Multi-grid WAVEWATCH III

Implementation of a new wave forecast model

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Talk outline

- Motivation
  - New model features
    - Multiple grids
    - Data partitioning
    - Obstruction grids
- Design of new forecast model suite
- Testing
  - Comparisons with old wave modeling suite
  - Comparisons with Hurricanes
    - Isabel
    - Katrina
- Summary

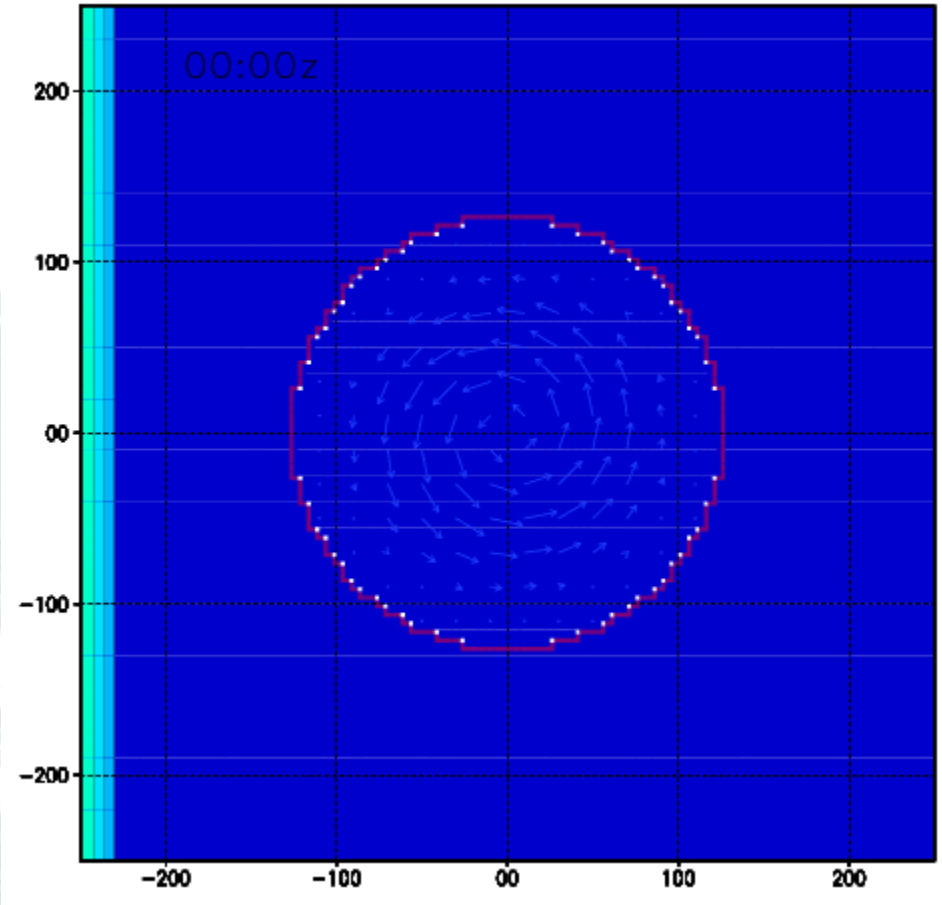
Motivation

- A new version of the WAVEWATCH III wind wave model that features
  - full two-way interactions between an arbitrary number of grids with an arbitrary range of resolutions.
  - Option to set nodes inactive (particularly useful in nested grids)
  - An elegant algorithm for proper partitioning of spectral energy
  - Shallow water breaking to account for surf-zone physics
  - Linear growth term (for sea states starting from rest)
- Our Aim
  - Providing consistent guidance for NDFD grids for deep-ocean, offshore and coastal grids with a single model (present implementation).
  - Provide wave guidance directly on GFDL and HWRF grids for coupled system (still under development).

The mosaic approach

- An unlimited number of grids that are run as separate wave models with full interaction between grids.
- Grids identified with rank number with lower rank identifying lower resolution, and same rank identifying similar, but not necessarily equal resolution.
- Basic interaction approaches:
  - Higher resolution grids get boundary data from lower resolution grids.
  - Lower resolution grid points covered by higher resolution grids obtain spatially averaged data.
  - Similar resolution grids are reconciled in their overlap.

Example – Two – way nesting



Current ring with circular inner domain. Input wave height is 2.50m, contours at 0.20m, including 2.40 and 2.60. Third order UQ scheme.

One-way nesting

Two-way nesting

Movie loop.

Wave field separation

- Partitioning provides for each wave field:

  H_s, T_p, L_p, θ_m, σ_m.

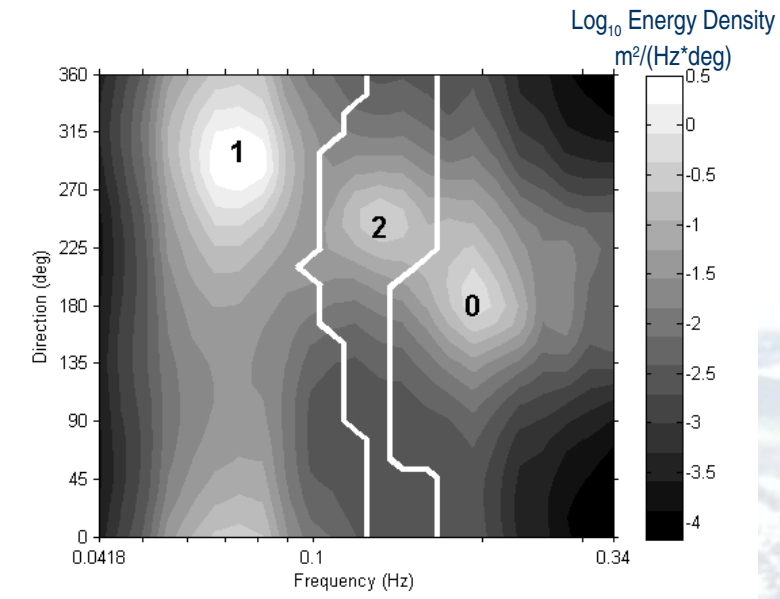
  Fraction of energy that is wind-driven.

- Conventional field output for

  Wind sea, primary and secondary swell (all 6 parameters).

  Overall wind sea fraction.

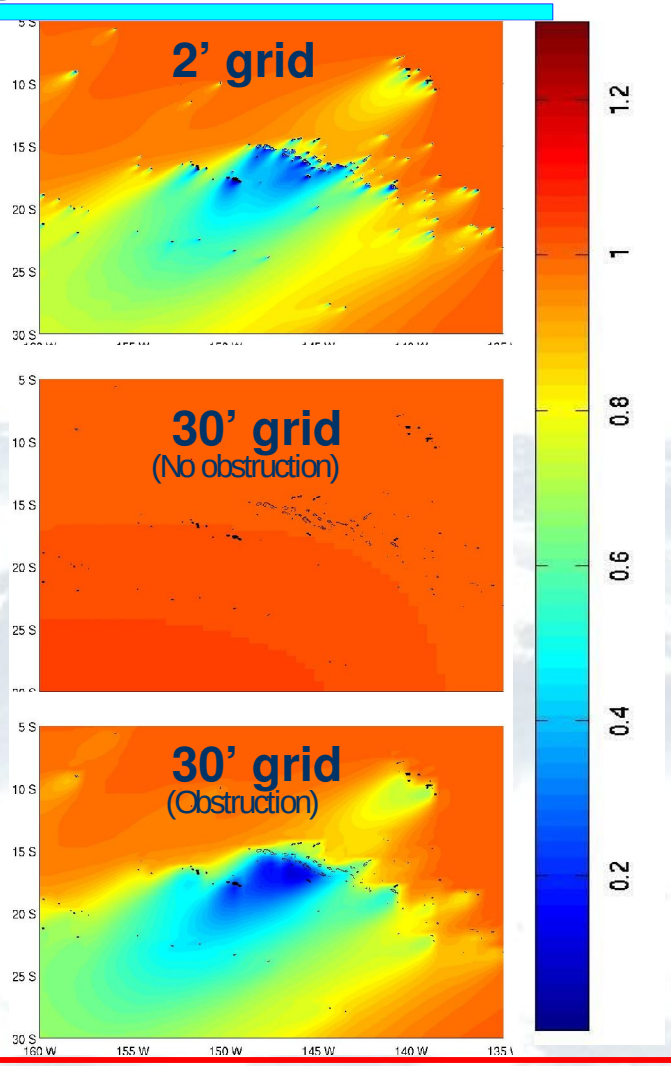
  Local number of wave fields.



Example of partitioned spectrum, courtesy of Jeff Hanson.

Obstruction grids

- Obstruction grids simulate sub-grid blocking
- Obstruction grids for NWW3 developed manually
- An algorithm developed for generating obstruction grids using a global shoreline database
  - Database consists of over 188000 shorelines (ranging from small atolls to continents)
  - Consistent obstruction grids across grids of different resolution



Multi-grid NWW3

1

- Our aim

  Provide forecast guidance at or near the NDFD grid resolutions in the deep ocean, shelf and coastal waters

  Ensure that a particular forecast cycle (from input file preparation to product generation) is completed in the allocated time slot for waves (30 minutes)

  Make our products ready for AWIPS build 8.3 (GRIB2)

  Continue providing old products (for the model suites being replaced) to provide enough transition time from the NWW3 modeling suites to the multi-grid NWW3 modeling suite

Multi-grid NWW3

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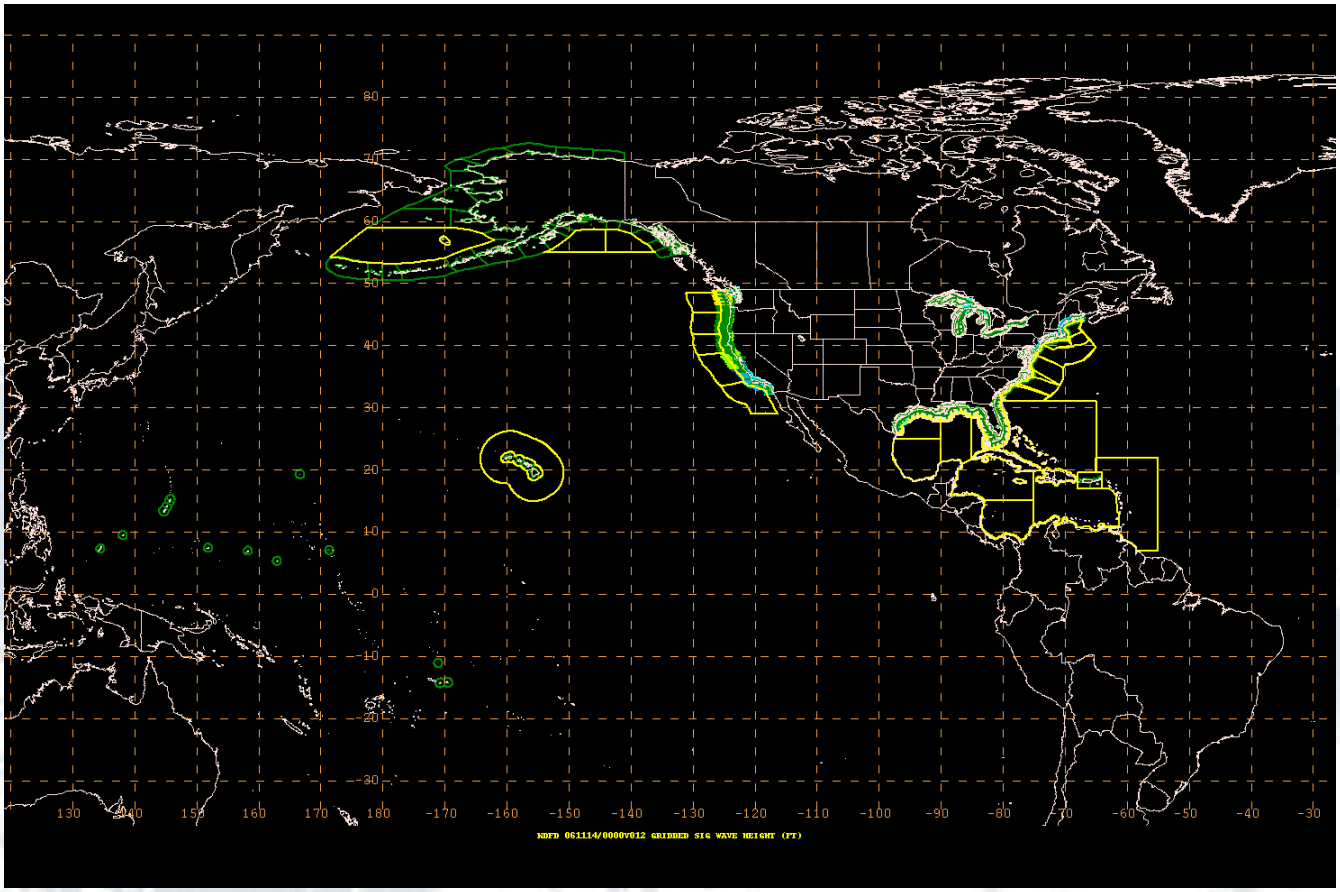

NWS areas of responsibilities and NDFD grids

Courtesy Joe Sienkiewicz

Multi-grid NWW3

3

- To provide consistent guidance for all these areas, the new operational NCEP model will consist of a mosaic of 8 grids:
  - A global 30' grid.
  - An offshore Atlantic 10' grid.
  - An offshore West Coast 10' grid.
  - An east Pacific 10' grid.
  - An Alaskan 10'x15' grid.
  - A coastal Atlantic 4' grid.
  - A coastal West Coast 4' grid.
  - A coastal Alaskan 4'x8' grid.

- Note: previous highest model resolution was 15'.

Multi-grid NWW3

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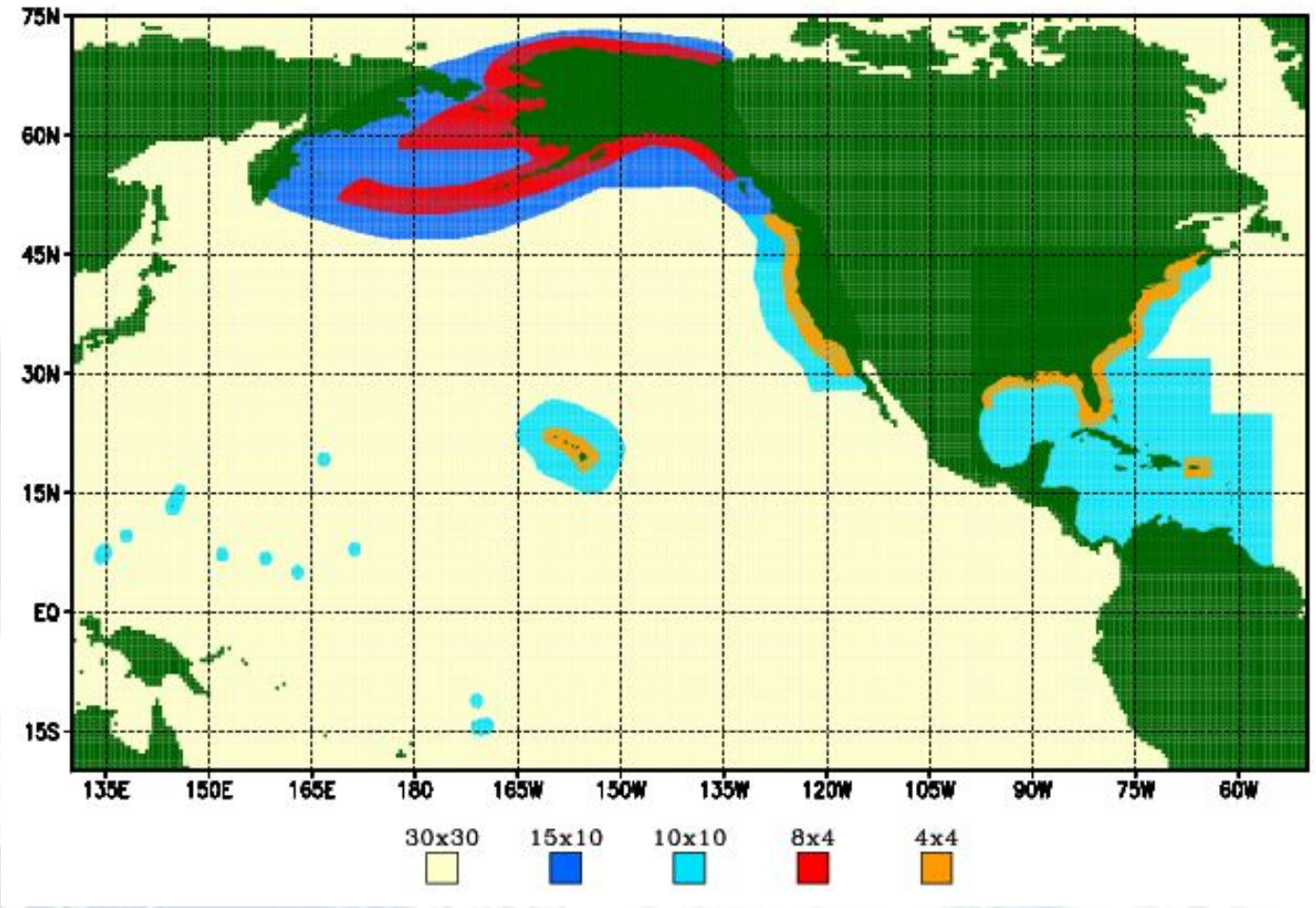
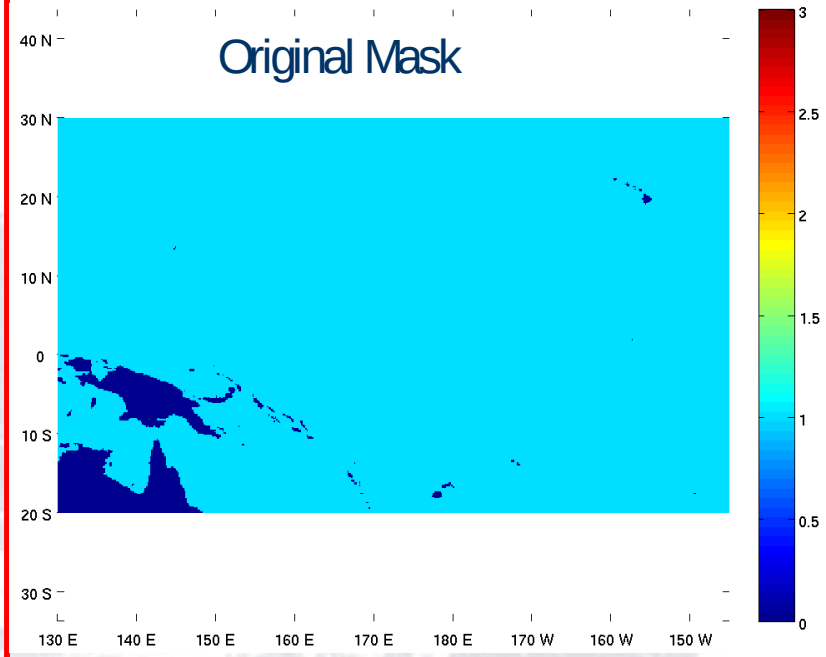
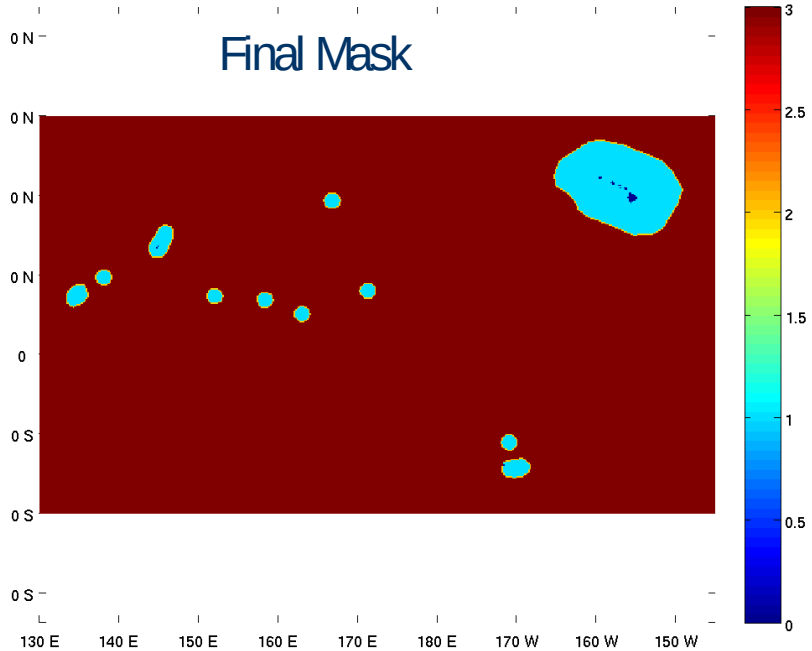


Resolution in minutes of the 8 grids making up the multi-grid model

Multi-grid NWW3





Computational domain for the Eastern Pacific regional grid (10')

Multi-grid NWW3

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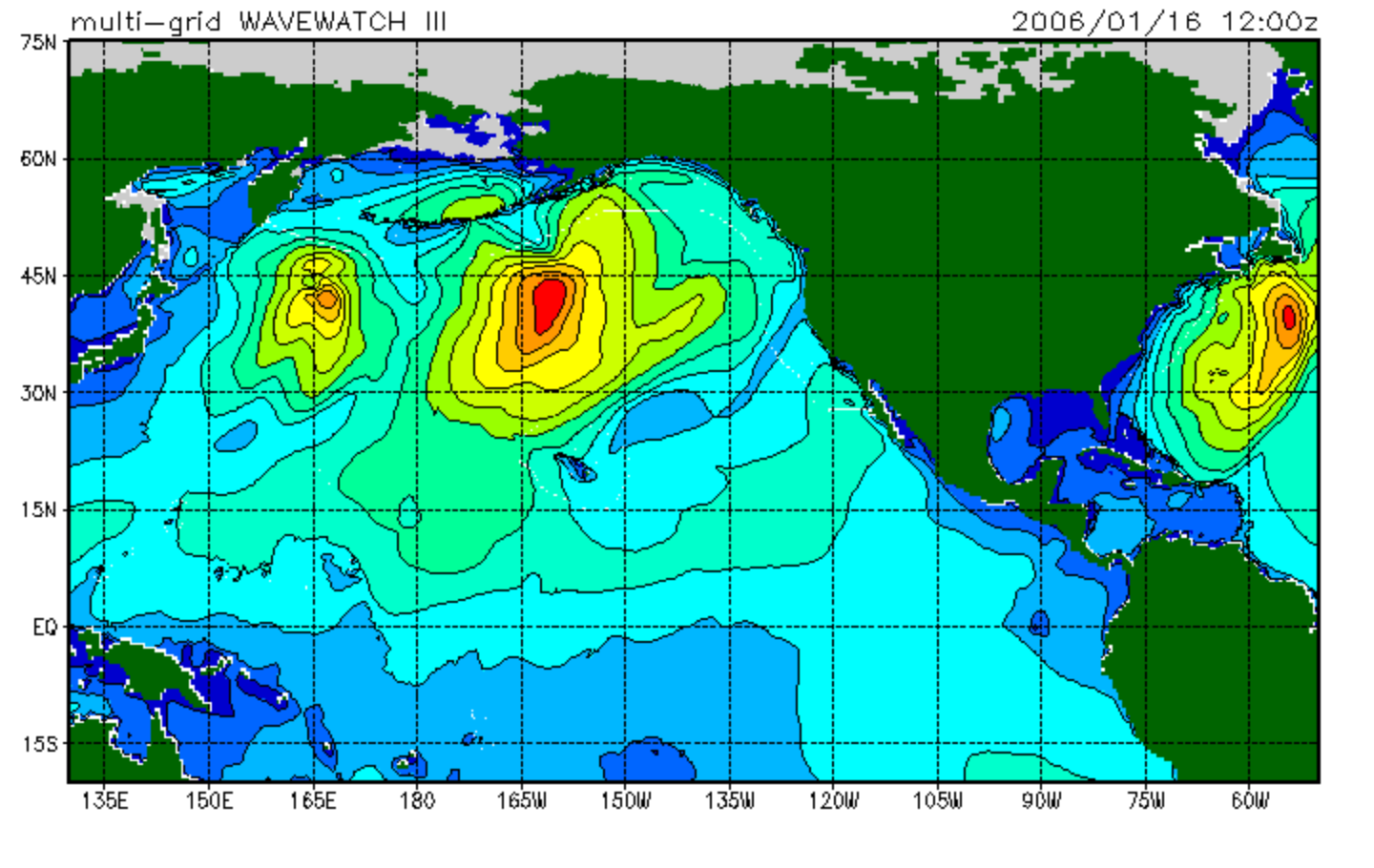

Example of consistency between grids

Multi-grid NWW3

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- Additional Features
  - Consistent obstruction grids across different resolutions
  - Input forcings (wind and ice) on single global grids
  - All output directly written in GRIB2 format
  - Option to dedicate nodes for I/O (reduces model run time)
  - Unified point output (extracted from the highest resolution grid)
  - Additional outputs due to energy partitioning algorithm
    - Wave height data partitioned to – Wind seas, Primary and secondary swells
    - Same for peak period and mean direction as well

Multi-grid NWW3

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- New grids will go into AWIPS build 8.3.
- For now, all old grids are populated with results from new model.
  - New results will go into present AWIPS on old grids.
  - No impact on NCEP web site.
- Run particulars
  - 4 cycles a day (00z, 06z, 12z,18z).
  - Each cycle is 9h hindcast and 180h forecast.
  - Output
    - Point output (over 500 selected locations) – spectral and bulletin files with hourly information
    - Field output – GRIB2 files with a time increment of 3 hours
- New MMAB web site available with high-resolution data (Todd Spindler)
  - Maps available for 15 different regions (trivial to add a new region)
  - Clickable maps for point data
  - Data access available up to 6 cycles back (including latest run)

Multi-grid NWW3

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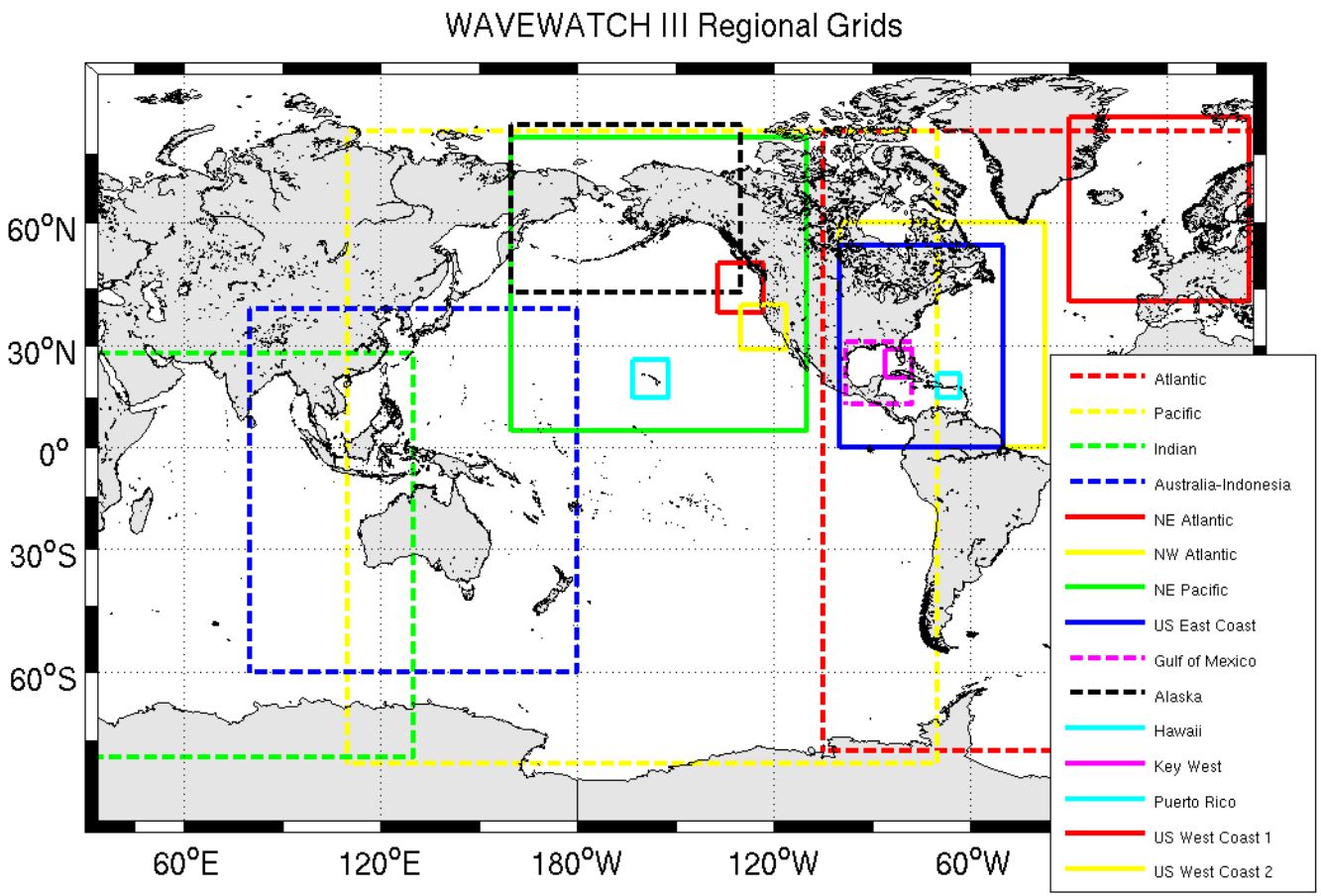


Modeling suite overview

- Old
  - AKW, WNA and ENP regional models (15' grid)
  - NWW3 global model (1° x 1.25° grid)
  - NPH hurricane model (15' grid)
  - NAH hurricane model (15' grid)
  - Data assimilation model (from NWW3 global)
  - Ensemble model (from NWW3)
- New
  - One multi – grid model to replace the AKW, WNA and ENP suites
  - Maintain NWW3 for data assimilation and ensemble modeling projects only
  - NAH and NPH to be replaced later

Stages of a forecast cycle

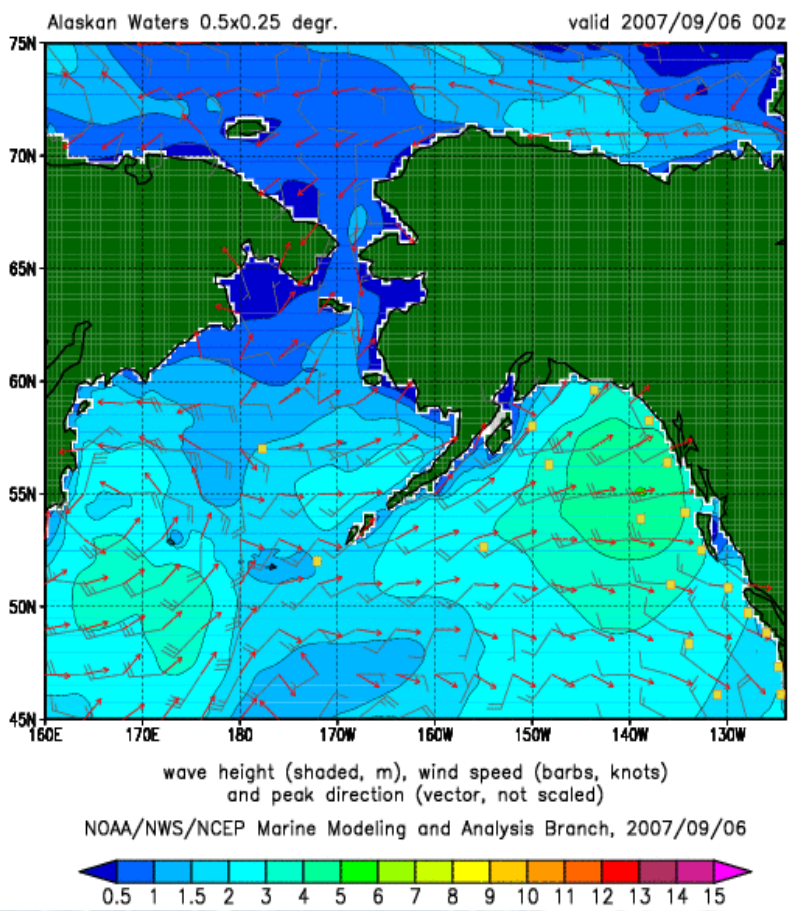
- Preparation (1 min 12 s)
  - Generates input and restart files for a forecast run
- Forecast run (26 min 40 s)
  - Creates the raw output
- Post processing (4 min 11 s)
  - Creates spectral data and bulletin files for point output locations
  - Creates GRIB2 files
  - Interpolates to old AKW, WNA and ENP grids and generates GRIB1 files
- Web products (6 min 20 s)
  - Station plots
  - Maps of wave field statistics
- Data transfer (11 min 25 s)
  - Transfer of images, GRIB2 files, spectral and bulletin files to FTP and WEB server (for MMAB waves website)
- Archiving
  - Input forcing files
  - Altimetry data and collocated model output
  - Point output files (for buoy data only)

Testing

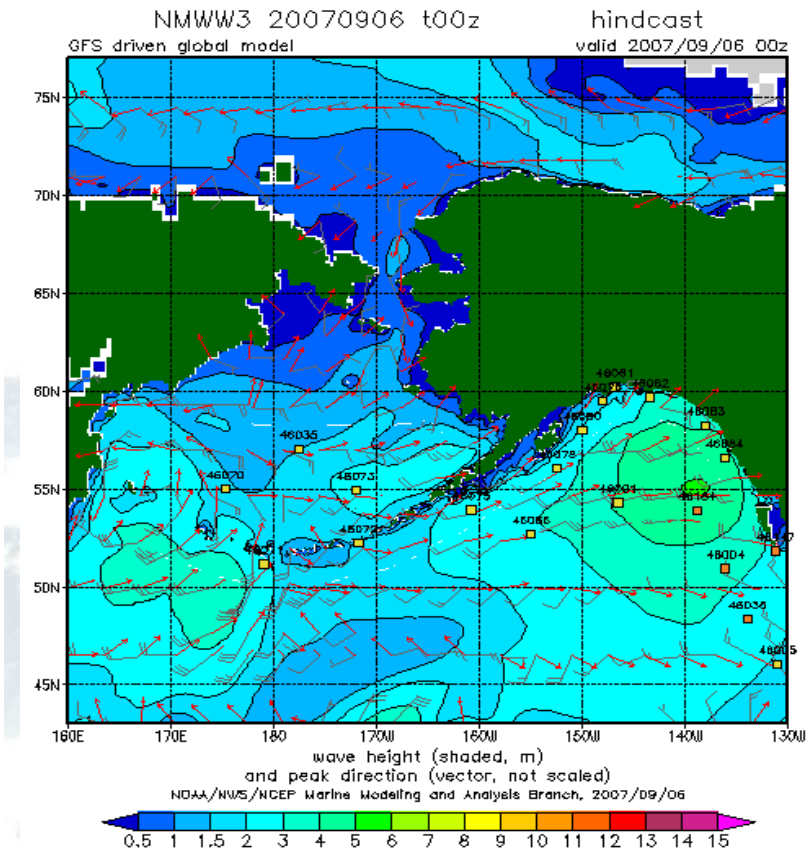
- MMAB has been running this model in parallel since March 2007.
- Comparison between old and new forecast runs show no notable impact on deep ocean or shelf behavior.
  - As expected for technology upgrade.
  - As confirmed by TPC and others.
- Reruns of Isabel and Katrina to :
  - Demonstrate impact of increased resolution and representation of unresolved islands as obstructions.
  - Demonstrate model improvement by adding surf-zone physics for extreme coastal waves

Forecast Comparisons

1

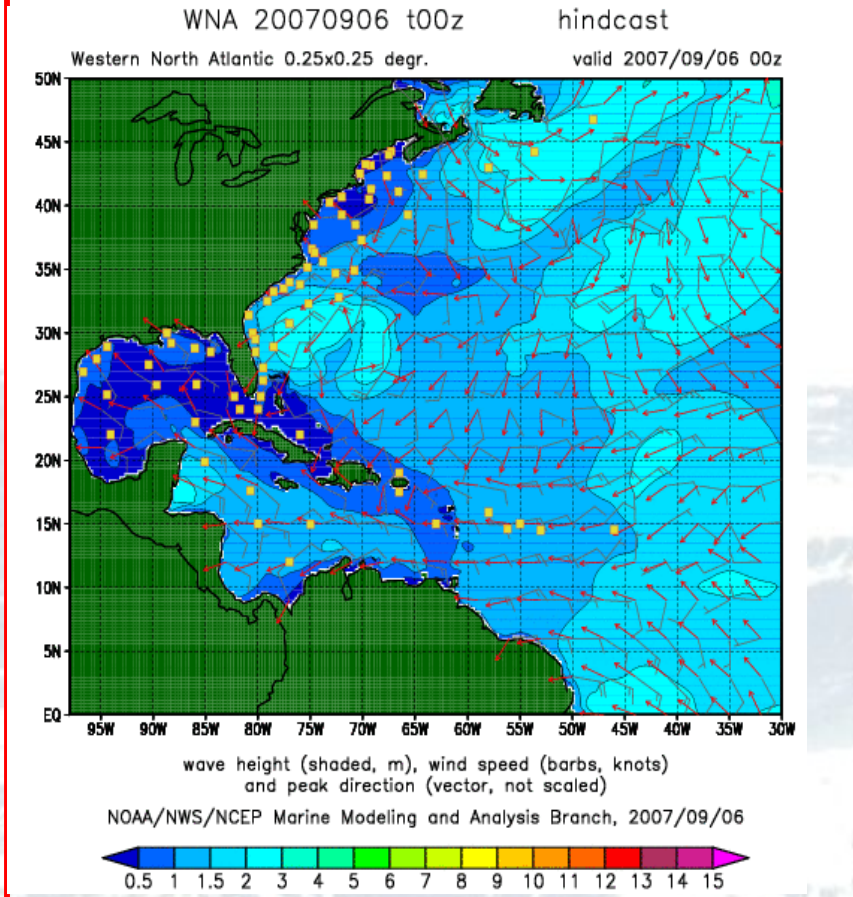


old AKW model

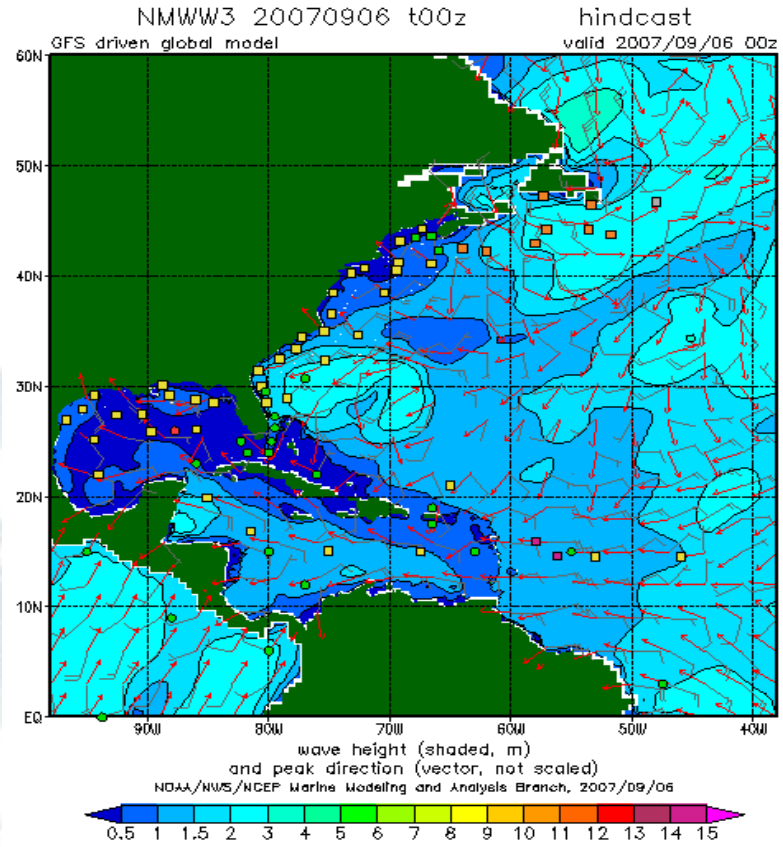


New multi-grid model

Forecast Comparisons 2

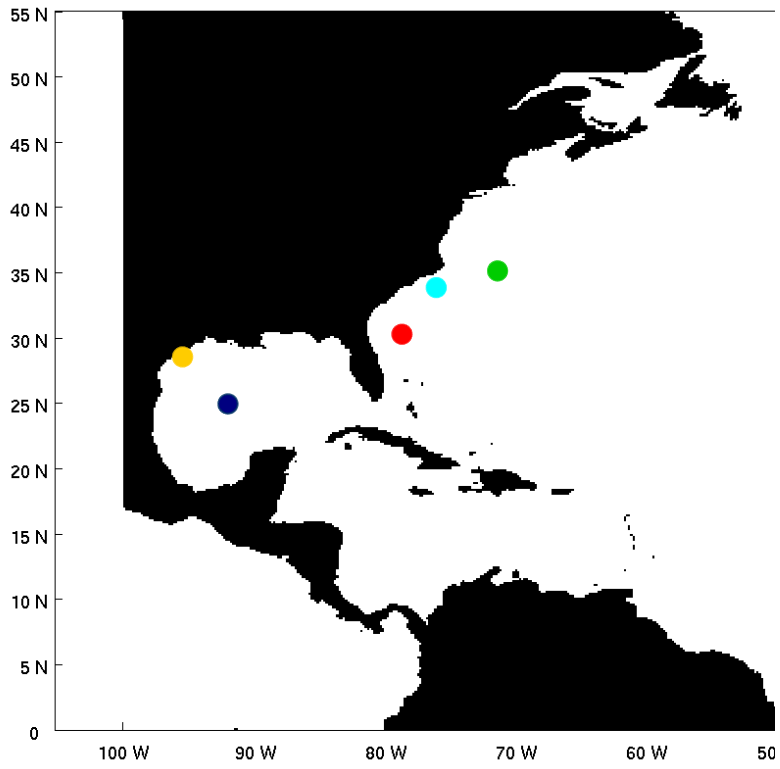


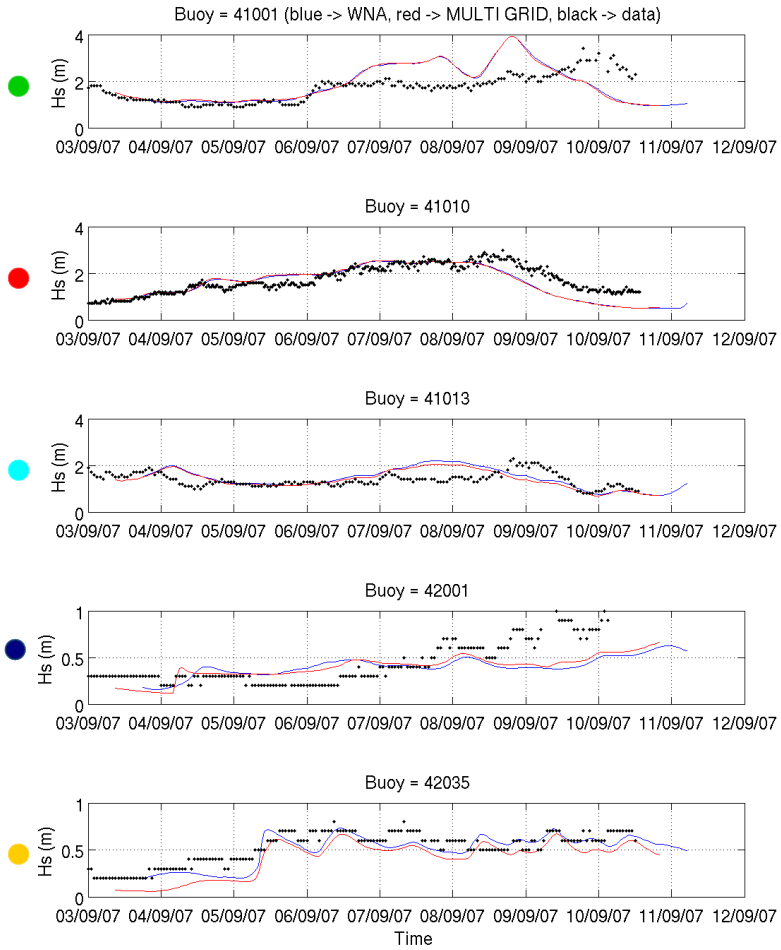
old WNA model



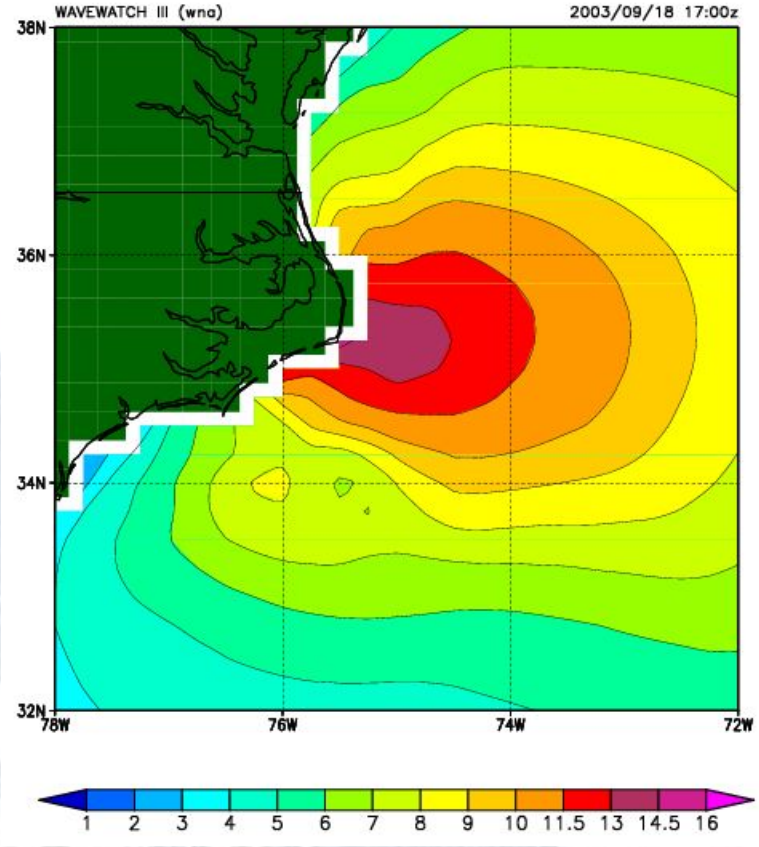
New multi-grid model

Forecast Comparisons 3

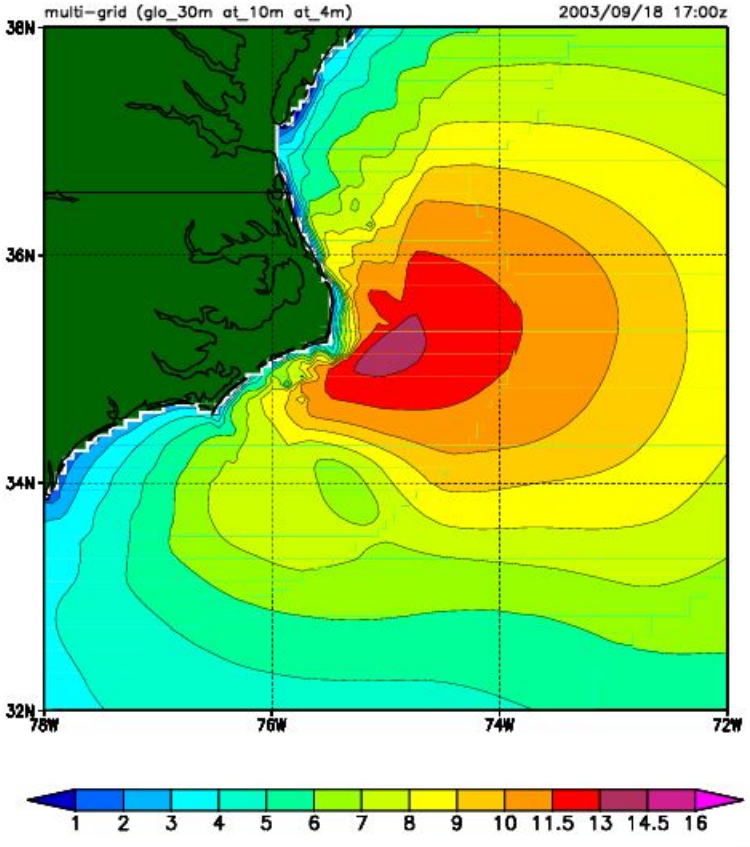




Isabel 1



old WNA model

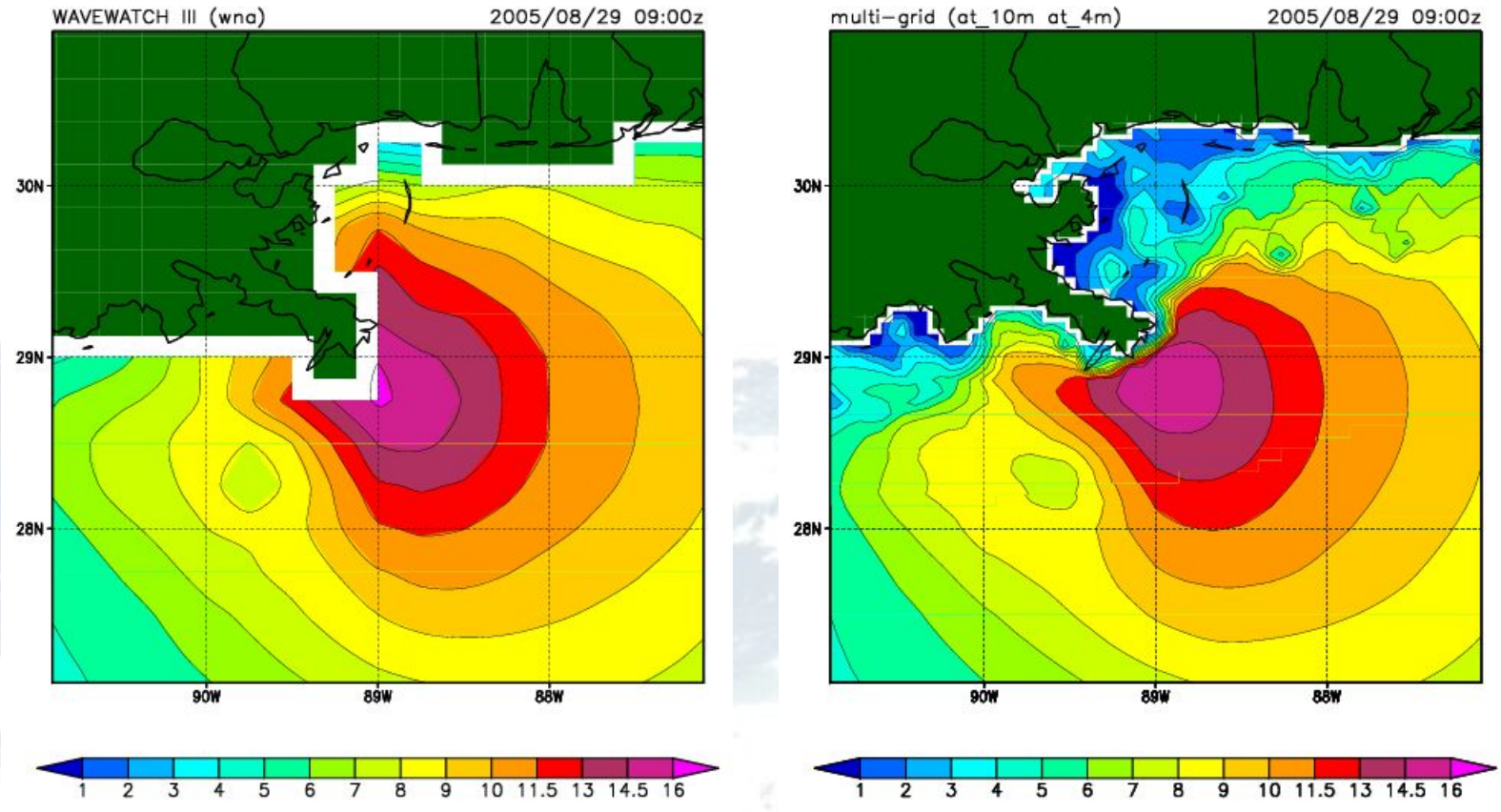


new multi-grid model including surf zone physics

Isabel 2

- Observations from previous slide:
  - Deep-ocean wave conditions virtually identical.
  - Massive improvement of coastal resolution.
  - Appropriate attenuation of wave heights is shallow coastal areas in new model due to added surf zone physics.
    - Wave height to water dept ratios in new model stay below 0.5-0.6 in new model (as expected based on beach observations).
    - In the old model this ratio is larger than 1.5 in selected areas (illustrated for Katrina in the following slides).

Katrina 1



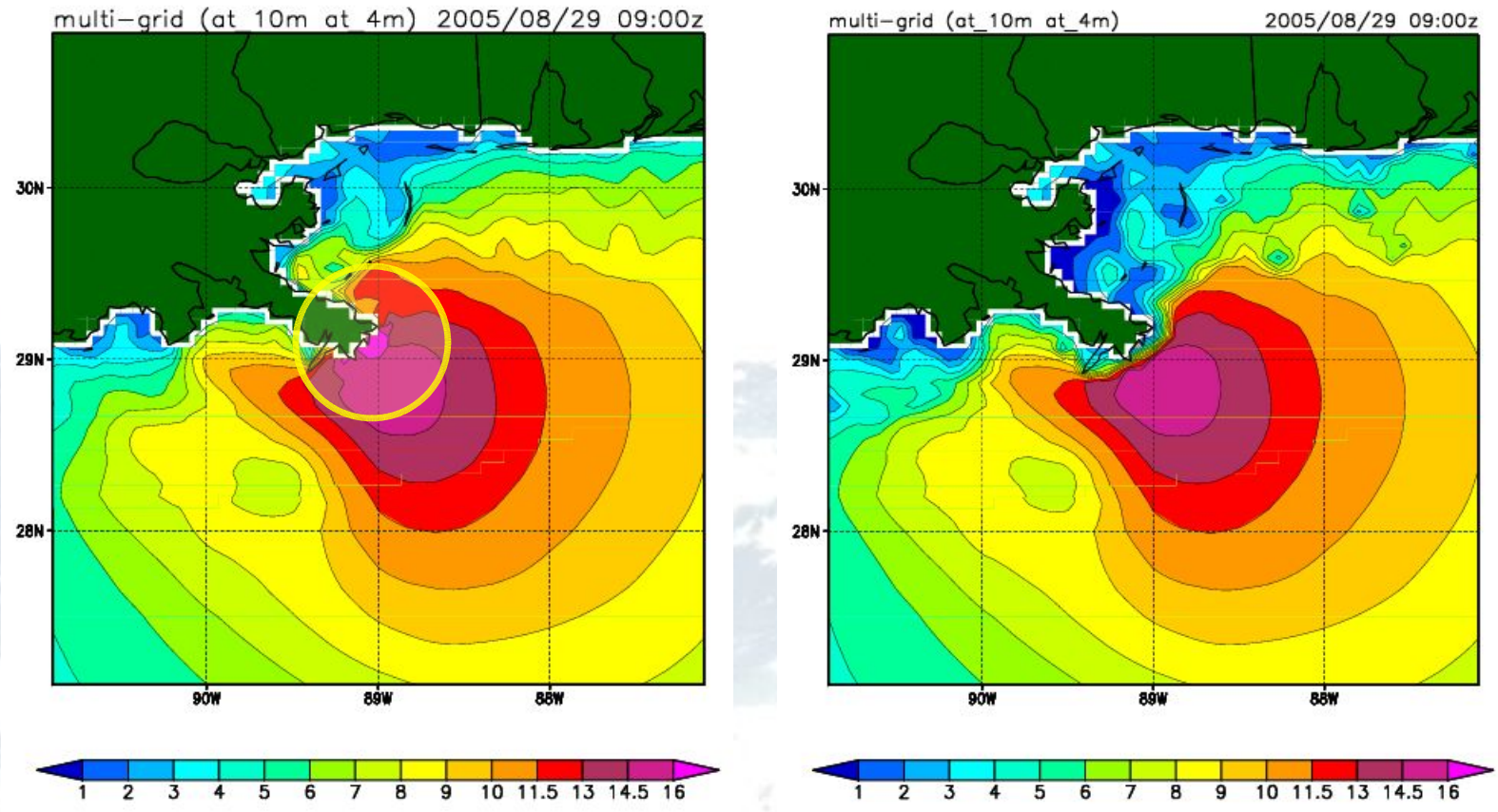
old WNA model

new multi-grid model including surf zone physics

Katrina 2

- Observations from previous slide are almost the same as for Isabel:
  - Deep-ocean wave conditions virtually identical.
  - Massive improvement of coastal resolution, and of obstructions to reproduce blocking effects of Chandeleur islands.
  - Adding first surf-zone physics to model (depth-induced wave breaking has major positive impact on model (see following slides).
    - Removing bulls eyes in wave heights.
    - Realistically limits wave heights to fraction of water depth. Previously wave heights could be multiples of water depth.

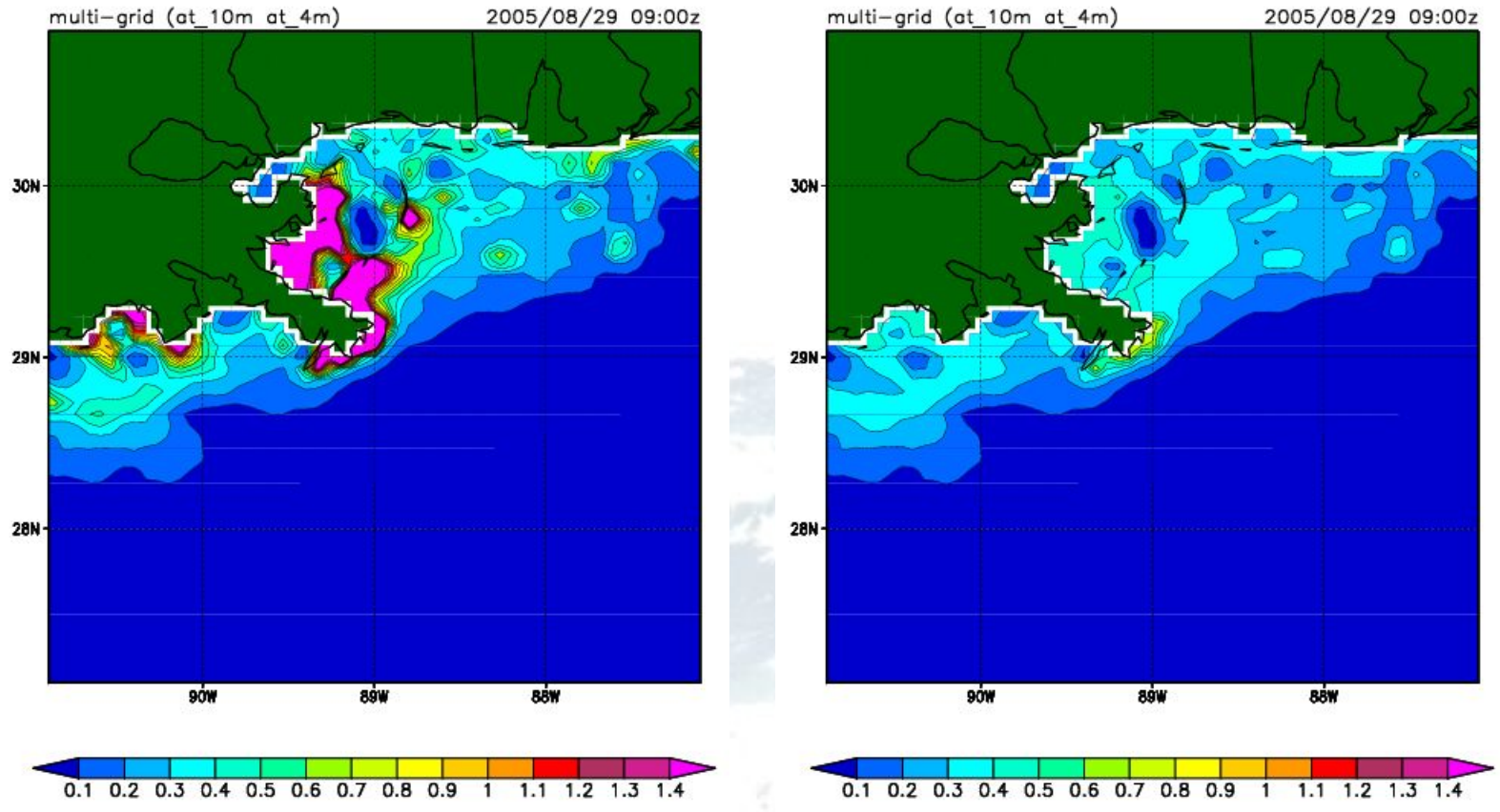
Katrina 3



new multi-grid model without surf zone physics

new multi-grid model including surf zone physics

Katrina 4



Corresponding wave height to water depth ratio without (left) and with (right) surf-zone physics. In the latter case, waves no longer get higher than water depth.

Summary of Changes

- 3 regional models replaced by a single multi – grid model (global model to be replaced later)
- Grid resolution in the new model chosen to provide wave guidance on the NDFD grids
- New model provides output in GRIB2 format (as opposed to GRIB 1 for the old models)
- Additional wave fields from partitioning of wave spectra
- Each cycle consists of 9h of hindcast and 180h of forecast
- Changes in the model physics algorithm
    - Improved shallow water physics in the surf zone
    - A new linear growth term for simulations starting from calm (no waves) conditions