



# Wave Model Operations at NCEP

## NOAA WAVEWATCH III



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# Overview

Some history and background.  
Operational models at NCEP.  
Recent improvements.  
In the pipeline.



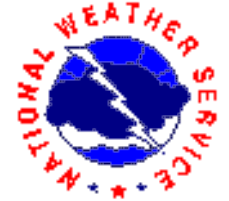
# History<sup>1</sup>

- First operational forecasting for D-day, 1944.
- Up to the late 1950's, parametric relation between the significant wave height and the local wind speed.
- Gelci et al., late 1950's, introduced spectral concept to numerical wave modelling.
- Up to the late 1980's many models developed, using simple nonlinear interaction approximations and/or assumptions on spectral shape (first and second generation models).
- After SWAMP study in mid 1980's, community effort to develop WAM with explicit treatment of nonlinear interactions (third generation models), essentially replacing all previous models.



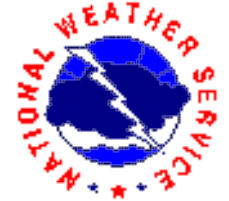
# History<sup>2</sup>

- NCEP's first computer-aided wave forecast was made in 1956, producing only a wave heights and period based on present and recent local winds.
- In 1968, the system was expanded to estimate a single wind seas and a single swell ( $H_s$ ,  $T_p$ ).
- The first operational spectral wave was introduced at NCEP in 1985, and was based on Cardone's second generation SAIL model (first global, later regional).
- Some of these models were replaced by cycle 4 of the WAM model in 1994 and 1997.
- Development of an in-house third-generation model (WAVEWATCH III) started in 1993.



# Why a new model ?

- Although WAM was a major step forward, it was never intended to be the "final answer". After WAM became operational at NCEP, we came to the conclusion that there was significant room for improvement.
- WAM was designed specifically to run optimally on a Cyber 205 supercomputer. The resulting model architecture now hampers further development, and has resulted in a model that is less than optimally suited for new computer architectures (MPP).



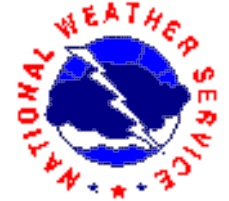
# WAVEWATCH vs. WAM

- New model design based on physics, but also with emphasis on transparency, vectorization and parallelization (plug compatible, portable).
- More general governing transport equation, allowing for later full coupling with ocean models.

Improved propagation schemes (third order versus first order, accounting for unresolved islands).

Improved physics integration scheme (follows small time scale evolution more closely, yet more economical).

Improved physics of wave growth and decay.



# WAVEWATCH III

NOAA/NCEP operational model since 03/2000.

About 35,000 hits on our web site per day,  
corresponding to about 160,000 individual graphical  
products.

Several mirror / reprocessing sites.

Operational at FNMOG and others.

WAVEWATCH III version 1.18 available 04/1999.

Through August 2002, more than 550 requests for  
code. Code still available on web but no more  
logging of requests, updates on bugs page

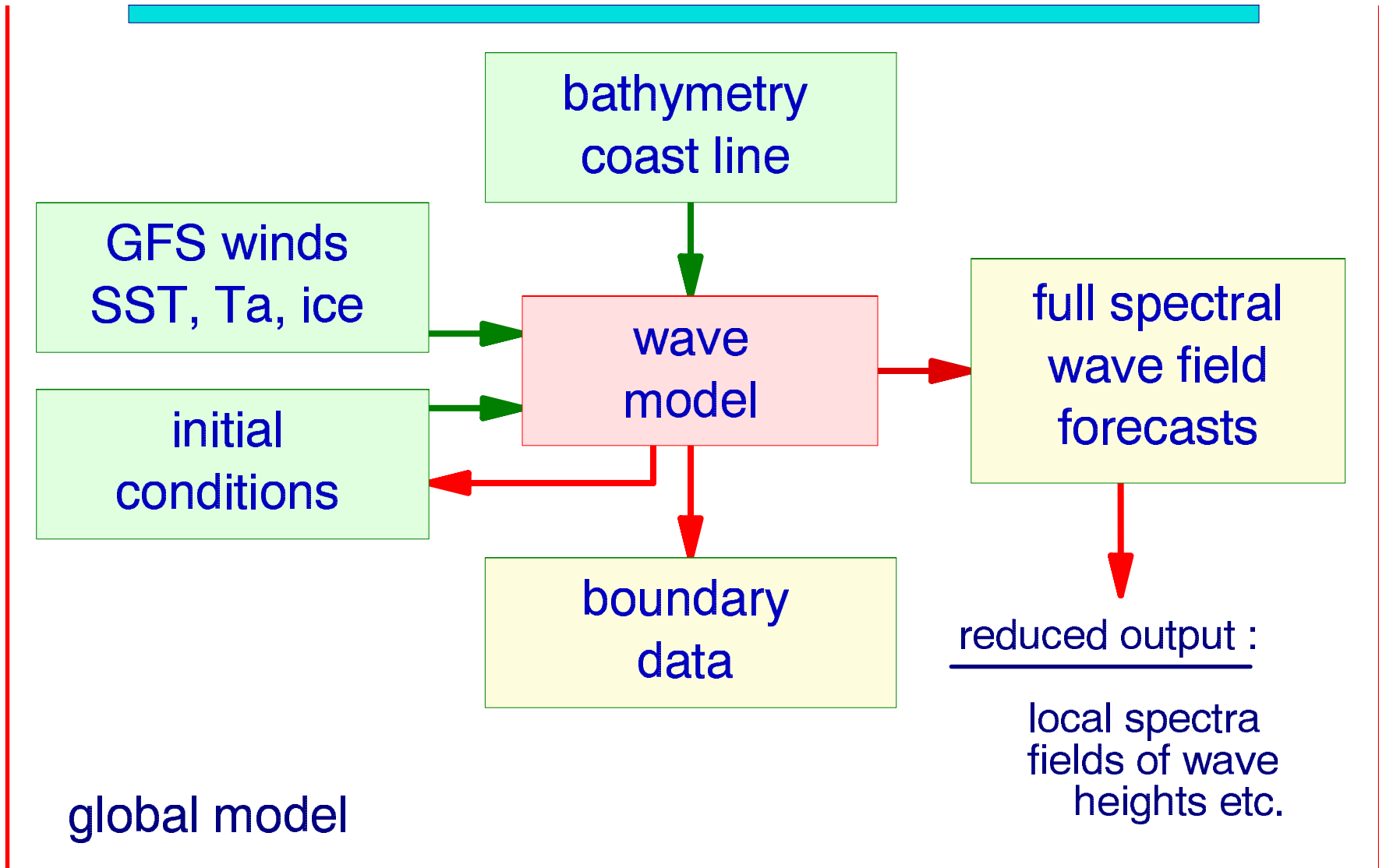
WAVEWATCH III version 2.22 available 09/2002.

257 code requests by April 1 2003.

<http://polar.ncep.noaa.gov/waves/wavewatch>



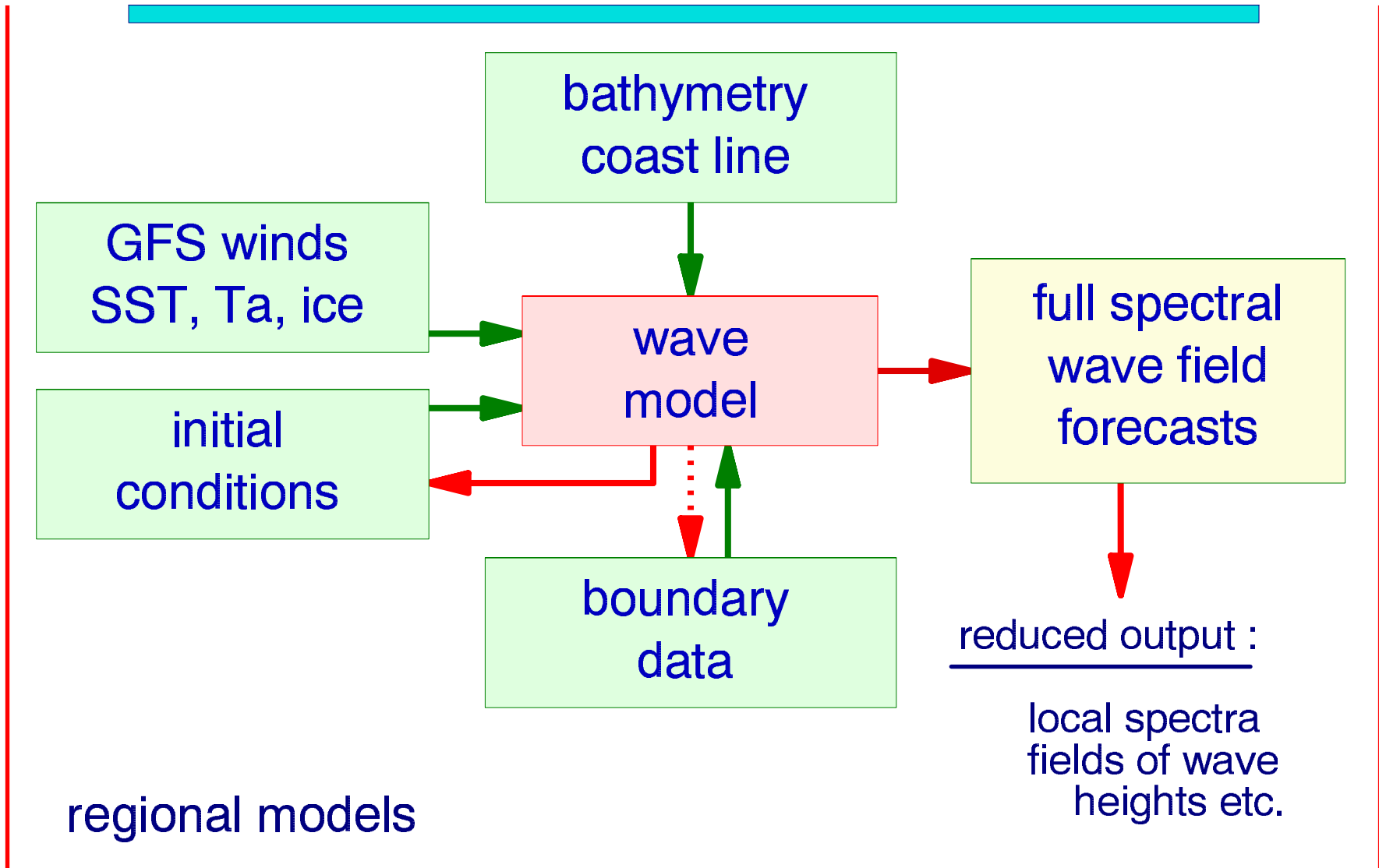
# Operational models <sup>1</sup>







# Operational models <sup>2</sup>





# Operational models

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NOAA WAVEWATCH III models :

Global 1.25x1° NWW3 model (168h).

Alaskan Waters (AKW, 0.5x0.25°, 168h).

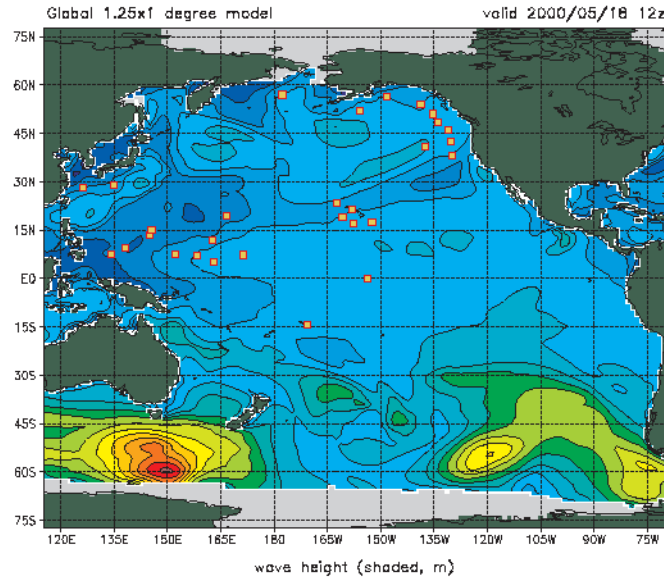
Western North Atlantic (WNA, 0.25x0.25°, 168h), with seasonal Hurricane version (72h, hourly winds).

Eastern North Pacific (ENP, 0.25x0.25°, 168h), with Hurricane version coming (parallel version already on website).

All models use 24 directions, 25 frequencies, GFS / AVN winds at 3 hour intervals, 00z, 06z, 12z and 18z cycle runs, 6 hour hindcasts for continuity.



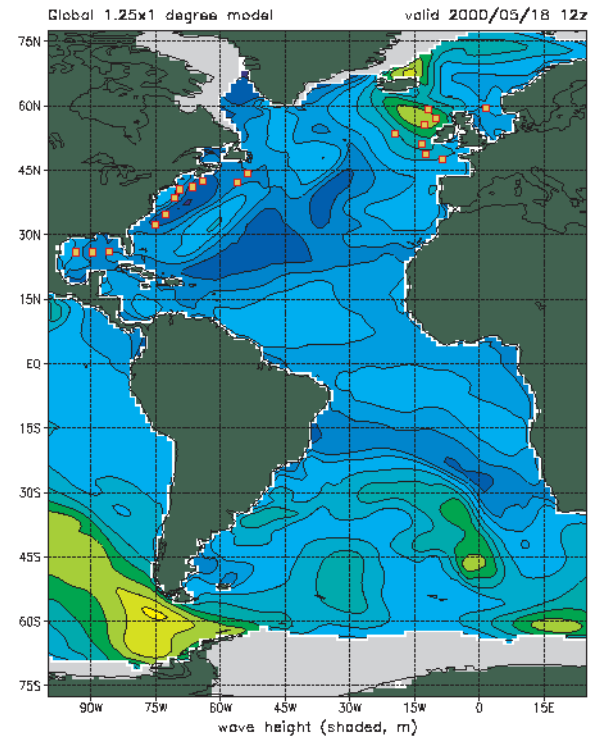
NWW3 20000515 t12z 72h forecast



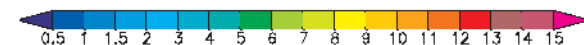
NOAA/NWS/NCEP Ocean Modelling Branch, 2000/05/15



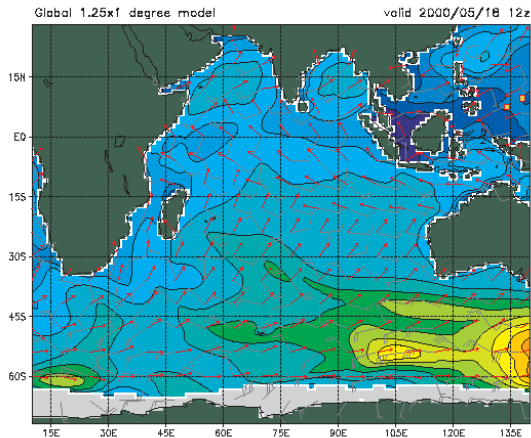
NWW3 20000515 t12z 72h forecast



NOAA/NWS/NCEP Ocean Modelling Branch, 2000/05/15



NWW3 20000515 t12z 72h forecast



NOAA/NWS/NCEP Ocean Modelling Branch, 2000/05/15



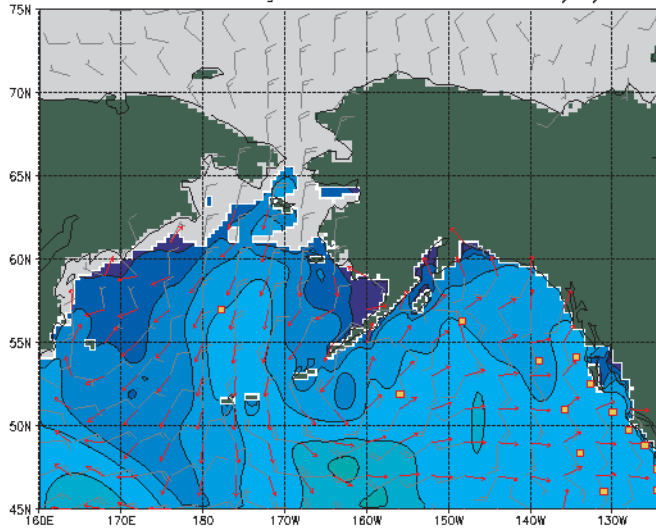
Global  
NWW3  
model

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



NWW3 20000515 t12z 72h forecast

Alaskan Waters 0.5x0.25 degr. valid 2000/05/18 12z



wave height (shaded, m), wind speed (barbs, knots)  
and peak direction (vector, not scaled)

NOAA/NWS/NCEP Ocean Modeling Branch, 2000/05/15



NWW3  
regional  
models

Alaskan Waters (AKW)

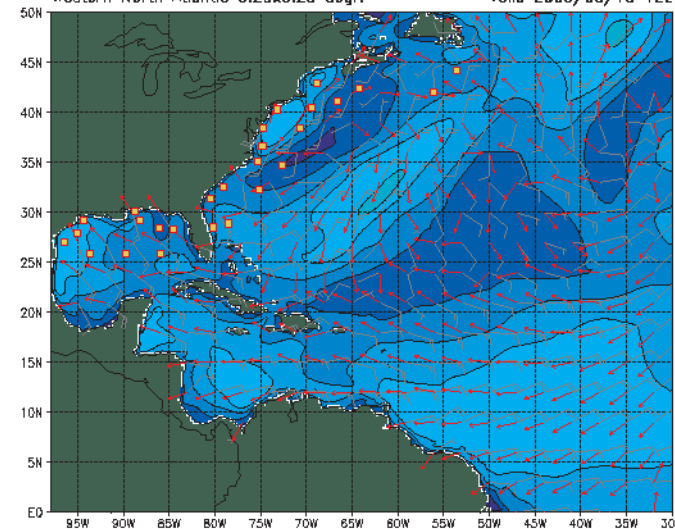


Western North Atlantic (WNA)



NWW3 20000515 t12z 72h forecast

Western North Atlantic 0.25x0.25 degr. valid 2000/05/18 12z



wave height (shaded, m), wind speed (barbs, knots)  
and peak direction (vector, not scaled)

NOAA/NWS/NCEP Ocean Modeling Branch, 2000/05/15

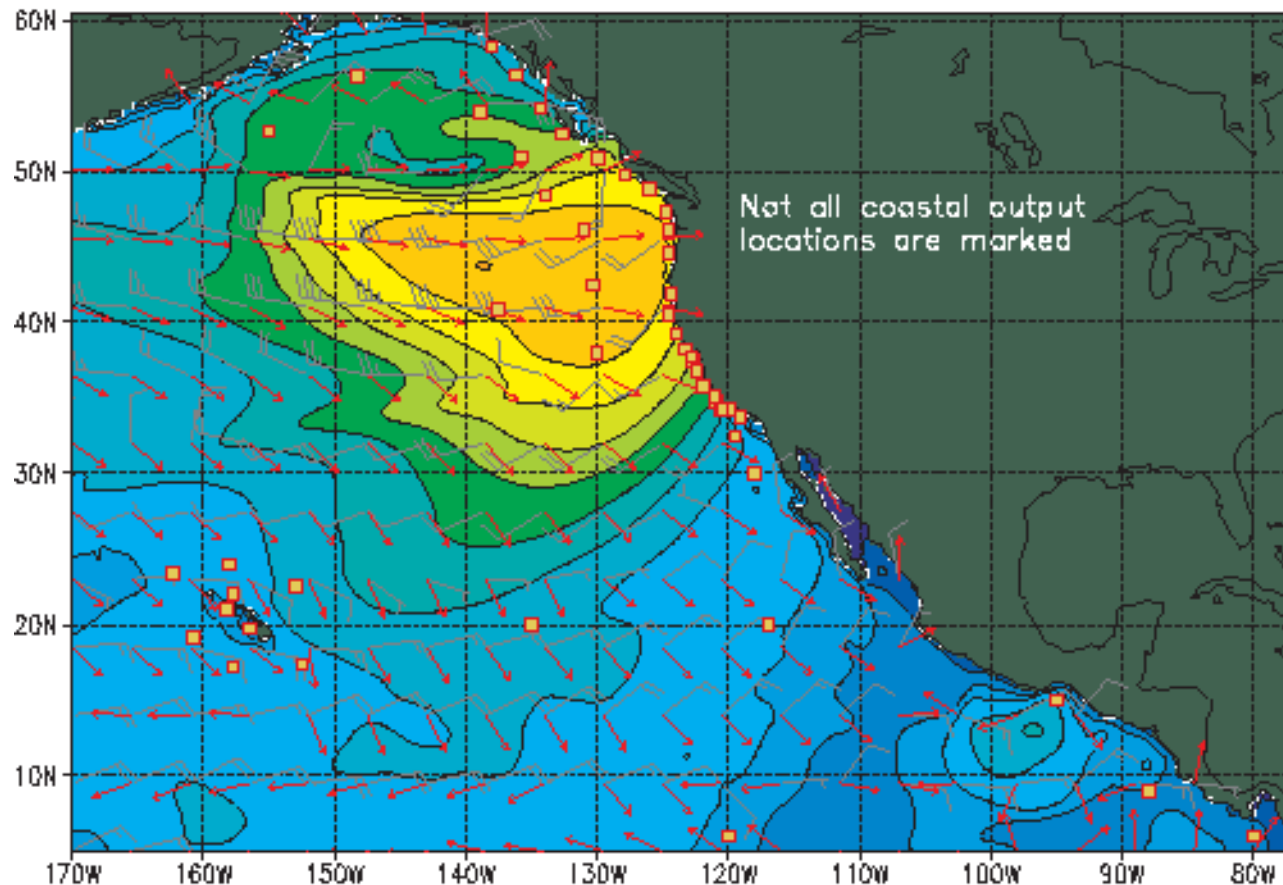




# NOAA WAVEWATCH III 24h forecast

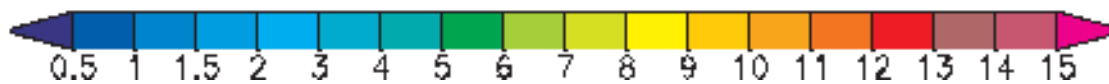
Eastern North Pacific 0.25x0.25 degr.

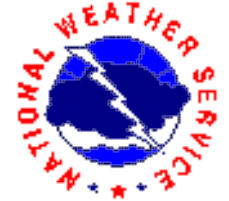
valid 2002/11/08 12z



wave height (shaded, m), wind speed (barbs, knots)  
and peak direction (vector, not scaled)

NOAA/NWS/NCEP Marine Modeling and Analysis Branch, 2002/11/13





# Operational models <sup>4</sup>

Why do we need a special Hurricane version (NAH, NPH) of regional models (WNA, ENP).

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.

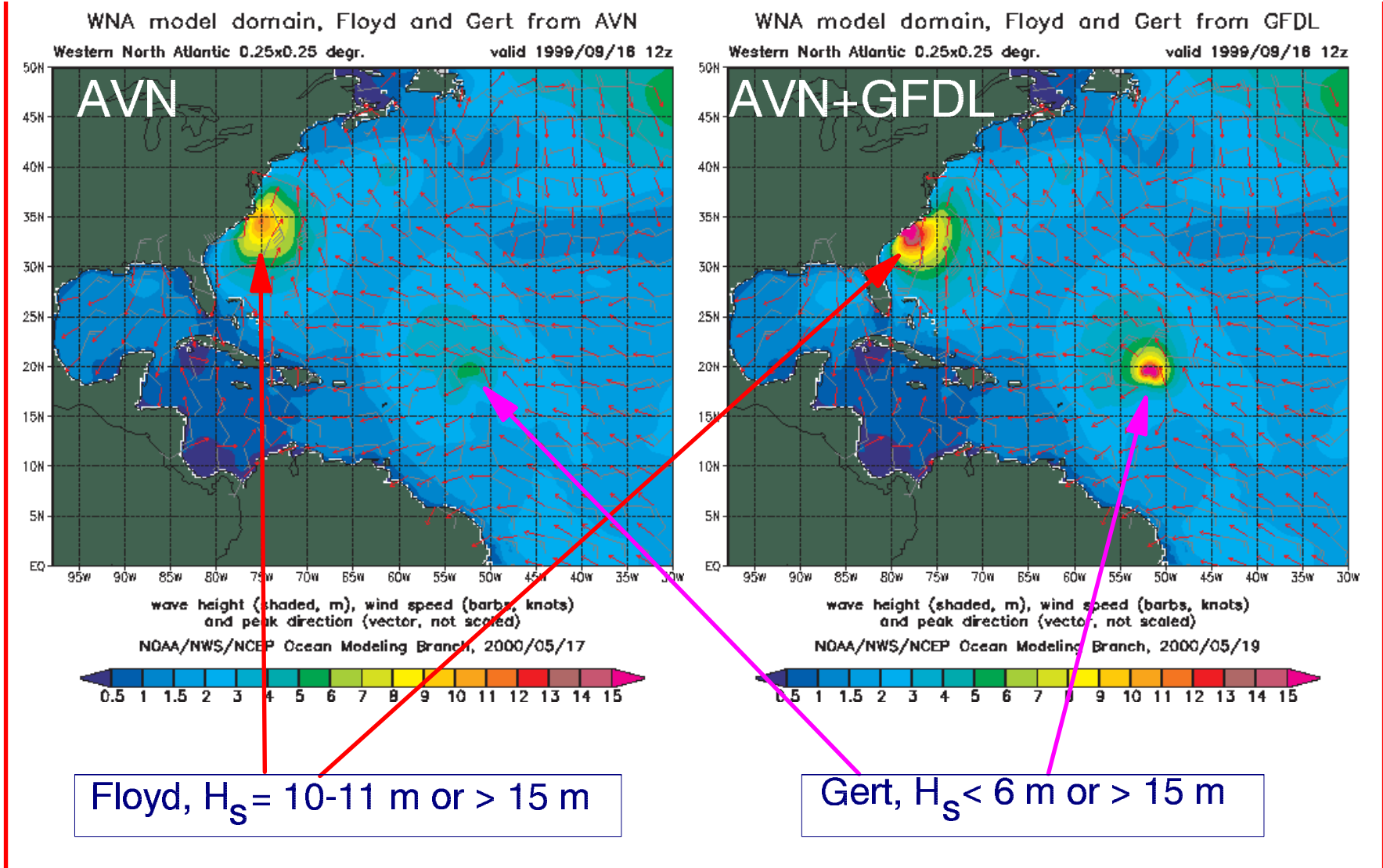
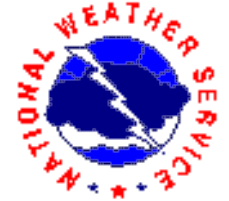
Better results expected when higher resolution models are used such as the GFDL model.

Need for blended GFS/GFDL winds.

Recent update: hourly wind fields from GFDL.



# Hurricanes Floyd and Gert (Chao & Tolman)

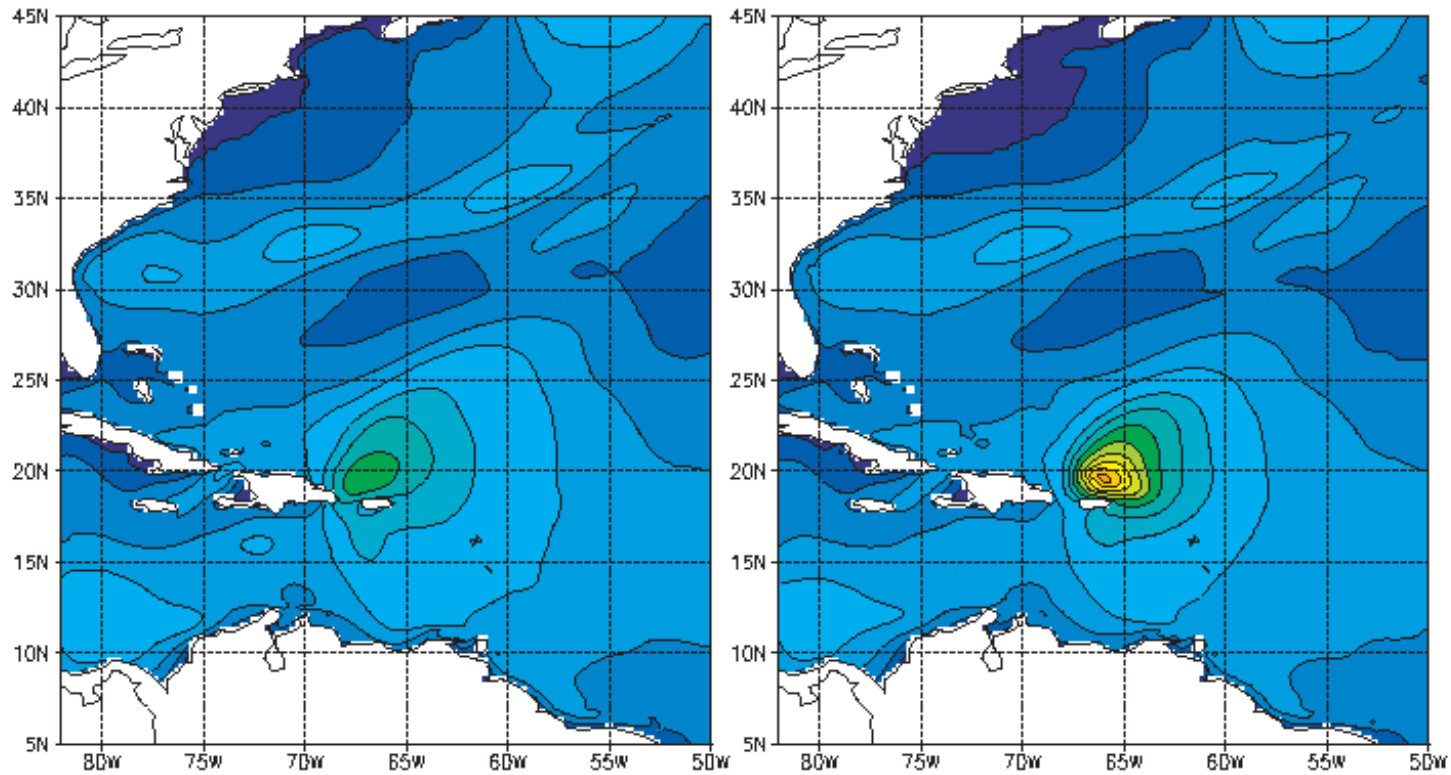




# Debby significant wave height (m) 2000/08/22 00z

AVN winds

AVN + GFDL winds



wave height (shaded, m), hindcast valid 2000/08/23 00z



NOAA/NWS/NCEP Ocean Modeling Branch, 2001/03/02

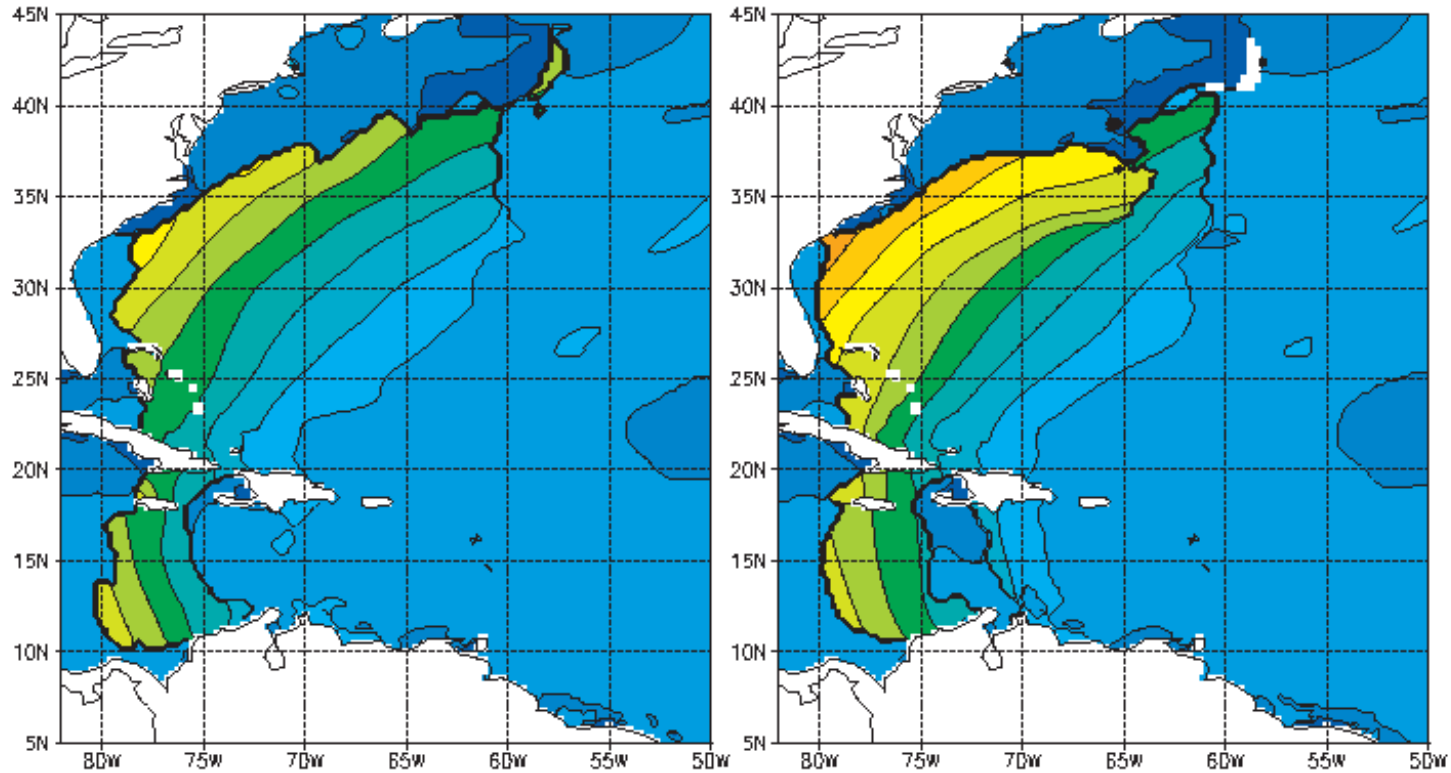




# Debby peak wave period (s) 2000/08/23 12z (+ 36 h)

AVN winds

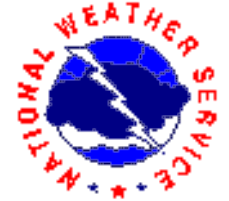
AVN + GFDL winds



peak wave period (shaded, s), hindcast valid 2000/08/24 12z



NOAA/NWS/NCEP Ocean Modeling Branch, 2001/03/02



5

# Operational models

## Michelle at 11/04/2001 15z

wind speeds

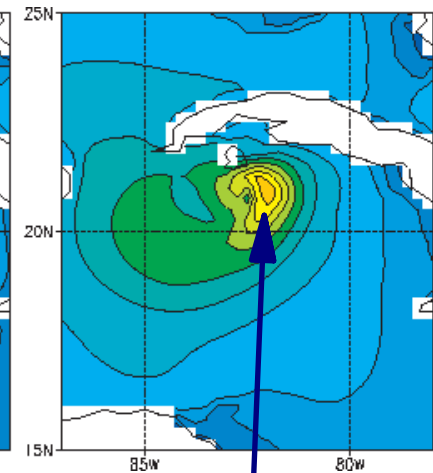
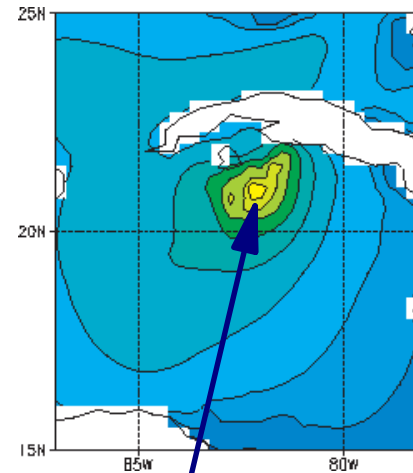
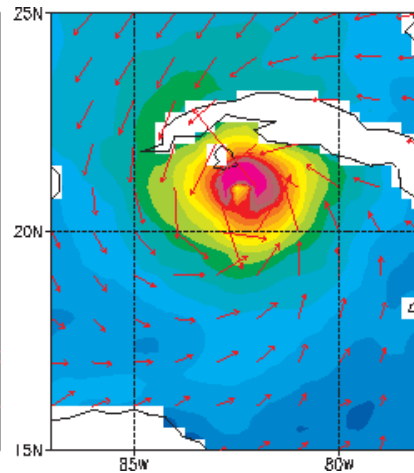
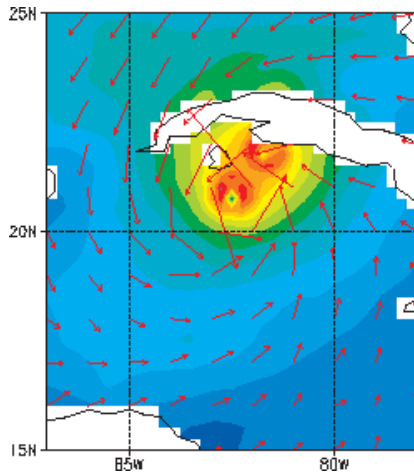
every 6 hours

every 1 hour

wave heights

6 hours winds

1 hour winds

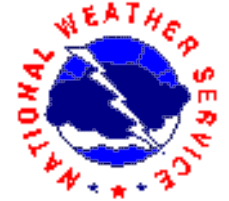


Six hourly wind fields show two centers at off hour. These are in fact the centers at 12z and 18z, respectively. Unrealistic wind fields are caused by necessary interpolation, and do not occur with hourly winds.

8-9 m

10 m

Wave heights from hourly winds are noisy and low. Wave heights from hourly fields are more consistent and higher.



# Operational models <sup>6</sup>

Fully allocatable FORTRAN 90 version with standard default settings.

Improved source term integration (Hargreaves & Annan).

New propagation scheme :

Alternative methods to eliminate the Garden Sprinkler Effect.

Accounting for unresolved islands (and sea ice).

Retuning

upgrades in WAVEWATCH III version 2.22



# In the pipeline

The following changes and expansions to WAVEWATCH are planned / investigated :

NNIA (XNL included already).

All other source terms.

Alternative grids.

Data assimilation. **Chen**

Two-way nesting with moving grids.



1

# Nonlinear interactions

The parametrization of the nonlinear interactions forms the heart and soul of any third generation wave model :

`Exact' algorithms available but at least a factor 100 too expensive to use in practical models.

DIA cheap enough to make model feasible, but its accuracy is generally recognized as the stumbling block for further development of model physics.

Limited progress since 1985, partially because the DIA was barely feasible until recently.

ONR funding for NCEP and others to develop new parameterizations.



2

# Nonlinear interactions

Recent developments in the parameterization of nonlinear interactions :

`Exact' algorithms have become much more economical, but still too expensive for practical applications (and will always be so?).

Filtered exact interaction may be feasible in practical models within the next decade (SRIAM as developed in Japan).

Modified DIA's less than 10 times more expensive and much more accurate (some feasible on class 9 machine).

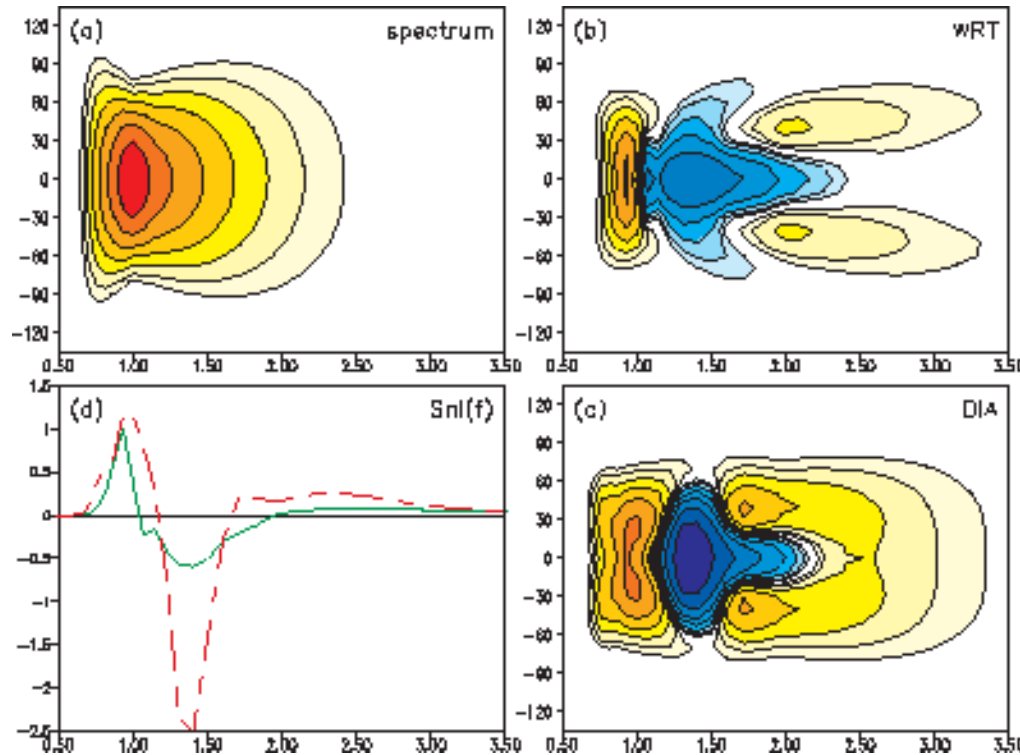
Neural Network Interaction parameterizations may even be cheaper than DIA.

NCEP funded by ONR



3

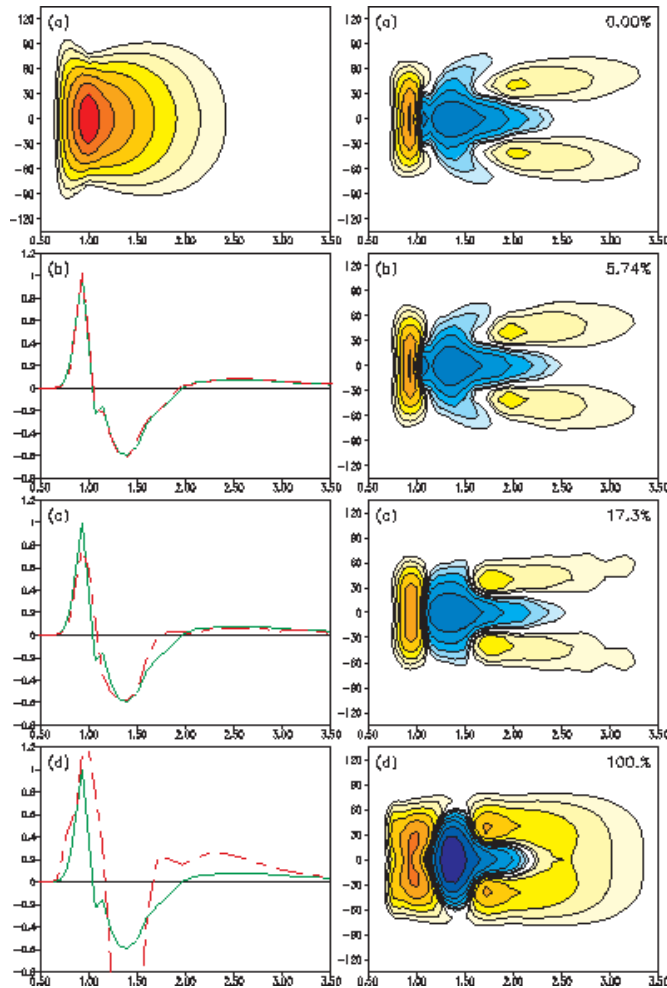
# Nonlinear interactions



Test spectrum, exact interactions and DIA. Limited accuracy of DIA is obvious. DIA set up (only) to describe positive lobe at low frequencies accurately.



# Nonlinear interactions



Alternative forms of the DIA as developed at NCEP.

Multiple DIA (second set of panels) is 17 times more accurate, at about 10 times the costs, needs to be combined with NN.

Variable DIA (third set of panels) is 5 times more accurate at about 4 times the costs of the DIA, and is defined independent of spectrum.

Both methods under active development.

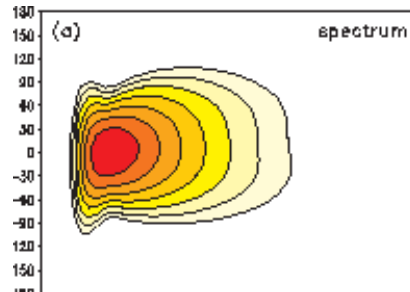




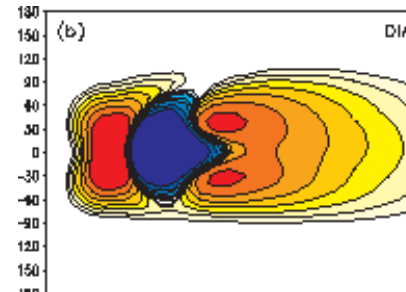
5

# Nonlinear interactions

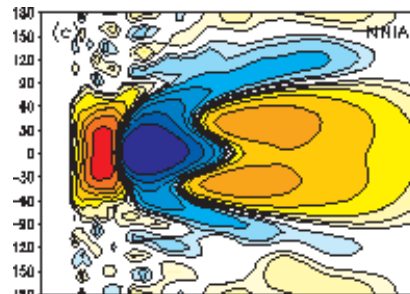
spectrum



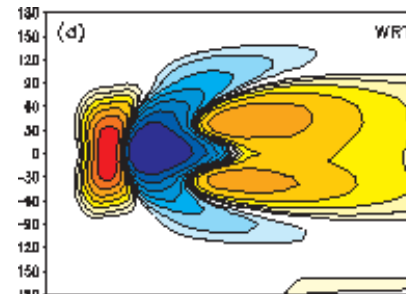
DIA



NNIA



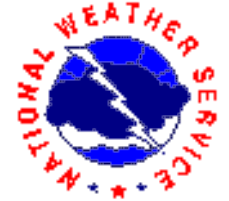
WRT



A Neural Network can be trained to estimate interactions directly from the spectrum, and can be 5 to 10 times more accurate than a DIA at about the same costs.

Example from older NNIA,

Wiggles a problem, robustness in model integration not yet satisfactorily addressed.



1

# Multiscale wave model

The next step in expanding the functionality of WAVEWATCH III is to generate a multi-scale version of this model :

Two-way nesting of models with different scales that run simultaneously.

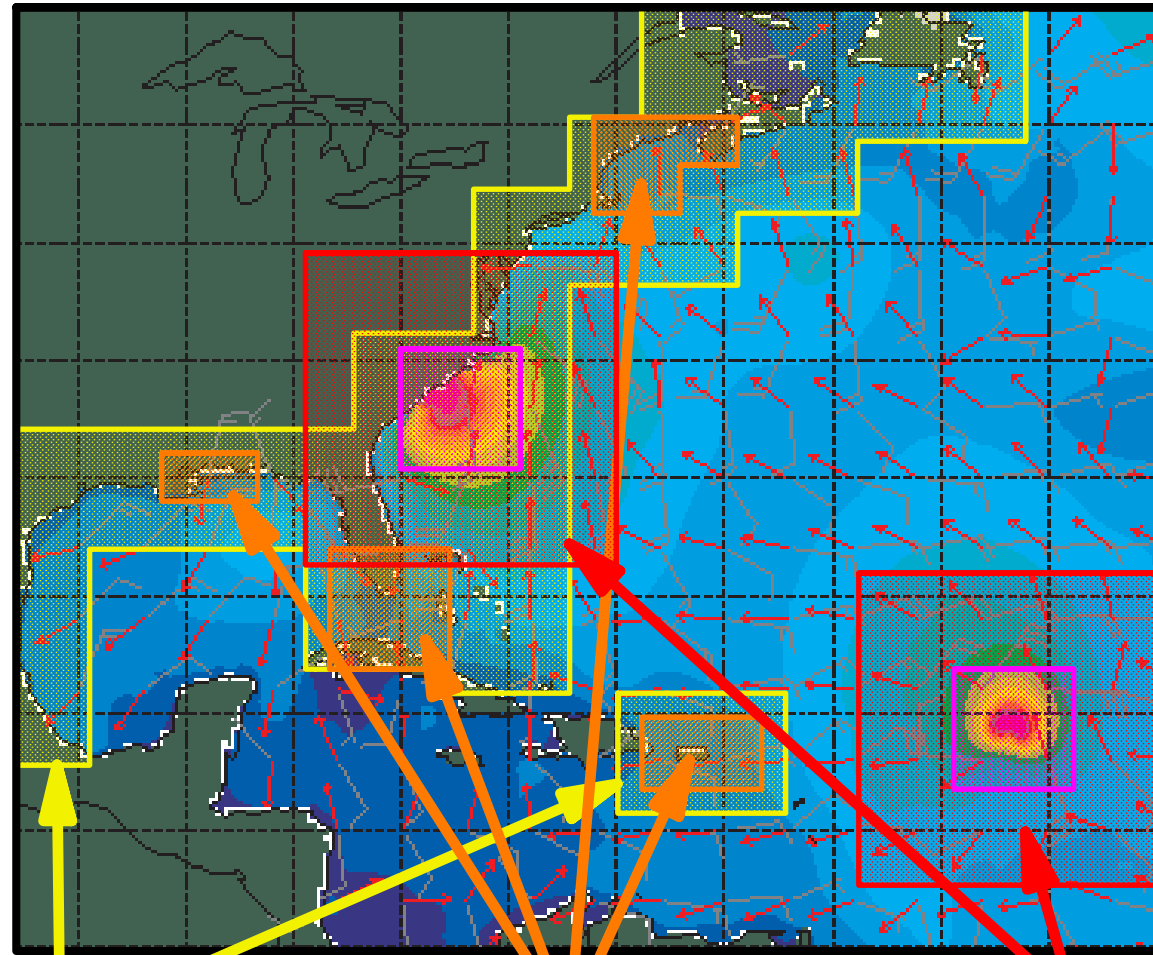
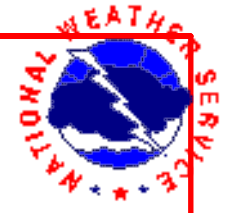
coupling with WRF

Moving nests follow features of interest, particularly hurricanes.

Hurricane nests plus coastal nests remove the need for running separate large regional models.

Selective application of highest resolution nests makes ensemble wave forecasting more feasible.

Good potential for external funding from navy.



medium resolution nest (fixed)

high resolution nest (fixed)

moving hurricane nests



## Concluding remarks

WAVEWATCH III becoming popular world wide, either as NWW3 products from NOAA, or as source code run locally.

New model release (version 2.22) well received.

Much in the pipeline. New nonlinear interactions will remove last 'hard link' to the old WAM model, and new functionality (nesting) will greatly enhance model capabilities.