HWRF Multi-storm Modeling System (HWRF-B)

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AOML/HRD & UM/CIMAS

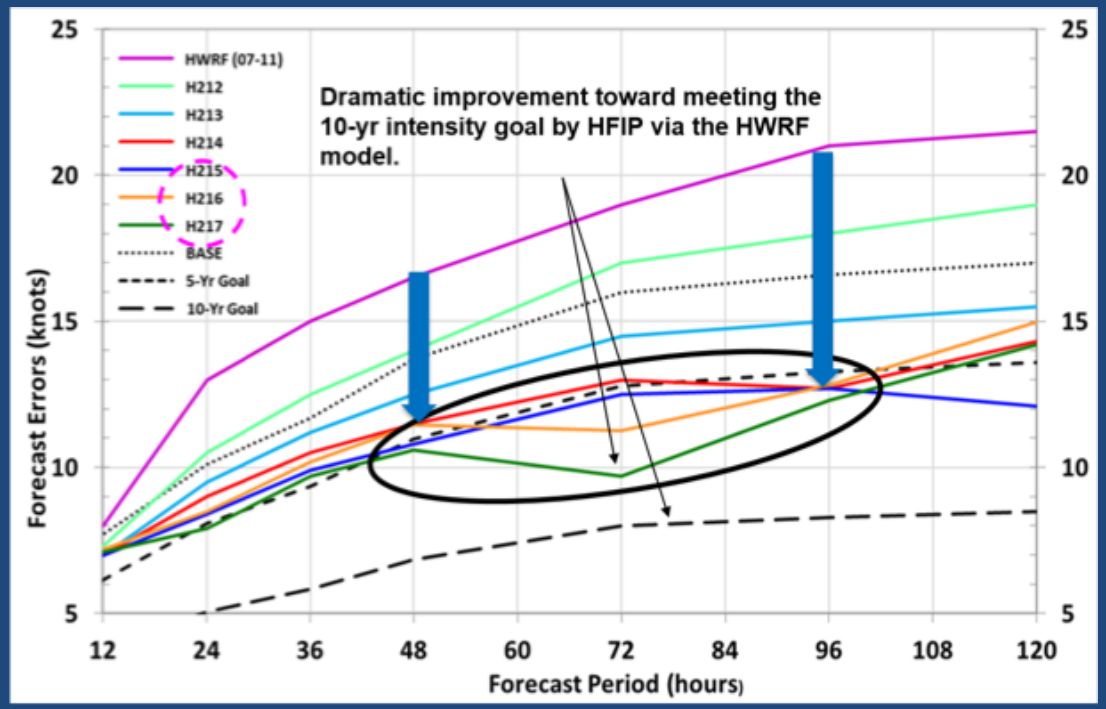
Acknowledgements

Collaborators: EMC Hurricane Project (Lead: M. Avichal); DTC (Lead: K. Newman); HRD Modeling Group (Lead: Gopalakrishnan)
Computer resource: Jet supercomputer
HFIP support

HFIP Vision and Goals (2009-2018)

VISION

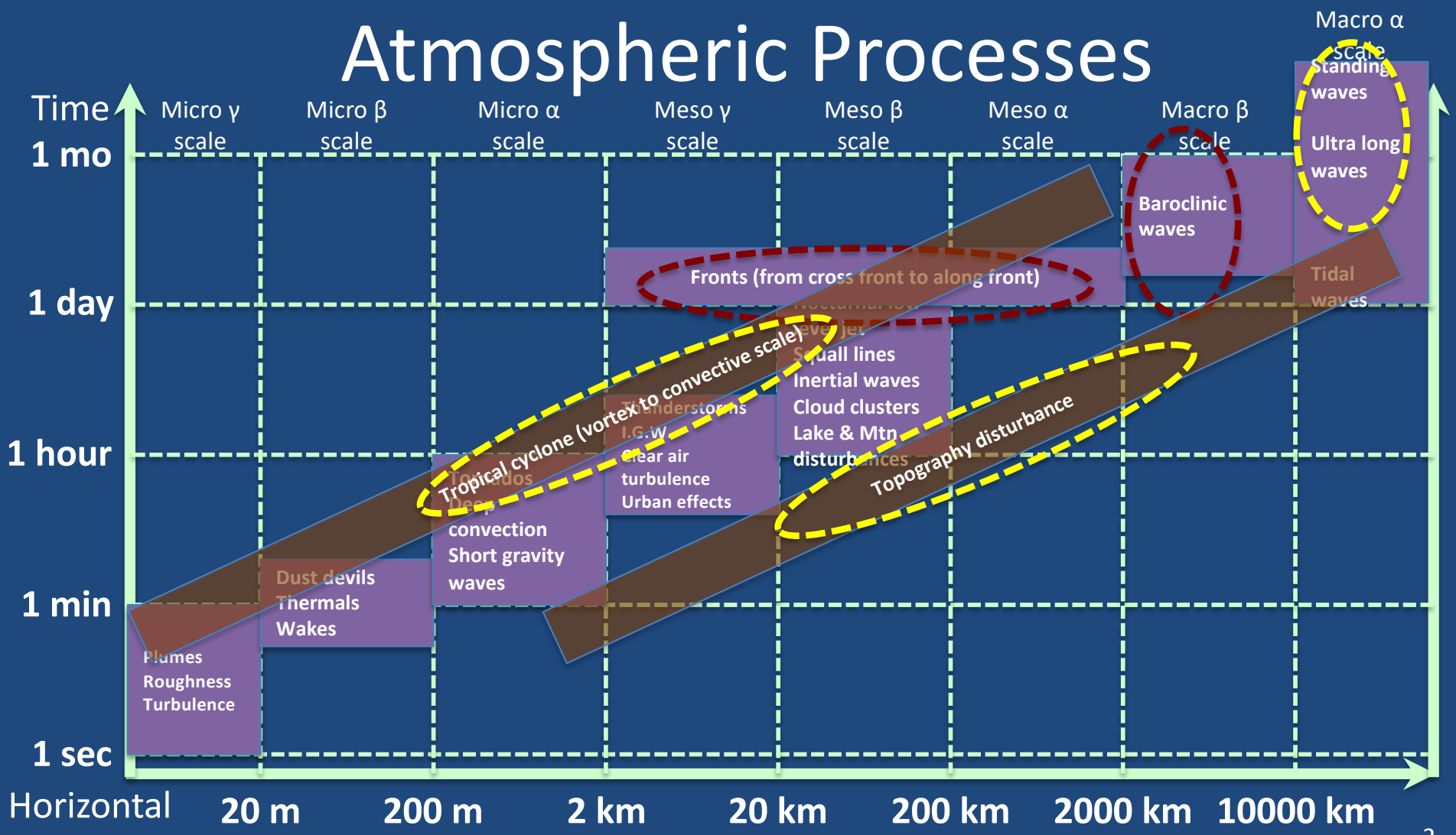
Organize the hurricane community to dramatically improve numerical forecast guidance to NHC in 5-10 years.



GOALS

- Reduce numerical forecast errors in track and intensity by 20% in 5 years, 50% in 10 years
- Extend forecast guidance to 7 days with skill comparable to 5 days at project inception
- Increase probability of predicting rapid intensification (RI) at day 1 to 90% and 60% at day 5
- Improve products on storm surge prediction

Horizontal-Temporal Scales of Atmospheric Processes



Adopted from Orlanski (1975)

Scientific Objectives

- Preserve across-scale processes on TC genesis, intensifying, decaying, and landfall processes within an integrated modeling system to:
  - Represent the full-scale spectrum of atmospheric waves
  - Study on multi-scale interactions e.g. storm-storm interaction, TC-terrain interaction, and landfall processes and QPF etc.
- Enhance resolved resolution that can represent TC inner core physics and can predict TC dynamics (3 km or less)
  - Non-hydrostatic model becomes required
  - Physics schemes should be suitable to the high-resolution model

Model Development Objectives

- Tailor a tool that is operationally feasible and transferable at minimum cost in the near future
- Experiment new R&D for the next generation across-scale TC forecast model
- Facilitate coherent capacity of cycling and initialization that can be utilized for testing high-resolution physics, advanced data assimilation, ensemble forecast, etc. as operational HWRF does
- Quantify model bias and diagnose sources of model errors

Features of Current Models for Hurricanes

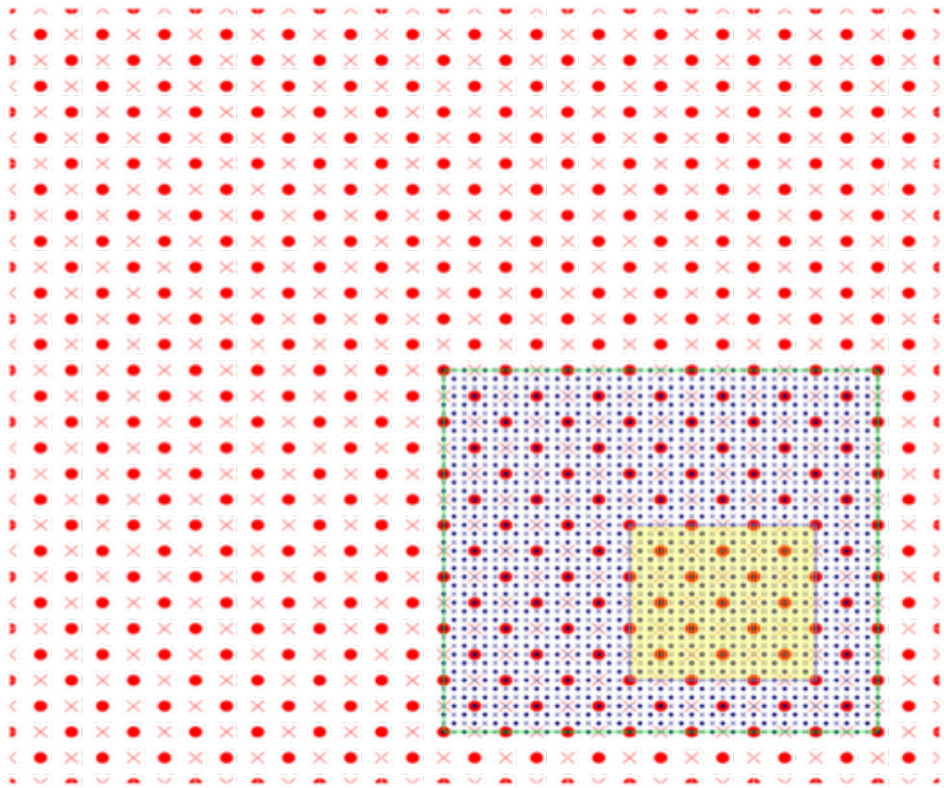
Features	HWRF	HMON	HWRF-B	GFS	GEFS	FV3GFS	FV3NES
SC/BC/G	SC	SC	SC/BC	G	G	G	BC/G
DA	Vor DA	N	Vor DA	DA	DA	DA	N
CYL	Partial	N	Partial	Full	Full	N	N
Ocn-CPL	Y	N	N	N	N	N	N
NEST	Y	Y	Y	N	N	N	Y
MOV	Y	Y	Y	N	N	N	N
MAX RES	2 KM	2 KM	2 KM	13 KM	27 KM	13 KM	3 KM
PHY	Hi-Res	Hi-Res	Hi-Res	GFS	GFS	GFS	GFDL

HWRF, HMON, GFS, GEFS: Operational

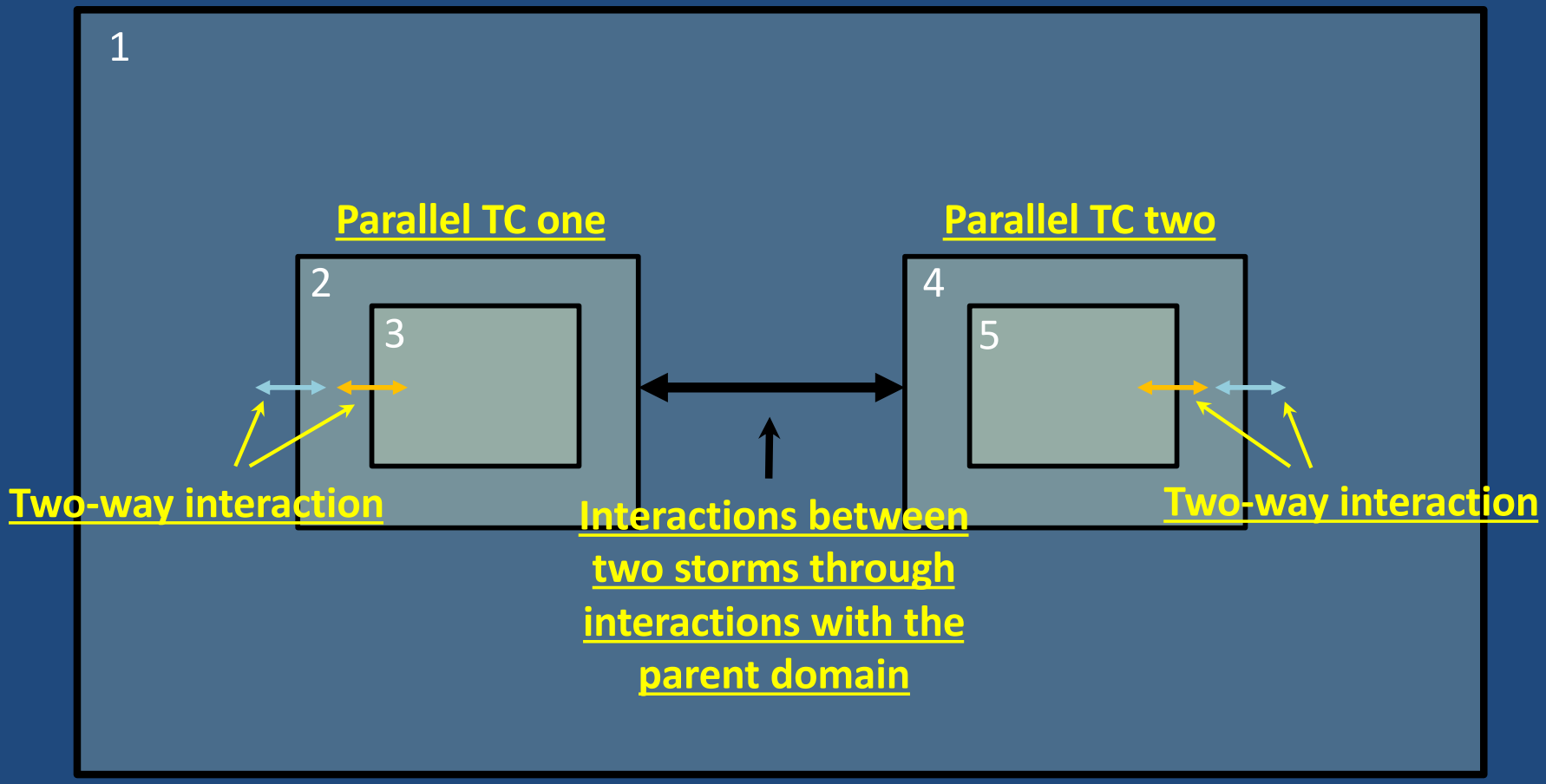
HWRF-B, FV3NES: HFIP real-time demo, stream 2

FV3GFS: Real-time parallel

Idea of Moving Nest

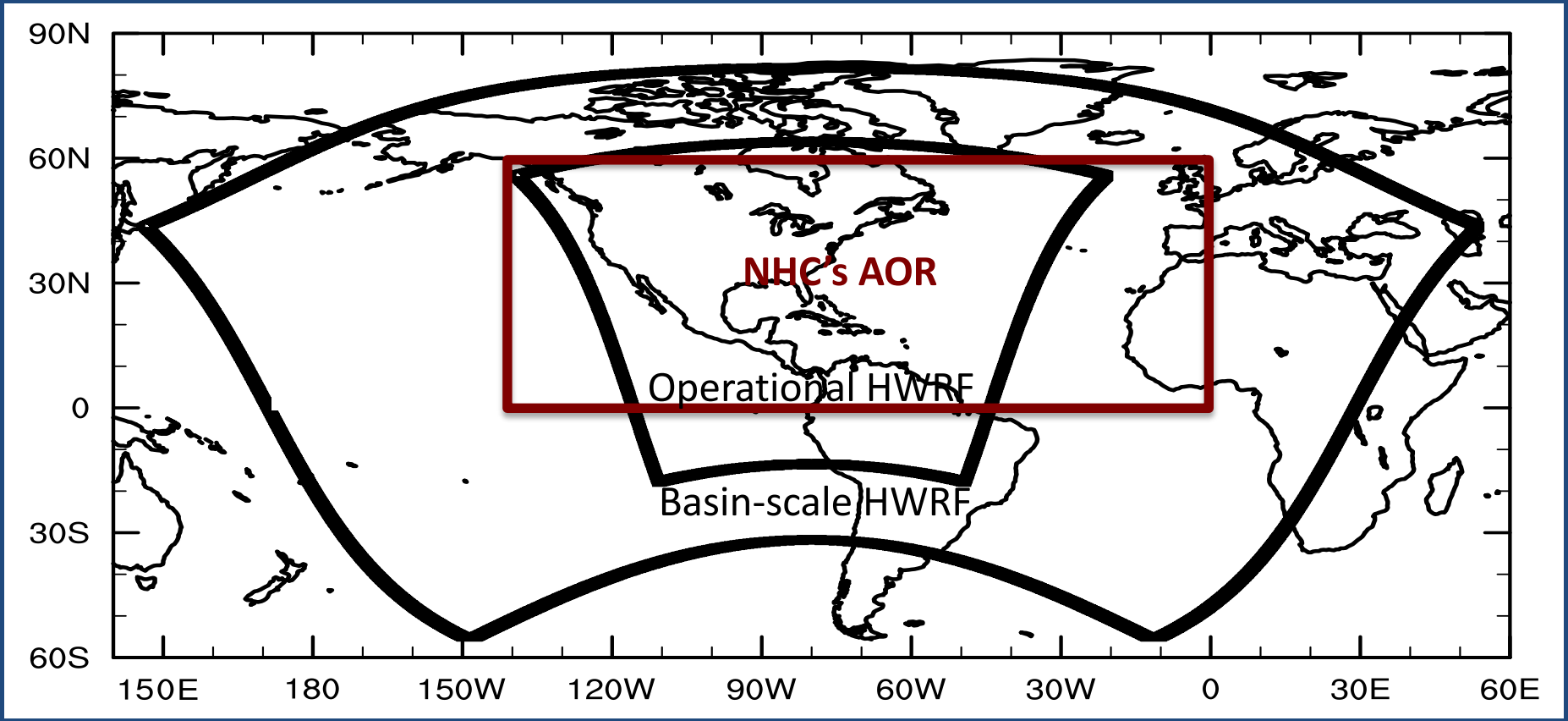


Nesting scheme and feedback



The basin-scale HWRF

Operational HWRF vs. Basin-Scale HWRF

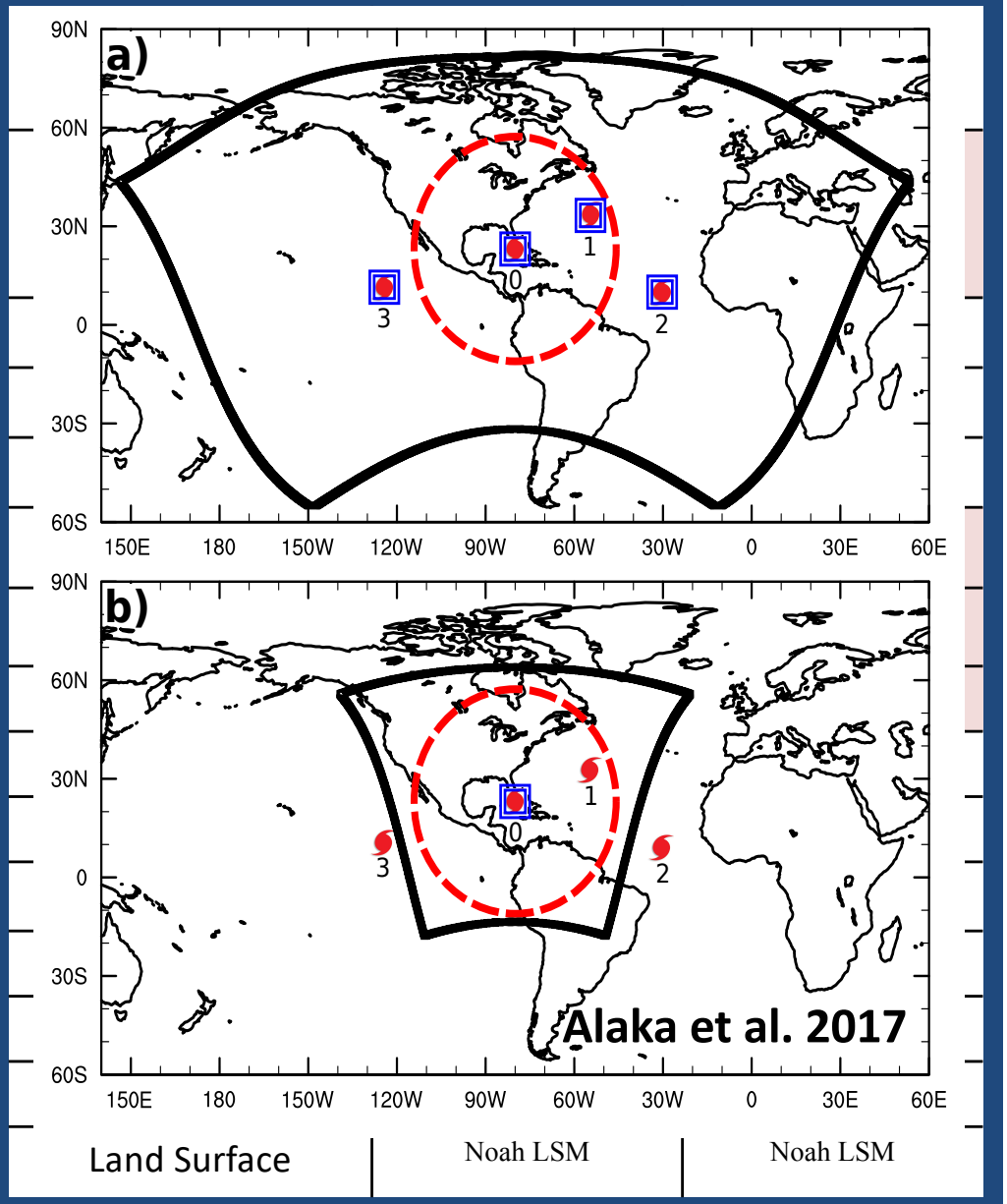


Outer black box: Basin-scale HWRF; Inner black box: Operational HWRF

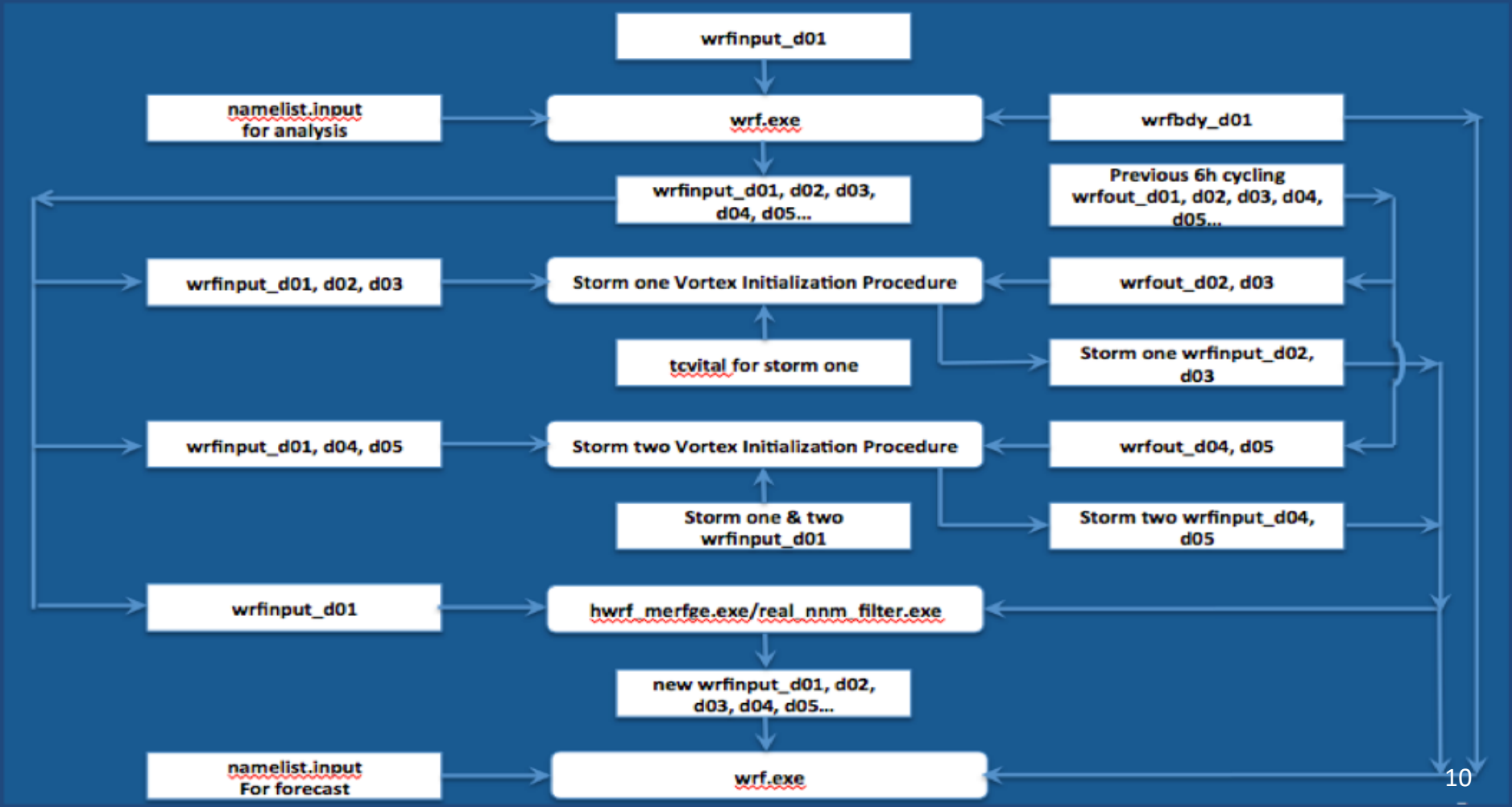
Red box: NHC's Areas of Responsibility

HWRF-B: Configuration

- Dynamical core is identical to the 2017 operational HWRF (**H217**)
- Most configuration options are identical
  - All physics, vertical resolution, 18-06-02km horizontal resolution
- Key configuration differences
  - **Outermost domain size**
    - Spans Atlantic & E. Pacific basins
  - **Multi-storm**
    - Up to 3 storms in real-time this year
  - **Data assimilation**
    - No TDR ensemble
  - **Ocean coupling**
    - Work in progress



HWRF-B: Real-time Initialization



HWRF-B: Develping DA and Ensemble Prediction System

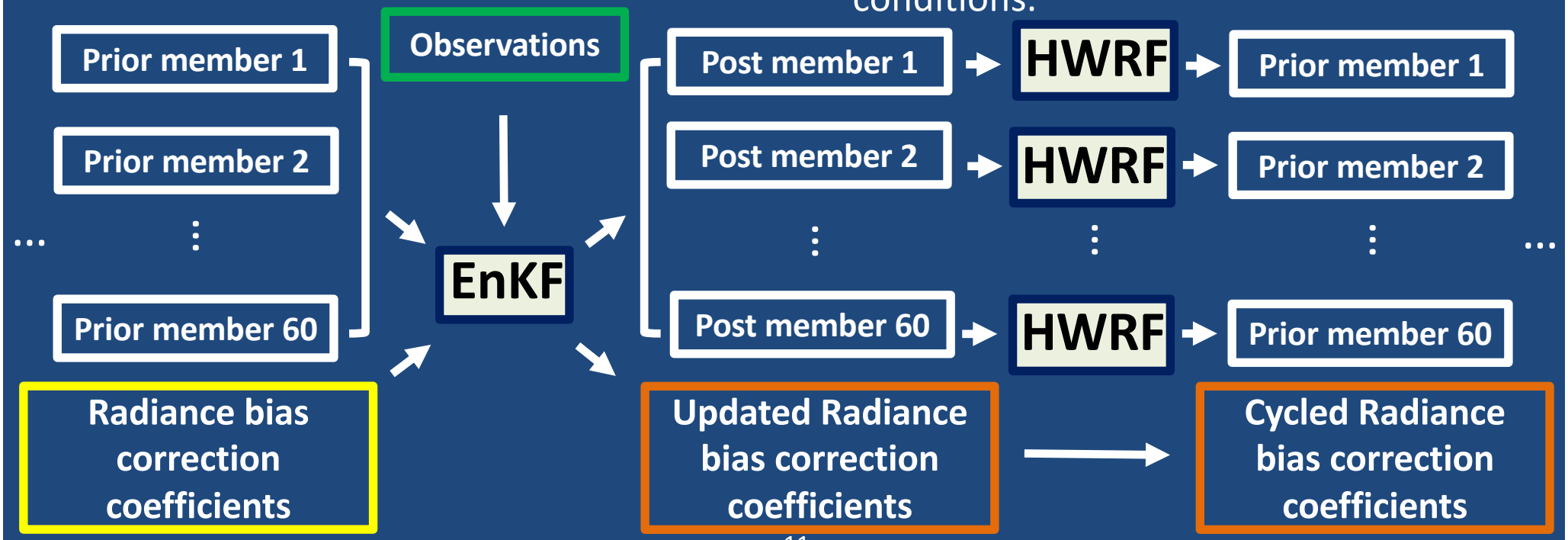
Developed by J. Poterjoy

Data Assimilation Step

EnKF updates HWRF ensemble and radiance bias correction coefficients for next cycle.

Forecast Step

A 6-h HWRF forecast runs from each posterior EnKF member using GFS surface and lateral boundary conditions.



HWRF-B: Major Findings & Milestones

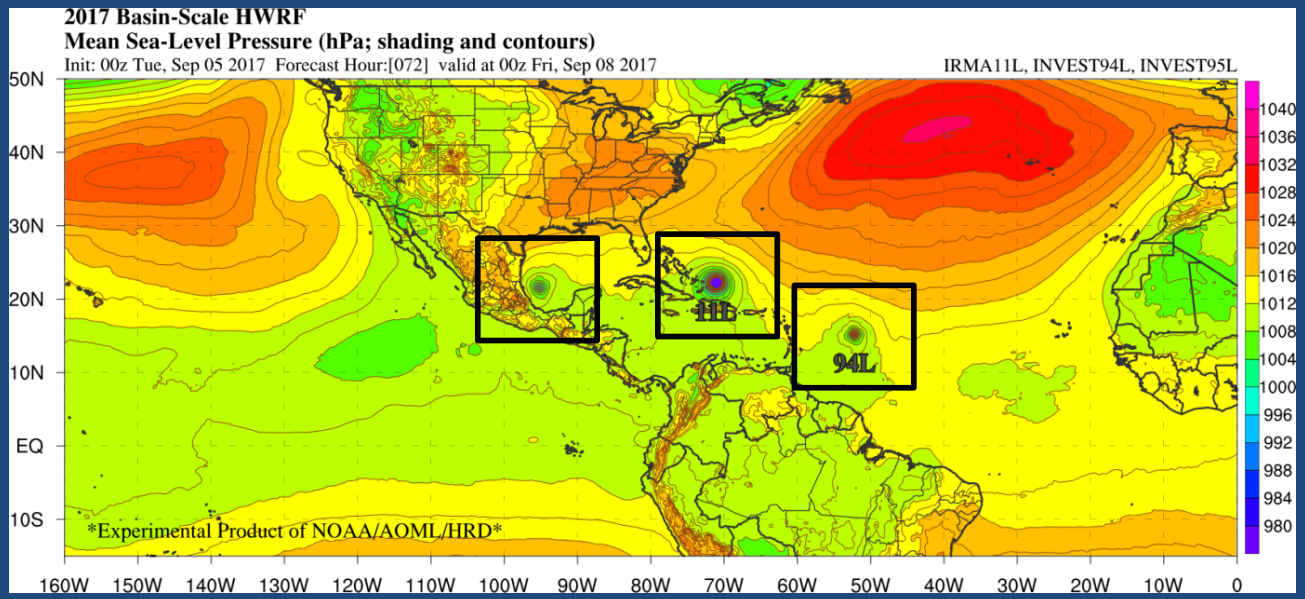
Scientific Findings

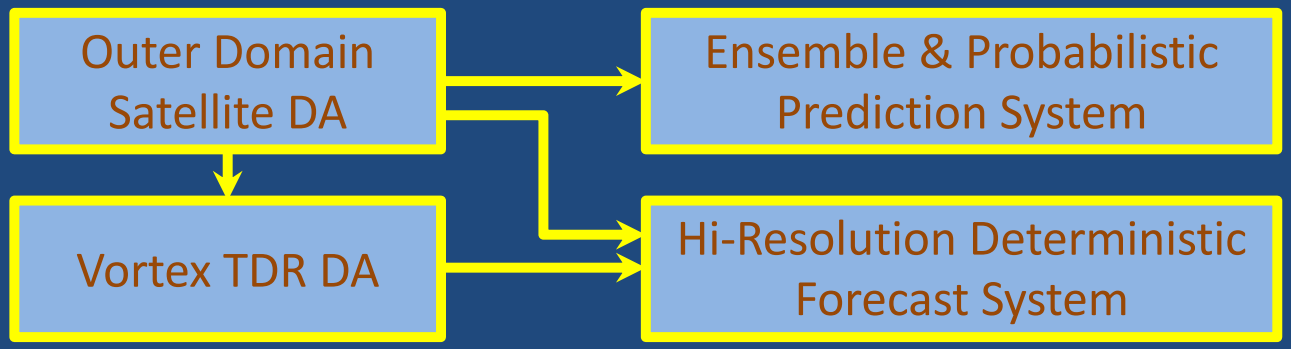
- Better track forecasts than **H217** & **GFS** at longer lead times (> 72h)
- Improved track forecasts when "far-field TCs" were present
- Excellent track forecasts for high-impact TCs (Harvey, Irma, Maria)
- Excellent rapid intensification forecasts for Harvey
- Irma forecasts shifted west near FL before **H217**/**GFS**

Project-Oriented Milestones

- Ran 4x daily in real-time under the HFIP demo on Jet
- Provided guidance in near-real-time for the NOAA Hurricane Field Program
- Assimilated TDR & HDOB data in real-time starting with Harvey
- All Basin-Scale HWRF options were committed to the DTC trunk (thx to Evan & Jim)
- Created interpolated (early) forecasts in real-time
- Cycled data assimilation system developed for the outermost domain

Suggested Pathway for Model Developments and Priorities

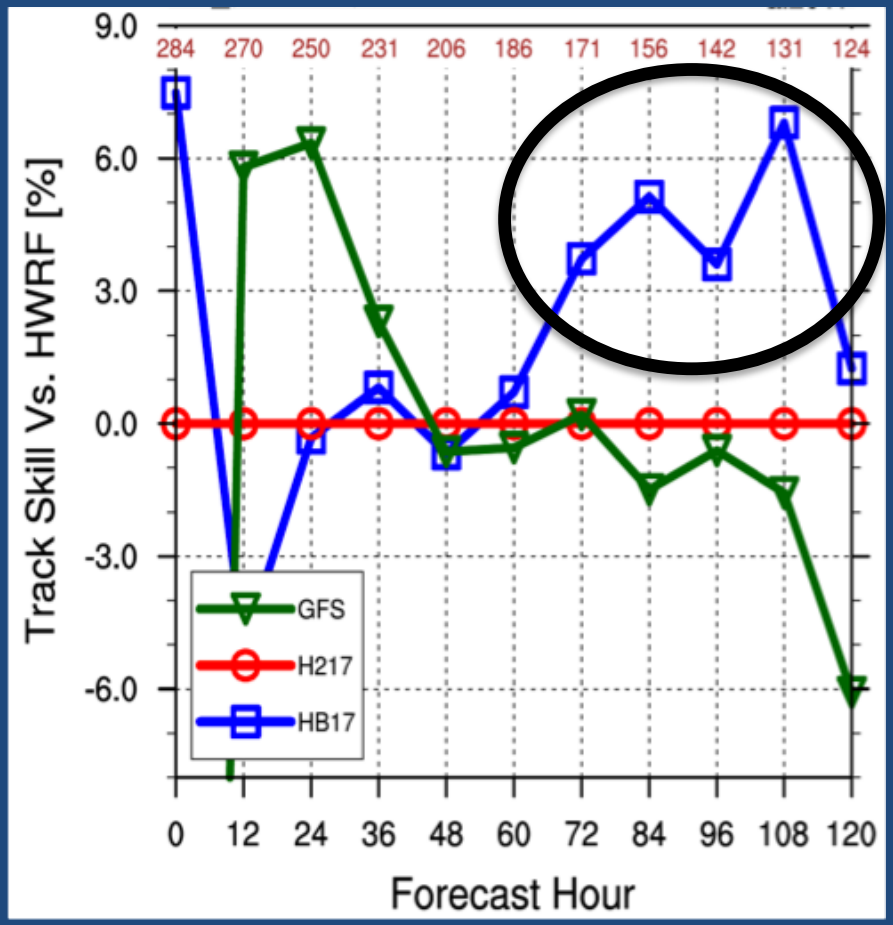




- **Potential R2O transitions [low costs]**
  - All current basin-scale HWRF developments are built in the operational HWRF workflow , scripting, and source code using software packages in NOAA's R&D supercomputers
- **Research and forecast applications**
  - Basin-scale HWRF DA has no dependence on GFS for initial conditions and GEFS radiance bias correction, thus allowing for more vigorous validations of the HWRF potential model and physics upgrades
  - Basin-scale HWRF system provides a platform for satellite DA research that transitions seamlessly into community packages used by operational models
  - Basin-scale HWRF system is capable of probabilistic multi-scale weather prediction and deterministic forecast of TC track and intensity

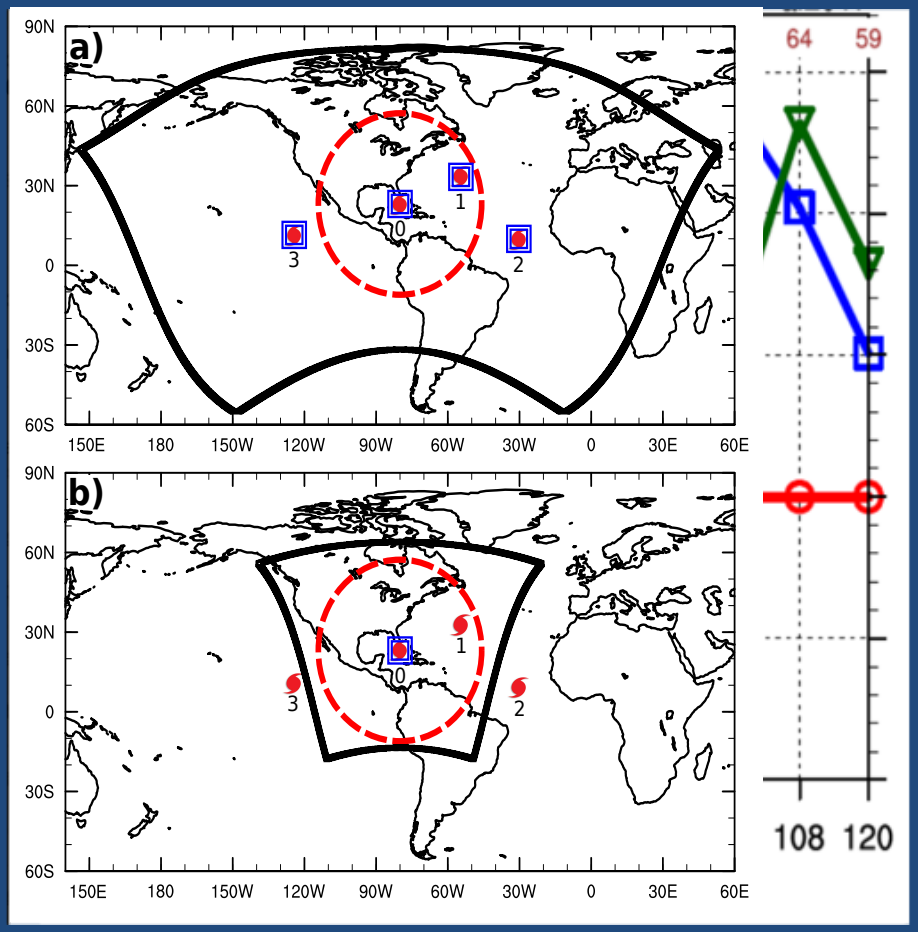
HWRF-B: 2017 Atlantic Verification

- **HB17** excels at long lead times
  - Best improvement at 108 h (7%)
  - Better than **H217** & GFS at 60+ h lead times
  - Improvements amplified for 06z/18z cycles → **Why? Restricted data?**
  - Note actual errors are small at short lead times
- Track was the primary focus with Basin-Scale HWRF this year
  - TC-TC interactions
  - TC-land interactions
  - TC-environment interactions

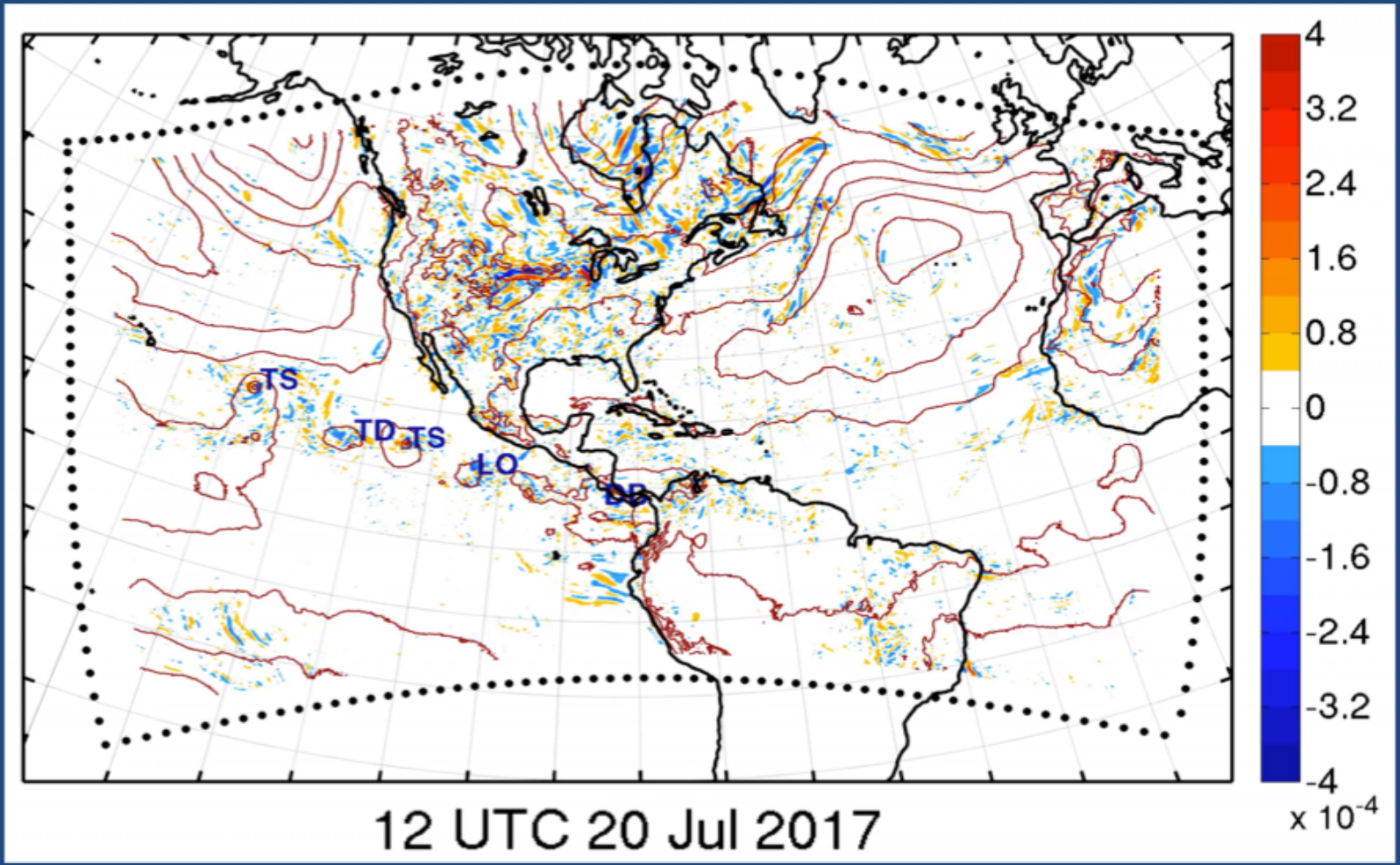


HWRF-B: Verification of Multiple Storms

- **For 2 extra TC/invest anywhere**
  - 96/124 cases at 120 h
  - **HB17** track skill increases to 8% at 96 h, 108 h
  - **GFS** track skill too
- **Far-field Storms** are TCs/invests that are >3500 km away from the verified TC.
- See Alaka et al. 2016
- **For 1+ extra Far-Field Storm**
  - 59/124 cases retained at 120 h
  - **HB17** track skill increases to over 14% at 96 h
  - **GFS** track skill also increases



Basin-Scale HWRF DA and Ensemble Prediction System

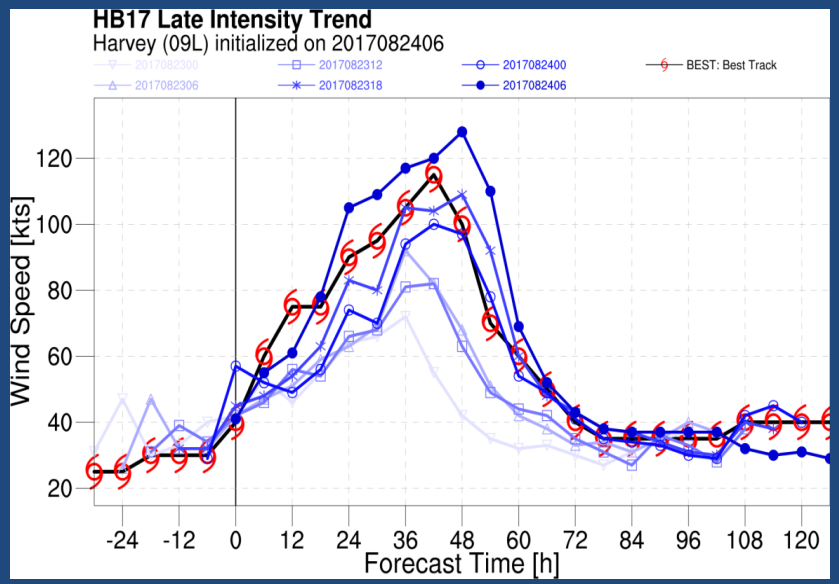


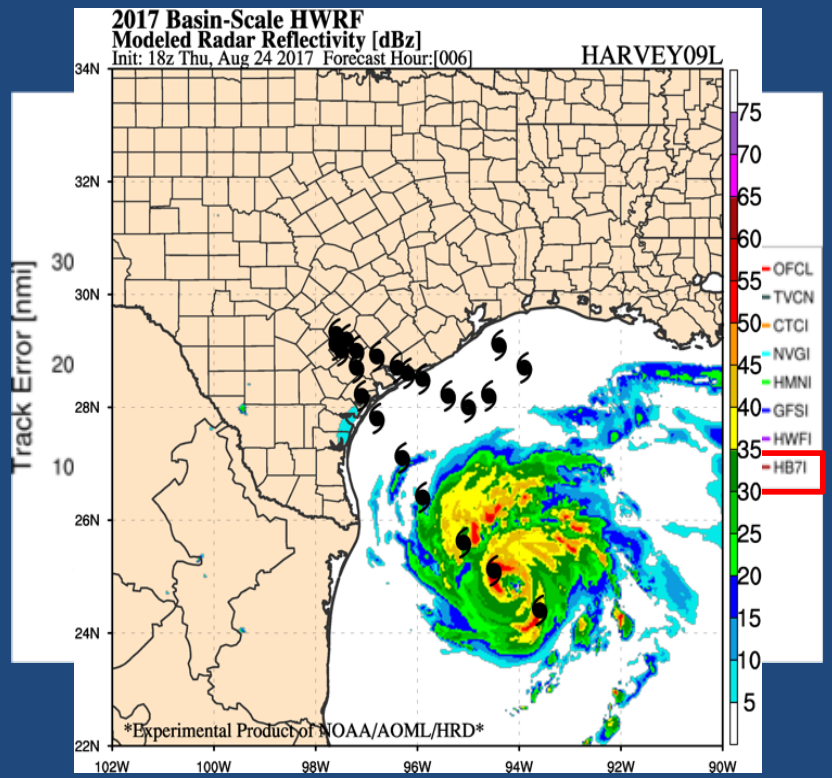
MSLP (red lines) and 850-mb vorticity increments for single member

Provided by J. Poterjoy

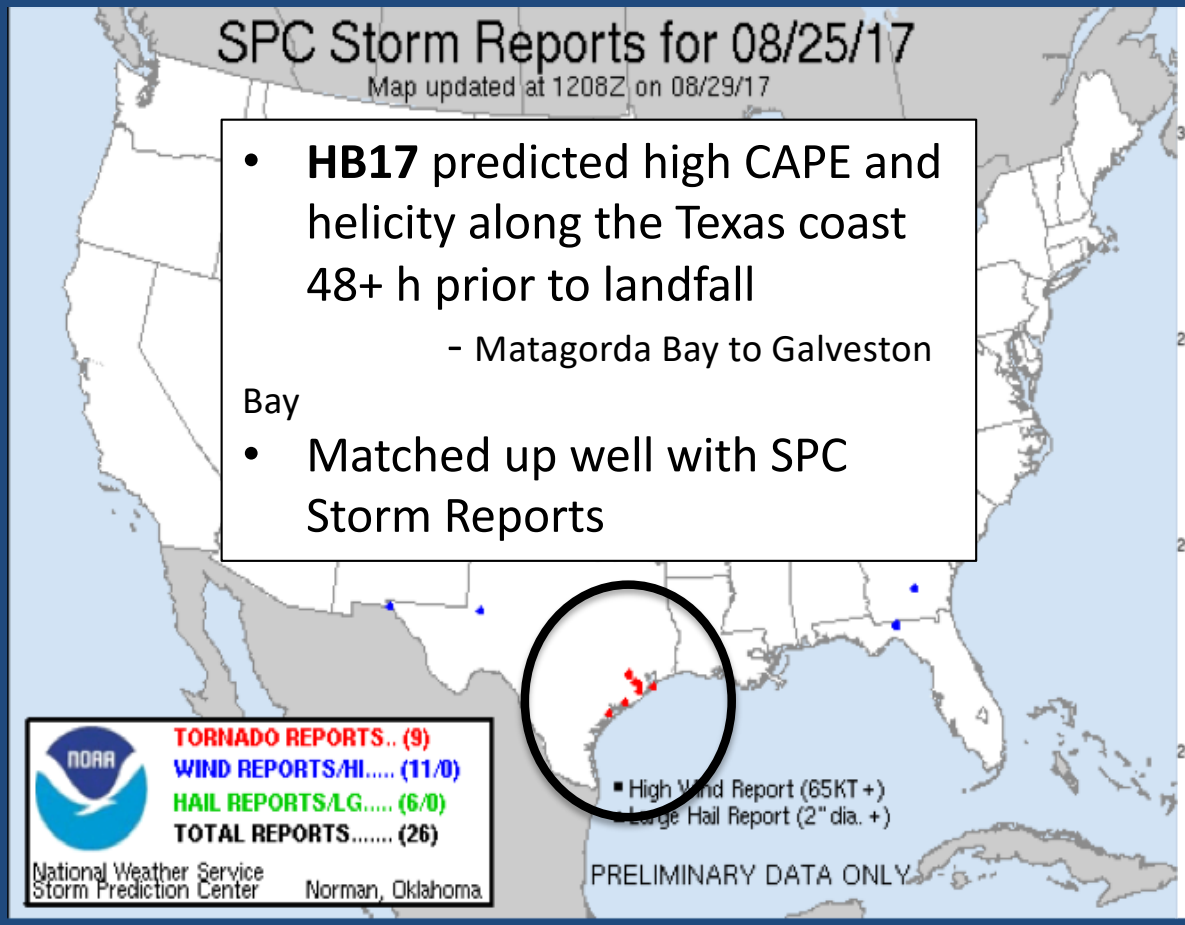
HWRF-B: Hurricane Harvey

- Basin-Scale HWRF was the best NOAA model for Harvey track forecasts
- RECON data was successfully assimilated in real-time for the first time
- Excellent rapid intensification forecasts

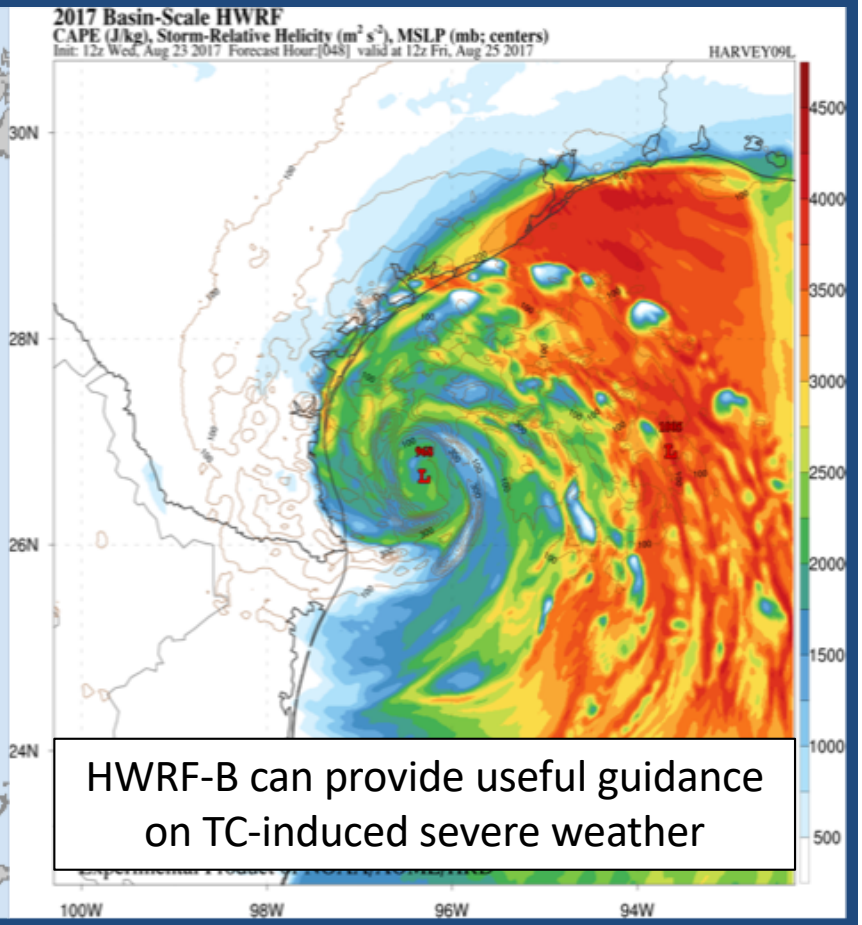




HWRF-B: Severe Weather in Harvey



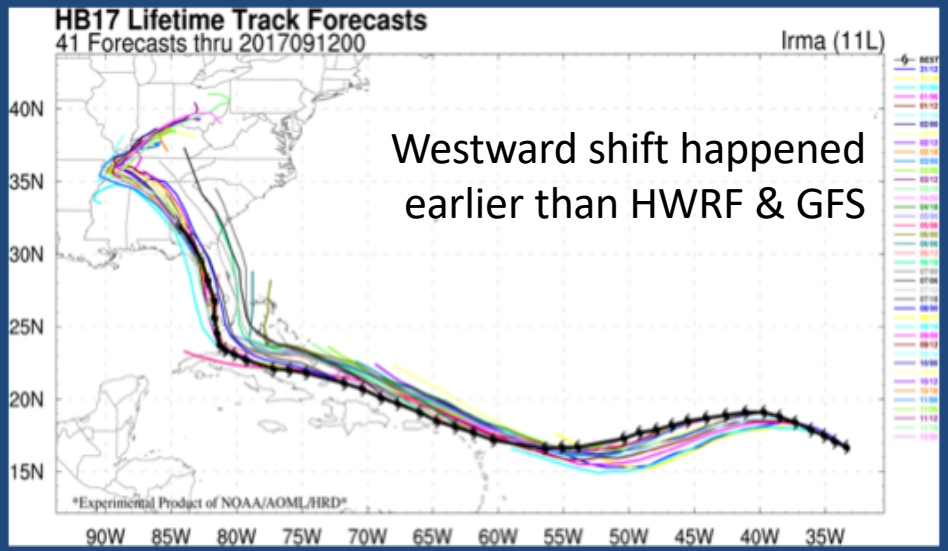
- **HB17** predicted high CAPE and helicity along the Texas coast 48+ h prior to landfall
  - Matagorda Bay to Galveston Bay
- Matched up well with SPC Storm Reports

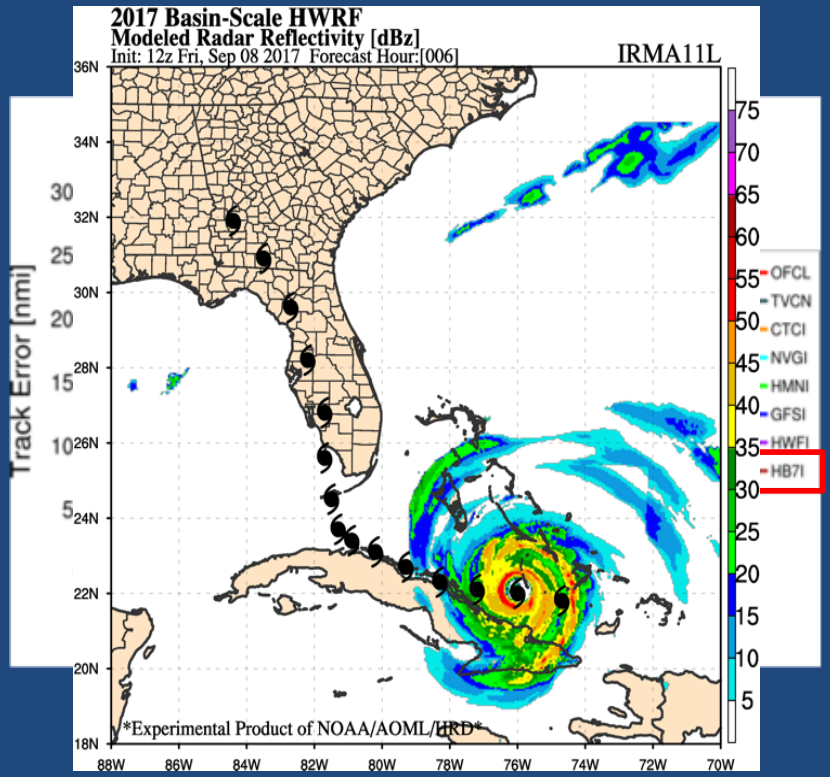


HWRF-B can provide useful guidance on TC-induced severe weather

HWRF-B: Hurricane Irma

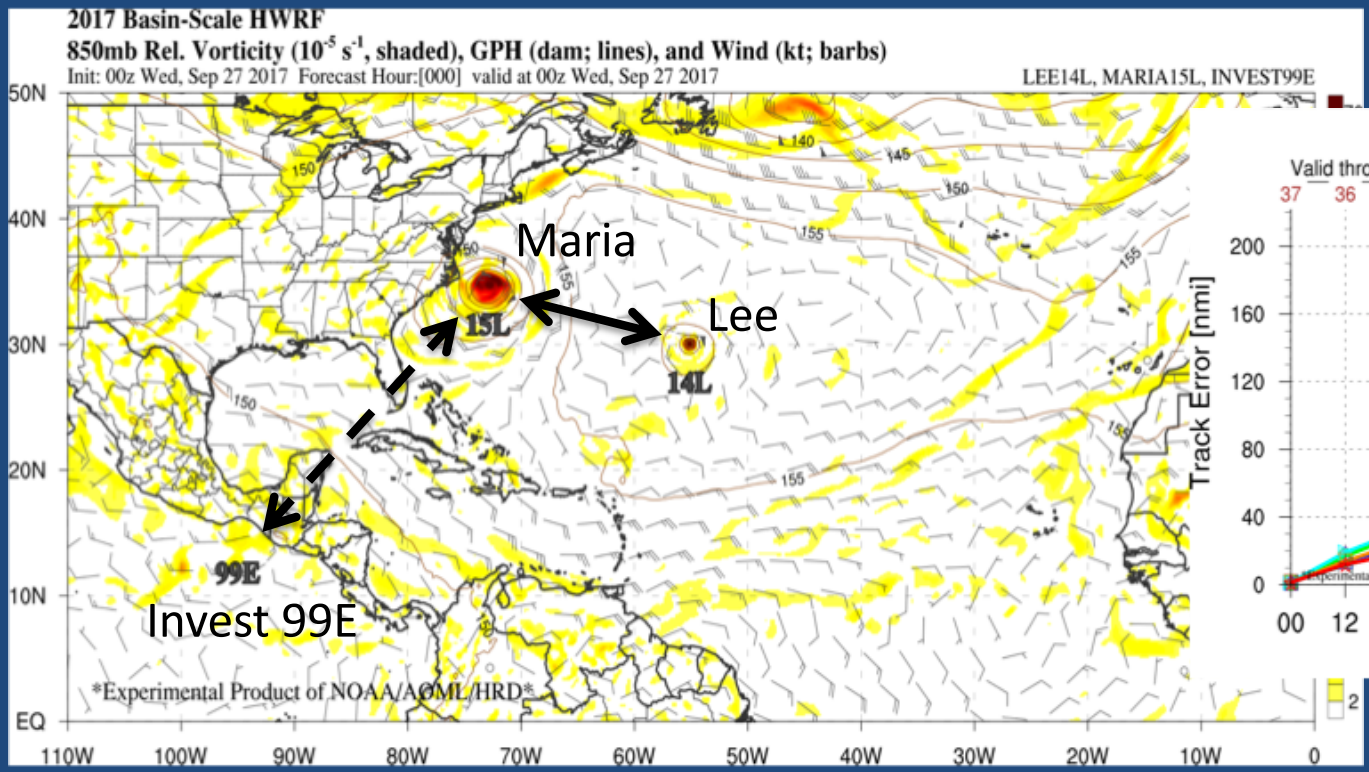
- Basin-Scale HWRF was the best NOAA model for Irma track forecasts at Days 4-5.
- Rainband structure accurately predicted along FL east coast.
- RECON data was successfully assimilated.

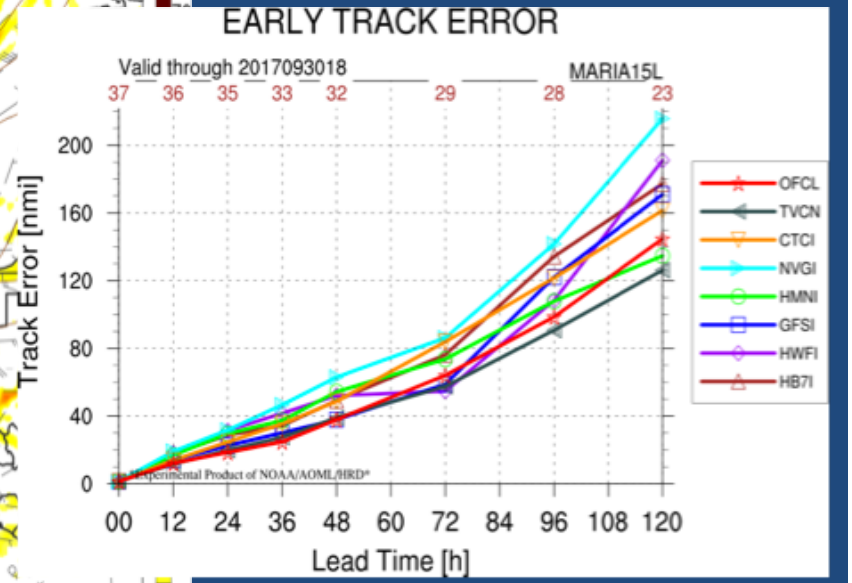




HWRF-B: Hurricane Maria

- Multi-storm interactions
  - Interactions with **Jose** (not shown), **Lee**, and **Invest 99E**
- Subtropical high provided primary steering currents → variations?





Summary

- The HWRF multi-storm modeling system was developed in AOML/HRD in collaboration with NCEP/EMC and DTC under the support of NOAA's HFIP
- The system can support multiple high-resolution movable nests centered on storms that may exist in the regional domain
- The system can not only provide simultaneous high-resolution forecasts for multiple storms, but also improve the representation of storm-storm interactions, synoptic-scale flows, and the TC life cycle from genesis, intensifying, decaying to landfall
- The system may apply to various unique researches on TCs, such as storm-storm interaction, model bias diagnostics, physical scheme evaluation and improvement, and localized multiple-vortex initialization and advanced data assimilation