Representing Multi-scale Interactions in HWRF Modeling System

--Rationale of developing basin-scale modeling system

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- S. G. Gopalakrishnan and V. Tallapragada lead and guide this effort on developing the basin-scale HWRF modeling system
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- R. Rogers & S. Murillo's constructive reviews and comments on this talk

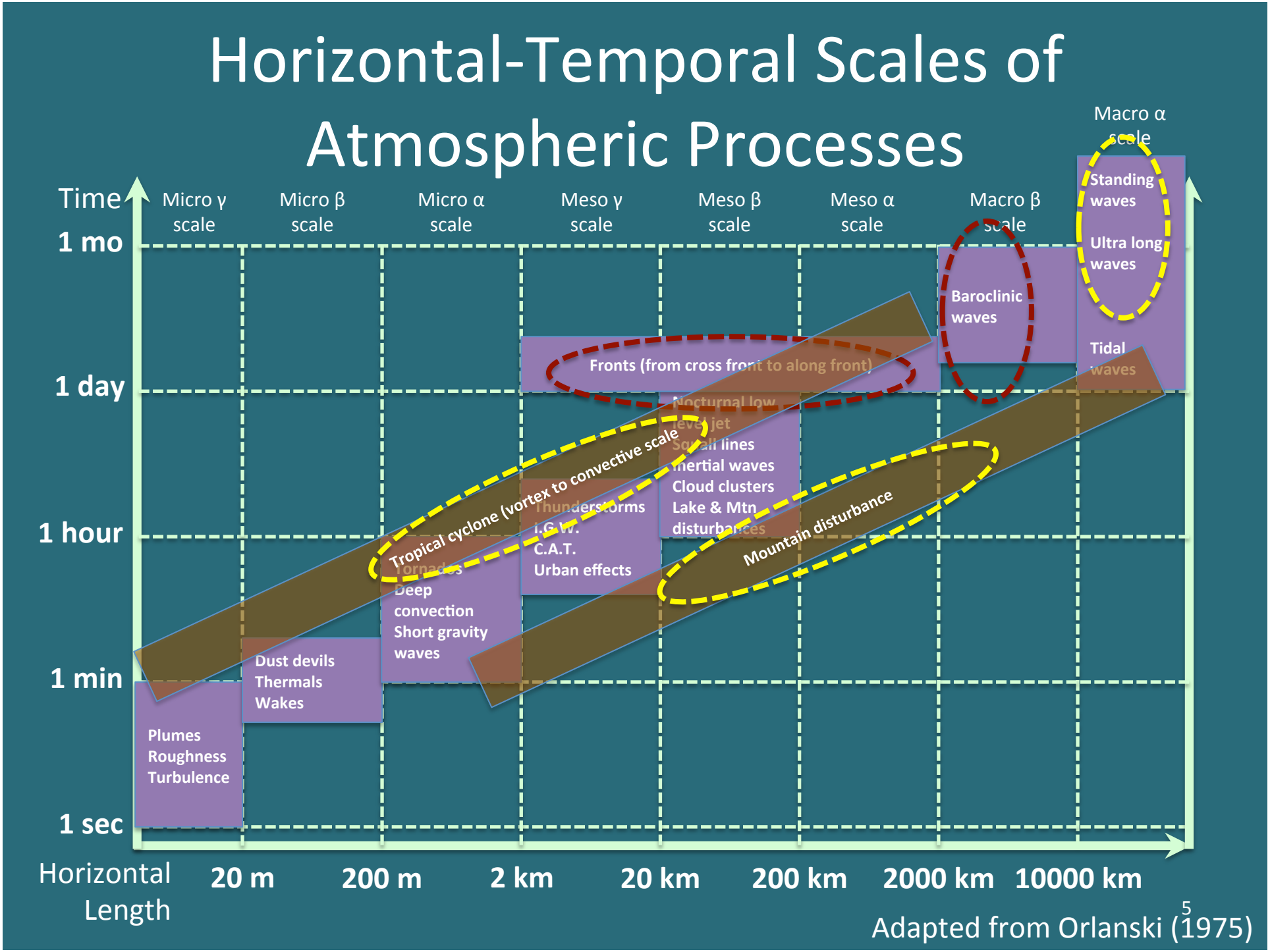
Outline

- Motivation
- Model Configuration
- Forecast Verification
- Case Verification
- Forecast Applications and Further Development
- Summary

Motivation

- Preserve across-scale TC genesis, development, and landfall processes within an integrated modeling system but
  - Represent better on long wave end of scale spectrum

Horizontal-Temporal Scales of Atmospheric Processes



Adapted from Orlanski (1975)

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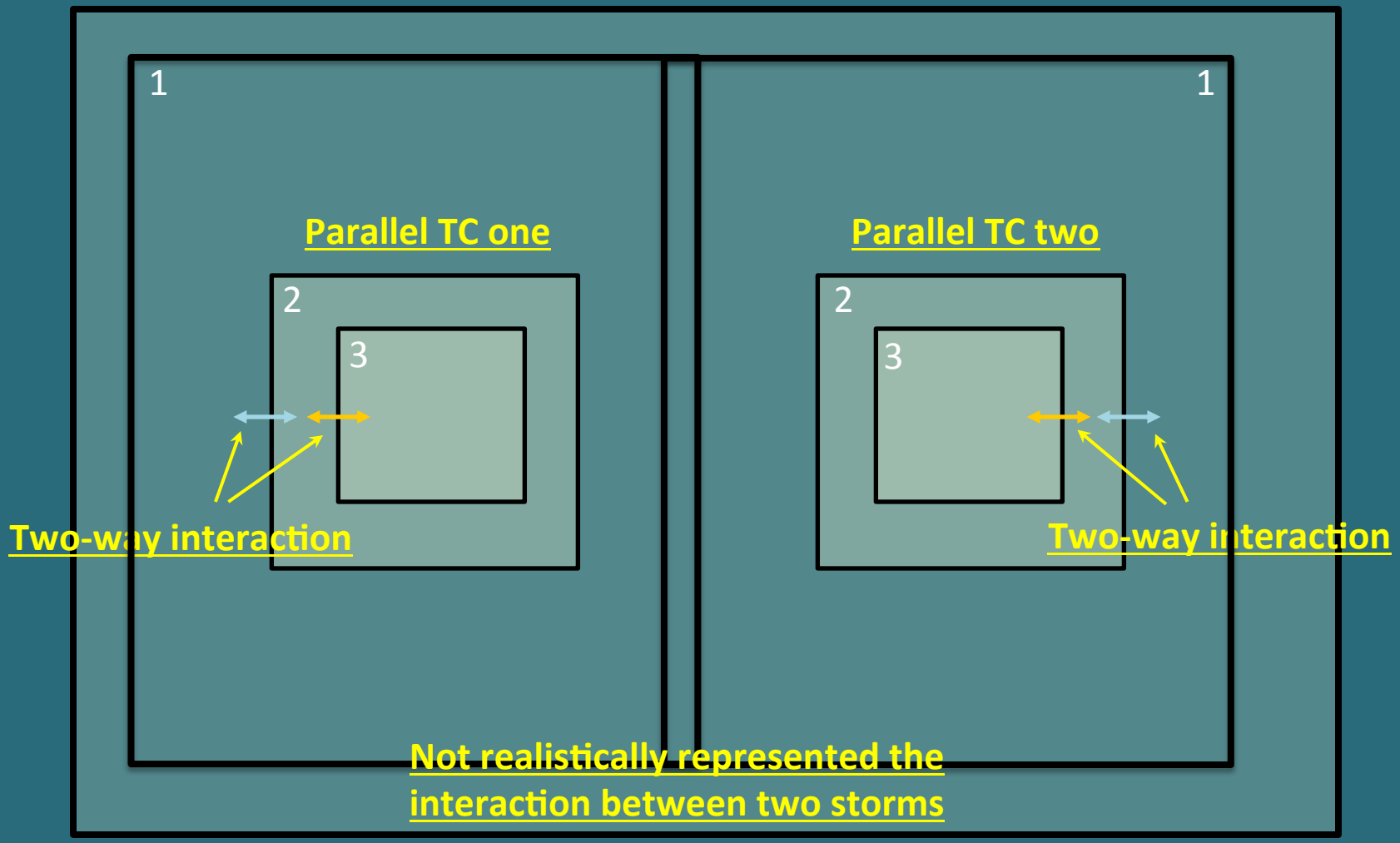
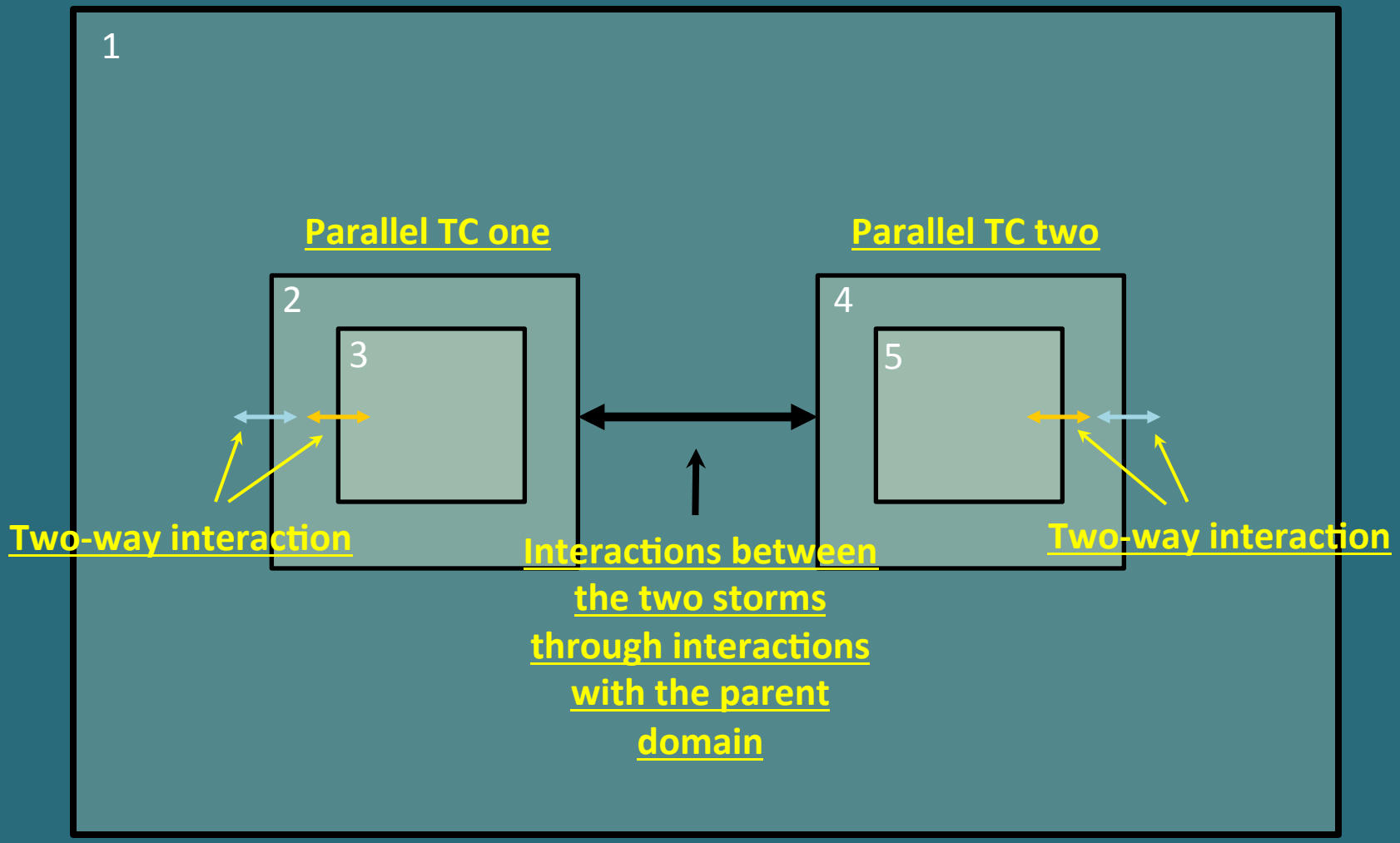
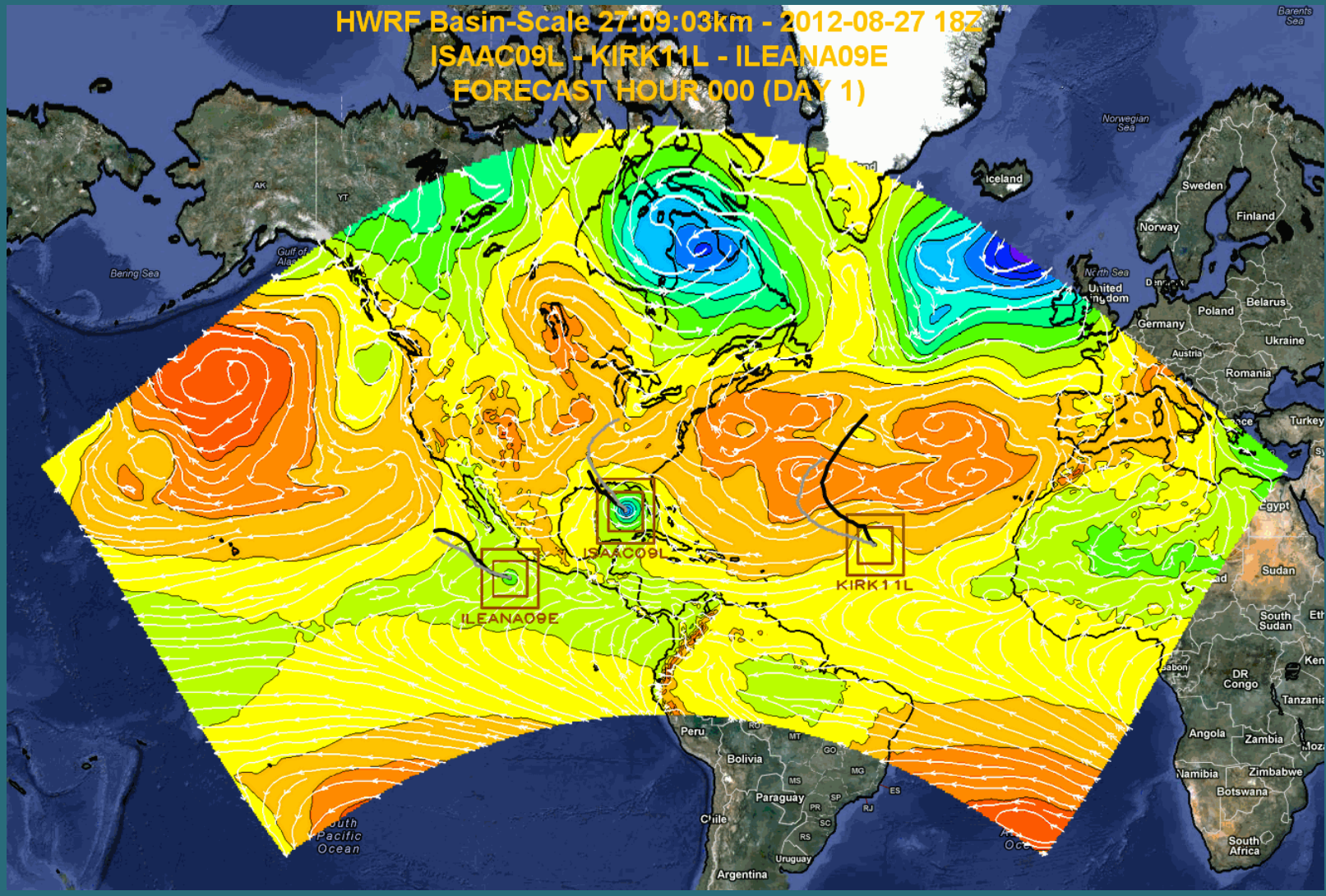
The Operational HWRF system



The basin-scale HWRF system



Multiple Movable Nests HWRF System



Isaac-Ileana-Kirk real-time 3-km predictions

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- Facilitate coherent capacity of cycling and initialization that can be utilized for testing high-resolution physics, advanced data assimilation method, ensemble forecast, etc.

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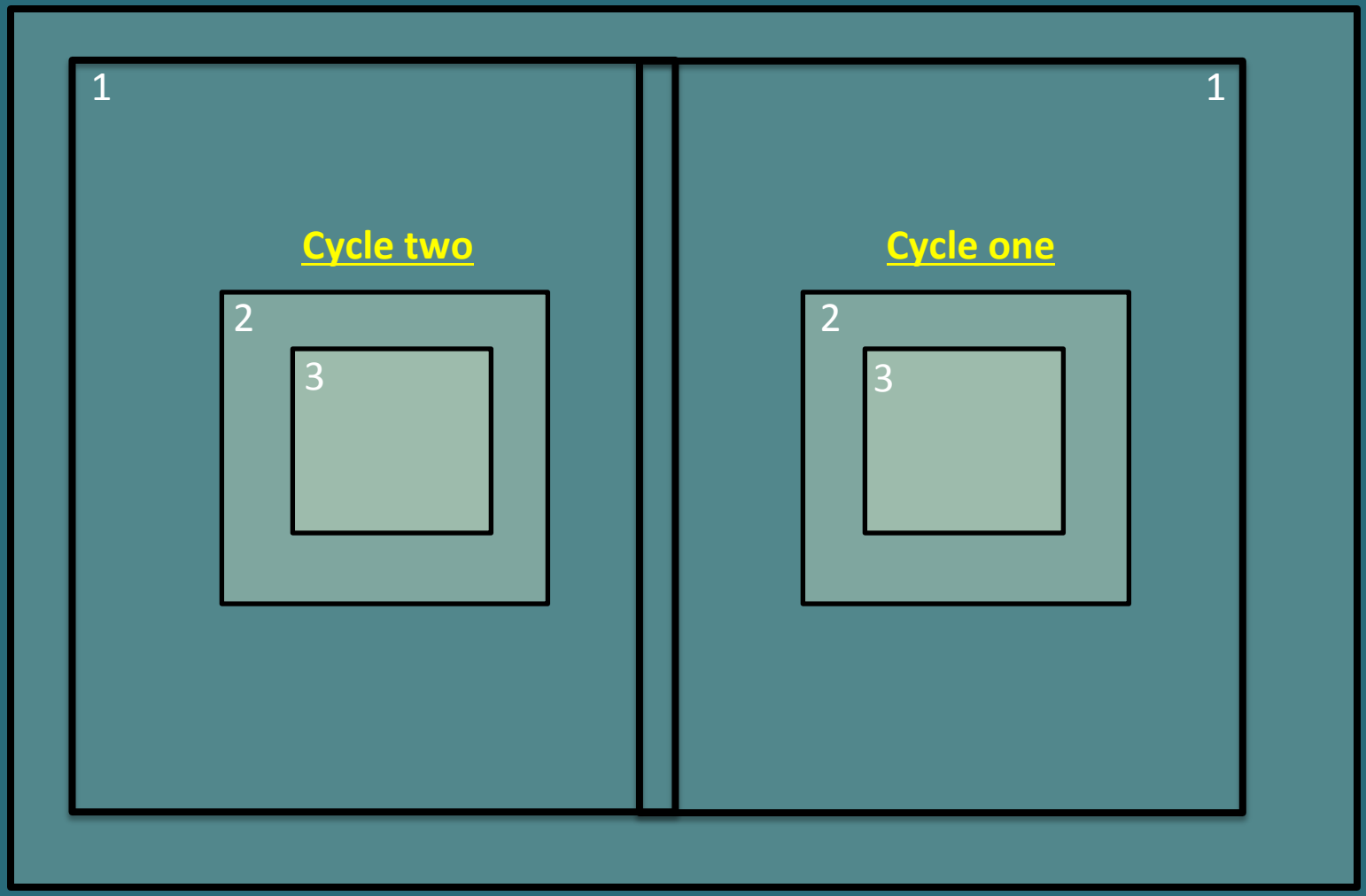
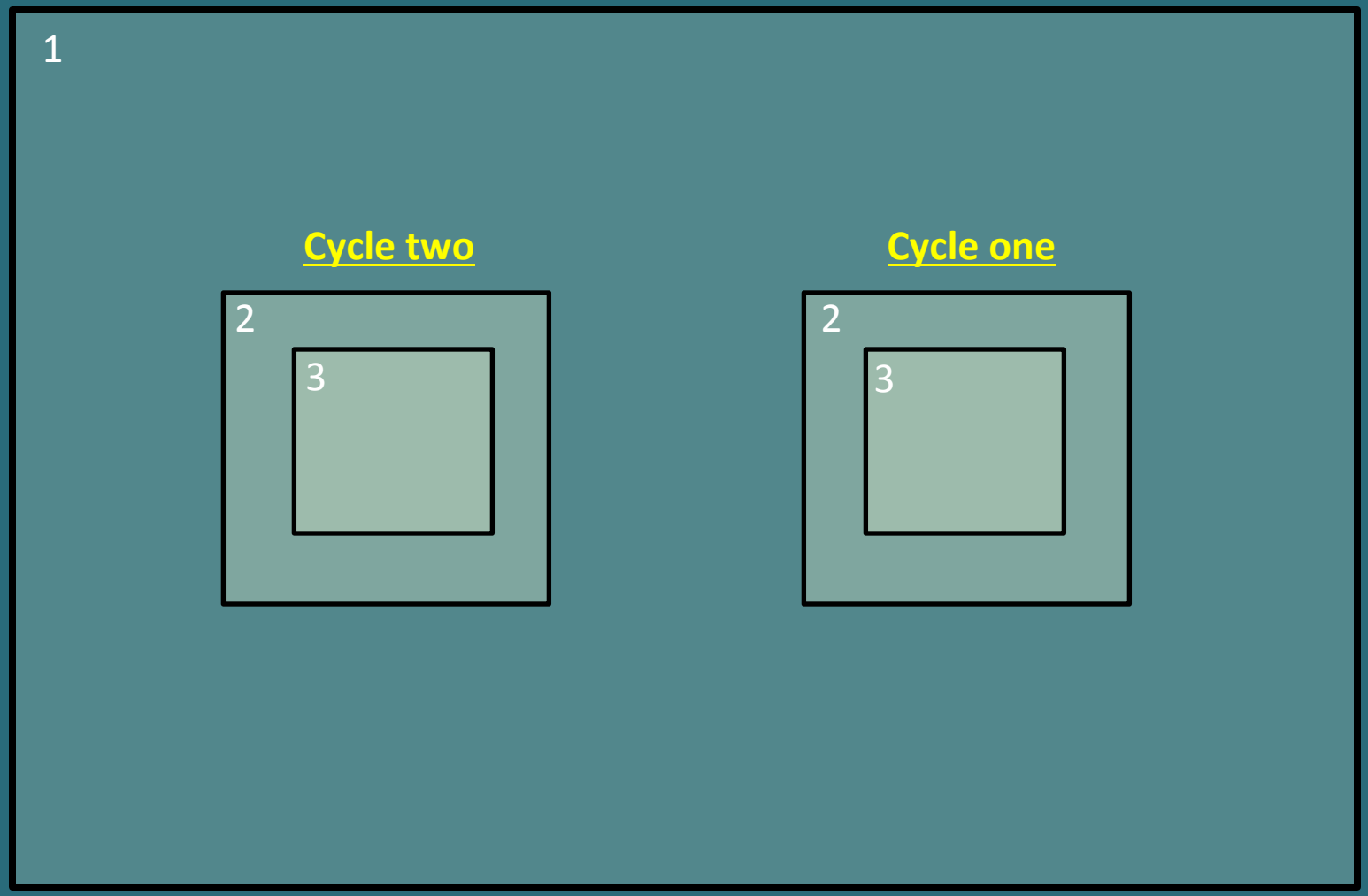


The basin-scale HWRF system



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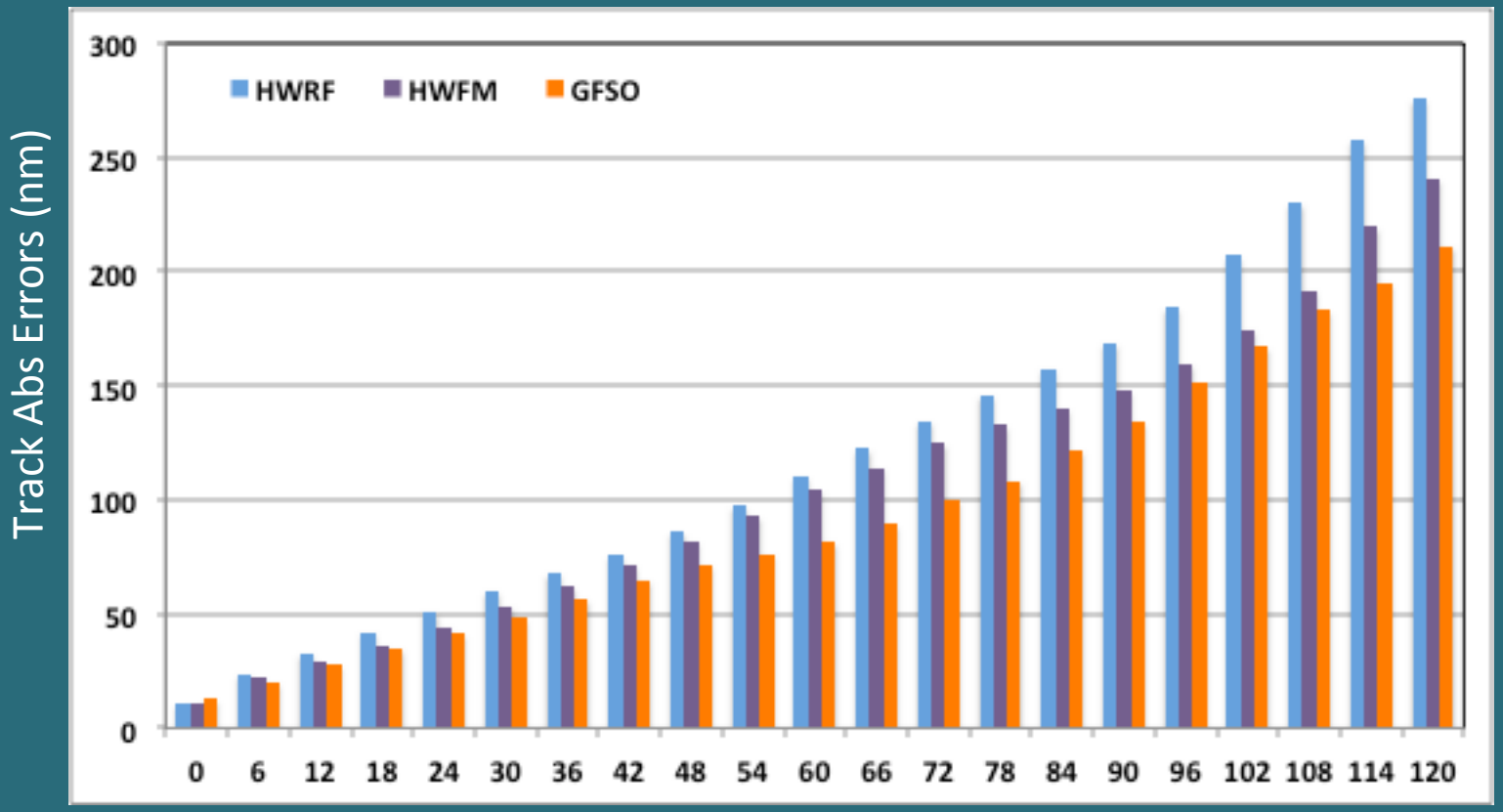
- Facilitate coherent capacity of cycling and initialization that can be utilized for testing high-resolution physics, advanced data assimilation method, ensemble forecast, etc.
- Quantify model bias and diagnose sources of model errors
- Tailor a tool that is operationally feasible and transferable at minimum cost
- Experiment global to convective scale next generation hurricane forecast model

Basin-wide HWRF Configurations

	2013 Operational HWRF	Basin-wide HWRF
Domain	27 KM: 77.76˚ X 77.76˚ 9 KM: 10.56˚ X 10.2˚ 3 KM: 6.12˚ X 5.42˚	27 KM: 178.20˚ X 77.58˚ 9 KM: 10.56˚ X 10.2˚ 3 KM: 6.12˚ X 5.42˚
Vertical Levels and Model Top	42 levels 50hPa	61 levels 2hPa
Vortex Initialization	Modified Vortex Initialization at 3 KM and One-way Hybrid DA	Modified Vortex Initialization at 3 KM
Cycling	Yes (9-3 km vortex only)	Yes (cycle 9-3 km vortex each storm)
Ocean Coupling	27-9 KM: Yes 3 KM: No, Downscaled	No
Physics schemes		
Microphysics	Modified Ferrier (High-Res)	**Modified Ferrier (High-Res)**
Radiation	GFDL	**GFDL**
Surface	GFDL (High_res)	**GFDL (High-res)**
PBL Scheme	2012 GFS (High_res)	**2012 GFS (High-res)**
Convection	SAS (High-Res), No CP (3 KM), Shallow Convection	**SAS (High-Res), No CP (3 KM), Shallow Convection**
Land Surface	GFDL Slab	**GFDL Slab**

Atlantic Basin 2012-13

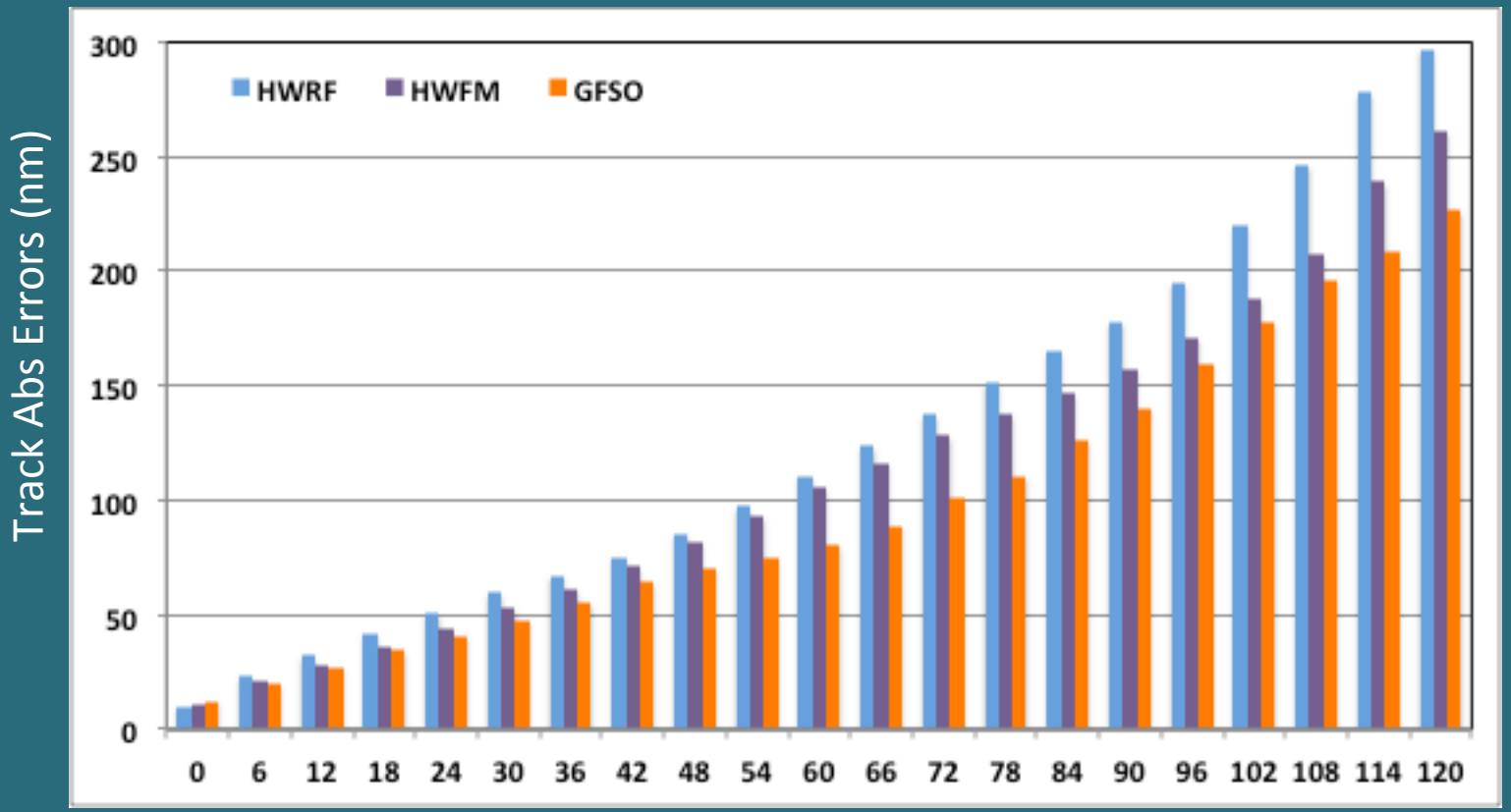
Case#: 481 453 428 403 378 356 333 310 284 263 244 226 210 195 181 168 157 148 140 133 130



Track Verification

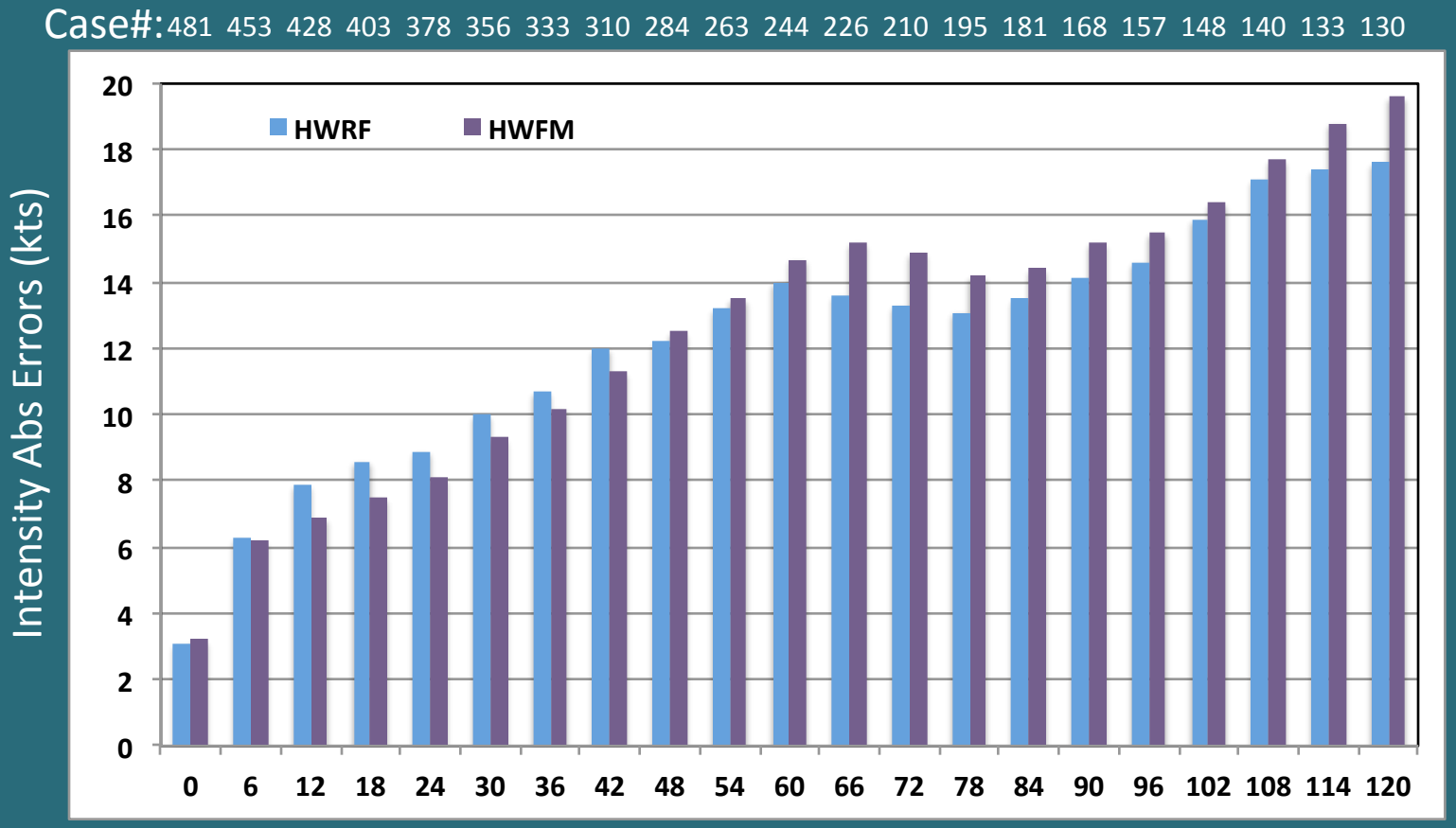
Atlantic Basin 2012-13 w/o Leslie

Case#: 461 433 408 383 358 336 313 290 264 243 224 206 190 175 161 148 137 128 120 113 110



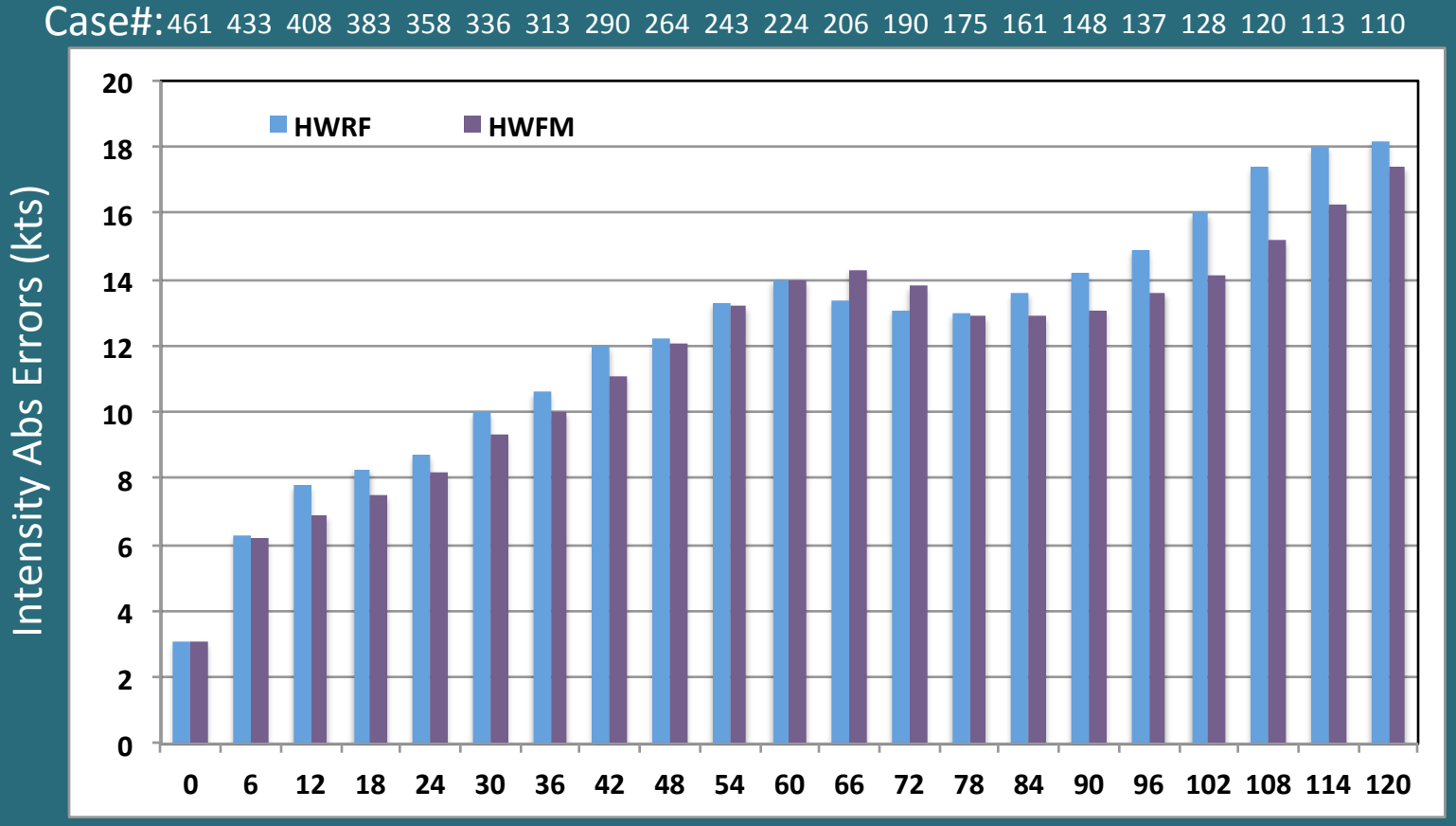
Track Verification

Atlantic Basin 2012-13



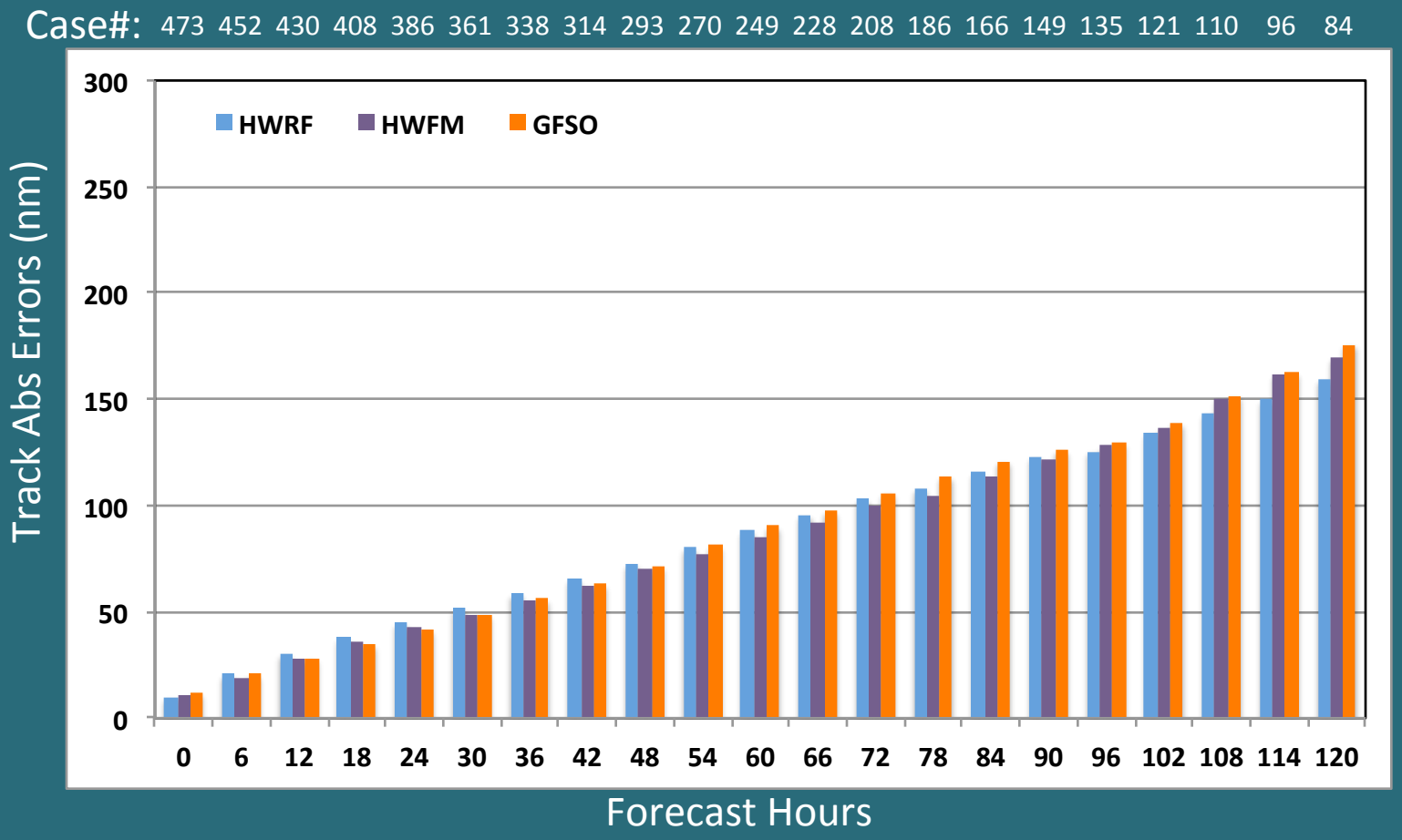
Intensity Verification

Atlantic Basin 2012-13 w/o Leslie



Intensity Verification

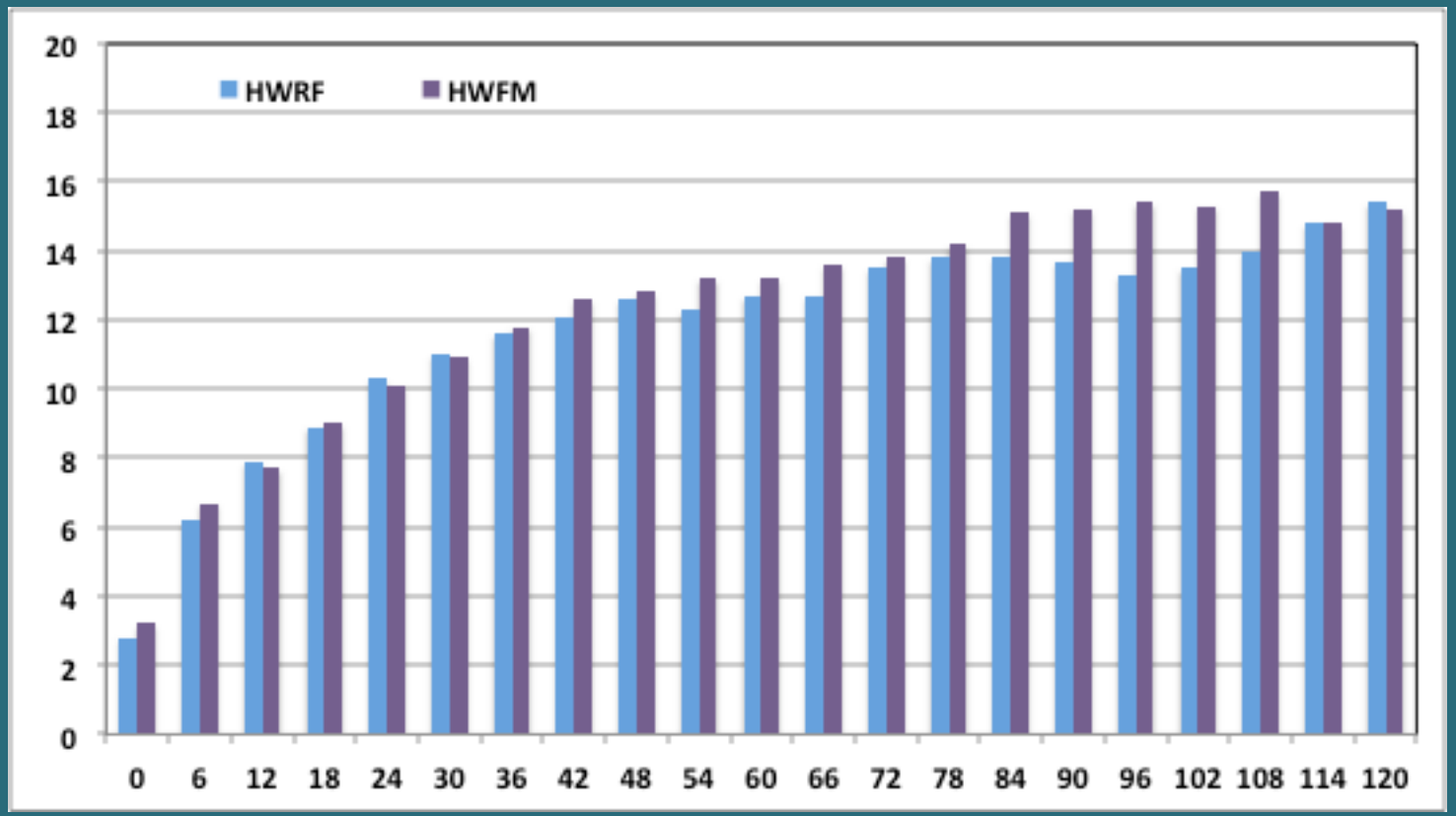
E. Pacific Basin 2012-13



Track Verification

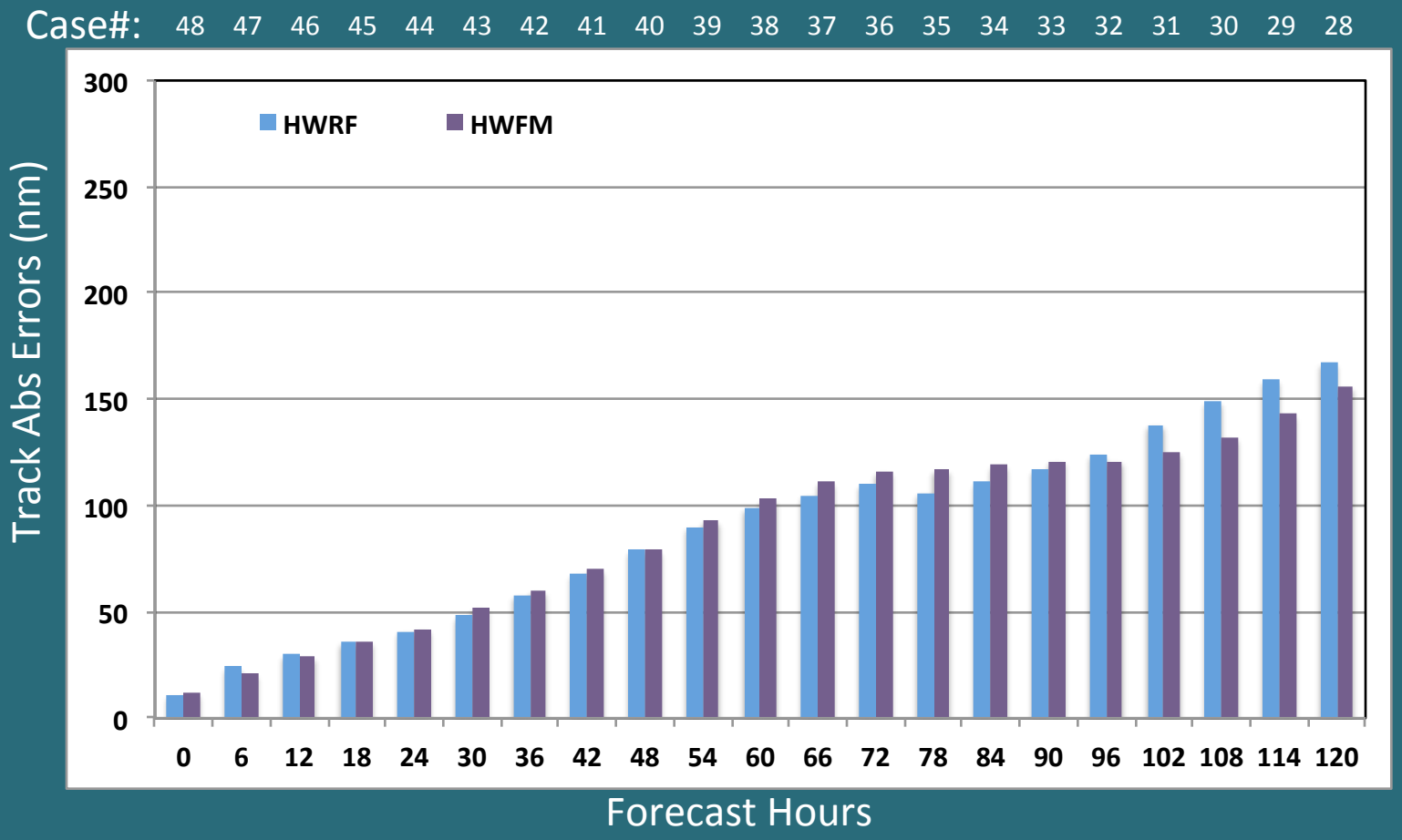
E. Pacific Basin 2012-13

Case#: 473 452 430 408 386 361 338 314 293 270 249 228 208 186 166 149 135 121 110 96 84



Intensity Verification

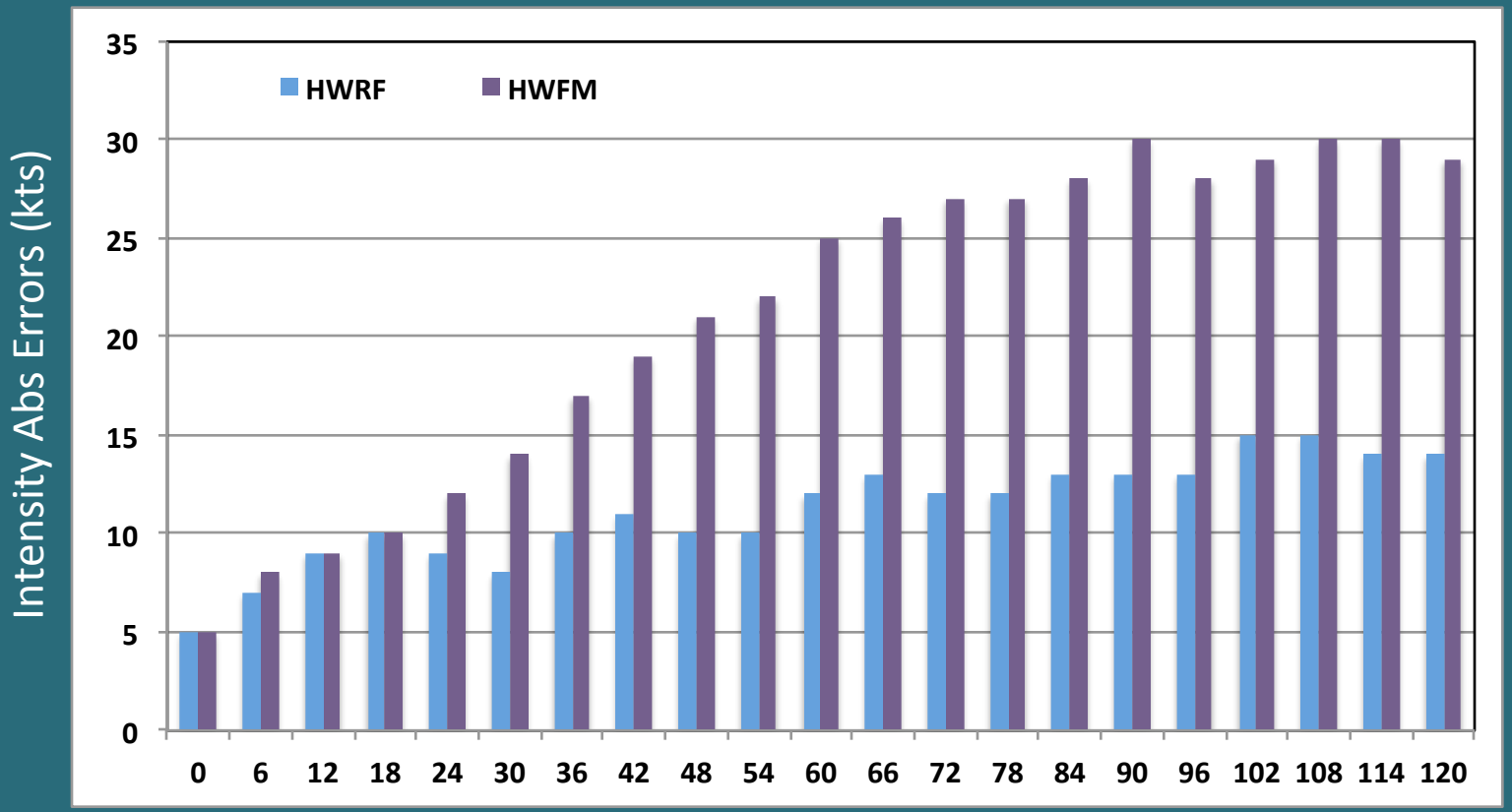
Hurricane Leslie



Track Verification

Hurricane Leslie

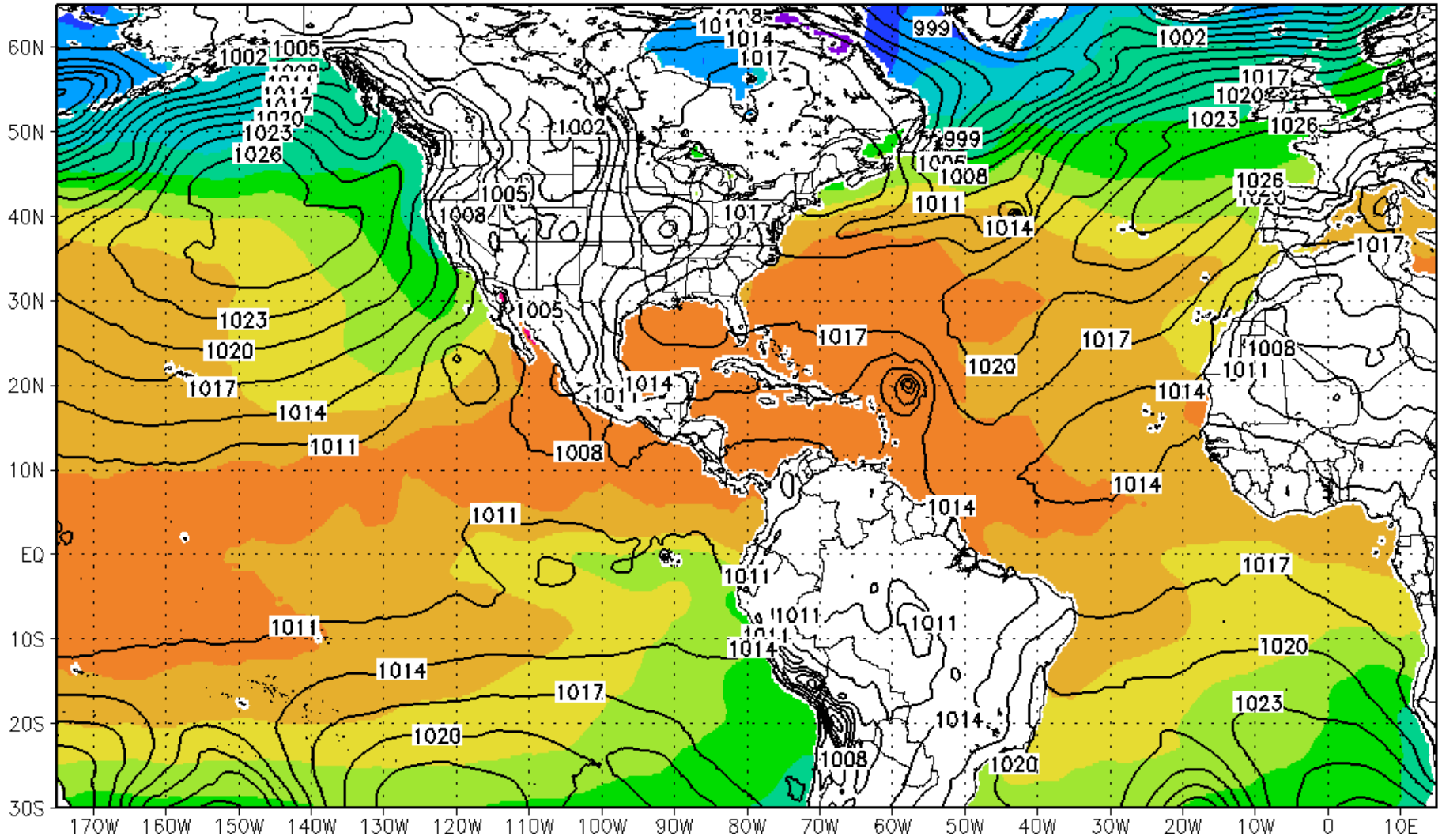
Case#: 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28



Intensity Verification

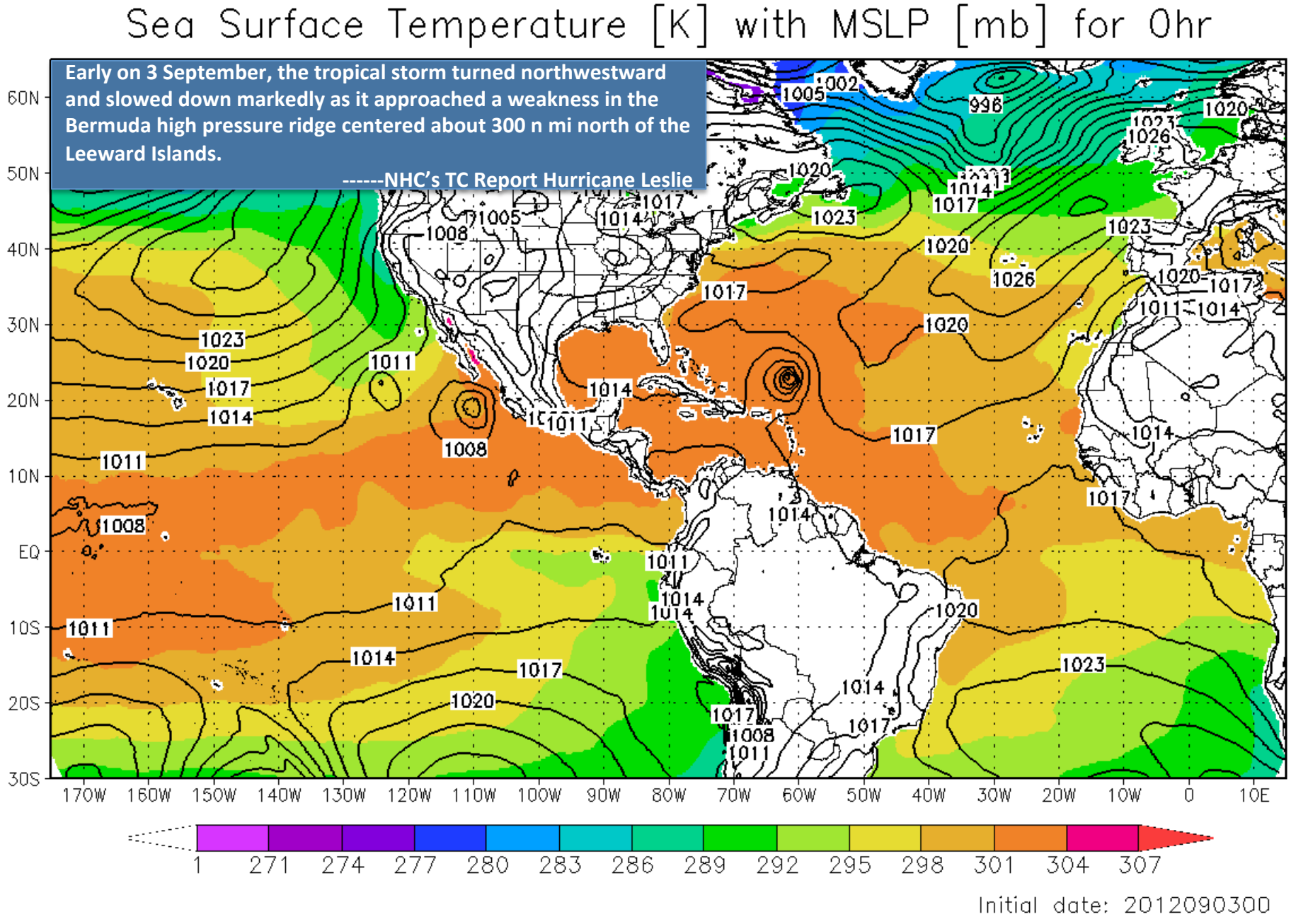
Experimental Product

Sea Surface Temperature [K] with MSLP [mb] for 0hr

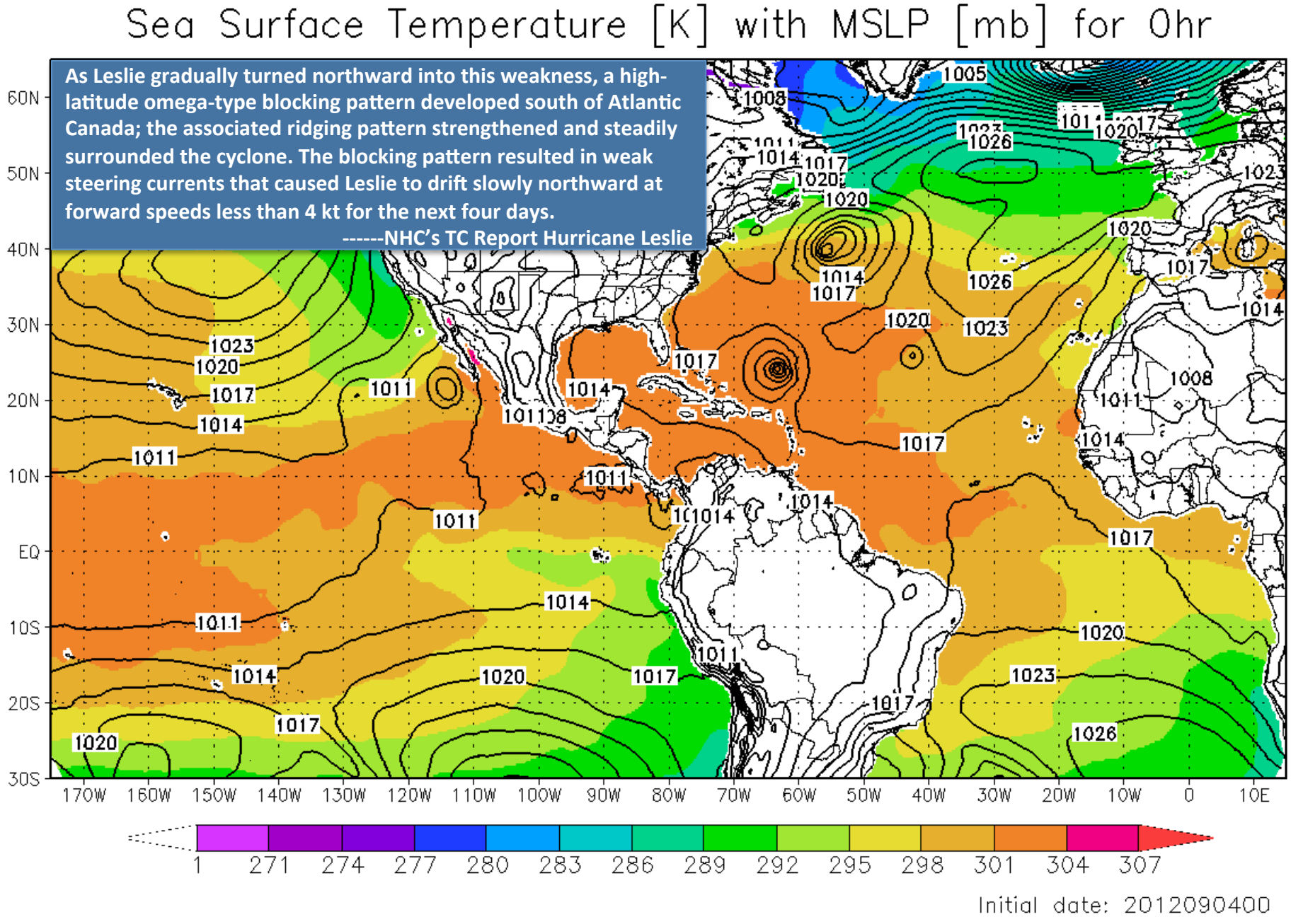


Initial date: 2012090200

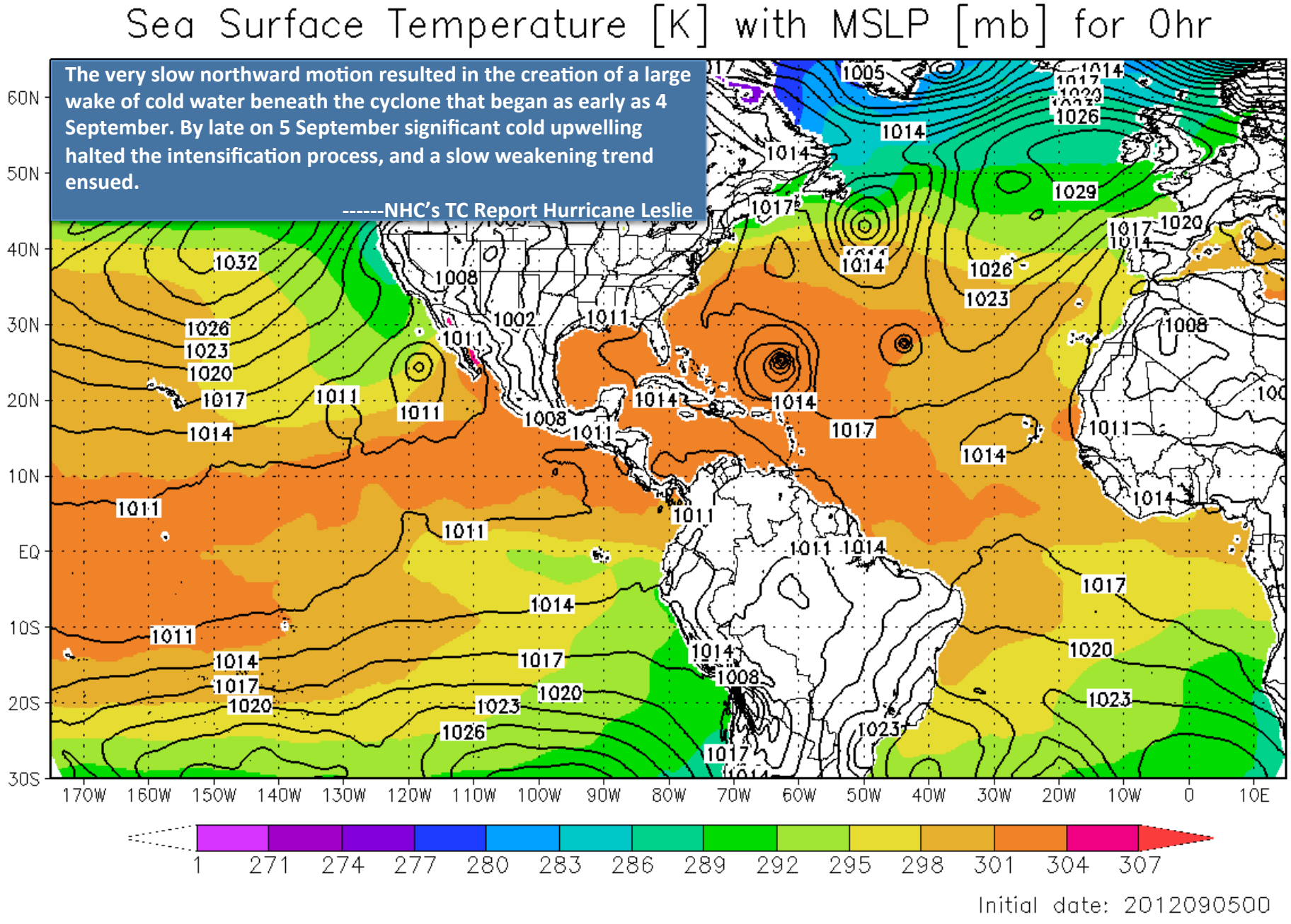
Experimental Product



Experimental Product

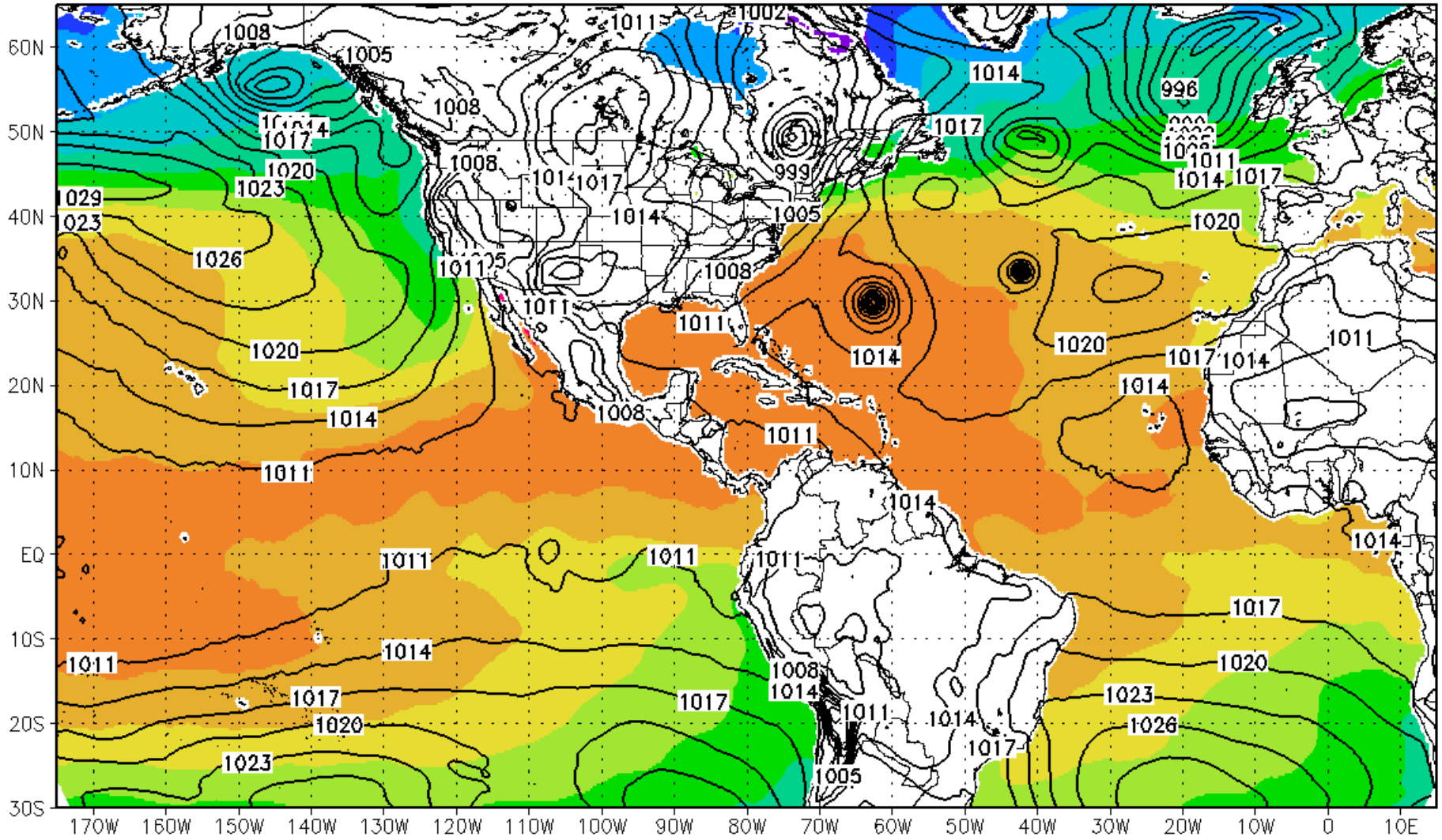


Experimental Product



Experimental Product

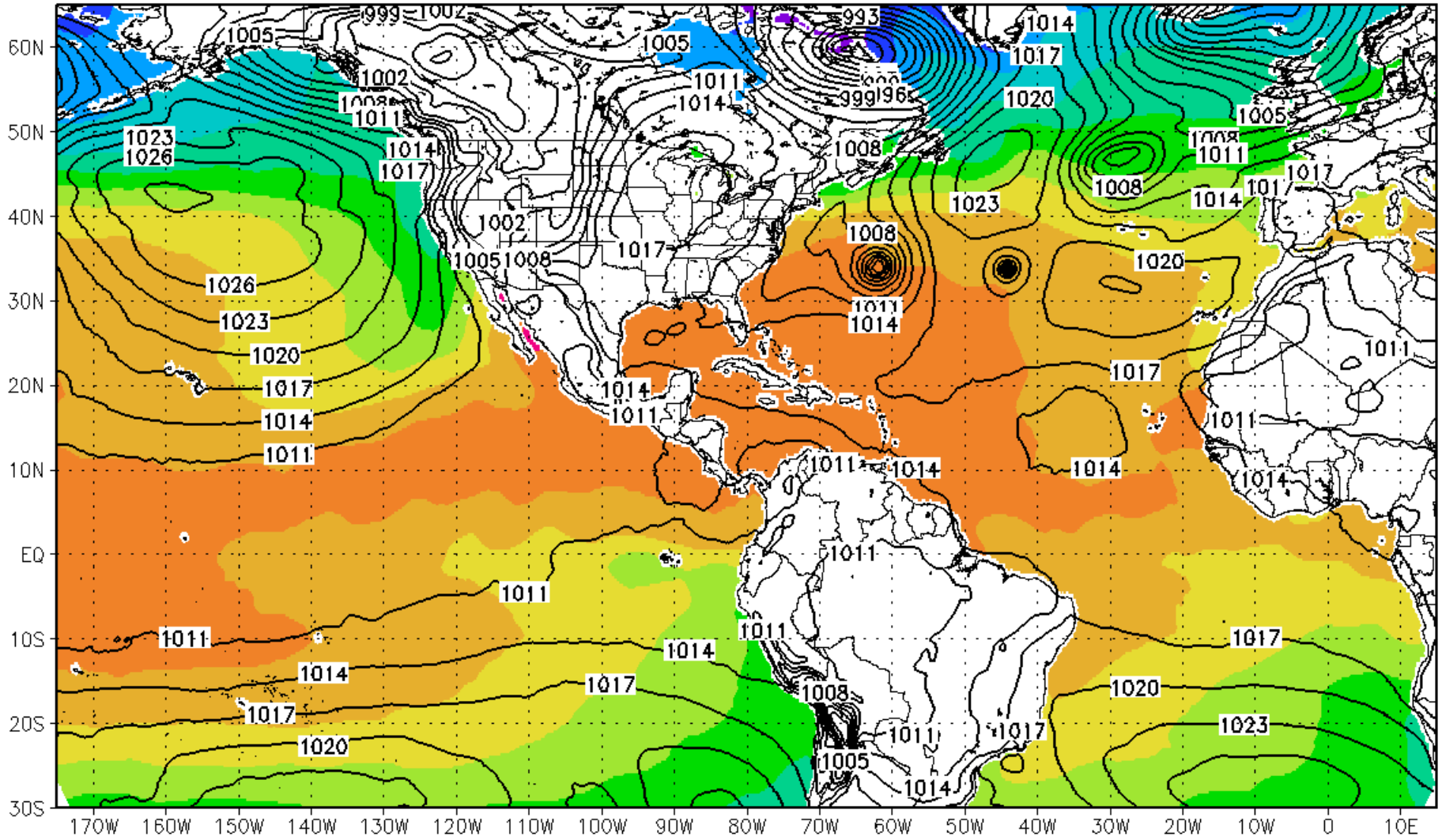
Sea Surface Temperature [K] with MSLP [mb] for 0hr



Initial date: 2012090900

Experimental Product

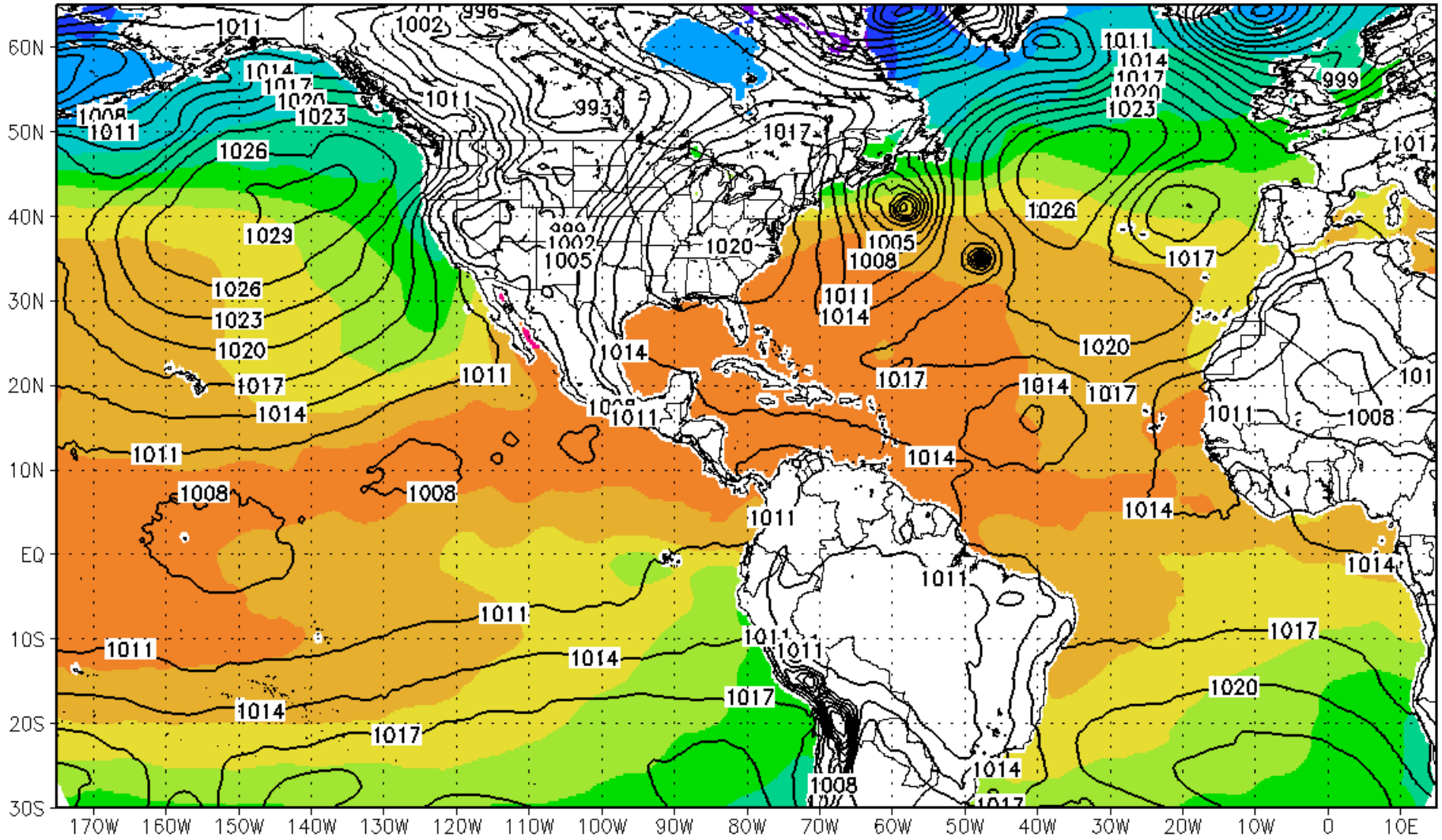
Sea Surface Temperature [K] with MSLP [mb] for 0hr



Initial date: 2012091000

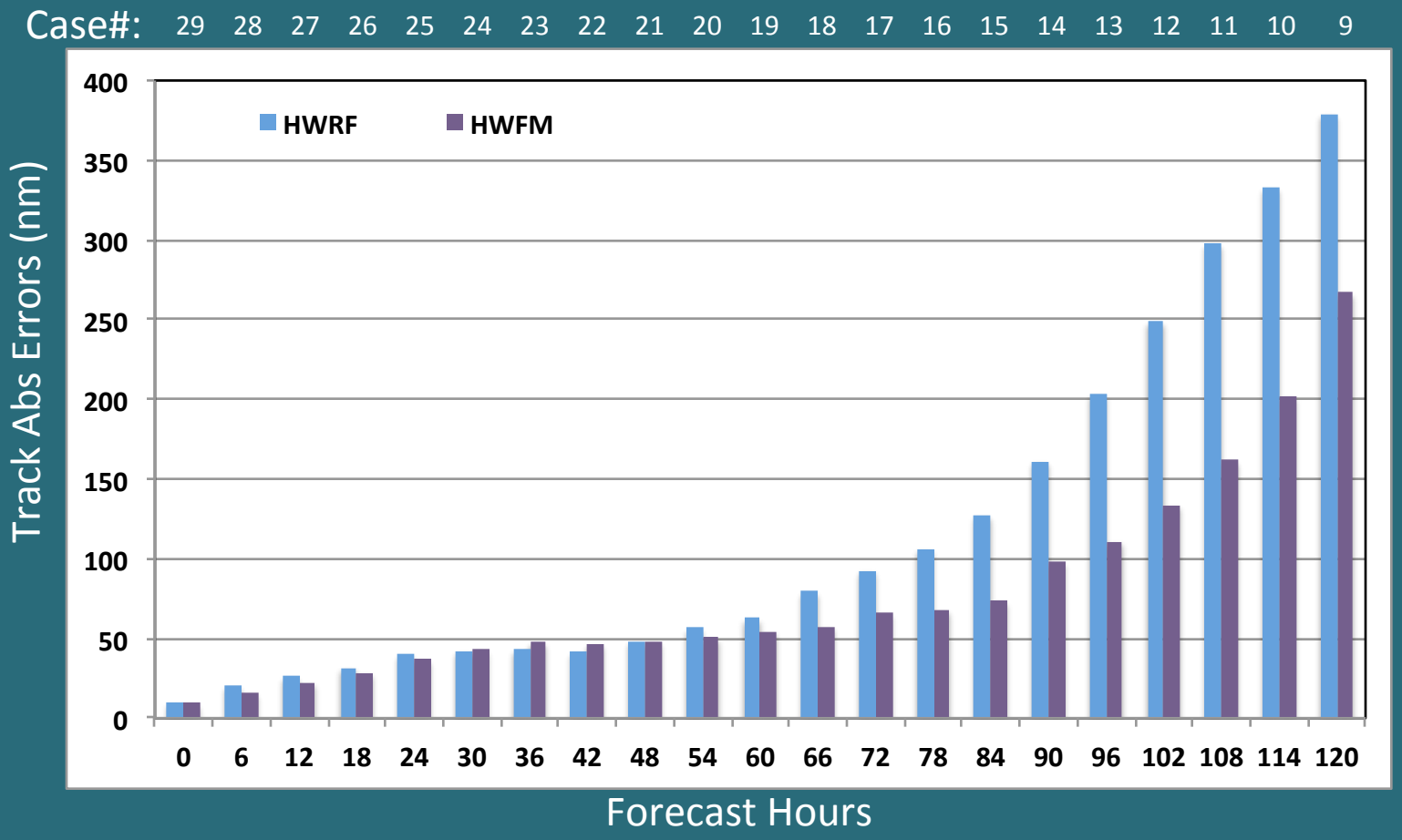
Experimental Product

Sea Surface Temperature [K] with MSLP [mb] for 0hr



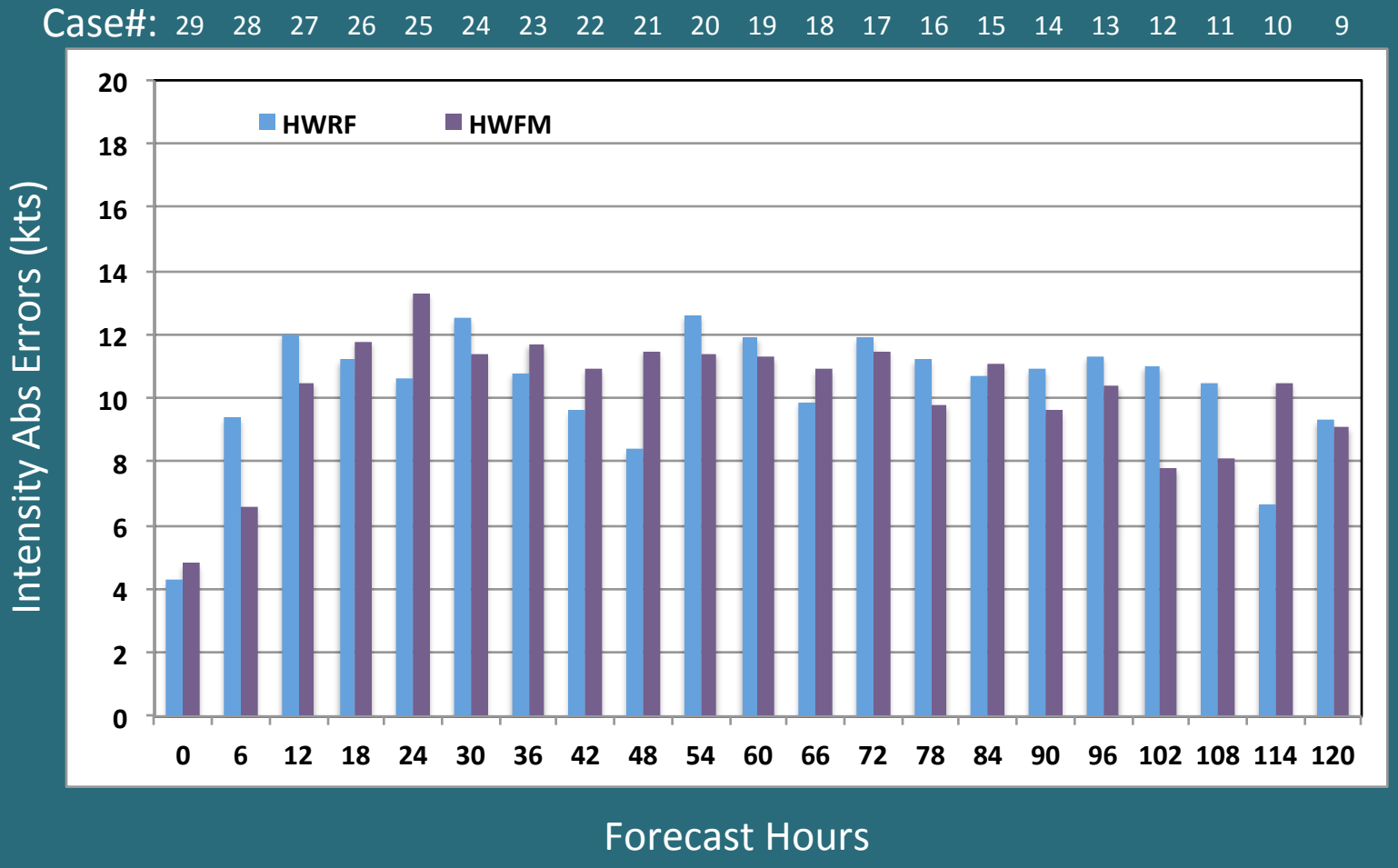
Initial date: 2012091100

Hurricane Sandy



Track Verification

Hurricane Sandy



Intensity Verification

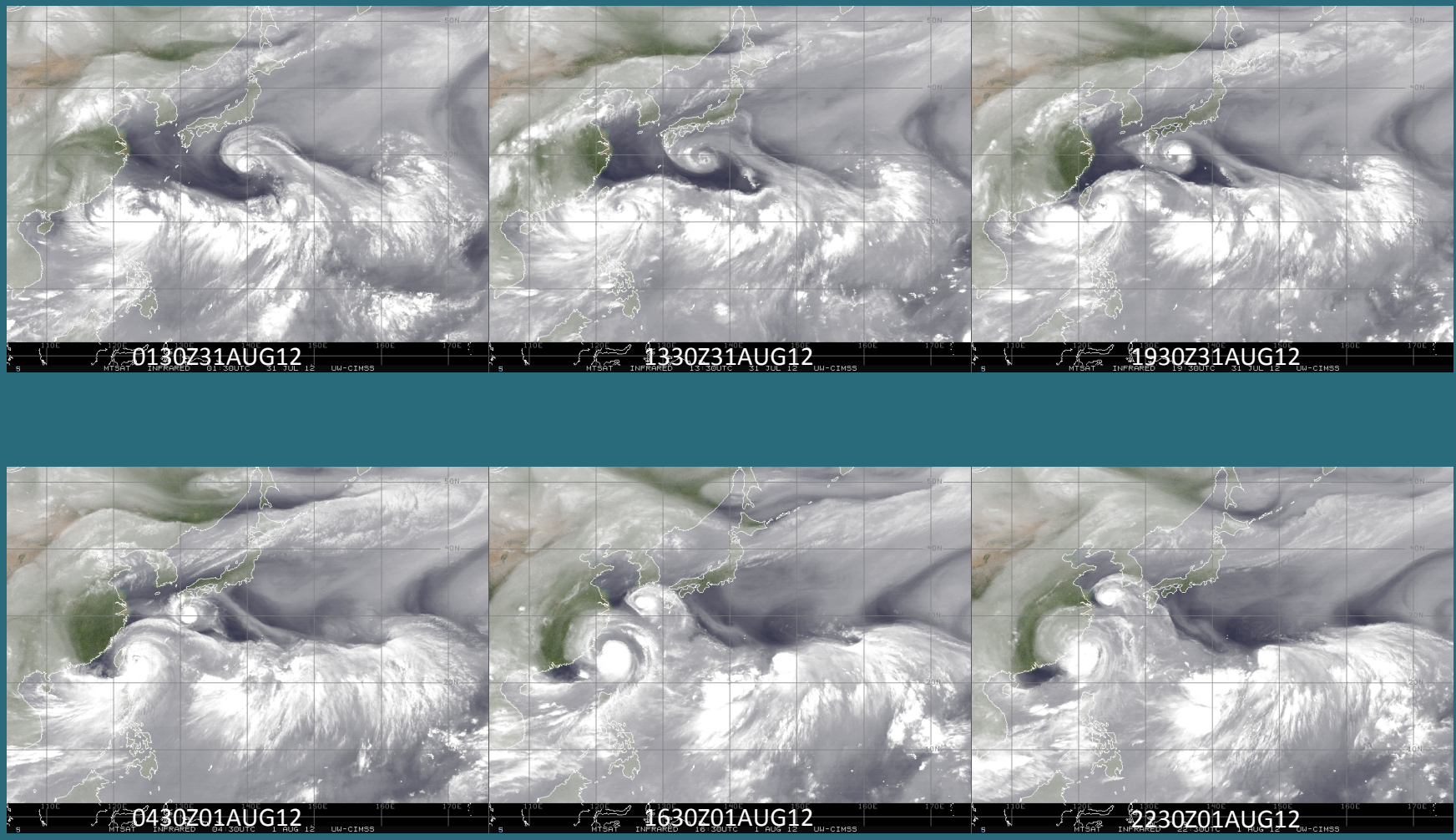
Storm-Storm Interaction

- How often does the storm-storm interaction happen?
- What is the forecast implication?
- What are the interaction process?

2010 Hurricane Danielle-Earl-Fiona-Gaston-Hermine-Igor-Julia-Karl-Lisa-Matthew

- Danielle interacts with Earl
- Earl interacts with Fiona
- Igor interacts with Julia

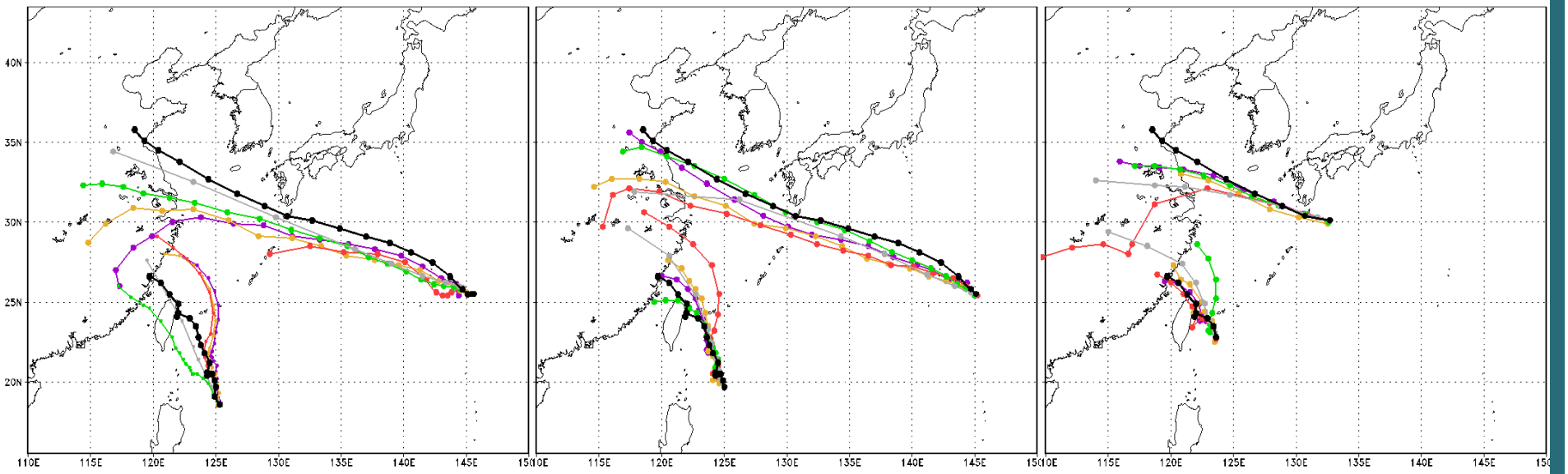
Example of Binary TC interaction



Forecast Issue

- Basin-wide model forecast produced superior tracks after 3000Z
- JTWC operational forecast struggled except at early stage because of the complicate interactions
- All models including GFS have bigger landfall location errors even 48 hour forecast

Black: best track; Purple: Basin HWRF; Orange: Oper. HWRF; Red: GFS; Green: GFDL



Initial time 2012072912

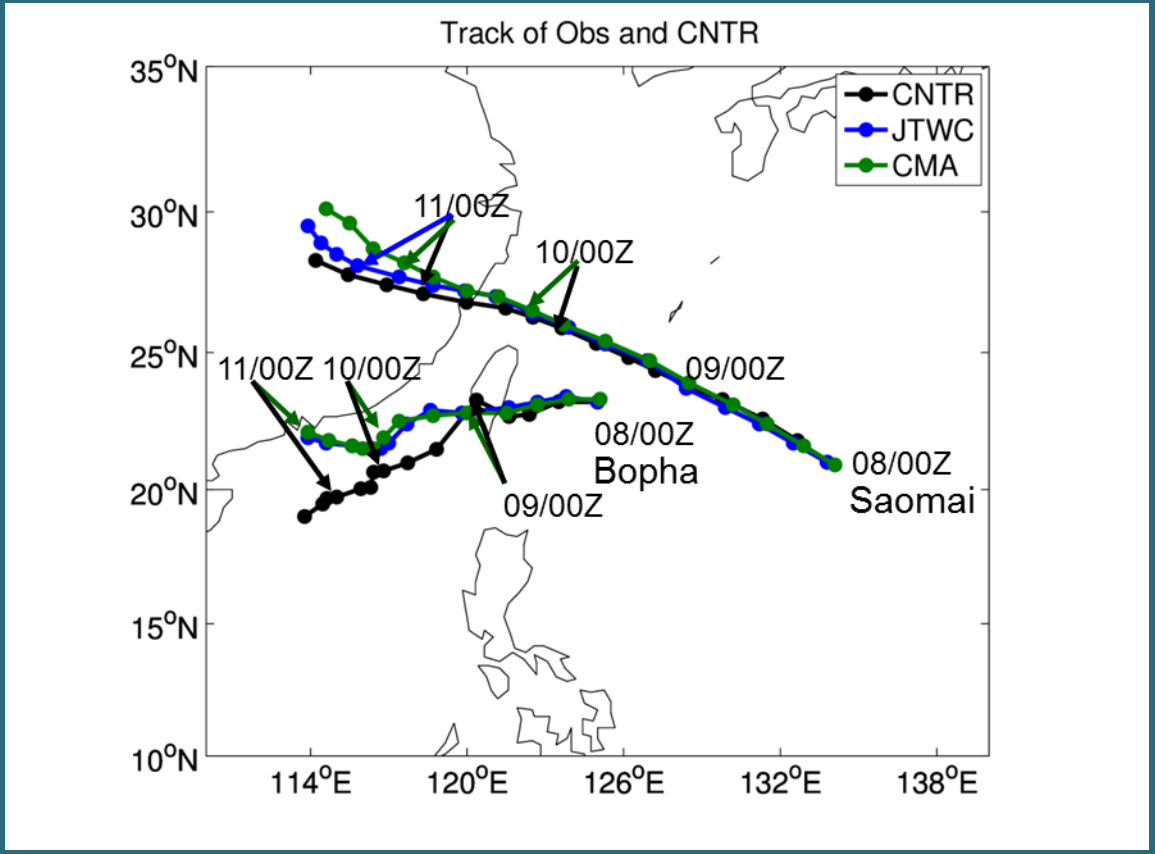
Initial time 2012073000

Initial time 2012080100

Binary TC interaction

- Fujiwhara effect (Fujiwhara, 1921, 1923, 1931)
  - Two cyclonic vortices can orbit each other and close the distance between the circulations of their corresponding areas
  - Smaller circulations can cause the development of a larger cyclone or cause two cyclones to merge into one

Saomai & Bopha Interaction



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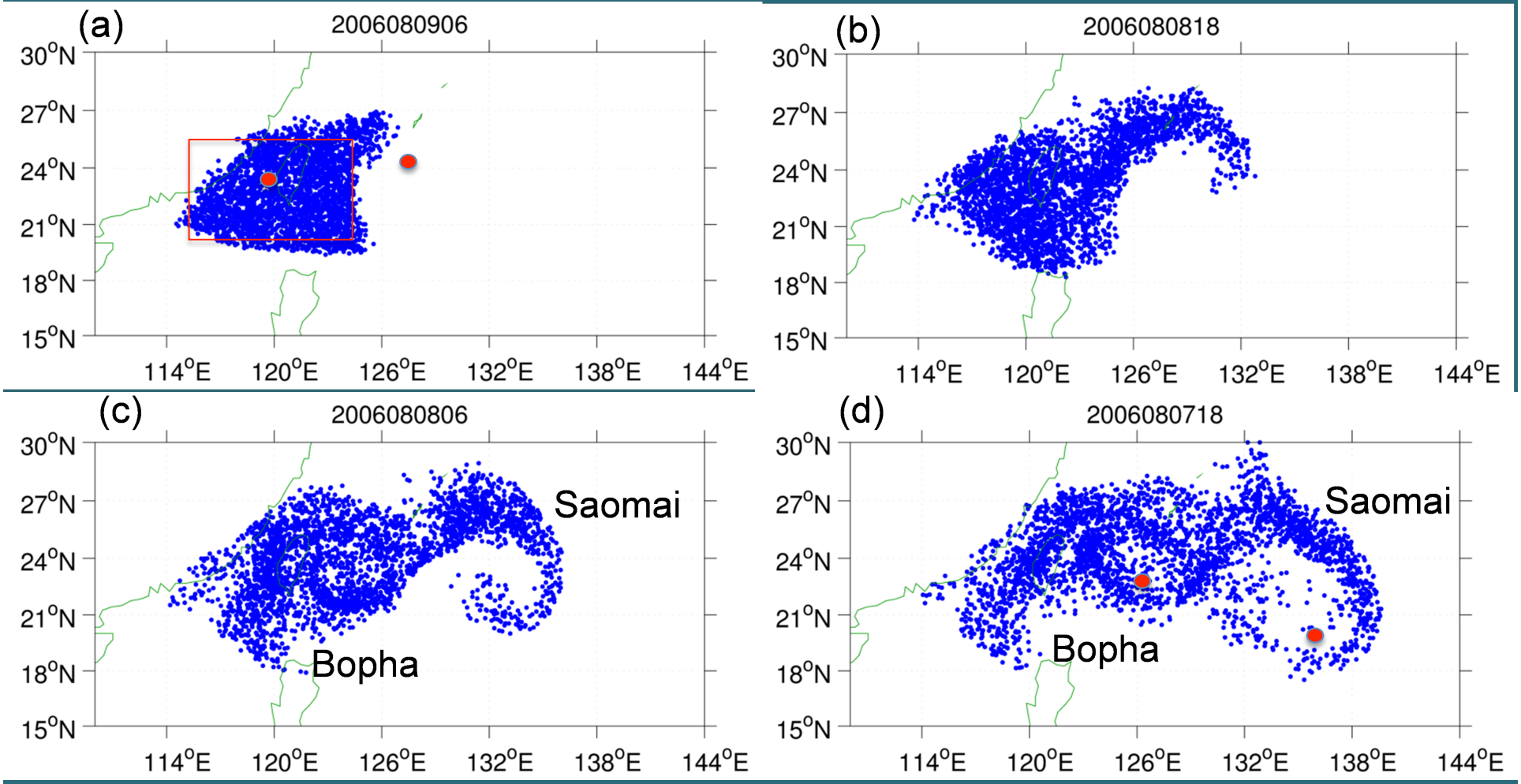
Moisture transport process



Back trajectories of the cluster of moisture particles released at 1200 UTC 9 August in Bopha (115.5~125.5◦E, 20.1~25.0◦N) in the FLEXPART model at (a) 0600 UTC 09 August, 2006, (b) 1800 UTC 08 August, (c) 0600 UTC 08 August, and (d) 1800 UTC 07 August.

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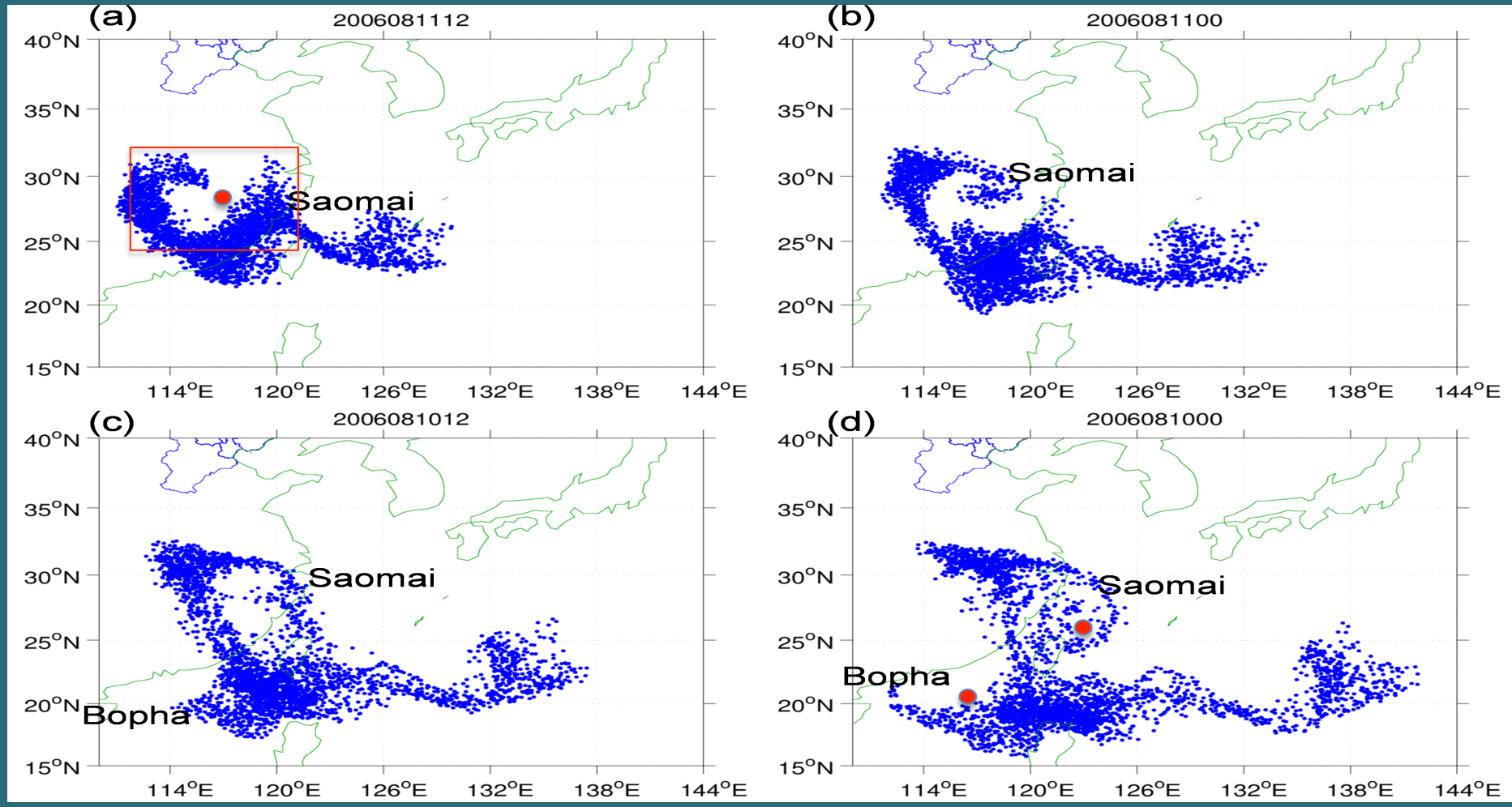
Saomai & Bopha Interaction



Back trajectories of the cluster of moisture particles released at 0000 UTC 13 August in Saomai (114.5~120.5◦E, 26~33.5◦N) in the FLEXPART model at (a) 1200 UTC 11 August, (b) 0000 UTC 11 August, (c) 1200 UTC 10 August, and (d) 0000 UTC 10 August, 2006.

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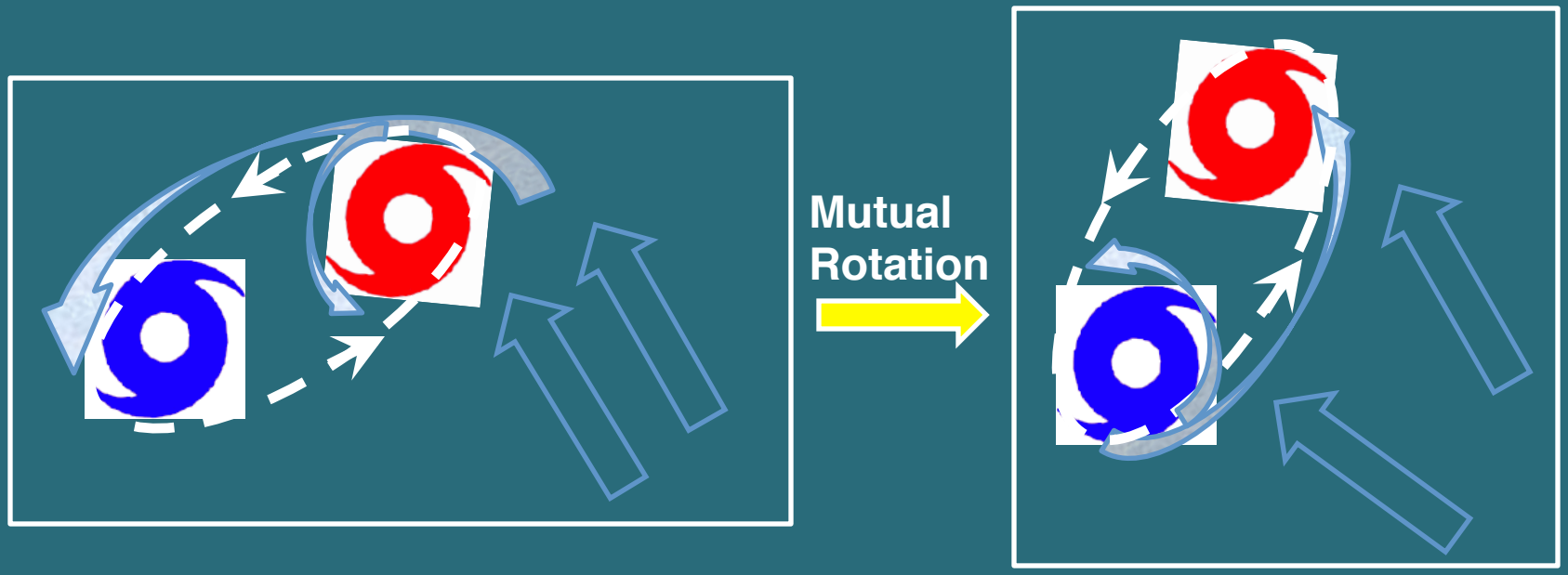

Xu et al. AIM, 2013

Transition to Operation

- Transfer all developments into HWRF repository
  - Multiple movable nest capacity (completed)
  - Multiple nest initialization (ongoing)
  - Code speed up framework (completed)
  - Forecast scripts (ongoing)
- Transfer current capacity into next generation hurricane model
  - Planned according to operational priority

Summary

- We have developed a basin-scale multiple movable nest experimental forecast system
- The system can better represent multi-scale processes and interactions of TC that may translate into better forecast guidance both on track and intensity
- The system provides very promising forecast results during 2012-13 hurricane seasons
- The system can also be utilized as a research tool to explore advanced DA, genesis, terrain-TC interaction, landfall processes, storm-storm interactions, etc.
- The development can also be applied and transferred to next generation global hurricane model development
- Real-time products website: https://storm.aoml.noaa.gov/basin