Advances in wind wave modeling

1944 - Presidents Day Storm 1979 – now

Focus on history and technological advances.

Hendrik L. Tolman
Acting Director, Environmental Modeling Center
Chief, Marine Modeling and Analysis Branch
NOAA / NWS / NCEP / EMC

Hendrik.Tolman@NOAA.gov

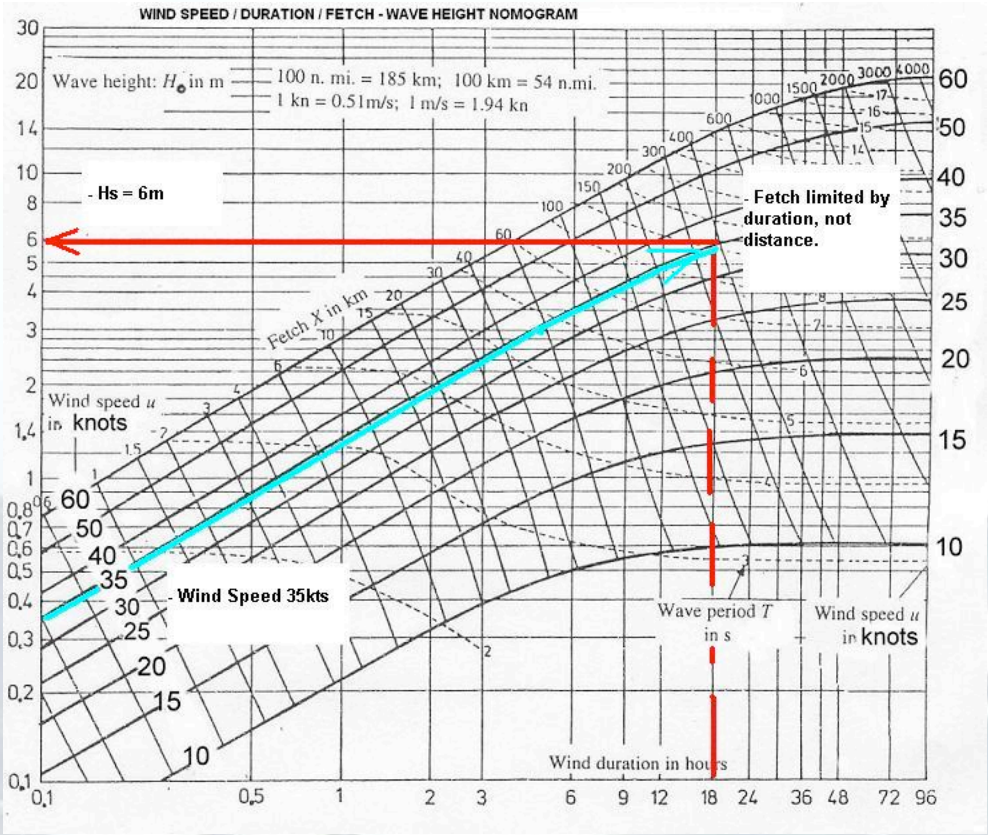
Generally, predictions of wave conditions for D-Day (June 1944) are considered the first attempt at operational wave forecasting.

- Mulberry harbors of Gold Beach June 1944.

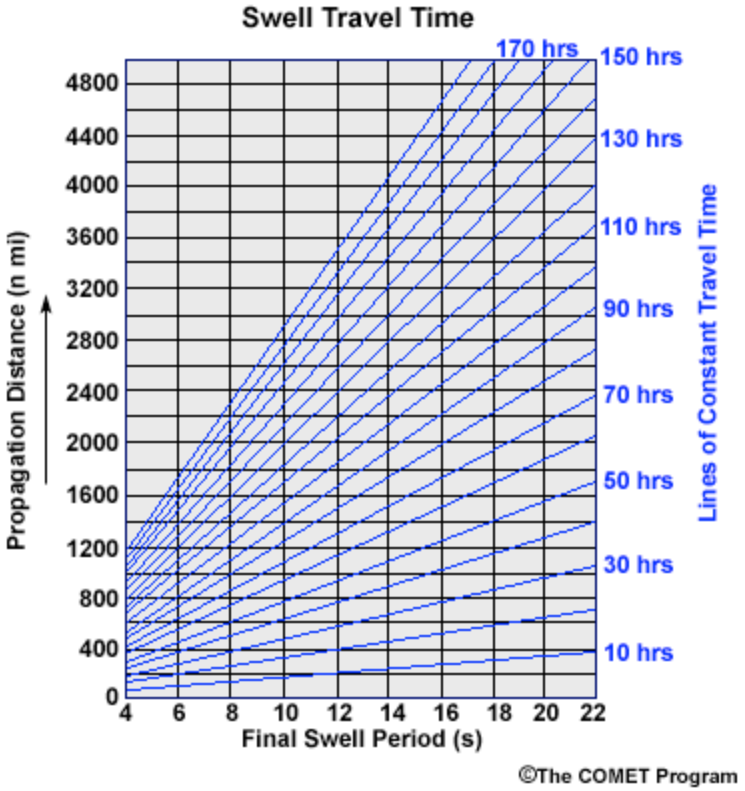
History of NCEP/EMC (and predecessors) guidance:

- 1956: Single a wave height and period based on present and recent local winds.
- 1968: The system was expanded to estimate a single wind seas and a single swell (H_s, T_p).
- 1985: First operational spectral wave model.
- 1994: First third-generation spectral model (WAM).
- 1993: WAVEWATCH III model development starts.
- 1999: First WAVEWATCH III implementation.
  - Swell prediction.
- 2007: Multi-grid modeling.
- 2012: Nearshore Wave Prediction System.

Nomogram Era, before 1985



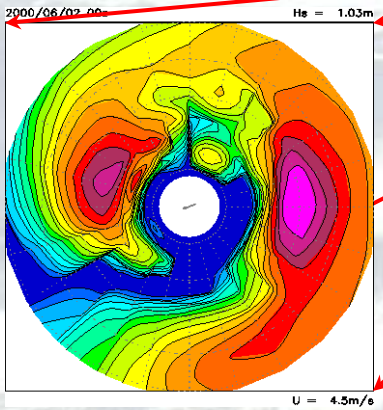
Groen and Dorrestein (1976)

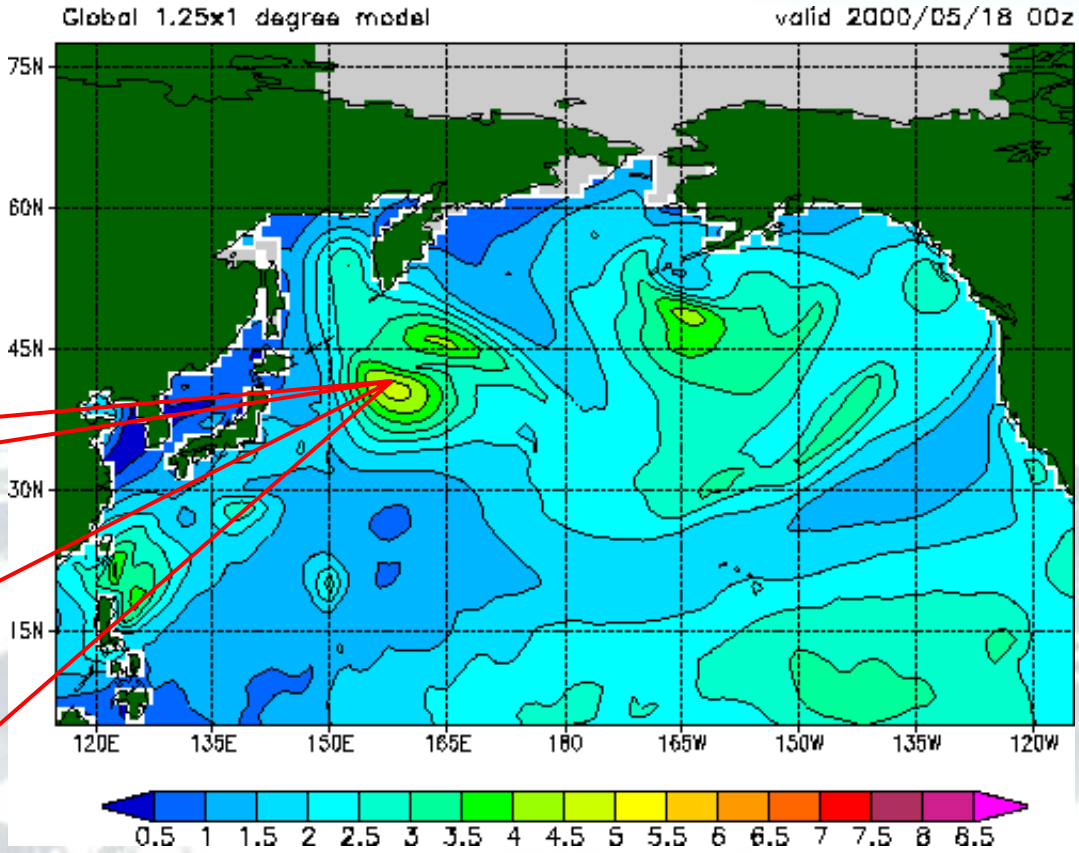


Spectral Era, 1956 literature, 1985 NCEP

significant wave height (m)

Spectral description of wave field at each grid point





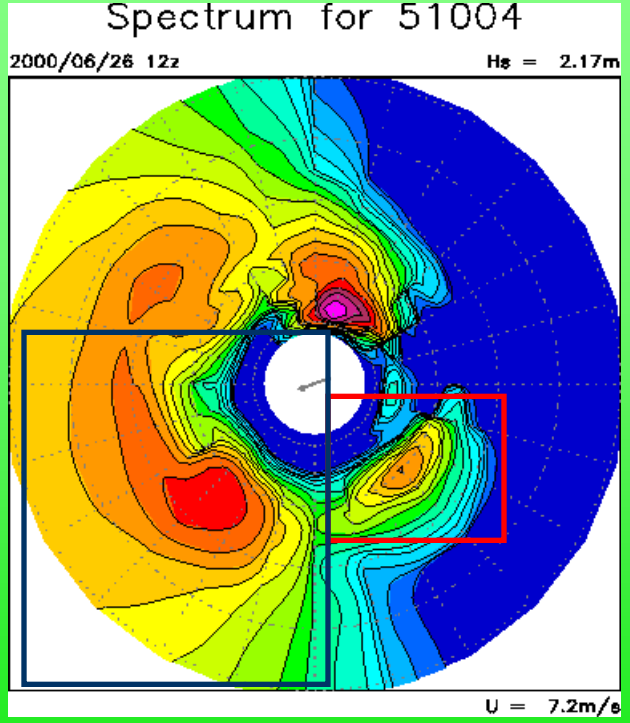
With the introduction of the spectral models, the technology reached present day levels, but forecasters would only get mean parameters. Info in internal spectra was not available.

Spectral Era, WAVEWATCH III

First time we produced spectral information for forecasters:
From the original web page primer

The energy in the red box thus represents an individual wave field traveling in SE direction with a peak period of about 10s Because wave energy is concentrated in frequency and direction this corresponds to a fairly regular, well organized wave field.

The energy in the blue box travels in SW direction at lower periods, and is more chaotic as energy is distributed over a wider range in directions and frequencies.



First time we produced spectral information for forecasters:
From the original web page primer

The spectral plots from the wave model mostly give qualitative information. The corresponding quantitative information can be found in the bulletins.

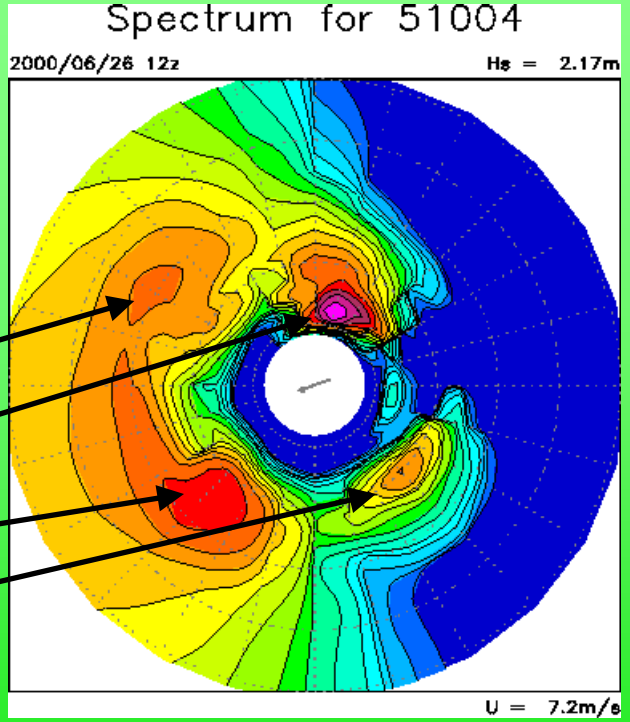
A piece of such a bulletin is presented below. The first column gives date and hour, the second the overall wave height and number of identified individual wave fields. The next six columns (only two shown here) identify wave fields by height, period and direction.

```
Location : 51004      (17.40N 152.50W)
 Model    : NWW3 global 1x1.25 degr.
 Cycle    : 20000626 t00z
+-------+-----------+------------------+------------------+
| day & |  Hst  n x |     Hs   Tp dir |     Hs   Tp dir |
|  hour |  (m)  - - |    (m)  (s) (d) |    (m)  (s) (d) |
+-------+-----------+------------------+------------------+
| 25 12 |  1.9  7   |    1.0 17.5  19 |    1.0  7.0 292 |
| 25 13 |  1.9  7   |    1.0 17.6  19 |    1.0  7.0 292 |
| 25 14 |  1.9  6   |    1.1 17.6  19 |    0.9  7.1 292 |
```

First time we produced spectral information for forecasters:
From the original web page primer

The info in the spectral plots and the bulletins can be combined as follows (H_s is significant wave height, T_p is peak or dominant period)

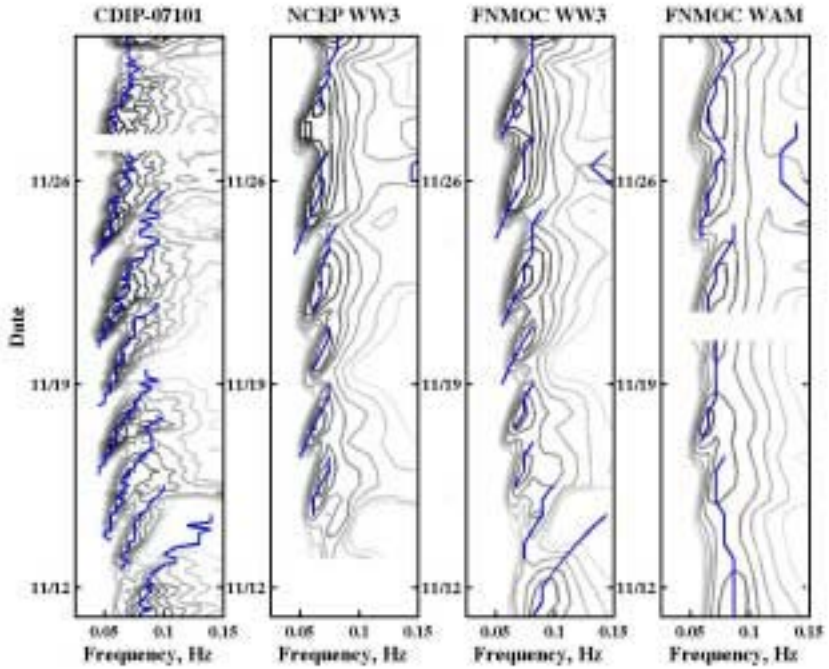
H_s = 0.7m, T_p = 6.6s
H_s = 1.4m, T_p = 15.9s
H_s = 1.4m, T_p = 7.0s
H_s = 0.3m, T_p = 9.9s

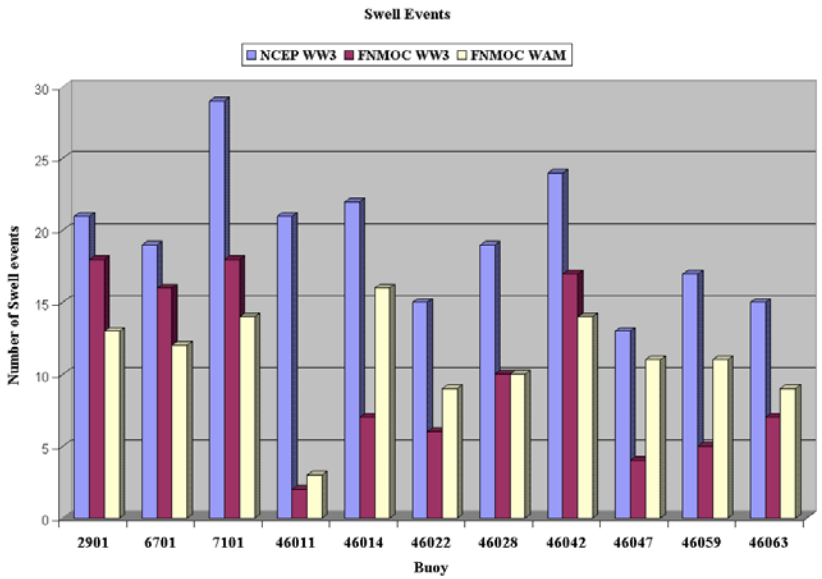



```
| 26 12 |  2.2  4 | 1.4 15.9  16 | 0.7  6.6 306 | 1.4  7.0 239 | 0.3  9.9 136 |
```

Spectral Era, WAVEWATCH III

Joe Sienkiewicz, ca 1999: “This is the first model that we can actually use for swell prediction”

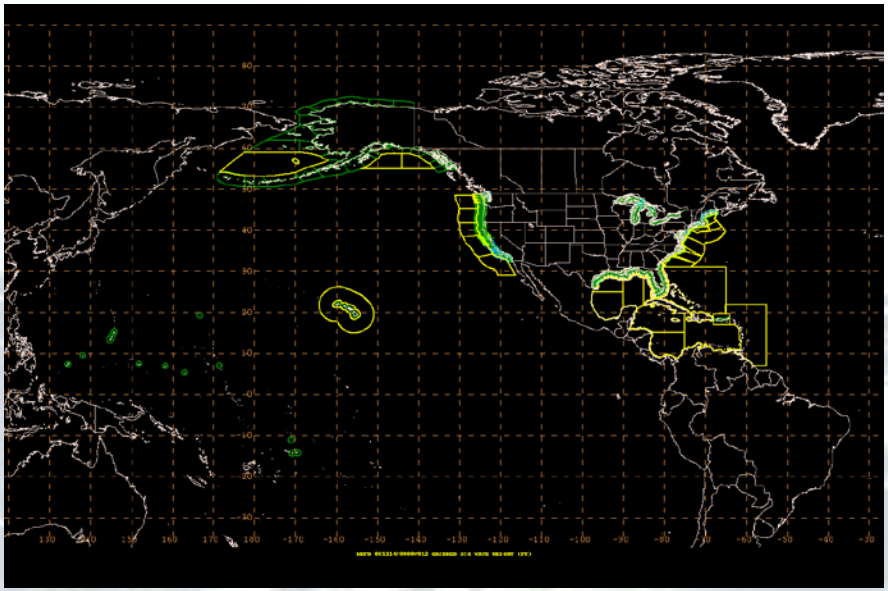




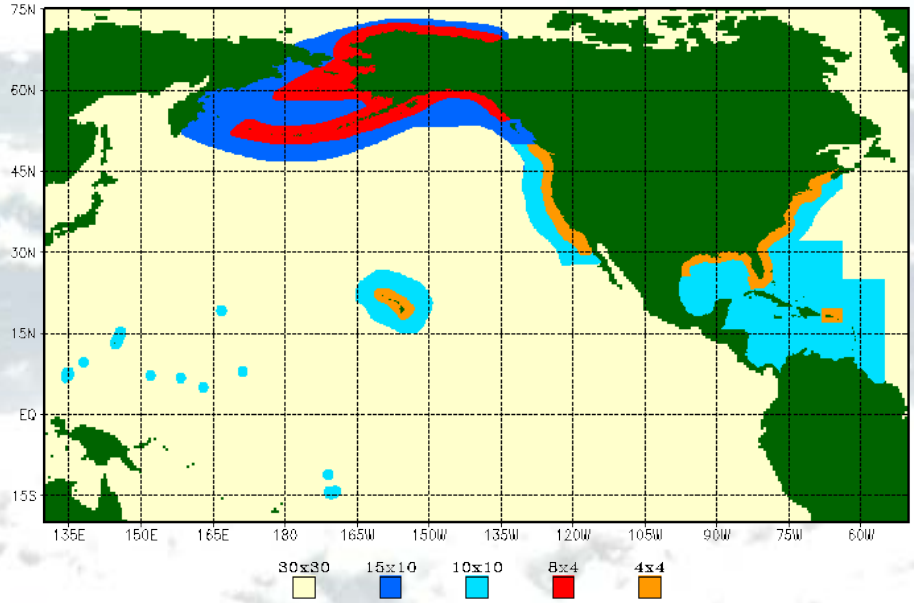
Wingeart et al., 2001, swell system detection.

Multi-grid technology (2007)

Introducing two-way nested grid technology to better serve needs of the OPC / NHC and WFO forecasters.

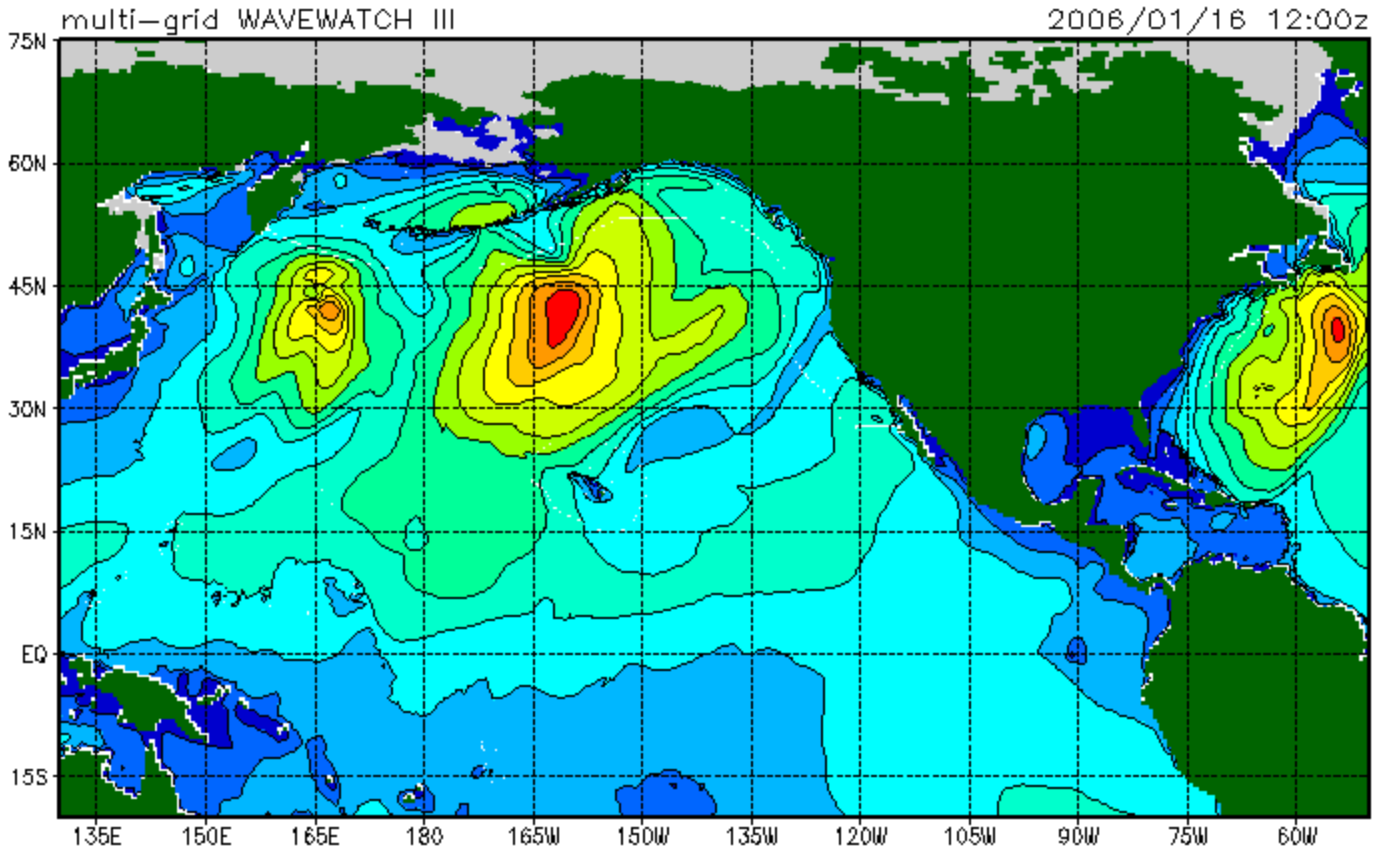


OPC / NDFD areas / grids



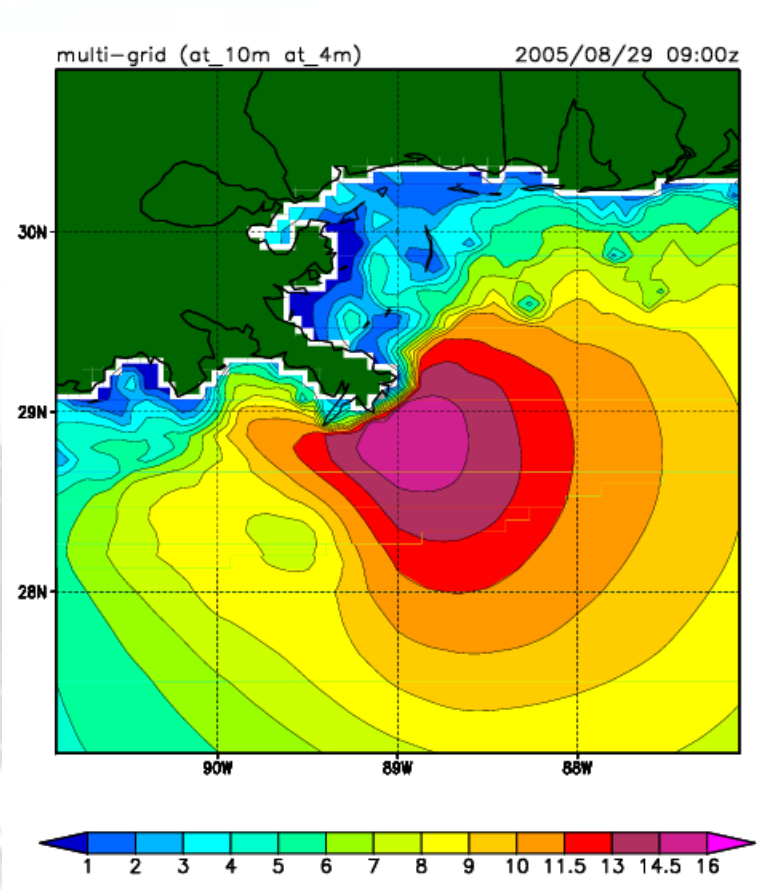
Available resolution in NCEP multi-grid model (minutes).

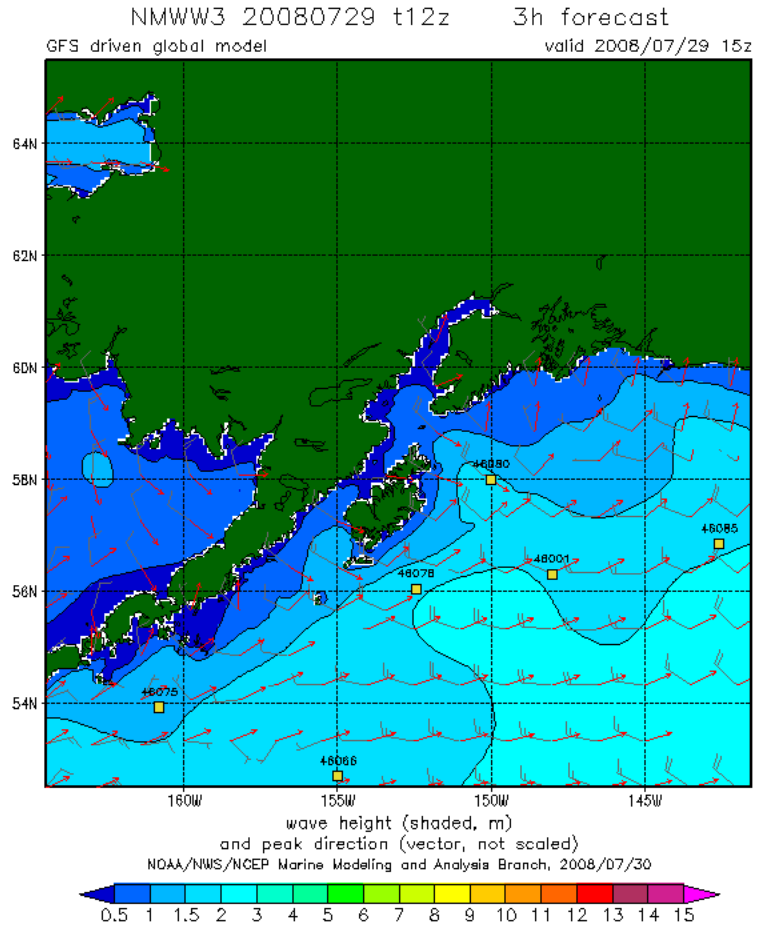
Multi-grid technology (2007)



Example of consistency between grids

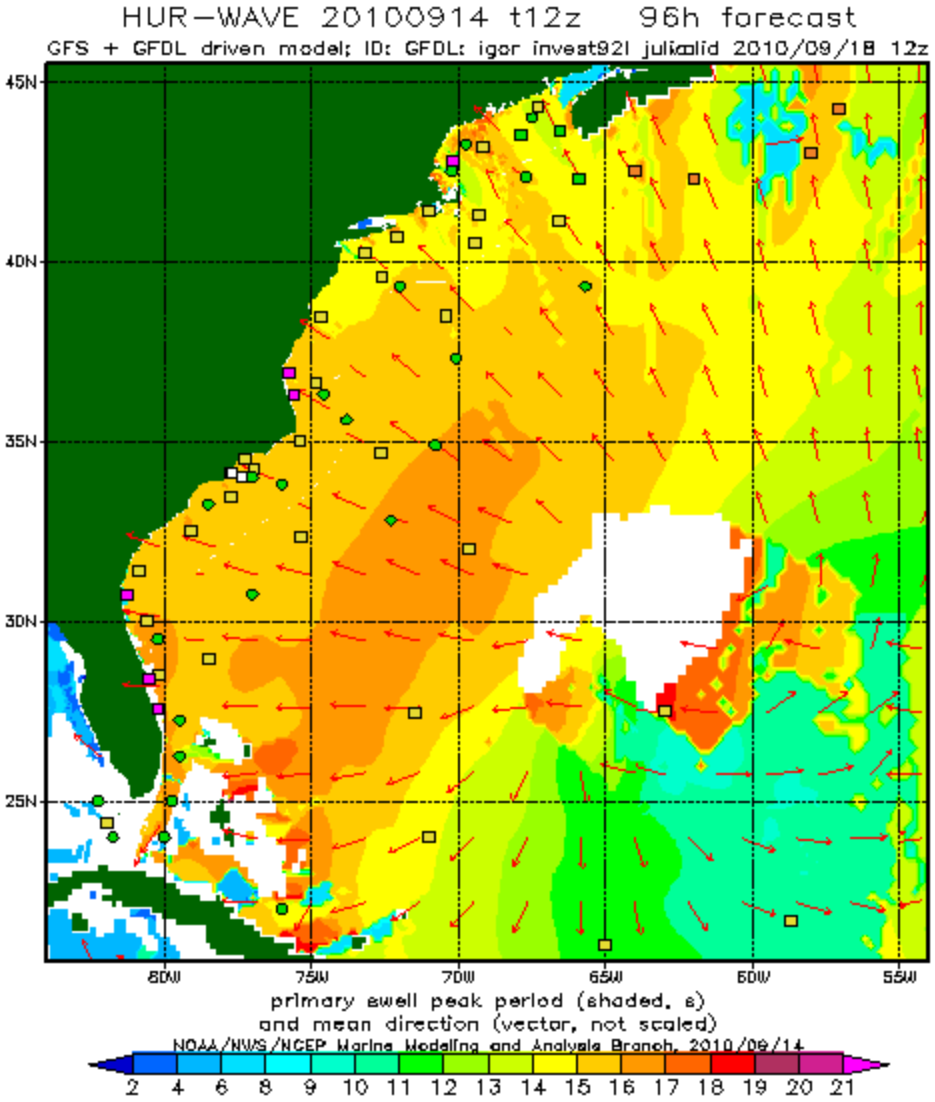
Multi-grid technology (2007)





Examples of increased resolution and shallow physics

Multi-grid technology (2010)



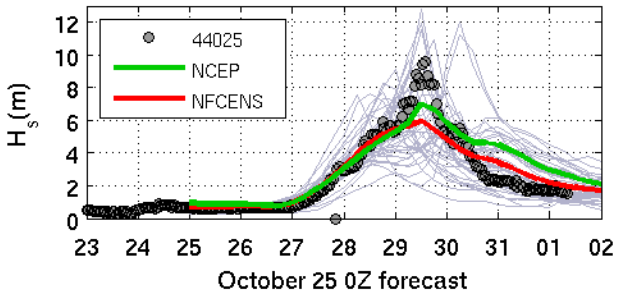
Igor in the multi-grid hurricane wave model:

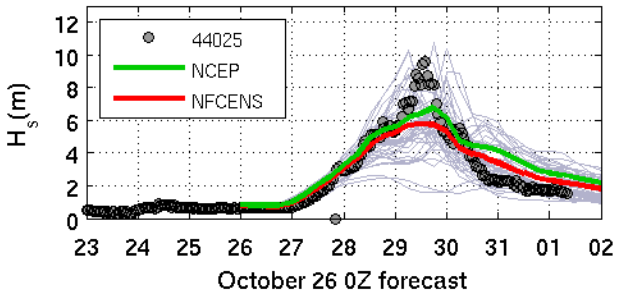
- 7.5km coastal resolution.
- Shallow water physics.
- Note shadow zones behind Bahamas and Bermuda (!).
- Wave system based wind sea and swell separation (from USACE)
- Garden Sprinkler Effect will be more prevalent for hurricanes than for larger scale wave systems.
  - Subject of more research to solve rather than alleviate GSE.

Ensembles: Sandy

Wave Ensembles, Forecasts during Hurricane Sandy, Oct 2012

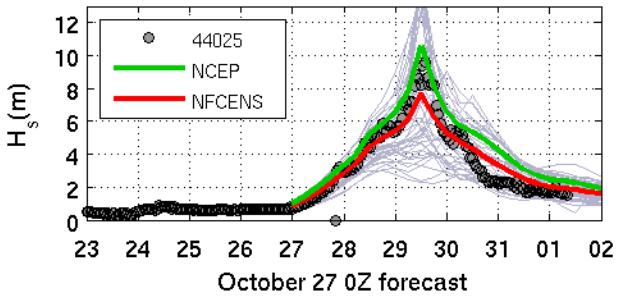
120h

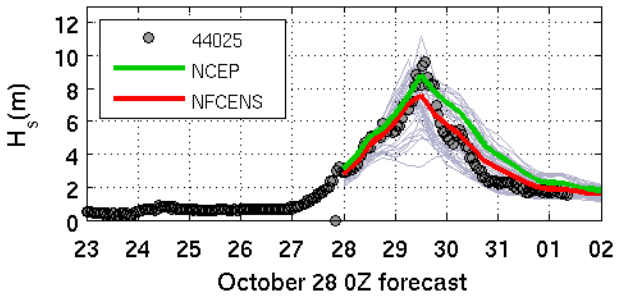




96h

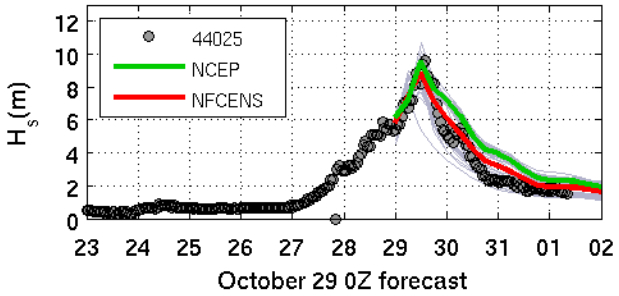
72h

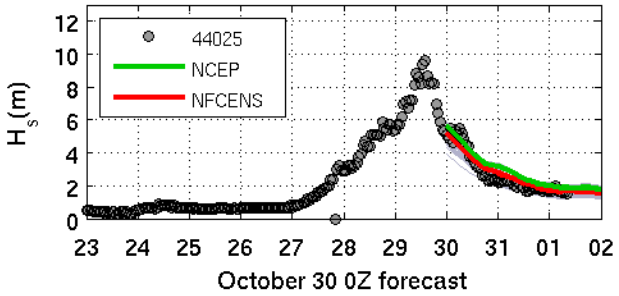




48h

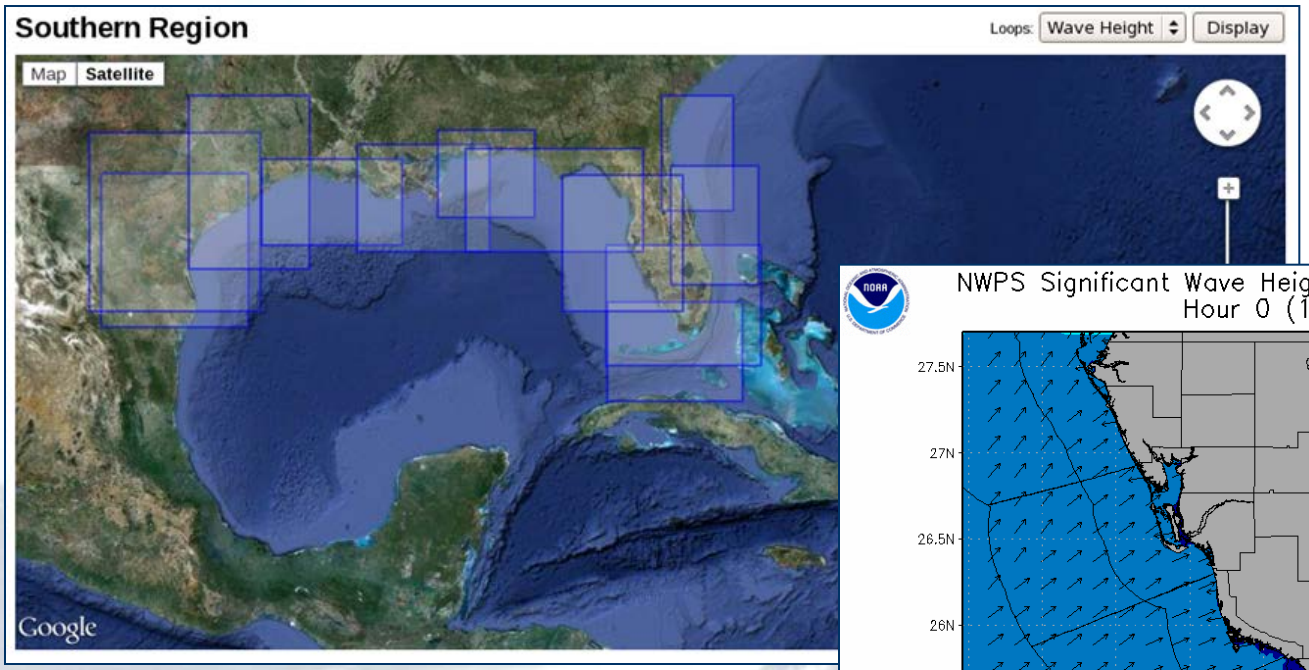
24h



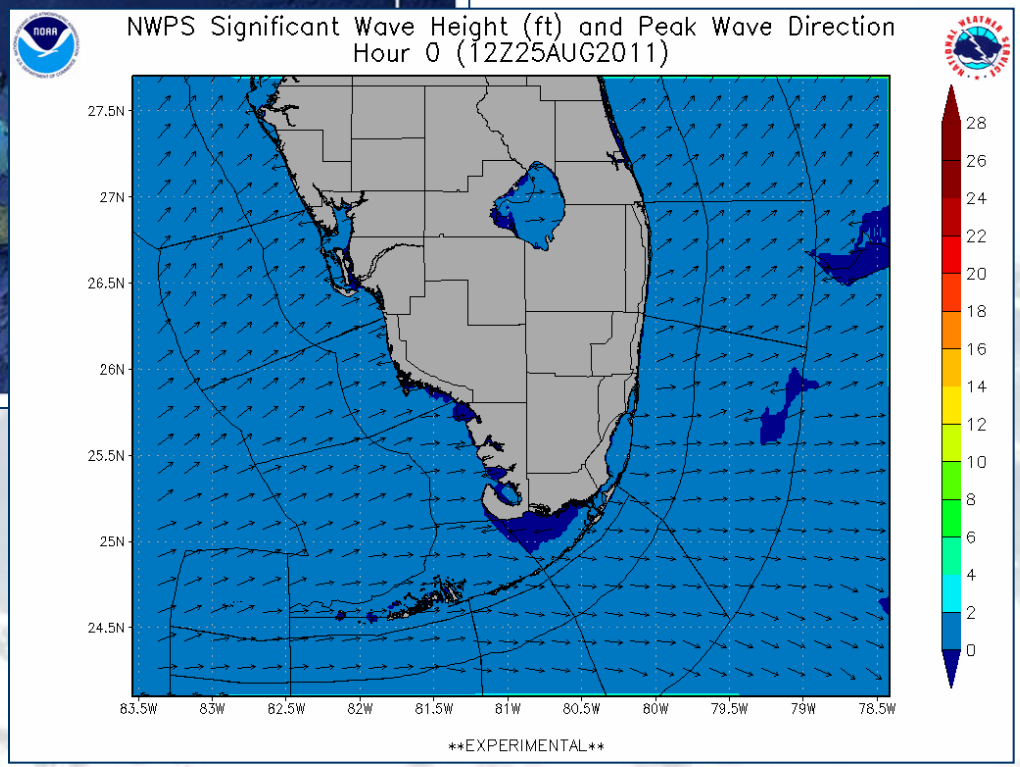


0h

20now: Nearshore Wave Prediction System



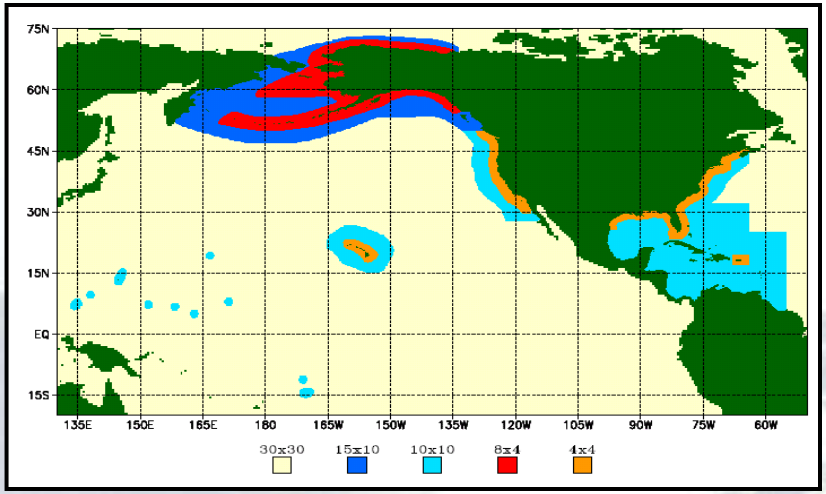
WFO MFL



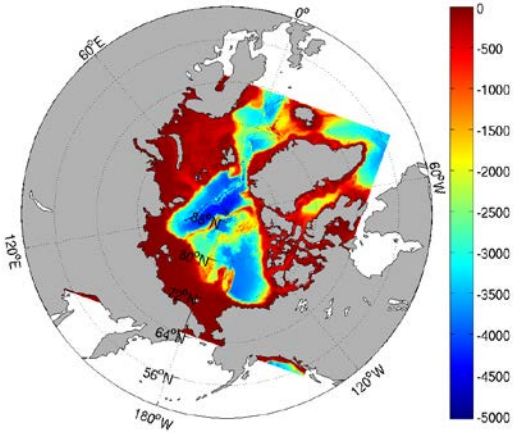
- Alpha testing at all SR WFOs, NHC/TAFB, select WC and EC WFOs
- 1 arc-min grid, nesting down to 500 m
- 90 h forecast, 3 hourly

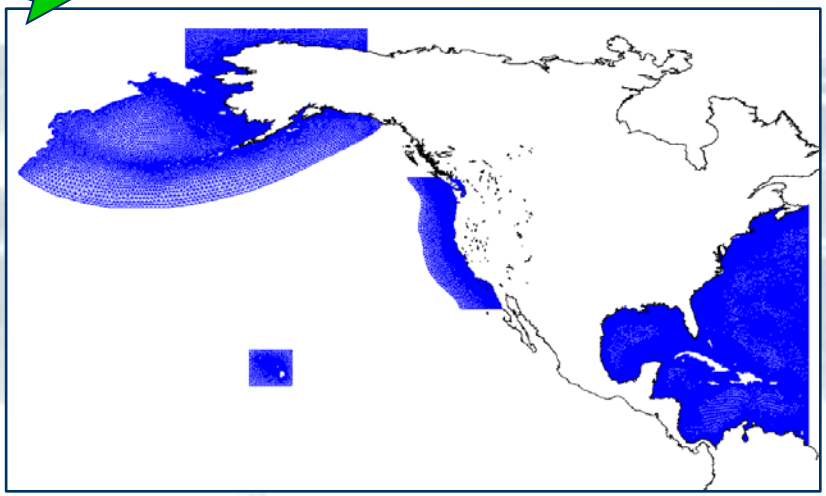
Near Future: global system

Curvilinear Arctic grid to replace regular Arctic grid



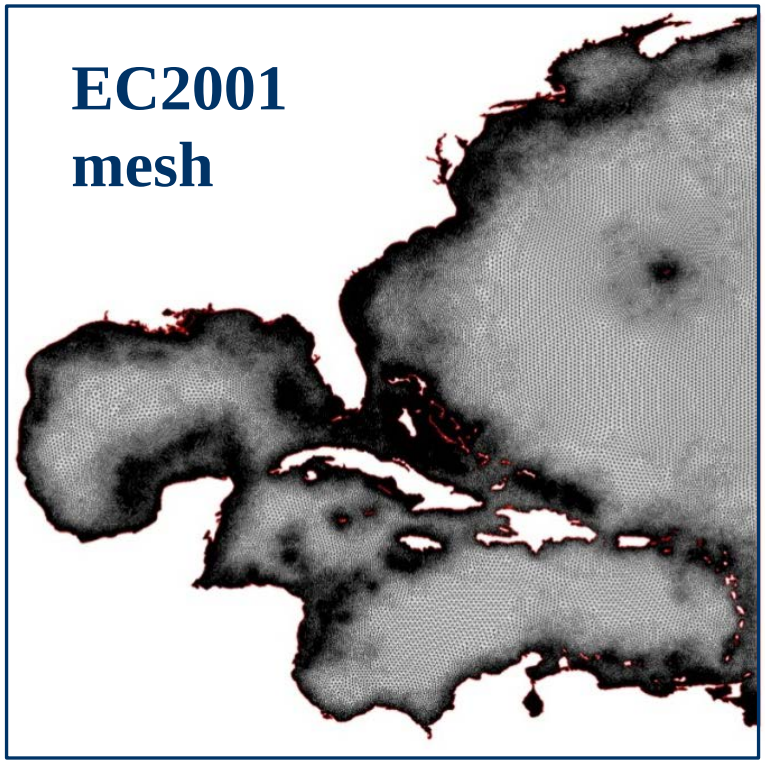
Resolution: 4 arc-min (coastal) and 10 arc-min (regional) grids

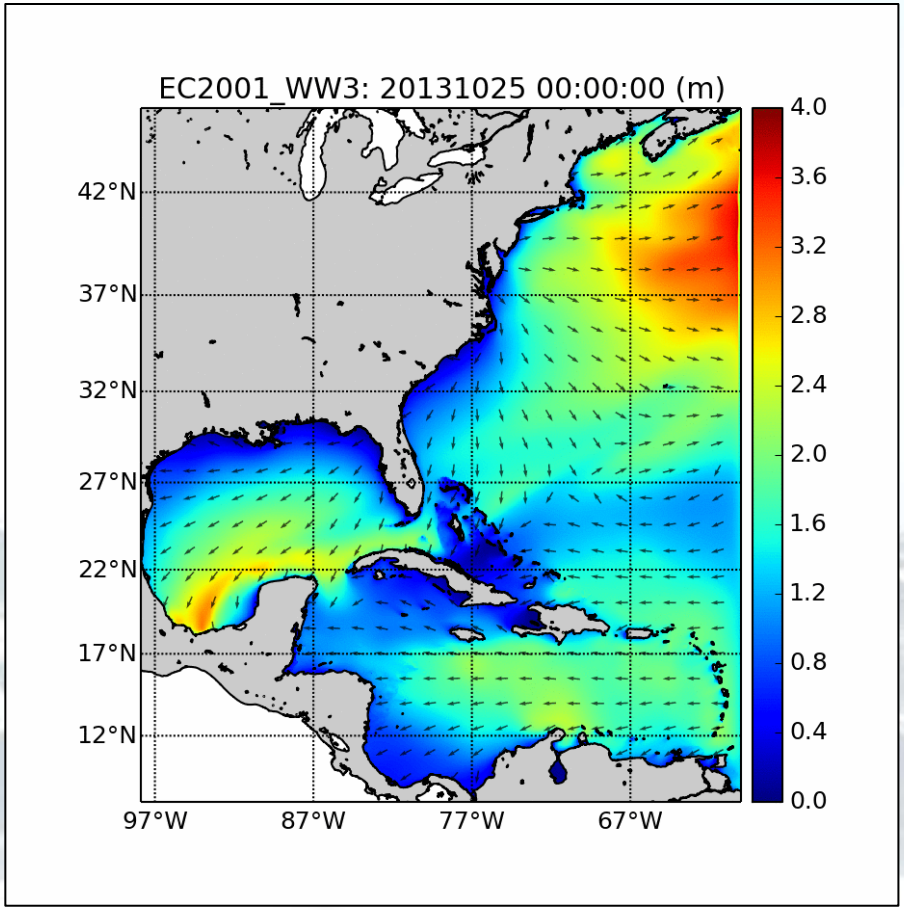




Resolution: 0.25 deg (offshore) to ~2 km (nearshore)
Replaces 4 and 10 arc-min regular grids

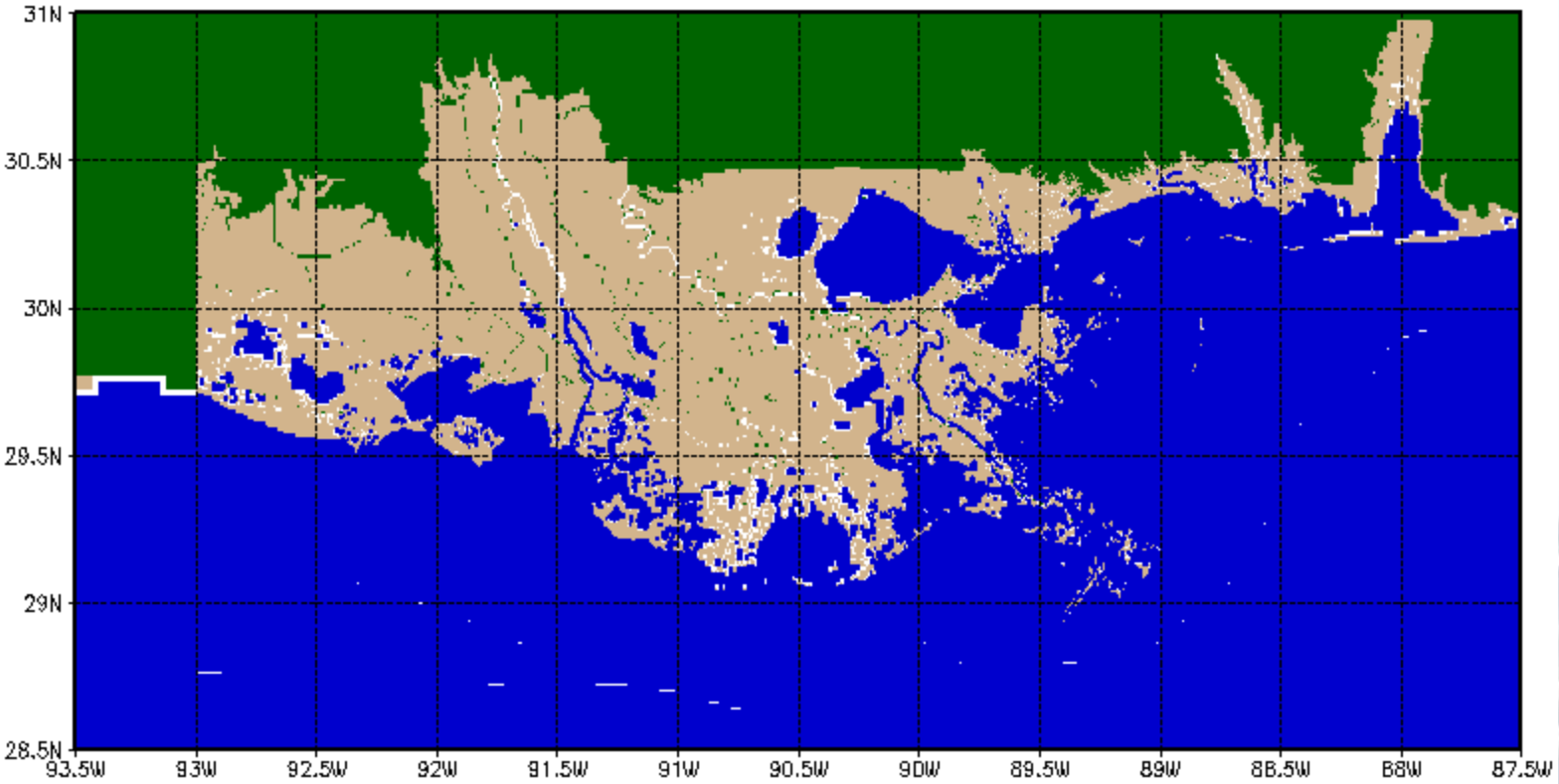
Near Future: unstructured grids





Going to unstructured grids for the coast:
Jump from 7.5km → 2km resolution on the coast.
Coupling to “storm” surge ……

Future: coupling



Hurricane Gustav example of coupling wave and surge:
Where the water meets the people …..


Thank you!