Impact of QuikSCAT Surface Marine Winds on Wave Hindcasting

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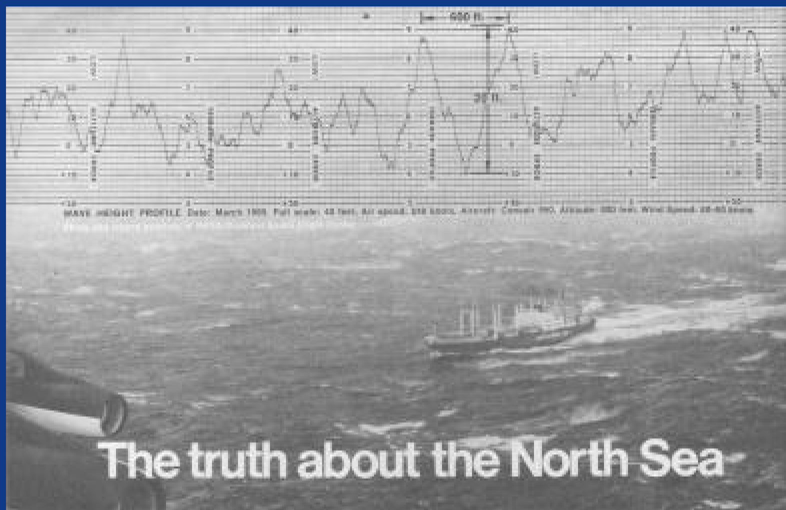
Outline

- Brief Look Back - Scatterometry
- Accuracy and Dynamic Range of QuikSCAT Scatterometer Winds
- Application of QuikSCAT to Reduction of Systematic Effects in NWP Reanalysis Products
- Impact of QuikSCAT on Wave Hindcasting

History of Scatterometry



Aircraft Experiments - 11/1969

SKYLAB 1973-1974

6/1978-9/1978

I: 9/1996-6/1997
II: 12/2002-10/2003

6/1999-

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1973

Highlighted L to R: Willard Pierson, Manley St. Denis, Vince Cardone

2002

Linwood Jones, Willard Pierson, Vince Cardone

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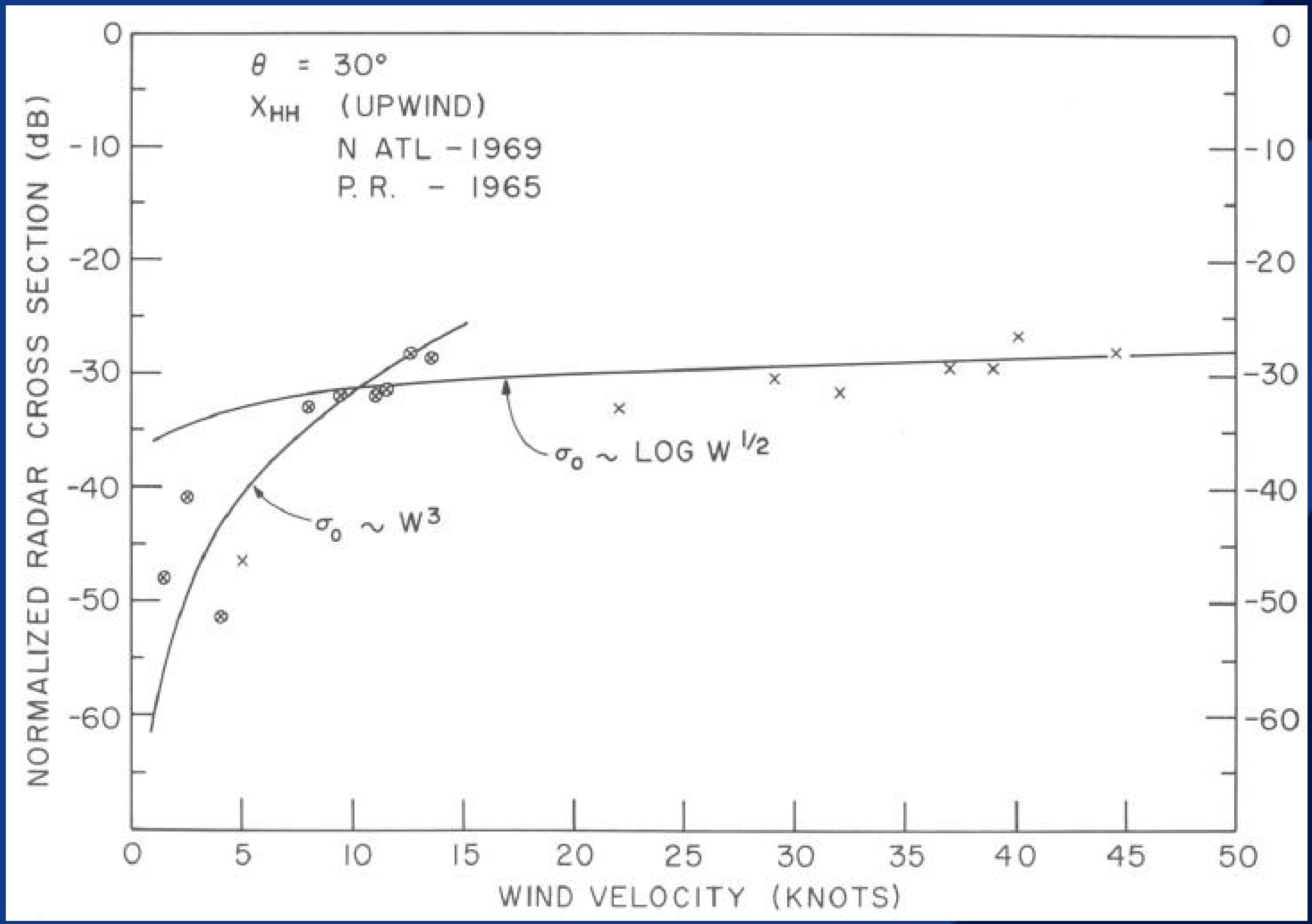

From N. W. Guinard, 1969: The variation of the RCS of the sea with increasing roughness. Microwave Observations of the Ocean Surface, SP-152, 11-12 June 1969, Analyses of the NASA/Navy Review, 175-203.

PBL Wind Profile

Variation of Mean Wind With Height: Surface Layer

Neutral Stratification

$$U_z = \frac{U*}{k} \log \frac{z}{z_0} \qquad where \quad U* = \sqrt{t / r}$$

$$z_0 = roughness \;\; parameter$$

$$\text{since } t = r \, \mathrm{C_z} \, \mathrm{U_z}^2$$

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

Stability Effect

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

j = stability function

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

H = heat flux

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

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

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

Evaluation of QuikSCAT Against Buoys

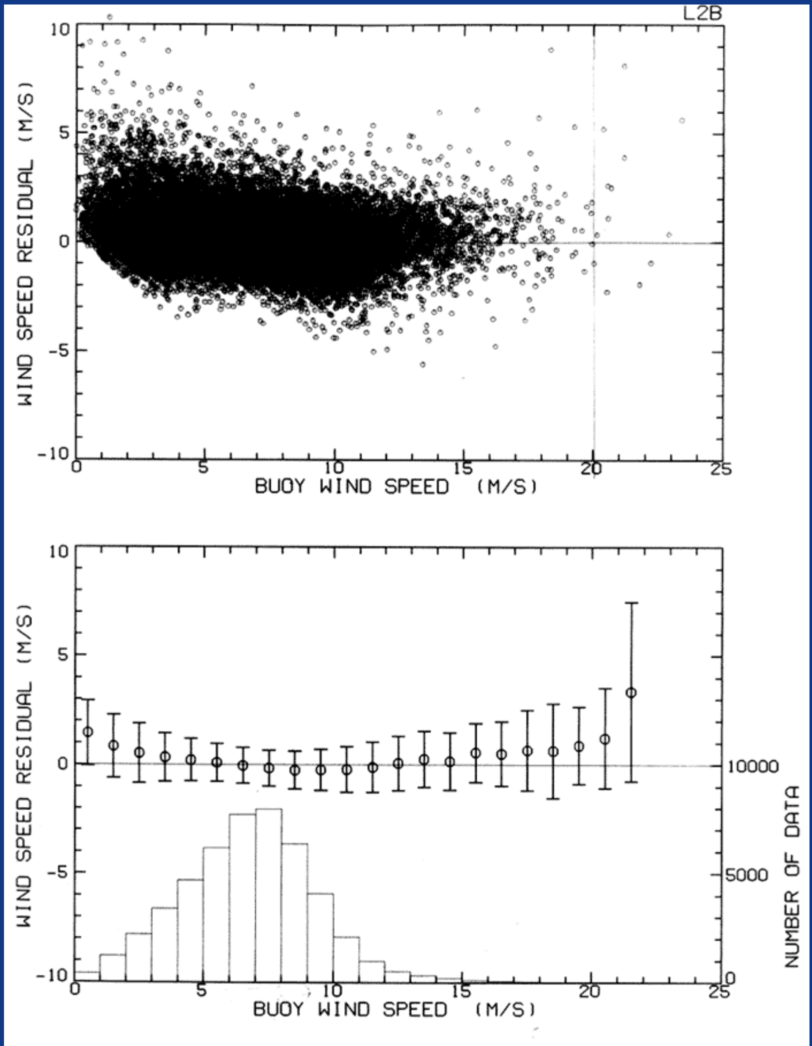

FIG. 3. Dependence of wind speed residual (QSCAT − buoy) on the buoy wind speed for the L2B winds. (upper panel) Scatterplots and (lower panel) numbers of data points, averages, (circles) and standard deviations (vertical lines) calculated in bins of buoy wind speed of 1 m s^{-1}.

Wind Speed

Number of Collocations	48,540
Bias	0.05 m/s
RMS Difference	1.00 m/s
Correlation Coefficient	0.927

Wind Direction

Number of Collocations	48,519
Bias	1.5º
RMS Difference	28.3º
Correlation Coefficient	0.952

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

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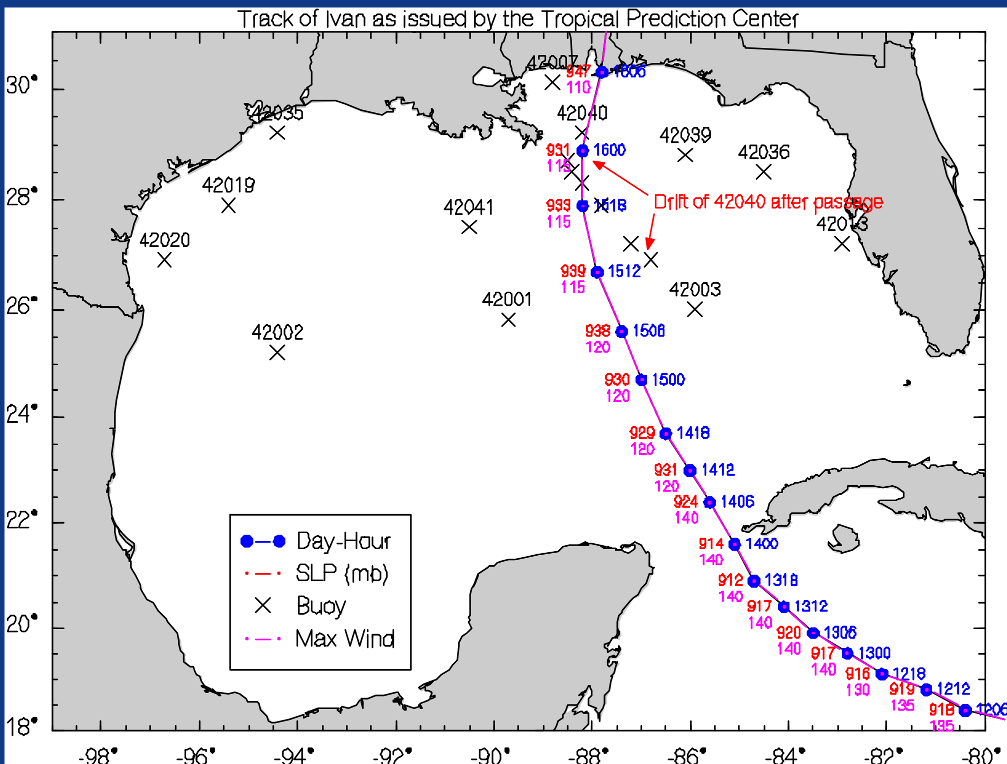
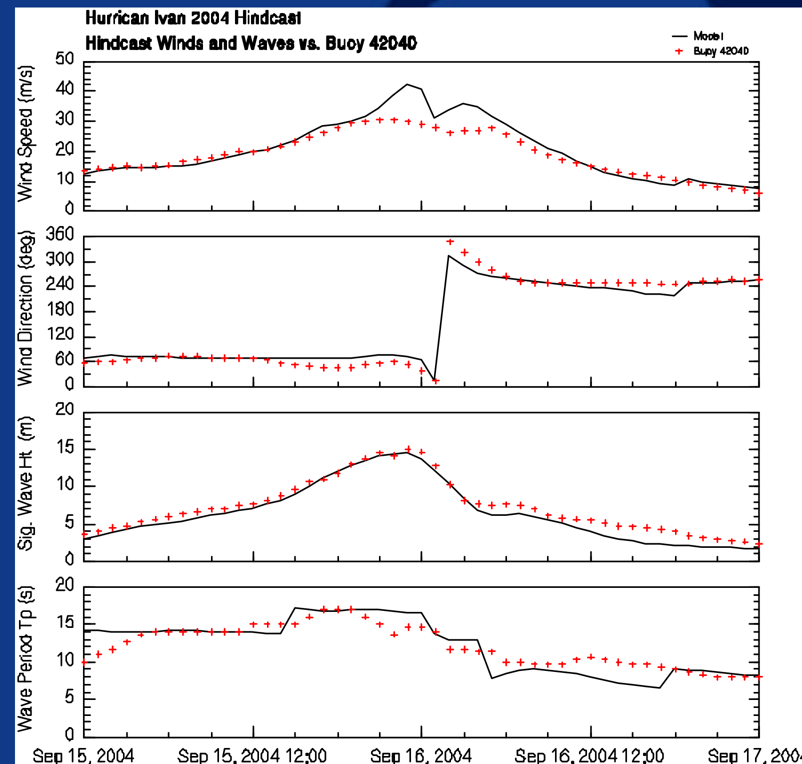
Buoy 42040 during Hurricane Ivan 2004





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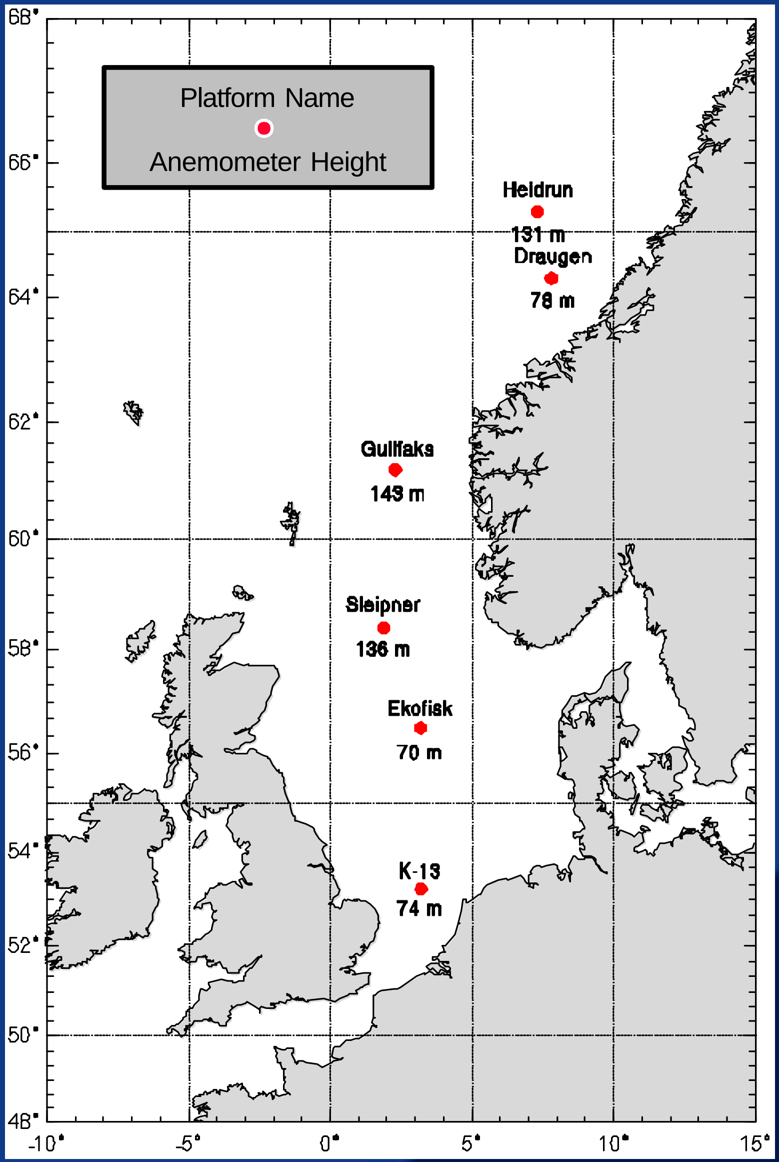
Evaluation of QuikSCAT against Platforms



North Cormorant Platform: North Sea

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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 >25 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...

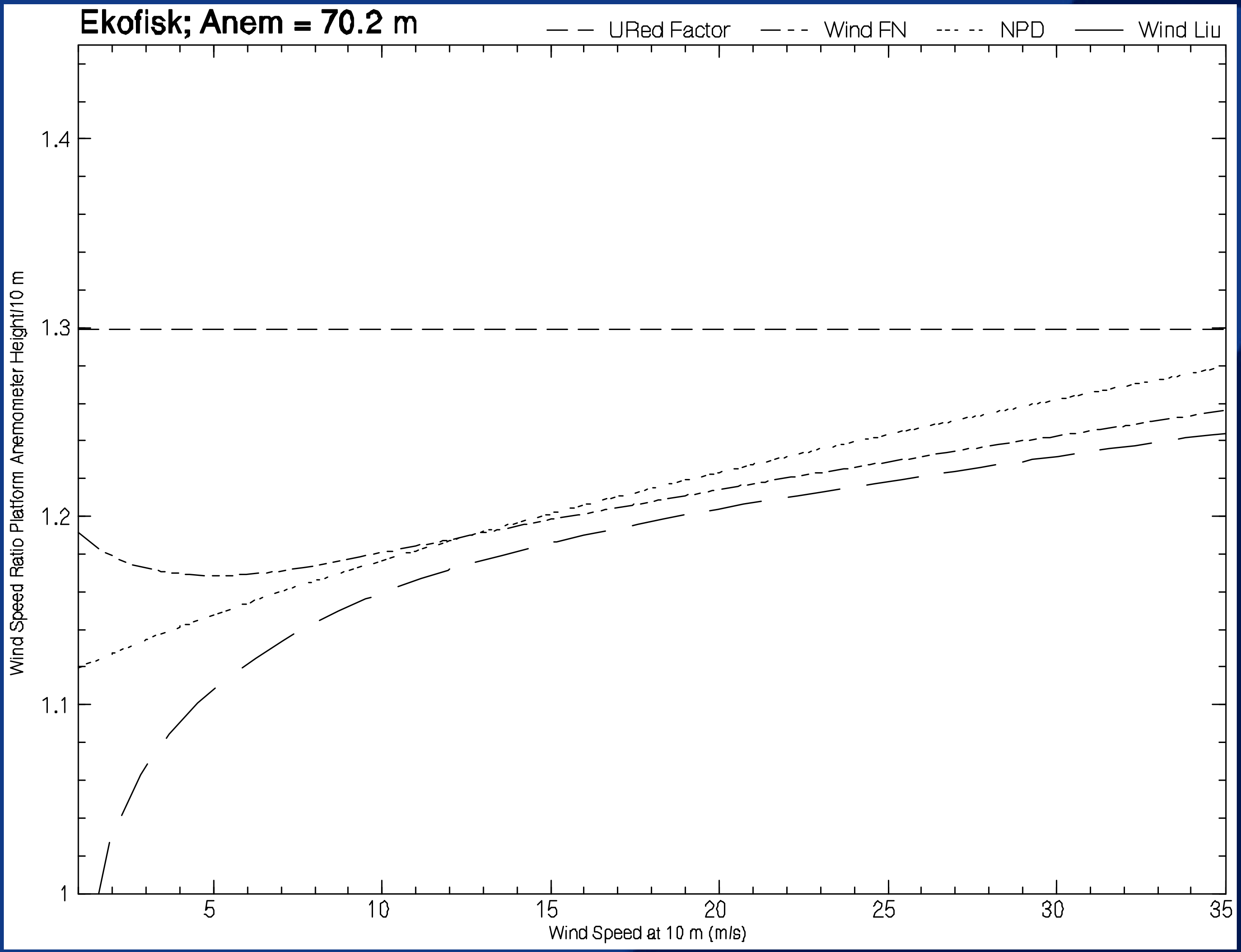
Platform Data Processing

- 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.

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

Comparison of Wind Speed Reduction Factors - Ekofisk Platform



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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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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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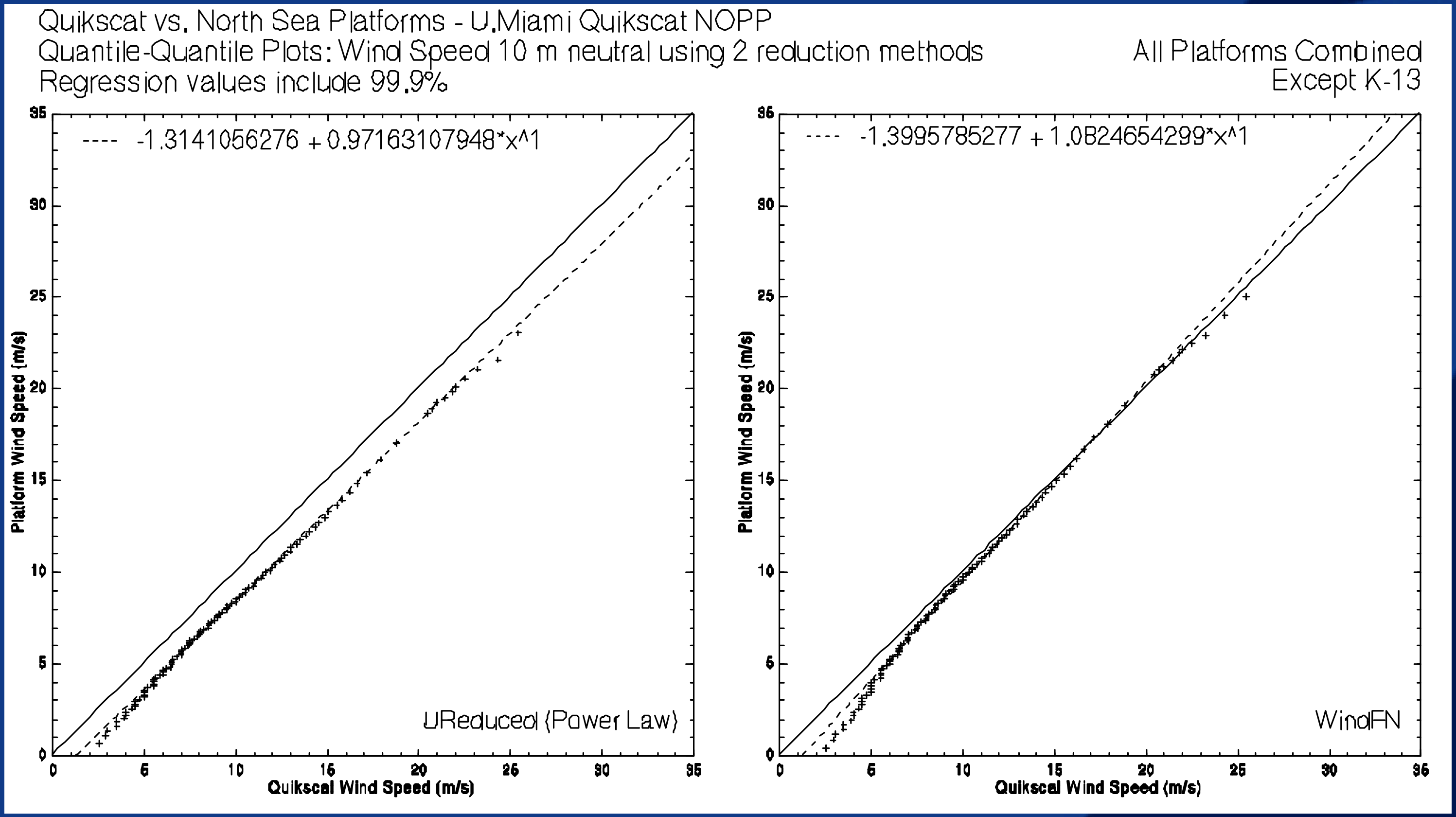
Q-Q Plot



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: 229.30º

Mean Platform WS: 233.32º

Mean Diff (Q-P): 3.31

Stnd Dev: 12.44

Scat Index: 0.04

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Horns Rev

60m measurement station at Horns Rev, Denmark

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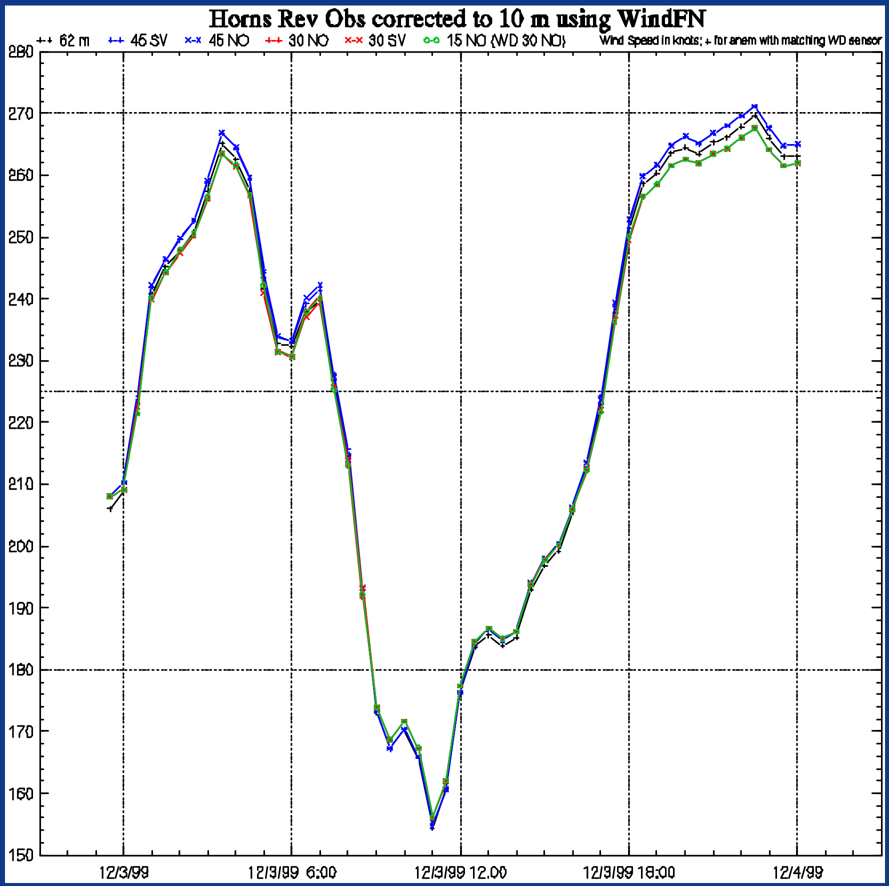
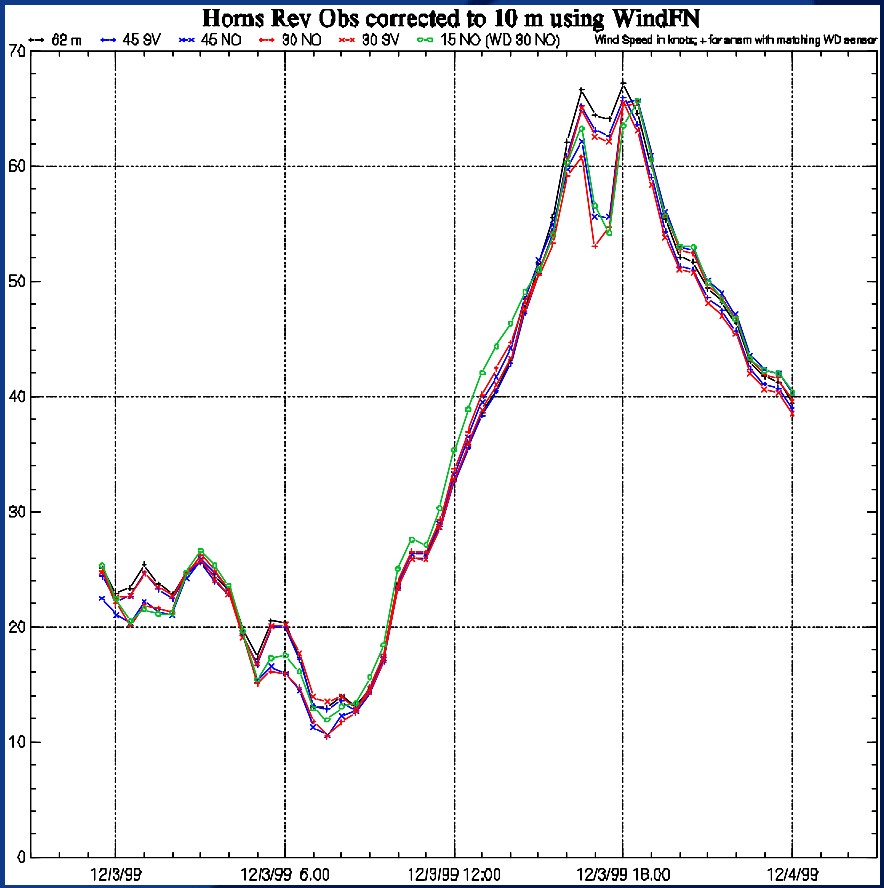
Winds Observed in North Sea “Hurricane” by Horns Rev





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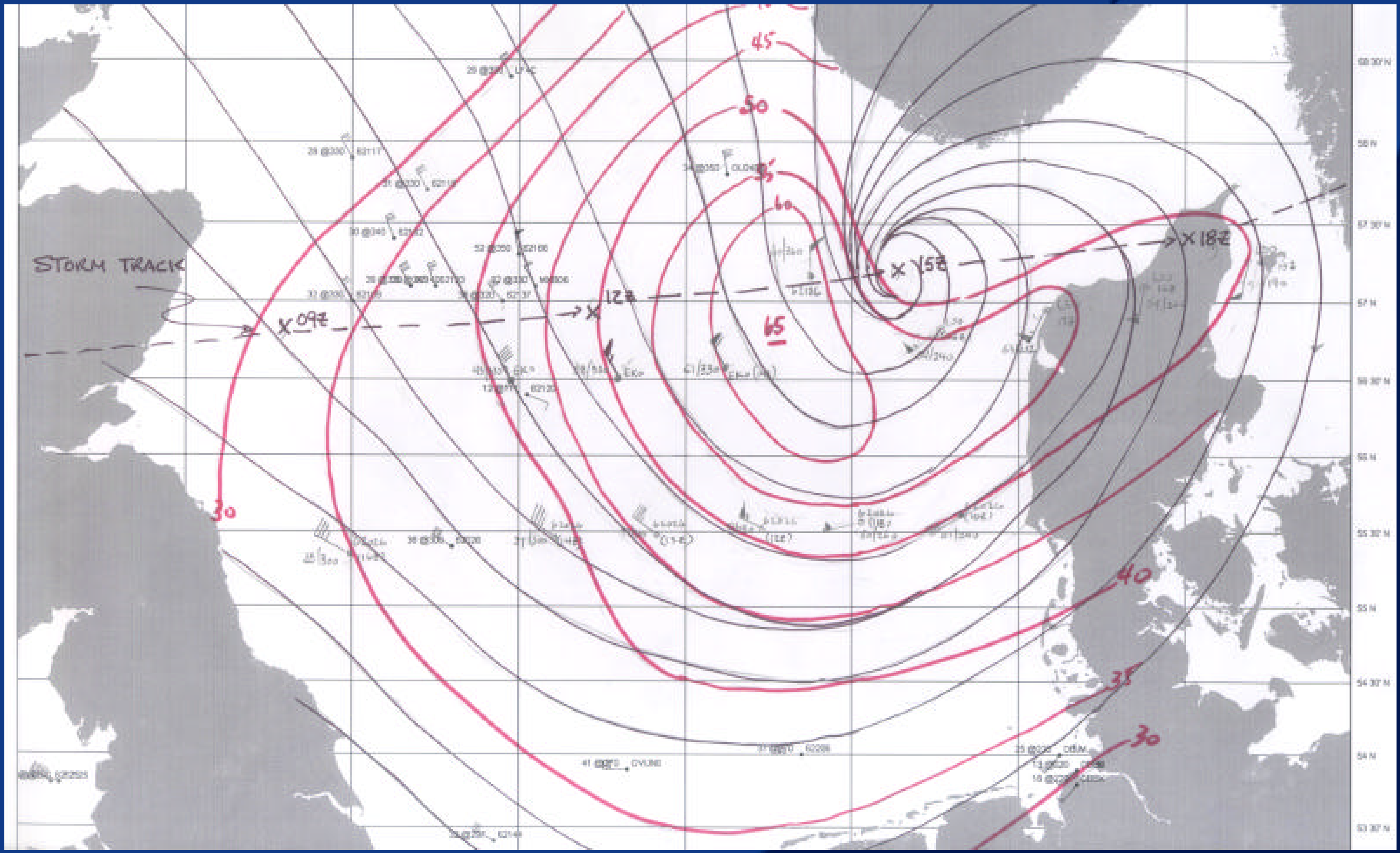
North Sea “Hurricane”

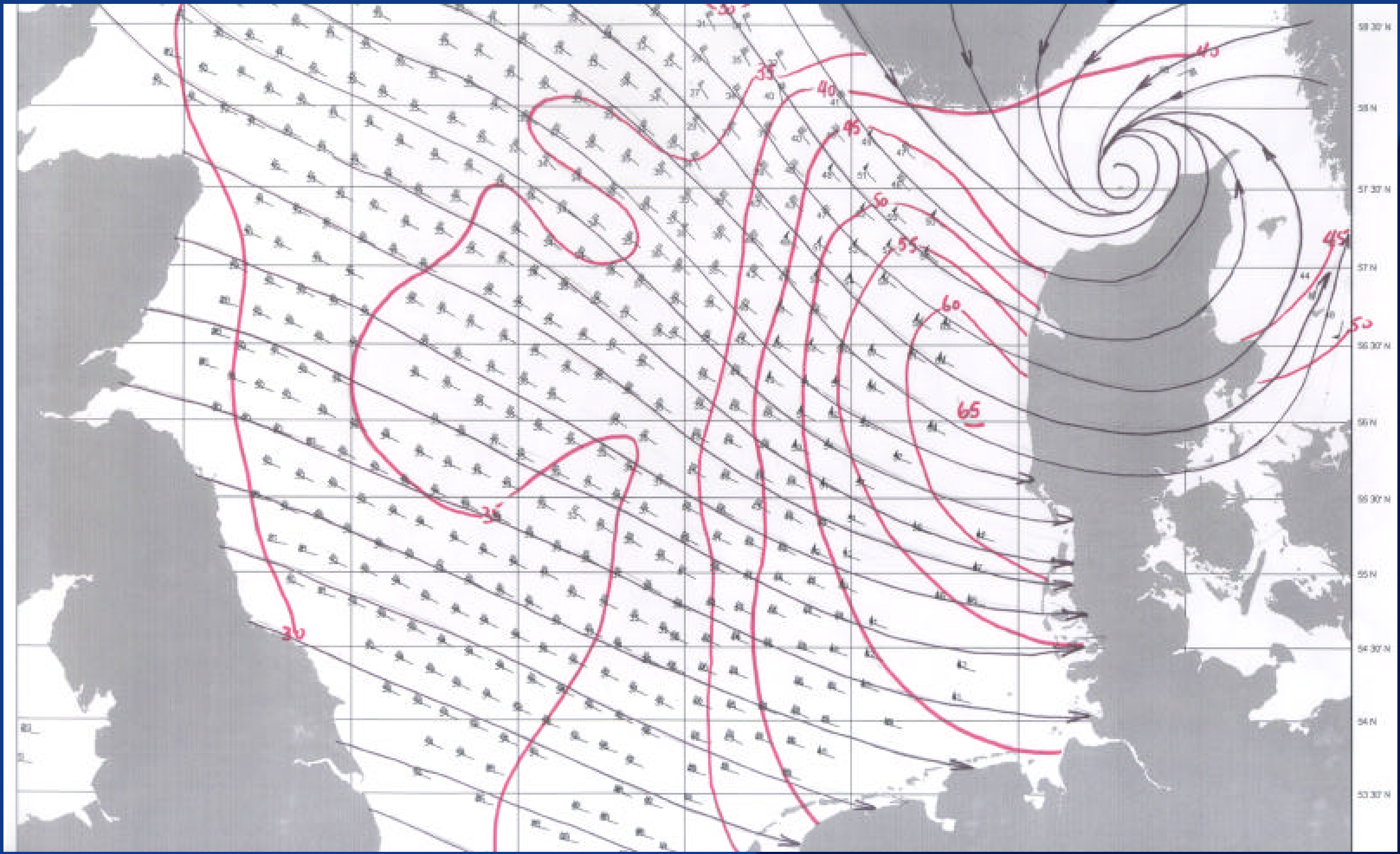
Kinematic Analysis to QuikSCAT Data

1500 UTC December 3, 1999



North Sea “Hurricane”

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



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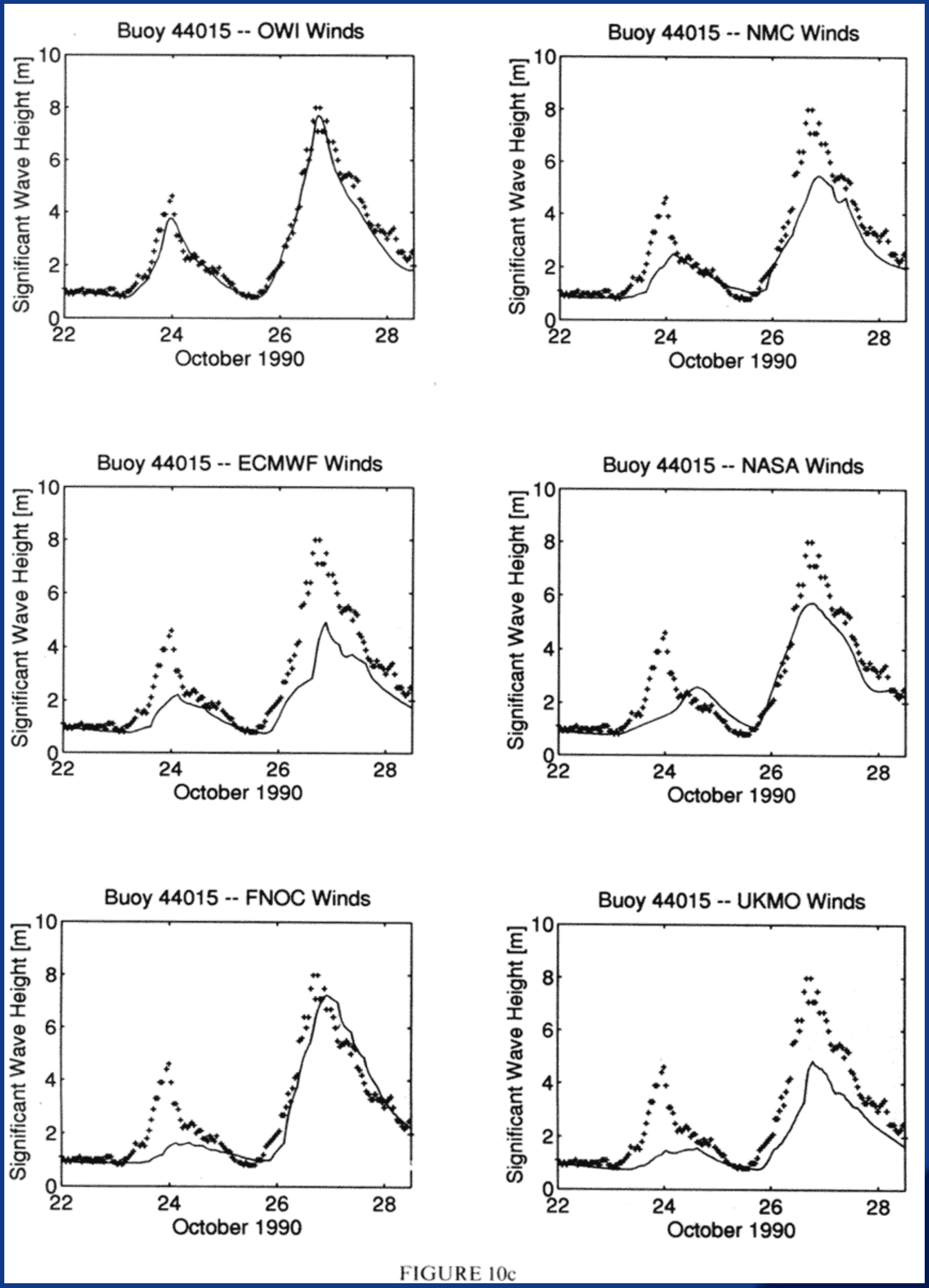

Alternative SWADE IOP-1 WAM hindcasts compared to buoy 44015 measurements

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Impact of QuikSCAT on Current Practice of IOKA

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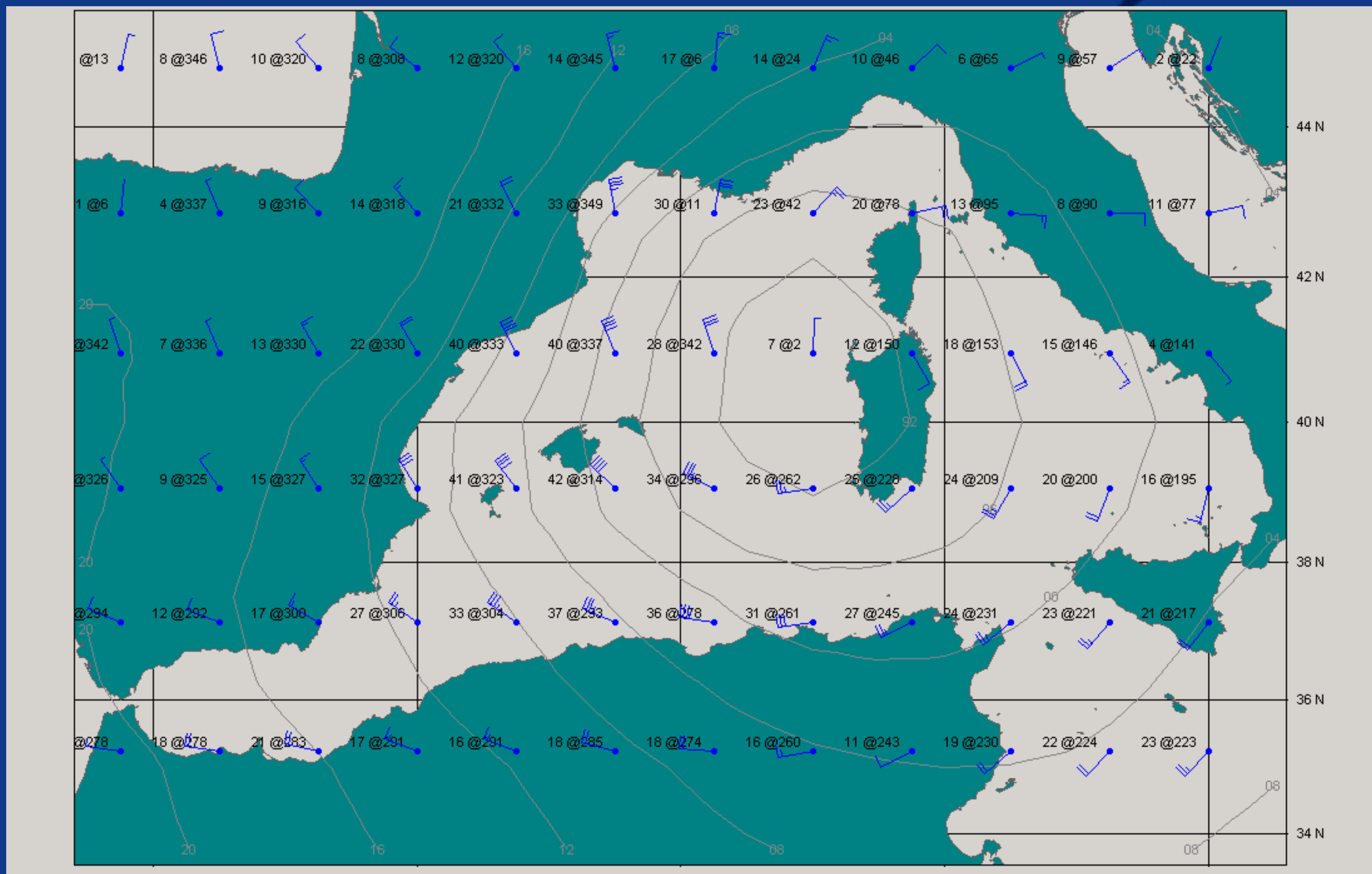
Uncorrected NCEP Reanalysis Project Surface Pressure and 10-m Wind Analysis

December 28, 2000



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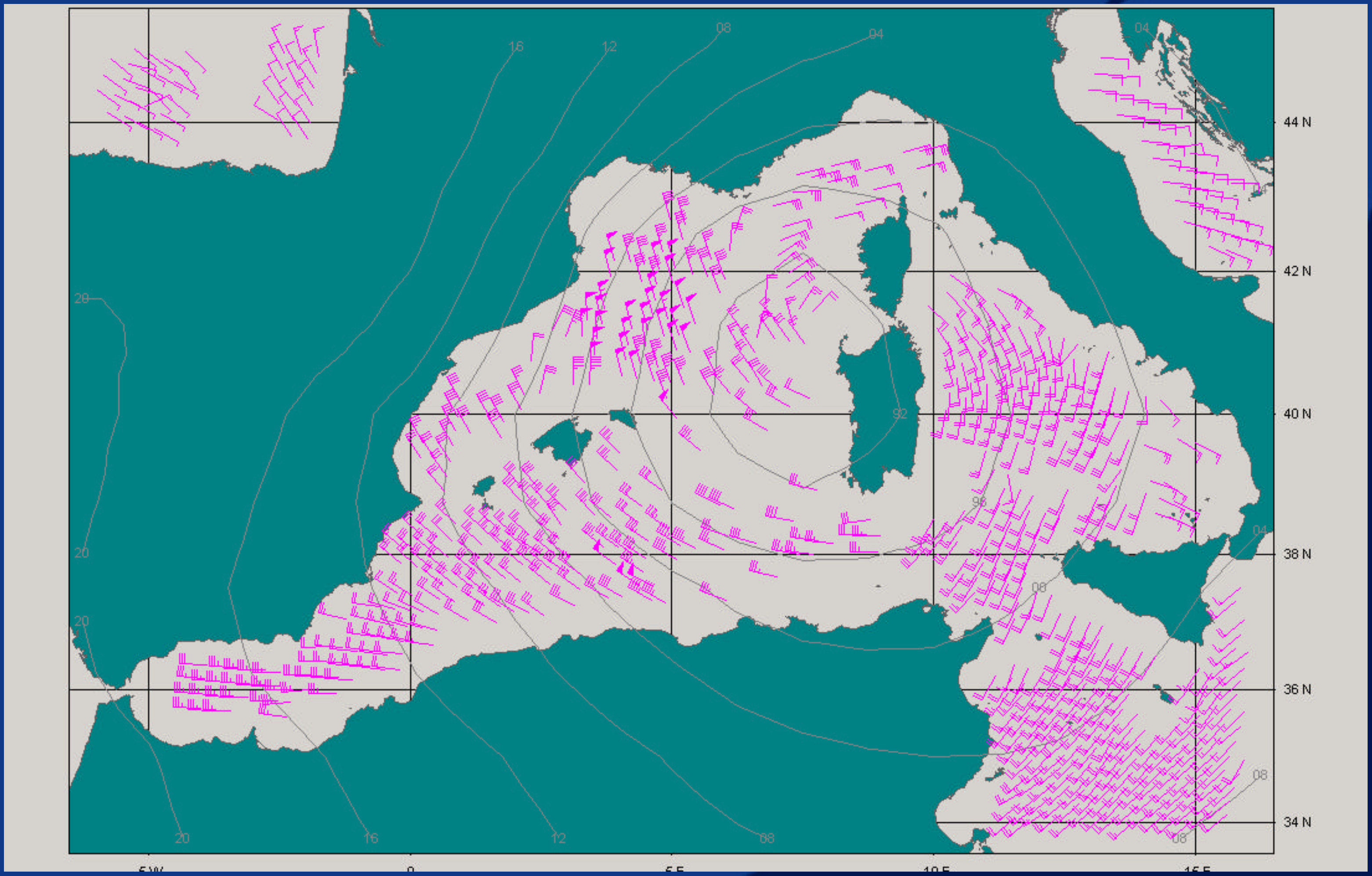
QuikSCAT Winds in One Pass



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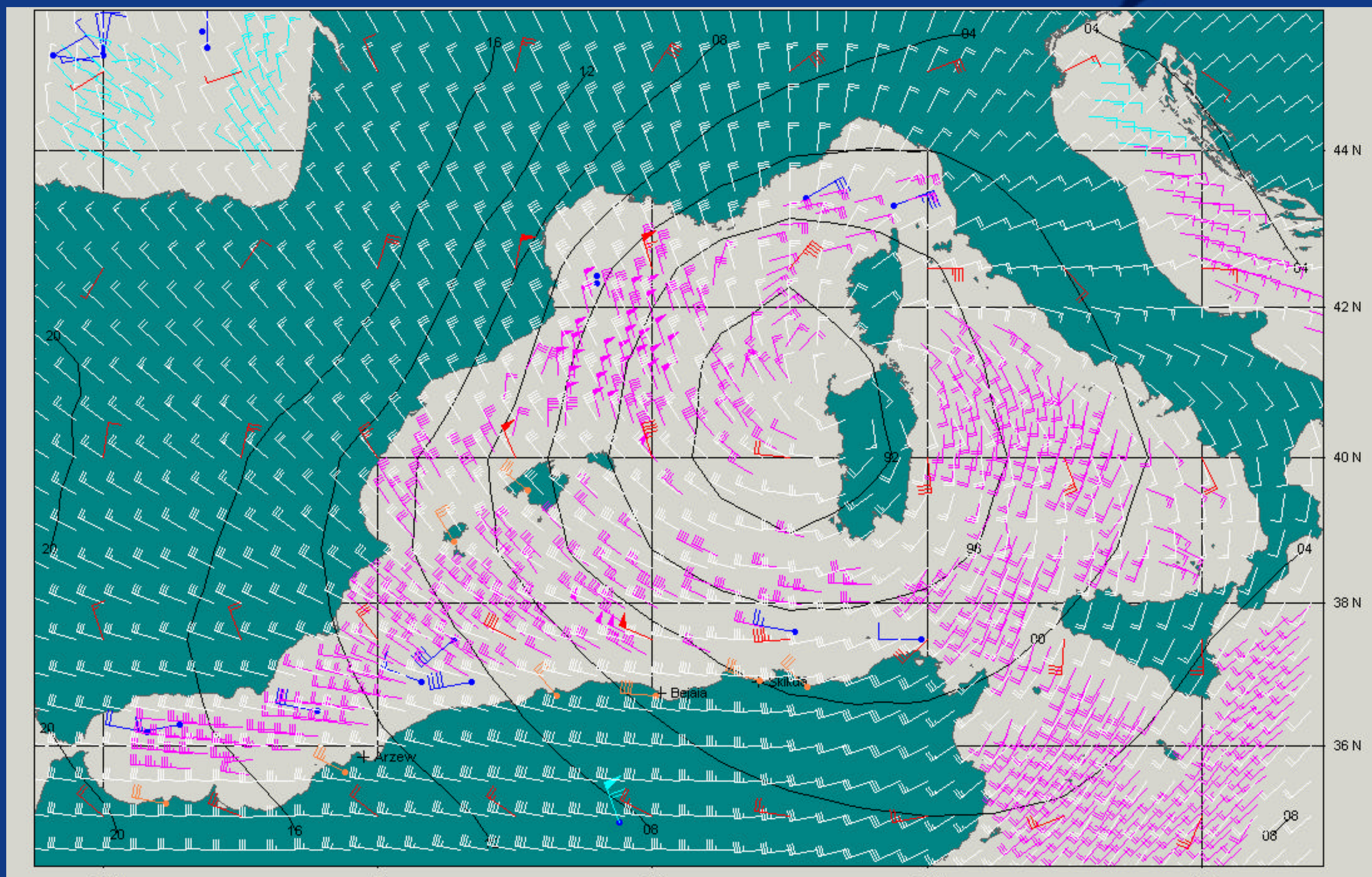
Wind Workstation



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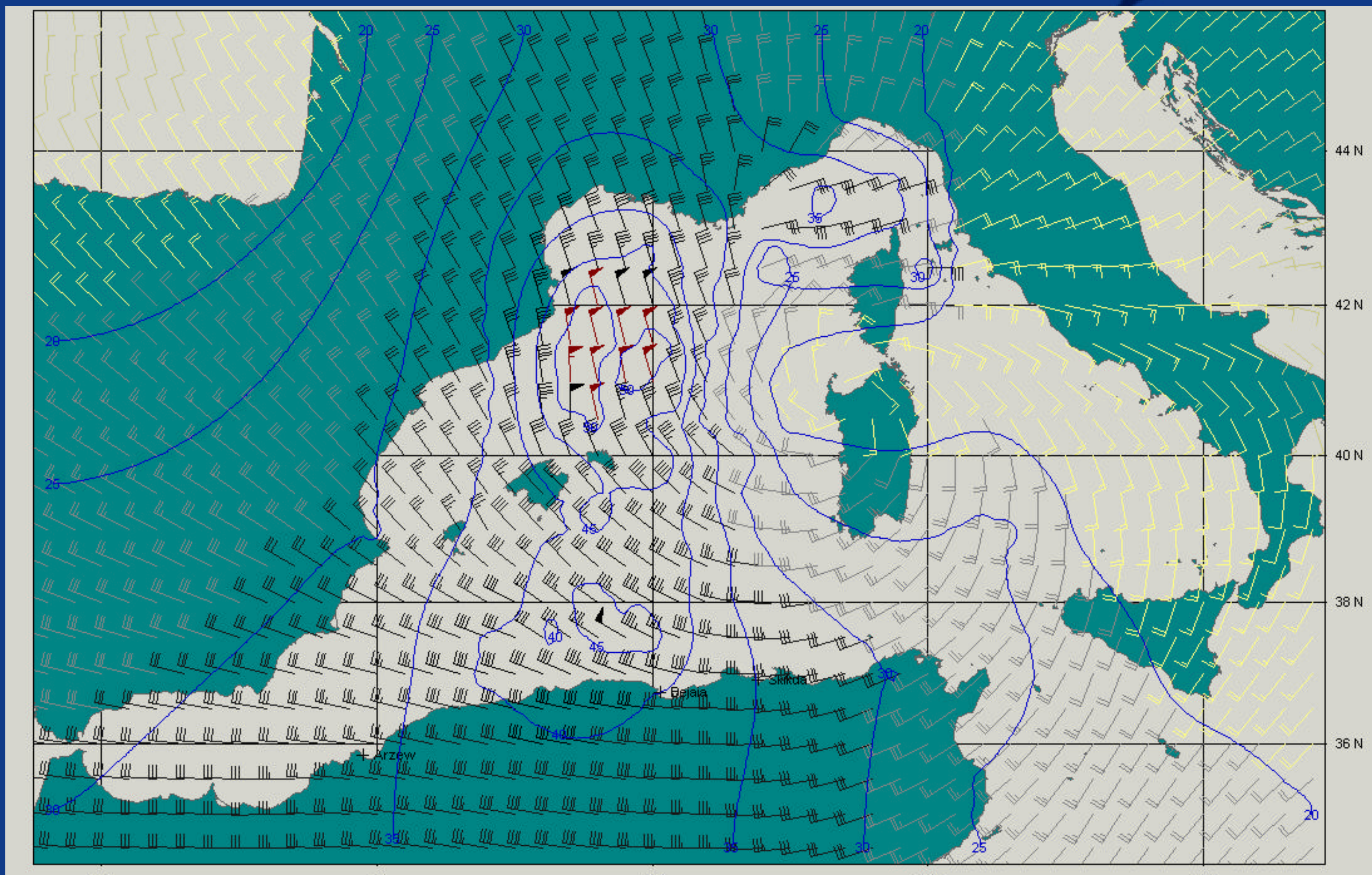
Final IOKA Wind Field



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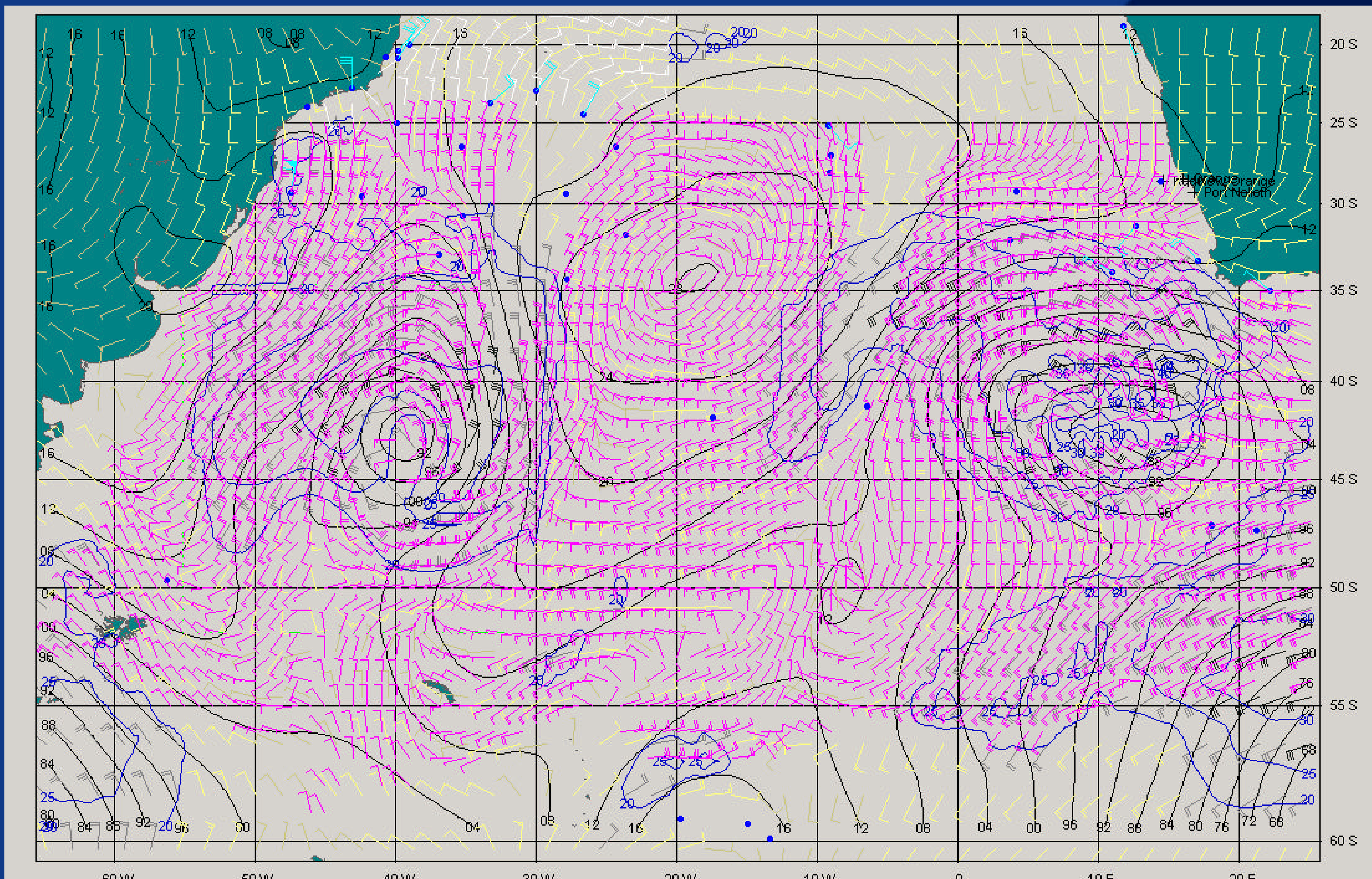
Wind Field for 01-Sep-2000 18Z



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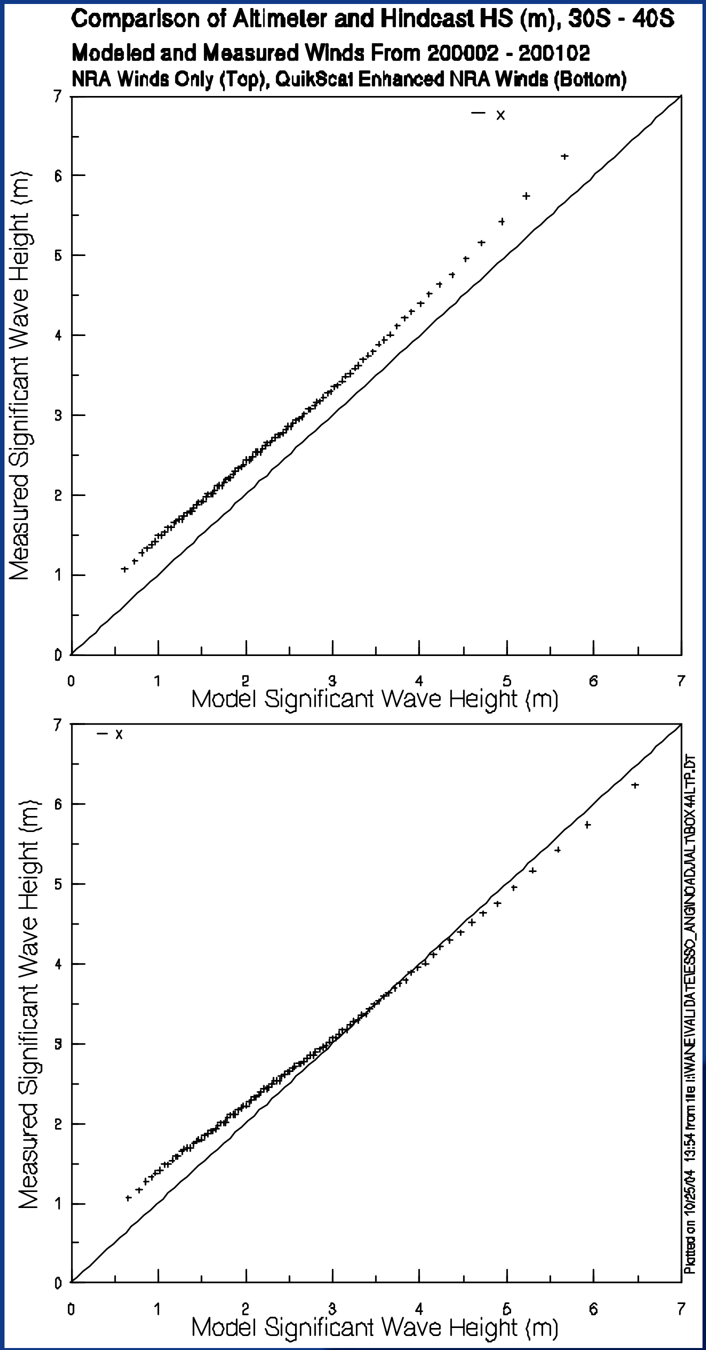

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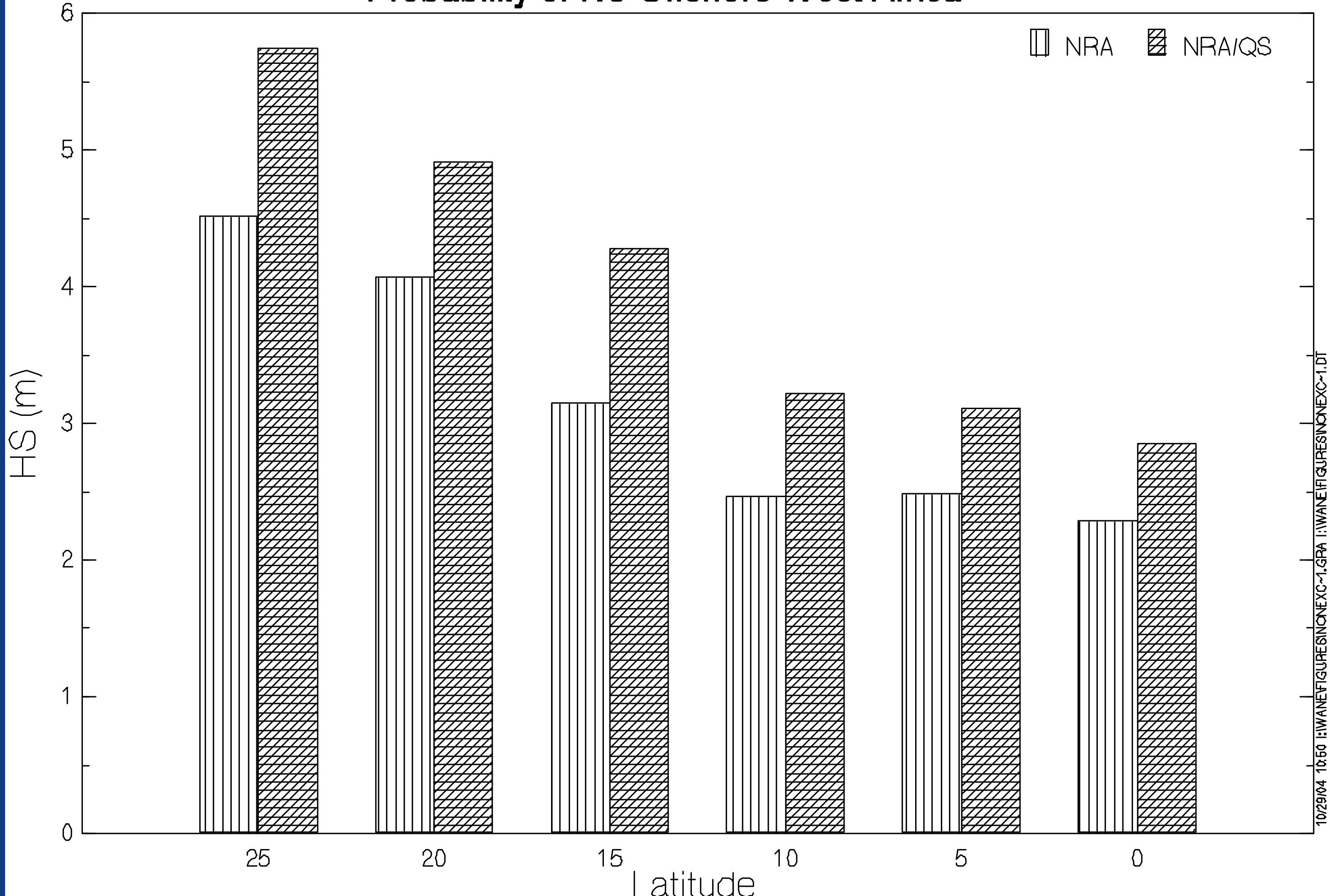
Comparison of NRA and NRA/QS 99% Annual Non-Exceedance Probability of HS Offshore West Africa



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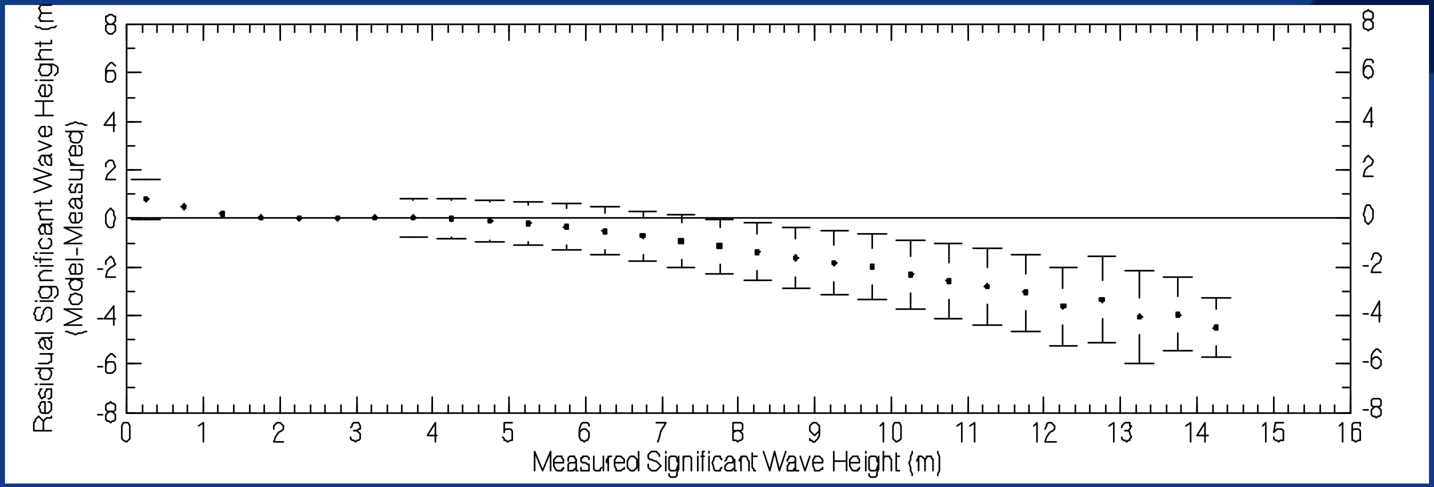
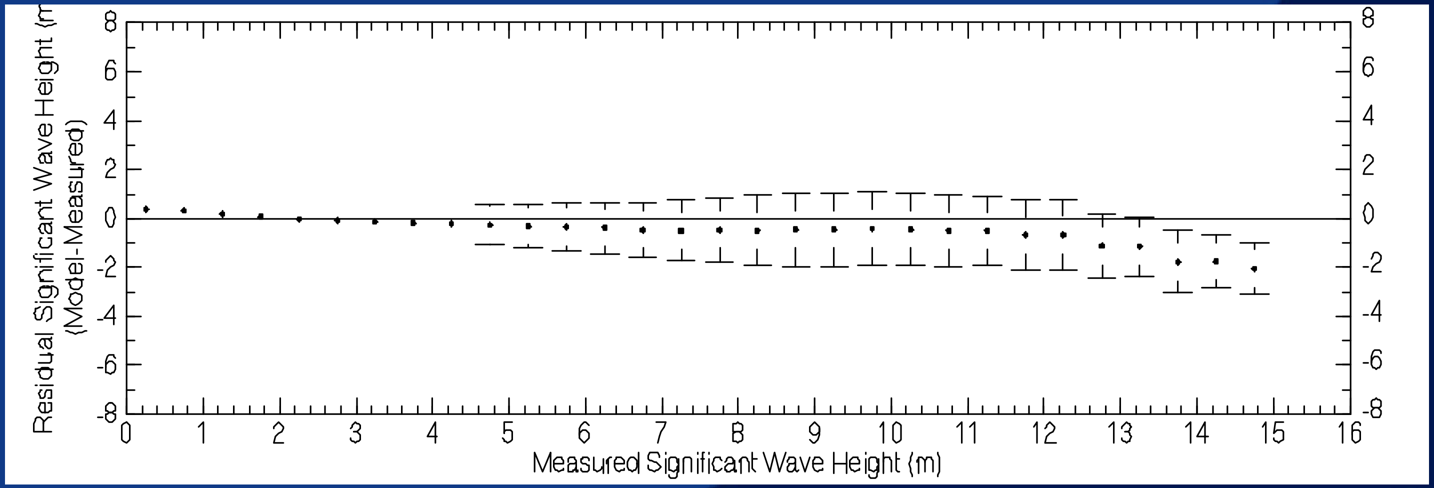
Evaluation of GROW hindcast driven by NRA wind fields



Evaluation of AES40 hindcast driven by reanalyzed NRA wind fields



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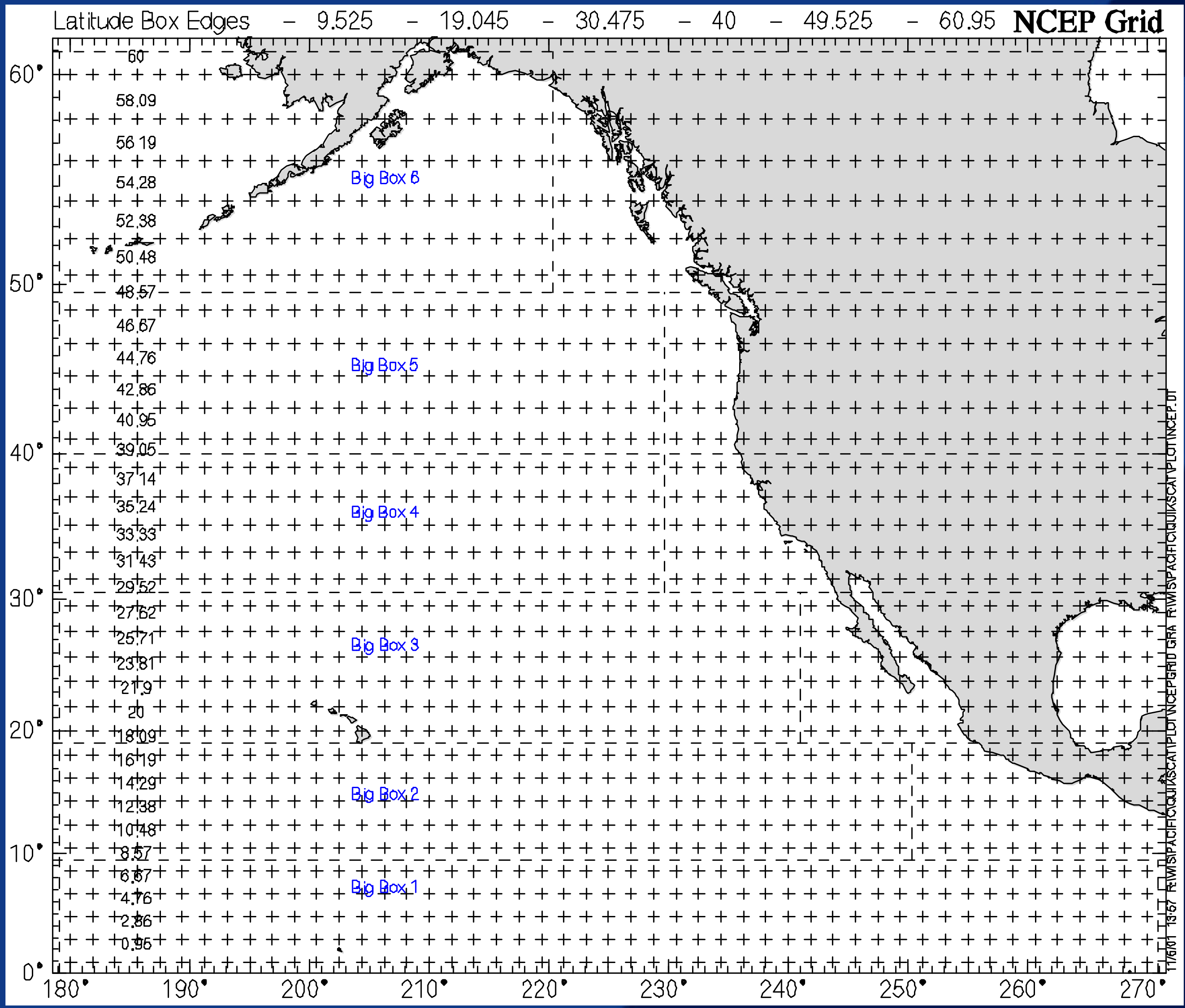
NCEP Grid - Big Boxes



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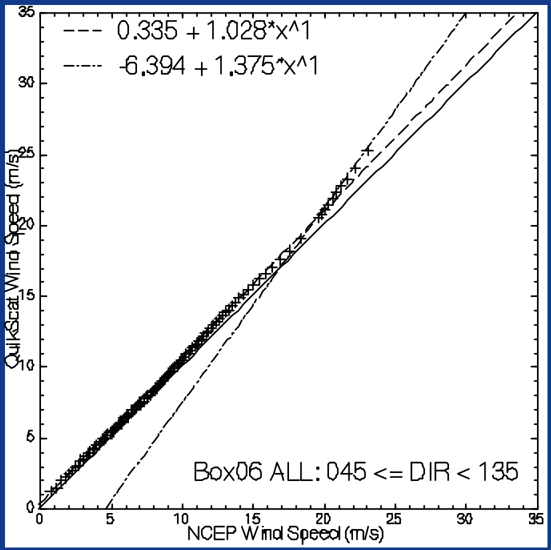
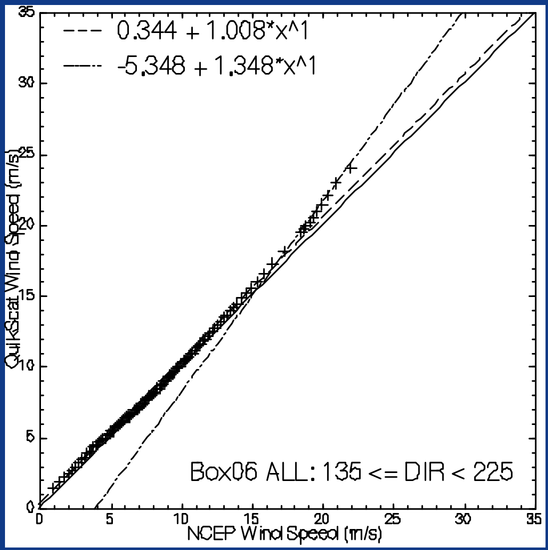
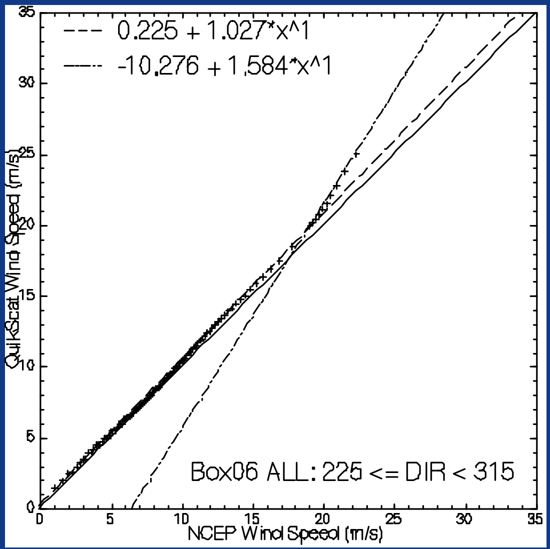
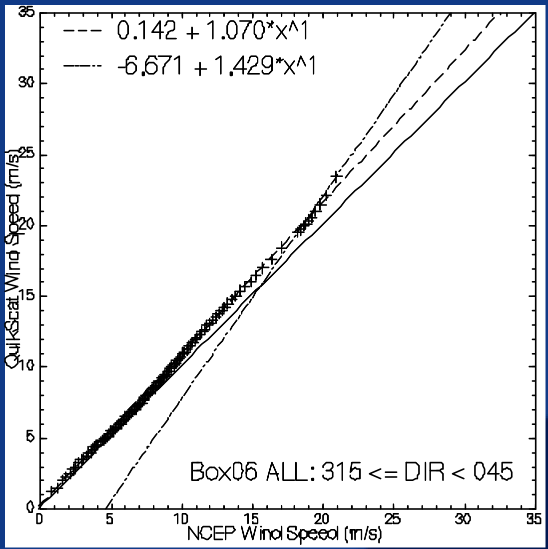
Primary/Secondary Regression Lines on Q-Qs Big Box 6









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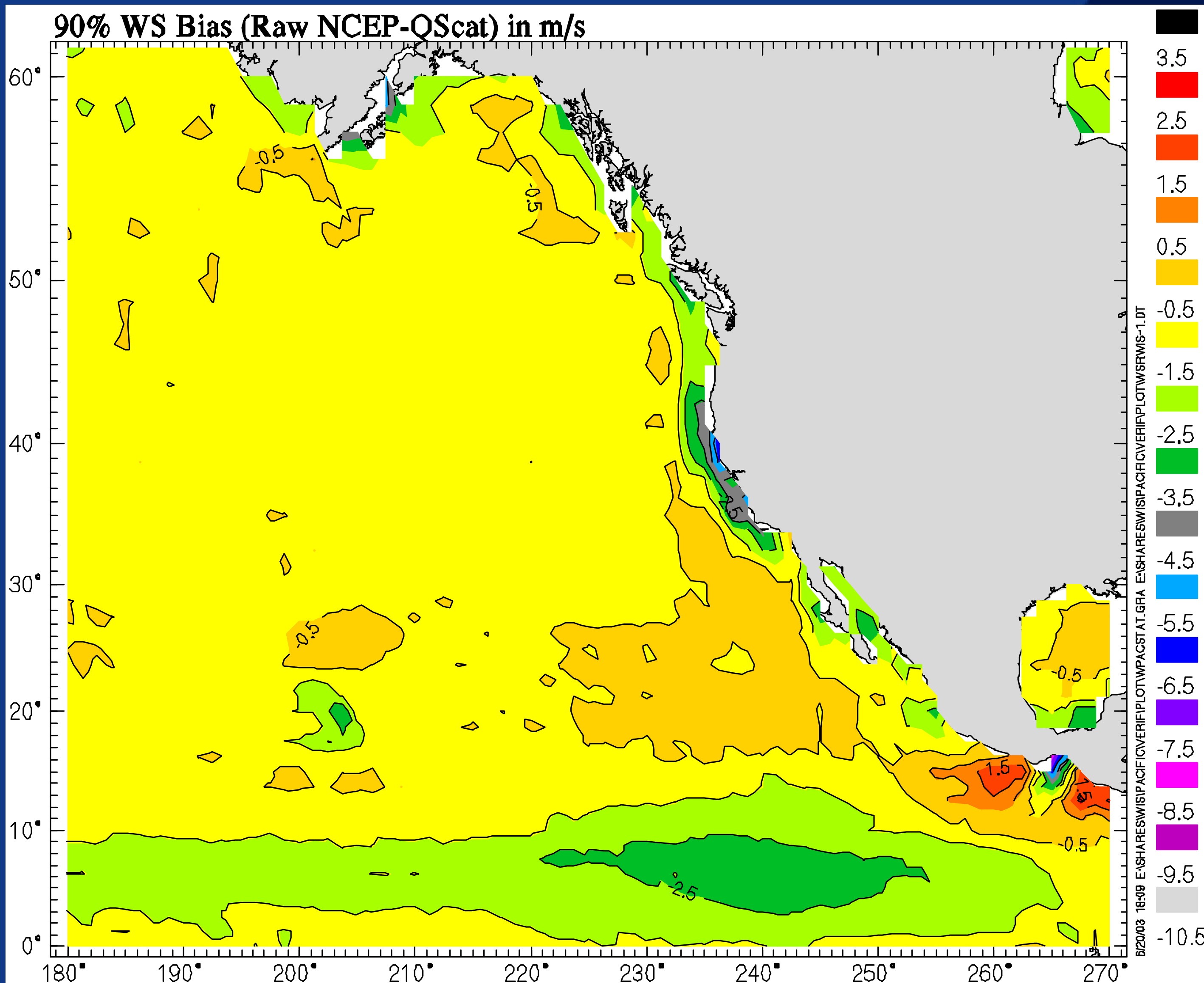
Quikscat vs. NCEP Unadjusted 90% Exceedance WS Bias All Dir Combined (N-Q) in m/s



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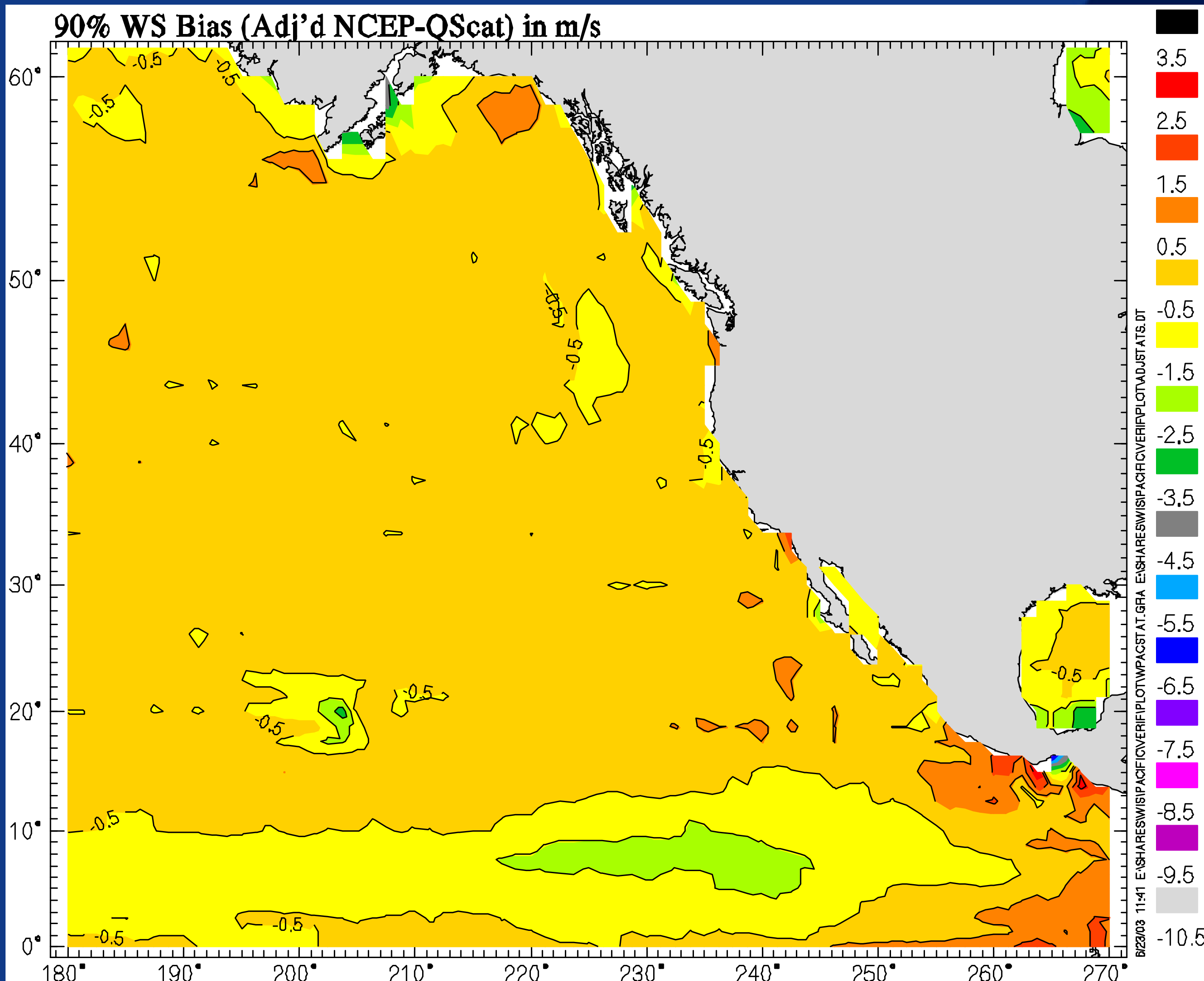
Quikscat vs. NCEP Adjusted 90% Exceedance WS Bias All Dir Combined (N-Q) in m/s



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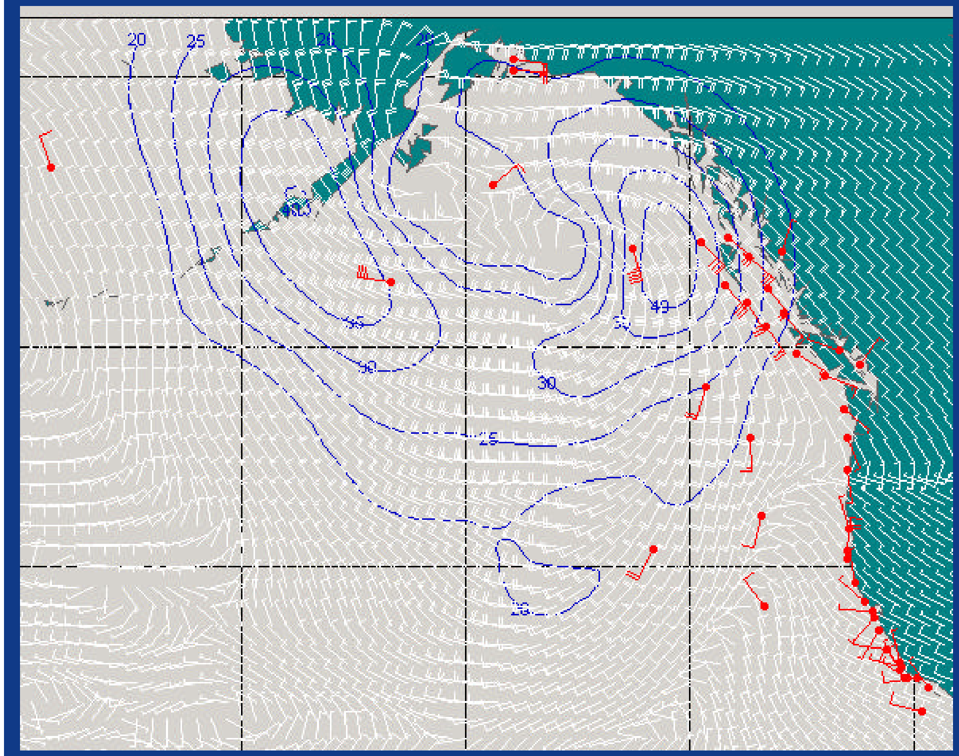
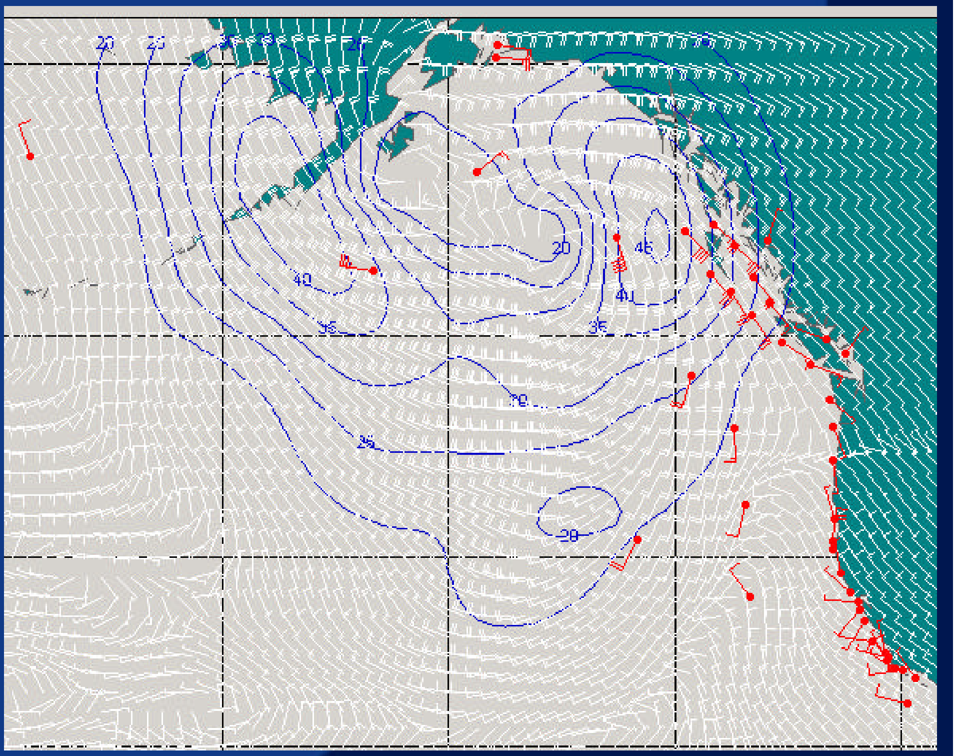
Sample Level I
Base Case Wind Field
October 7, 2000 06Z



Sample Level II
Wind Field
October 7, 2000 06Z



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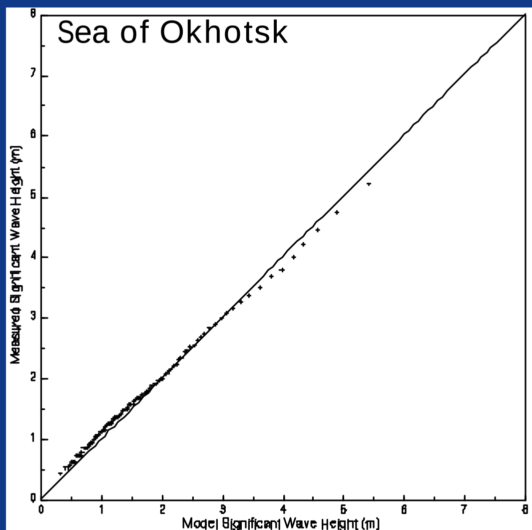
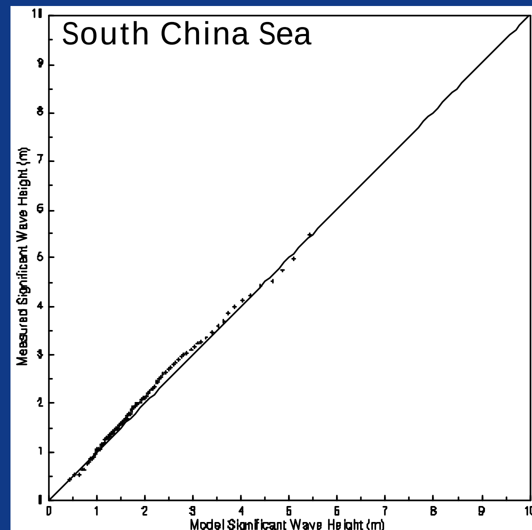
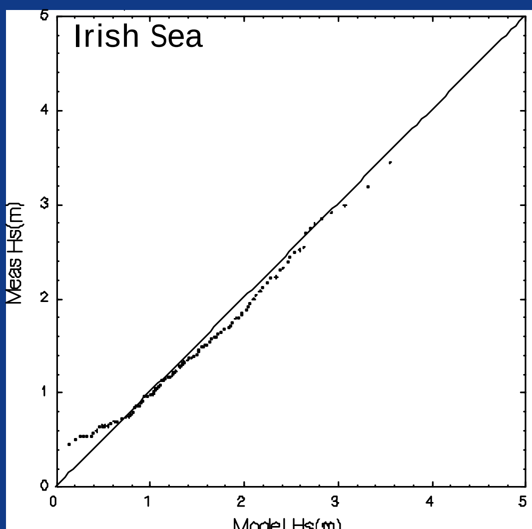
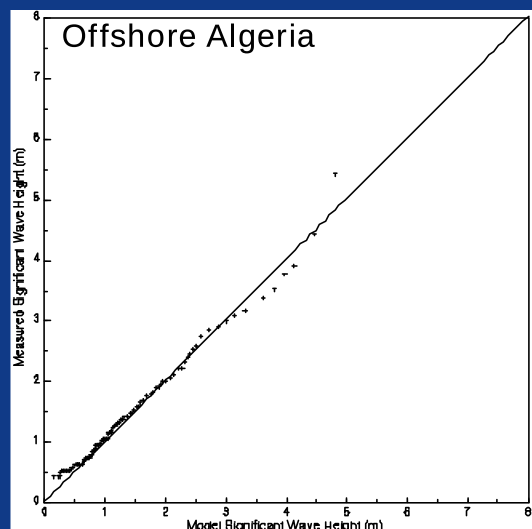
Examples of HS biases in terms of model vs. altimeter Q-Q scatter plots in hindcasts driven by QuikSCAT corrected wind fields









Location	# Pts	Bias (H-Alt)	Scat. Ind.	Corr Coeff
Sea of Okhotsk	12109	-0.08	0.27	0.90
S. China Sea	2631	-0.09	0.25	0.89
Irish Sea	676	0.01	0.30	0.84
Offshore Algeria	702	-0.07	0.37	0.86

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Conclusions

- NRA marine surface winds an improvement over previous operational NWP base products
- NRA winds may be further improved:
- -assimilate SCAT winds directly from 1999

  - use SCAT winds to identify and remove systematic effects in historical fields

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

Present Focus

- Producing 5-year global QuikSCAT enhanced winds via IOKA – may serve as a reference set for future global wave model validation (e.g. explore subtle southern vs northern ocean wave climate effects)
- Producing 50-year adjusted NRA winds with systematic errors minimized for third pass at GROW

Direct Assimilation of QuikSCAT into Global Wind Fields Currently Underway at Oceanweather