NOAA WAVEWATCH III

NCEP's operational ocean wave model

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Outline

- ✓ Which waves?
- ✓ What is a wave model ...
  - (excerpts from the web page primer)
- ✓ Products
  - what
  - how to get
- ✓ NCEP ocean wave guidance
  - Guidance for East Coast.
  - WNA versus NAH models.
- ✓ Strong and weak point of new models
- ✓ The future.

Wind waves [1]

- ✓ Wind waves are the waves at sea that are generated by local or distant winds. Waves generated locally are usually referred to as wind sea. Waves generated at distant locations in the past are referred to as swell.
- ✓ Wind waves range in wave height from negligible to 30m (100ft) and more, and in length (distance between consecutive waves) from centimeters to 1 km.
- ✓ Corresponding wave periods (i.e., the time it takes for two consecutive waves to pass a given location) range from less than 1 second to about 25s.

http://polar.ncep.noaa.gov/waves/pres/primer

Wind waves 2

- ✓ Although wind wave conditions generally change slowly, no two consecutive waves are identical. Furthermore, individual waves are so small that it would be practically impossible to predict every individual wave. Instead the wave field is described with average measures for wave heights.
- ✓ The commonly used wave height to describe the wave field is the significant wave height H_s, which is usually defined as the average wave height of the highest 33% of all individual waves. Because smaller waves are generally not seen against the background of the larger ones, this corresponds closely to the visually observed mean wave height.

primer

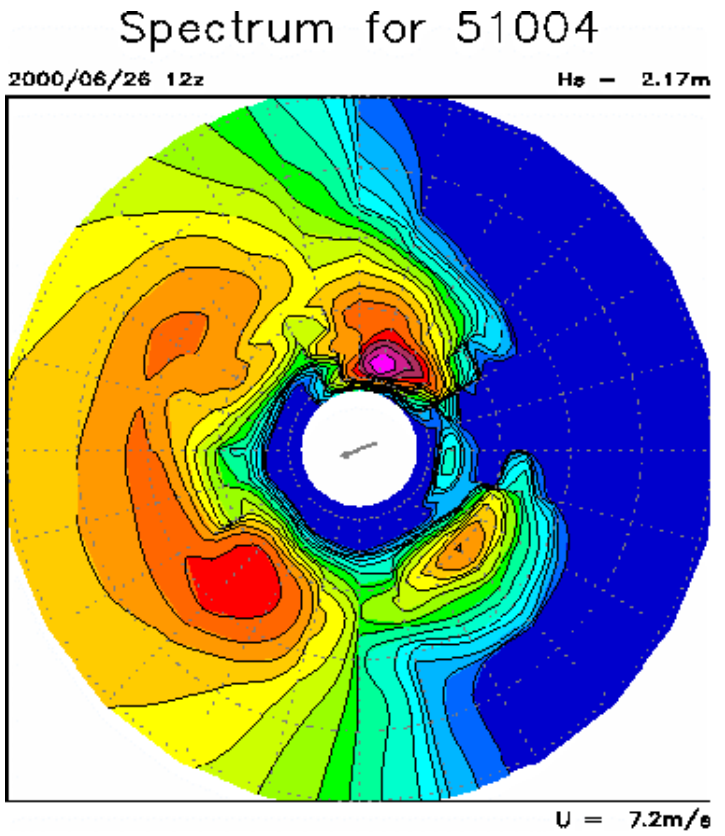
Wind waves 3

- ✓ Generally, it is assumed that individual wave heights can be described using a Rayleigh distribution. This implies that for a significant wave height H_s = 10m (33ft), one can expect :
  - ➢ 1 in 10 waves to be larger than 10.7m (36ft).
  - ➢ 1 in 100 waves to be larger than 15.1m (51ft).
  - ➢ 1 in 1000 waves to be larger than 18.6m (62ft).
- ✓ This implies that the largest individual wave that one might encounter in a storm is roughly twice as high as the significant wave height !
- ✓ In rapidly changing conditions the disparity between the significant wave height and the largest individual waves might even be larger.

primer

Wave spectra [1]

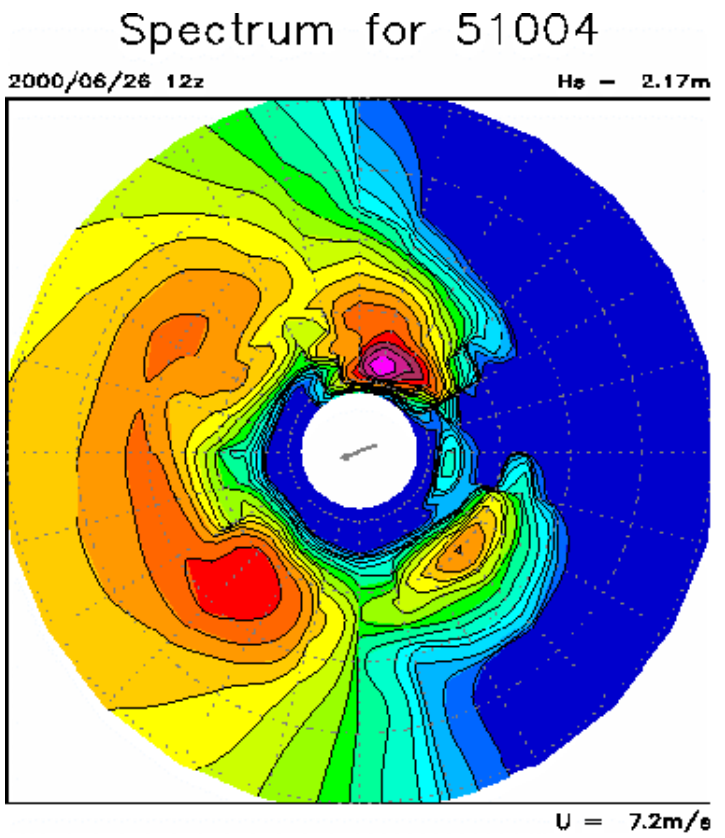
- ✓ In advanced wave observations and inside wave models, the wave field is not described with a single wave height, but with a so-called wave spectrum, which describes the distribution of wave energy over wave directions and frequencies at a fixed location.
- ✓ A graphical representation of such a spectrum as can be found on the web page is shown here (buoy location 51004, SE of Hawaii).



primer

Wave spectra 2

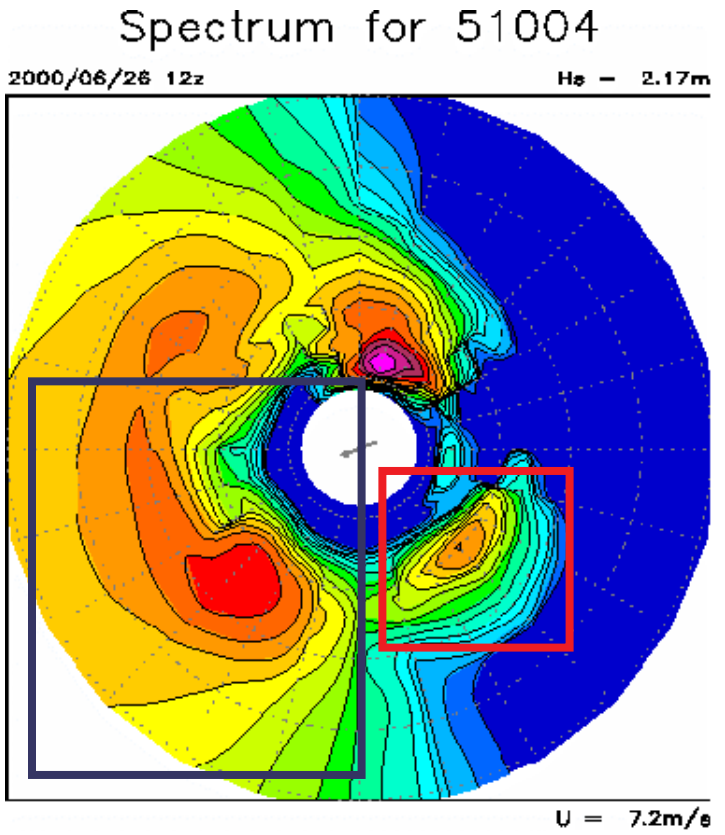
- ✓ Dark blue indicates absence of wave energy, light purple the local maximum. Each new contour level corresponds to a factor of two increase of wave energy
- ✓ The direction relative to the center of the plot indicates the direction in which the waves travel. The frequency increases from about 0.04Hz (25s wave period) at the center of the plot to 0.25Hz (4s wave period) at the outside of the plot.



primer

Wave spectra 3

- ✓ 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.



primer

Wave spectra [4]

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

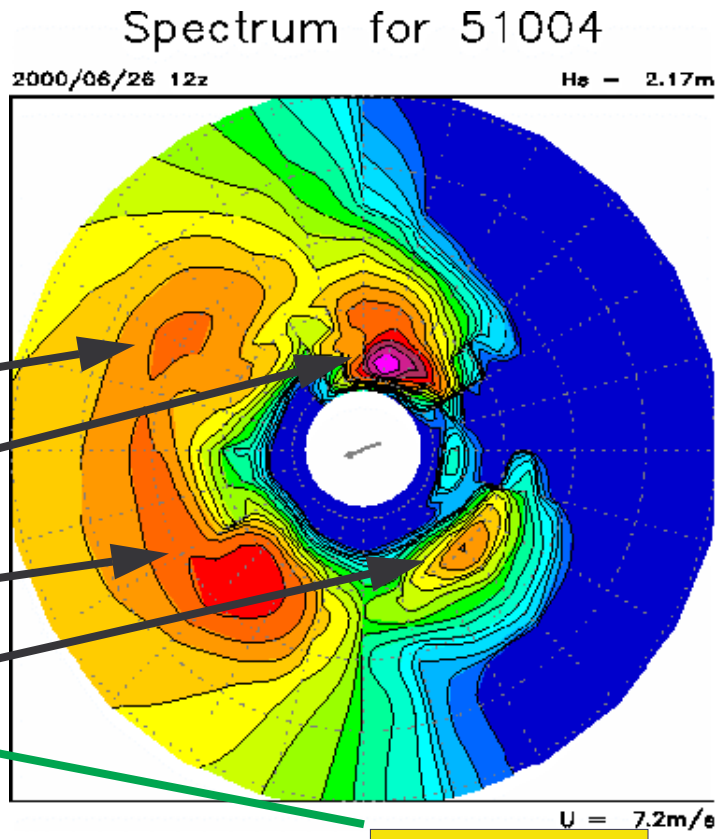
```
Location : 51004      (17.40N 152.50W)
 Model    : NWW3 global 1x1.25 degr.
 Cycle    : 20000626 t00z
+-------+----------+-----------------+-----------------+
| day & |  Hst  n x |     Hs   Tp dir |     Hs   Tp dir |
|  hour |  (m)  - - |    (m)  (s) (d) |    (m)  (s) (d) |
+-------+----------+-----------------+-----------------+
| 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 |
```

AWIPS : feet, dir. from

primer

Wave spectra 5

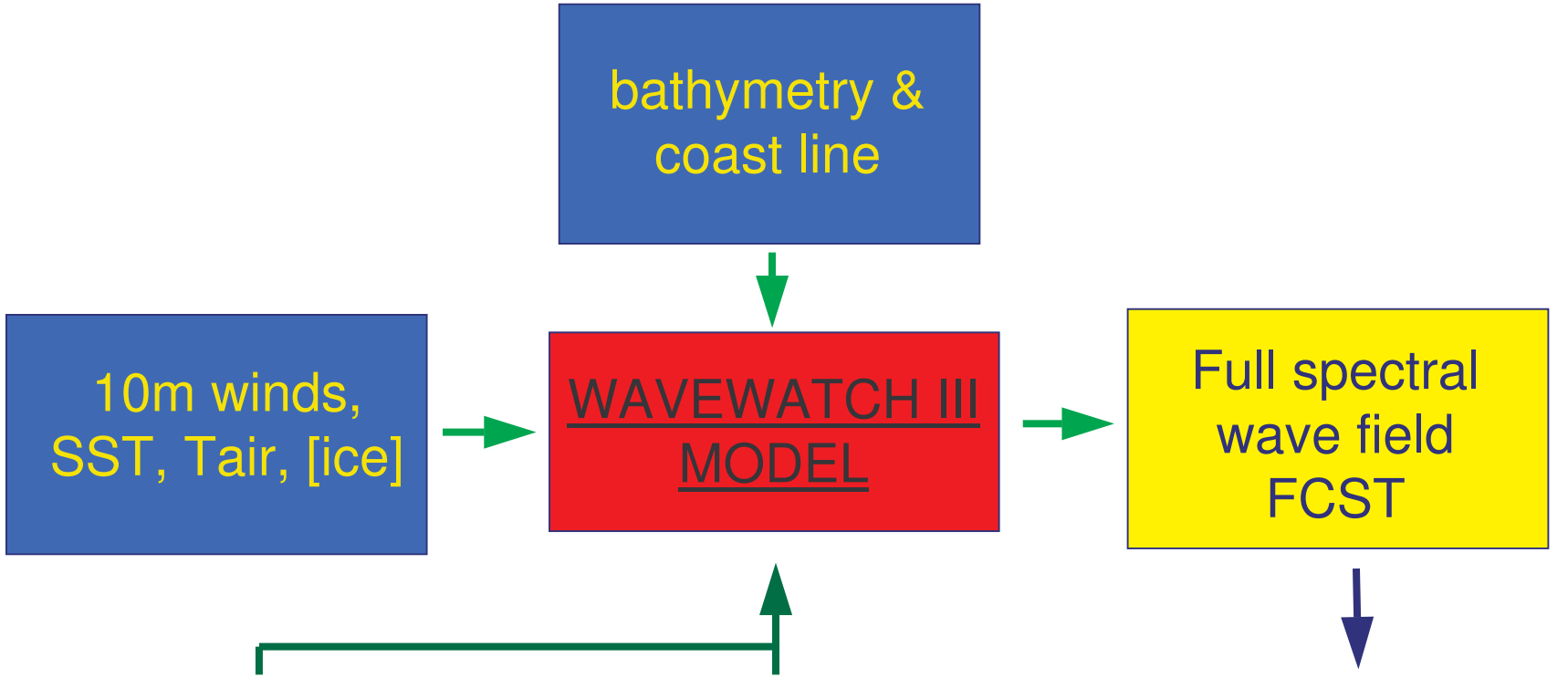
- ✓ The info in the spectral plots and the bulletins can be combined as follows (***Hs*** is significant wave height, ***Tp*** is peak or dominant period)
  - ➢ ***Hs*** = 0.7m, ***Tp*** = 6.6s
  - ➢ ***Hs*** = 1.4m, ***Tp*** = 15.9s
  - ➢ ***Hs*** = 1.4m, ***Tp*** = 7.0s
  - ➢ ***Hs*** = 0.3m, ***Tp*** = 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 |

primer

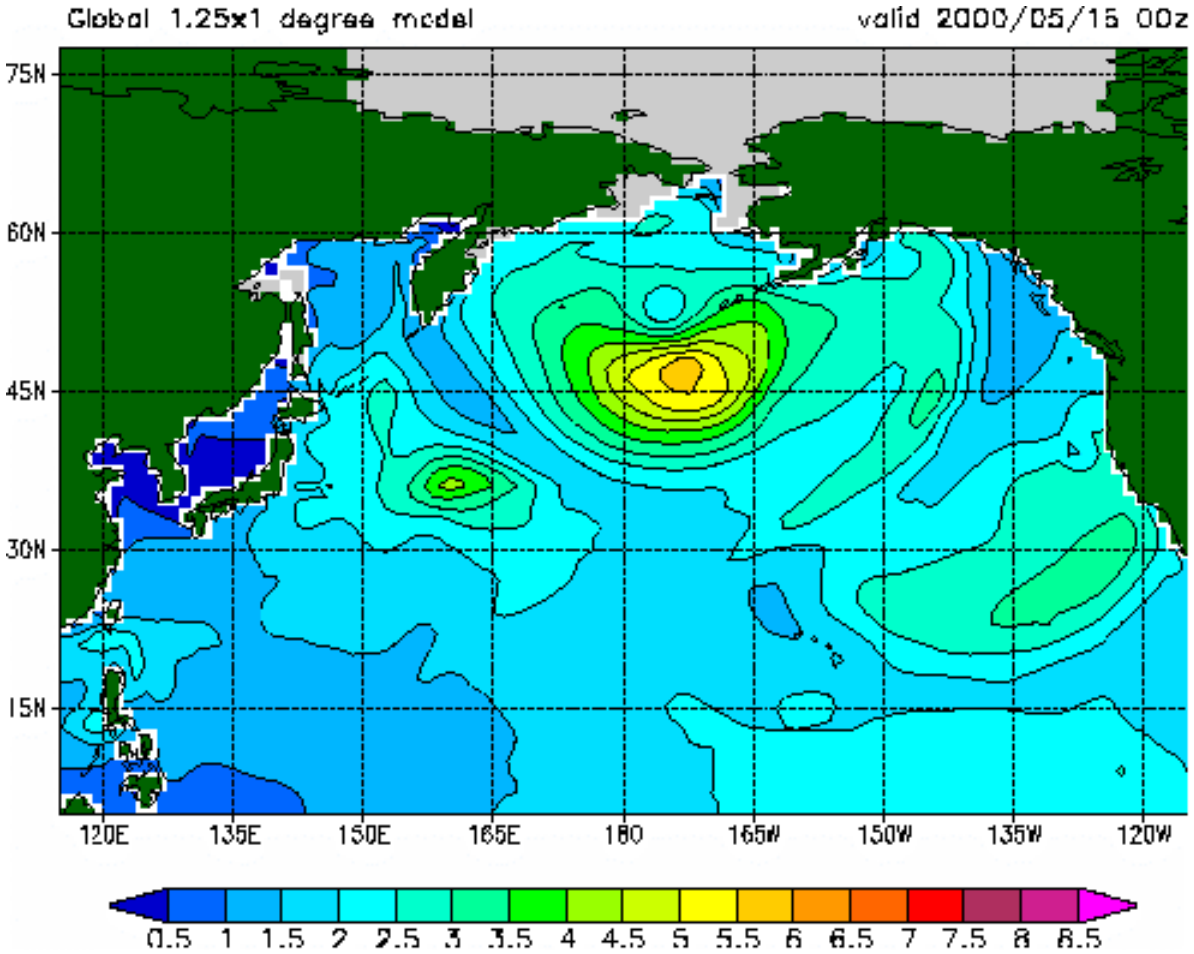
Numerical wave models



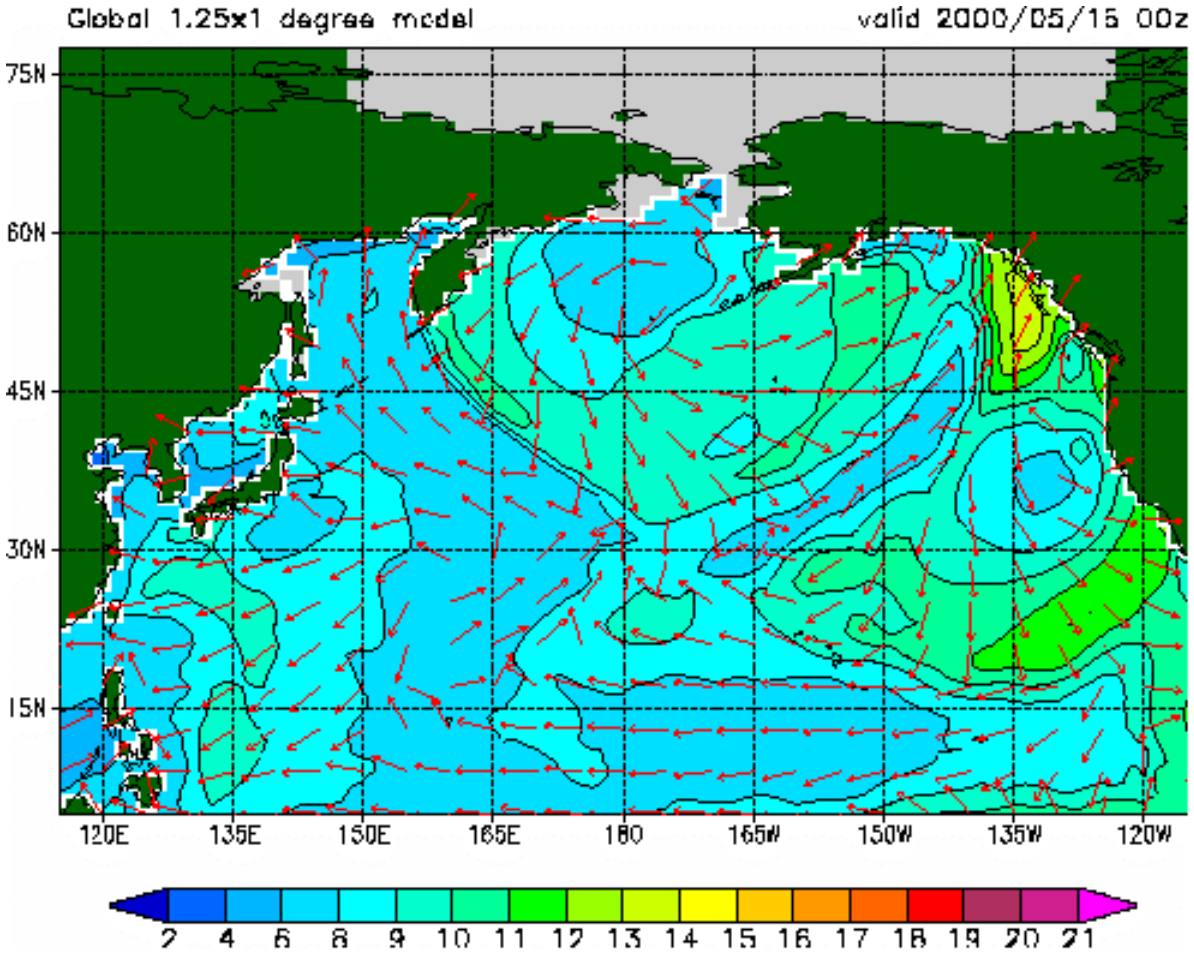
Products (what)

- ✓ Mean wave parameters in GRIB format
  - ➢ Overall significant wave height.
  - ➢ Mean direction and period.
  - ➢ Peak direction and period.
  - ➢ Wind sea direction and period.
  - ➢ Surface wind speed and direction.
  - ➢ NOT AVAILABLE : swell height and direction
- ✓ Text bulletins with different wave systems for output locations.

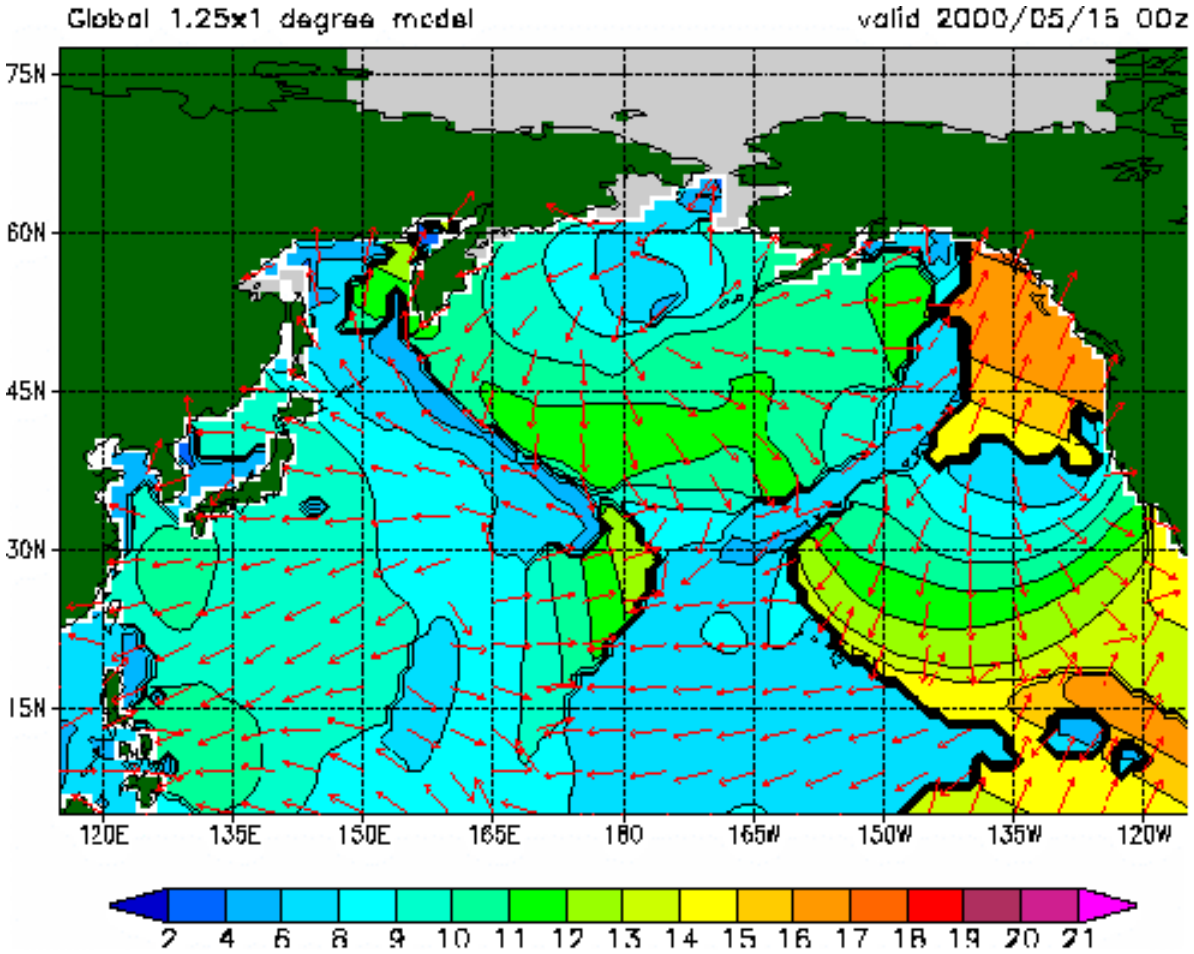
Significant wave height (m)



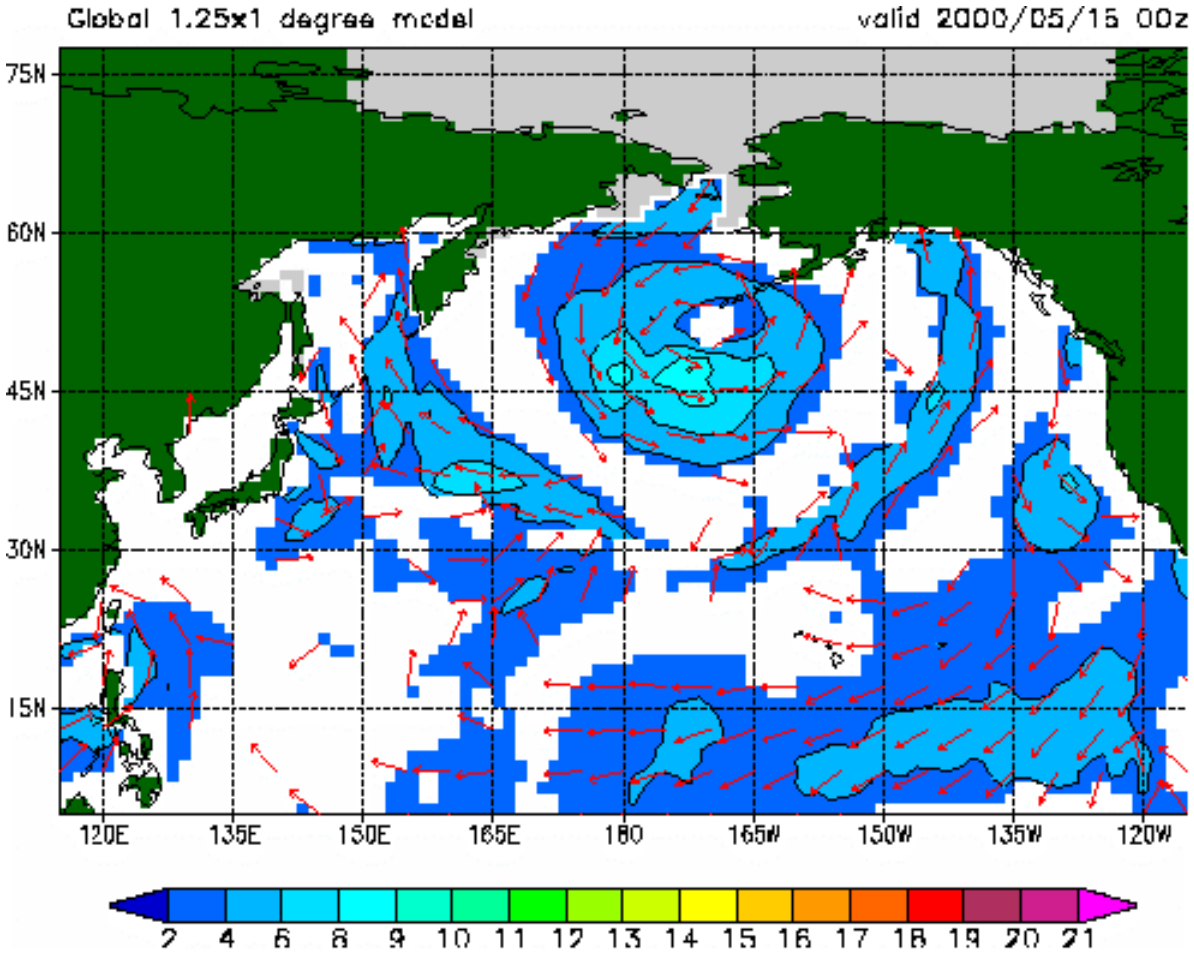
Mean wave period (s) and direction



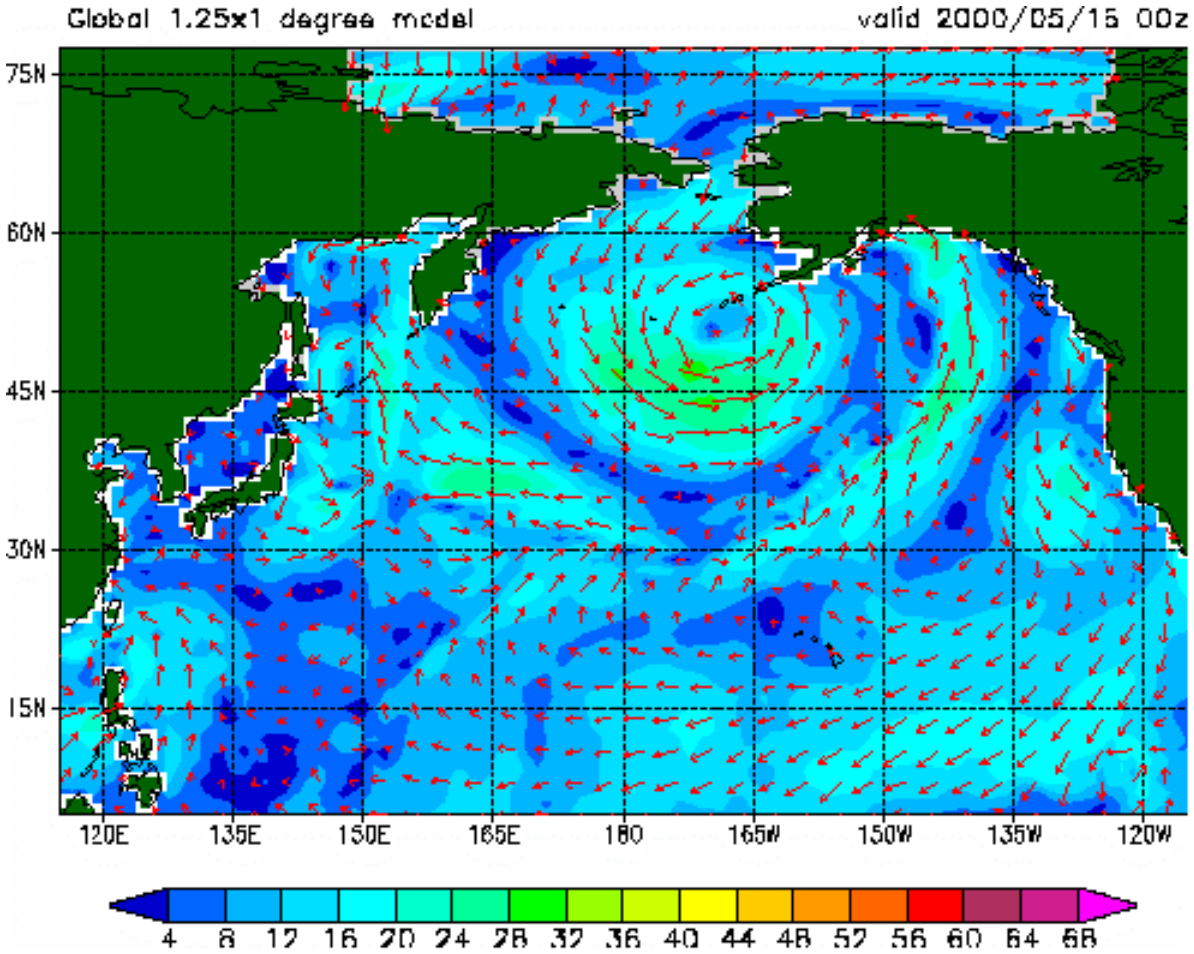
Peak period (s) and direction



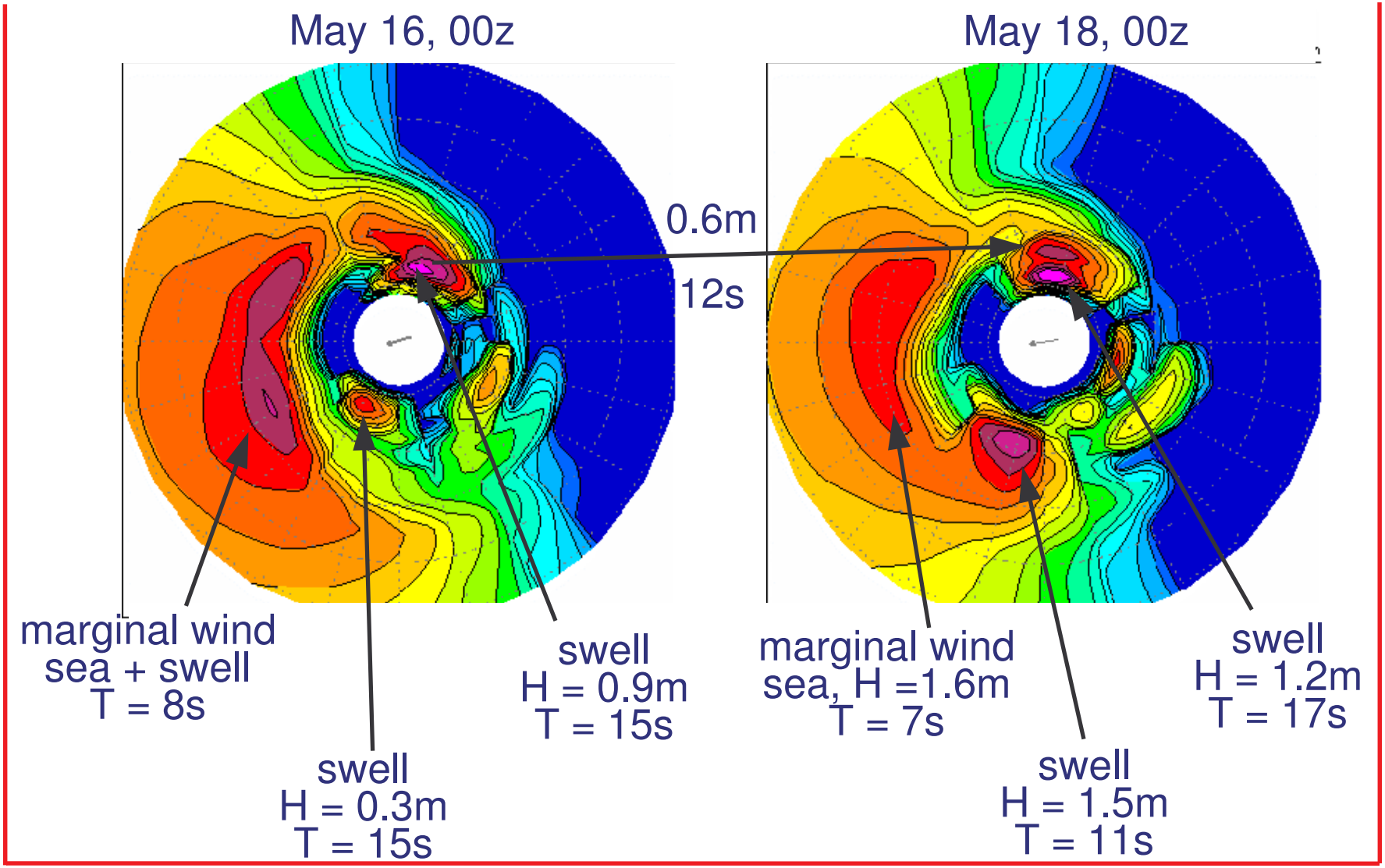
Wind sea period (s) and direction



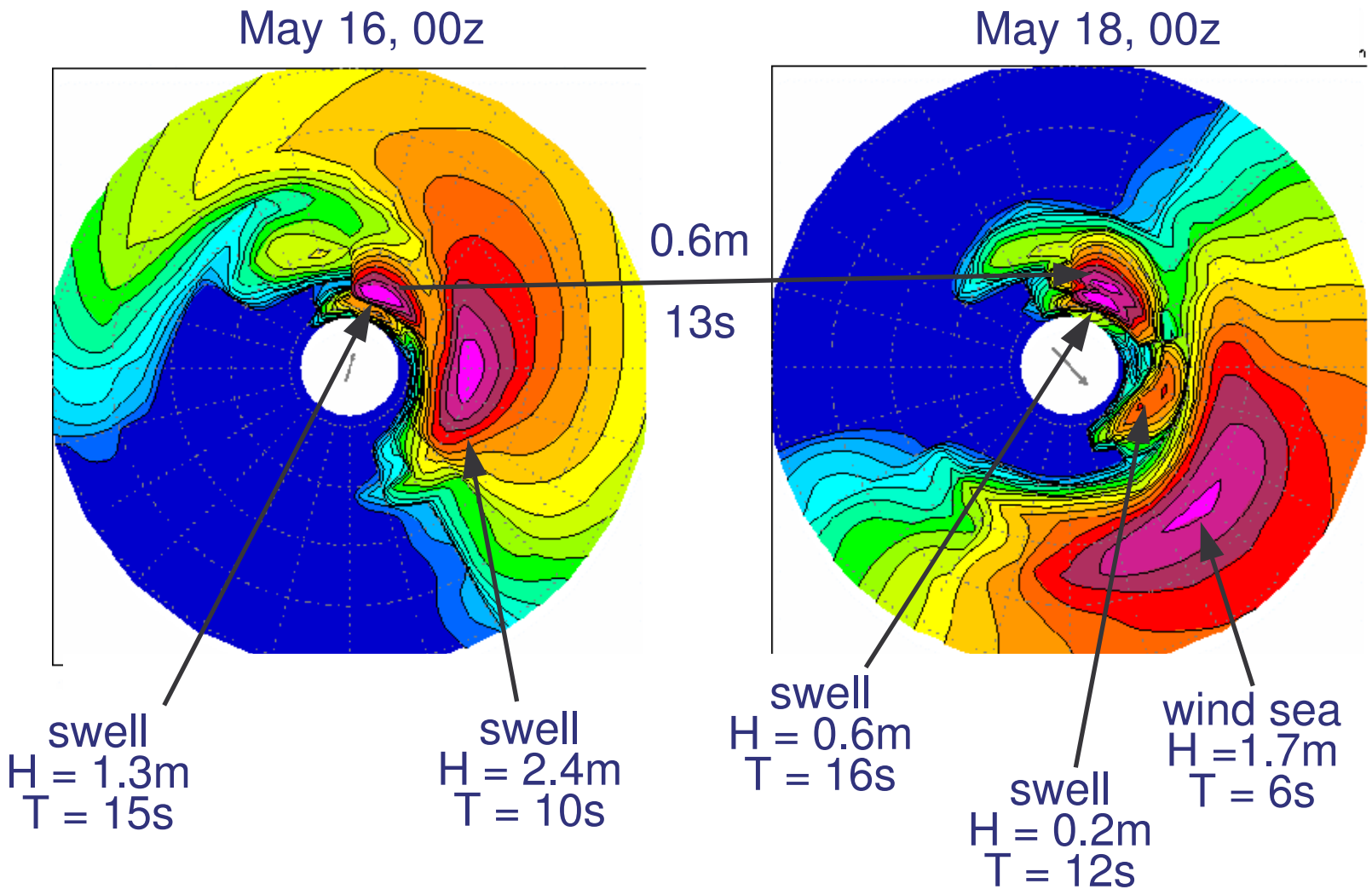
Wind speed (kn) and direction



location 51004 (SE Hawaii)



Monterey (no buoy)



Products (where) [1]

- ✓Global model fields are available in AWIPS up to 72 hour forecast.
- ✓Errors in AWIPS graphics near coast.
- ✓The regional model fields have finally become available in latest versions of AWIPS.
- ✓Seem to have similar problems near the coast as found in the global model.

Products (where) 2

- ✓ Text bulletins are on AWIPS in version modified for the use of WFOs (height in feet, meteorological directions).
- ✓ ALL model data availble on the web, usually within 1 hour of the model run.
- ✓ Historical hindcast data available on web.
- ✓ We will work with any WFO or region to get products out as needed.

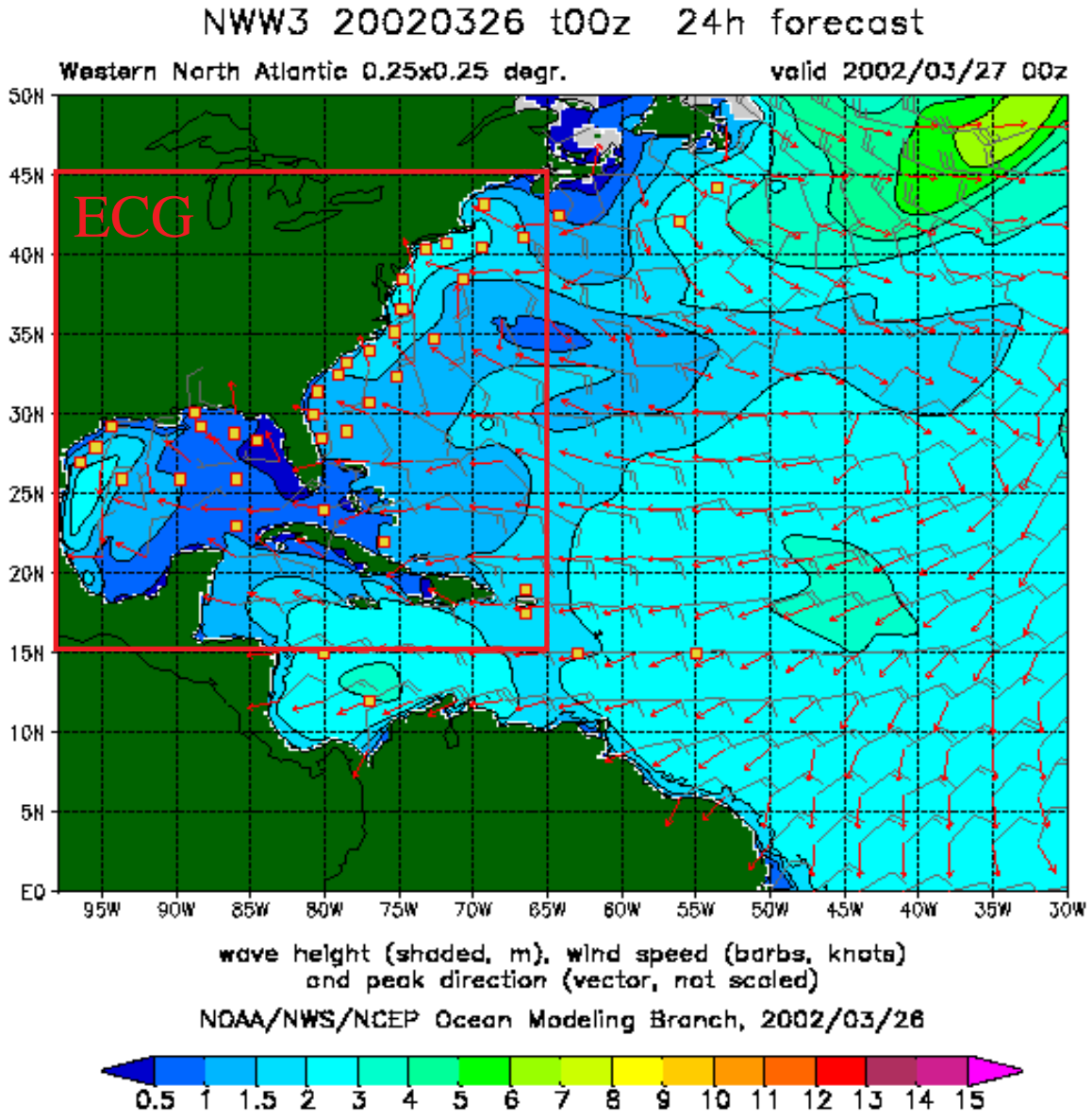
http://polar.ncep.noaa.gov/waves
http://polar.ncep.noaa.gov/NEW.waves

NCEP Guidance for EC

- ✓ NOAA WAVEWATCH III version 1.18 replaced all previous operational wave models at NCEP by March 2000. Version 2.22 is operational since Aug. 2002
  - NWW3: Global model, 1.25x1º, 168h, GFS winds every 3 hours
  - WNA: Western North Atlantic model, 0.25x0.25º, 168h, GFS winds every 3 hours
  - NAH: Seasonal Hurricane version of WNA, GFDL 72h, blended GFS + GFDL winds every hour.
  - All models use 24 directions, 25 frequencies, run on 4 daily cycles (00z, 06z, 12z and 18z) with 6 hour hindcasts for continuity.

http://polar.ncep.noaa.gov/waves

- ✓ WNA/NAH model domain
- ✓ Red square: previous EC WAM domain



NAH versus WNA

✓Why do we need a special Hurricane version (NAH) of the Western North Atlantic model (WNA)?

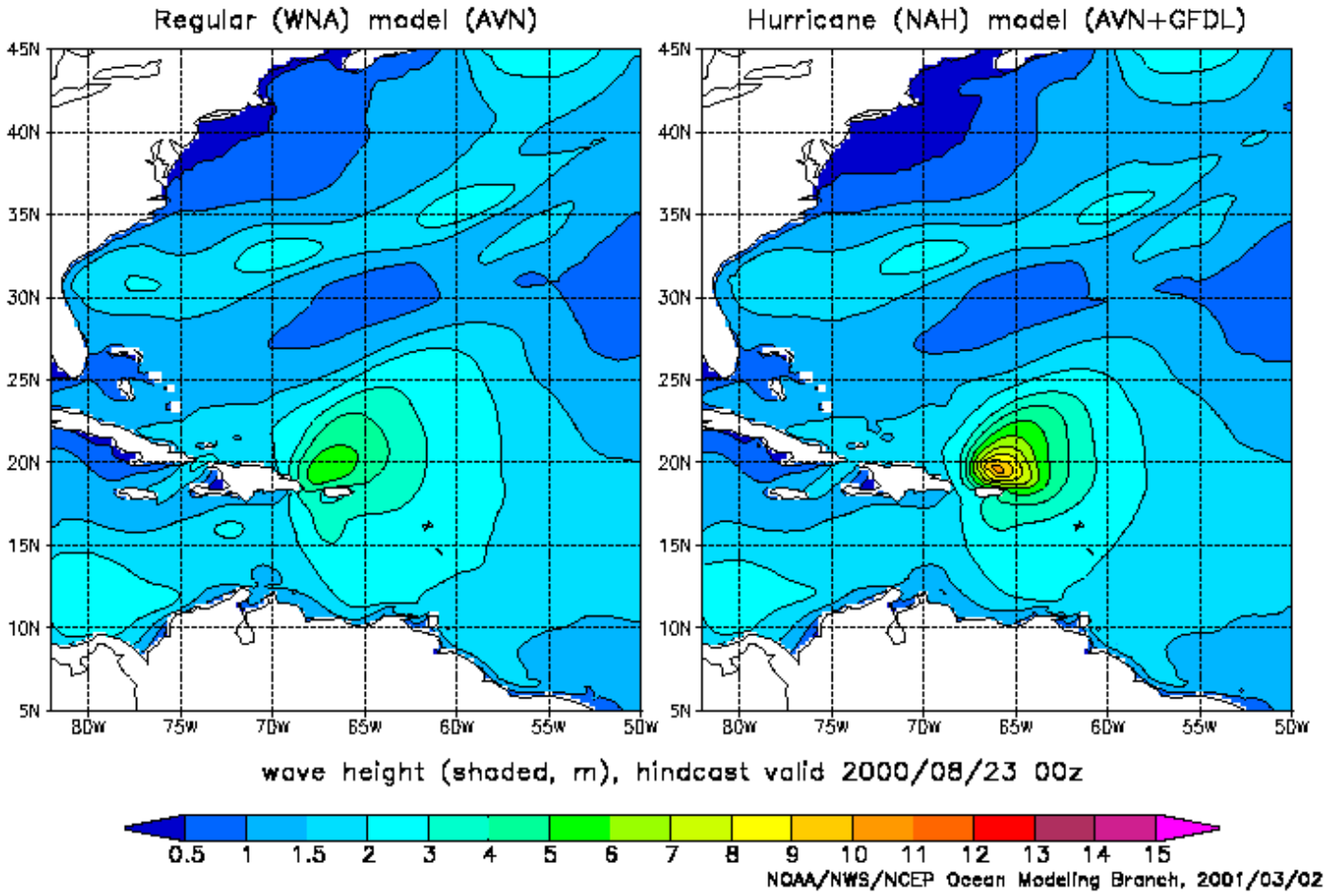
- ➢Wave model can only be as good as the winds that drive it.
- ➢Hurricane winds are not done particularly well by the GFS due to resolution problems and due to limitations of the model physics.
- ➢Better results expected when higher resolution models are used such as the GFDL model.
- ➢Need for blended GFS/GFDL winds.

http://polar.ncep.noaa.gov/waves

Debby significant wave height (m)
2000/08/22 00z

AVN winds

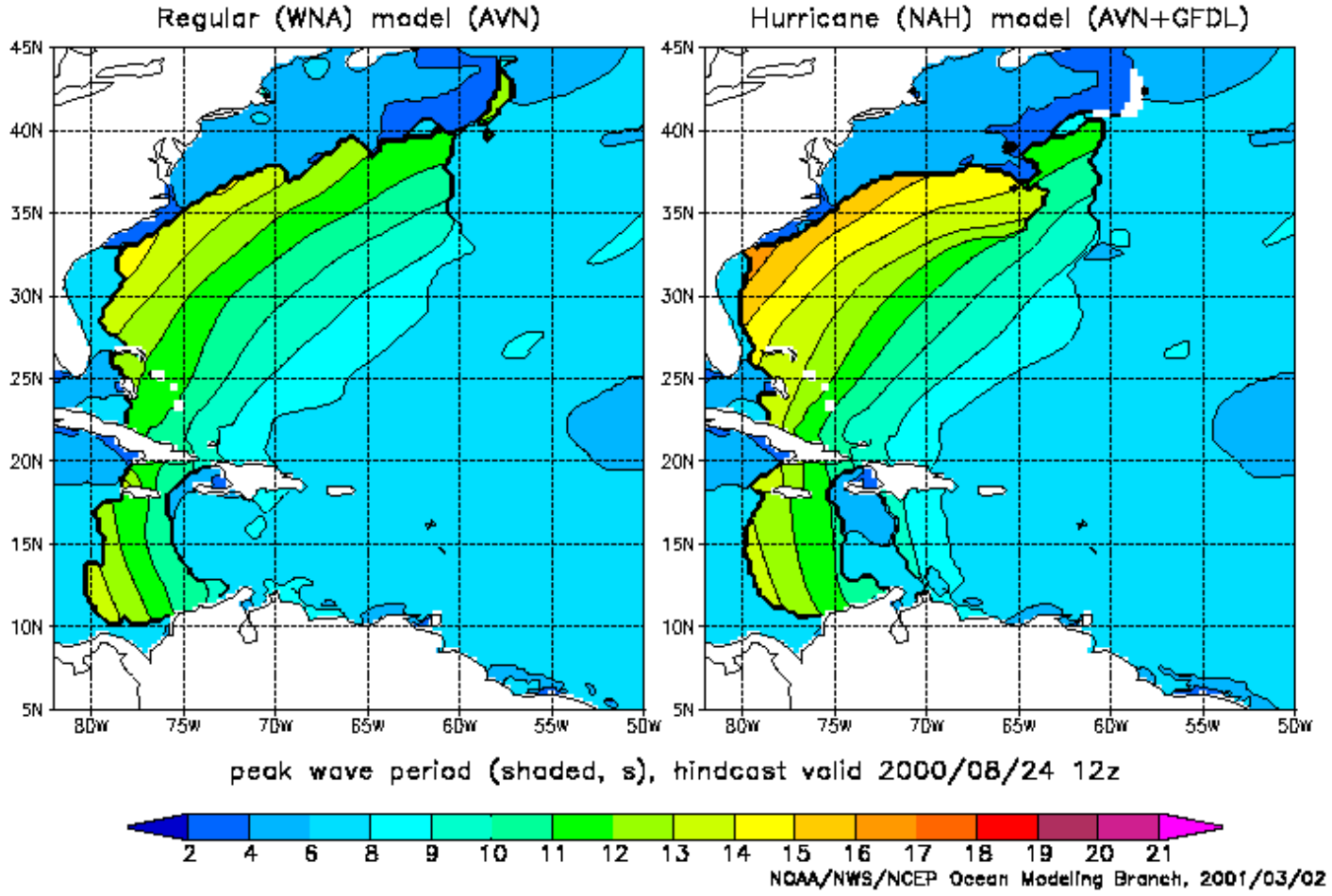
AVN + GFDL winds



Debby peak wave period (s)
2000/08/23 12z (+ 36 h)

AVN winds

AVN + GFDL winds



Quality of Guidance

- ✓ There is a large amount of validation data available at the web. :
  - ➢ Several statistics per month / season against buoys or satellite observations. Starting Feb 1997 for global model, Aug. 2000 for regional models.
  - ➢ Results of a six-month comparison with old operational global model including a large number of time series plots.

http://polar.ncep.noaa.gov/waves/validation.html

Quality of Guidance

- ✓ Strong points (wave model):
  - ➢ Good overall performance (rms errors typically 10-20% of mean measured wave heights).
  - ➢ Maximum and minimum wave heights from storms are a better predicted than in previous operational models.
  - ➢ Better swell predictions than in previous models.
  - ➢ Good control of GSE.
  - ➢ Comprehensive coverage of areas of interest by regional models.

Quality of Guidance (Winds)

- ✓ Weak points of wave model due to external forcing:
  - ➢ Wave models can only be as good as its driving forces (bad forcing = bad wave products).
  - ➢ Winds are the most critical, although near the coast bathymetry too (lesser problem for our models: essentially deep water).
  - ➢ Most important problems have to do with spatial and temporal resolutions of model grids and output data in GFS and GFDL models (sources of forcing fields for us).

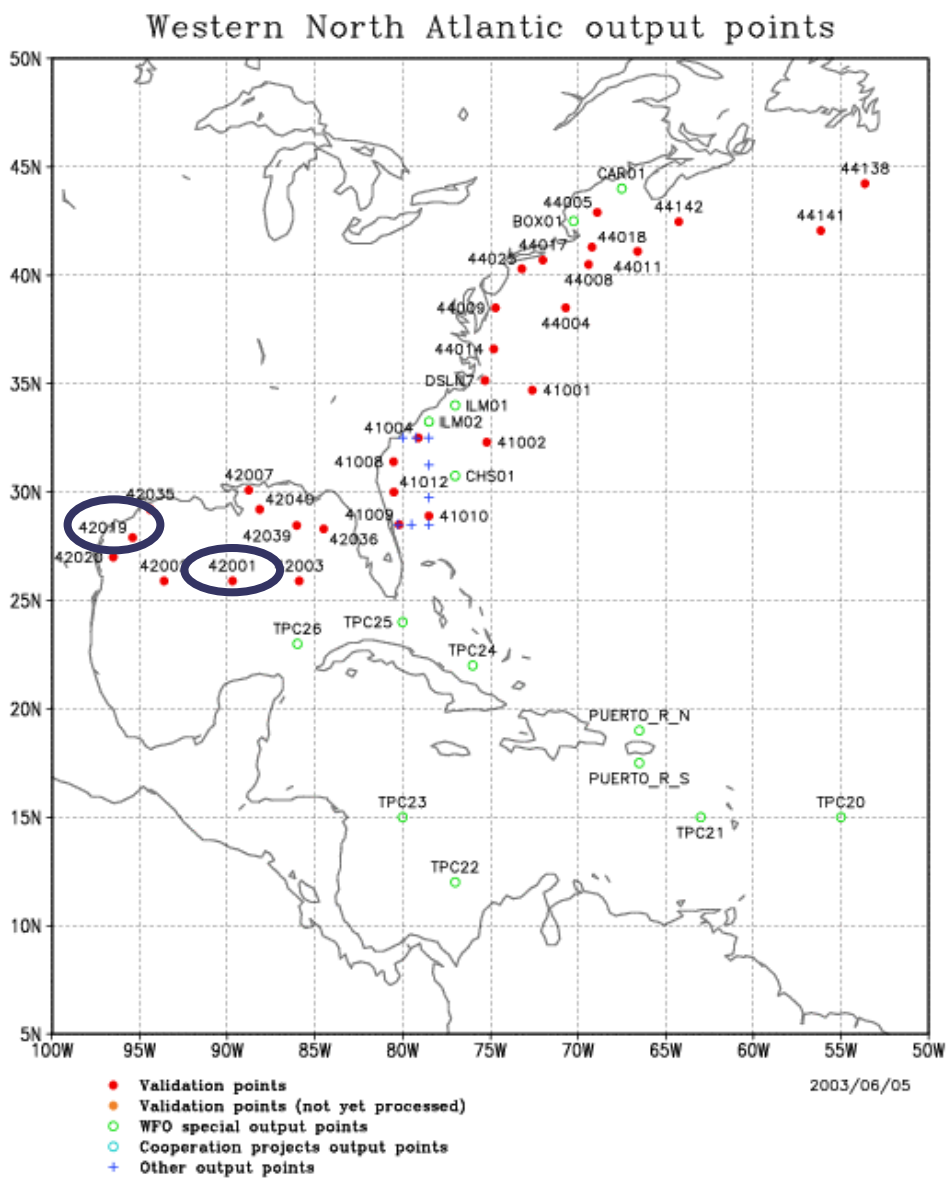
Quality of Guidance (Winds)

- ✓ Temporal output resolution of GFS and GFDL is much coarser than internal model time step:
  - ➢ Interpolation smears out compact systems with strong winds, leading to underestimation of extremes.
  - ➢ Tentative solutions: shorter output step for surface fields + one-way coupling (MPI).
- ✓ Spatial resolution in GFS and GFDL are constrained by economical considerations (more difficult issues):
  - ➢ Problems with prediction of small-scale systems (frontal system moving offshore GMex and EC).
  - ➢ Poor land-sea (boundary layer) transition: problem for wave growth within systems moving offshore.
- ✓ Other limitations and peculiarities of GFS and GFDL that you would know better than us (so tell us, maybe we can improve a few things).

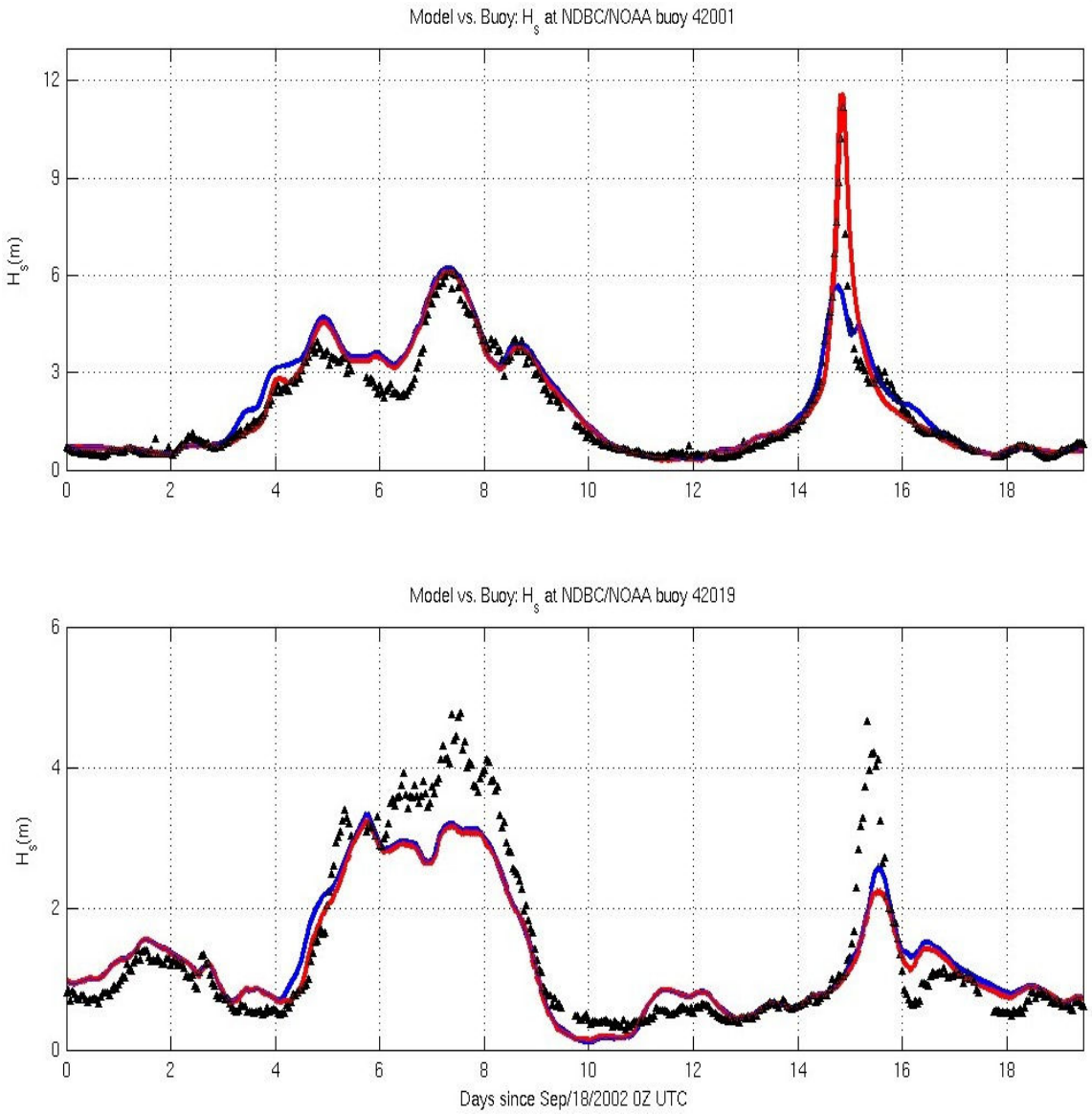
Quality of Guidance (Waves)

- ✓ Weak points of the present wave models.
- ✓ Resolution:
  - ➢ Spectral resolution is “borderline” enough/lacking for swell dispersion.
  - ➢ Spatial resolution could locally be better for islands (partially solved) and hurricanes when GFDL winds are available
  - ➢ Shelf bathymetry not well resolved nearshore: problem for propagation of waves generated offshore
- ✓ Physics:
  - ➢ Slow initial growth, but good predictions of peak and waning stages of storm.
  - ➢ Errors in spectral shape near peak make swell front arrival gradual and slightly late (DIA + numerical).

- ✓ Latest quality snapshot of NAH vs. WNA during 2002 hurricanes
- ✓ Time-series in next slide show simulated wave height at two buoys circled.



- ✓Buoy data: triangles.
- ✓WNA: blue
- ✓NAH: red
- ✓Excellent Hs simulated by NAH in deep water (42001)
- ✓Problems in shallow water (42019): Model's space/time resolution? Shallow-water physics?



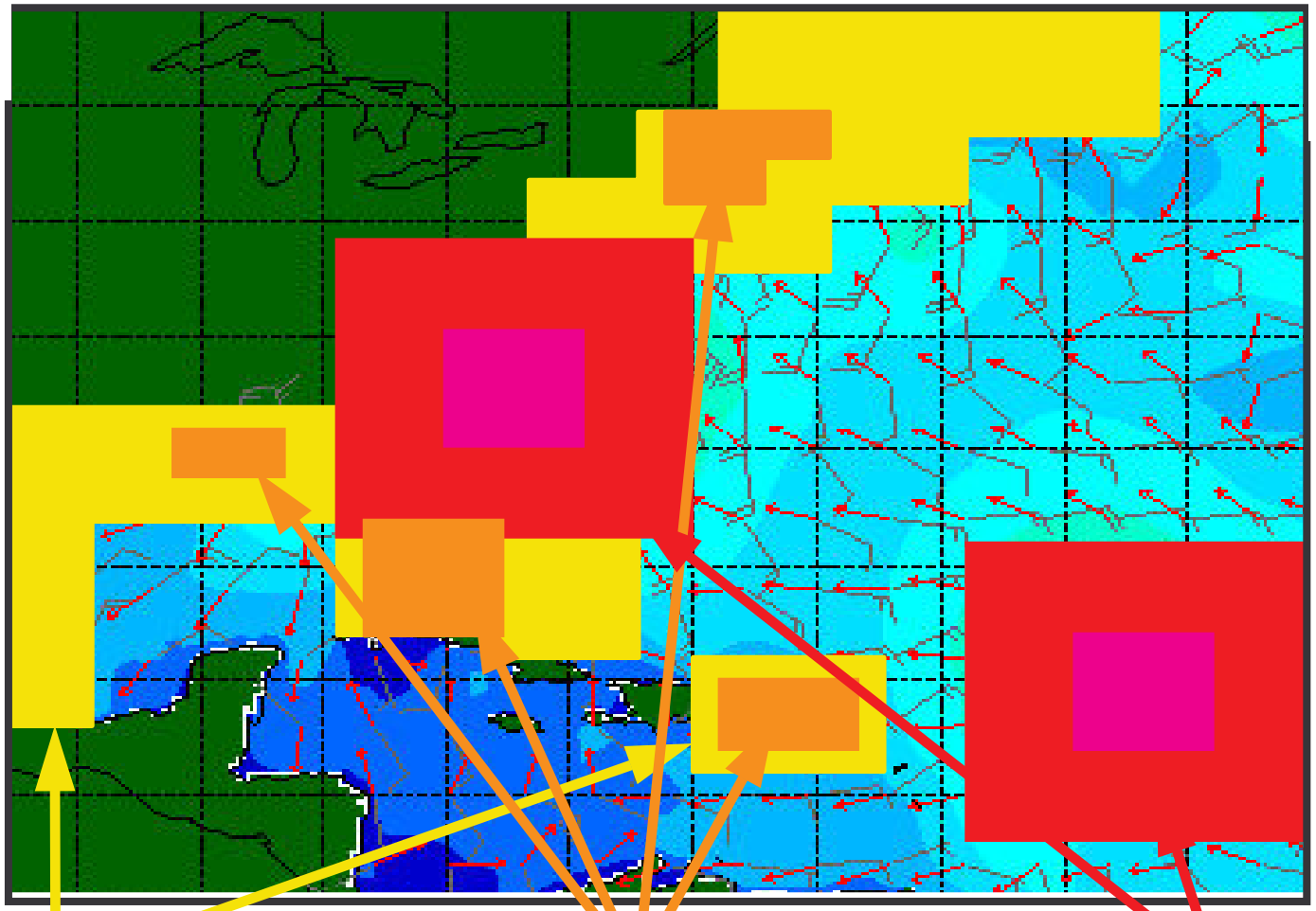
Latest Upgrades

- ✓ Forecast horizon extended to 7 days for global and WNA models (still 3 days for NAH model: GFDL).
- ✓ Island shadowing.
- ✓ Higher spatial resolution in winds due to upgrade of GFS grid from T170L64 to T254L64 (in first 84h).
- ✓ Smaller time step for wind intake in NAH (3h to 1h).
- ✓ Fully allocatable FORTRAN 90 version.
- ✓ Improved source term integration.
- ✓ New propagation scheme for eliminating GSE.
- ✓ Updated and added output points.

Future plans

- ✓ Data assimilation for the global NWW3 model (testing).
- ✓ Additional products (swell, steepness) will be considered without firm plans or time lines (MPC!, WFO?).
- ✓ Physics upgrades are making good progress, no tentative date for implementation yet.
- ✓ Plans for a multi-scale wave model: higher near coast resolution and around hurricanes:
  - ➢ A single model would replace the present set of global and regional models in about five years…

What a multi-scale wave model could look like



medium resolution nest (fixed)

high resolution nest (fixed)

moving nests (hurricanes)

Finally ....

For fast response to questions, remarks, requests etc., contact us at

NCEP.EMC.waves@NOAA.gov

This E-mail will be distributed automatically among our entire wave staff, and therefore will give you the fastest response. To get us personally, try

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Henrique.Alves@NOAA.gov