Monitoring statistics of the ERS-2 scatterometer for ESA

cycle 101

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1 Introduction

The quality of the UWI product was monitored at ECMWF for cycle 101. 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). No corrections for duplicate observations were applied.

During cycle 101 data was received between 21:04 UTC 13 December 2004 and 19:46 UTC 17 January 2005. No data was received for the 6-hourly data batches between 12 UTC and 18 UTC 14 December 2004, for 00 UTC 15 December 2004, between 00 UTC and 06 UTC 17 December 2004, and for the period from 06 UTC 26 December 2004 to 18 UTC 28 December 2004. In general, largest volumes (typically above 10,000) were received for 6-hourly data batches centered at 00 UTC and 12 UTC.

Data is being recorded whenever within the visibility range of a ground station, leading for cycle 101 to a coverage of 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 2).

After the data gap at 28 December 2004, the asymmetry between the fore and aft incidence angles showed the development of enhanced peaks. The k_p-yaw ESA flag had been set accordingly.

Compared to cycle 100, the comparison with ECMWF first-guess (FG) fields showed an increased relative standard deviation (from 1.59 m/s to 1.68 m/s). It is related to seasonal variations of the non-global data coverage, and a similar trend was observed one year before (Figure 1). The relative bias has become more negative (from -0.65 m/s to -0.80 m/s). The negative bias for CMOD5 winds has grown somewhat as well (from -0.10 m/s to -0.19 m/s). Relative bias levels are comparable to those for 2000; the relative standard deviation is larger (see Figure 1).

Ocean calibration shows that both bias levels and internode differences are small and stable.

The cycle-averaged evolution of performance relative to ECMWF first-guess (FG) winds is displayed in Figure 1. Figure 2 shows global maps of the over cycle 101 averaged UWI data coverage and wind climate, Figure 3 for performance relative to FG winds.

The ECMWF assimilation system was not changed during cycle 101.

2 ERS-2 statistics from 14 December 2004 to 17 January 2005

2.1 Sigma0 bias levels

The average sigma0 bias levels (compared to simulated sigma0's based on ECMWF model FG 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 4.

Bias levels are very similar to those during cycle 100. Inter-node and inter-beam dependencies are small. Average bias level is around -0.30 dB, which is 0.20 dB less negative than for nominal data in 2000 (see Figure 1 of the reports for cycle 48 to 59).

The data volume of descending and ascending tracks is 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 5 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.

Since the start of 2005, peaks have become more pronounced, reaching values of 6 degrees. As a result of this, a larger than usual amount of data was flagged as being potentially degraded. During this period solar activity has been rather large (source: www.spaceweather.com).

2.3 Distance to cone history

The distance to the cone history is shown in Figure 6. 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).

Like for cycle 100, time series are (due to lack of statistics) very noisy, especially for the first nodes. Most spikes were found to be the result of low data volumes. Note the large amount of rejections around the event discussed above. Compared to cycle 100, rejection rates are higher, being the result of the more volatile behaviour of the yaw attitude error.

Compared to cycle 100, the average level was almost equal (from 1.18 to 1.19), and is now about 10% higher than for nominal data (see top panel Figure 1).

2.4 UWI minus First-Guess wind history

In Figure 7, the UWI minus ECMWF first-guess wind-speed history is plotted.

The history plot shows several peaks, most of which are related to low data volumes. Similar results apply for the history of de-aliased CMOD4 winds versus FG (Figure 9).

Figure 11 displays the locations for which UWI winds were more than 8 m/s weaker (top panel) and more than 8 m/s stronger (lower panel) than FG winds. Like for cycle 100, the number of such collocations is reasonably low.

In Figure 12 two cases from the in Figure 11 shown collocations are illuminated. The top panel displays a case for 17 January 2005 South-East of Greenland. It shows some differences in the details near the center of the low. The compared to ECMWF winds much weaker UWI winds (35 versus 60 knots) a few degrees to the south is for a large part due to the saturation behaviour of the CMOD4 geophysical model function.

The lower panel shows for 17 December 2004 a Mistral case West of Marseille, observed by ERS-2 but underestimated by the ECMWF first-guess field.

Average bias levels and standard deviations of UWI winds relative to FG winds are displayed in Table 1. From this it is seen that the bias of both the UWI and CMOD4 product have become more negative, in a rather homogeneous manner. The average bias level comparable to that for nominal data in 2000 (UWI: -0.80 m/s now, was -0.79 m/s for cycle 59). The evolution of the bias from cycles 92 to 101 is displayed in the top panel of Figure 17. The red curve is the 5-day moving average for the at ECMWF inverted ERS-2 winds; i.e., CMOD5 since 9 March 2004. Blue vertical dashed lines indicate ECMWF model changes. This plot shows that the up-going line since end July 2004 has stabilized since November 2004. For QuikSCAT, the positive trend in the globally averaged bias of (at ECMWF inverted and bias-corrected) QuikSCAT winds (middle panel) did continue, however, showed a swift drop in January 2005.

The standard deviation of UWI winds compared to cycle 100 has become higher (1.68 m/s, was 1.59 m/s) in a rather uniform way. The seasonal trend makes an objective statement on quality evolution impossible.

For cycle 100 the (UWI - FG) direction standard deviations were ranging between 15 and 60 degrees (Figure 8). Sharp peaks are the result of low data volumes. The average performance for UWI wind direction has improved (STDV 27.9 degrees, was 44.6 degrees, bias -2.8 degrees, was -2.1 degrees), the difference being the result

	cycle 100		cycle 101	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.59	1.57	1.68	1.66
node 1-2	1.70	1.65	1.85	1.79
node 3-4	1.59	1.57	1.70	1.68
node 5-7	1.51	1.50	1.62	1.61
node 8-10	1.51	1.50	1.56	1.54
node 11-14	1.54	1.53	1.61	1.60
node 15-19	1.58	1.57	1.65	1.65
speed BIAS	-0.65	-0.63	-0.80	-0.77
node 1-2	-1.27	-1.22	-1.48	-1.42
node 3-4	-0.96	-0.89	-1.13	-1.06
node 5-7	-0.68	-0.63	-0.81	-0.77
node 8-10	-0.49	-0.47	-0.60	-0.59
node 11-14	-0.45	-0.45	-0.58	-0.57
node 15-19	-0.44	-0.45	-0.57	-0.57
direction STDV	44.6	19.4	27.9	18.1
direction BIAS	-2.1	-3.4	-2.8	-3.2

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

of an anomaly observed in the de-aliasing for cycle 100 (for details, see previous monitoring report).

2.5 Scatterplots

Scatterplots of FG 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).

The scatterplot of UWI wind speed versus FG (Figure 13) is very similar to that for (at ECMWF inverted) de-aliased CMOD4 winds (Figure 15). It confirms that the ESACA inversion scheme is working properly. The enhanced standard deviation compared to cycle 100 (1.71 m/s, was 1.61 m/s), originates from a more intense wind climate.

Winds derived on the basis of CMOD5 are displayed in Figure 16. The relative standard deviation is lower than for CMOD4 winds (1.62 m/s versus 1.70 m/s). Compared to ECMWF FG, CMOD5 winds are -0.19 m/s slower. However a much larger negative bias is observed for strong winds.

Figure Captions

Figure 1: Evolution of the performance of the ERS-2 scatterometer averaged over 5-weekly cycles from 12 December 2001 (cycle 69) to 17 January 2005 (end cycle 101) 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 FG 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 FG.

Figure 2: Average number of observations per 12H and per 125km grid box (top panel) and wind-climate (lower panel) for UWI winds that passed the UWI flags QC and a check on the collocated ECMWF land and sea-ice mask.

Figure 3: The same as Figure 2, but now for the relative bias (top panel) and standard deviation (lower panel) with ECMWF first-guess winds.

Figure 4: Ratio of $< \sigma_0^{0.625} > / < \text{CMOD4(FirstGuess)}^{0.625} >$ 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 5: 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 6: 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 and sea-ice 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 7: 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 8: Same as Fig. 7, but for the wind direction difference. Statistics are computed only for wind speeds higher than 4 m/s.

Figures 9 and 10: Same as Fig. 7 and 8 respectively, but for the de-aliased CMOD4 data.

Figure 11: Locations of data during cycle 101 for which UWI winds are more than 8 m/s weaker (top panel) respectively stronger (lower panel) than FG, and on which QC on UWI flags and the ECMWF land/sea-ice mask was applied.

Figure 12: Comparison between UWI (red) and ECMWF FG (blue) winds for an Atlantic case on 17 January 2005 (top panel) and a case in the Mediterranean

on 17 December 2004 (lower panel).

Figure 13: 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 and sea-ice 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.

Figure 17: Bias relative to FG winds of the wind speed of ERS-2 winds (based on bias-corrected CMOD4 before 9 March 2004, and on CMOD5 afterwards) for nodes 1-19 (top panel) respectively of 50-km QuikSCAT (based on the QSCAT-1 model function) for nodes 5-34 (i.e., inner-beam zone; middle and lower panels) versus ECMWF first guess for the period of cycle 92 to 101. Curves represent centered 15-day running means for the top and middle panel, and a 30-day running mean for the lower panel. Vertical dashed blue lines mark ECMWF model changes.

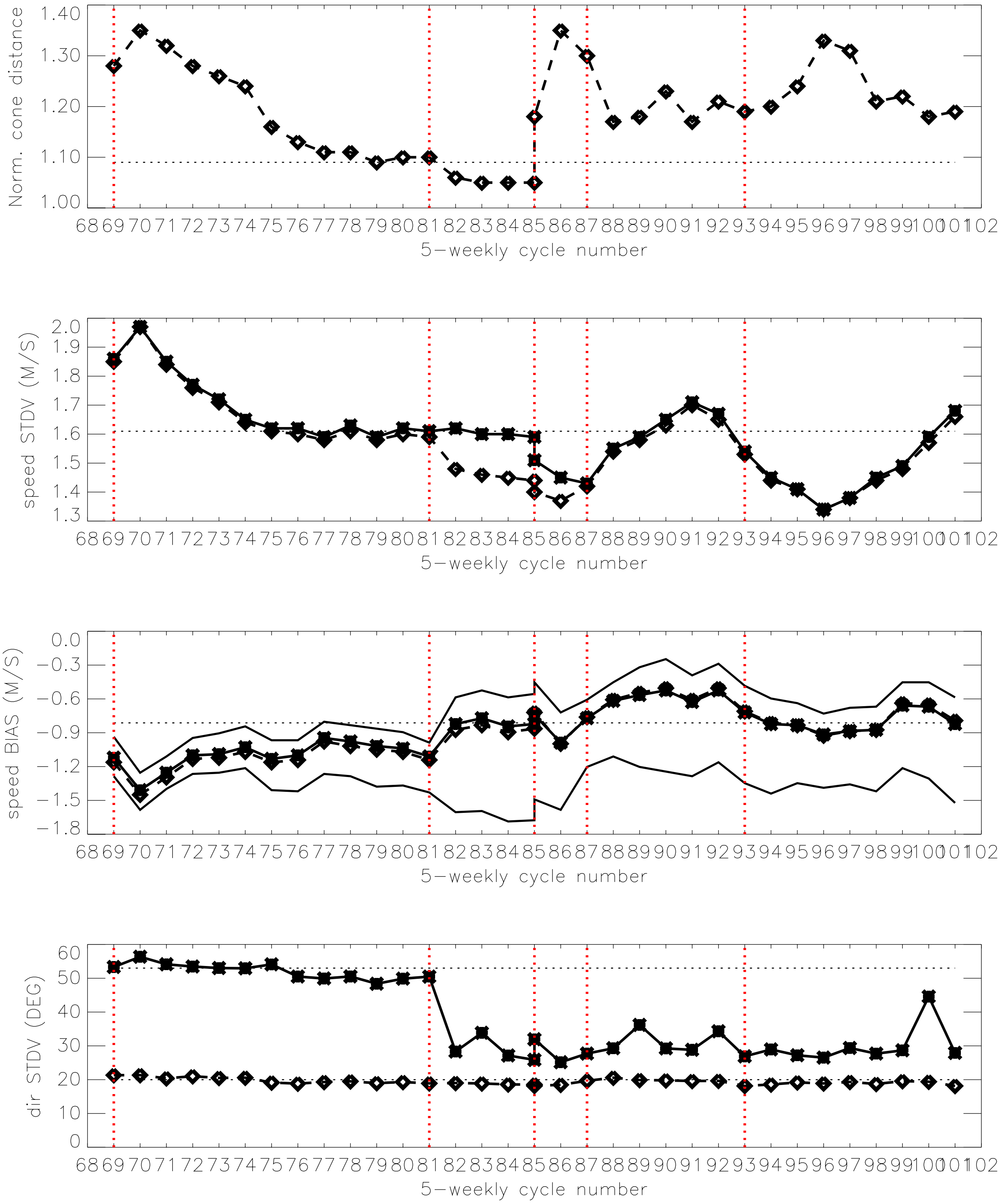

Norm. cone distance
1.40
1.30
1.20
1.10
1.00
68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102
5−weekly cycle number
speed STDV (M/S)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102
5−weekly cycle number
speed BIAS (M/S)
0.0
−0.3
−0.6
−0.9
−1.2
−1.5
−1.8
68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102
5−weekly cycle number
dir STDV (DEG)
60
50
40
30
20
10
0
68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102
5−weekly cycle number

Figure 1

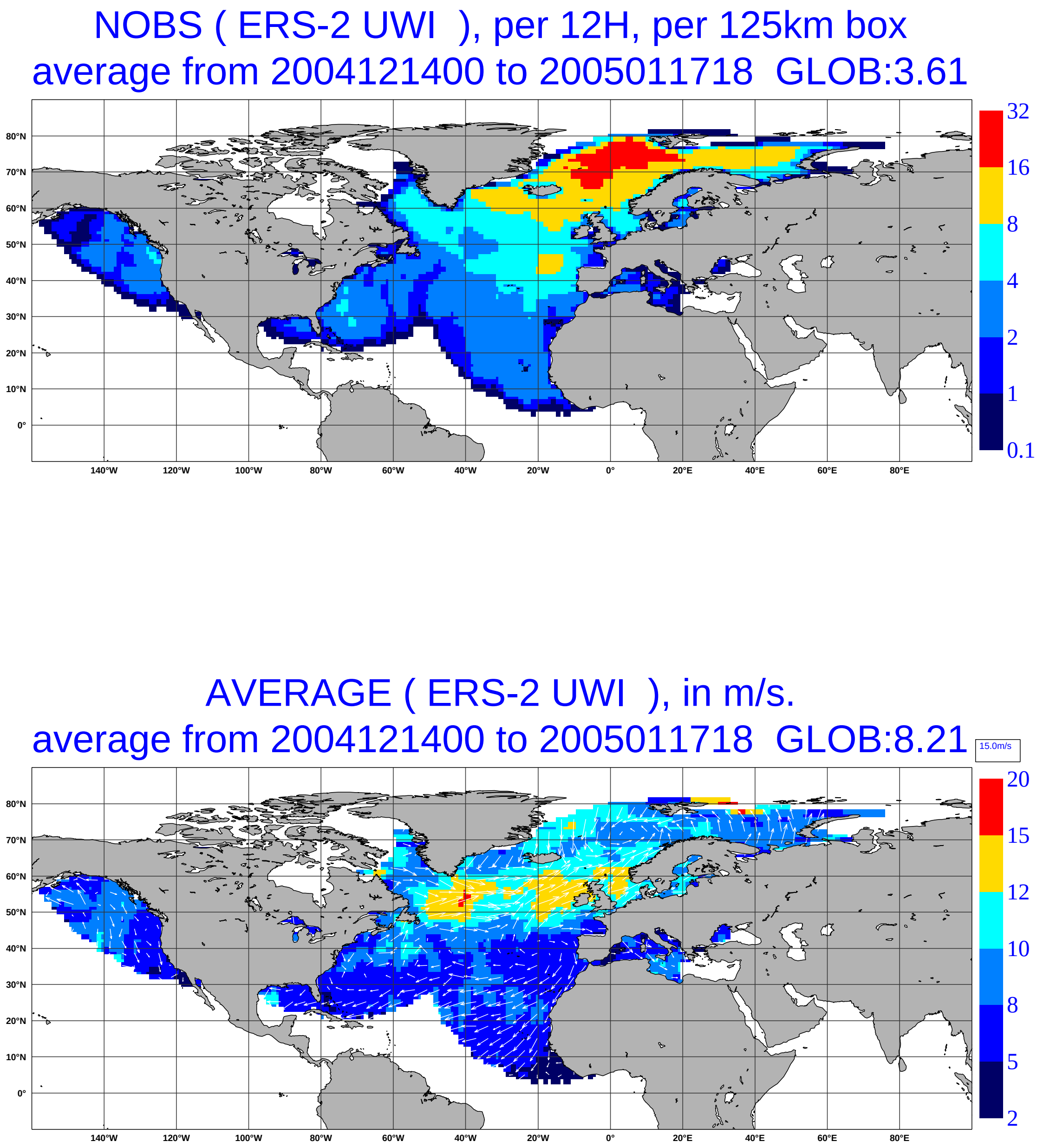
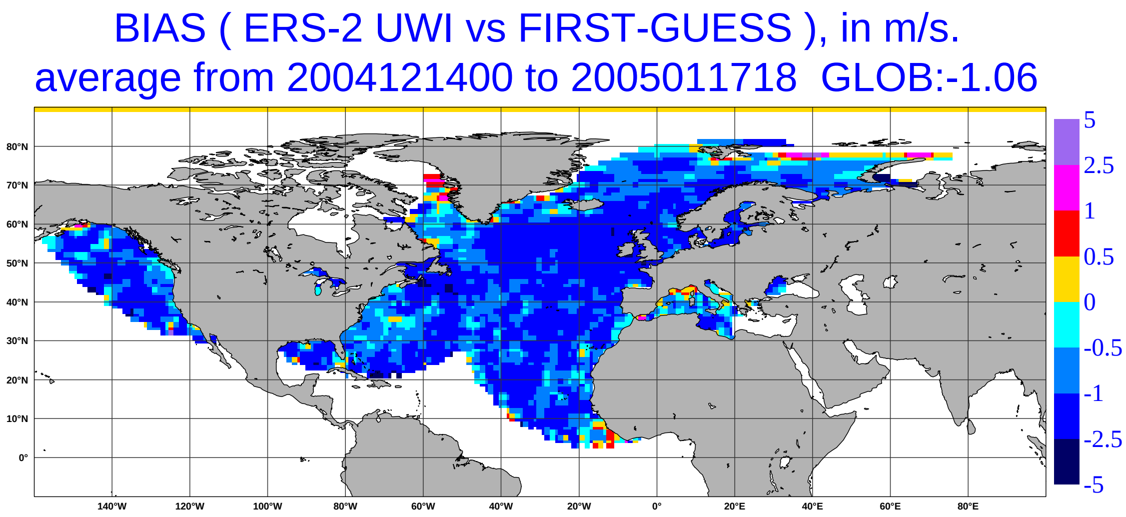

NOBS (ERS-2 UWI), per 12H, per 125km box
average from 2004121400 to 2005011718 GLOB:3.61
32
16
8
4
2
1
0.1
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
140°W
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
AVERAGE (ERS-2 UWI), in m/s.
average from 2004121400 to 2005011718 GLOB:8.21
15.0m/s
20
15
12
10
8
5
2

Figure 2


BIAS (ERS-2 UWI vs FIRST-GUESS), in m/s.
average from 2004121400 to 2005011718 GLOB:-1.06
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
140°W
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
5
2.5
1
0.5
0
-0.5
-1
-2.5
-5

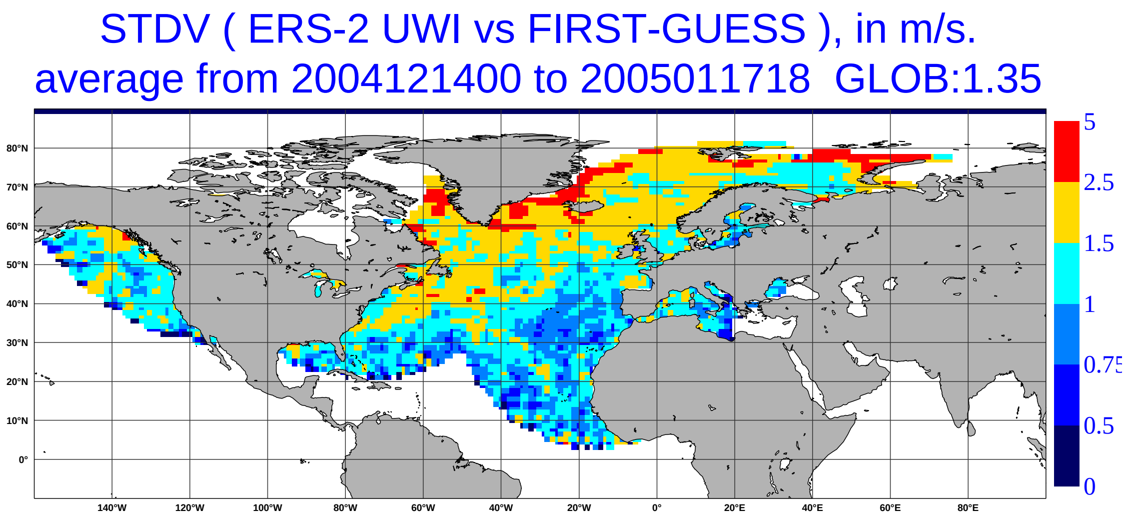

STDV (ERS-2 UWI vs FIRST-GUESS), in m/s.
average from 2004121400 to 2005011718 GLOB:1.35
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
140°W
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
5
2.5
1.5
1
0.5
0

Figure 3

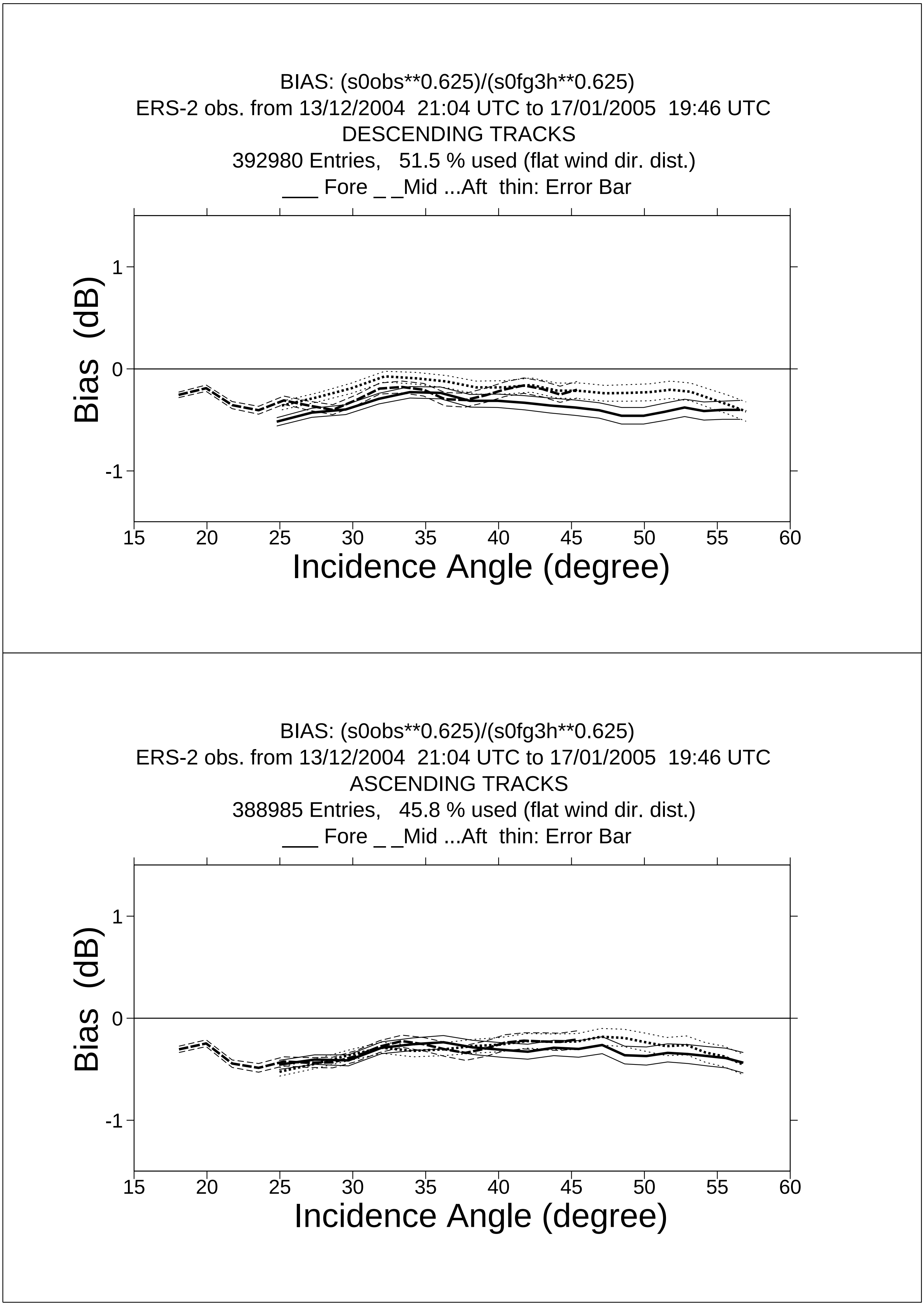

BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 13/12/2004 21:04 UTC to 17/01/2005 19:46 UTC
DESCENDING TRACKS
392980 Entries, 51.5 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)
BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 13/12/2004 21:04 UTC to 17/01/2005 19:46 UTC
ASCENDING TRACKS
388985 Entries, 45.8 % 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 4

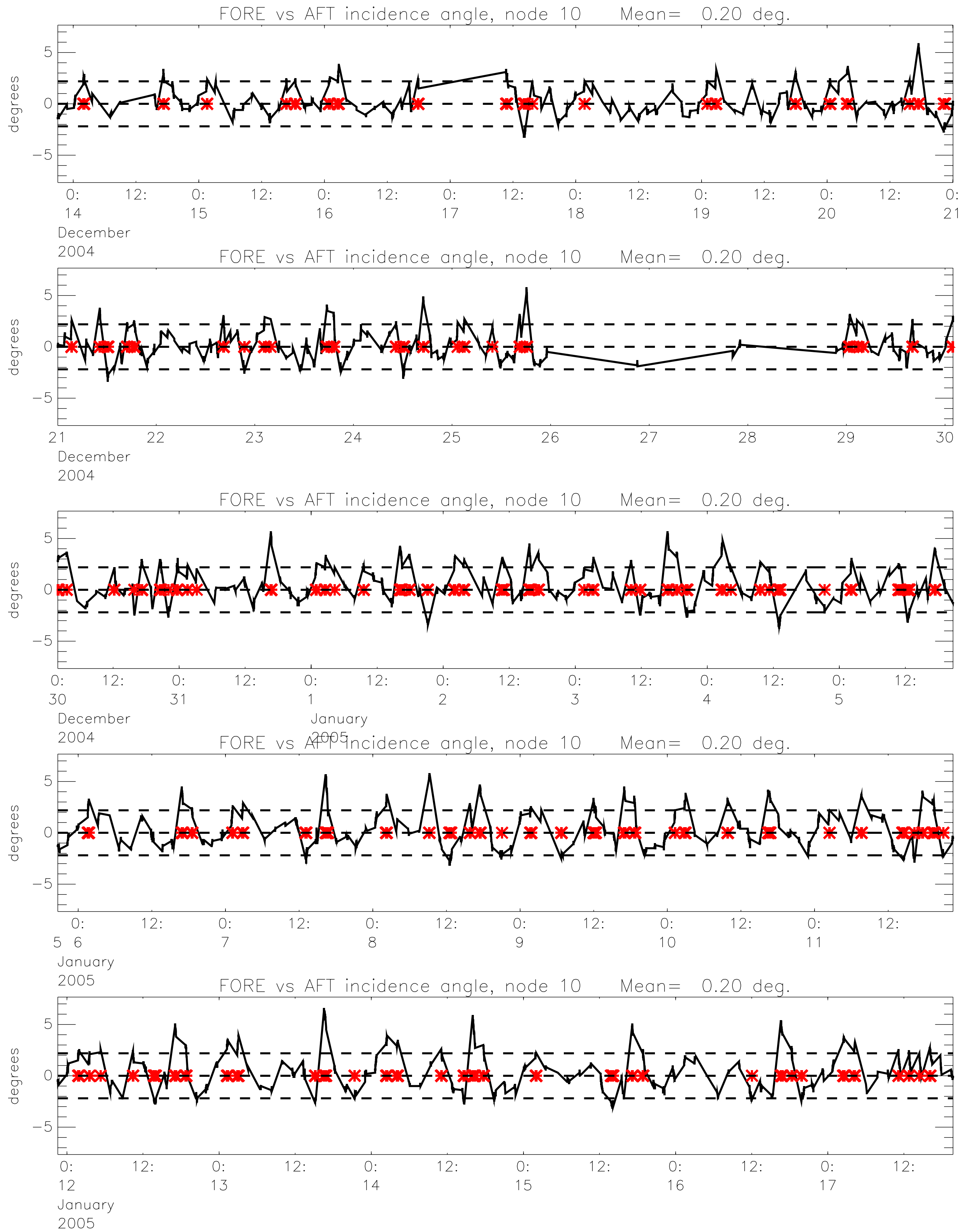
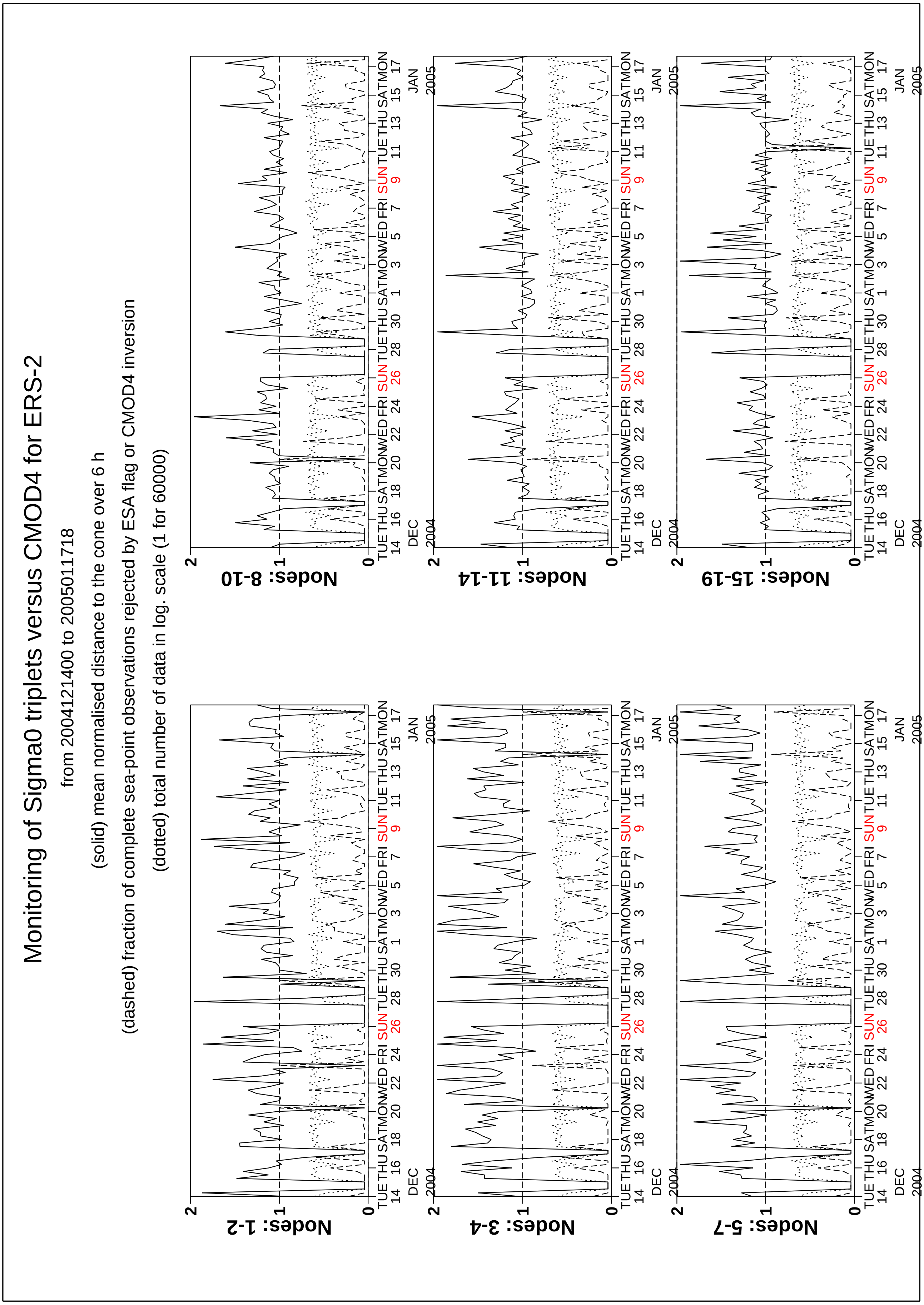

FORE vs AFT incidence angle, node 10 Mean= 0.20 deg.
degrees
5
0
−5
0: 14
12:
0: 15
12:
0: 16
12:
0: 17
12:
0: 18
12:
0: 19
12:
0: 20
12:
0: 21
December 2004
FORE vs AFT incidence angle, node 10 Mean= 0.20 deg.
degrees
5
0
−5
21 22 23 24 25 26 27 28 29 30
December 2004
FORE vs AFT incidence angle, node 10 Mean= 0.20 deg.
degrees
5
0
−5
0: 30
12:
0: 31
12:
0: 1
12:
0: 2
12:
0: 3
12:
0: 4
12:
0: 5
12:
December 2004
January 2005
FORE vs AFT incidence angle, node 10 Mean= 0.20 deg.
degrees
5
0
−5
5
0: 6
12:
0: 7
12:
0: 8
12:
0: 9
12:
0: 10
12:
0: 11
12:
January 2005
FORE vs AFT incidence angle, node 10 Mean= 0.20 deg.
degrees
5
0
−5
0: 12
12:
0: 13
12:
0: 14
12:
0: 15
12:
0: 16
12:
0: 17
12:
January 2005

Figure 5



Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2004121400 to 2005011718
(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
DEC 2004
JAN 2005

Figure 6

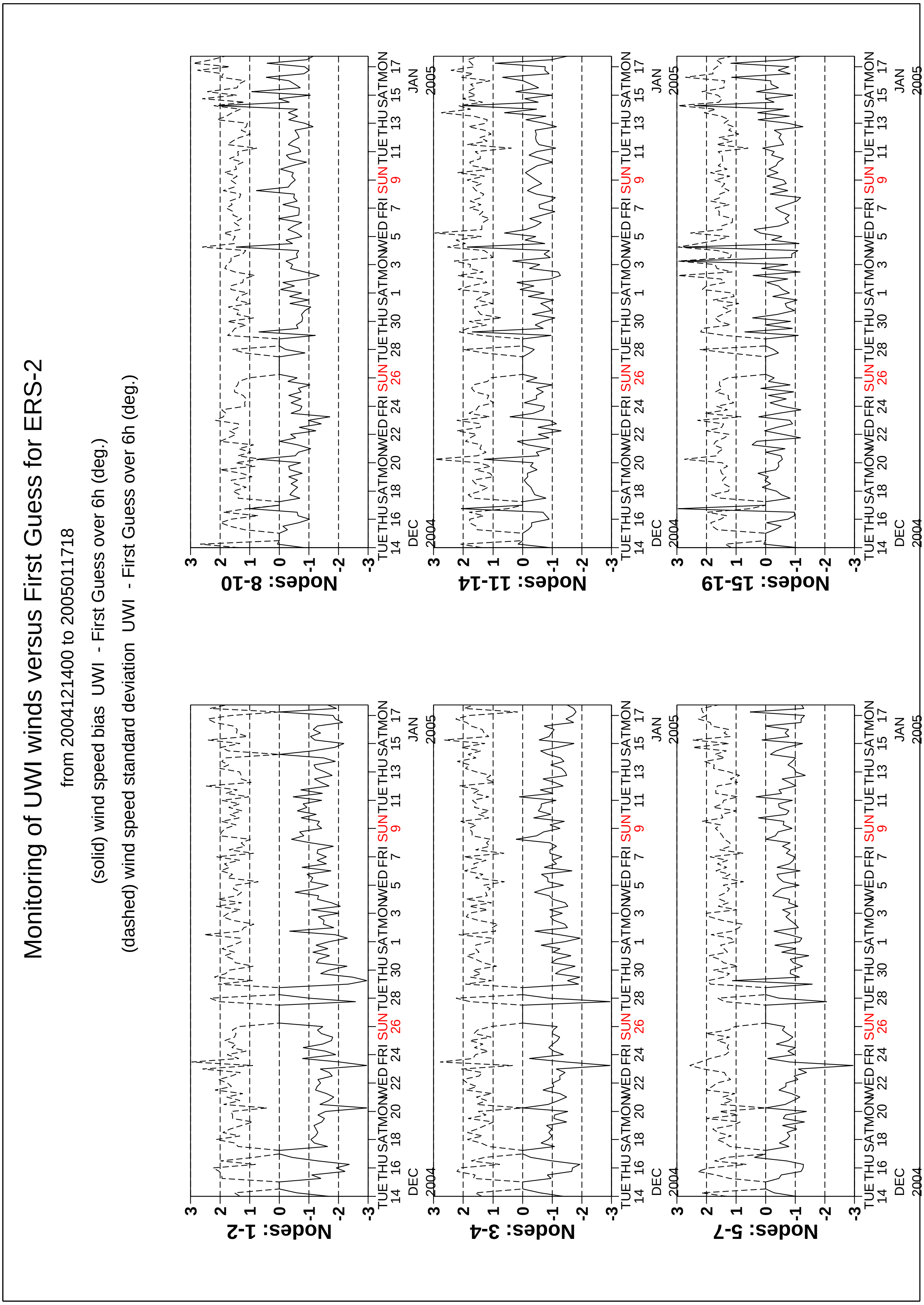

Monitoring of UWI winds versus First Guess for ERS-2
from 2004121400 to 2005011718
(solid) wind speed bias UWI - First Guess over 6h (deg.)
(dashed) wind speed standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
DEC 2004
JAN 2005

Figure 7

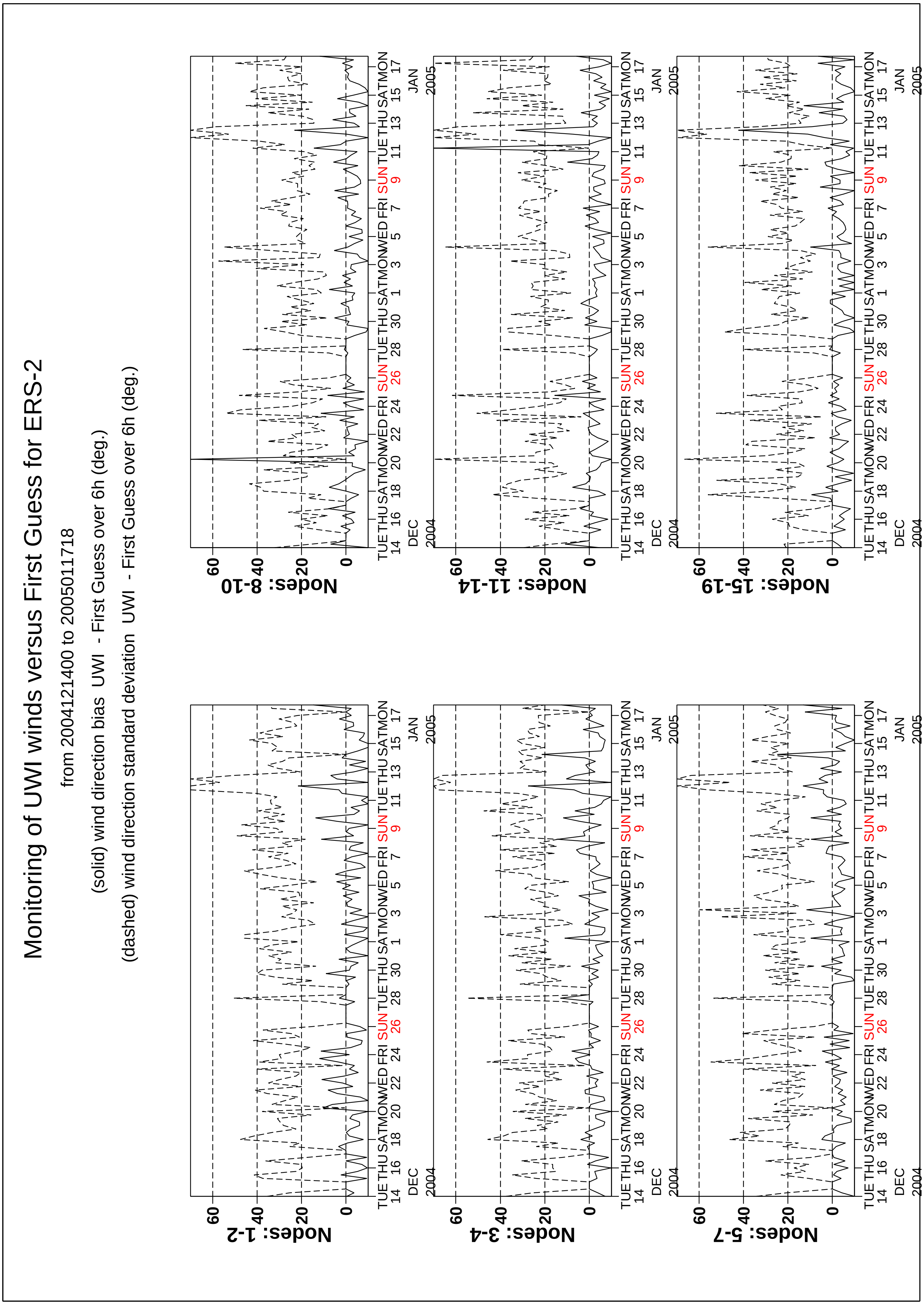

Monitoring of UWI winds versus First Guess for ERS-2
from 2004121400 to 2005011718
(solid) wind direction bias UWI - First Guess over 6h (deg.)
(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
DEC 2004
JAN 2005

Figure 8

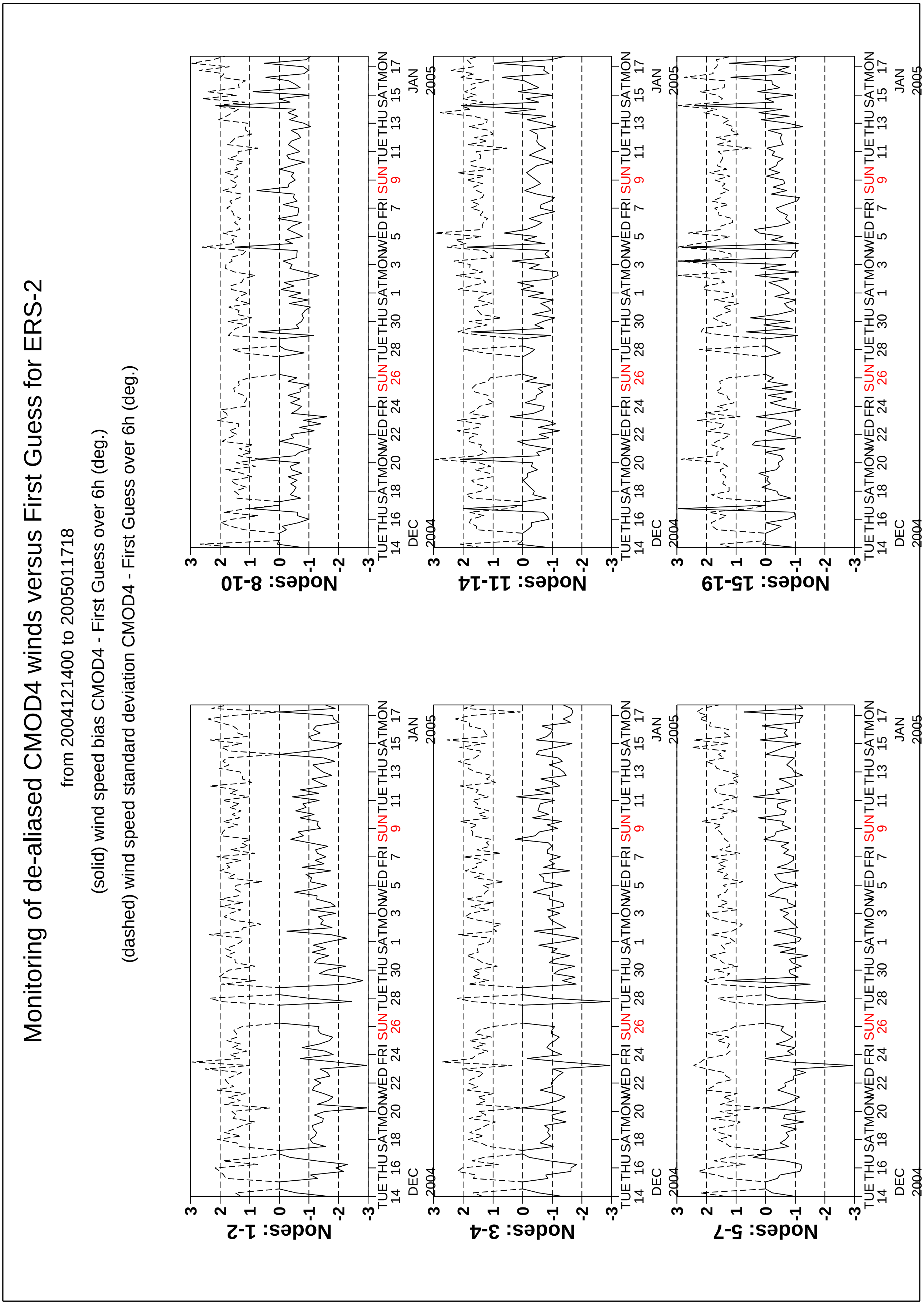
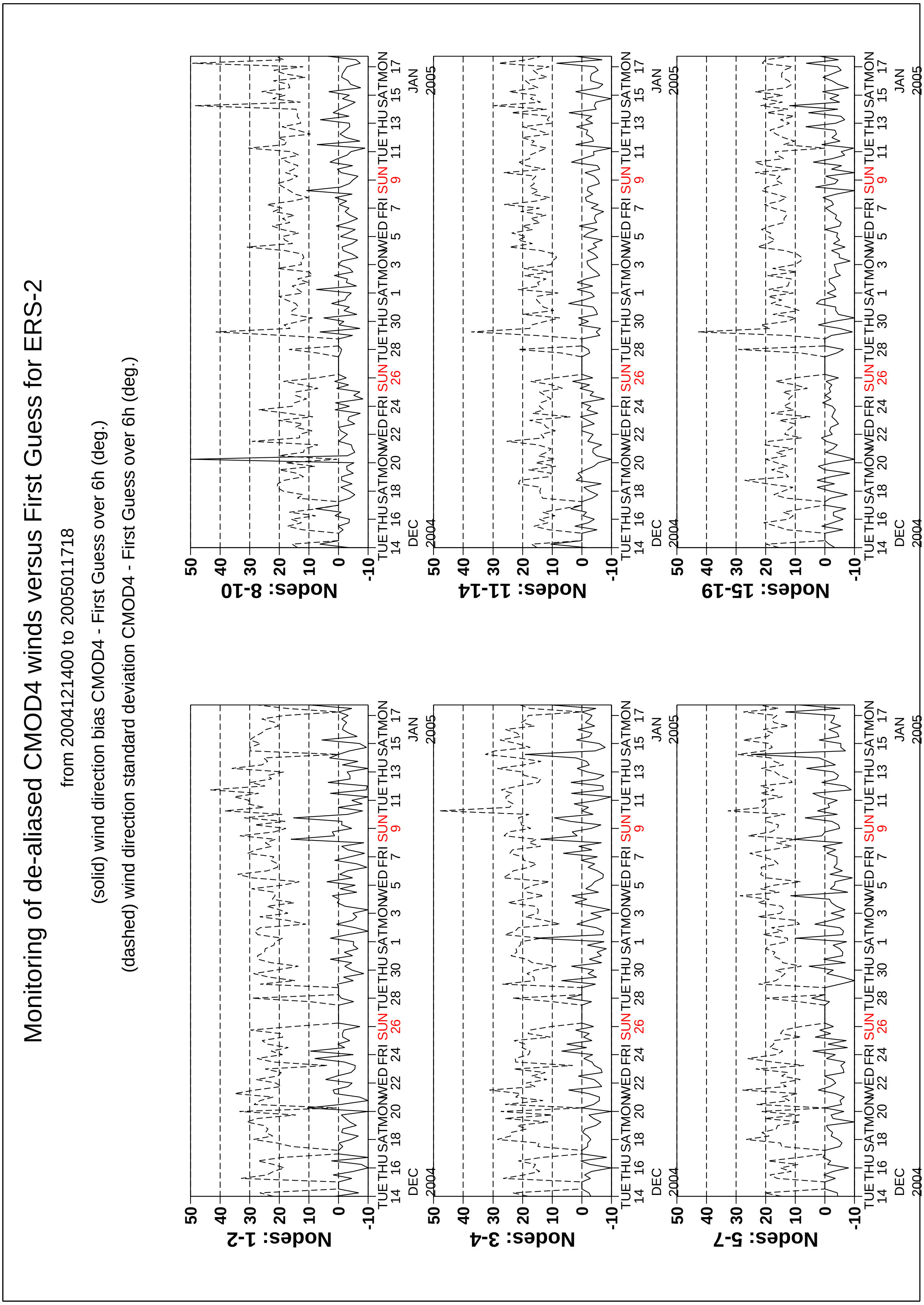

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2004121400 to 2005011718
(solid) wind speed bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind speed standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 3-4
Nodes: 5-7
Nodes: 8-10
Nodes: 11-14
Nodes: 15-19
DEC 2004
JAN 2005

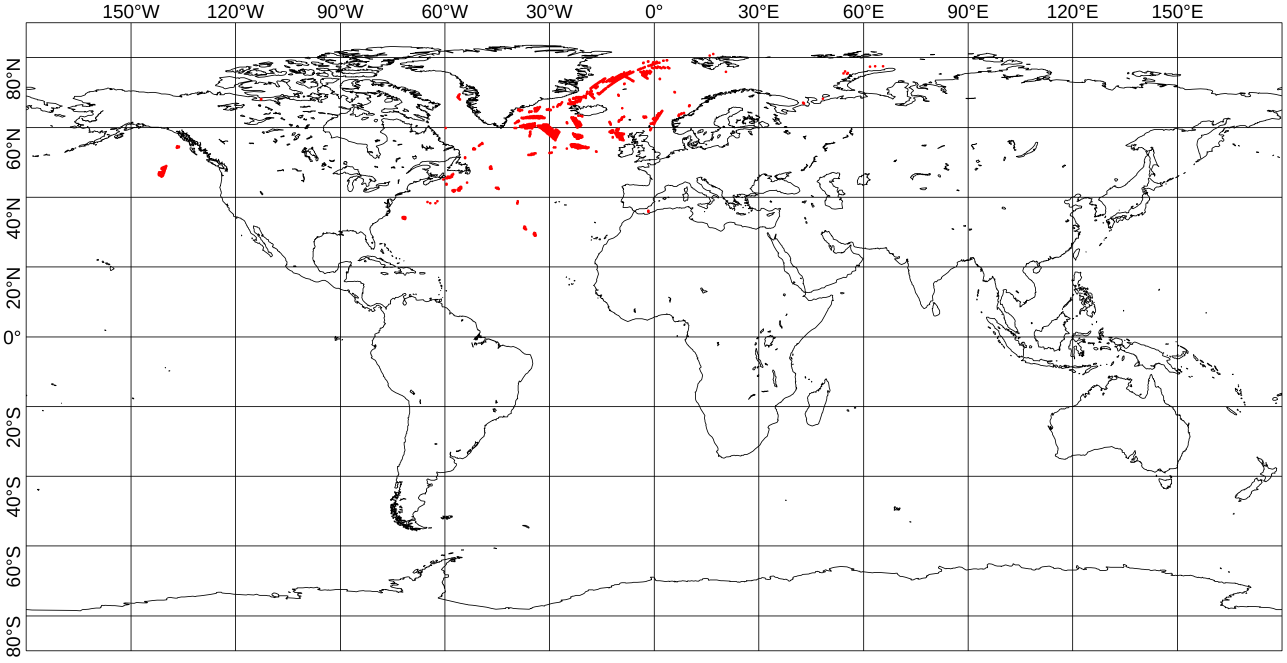
Figure 9



Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2004121400 to 2005011718
(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

Figure 10

UWI winds more than 8 m/s weaker than FGAT
CYCLE 101, 2004121400 to 2005011718, QC on ESA flags



UWI winds more than 8 m/s stronger than FGAT
CYCLE 101, 2004121400 to 2005011718, QC on ESA flags

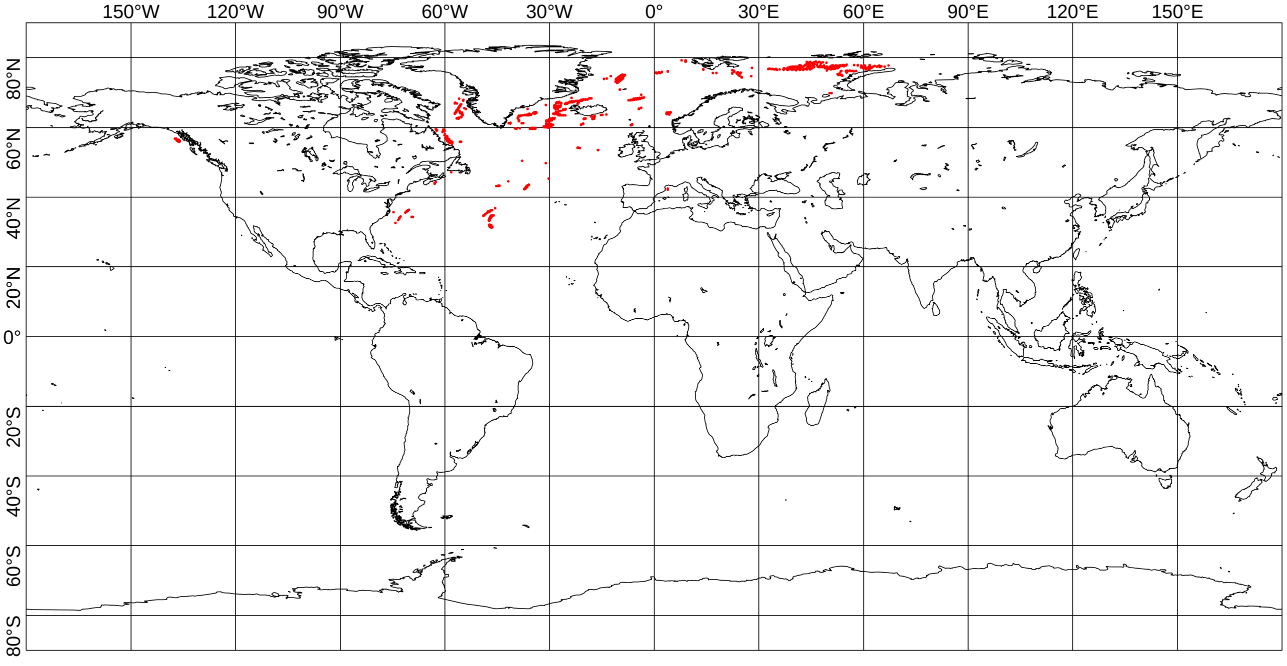
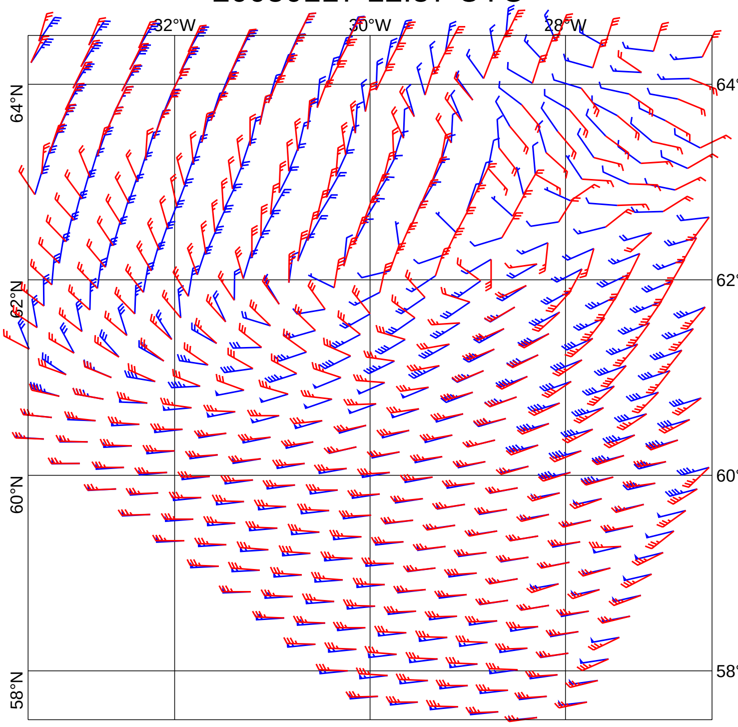


Figure 11

CMOD4 winds (red) versus FGAT winds (blue)
20050117 12:57 UTC



CMOD4 winds (red) versus FGAT winds (blue)
20041217 22:13 UTC

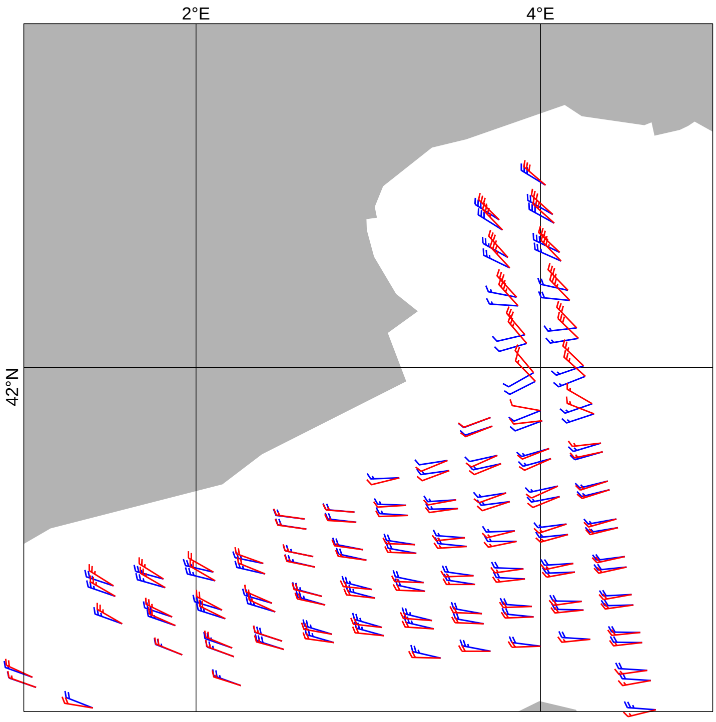


Figure 12

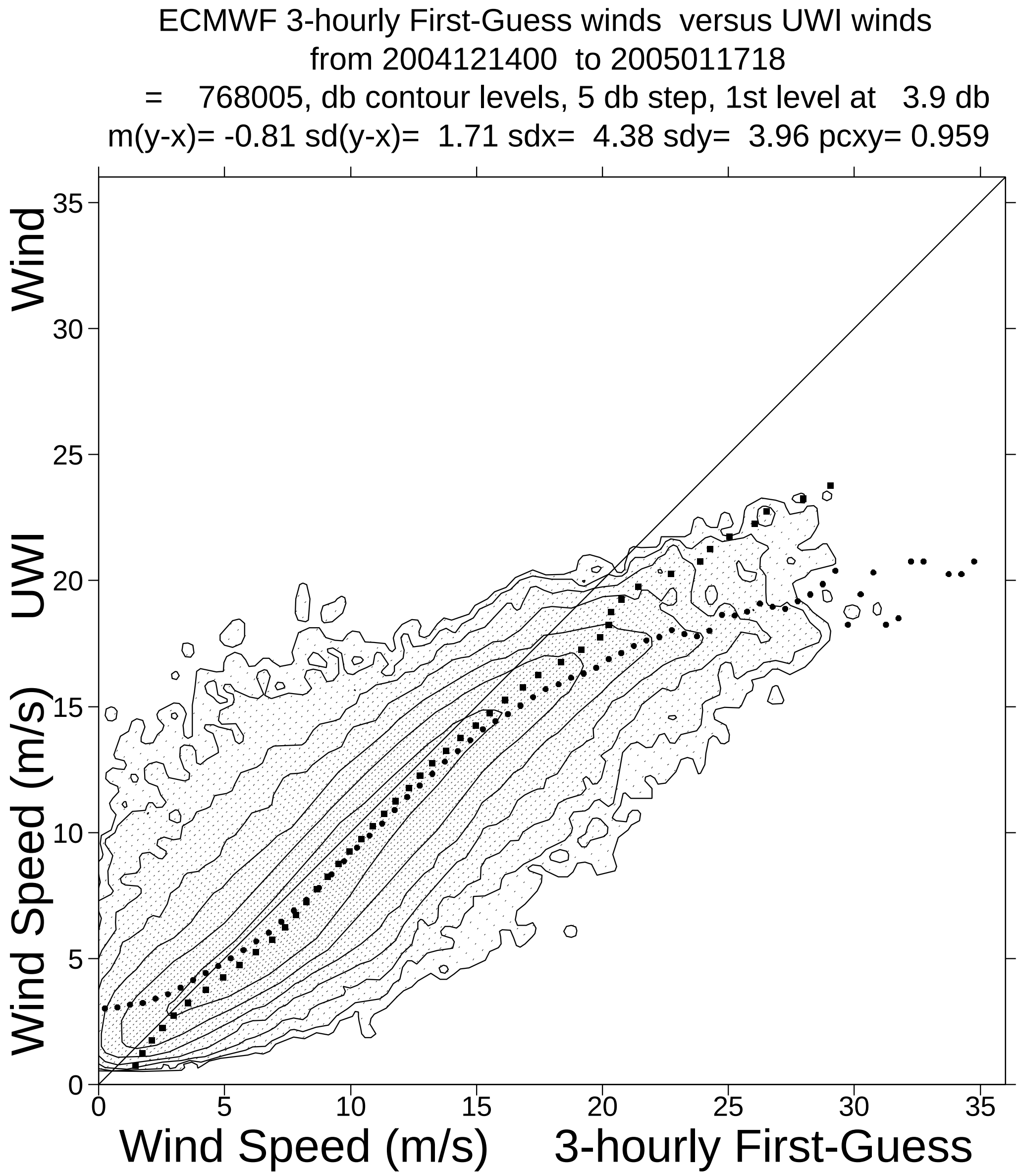

ECMWF 3-hourly First-Guess winds versus UWI winds
from 2004121400 to 2005011718
= 768005, db contour levels, 5 db step, 1st level at 3.9 db
m(y-x)= -0.81 sd(y-x)= 1.71 sdx= 4.38 sdy= 3.96 pcxy= 0.959
0
5
10
15
20
25
30
35
Wind Speed (m/s) UWI Wind
Wind Speed (m/s) 3-hourly First-Guess

Figure 13

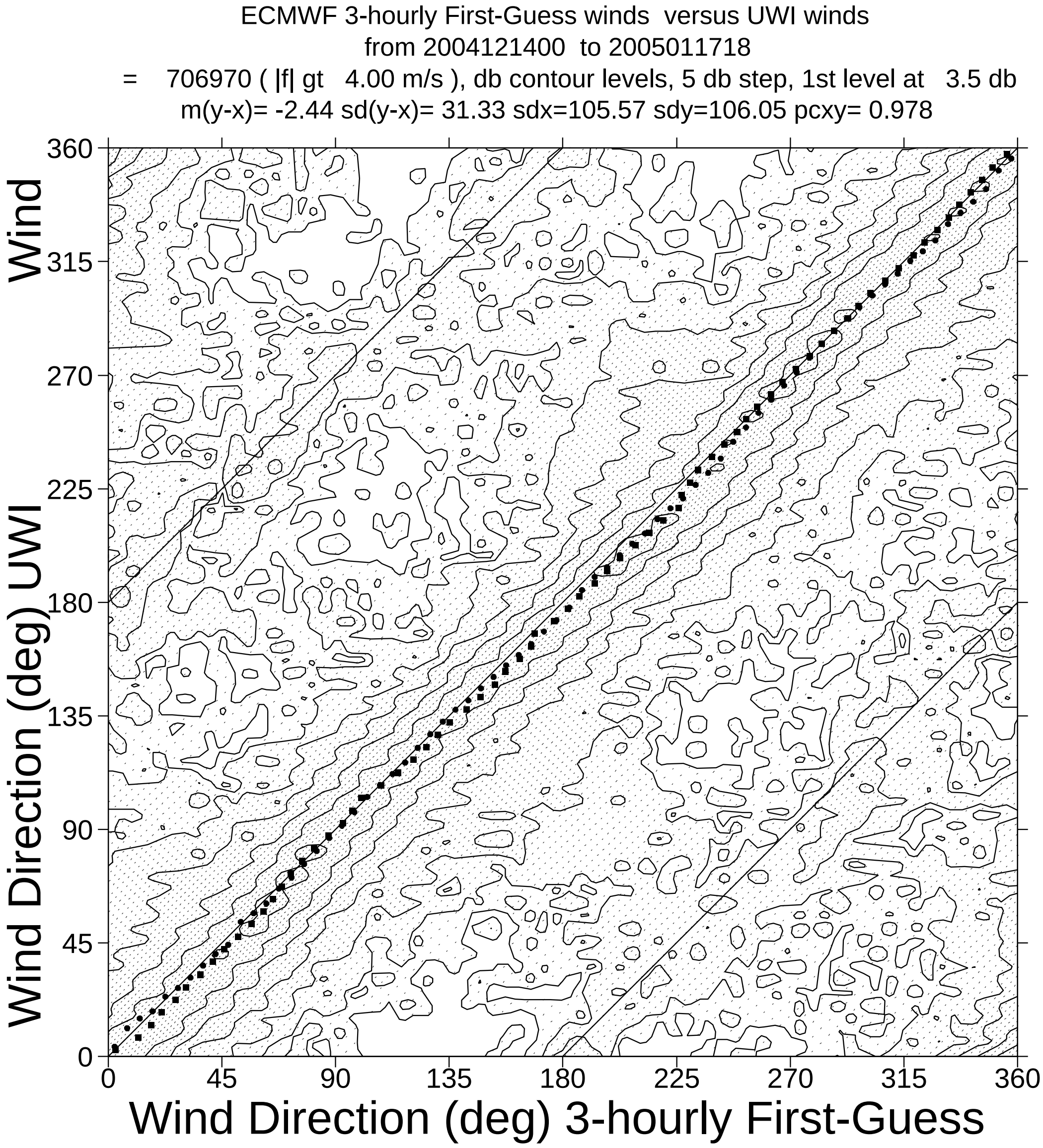

ECMWF 3-hourly First-Guess winds versus UWI winds
from 2004121400 to 2005011718
= 706970 (|f| gt 4.00 m/s), db contour levels, 5 db step, 1st level at 3.5 db
m(y-x)= -2.44 sd(y-x)= 31.33 sdx=105.57 sdy=106.05 pcxy= 0.978
Wind Direction (deg) UWI Wind
Wind Direction (deg) 3-hourly First-Guess
0
45
90
135
180
225
270
315
360

Figure 14

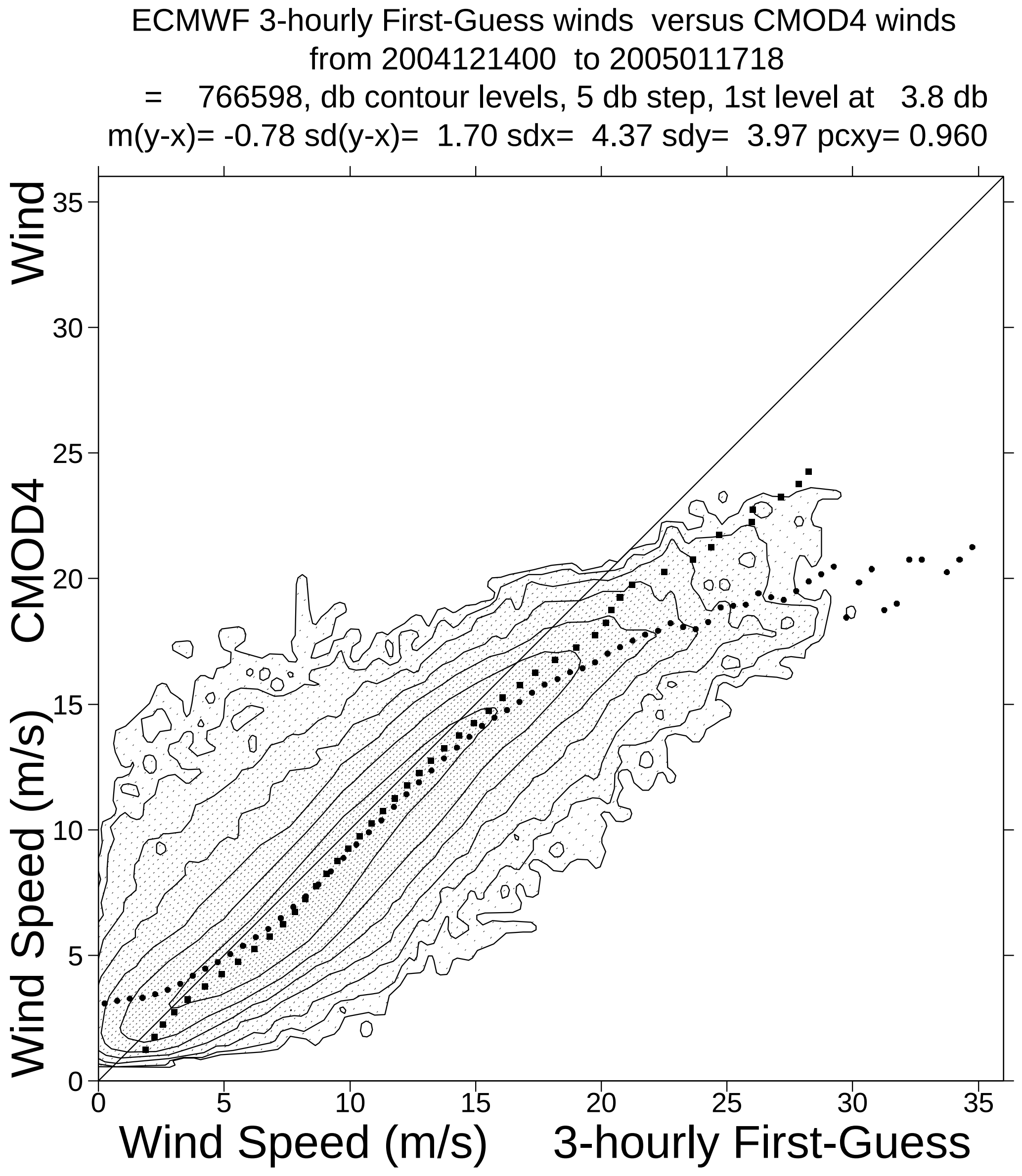
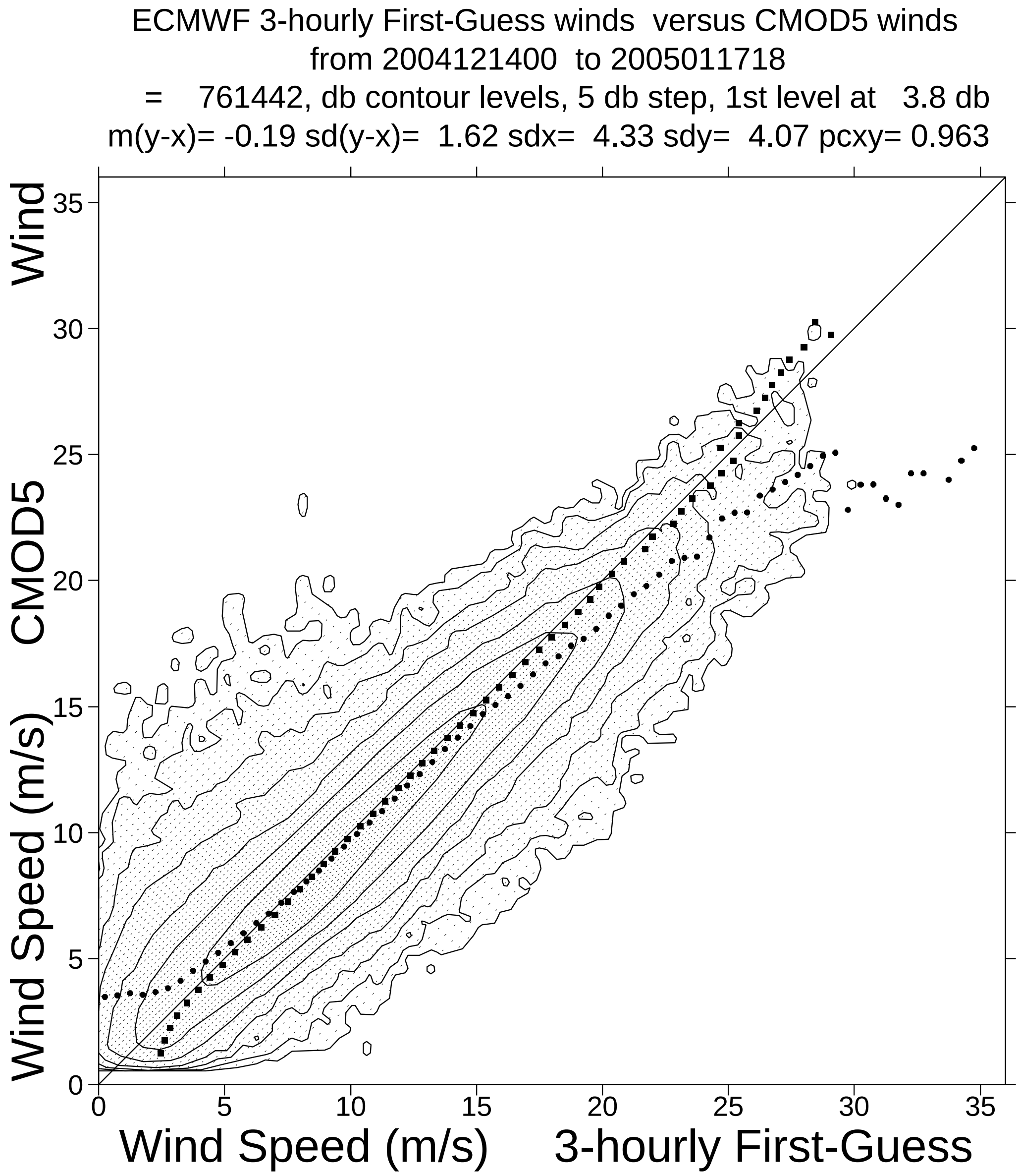

ECMWF 3-hourly First-Guess winds versus CMOD4 winds
from 2004121400 to 2005011718
= 766598, db contour levels, 5 db step, 1st level at 3.8 db
m(y-x)= -0.78 sd(y-x)= 1.70 sdx= 4.37 sdy= 3.97 pcxy= 0.960
Wind Speed (m/s) CMOD4 Wind
Wind Speed (m/s) 3-hourly First-Guess
0
5
10
15
20
25
30
35

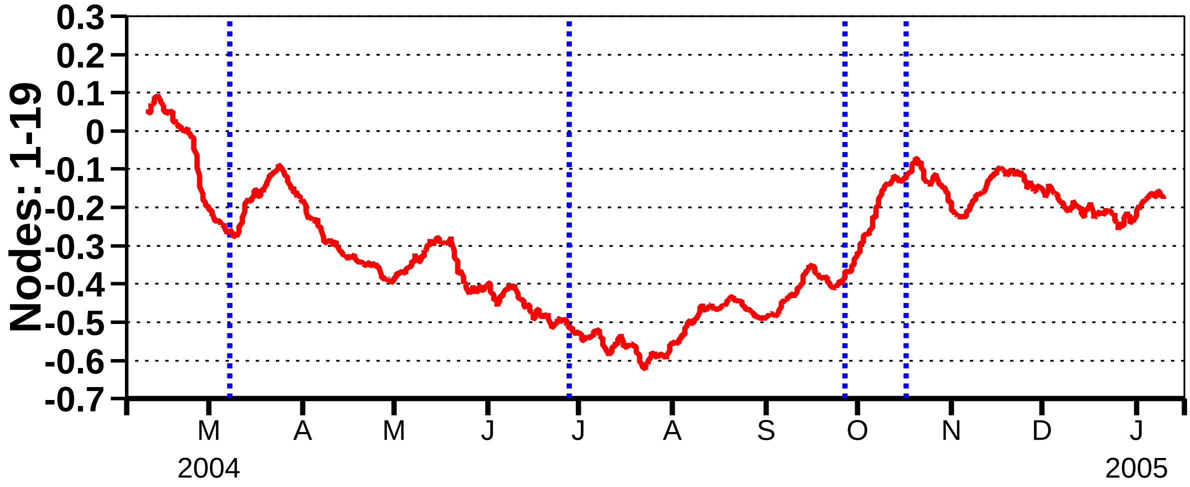
Figure 15



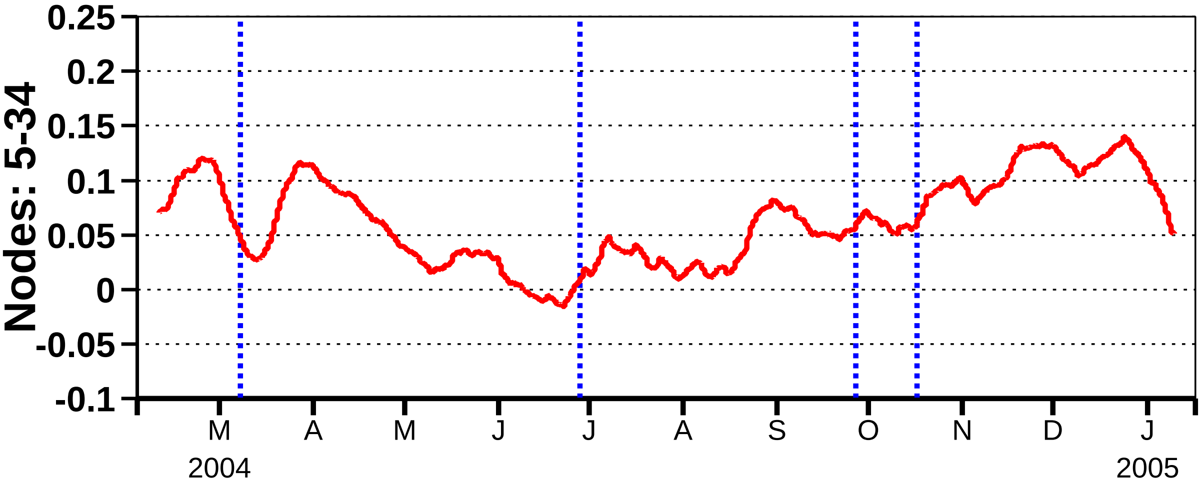
ECMWF 3-hourly First-Guess winds versus CMOD5 winds
from 2004121400 to 2005011718
= 761442, db contour levels, 5 db step, 1st level at 3.8 db
m(y-x)= -0.19 sd(y-x)= 1.62 sdx= 4.33 sdy= 4.07 pcxy= 0.963
Wind Speed (m/s) CMOD5 Wind
Wind Speed (m/s) 3-hourly First-Guess
0
5
10
15
20
25
30
35

Figure 16

ERS-2 (CMOD5)



QuikSCAT (QSCAT-1)



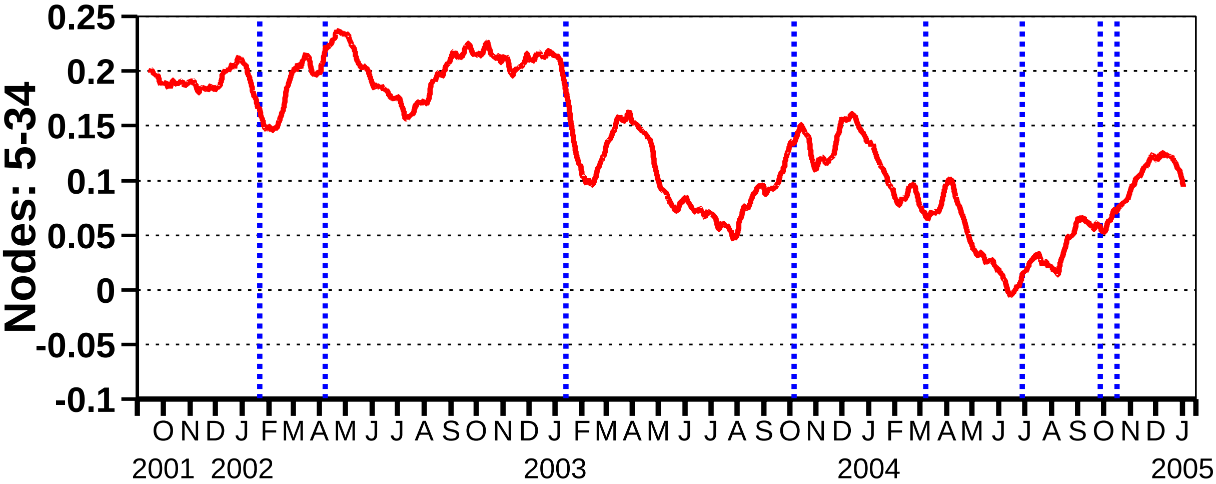


Figure 17