# Monitoring statistics of the ERS-2 scatterometer for ESA

# cycle 112

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## 1 Introduction

The quality of the UWI product was monitored at ECMWF for cycle 112. 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 112 data was received between 21:01 UTC 2 January and 20:57 UTC 6 February 2006. No data was received for the 6-hourly batches centred around 06 UTC 12 January 2006, 12 UTC 17 January 2006, 00 UTC 19 January 2006 and around 06 UTC 20 January 2006.

Data is being recorded whenever within the visibility range of a ground station. For cycle 112 data coverage was over the North-Atlantic, part of the Mediterranean, the Caribbean, the Gulf of Mexico, a small part of the Pacific west from the US, Canada and Central America, the Chinese and Japanese Sea, and the Southern Ocean south of Australia and New Zealand (see Figure 2).

During cycle 112, the asymmetry between the fore and aft incidence angles showed, by times, enhanced activity; large peaks frequently occurred. Solar wind activity was in general very low (source:www.spaceweather.com).

Compared to cycle 111, the UWI wind speed relative to ECMWF first-guess (FG) fields showed an slightly increased standard deviation (from 1.60 to 1.63 m/s), representing a natural seasonal trend, also observed one year ago. Bias levels have become more negative (from -0.69 m/s to -0.85 m/s), a similar trend being observed for QuikSCAT data within the area of ERS-2 data coverage.

During cycle 112, the performance of the UWI wind direction was nominal.

Ocean calibration shows that inter-node and inter-beam dependency of bias levels was stable (overall relative bias -0.39 dB, was -0.36 dB; see Figure 4).

The ECMWF assimilation/forecast system was changed on 2 February 2006. Atmospheric horizontal model resolution resolution was increased from 40km to 25km, and the number of vertical levels was increased from 60 to 91. Lowest model level remained at approximately 10-metre height, though. Jason altimeter wave height data and ENVISAT ASAR spectra are now used by the ocean-wave assimilation, while ERS-2 SAR spectra are no longer used. Monitoring of test runs of this new model cycle only showed minor differences between first-guess winds and scatterometer data.

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 112 averaged UWI data coverage and wind climate, Figure 3 for performance relative to FG winds.

# 2 ERS-2 statistics from 2 January to 6 February 2006

## 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.

Inter-node and inter-beam (mainly mid versus the fore/aft beam) dependencies are similar to that of cycle 111. As function of incidence angle the bias is quite flat. Average bias level remained almost unaltered (-0.39 dB, was -0.36 dB), being less negative to that for nominal data in 2000 (see Figure 1 of the reports for cycle 48 to 59).

The data volume of descending tracks was considerably lower (39%) than for ascending tracks.

## 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.

During cycle 112, several occasions of volatile behaviour occurred. Maximum peaks were around 7 degrees. During the last two week of cycle 112, however, fluctuations calmed down. Solar wind activity was in general low during cycle 112 (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, and subject to the land and sea-ice check at ECMWF (see cyclic report 88 for details).

Like for cycle 111, time series are (due to lack of statistics) very noisy, especially for the near-range nodes. Most spikes were found to be the result of low data volumes.

Compared to cycle 111, the average level was slightly higher (1.20), i.e., about 10% higher than for nominal data (see top panel Figure 1).

The fraction of data that did not pass QC is displayed in Figure 6 as well (dash curves). High rejection rates are mostly related to activity of the $k_p$-yaw flag.

## 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 111, such collocations are isolated, and usually indicate meteorologicaly active regions, for which UWI data and ECMWF model field show reasonably small differences in phase and/or intensity.

Two cases where UWI and ECMWF wind speed differ significantly are presented in Figure 12. Top panel shows a case in the Labrador Sea, on 23 January 2006. It shows a likely degraded patch of ERS-2 winds in a field of, in general, strong winds.

The lower panel shows a situation North of Spitsbergen (25 January 2006). The strong ERS-2 winds at the top row possibly indicate a situation of ice contamination. Similar situations, indicating imperfections in the sea-ice map used at ECMWF, occur frequently, as can be seen in the lower panel of Figure 11.

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 has become more negative and are now slightly more negative than that for nominal data in 2000 (UWI: -0.85 m/s now, was -0.79 m/s for cycle 59).

The trend of negative bias was also observed in 2004 (see Figure 1). As was highlighted in previous cyclic reports, it is believed that this yearly trend is induced by changing local geophysical conditions, variation in the atmospheric density stratification being the most likely candidate. Strong indication for this is a similar trend observed for QuikSCAT data when restricted to an area well-covered by ERS-2 (20N-90N, 80W-20E). Figure 17 shows time series for that area for both ERS-2

| | cycle 111 | | cycle 112 | |
|---|---|---|---|---|
| | UWI | CMOD4 | UWI | CMOD4 |
| speed STDV | 1.60 | 1.59 | 1.63 | 1.62 |
| node 1-2 | 1.62 | 1.59 | 1.77 | 1.72 |
| node 3-4 | 1.58 | 1.57 | 1.65 | 1.63 |
| node 5-7 | 1.54 | 1.53 | 1.58 | 1.58 |
| node 8-10 | 1.56 | 1.55 | 1.57 | 1.57 |
| node 11-14 | 1.58 | 1.57 | 1.56 | 1.56 |
| node 15-19 | 1.59 | 1.58 | 1.57 | 1.56 |
| speed BIAS | -0.69 | -0.67 | -0.85 | -0.84 |
| node 1-2 | -1.28 | -1.26 | -1.51 | -1.47 |
| node 3-4 | -1.00 | -0.95 | -1.21 | -1.14 |
| node 5-7 | -0.75 | -0.71 | -0.92 | -0.89 |
| node 8-10 | -0.57 | -0.55 | -0.69 | -0.68 |
| node 11-14 | -0.48 | -0.47 | -0.60 | -0.60 |
| node 15-19 | -0.46 | -0.45 | -0.62 | -0.63 |
| direction STDV | 52.6 | 19.5 | 29.7 | 19.1 |
| direction BIAS | -1.0 | -2.9 | -2.9 | -2.6 |

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

(top panel) and QuikSCAT (lower panel) for the period between 1 January 2004 and 6 February 2006 (end of cycle 112). Results are displayed for at ECMWF actively assimilated data, i.e., CMOD5 winds for ERS-2 and 4%-reduced QuikSCAT winds on a 50km resolution.

The standard deviation of UWI wind speed compared to cycle 111 has slightly increased (1.63 m/s, was 1.60 m/s), the main reason being a less mild wind climate.

For cycle 112 the (UWI - FG) direction standard deviations were mostly ranging between 20 and 40 degrees (Figure 8), being nominal variations. Averaged over the entire cyclic period, STDV for UWI wind direction was 29.7 degrees. This was much better than for cycle 111 (52.6 degrees), since within that period, de-aliasing had been troublesome. Performance for at ECMWF de-aliased winds was 19.1 degrees, almost identical to that for cycle 111 (STDV 19.5 degrees).

## 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 by 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.

Winds derived on the basis of CMOD5 are displayed in Figure 16. The relative standard deviation is lower than for CMOD4 winds (1.60 m/s versus 1.64 m/s). Compared to ECMWF FG, CMOD5 winds are 0.30 m/s slower; this average arising from mostly moderate winds. However, for the more extreme winds there is some tendency of underestimation as well.

# 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 6 February 2006 (end cycle 112) 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 a global set, the second one for a regional set (for details see the corresponding cyclic report). 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 extremes in node-wise 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 $< \sigma_0^{0.625} > / <$ 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). 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 for winds stronger 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 112 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 a case on 23 January 2006 in the Labrador Sea (top panel) and for a situation North of Spitsbergen on 25 January 2006 (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 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 winds stronger 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:** Wind-speed bias relative to FG winds for actively assimilated ERS-2 winds (based on CMOD5) for nodes 1-19 (top panel) respectively 50-km QuikSCAT (based on the QSCAT-1 model function and reduced by 4%) for nodes 5-34 (lower panel), averaged over the area (20N-90N, 80W-20E), and displayed for the period 01 January 2004 - 6 February 2006. Fat curves represent centred 15-day running means, thin curves values for 6-hourly periods. Vertical dashed blue lines mark ECMWF model changes.

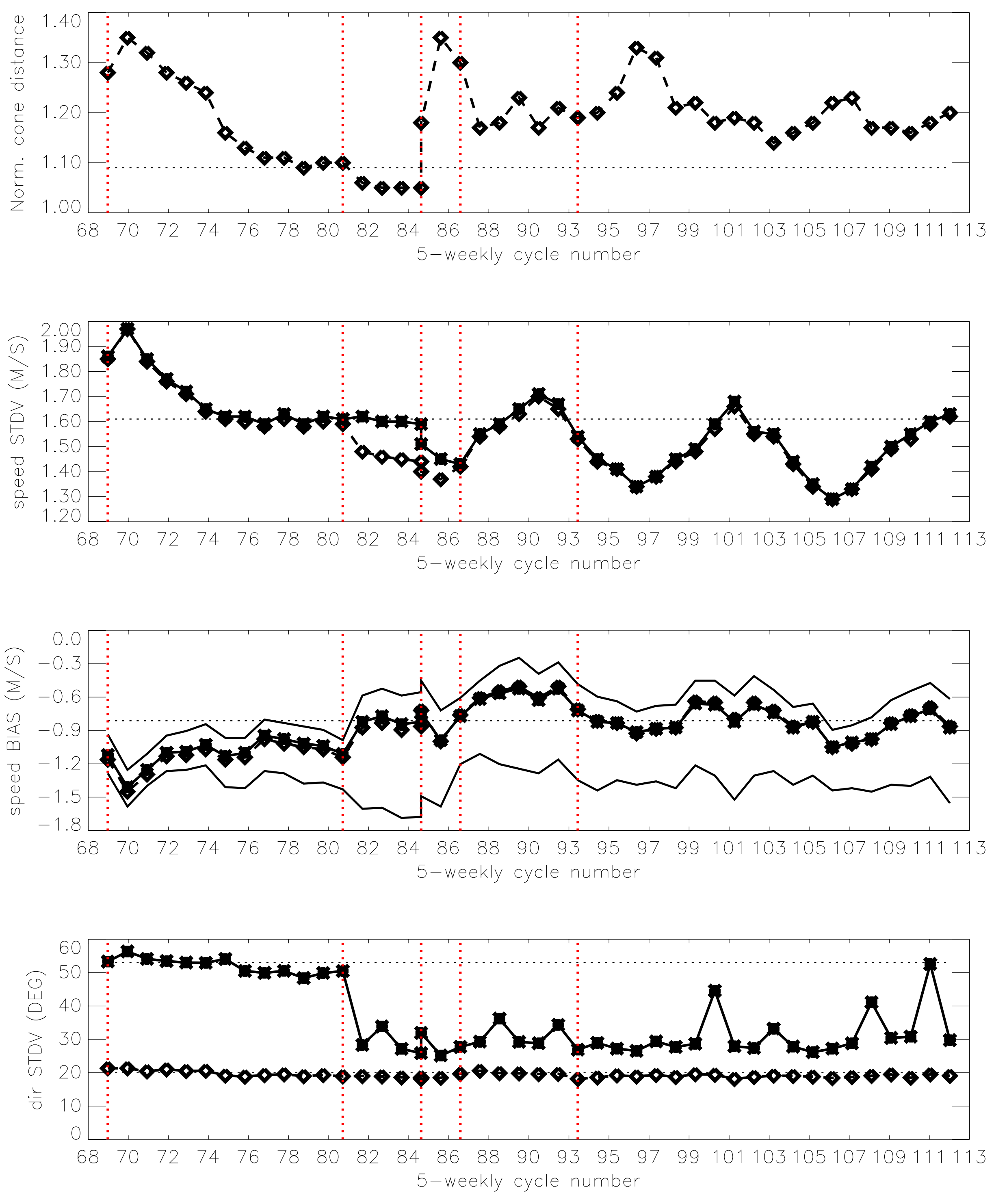

Norm. cone distance
speed STDV (M/S)
speed BIAS (M/S)
dir STDV (DEG)
5−weekly cycle number

Figure 1

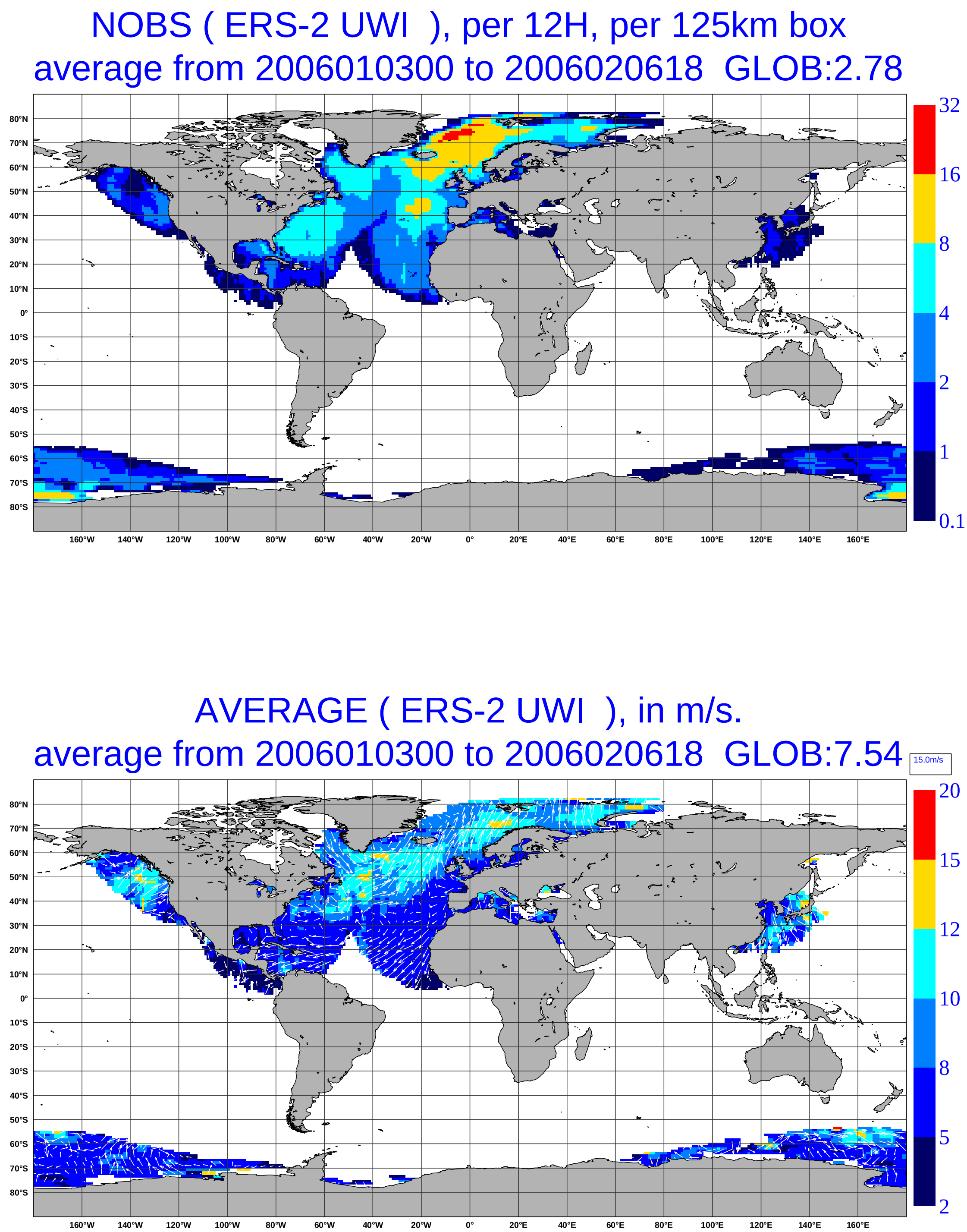
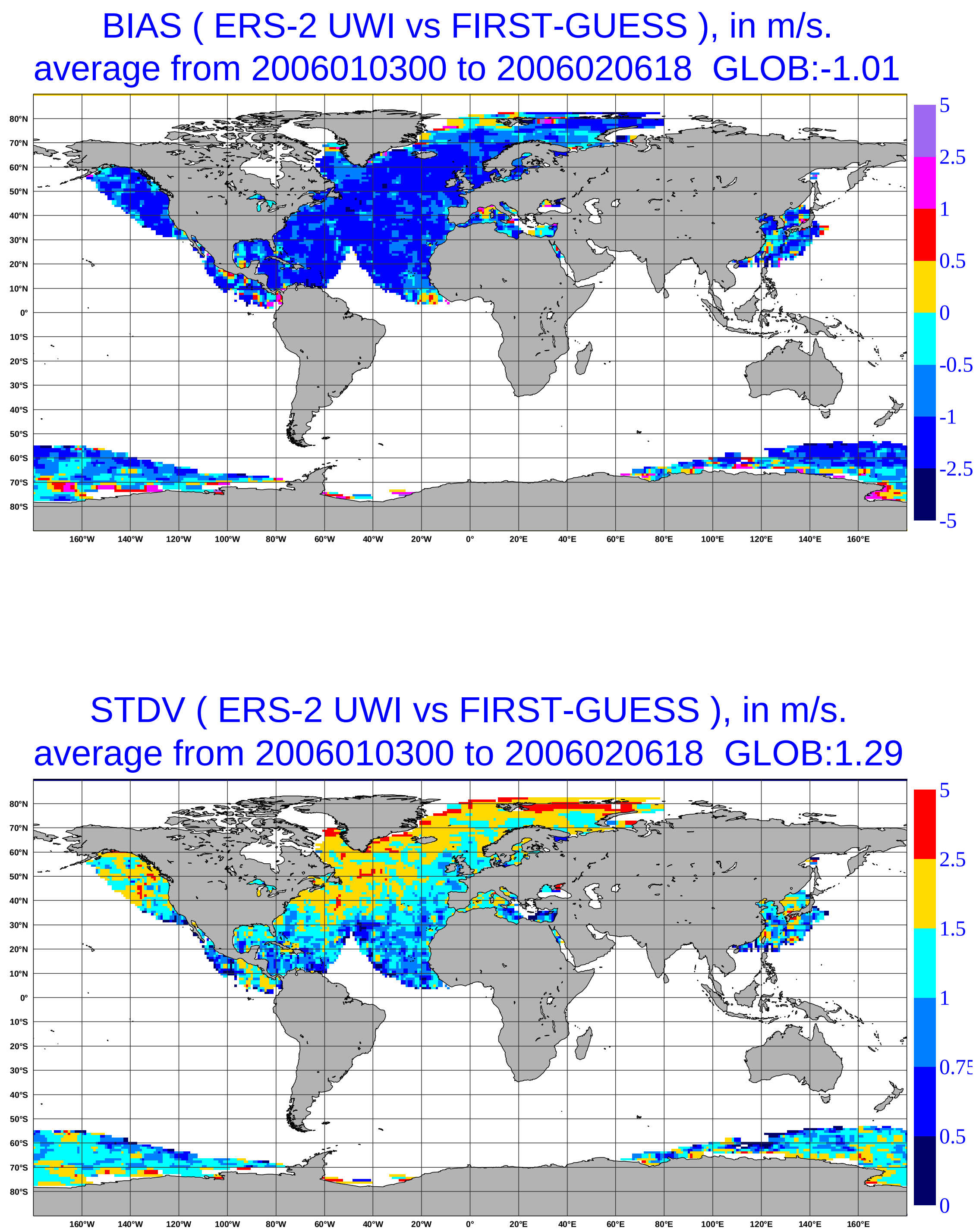
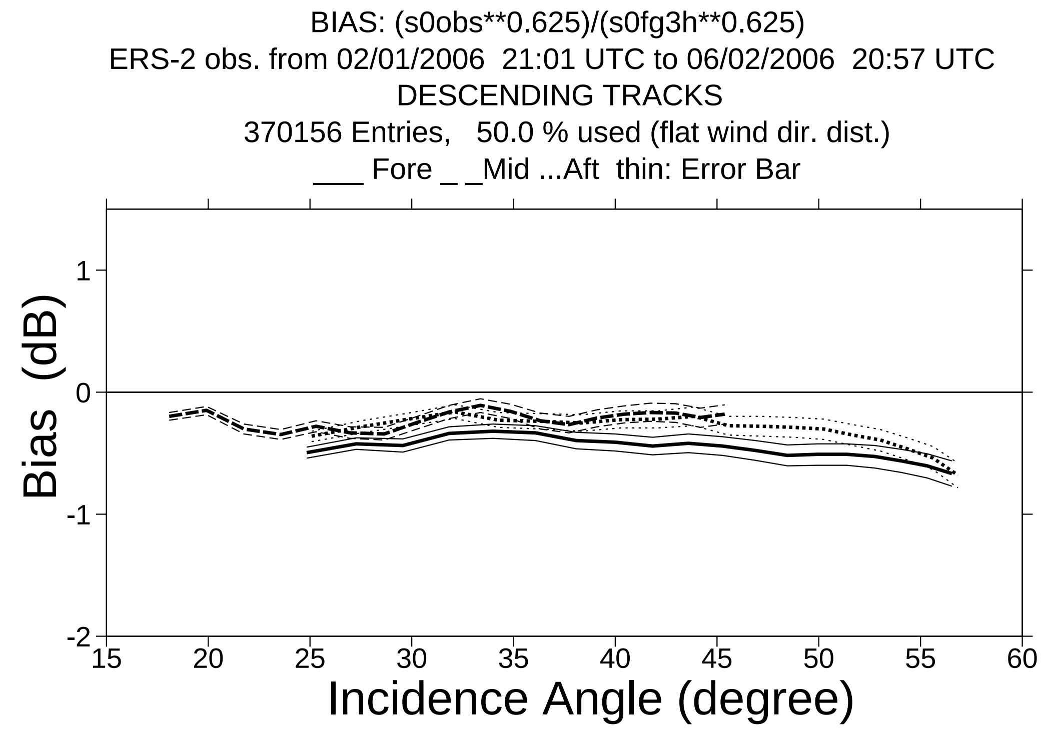

NOBS ( ERS-2 UWI ), per 12H, per 125km box
average from 2006010300 to 2006020618 GLOB:2.78
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
70°S
80°S
160°W 140°W 120°W 100°W 80°W 60°W 40°W 20°W 0° 20°E 40°E 60°E 80°E 100°E 120°E 140°E 160°E
32
16
8
4
2
1
0.1
AVERAGE ( ERS-2 UWI ), in m/s.
average from 2006010300 to 2006020618 GLOB:7.54
15.0m/s
20
15
12
10
8
5
2

Figure 2

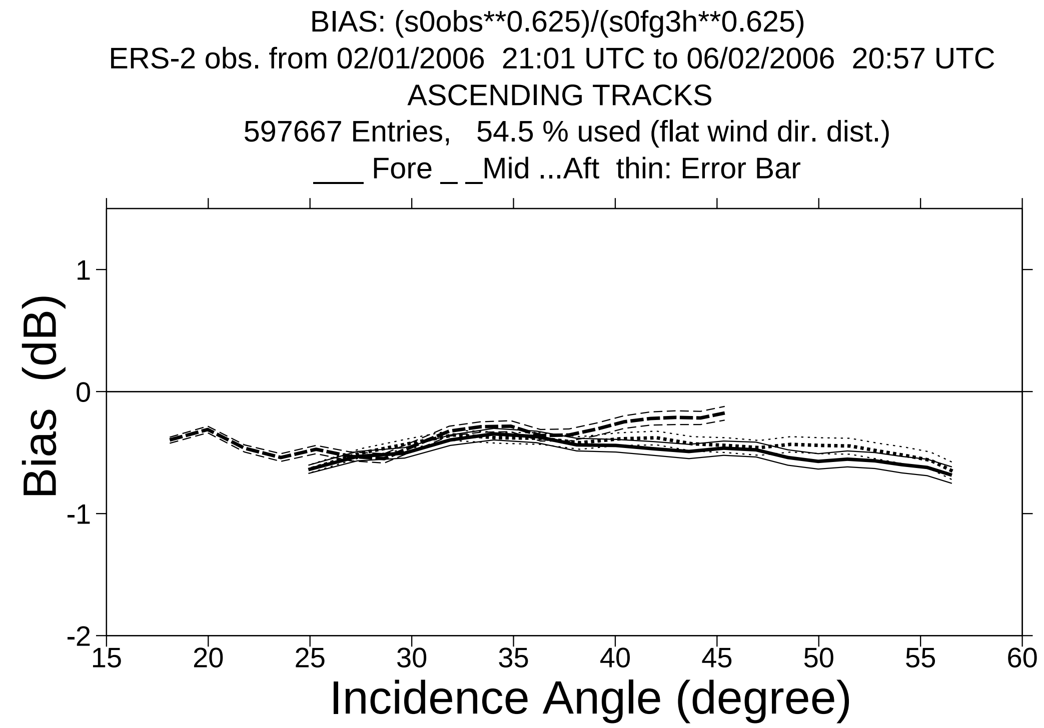


BIAS ( ERS-2 UWI vs FIRST-GUESS ), in m/s.
average from 2006010300 to 2006020618 GLOB:-1.01
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
70°S
80°S
160°W 140°W 120°W 100°W 80°W 60°W 40°W 20°W 0° 20°E 40°E 60°E 80°E 100°E 120°E 140°E 160°E
5
2.5
1
0.5
0
-0.5
-1
-2.5
-5
STDV ( ERS-2 UWI vs FIRST-GUESS ), in m/s.
average from 2006010300 to 2006020618 GLOB:1.29
5
2.5
1.5
1
0.75
0.5
0


Figure 3



BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 02/01/2006 21:01 UTC to 06/02/2006 20:57 UTC
DESCENDING TRACKS
370156 Entries, 50.0 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
-2
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)

BIAS: (s0obs**0.625)/(s0fg3h**0.625)
ERS-2 obs. from 02/01/2006 21:01 UTC to 06/02/2006 20:57 UTC
ASCENDING TRACKS
597667 Entries, 54.5 % used (flat wind dir. dist.)
___ Fore _ _Mid ...Aft thin: Error Bar
Bias (dB)
1
0
-1
-2
15
20
25
30
35
40
45
50
55
60
Incidence Angle (degree)


Figure 4

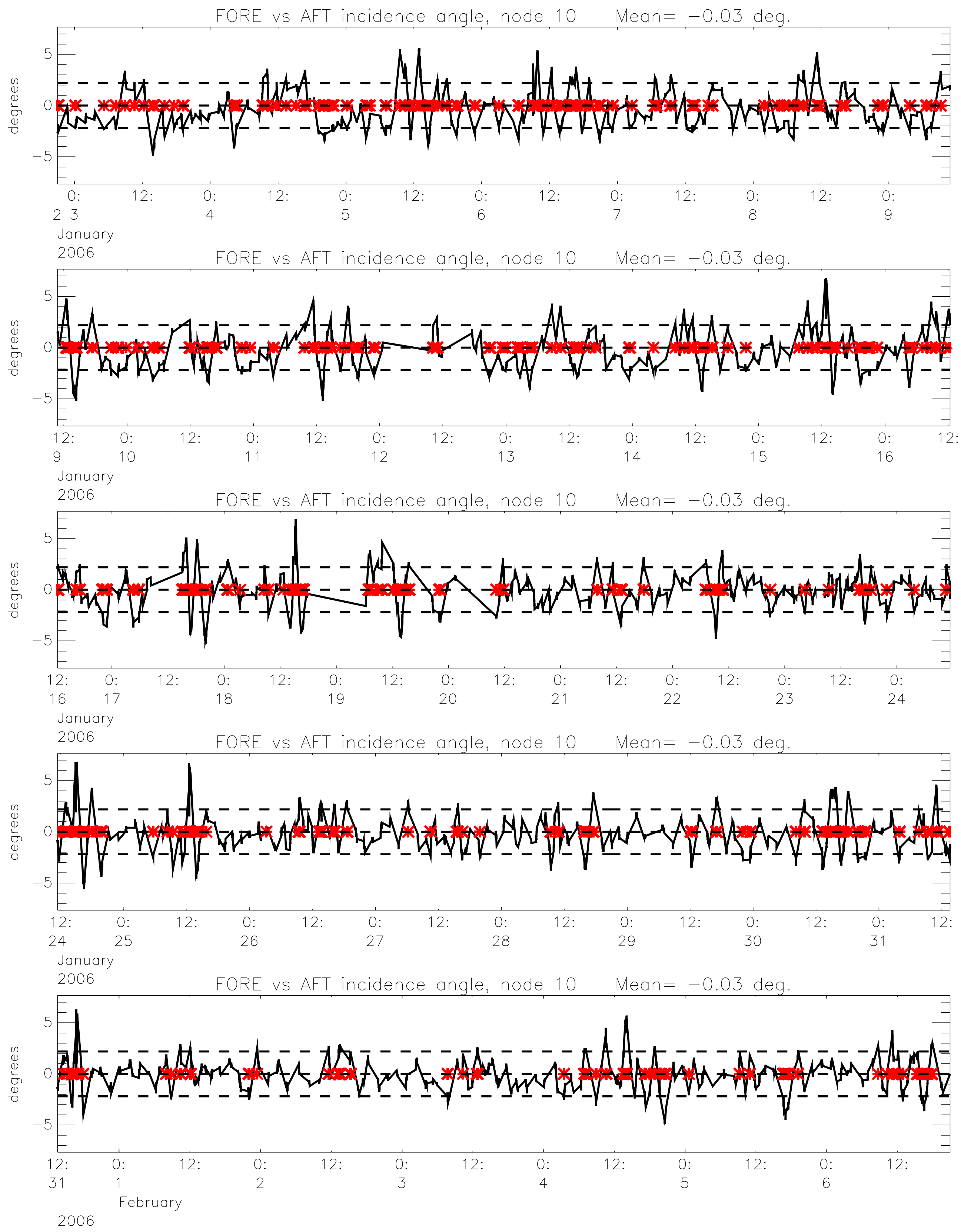

FORE vs AFT incidence angle, node 10 Mean= −0.03 deg.
degrees
5
0
−5
0: 2 3
12:
0: 4
12:
0: 5
12:
0: 6
12:
0: 7
12:
0: 8
12:
0: 9
January 2006
FORE vs AFT incidence angle, node 10 Mean= −0.03 deg.
degrees
12: 9
0: 10
12:
0: 11
12:
0: 12
12:
0: 13
12:
0: 14
12:
0: 15
12:
0: 16
12:
January 2006
FORE vs AFT incidence angle, node 10 Mean= −0.03 deg.
degrees
12: 16
0: 17
12:
0: 18
12:
0: 19
12:
0: 20
12:
0: 21
12:
0: 22
12:
0: 23
12:
0: 24
January 2006
FORE vs AFT incidence angle, node 10 Mean= −0.03 deg.
degrees
12: 24
0: 25
12:
0: 26
12:
0: 27
12:
0: 28
12:
0: 29
12:
0: 30
12:
0: 31
12:
January 2006
FORE vs AFT incidence angle, node 10 Mean= −0.03 deg.
degrees
12: 31
0: 1
12:
0: 2
12:
0: 3
12:
0: 4
12:
0: 5
12:
0: 6
12:
February
2006

Figure 5

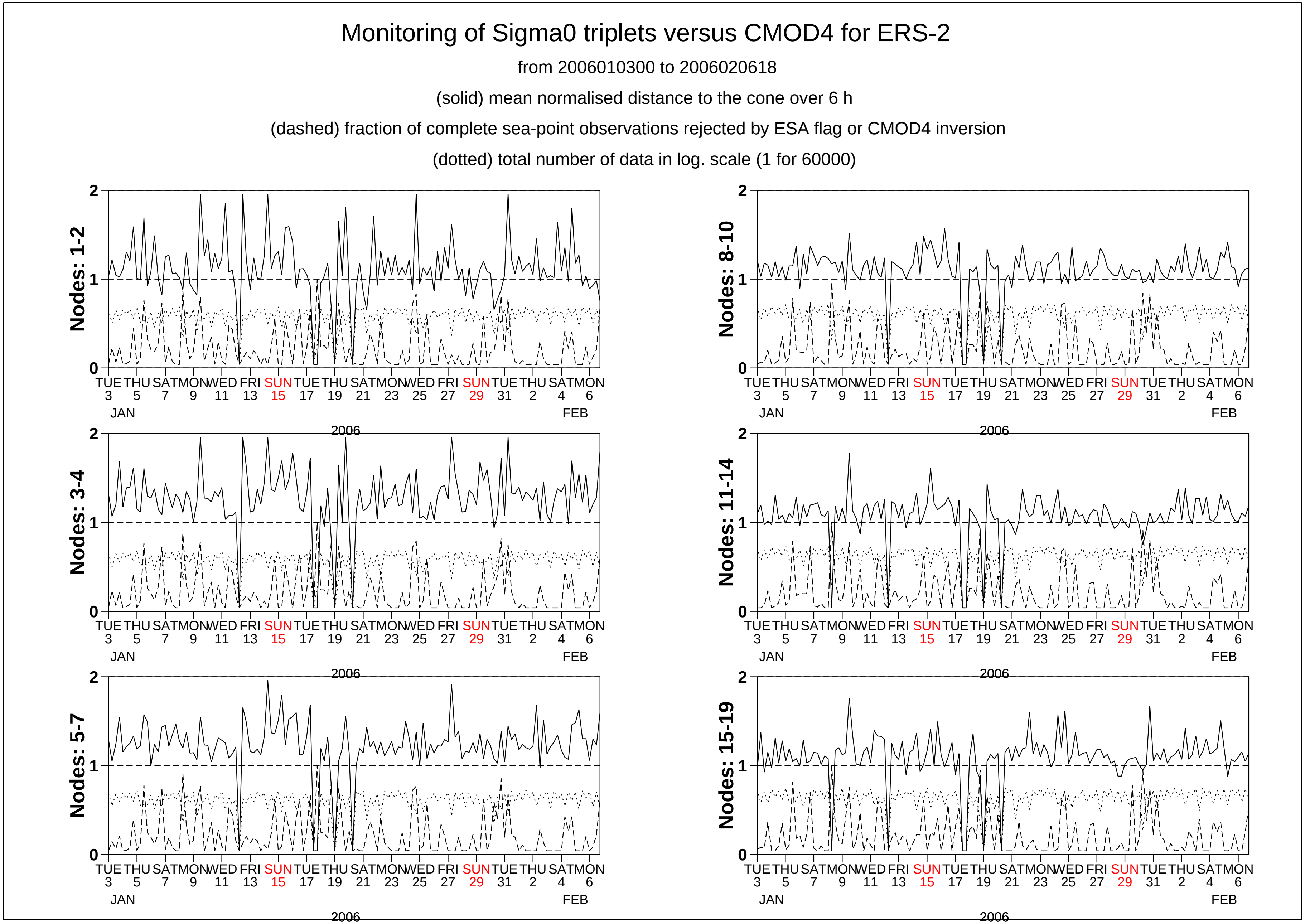
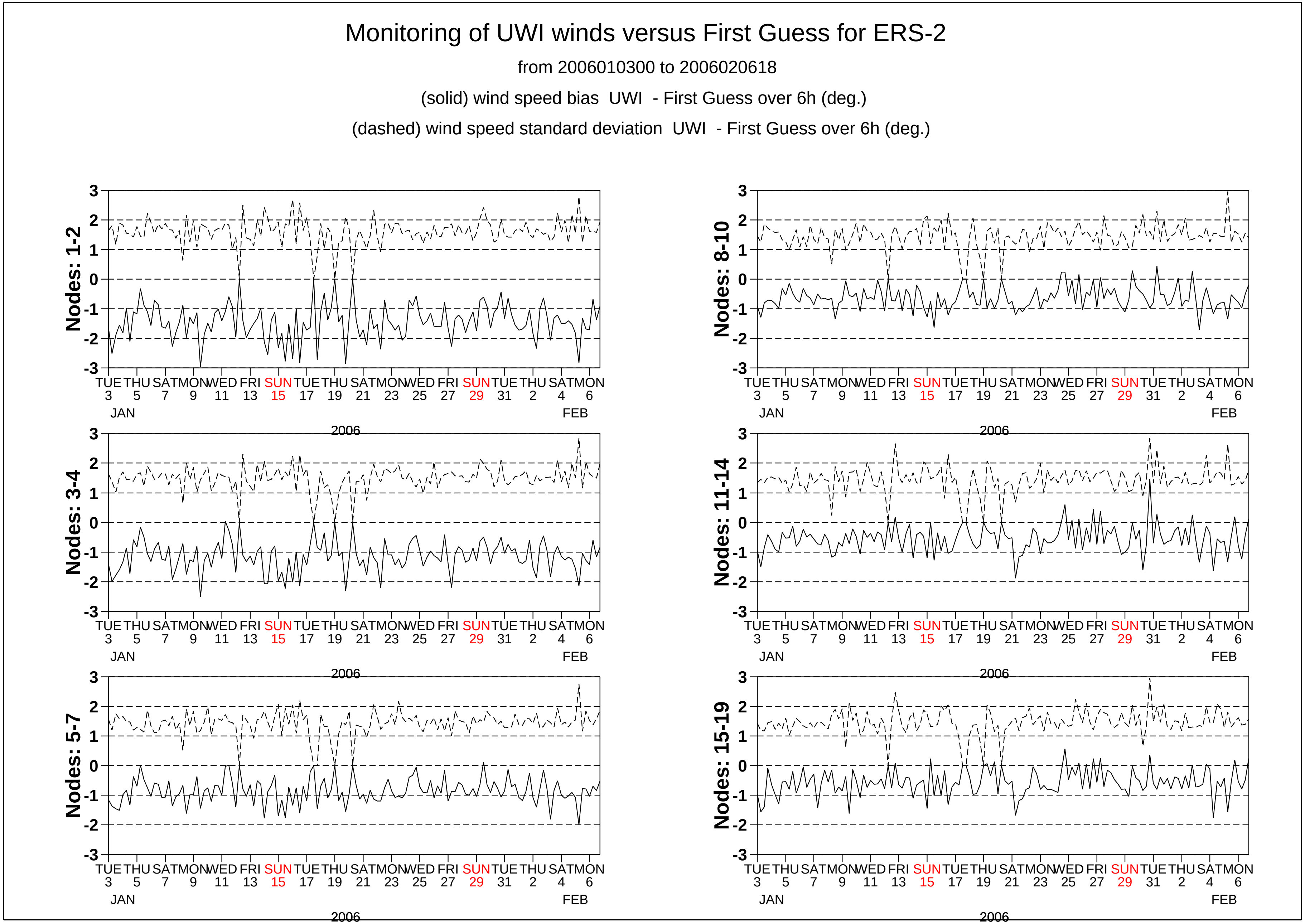

Monitoring of Sigma0 triplets versus CMOD4 for ERS-2
from 2006010300 to 2006020618
(solid) mean normalised distance to the cone over 6 h
(dashed) fraction of complete sea-point observations rejected by ESA flag or CMOD4 inversion
(dotted) total number of data in log. scale (1 for 60000)
Nodes: 1-2
Nodes: 8-10
Nodes: 3-4
Nodes: 11-14
Nodes: 5-7
Nodes: 15-19
TUE THU SAT MON WED FRI SUN TUE THU SAT MON WED FRI SUN TUE THU SAT MON
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6
JAN
FEB
2006

Figure 6



Monitoring of UWI winds versus First Guess for ERS-2
from 2006010300 to 2006020618
(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: 8-10
Nodes: 3-4
Nodes: 11-14
Nodes: 5-7
Nodes: 15-19
TUE THU SAT MON WED FRI SUN TUE THU SAT MON WED FRI SUN TUE THU SAT MON
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6
JAN
FEB
2006


Figure 7

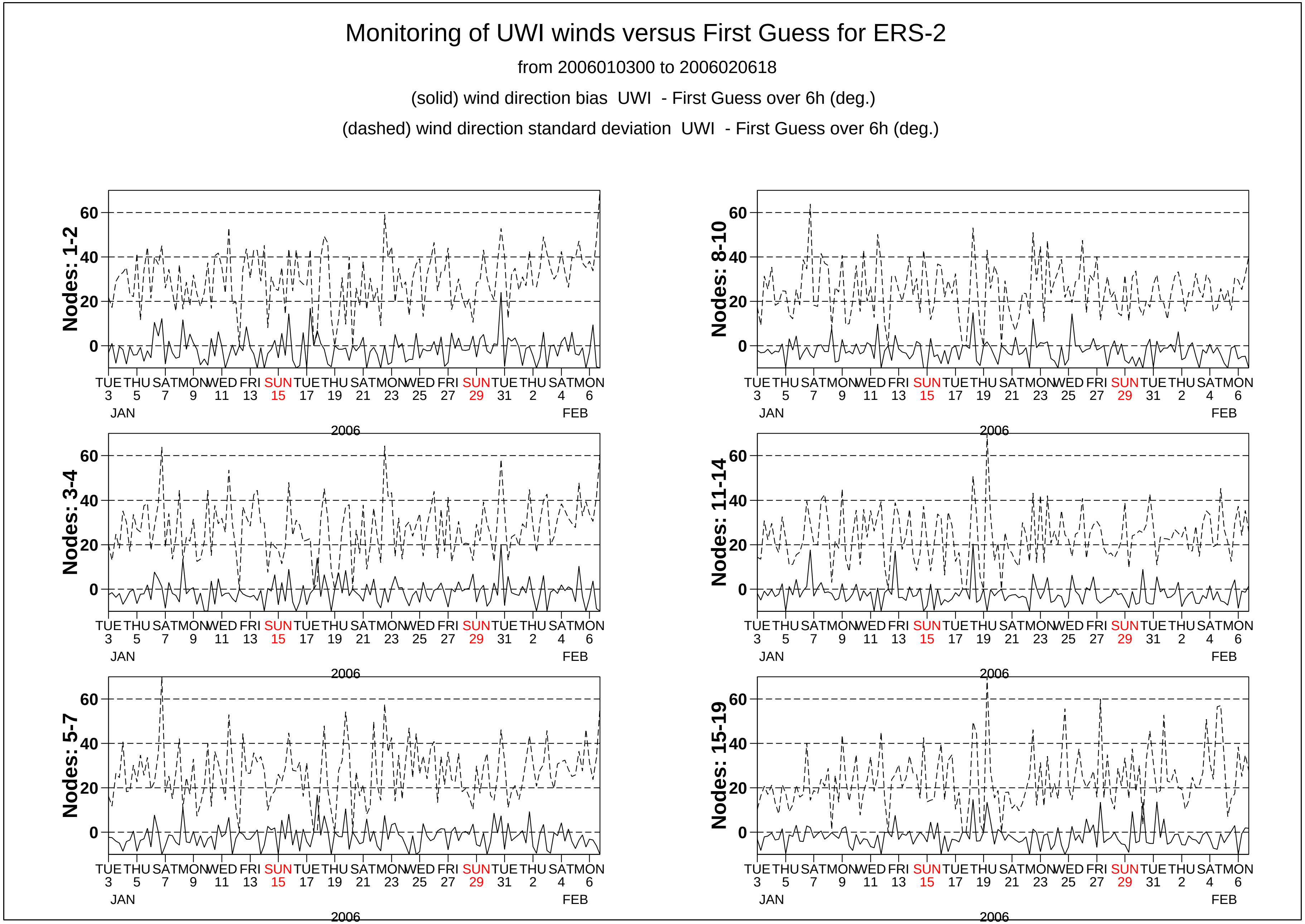
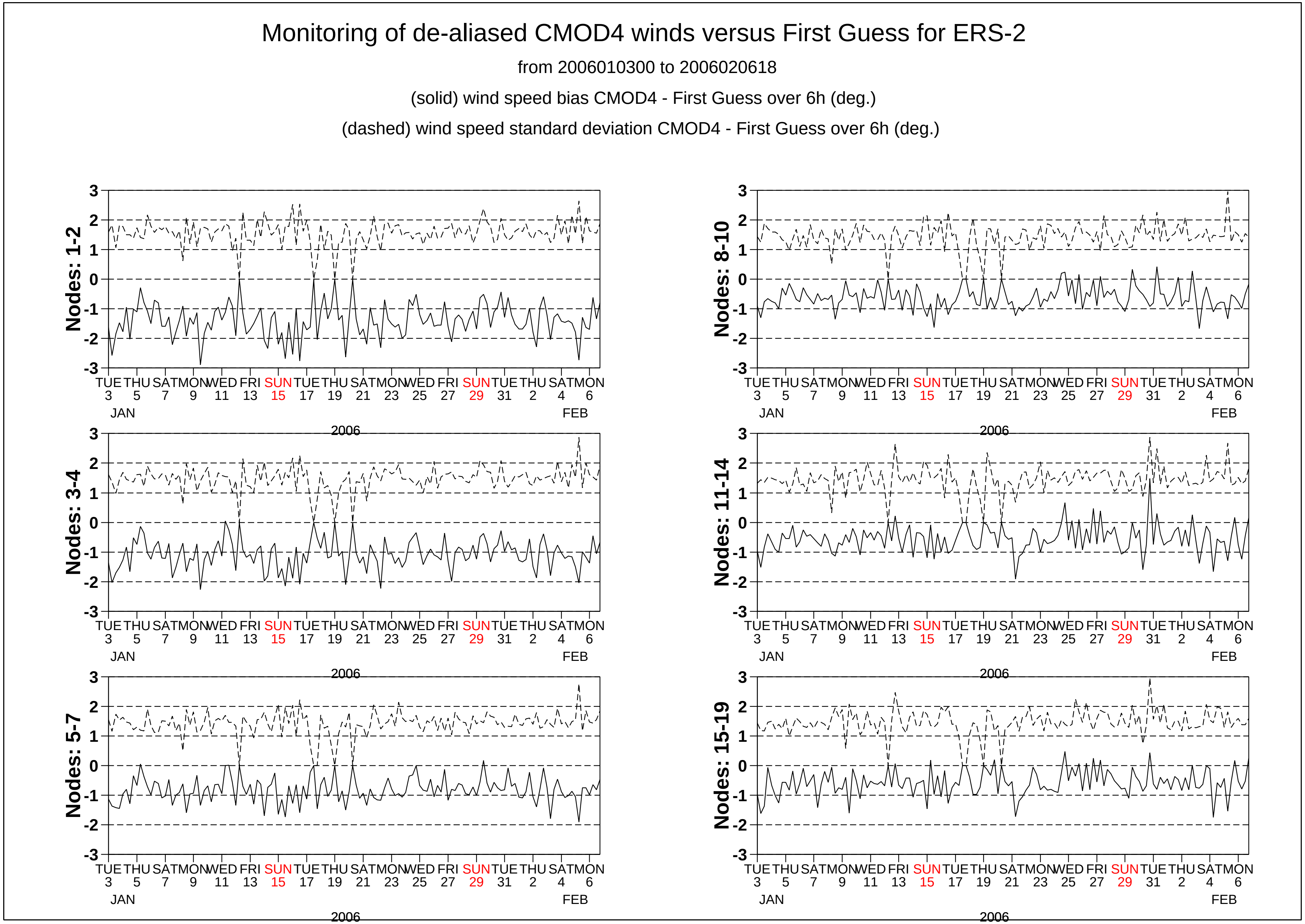

Monitoring of UWI winds versus First Guess for ERS-2
from 2006010300 to 2006020618
(solid) wind direction bias UWI - First Guess over 6h (deg.)
(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 8-10
Nodes: 3-4
Nodes: 11-14
Nodes: 5-7
Nodes: 15-19
0
20
40
60
TUE THU SAT MON WED FRI SUN TUE THU SAT MON WED FRI SUN TUE THU SAT MON
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6
JAN
FEB
2006

Figure 8



Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2006010300 to 2006020618
(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
TUE THU SAT MON WED FRI SUN TUE THU SAT MON WED FRI SUN TUE THU SAT MON
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6
JAN
FEB
2006


Figure 9

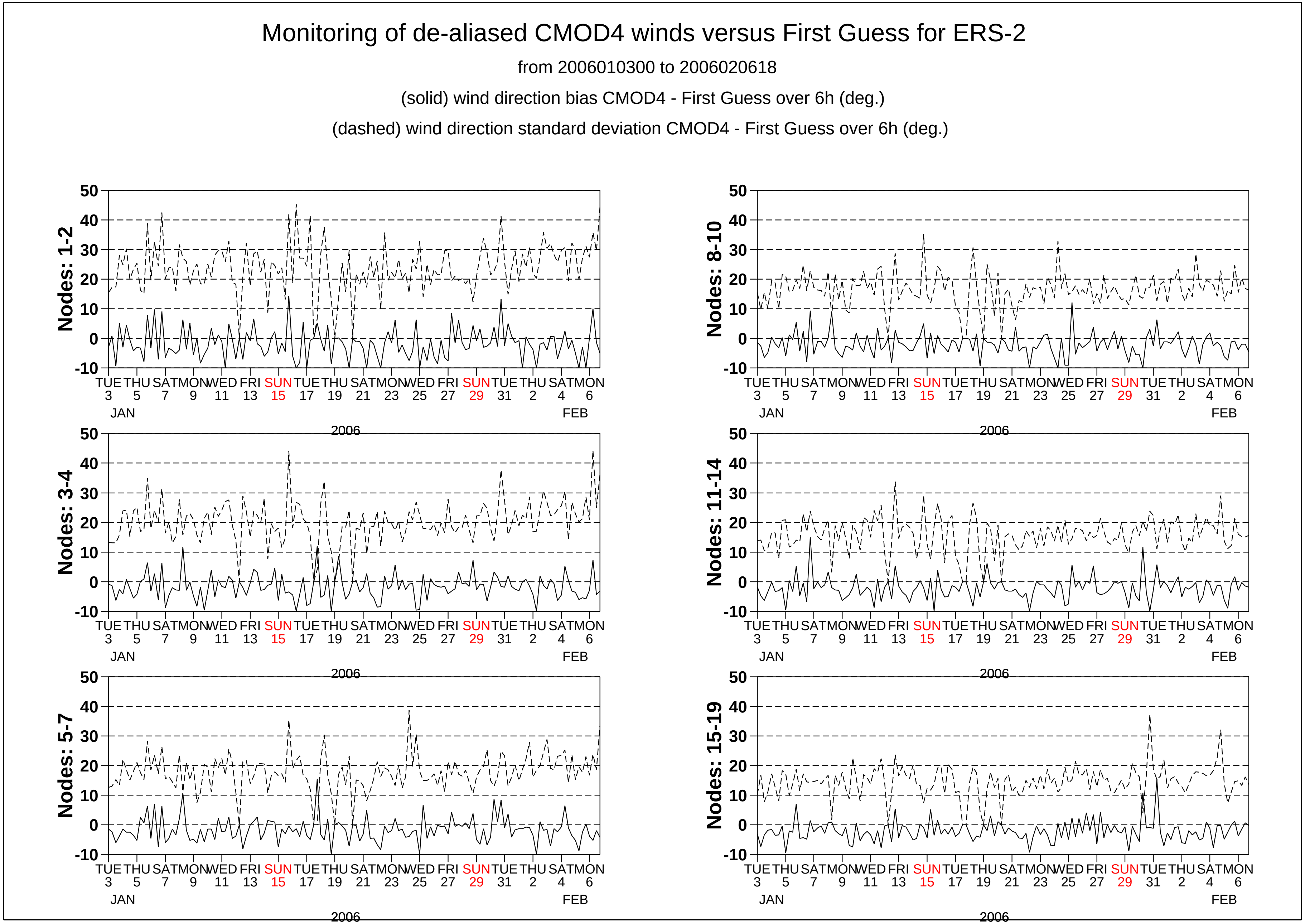
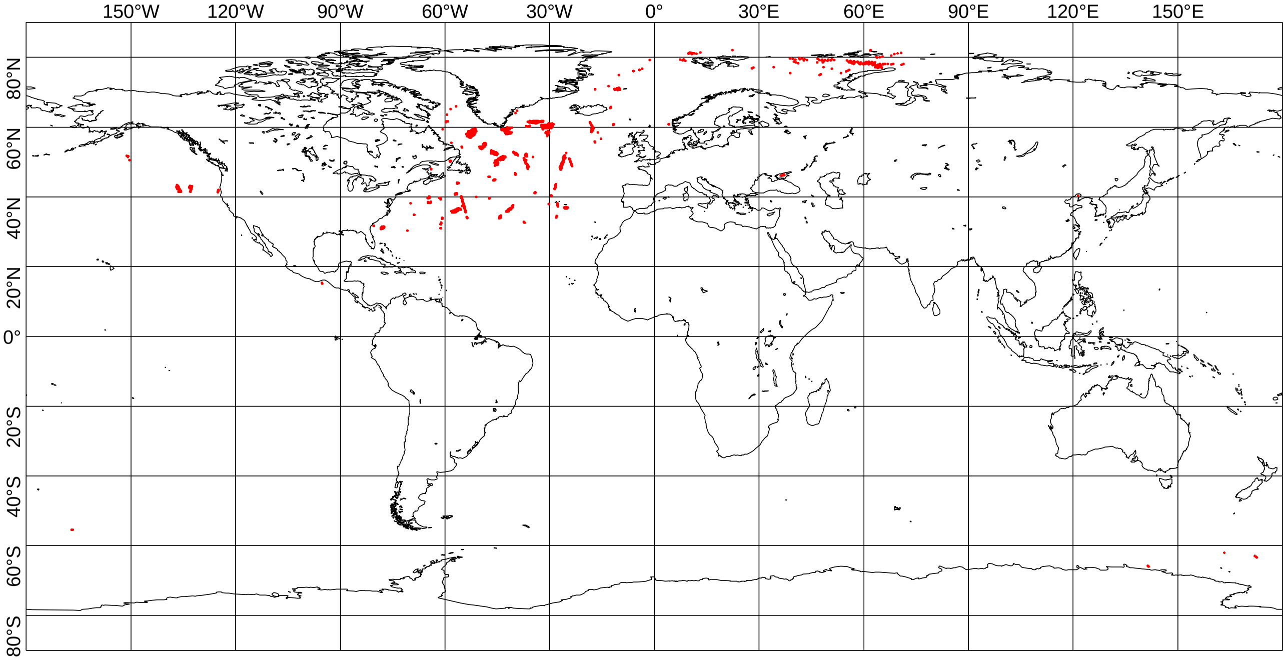

Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2
from 2006010300 to 2006020618
(solid) wind direction bias CMOD4 - First Guess over 6h (deg.)
(dashed) wind direction standard deviation CMOD4 - First Guess over 6h (deg.)
Nodes: 1-2
Nodes: 8-10
Nodes: 3-4
Nodes: 11-14
Nodes: 5-7
Nodes: 15-19
50
40
30
20
10
0
-10
TUE THU SAT MON WED FRI SUN TUE THU SAT MON WED FRI SUN TUE THU SAT MON
3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6
JAN
FEB
2006

Figure 10

UWI winds more than 8 m/s weaker than FGAT
CYCLE 112, 2006010300 to 2006020618, QC on ESA flags




UWI winds more than 8 m/s stronger than FGAT
CYCLE 112, 2006010300 to 2006020618, QC on ESA flags

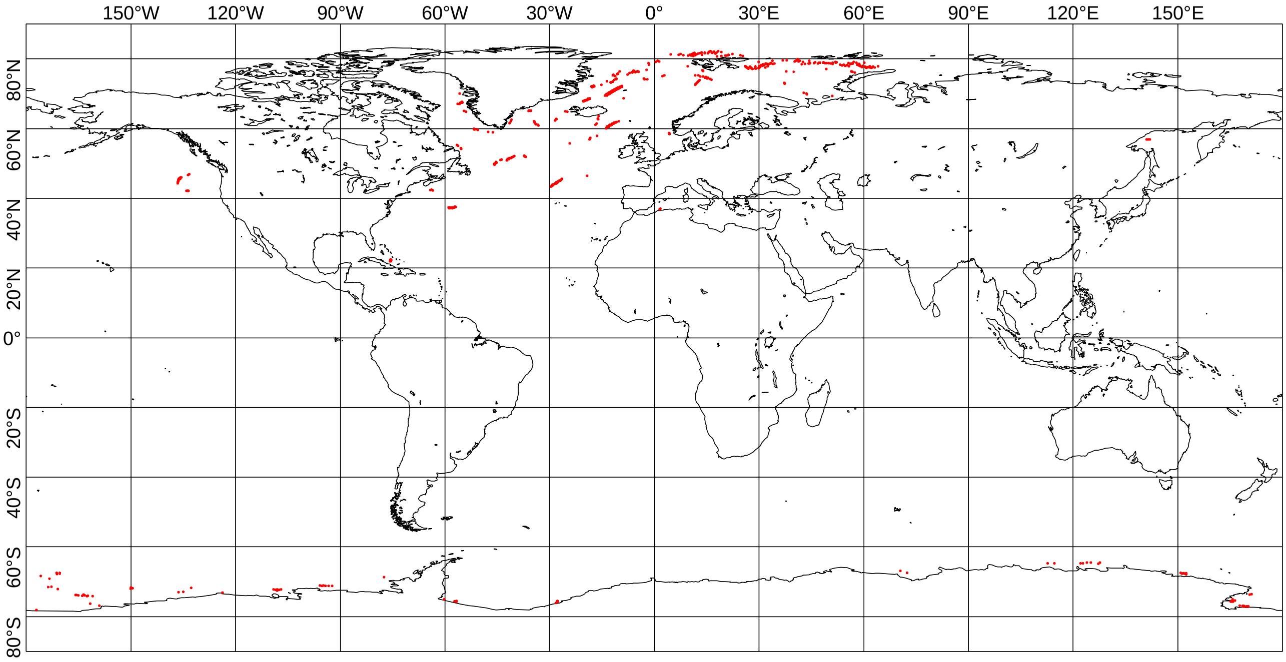
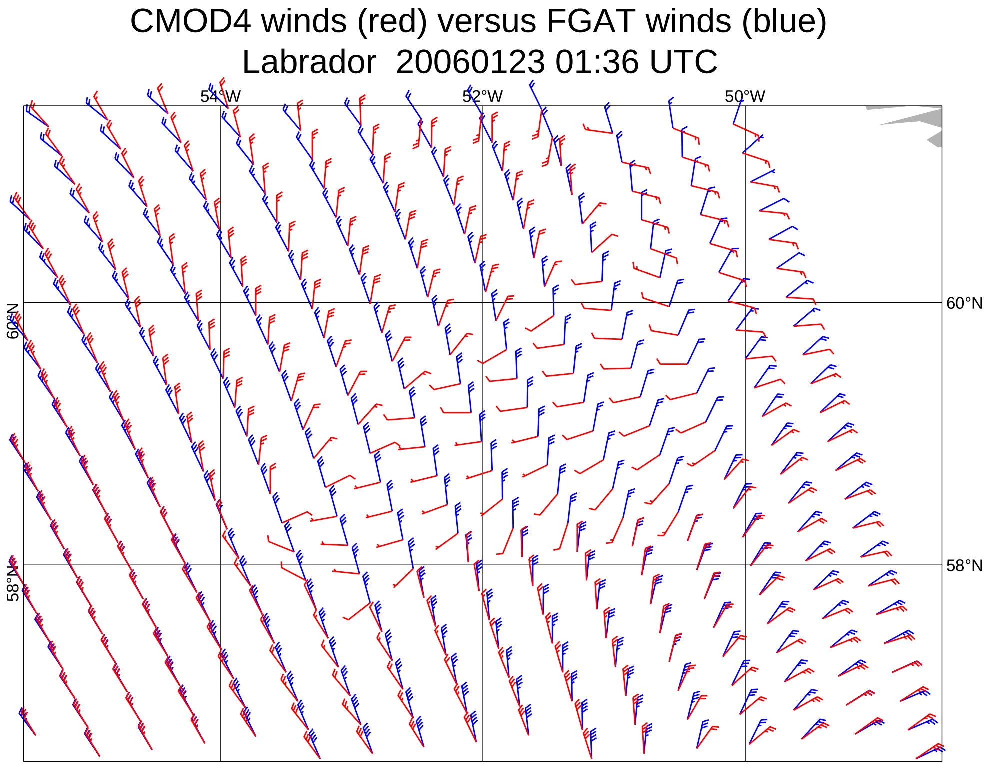



Figure 11


CMOD4 winds (red) versus FGAT winds (blue)
Labrador 20060123 01:36 UTC
54°W
52°W
50°W
60°N
58°N

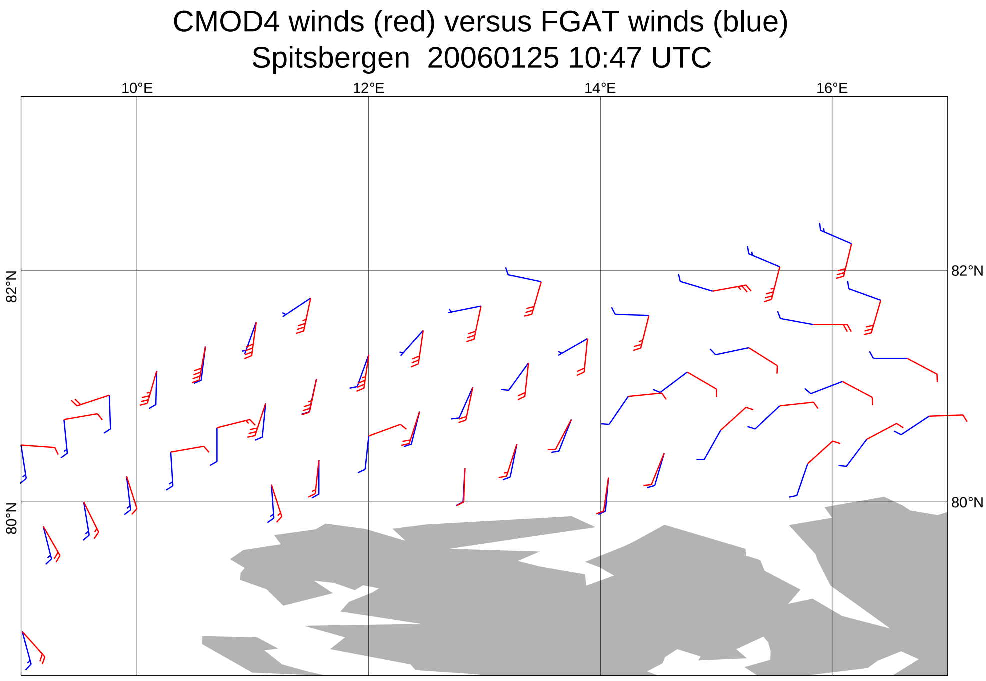

CMOD4 winds (red) versus FGAT winds (blue)
Spitsbergen 20060125 10:47 UTC
10°E
12°E
14°E
16°E
82°N
80°N

Figure 12

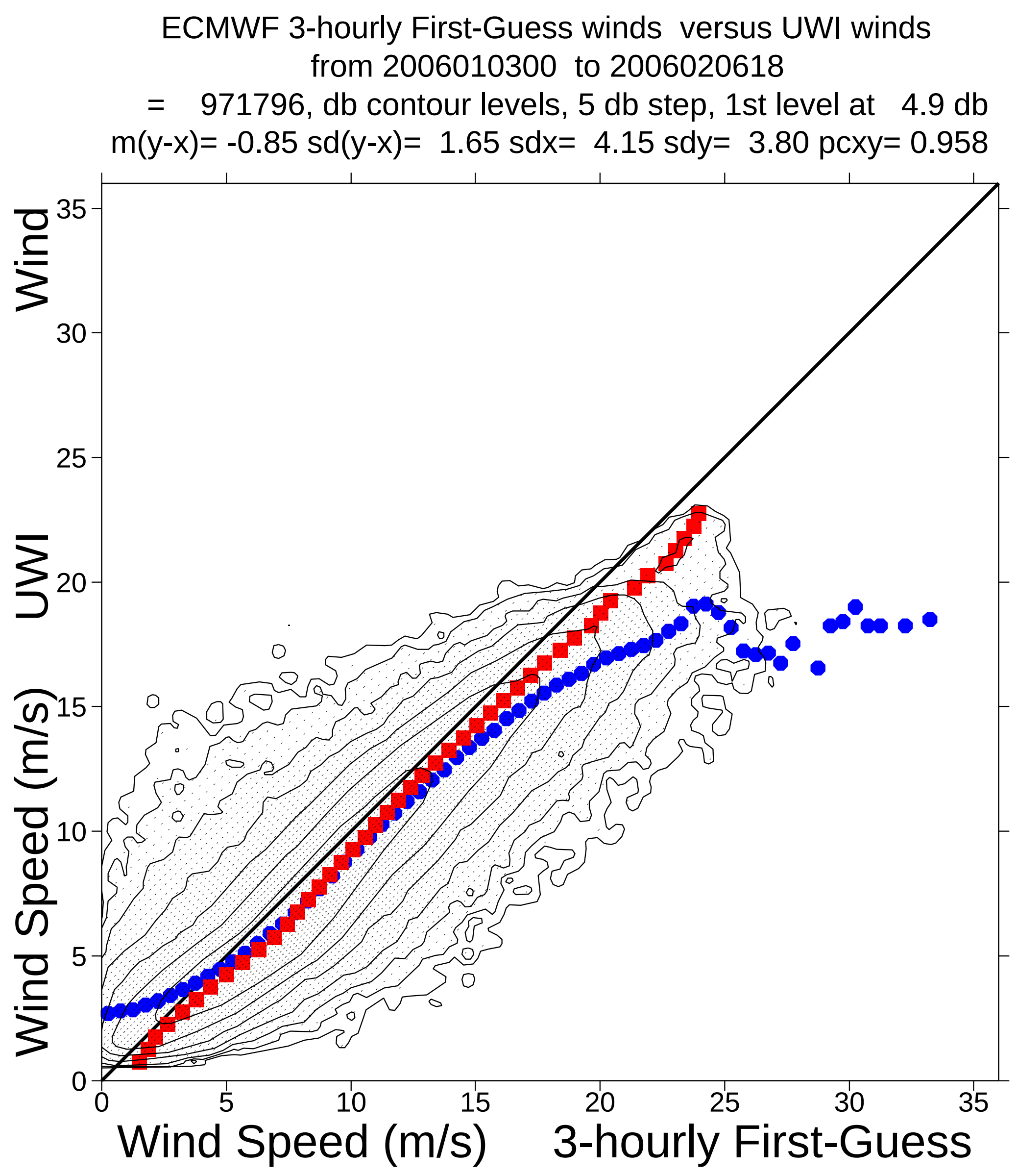

ECMWF 3-hourly First-Guess winds versus UWI winds
from 2006010300 to 2006020618
= 971796, db contour levels, 5 db step, 1st level at 4.9 db
m(y-x)= -0.85 sd(y-x)= 1.65 sdx= 4.15 sdy= 3.80 pcxy= 0.958
Wind Speed (m/s) UWI Wind
Wind Speed (m/s) 3-hourly First-Guess
0
5
10
15
20
25
30
35

Figure 13

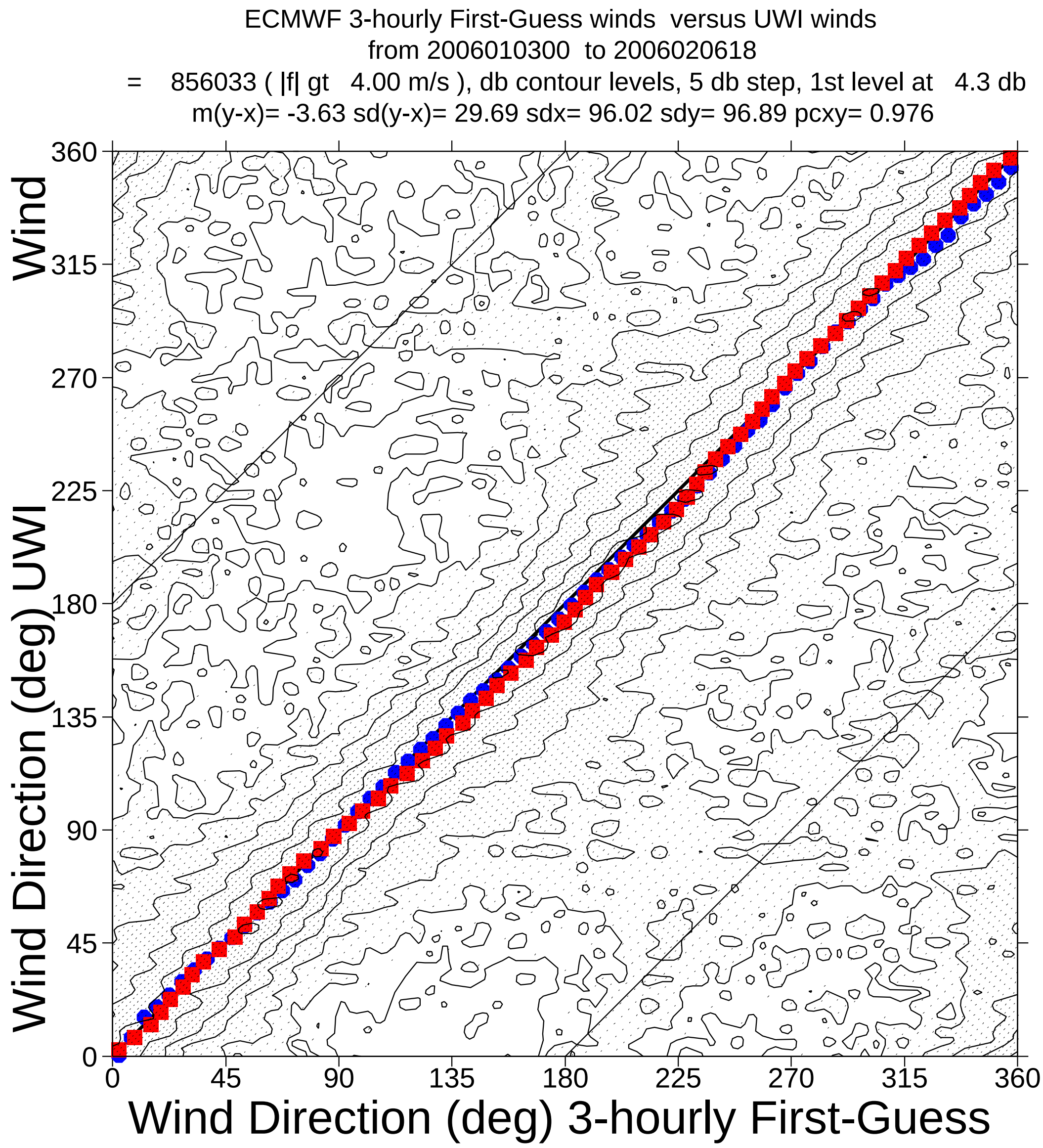
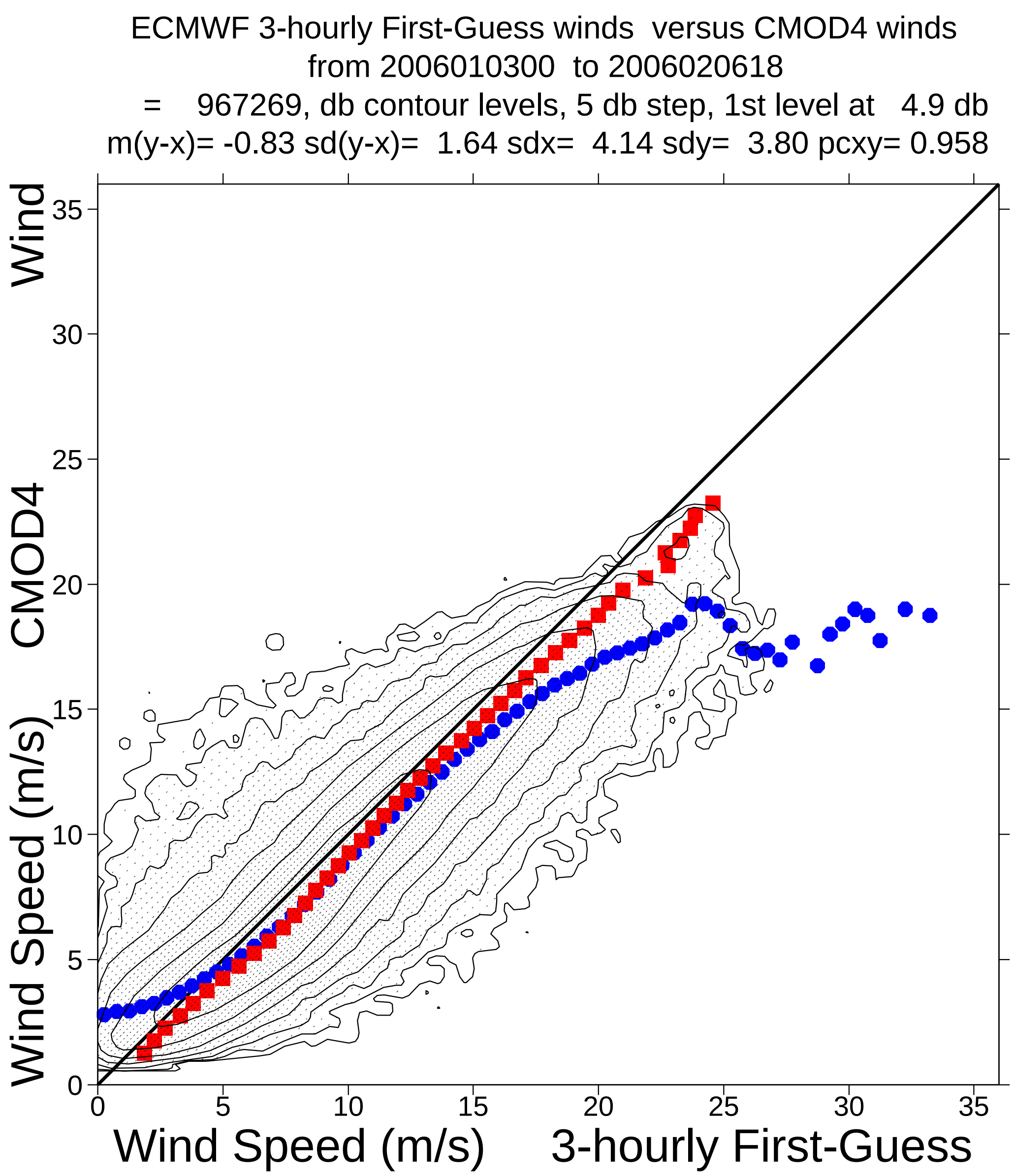

ECMWF 3-hourly First-Guess winds versus UWI winds
from 2006010300 to 2006020618
= 856033 ( |f| gt 4.00 m/s ), db contour levels, 5 db step, 1st level at 4.3 db
m(y-x)= -3.63 sd(y-x)= 29.69 sdx= 96.02 sdy= 96.89 pcxy= 0.976
Wind Direction (deg) UWI Wind
Wind Direction (deg) 3-hourly First-Guess
0
45
90
135
180
225
270
315
360

Figure 14



ECMWF 3-hourly First-Guess winds versus CMOD4 winds
from 2006010300 to 2006020618
= 967269, db contour levels, 5 db step, 1st level at 4.9 db
m(y-x)= -0.83 sd(y-x)= 1.64 sdx= 4.14 sdy= 3.80 pcxy= 0.958
Wind Speed (m/s) CMOD4 Wind
Wind Speed (m/s) 3-hourly First-Guess
0
5
10
15
20
25
30
35


Figure 15

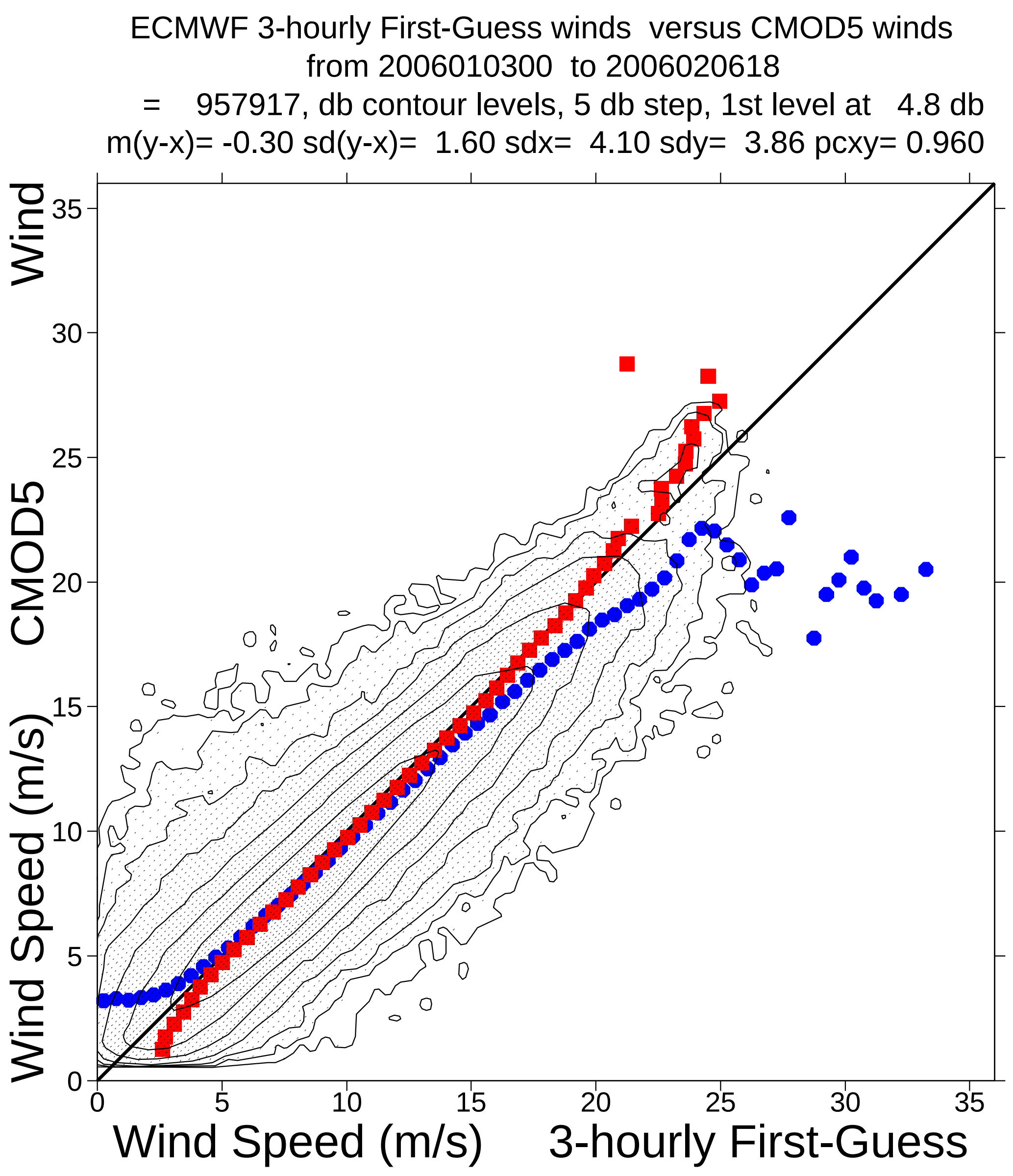
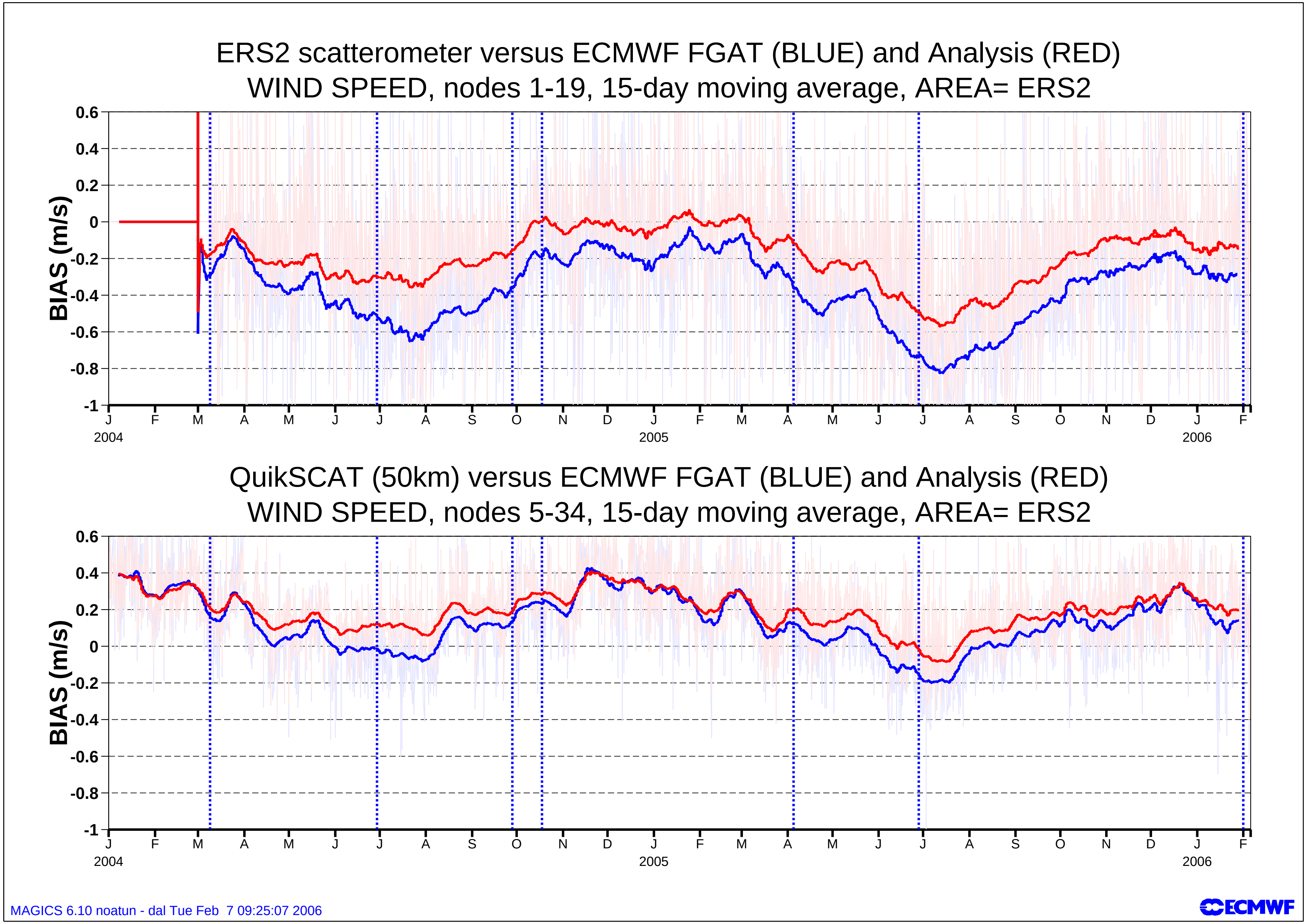

ECMWF 3-hourly First-Guess winds versus CMOD5 winds
from 2006010300 to 2006020618
= 957917, db contour levels, 5 db step, 1st level at 4.8 db
m(y-x)= -0.30 sd(y-x)= 1.60 sdx= 4.10 sdy= 3.86 pcxy= 0.960
Wind Speed (m/s) CMOD5 Wind
Wind Speed (m/s) 3-hourly First-Guess
0
5
10
15
20
25
30
35

Figure 16



ERS2 scatterometer versus ECMWF FGAT (BLUE) and Analysis (RED)
WIND SPEED, nodes 1-19, 15-day moving average, AREA= ERS2
BIAS (m/s)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
J F M A M J J A S O N D J F M A M J J A S O N D J F
2004
2005
2006
QuikSCAT (50km) versus ECMWF FGAT (BLUE) and Analysis (RED)
WIND SPEED, nodes 5-34, 15-day moving average, AREA= ERS2
BIAS (m/s)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
J F M A M J J A S O N D J F M A M J J A S O N D J F
2004
2005
2006
MAGICS 6.10 noatun - dal Tue Feb 7 09:25:07 2006
ECMWF


Figure 17