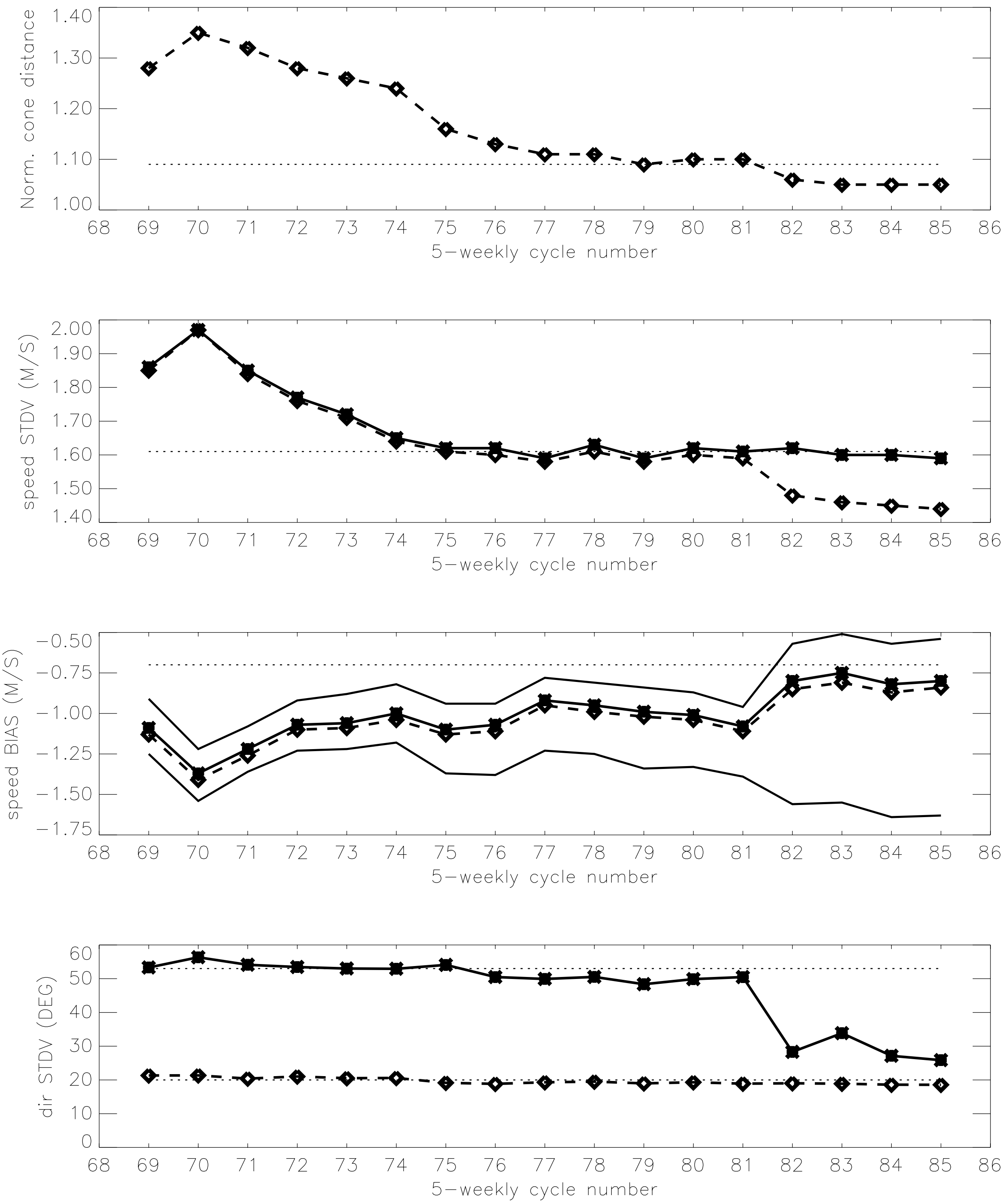

Norm. cone distance
speed STDV (M/S)
speed BIAS (M/S)
dir STDV (DEG)
5−weekly cycle number

Figure 9

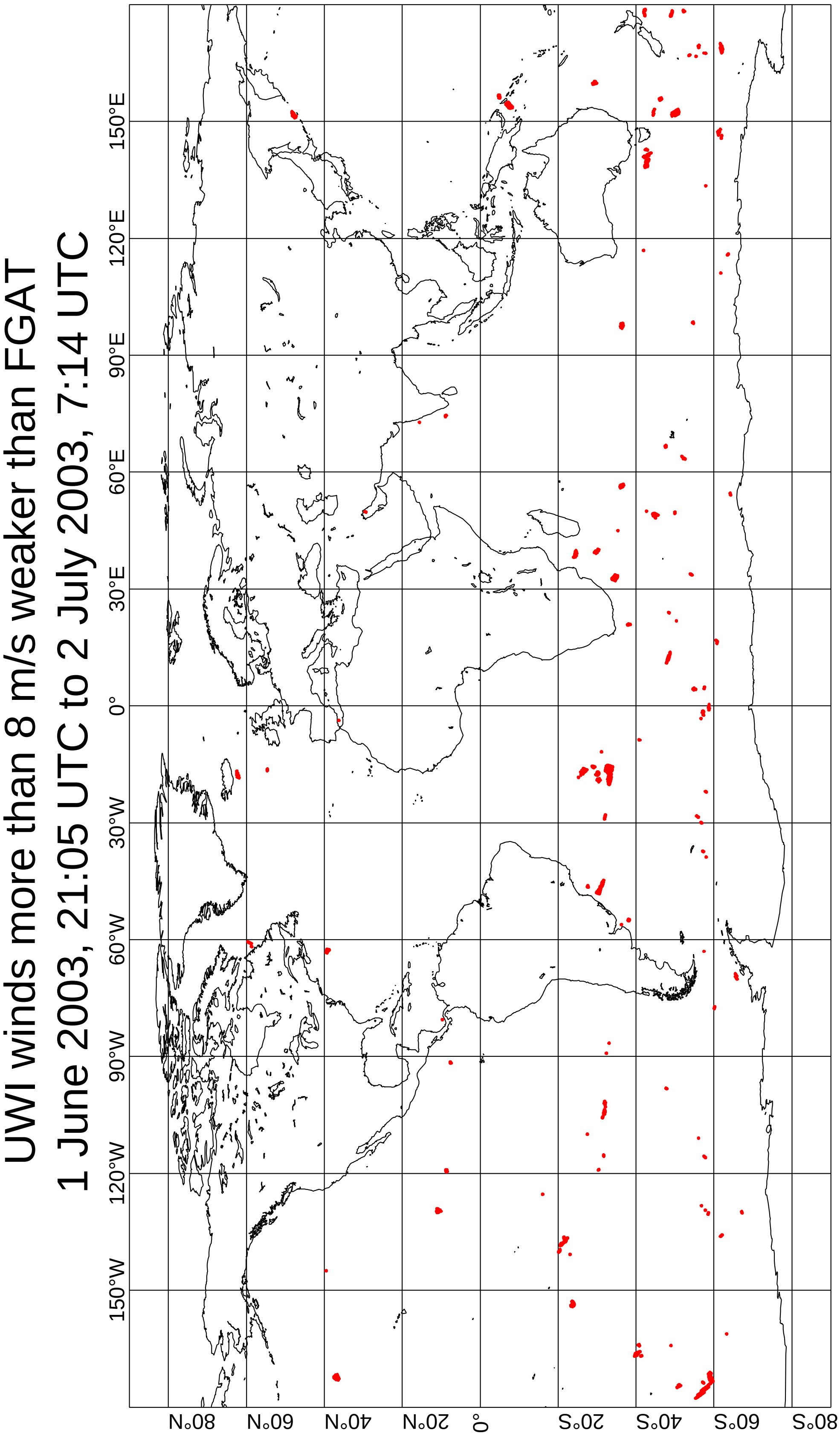
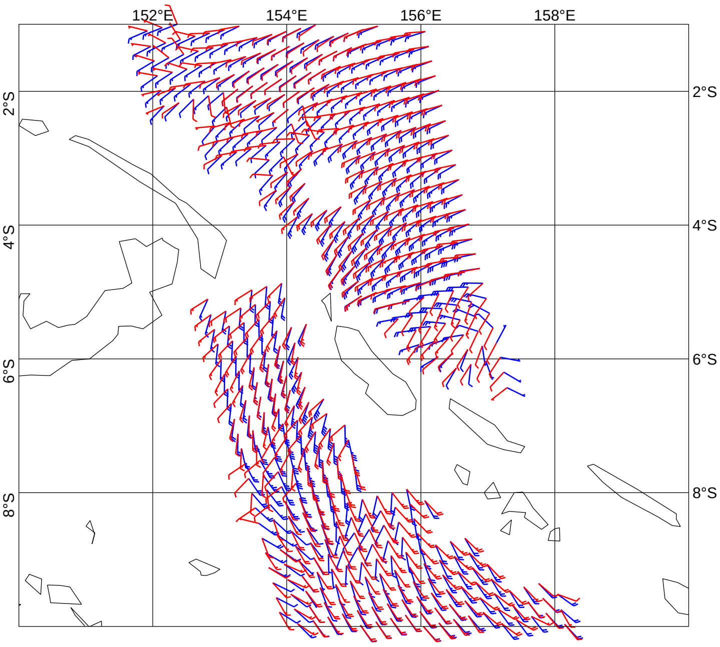

UWI winds more than 8 m/s weaker than FGAT
1 June 2003, 21:05 UTC to 2 July 2003, 7:14 UTC
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S

Figure 10

UWI winds (red) versus FGAT winds (blue)
5 June 2003, 12:27 UTC



UWI winds (red) versus FGAT winds (blue)
13 June 2003, 10:57 UTC

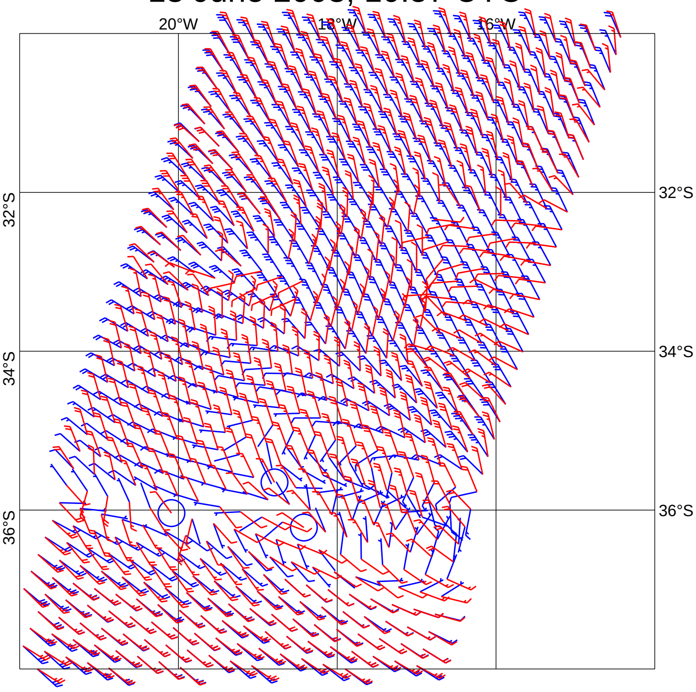


Figure 11

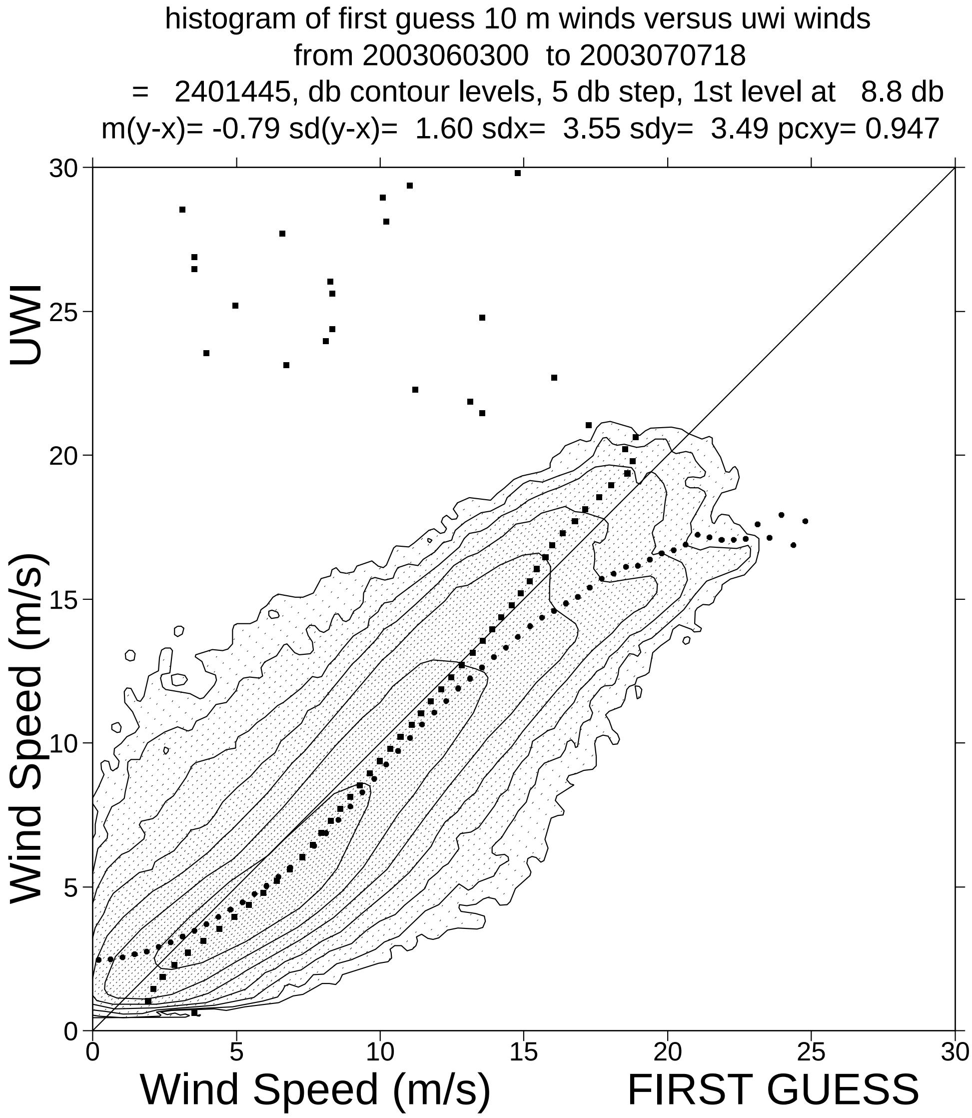

histogram of first guess 10 m winds versus uwi winds
from 2003060300 to 2003070718
= 2401445, db contour levels, 5 db step, 1st level at 8.8 db
m(y-x)= -0.79 sd(y-x)= 1.60 sdx= 3.55 sdy= 3.49 pcxy= 0.947
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 12

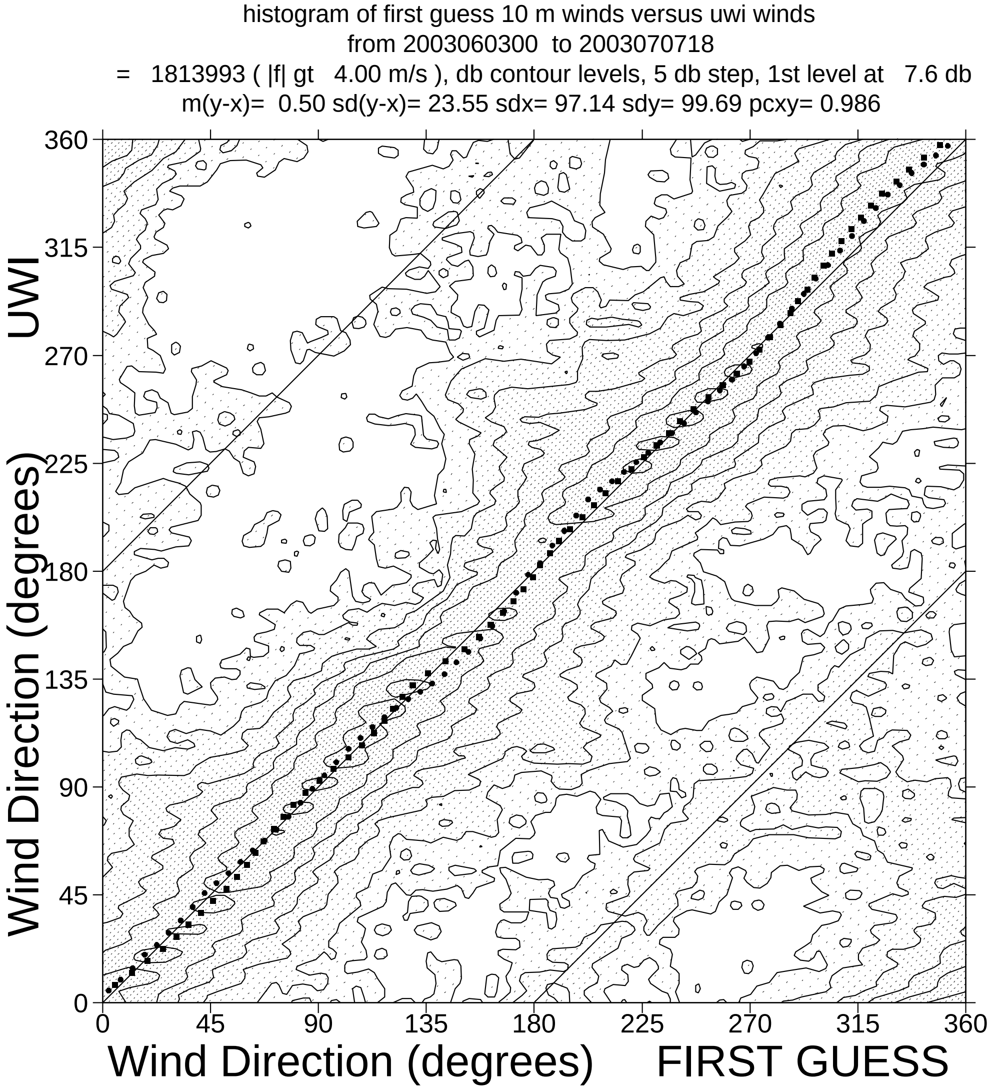

histogram of first guess 10 m winds versus uwi winds
from 2003060300 to 2003070718
= 1813993 (|f| gt 4.00 m/s), db contour levels, 5 db step, 1st level at 7.6 db
m(y-x)= 0.50 sd(y-x)= 23.55 sdx= 97.14 sdy= 99.69 pcxy= 0.986
UWI
Wind Direction (degrees)
0
45
90
135
180
225
270
315
360
Wind Direction (degrees) FIRST GUESS

Figure 13

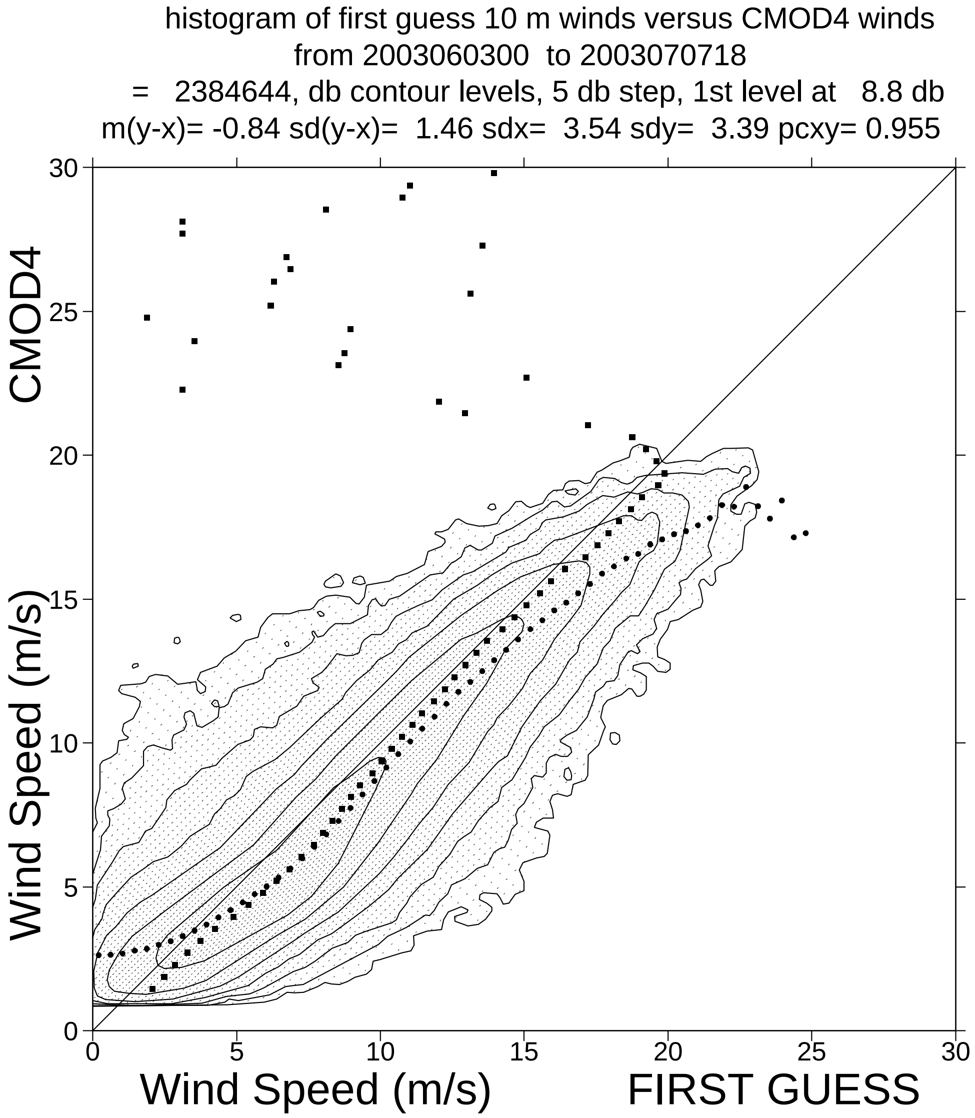

histogram of first guess 10 m winds versus CMOD4 winds
from 2003060300 to 2003070718
= 2384644, db contour levels, 5 db step, 1st level at 8.8 db
m(y-x)= -0.84 sd(y-x)= 1.46 sdx= 3.54 sdy= 3.39 pcxy= 0.955
CMOD4
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 14

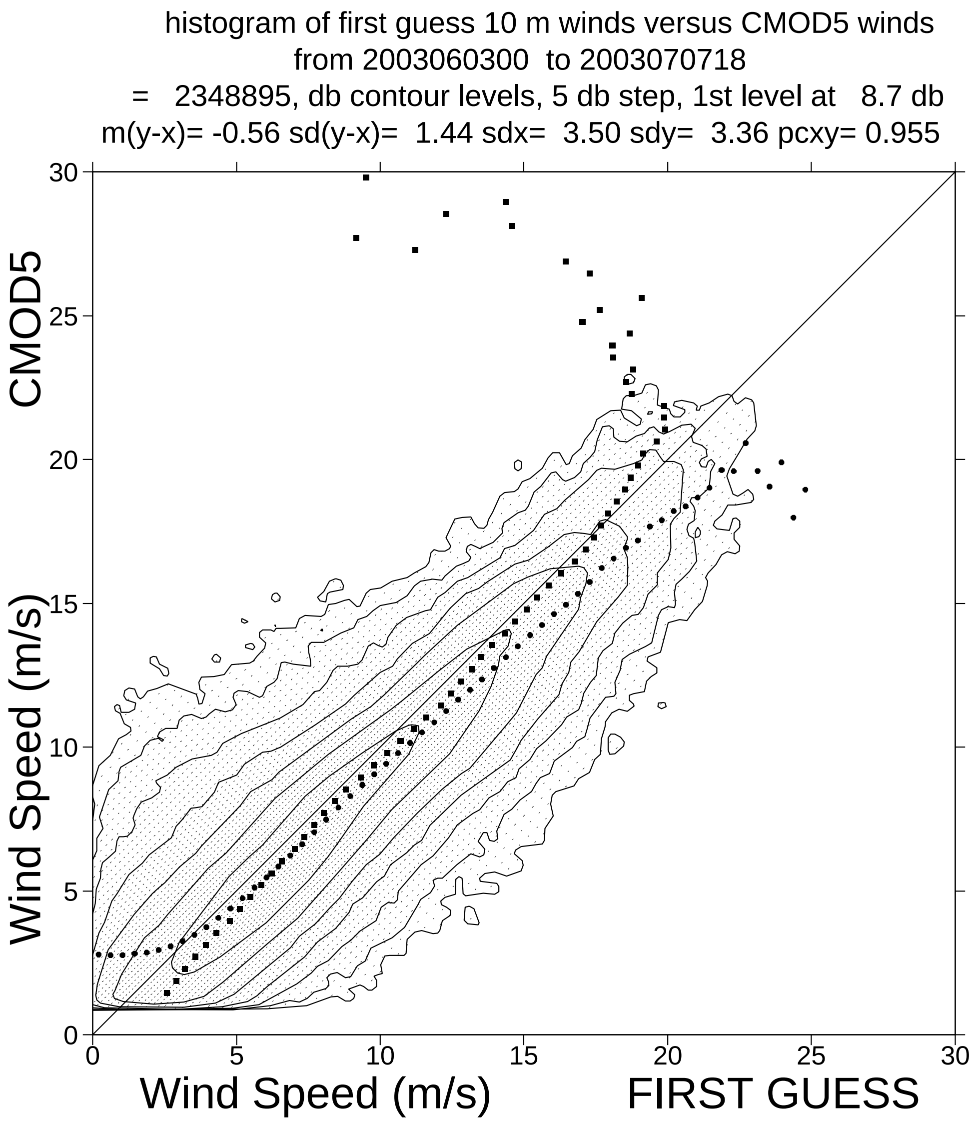

histogram of first guess 10 m winds versus CMOD5 winds
from 2003060300 to 2003070718
= 2348895, db contour levels, 5 db step, 1st level at 8.7 db
m(y-x)= -0.56 sd(y-x)= 1.44 sdx= 3.50 sdy= 3.36 pcxy= 0.955
CMOD5
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 15