Monitoring statistics of the ERS-2 scatterometer for ESA

cycle 84

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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 84. 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 report of cycle 82) to be of good quality, the quality control check on k_p was, like for cycles 82 and 83, 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 first-guess (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).

In the meantime, ESRIN has been able to remedy these imperfections. However, the appropriate updates of the ESACA processor have not yet been implemented for Kiruna station.

During cycle 84, data was received between 21:01 UTC 28 April and 20:55 UTC 2 June 2003. Due to the reception of data from Kiruna station only, for most days in cycle 84, 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 data was received for the 6-hourly periods from 00 UTC to 12 UTC 13 May 2003, and from 18 UTC 16 May to 00 UTC 20 May 2003.

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 6 degrees. No clear signals for enhanced solar activity were observed.

For cycle 84, the potential quality of the wind product is high and stable. No patches of poor quality data were observed.

Compared to FGAT winds, the random error of the UWI wind speed was for cycle 84 comparable to that for data received during cycle 83. However, bias levels became more negative. Especially at lower nodes, the enhancement of the already considerable negative bias is worrying. As mentioned above, it is the result of large negative biases of the near-range sigma0 levels of the fore and aft beam.

The quality of the UWI wind direction was comparable to that for data received during cycle 82, i.e., the small deterioration as observed during cycle 83 has disappeared.

On 29 April 2003, the assimilation system at ECMWF was changed. This update had a purely technical character, i.e., it had no effect on the quality of ECMWF surface winds.

2 ERS-2 statistics from 28 April to 2 June 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 83. In general, bias levels have become more negative (0 - 0.15 dB) for all tracks, beams and incidence angles. The change was largest for descending tracks at low incidence angles. As a result the following picture (see Figure 1) emerges. Bias levels are between 0.3 and 1.1 dB too low. With the exception of the fore and aft beam at low incidence angles, levels are rather uniform. Compared to cycle 83, inter-beam differences are slightly larger. 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,

	cycle 83		cycle 84	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.60	1.46	1.60	1.45
node 1-2	1.60	1.54	1.56	1.51
node 3-4	1.49	1.45	1.46	1.42
node 5-7	1.52	1.42	1.51	1.39
node 8-10	1.59	1.41	1.59	1.39
node 11-14	1.60	1.40	1.61	1.39
node 15-19	1.58	1.41	1.60	1.41
speed BIAS	-0.75	-0.81	-0.82	-0.87
node 1-2	-1.55	-1.60	-1.64	-1.70
node 3-4	-1.13	-1.14	-1.21	-1.22
node 5-7	-0.79	-0.79	-0.85	-0.85
node 8-10	-0.55	-0.59	-0.60	-0.64
node 11-14	-0.51	-0.61	-0.57	-0.66
node 15-19	-0.58	-0.68	-0.64	-0.73
direction STDV	33.9	18.9	27.1	18.6

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

showing rapid variations, which are typical for yaw attitude errors. Several peaks are observed, the largest occurring around 15 UTC 30 April 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 (only at lower nodes) at 12 UTC 21 May and 12 UTC 23 May 2003 are not connected to a low data volume. For these peaks, the quality of the UWI winds was not lower than average (see Figure 4).

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 does not show large peaks.

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 83, the average bias level has become 0.07 m/s more negative (-0.82 m/s, was -0.75 m/s).

Especially the large negative wind bias at the lower nodes has been further increased -1.64 m/s, was -1.55 m/s). It is a result of the large negative biases in sigma0 levels (see Figure 1). Standard deviations were unchanged (average 1.60 m/s).

Like for ESACA data received for cycle 83, 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 1.45 m/s versus 1.60 m/s). Best results are obtained for CMOD5 (shown below).

For cycle 84 the (scatterometer - model) direction standard deviations were ranging between 20 and 40 degrees (Figure 5). The sharp peaks for 00 UTC 5 May and 00 UTC 21 May 2003 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 83, and comparable to that for cycle 82 (see also lower panel of Figure 8). The quality of the de-aliased CMOD4 wind direction is stable.

In Figure 9 all locations are plotted for which UWI winds were more than 8 m/s weaker than the FGAT winds. The number of such collocations and their rather point-wise distribution is comparable to that for cycles 81 and 82. There are no 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 9. For two cases, wind fields are shown in Figure 10. In the top panel (North-West of Scotland) the large local difference in wind speed between UWI and FGAT winds is the result of a misplacement of a front. It is likely that the location indicated by the UWI winds is the more accurate one. In the lower panels of Figure 10 (South-East of Australia), there is also some displacement of a weather system. Moreover, differences mainly arise from a general underestimation (left panel) of UWI winds at strong wind conditions (FGAT shows values of 30 m/s). This underestimation is less present for winds inverted on the basis of CMOD5 (right panel). In addition, CMOD5 winds do not show the strange directional behavior of UWI winds around 55^o S and 157^o E. This patch, which is also absent in CMOD4 winds (not shown) must be the result of the non-optimal inversion in ESACA (discussed above). To conclude for the two cases displayed in Figure 10, the large differences in speed between UWI and FGAT winds are not the result of an instrument anomaly. This statement is supported by the observation that for these cases the difference between the fore and aft beam incidence angles did not show large peaks, indicating that the error in the yaw attitude was not large.

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 83, 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 83.

The average bias of the UWI wind direction (Figure 12) is small (0.6 degrees, was 0.7). Its standard deviation has decreased substantially (25.0 degrees, was 32.1) w.r.t. cycle 83, and is just below the level obtained for cycle 82 (25.8 degrees).

There were only few collocations of low UWI winds and high ECMWF FGAT winds (Figure 11). These usually originate from large errors in yaw attitude control.

Winds derived on the basis of CMOD5 are displayed in Figure 13. Compared to cycle 83, the bias level has become more negative (-0.58 m/s, was -0.53 m/s) and the standard deviation slightly increased (1.46 m/s, was 1.45 m/s). CMOD5 winds are of higher quality than the CMOD4 (Figure 13) and UWI winds (Figure 11). 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 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 averaged over 5-weekly cycles from 12 December 2001 (cycle 69) to 2 June 2003 (end cycle 84) 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: Locations of data during cycle 84 for which UWI winds (top panel), respectively CMOD5 winds (lower panel) are more than 8 m/s weaker than the collocated FGAT winds.

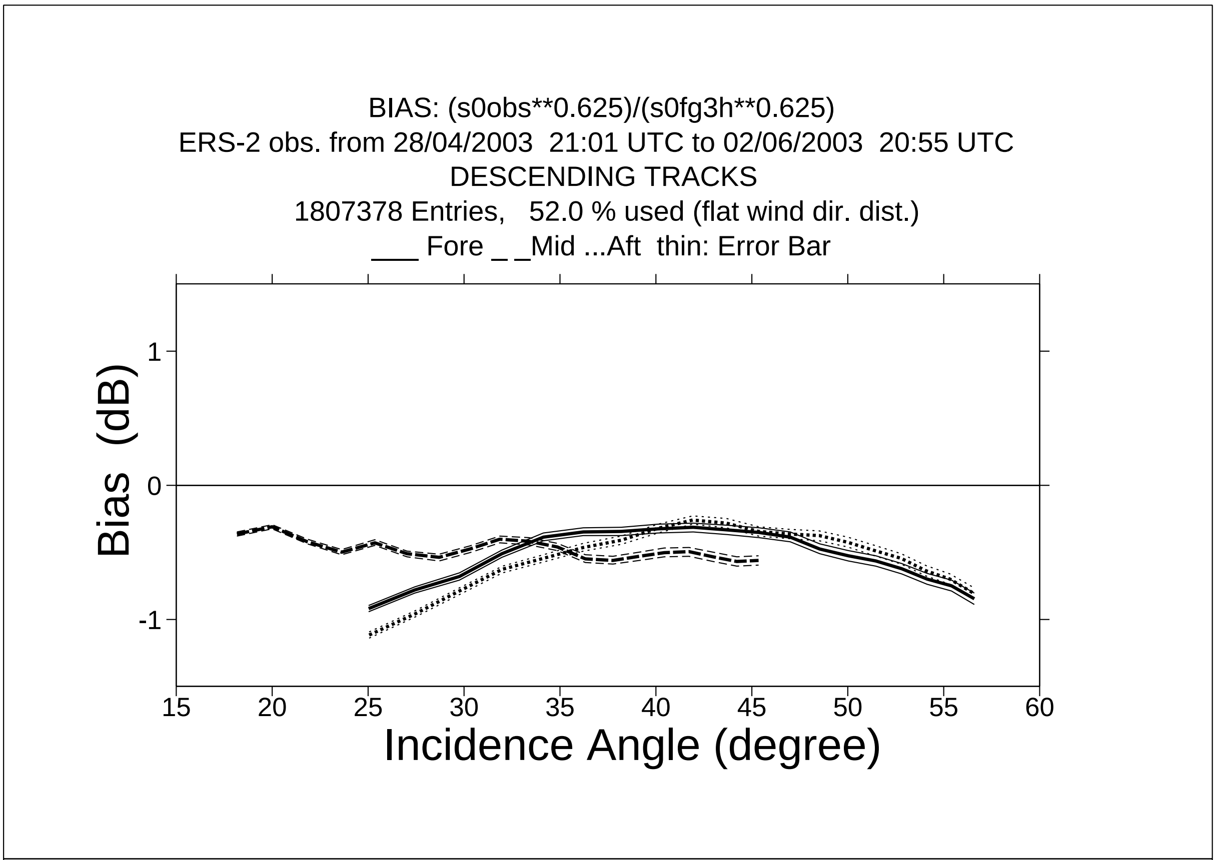
Figure 10: UWI or CMOD5 wind vectors (red) and collocated FGAT wind vectors (blue) North-West of Scotland for 4 May 2003 (top panel) and South-East of Australia for 31 May 2003 (lower panels).

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 28/04/2003 21:01 UTC to 02/06/2003 20:55 UTC
DESCENDING TRACKS
1807378 Entries, 52.0 % 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)

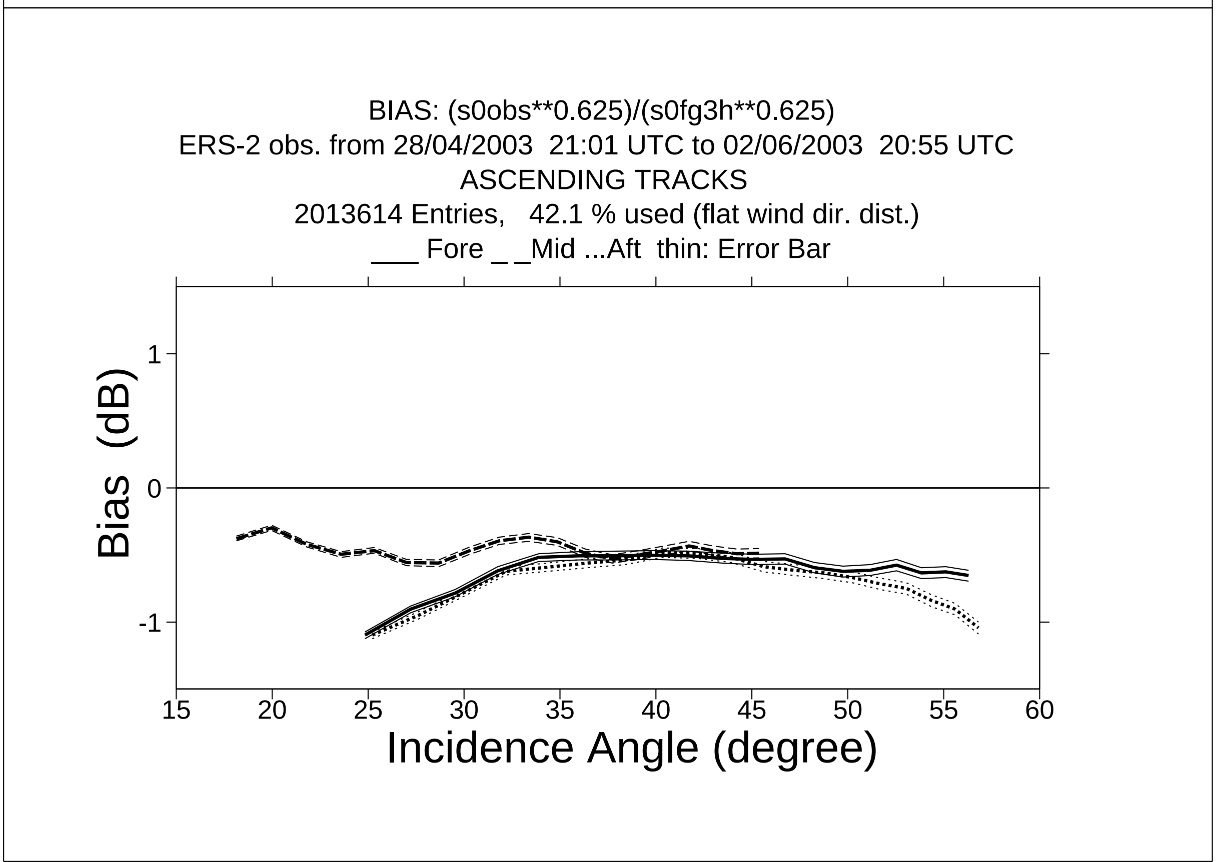
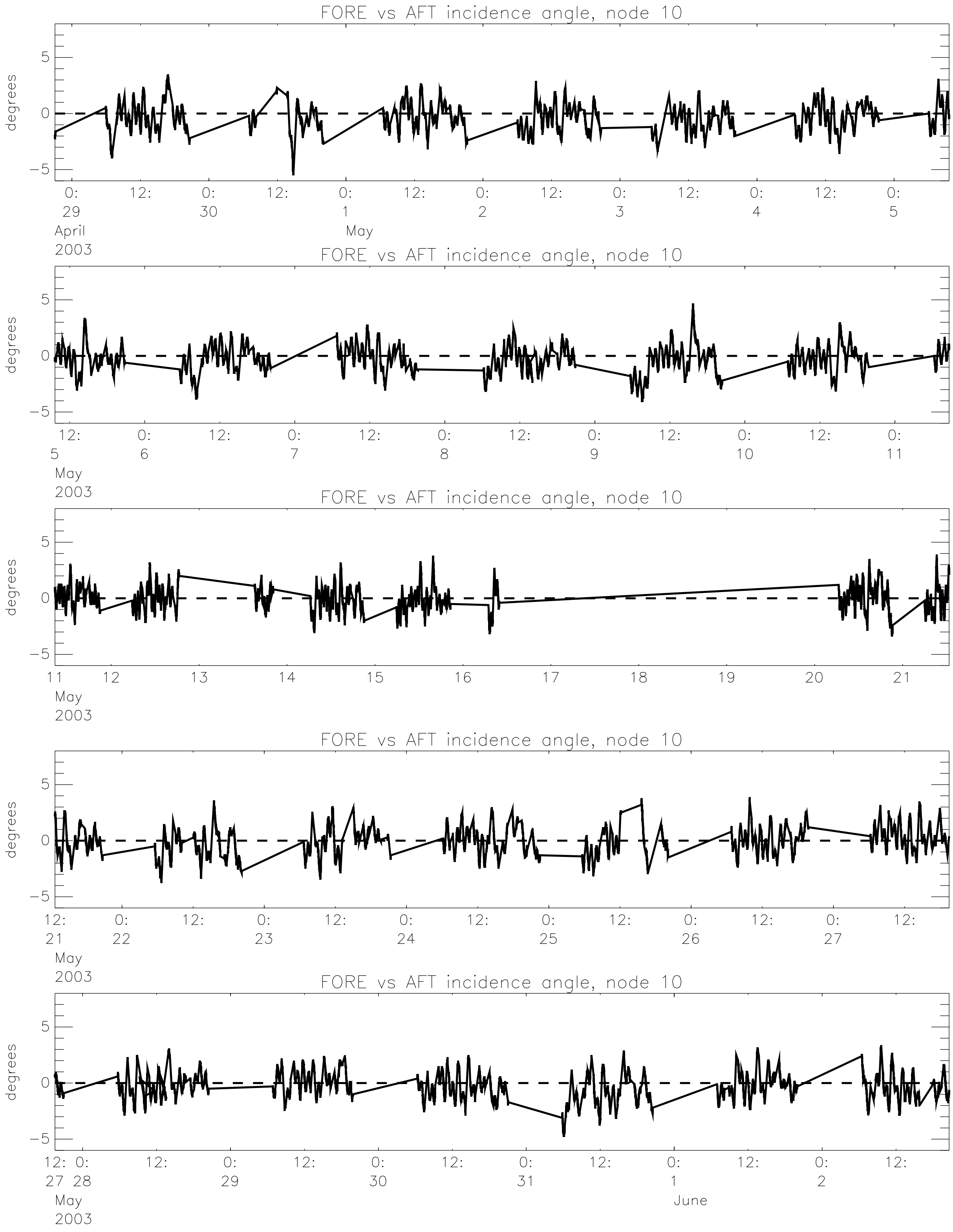

BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 28/04/2003 21:01 UTC to 02/06/2003 20:55 UTC
ASCENDING TRACKS
2013614 Entries, 42.1 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)

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

Figure 2

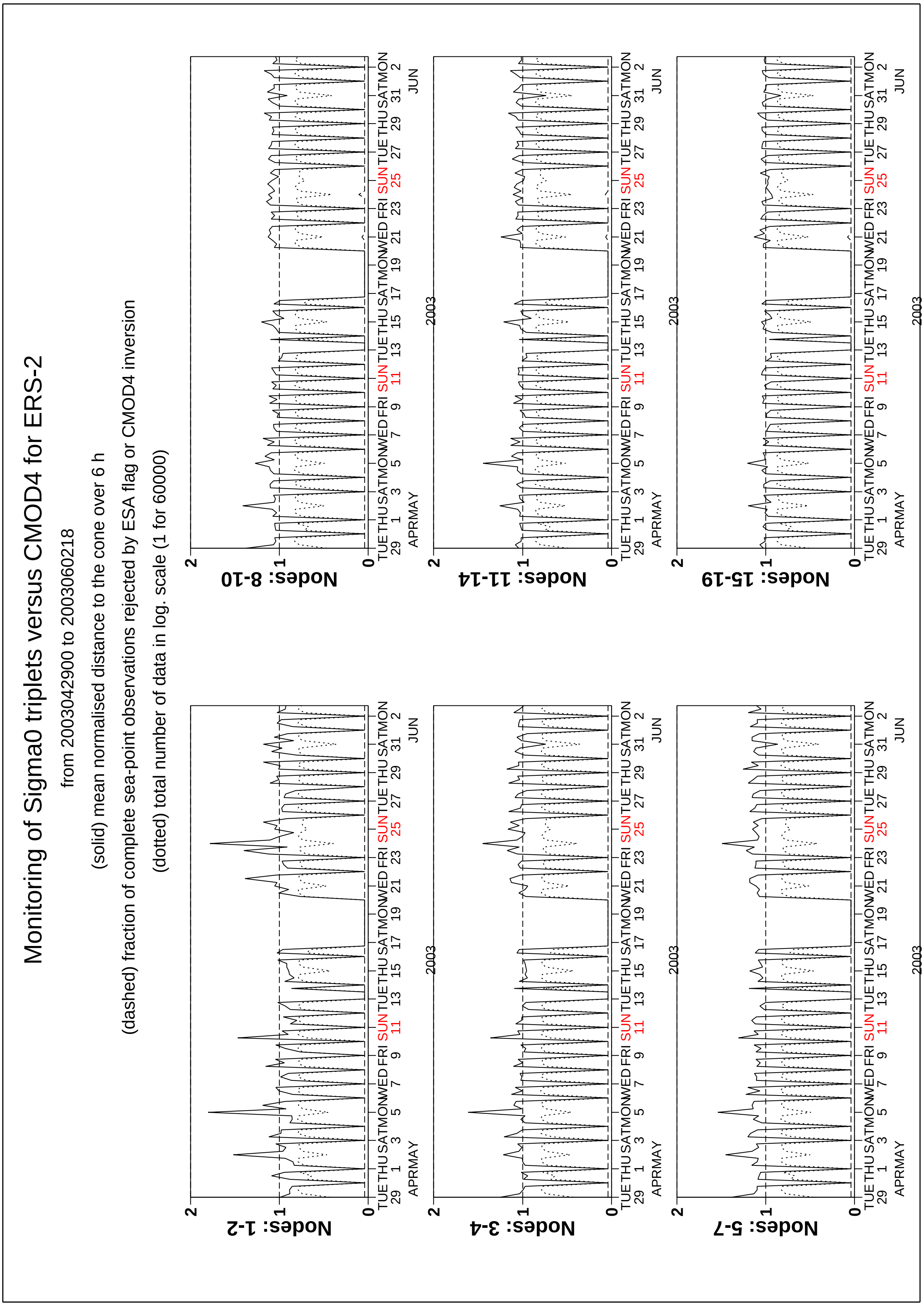

Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2003042900 to 2003060218
(solid) mean normalised distance to the cone over 6 h
(dashed) fraction of complete sea-point observations rejected by ESA flag or CMOD4 inversion
(dotted) total number of data in log. scale (1 for 60000)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
APR MAY JUN 2003

Figure 3

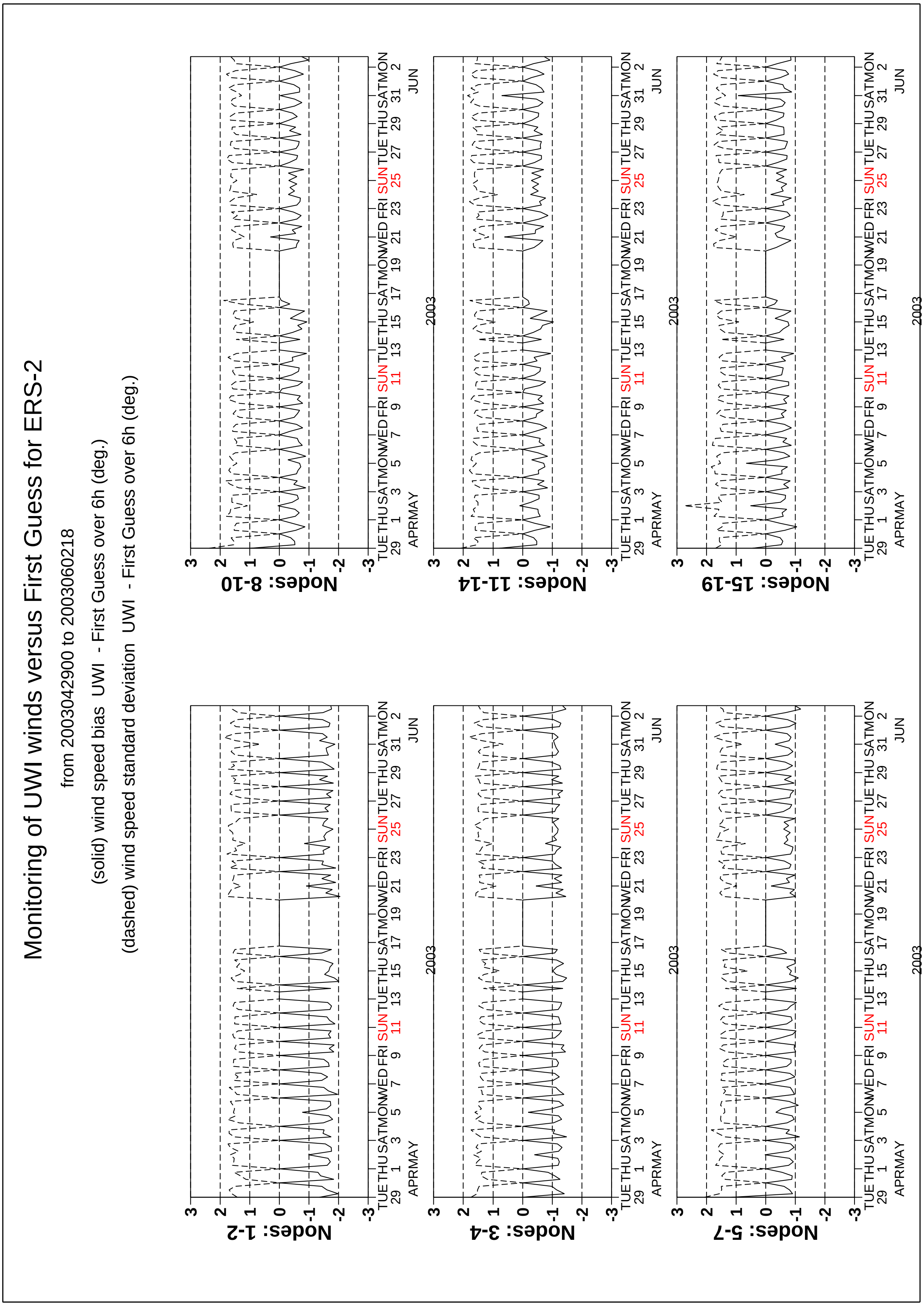

Monitoring of UWI winds versus First Guess for ERS-2
from 2003042900 to 2003060218
(solid) wind speed bias UWI - First Guess over 6h (deg.)
(dashed) wind speed standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
2003
APR MAY JUN

Figure 4

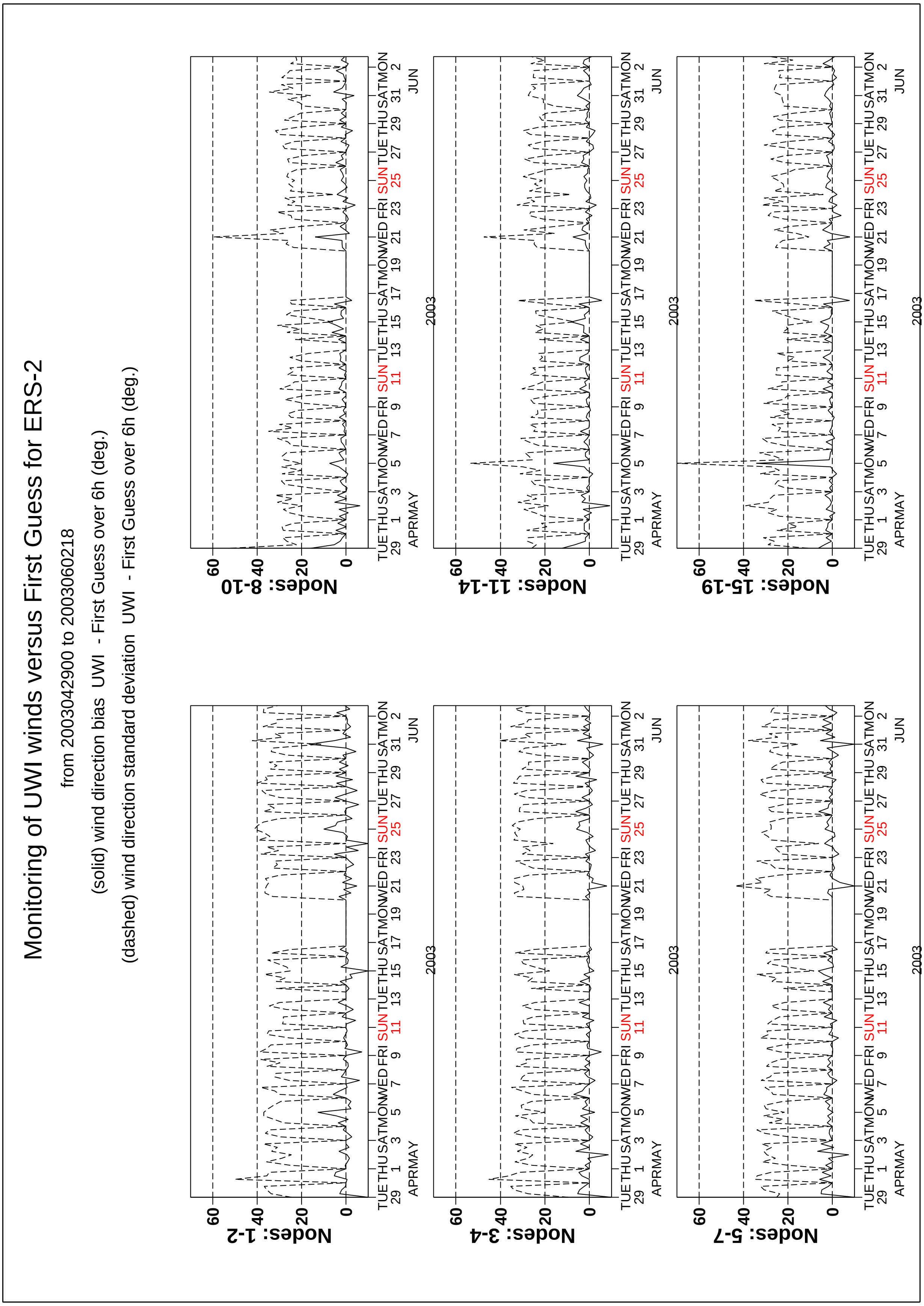

Monitoring of UWI winds versus First Guess for ERS-2
from 2003042900 to 2003060218
(solid) wind direction bias UWI - First Guess over 6h (deg.)
(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
2003
APR
MAY
JUN

Figure 5

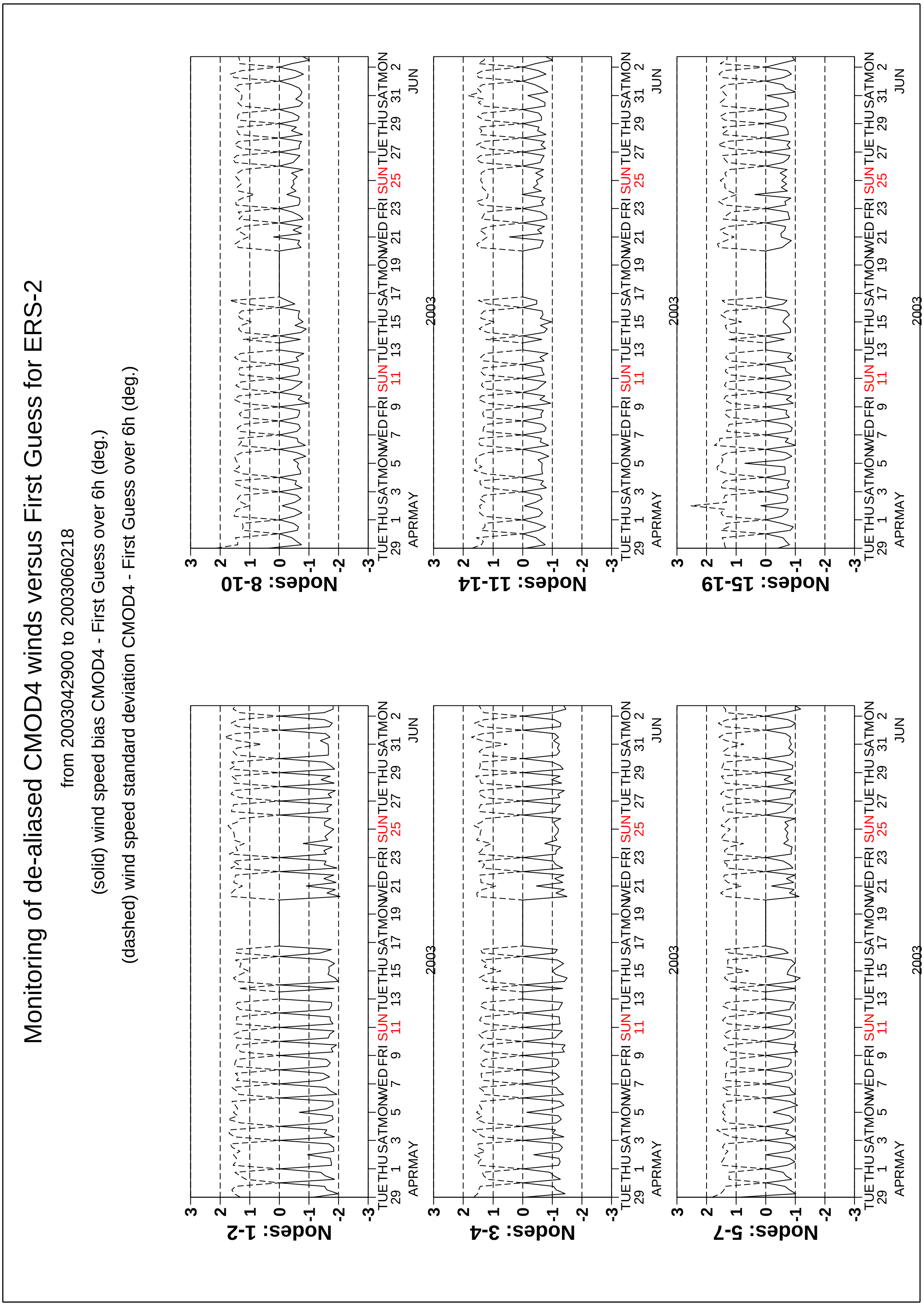

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003042900 to 2003060218
(solid) wind speed bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind speed standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
APR MAY JUN
2003

Figure 6

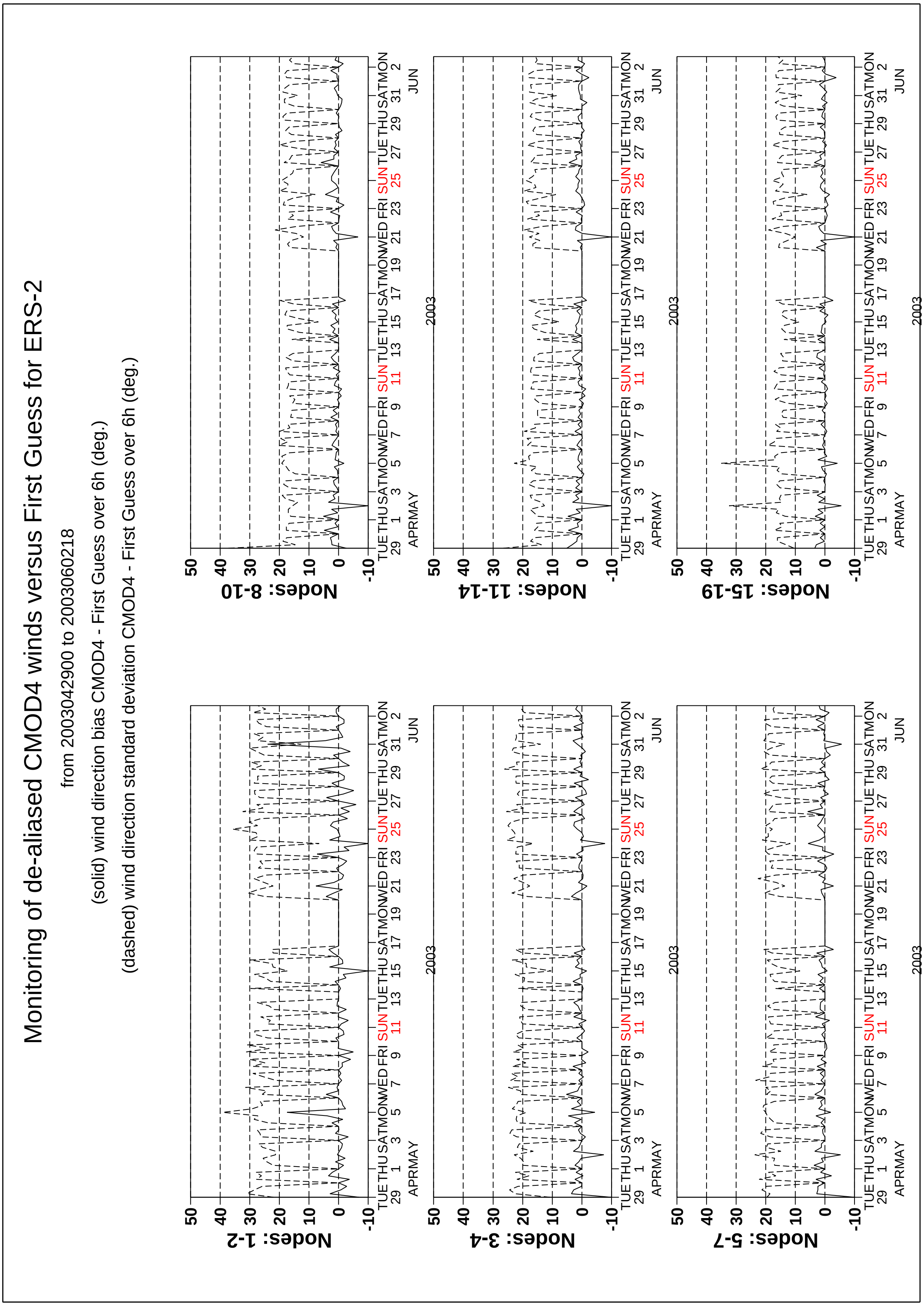

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003042900 to 2003060218
(solid) wind direction bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind direction standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
2003
APR
MAY
JUN

Figure 7

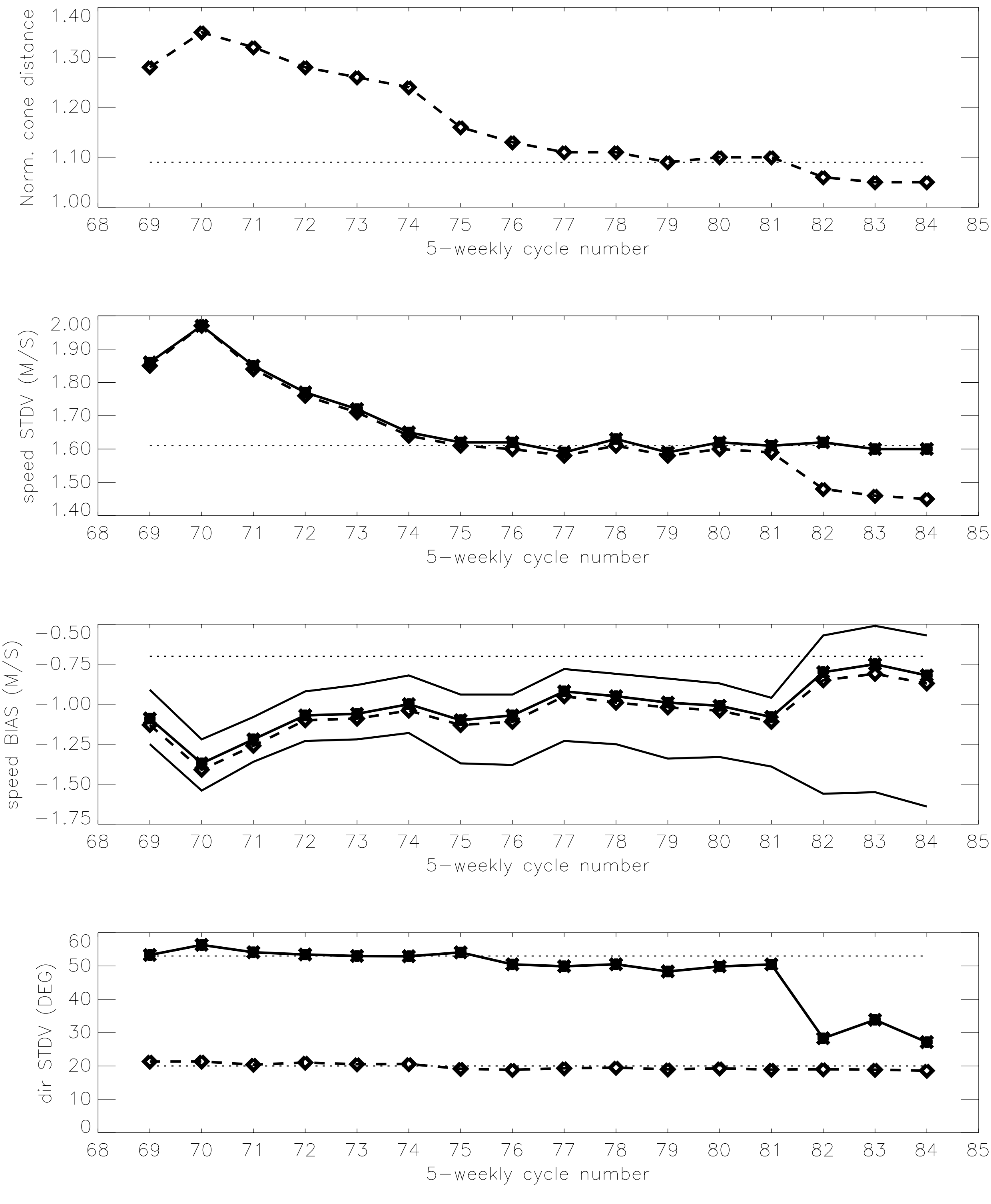

Norm. cone distance
5−weekly cycle number
speed STDV (M/S)
5−weekly cycle number
speed BIAS (M/S)
5−weekly cycle number
dir STDV (DEG)
5−weekly cycle number

Figure 8

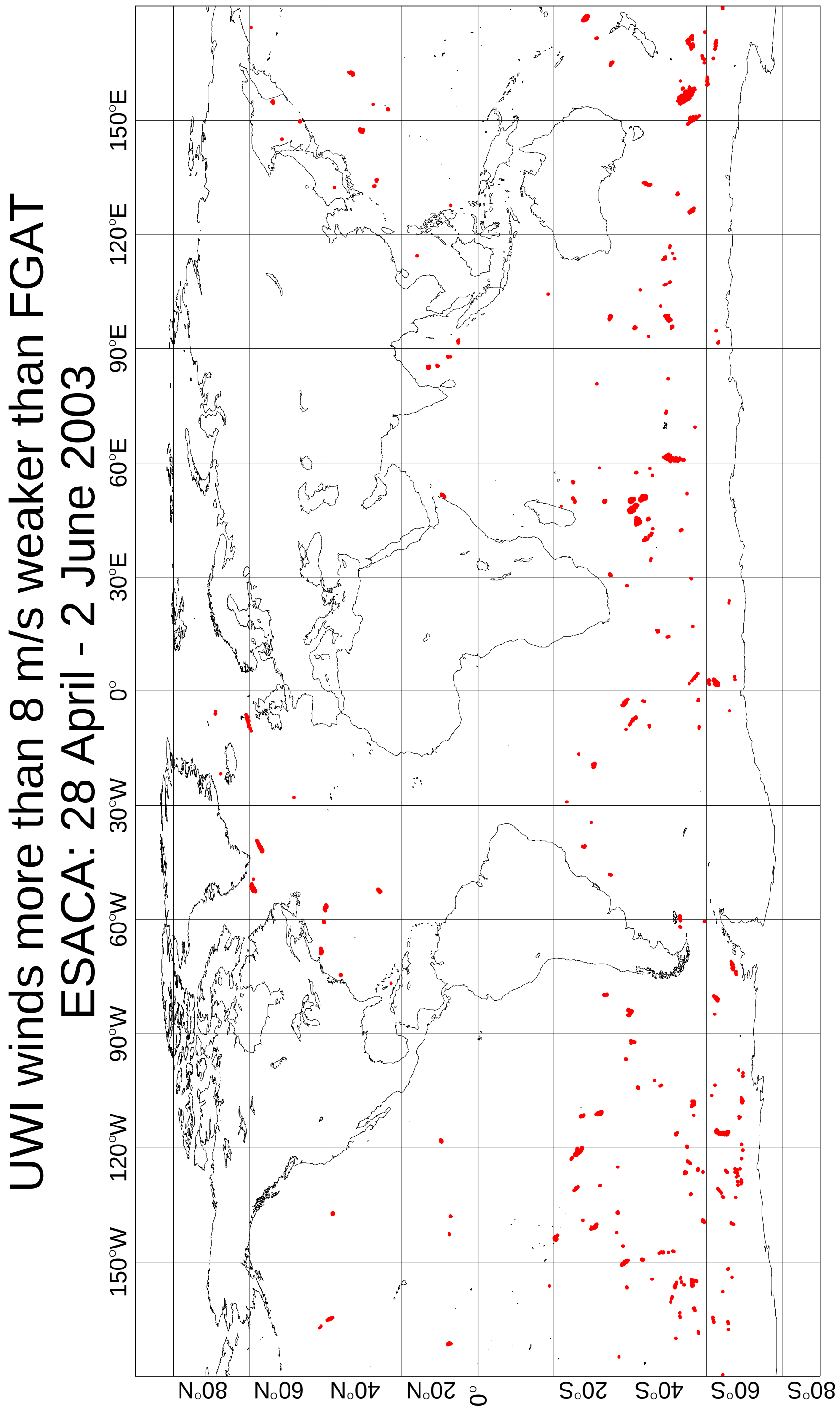
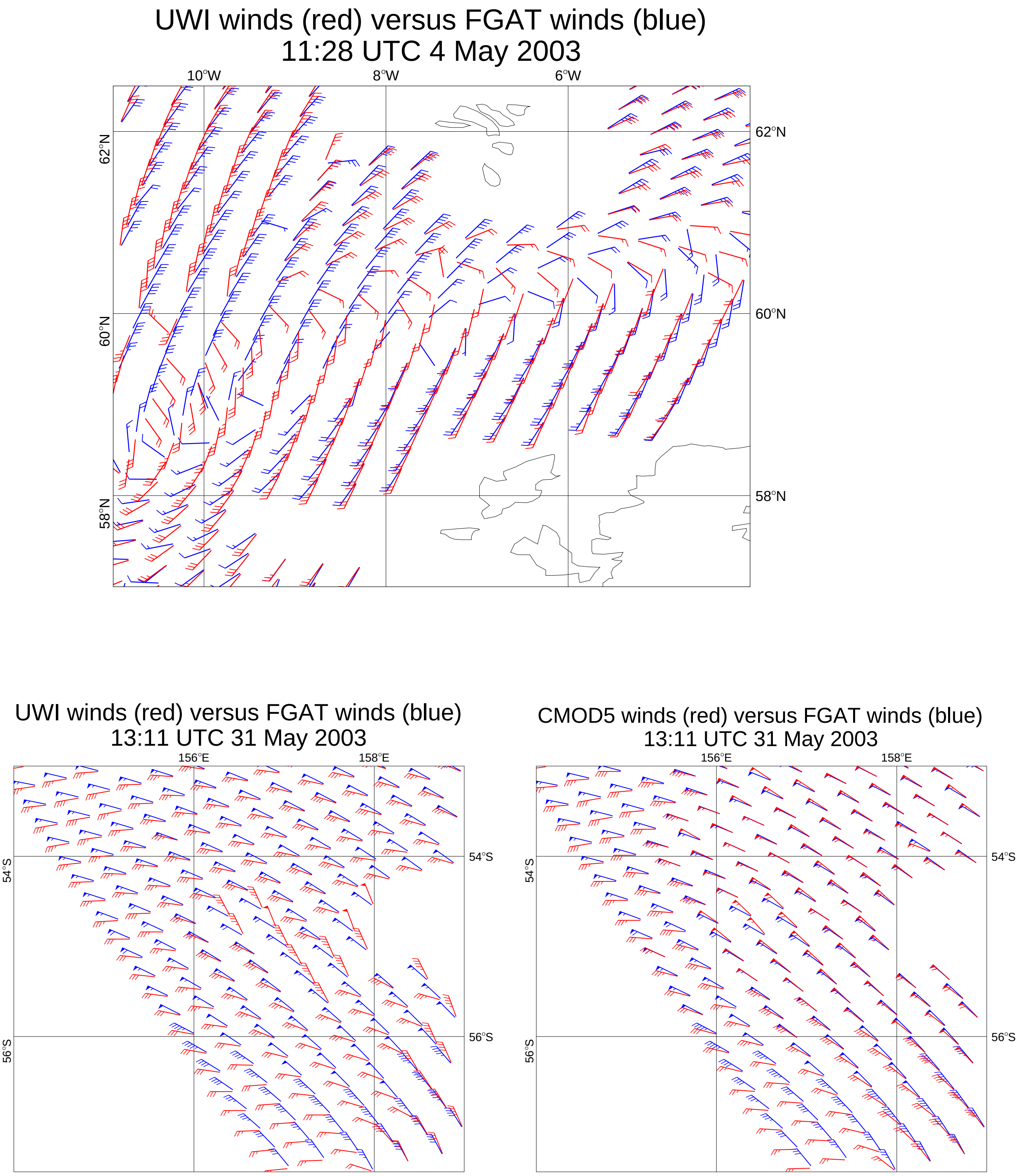

UWI winds more than 8 m/s weaker than FGAT
ESACA: 28 April - 2 June 2003
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S

Figure 9



UWI winds (red) versus FGAT winds (blue)
11:28 UTC 4 May 2003
10°W
8°W
6°W
62°N
60°N
58°N
UWI winds (red) versus FGAT winds (blue)
13:11 UTC 31 May 2003
156°E
158°E
54°S
56°S
CMOD5 winds (red) versus FGAT winds (blue)
13:11 UTC 31 May 2003
156°E
158°E
54°S
56°S

Figure 10

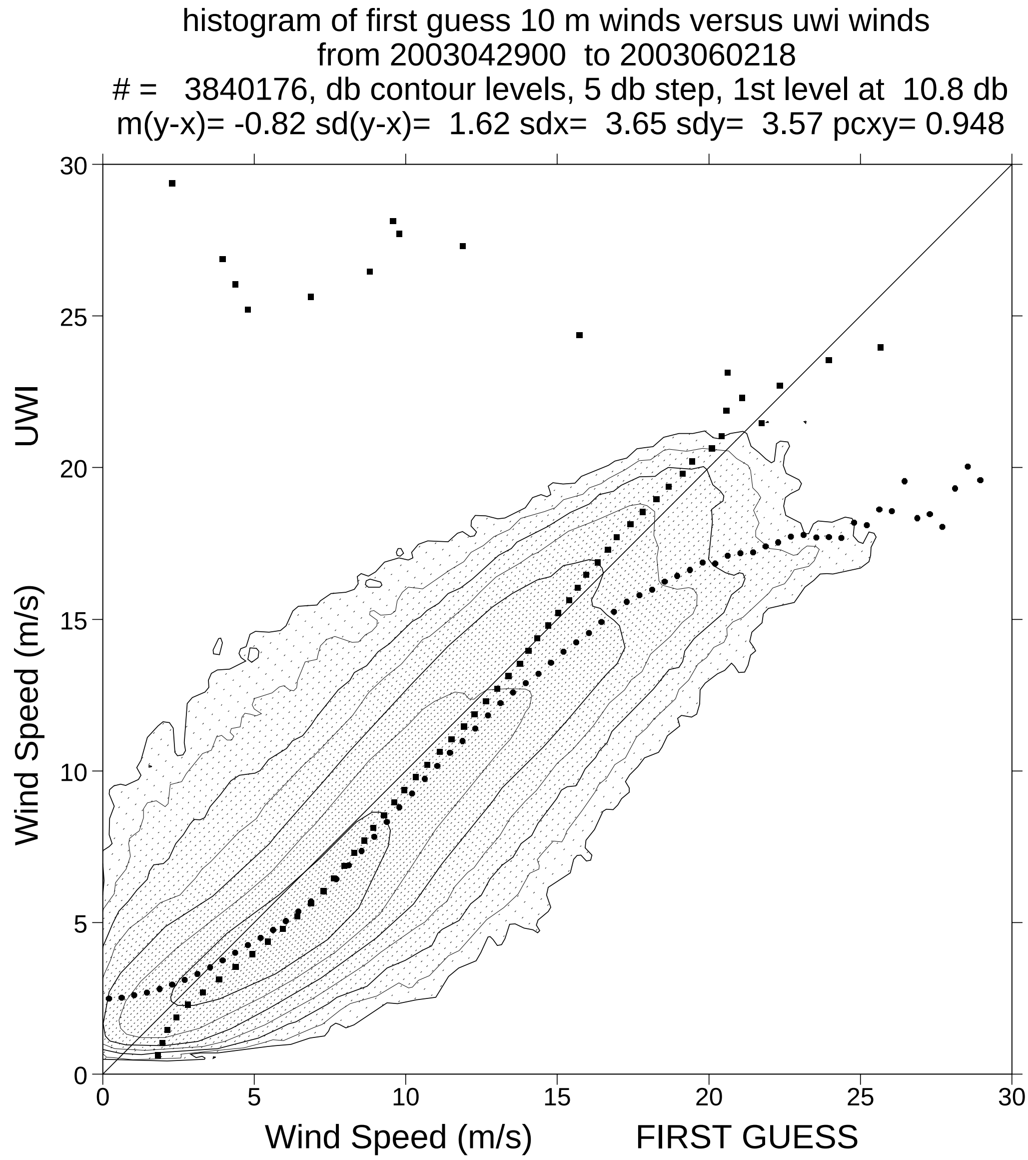
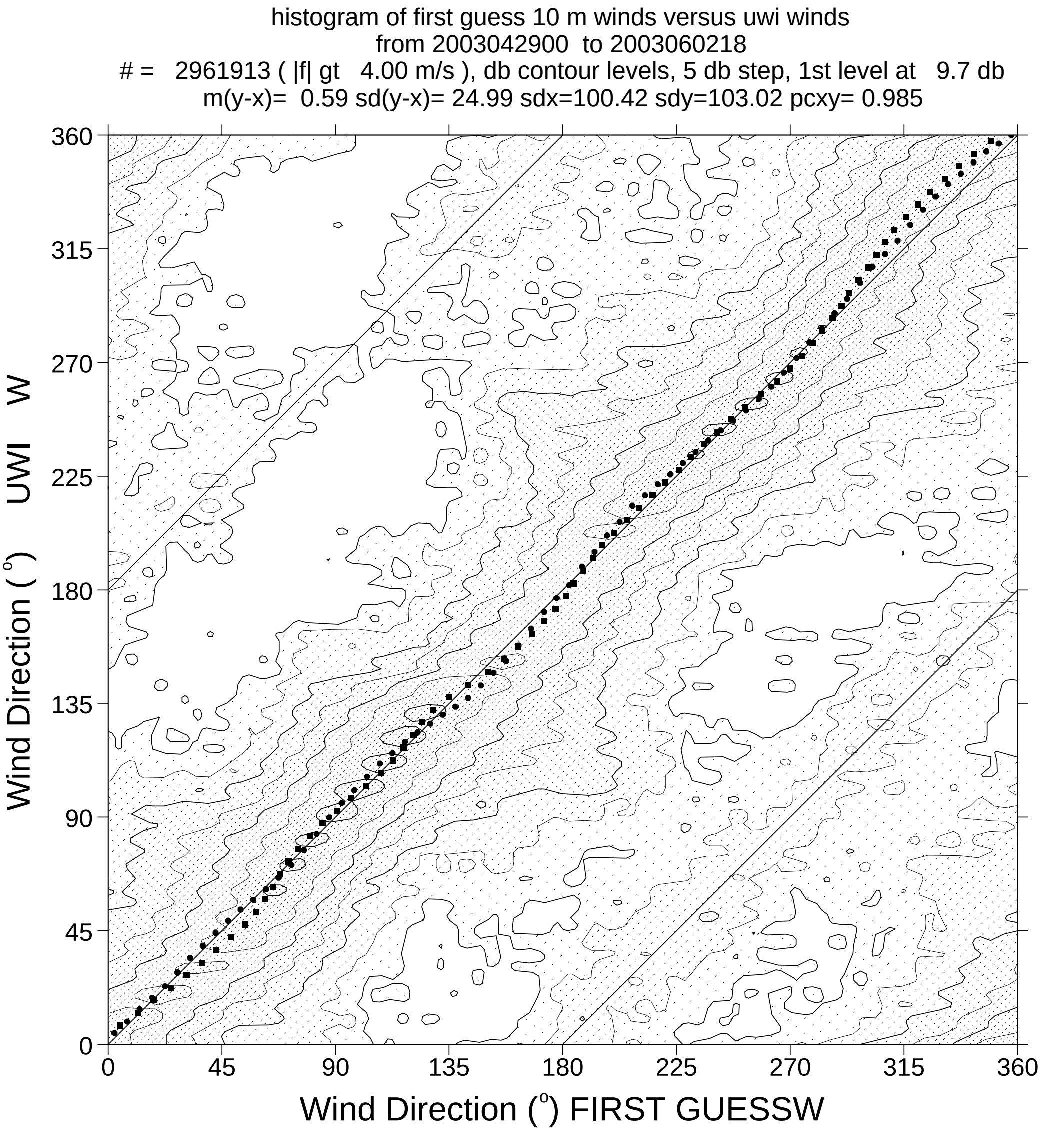

histogram of first guess 10 m winds versus uwi winds
from 2003042900 to 2003060218
= 3840176, db contour levels, 5 db step, 1st level at 10.8 db
m(y-x)= -0.82 sd(y-x)= 1.62 sdx= 3.65 sdy= 3.57 pcxy= 0.948
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 11



histogram of first guess 10 m winds versus uwi winds
from 2003042900 to 2003060218
= 2961913 (|f| gt 4.00 m/s), db contour levels, 5 db step, 1st level at 9.7 db
m(y-x)= 0.59 sd(y-x)= 24.99 sdx=100.42 sdy=103.02 pcxy= 0.985
Wind Direction (°) UWI W
Wind Direction (°) FIRST GUESSW
0
45
90
135
180
225
270
315
360

Figure 12

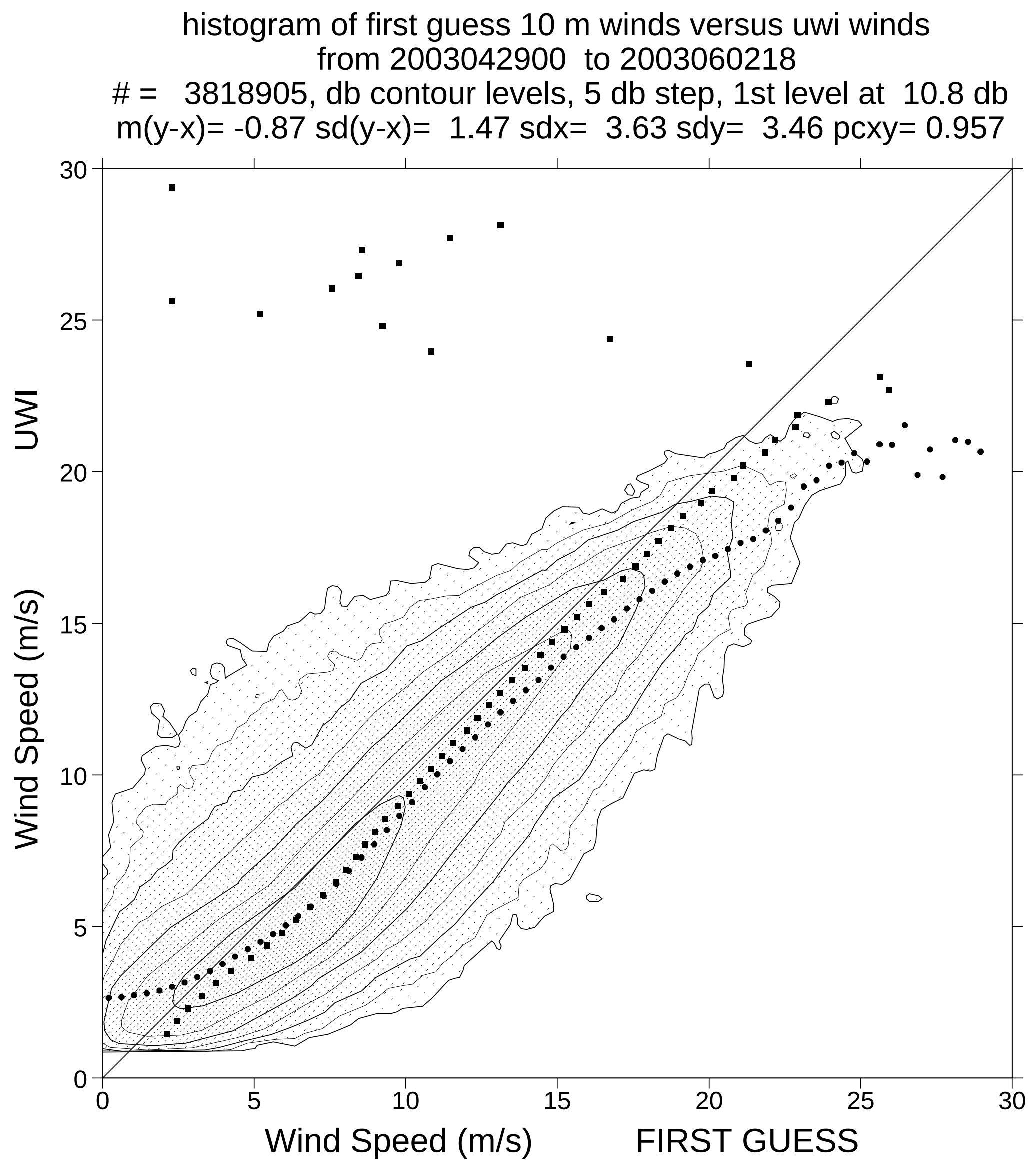

histogram of first guess 10 m winds versus uwi winds
from 2003042900 to 2003060218
= 3818905, db contour levels, 5 db step, 1st level at 10.8 db
m(y-x)= -0.87 sd(y-x)= 1.47 sdx= 3.63 sdy= 3.46 pcxy= 0.957
UWI
Wind Speed (m/s)
0
5
10
15
20
25
30
Wind Speed (m/s)
FIRST GUESS

Figure 13

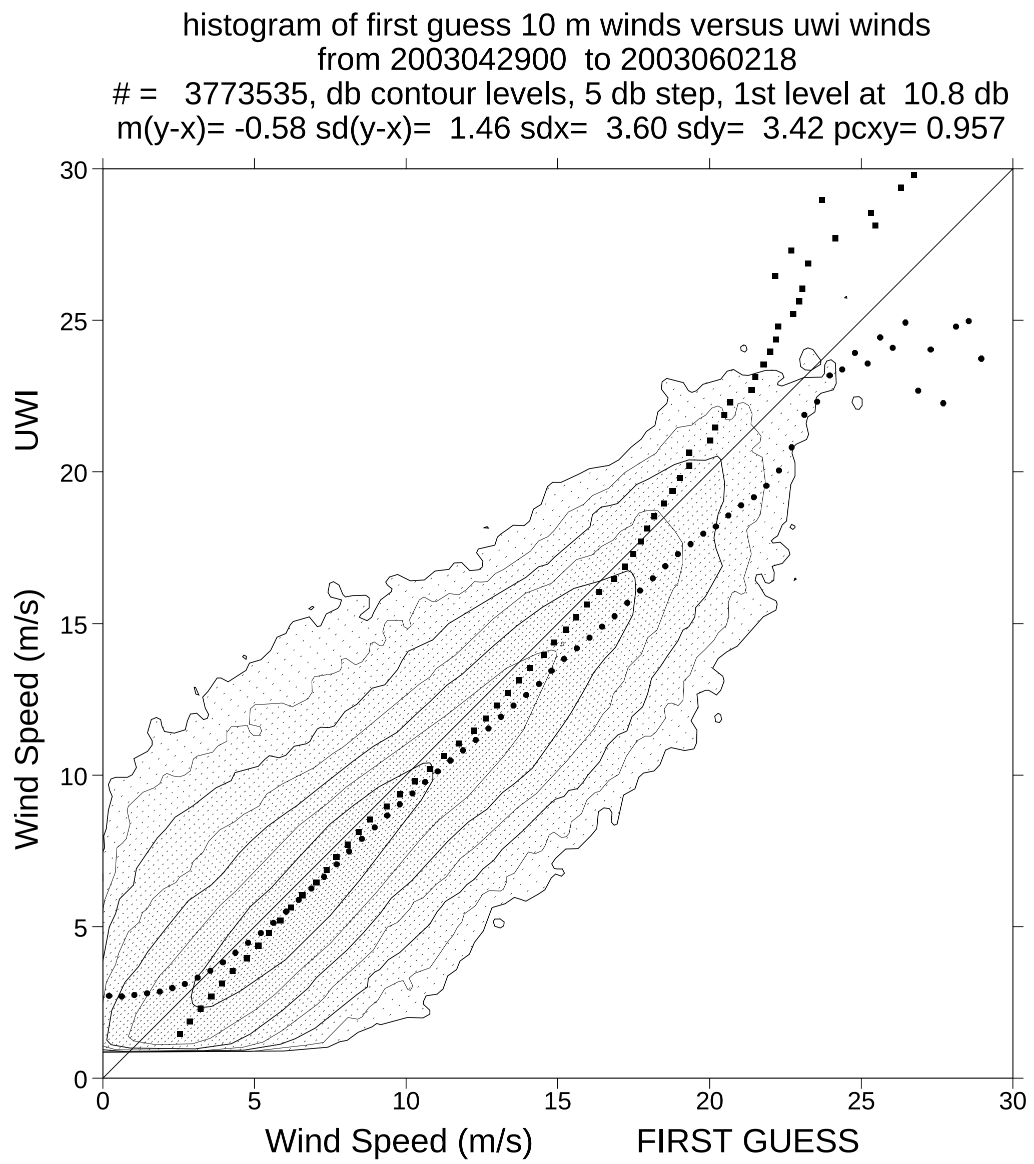

histogram of first guess 10 m winds versus uwi winds
from 2003042900 to 2003060218
= 3773535, db contour levels, 5 db step, 1st level at 10.8 db
m(y-x)= -0.58 sd(y-x)= 1.46 sdx= 3.60 sdy= 3.42 pcxy= 0.957
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30
0
5
10
15
20
25
30

Figure 14