Monitoring statistics of the ERS-2 scatterometer for ESA

cycle 90

(Project Ref. 15990/02/I-LG)

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January 16, 2004

1 Introduction

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 1). Since 8 December 2003, a new ground station became operational in West Freugh (Scotland, UK), filling the gap in the data coverage in the North-Atlantic. However, during cycle 90, data from this station was not received at ECMWF, so the gap remained (see Figure 1).

The quality of the UWI product was monitored at ECMWF for cycle 90. 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 within a few months.

During cycle 90, data was received between 21:01 UTC 24 November and 19:46 UTC 29 December 2003. No data was received for the 6-hourly batch centered around 06 UTC 03 December 2003. Due to an internal software problem at ECMWF, data was not available for the period between 18 UTC 08 December and 06 UTC 12 December 2003.

With some exceptions, the asymmetry between fore and aft incidence angles was within bounds. On 26 November 2003 deviations were larger than average (up to 7 degrees for node 10) and the combined k_p and yaw-error flag was set for most data received during that day. This anomaly in yaw steering control was not induced by solar activity. In fact, no periods of significantly enhanced solar activity were observed during cycle 90.

Compared to cycle 89, the agreement with ECMWF first-guess (FGAT) fields was somewhat worse. Although relative bias levels have been slightly reduced (from -0.55 m/s to -0.51 m/s), scatter has increased (from 1.59 m/s to 1.65 m/s). One should note, however, that due to the lack of global coverage, this trend is likely to be a result of seasonal variations. The quality of the UWI wind direction has improved. After the negative trend observed for cycle 89, performance is back on the level of cycle 88. The quality of de-aliased CMOD4 winds (that did not show a degradation for cycle 89) remained the same.

Compared to nominal data in 2000, both backscatter and wind speed bias levels are somewhat more optimal. Internode and inter-beam dependent trends were found to be similar to the old situation. 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 90.

2 ERS-2 statistics from 25 November to 29 December 2003

2.1 Sigma0 bias levels

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 2.

Compared to cycle 89, bias levels were nearly unchanged. Largest differences were observed at the near range descending tracks where levels have become 0.1 dB less negative. The situation is slightly better than that for nominal data in 2000 (see Figure 1 of the cyclic reports for cycle 48 to 59). The dependency of the bias as function of incidence angle is small, and the tendency of being somewhat more negative at the far range has been suppressed. In fact, now levels are 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.

The data volume of ascending and descending tracks are similar.

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 3 gives a time evolution of this asymmetry, showing rapid variations, which are typical for yaw attitude errors. Also in this figure, the occasions for which the combined k_p-yaw quality flag was set are indicated by red stars. The relation with incidence-angle asymmetries is obvious.

From Figure 3 it is seen that during cycle 90 there was one anomalous period (26 November). It was not induced by solar activity. As will be shown below (Figures 10 and 11), data quality was degraded, but was successfully removed by the combined k_p yaw-angle error.

2.3 Distance to cone history

The distance to the cone history is shown in Figure 4.

Compared to cycle 89, average levels have increased from 1.18 to 1.23 and are now about 13% higher than for nominal data (see top panel Figure 9). This trend may be linked to the seasonal trend of the underlying wind climate. Time series are (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 appear at very low data volumes.

2.4 UWI minus First-Guess wind history

In Figure 5, the UWI minus ECMWF first-guess wind-speed history is plotted. Curves are based on data that passed all QC, including the test on the k_p-yaw flag, however subject to the land and sea-ice check at ECMWF (see cyclic report 88 for details).

The history plot shows many peaks, most of them being a result of low data volume. Other ones indicate a real discrepancy between UWI and ECMWF winds. An example is shown for 01 UTC 22 December 2003 near the Labrador sea (top panel of Figure 11). It presents a situation in which UWI and ECMWF are nearly orthogonal. There are clearly some problems with the dealising algorithm, although due to the large difference in wind direction, dealiased CMOD4 winds show a similar pattern.

Average bias levels and standard deviations of UWI winds relative to FGAT winds are displayed in Table 1. 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 (see third panel of Figure 9). The average bias level is better than for nominal data in 2000 (UWI: -0.51 m/s now, was -0.79 m/s for cycle 59).

Although bias levels have become more optimal, the standard deviation of UWI winds compared to cycle 89 has worsened (1.65 m/s, was 1.59 m/s). This increase is similar for all nodes. Like for nominal data, lowest scatter is achieved around node 5. The observed trends in the UWI wind product may be a result of the in time changing wind climate for the now regional data.

For cycle 90 the (UWI - model) direction standard deviations were ranging between 20 and 40 degrees (Figure 6). Sharp peaks are the result of low data volumes.

	cycle 89		cycle 90	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.59	1.58	1.65	1.63
node 1-2	1.59	1.55	1.63	1.58
node 3-4	1.51	1.50	1.56	1.54
node 5-7	1.50	1.50	1.56	1.56
node 8-10	1.54	1.54	1.60	1.59
node 11-14	1.58	1.58	1.61	1.61
node 15-19	1.62	1.61	1.68	1.68
speed BIAS	-0.55	-0.53	-0.51	-0.49
node 1-2	-1.17	-1.14	-1.21	-1.16
node 3-4	-0.89	-0.82	-0.89	-0.81
node 5-7	-0.58	-0.54	-0.56	-0.52
node 8-10	-0.36	-0.34	-0.32	-0.31
node 11-14	-0.31	-0.31	-0.28	-0.28
node 15-19	-0.34	-0.35	-0.24	-0.23
direction STDV	36.2	19.9	29.3	19.8
direction BIAS	-2.3	-2.8	-3.3	-2.9

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

For de-aliased CMOD4 winds values between 20 and 30 degrees are most common (Figure 8). With respect to cycle 89, the average standard deviation (see Table 1) of the UWI wind direction has improved (29.3 degrees, was 36.2 degrees) and is therefore back on the level of cycle 88. The lower performance during cycle 89 was mainly caused by the period between 4 and 20 November 2003 (see previous cyclic report). The quality of the de-aliased CMOD4 wind direction is stable (19.8 degrees, was 19.9 degrees). Bias levels in wind direction have become more negative for UWI winds (-3.3 degrees, was -2.3 degrees) but was stable for de-aliased CMOD4 winds (-2.9 degrees, was -2.8 degrees).

Top panel of Figure 10 shows all locations for which UWI winds are more than 8 m/s weaker than colocated FGAT winds for all cases in which there was a wind product reported, though restricted to sea points (according to the ECMWF ice and land-sea mask; see report for cycle 88). It does includes data rejected by the UWI flags. The lower panel shows the same, but now restricted to data that did satisfy the UWI flags. As can be seen, the UWI flag efficiently filters out low quality data, such as the combined k_p-yaw flag does for 26 November (track in the Hudson bay and Labrador sea, see middle respectively lower panel of Figure 11).

2.5 Scatterplots

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).

The scatterplot of UWI wind speed versus FGAT (Figure 12) is very similar to that for (at ECMWF inverted) de-aliased CMOD4 winds (Figure 14). It confirms that the ESACA inversion scheme is working properly. The standard deviation for the CMOD4 winds is higher than for cycle 89 (1.66 m/s was 1.61 m/s), probably the result of the more extreme winds encountered in winter time. The UWI wind bias, has been reduced (-0.51 m/s, was -0.55 m/s).

The average bias of the UWI wind direction was nearly unchanged (Figure 13, -3.2 degrees, was -3.0 degrees), as can be seen from Figure 13. Standard deviation in UWI wind direction has become lower (27.7 degrees, was 33.2 degrees).

Winds derived on the basis of CMOD5 are displayed in Figure 15. The bias compared to FGAT winds remains small (0.06 m/s, was 0.01 m/s). The quality of these winds is higher than that of the CMOD4 winds.

Figure Captions

Figure 1: 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 ans sea-ice mask.

Figure 2: 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 3: Time series of the difference in incidence angle between the fore and aft beam. Red stars indicate the occurrences for which the combined k_p-yaw flag was set.

Figure 4: 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 (based on the land-sea mask at ECMWF) sea-located triplets rejected by ESA flags, or by the wind inversion algorithm (0: all data kept, 1: no data kept).

Figure 5: 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 6: Same as Fig. 5, but for the wind direction difference. Statistics are computed only for wind speeds higher than 4 m/s.

Figures 7 and 8: Same as Fig. 5 and 6 respectively, but for the de-aliased CMOD4 data.

Figure 9: Evolution of the performance of the ERS-2 scatterometer averaged over 5-weekly cycles from 12 December 2001 (cycle 69) to 29 December 2003 (end cycle 90) for the UWI product (solid, star) and de-aliased winds based on CMOD4 (dashed, diamond). Results are based on data that passed the UWI QC flags. For cycle 85 two values are plotted; the first value for the global set, the second one for the regional set. 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 90 for which UWI winds are more than 8 m/s weaker than FGAT winds in case no QC on UWI flags was applied (top) respectively they were taken into account (lower panel).

Figure 11: Comparison between UWI (red) and ECMWF FGAT (blue) winds for two locations in the Labrador sea (top and lower panel) and for a location in the Hudson bay (middle panel).

Figure 12: Two-dimensional histogram of first guess and UWI wind speeds, for the data kept by the UWI flags, and QC based on the ECMWF ice and land-sea mask. 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.

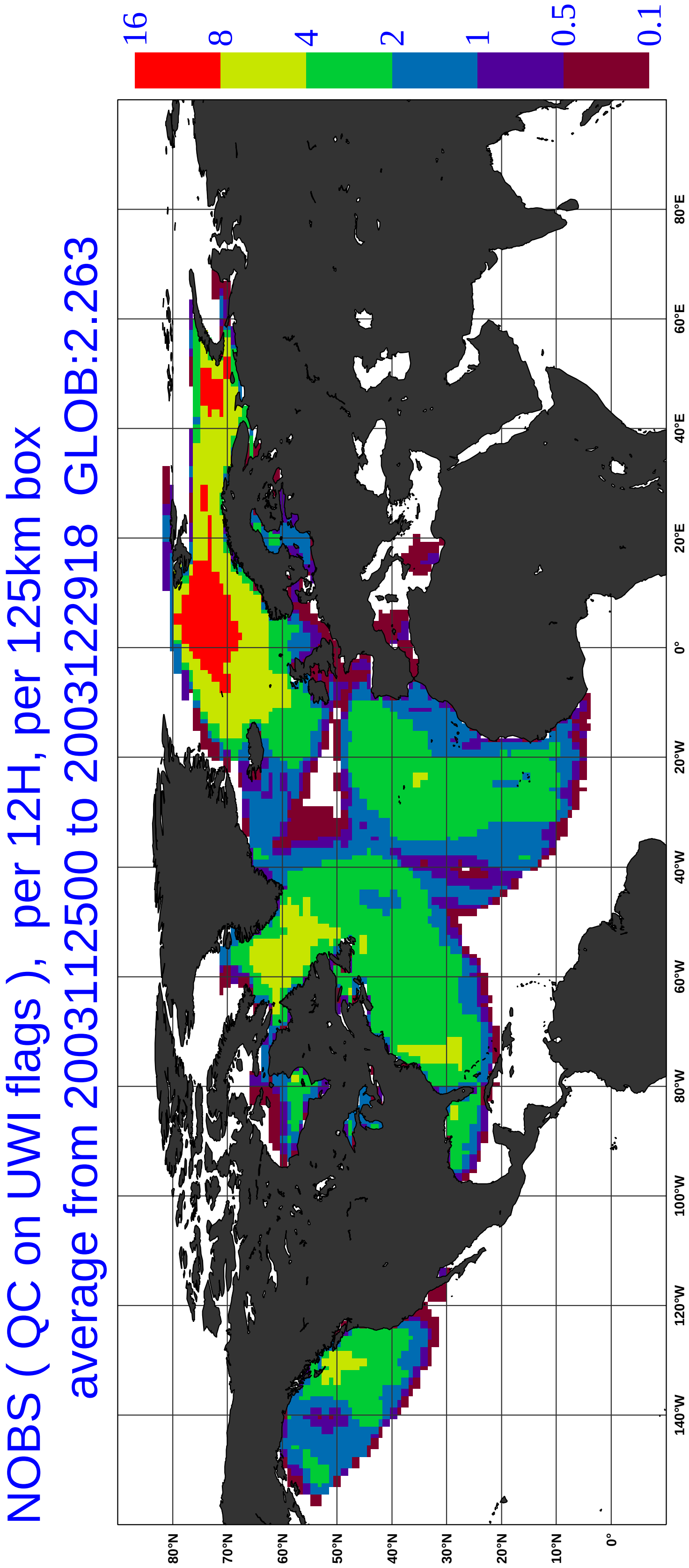
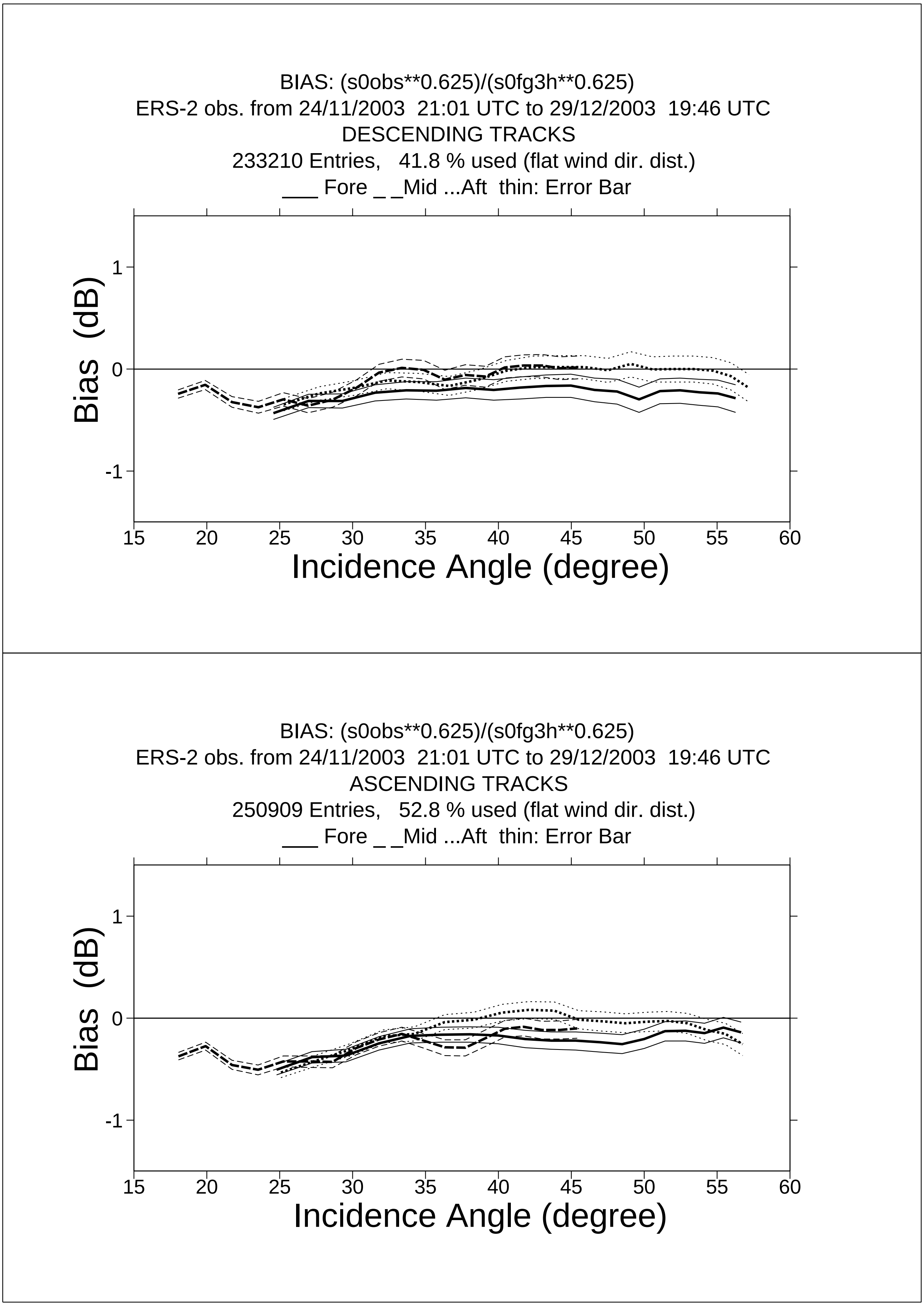

NOBS (QC on UWI flags), per 12H, per 125km box
average from 2003112500 to 2003122918 GLOB:2.263
16
8
4
2
1
0.5
0.1

Figure 1



BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 24/11/2003 21:01 UTC to 29/12/2003 19:46 UTC
DESCENDING TRACKS
233210 Entries, 41.8 % 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 24/11/2003 21:01 UTC to 29/12/2003 19:46 UTC
ASCENDING TRACKS
250909 Entries, 52.8 % 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)

Figure 2

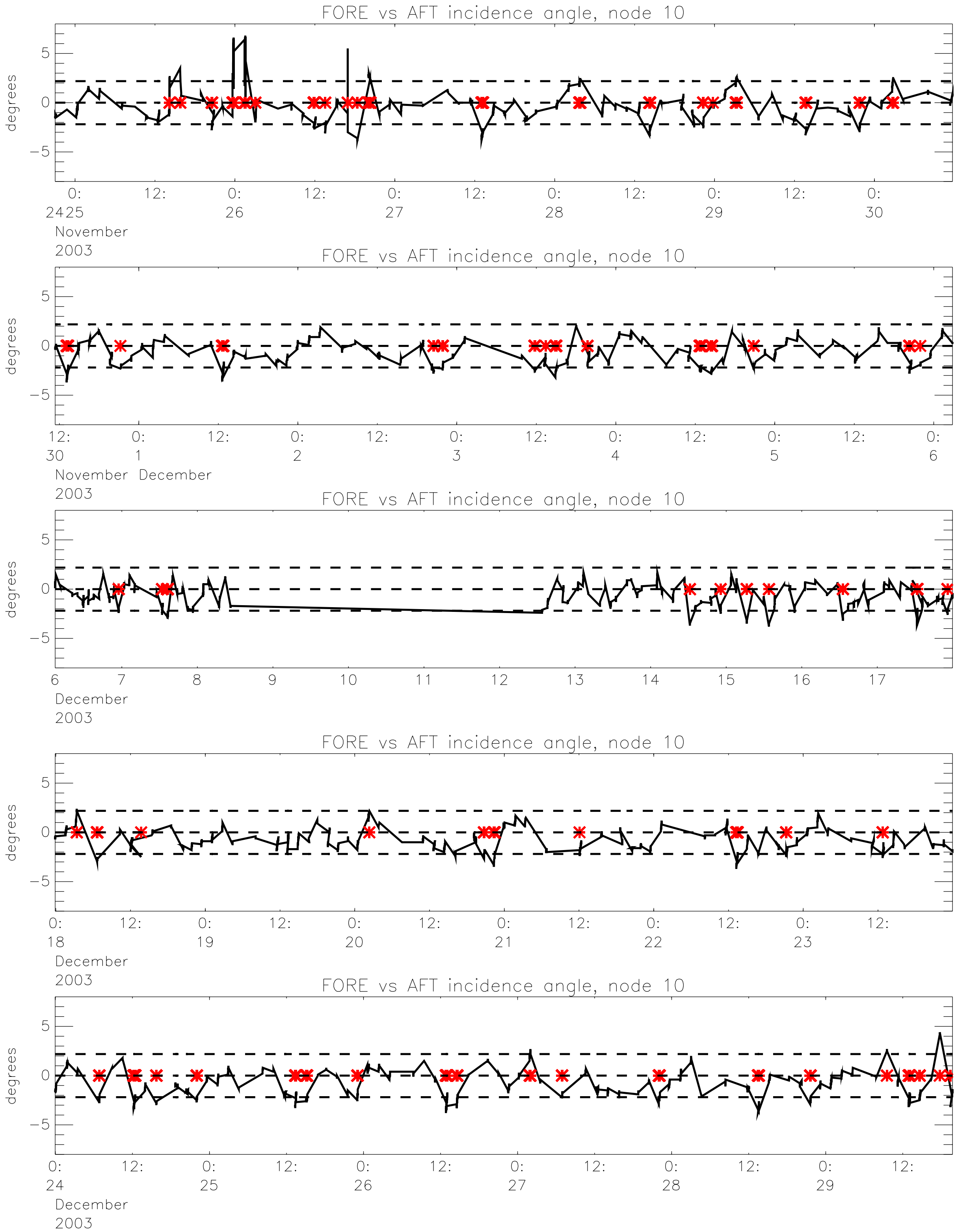
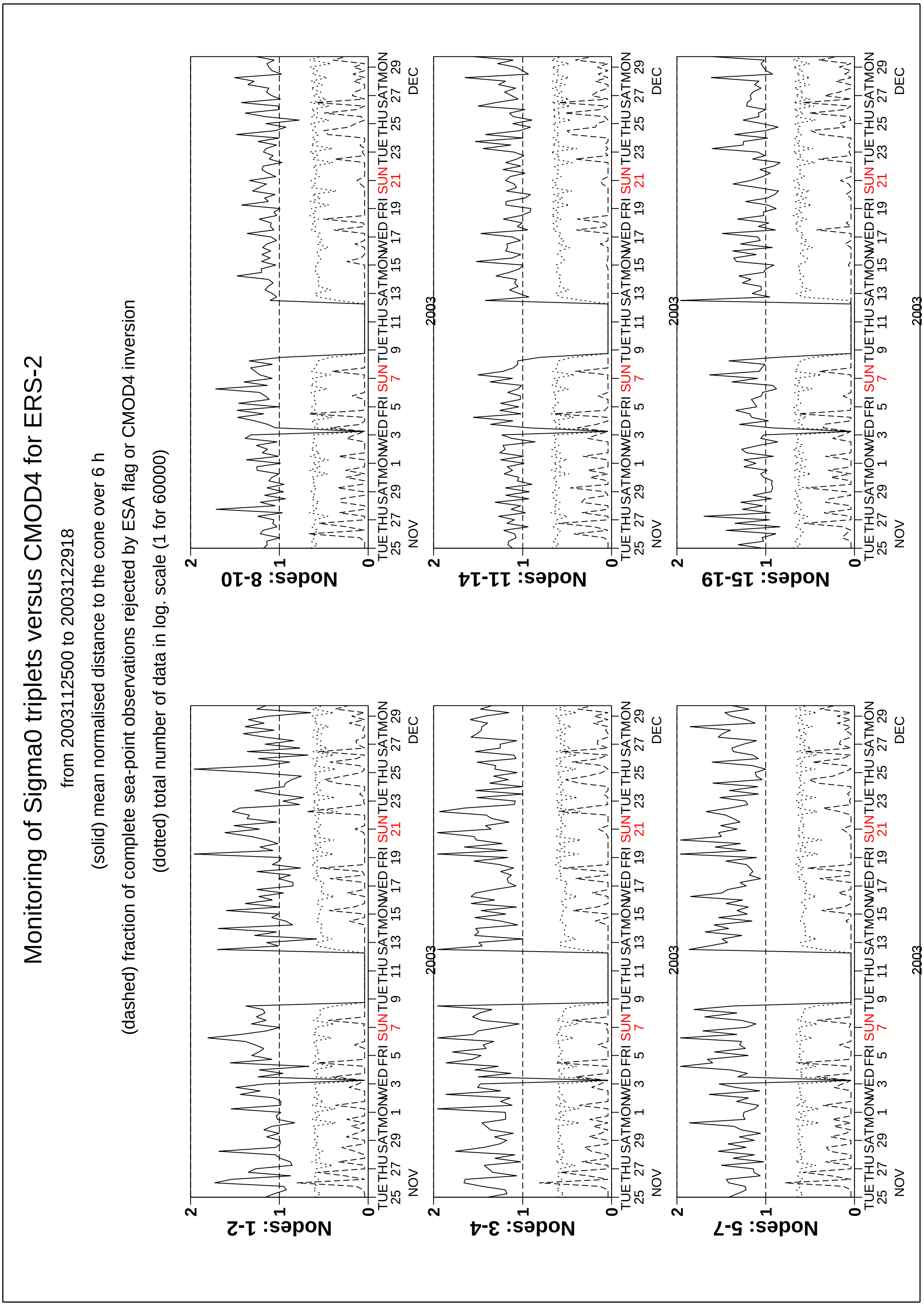

FORE vs AFT incidence angle, node 10
degrees
5
0
−5
0:
12:
2425
26
27
28
29
30
November
2003
FORE vs AFT incidence angle, node 10
degrees
12:
0:
30
1
2
3
4
5
6
November December
2003
FORE vs AFT incidence angle, node 10
degrees
6
7
8
9
10
11
12
13
14
15
16
17
December
2003
FORE vs AFT incidence angle, node 10
degrees
18
19
20
21
22
23
December
2003
FORE vs AFT incidence angle, node 10
degrees
24
25
26
27
28
29
December
2003

Figure 3



Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2003112500 to 2003122918
(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
TUE THU SAT MON WED FRI SUN TUE THU SAT MON WED FRI SUN TUE THU SAT MON
25 27 29 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
NOV
DEC
2003

Figure 4

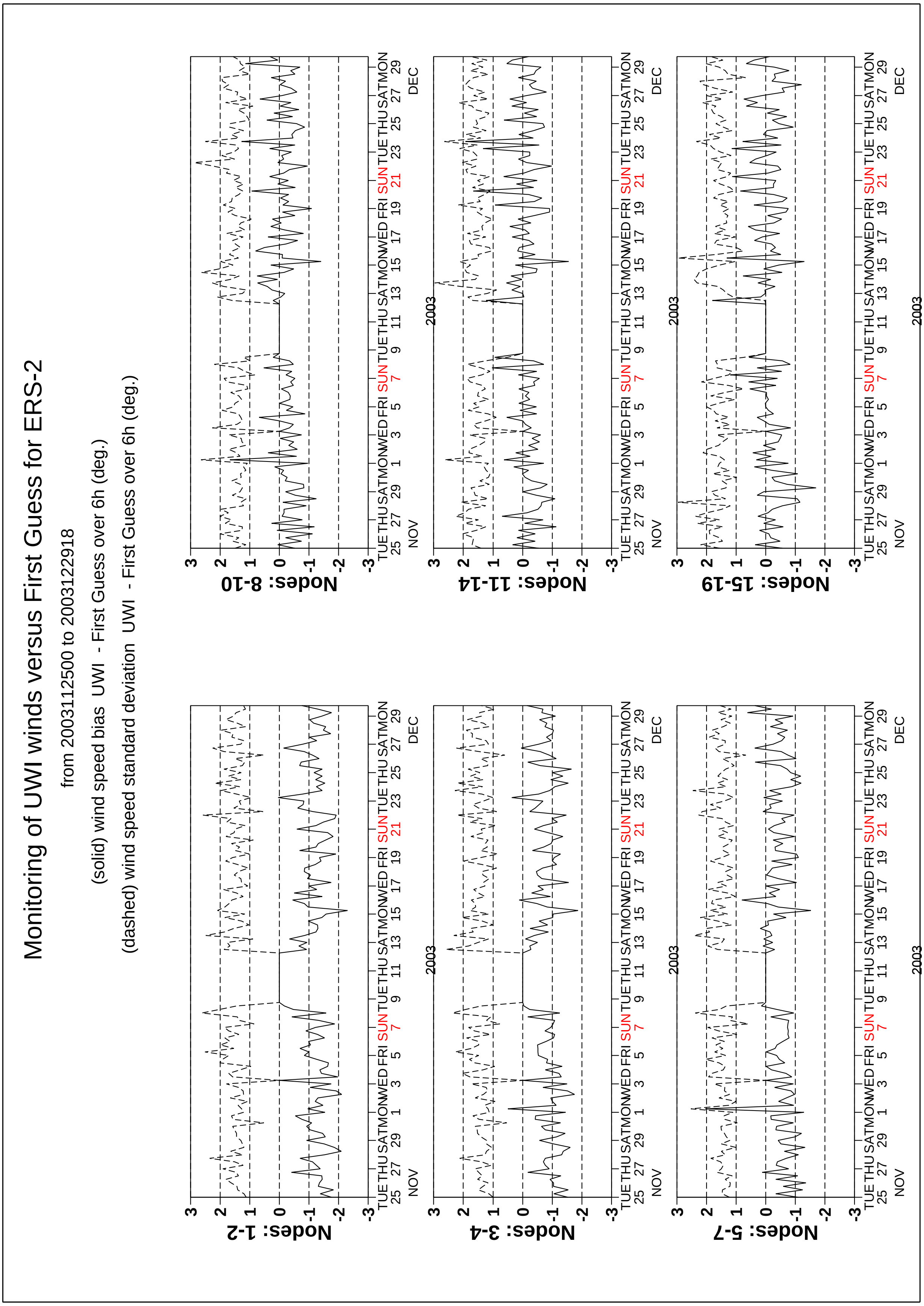

Monitoring of UWI winds versus First Guess for ERS-2
from 2003112500 to 2003122918
(solid) wind speed bias UWI - First Guess over 6h (deg.)
(dashed) wind speed standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
NOV
DEC
2003

Figure 5

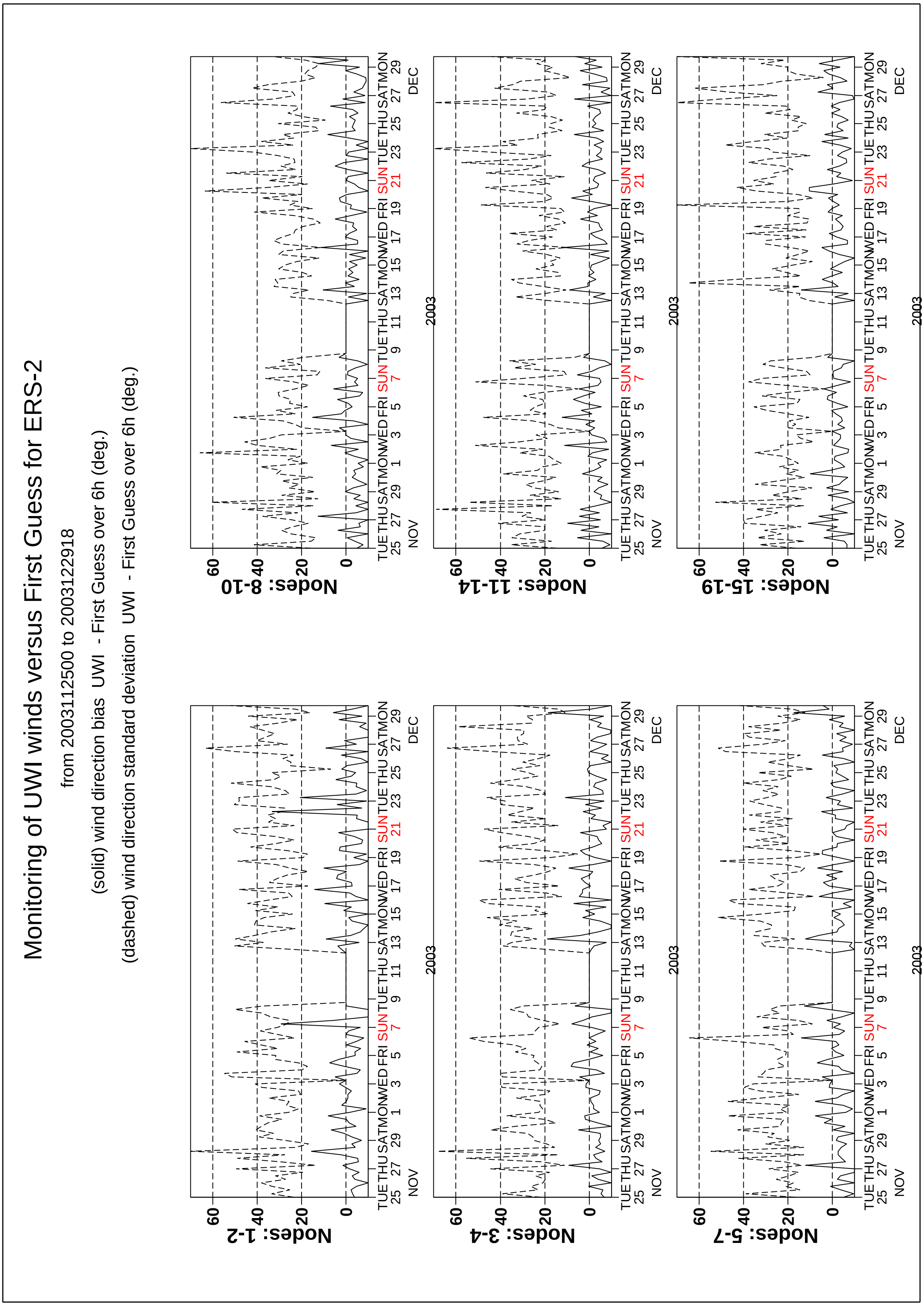

Monitoring of UWI winds versus First Guess for ERS-2
from 2003112500 to 2003122918
(solid) wind direction bias UWI - First Guess over 6h (deg.)
(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
NOV
DEC
2003

Figure 6

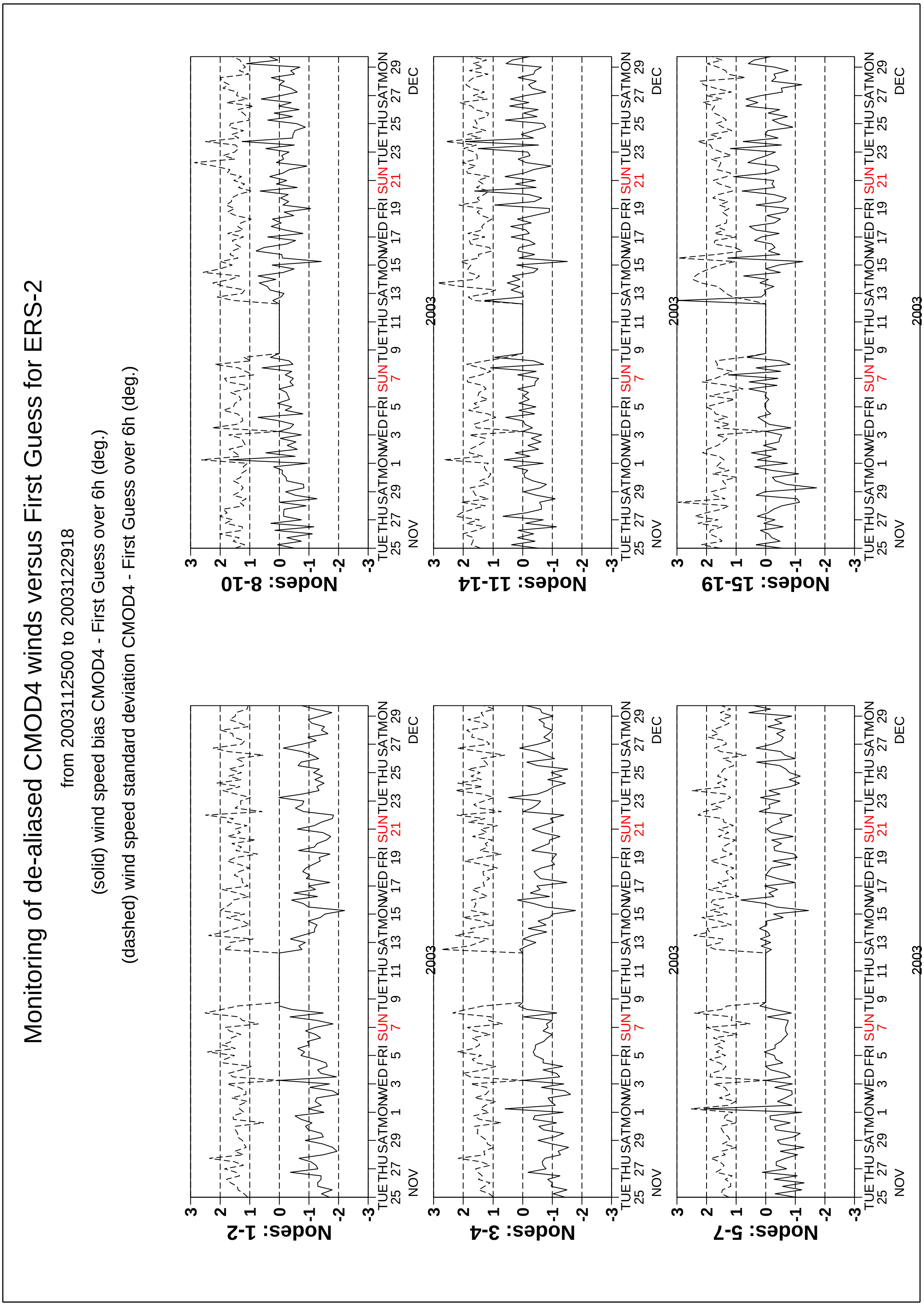
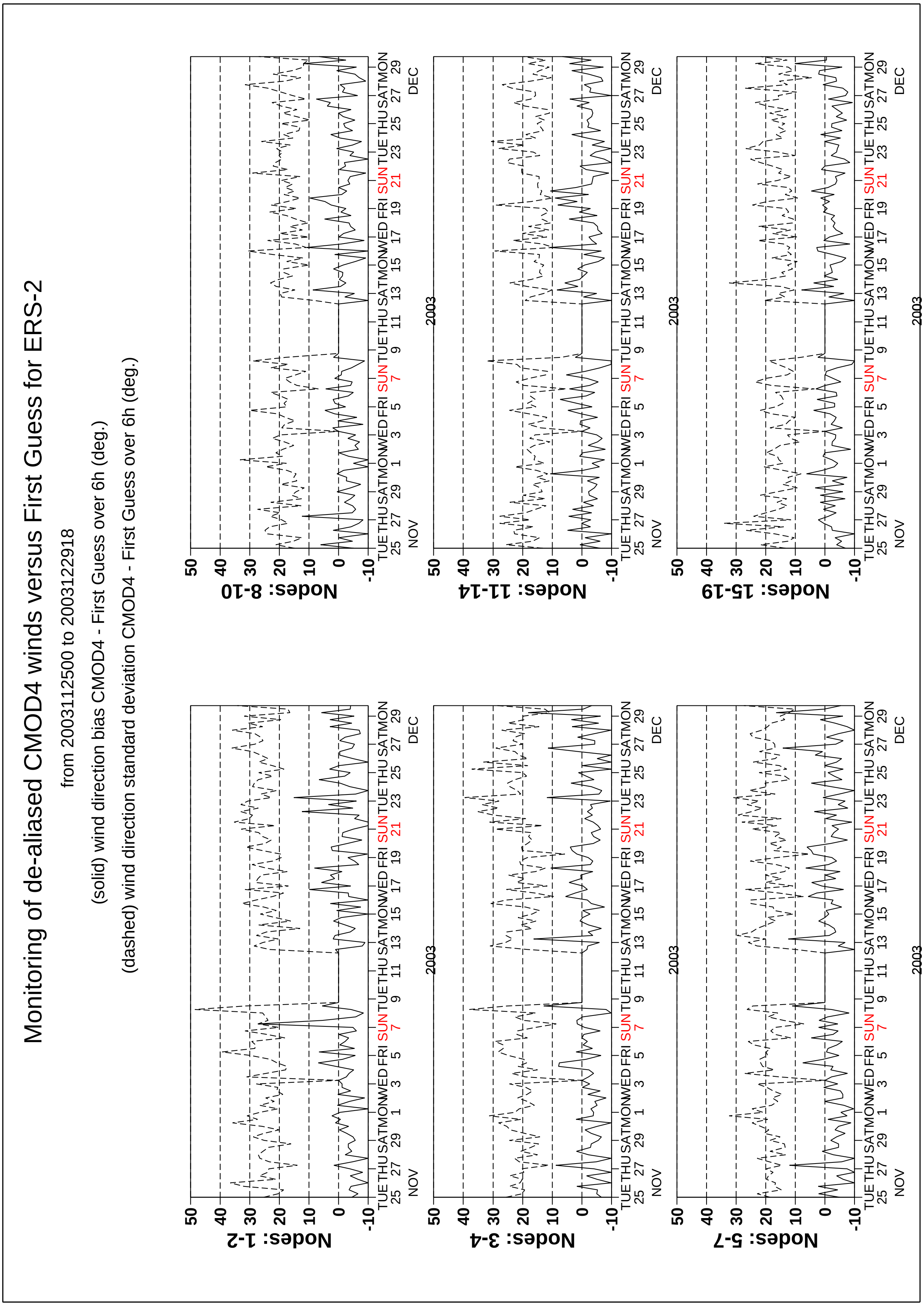

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003112500 to 2003122918
(solid) wind speed bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind speed standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
NOV
DEC
2003

Figure 7



Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003112500 to 2003122918
(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
NOV
DEC
2003

Figure 8

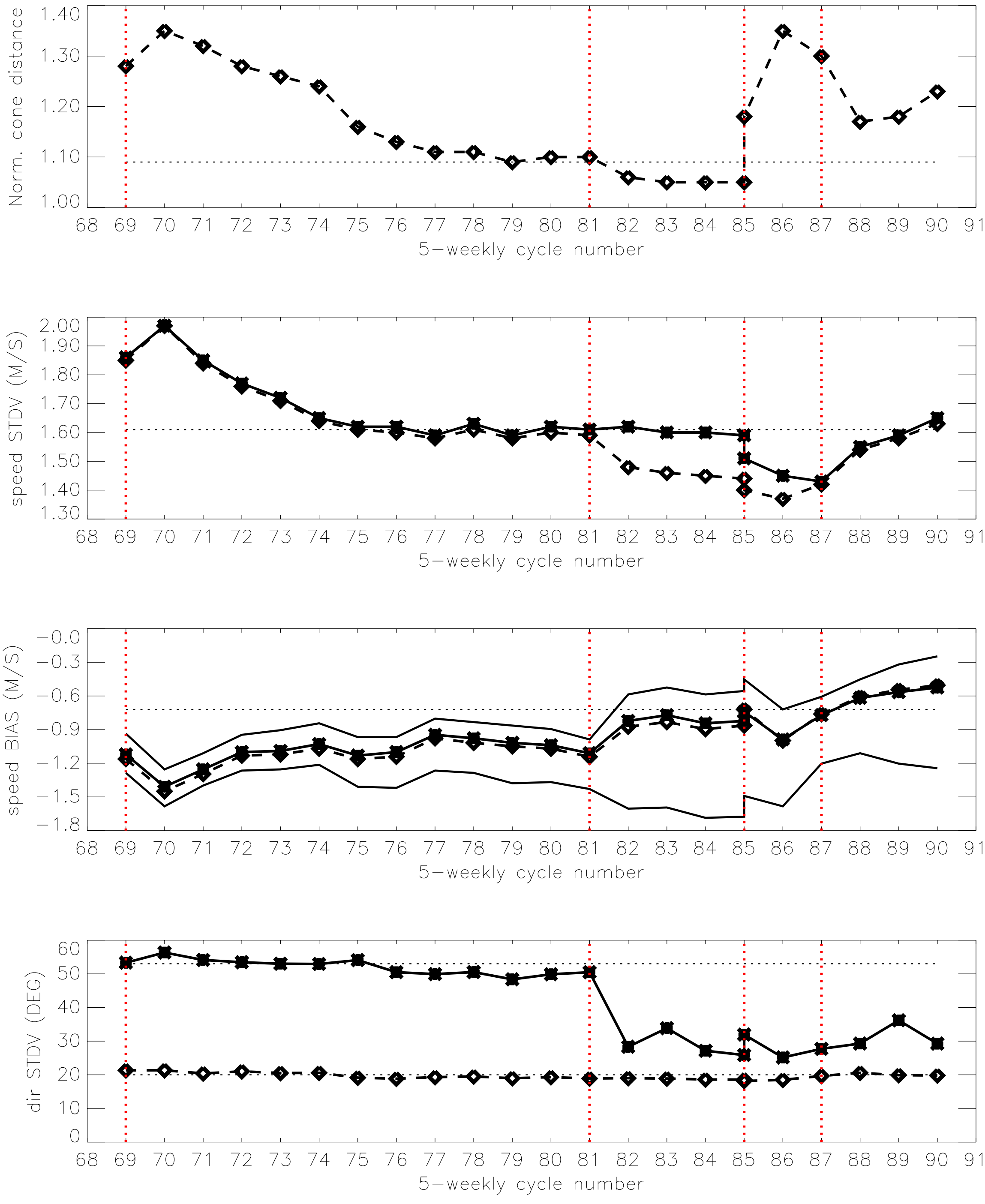
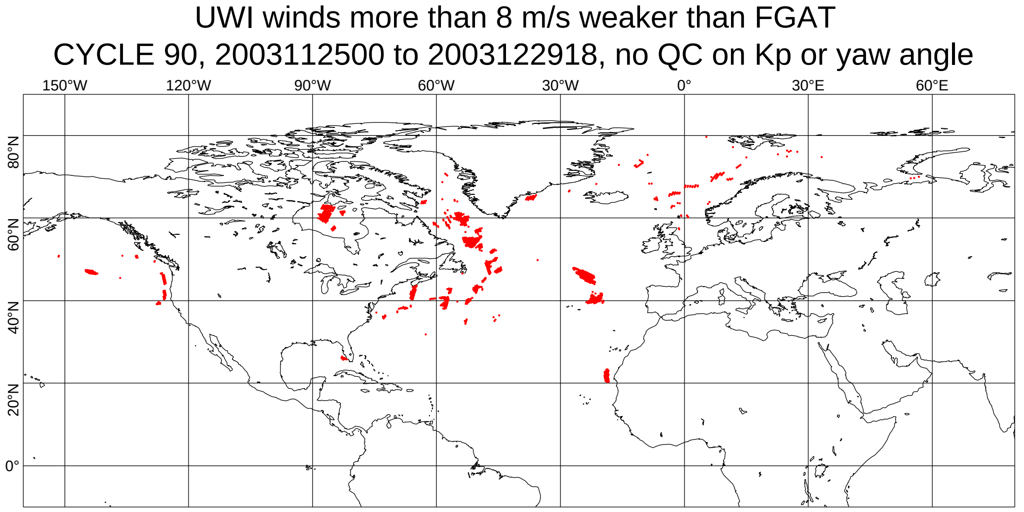

Norm. cone distance
5−weekly cycle number
speed STDV (M/S)
5−weekly cycle number
speed BIAS (M/S)
5−weekly cycle number
dir STDV (DEG)
5−weekly cycle number

Figure 9


UWI winds more than 8 m/s weaker than FGAT
CYCLE 90, 2003112500 to 2003122918, no QC on Kp or yaw angle
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
80°N
60°N
40°N
20°N
0°

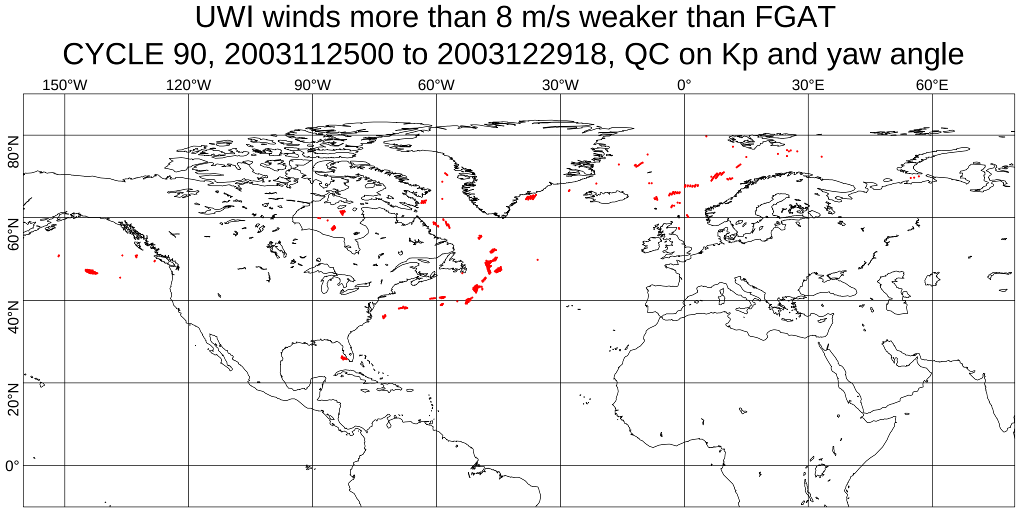

UWI winds more than 8 m/s weaker than FGAT
CYCLE 90, 2003112500 to 2003122918, QC on Kp and yaw angle
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
80°N
60°N
40°N
20°N
0°

Figure 10

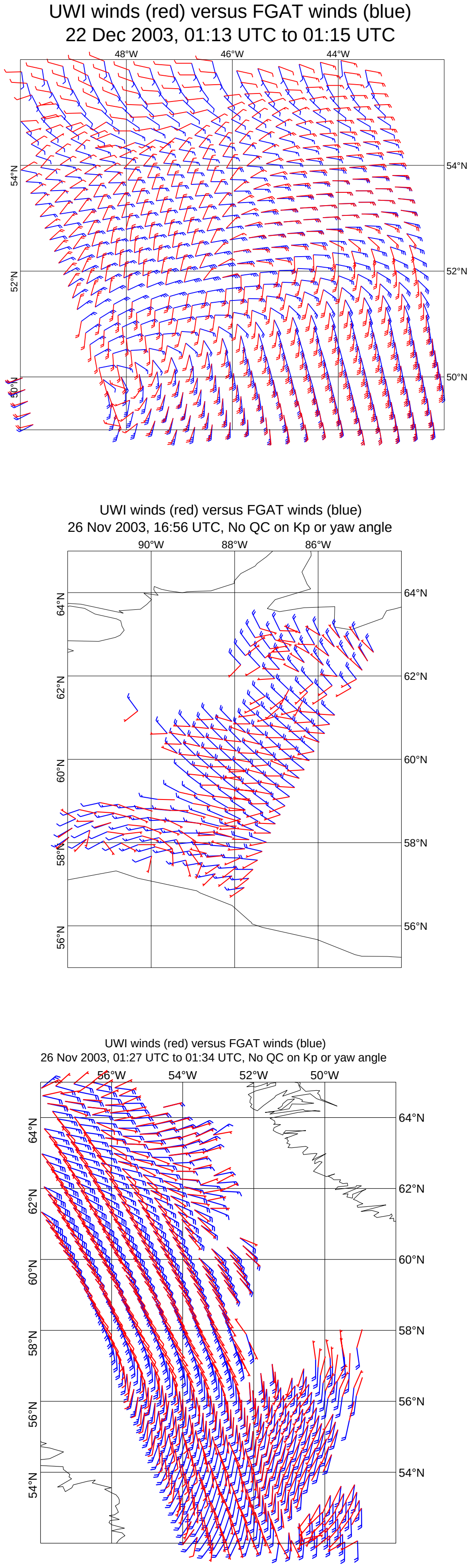

UWI winds (red) versus FGAT winds (blue)
22 Dec 2003, 01:13 UTC to 01:15 UTC
48°W
46°W
44°W
54°N
52°N
50°N
UWI winds (red) versus FGAT winds (blue)
26 Nov 2003, 16:56 UTC, No QC on Kp or yaw angle
90°W
88°W
86°W
64°N
62°N
60°N
58°N
56°N
UWI winds (red) versus FGAT winds (blue)
26 Nov 2003, 01:27 UTC to 01:34 UTC, No QC on Kp or yaw angle
56°W
54°W
52°W
50°W
64°N
62°N
60°N
58°N
56°N
54°N

Figure 11

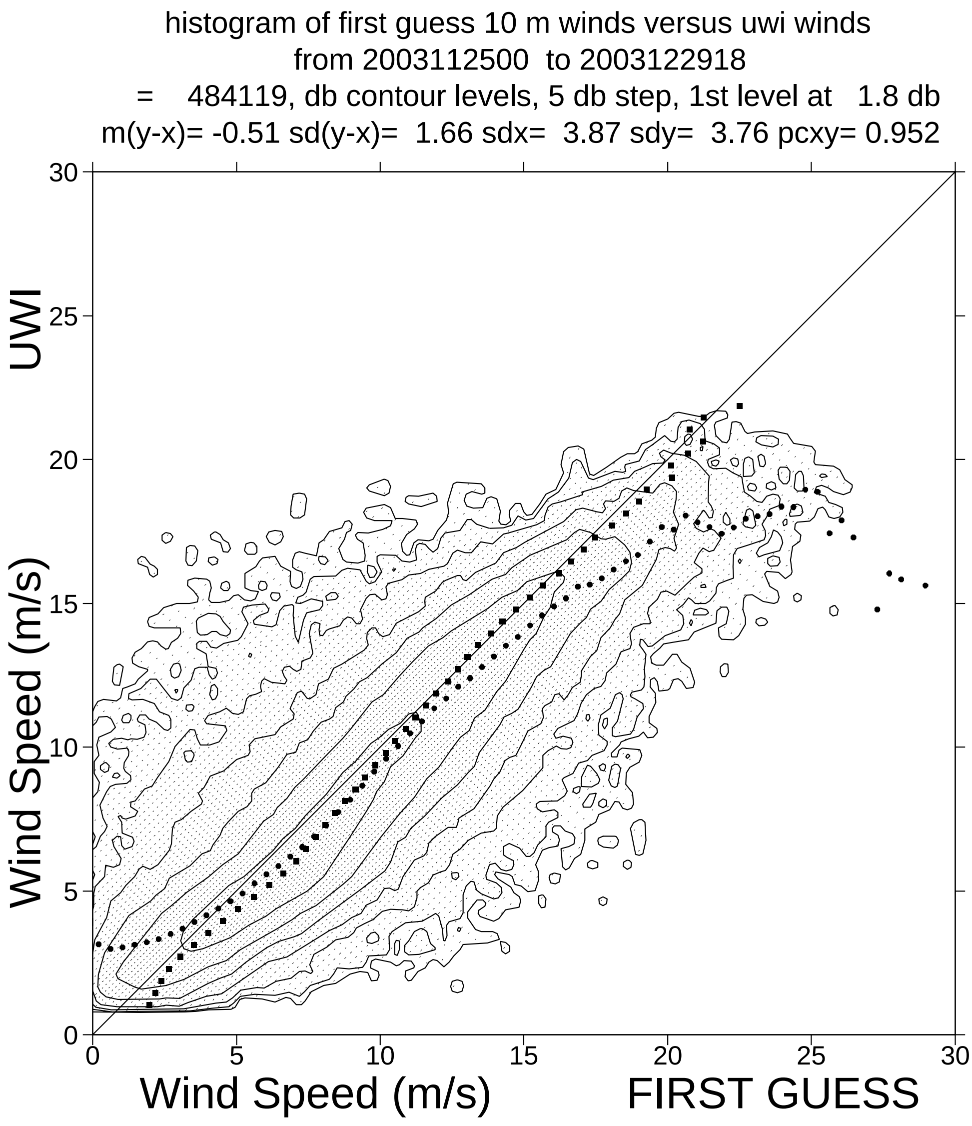

histogram of first guess 10 m winds versus uwi winds
from 2003112500 to 2003122918
= 484119, db contour levels, 5 db step, 1st level at 1.8 db
m(y-x)= -0.51 sd(y-x)= 1.66 sdx= 3.87 sdy= 3.76 pcxy= 0.952
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 12

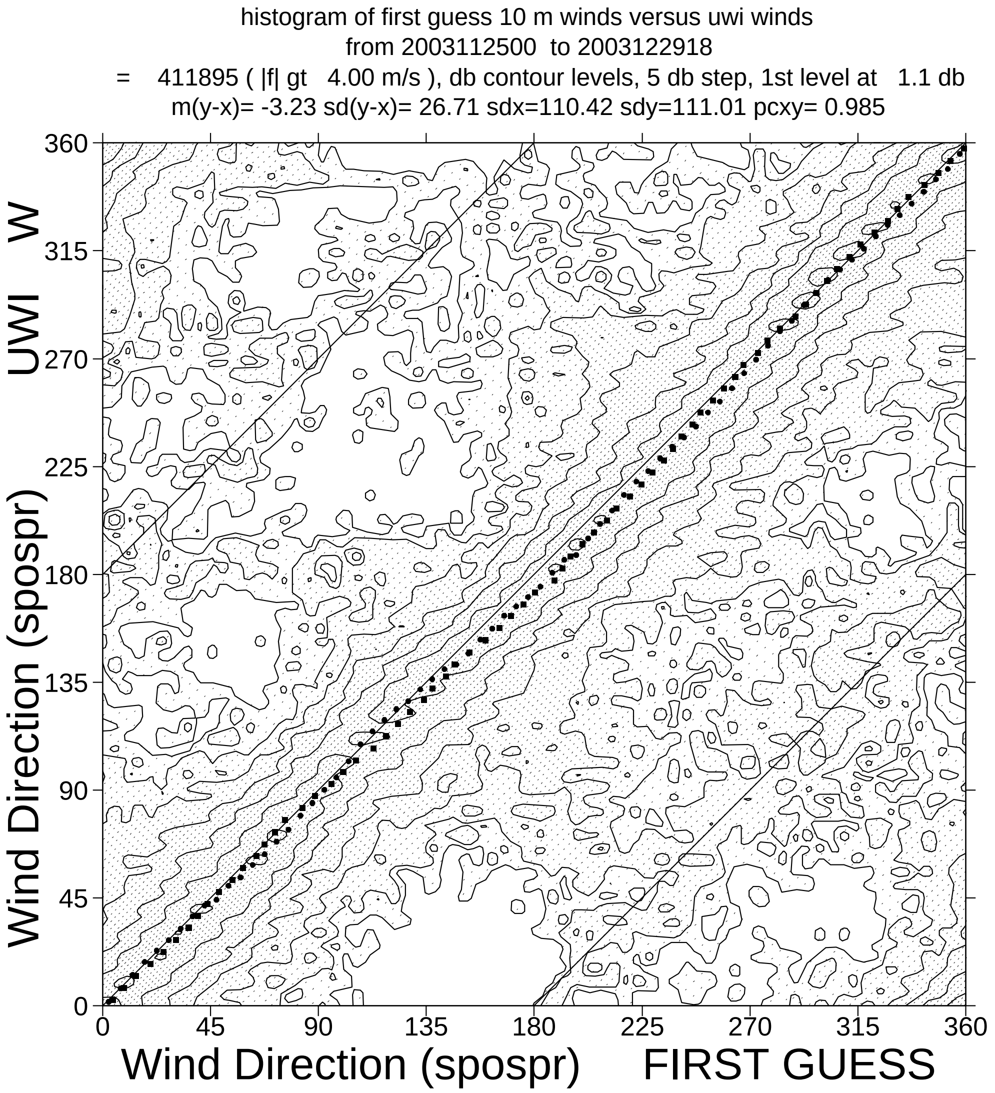
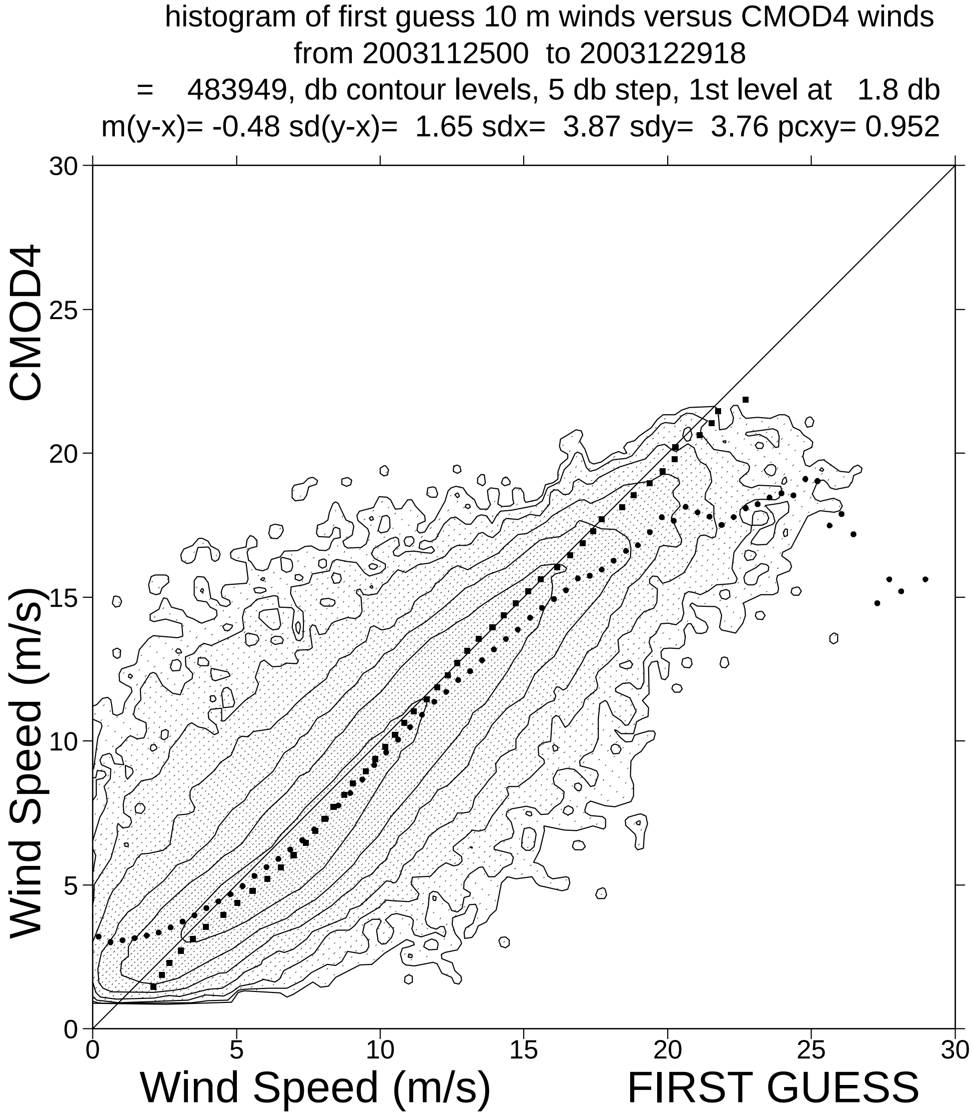

histogram of first guess 10 m winds versus uwi winds
from 2003112500 to 2003122918
= 411895 (|f| gt 4.00 m/s), db contour levels, 5 db step, 1st level at 1.1 db
m(y-x)= -3.23 sd(y-x)= 26.71 sdx=110.42 sdy=111.01 pcxy= 0.985
Wind Direction (spospr) UWI W
Wind Direction (spospr) FIRST GUESS
0
45
90
135
180
225
270
315
360

Figure 13



histogram of first guess 10 m winds versus CMOD4 winds
from 2003112500 to 2003122918
= 483949, db contour levels, 5 db step, 1st level at 1.8 db
m(y-x)= -0.48 sd(y-x)= 1.65 sdx= 3.87 sdy= 3.76 pcxy= 0.952
CMOD4
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 14

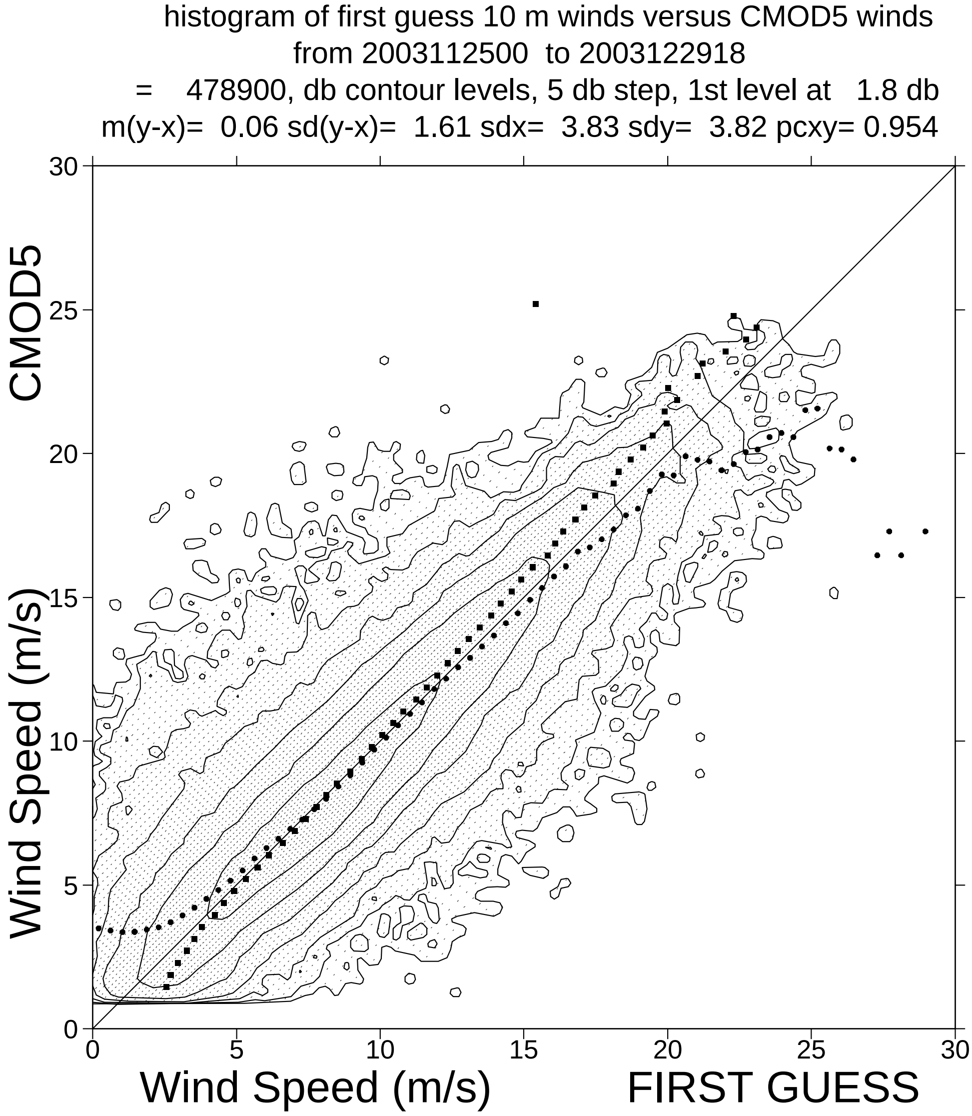

histogram of first guess 10 m winds versus CMOD5 winds
from 2003112500 to 2003122918
= 478900, db contour levels, 5 db step, 1st level at 1.8 db
m(y-x)= 0.06 sd(y-x)= 1.61 sdx= 3.83 sdy= 3.82 pcxy= 0.954
CMOD5
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 15