Validation of a multi-grid WAVEWATCH III™ modeling system

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MOTIVATION

- **New operational system** since November 2007,
  - A single multi-grid model (WAVEWATCH III™ v 3.14) replacing suite of earlier models
  - Hindcast database available for detailed multi-year validation study.
- A new data analysis system (**IMEDS**)
  - quantifies skill of individual wave components (wind seas and swells)
- A four year **NOPP initiative** to improve physics of 3rd generation wind wave models
  - Initiative is in its nascent stages.
  - WAVEWATCH III™ to be a modeling test bed for many of the participants
  - This study provides a baseline skill (in an operational setting)

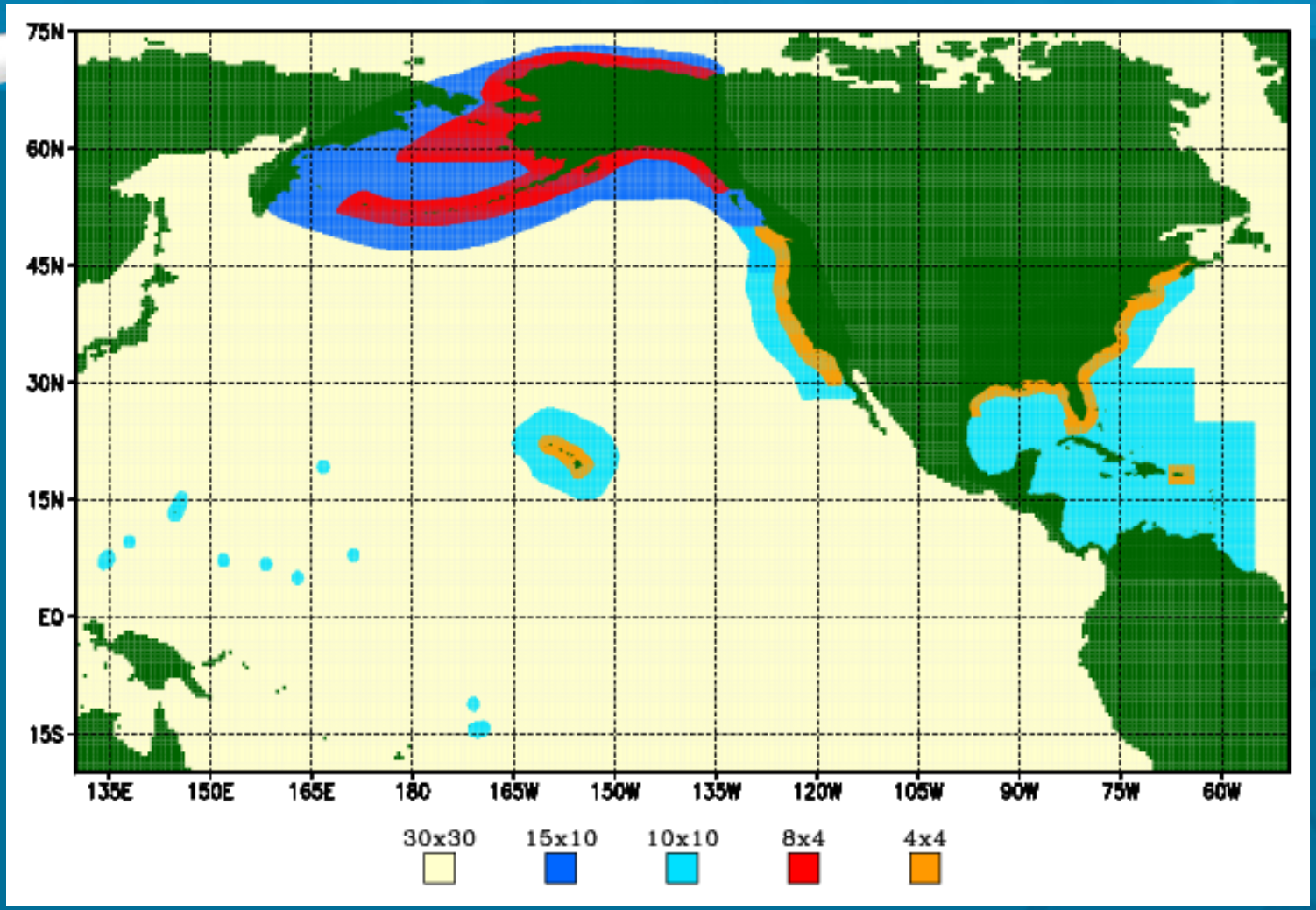
MODEL – DATA comparisons

- Modeling System
  - 8 grid global system using the two-way coupled multi-grid WAVEWATCH III™ model
  - Model forced with GFS winds and sea ice derived from daily passive microwave analysis
- Analysis
  - Analysis includes regular forecasts (4 cycles a data) and a 5 year hindcast (2005-2009)
  - Collocated model – altimeter comparisons with Jason-1 satellite data
  - Comparison of bulk spectral parameters with a global network of buoys
  - Spectral analysis (at select buoy locations) with IMEDS (Interactive Model Evaluation and Diagnostics System)

CONCLUSIONS

- A persistent positive bias (wave heights) in the Southern Hemisphere.
  - Development of bias coincides with the GFS winds becoming more energetic in this region
- Seasonal bias patterns in the Northern Hemisphere
  - Positive biases in the swell dominated eastern parts of the basin
  - Negative biases in the wind wave dominated western parts of the basin
- Spectral analysis shows
  - Negative biases in wind waves
  - Swell picture is more complex
    - Positive biases in the US West Coast buoys
    - Negative biases in the US East Coast buoys
    - Mixed (positive and negative) biases in the Alaska buoys

MODEL GRIDS



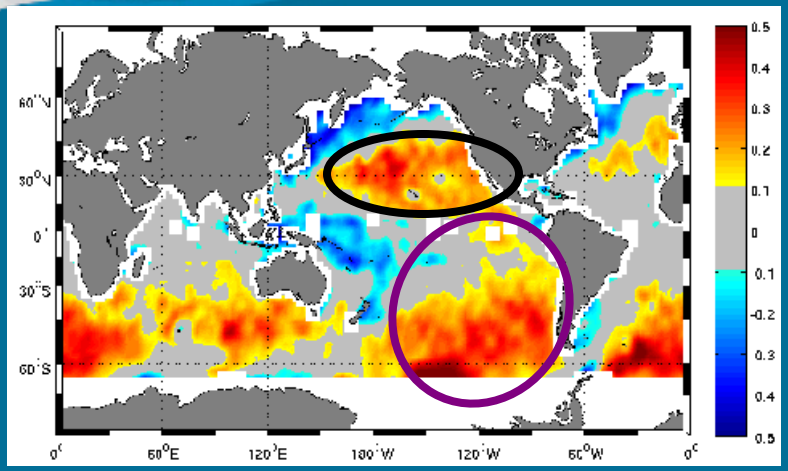
Grid resolution in minutes

MODEL – ALTIMETER COMPARISONS

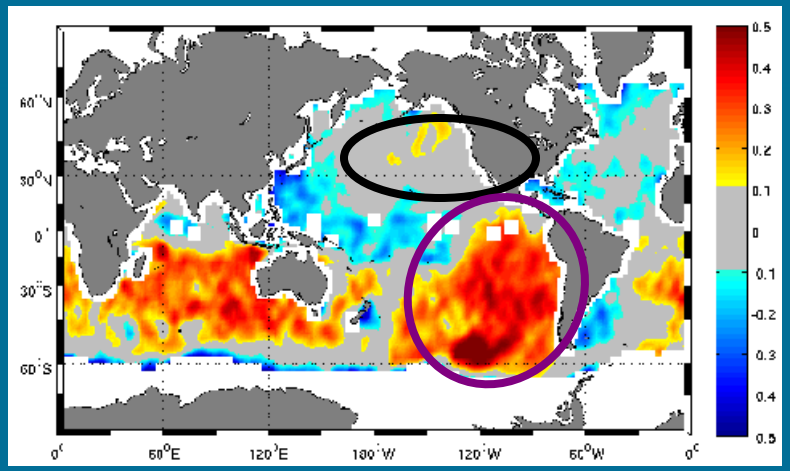
- Model skill assessment done using collocated altimeter (Jason-1 satellite) and model data
- Collocation done for 9 periods (hindcast, nowcast, and 1 – 7 day forecast)
- Error estimates (Scatter Index and bias) developed using month long archives
- Altimeter data de-spiked (also removes island features that are not resolved by the model) and filtered
- Error maps developed using 3 month records (to provide statistically significant sample sizes) and binning the data in 2^o X 2^o bins

MODEL – ALTIMETER COMPARISONS (contd.)

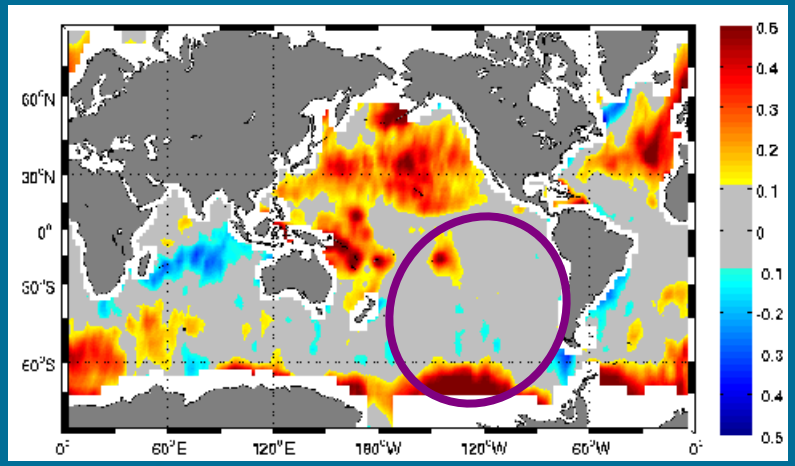
Hindcast Bias Maps



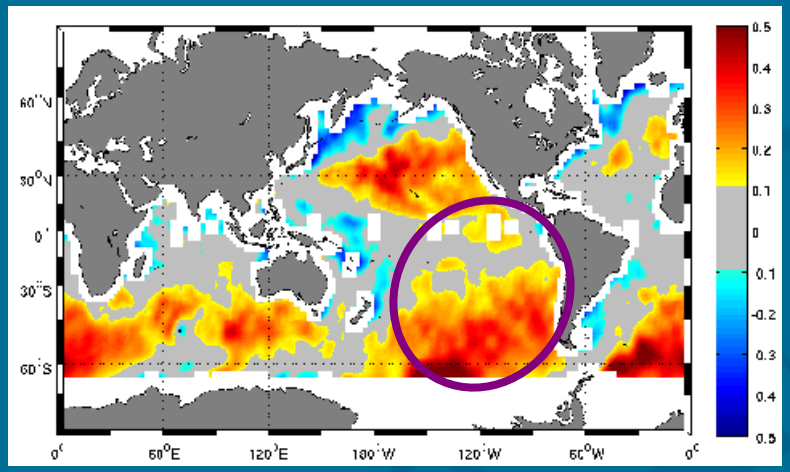
Jan – Mar, 2008



Jul – Sep, 2008



Jan – Mar, 2002 (old model)

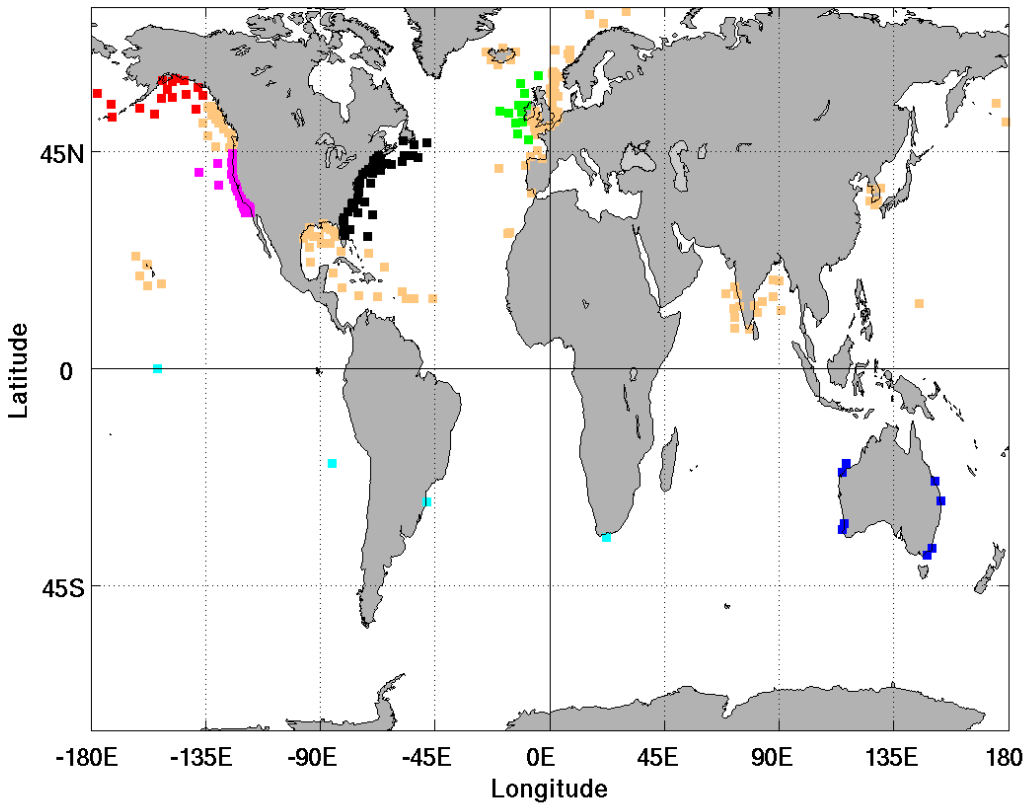


Jan – Mar, 2008 (old model)

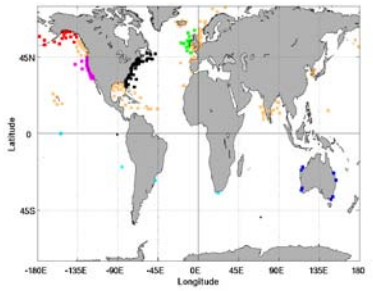
BUOY COMPARISONS

Buoy Data

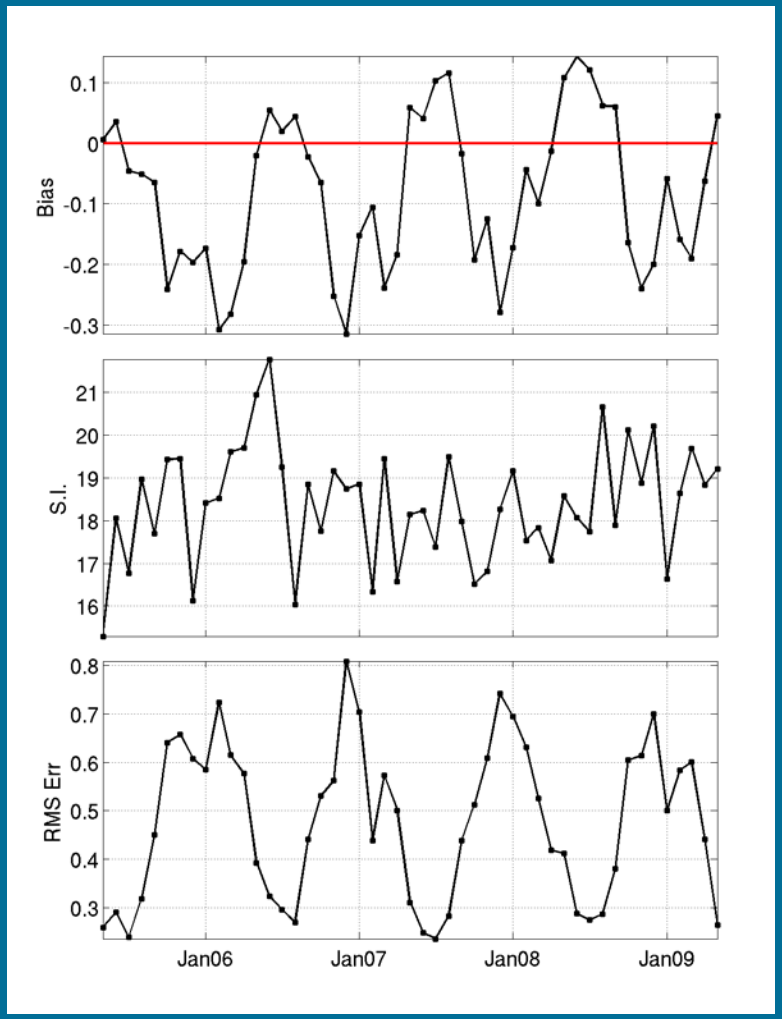
- Global network of buoy data, quality controlled and archived at ECMWF as part of inter-agency model comparison project.
- Hourly buoy data averaged over 4 hr interval, centered at the 4 synoptic time cycles of wave forecasts (0,6,12 and 18)



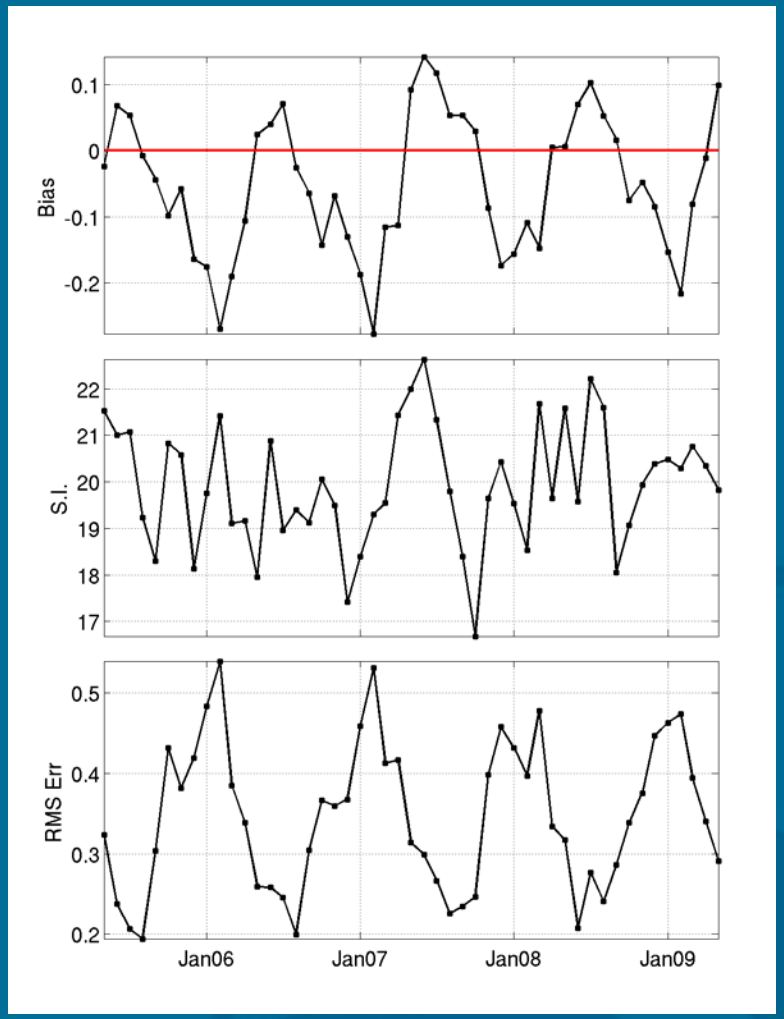
BUOY COMPARISONS (contd.)



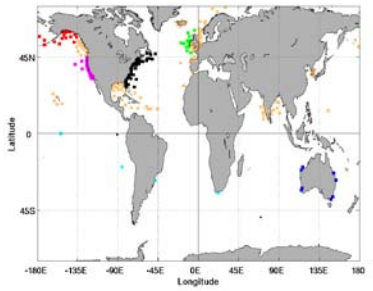
ALASKA Buoys



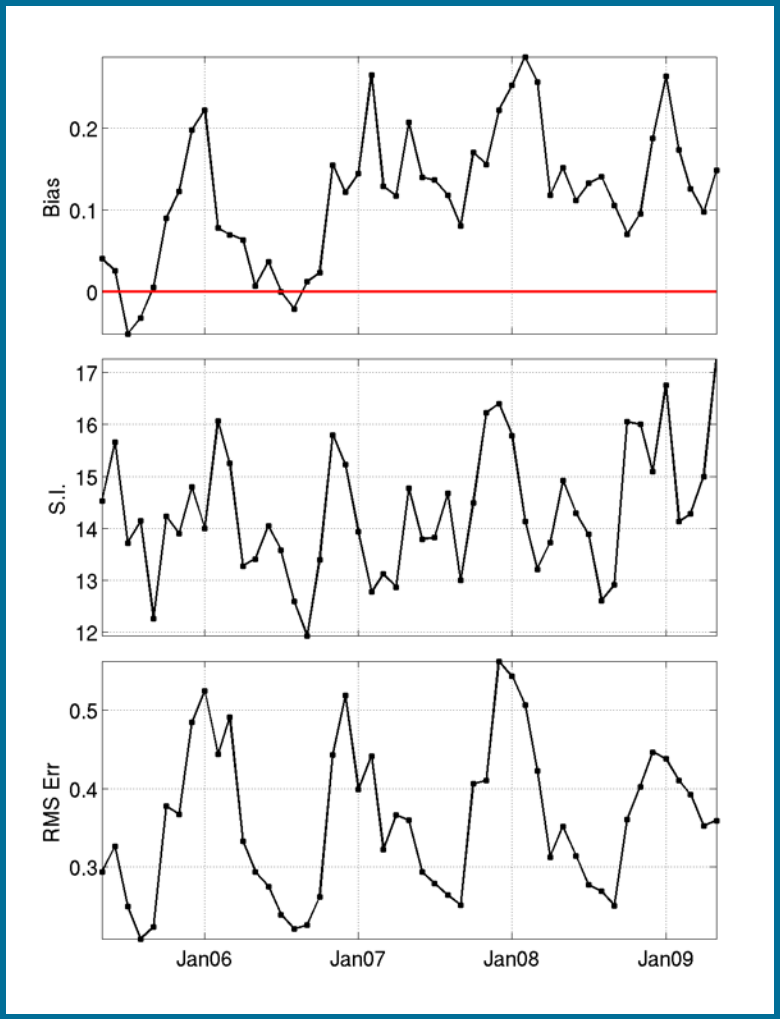
US East Coast Buoys



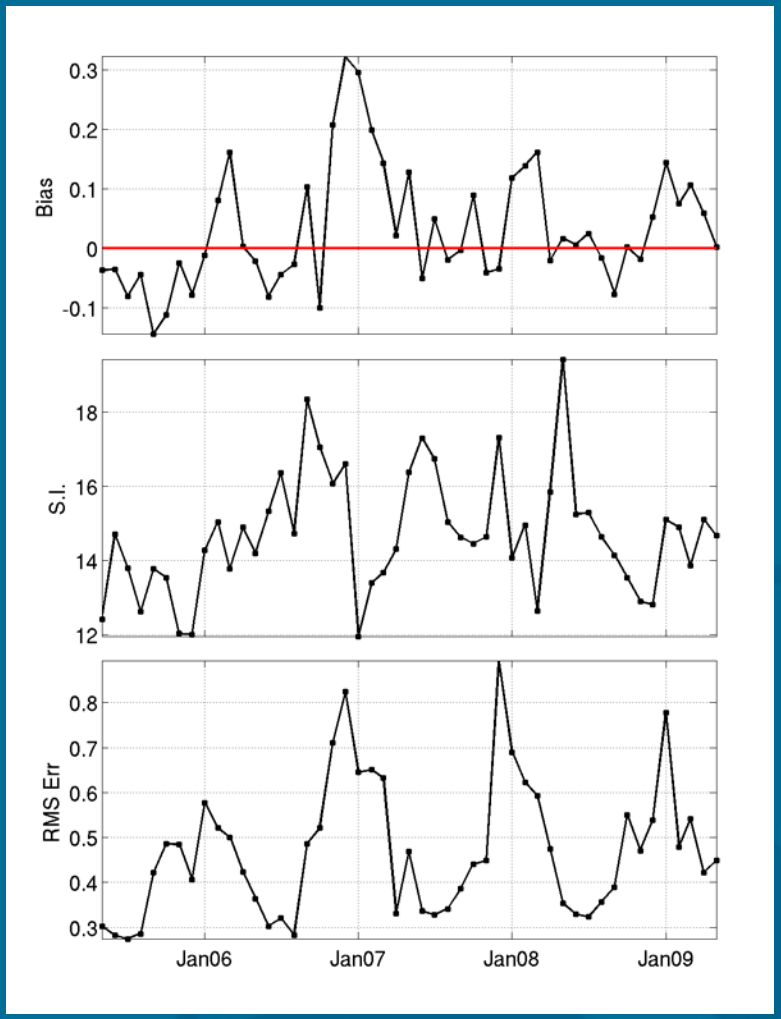
BUOY COMPARISONS (contd.)

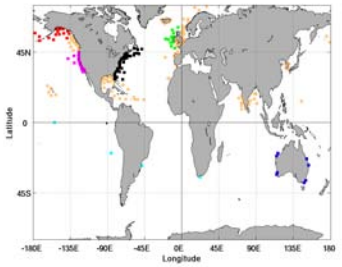


US West Coast Buoys



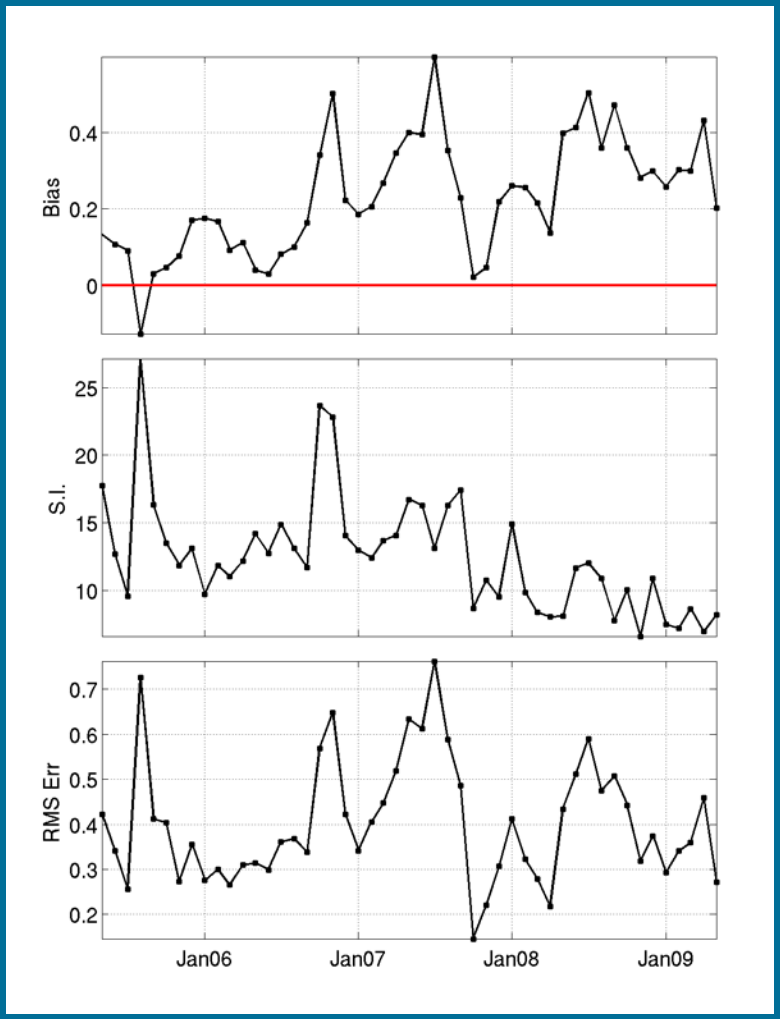
European Buoys



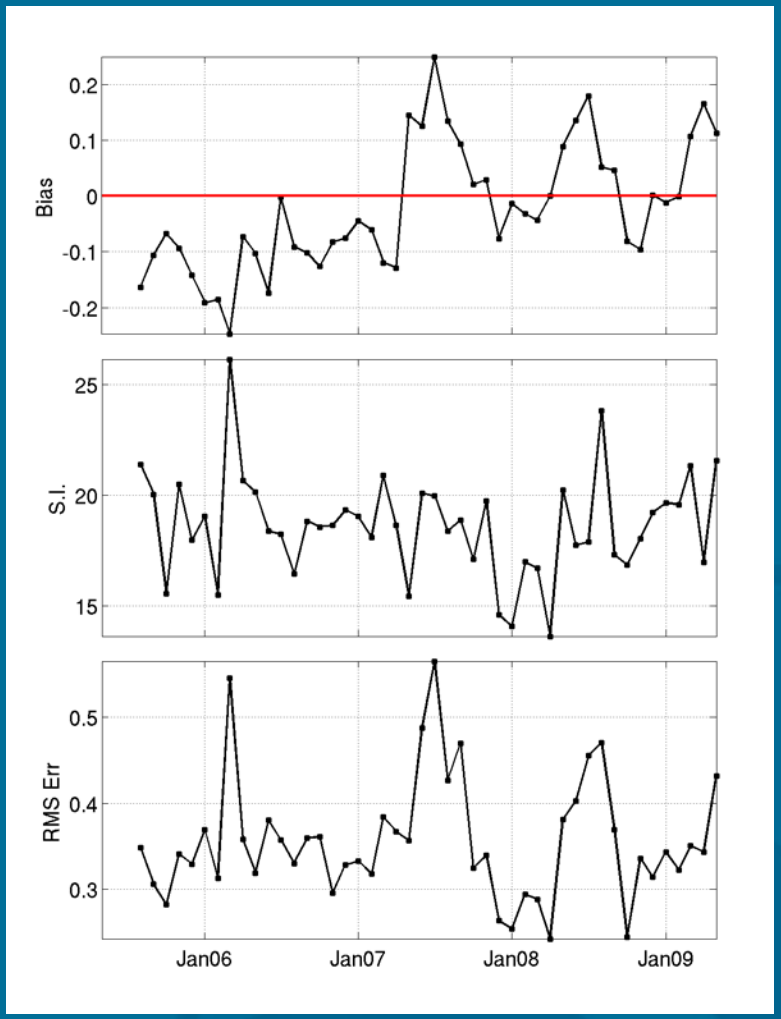


BUOY COMPARISONS (contd.)

Southern Hemisphere Buoys

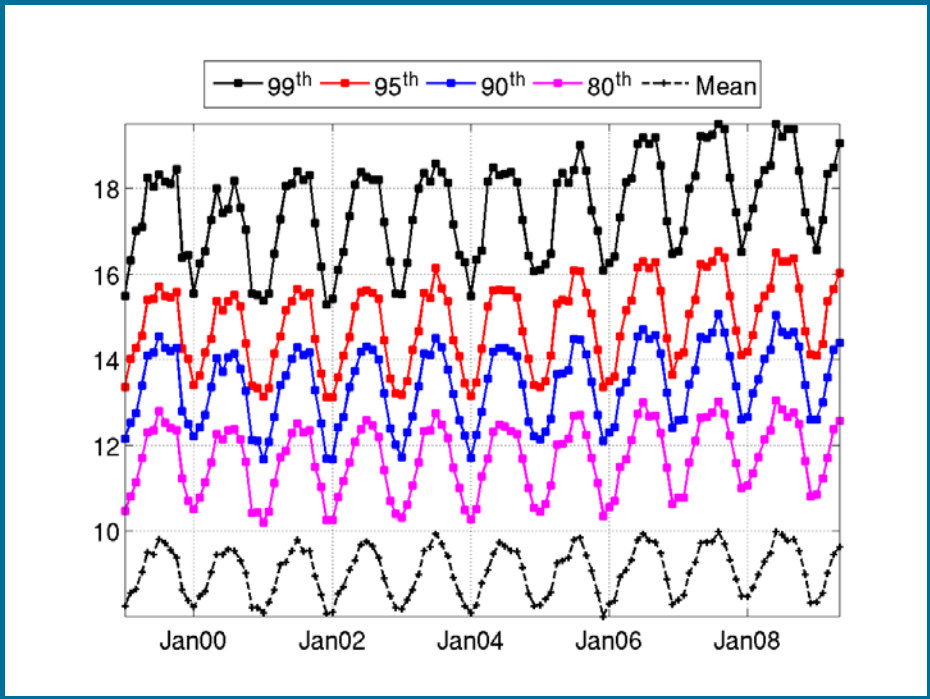


Australia Buoys

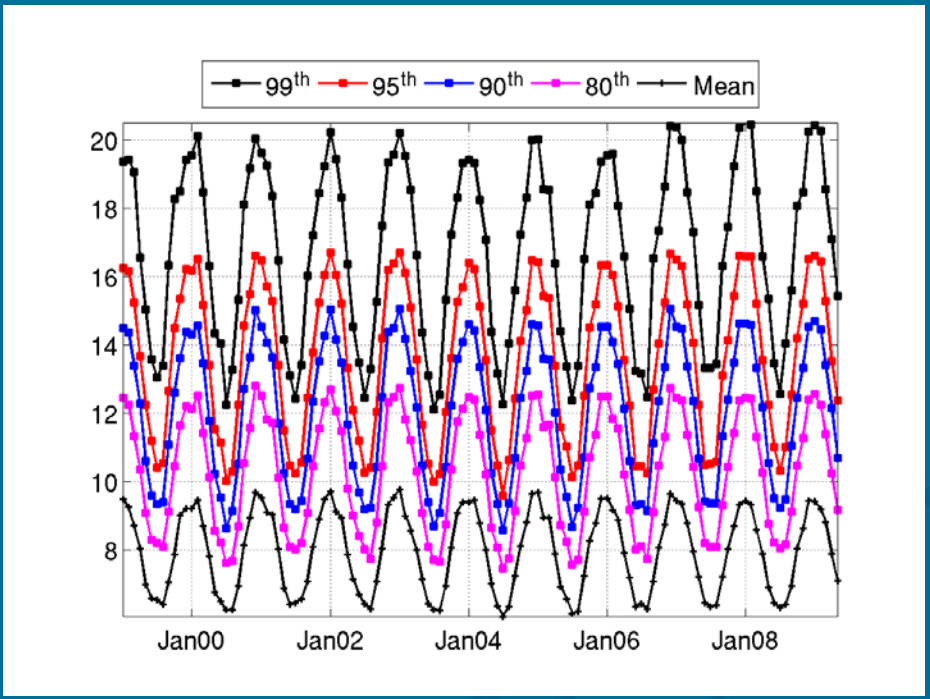


BUOY COMPARISONS (contd.)

GFS wind speed statistics (over water)



Southern Hemisphere
(60°S to 25°S)

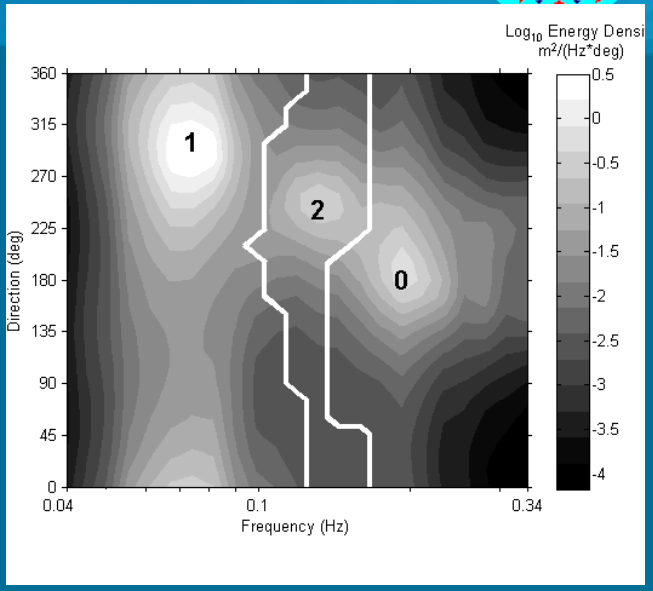


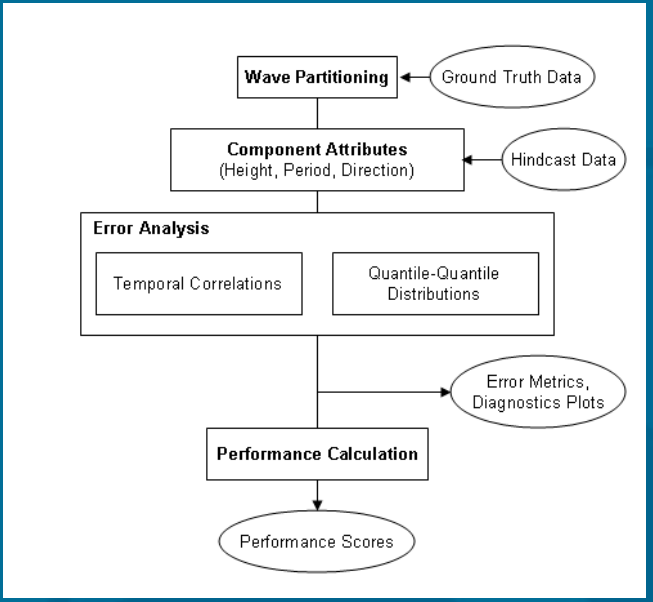
Northern Hemisphere
(25°N to 60°N)

Interactive Model Evaluation and Diagnostics System (IMEDS)

Methodology

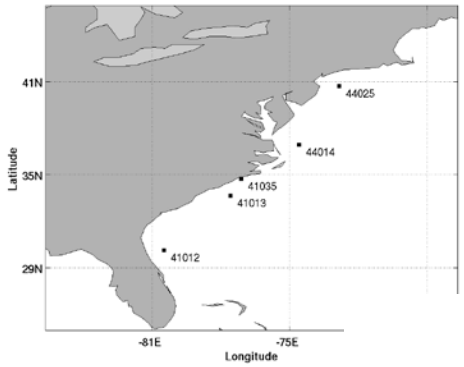
- A diagnostic analysis tool for wind wave models developed by USACE (Hanson et al 2009)
- IMEDS provides additional information on model skill by
  - Using a partitioning algorithm to separate individual peaks in the spectrum of the data
  - Use partition boundaries to identify model and data component attributes
  - Do error analysis over individual components and develop error metrics and skill scores
- IMEDS separates spectral peaks into 3 types – wind waves, young and mature swells
- Directional age criterion to separate wind waves from swells
- Frequency cut-off to separate young and mature swells

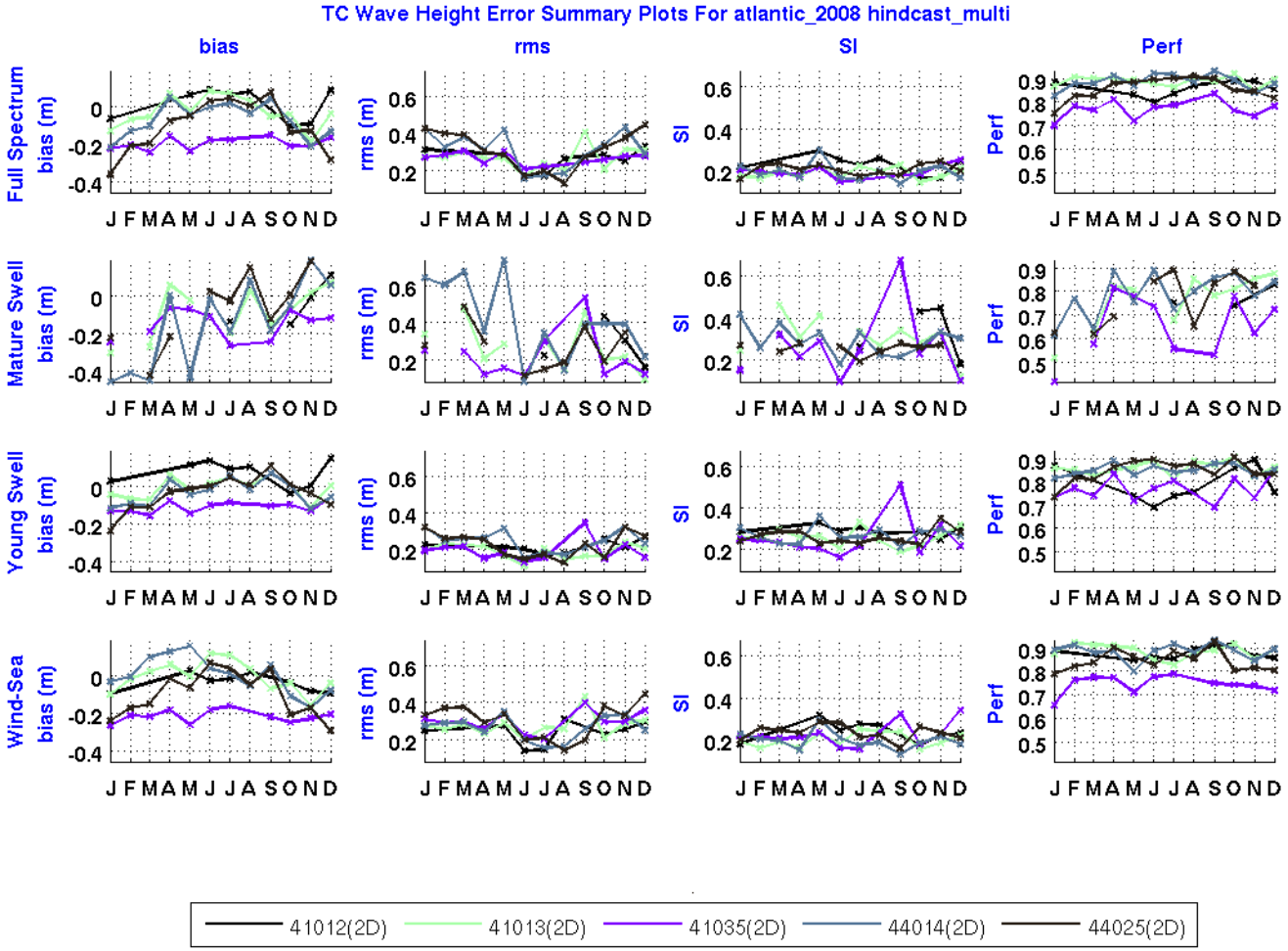


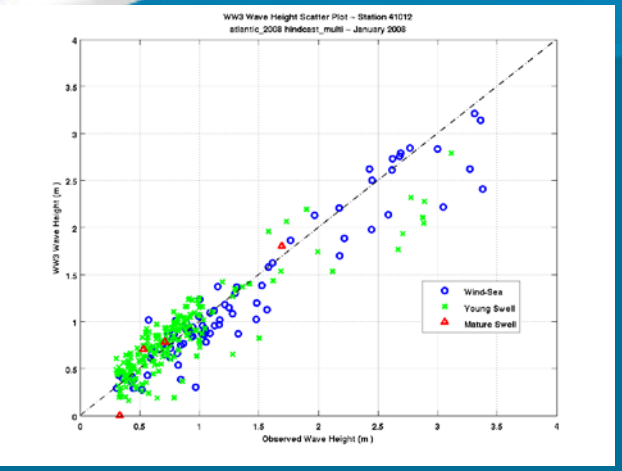


IMEDS (contd.)

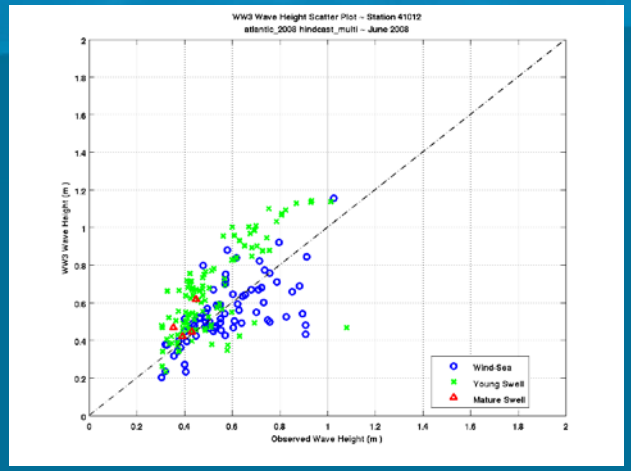
Atlantic buoys



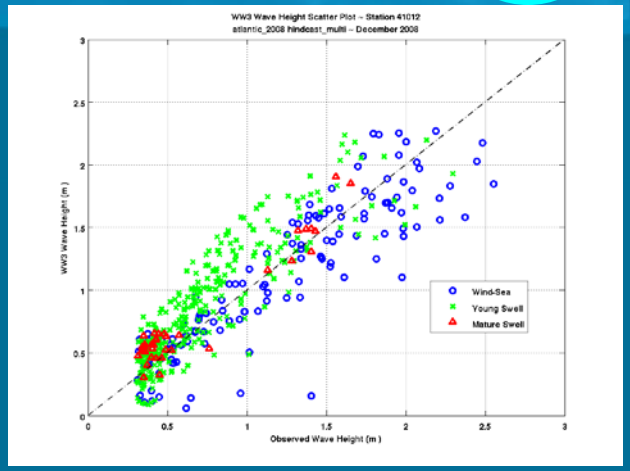




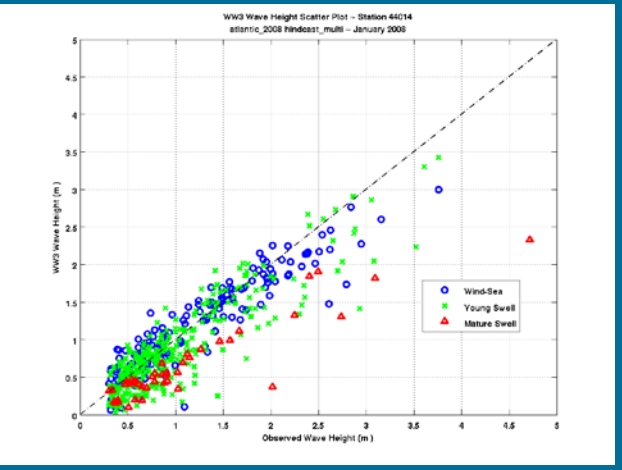
41012 – Jan,2008

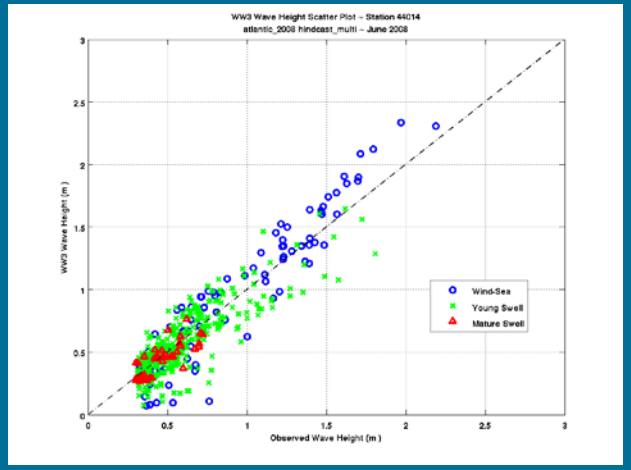


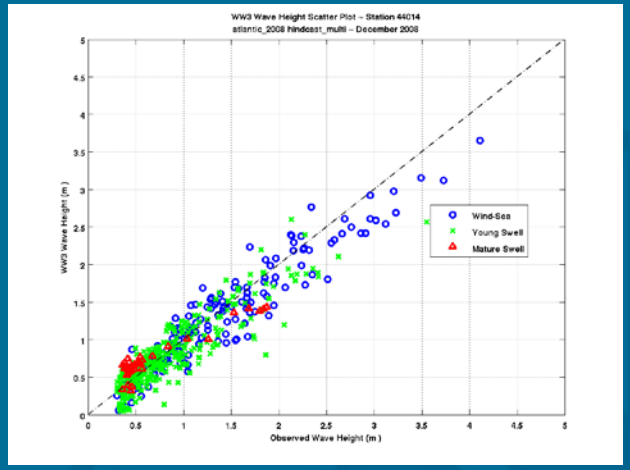
41012 – Jun,2008



41012 – Dec,2008

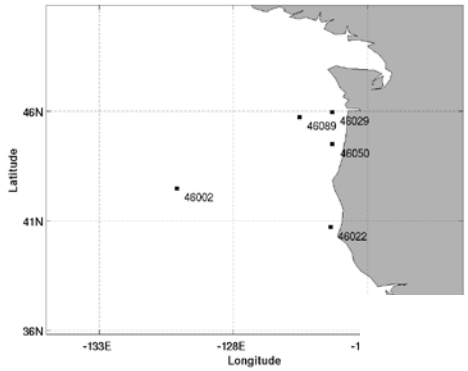


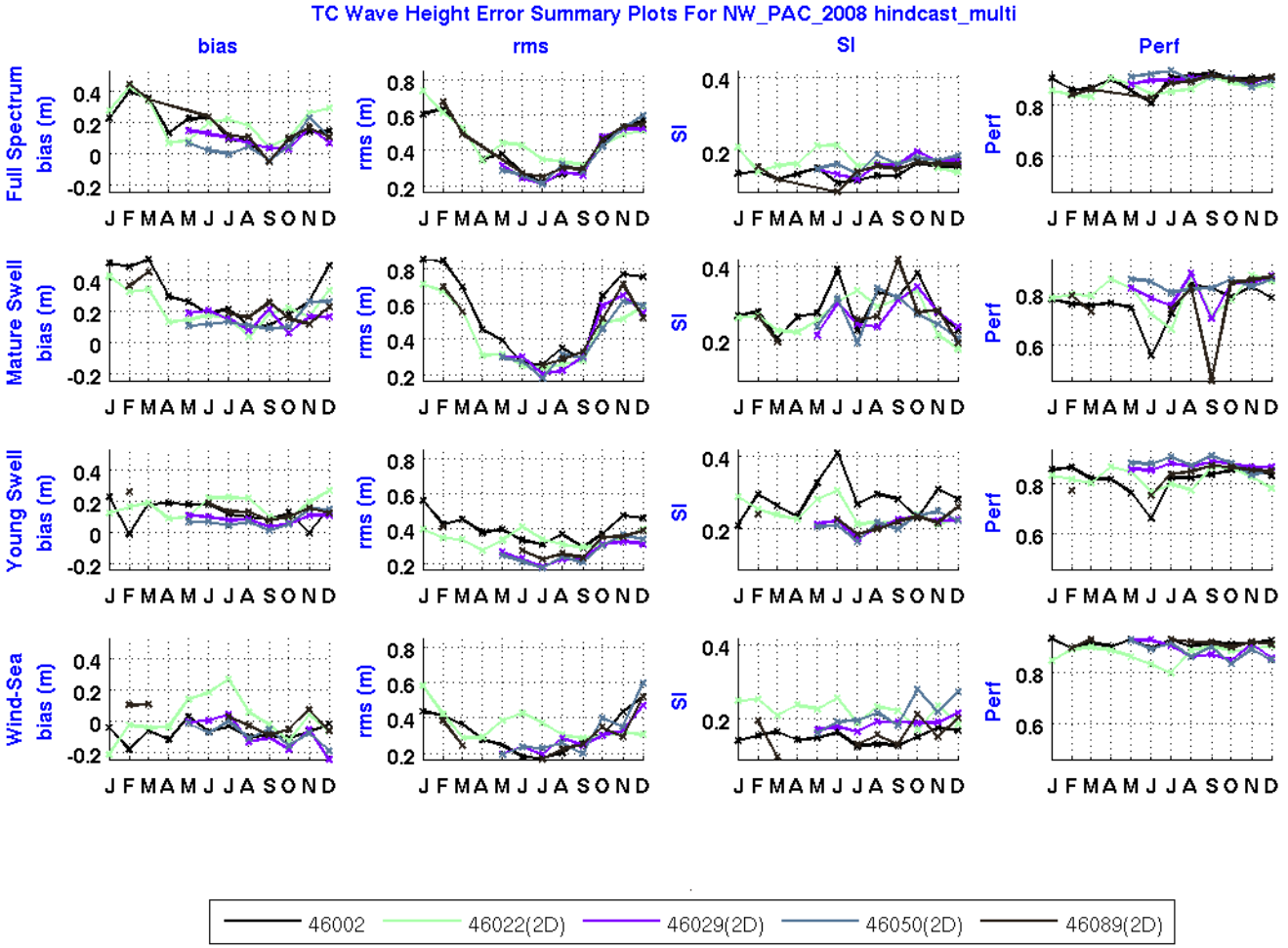


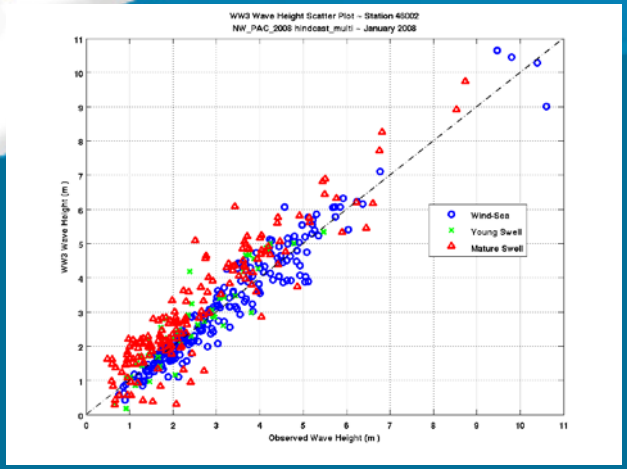


IMEDS (contd.)

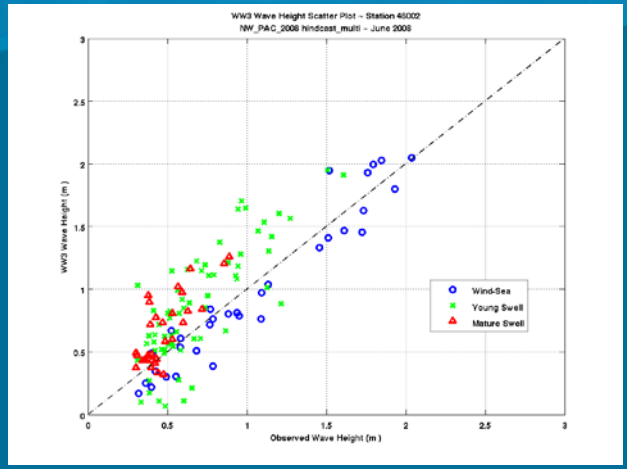
Pacific Buoys







46002 – Jan,2008



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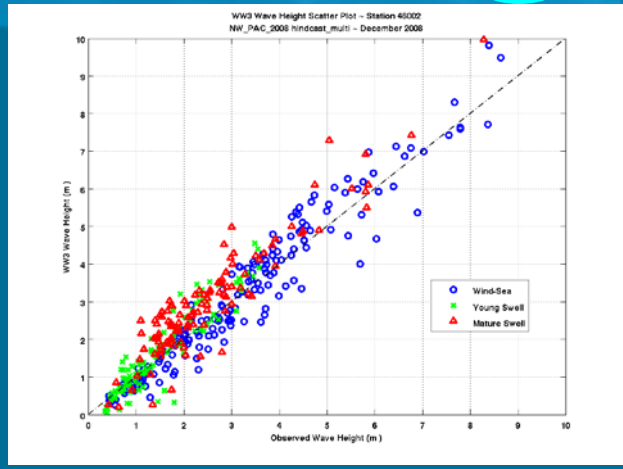

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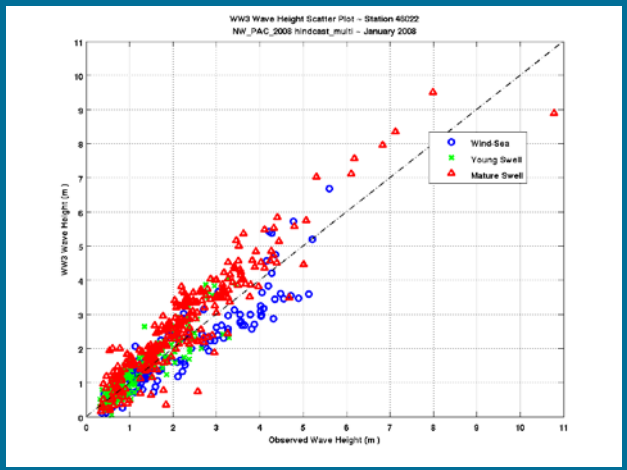

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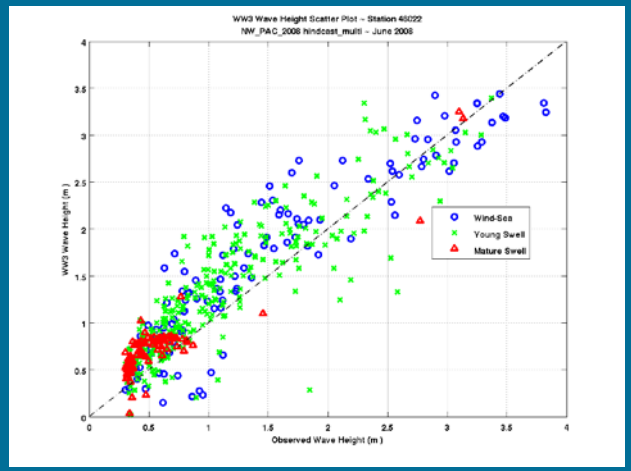

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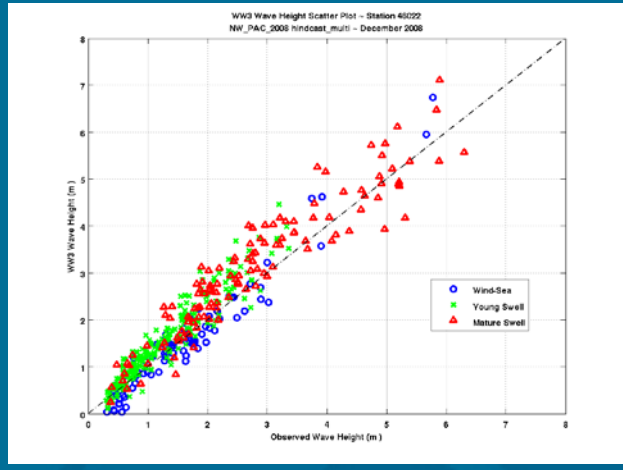

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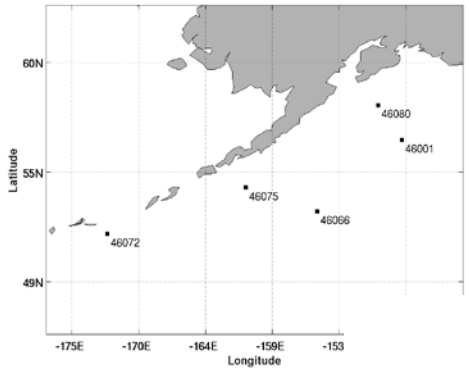
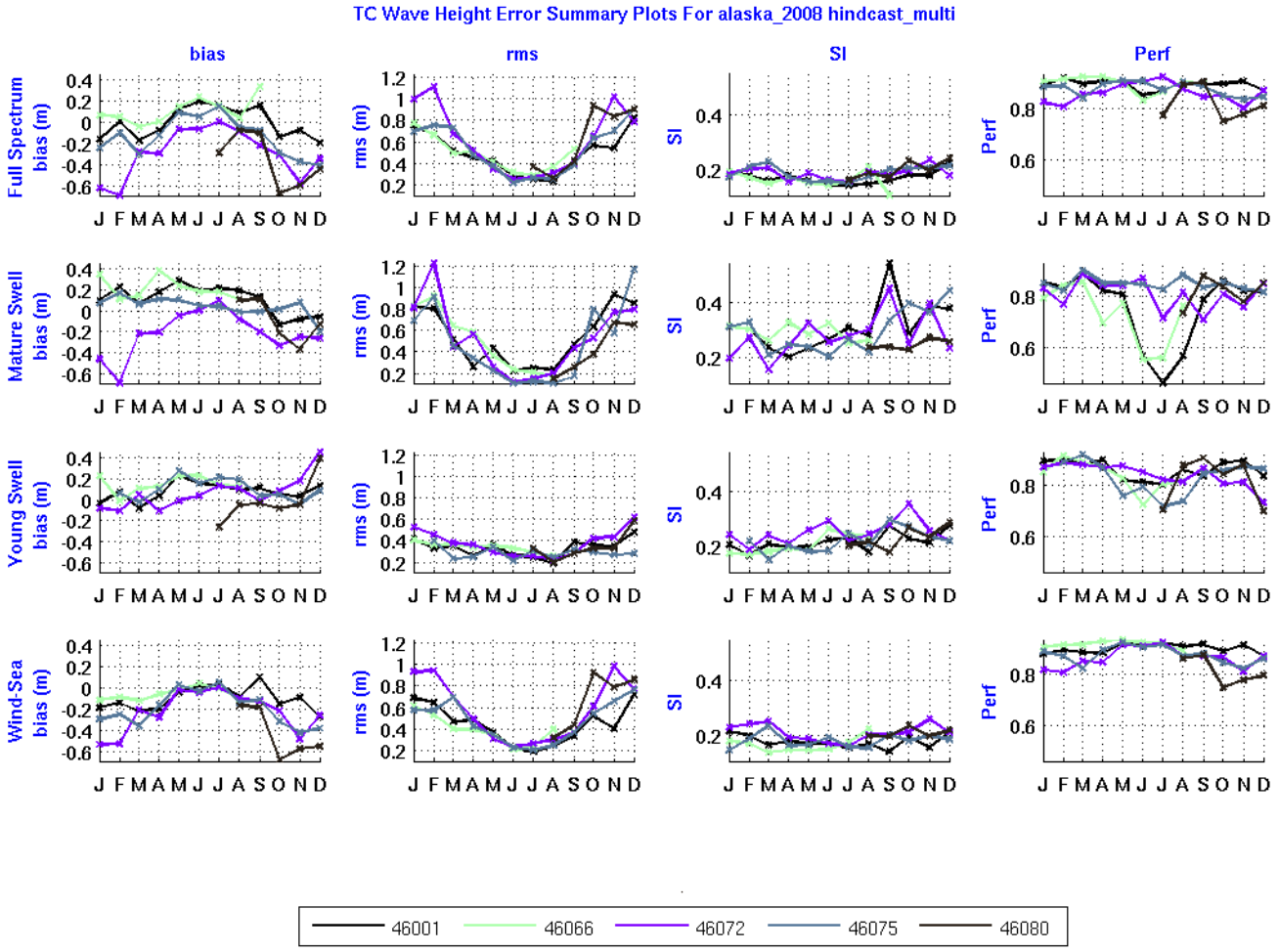
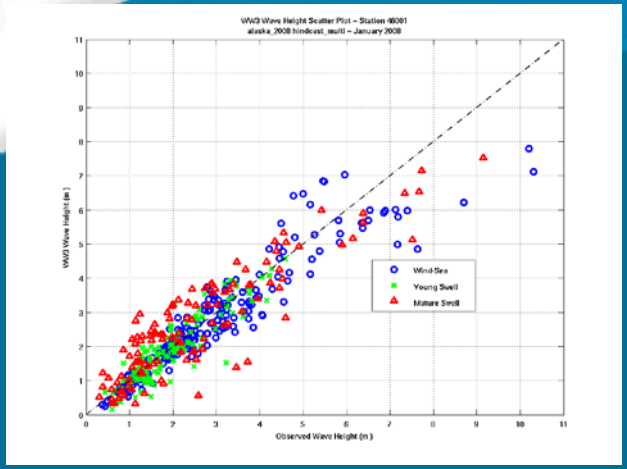
IMEDS (contd.)

Alaska buoys







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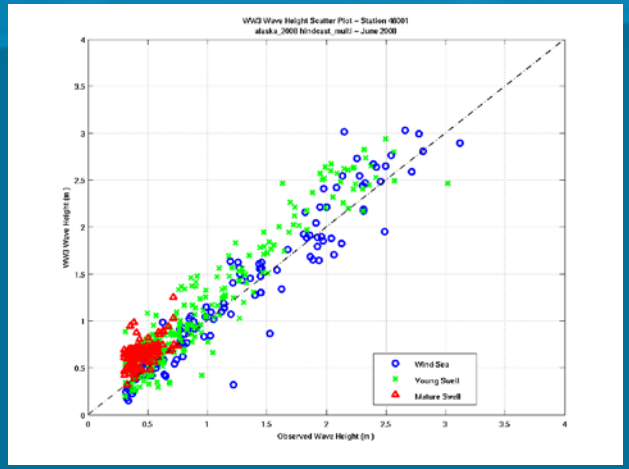

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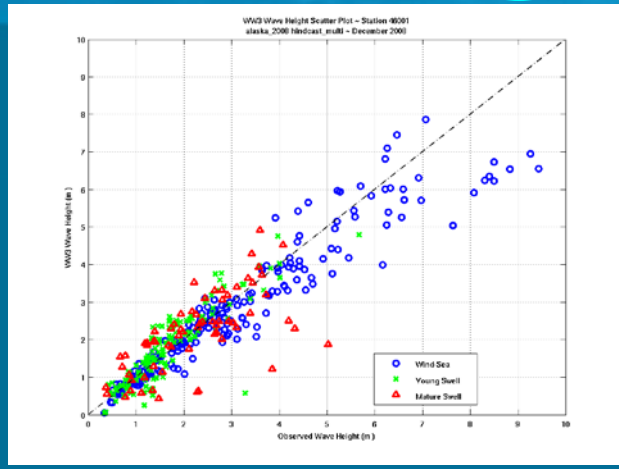

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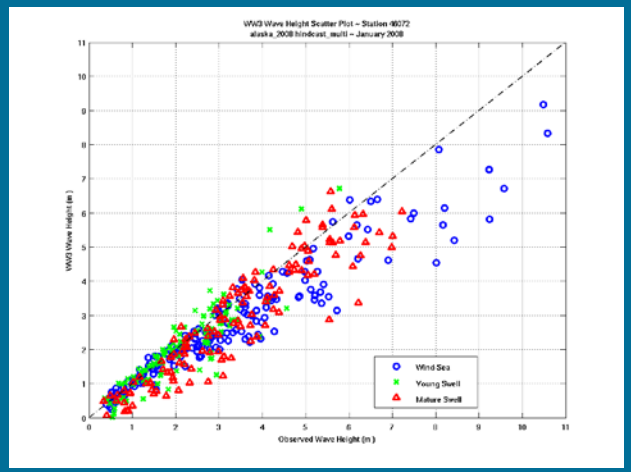

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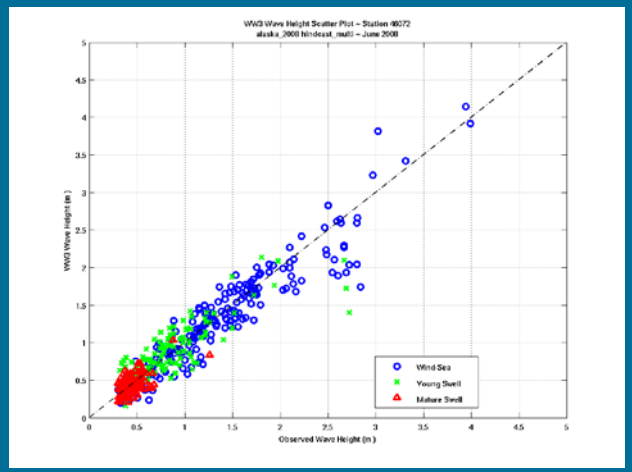

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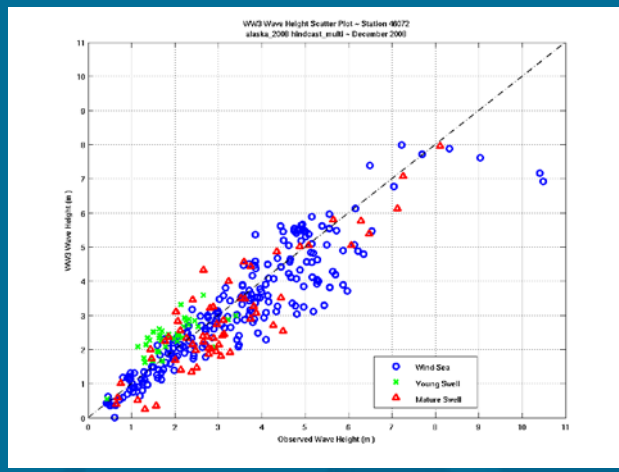

46072 – Dec,2008

CONCLUSIONS

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  - Development of bias coincides with the GFS winds becoming more energetic in this region
- Seasonal bias patterns in the Northern Hemisphere
  - Positive biases in the swell dominated eastern parts of the basin
  - Negative biases in the wind wave dominated western parts of the basin
- Spectral analysis shows
  - Negative biases in wind waves
  - Swell picture is more complex
    - Positive biases in the US West Coast buoys
    - Negative biases in the US East Coast buoys
    - Mixed (positive and negative) biases in the Alaska buoys

CONCLUDING REMARKS

- Bias patterns indicate the need to re-visit the tuning parameters in WAVEWATCH
- IMEDS analysis shows that the model
  - Slightly under predicts the wave heights in the wind wave component
  - Over predicts the wave heights for swells propagating large distances (maybe)
- Swell dissipation in WAVEWATCH is primarily a tuning parameter
- Ardhuin et al (2009) show swell dissipation to be a non-linear process related to wave steepness
- Tuning WAVEWATCH parameters may be delayed till after we get the new physics in (NOPP initiative)