Monitoring statistics of the ERS-2 scatterometer for ESA

cycle 88

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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.

The quality of the new UWI product was monitored at ECMWF for cycle 88. 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 scatterometer data was not used in the 4D-Var data assimilation system at ECMWF. However, it is being processed passively, with the aim that it will become active within the next few months.

During cycle 88, data was received between 21:01 UTC 15 September and 19:46 UTC 20 October 2003. There were no data gaps within this 5-weeks period, although for about one-third of the 6-hourly batches at 6 UTC, much lower (up to 10%) than usual volumes were received.

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 up to 3.0 degrees. These peaks correspond well with the combined k_p and yaw attitude error flag. No clear signals for enhanced solar activity were observed.

Compared to cycle 87, the agreement with ECMWF first-guess (FGAT) fields was somewhat worse. Scatter has mainly increased for moderate winds. Part of such collocations seem to be concentrated in isolated events, in which both UWI and ECMWF winds look meteorologicaly sensible. These include the coverage of hurricanes Isabel and Kate. For other cases it seems that the UWI winds are of reduced quality. The relative bias levels of UWI winds compared to FGAT fields has become less negative. This is consistent with an observed trend towards less negative bias levels in backscatter space.

Compared to nominal data in 2000, both wind and backscatter bias levels are somewhat more optimal. Internode and interbeam dependent trends were found to be very similar to the old situation. Standard deviations of wind speed, are comparable to those for 2000, which is a step back compared to cycle 87 and before.

It was observed that for the new ESACA processor, the land-sea mask is too detailed. As a result, vector cells close to land and above many lakes are now flagged as sea, but are in fact land contaminated. This leads to far too strong UWI winds, as a comparison to FGAT winds easily shows.

The ECMWF assimilation system was changed on 7 October 2003. AIRS data (from AQUA), AMSUB (from NOAA16 and 17), MET5 radiances, GOES9 and GOES12 radiances, GOES12 atmospheric motion vectors, and AMSUA on AQUA were introduced in the assimilation cycle. The impact on surface winds (confirmed by time series of QuikSCAT data) is expected to be limited.

2 ERS-2 statistics from 16 September to 20 October 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 1.

Compared to cycle 87, bias levels have become less negative. For descending tracks there has been a rather uniform adjustment of 0.2 dB, while for the ascending beams the negative biases have been reduced most effectively at high incidence angles (0.3 dB; 0.1 dB in near range).

The situation is now even 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. Internode differences are smaller than for the nominal period. Bias levels are in between -0.25 and -0.6 dB.

The data volume of ascending and descending tracks are similar again.

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. 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. For most cases in which this asymmetry exceeds 2.2 degrees (corresponding to a yaw error of 2 degrees), the flag is set. However, for some cases of large negative asymmetry (e.g., 15 UTC 09 October 2003) the flag is not set. However, such peaks are close to the threshold value.

The amplitude of peaks is similar to that observed during cycle 87.

2.3 Distance to cone history

The distance to the cone history is shown in Figure 3. Many peaks, e.g. for 06 UTC 27 September 2003 and 06 UTC 05 October 2003, are due to low data volumes. In general the lower data volumes that were encountered since the failure of the LBR tape recorders in June 2003, make the histograms noisier and, therefore, more difficult to analyze. The peak at 06 UTC 15 October 2003 occurred for a rather high data volume. The wind quality (see Figures 4 to 7) was not lower than average during this 6-hourly period.

Compared to cycles 86 and 87, average levels have come down quite significantly. Although bias levels are still high (and noisy) at the lowest nodes, the average level was reduced from 1.30 (cycle 87) to 1.17. It now is on the same level as for the regional set of cycle 85 (see monitor report for cycle 86 for details).

2.4 UWI minus First-Guess wind history

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

Like it is the case for the history of the cone distance, the low data volumes make it difficult to separate instrument anomalies from numerical noise. Averages over periods longer than 6 hours may be necessary in future. The history plot shows many peaks. Some of them are related to a low volume (e.g., caused by the high fraction of rejections for 00 UTC 09 October 2003). Others are induced by extreme situations, such as the coverage of hurricanes Isabel (06 UTC and 18 UTC 17 September 2003) and Kate (00 UTC and 12 UTC 05 October 2003) and a peculiar case south of Greenland (00 UTC 10 October 2003). Other peaks, such on 18 UTC 17 October 2003, seem to arise from low-quality UWI winds (see Figures 9 and 10).

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 0.15 m/s. The average bias level is better than for the nominal data in 2000 (UWI: -0.60 m/s now, was -0.79 m/s for cycle 59).

Although bias levels have become more optimal, the standard deviation of CMOD4 winds compared to cycle 87 has increased substantially (1.54 m/s, was 1.42 m/s). Comparing Figure 12 with that of cycle 87 learns that this increase is mainly caused by moderate winds. For cycle 88 a number of extreme wind conditions were covered.

	cycle 87		cycle 88	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.43	1.42	1.55	1.54
node 1-2	1.47	1.45	1.61	1.59
node 3-4	1.44	1.43	1.55	1.54
node 5-7	1.40	1.40	1.50	1.49
node 8-10	1.42	1.41	1.49	1.49
node 11-14	1.40	1.39	1.53	1.53
node 15-19	1.39	1.39	1.52	1.52
speed BIAS	-0.75	-0.74	-0.60	-0.59
node 1-2	-1.17	-1.14	-1.08	-1.04
node 3-4	-0.96	-0.92	-0.83	-0.78
node 5-7	-0.77	-0.74	-0.61	-0.58
node 8-10	-0.62	-0.62	-0.47	-0.46
node 11-14	-0.59	-0.59	-0.45	-0.46
node 15-19	-0.60	-0.61	-0.44	-0.45
direction STDV	27.7	19.7	29.3	20.6
direction BIAS	-3.5	-3.6	-3.1	-3.1

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

This may for a part be the cause for the increase in scatter. Two examples are given in Figure 9, showing hurricanes Isabel and Kate. Both UWI winds and FGAT winds look realistic, however, it is most likely that the UWI winds are the most accurate ones. In other cases there is an indication that the UWI winds are of lower quality, as displayed in Figure 10.

Internode differences in bias levels have been further reduced (see third panel of figure 8). Their present values are better than the situation in 2000 (-1.08 m/s for node 1-2 to -0.44 for node 15-19; was -1.15 m/s respectively -0.62 for cycle 58). The internode trend is similar.

Like for cycle 87, the internode dependency of standard deviation is different from the situation in 2000 (top right panel of Figure 9 and middle-right panel of Figure 10 of cyclic report 87). Optimal results used to be achieved around node 5, and being worse in the far range. The situation is now more evenly distributed.

For cycle 88 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 lower than for cycle 88 (29.3 degrees, was 27.7 degrees, see also lower panel of Figure 8). The quality of the de-aliased CMOD4 wind direction is lower as well (20.6 degrees versus 19.7 degrees).

In the top (lower) panel of Figure 11 all locations are plotted for which UWI winds were more than 8 m/s weaker (stronger) than the FGAT winds. 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 11. However, the number of collocations has increased considerably. Note that in Figure 11 only winds were plotted that passed the QC check of the ECMWF land-sea mask. It appears that the UWI land flag is less strict and is not set for wind-vector cells that are close to land and above lakes. In the lower panel of Figure 12 those extra cells are for a three weeks period in cycle 88 indicated by red dots. The scatterplots of CMOD5 winds versus FGAT winds in the top panels, clearly show that such winds are land contaminated. At the moment, at ESRIN, the UWI land flagging algorithm is under review.

2.5 Scatterplots

Scatterplots of model 10 m first-guess winds versus ERS-2 winds are displayed in Figures 13 to 16. 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 trends described in the previous subsection.

The scatterplot of UWI wind speed versus FGAT (Figure 13) is very similar to that for (at ECMWF inverted) de-aliased CMOD4 winds (Figure 15). It confirms that the present inversion scheme of ESACA is working properly. The standard deviation for the CMOD4 winds is higher than for cycle 87 (1.56 m/s was 1.44 m/s). Especially for moderate winds the scatter has increased. The wind bias, however, has been reduced (-0.61 m/s, was -0.74 m/s).

The average bias of the UWI wind direction has become less negative (Figure 14, -2.4 degrees, was -3.6 degrees).

Winds derived on the basis of CMOD5 are displayed in Figure 16. Compared to cycle 87, the bias level has become less negative (-0.11 m/s, was -0.30 m/s). The quality of these winds is higher than that of the CMOD4 winds, especially for the extreme hurricane winds that were encountered during this cycle.

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. Red stars indicate the occurences for which the combined k_p-yaw flag was set.

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 (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 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 20 October 2003 (end cycle 88) for the UWI product (solid, star) and de-aliased winds based on CMOD4 (dashed, diamond). 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 9: Comparison between UWI (red) and FGAT (blue) winds for hurricanes ISABEL (top panel) and Kate (lower panel).

Figure 10: Comparison between UWI (red) and FGAT (blue) winds for a case south of Greenland (top panel) and west of California (lower panel).

Figure 11: Locations of data during cycle 88 for which UWI winds are more than 8 m/s weaker (top) respectively stronger (lower panel) than FGAT winds.

Figure 12: Two-dimensional histogram of first guess and CMOD5 winds for a three weeks period in cycle 88, based on the UWI land flag (top left) respectively based on the ECMWF land-sea mask (top right). The locations of data points being present in the top left panel but not in the top right panel are indicated by red dots in the lower panel.

Figure 13: Two-dimensional histogram of first guess and UWI wind speeds, for the data kept by the quality control, including the QC on k_p and QC based on the ECMWF land-sea mask. Circles denote the mean values in the y-direction, and squares those in the x-direction.

Figure 14: Same as Fig. 13, but for wind direction. Only wind speeds higher than 4m/s are taken into account.

Figure 15: Same as Fig. 13, but for de-aliased CMOD4 winds.

Figure 16: Same as Fig. 13, but for de-aliased CMOD5 winds.

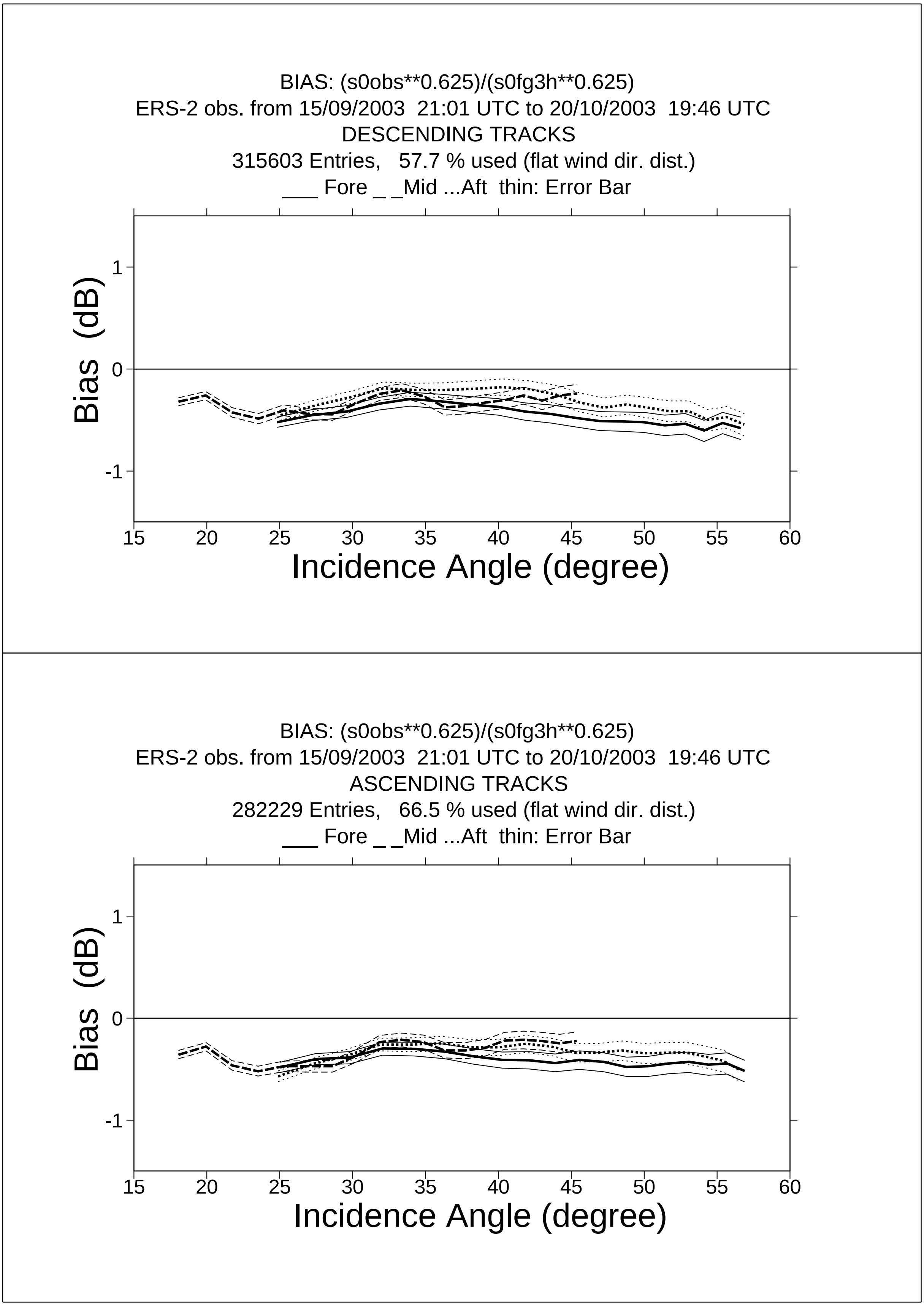

BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 15/09/2003 21:01 UTC to 20/10/2003 19:46 UTC
DESCENDING TRACKS
315603 Entries, 57.7 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)
BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 15/09/2003 21:01 UTC to 20/10/2003 19:46 UTC
ASCENDING TRACKS
282229 Entries, 66.5 % 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

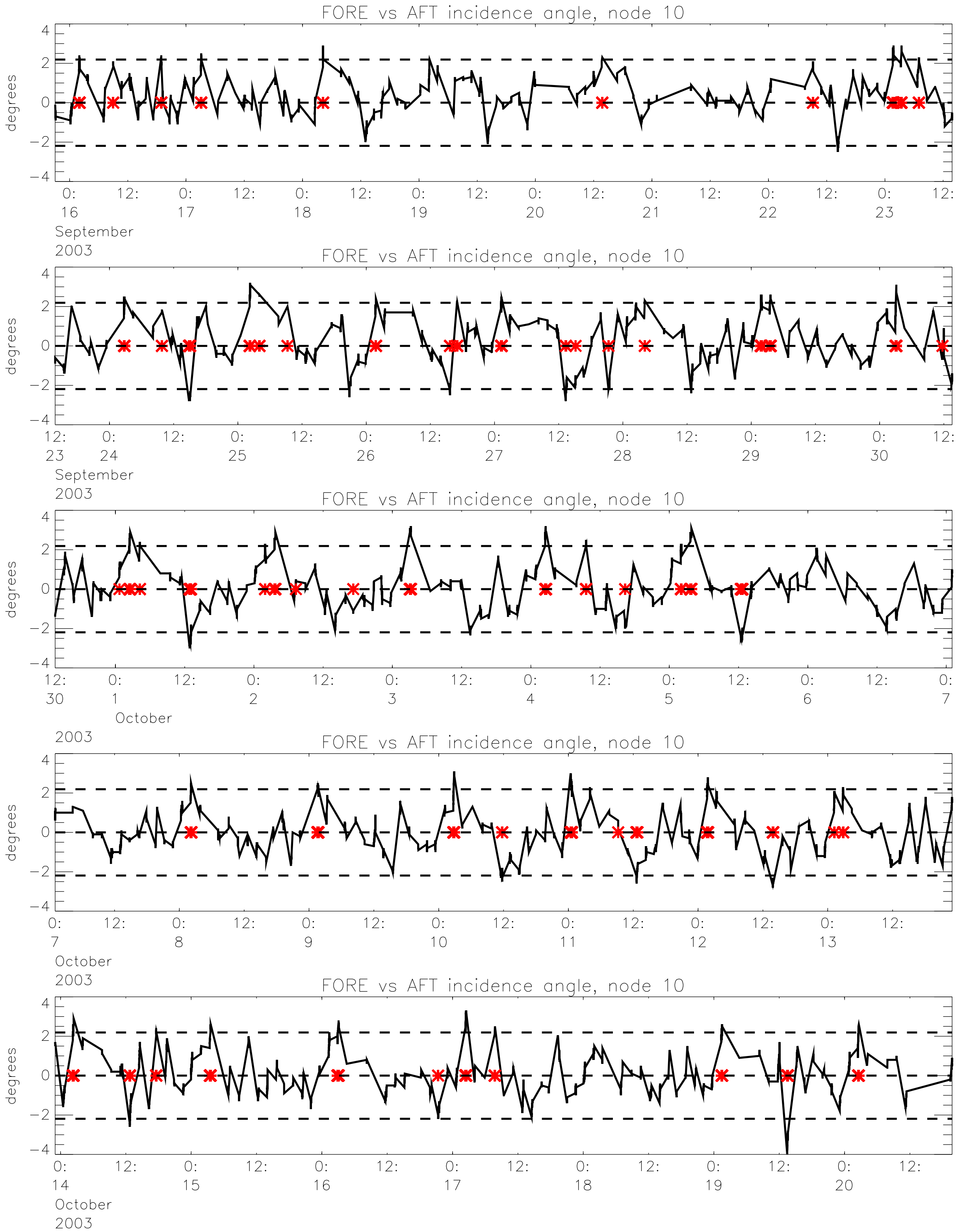

FORE vs AFT incidence angle, node 10
degrees
September
2003
FORE vs AFT incidence angle, node 10
September
2003
FORE vs AFT incidence angle, node 10
October
2003
FORE vs AFT incidence angle, node 10
October
2003
FORE vs AFT incidence angle, node 10
October
2003

Figure 2

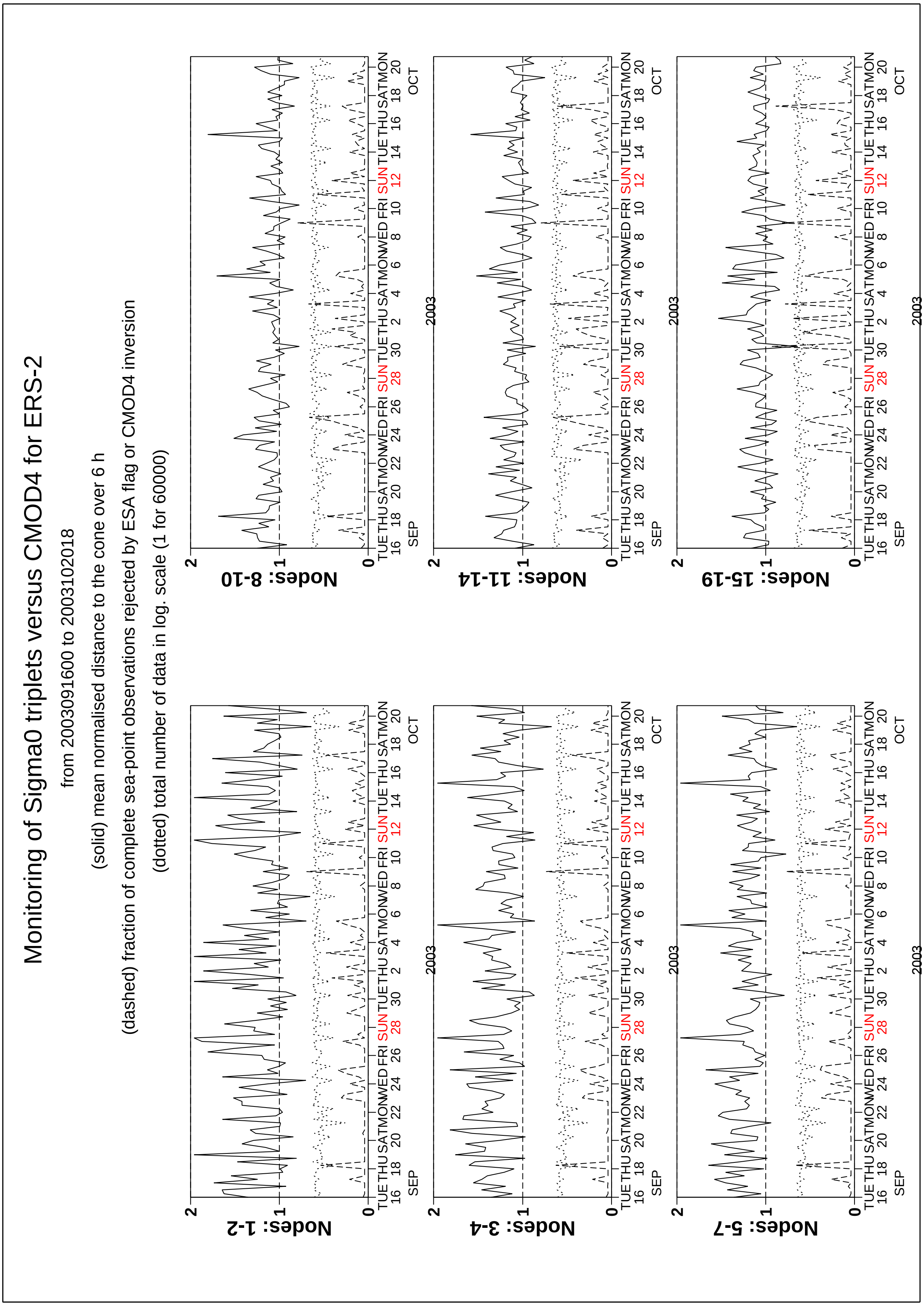

Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2003091600 to 2003102018
(solid) mean normalised distance to the cone over 6 h
(dashed) fraction of complete sea-point observations rejected by ESA flag or CMOD4 inversion
(dotted) total number of data in log. scale (1 for 60000)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
SEP
OCT
2003

Figure 3

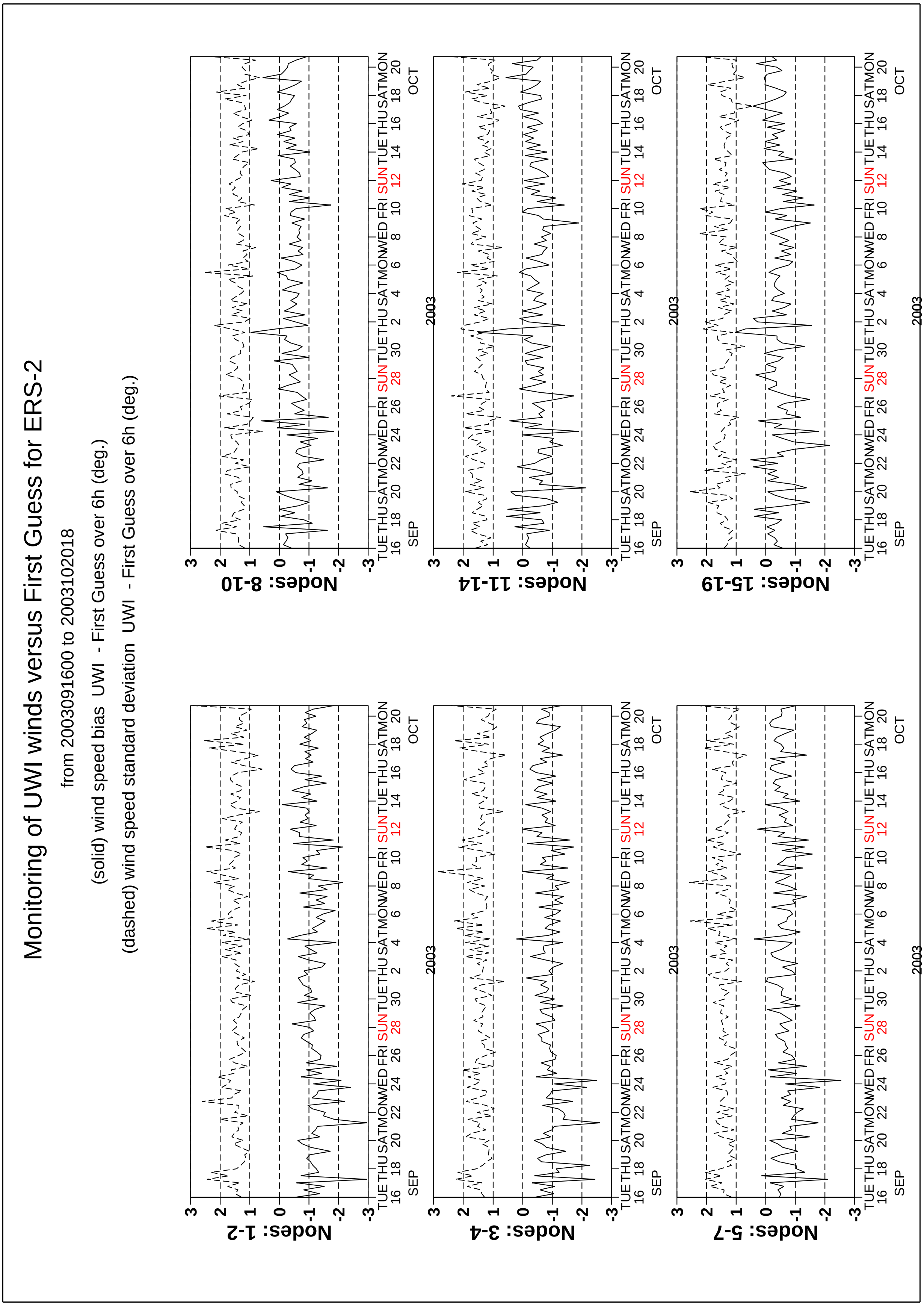

Monitoring of UWI winds versus First Guess for ERS-2
from 2003091600 to 2003102018
(solid) wind speed bias UWI - First Guess over 6h (deg.)
(dashed) wind speed standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
SEP
OCT
2003

Figure 4

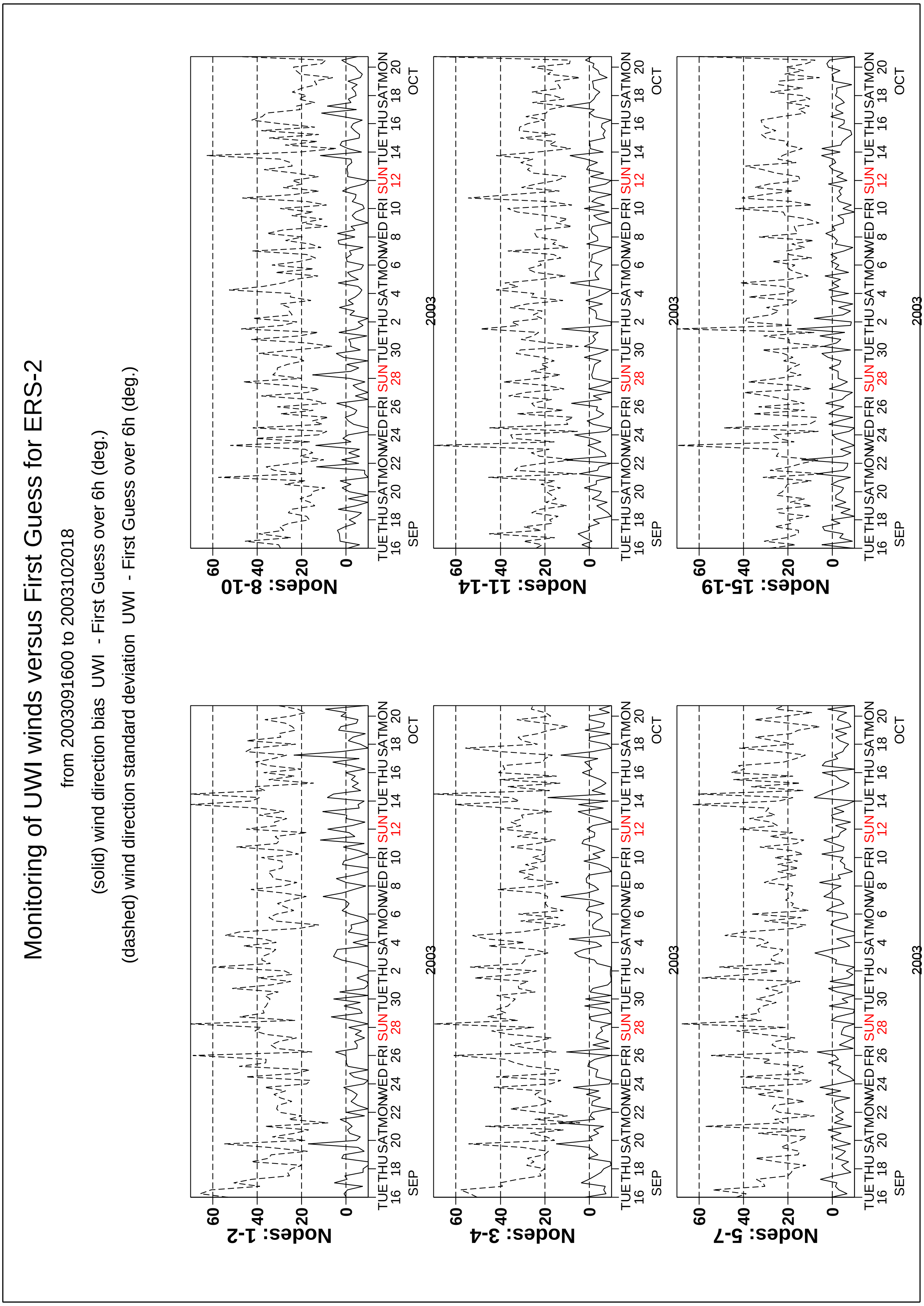
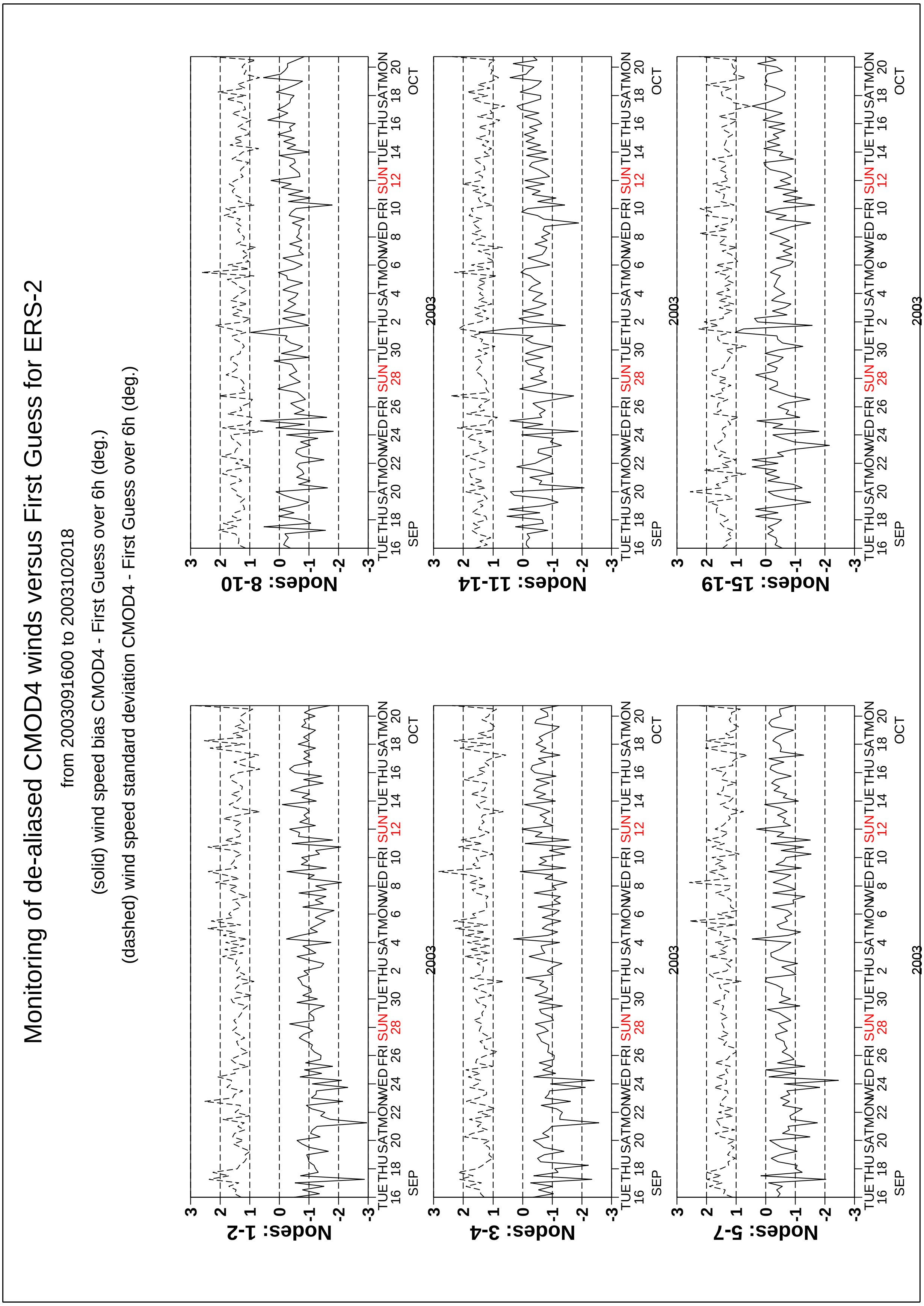

Monitoring of UWI winds versus First Guess for ERS-2
from 2003091600 to 2003102018
(solid) wind direction bias UWI - First Guess over 6h (deg.)
(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
SEP
OCT
2003

Figure 5



Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003091600 to 2003102018
(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
SEP
OCT
2003

Figure 6

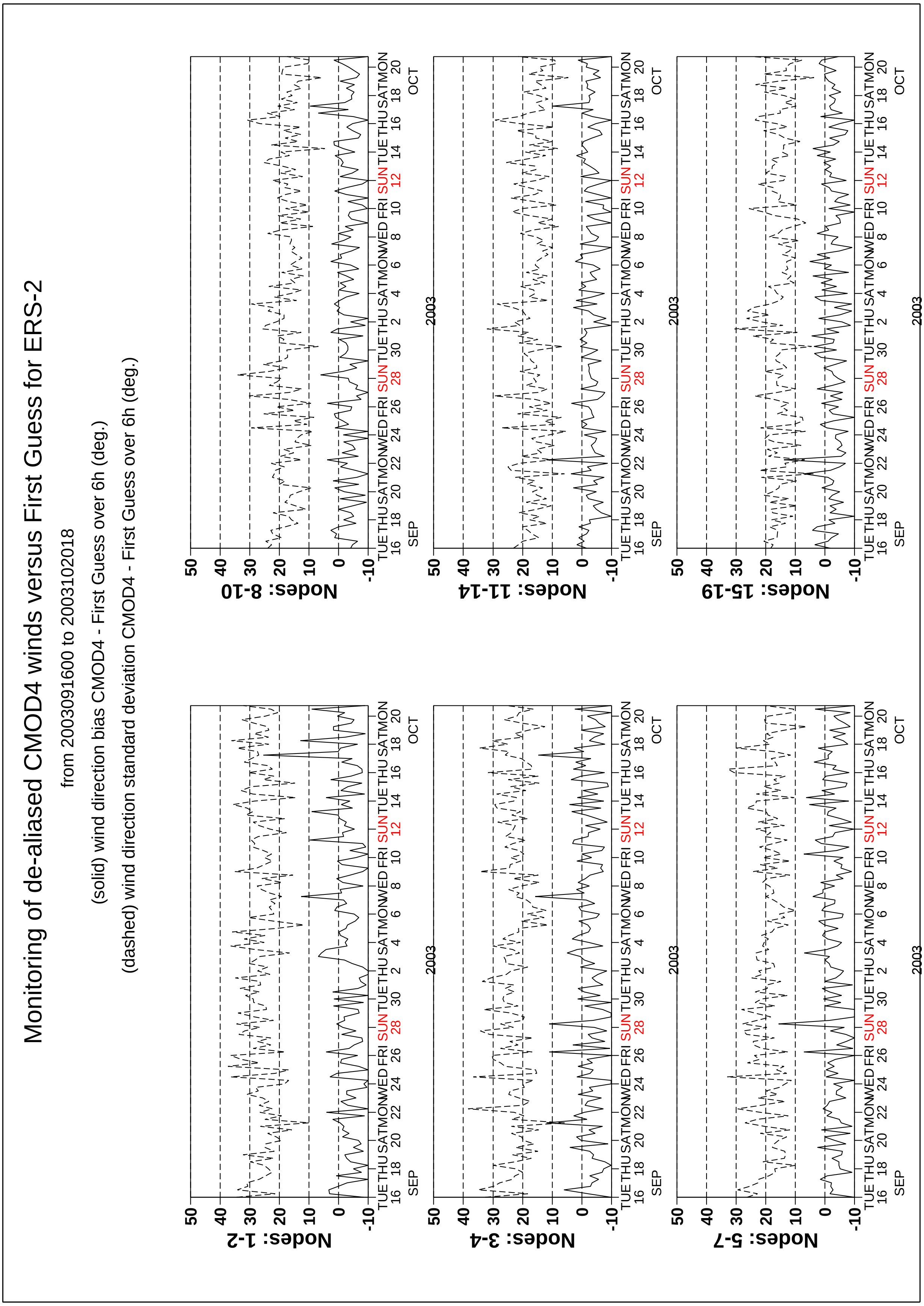

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2003091600 to 2003102018
(solid) wind direction bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind direction standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
SEP
OCT
2003

Figure 7

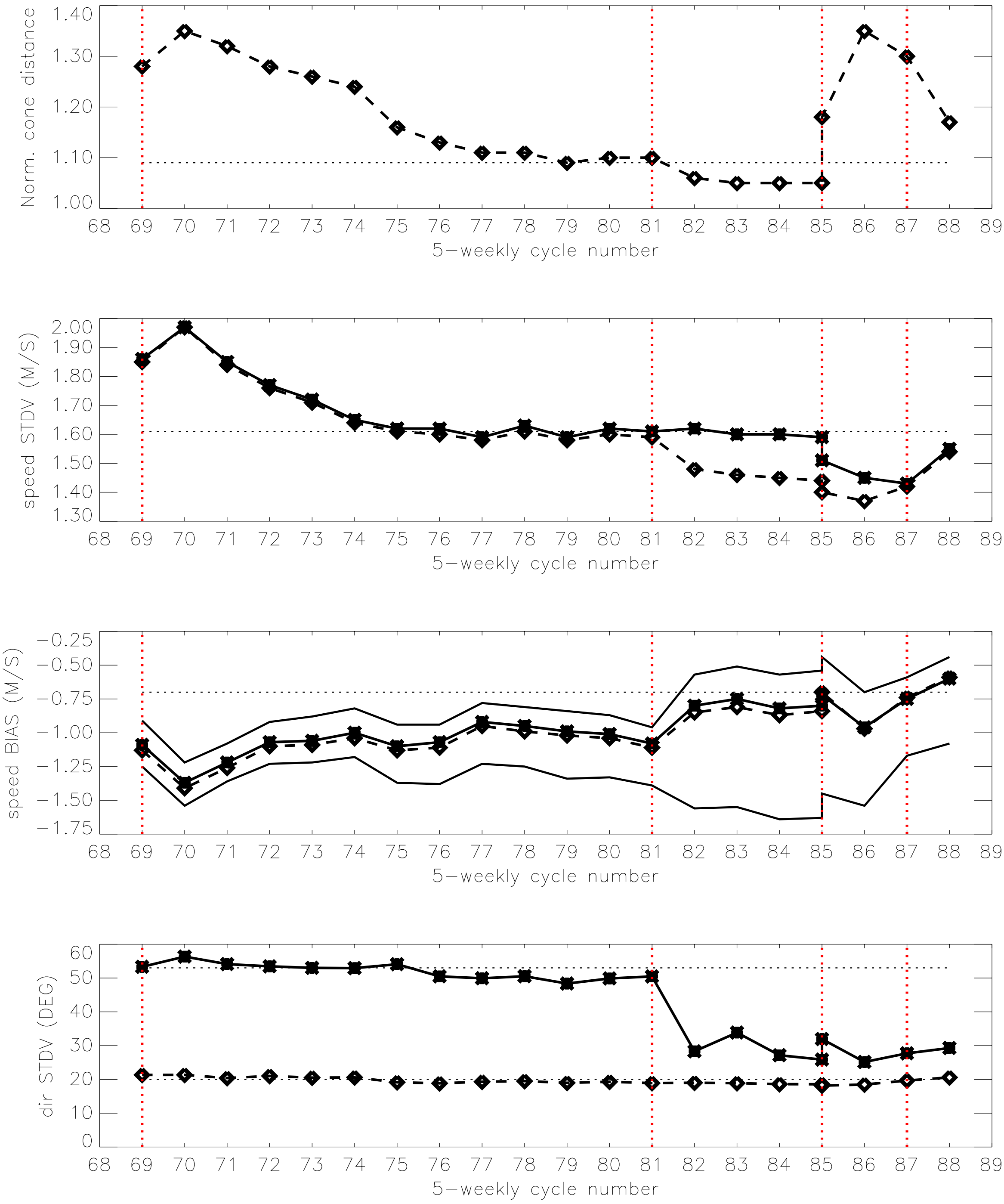

Norm. cone distance
5−weekly cycle number
speed STDV (M/S)
5−weekly cycle number
speed BIAS (M/S)
5−weekly cycle number
dir STDV (DEG)
5−weekly cycle number

Figure 8

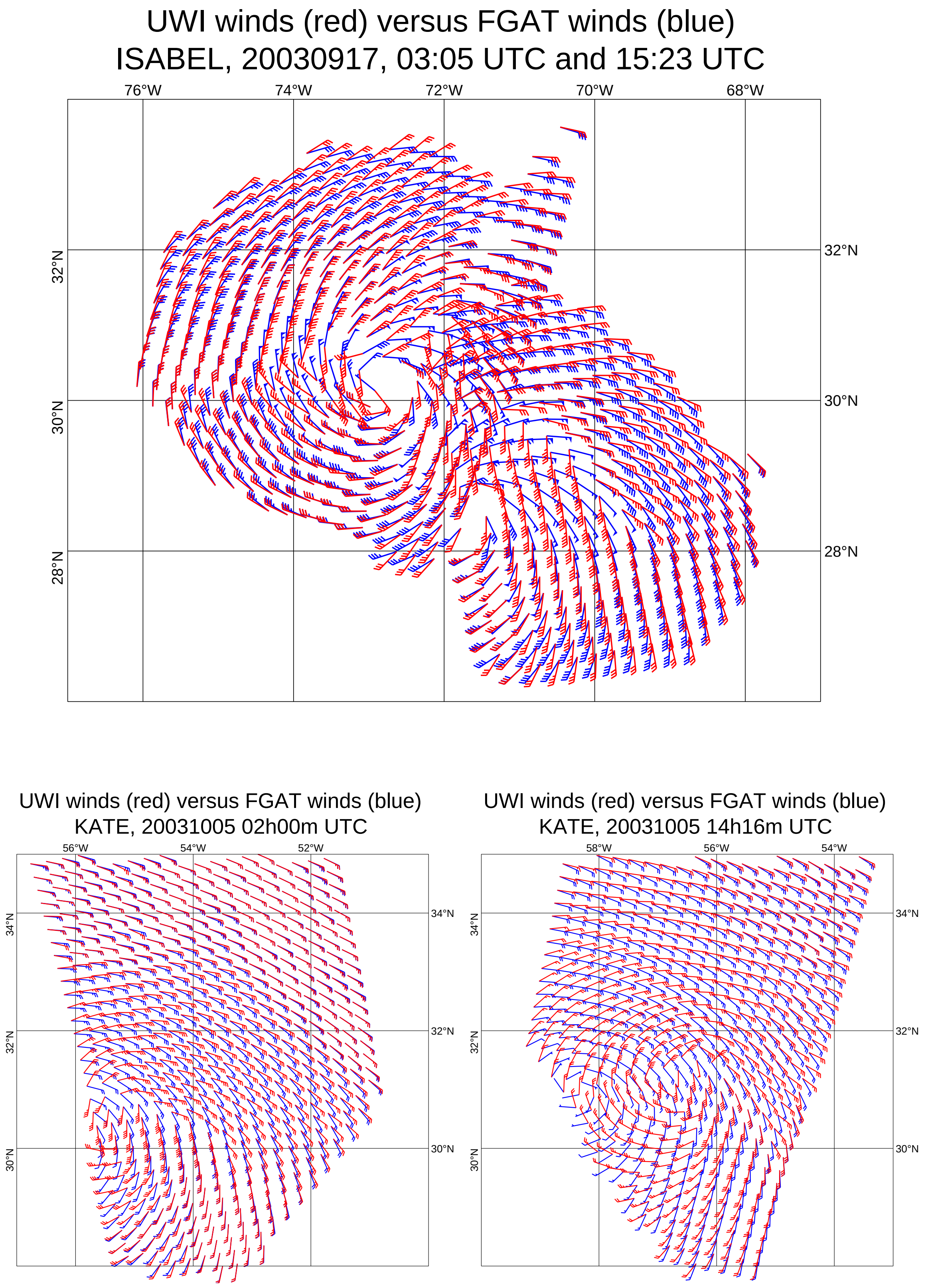
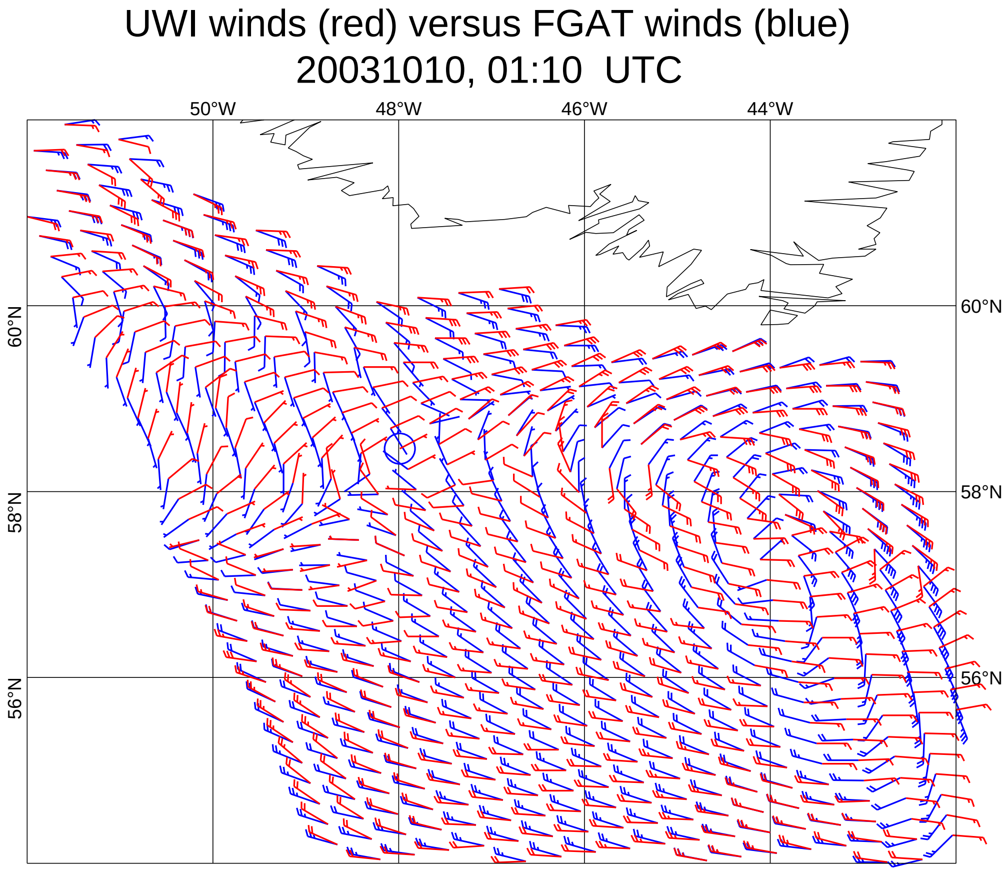

UWI winds (red) versus FGAT winds (blue)
ISABEL, 20030917, 03:05 UTC and 15:23 UTC
76°W
74°W
72°W
70°W
68°W
32°N
30°N
28°N
UWI winds (red) versus FGAT winds (blue)
KATE, 20031005 02h00m UTC
56°W
54°W
52°W
34°N
32°N
30°N
UWI winds (red) versus FGAT winds (blue)
KATE, 20031005 14h16m UTC
58°W
56°W
54°W
34°N
32°N
30°N

Figure 9


UWI winds (red) versus FGAT winds (blue)
20031010, 01:10 UTC
50°W
48°W
46°W
44°W
60°N
58°N
56°N

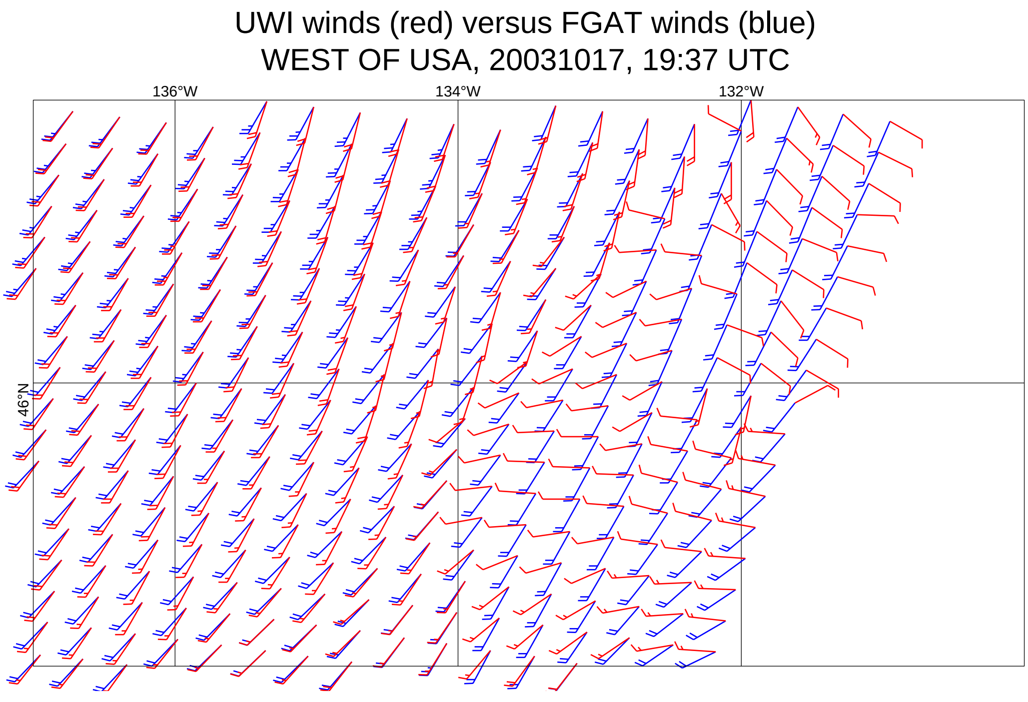
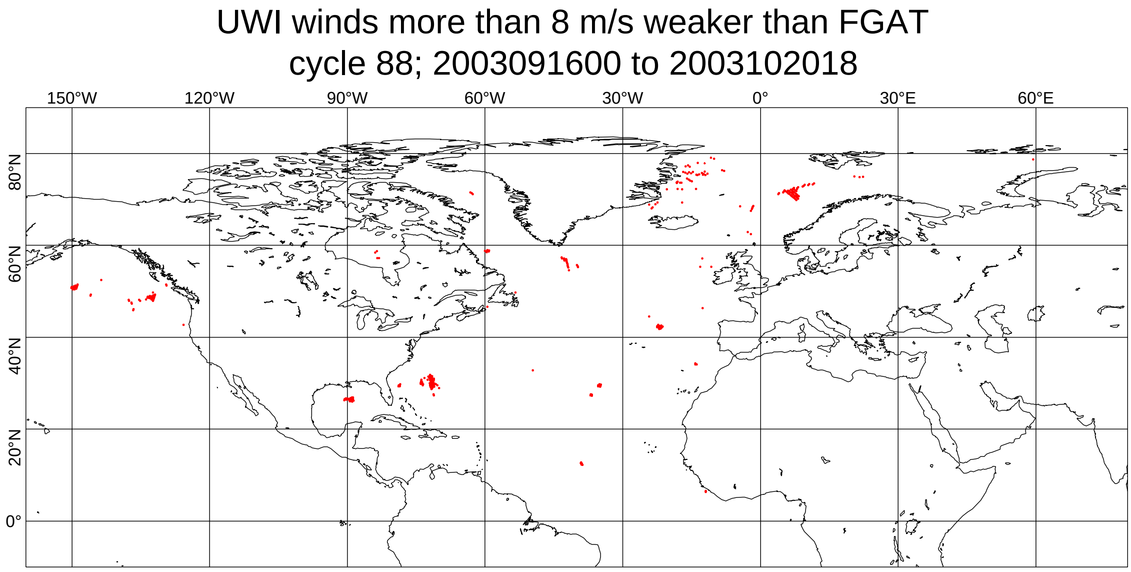

UWI winds (red) versus FGAT winds (blue)
WEST OF USA, 20031017, 19:37 UTC
136°W
134°W
132°W
46°N

Figure 10


UWI winds more than 8 m/s weaker than FGAT
cycle 88; 2003091600 to 2003102018
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
80°N
60°N
40°N
20°N
0°

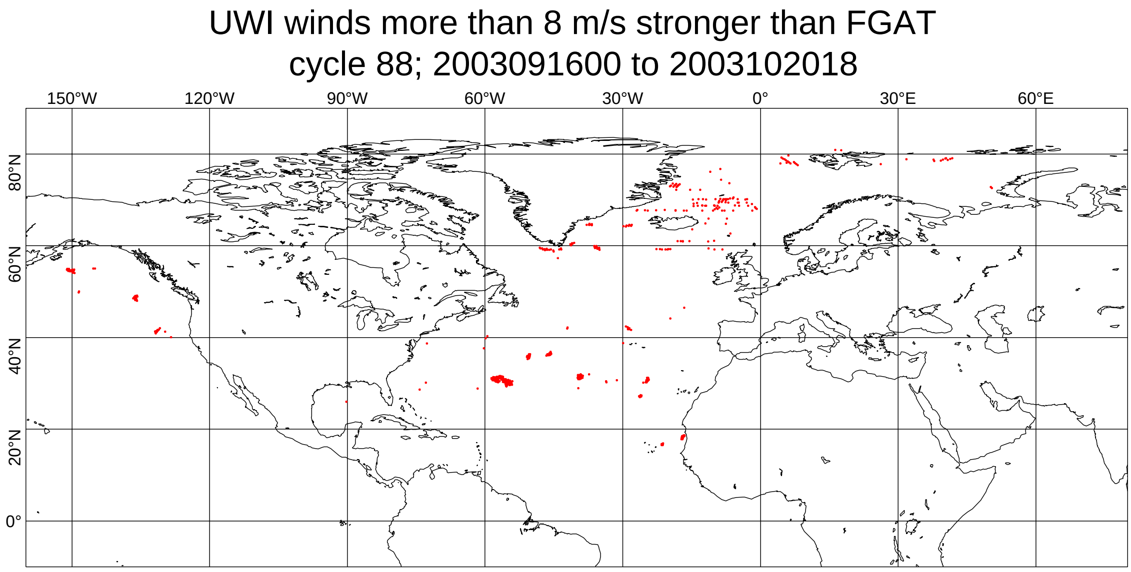
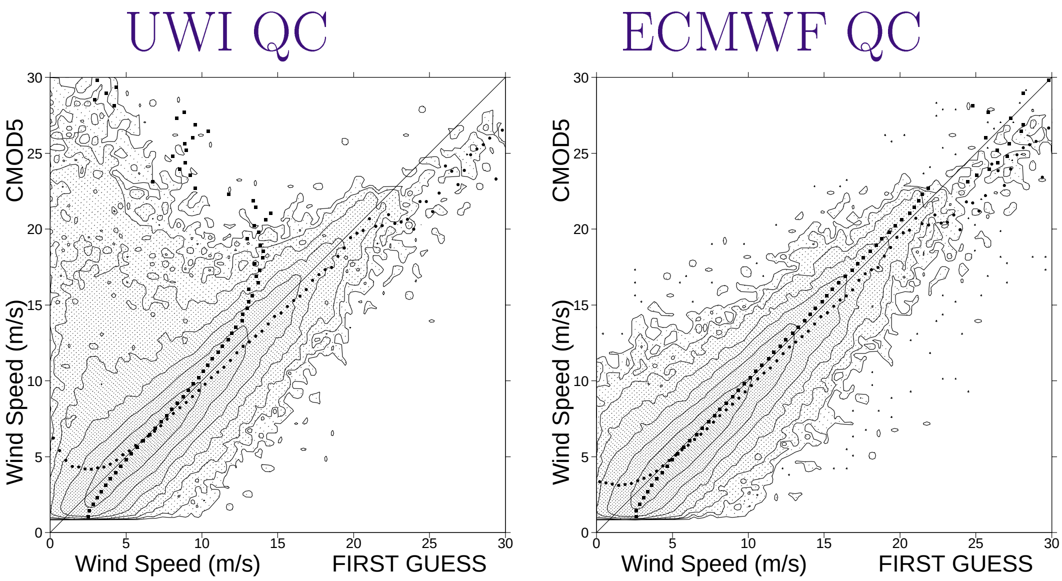

UWI winds more than 8 m/s stronger than FGAT
cycle 88; 2003091600 to 2003102018
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
80°N
60°N
40°N
20°N
0°

Figure 11


UWI QC
ECMWF QC
CMOD5
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS

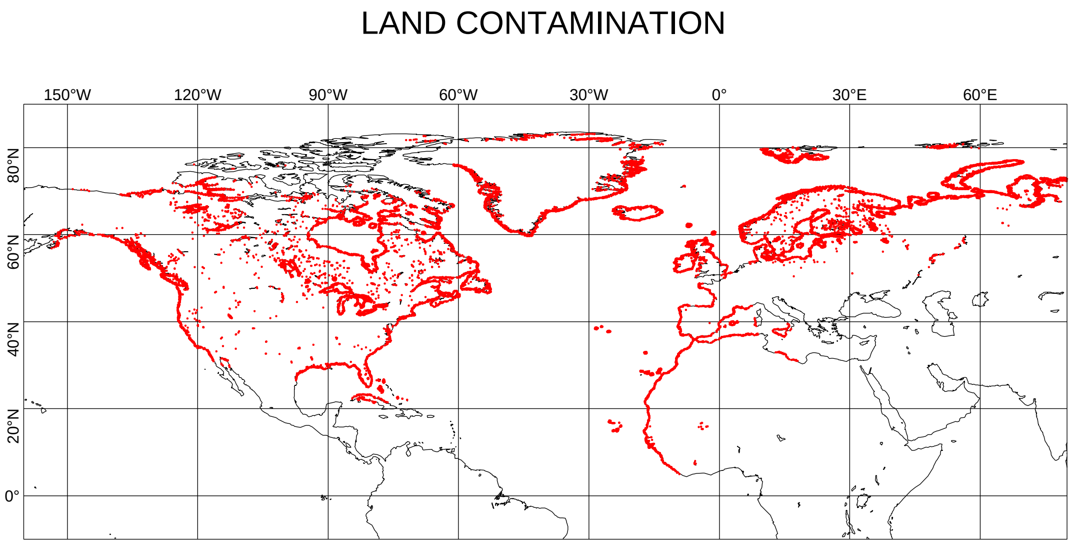
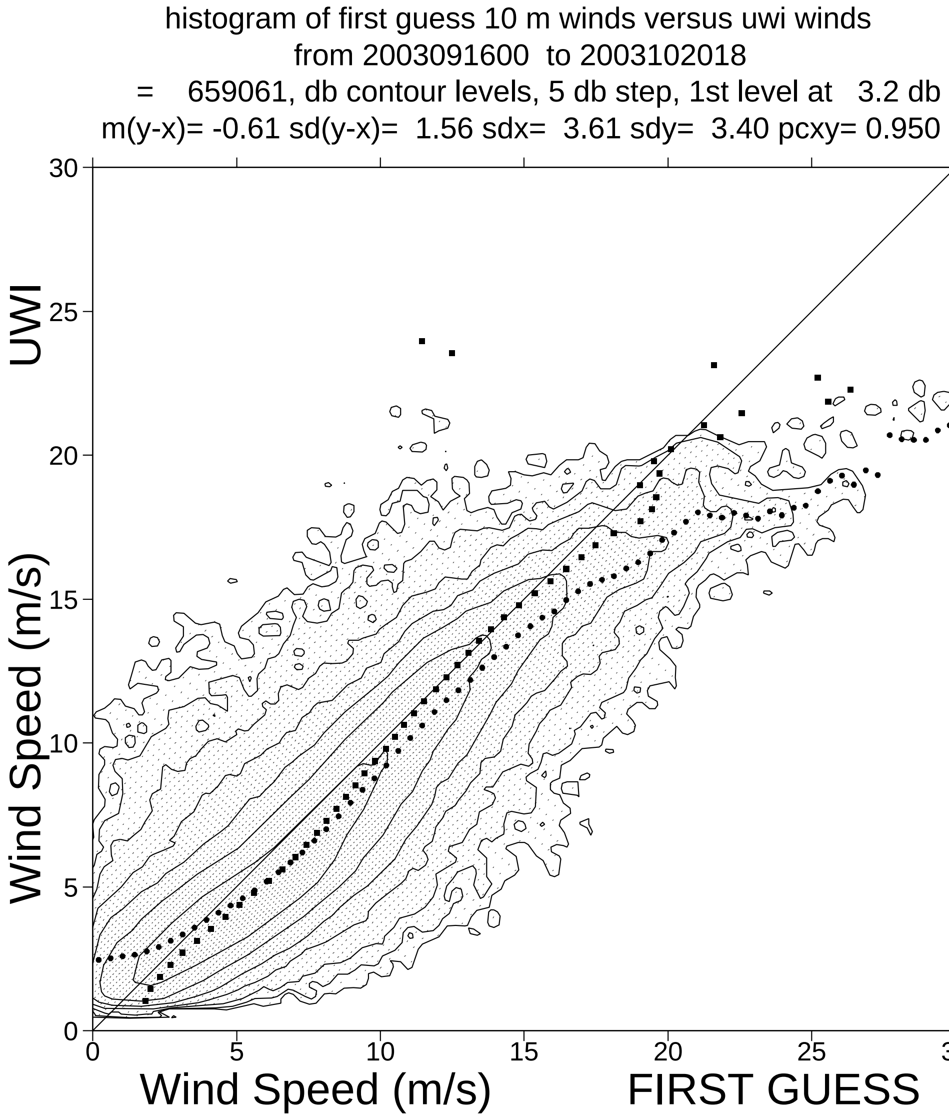

LAND CONTAMINATION
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
80°N
60°N
40°N
20°N
0°

Figure 12



histogram of first guess 10 m winds versus uwi winds
from 2003091600 to 2003102018
= 659061, db contour levels, 5 db step, 1st level at 3.2 db
m(y-x)= -0.61 sd(y-x)= 1.56 sdx= 3.61 sdy= 3.40 pcxy= 0.950
Wind Speed (m/s) UWI
Wind Speed (m/s) FIRST GUESS
0
5
10
15
20
25
30

Figure 13

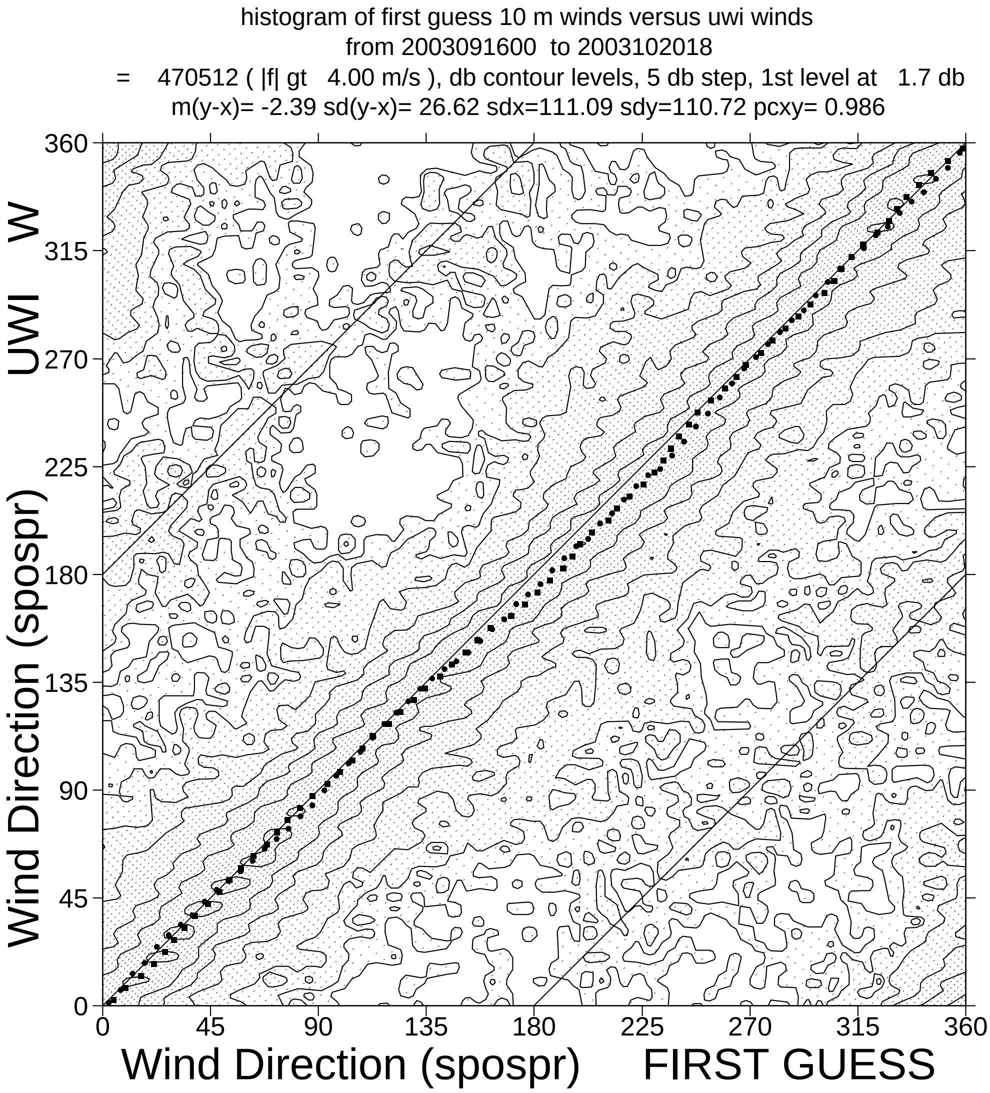

histogram of first guess 10 m winds versus uwi winds
from 2003091600 to 2003102018
= 470512 (|f| gt 4.00 m/s), db contour levels, 5 db step, 1st level at 1.7 db
m(y-x)= -2.39 sd(y-x)= 26.62 sdx=111.09 sdy=110.72 pcxy= 0.986
Wind Direction (spospr) UWI W
Wind Direction (spospr) FIRST GUESS
0
45
90
135
180
225
270
315
360

Figure 14

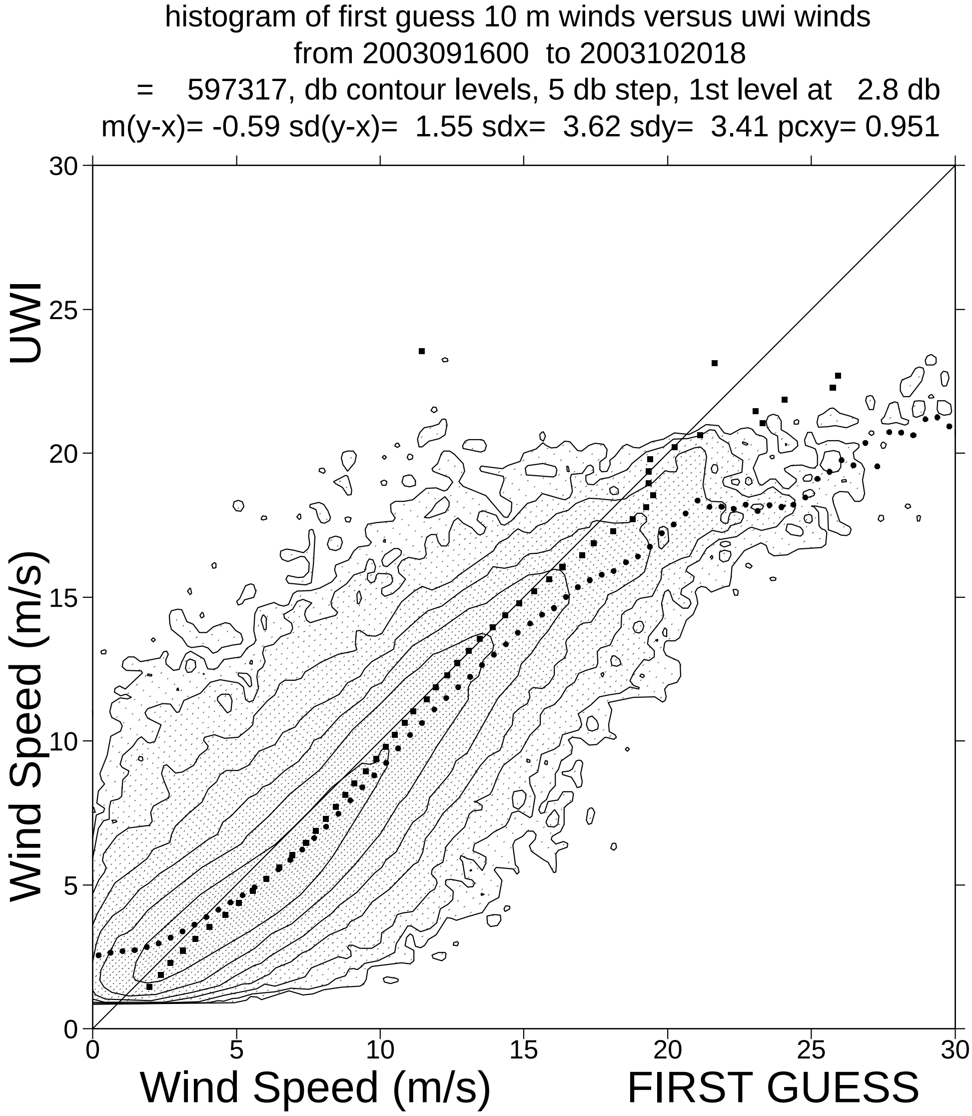

histogram of first guess 10 m winds versus uwi winds
from 2003091600 to 2003102018
= 597317, db contour levels, 5 db step, 1st level at 2.8 db
m(y-x)= -0.59 sd(y-x)= 1.55 sdx= 3.62 sdy= 3.41 pcxy= 0.951
0
5
10
15
20
25
30
Wind Speed (m/s)
FIRST GUESS
Wind Speed (m/s)
UWI

Figure 15

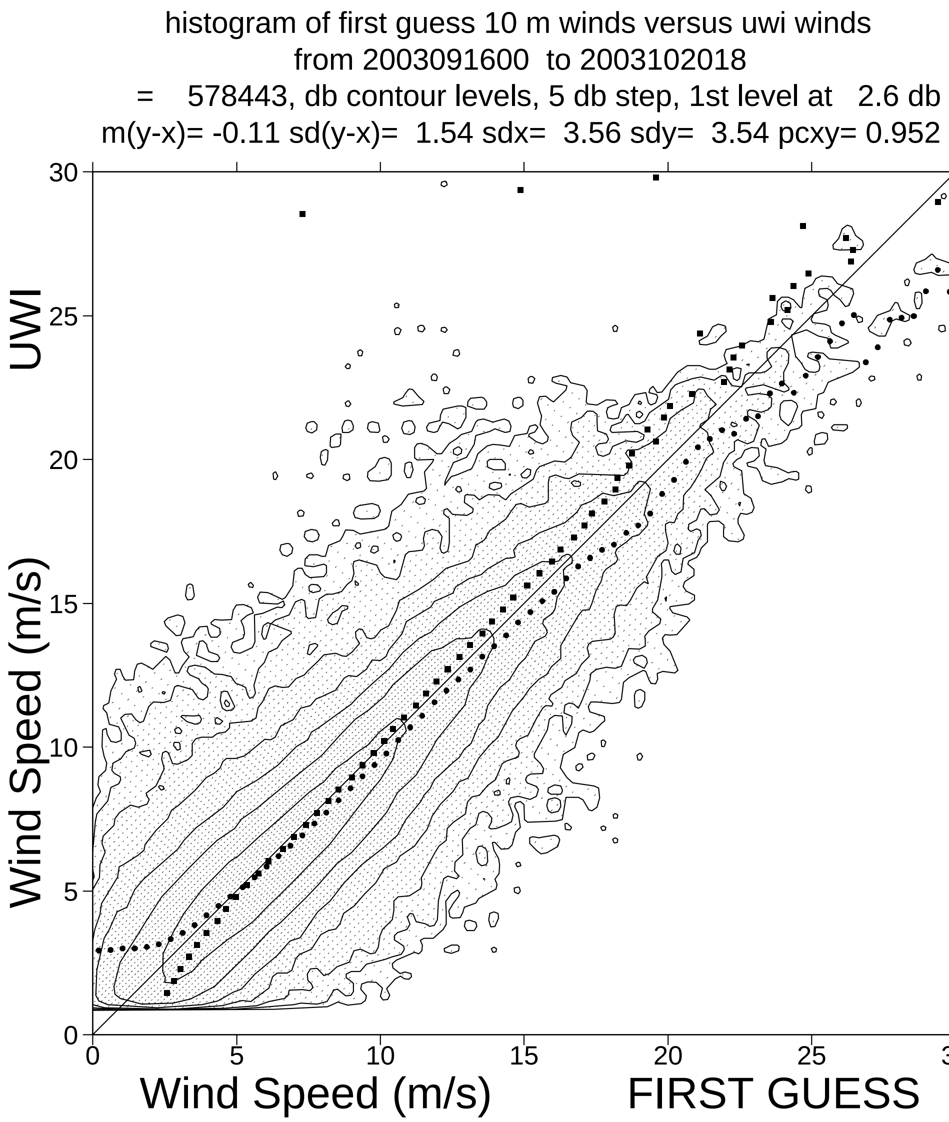

histogram of first guess 10 m winds versus uwi winds
from 2003091600 to 2003102018
= 578443, db contour levels, 5 db step, 1st level at 2.6 db
m(y-x)= -0.11 sd(y-x)= 1.54 sdx= 3.56 sdy= 3.54 pcxy= 0.952
UWI
Wind Speed (m/s)
Wind Speed (m/s)
FIRST GUESS
0
5
10
15
20
25
30

Figure 16