Hindcasting Winds and Waves Using Kinematic Analysis

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OUTLINE

- Introduction
- Data Sources
- Wind Analysis
- Generation of wave hindcasts
- Wind and wave validation
- Climate analysis and products
- Summary and conclusions

NORTH ATLANTIC WIND AND WAVE REANALYSIS

OBJECTIVE

To produce a ***high quality***, ***homogeneous***, ***long term*** wind and wave data base for assessment of trend and variability in the wave and storm climate of the North Atlantic Ocean

Data Sources

- NCEP-NCAR Reanalysis 6-hourly surface (10m) winds, 2m surface temperature, SST
- COADS – ship, buoys, platforms, C-MAN
- Extra buoy data not in COADS – e.g. hourly Cdn data
- Scatterometer - ERS 1/2, NSCAT, Quikscat
- †Altimeter – ERS 1/2, Topex/Poseidon
- Tropical Prediction Center (TPC) HURDAT and detailed storm reconnaissance data
- Ice concentration data – Walsh and Johnson, Arctic and Antarctic Sea Ice Data, US Navy/NOAA Ice Center

Wind Analysis

Import NRA surface (10m) winds every 6 hours as background

- Compute equivalent neutral wind using NRA T_a and T_s

Display and interactively select (QC) all marine wind data including buoys, ships, platforms, C-MAN, ERS-1/2, Quikscat scatterometer into WindWorkstation®

- All winds adjusted to 10 m using correct anemometer height (WMO47), stability, estimated flag
- Adjustment for buoy vector to scalar wind

Tropical storm wind overlay

- Detailed track and reconnaissance data from TPC input to tropical cyclone boundary layer model (CERC-94-14: Cardone et. al.)
- Winds for tropical storms exported on 0.5° grid to WWS for blending

Final detailed kinematic analysis

KINEMATIC WIND ANALYSIS

Kinematically (manually) reanalyze each 6-hourly wind field

Incorporate kinematic analyses from previous detailed storm studies

Blend tropical wind overlays into surface wind fields

Assimilate all data sources (at 10m) into final wind fields

Interpolate final wind fields onto wave model grid at 1-hour time step

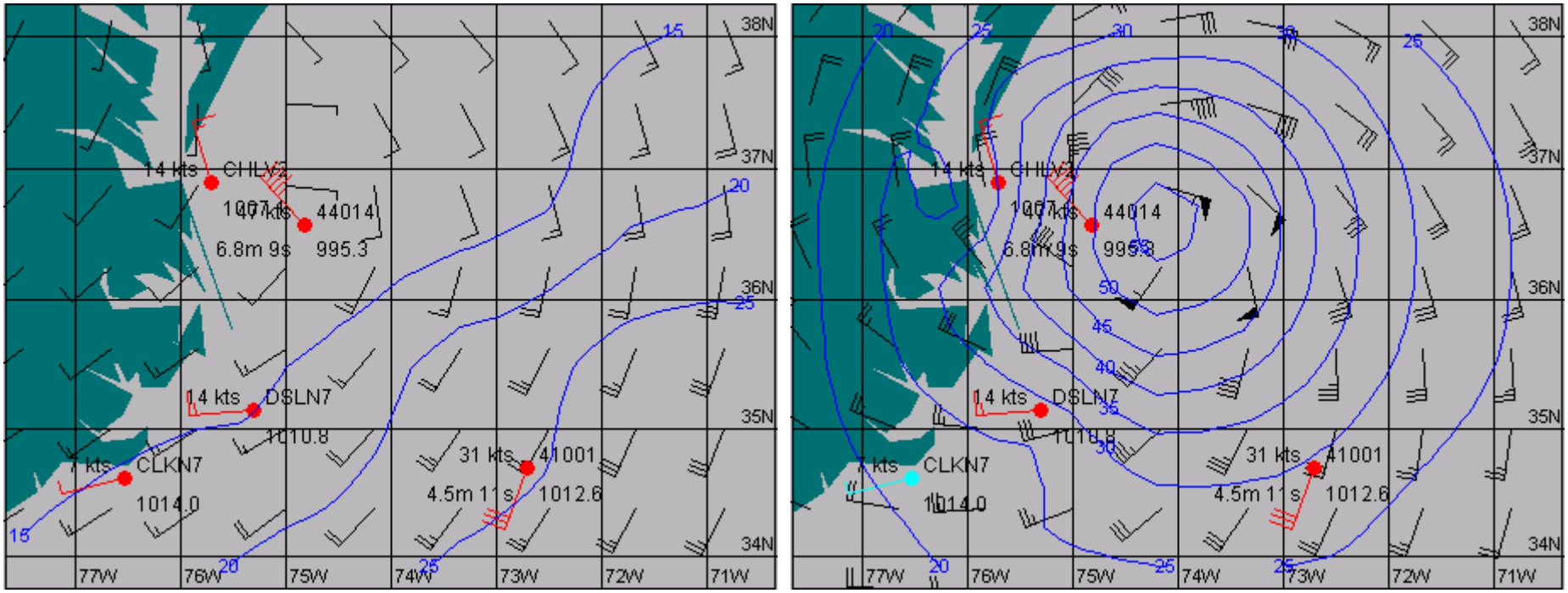
10,000 hours of meteorologist effort in manual, interactive kinematic analysis of >58,400 surface wind analysis over 40+ years using WindWorkstation®

Wave Analysis

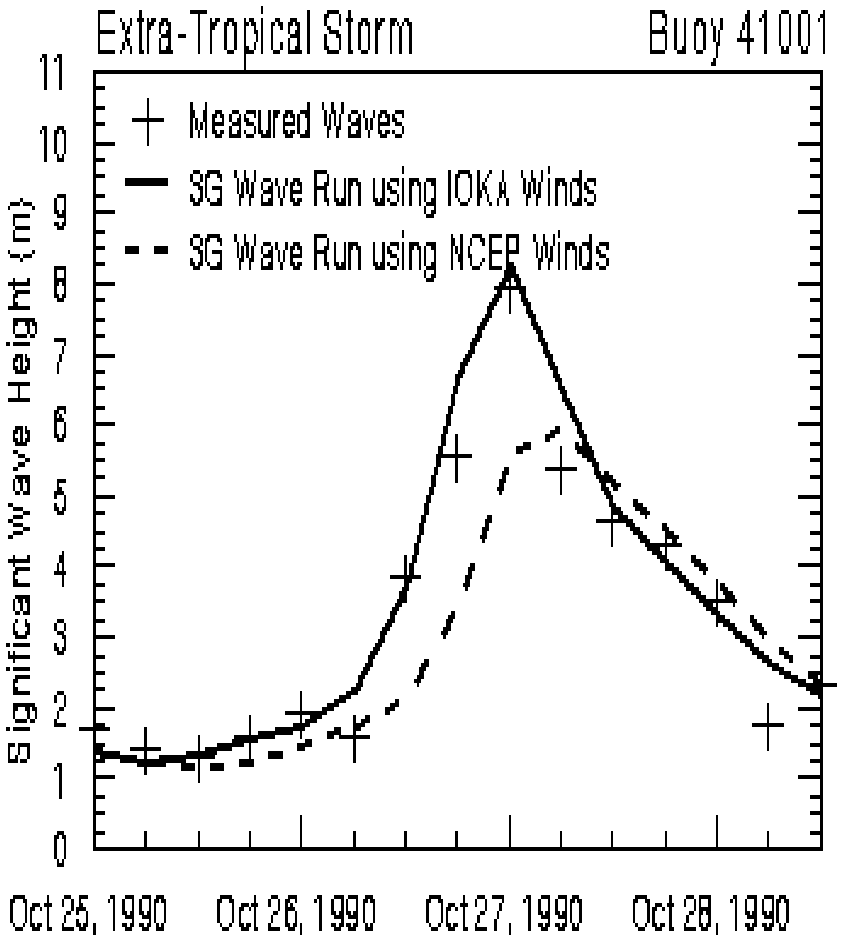
- Import final kinematic surface (10m) winds interpolated to one hour time step
- OWI 3G discrete spectral Wave Model – deep water – 0.625° lat x 0.833° long
- Hindcast Domain 20°E to 80°W; 0° to 76°N
- Use actual mean monthly sea ice fields
- Include cross-equator energy propagation from global model
- Output 17 “fields” at all 9023 points, 2-D spectra at 233 points (incl. WS, WD, HS, TP, VMD, sea, swell)

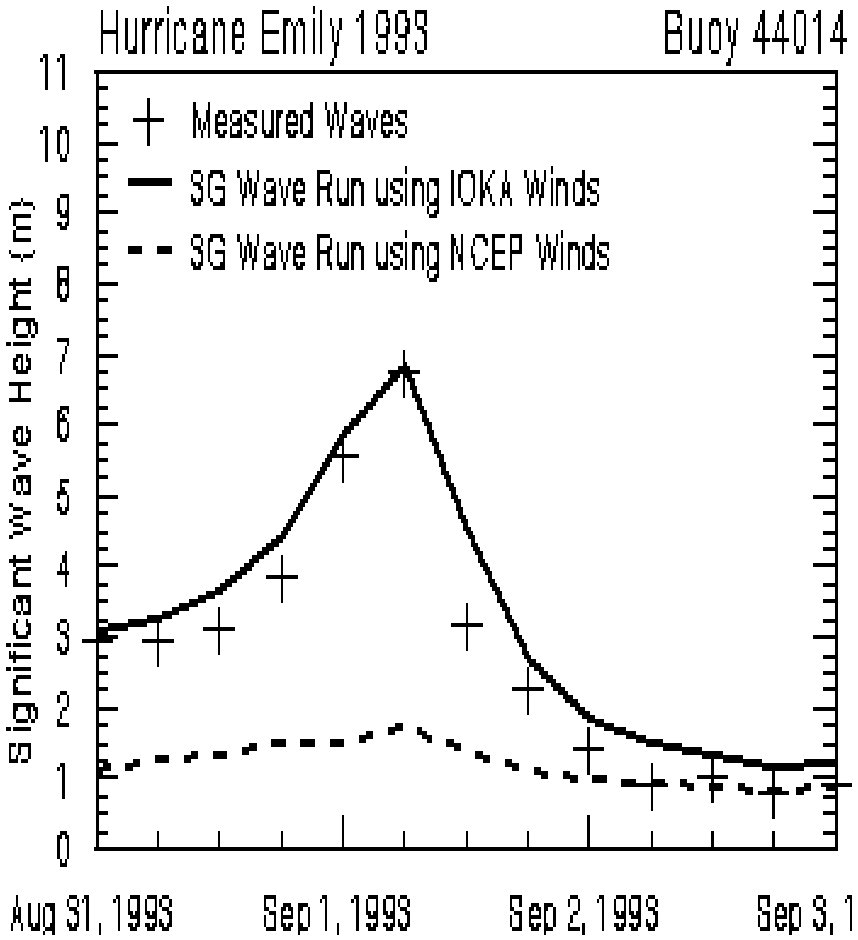
NCEP

MSC



COMPARATIVE DEPICTIONS OF HURRICANE EMILY


Extra-Tropical Storm
Buoy 41001
Measured Waves
SG Wave Run using IOKA Winds
SG Wave Run using NCEP Winds
Significant Wave Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
Oct 25, 1990
Oct 26, 1990
Oct 27, 1990
Oct 28, 1990


Hurricane Emily 1993
Buoy 44014
Measured Waves
SG Wave Run using IOKA Winds
SG Wave Run using NCEP Winds
Significant Wave Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
Aug 31, 1993
Sep 1, 1993
Sep 2, 1993
Sep 3, 1993

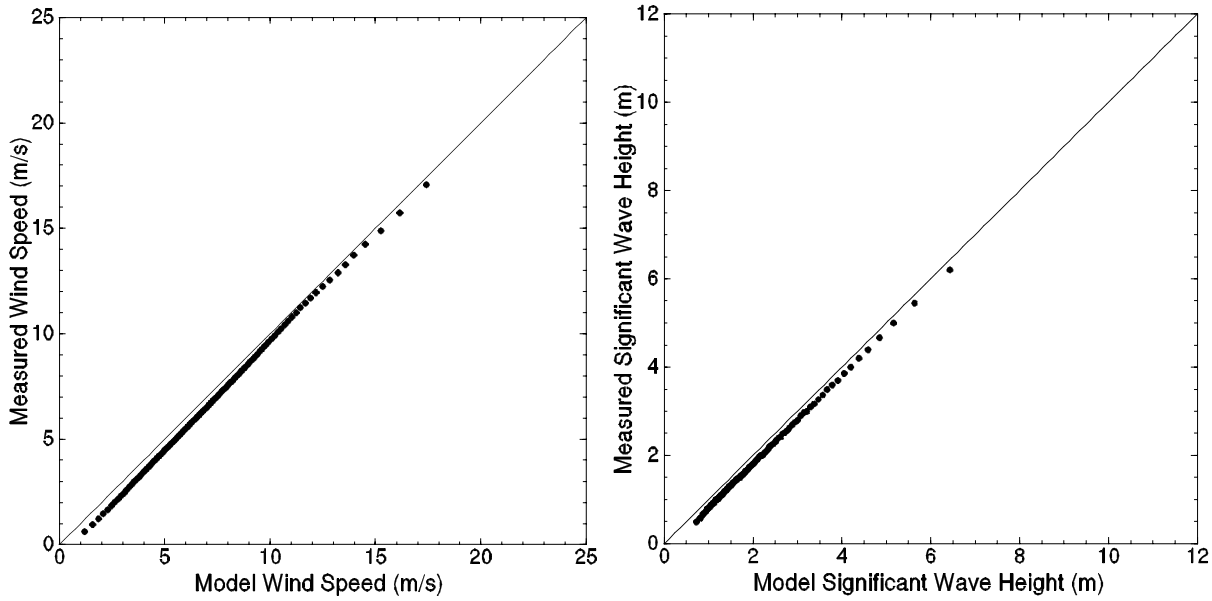
Validation Data Sets

In Situ

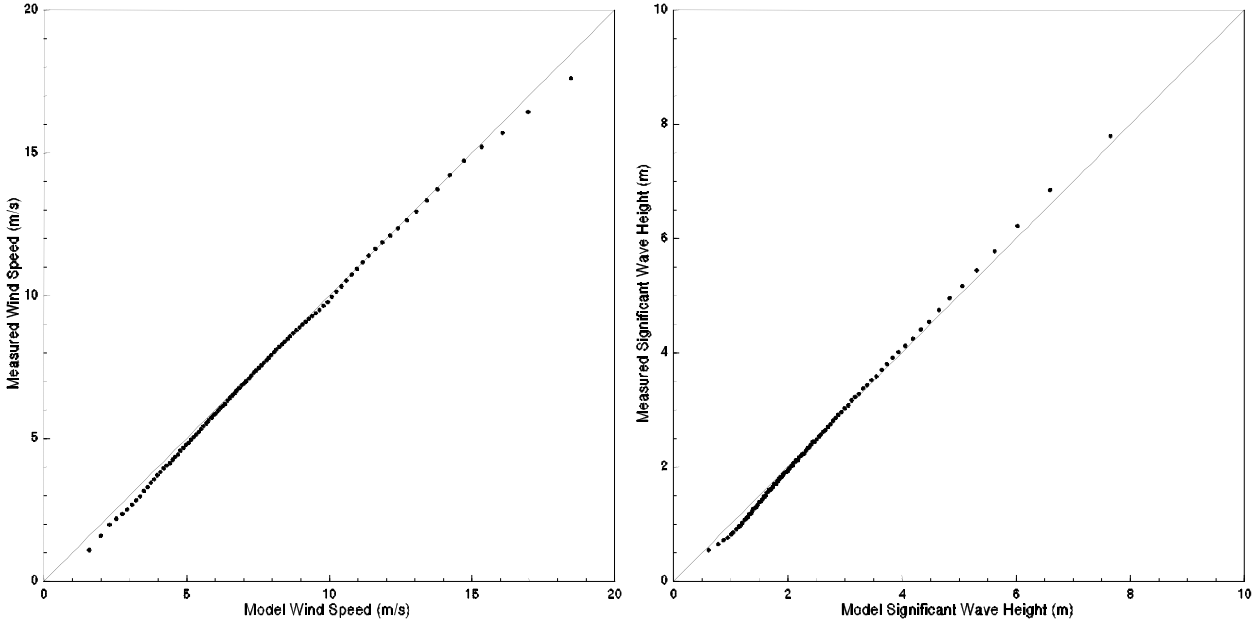
Satellite

- **US and Canadian buoys on CD-ROM**
- **Buoys and platforms altimeter from COADS**
- **Ocean Weather Ships**
- **OGP Waverider buoys**

- **ERS-1 altimeter**
- **ERS-2 altimeter**
- **TOPEX**
- **GEOSAT altimeter**

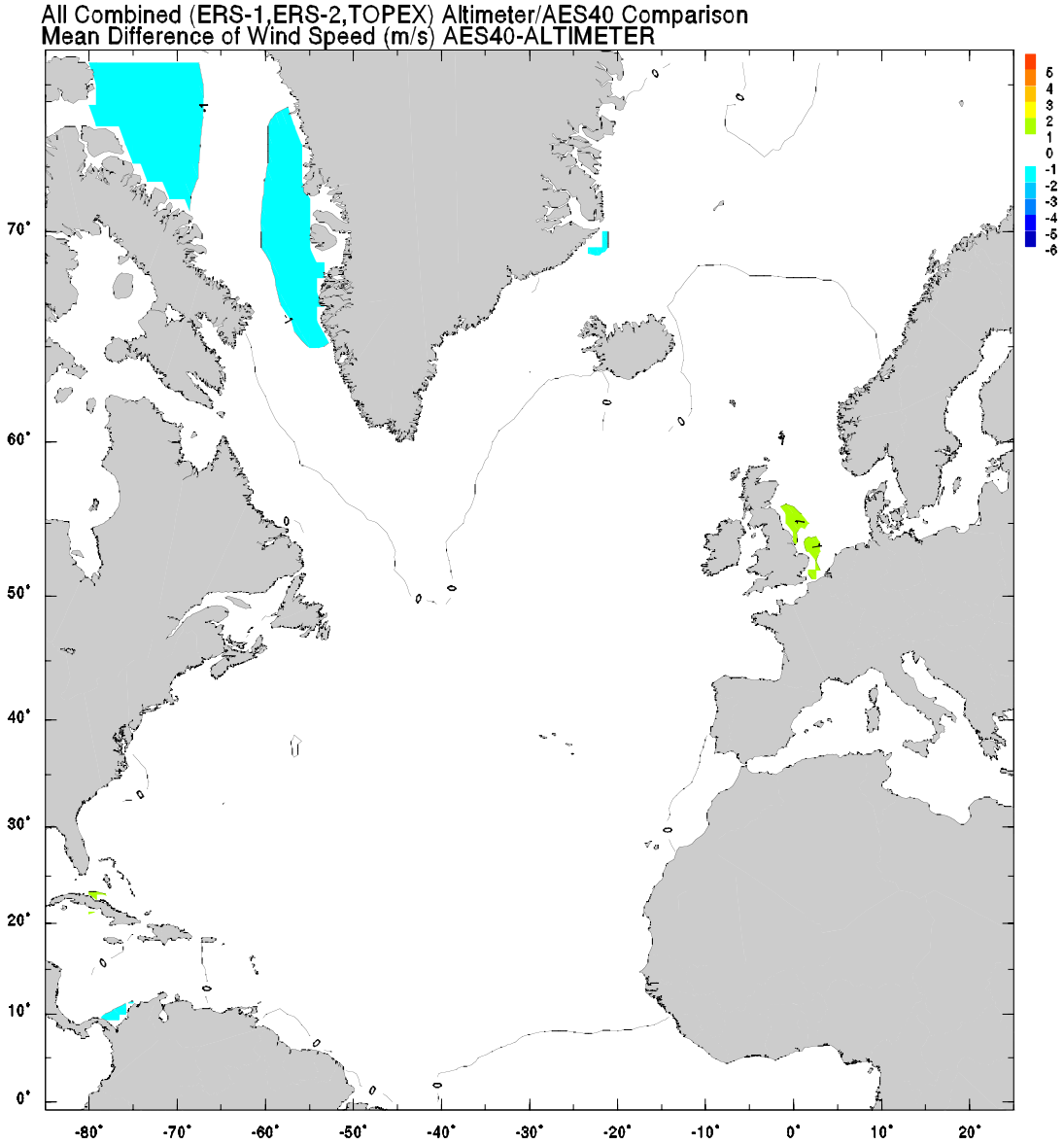


Q-Q comparison from 1 to 99% for combined U.S. and Canadian buoys vs. MSC40 wind speed (m/s, left) and significant wave height (m, right).

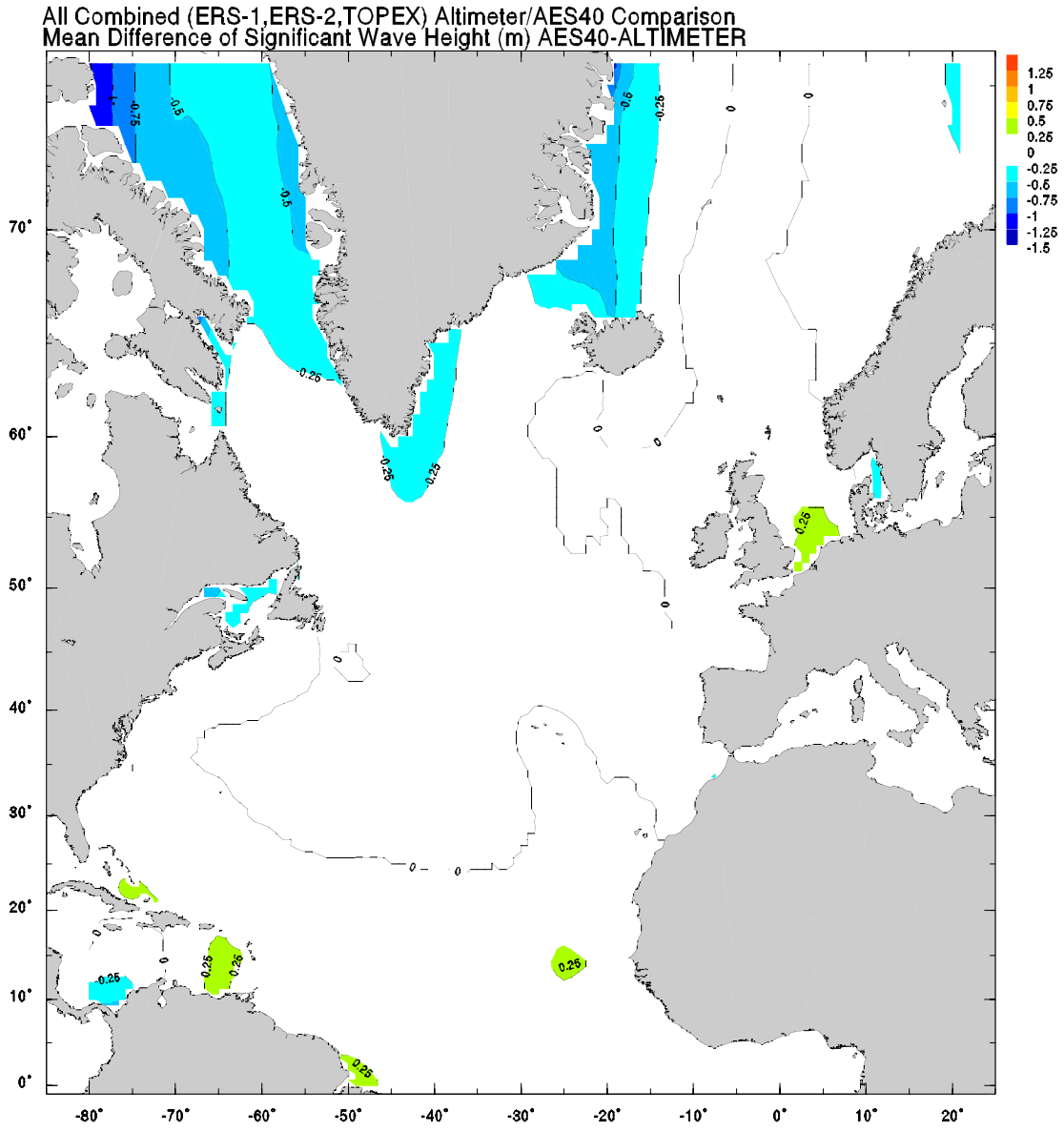


Q-Q wind speed (m/s) and wave height (m) comparisons of AES40 and altimeter measurements

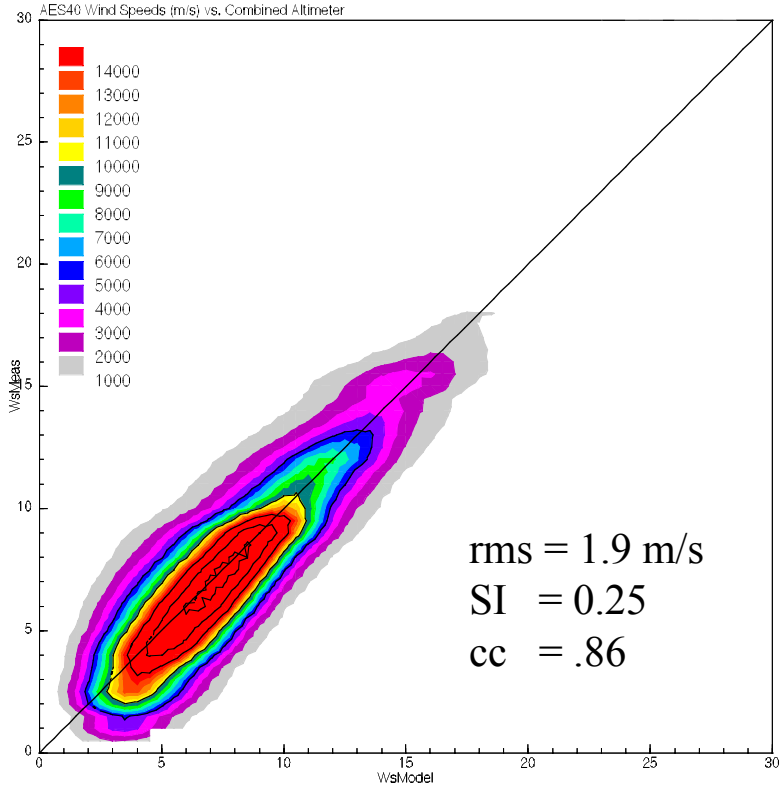
MSC40 Wind Bias

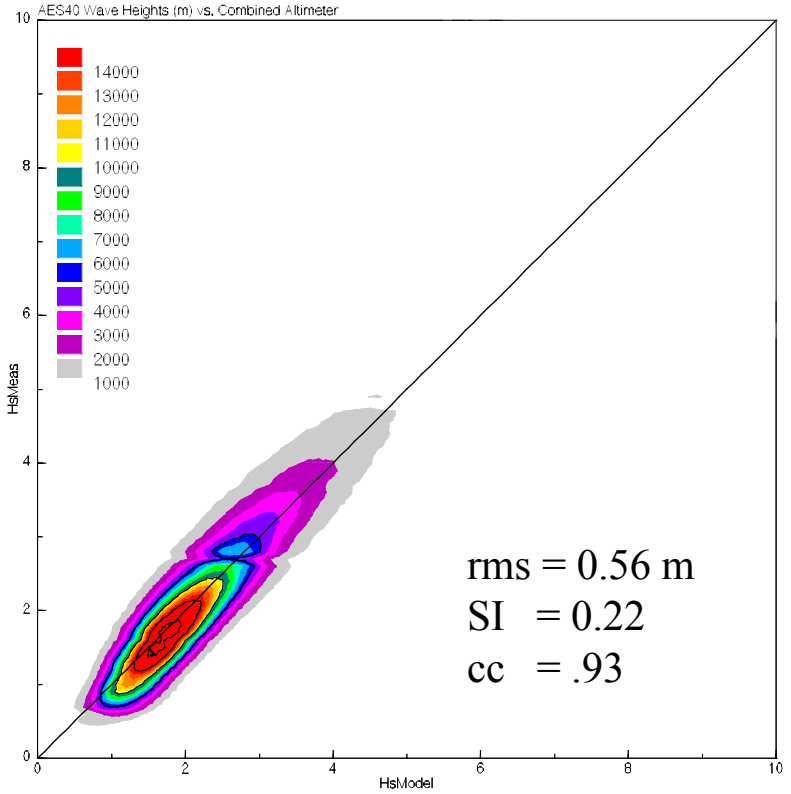


MSC40 Wave Bias



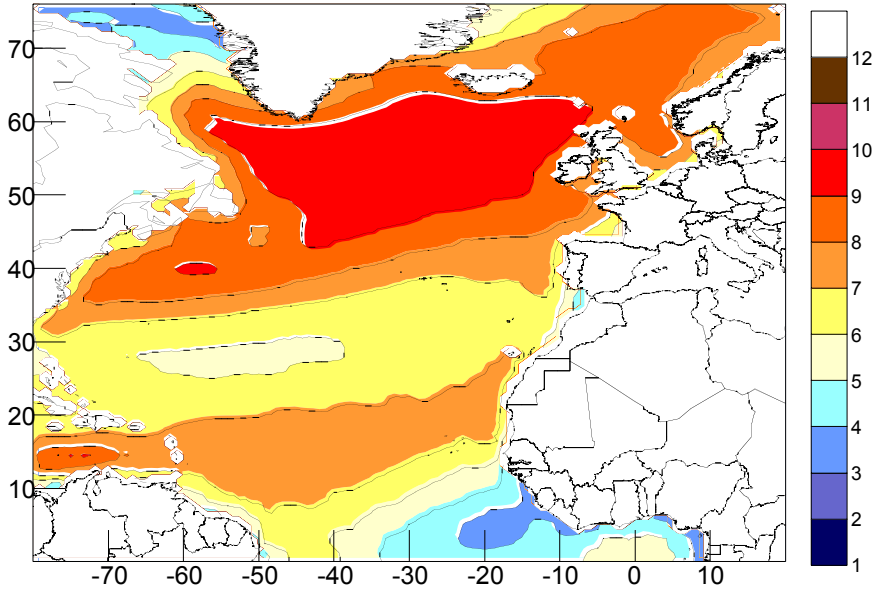
MSC40 vs. Altimeter Contoured Scatter



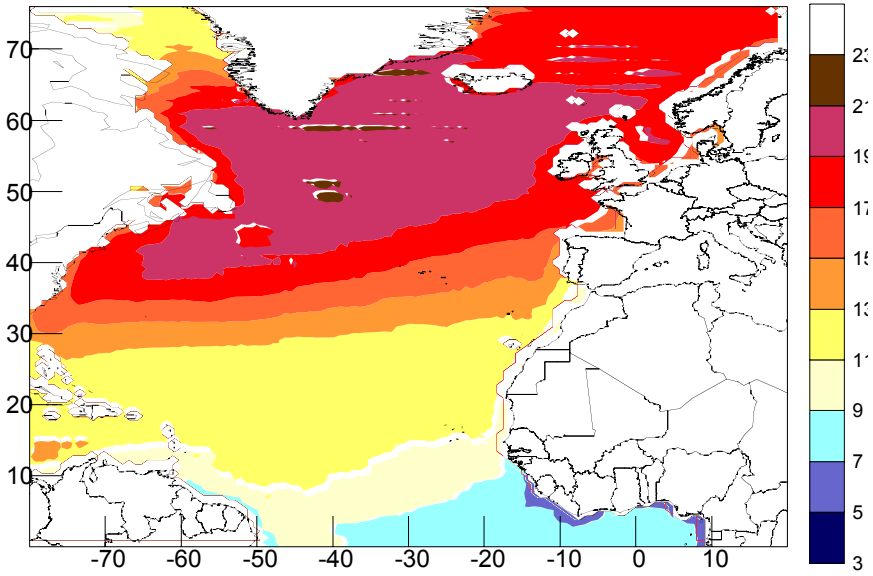


Climate Analysis

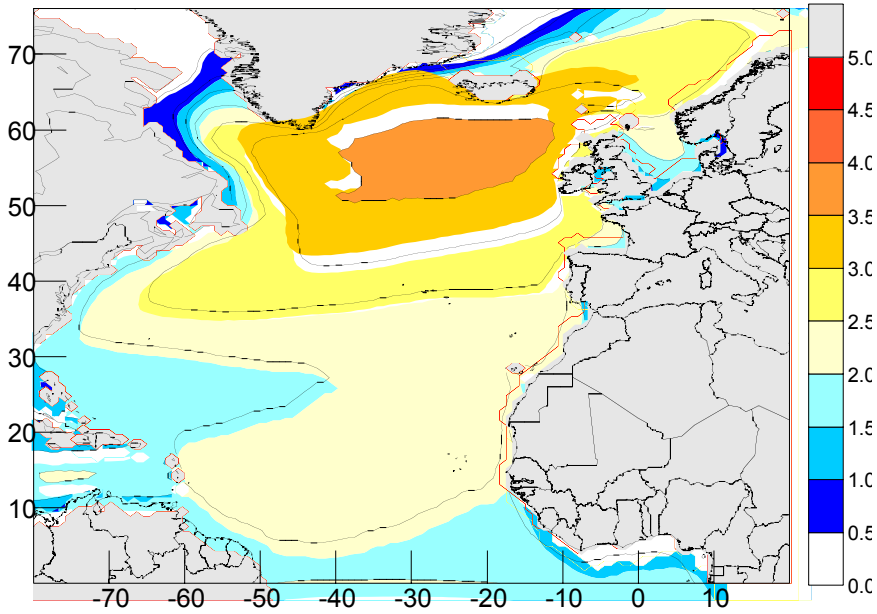
- **Climate products**
  - **For wind speed and significant wave height**
  - **Monthly, seasonal and annual statistics**
  - **15 statistics including mean, sdev, skew, kurtosis, max, 50th, 90th, 95th, 99th %ile, # > 6 thresholds**
  - **Extreme values analysis out to 100-year RP**
- **Trend and variability analyses**
  - **Simple trend analysis for points, maps**
  - **Homogeneity assessment**
  - **EOF analysis of wind & wave trends, SLP, storm tracks**
  - **Statistical downscaling; scenarios for 2099**



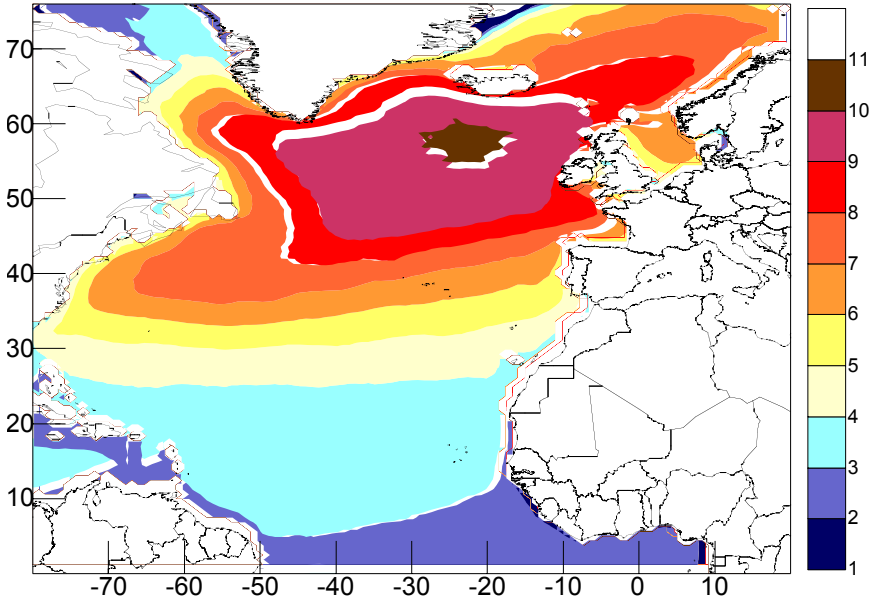
MEAN WIND – ANNUAL (M/S)



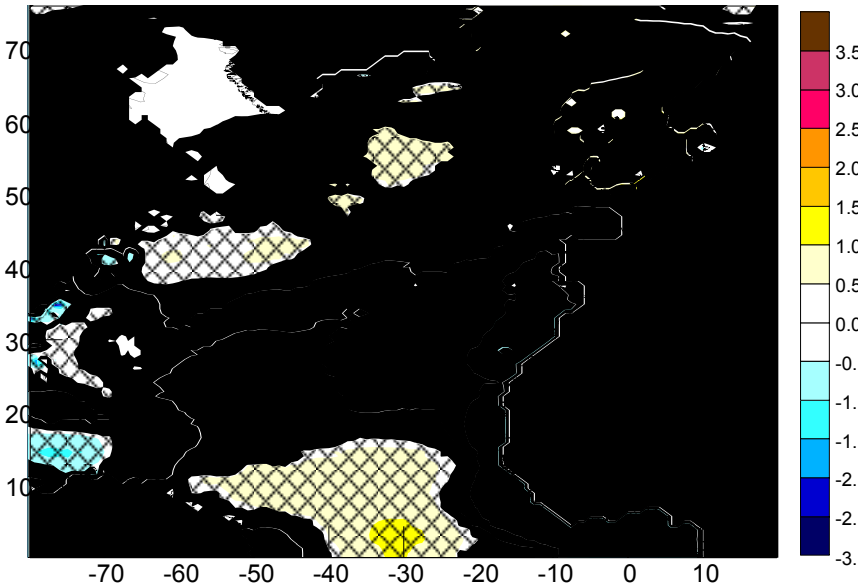
99 % ILE WIND – ANNUAL (M/S)



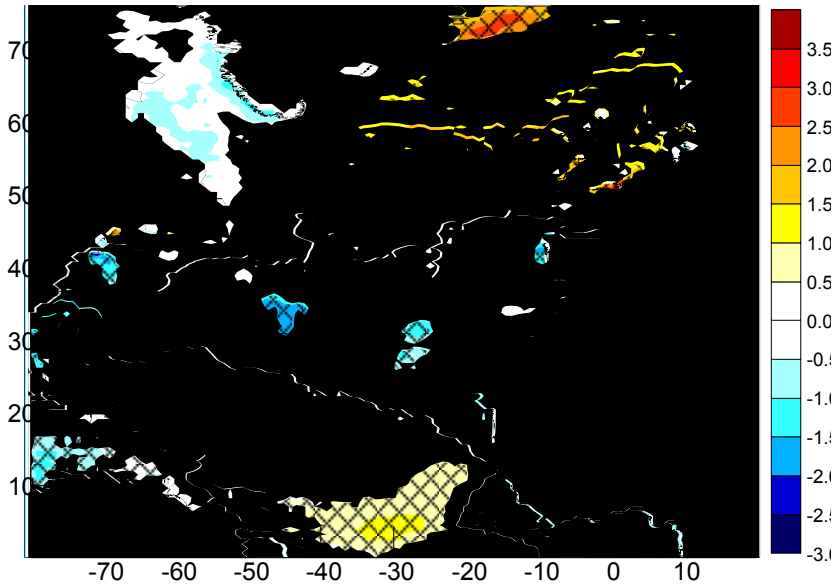
MEAN WAVE – ANNUAL (M)



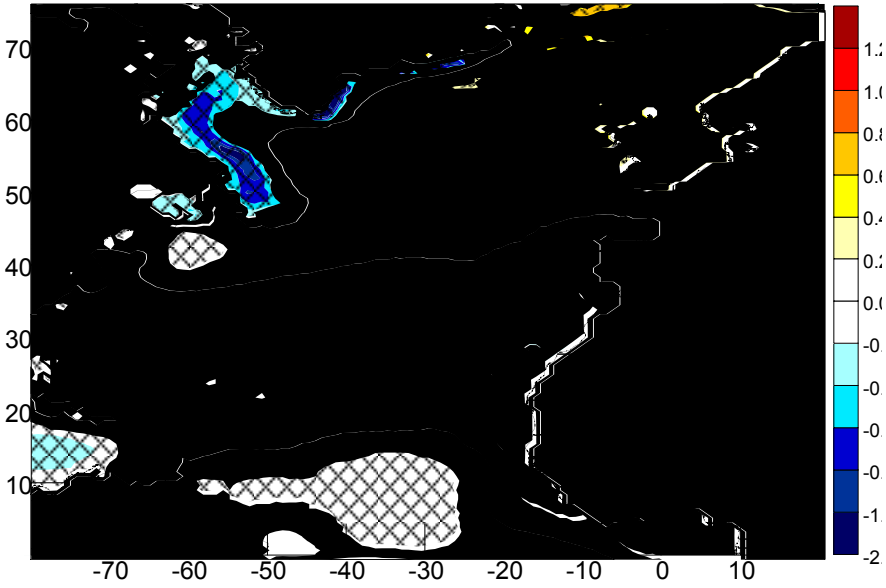
99 % ILE WAVE – ANNUAL (M)



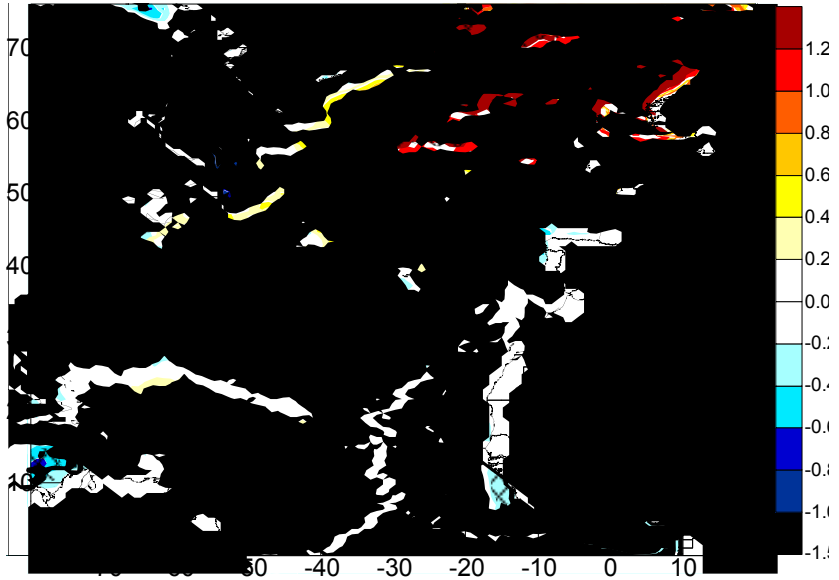
40-YR CHANGE IN MEAN WIND (M/S)



40-YR CHANGE IN 99ILE WIND (M/S)



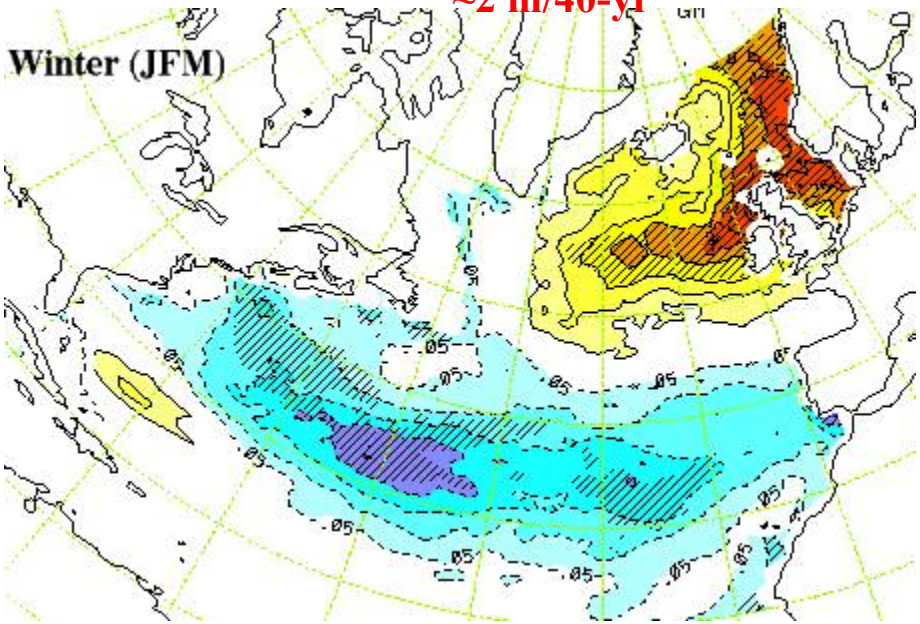
40-YR CHANGE IN MEAN WAVE (M)

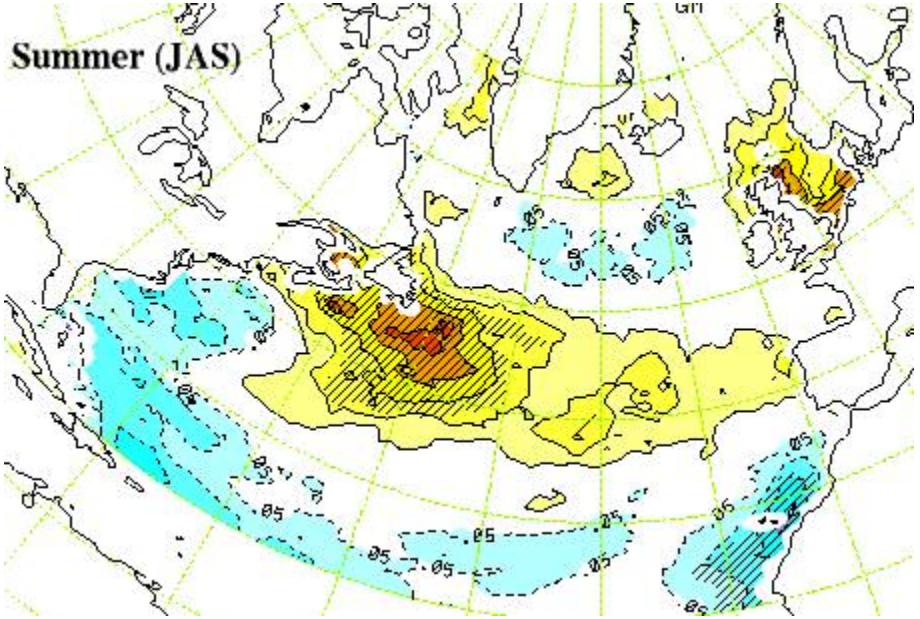


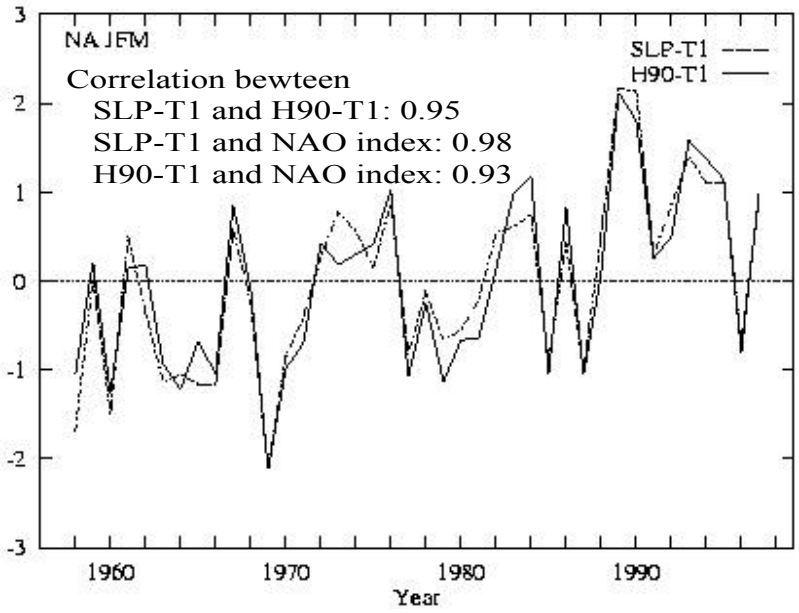
40-YR CHANGE IN 99ILE WAVE (M)

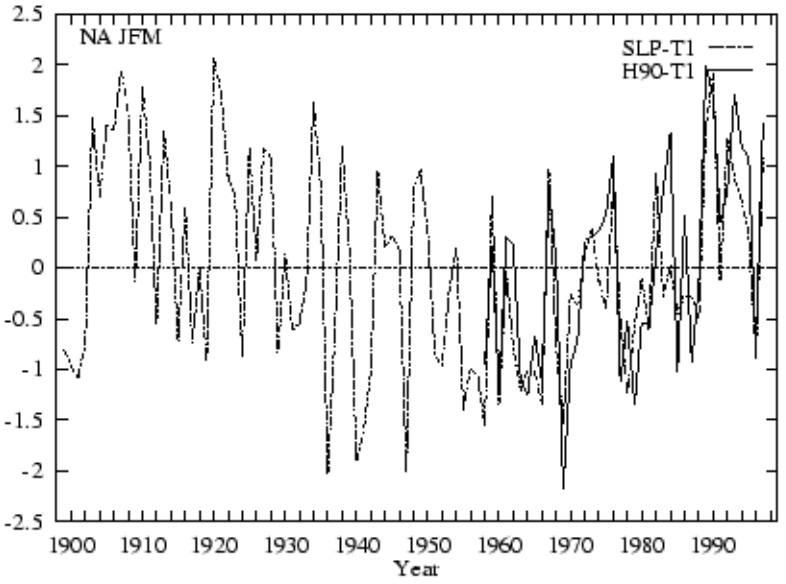
Seasonal 90-percentiles: 40-year changes/mean. Hatching: significant at least at 5% level

~2 m/40-yr

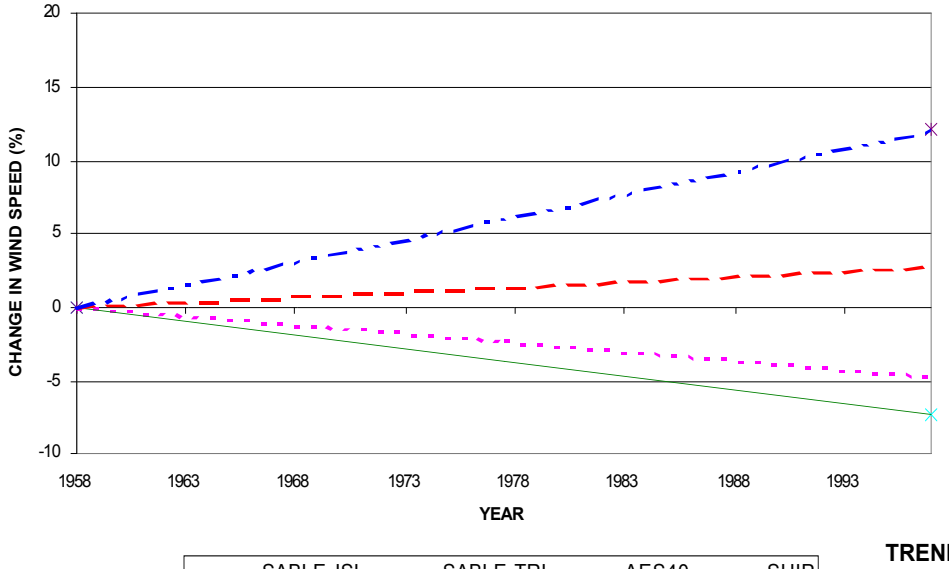





NA JFM
SLP-T1
H90-T1
Correlation bewteen
SLP-T1 and H90-T1: 0.95
SLP-T1 and NAO index: 0.98
H90-T1 and NAO index: 0.93
3
2
1
0
-1
-2
-3
1960
1970
1980
1990
Year

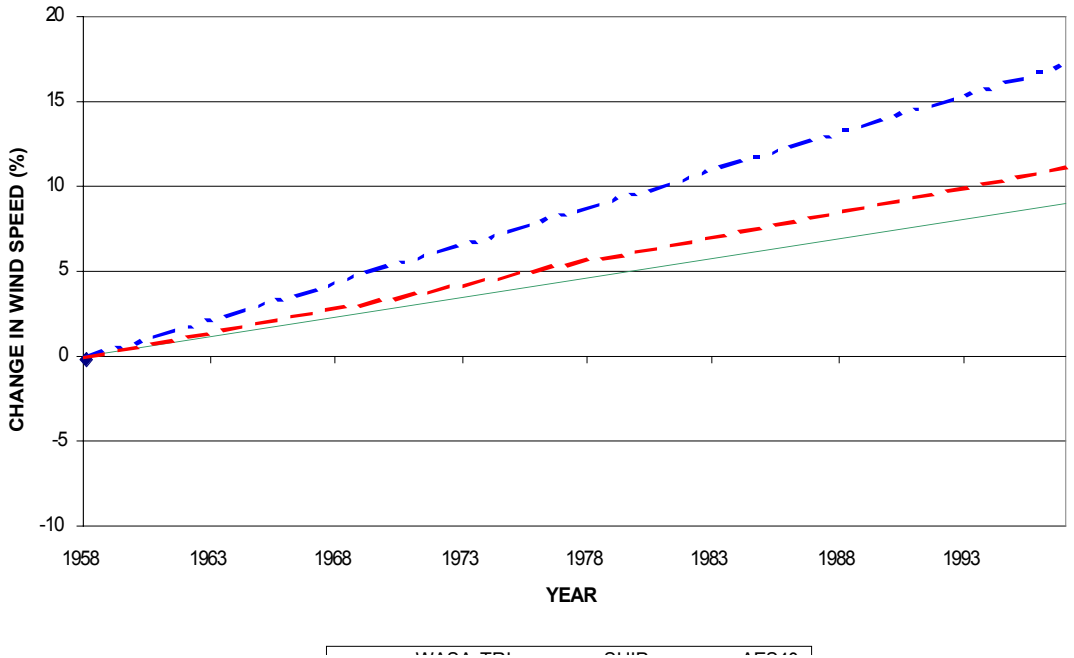

NA JFM
SLP-T1
H90-T1
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year

TREND IN 99TH PERCENTILE WIND SPEED - SCOTIAN SHELF



TREND IN 90TH PERCENTILE WIND SPEEDS TRIANGLE T-A-B

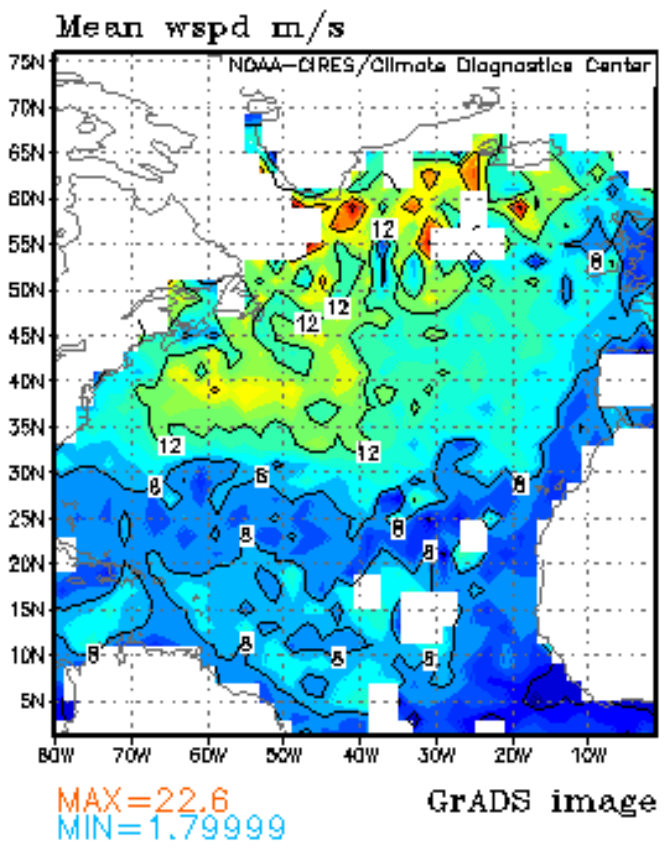
Trends in MSC40 wind speeds and corresponding point trends expressed as the inferred percent change in 99th (lower panel 90th) percentile wind speed over the period 1958-1997 for the Sable Island area (upper) and the WASA triangle Thorshavn-Aberdeen-Bergen (lower)



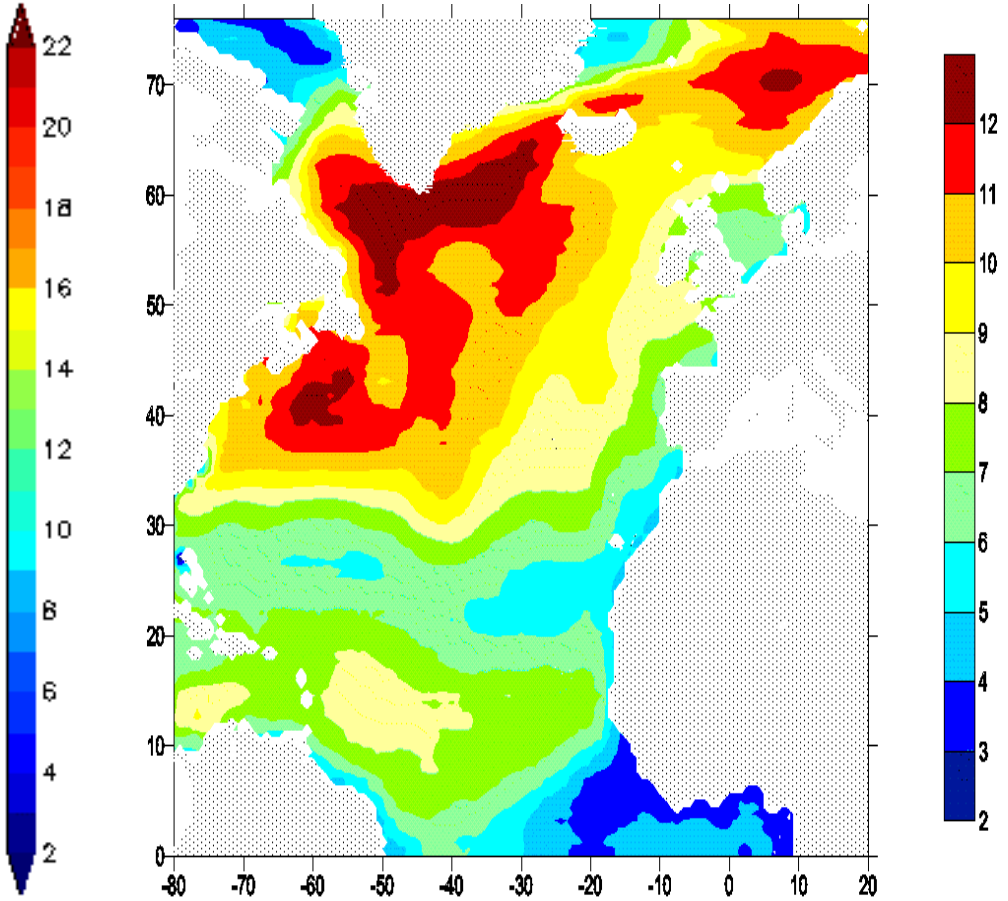
Comparison with COADS Statistics

- Comparison of hindcast statistics with COADS
- Production of ***COADS-type statistics*** – means, s.d., sextiles, monthly, annual, (decadal) for hindcast winds and waves

COADS

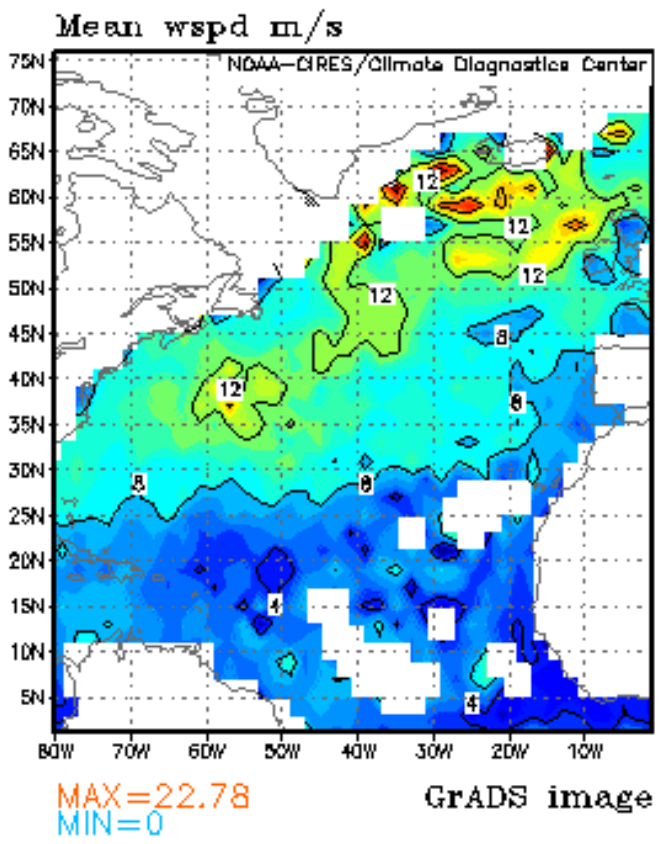


SWAIL

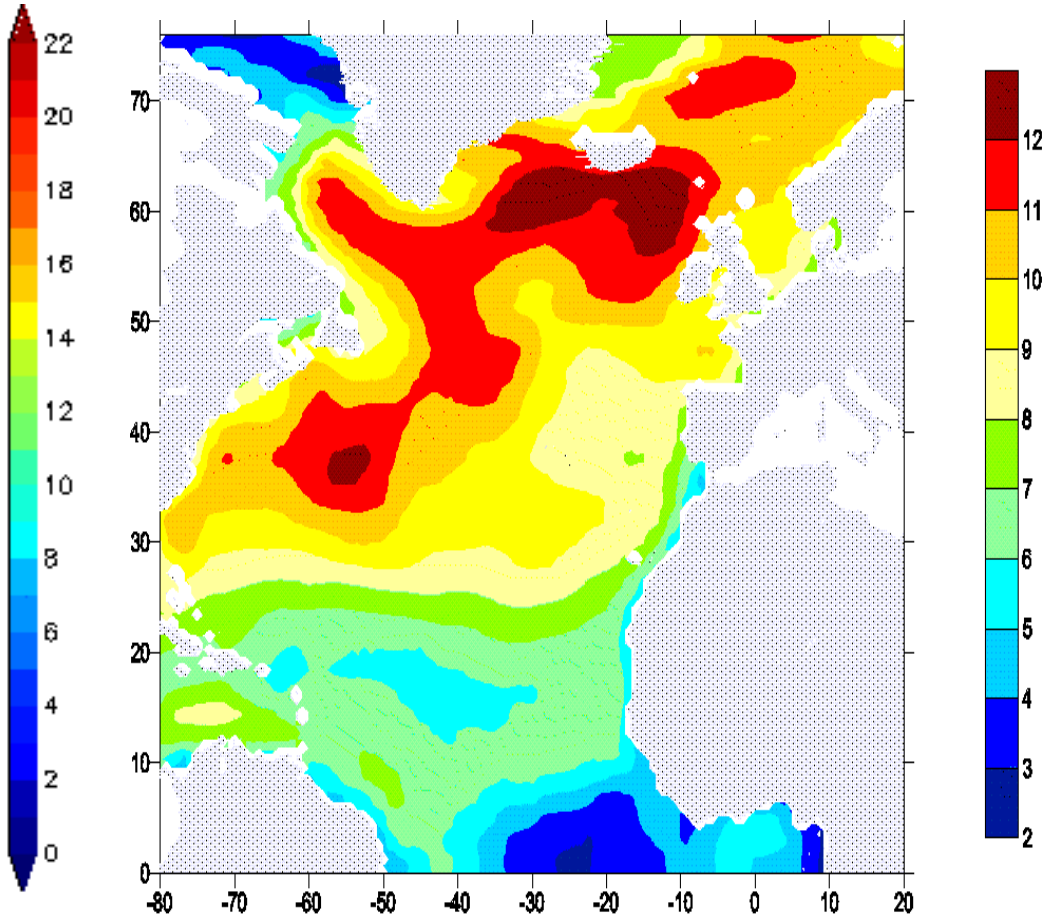


JANUARY 1997 MEAN WIND SPEED

COADS

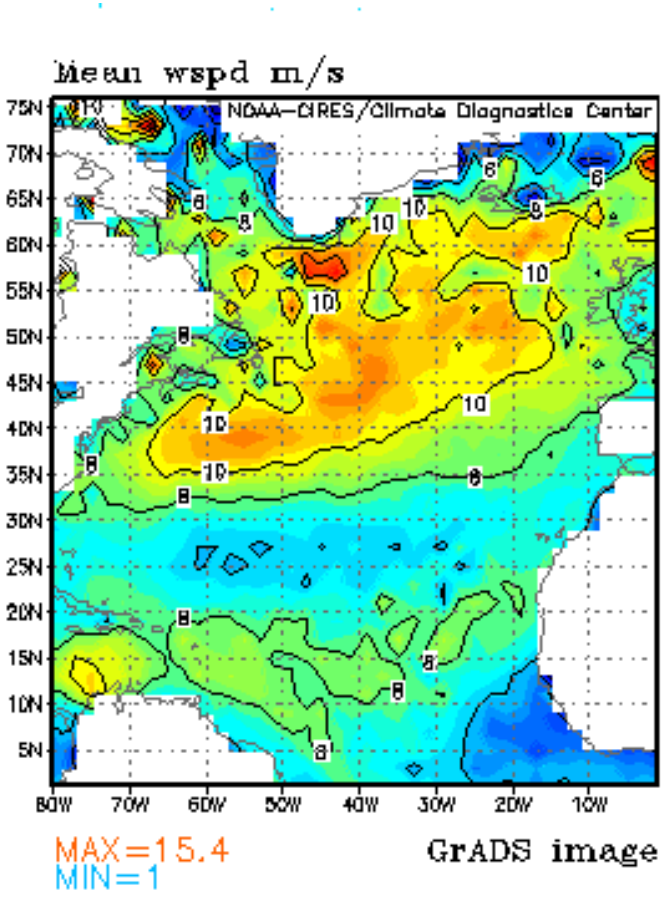


SWAIL

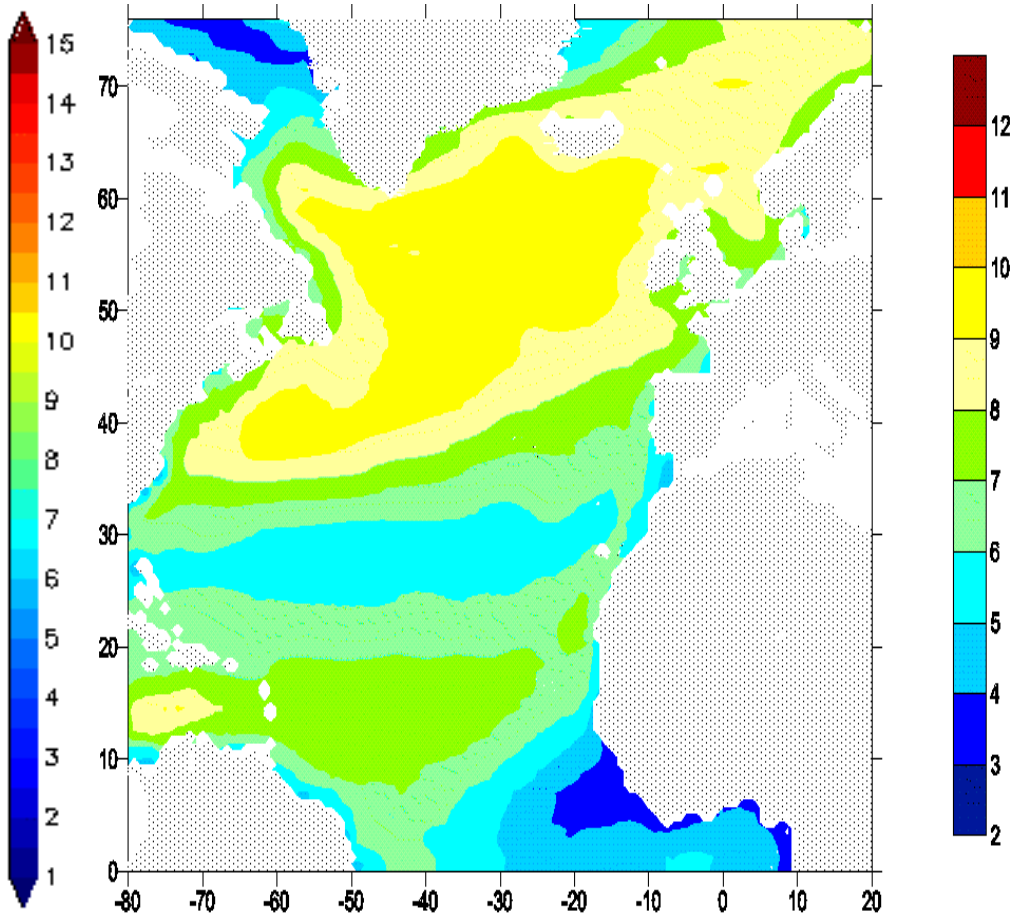


JANUARY 1958 MEAN WIND SPEED

COADS



SWAIL



ANNUAL 1997 MEAN WIND SPEED

SUMMARY

We have produced a very good 40+ year NA wind and wave hindcast based on the NRA surface wind fields, with re-assimilation of all surface data, intensive kinematic reanalysis of storm winds and inclusion of a tropical storm wind model, which verifies very well in ALL situations compared to both *in situ* and satellite winds and waves. ***The results have been widely accepted by the oil and gas industry for engineering purposes***. This should be a very useful complement to existing long term wind and wave climatologies.

Swail, V.R. and A.T. Cox, 2000. *On the use of NCEP/NCAR reanalysis surface marine wind fields for a long term North Atlantic wave hindcast*. J. Atmos. Ocean. Technol., **17**, 532-545.

Swail, V.R., E.A. Ceccacci and A.T. Cox, 2000. *The AES40 North Atlantic Wave Reanalysis: Validation and Climate Assessment*. Proceedings 6th International Workshop on Wave Hindcasting and Forecasting, Monterey, CA, 6-10 November 2000.

Wang, X.L. and V.R. Swail**,** 2002. *Trends of Atlantic wave extremes as simulated in a 40-year wave hindcast using kinematically reanalyzed wind fields*. J. Climate..


THE END