

## Degui Cao, Hendrik L. Tolman, Hsuan S.Chen, Arun Chawla and Vera M. Gerald

NOAA /National Centers for Environmental Prediction Environmental Modeling Center Marine Modeling and Analysis Branch Camp Springs, Maryland, USA

Degui.Cao@NOAA.gov

NCENTERS FOR ENVIRONMENTAL AREIN

Cao et al, Oct. 2009

Halifax 2009, 1/15

## Motivation



- The Global Ensemble Ocean Wave Forecast System (GEOWaFS) was initially implemented in April 2004, and was upgraded on May 30, 2008.
- Motivation for upgrades:
  - > Eventual joining of NCEP and FNMOC ensembles.
  - Cycle initial conditions of individual ensemble members to naturally perturb swell events.
- Motivation for present study:
  - Evaluate the improvement of the new GEOWaFS comparing to the old system
  - Conduct statistical analyses on the performance of the new system.

### Methodology



### Comparison of old and new ensemble systems:

- Deterministic model error versus ensemble spread.
  - Based on buoy data.
- Example wave height files.

# Quality of new ensemble

- Above results.
- Example spaghetti plots.
- Monthly ensemble bias, spread and rns error.
- Talagrande (rank) histograms

### Conclusions



The new GEOWaFS ensemble forecast system shows a significant improvement over the old system.

- Model spread of new system comparable to deterministic model errors, whereas old model had much smaller ensemble spread.
- New ensemble behavior of wave height spread comparable with behavior of spread in forcing.
- The new GEOWaFS system shows encouraging performance.
- Much work remains to be done:
  - > Detailed analysis including Brier scores ongoing.
  - > Expand analysis to include altimeter data.
  - Address wind sea and swell behavior separately to address if the new initialization adequately describes swell perturbations.

### Validation data





Red dots identify buoy locations used for validation in the old system, blue dots identify buoys added for validation in the new system. We are working on validation against altimeter data.

Cao et al, Oct. 2009

Halifax 2009, 5/15

# Ensemble spread vs model error





Old and new ensemble use same winds. Wind spreads are somewhat lower than wind errors but compatible.

Old wave ensemble severely underestimated ensemble spread compared to deterministic model error. New model is a massive improvement, with wave height behavior comparable to wind speed behavior.

# System comparison





Old ensemble setup, ensemble with cycling of initial conditions and wind bias correction (BC).

Mean wave height (contours) and spread (shading)

2008/03/28 t06z nowcast



# System comparison





2008/03/28\_06z, 048 fest\_hr Ensemble Mean (contour, m) & Spread of Hs Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Valid 2008/03/30 06z Cycle Valid 2008/03/30 06z Cycle Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Valid 2008/03/30 06z Cycle Cycle Valid 2008/03/30 06z Cycle Cycle Cycle Valid 2008/03/30 06z Cycle Cycl

#### 2008/03/28 t06z 48h forecast

Old system has still not caught up with spread of new system in nowcast. This suggests that cycling of initial conditions adds `memory' of more than 48h.



# System comparison





2008/03/28\_06z, 120 fcst\_hr Ensemble Mean (contour, m) & Spread of Hs Valid 2008/04/02 06z Cycle Cycle

#### 2008/03/28 t06z 120h forecast

Old system has significant spread in storm tracks, but still very limit spread near equator.

Swell has `memory' of up to a week.



# Example spaghetti plot





Example of information content of ensemble: Obs are generally in ensemble range, ensemble mean generally outperforms deterministic control, clear change in predictability at 100h, with waves lagging winds.

# Wind and wave bias





Wind and wave biases as a function of forecast hour for individual months. Wave biases are generally very small [0(0.1m)], and show now relevant systematic behavior.

# Wind and wave spread





Corresponding spreads. Spreads are larger in winter periods, corresponding to larger mean state..

### Wind and wave rmse





Corresponding errors against buoy data. Errors are larger in winter periods, corresponding to larger mean state..

# Wave Talagrande histogram





Talagrande (rank) histograms for wave heights show some underestimation of spreads, but no significant bias or othe spurious behavior.

### Conclusions



The new GEOWaFS ensemble forecast system shows a significant improvement over the old system.

- Model spread of new system comparable to deterministic model errors, whereas old model had much smaller ensemble spread.
- New ensemble behavior of wave height spread comparable with behavior of spread in forcing.
- The new GEOWaFS system shows encouraging performance.
- Much work remains to be done:
  - > Detailed analysis including Brier scores ongoing.
  - > Expand analysis to include altimeter data.
  - Address wind sea and swell behavior separately to address if the new initialization adequately describes swell perturbations.