

# Monitoring statistics of the ERS-2 scatterometer for ESA cycle 104

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## 1 Introduction

The quality of the UWI product was monitored at ECMWF for cycle 104. 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 104 data was received between 21:04 UTC 28 March 2005 and 20:57 UTC 2 May 2005. No data gaps were observed, however, due to a larger than average anomaly in yaw attitude almost all data points in the processing chain at ECMWF were rejected for the 6-hourly data batch of 18 UTC 16 April 2005.

Data is being recorded whenever within the visibility range of a ground station, leading for cycle 104 to a coverage of the North-Atlantic, part of the Mediterranean, the Gulf of Mexico, and to a small part of the Pacific west from the US, Canada and Central America (see Figure 2). Since the inclusion of a ground station in Miami during cycle 102, the entire Caribbean has been covered as well.

The asymmetry between the fore and aft incidence angles showed many peaks, however, all behaving within bounds. The  $k_p$ -yaw ESA flag was set accordingly. Between 17 and 26 April 2005, asymmetries were on average slightly negative.

Compared to cycle 103, the comparison of the UWI wind speed with ECMWF first-guess (FG) fields showed a reduced relative standard deviation (from 1.55 m/s to 1.44 m/s). The relative bias has become more negative (from -0.72 m/s to -0.85 m/s). For winds based on CMOD5 the negative bias has grown as well (from -0.18 m/s to -0.34 m/s). Standard deviation is lower than that for 2000, though the bias is more negative. A similar behavior was observed for the same period in 2004 (see

Figure 1). The reduced standard deviation is obviously connected to a less extreme wind climate; the cause for the larger negative bias is more difficult to trace.

The performance of the UWI wind direction was, with the exception of a few isolated cases, stable for cycle 104.

Ocean calibration shows that bias levels have become more negative by about 0.2 dB. Internode and interbeam differences have grown somewhat.

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

The ECMWF assimilation/forecast system was changed on 5 April 2005. Besides a new method for the estimation of the model background error, METAR data and MODIS winds from AQUA were introduced in the assimilation, while PAOBS observations and 10 AIRS channels were excluded. Some improvements in the atmospheric and ocean-wave model were introduced as well. The effect on surface winds is expected to be small.

## 2 ERS-2 statistics from 29 March to 2 May 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 about 0.2 dB more negative compared to those during cycle 103. Inter-node and inter-beam dependencies have grown somewhat. Bias levels of the fore beam are the most negative, especially at high incidence angles. Average bias level is around -0.6 dB, which is 0.15 dB more negative than for nominal data in 2000 (see Figure 1 of the reports for cycle 48 to 59).

The data volume of descending tracks was about 2% lower 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 104 no large peaks were observed. Although, between 17 and 26 April 2005, asymmetries were on average slightly negative, leading to more than

average rejections, and almost 100% rejections for the batch around 18 UTC 16 April 2005.

## 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 103, 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.

Compared to cycle 103, the average level was very similar (from 1.14 to 1.16), and is now about 7% 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). The peak for 18 UTC 9 April 2005, however, is to be connected with patches of anomalous UWI winds (see upper panel of Figure 12).

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 103, the number of such collocations is reasonably low.

The lower panel of Figure 12 displays a case of moderate UWI winds on 14 April 2005, near the West-African coast, and where ECMWF first-guess winds are very weak. It marks an area in which ECMWF FG winds are in general too low compared to scatterometer data.

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. The average bias level is now more negative to that for nominal data in 2000 (UWI: -0.85 m/s now, was -0.79 m/s for cycle 59). The evolution of the bias from cycles 92 to 104 is displayed in the top panel of Figure 17. The red curve is the 15-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 for ERS-2 a negative bias is developing rapidly since March 2005. For QuikSCAT (at ECMWF inverted and bias-corrected) such a trend is not observed. However, these latter results are based on global statistics.

The standard deviation of UWI wind speed compared to cycle 103 has been reduced significantly (1.44 m/s, was 1.55 m/s), the main reason being a milder wind climate.

For cycle 104 the (UWI - FG) direction standard deviations were mostly ranging between 15 and 40 degrees (Figure 8). Sharp peaks are the result of low data volumes. The average performance for UWI wind direction was somewhat higher (STDV 27.8 degrees, was 33.2 degrees, bias -3.7 degrees, was -2.7 degrees).

	cycle 103		cycle 104	
	UWI	CMOD4	UWI	CMOD4
speed STDV	1.55	1.54	1.44	1.43
node 1-2	1.62	1.59	1.54	1.51
node 3-4	1.56	1.55	1.47	1.46
node 5-7	1.48	1.48	1.41	1.41
node 8-10	1.48	1.48	1.39	1.39
node 11-14	1.51	1.51	1.40	1.40
node 15-19	1.55	1.55	1.37	1.37
speed BIAS	-0.72	-0.70	-0.85	-0.84
node 1-2	-1.23	-1.20	-1.35	-1.32
node 3-4	-0.94	-0.89	-1.09	-1.04
node 5-7	-0.74	-0.70	-0.88	-0.85
node 8-10	-0.60	-0.59	-0.72	-0.72
node 11-14	-0.57	-0.57	-0.68	-0.69
node 15-19	-0.52	-0.53	-0.67	-0.70
direction STDV	33.2	19.1	27.8	19.0
direction BIAS	-2.7	-3.0	-3.7	-3.4

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

## 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.

Winds derived on the basis of CMOD5 are displayed in Figure 16. The relative standard deviation is lower than for CMOD4 winds (1.43 m/s versus 1.46 m/s). Compared to ECMWF FG, CMOD5 winds are -0.34 m/s slower. For strong winds, a large negative bias as observed before cycle 102 was less present.

## 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 2 May 2005 (end cycle 104) 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  $\langle \sigma_0^{0.625} \rangle / \langle \text{CMOD4}(\text{FirstGuess})^{0.625} \rangle$  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 104 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 in the North Atlantic 9 April 2005 (top panel) and near West Africa on 14 April 2005 (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 104. Curves represent centered 15-day running means. Vertical dashed blue lines mark ECMWF model changes.

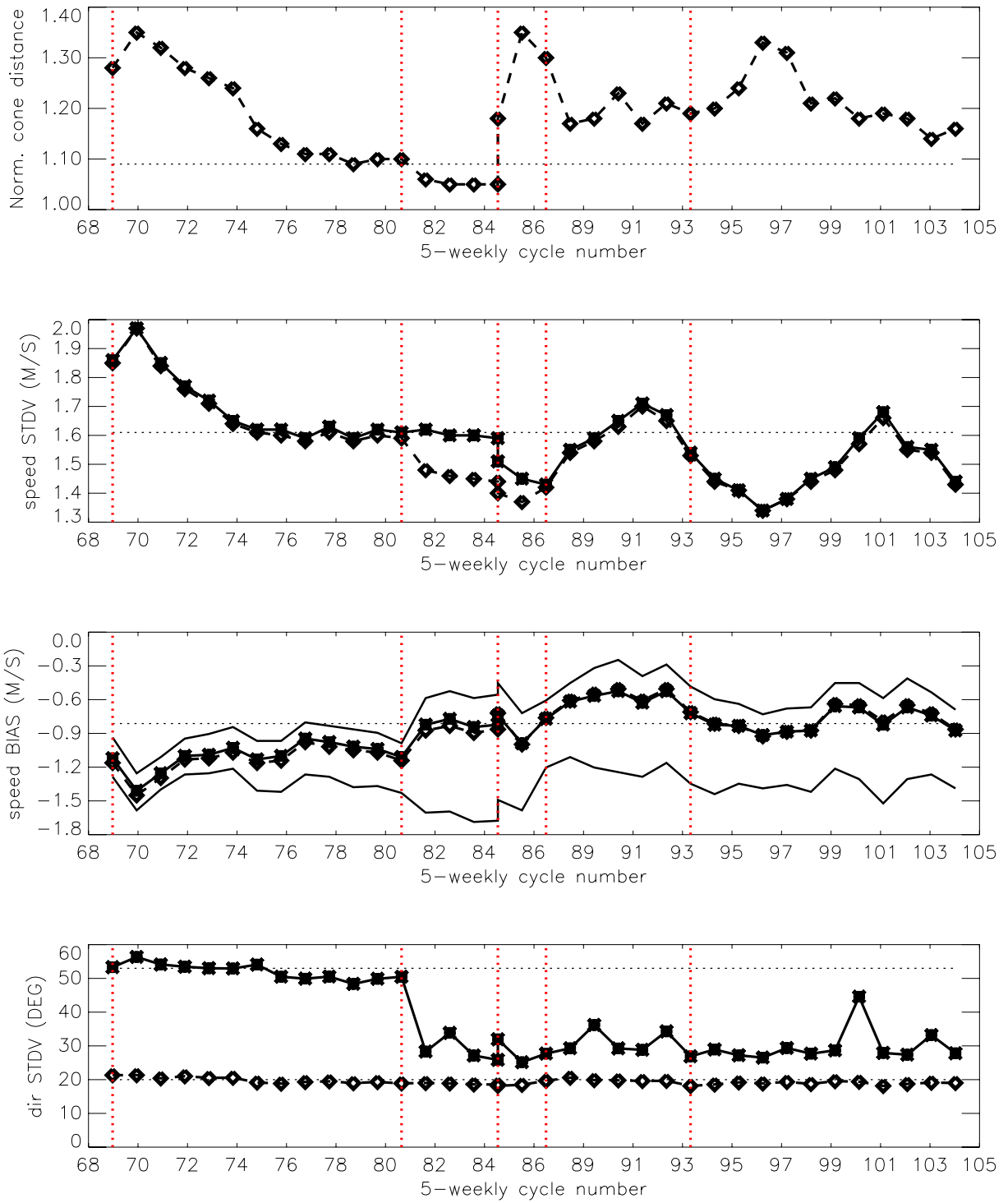
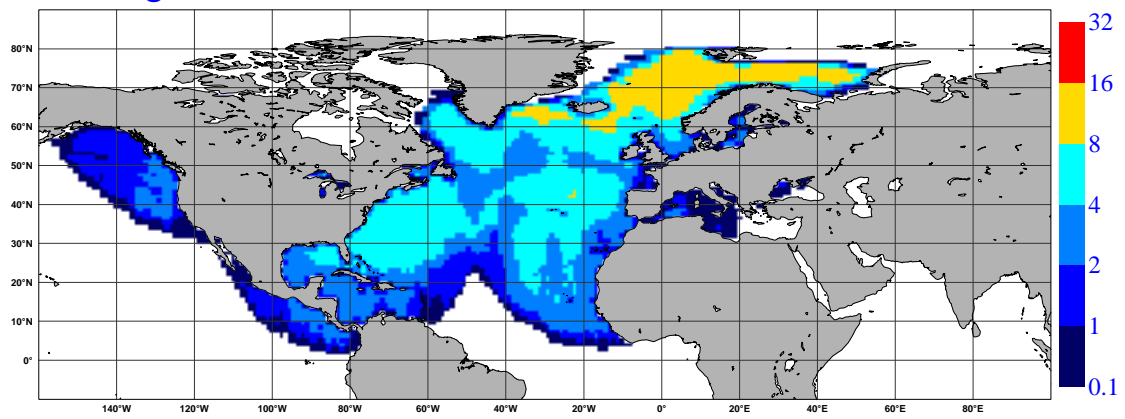


Figure 1

NOBS ( ERS-2 UWI ), per 12H, per 125km box  
average from 2005032900 to 2005050218 GLOB:3.33



AVERAGE ( ERS-2 UWI ), in m/s.  
average from 2005032900 to 2005050218 GLOB:5.98

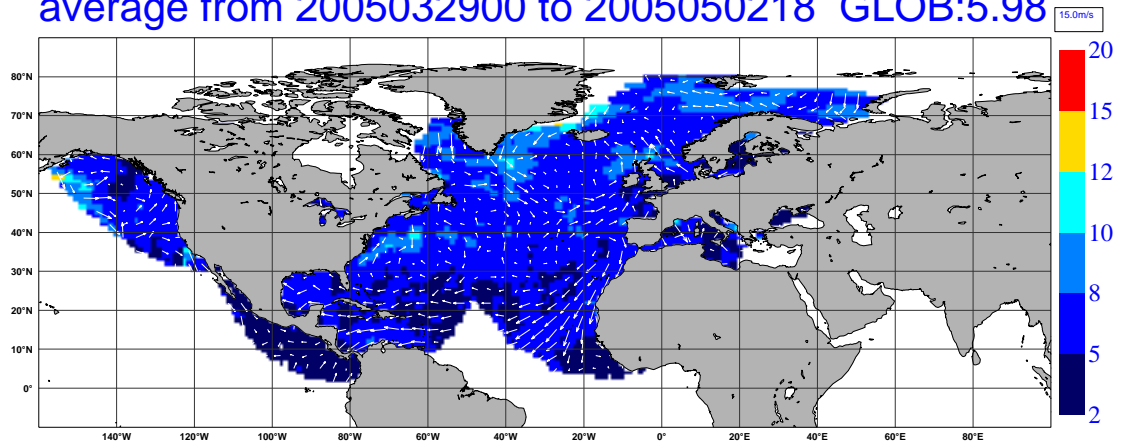
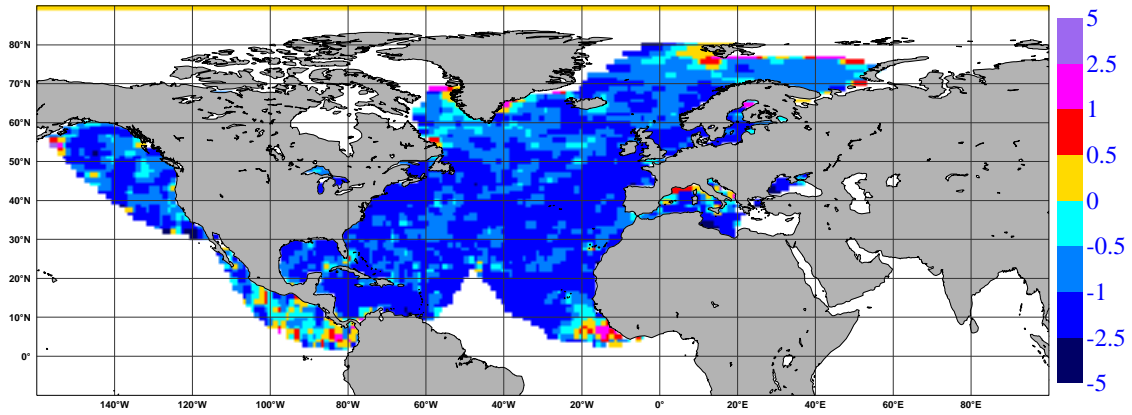


Figure 2



BIAS ( ERS-2 UWI vs FIRST-GUESS ), in m/s.  
average from 2005032900 to 2005050218 GLOB:-1.03



STDV ( ERS-2 UWI vs FIRST-GUESS ), in m/s.  
average from 2005032900 to 2005050218 GLOB:1.18

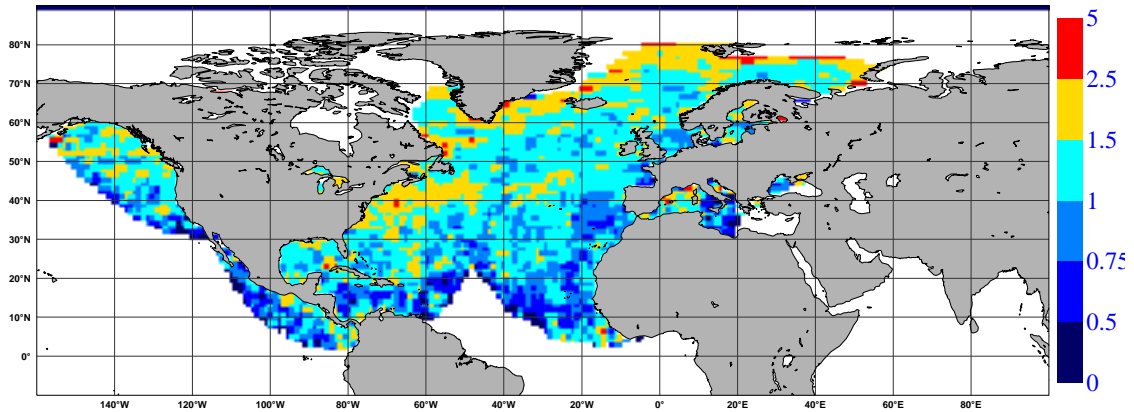
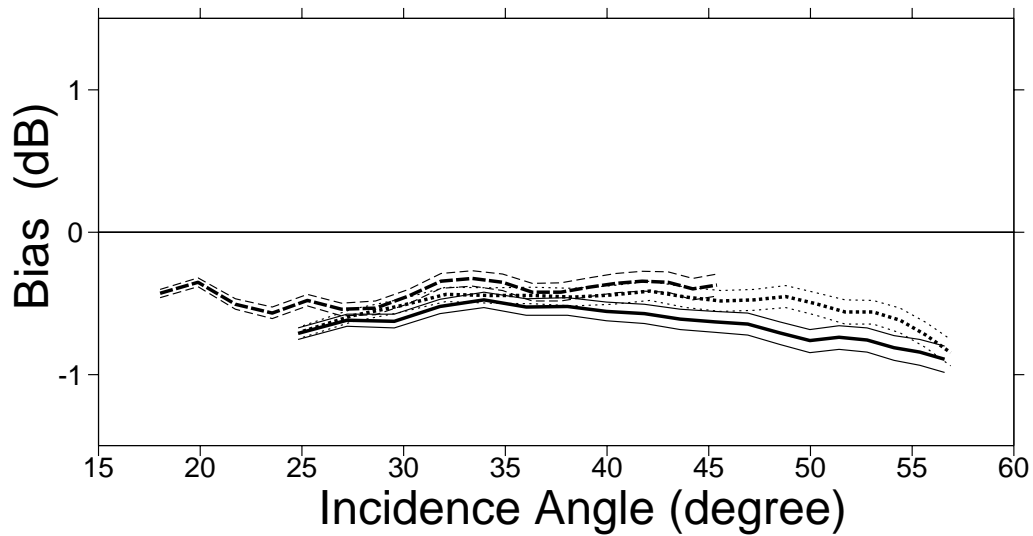


Figure 3

BIAS:  $(s_{0obs}^{**0.625}) / (s_{0fg3h}^{**0.625})$   
ERS-2 obs. from 28/03/2005 21:01 UTC to 02/05/2005 20:57 UTC  
DESCENDING TRACKS  
421397 Entries, 61.5 % used (flat wind dir. dist.)  
\_\_\_ Fore \_\_Mid ...Aft thin: Error Bar



BIAS:  $(s_{0obs}^{**0.625}) / (s_{0fg3h}^{**0.625})$   
ERS-2 obs. from 28/03/2005 21:01 UTC to 02/05/2005 20:57 UTC  
ASCENDING TRACKS  
428146 Entries, 58.6 % used (flat wind dir. dist.)  
\_\_\_ Fore \_\_Mid ...Aft thin: Error Bar

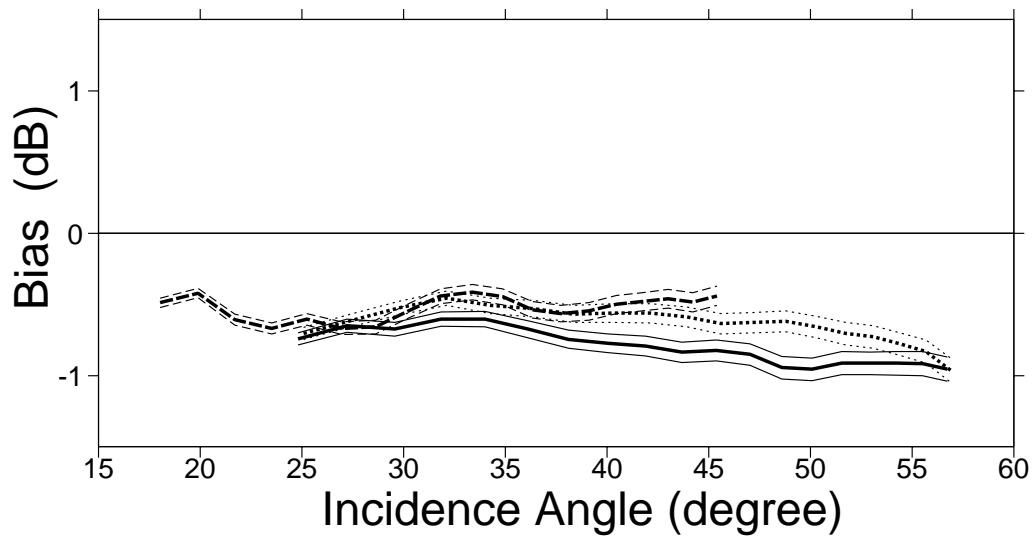


Figure 4



# Monitoring of Sigma0 triplets versus CMOD4 for ERS-2

from 2005032900 to 2005050218

(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)

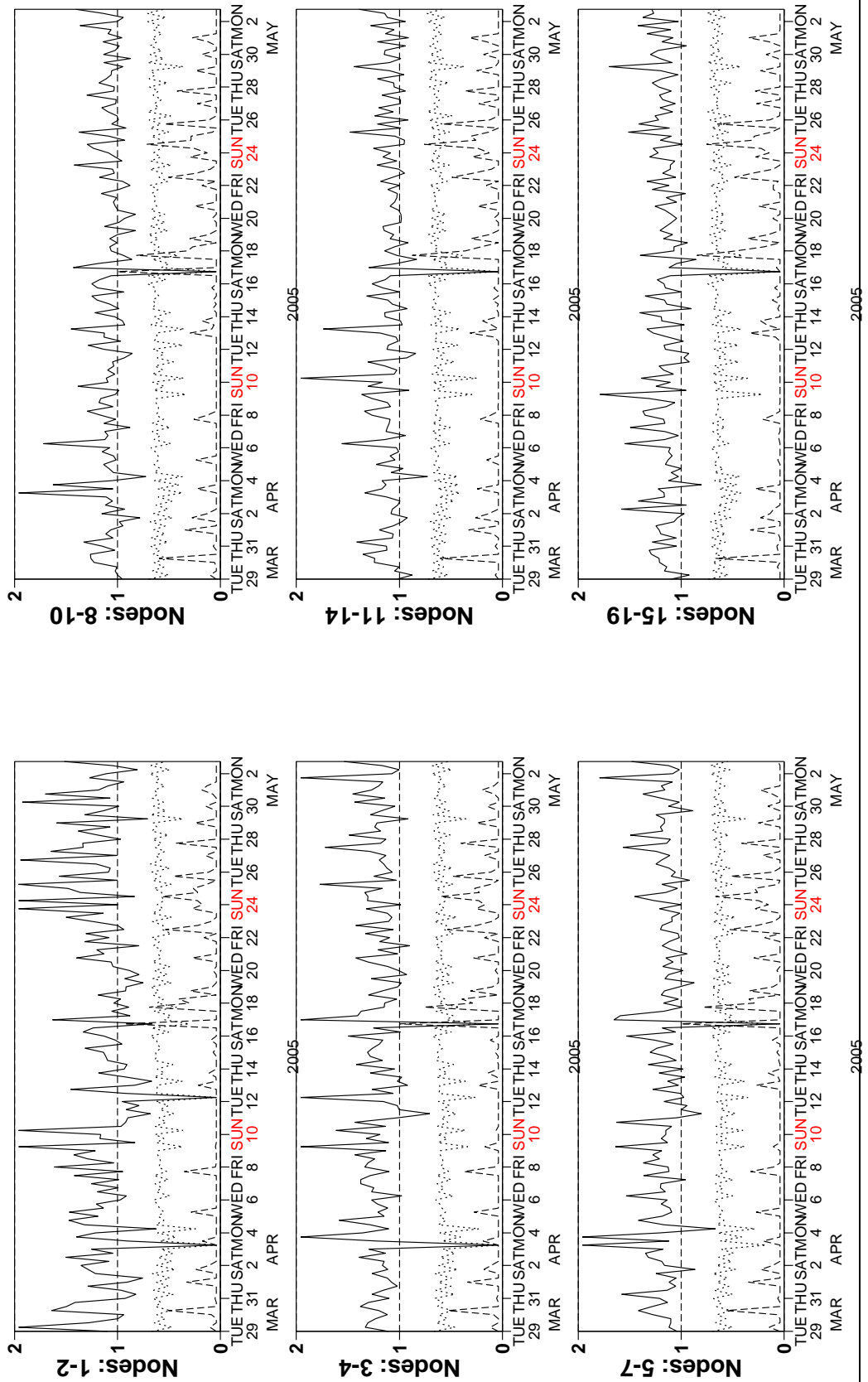


Figure 6

# Monitoring of UWI winds versus First Guess for ERS-2

from 2005032900 to 2005050218

(solid) wind speed bias UWI - First Guess over 6h (deg.)

(dashed) wind speed standard deviation UWI - First Guess over 6h (deg.)

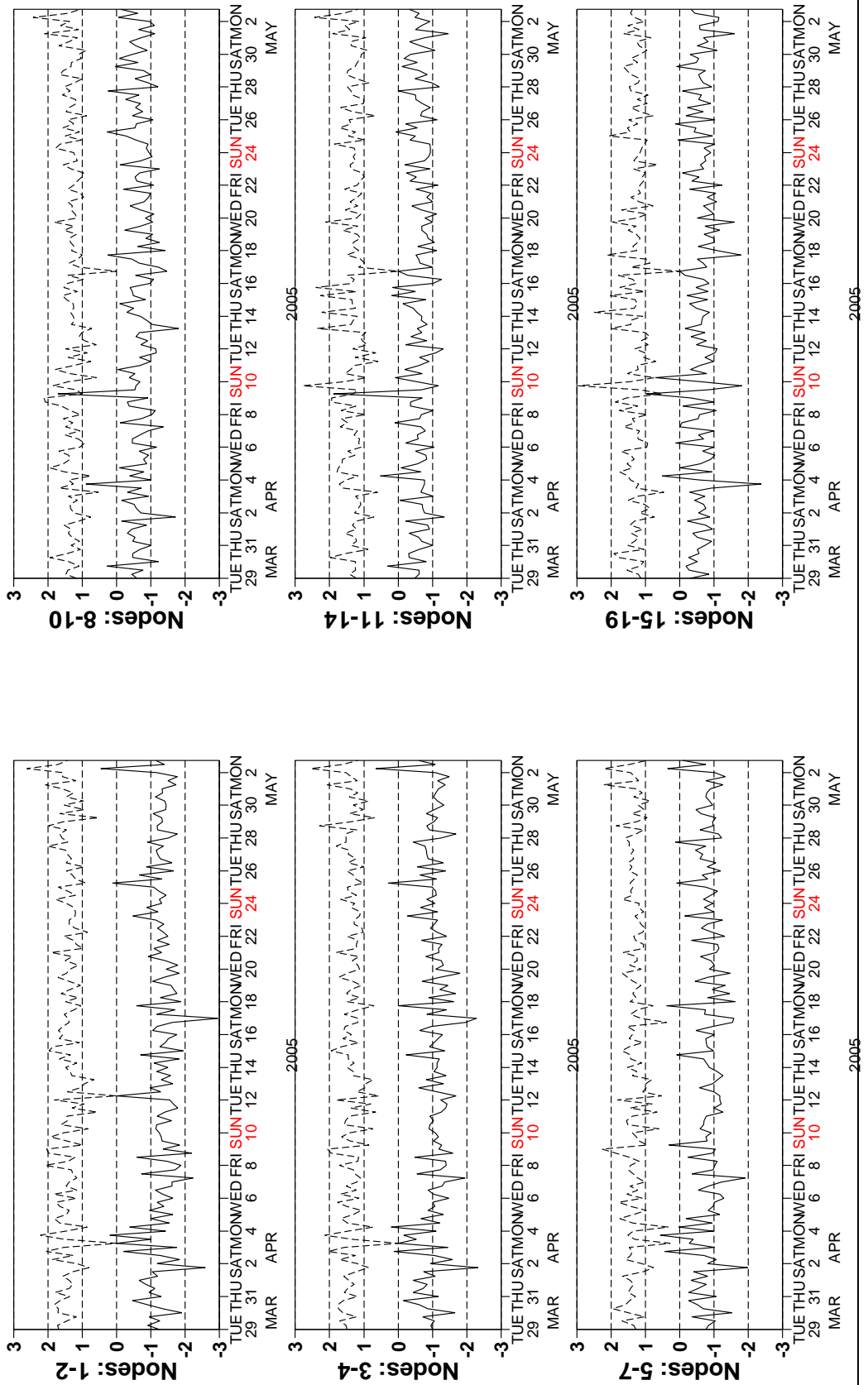


Figure 7

# Monitoring of UWI winds versus First Guess for ERS-2

from 2005032900 to 2005050218

(solid) wind direction bias UWI - First Guess over 6h (deg.)

(dashed) wind direction standard deviation UWI - First Guess over 6h (deg.)

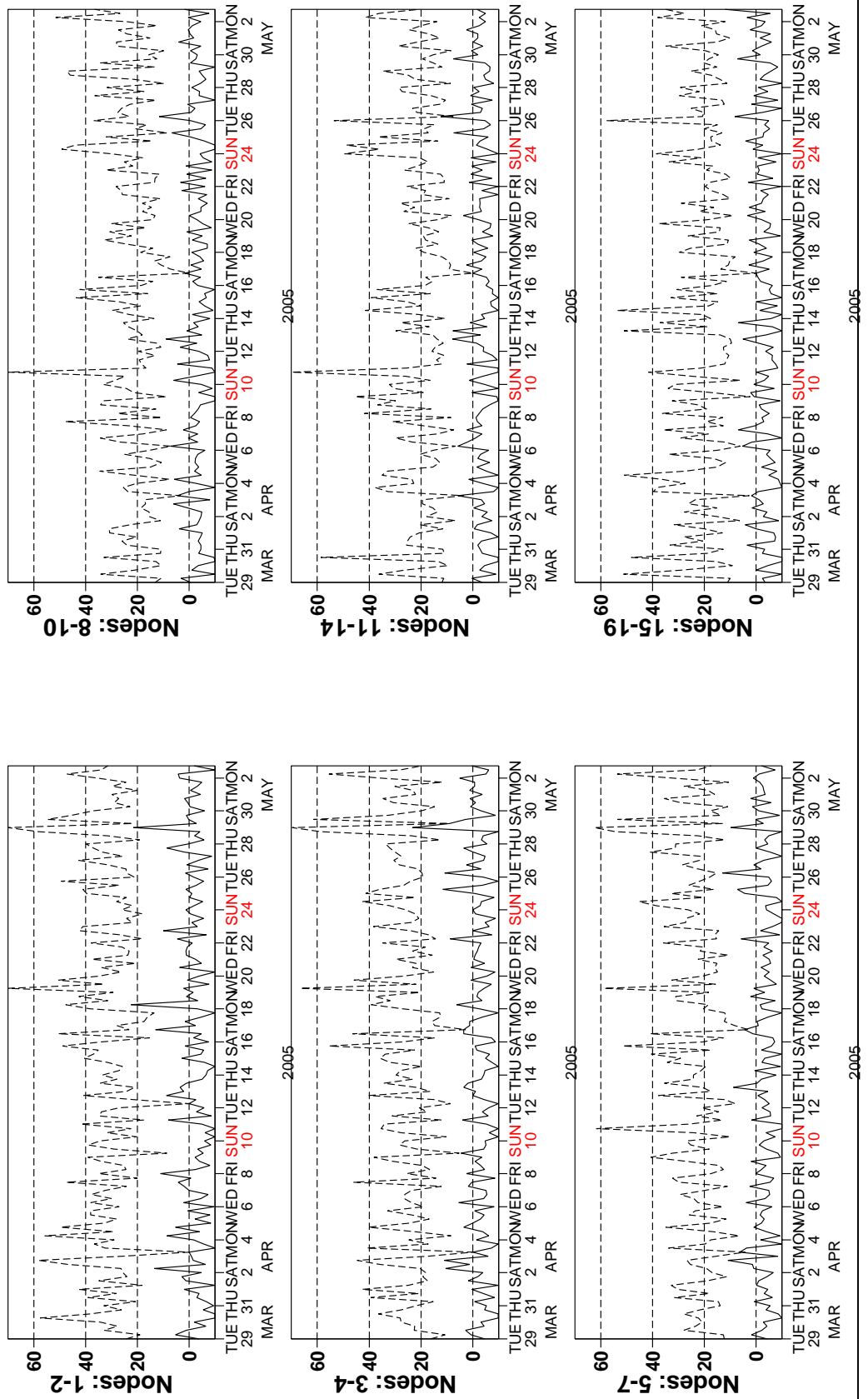


Figure 8

# Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2

from 2005032900 to 2005050218

(solid) wind speed bias CMOD4 - First Guess over 6h (deg.)

(dashed) wind speed standard deviation CMOD4 - First Guess over 6h (deg.)

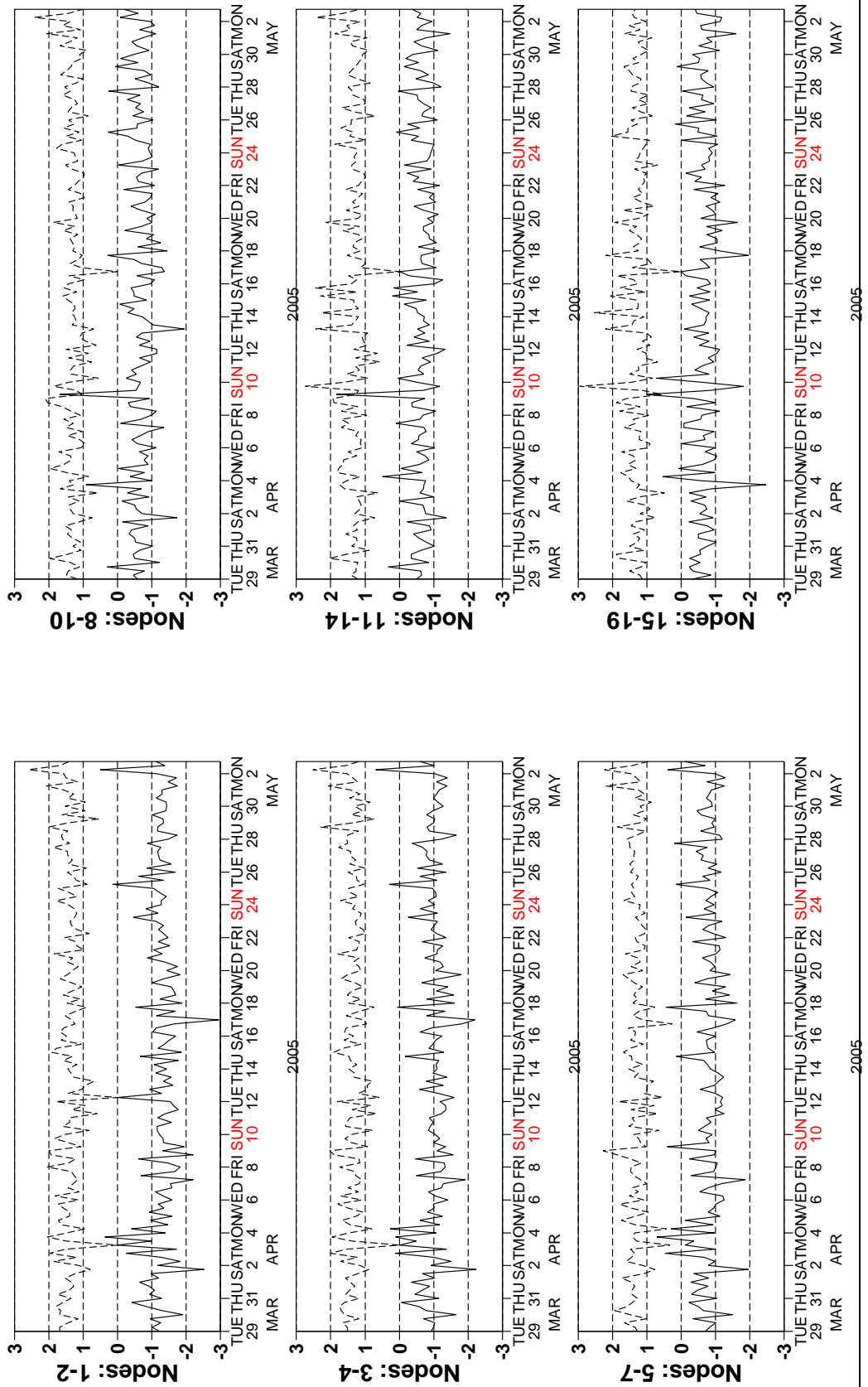


Figure 9

# Monitoring of de-aliased CMOD4 winds versus First Guess for ERS-2

from 2005032900 to 2005050218

(solid) wind direction bias CMOD4 - First Guess over 6h (deg.)

(dashed) wind direction standard deviation CMOD4 - First Guess over 6h (deg.)

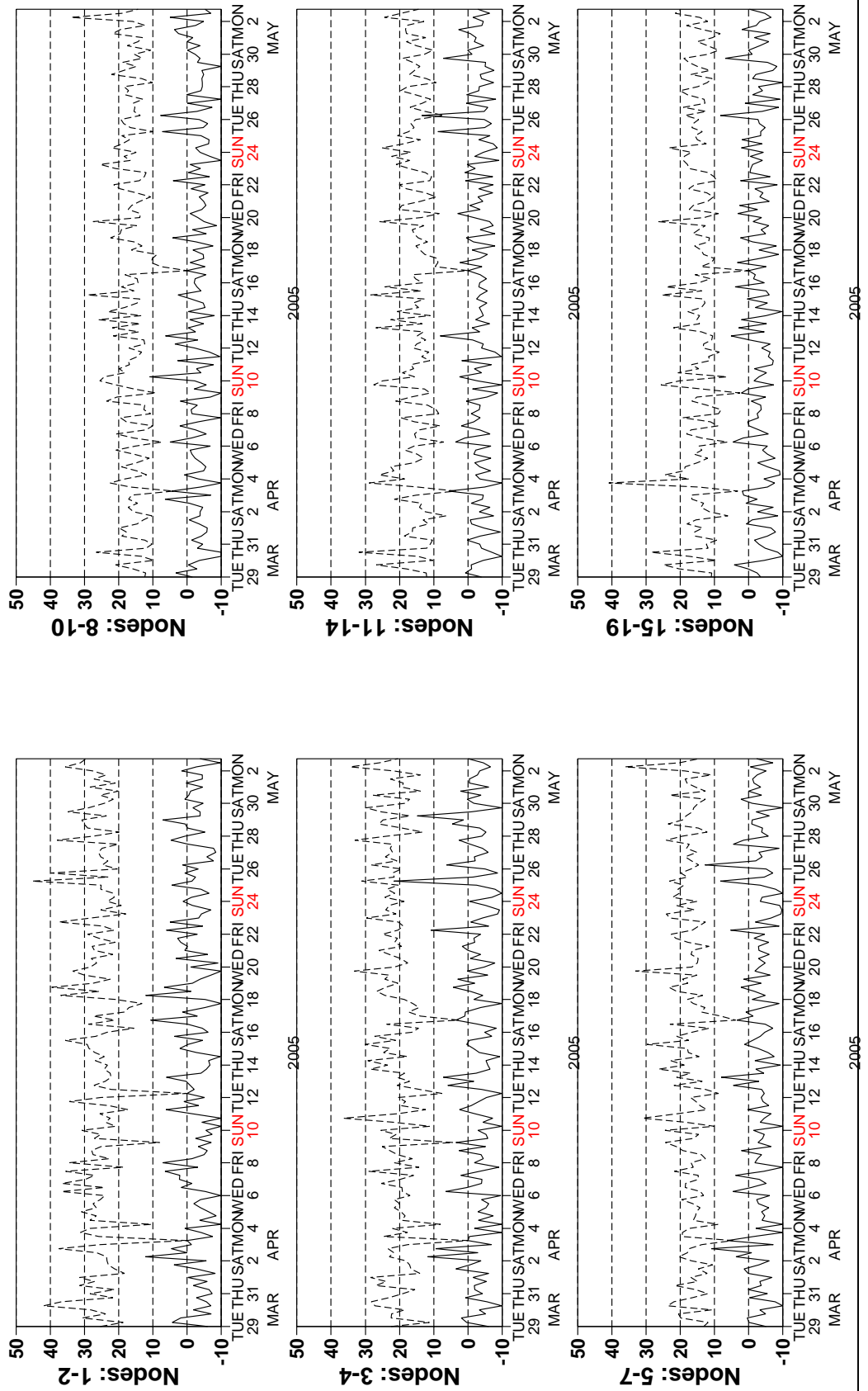
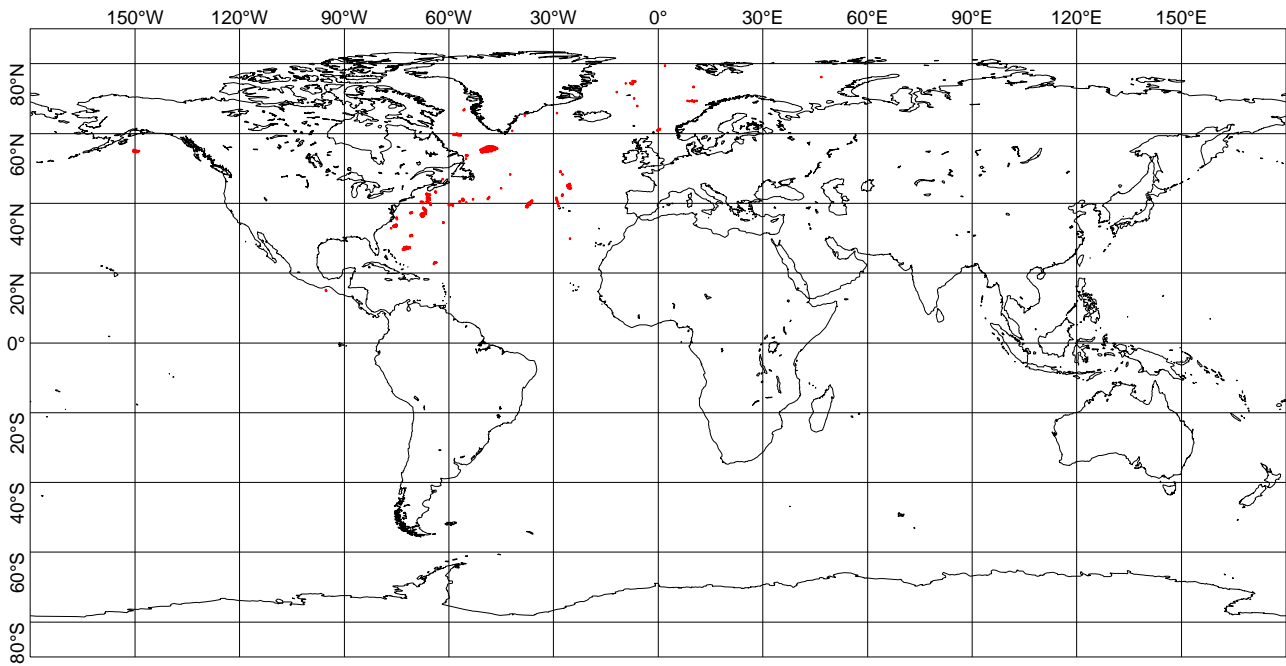


Figure 10



UWI winds more than 8 m/s weaker than FGAT  
CYCLE 104, 2005032900 to 2005050218, QC on ESA flags



UWI winds more than 8 m/s stronger than FGAT  
CYCLE 104, 2005032900 to 2005050218, QC on ESA flags

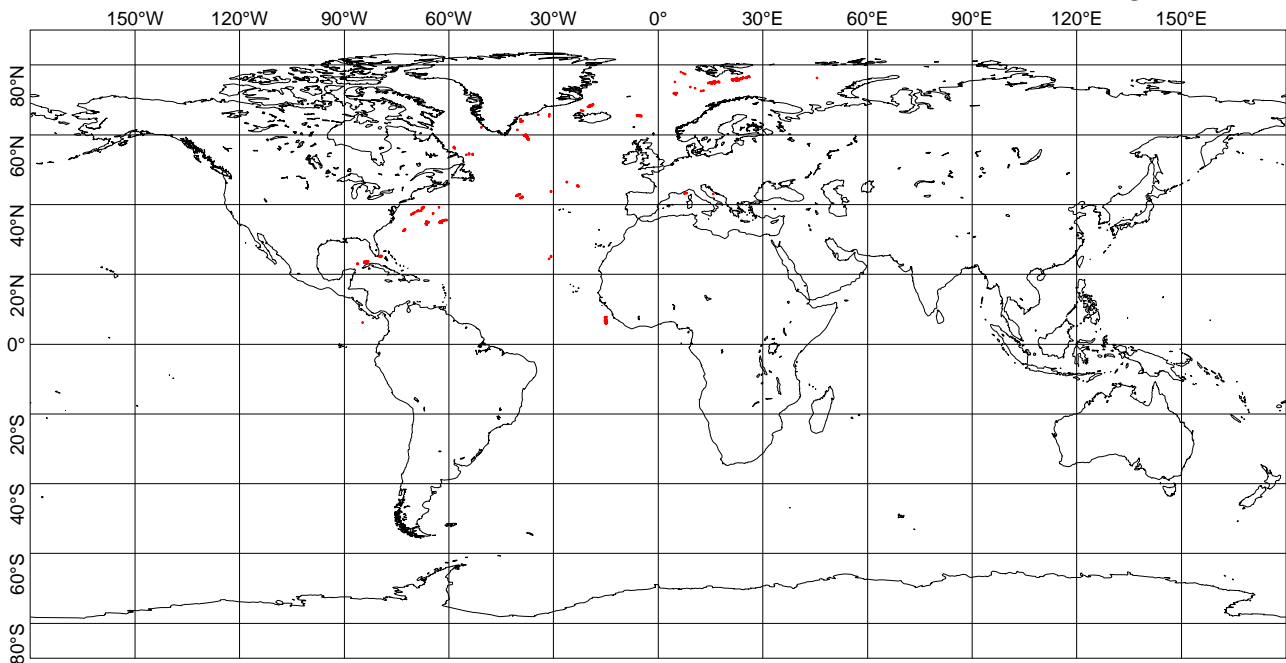
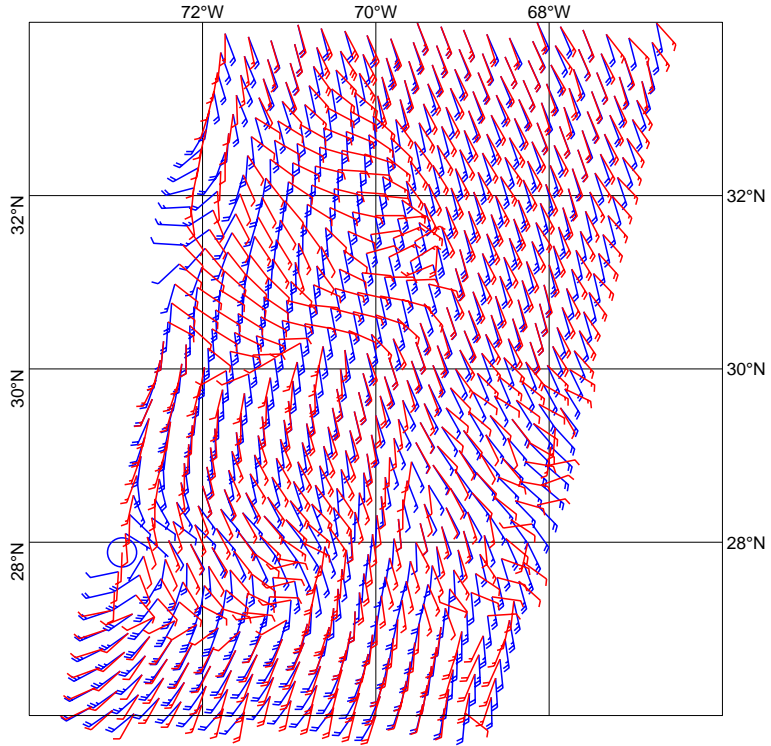


Figure 11

CMOD4 winds (red) versus FGAT winds (blue)  
20050409 15:10 UTC



CMOD4 winds (red) versus FGAT winds (blue)  
20050414 23:34 UTC

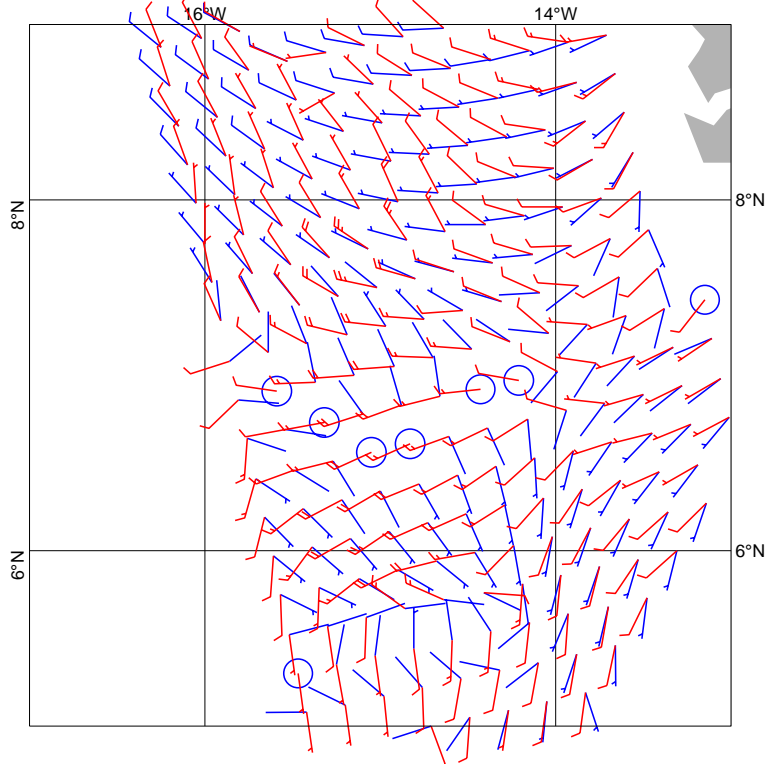


Figure 12

ECMWF 3-hourly First-Guess winds versus UWI winds  
from 2005032900 to 2005050218  
= 849543, db contour levels, 5 db step, 1st level at 4.3 db  
 $m(y-x) = -0.85$   $sd(y-x) = 1.46$   $sdx = 3.43$   $sdy = 3.19$   $pcxy = 0.951$

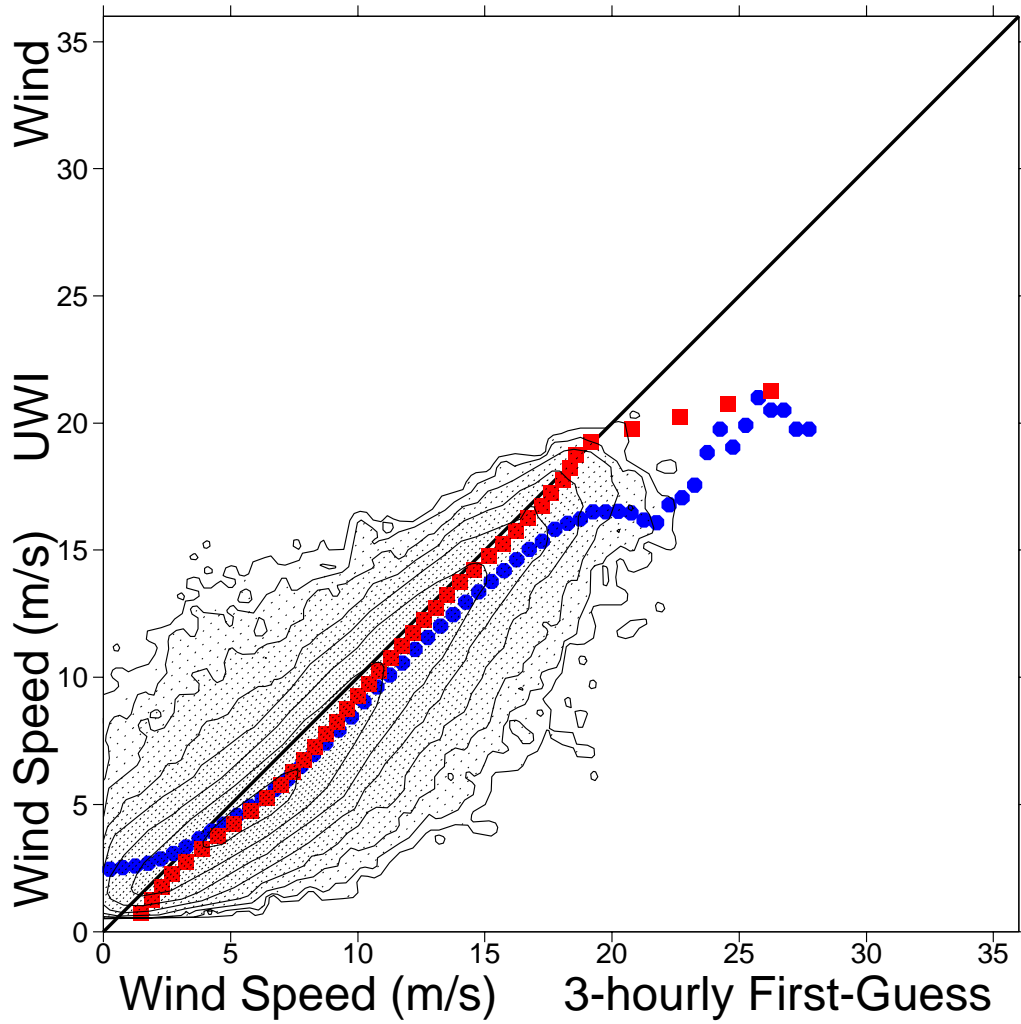


Figure 13

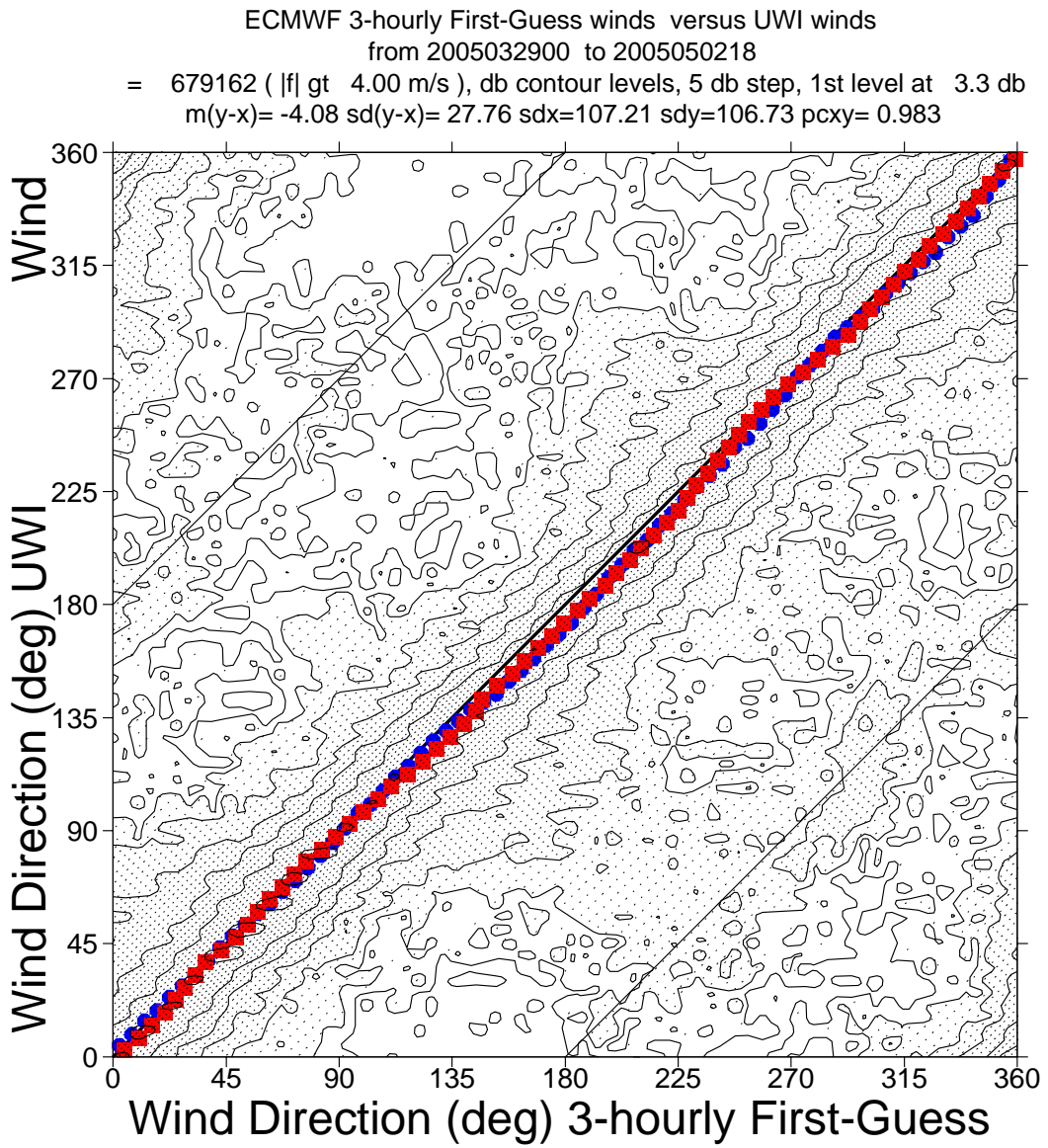


Figure 14

ECMWF 3-hourly First-Guess winds versus CMOD4 winds  
from 2005032900 to 2005050218  
= 843021, db contour levels, 5 db step, 1st level at 4.3 db  
 $m(y-x) = -0.84$   $sd(y-x) = 1.46$   $sdx = 3.41$   $sdy = 3.17$   $pcxy = 0.951$

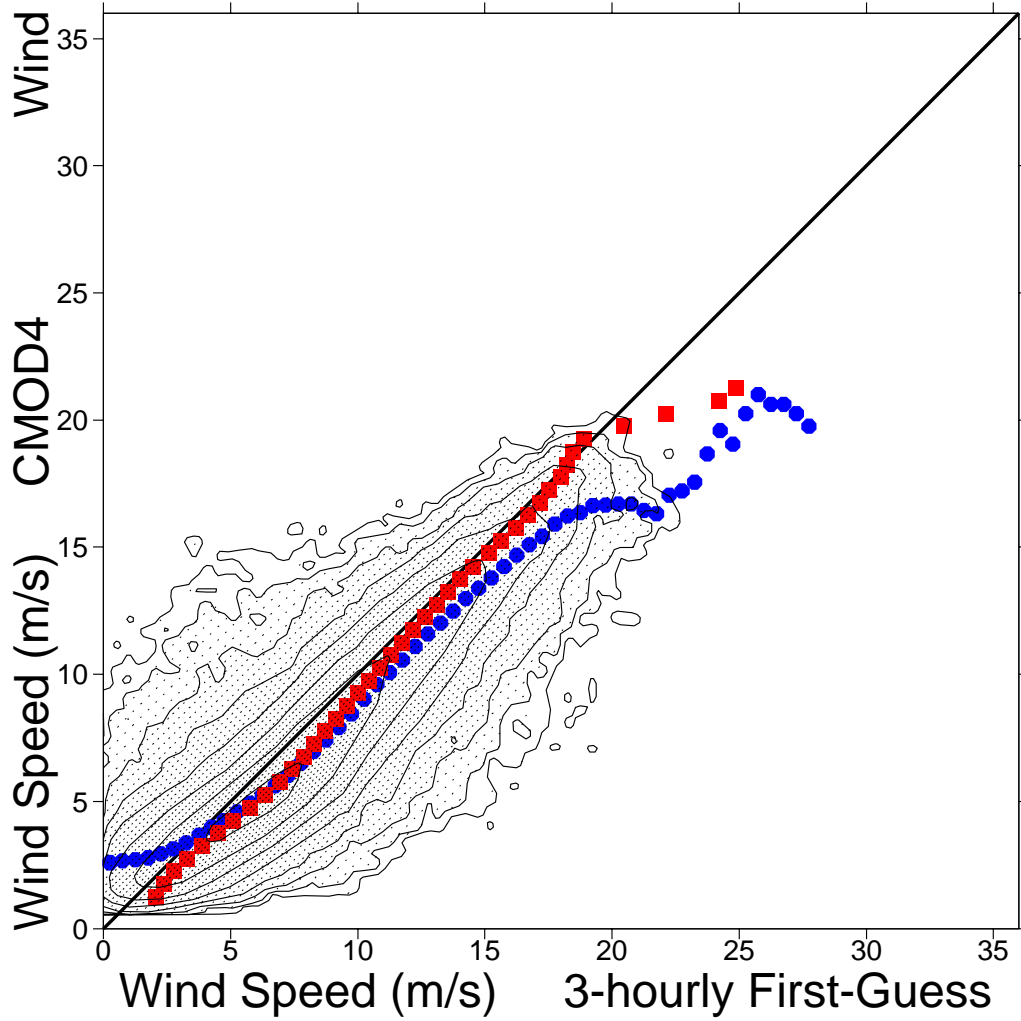


Figure 15

ECMWF 3-hourly First-Guess winds versus CMOD5 winds  
from 2005032900 to 2005050218  
= 824431, db contour levels, 5 db step, 1st level at 4.2 db  
 $m(y-x) = -0.34$   $sd(y-x) = 1.43$   $sdx = 3.35$   $sdy = 3.26$   $pcxy = 0.952$

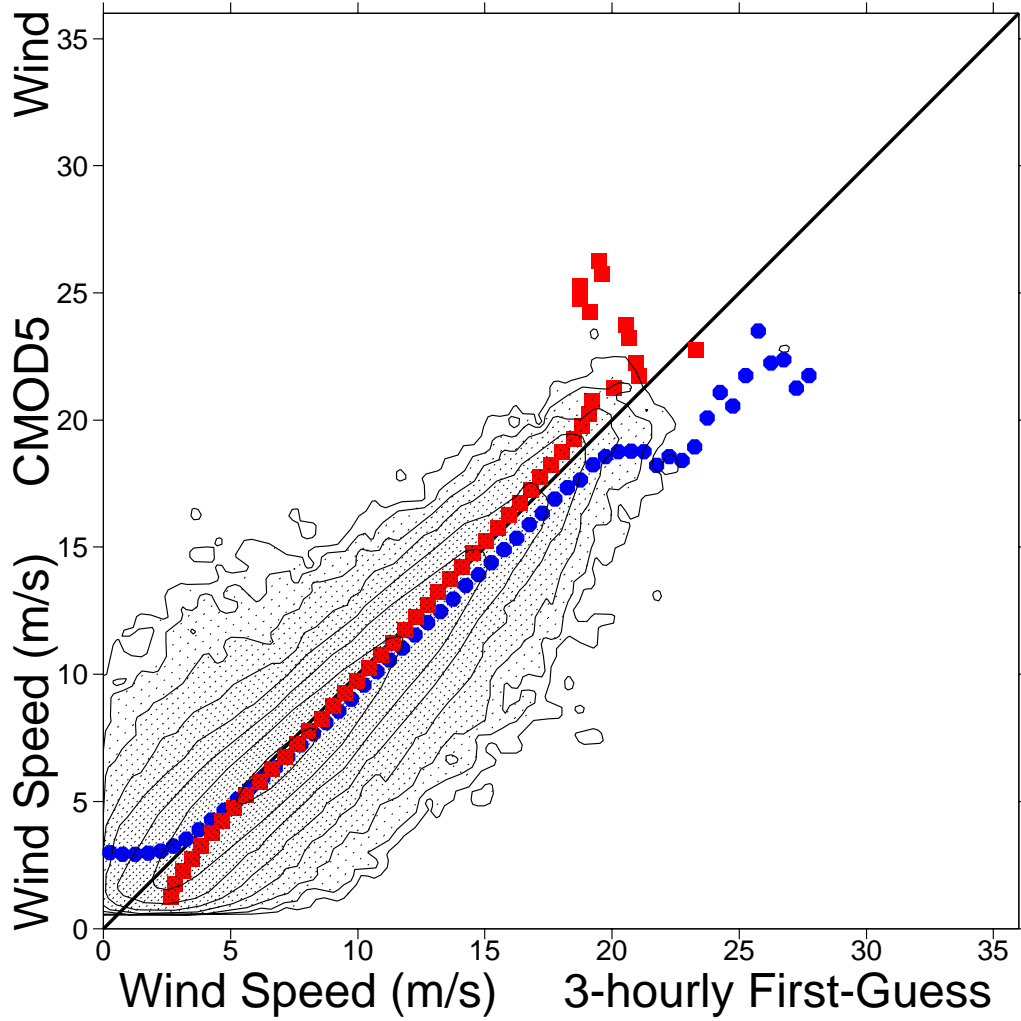
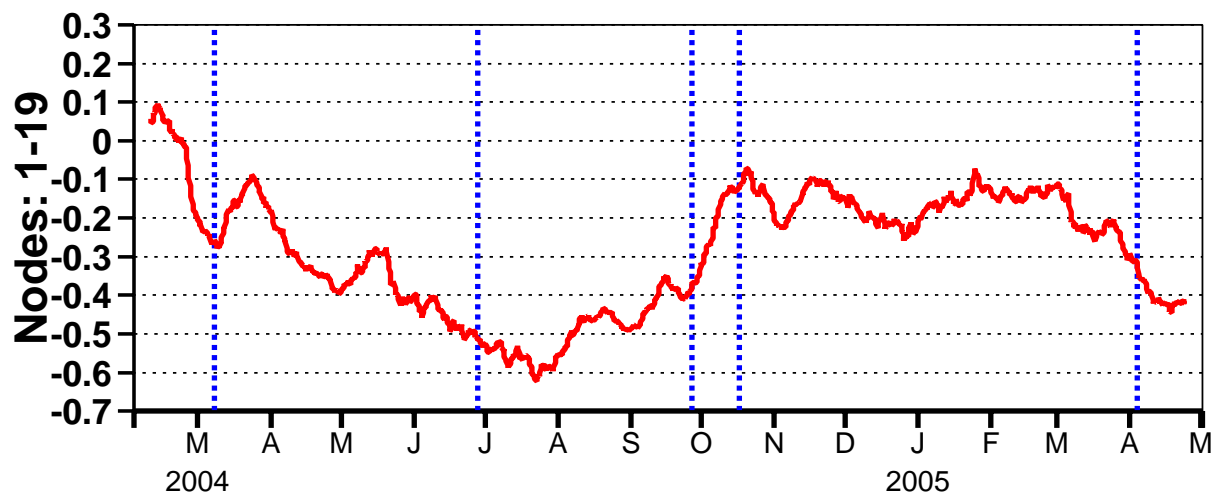


Figure 16

## ERS-2 (CMOD5)



## QuikSCAT (QSCAT-1)

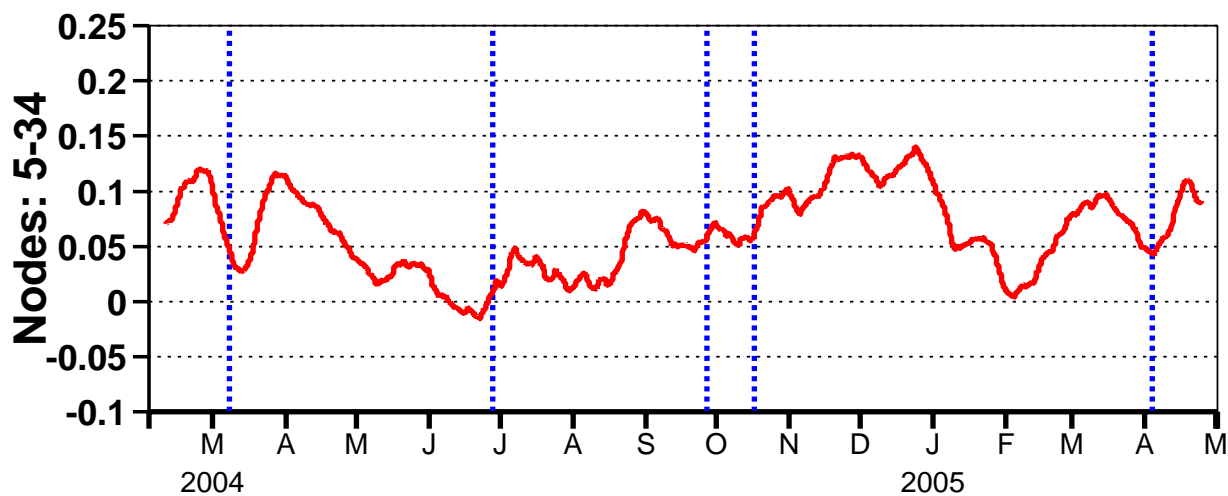


Figure 17