Reduction of Uncertainty of Marine Wind Fields for Ocean Response Modeling by Utilizing the QuikSCAT Dataset

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Outline

- Accuracy of Conventional Marine Surface Wind Data
- Accuracy and Dynamic Range of Scatterometer Winds
- Reduction of Systematic Effects in NWP Products
- Impact of QuikSCAT on Extratropical Regimes

Surface and PBL Structure

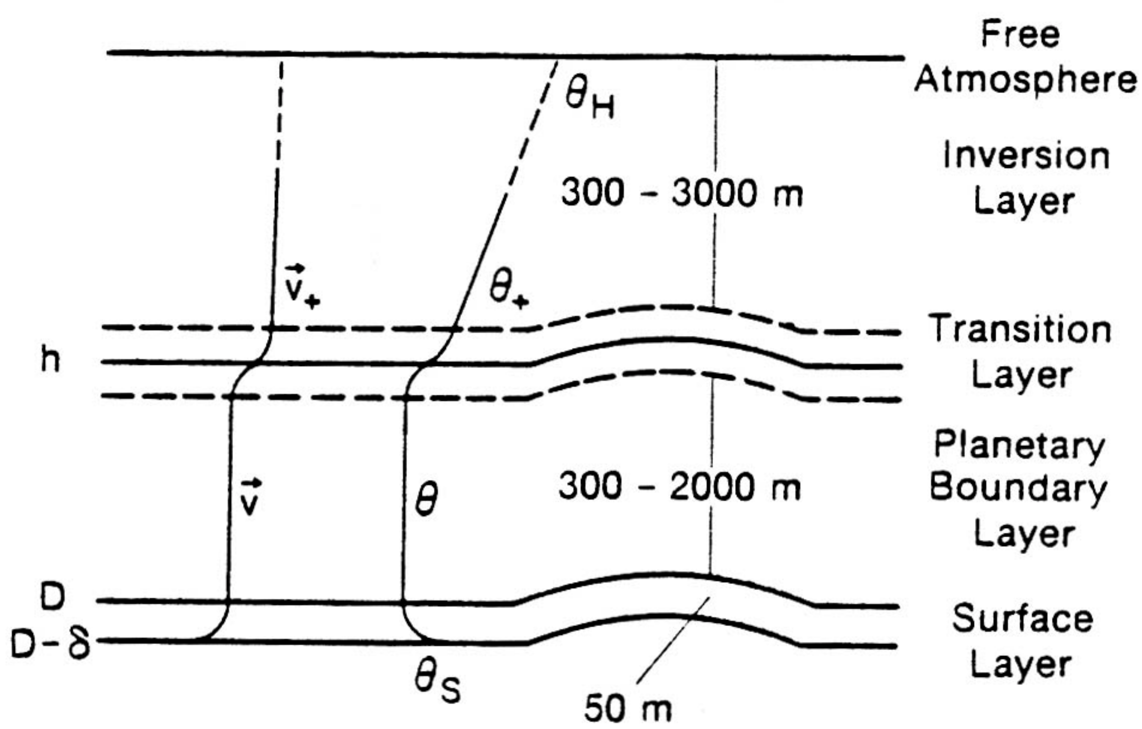

Figure 1.—Model-defined parameters of height, velocity, and potential temperature.

From Overland et al., 1979

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PBL Wind Profile

Variation of Mean Wind With Height: Surface Layer

Neutral Stratification

$$U_z = \frac{U^*}{k} \log \frac{z}{z_0} \qquad \textit{where} \quad U^* = \sqrt{\tau / \rho}$$

$$z_0 = \textit{roughness parameter}$$

$$\text{since } \tau = \rho \, \mathrm{C_z} \, \mathrm{U_z}^2$$

$$C_z = k^2 \Big/ (\log z / z_0)^2 \qquad C_z = \textit{drag coefficient}$$

Stability Effect

$$U_z = \frac{U^*}{k} \left[\log \frac{z}{z_0} - \varphi \left(\frac{z}{L} \right) \right]$$

$$C_z = k^2 \Big/ \left[\log \frac{z}{z_0} - \varphi \left(\frac{z}{L} \right) \right]^2$$

φ = stability function

L = stability length $\sim \frac{U^{*3}}{H}$

H = heat flux

C_{10n} is drag coefficient referred to 10m at neutral stratification

PBL Wind Profile cont...

Planetary Boundary Layer

$$f\left(v-v_g\right)+\frac{d}{dz}\left[Km\frac{d}{dz}\left(u-u_g\right)\right]=0$$

Where Km = eddy viscosity

$$-f\left(u-u_g\right)+\frac{d}{dz}\left[Km\frac{d}{dz}\left(v-v_g\right)\right]=0$$

b.c $u = ug \quad z \rightarrow \infty$

$u = v = 0 \quad z = 0$

$$u = u_g\left(1-e^{-az}\cos az\right)$$

$$v = u_g\left(e^{-az}\sin az\right)$$

$$a=\sqrt{f/2Km}$$

Two Layer Models $\frac{U^*}{U_g} = F\left(\frac{U_g}{fz_0}, \frac{U_g}{fL}, \frac{1}{f}\frac{\partial U_g}{\partial z}\ldots\right)$

Equivalent Neutral Wind

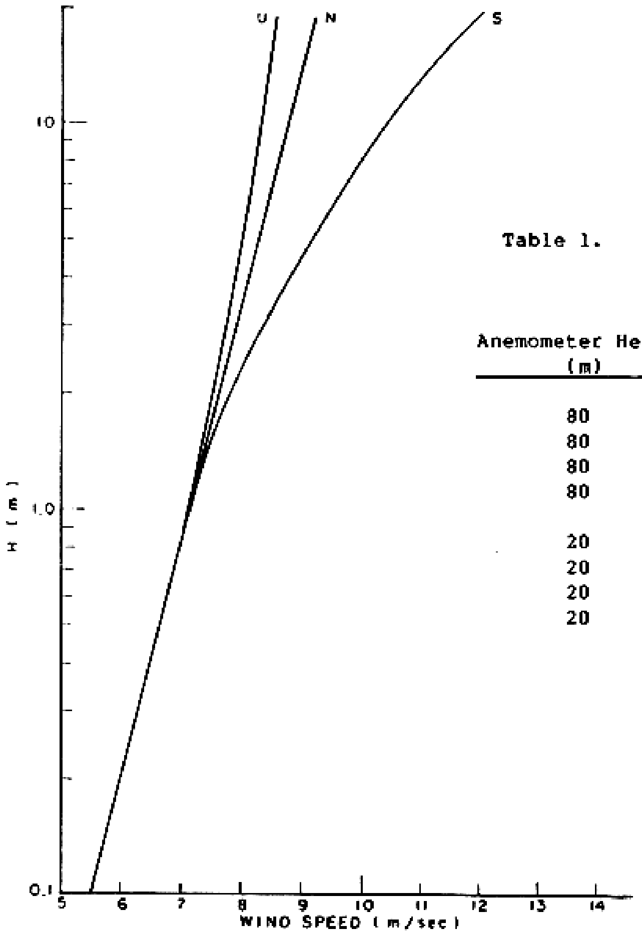

FIG. 3

Theoretical wind profiles in the marine surface boundary layer for a surface stress of 1 dyne/cm^2 and neutral (N), unstable (U), and stable (S) stratification.

Table 1. Effective Neutral 20 m Wind Speeds for Indicated Measurement Height, Air-sea Temperature Differences, and Wind Speeds

Anemometer Height (m)	Air-Sea Temp (°C)	Measured Wind Speed (knots) 20	40	60
80	-8	21.1	38.9	55.8
80	-4	20.3	37.7	54.4
80	0	17.9	35.2	52.1
80	+2	10.6	30.7	49.2
20	-8	22.1	41.8	61.5
20	-4	21.4	41.0	60.8
20	0	20.0	40.0	60.0
20	+2	17.8	38.9	59.2

speed at a reference height. The effective neutral wind speed U_e is the "virtual" wind speed that at height z_e imparts, in neutral thermal surface boundary layer stratification and for the assumed drag law, the same stress as imparted by the measured, U_m, measured at height z_m in a thermally stratified boundary layer:

$$U_e = U_m \frac{\log(z_e/z_0)}{\log[z_m/z_0 - \psi(z_m/L)]}, \qquad (1)$$

where L is the Monin–Obukhov length and ψ is the "profile" stability function [for a more detailed description of the iterative procedure used to calculate U_e from the three known quantities: measured wind speed, measurement height, and air–sea temperature difference, see Cardone (1969) or Ross et al. (1980)]. The calculation

PBL Model Winds

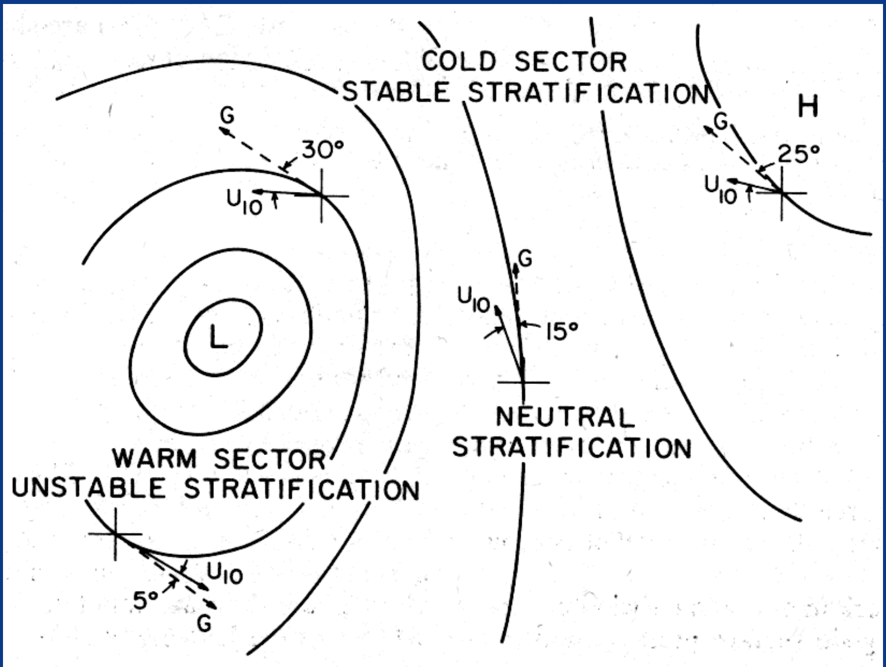

FIG. 8. Sketch of a typical synoptic situation indicating stratification effect on U_{10}/G relation.

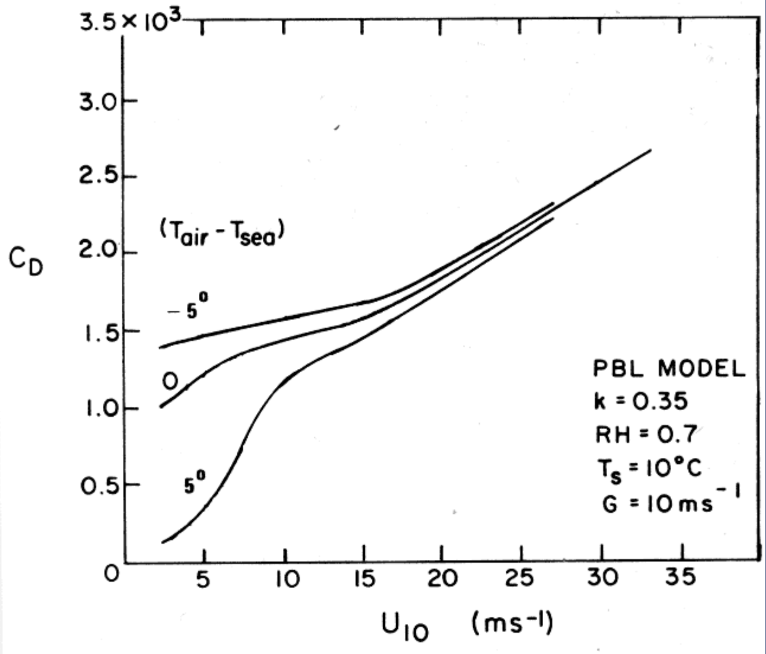

FIG. 7. The drag coefficient $C_D = (u_*/U_{10})^2$, versus the 10 m wind for various air-sea temperature differences (−5, 0, +5°C).

Brown and Liu (1982); J. Appl. Meteor., 21, 261-269

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Skill in MPBL Model Winds

Table 1. Reported scalar wind-speed difference between winds derived from the indicated pressure fields, using Cardone's MPBL model, and the indicated measured data types.

Study	Comparison data	Pressure fields	Basin	Mean diff. (MPBL data) (m/s)	Scatter (rms) (m/s)
Cardone[10]	NDBO buoys	NOAA LFM	USEC	−0.8	3.0
			USGC	−0.5	2.9
			USWC	−0.4	2.8
Overland & Gemmill[12]	NDBO buoys	NOAA LFM	NY Bight	−0.5	2.4
Eid et al.[8]	Buoys/rigs	NOAA LFM	N. Atlantic	−0.6	3.0
Gemmill et al.[11]	NDBO buoys	NOAA obj	N. Atlantic	−0.1	2.9
	NDBO buoys	NOAA obj	N. Pacific	+0.6	3.2
	Ships	NOAA obj	N. Atlantic	−2.9	5.1
	Ships	NOAA obj	N. Pacific	−2.0	4.7
Cardone et al.[3]	Ships (adj)	NMC final	N. Pacific	−1.6	4.5
	Ships (adj)	FNOC obj	N. Pacific	−1.6	3.6
Dobson & Chaykovsky (this volume)	Geosat	LEWEX rean	N. Atlantic	−0.6	3.4
Composite	NDBO buoys			−0.3	2.9
	Geosat			−0.6	3.4
	Transient ships (adjusted)			−1.6	4.0
	Transient ships (as reported)			−2.4	4.9

Note: NDBO = NOAA National Data Buoy Office, LFM = NOAA Limited Area Fine Mesh Model, USEC = U.S. East Coast, USGC = U.S. Gulf Coast, USWC = U.S. West Coast, NMC = National Meteorological Center, FNOC = Fleet Numerical Oceanography Center, MPBL = Marine Planetary Boundary Layer model, adj = adjusted ship wind speeds, obj = objectively analyzed pressure fields, and rean = reanalyzed pressure fields.

Marine Wind Data

- Ships
- Buoys
- Platforms
- Satellite: SCAT, ATL, SMMR…
- GPS Dropwindsonde

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SHIP REPORTS

- Error structure of measured and estimated winds speeds better understood except for flow distortion
- Wind speed errors lower than generally thought
- Still an important source for historical hindcasting and ocean surface climate assessment
- Room for improvement in accuracy, encoding, transmission, collection etc.
- Dynamic range limited to about 0-30 m/s

Adjustment of SHIP REPORTS

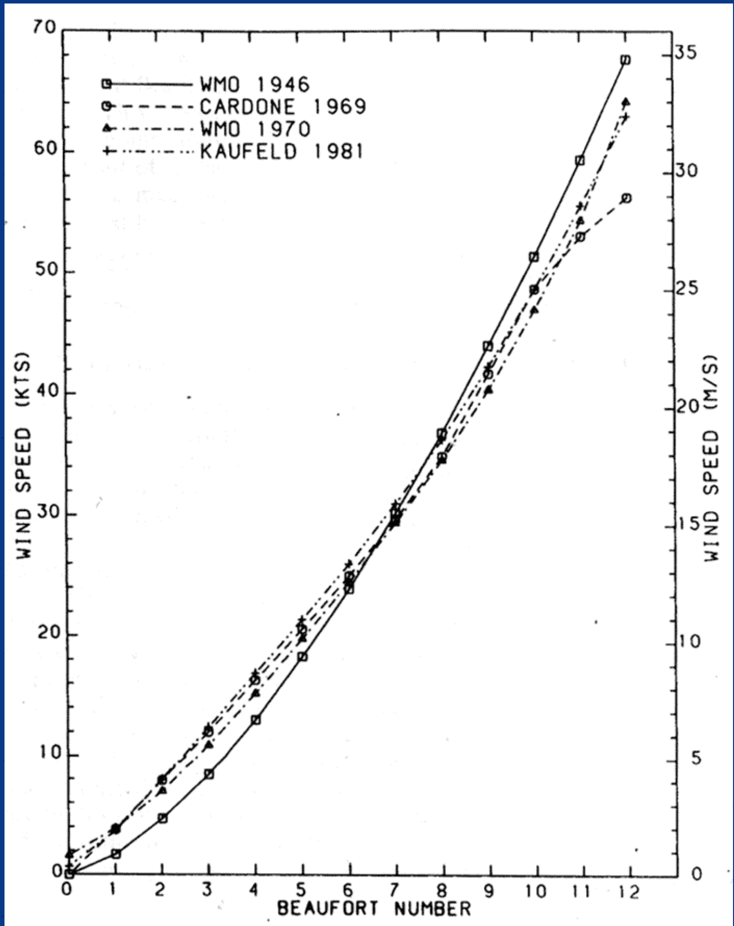

FIG. 2. Comparison of Beaufort number–wind speed equivalents.

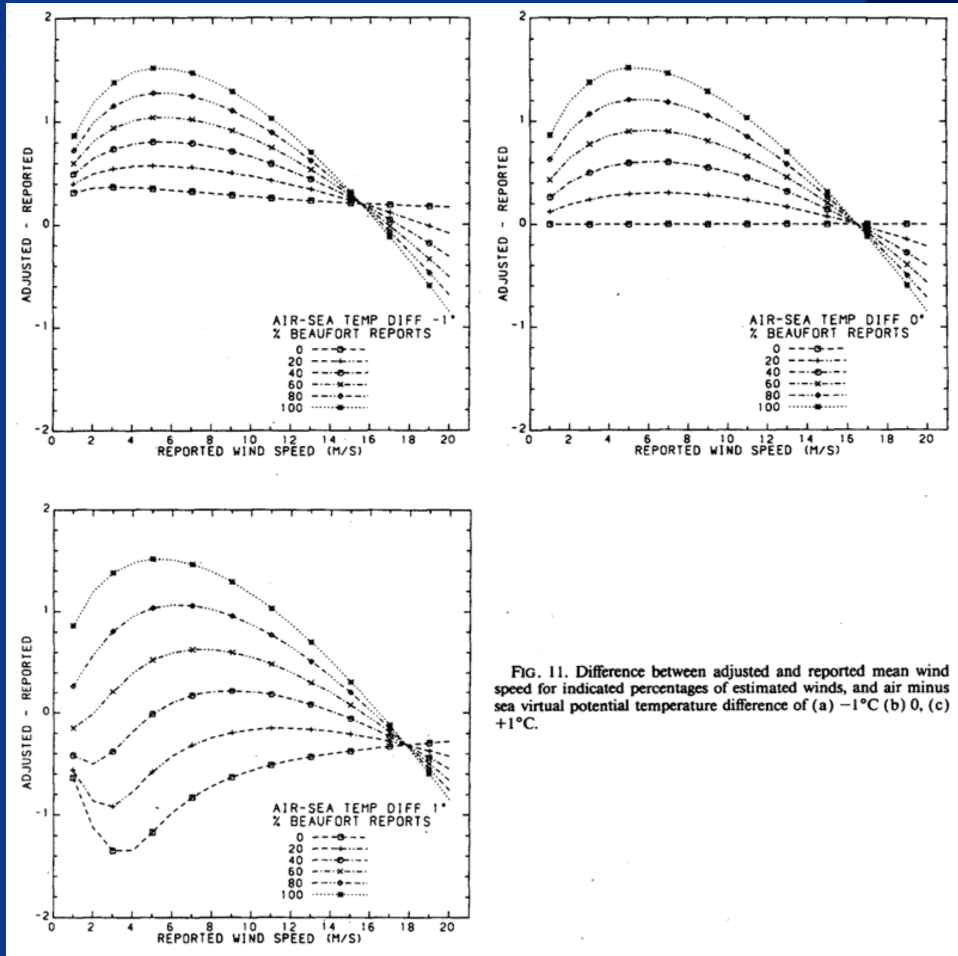

FIG. 11. Difference between adjusted and reported mean wind speed for indicated percentages of estimated winds, and air minus sea virtual potential temperature difference of (a) −1°C (b) 0, (c) +1°C.

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Ship Report Wind Speed Errors

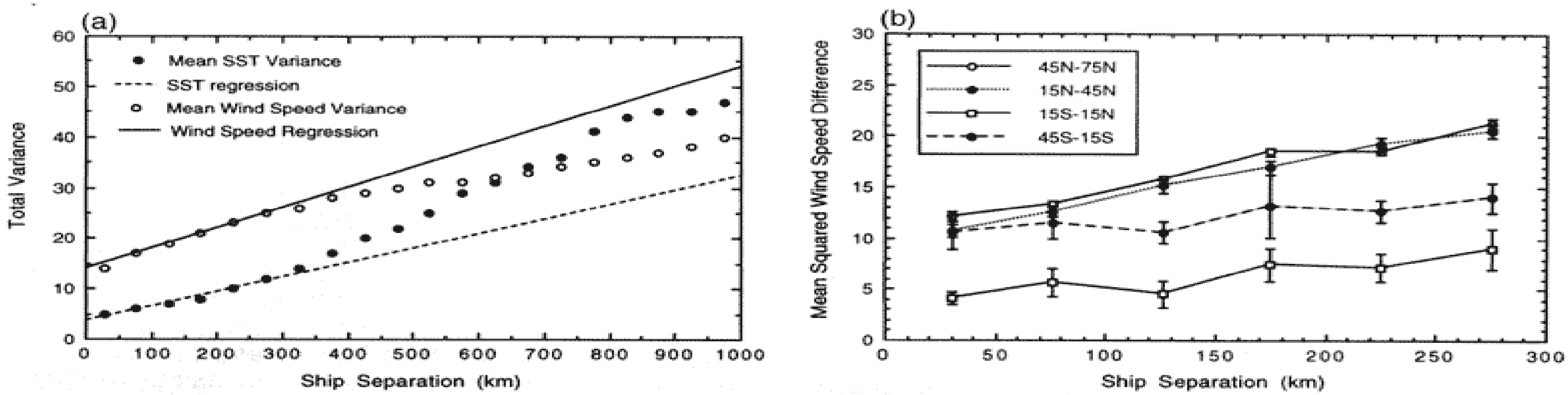

FIG. 2. (a) Examples of semivariograms for SST and 10-m-corrected wind speed in the North Pacific for January 1980. The dark circles are the SST mean variance (°C²), and the open circles are the wind speed mean variance ($m^2 s^{-2}$) in 50-km ranges for ship-pair separations below 1000 km. The lines are a regression on the individual points for data pairs up to 300-km separation. The intercept of the plot is twice the error variance. The regression lines are $y = 0.029 (\pm 0.001) x + 3.65 (\pm 0.1)$ for SST, and $y = 0.040 (\pm 0.001) x + 13.9 (\pm 0.3)$ for wind. (b) Examples of semivariograms for 10-m-corrected wind speed ($m^2 s^{-2}$) between 0° and 30°E. Plotted is the mean wind speed variance in 50-km bins between 0- and 300-km separation for each 30° latitude range from 45°S to 75°N. The total number of data pairs ranges from 406 (15°S–15°N) to 29 037 (45°–75°N). Error bars are the standard error of the mean.

Error Estimates in VOS Ship Reports and Buoy Measurements			
	Random Error	Systematic Error	
Wilkerson and Earle (1990) (paired difference method)	3.5 – 4 m/sec	1 - 2 m/sec	VOS
Kent et al. (1999) (semivariogram method)	2.1 m/sec	0.2 m/sec	VOS
Gilhousen (1987)	0.5 m/sec	0.1 m/sec	Buoy

Buoys

- Very useful for calibration and validation of models, analysis schemes, remote sensors
- Error structure a function of buoy type and payload which are far from standardized
- Systematic errors may arise above about 25 m/sec

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Platforms

- fixed vertical reference frame
- top of derrick mount minimizes flow distortion errors
- the only potential source of accurate extreme winds (U10 >35 m/s)
- heights of 50 m-140 m create new challenges for reduction to 10 m
- difficult to use because non-standard reporting practices, confidentiality...

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Platforms

60m measurement station at Horns Rev, Denmark

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North Cormorant Platform: North Sea

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Remote Sensing Winds

- Passive microwave - SMMR
- Active microwave - SASS, SCAT, NSCAT QUIKSCAT, SEAWINDS….
- Issues of dynamic range and calibration
- Evidence of sensitivity to 40 m/s for Ku band
- GPS dropwindsonde a new tool for evaluation and research

Evaluation of QuikSCAT Against Buoys

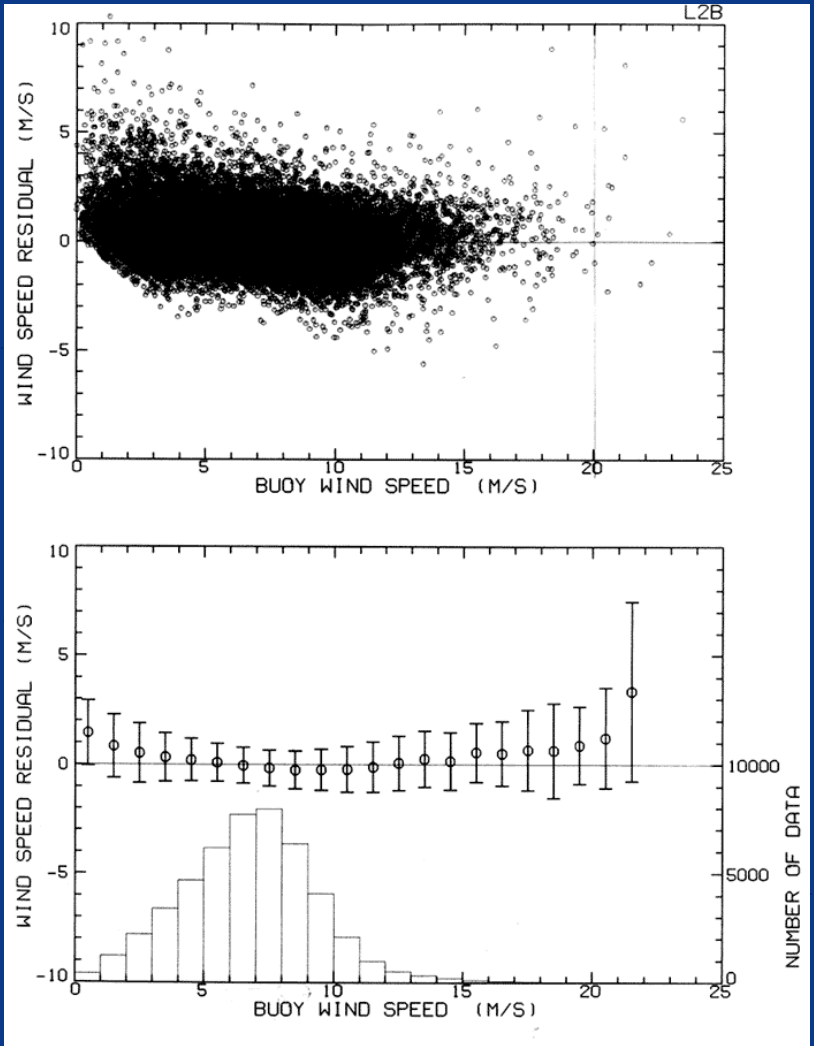

FIG. 3. Dependence of wind speed residual (QSCAT − buoy) on the buoy wind speed for the L2B winds. (upper panel) Scatterplots and (lower panel) numbers of data points, averages, (circles) and standard deviations (vertical lines) calculated in bins of buoy wind speed of 1 m s^{-1}.

Ebuchi et al. (2002);
J. Atmos. Oceanic Technol., 19, 2049-2062

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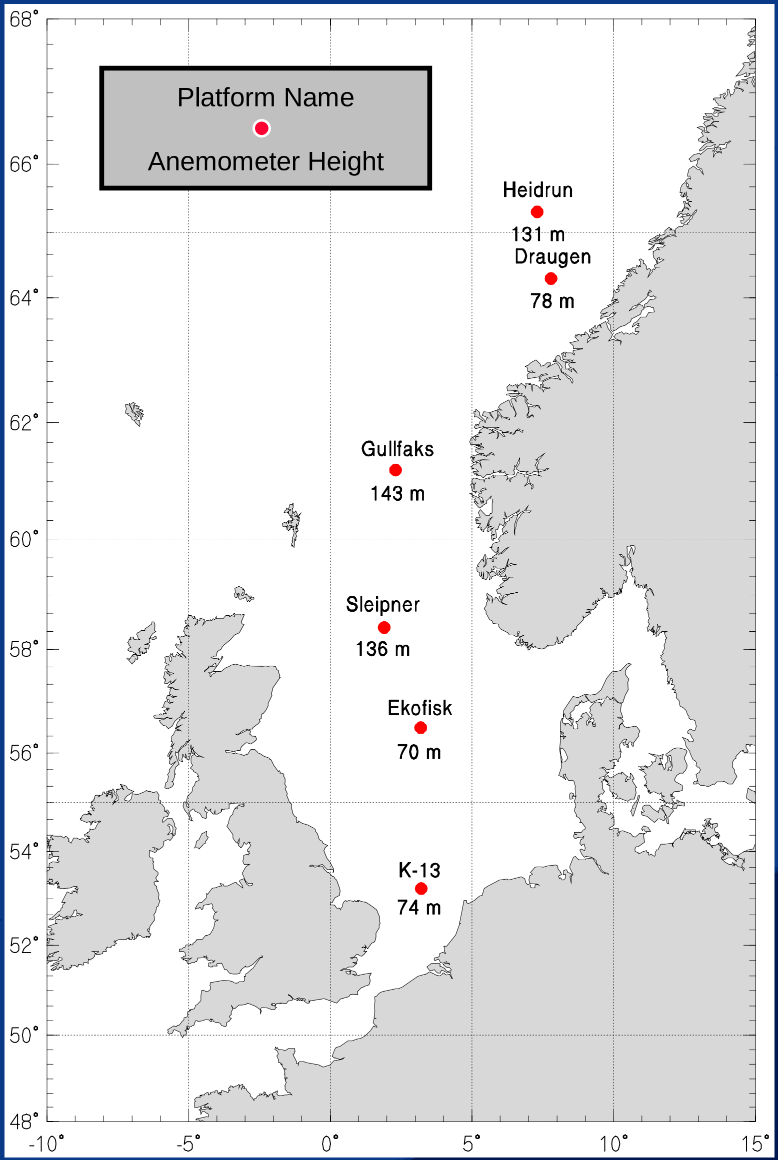
Statistics of the comparisons of QSCAT wind speed and direction with buoy data

TABLE 1. Statistics of the comparisons of QSCAT wind speed and direction with buoy data.

	Number of data	Bias	Rms difference	Correlation coefficient
L2B				
Wind speed (m s^{-1})	48 540	0.02	1.01	0.925
Wind direction (deg.)				
(Buoy wind speed > 0 m s^{-1})	48 519	1.5	29.6	0.948
(Buoy wind speed > 3 m s^{-1})	43 952	1.6	23.3	0.965
(Buoy wind speed > 5 m s^{-1})	35 092	1.7	19.5	0.973
DIRTH				
Wind speed (m s^{-1})	48 540	0.05	1.00	0.927
Wind direction (deg.)				
(Buoy wind speed > 0 m s^{-1})	48 519	1.5	28.3	0.952
(Buoy wind speed > 3 m s^{-1})	44 160	1.5	22.4	0.967
(Buoy wind speed > 5 m s^{-1})	35 619	1.6	18.8	0.975
RSS				
Wind speed (m s^{-1})	34 167	−0.02	1.01	0.925
Wind direction (deg.)				
(Buoy wind speed > 0 m s^{-1})	34 119	1.7	26.5	0.959
(Buoy wind speed > 3 m s^{-1})	31 101	1.7	20.5	0.973
(Buoy wind speed > 5 m s^{-1})	24 992	1.9	18.6	0.977

Ebuchi et al. (2002); J. Atmos. Oceanic Technol., 19, 2049-2062

Evaluation of QuikSCAT against Platforms



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Platform Data Processing

- Platform data arrived already reduced to 10m using onboard power law factor (URed) except K-13, which used KNMI's potential wind speed profile.
- Two alternative reductions to 10m applied:
  - Cardone (1969): first inverted power law factor to restore wind speeds to anemometer height then computed 10 m neutral wind speed using NCEP air and sea temperatures (WindFN).
  - WindFN Neutral: same as WindFN but assuming air-sea temperature difference =0.

Collocation Process

- Read NASA JPL Level 2B (L2B) file processed using DIRTH. Retrievals flagged for land, rain, or ice were not included in this analysis.
- Search 100 x 100 km box centered on the platform within a +/- 30 minute time window of the platform wind.
- Always match the single nearest QuikSCAT wind within the time and space filter.
- Found 21,454 matches total for all six platforms from 199907-200212.

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North Sea Platforms Used to Evaluate QuikSCAT

Platform	Location	Anemometer Height (m)	Water Depth (m)	Reduction Factor	Measurement Interval
Draugen	64.3N 7.8E	78	251	0.77	199907-200212: 20 min
Ekofisk	56.5N 3.2E	116 & 70.2	70	0.73 & 0.77	199907-200212: 20 min
Gullfaks	61.2N 2.3E	143	217	0.71	199907-200106: 20 min 200107-200212: 10 min
Heidrun	65.3N 7.3E	131	350	0.72	199907-200112: 20 min 200201-200206: 10 min 200207-200212: 20 min
K-13	53.22N 3.22E	74	23	~0.81	199907-200212: 1-hr (WD last 10-min of preceding hour)
Sleipner	58.4N 1.9E	136	82	0.71	199907-200212: 20 min

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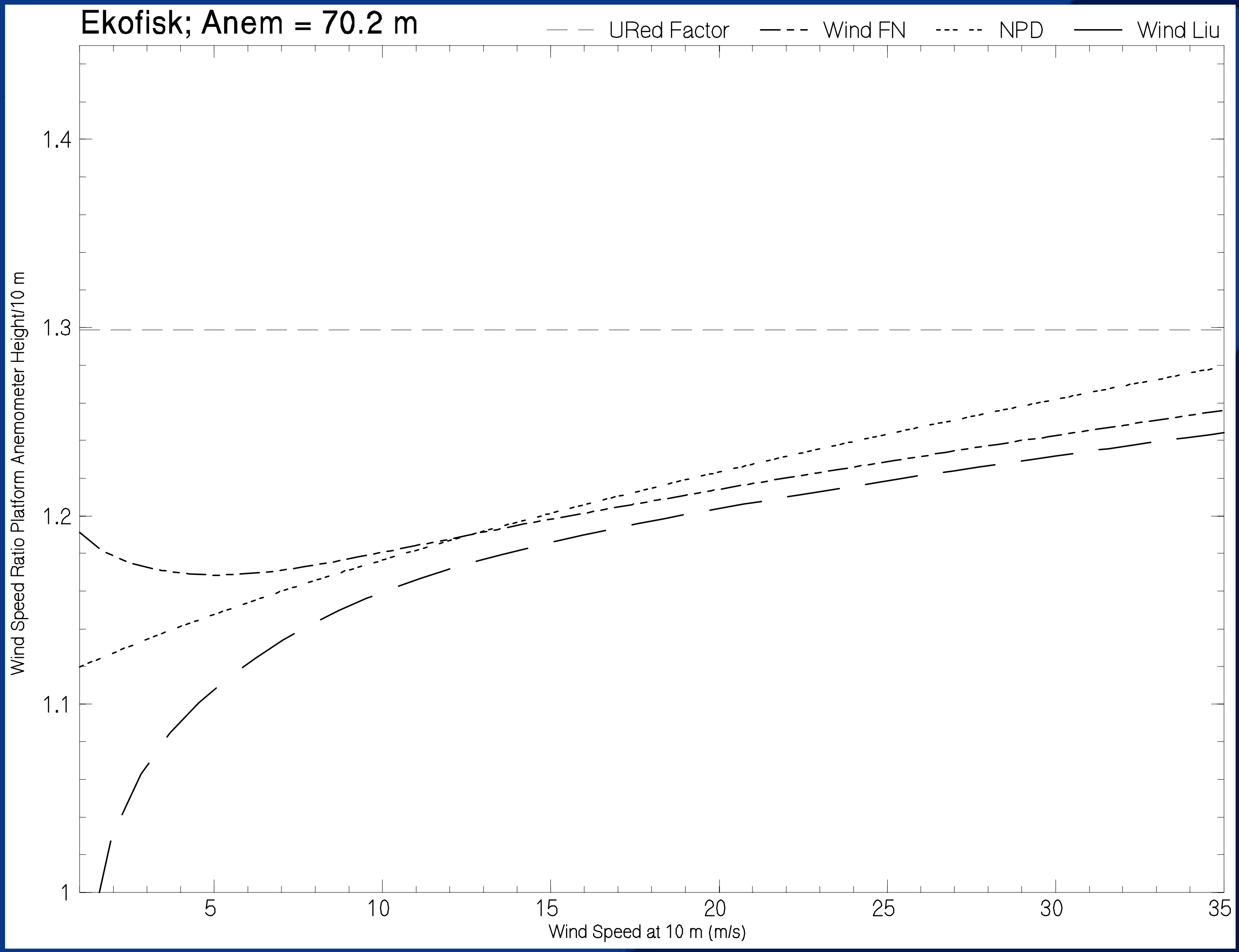
Comparison of Wind Speed Reduction Factors - Ekofisk Platform



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Platform Winds Reduced to 10 m using WindFN

Platform	Wind Speed (m/s)								Wind Direction (deg)					
	No.	Mean Plat	Mean QS	Diff (Q-P)	RMS Error	Stnd Dev	Scat Index	Corr Coeff	No.	Mean Plat	Mean QS	Diff (Q-P)	Stnd Dev	Scat Index
Draugen	3848	8.29	8.46	0.17	1.77	1.76	0.21	0.93	3848	258.28	236.05	0.43	31.31	0.09
Ekofisk	3172	7.98	8.94	0.96	1.86	1.59	0.20	0.92	3171	238.08	235.38	-2.31	24.52	0.07
Gullfaks	3671	9.21	9.75	0.54	1.82	1.74	0.19	0.94	3662	245.61	215.55	-17.39	31.60	0.09
Heidrun	4481	8.24	9.07	0.84	1.70	1.48	0.18	0.94	4482	247.50	251.69	-4.45	26.28	0.07
K-13*	2954	8.14	8.32	0.18	1.73	1.72	0.21	0.90	2878	236.36	233.14	-3.75	25.96	0.07
Sleipner	3328	8.54	9.13	0.59	1.67	1.57	0.18	0.94	3328	237.43	226.84	-3.98	25.63	0.07
All (except K-13)	18500	8.45	9.07	0.62	1.76	1.65	0.20	0.93	18491	243.27	231.38	-5.47	28.72	0.08

* K-13 statistics using potential wind speed profile by KNMI

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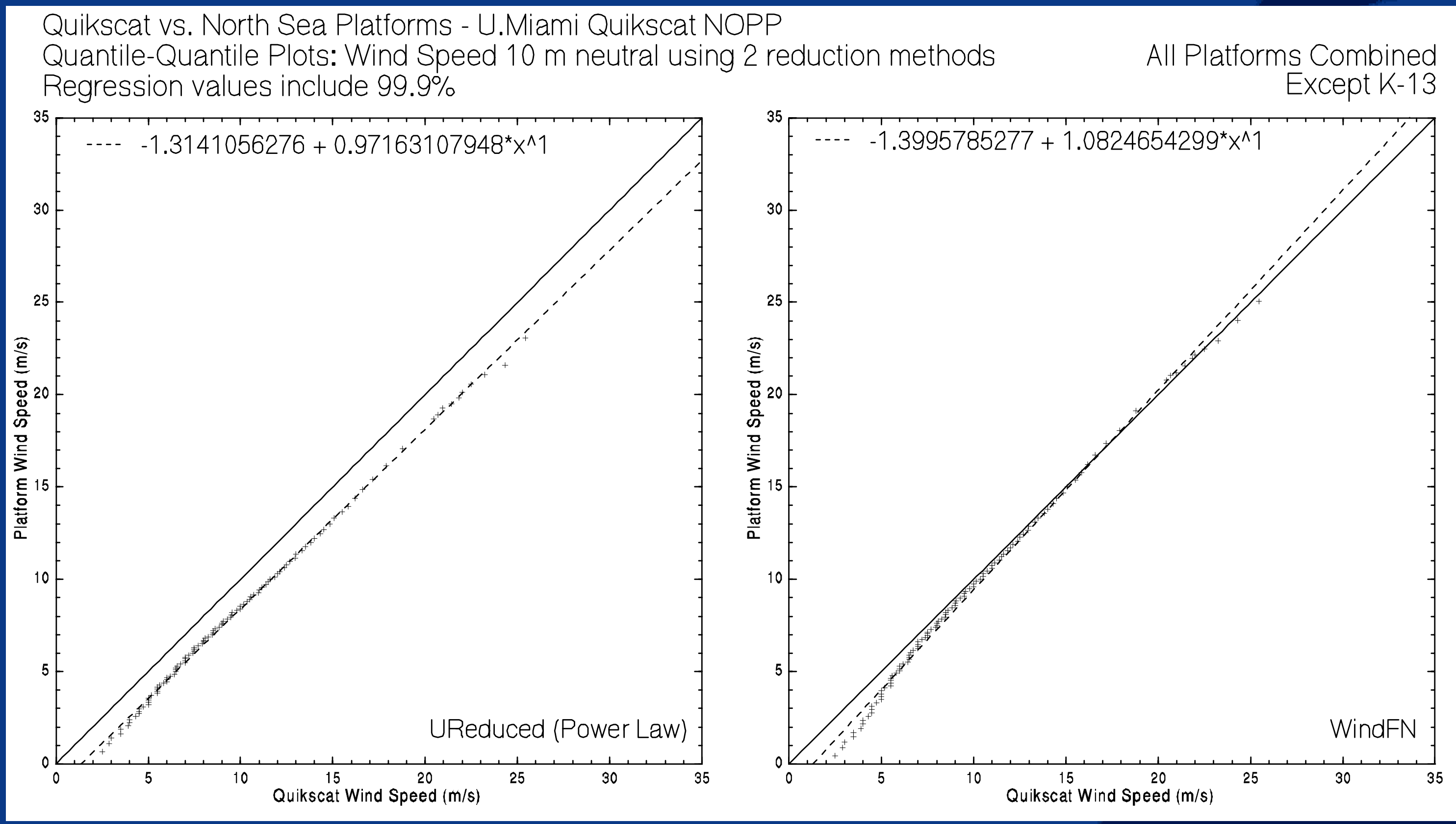
Q-Q Plot



Data Period : 01-JUL-1999 00:00:00 to 01-JAN-2003 00:00:00

	Platform	Method	Number of Pts	Mean Plat	Mean QScat	Diff (Q-P)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Wind Spd. (m/s)	All	URed	18500	7.50	9.07	1.56	2.31	1.70	0.23	0.85	0.91
Wind Spd. (m/s)	All	WindFN	18500	8.45	9.07	0.62	1.76	1.65	0.20	0.63	0.93
Wind Dir. (deg)	All	URed-FN	18491	243.28	231.38	-5.47	N/A	28.72	0.08	N/A	N/A

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Platform-QS Pairs Where Either Exceeds 25 m/s

YYYYMM	DDHHMM	Platform	Quikscat WS	Platform WS	Quikscat WD	Platform WD
200001	291900	Sleipner	31.0	31.3	284.5	296.6
200111	301800	Gullfaks	27.1	27.2	150.2	176.8
200111	110400	Draugen	25.9	27.1	290.7	273.7
200111	102000	Heidrun	23.6	26.7	265.3	263.7
200010	301800	Ekofisk	22.0	26.7	210.0	245.0
199912	010300	Draugen	25.0	26.5	309.0	310.3
200010	302000	Draugen	23.6	26.0	83.5	90.0
200201	281900	Ekofisk	25.7	26.0	282.0	279.3
199911	301900	Sleipner	23.0	25.9	256.1	260.5
200002	231800	Gullfaks	26.7	25.9	172.7	183.0
200111	150400	Draugen	25.2	25.6	295.3	280.7
199912	010500	Draugen	23.0	25.4	316.0	304.7
200111	142000	Draugen	24.3	25.2	226.7	229.6
200111	102000	Draugen	25.3	25.2	265.5	270.6
200212	240500	Gullfaks	28.9	25.1	151.6	166.3
200212	240400	Gullfaks	26.0	25.1	150.6	164.4
200010	310300	Draugen	20.5	25.0	95.2	98.3
200111	110400	Heidrun	26.7	24.3	291.6	280.0
200202	141900	Draugen	27.6	24.1	230.7	225.0
200212	241800	Gullfaks	25.6	24.0	142.8	162.9
200212	231900	Gullfaks	27.8	24.0	155.4	167.8
200002	032000	Heidrun	25.7	23.9	213.2	203.7
199911	291900	Heidrun	26.0	23.7	255.8	255.2
200212	240400	Sleipner	25.1	23.4	132.1	132.7
200203	270300	Draugen	25.7	22.7	210.9	216.4
200212	200500	Draugen	25.7	20.5	12.4	0.0

Mean Quikscat WS: 25.49 m/s

Mean Platform WS: 25.25 m/s

Mean Diff (Q-P): -0.24

RMS: 2.60

Stnd Dev: 2.58

Scat Index: 0.10

Corr Coeff: 0.18

Mean Quikscat WD: 229.30 deg

Mean Platform WS: 233.32 deg

Mean Diff (Q-P): 3.31

Stnd Dev: 12.44

Scat Index: 0.04

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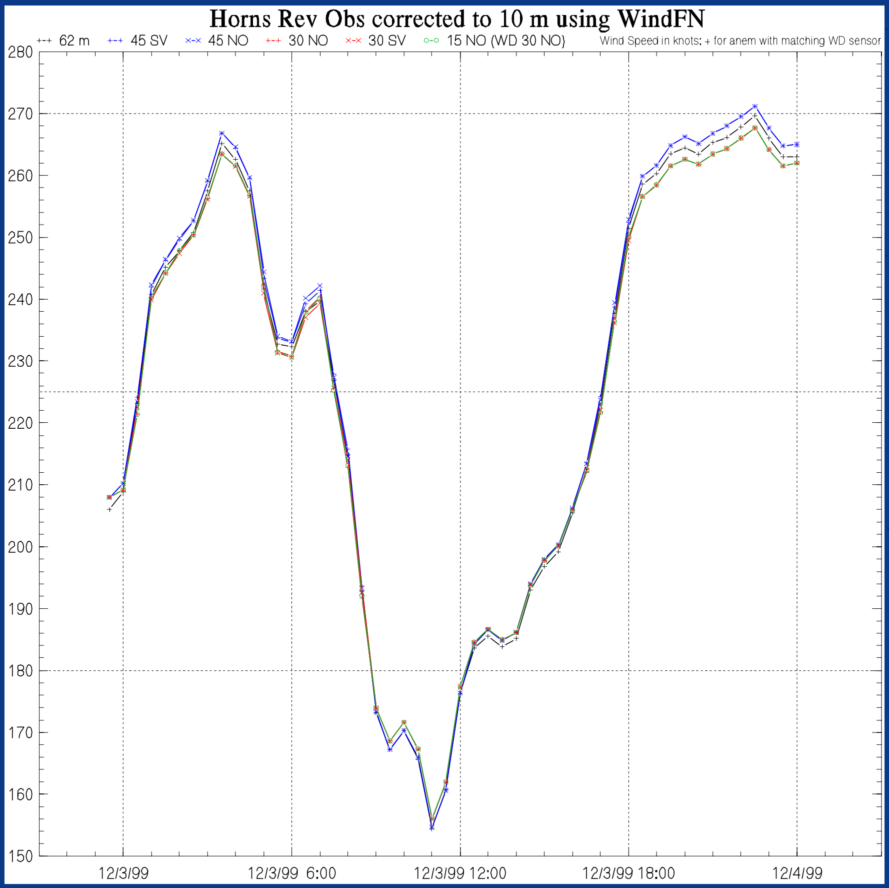
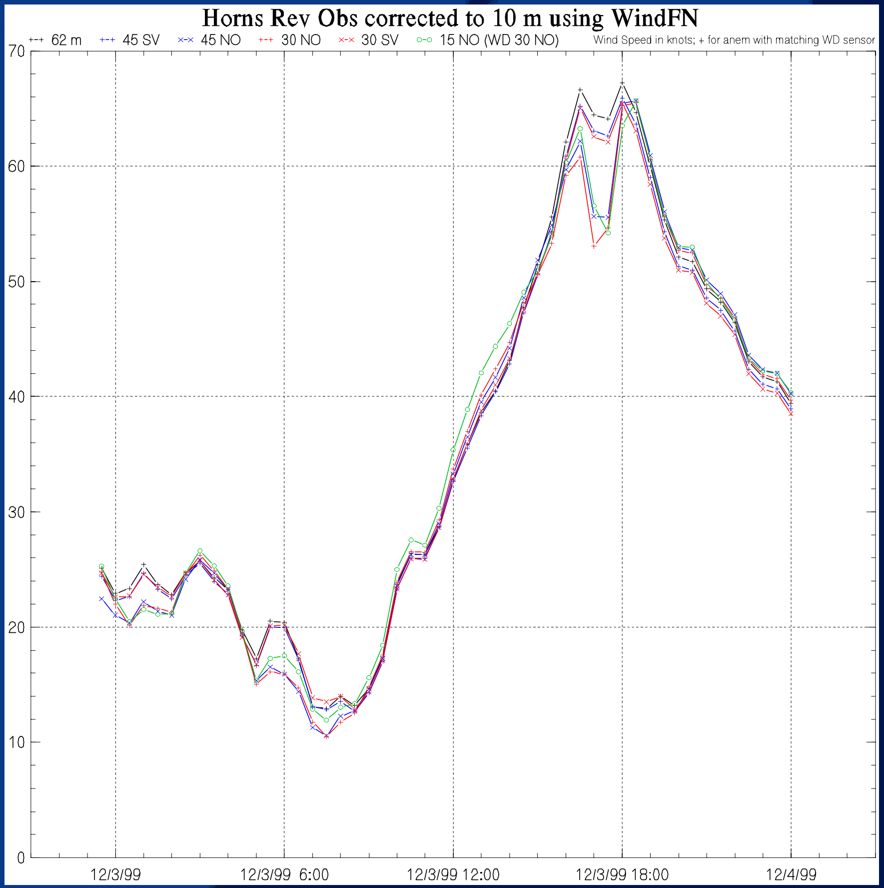
Winds Observed in North Sea “Hurricane” by Horns Rev





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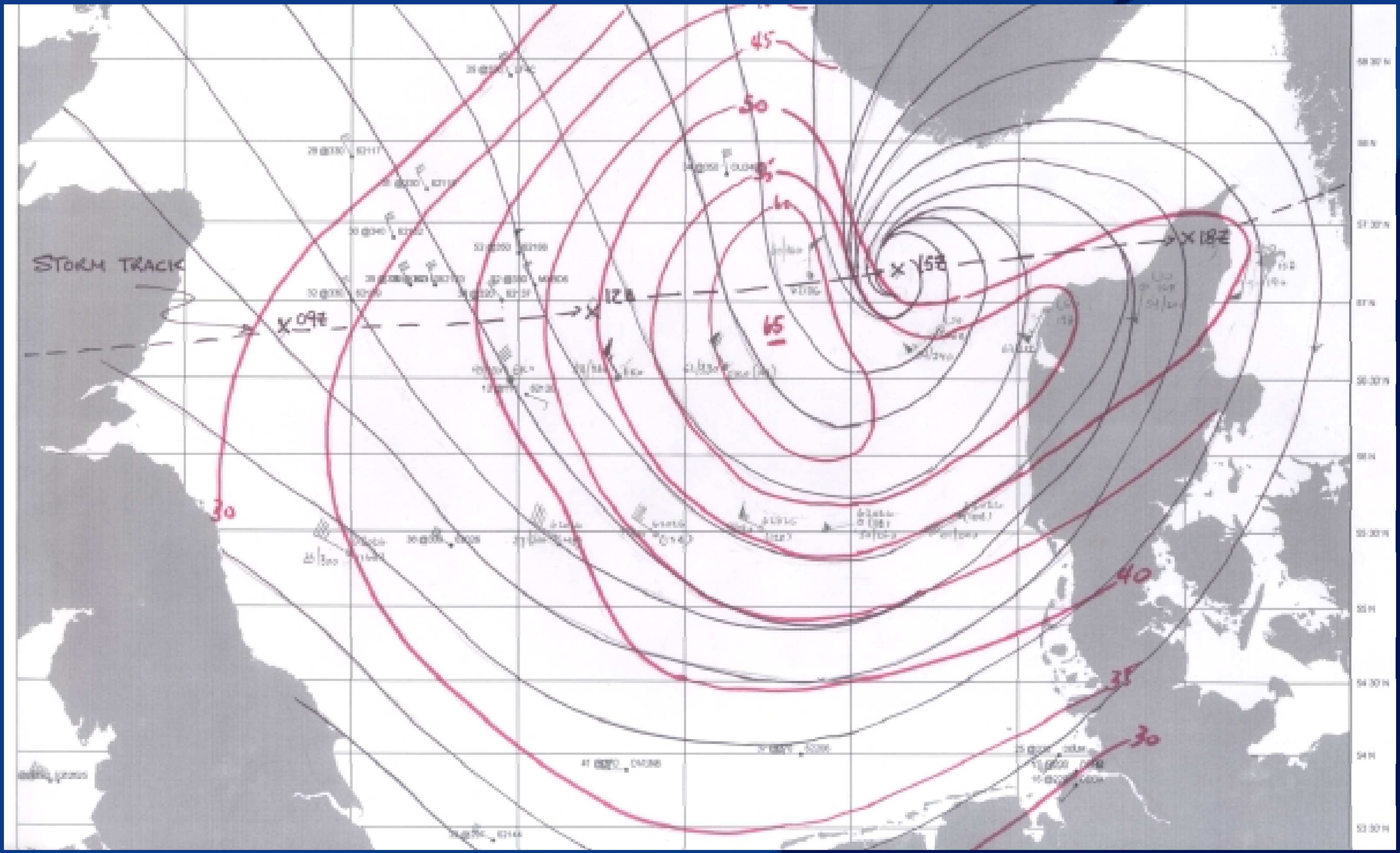
North Sea “Hurricane”

Kinematic Analysis to QuikSCAT Data
1500 UTC December 3, 1999



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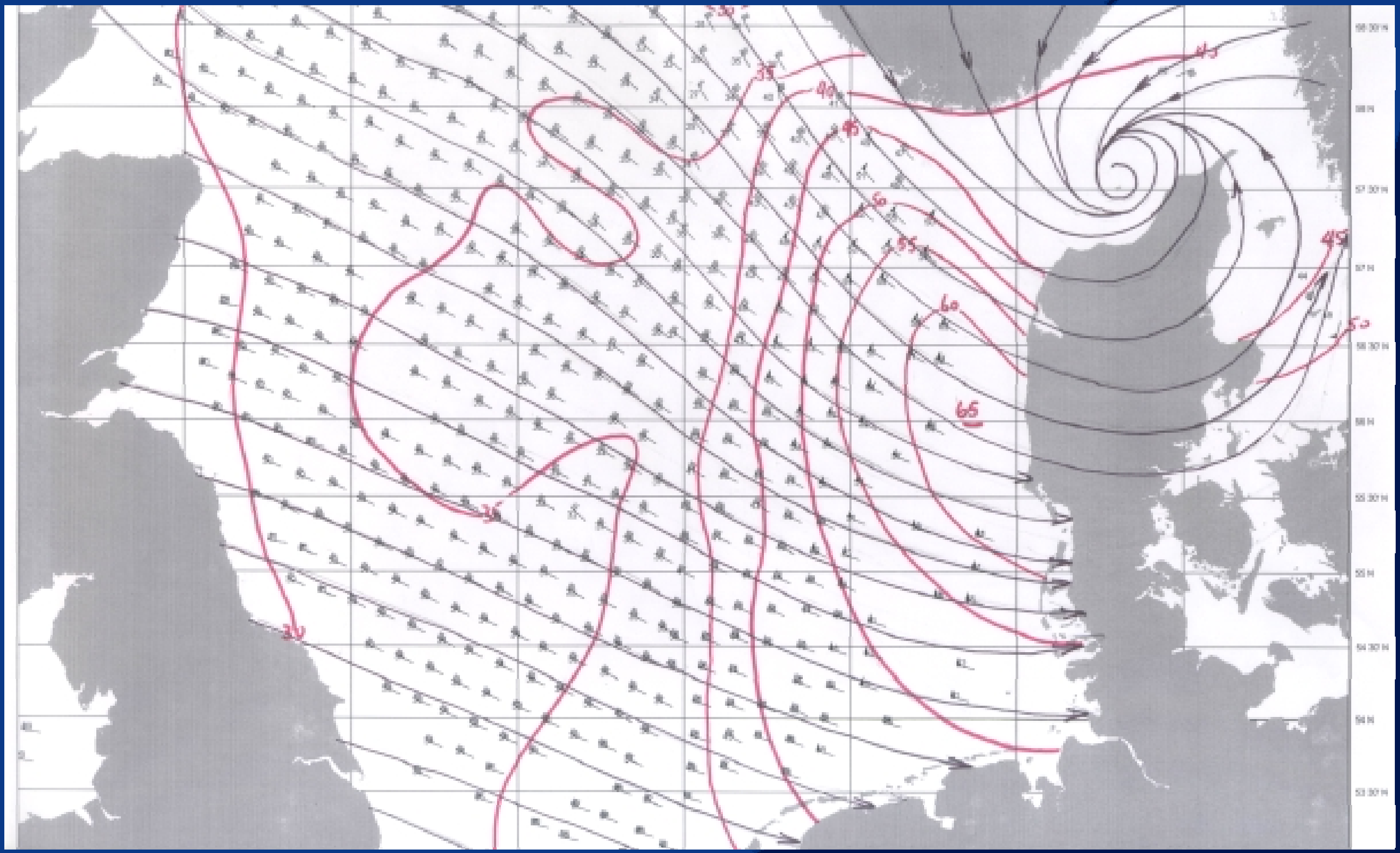
North Sea “Hurricane”

Kinematic Analysis to QuikSCAT Data
1800 UTC (Revs. At 1714 UTC and 1934 UTC)



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SWADE IOP1:

"The holy grail of wave hindcasting"

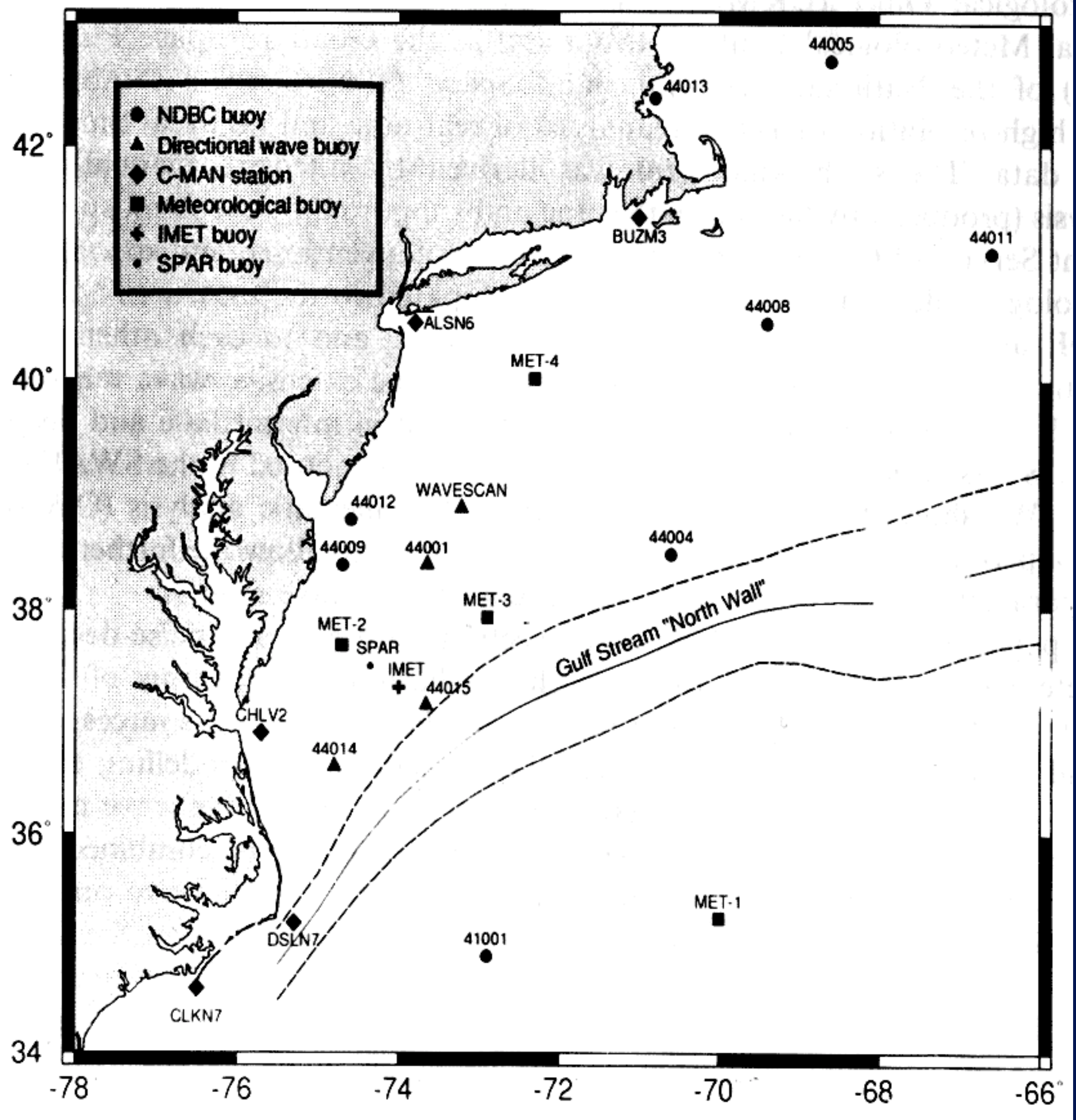

FIGURE 1 Location map of SWADE experimental domain.

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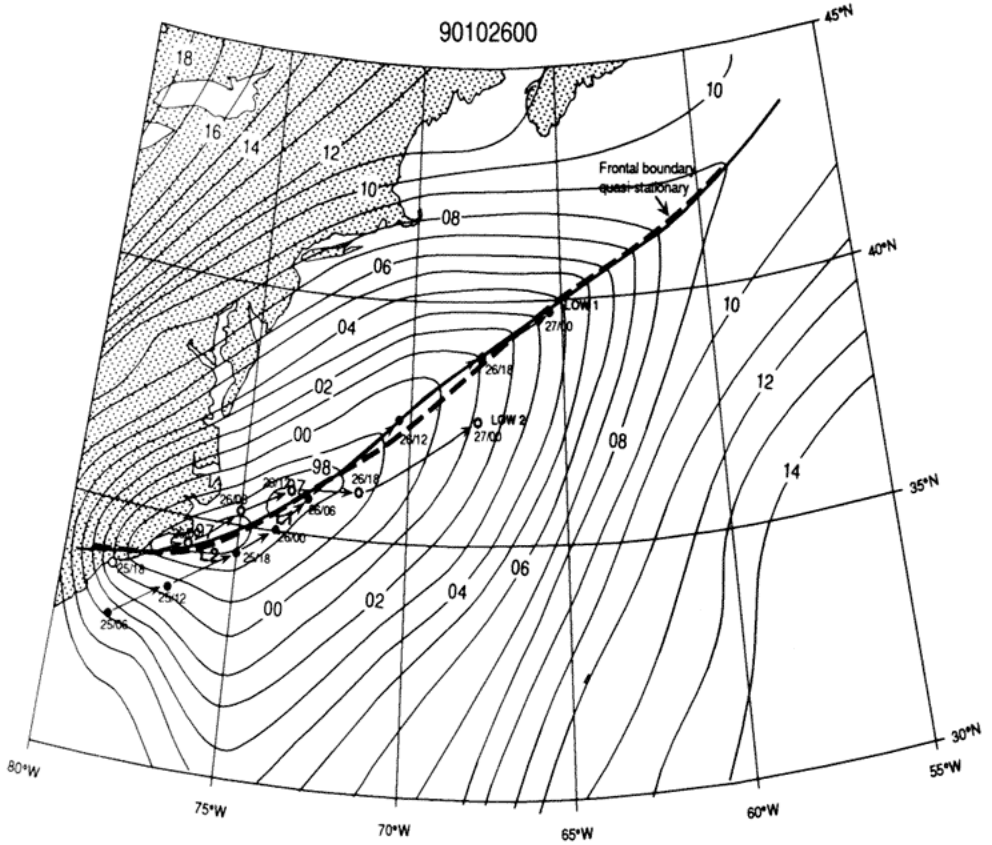

FIGURE 4 High-resolution sea level pressure analysis at 00 UT 24 October 1990 and position of frontal boundary and the space-time evolution of two low pressure systems from 25–27 October over the SWADE domain.

TABLE 2

Wind fields used to force WAM Cycle-4 in SWADE IOP-1.

Source	Method	Variables	Resolution		Reference
			spatial	temporal	
OW/AES	Kinematic analysis	U_{20}	0.5 deg	1-hourly	Cardone et al. (1980)
ECMWF	Optimum interpolation	U_{10}	1.125 deg	6-hourly	Shaw et al. (1987)
FNOC	Optimum interpolation	τ	1.25 deg	6-hourly	Barker (1992)
UKMO	Optimum interpolation	$U_{19.5}$	1.5 deg Lat 1.875 deg Long	2-hourly	Bell and Dickinson (1986)
NASA/GSFC	Successive correction	U_{10}	0.25 deg	3-hourly	Barker et al. (1984)
NOAA/NMC	Conditional relaxation	U_{10}	0.3 deg Lat 0.5 deg Long	6-hourly	Gemmill (1991)

TABLE 3

Summary of wind errors derived from previous numerical experiments in wave hindcasting.

Invesitgator/Experiment	Wind Speed			Wind Direction	
	N Obs.	Meas. Diff.	Scatter (*rms*)	Meas. Diff	Scatter (*rms*)
Overland & Gemmill (1977)	N.A.	−0.50	2.40	N.A.	N.A.
Gemmill *et al.* (1988)	N.A.	−0.10	2.90	N.A.	N.A.
Cardone (1992), ERICA IOP-2	351	0.22	3.10	7.3°	38.2°
SWADE IOP-1 (MPBL)	539	−0.41	2.87	11.1°	32.8°

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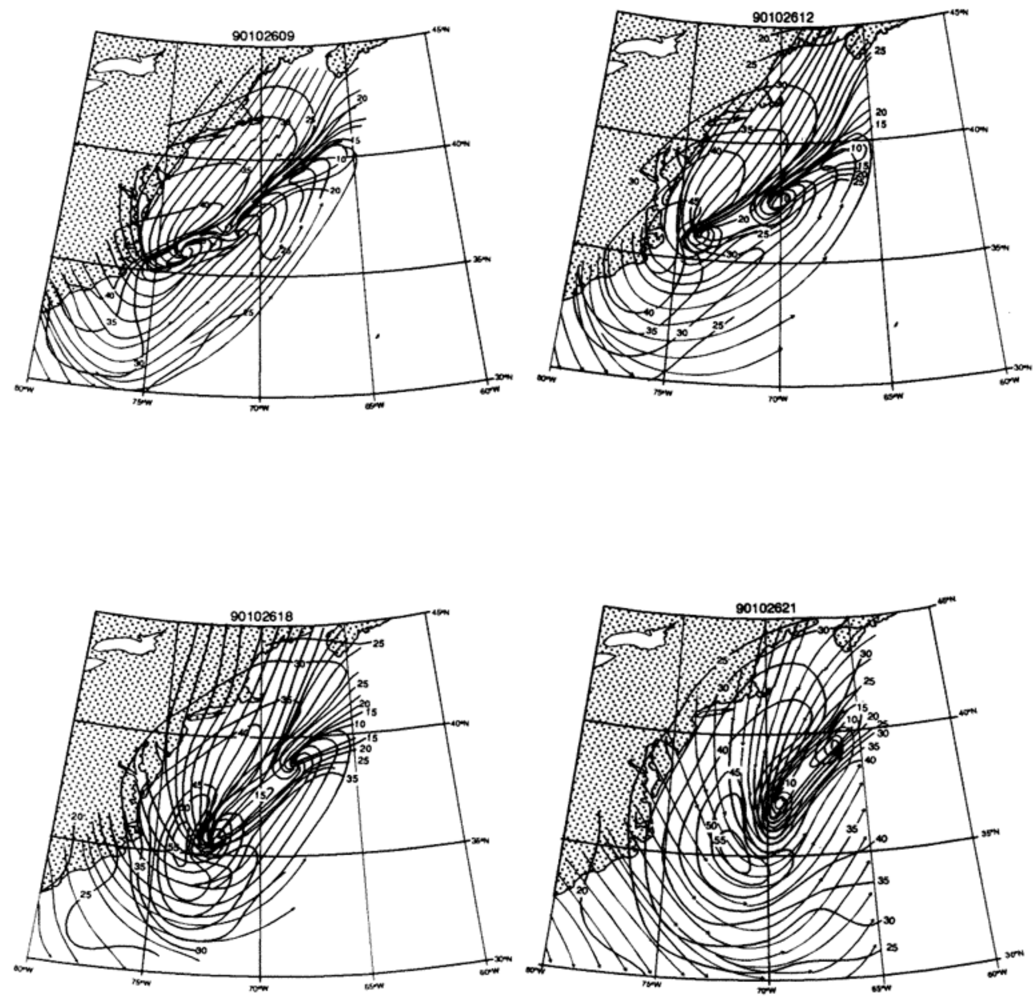

FIGURE 6 Sequence of atmospheric flow from 09–21 UT 26 October 1990 during SWADE IOP-1 in terms of streamline and isotachs (knots).

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SWADE IOP1 (OWI/EC) Kinematic Wind Analysis and WAM Cycle 4 Wave Hindcast Evaluated Against Measurements from 8 Offshore Buoys

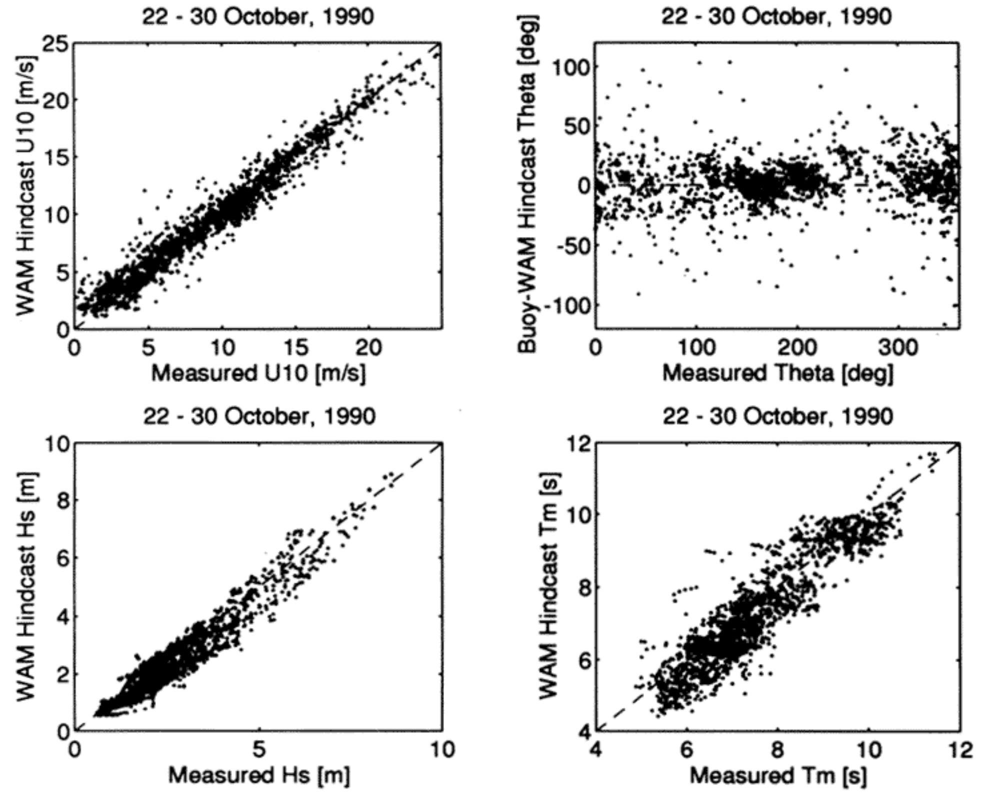

FIGURE 8 Scatter plots of OW/AES hindcast and measured wind (adjusted to 10-m neutral), direction difference, wave height and mean wave period at 8 offshore buoys.

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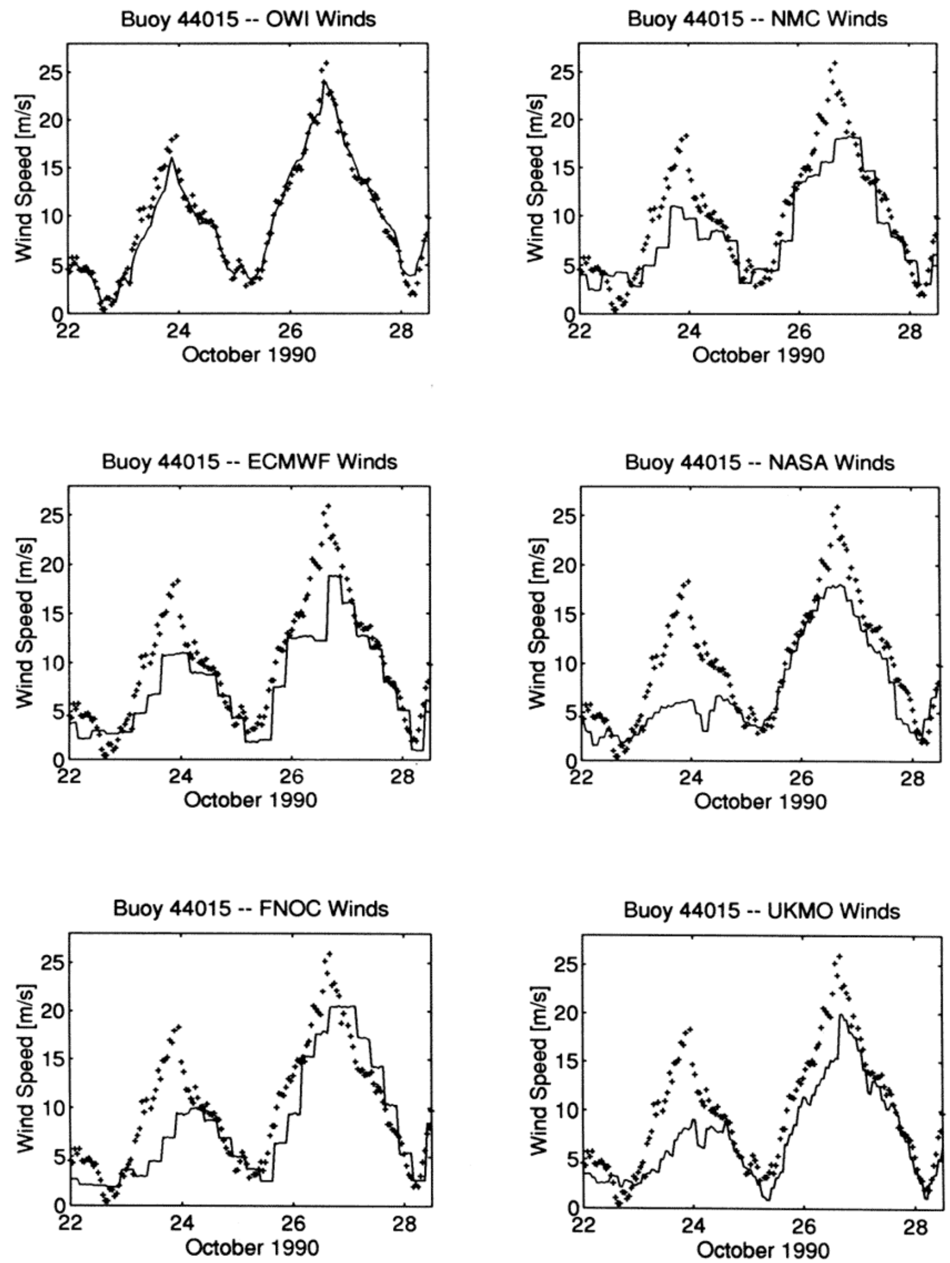

FIGURE 10a

Alternative SWADE IOP-1 windfields compared to buoy 44015 measurements

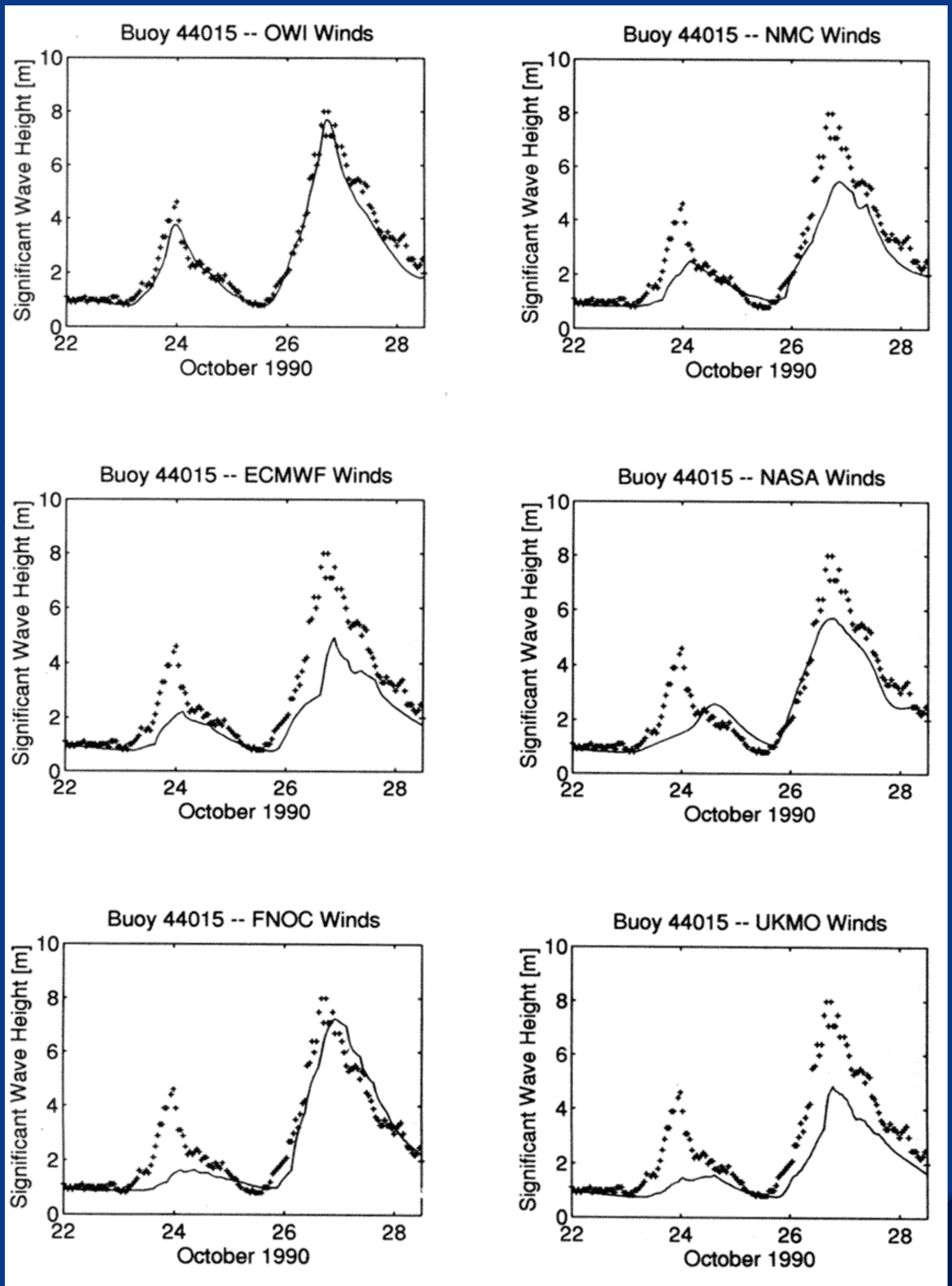

FIGURE 10c

Alternative SWADE IOP-1 WAM hindcasts compared to buoy 44015 measurements

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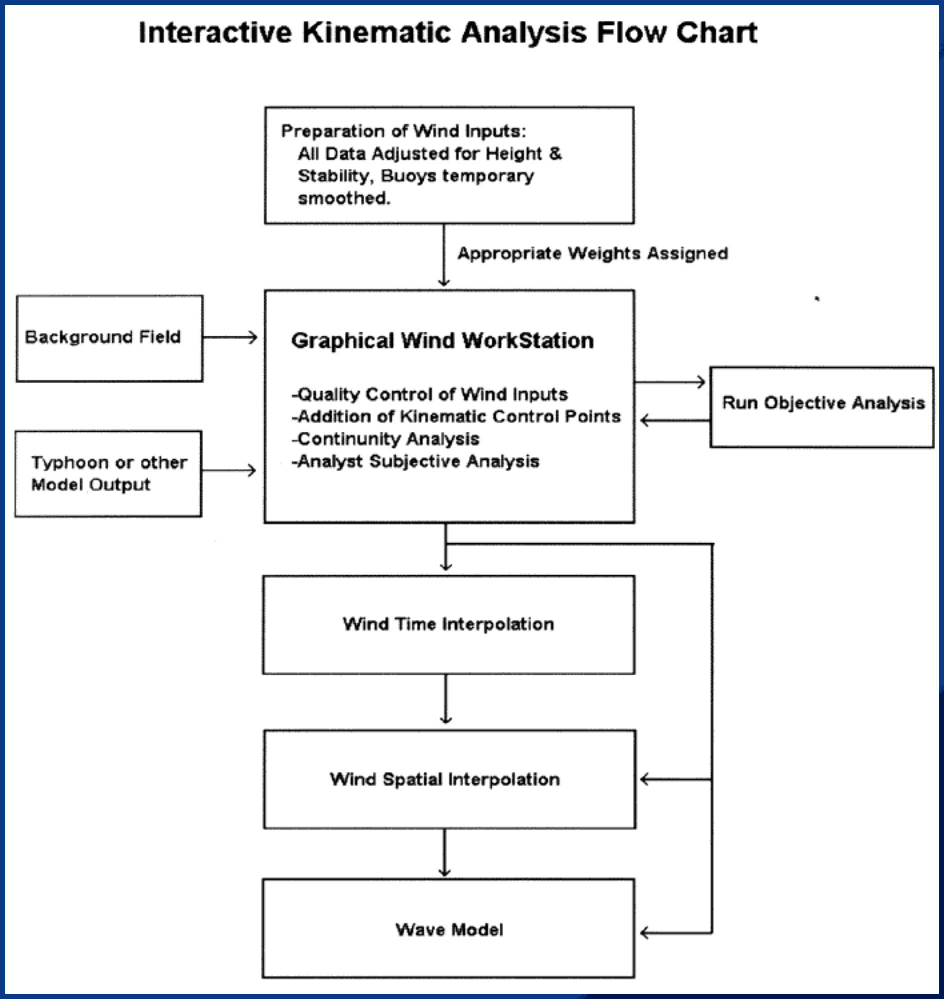
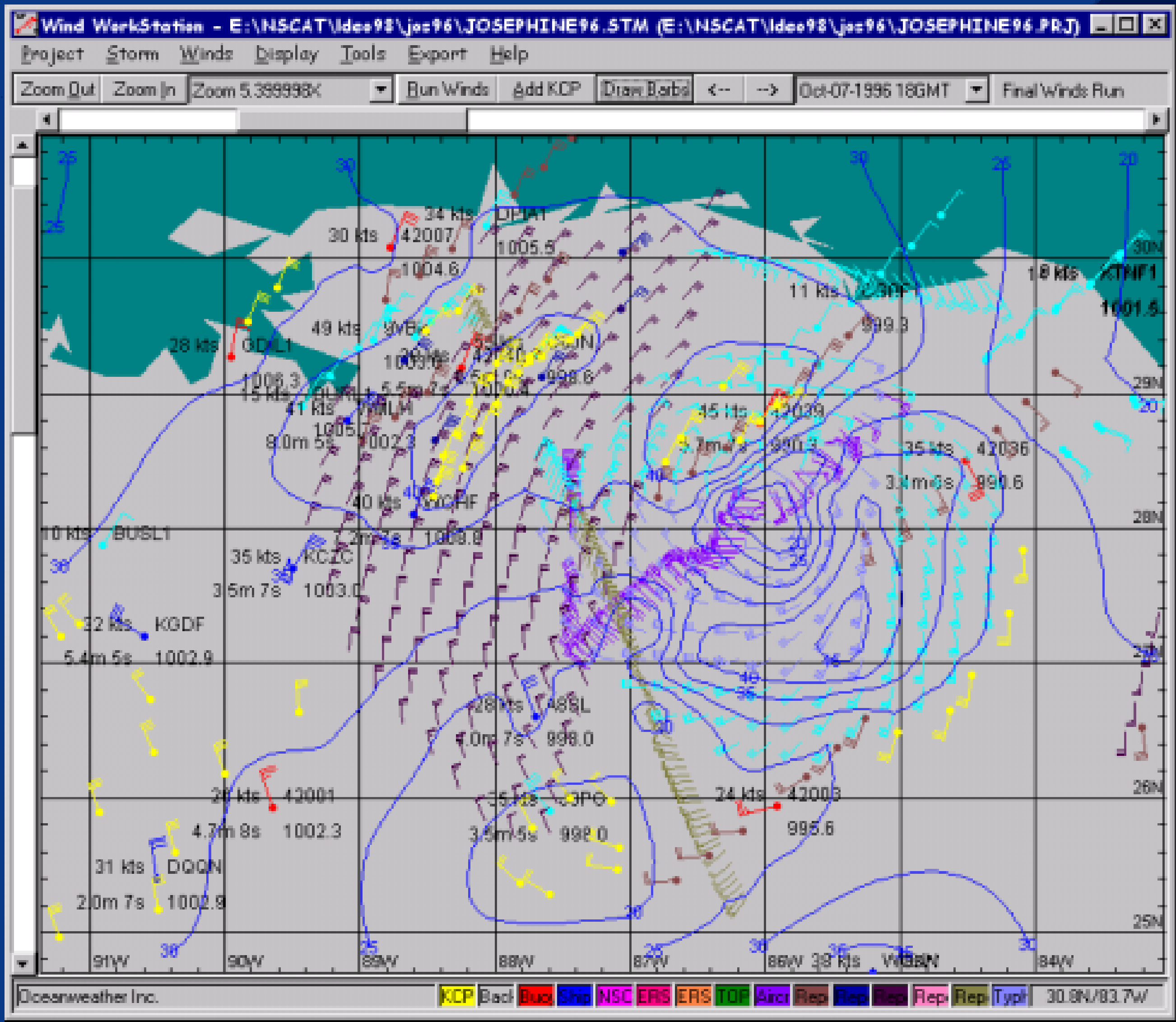
IOKA


Interactive Kinematic Analysis Flow Chart
Preparation of Wind Inputs:
All Data Adjusted for Height & Stability, Buoys temporary smoothed.
Appropriate Weights Assigned
Background Field
Typhoon or other Model Output
Graphical Wind WorkStation
-Quality Control of Wind Inputs
-Addition of Kinematic Control Points
-Continunity Analysis
-Analyst Subjective Analysis
Run Objective Analysis
Wind Time Interpolation
Wind Spatial Interpolation
Wave Model

Wind WorkStation



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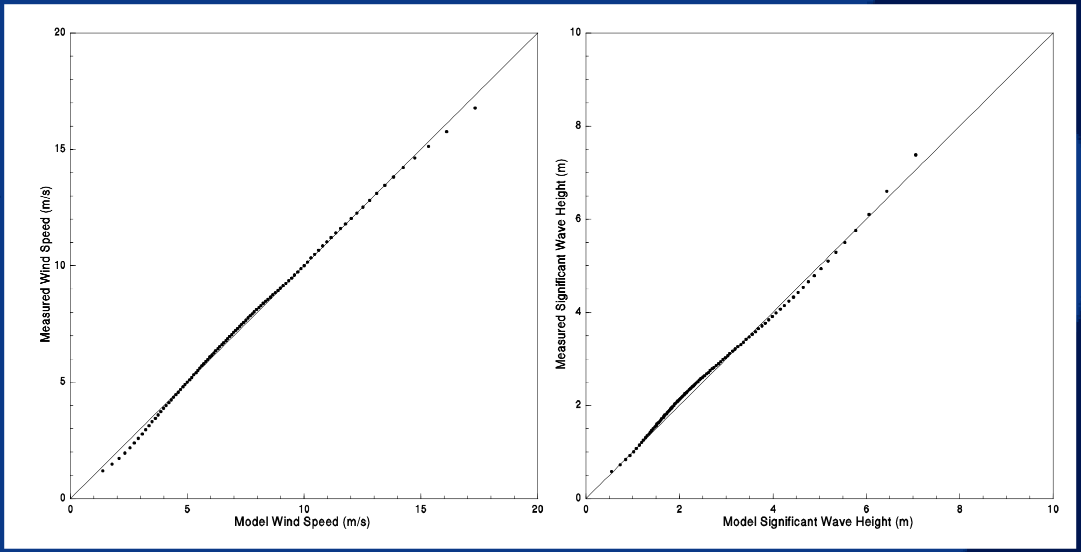
Altimeter Wind and Wave Comparisons

- ERS-1/2 and TOPEX Measurements Combined
- Individual Measurements Binned +/-3 Hours onto Wave Model Grid for Comparison

	Num Obs	Bias	SI
GROW Ws (m/s)	8,699,413	0.00	0.29
GROW Hs (m)	8,662,504	-0.04	0.24
AES40 Ws (m/s)	3,471,109	0.15	0.25
AES40 Hs (m)	3,523,575	-0.01	0.22

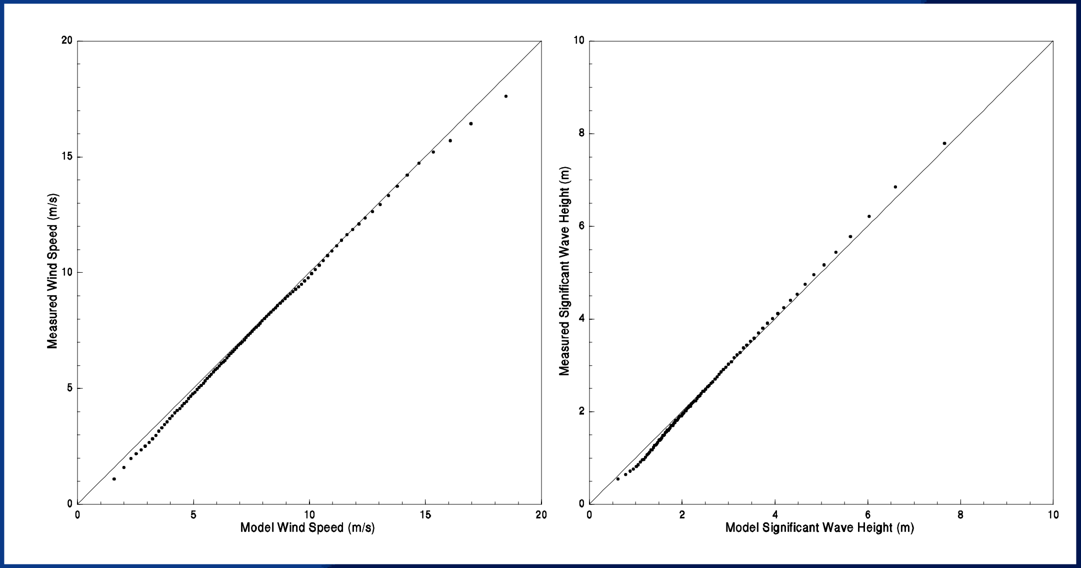
AES40: Swail and Cox (2000); J. Atmos. Oceanic Technol., 17, 532-545
GROW: Cox and Swail (2001); J. Geophys. Res. 106, 2313-2329

GROW



Altimeter Q-Q Comparisons

AES40



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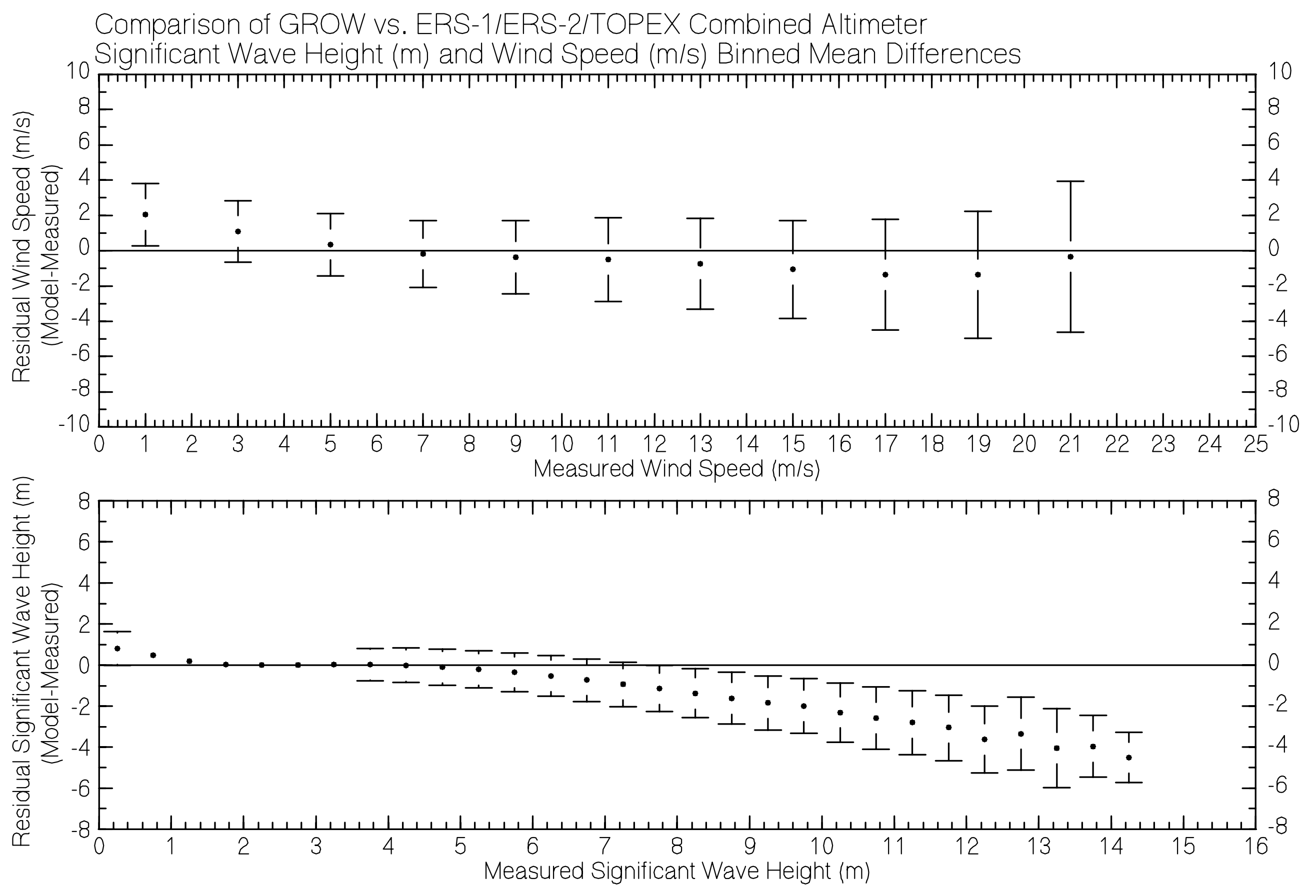
GROW Bias Binned by Measurements



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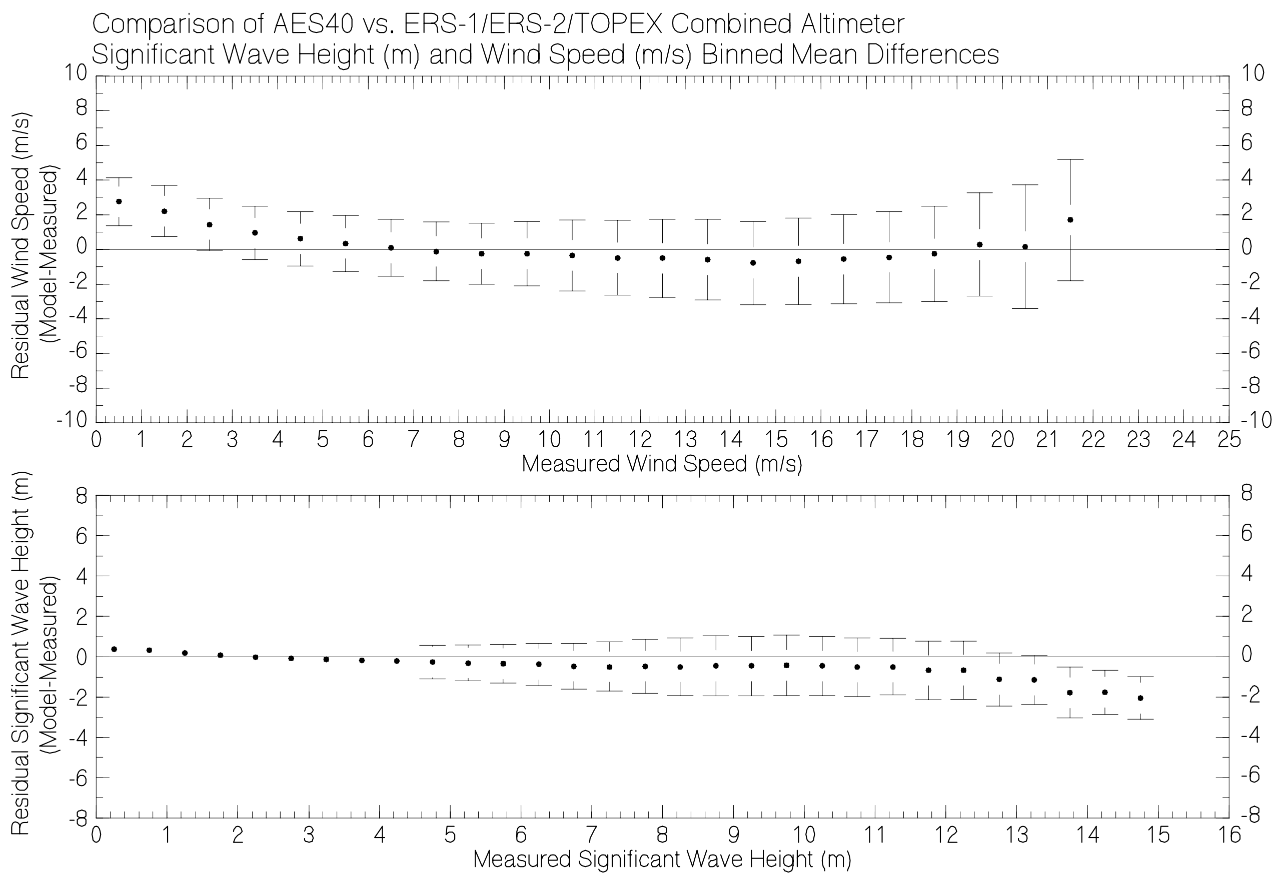
AES40 Bias Binned by Measurements



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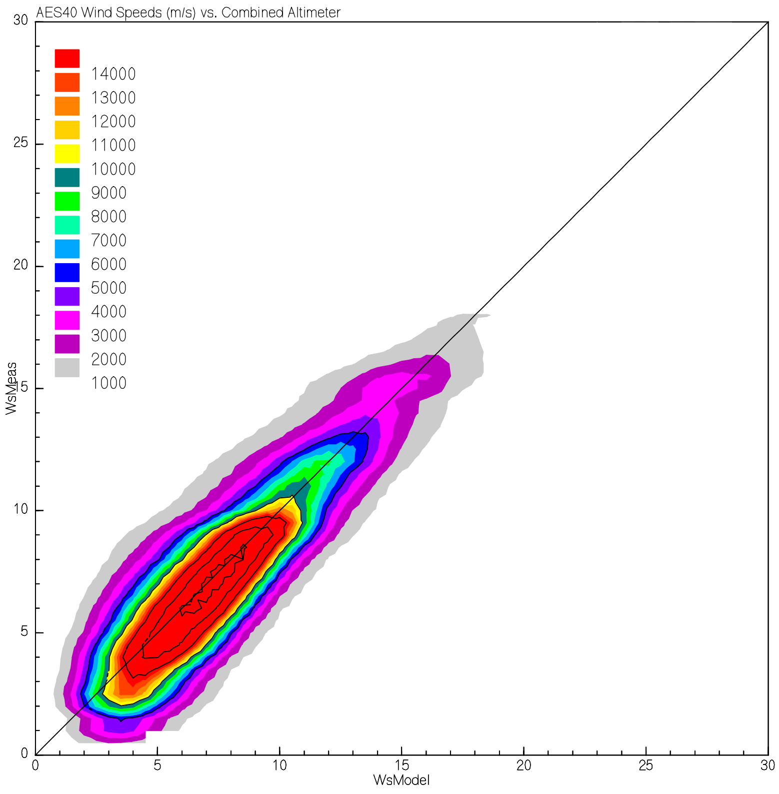
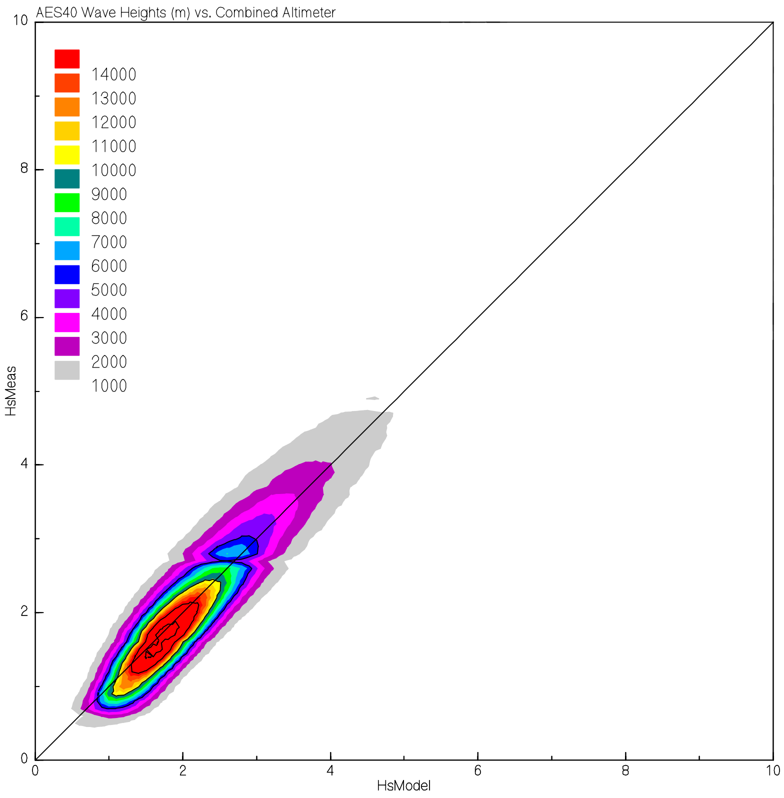
AES40 vs. Altimeter Contoured Scatter





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Impact of QuikSCAT on Current Practice of IOKA

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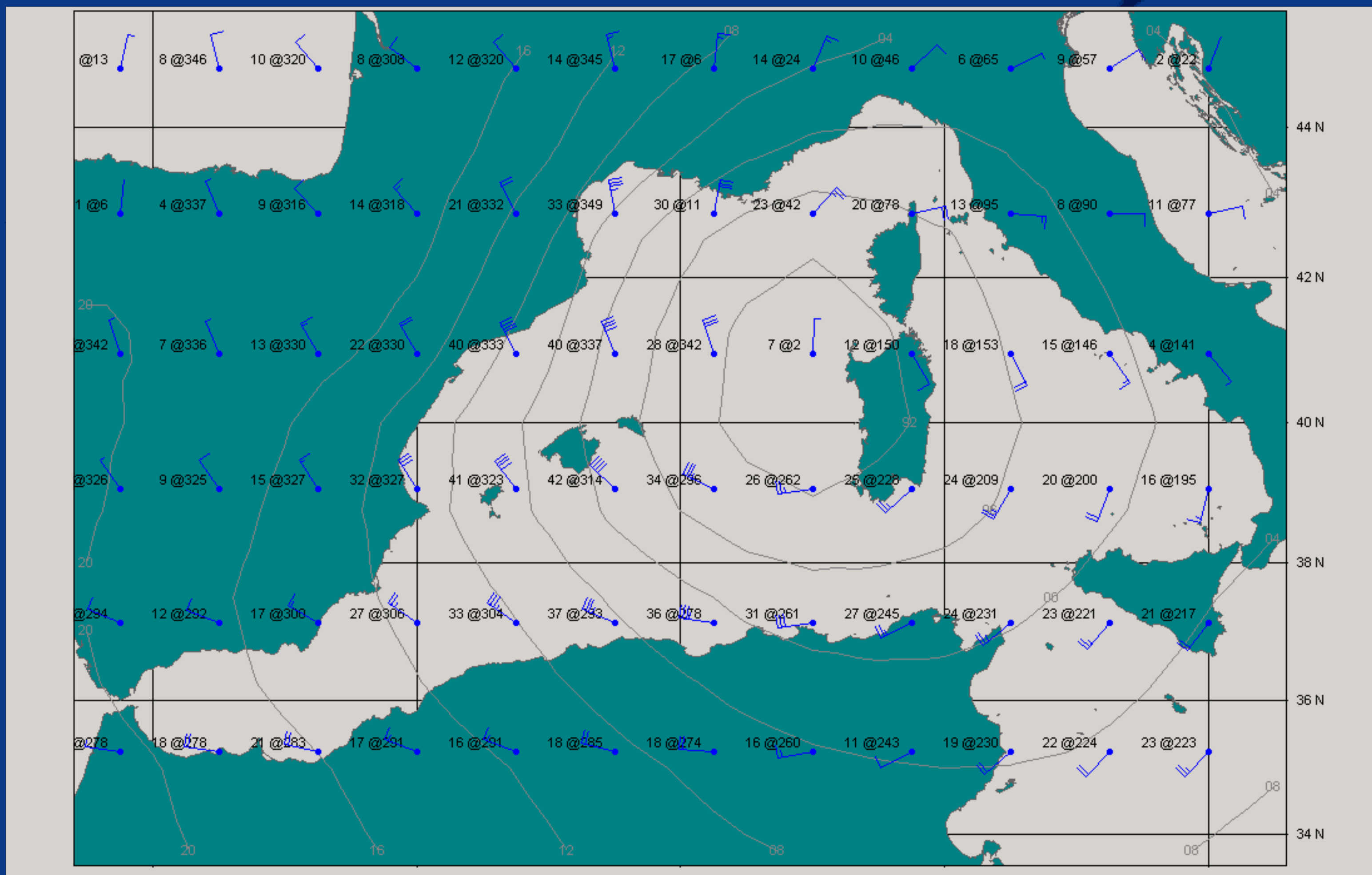
Uncorrected NCEP Reanalysis Project Surface Pressure and 10-m Wind Analysis

December 28, 2000



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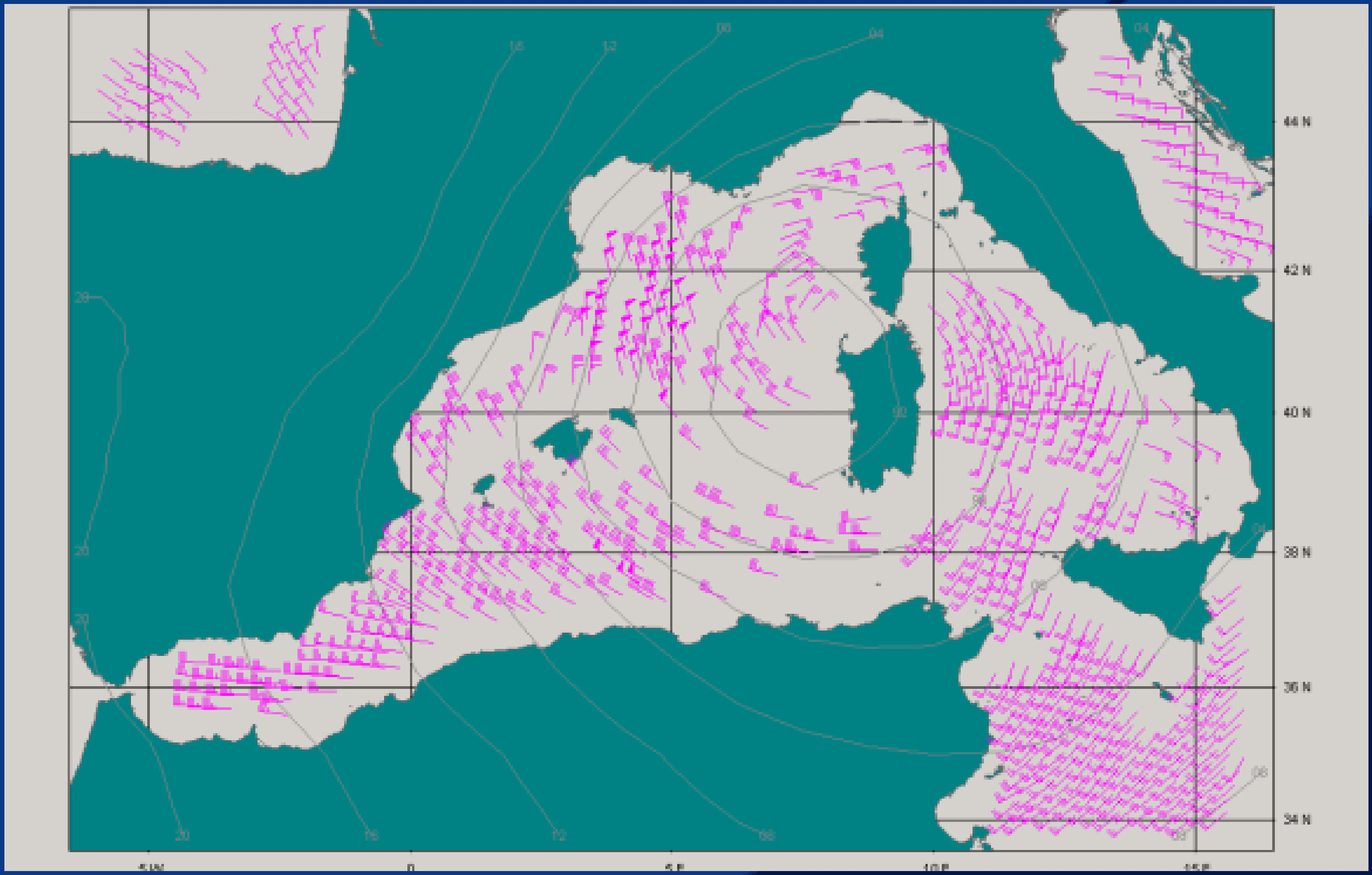
QuikSCAT Winds in One Pass



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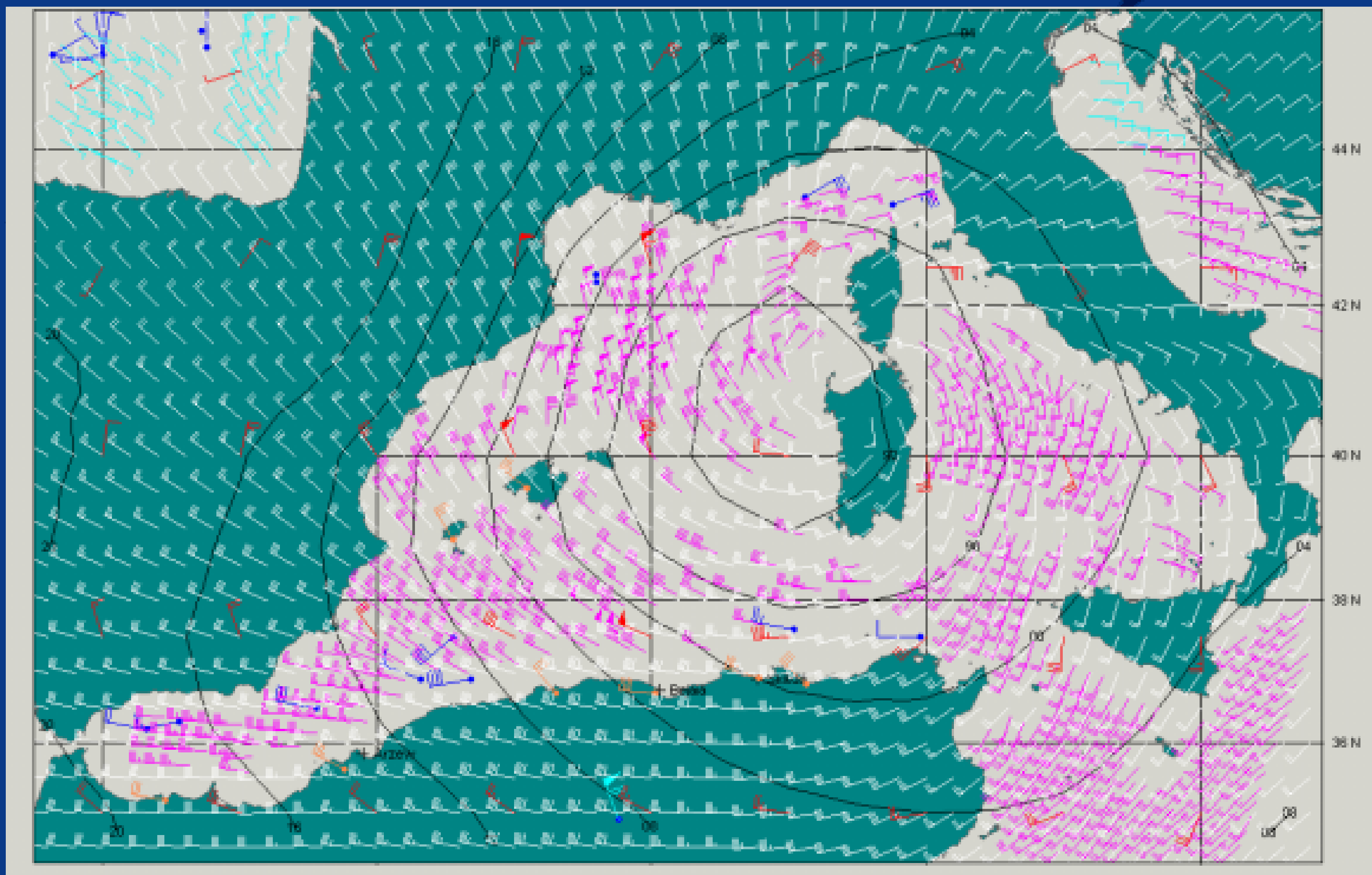
Wind Workstation



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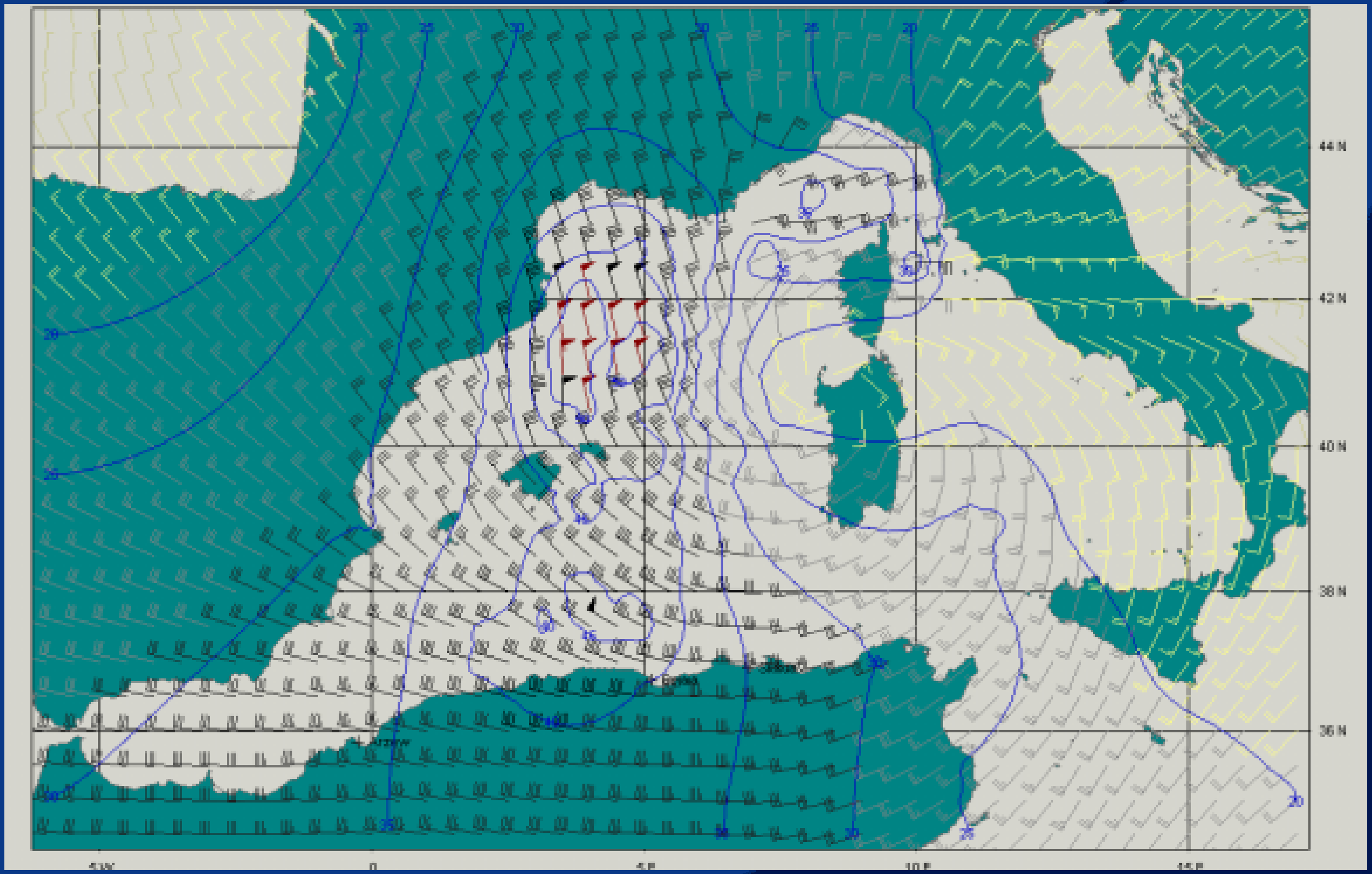
Final IOKA Wind Field



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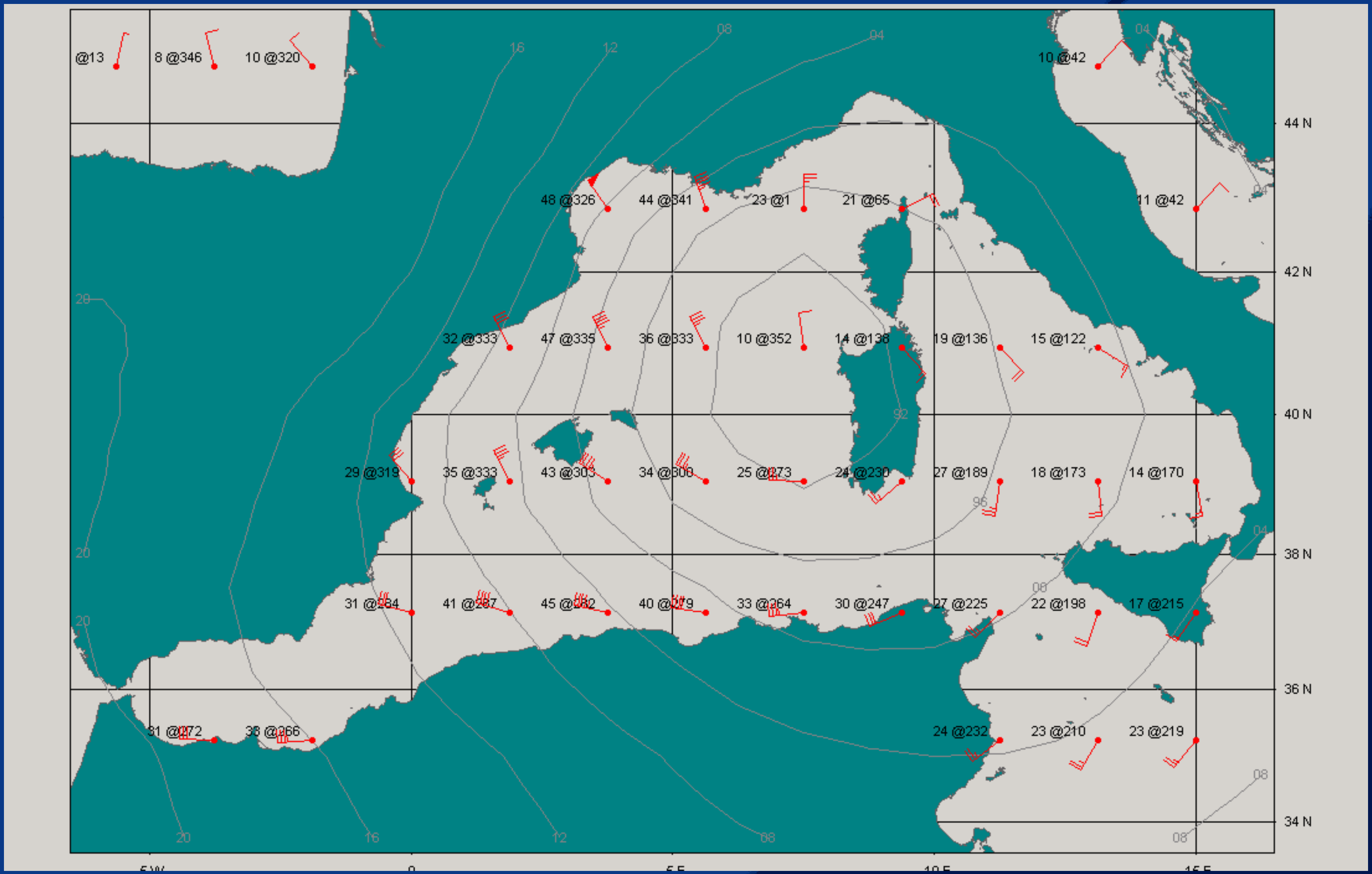
QuikSCAT Regression Enhanced of NRA



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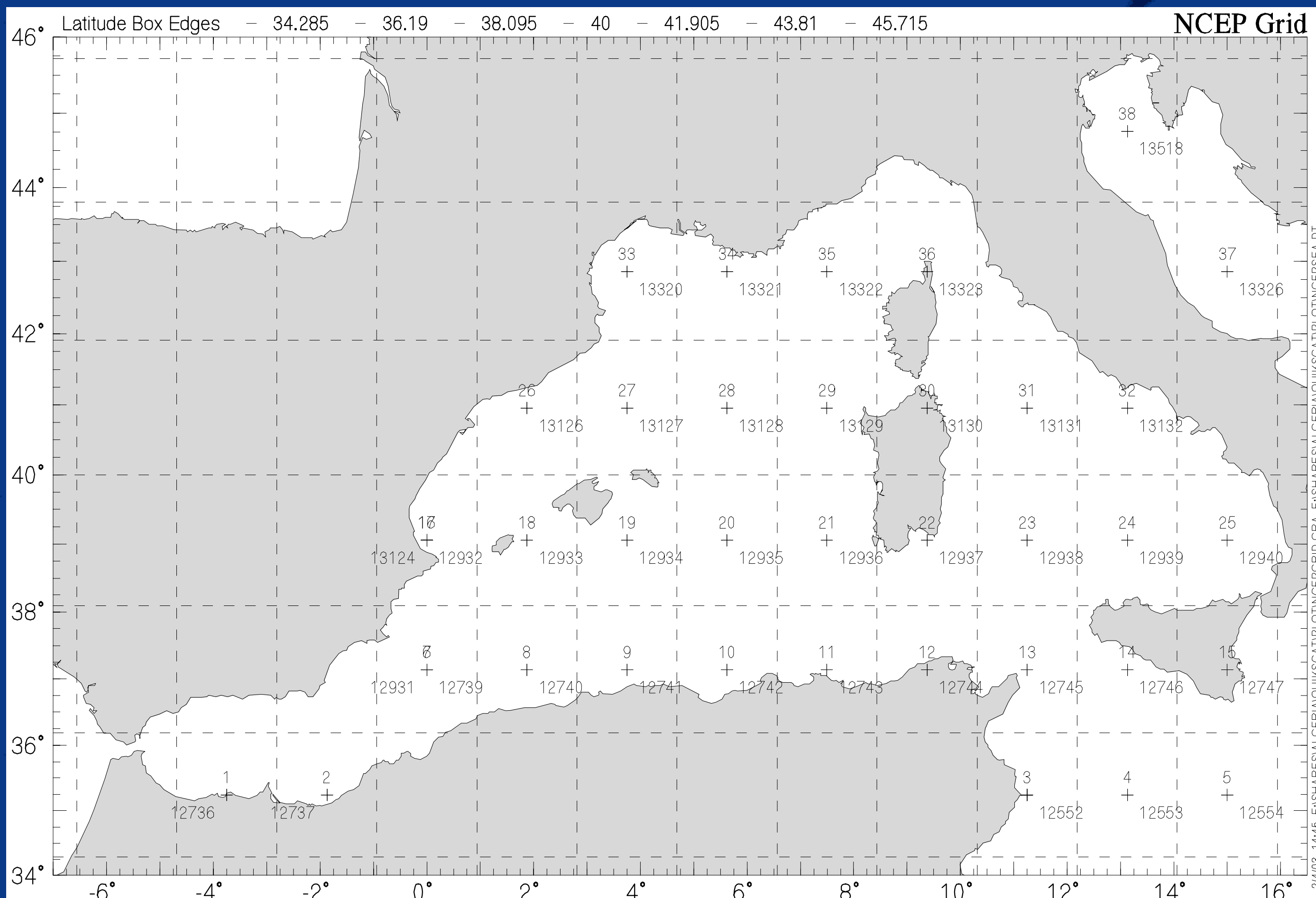
NRA Grid Boxes



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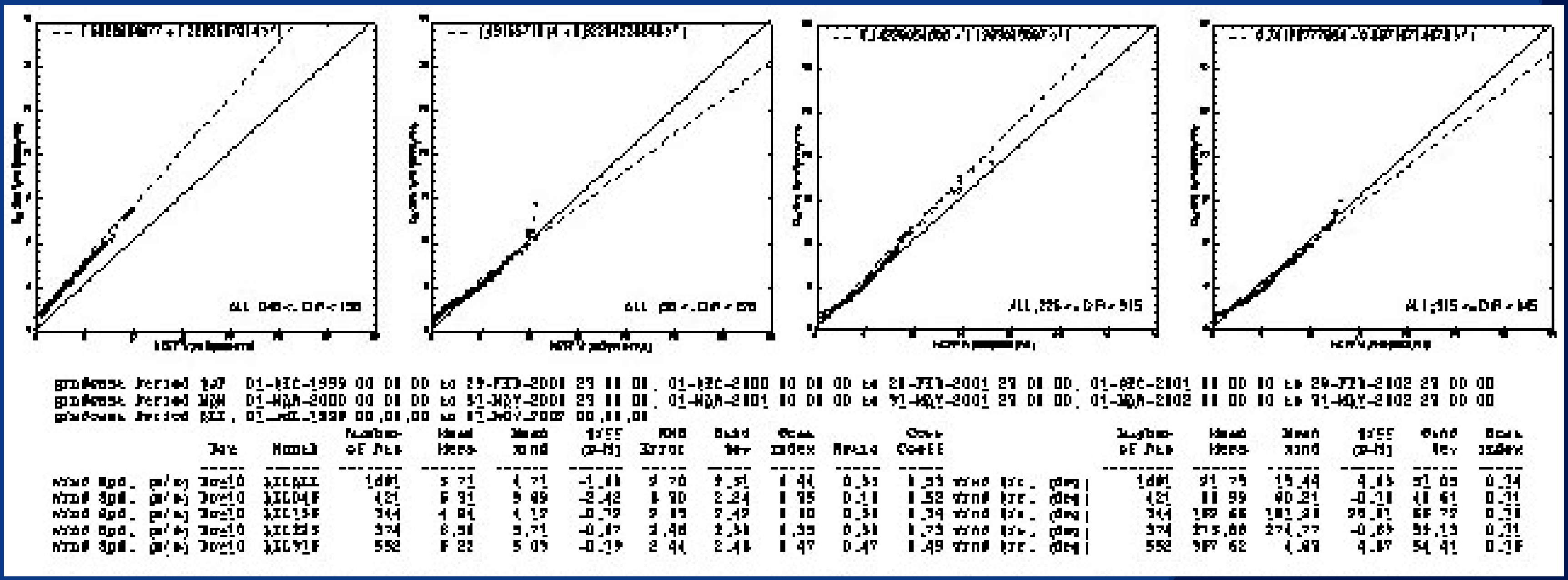
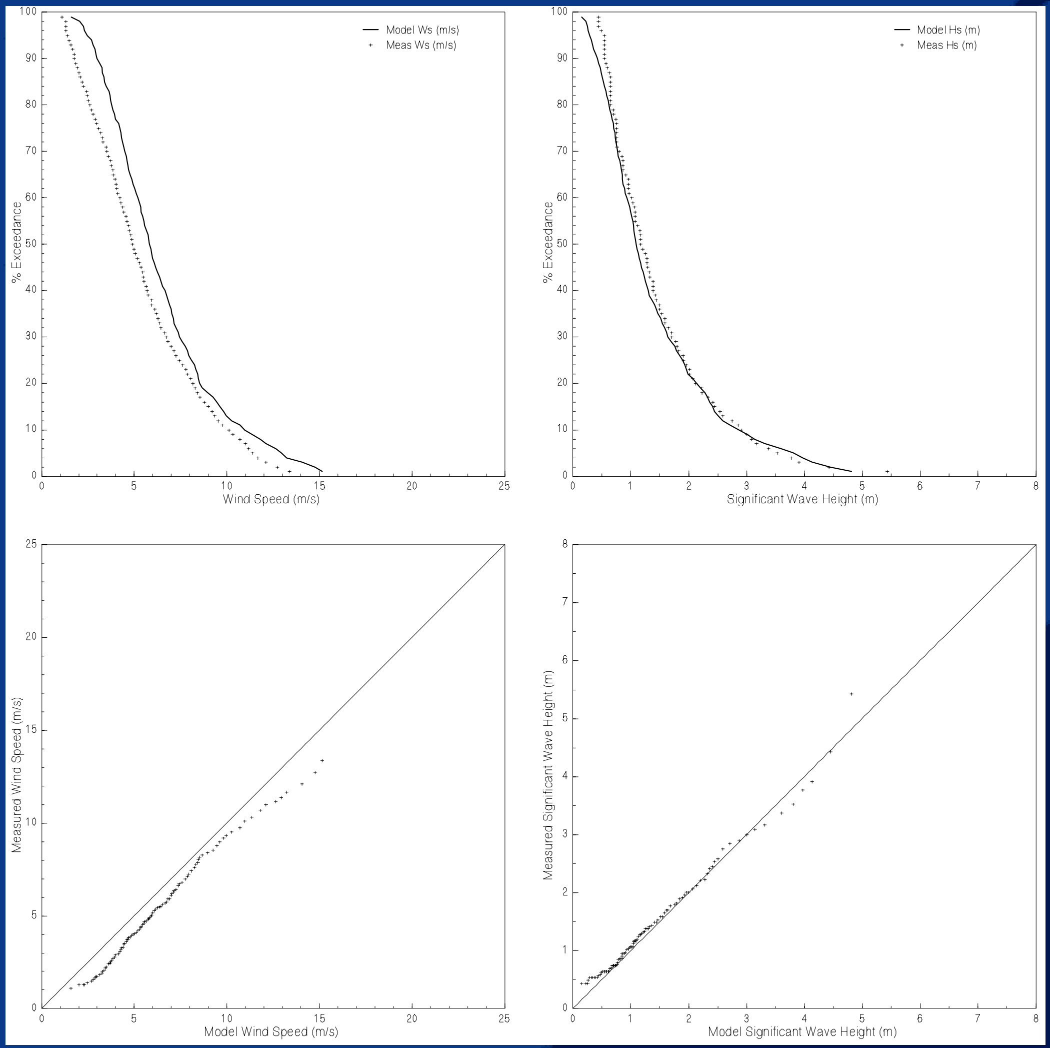
Comparison of QuikSCAT and NRA Winds in Box 10



Percent Exceedance and Quantile-Quantile Plots For all Altimeter Hits in 1 Degree Box Around Grid Point 644, Offshore Bejaia, 1996-2001



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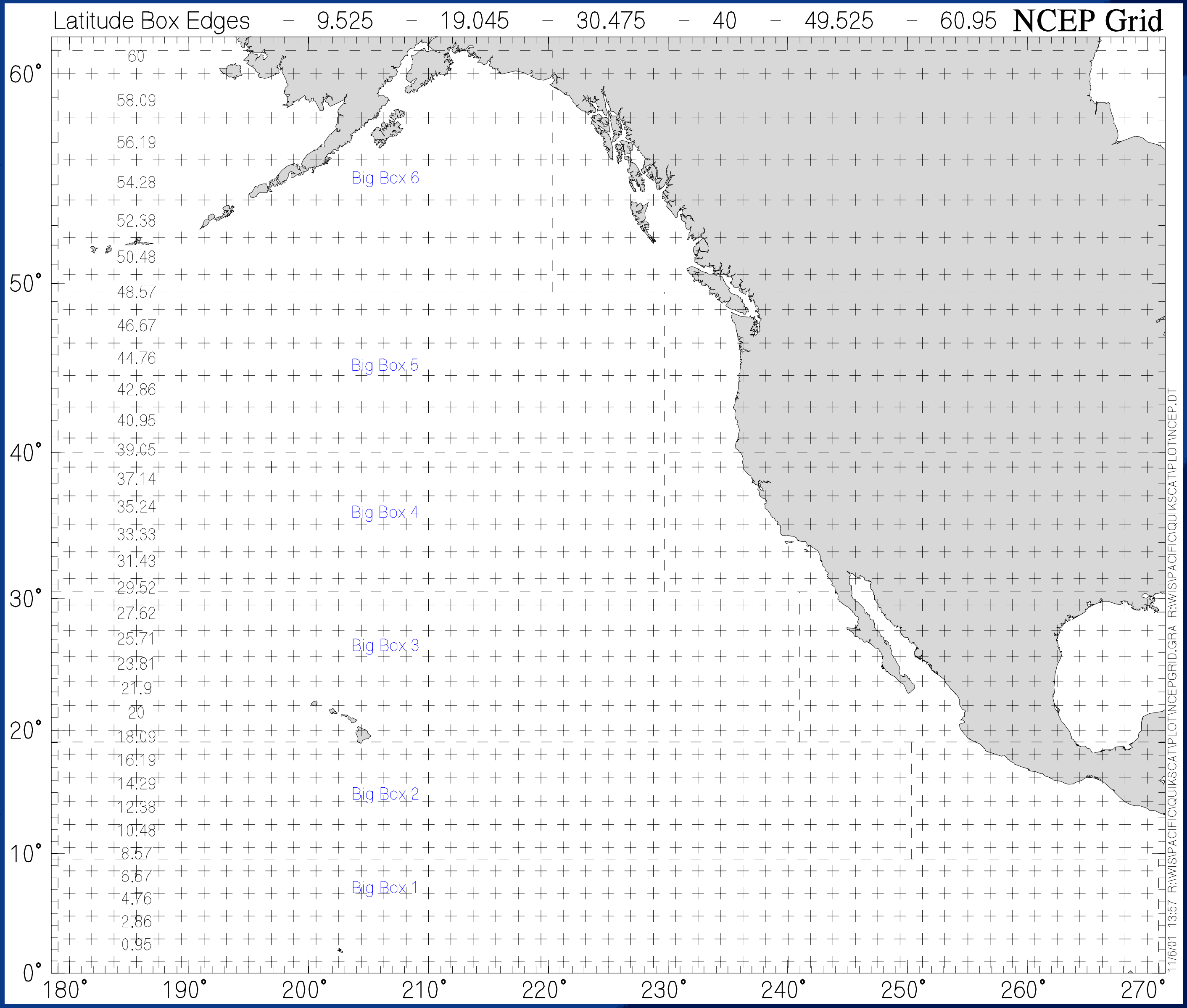
NCEP Grid - Big Boxes



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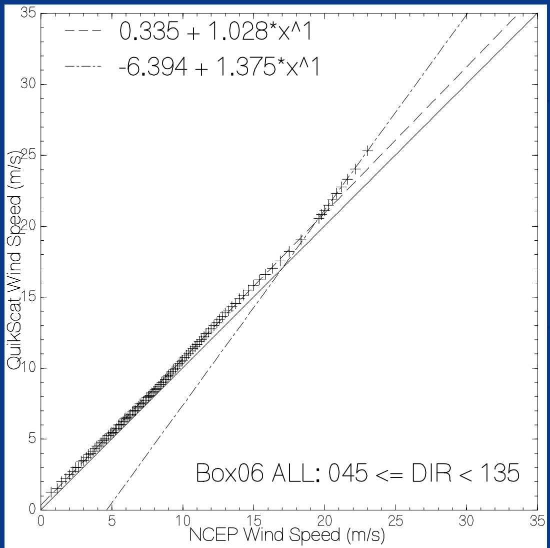
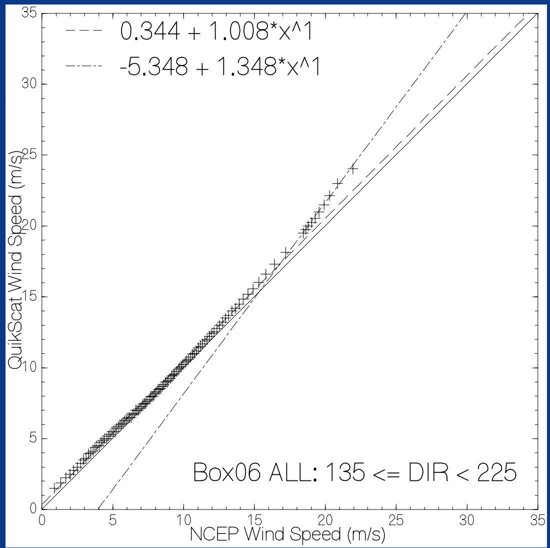
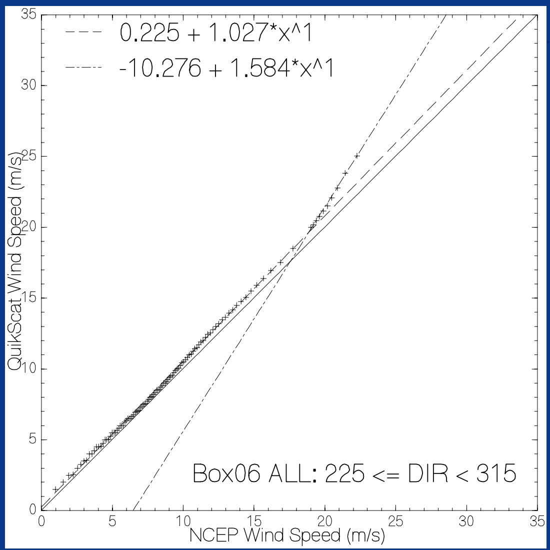
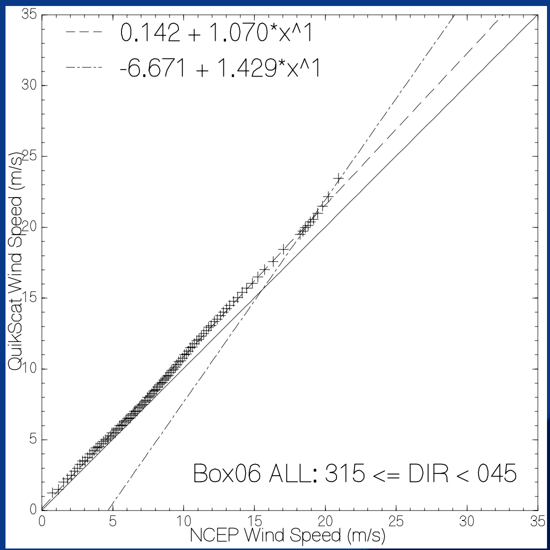
Primary/Secondary Regression Lines on Q-Qs Big Box 6









Date Range: 01-JUL-1999 00:00:00 to 30-JUN-2002 23:00:00

Wind Spd. (m/s):

Dir Bin	Number of Pts	Mean QScat	Mean NCEP	Diff (H-Q)	Stnd Dev	Scat Index	Corr Coeff
ALL	271439	8.80	8.28	-0.52	2.10	0.24	0.87
045	52309	8.94	8.36	-0.58	2.27	0.25	0.87
135	70643	8.68	8.26	-0.42	2.17	0.25	0.85
225	92876	8.86	8.40	-0.46	1.94	0.22	0.88
315	55611	8.73	8.02	-0.71	2.07	0.24	0.88

Wind Dir. (deg):

Dir Bin	Number of Pts	Mean QScat	Mean NCEP	Diff (H-Q)	Stnd Dev	Scat Index
ALL	271439	256.20	248.81	-0.95	24.78	0.07
045	52309	92.31	92.69	0.32	25.48	0.07
135	70643	185.18	183.44	-1.30	27.83	0.08
225	92876	270.71	268.66	-2.04	20.78	0.06
315	55611	353.18	353.79	0.16	26.17	0.07

Box	Dir (fr)	Init WS (m/s)	Adj'd Primary	Adj'd Secondary
6	E	22	22.96	23.87
6	S	22	22.52	24.31
6	W	22	22.83	24.57
6	N	22	23.68	24.77

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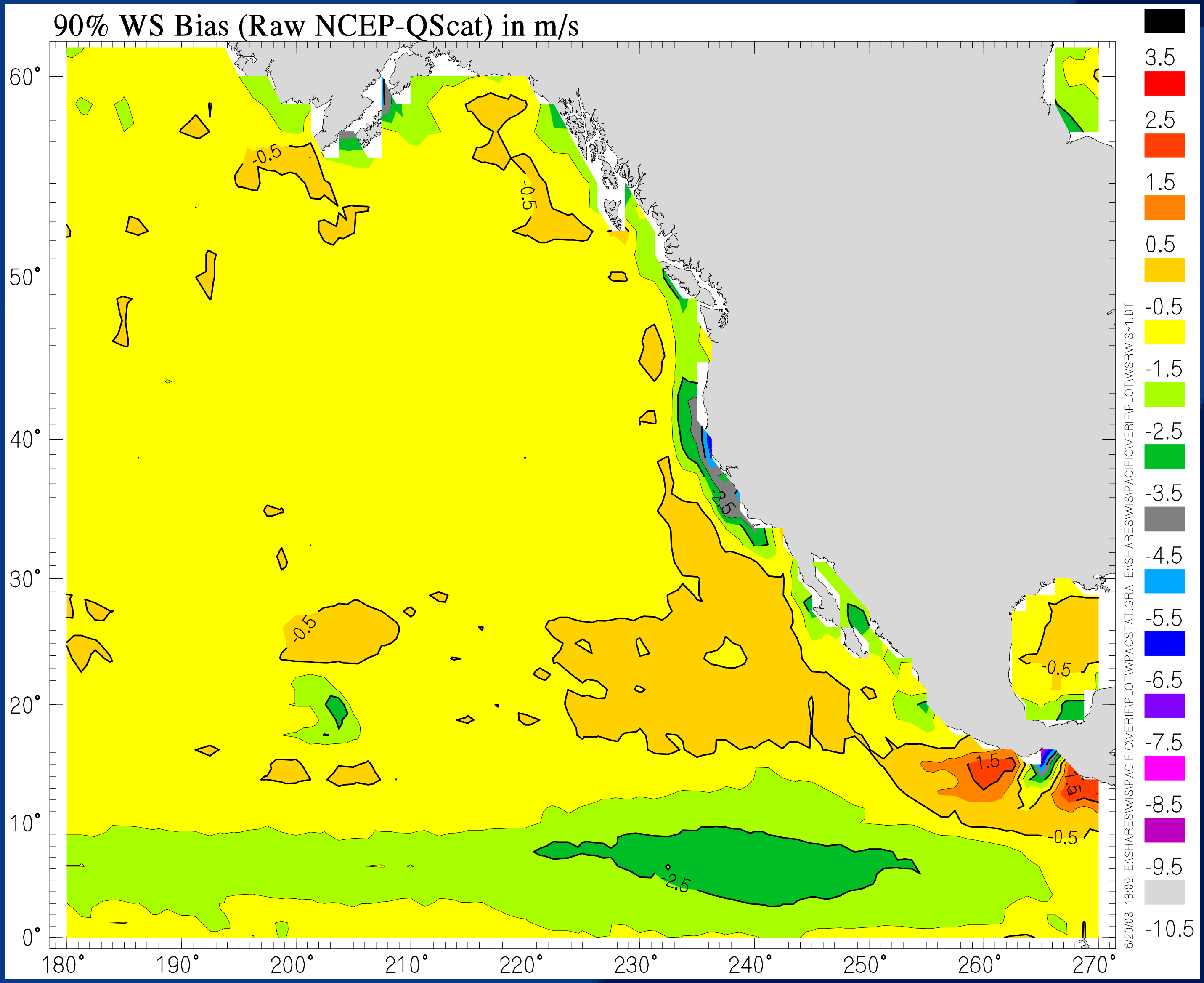
Quikscat vs. NCEP Unadjusted 90% Exceedance WS Bias All Dir Combined (N-Q) in m/s



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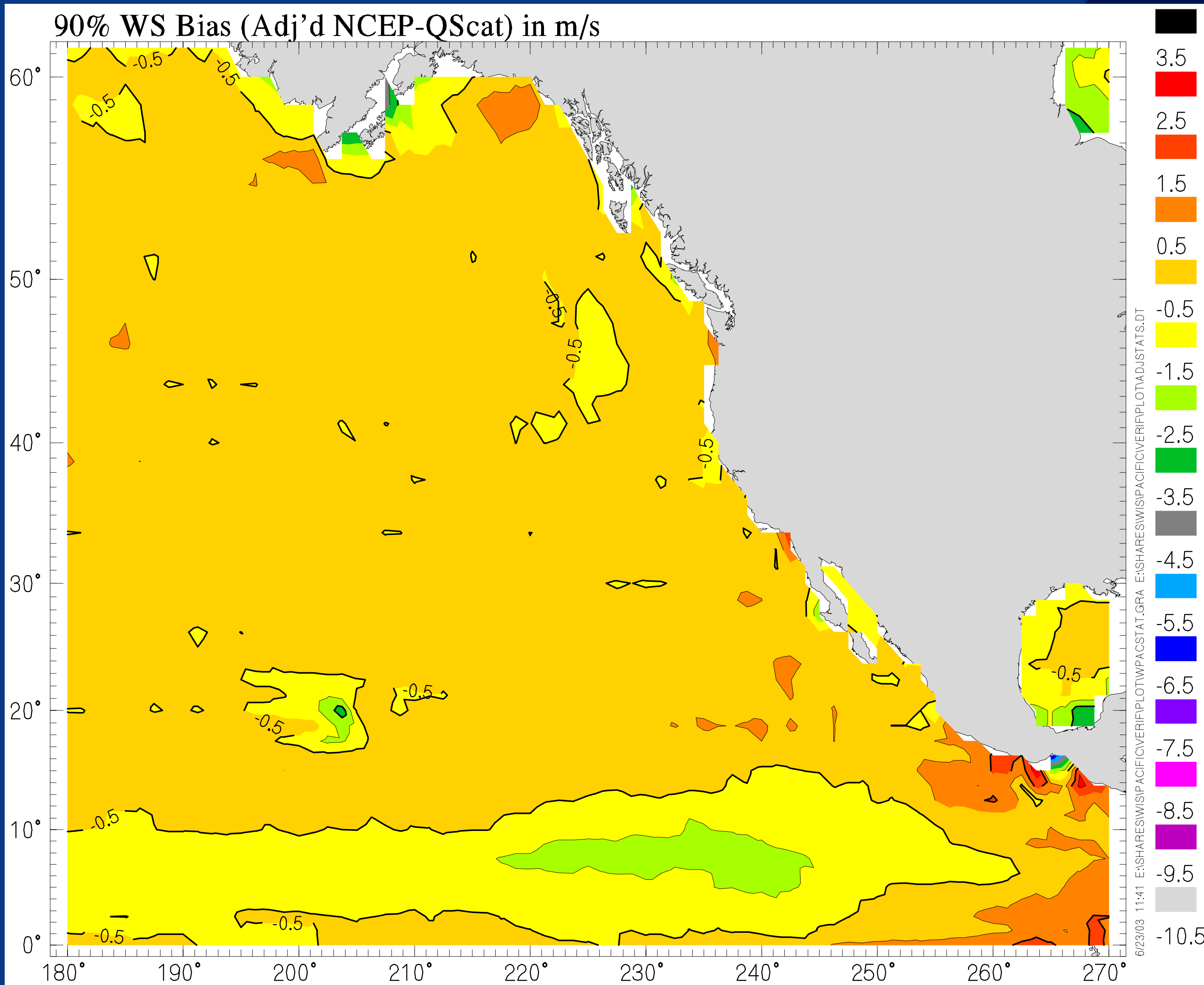
Quikscat vs. NCEP Adjusted 90% Exceedance WS Bias All Dir Combined (N-Q) in m/s



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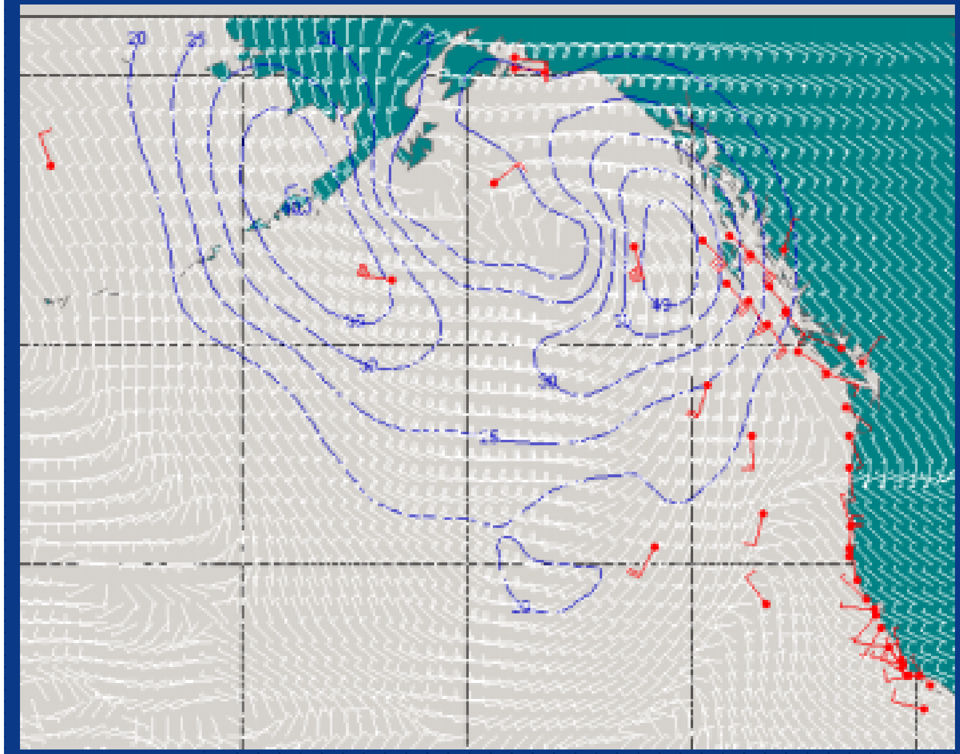
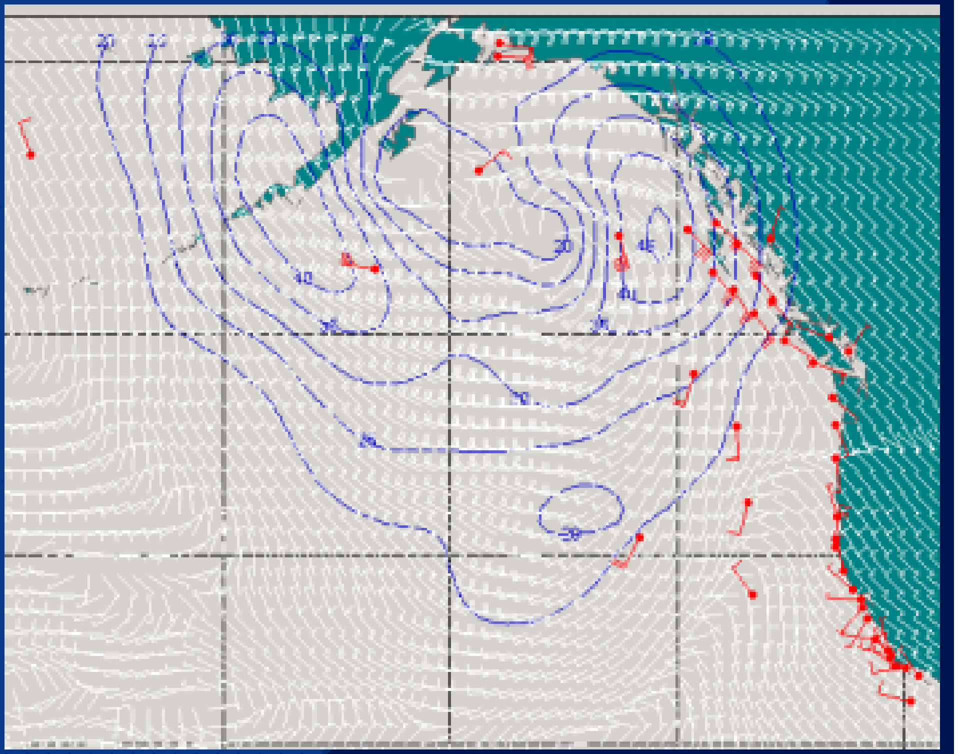
Sample Level I
Base Case Wind Field
October 7, 2000 06Z



Sample Level II
Wind Field
October 7, 2000 06Z



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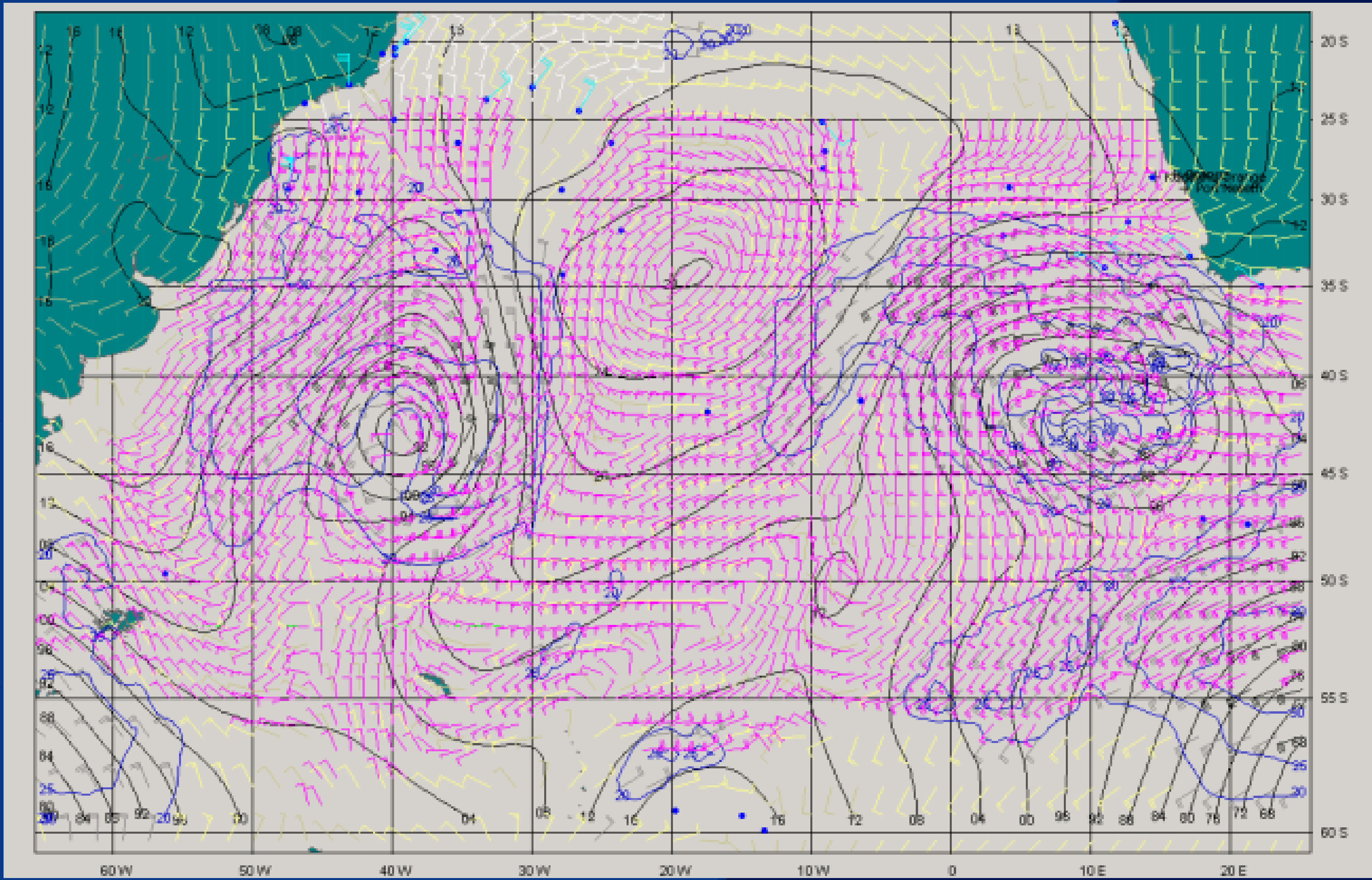
Wind Field for 01-Sep-2000 18Z



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Conclusions

- NRA marine surface winds an improvement over previous operational NWP base products
- NRA winds may be further improved:

  - use SCAT winds to identify and remove systematic effects

  - reassimilate adjusted surface data

  - overlay products of mesoscale models for tropical cyclones and terrain effects

  - interactive kinematic analysis for storms

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Conclusions cont…

- Research programs continue to add to resolution of errors of winds from ships, buoys and remote sensors
- QUIKSCAT, SEAWINDS, SCAT
  - "step-function" increase in skill of marine wind analyses in general and SH NWP

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