Development of the HWRF

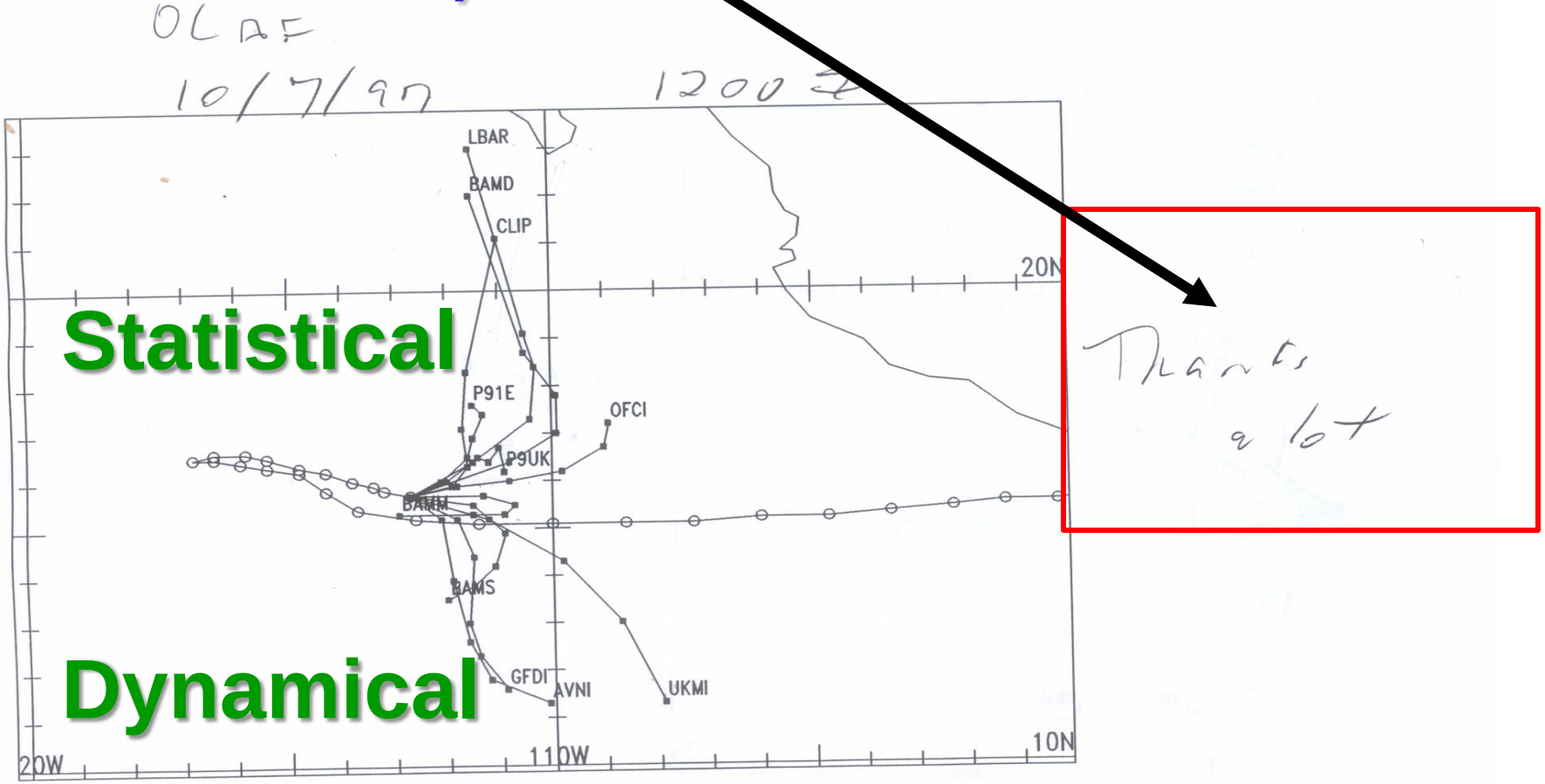
Naomi Surgi

and HWRF Team

NCEP/EMC/DTC

Joint EMC/MMM/DTC Hurricane Workshop
February 22-23, 2010

Max Mayfield left this for me on my desk at NHC (after he worked a mid shift)…….. It was 1997



HWRF '07 Implementation Strategy

- GFDL – overall most skill for track
- Retain strengths of operational GFDL system
  - Physics (convection, PBL, microphysics)
  - Ocean coupling
- Drive product system identical to GFDL
- Meet or exceed GFDL performance
- Document performance to meet TPC requirements
- Development & implementation cycle 2002-2007

HWRF Testing and Evaluation Implementation Strategy

- **Preliminary T&E (27 separate expt's. ~200 runs)**
  - Each component (dynamics, physics, ocean coupling) tested individually
  - Like GFDL, ocean mixed layer coupling in EPAC
  - No tuning for specific cases

- **Final implementation testing**
  - Homogeneous comparisons with GFDL system
  - '04, '05, '06 seasons (ran 3 full hurricane seasons)
  - ATL and EPAC basins
  - Total of
    - 1745 HWRF runs (4x/day)
    - 900 GFDL runs (2x/day)

❖ **Set standards for:**

Performance testing (case load; evaluation criteria) ; System functionality (Initialization, Coupling) ; Computational performance & execution timeliness; Software compliance for codes & scripts

Initial (2007) HWRF Configuration

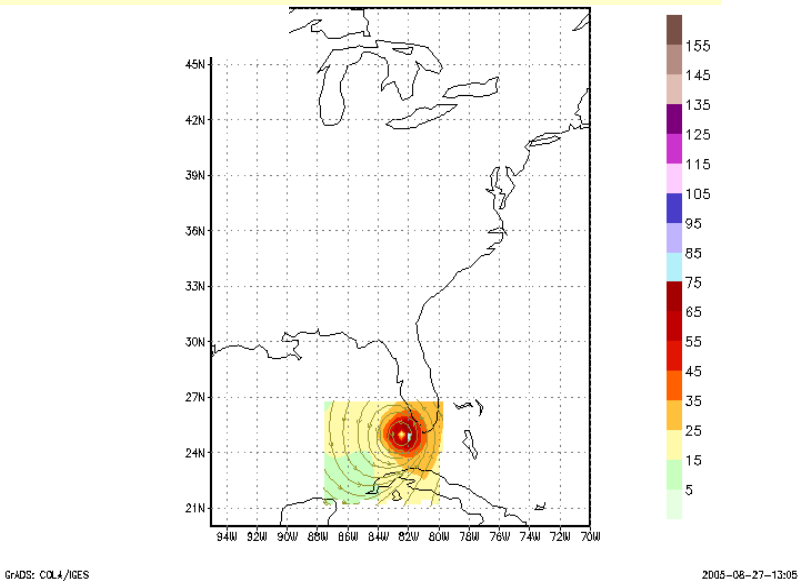
- **Movable, 2- way nested grid**

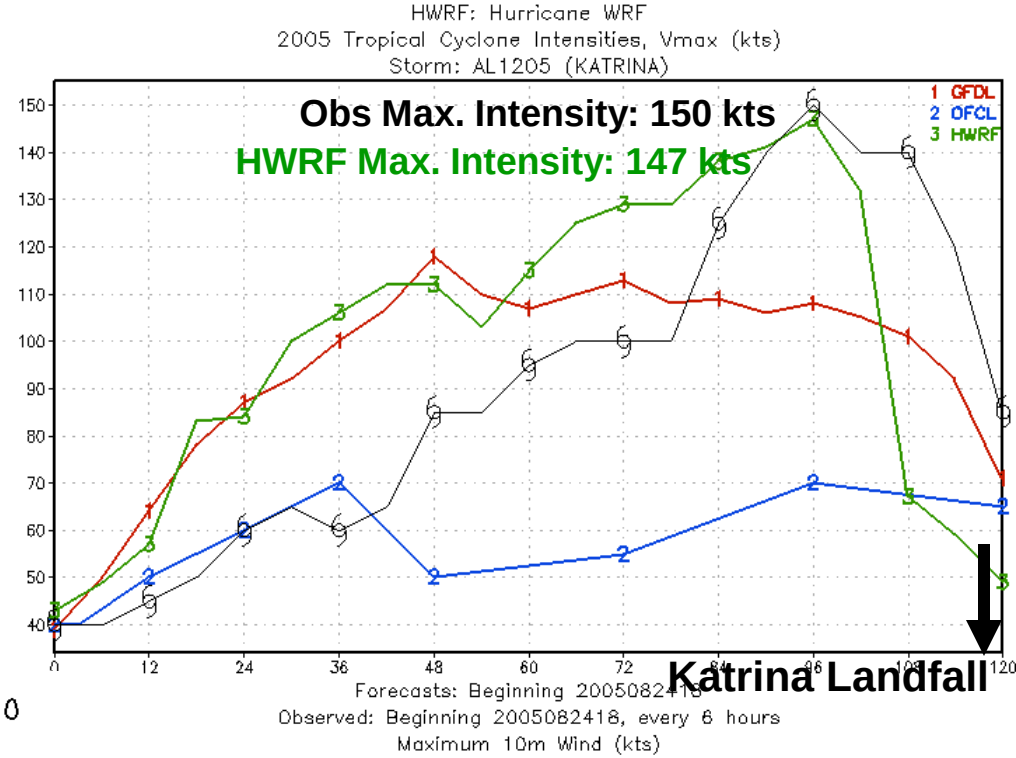
  9km inner nest; 27km parent domain/42L;

  ~75° X 75° domain

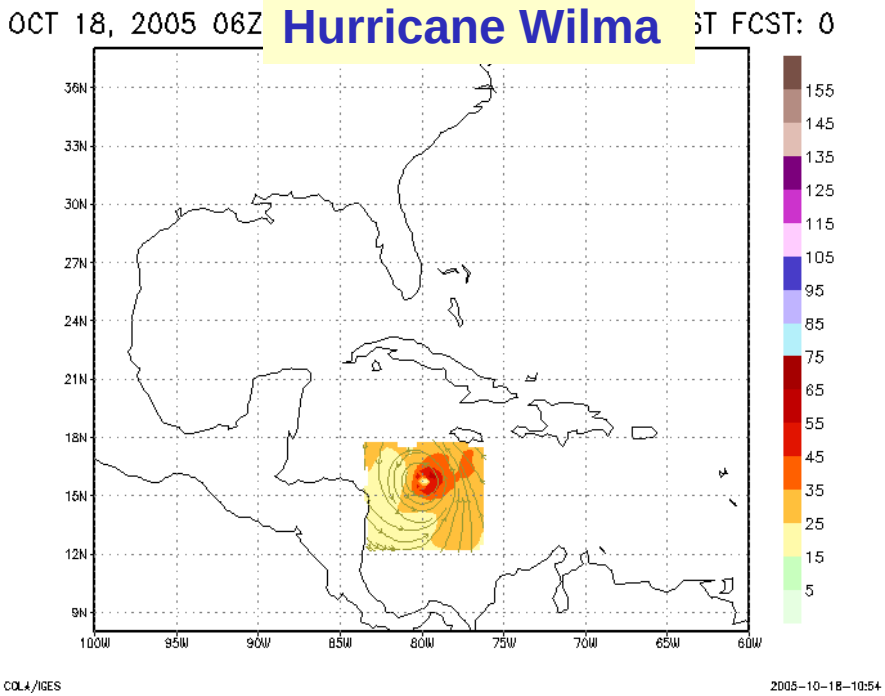
- **GFS & GFDL Physics- developed for TC applications**
- **Advanced vortex initialization - Advancement over GFDL bogus**
  - **Cycled (6 hr) initial state (makes use of obs.)**
  - **Prototype GSI 3D var (first step)**
- **Coupled to Princeton Ocean Model**
  - **loop current inititialization**

Hurricane Katrina





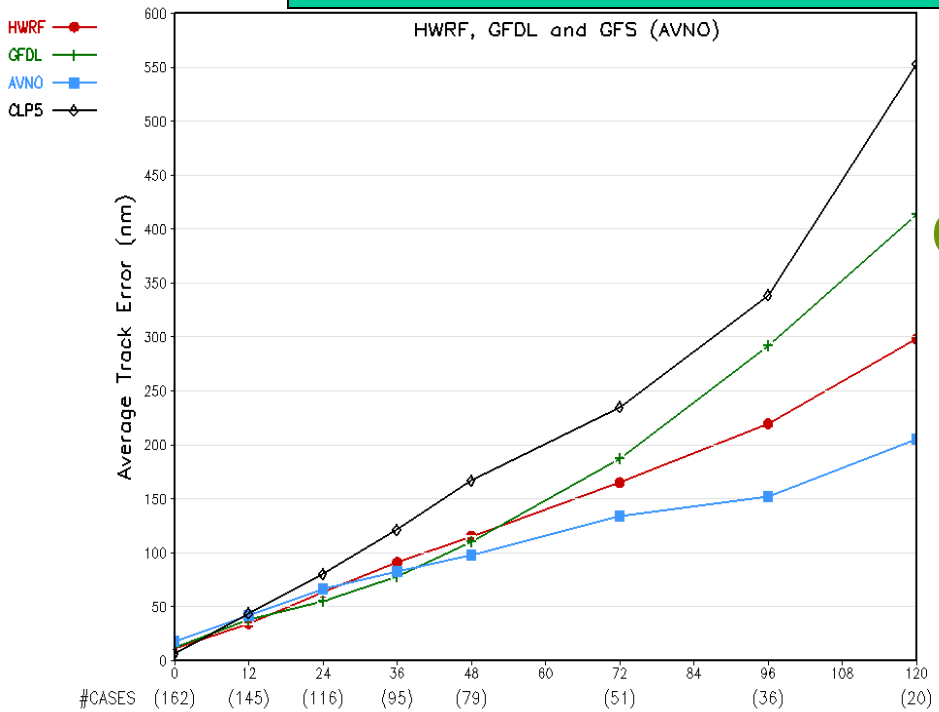
Hurricane Wilma



Good simulations of strong storms, e.g. Katrina, Wilma....

***Note**: but suspected weak storm intensity bias esp. at t=0, (implications for '09 hurricane season)*

2007 Performance

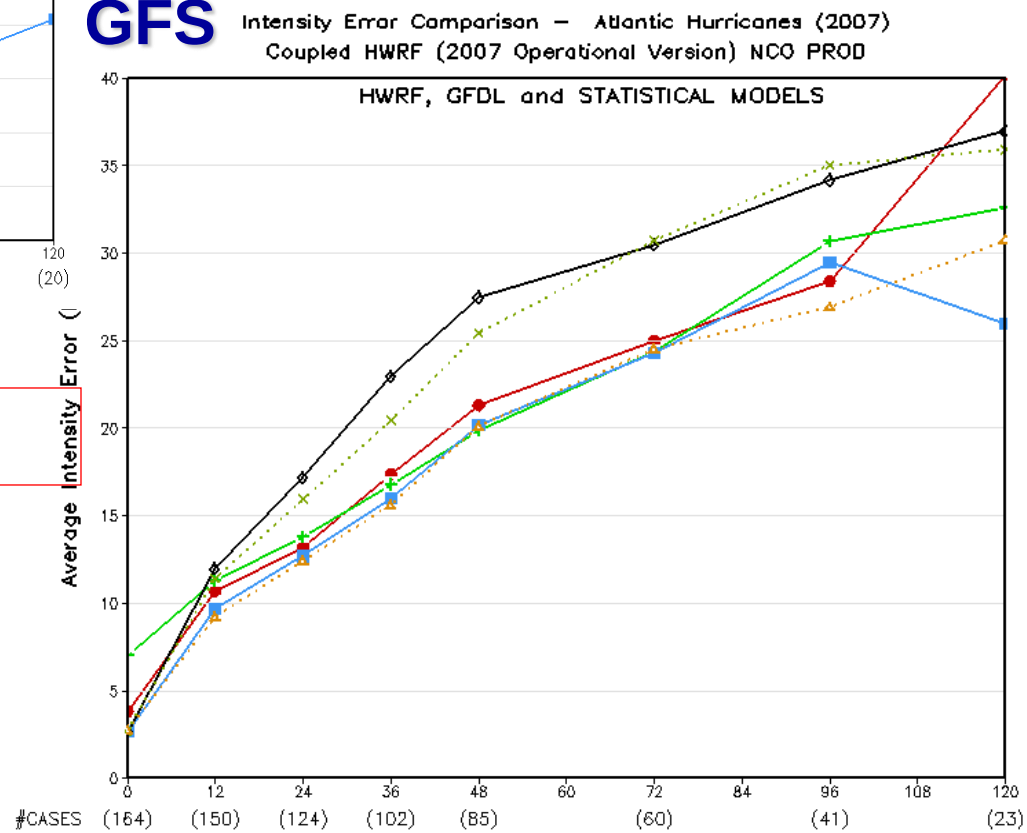


2007 TRACK ERROR

GFDL

HWRF

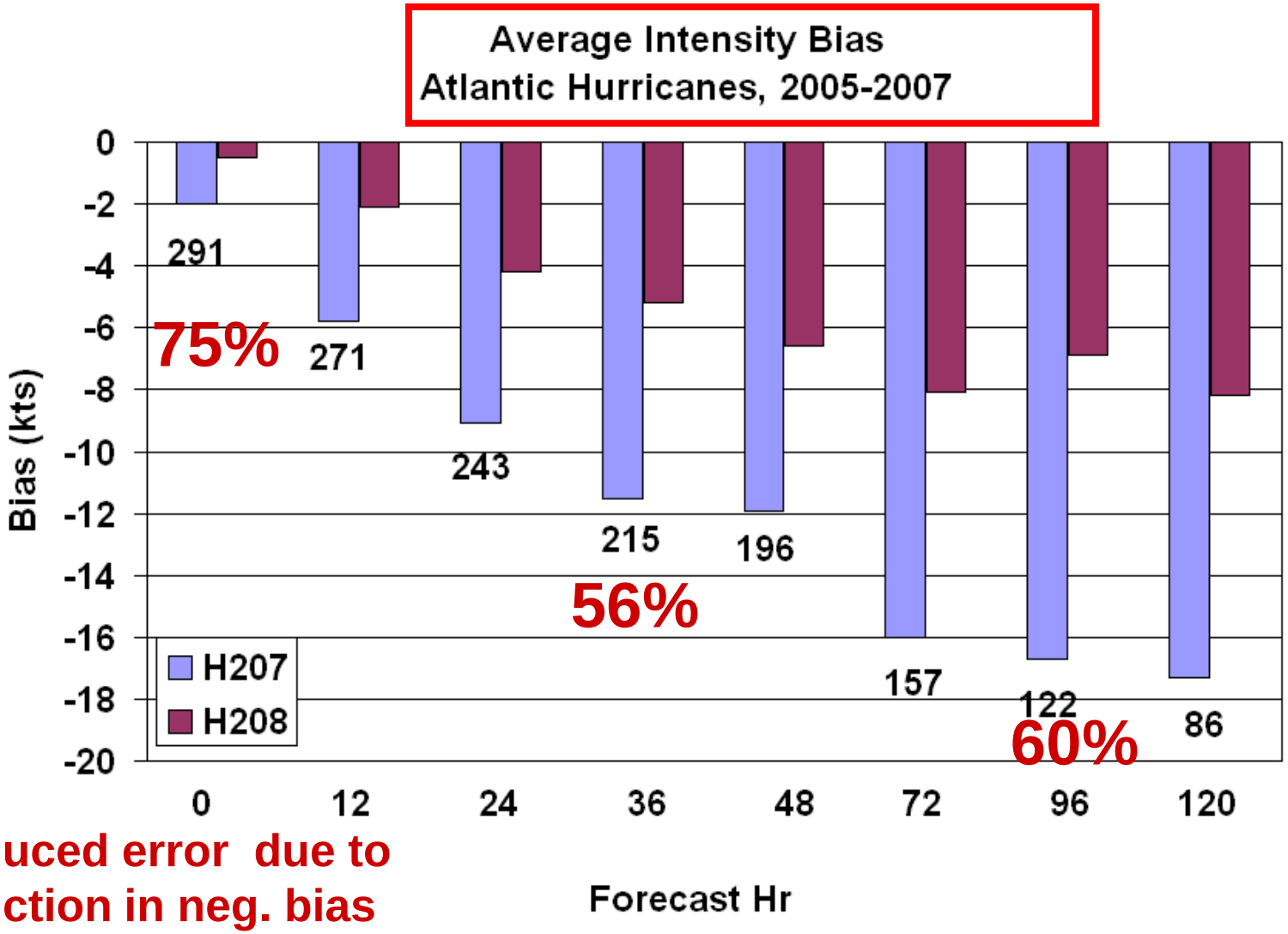
GFS



2007 INTENSITY ERROR

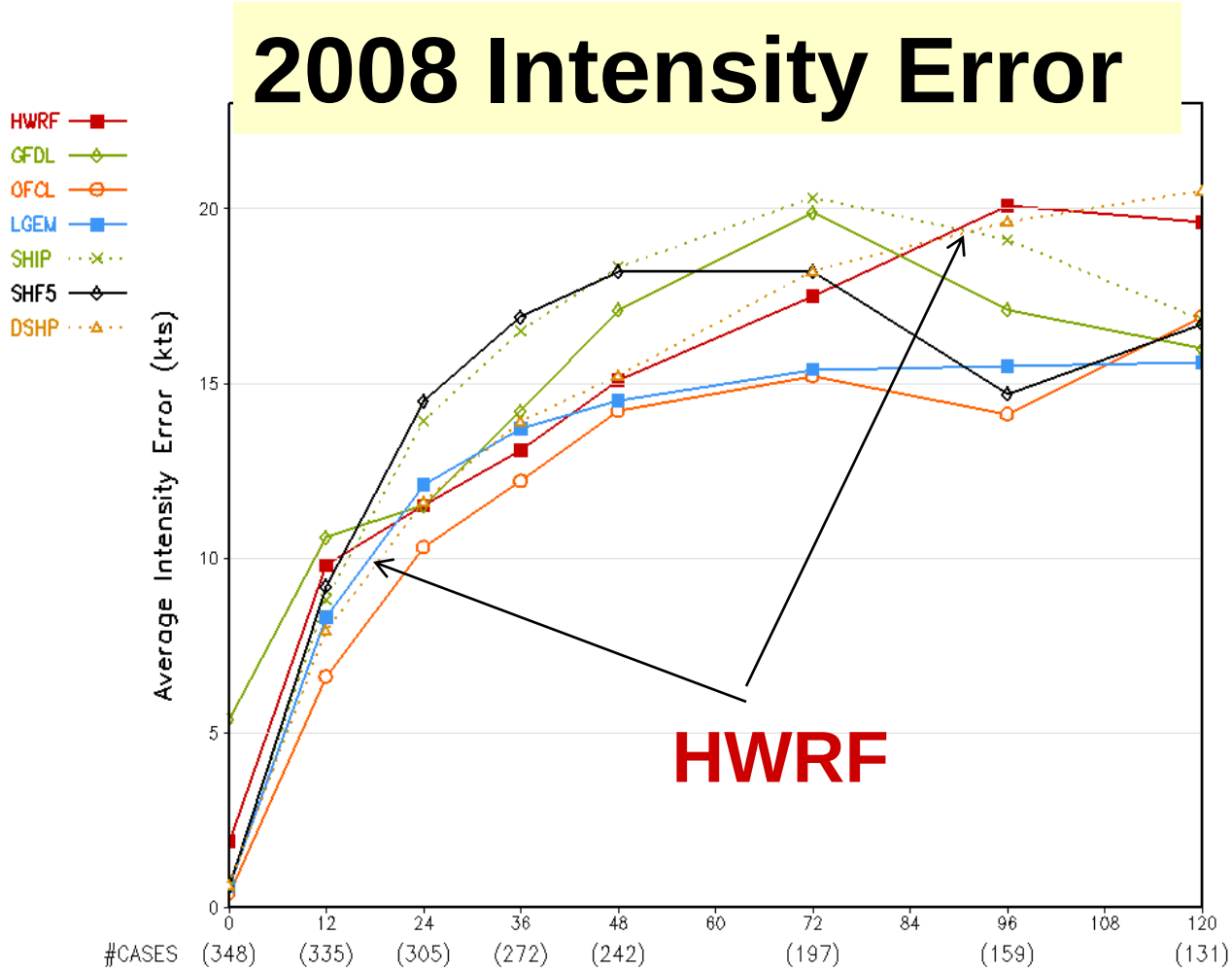
Promising inaugural Season performance

For '08 season: made some improvements to HWRF analyses for weaker storms – better use of observations to correct vortex structure, better balance; sfc. physics, initialization in POM

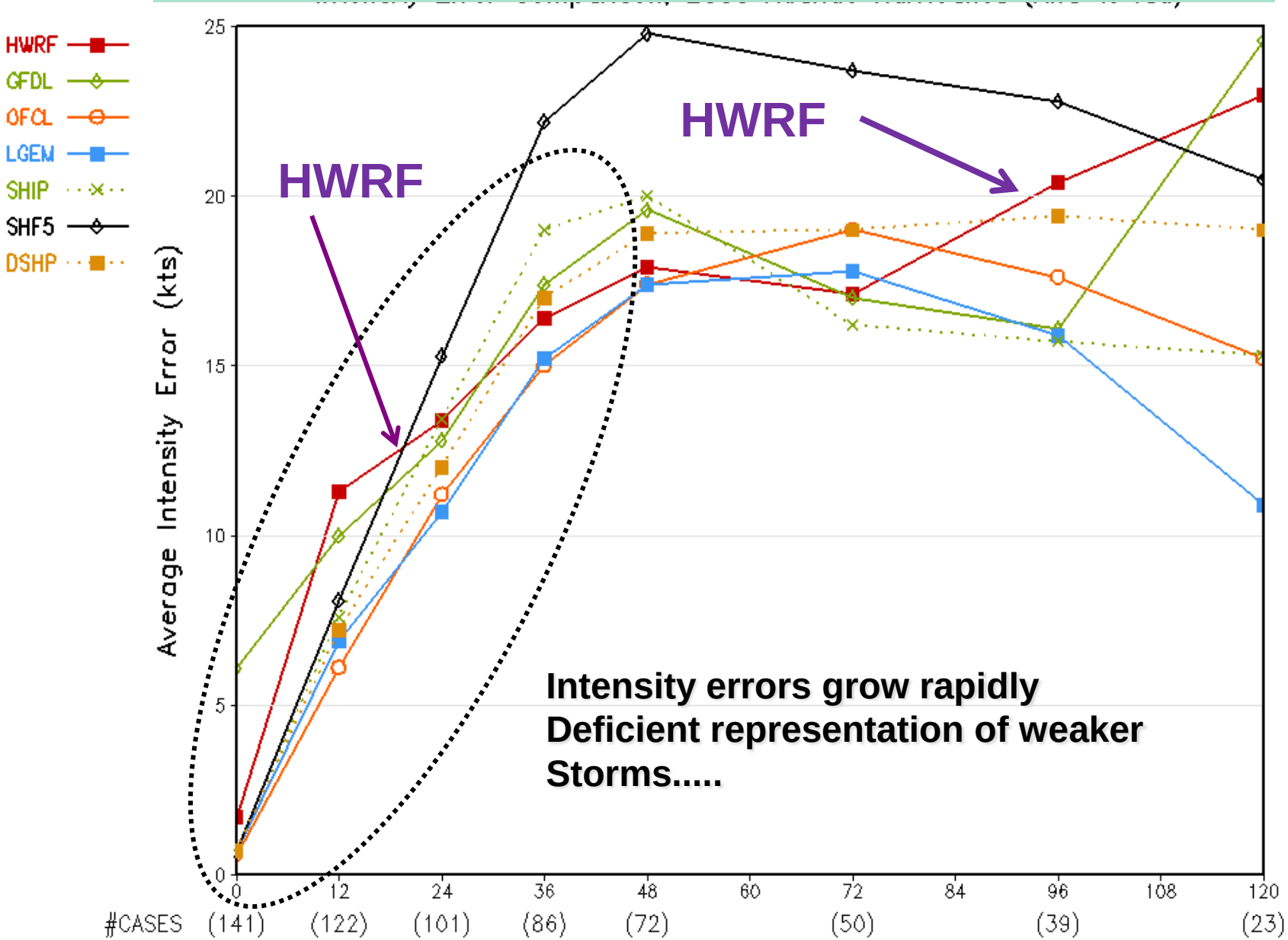


Reduced error due to reduction in neg. bias

Then in ’08 season ….went from negative bias to positive bias (e.g. Dolly, Fay) - Weaker storms too strong

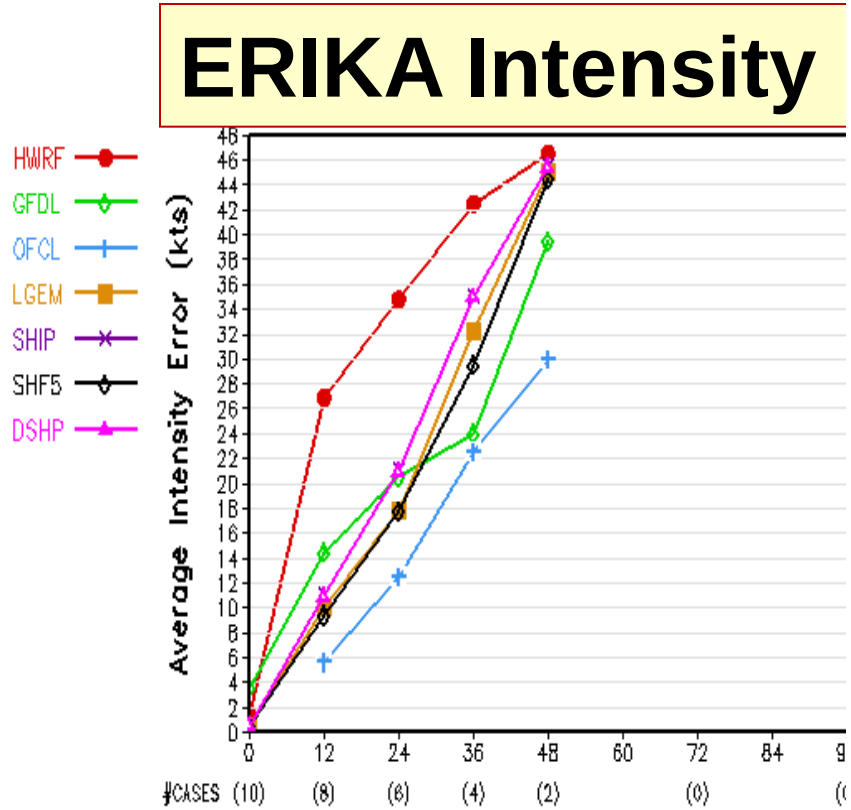


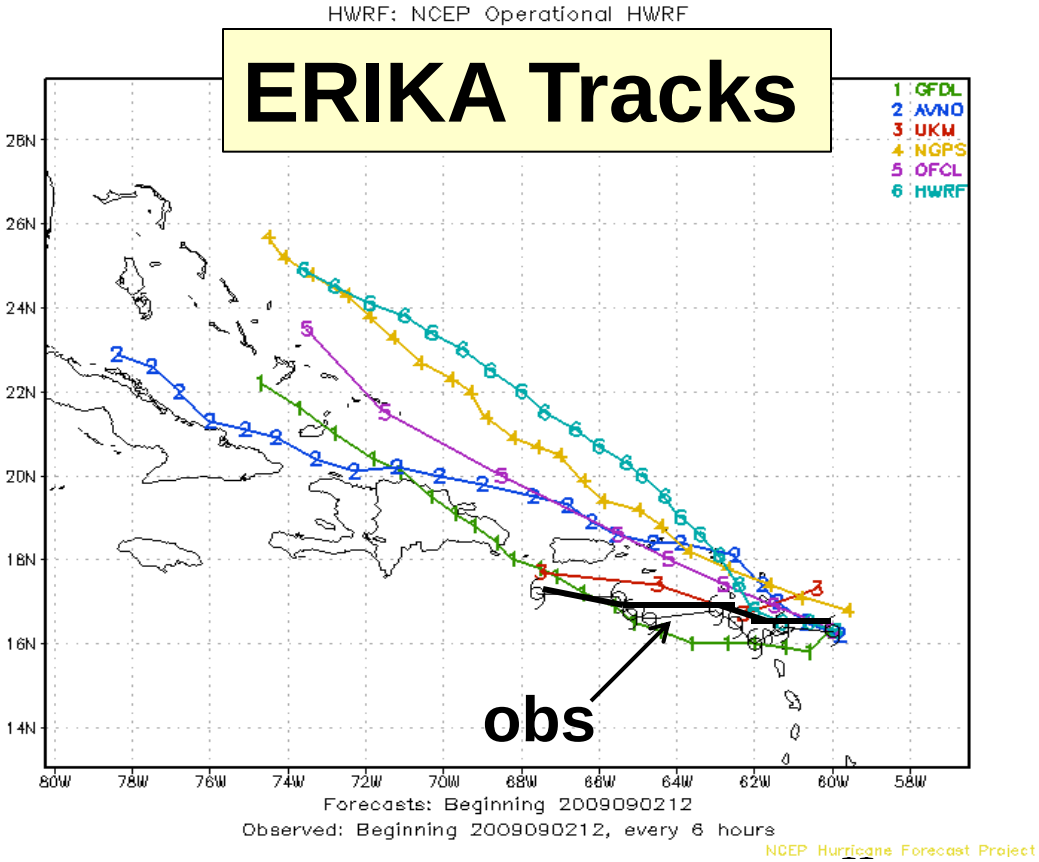
Intensity Error for 2009 Atlantic

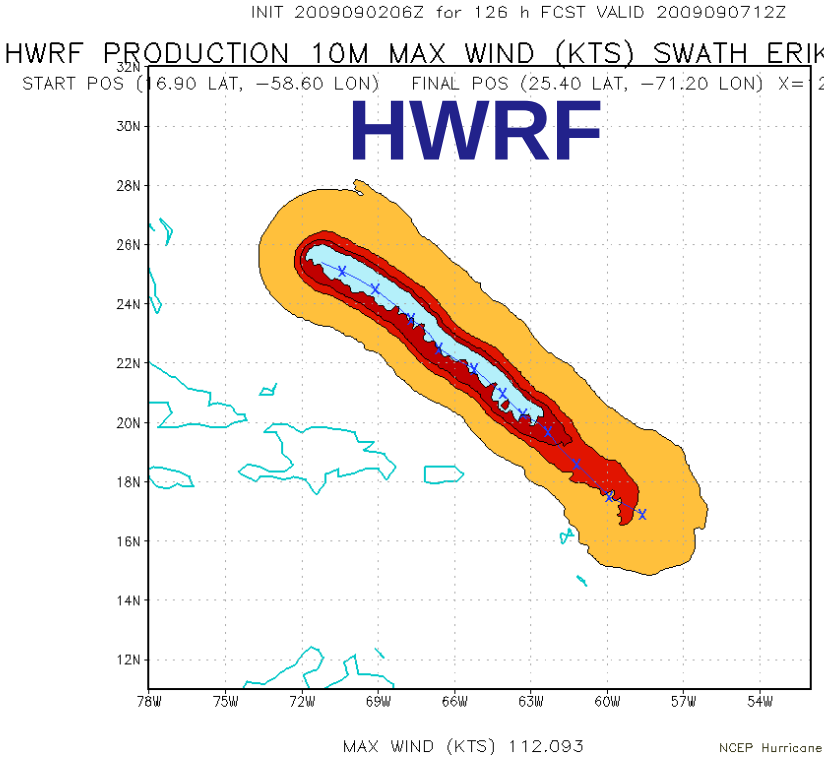


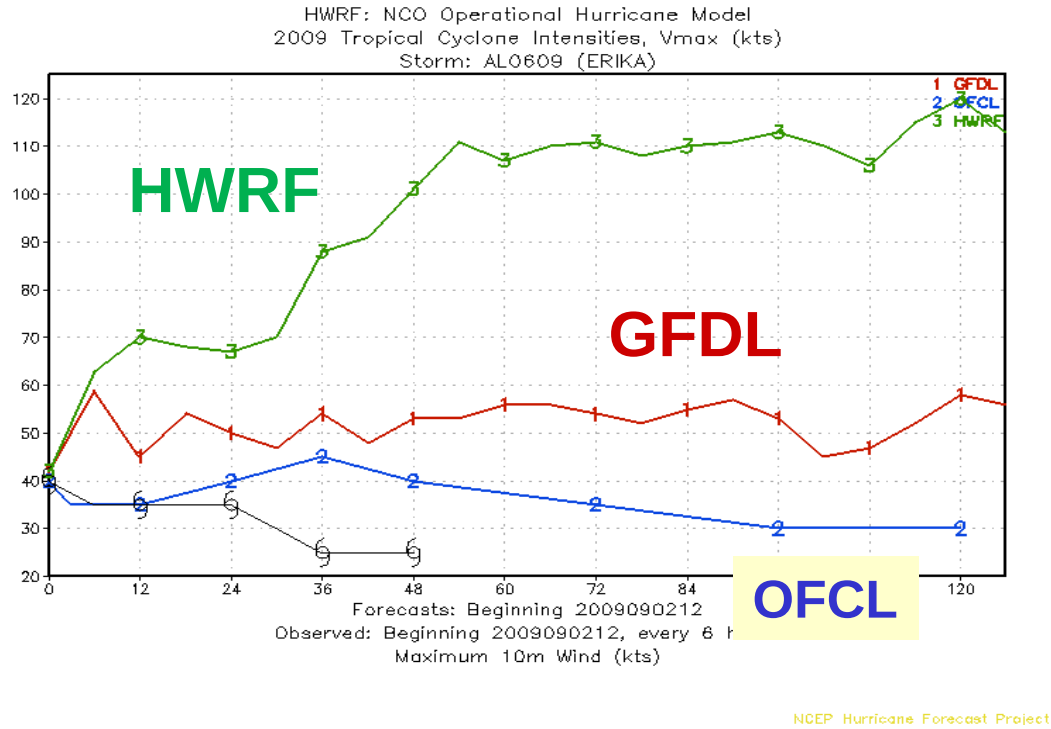
How did the operational models (including HWRF) do for the 2009 hurricane season?

Erika representative of ATL 09 sheared (weak) storms





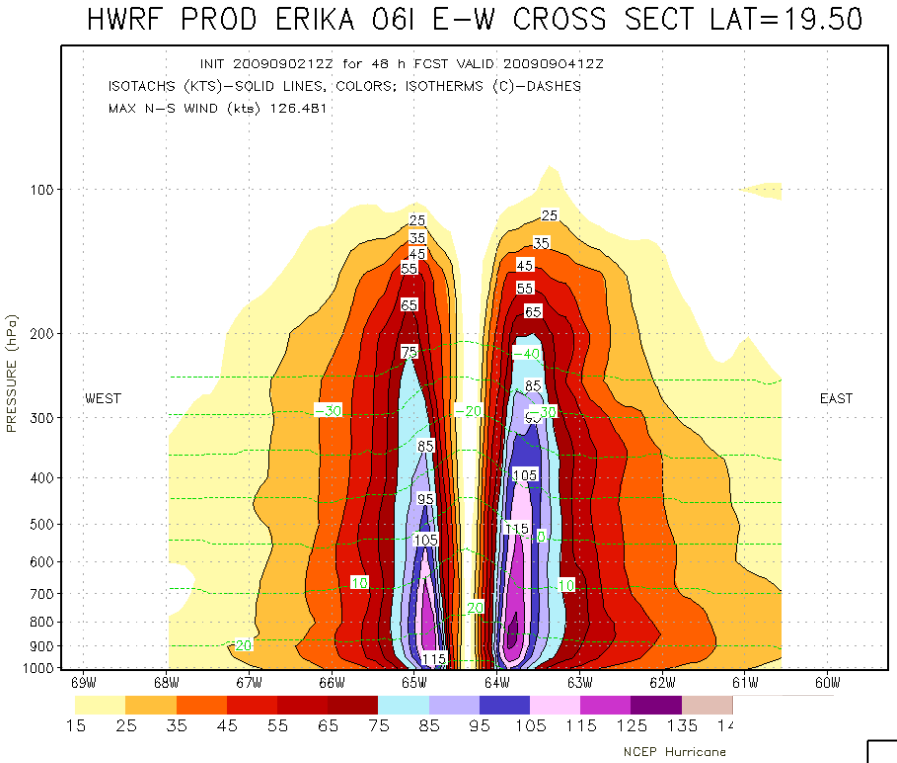




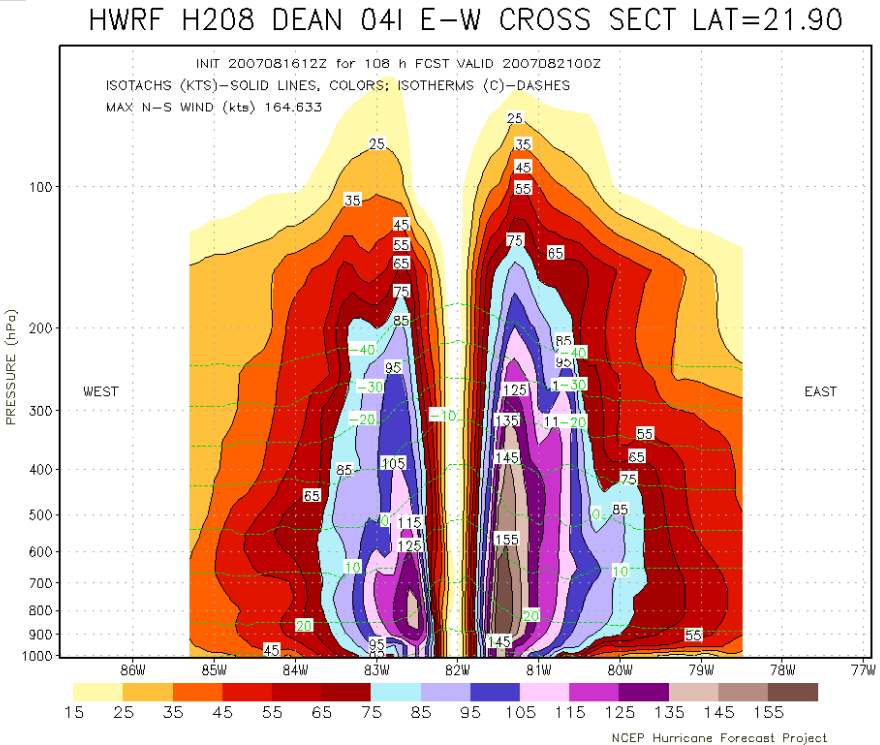
THE NHC INTENSITY FORECAST IS VERY SIMILAR TO THE PREVIOUS OFFICIAL FORECASTS...BUT BELOW THE CONSENSUS OF THE NUMERICAL INTENSITY GUIDANCE. IT SHOULD BE NOTED THAT SOME OF THESE NUMERICAL MODELS...SUCH AS THE HWRF AND GFDL... HAVE SHOWN A HIGH BIAS FOR A COUPLE OF THIS YEAR'S ATLANTIC TROPICAL CYCLONES.

HWRF

ERIKA (finis)



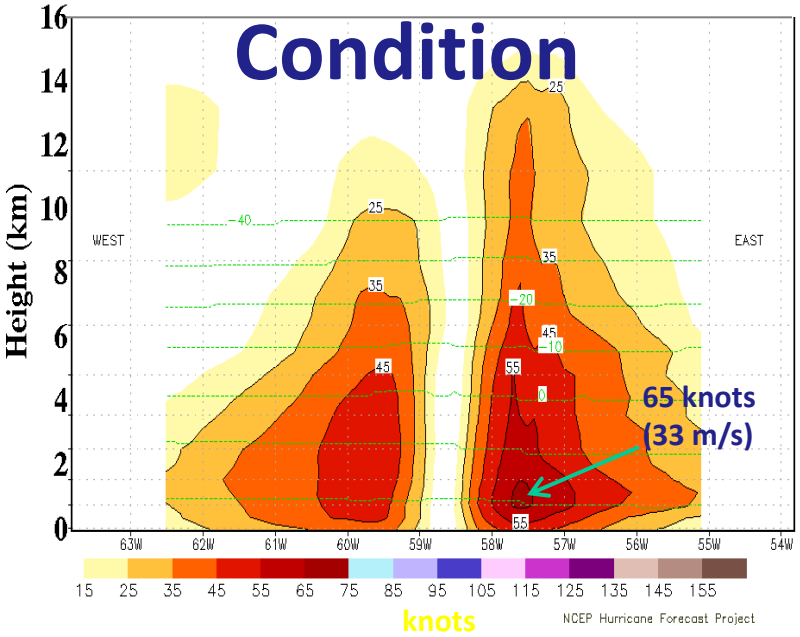
DEAN (CAT5)



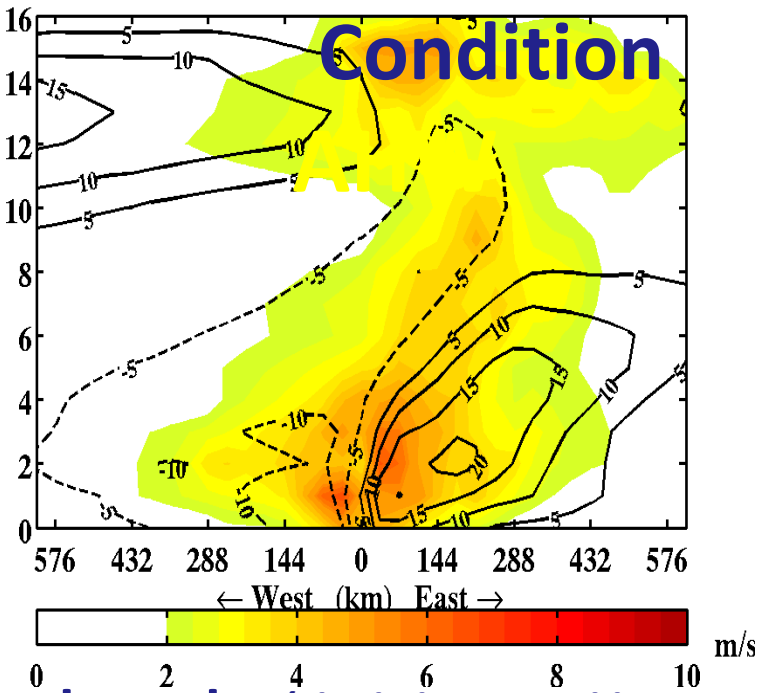
Importance of Initial Vortex Structure

- Tilted vertical structure in AHW (ensemble data assimilation)
- Non-tilted in HWRF: (3D-VAR)
- Tilt associated with subsidence above surface center

HWRF Initial Condition



AHW EnKF Initial Condition



Shown is meridional wind in east-west cross section

(Shaded is ensemble variance)

C. DAVIS

Lessons learned - Next steps

Need better initialization/DA

Need more appropriate physics for hires (HFIP mtg. Miami Nov. '09)

Take a step back....

Serious challenges.... No silver bullets

How to proceed.....

Short term; Long term

Physics/initialization/DA meeting

(convened by Davis, Surgi, Doyle) (HFIP)

- Posed hard questions (near and long) term: ocean complexity, ocean resolution, wave coupling, model atmos. resolution (hor/vert), air-sea physics, PBL, convection (deep, shallow)

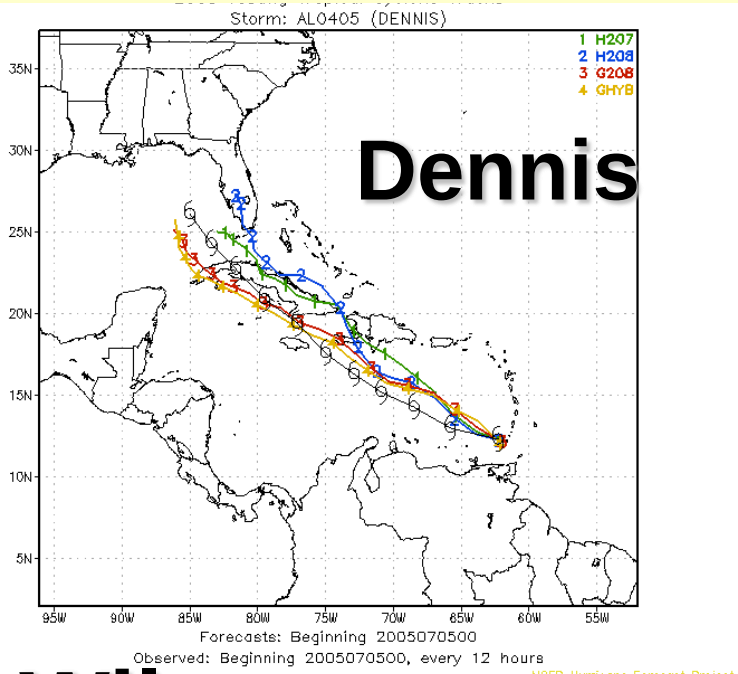
- Add Model complexity - uncertainly was the greatest?

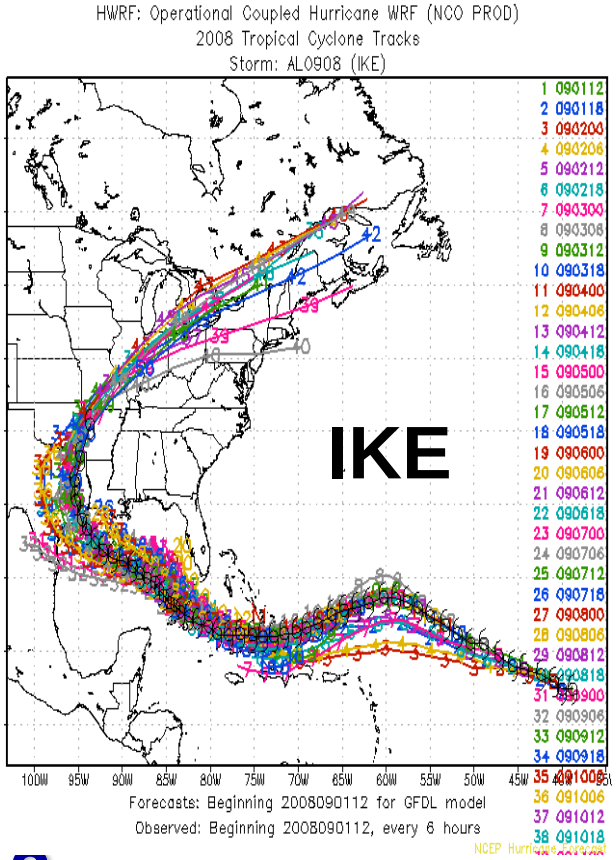
- Initialization/DA: obs for core/environment; insitu/remote, spinup, weak storms, relationship betwen physics/DA

- Require BIG effort in model diagnostics (DTC) – comparison to obs AND inter-model comparisons e.g. AHW, HWRF, COAMPS

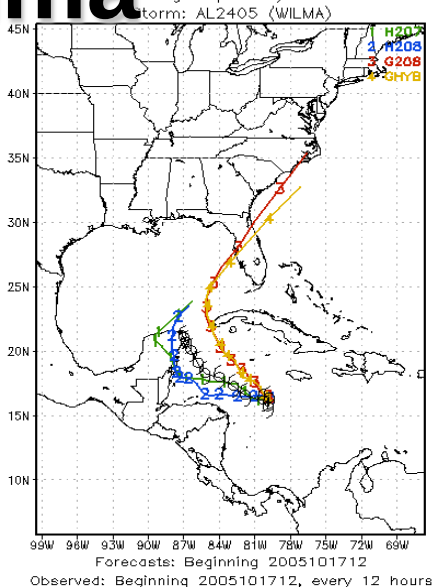
- We will produce report w/recommendations for action

Model challenges

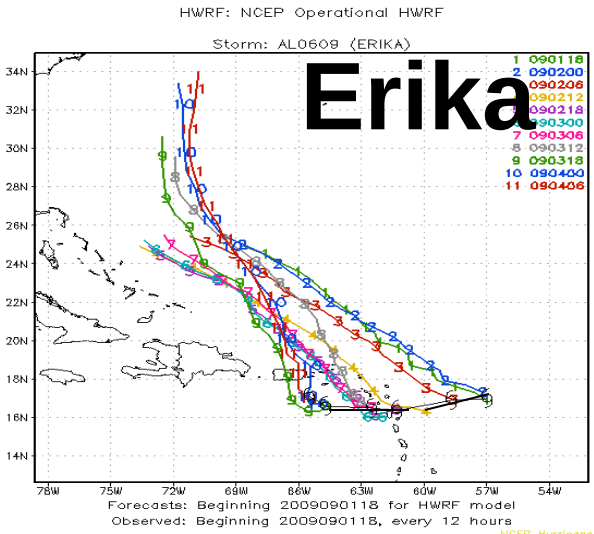




Wilma

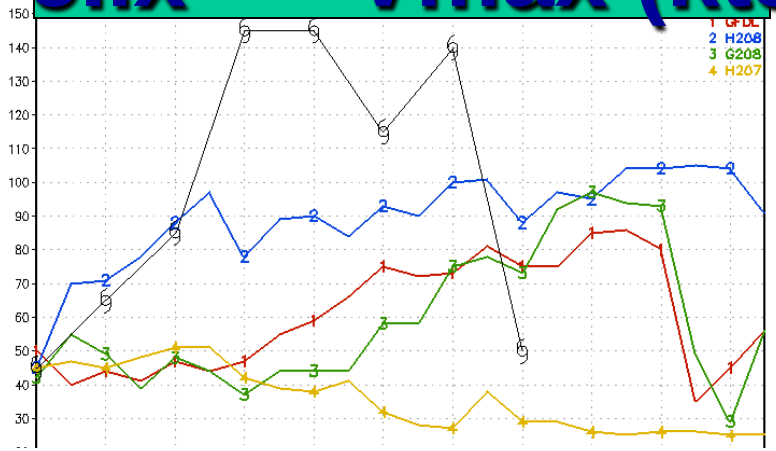


Track & Intensity related

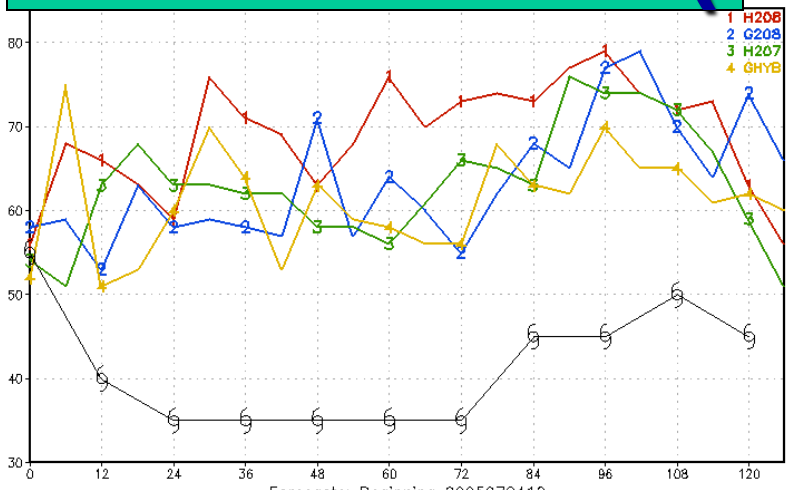


We're making progress…but many difficult problems ahead

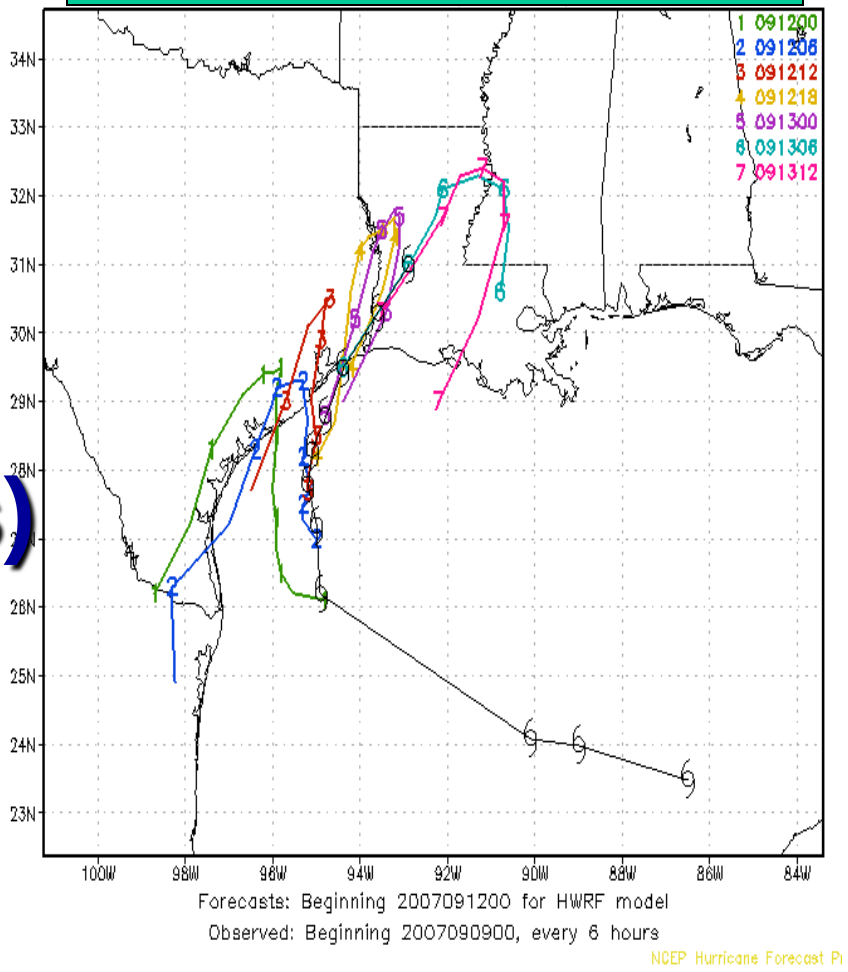
Felix - Vmax (kts)



Franklin - Vmax (kts)



Humberto 2007 9/09-9/12



New era for community collaboration

- **We have infrastructure in place to support the WRF community codes, e.g. The Developmental Test Center (DTC) TREMENDOUS ASSET**

  Support Research to Operations ; Operations to Research

  Carry out extensive testing for R&D (hi-res physics suite, data assimilation, ensembles) for transition to ops

  Provide NCEP with community contributions to help improve hurriacne forecasts . The DTC will support critical preliminary testing and evaluation for transitioning code to NCEP operations

HURRICANE SYSTEM ADVANCEMENTS

- Data assimilation/Vortex Initialization - critical
- Model Physics - suitable for high(er) resolution – critical
- Resolution – horizontal/vertical - critical
- Hurricane Ensembles for structure/intensity

  multi-model mesoscale ensemble (contain single model ens?)

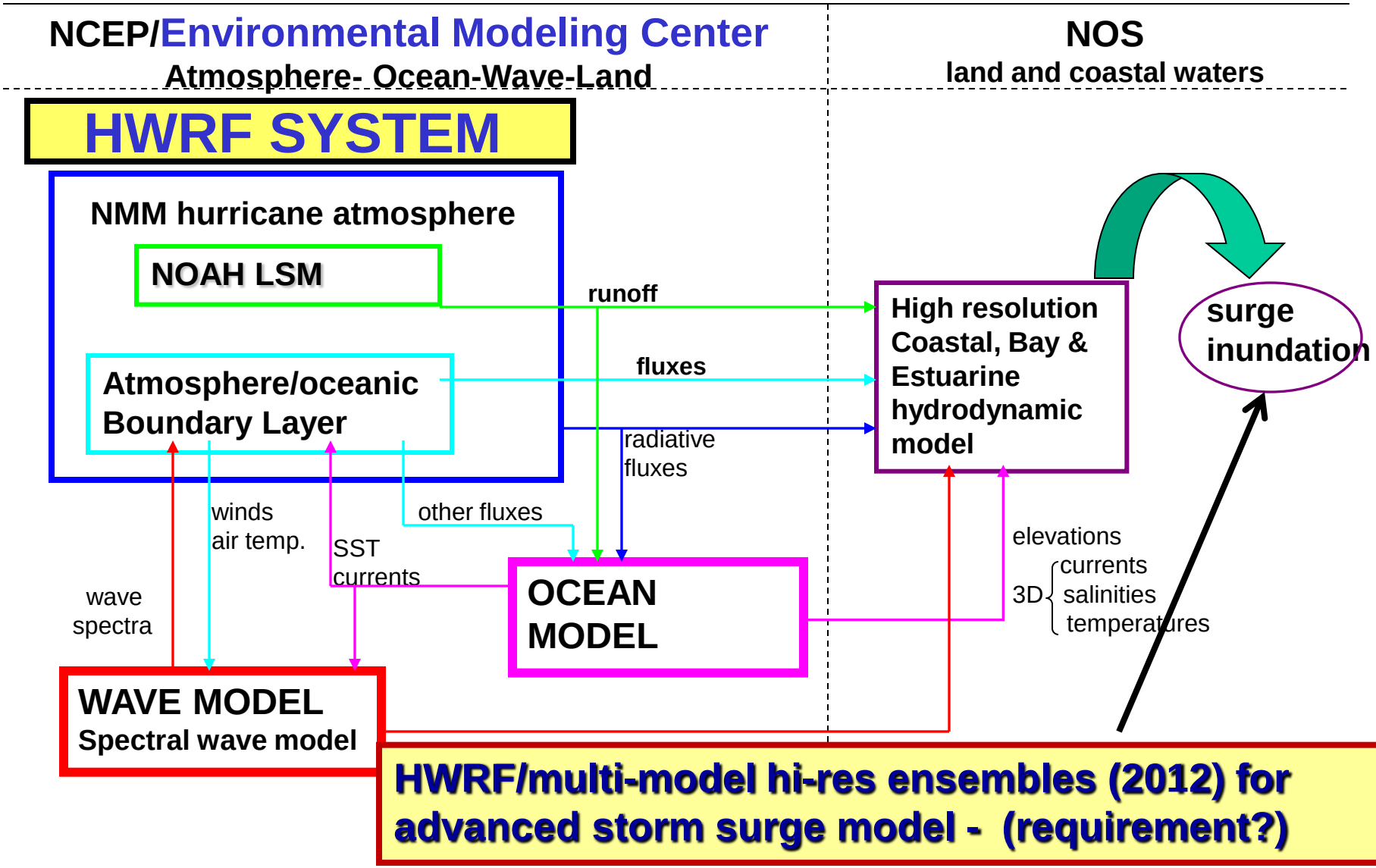
  value of very hi-resolution deterministic fcsts vs. ens?

- Couple to Ocean – what complexity? Ocean data assimilation;
- Couple w/Wave Model

  forecast waves up to the beach, ie: improve non-linear interactions, surf zone shallow water physics, wave interactions with currents

- **Coupling to land surface model**

  Advance Sfc. Physics for improved rainfall forecasts at landfall. Important input to hydrology and streamflow models to address inland flooding.

ALL hurricane model physics upgrades dependent on allowable resolution, e.g. affordable complexity of microphysics, sea spray, explicit representation of all clouds.

Hurricane-Wave-Ocean-Surge-Inundation Coupled Models