Specification of Unbiased and Homogeneous Marine Wind Analyses – Progress and Critical Issues

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OUTLINE

What drives our interest in marine wind climatology?

How have we and do we satisfy our needs?

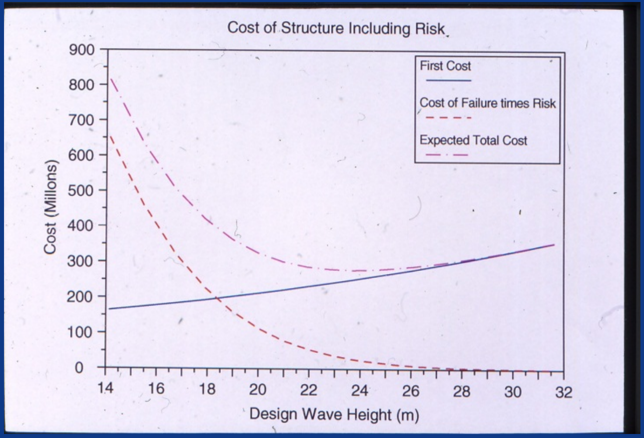
What has been the impact of remote sensing of marine surface winds vs traditional VOS source?

What has been the impact of global atmospheric "reanalyses"

Critical issues?

ESTABLISHMENT OF METOCEAN DESIGN CRITERIA

Jacket Structure: risk vs cost vs design wave height – min near 10^-2 ann. Prob.

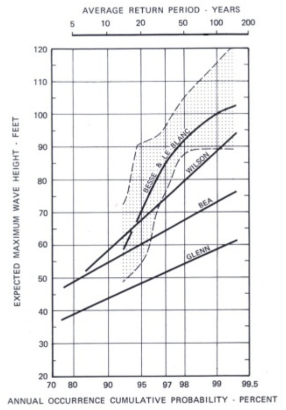


2005 Hurricane Impact Gulf of Mexico Platforms

	Katrina	Rita
Destroyed	47	66
Extensive Damage	20	32

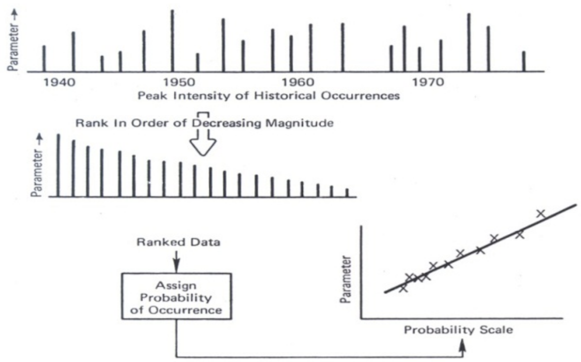
Gulf of Mexico Design Wave Height

Estimates circa 1970



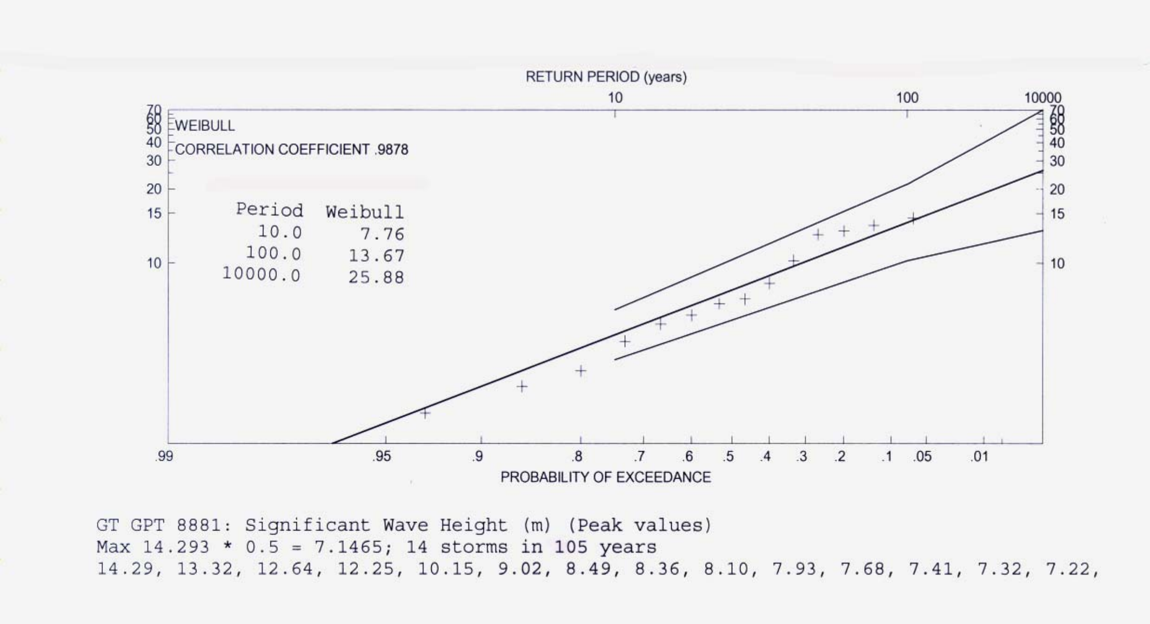
COMPARISON OF EXPECTED MAXIMUM WAVE HEIGHTS FROM PREVIOUS STUDIES

The Hindcast Approach: Winds drive ocean response models



Emphasis now is on 10^-4 Criteria (10,000 years!)

- Extremal analysis on latest Gulf of Mexico hindcast database spanning > 100 years at site in deep water south of Mississippi Delta yields a 100-year significant wave height of ~14 m
- At 10,000 yrs the Weibull extrapolates to “significant wave height” of ~26 m, which implies “maximum wave height” of ~ 46 m
- Limiting analysis to post 1950 storms increases extremes by about 10% to HS ~ 28 m and Hmax ~ 50 m for a “normal” max wave! Assoc TP~25s!
- Can a tropical cyclone on this planet generate such a sea state? Physics vs statistics!



Period	Weibull
10.0	7.76
100.0	13.67
10000.0	25.88

```
GT GPT 8881: Significant Wave Height (m) (Peak values)
Max 14.293 * 0.5 = 7.1465; 14 storms in 105 years
14.29, 13.32, 12.64, 12.25, 10.15, 9.02, 8.49, 8.36, 8.10, 7.93, 7.68, 7.41, 7.32, 7.22,
```

Wave measurements and recent hindcast studies in harsh extratropical regions (Eastern North Atlantic and North Pacific, Southern Indian Ocean) based on shorter historical periods (~60 years NH, ~40 years SH) indicate the same dynamic range and magnitude of extrapolations (for recent climate; what about climate change?)

SBL Wind Profile

Variation of Mean Wind With Height: Surface Layer

Neutral Stratification

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

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

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

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

Stability Effect

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

φ = stability function

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

H = heat flux

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

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

Homogenization of Ship Wind Reports to Equivalent Neutral Wind

(Cardone et at., JOC, 1990)

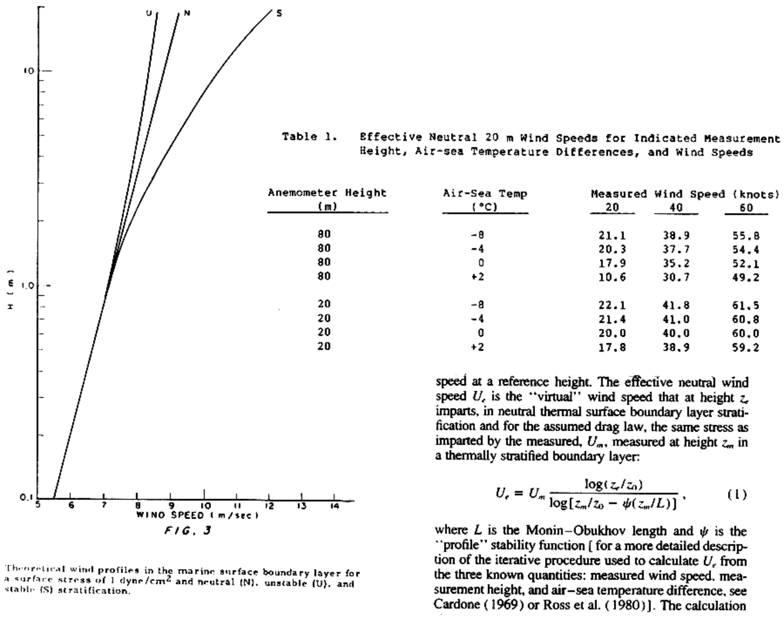


FIG. 3

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.

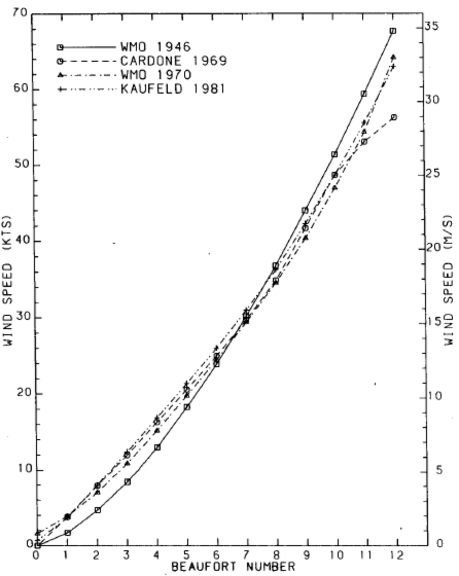
Table 1. Effective Neutral 20 m Wind Speeds for Indicated Measurement Height, Air-sea Temperature Differences, and Wind Speeds

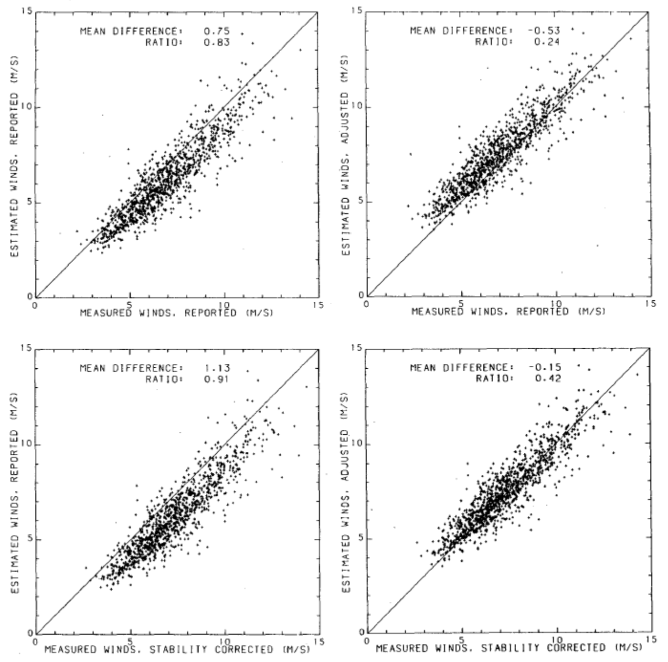
Anemometer Height (m)	Air-Sea Temp (°C)	Measured Wind Speed (knots) 20	40	60
80	-8	21.1	38.9	55.8
80	-4	20.3	37.7	54.4
80	0	17.9	35.2	52.1
80	+2	10.6	30.7	49.2
20	-8	22.1	41.8	61.5
20	-4	21.4	41.0	60.8
20	0	20.0	40.0	60.0
20	+2	17.8	38.9	59.2

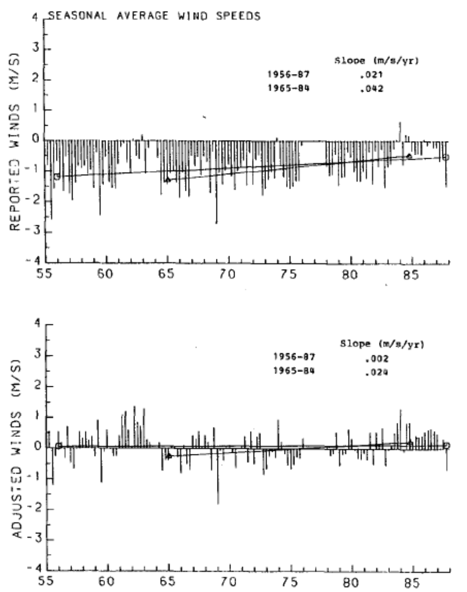
speed at a reference height. The effective neutral wind speed U_e is the "virtual" wind speed that at height z_e imparts, in neutral thermal surface boundary layer stratification and for the assumed drag law, the same stress as imparted by the measured, U_m, measured at height z_m in a thermally stratified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







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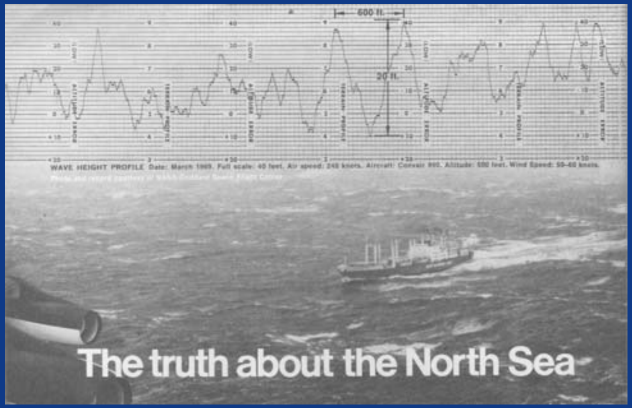
History of Ku Band Scatterometry



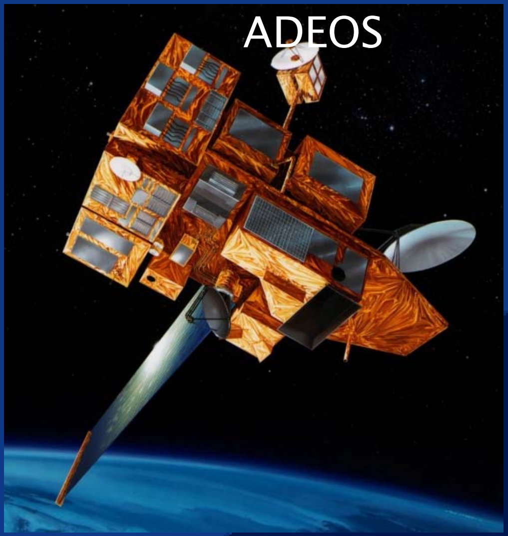
Aircraft Experiments – 11/1969

SKYLAB 1973-1974

SEASAT 6/78-9/78

Linny Jones, Bill Pierson, Me

ADEOS



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

QuikSCAT

6/99-11/09

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Evaluation of QuikSCAT Against Buoys

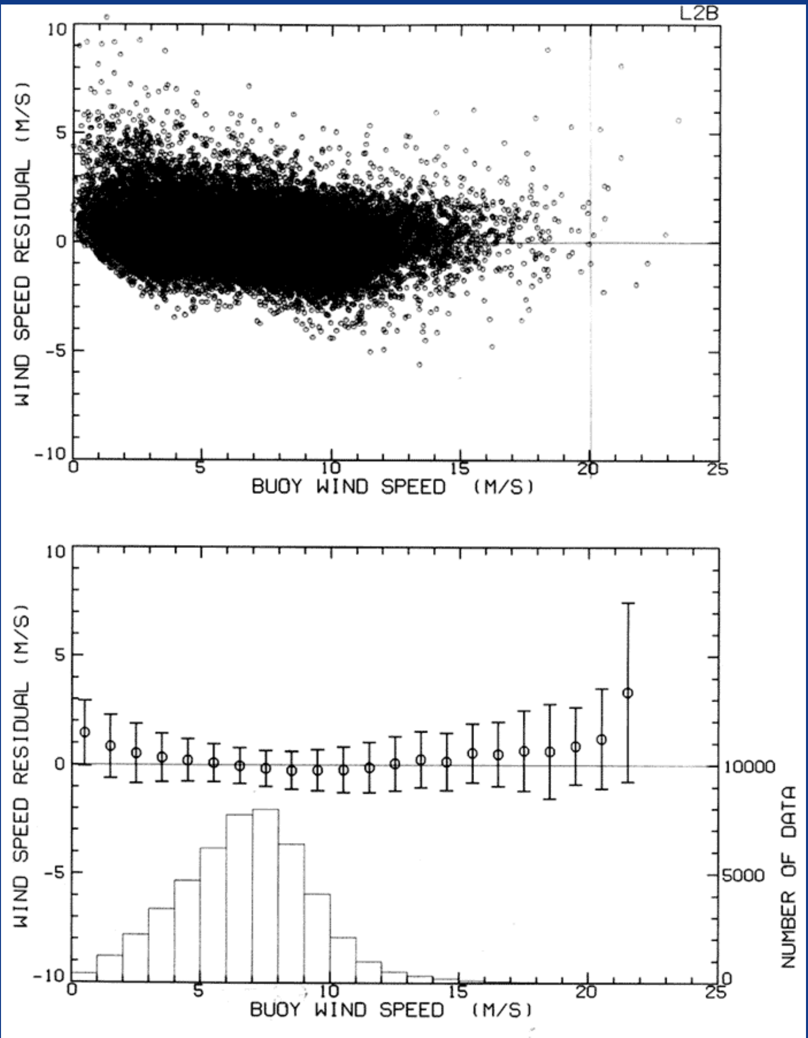


FIG. 3. Dependence of wind speed residual (QSCAT − buoy) on the buoy wind speed for the L2B winds. (upper panel) Scatterplots and (lower panel) numbers of data points, averages, (circles) and standard deviations (vertical lines) calculated in bins of buoy wind speed of 1 m s⁻¹.

Wind Speed

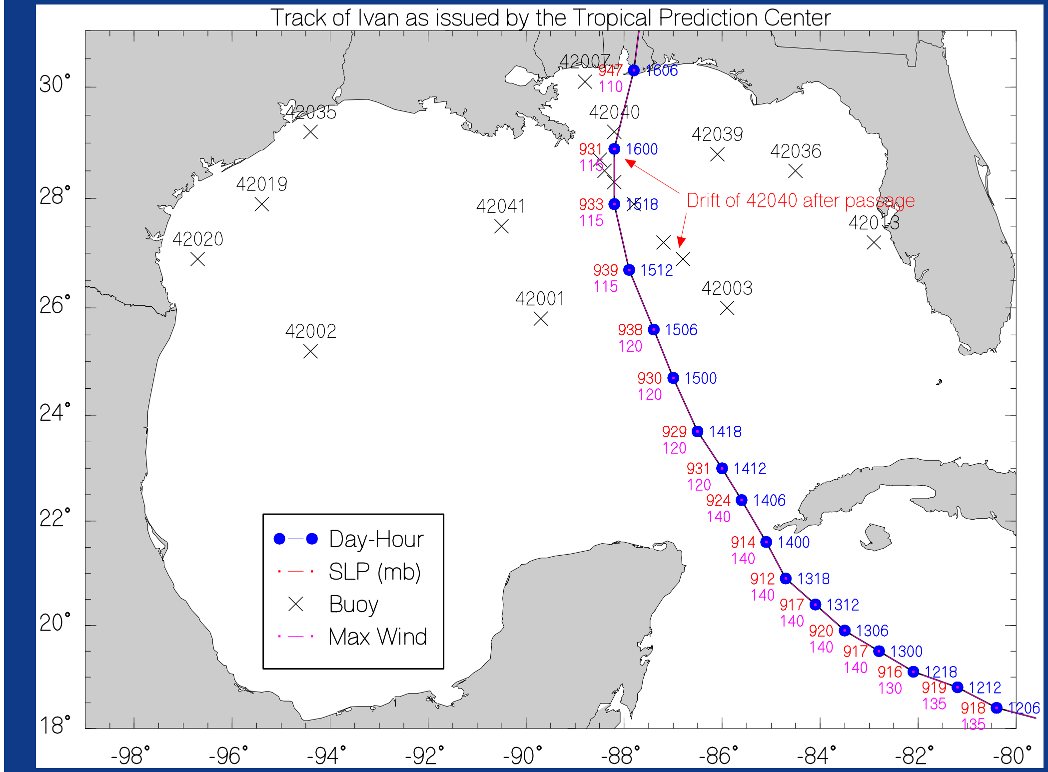
Number of Collocations	48,540
Bias	0.05 m/s
RMS Difference	1.00 m/s
Correlation Coefficient	0.927

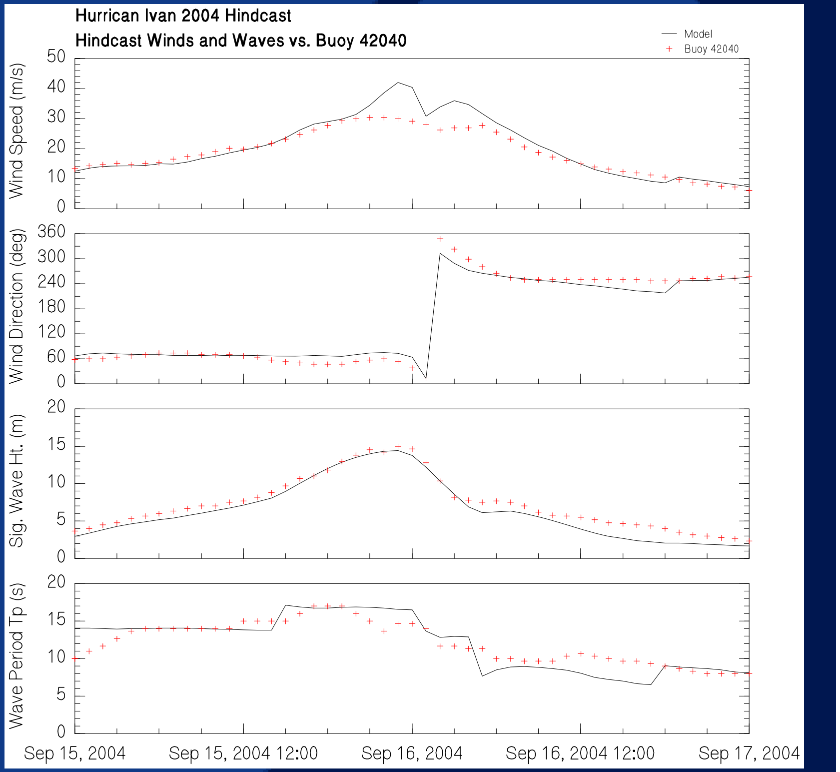
Wind Direction

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

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

Wind speed measurements from small (< ~ 10 m discus) metocean buoys appear to be biased low at high wind speeds. Sample evidence: buoy 42040 during Hurricane Ivan 2004





Large buoys (NOMAD hull, ~ 10 m discus) with anemometers mounted closer to 10 m appear slightly affected – a global albeit sparse array of such buoys moored in deep ocean harsh climate areas to augment the present array is needed to keep remote sensing honest!

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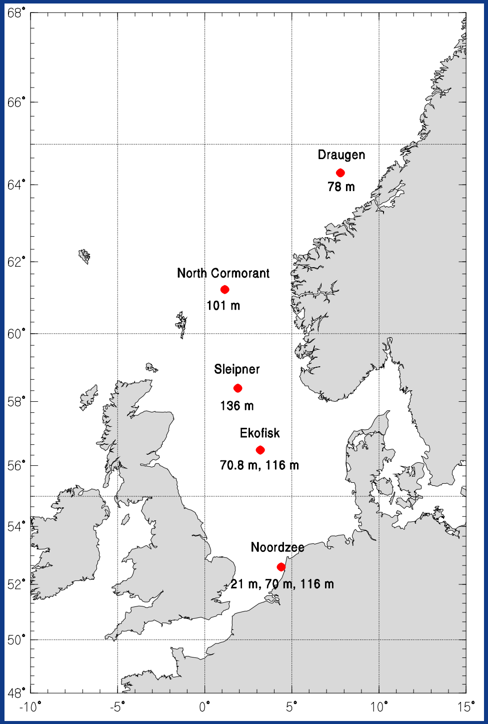
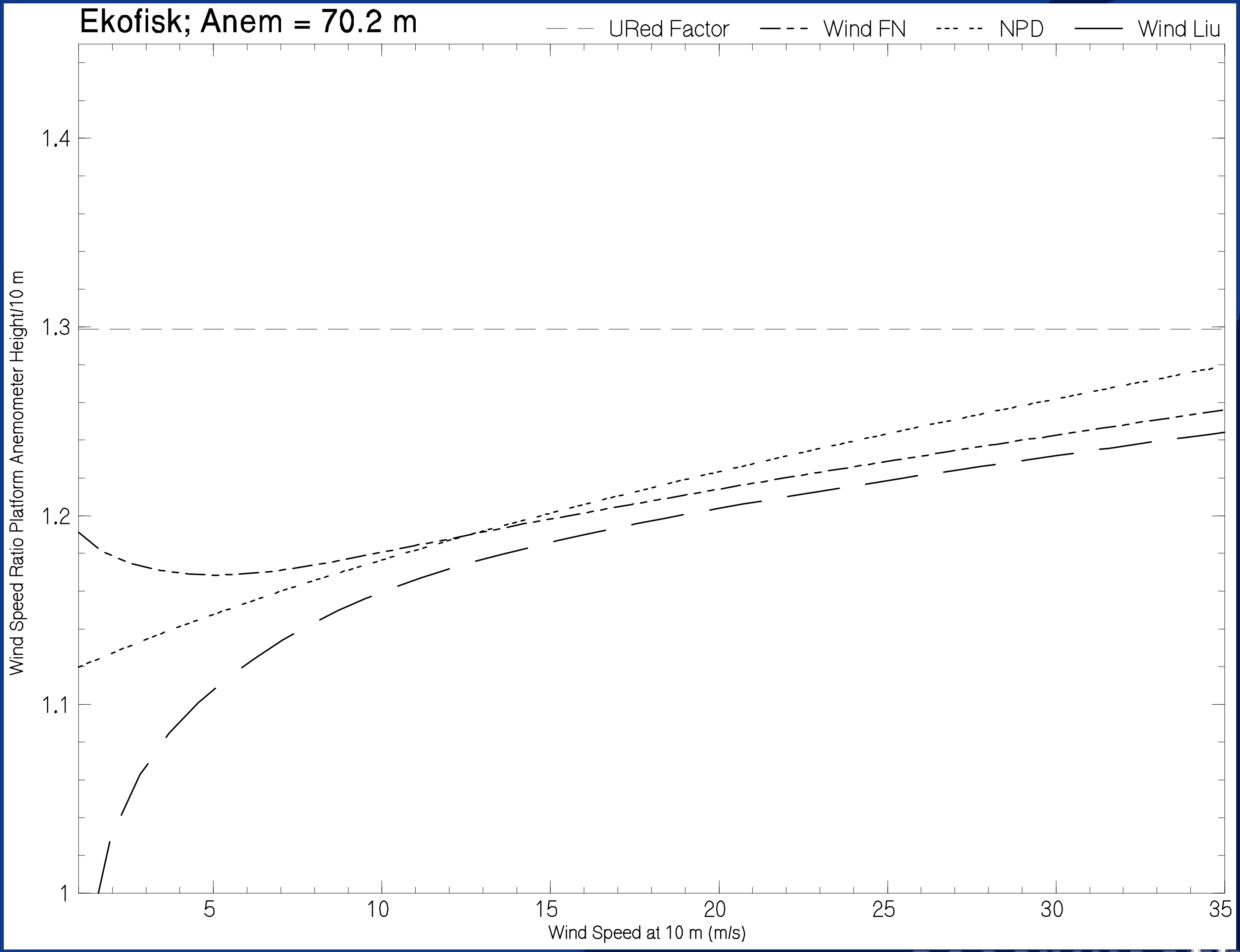
Extending the dynamic range of evaluation of remotely sensed marine surface winds: North Sea/Norwegian Sea Platforms



- Fixed vertical reference frame
- Top of derrick mount minimizes flow distortion errors
- Source of accurate extreme winds (U10 >25 m/s)
- Anemometer heights of 50 m-140 m create new challenges for reduction to 10 m
- Difficult to access and use because non-standard reporting practices, confidentiality...

The platforms typically employ an onboard power law reduction factor to go down 10 m wind speed. Since these are platform dependent constant factors and known we can back out the top of derrick wind and apply full SBL models to reduce to 10 m wind speed or 10 m equivalent neutral wind speed



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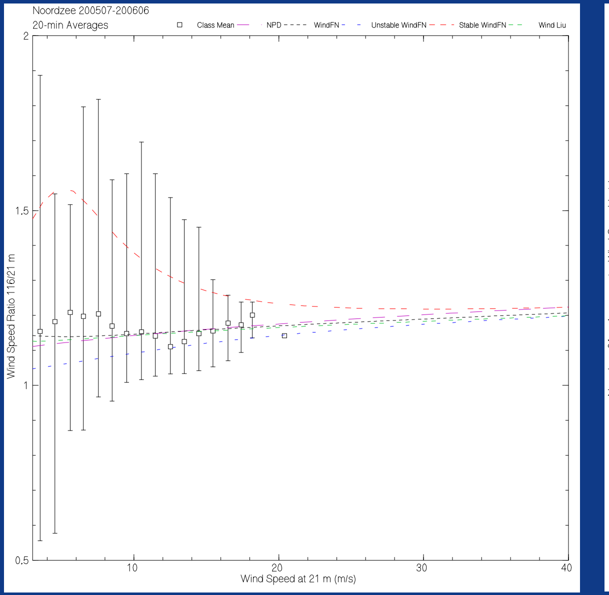
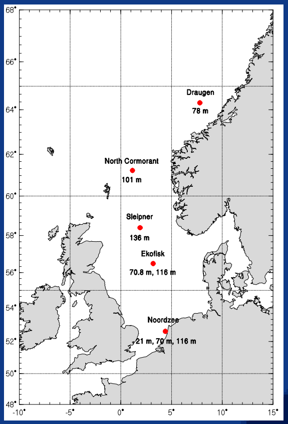
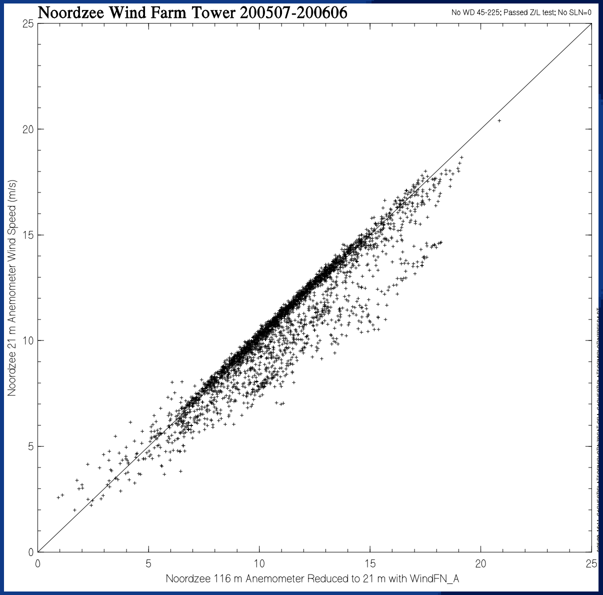
IS THERE ANY DIRECT EVIDENCE THAT SBL THEORY APPLIES TO HEIGHTS OF NORTH SEA PLATFORM ANEMOMETERS?

- Pre-wind farm data available online for 200507-200606
- Continuous 10-min records
- Anemometers at 21m, 70m, and 116 m on 3 sides of the tower
- Temperature sensors at each level and one at -3.8 m



Ratio of WS 116m/21/ for various wind profile models and stability classes Versus Nordzee measured data





Predicted wind speed at 21 m from measured wind speed at 116 m for Cardone (1969). About 10% of profiles not fit well (near land, baroclinicity, accelerated flows.

Even with the anomalous cases retained, WINDFN can be used to specify the 21 m wind speed from the 116 m wind speed with a CC of 0.95, a bias of 37 cm/sec (2% at 20 m/s), and a standard deviation of 98 cm/sec.

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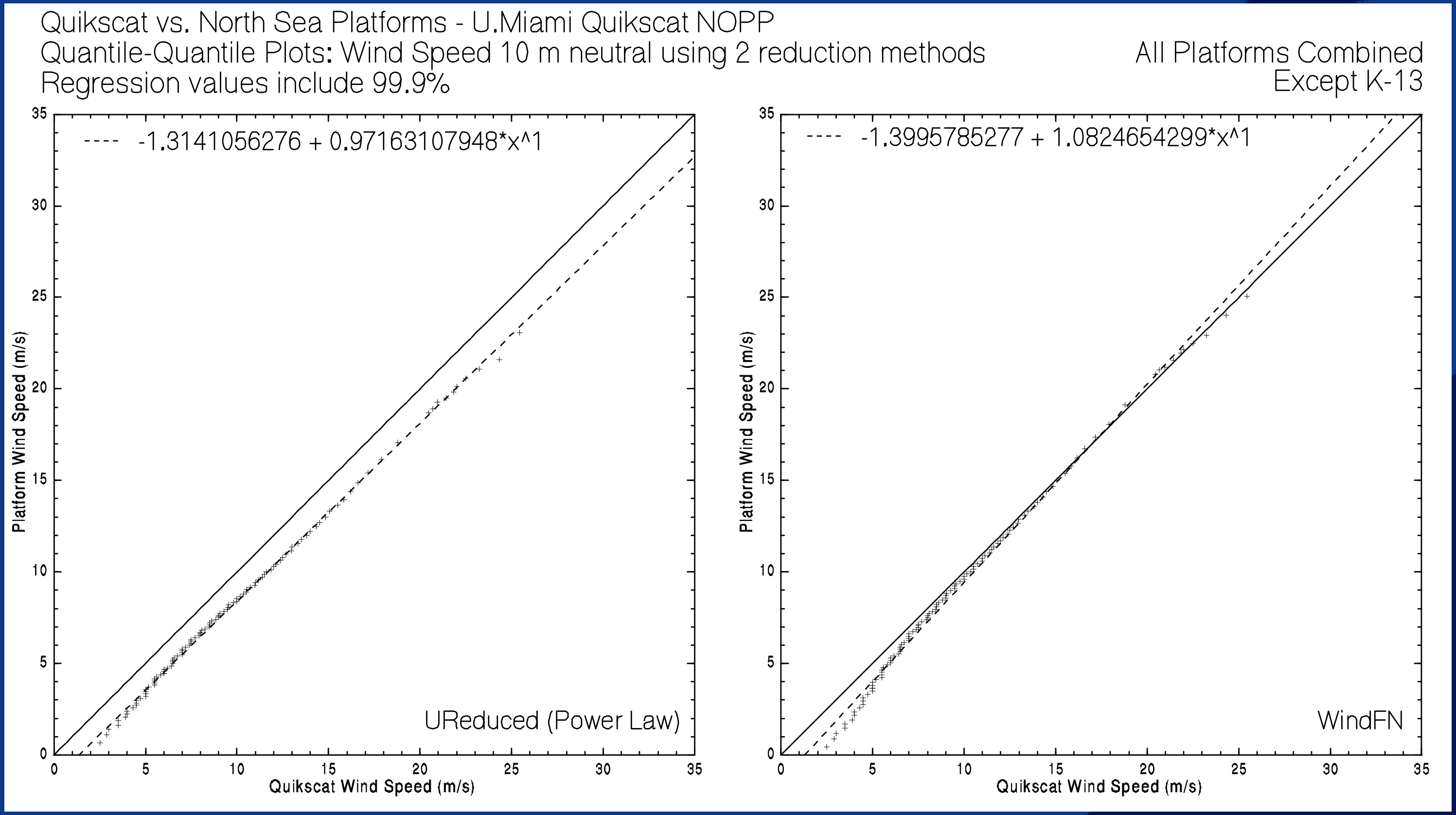
Collocation Process

- 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 ~20,000 matches total for all six platforms from 199907-200212.

Q–Q Plot



Quikscat vs. North Sea Platforms - U.Miami Quikscat NOPP
Quantile-Quantile Plots: Wind Speed 10 m neutral using 2 reduction methods
Regression values include 99.9%

All Platforms Combined
Except K-13

```
Data Period : 01-JUL-1999 00:00:00 to 01-JAN-2003 00:00:00
                                  Number     Mean    Mean     Diff    RMS   Stnd   Scat         Corr
               Platform  Method   of Pts     Plat    QScat   (Q-P)  Error    Dev  Index  Ratio  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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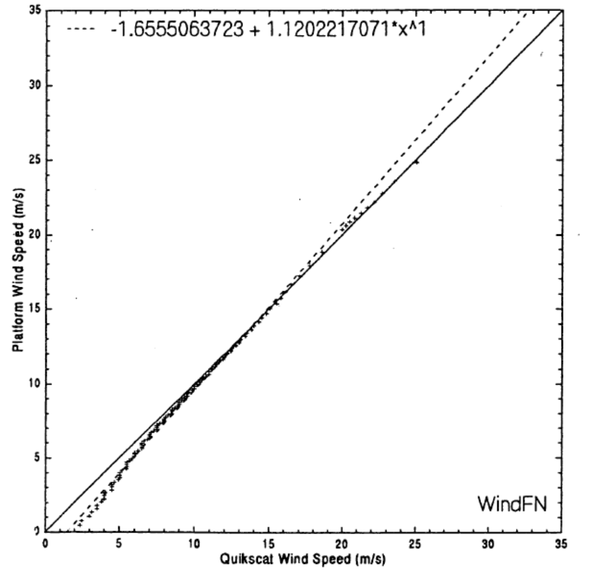
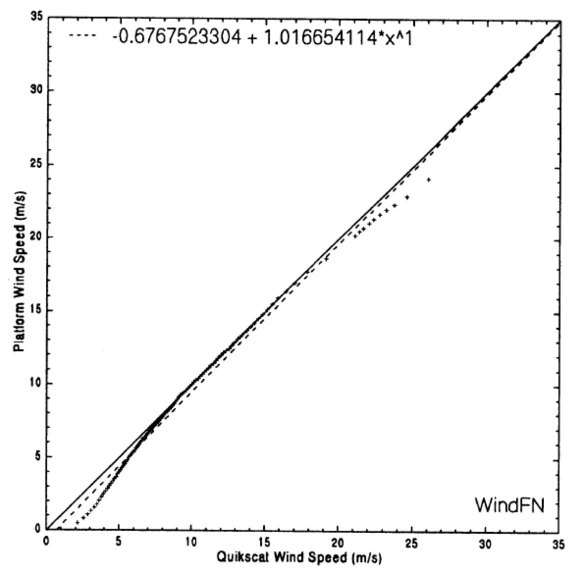
QuikSCAT vs platform wind speeds

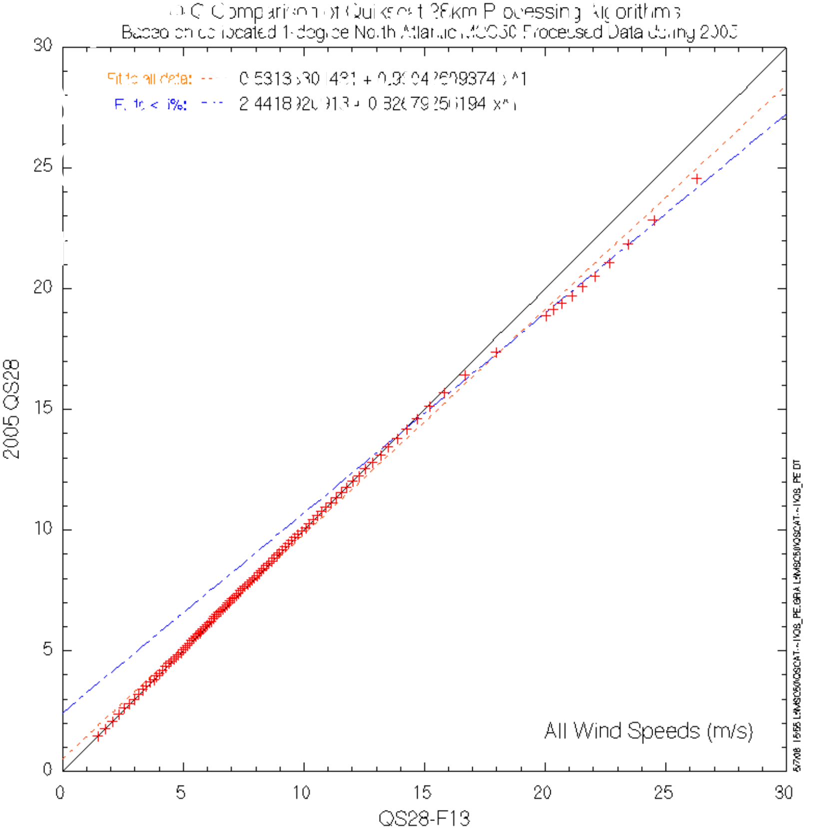
QSCAT-1



QSCAT-1/F13



Difference between QSCAT-1 and QSCAT-1/F13 scatterometer model function wind



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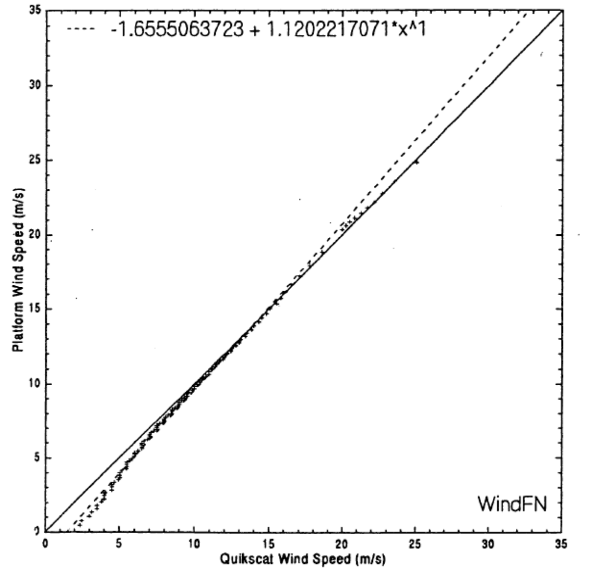
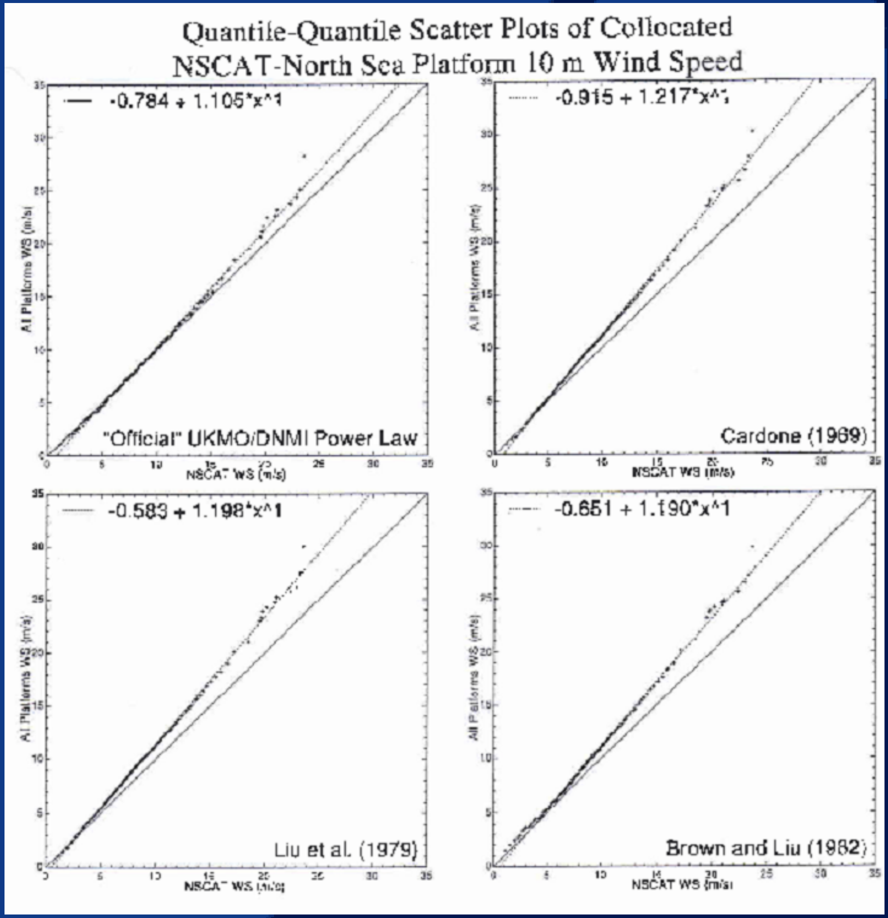
Apply same comparison methods to NSCAT

QuikSCAT




Quantile-Quantile Scatter Plots of Collocated NSCAT-North Sea Platform 10 m Wind Speed

Impact of Remotely Sensed Marine Surface Winds (mainly QuikSCAT) on Our Surface Marine Wind Reanalysis Practices and Ocean Response Modeling

- 1. Direct Assimilation into a background field such as NCEP/NCAR RA (NRA) that has not assimilated same using an Interactive Objective Kinematic Analysis System (IOKA)
- Have applied this approach to storms as well as long historical periods as allowed by the data record

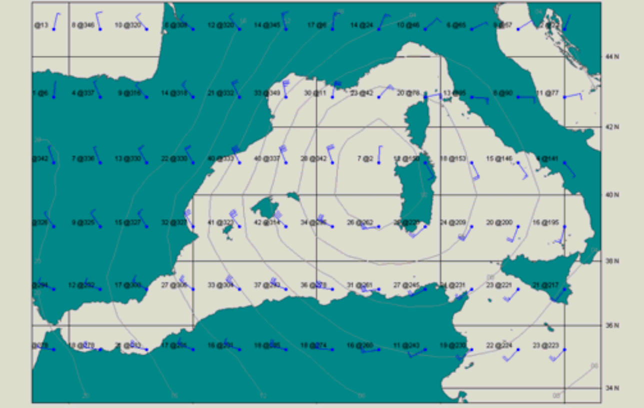
- 2. Develop Statistical Minimization Functions to apply to NRA over its full historical period, from the overlapping period of reanalyses and remote sensing databases

- 3. Test Newer Assimilative Reanalysis Products (US)

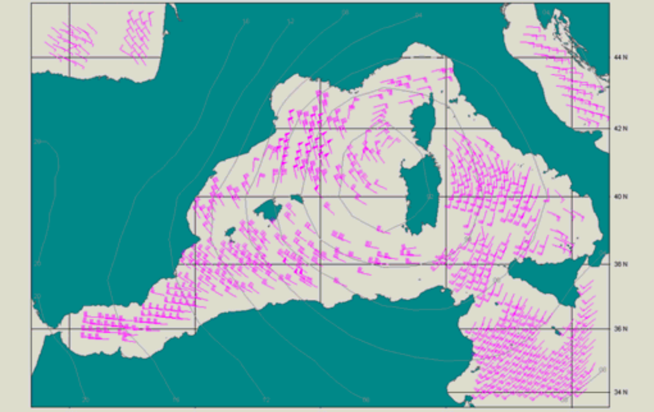
CoRA	QSCAT&ERS-1/NRA blend; 0.5-degree, 6-hr; Milliff et at., JTech, 2004
CCMP	All active and passive/ECMWF (ERA 40 & ECOP) VAM blend, 25-km, 6-hourly; Jul87 - Jun08; Atlas et al. BAMS, 2011
CFSR	All data, coupled, 38-km, hourly, Jan79-Dec09 Saha et al.,BAMS, 2010

Direct Insertion For Episodic Events Works Best

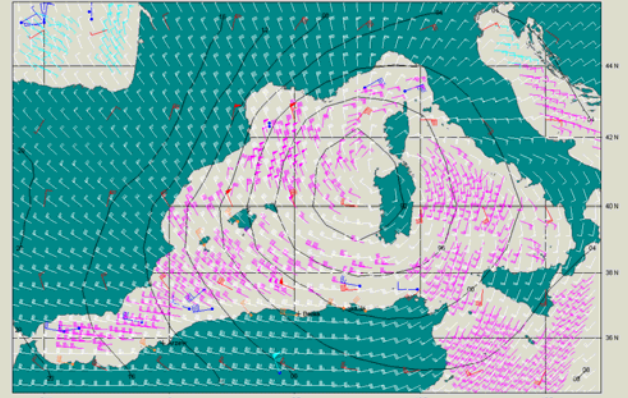
Uncorrected NCEP Reanalysis Project Surface Pressure and 10-m Wind Analysis 12/28/2000



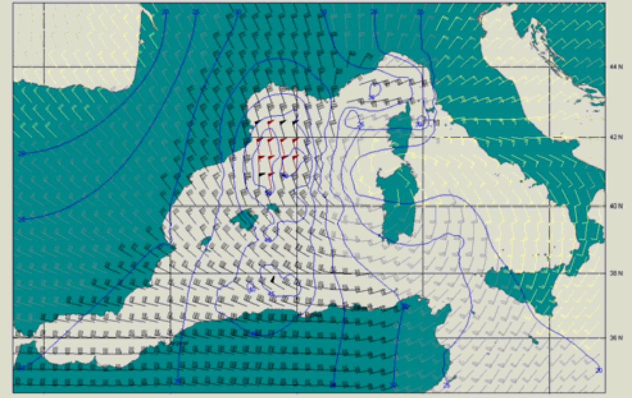
QuikSCAT Winds in One Pass



IOKA Wind WorkStation Diplay



Final Analysis



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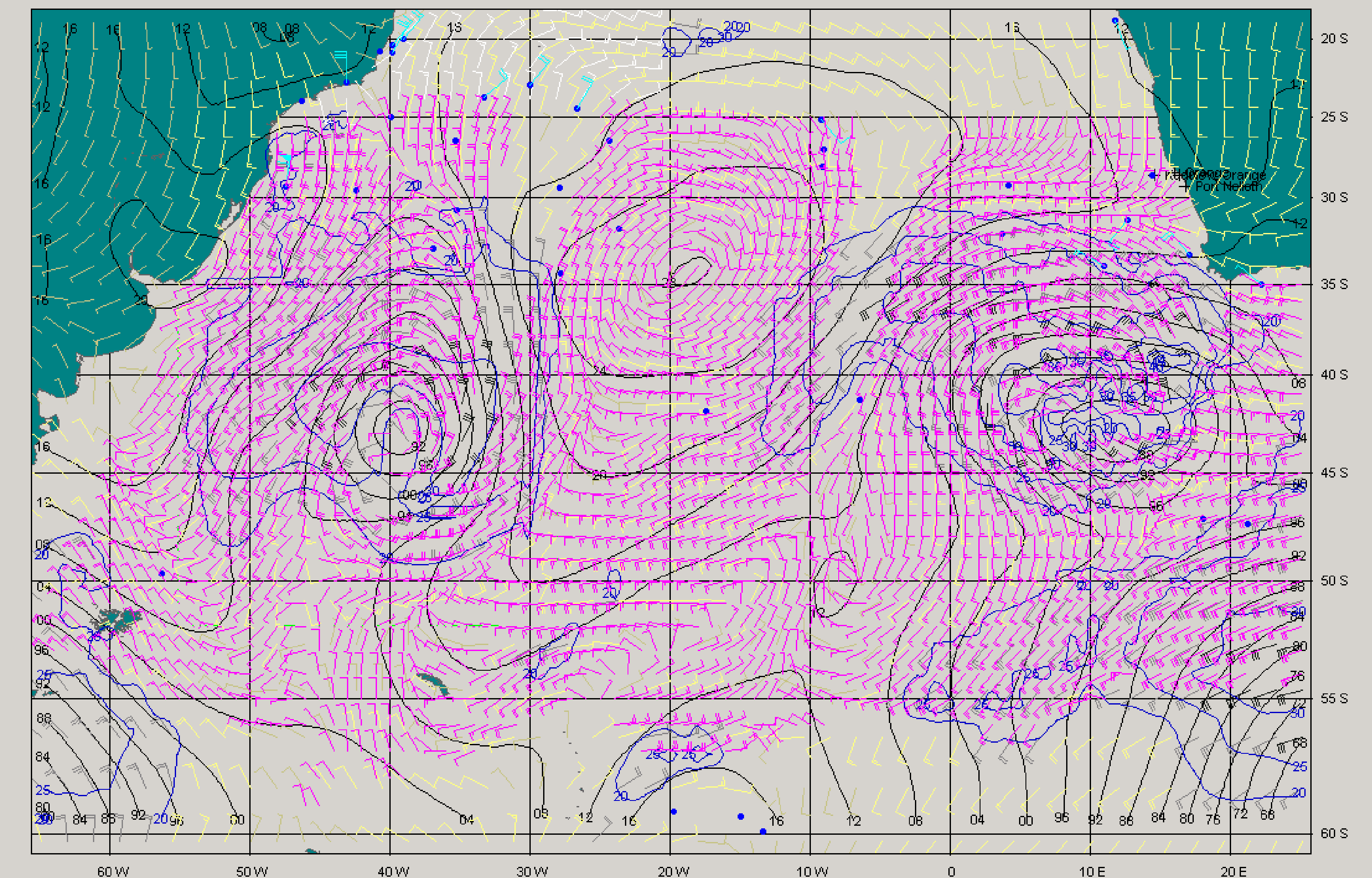
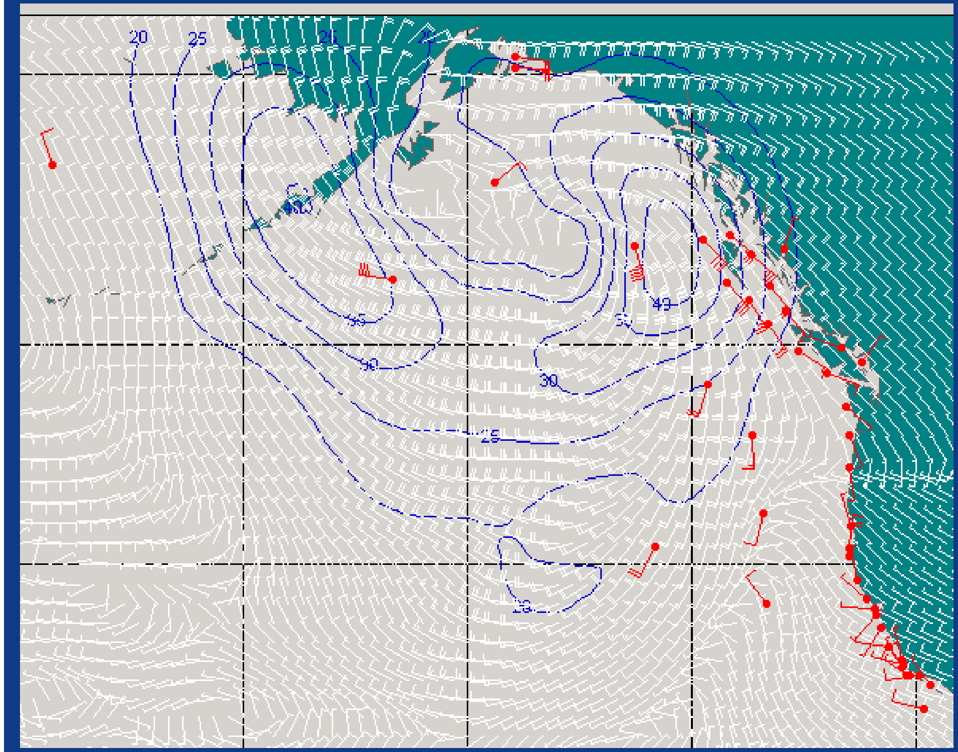
South Atlantic Basin Wind Field for 18 UTC Sep/01/2000
Satellite Winds Equalize the NH/SH

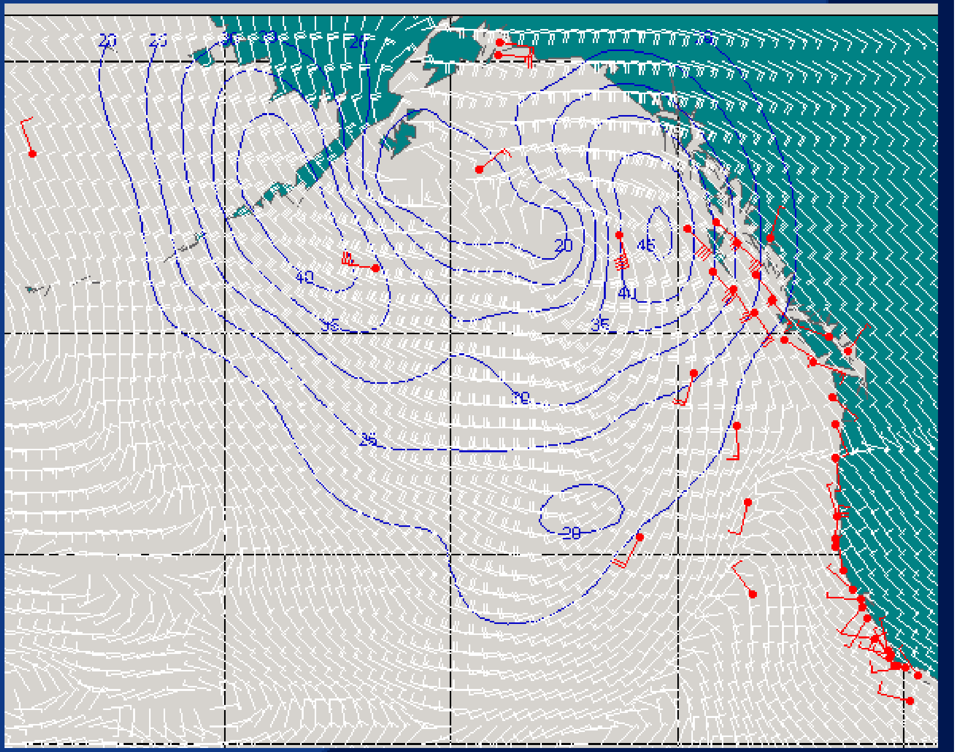


Example of Statistical Bias Minimization of NRA

Pure NCEP/NCAR NRA Surface Wind
Field Gulf of Alaska 06Z/Oct 7/2000



Statistically Unbiased
October 7, 2000 06Z



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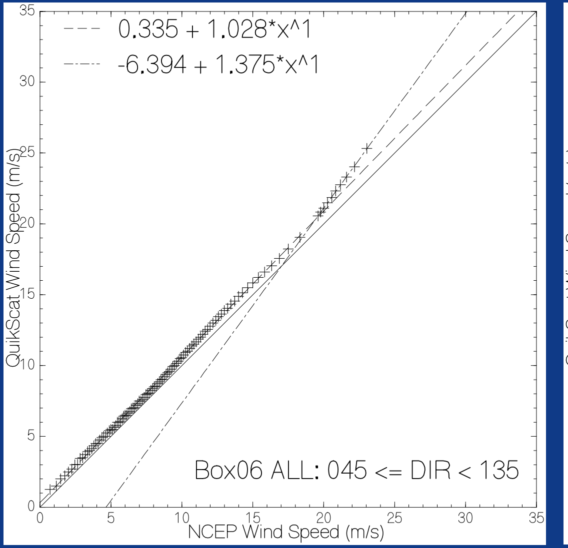
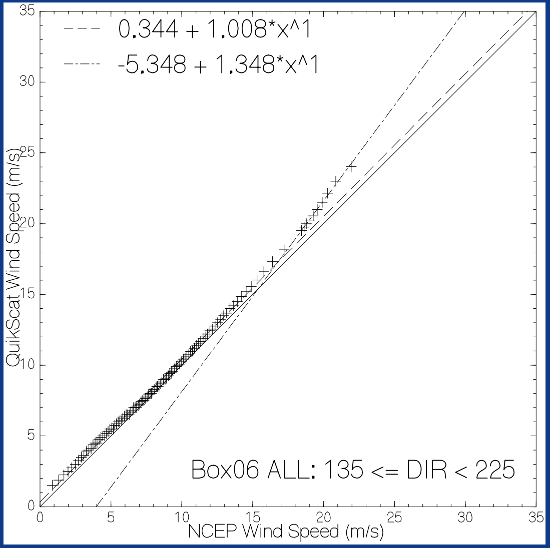
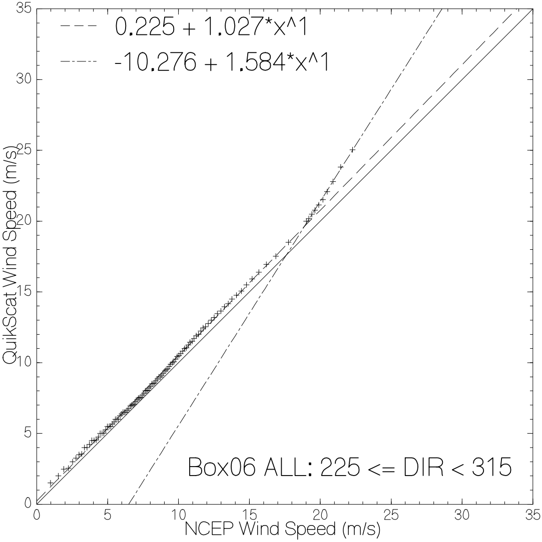
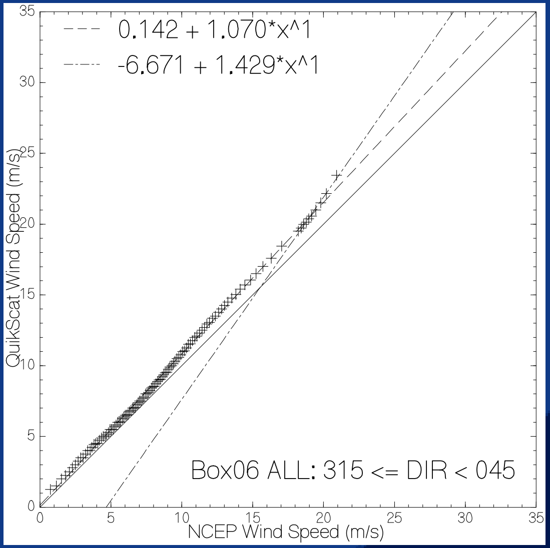
Primary/Secondary Regression Lines on Q-Qs Big Box 6







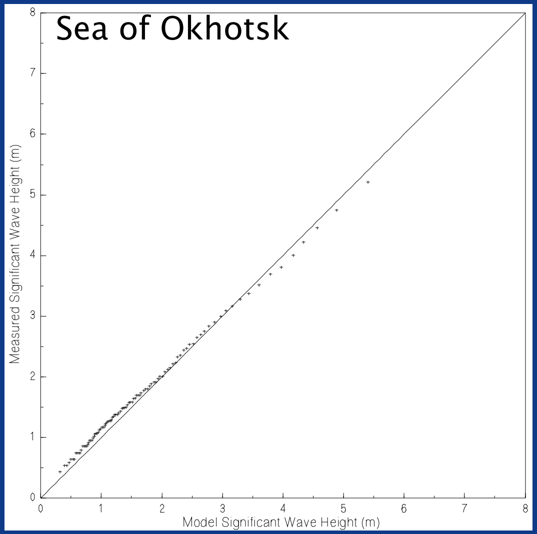


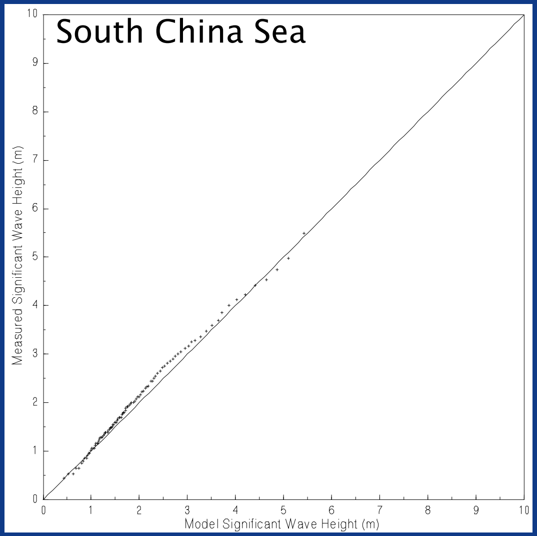
```
Date Range: 01-JUL-1999 00:00:00 to 30-JUN-2002 23:00:00
Wind Spd. (m/s):
Dir    Number     Mean     Mean     Diff    Stnd    Scat    Corr
Bin    of Pts    QScat     NCEP    (H-Q)     Dev   Index   Coeff
---   -------   ------   ------   ------   -----   -----   -----
ALL    271439     8.80     8.28    -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

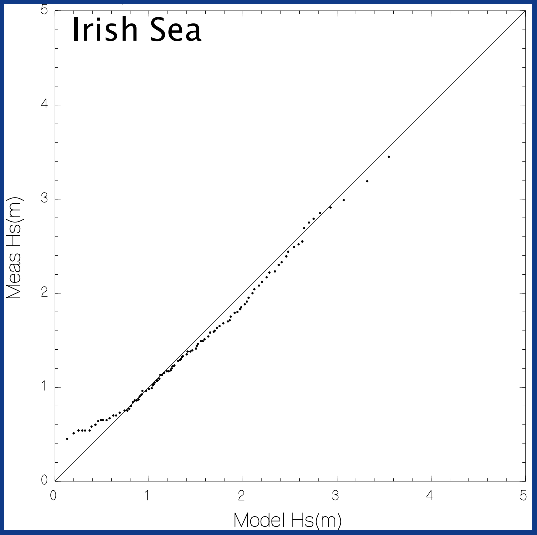
Wind Dir. (deg):
Dir    Number     Mean     Mean     Diff    Stnd    Scat
Bin    of Pts    QScat     NCEP    (H-Q)     Dev   Index
--- --------   ------   ------   ------   -----   -----
ALL    271439   256.20   248.81    -0.95   24.78    0.07
045     52309    92.31    92.69     0.32   25.48    0.07
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
```

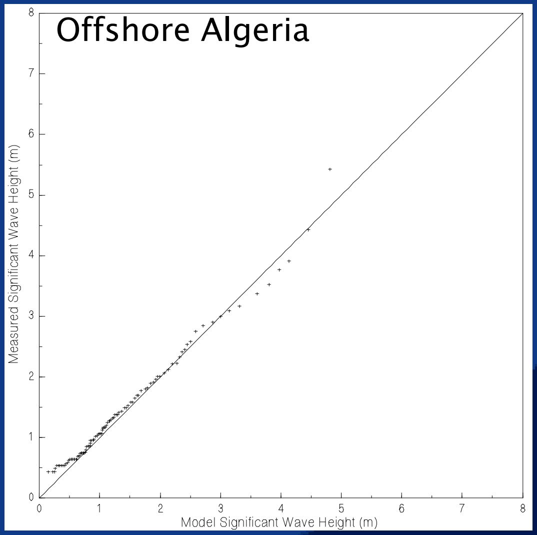
Box	Dir (fr)	Init WS (m/s)	Adj'd Primary	Adj'd Secondary
6	E	22	22.96	23.87
6	S	22	22.52	24.31
6	W	22	22.83	24.57
6	N	22	23.68	24.77

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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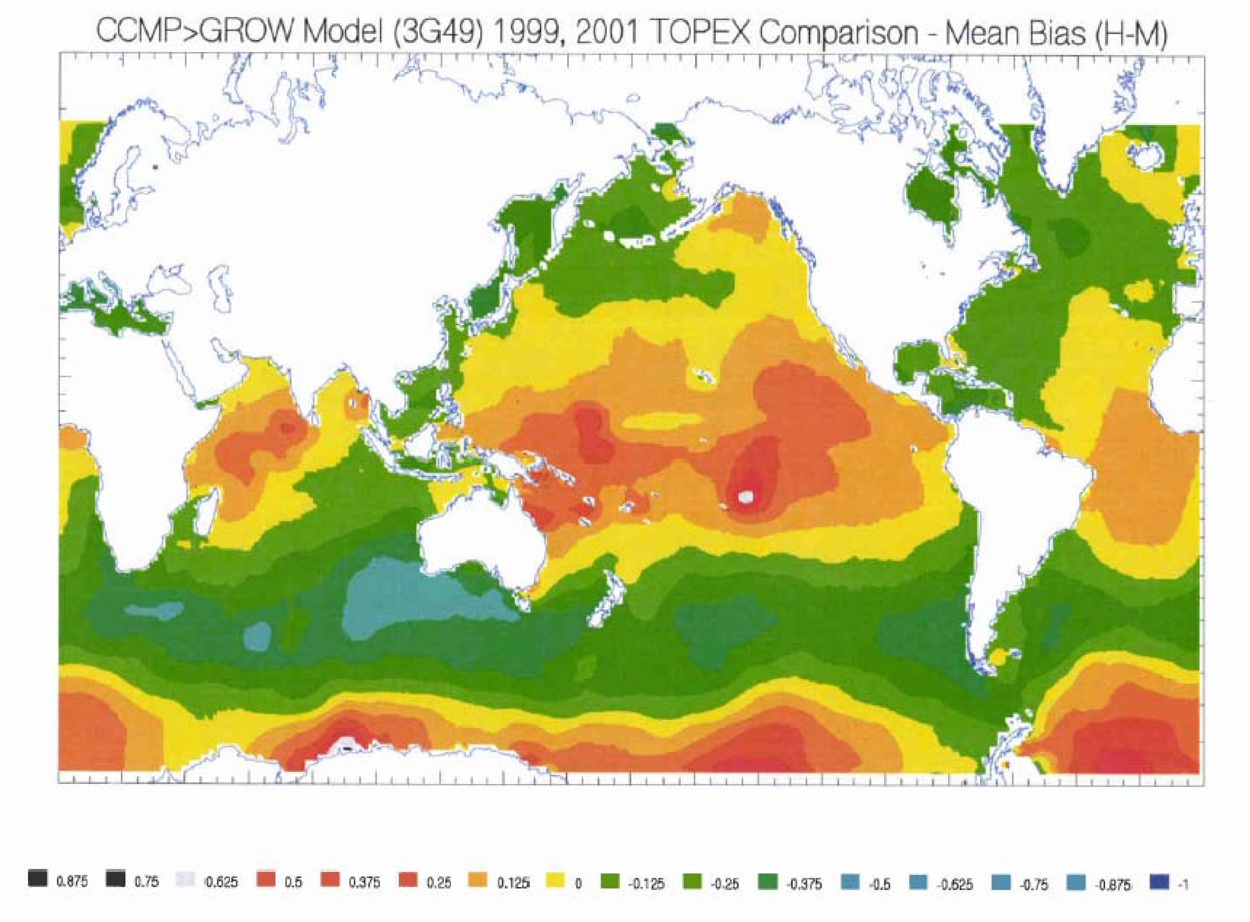
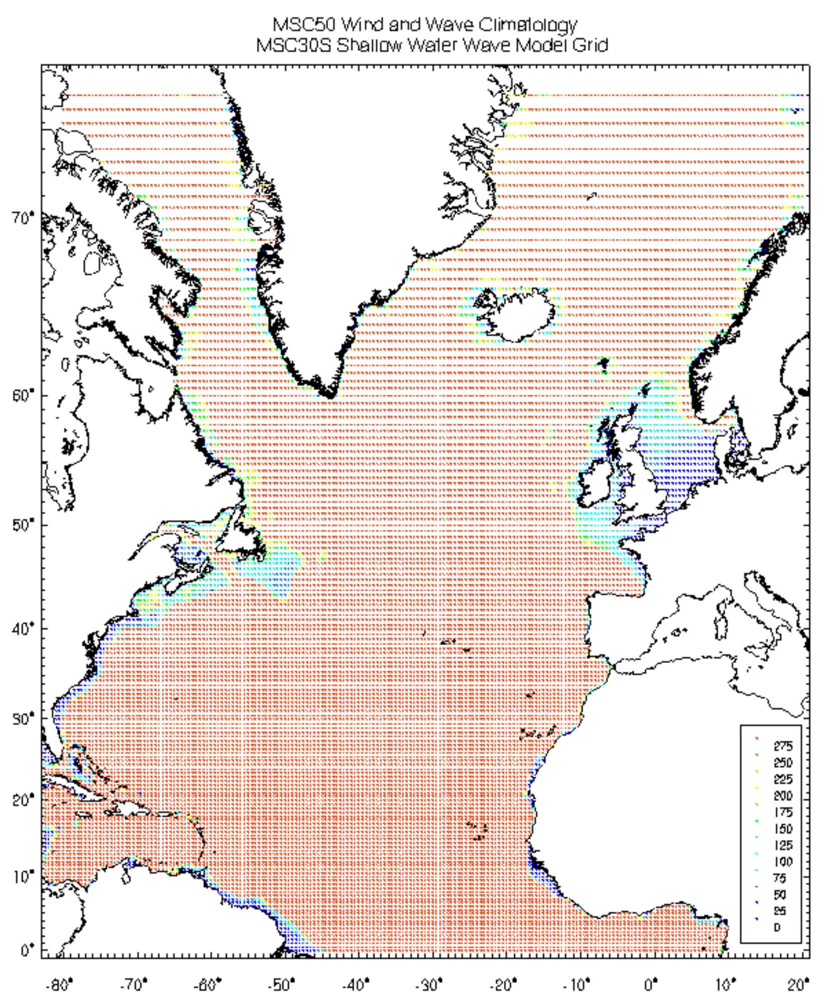
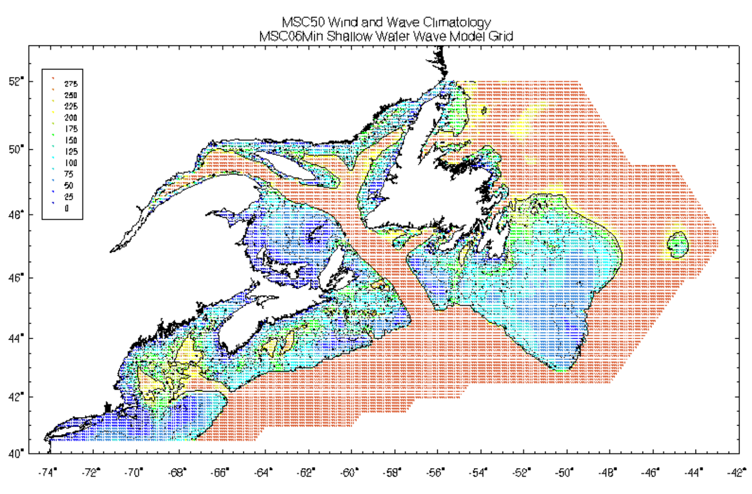
Two-year Global 3G Model Wave Hindcast to Evaluate Against Topex HS the new CCMP Reanalysis (Atlas et al., 2011)



CCMP is a 20-year 25-km resolution surface marine wind field database produced by variational analysis applied to cross-calibrated multiple satellite datasets combined with in situ data and ECMWF analyses.

Comparison of Fruits of Recent Reanalyses in NATL
Pure NCEP/NCAR vs MSC50 vs CFSR





MSC30S (left):

0.5-degree 3G Shallow

18637 active grid points

MSC06Min (Above):

0.1-degree 3G Shallow

18551 active grid points

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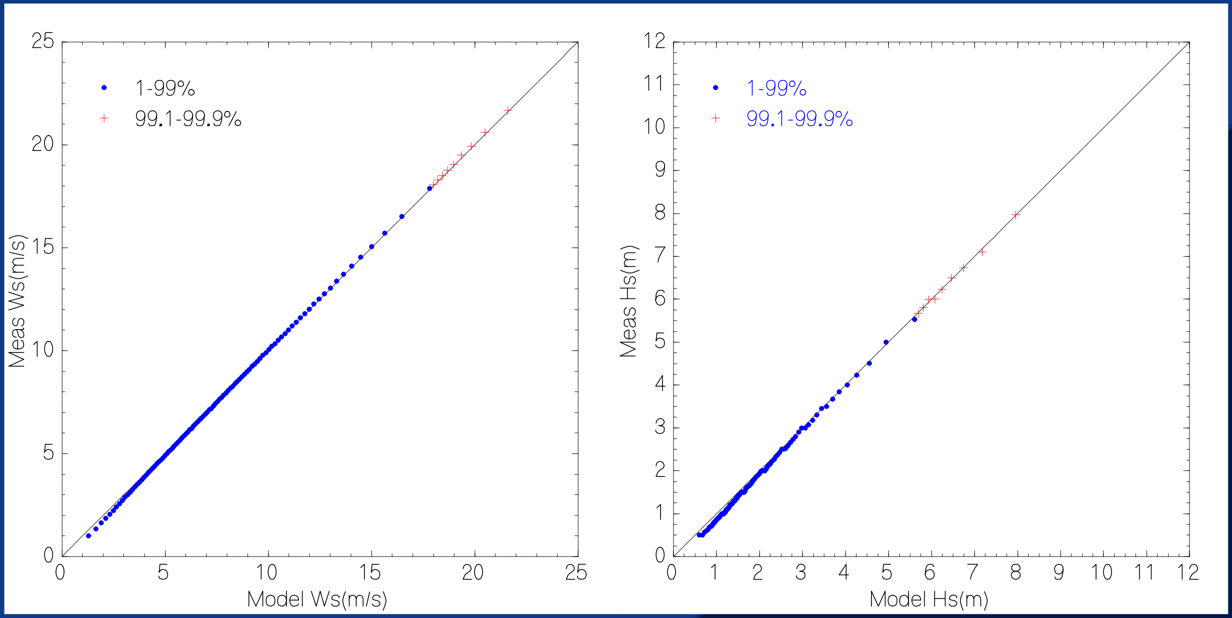
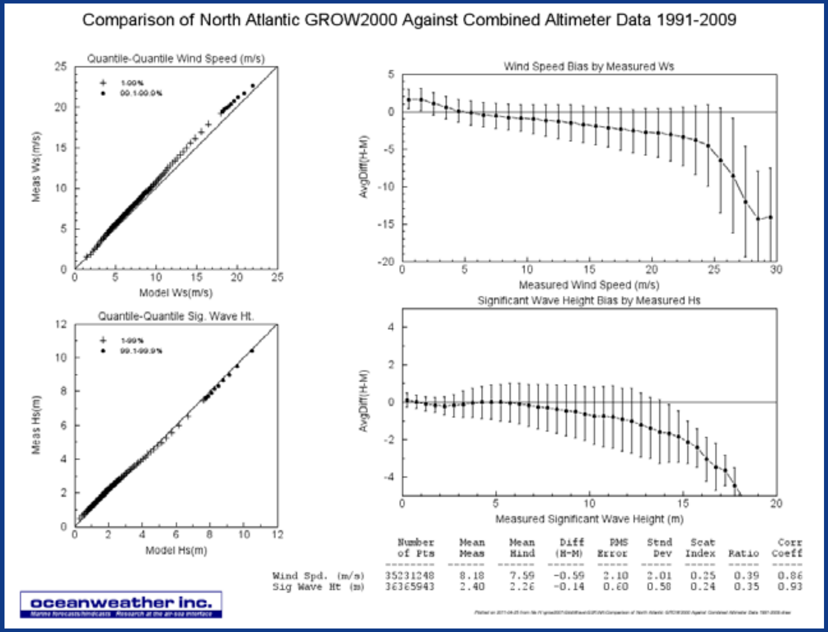
Validation: NA Basin Hindcast *Insitu* Validation

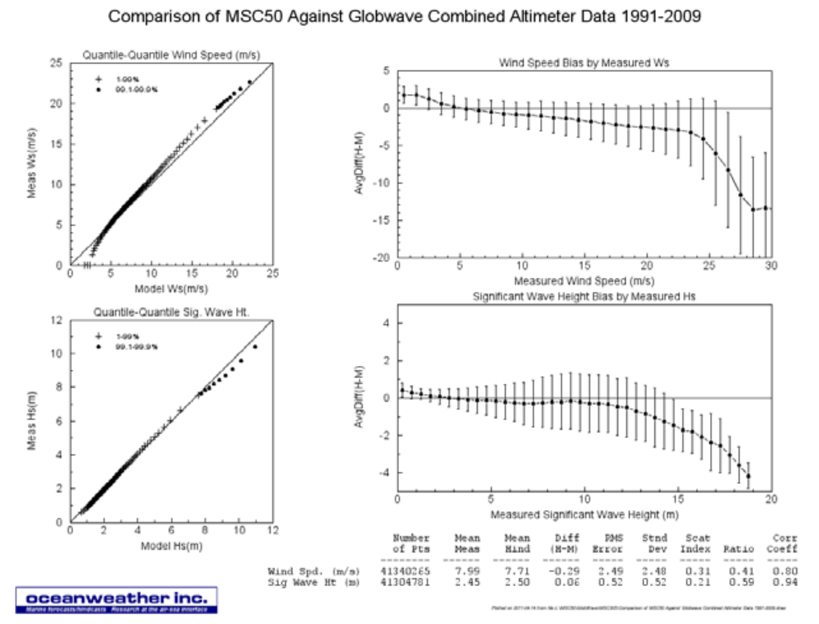
	Number of Points	Mean Meas	Mean Hind	Diff (H–M)	RMS Error	Std. Dev.	Scatter Index	Corr. Coeff.
Ws (m/s)	2827968	7.49	7.54	0.05	0.71	0.71	0.09	0.98
Wd (°)	2806995	242.94	243.61	–0.02	N/A	8.00	0.02	N/A
Hs (m)	2316795	1.83	1.93	0.10	0.32	0.30	0.17	0.96
Period (s)	2168226	6.37	6.10	–0.27	0.93	0.89	0.14	0.91
VMD(°)	241169	127.86	139.10	9.17	N/A	23.76	0.07	N/A





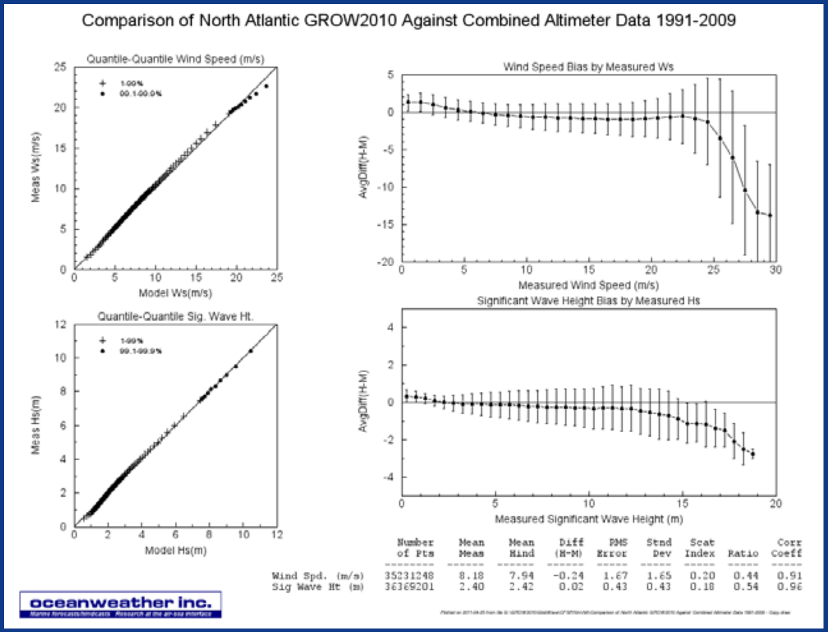
Comparison of North Atlantic GROW2000 Against Combined Altimeter Data 1991-2009

	Number of Pts	Mean Meas	Mean Hind	Diff (H-M)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Wind Spd. (m/s)	35231248	8.18	7.59	-0.59	2.10	2.01	0.25	0.39	0.86
Sig Wave Ht (m)	36365943	2.40	2.26	-0.14	0.60	0.58	0.24	0.35	0.93



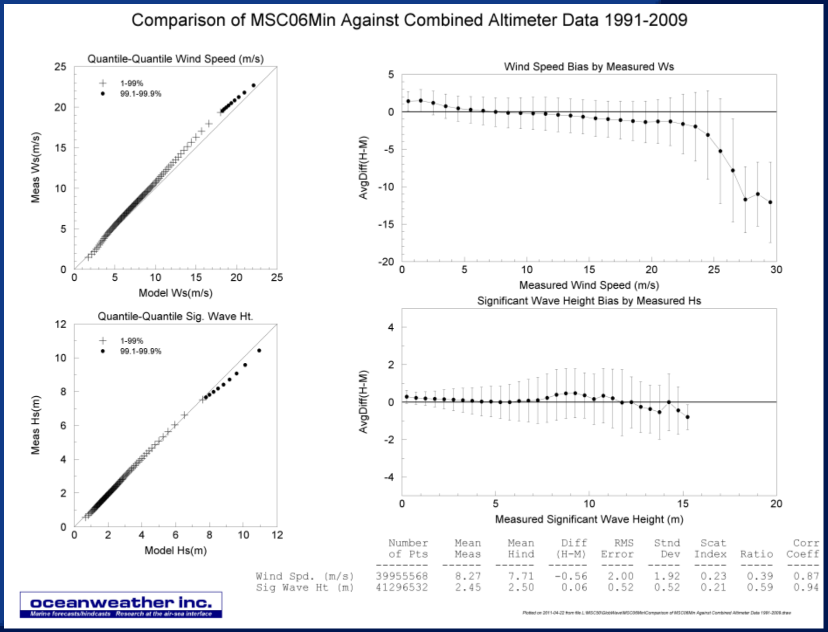
Comparison of MSC50 Against Globwave Combined Altimeter Data 1991-2009

	Number of Pts	Mean Meas	Mean Hind	Diff (H-M)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Wind Spd. (m/s)	41340265	7.99	7.71	-0.29	2.49	2.48	0.31	0.41	0.80
Sig Wave Ht (m)	41304781	2.45	2.50	0.06	0.52	0.52	0.21	0.59	0.94



Comparison of North Atlantic GROW2010 Against Combined Altimeter Data 1991-2009

	Number of Pts	Mean Meas	Mean Hind	Diff (H-M)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Wind Spd. (m/s)	35231248	8.18	7.94	-0.24	1.67	1.65	0.20	0.44	0.91
Sig Wave Ht (m)	36369201	2.40	2.42	0.02	0.43	0.43	0.18	0.54	0.96



Comparison of MSC06Min Against Combined Altimeter Data 1991-2009

	Number of Pts	Mean Meas	Mean Hind	Diff (H-M)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Wind Spd. (m/s)	39955568	8.27	7.71	-0.56	2.00	1.92	0.23	0.39	0.87
Sig Wave Ht (m)	41296532	2.45	2.50	0.06	0.52	0.52	0.21	0.59	0.94

Plotted on 2011-04-22 from file L:\MSC50\GlobWave\MSC06Min\Comparison of MSC06Min Against Combined Altimeter Data 1991-2009.draw

PROBING THE VESS TAIL
(VERY EXTREME SEA STATES)

VESS sampled to date from in-situ sources biased toward basin margins

Use altimeters to scan for global occurrences of storm peak HS > 12 m

First Pass Reported at 11th Int'l Wave Workshop, Halifax, NS (Oct, 2009)

Final data-center Q/C'd altimeter datasets contain spurious spikes

Scanned entire TOPEX, JASON-1, ENVISAT missions 1992-2007

Apply published bias adjustments and median filter along orbit segments

Refer to coincident NCEP/NCAR Reanalyses to filter remaining spikes

The most extreme sea state found was HS ~ 20 m in central North Atlantic extratropical "bomb" of February 9, 2007

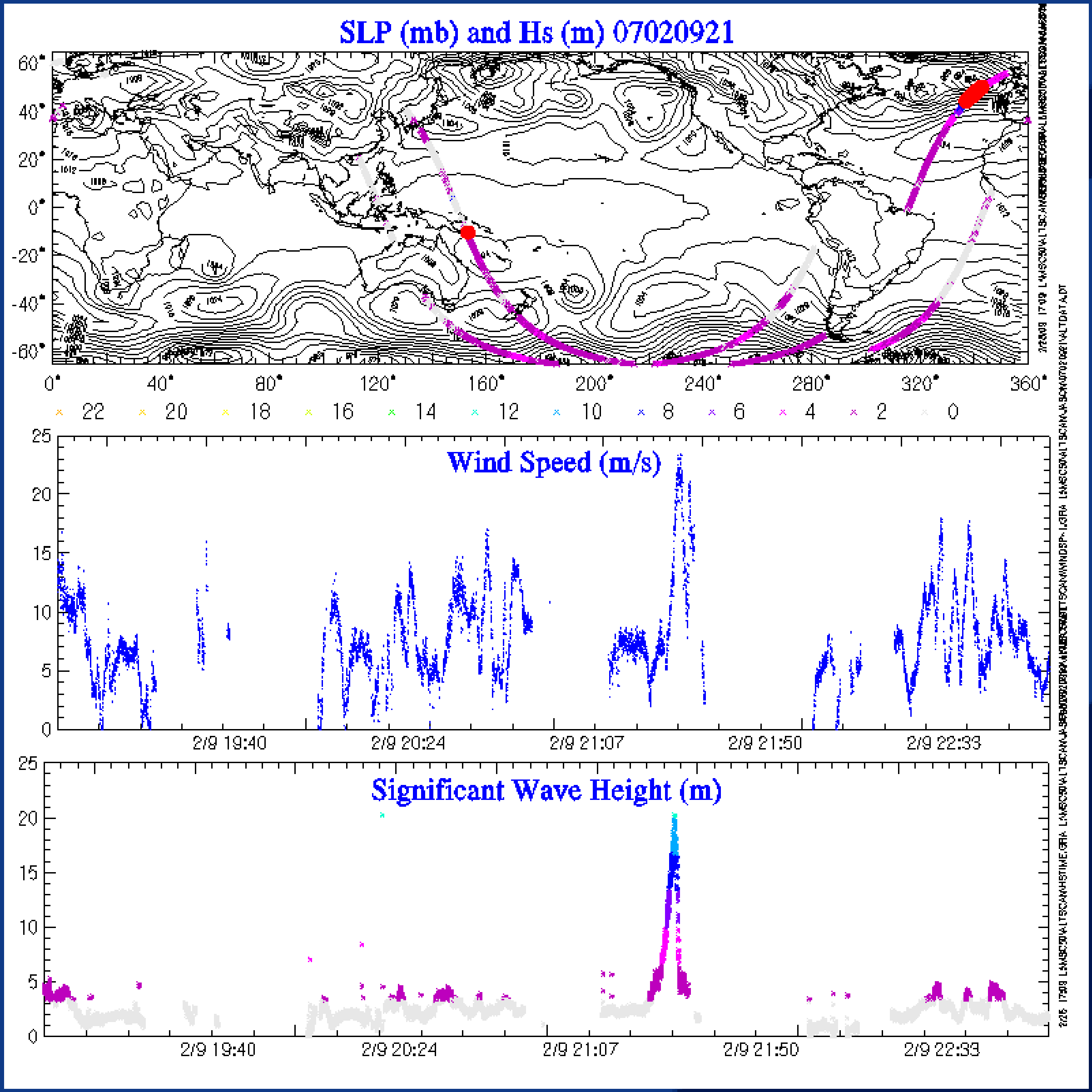
Second Pass Underway

Utilize new Ifremer GlobWave "homogenized" database 01/1991-03/2010

ERS-1, ERS-2, ENVISAT, TOPEX, Jason-1, Jason-2, GEOSAT FO

Virtually no spurious spikes; increased dynamic range of ALT winds, radical increase in ENVISAT high sea state occurrences

North Atlantic storm of Feb/2009 still top ranked but now has a few cousins

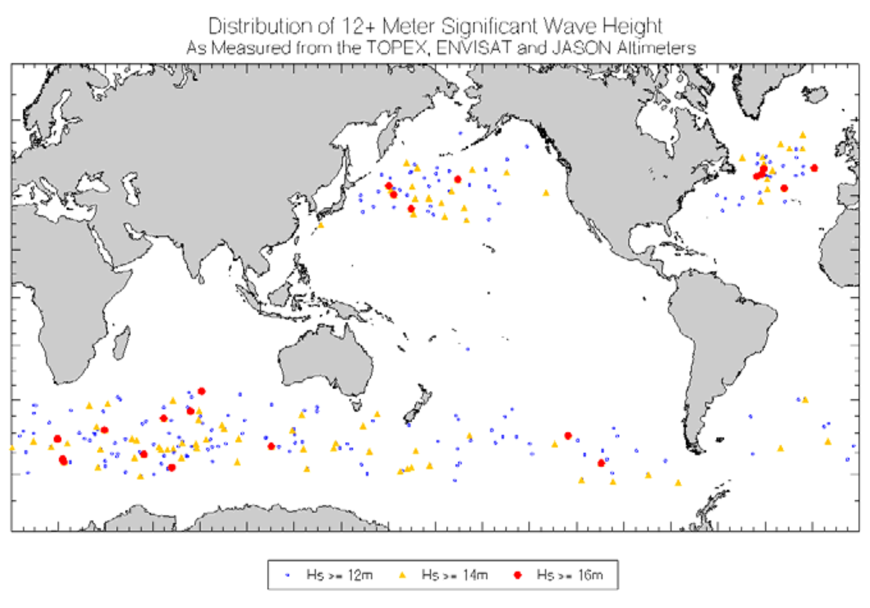


SLP (mb) and Hs (m) 07020921

Wind Speed (m/s)

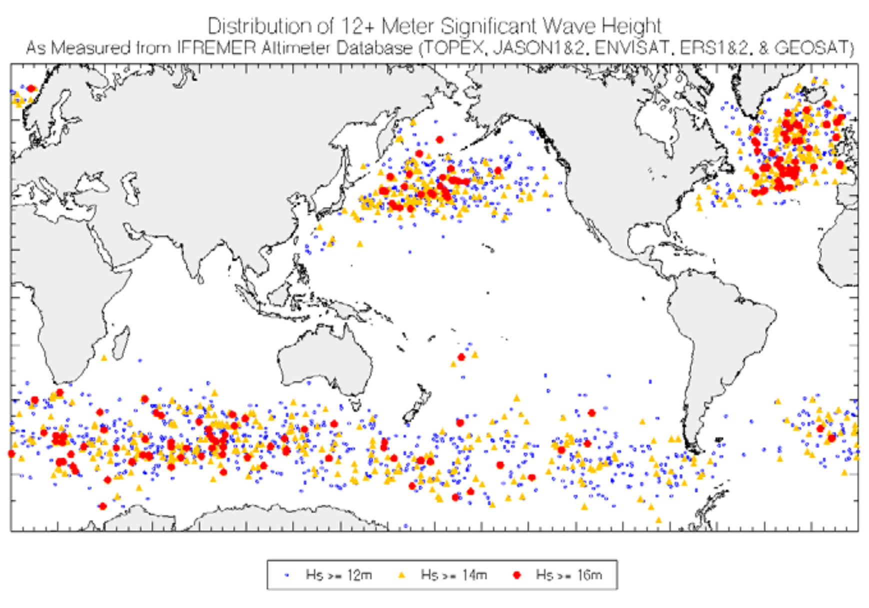
Significant Wave Height (m)

Original Study



		North Atlantic	North Pacific	Southern Oceans	Total
Total	>12	36	54	170	260
Peaks	>14	16	21	63	100
	>16	5	4	10	19
	>18	1	0	2	3

Preliminary Update w/ GlobWave



		North Atlantic	North Pacific	Southern Oceans	Total
Total	>12	383	364	1096	1843
Peaks	>14	189	141	383	713
	>16	50	26	75	151
	>18	14	4	4	22

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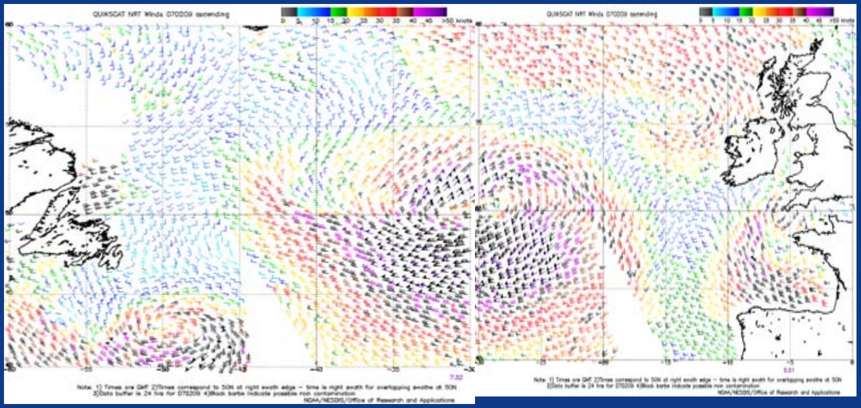
Hindcast Pass 1 Top Ranked
North Atlantic storm of February 7-10, 2007

- QuikSCAT swaths provided excellent monitoring of the time and space evolution of the surface wind field
- Important to use an unbiased scatterometer model function
- QSCAT-1/F13 finds max wind speed of 96 knots – if correct would imply peak sustained 1-min wind speed of ~ 115 knots equivalent to SS Category 4 hurricane Corrected wind speed is ~ 83 knots equivalent to Category 3 hurricane

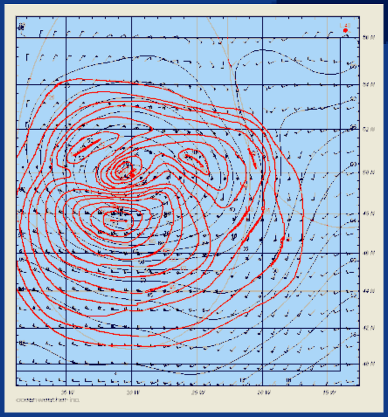
- MSC50 North Atlantic wave model serves as a good platform. Used a WAM Cycle-3 class (journal published as CSOWM model- 1994 ; the first to tune source term balance within the concept of an asymptotic drag law (C10 to 2.2 x 10-3 @ 30 m/s)

- Kinematic reconstruction of wind field was straightforward

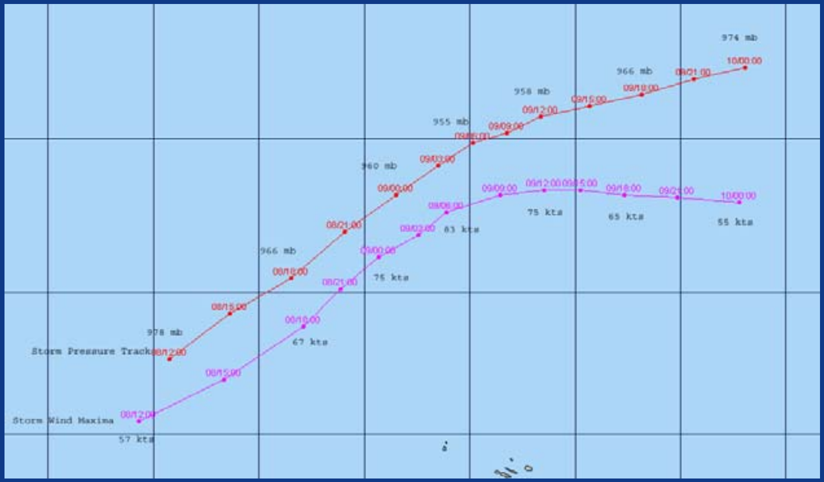
Progression of Kinematic Wind Field Reanalysis of North Atlantic Superstorm of Feb/2007



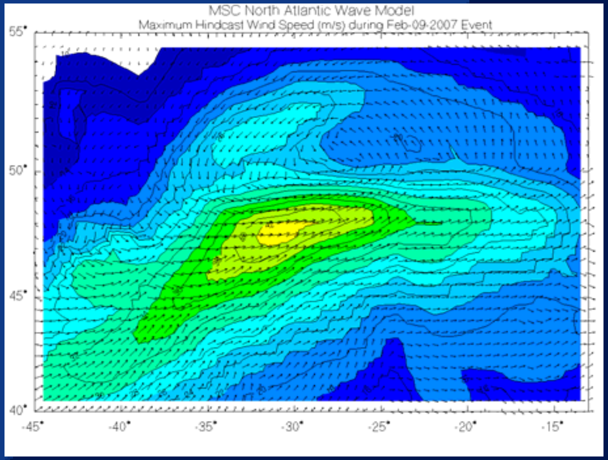
QuikSCAT passes at storm peak



Average wind speed at storm peak

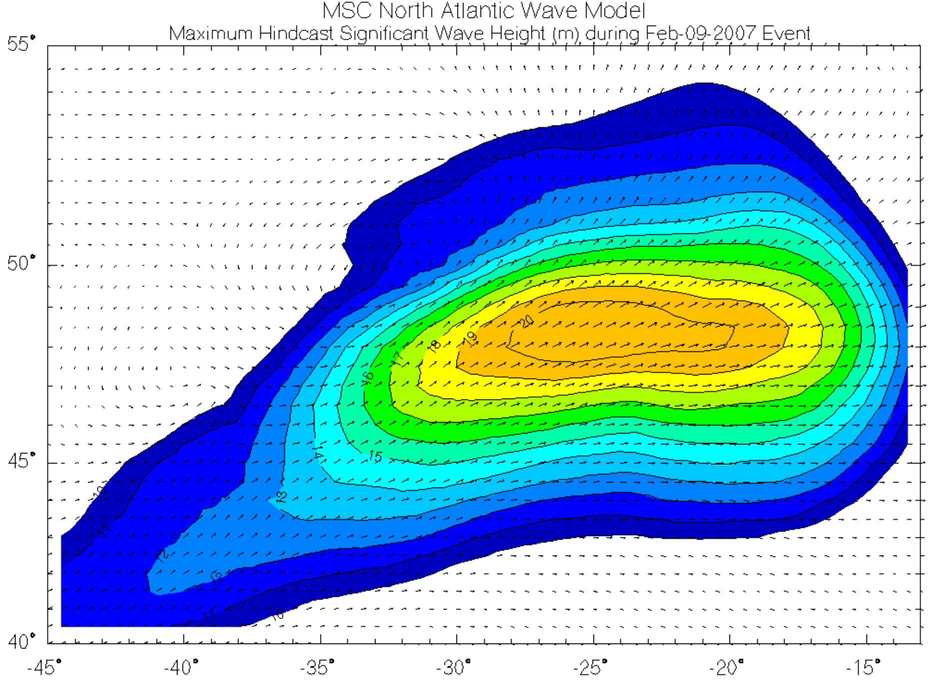


Continuity of storm center and associated surface wind jet streak

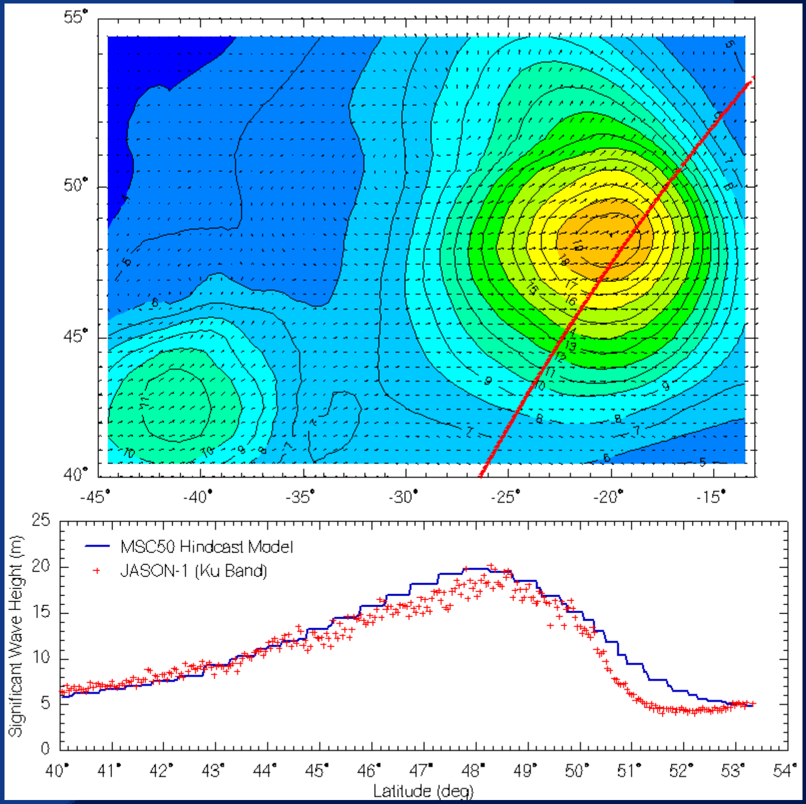


Envelope of final surface winds

Envelope of maximum hindcast significant wave height



Comparison of hindcast and Jason-1 ATL pass HS at pass time



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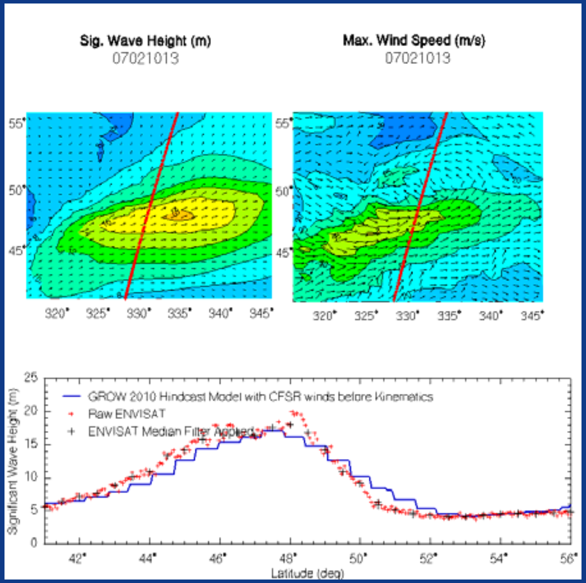
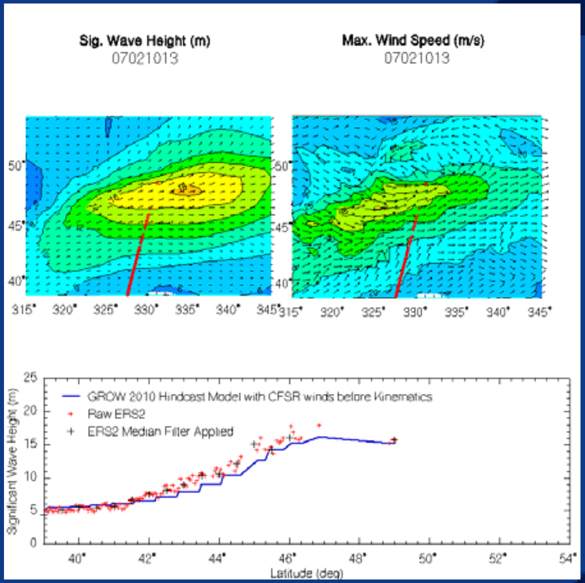
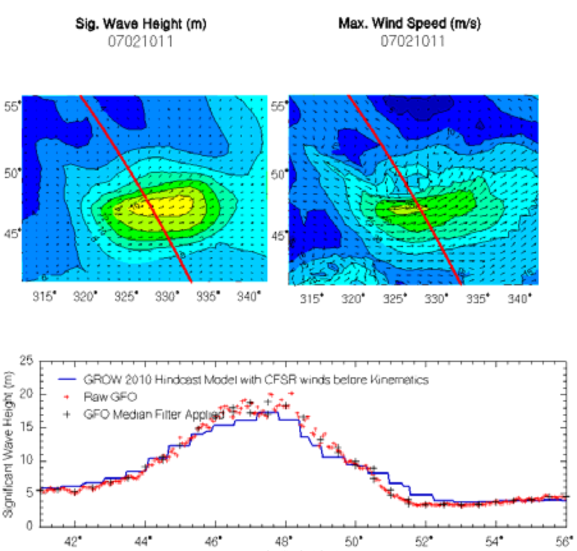
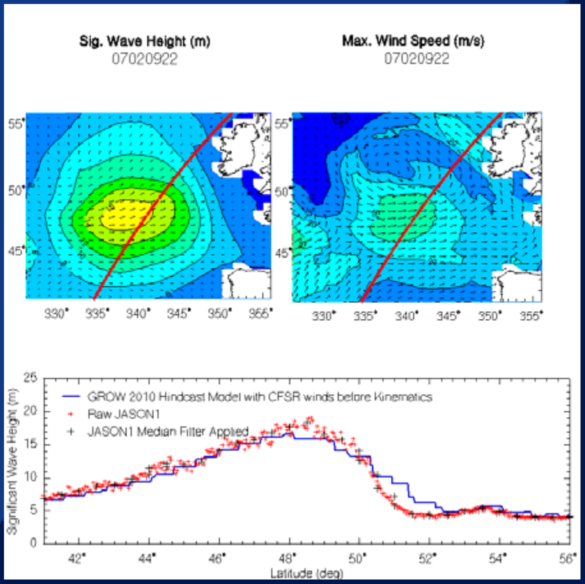
ENVISAT, ERS2, GFO, and JASON1 View “Superstorm” of Feb. 2007
CFSR Driven OWI 3G Wave Model Hindcast Shown for Reference









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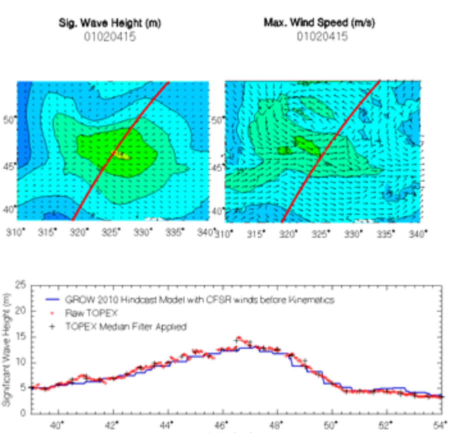
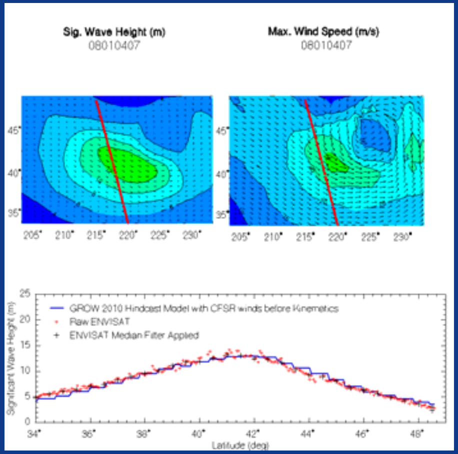
GROW 2010 Hindcast Model “Hits” with CFSR Wind Input by Basin

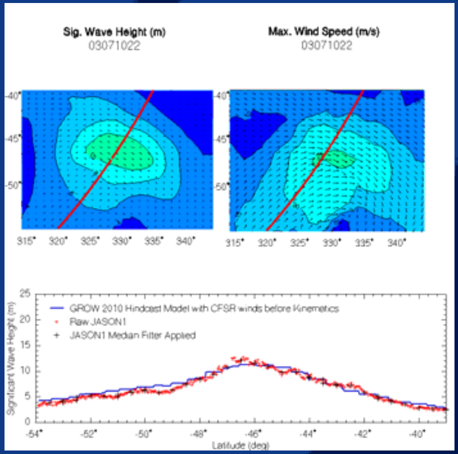
North Atlantic



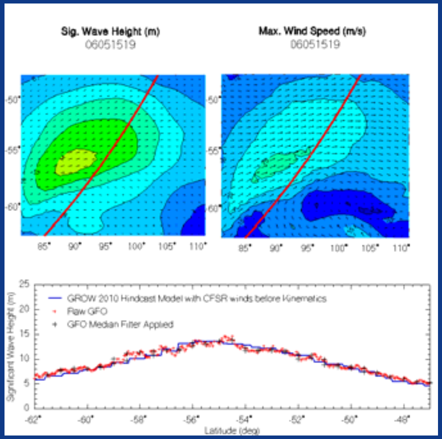
North Pacific



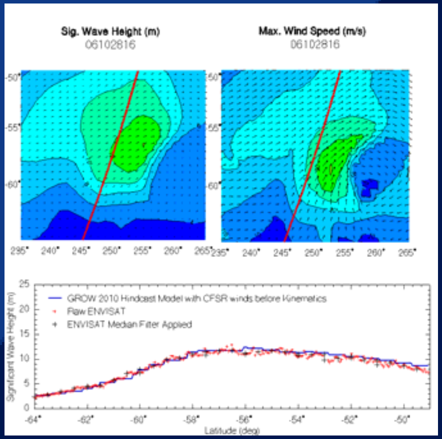
South Atlantic



South Indian



South Pacific



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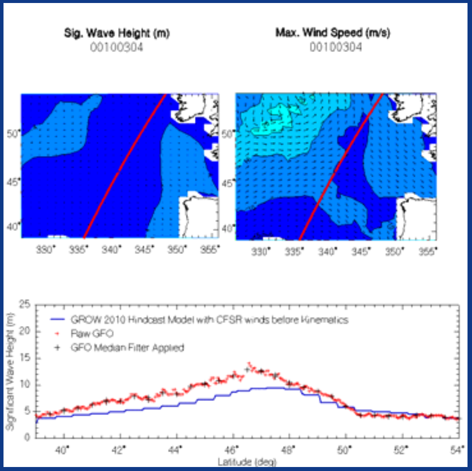
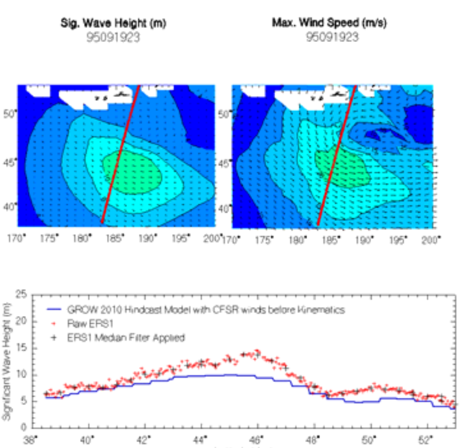
GROW2010 Hindcast Model “Misses” with CFSR Wind Input by Basin

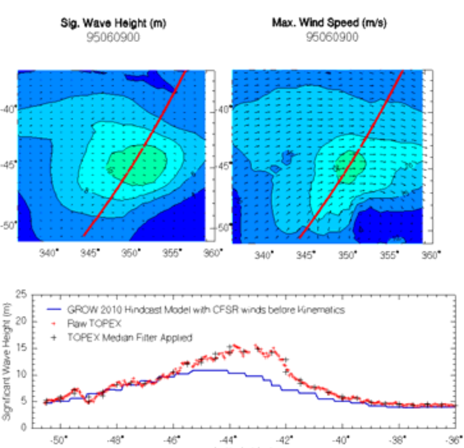
North Atlantic



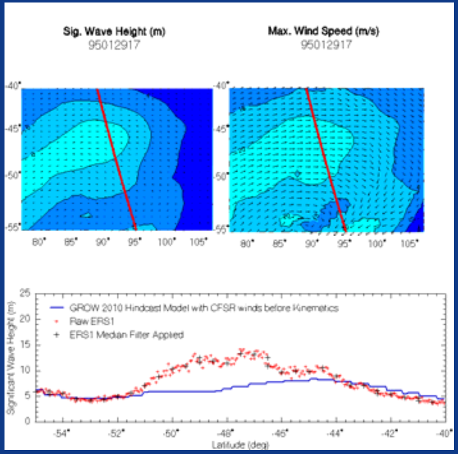
North Pacific



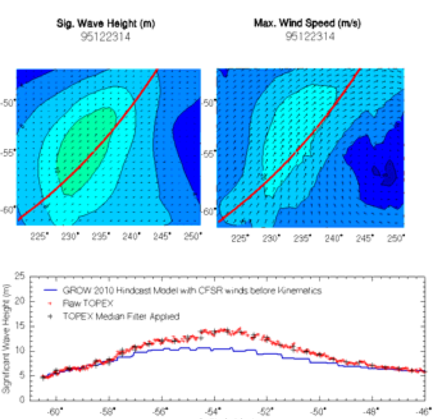
South Atlantic



South Indian



South Pacific



Preliminary Results of Hindcasts of Tropical and Extratropical Cyclone VESS.

Excluding the two GOM hurricane peaks at 42040 due to probable bias from buoy mean tilting, we find that over the remaining 15 cases in this table, the mean measurement peak HS is 17.6 m, the mean hindcast peak is 17.0 m and the scatter index is about 5%.

Measurement	Storm	Basin	Meas Hs (m)	Hind Hs (m)	Type
RRS Discovery	Feb 2000	North Atlantic	18.5	16.8	shipborne wave recorder
Polarfront	Nov 2001	North Atlantic	15.5	15.5	shipborne wave recorder
MEDS 44137	Oct 1991	North Atlantic	16.9	14.7	6 m NOMAD buoy
K Buoy 62109	Dec 2007	North Atlantic	18.3	17.0	3 m ODAS buoy
42040	Ivan (2004)	Gulf of Mexico	16.0	14.2	3 m discus buoy
42040	Katrina (2005)	Gulf of Mexico	16.9	13.9	3 m discus buoy
Platform	Jan 2006	North Atlantic	15.5	16.0	scanning radar
Redhawks	Rita (2005)	Gulf of Mexico	14.2	13.1	platform radar alt
Marlin	Ivan (2004)	Gulf of Mexico	15.4	15.8	platform radar alt
JASON-1	Feb 2007	North Atlantic	19.1	19.4	satellite altimeter
JASON-1	March 2003	North Atlantic	16.2	15.8	satellite altimeter
TOPEX	Feb 2003	North Atlantic	15.6	14.4	satellite altimeter
JASON-1	Mid Feb 2003	North Pacific	15.1	12.6	satellite altimeter
JASON-1	Early Feb 2003	North Pacific	16.6	17.3	satellite altimeter
JASON-1	Dec 2005	North Pacific	15.0	16.7	satellite altimeter
JASON-1	Oct 2006	South Indian	17.9	16.2	satellite altimeter
JASON-1	Aug 2005	South Indian	17.3	16.0	satellite altimeter
JASON-1	July 2002	South Indian	17.2	17.6	satellite altimeter

Personal View of Where We Are and Need to Go

- 1. The “recent” multi-decadal climate of the “normal” surface marine wind and waves over the open global oceans is effectively known by virtue of most recent reanalyses projects, the impact of scatterometry and progress in wave modeling

- 2. Not so for the climate of extremes over the global oceans associated with “winter hurricanes” and tropical cyclones. For both system classes, the structural evolution of the wind field is just as important as bulk intensity measure such as minimum central pressure or absolute peak wind speed. This climatology is critically needed for both engineering design purposes and to establish the climate of extremes of the present climate to serve as a baseline for climate change studies

- 3. Following the lead of the immensely successful and useful IFREMER GLOBWAVE altimeter data Q/C and homogenization and quality control, a similar effort should be directed toward the passive and active microwave remotely sensed wind data sets, including the currently operational WINDSAT, ASCAT and OCEANSAT-2

- 4. Add to the present mainly continental margin buoy array, an array in remote and harsh ocean environments to serve as a reference for remote sensing systems. Large hulled buoys better for winds, small hulled buoys better for waves…these conflicts need to be resolved.

- 5. Develop a sound physical basis for the evident wide dynamic range of Ku band scatterometry

Continued

- 6. Develop new conceptual model of kinematic properties of wind fields in “winter hurricanes”
- 7. Fully assimilative reanalysis approaches leave no surface marine wind data to independently assess skill but forcing of wave models and validation thereof against in-situ and altimeter wave measurements appears to provide a good substitute metric.
- 8. The CFSR is indeed a major advance in reanalysis but could be improved in marginal seas and open coast areas where the flows are strongly affected by coastal relief (sorry to time to demonstrate this but believe me!)
- 9. Prepare for the next generation consolidation of the global merchant fleet about super-giant container vessels that raise new challenges to continuation of VOS density of observations and accuracy thereof. Maersk has ordered 20 of this new Triple E (hold 18,000 containers) class, $190M each. 400 m long, 60 m wide, 73 m tall.

AND FINALLY

- 10. When considering the planning a long term global satellite marine climate monitoring system, bear in mind my two favorite mantras:
- “Its the winds stupid”
- “Measure the forcing,
  model the response”