Team members

- AOML/HRD (Team Lead: G. S. Gopalakrishnan)

  G. Alaka, R. Black, H. Chen, J. Delgado, S. Diaz, S. Goldenberg, K. Sellwood, R. St. Fleur, T. Quirino, J. Zhang, X. Zhang, and HRD colleagues

- NCEP/EMC (Brach Chief: V. Tallapragada; Team co-Lead: S. Trahan & Z. Zhang)

  B. Ferrier, Hyun-Sook Kim, Q. Liu, J. Michalakes, D. Sheinin, M. Tong, S. Trahan, W. Wang, Z. Zhang, and EMC/Hurricane team

- DTC (Task lead: Kathryn Newman)

  L. Bernardet, L. Carson, J. Frimel, C. Holt, and HWRF task team

- GFDL

  T. Marchok and M. Bender

- URI

  B. Thomas and I. Ginis

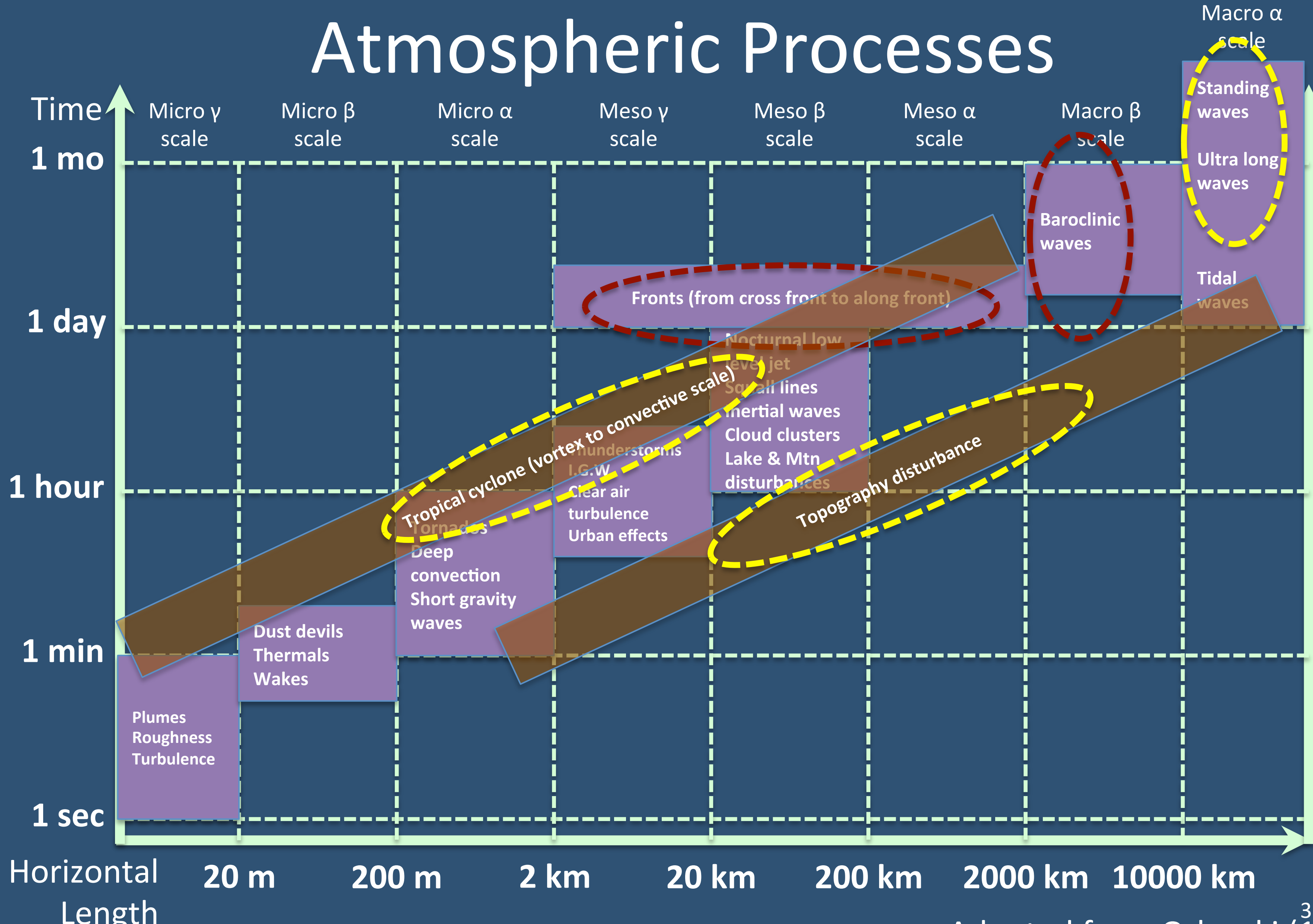
- NPS

  M. Boothe, M. Montgomery, and B. Rutherford

Operational Requirements

- Requirements for a TC prediction model
  - Model can provide customers required forecast guidance in a timely manner
  - Model parallelism can fit current and future supercomputer architecture
  - Model is operationally feasible
    - Operational framework (software and hardware)
    - Forecast center infrastructure

Horizontal-Temporal Scales of Atmospheric Processes



Adopted from Orlanski (1975)

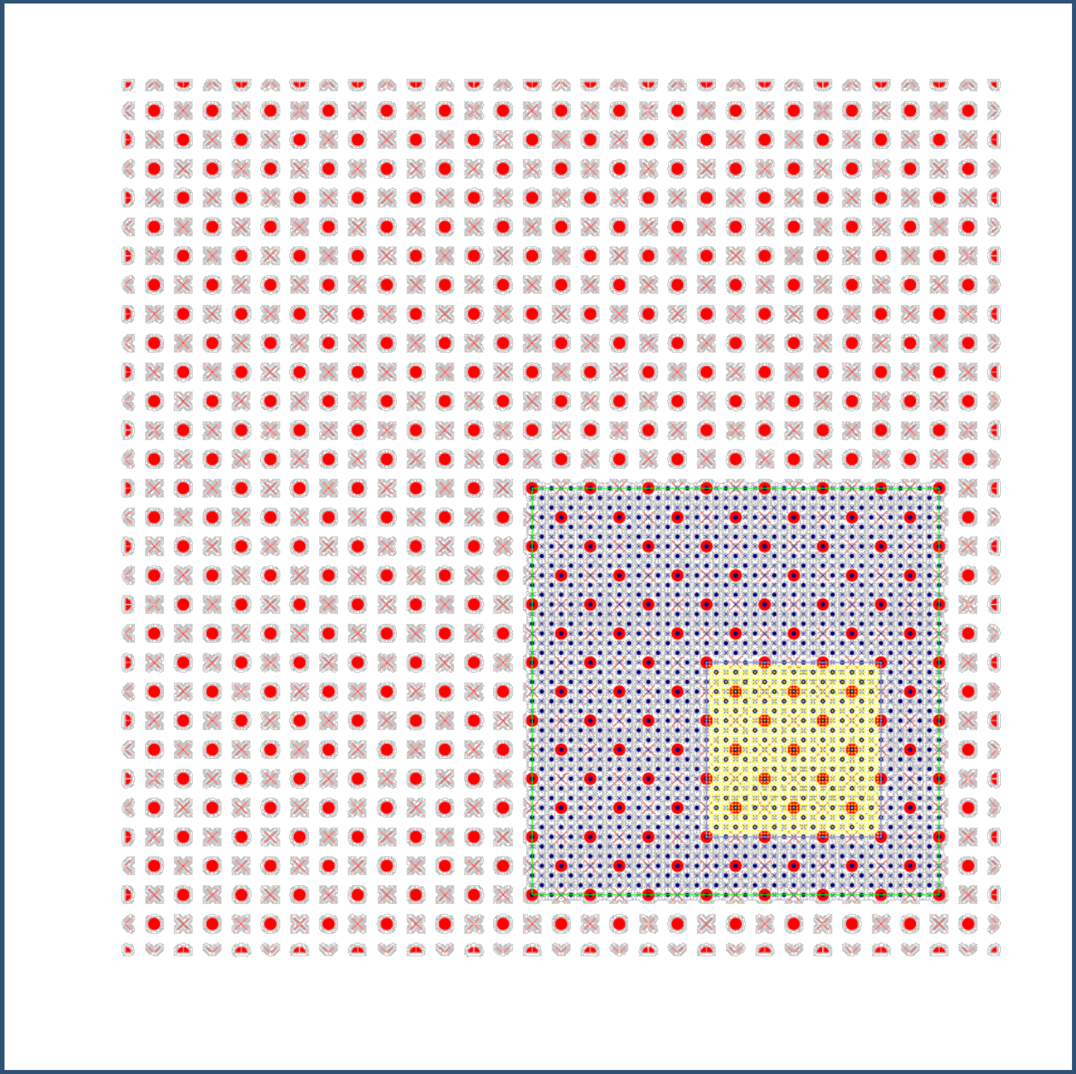
Scientific Requirements

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

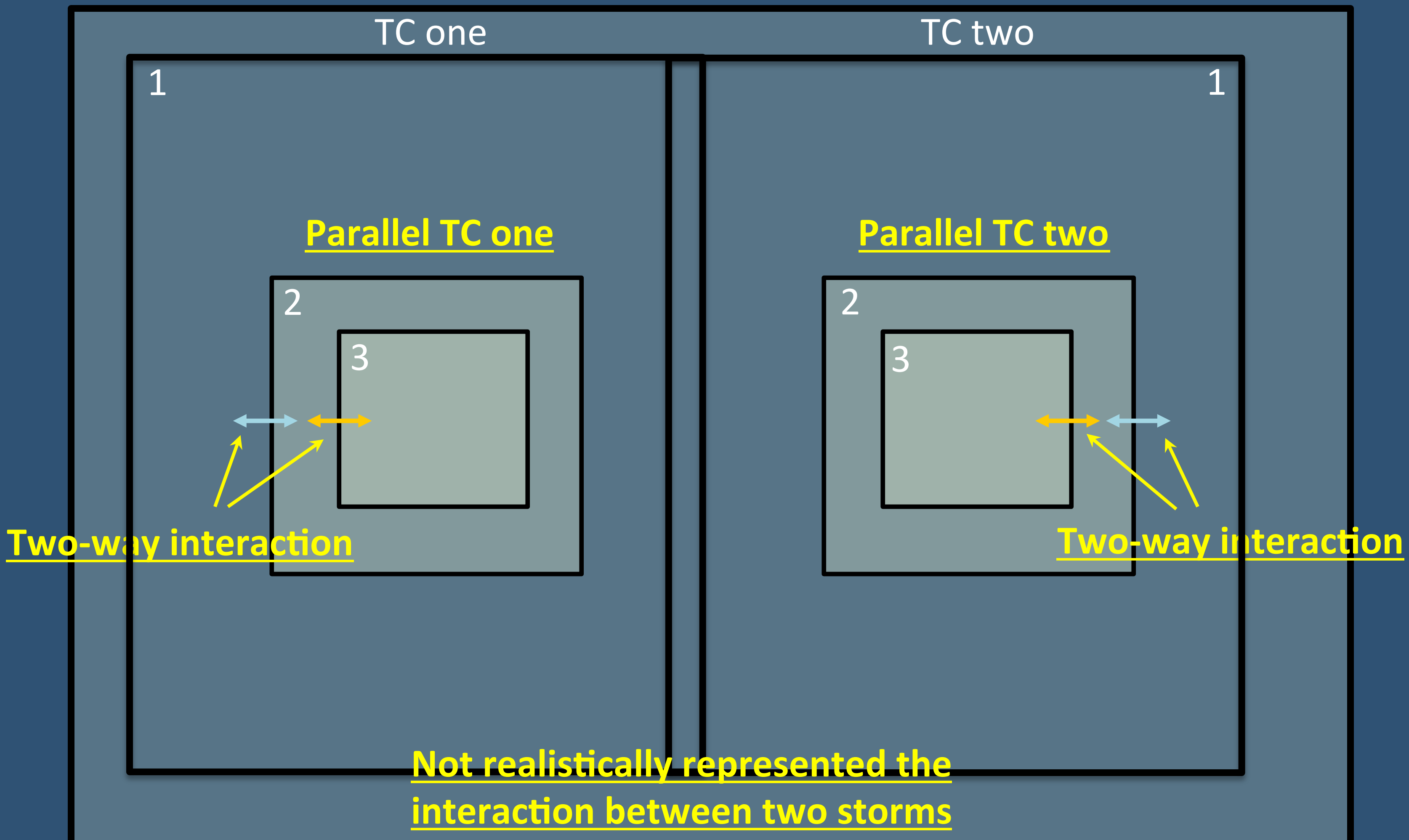
Objectives

- Tailor a tool that is operationally feasible and transferable at minimum cost in the near future
- Create a model for R&D of the next generation across-scale TC forecast system
- Maintain all capabilities available to operational HWRF, including cycling and initialization that can be utilized for testing high-resolution physics, advanced data assimilation, ensemble forecast, etc.
- Quantify model bias and diagnose sources of model errors

Idea of Moving Nest

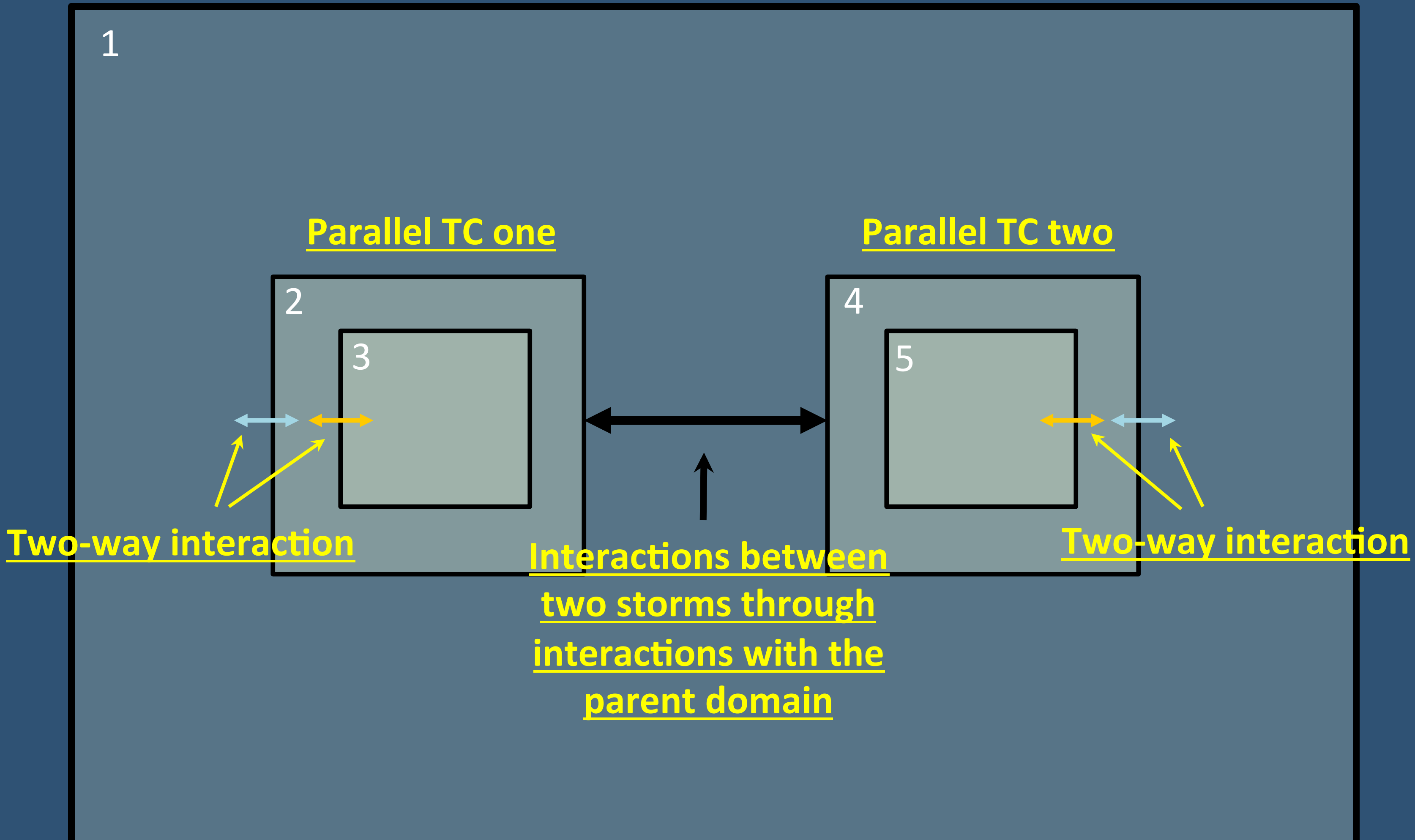


Nesting Scheme and Feedback



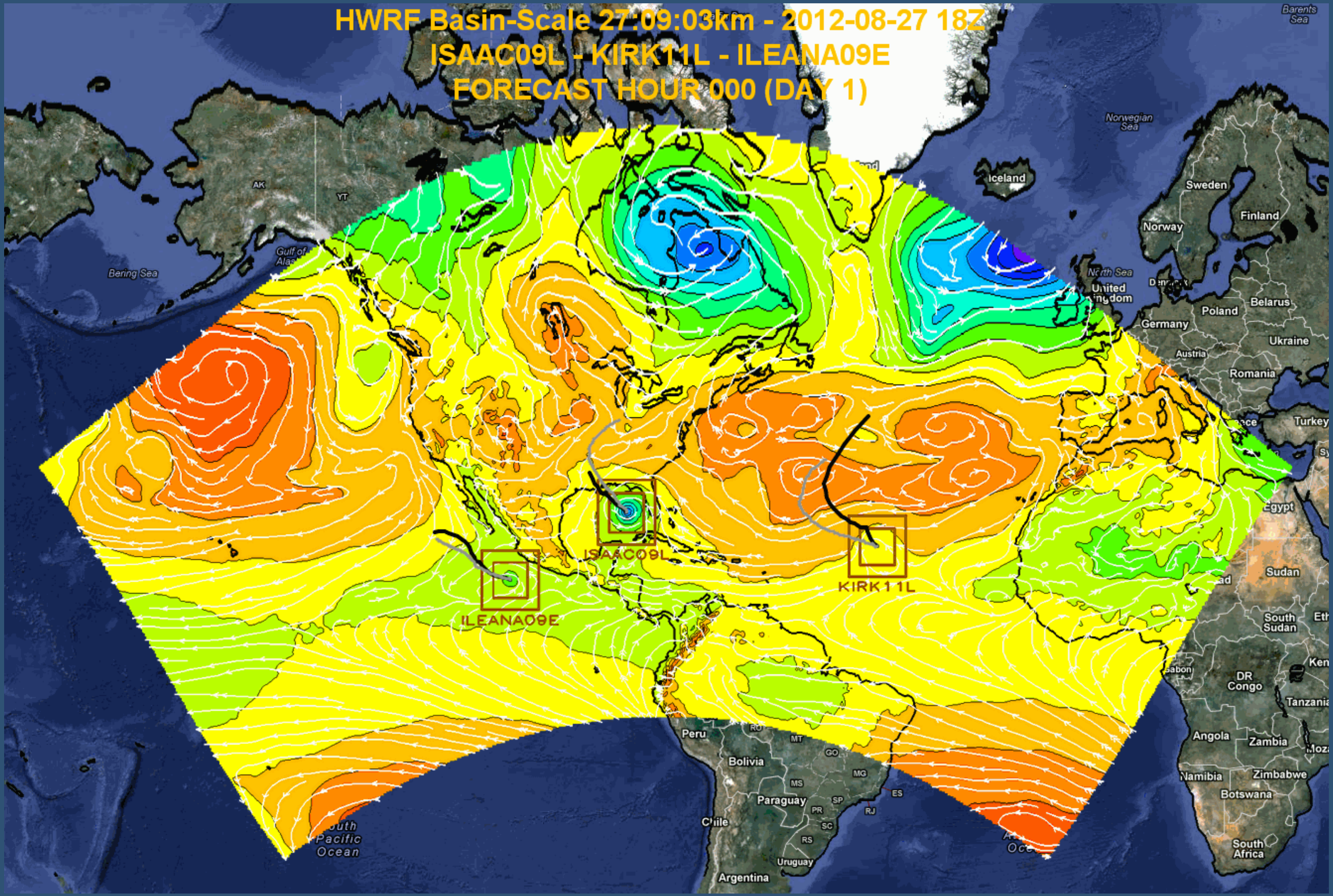
The operational HWRF

Nesting Scheme and Feedback



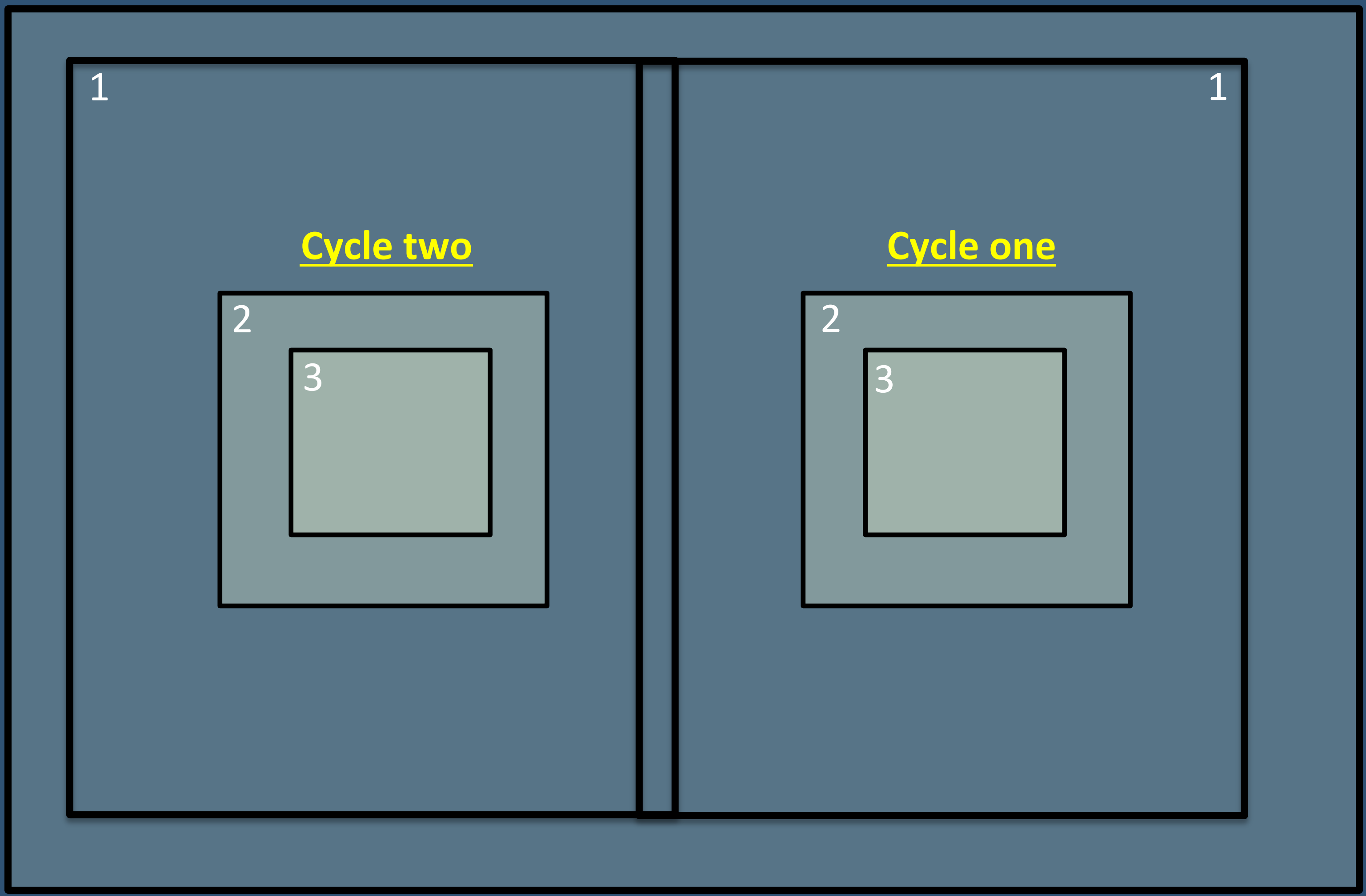
The basin-scale HWRF

Multiple Movable Nests HWRF System



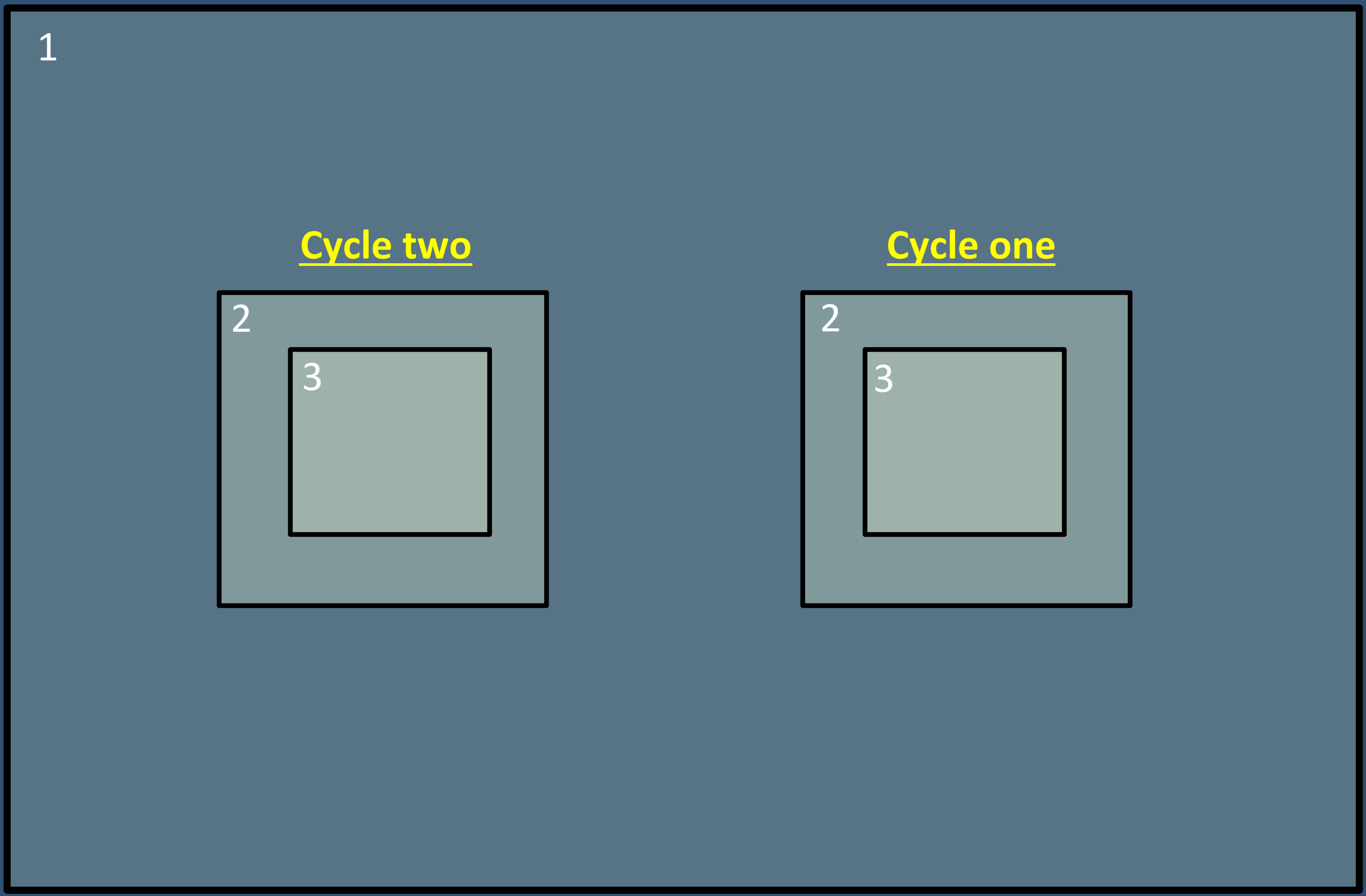
Isaac-Ileana-Kirk real-time 3-km predictions

Cycling scheme



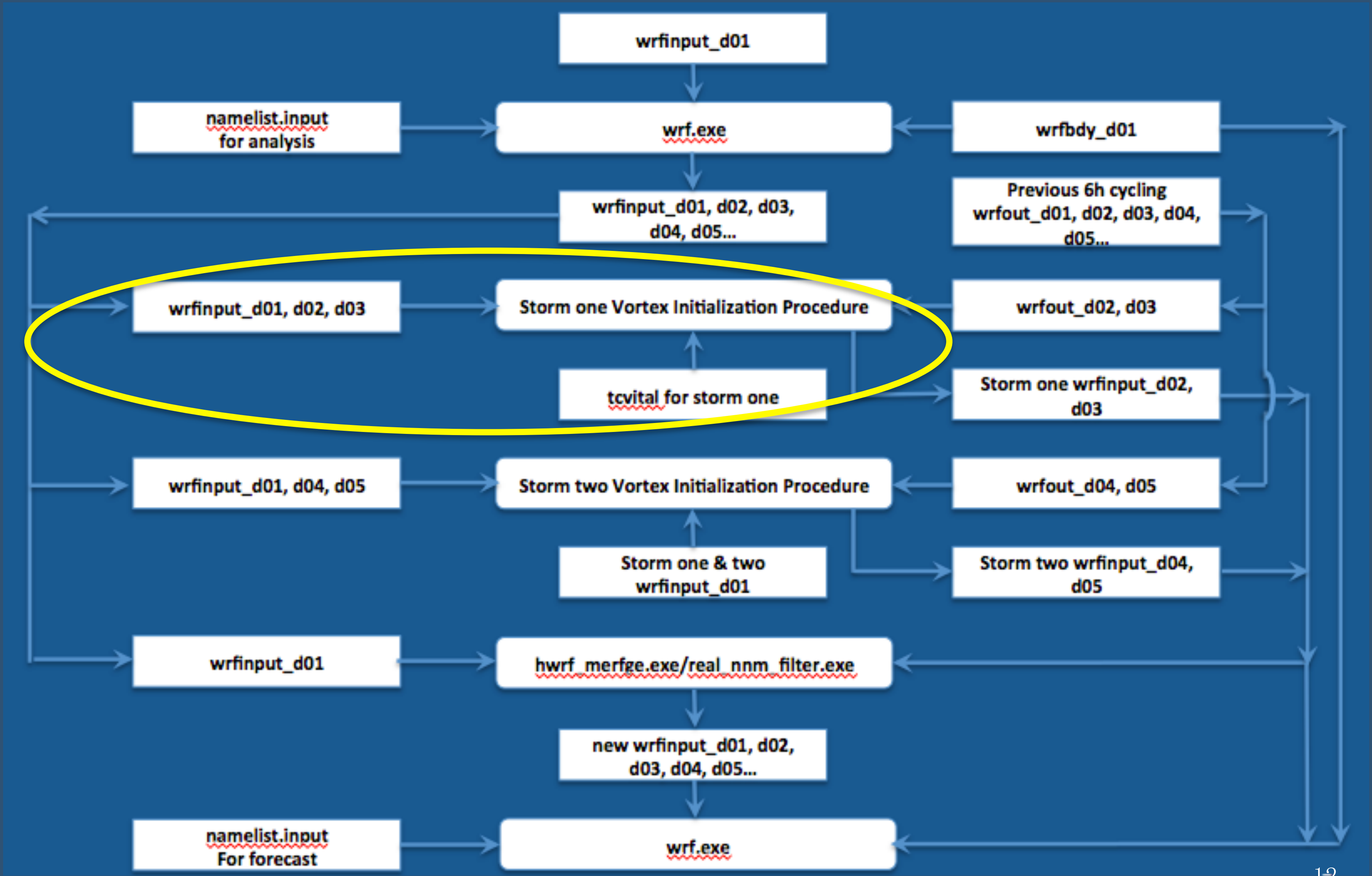
The operational HWRF

Cycling scheme



The basin-scale HWRF

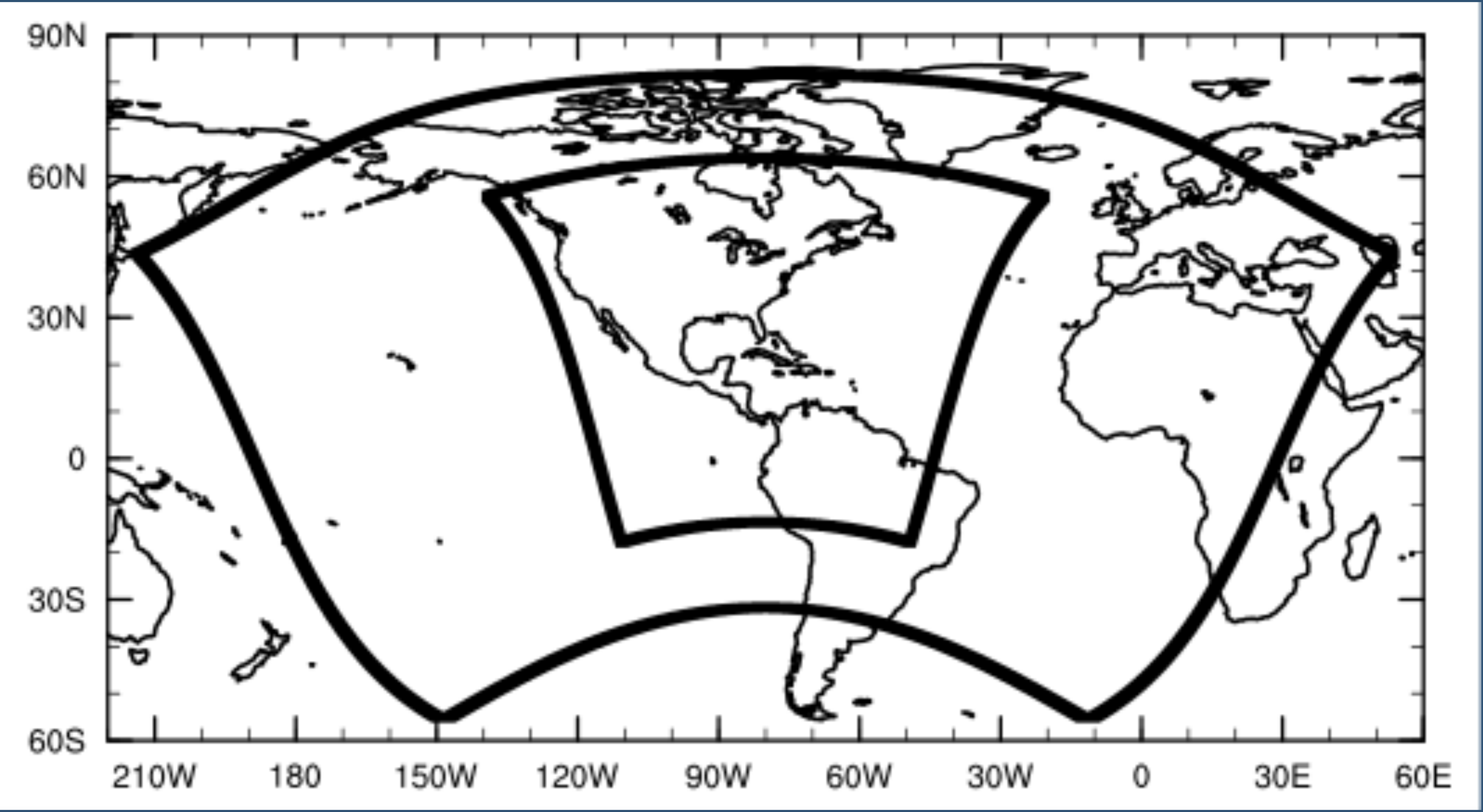
Multi-storm Initialization



Basin-scale HWRF vs. Operational HWRF

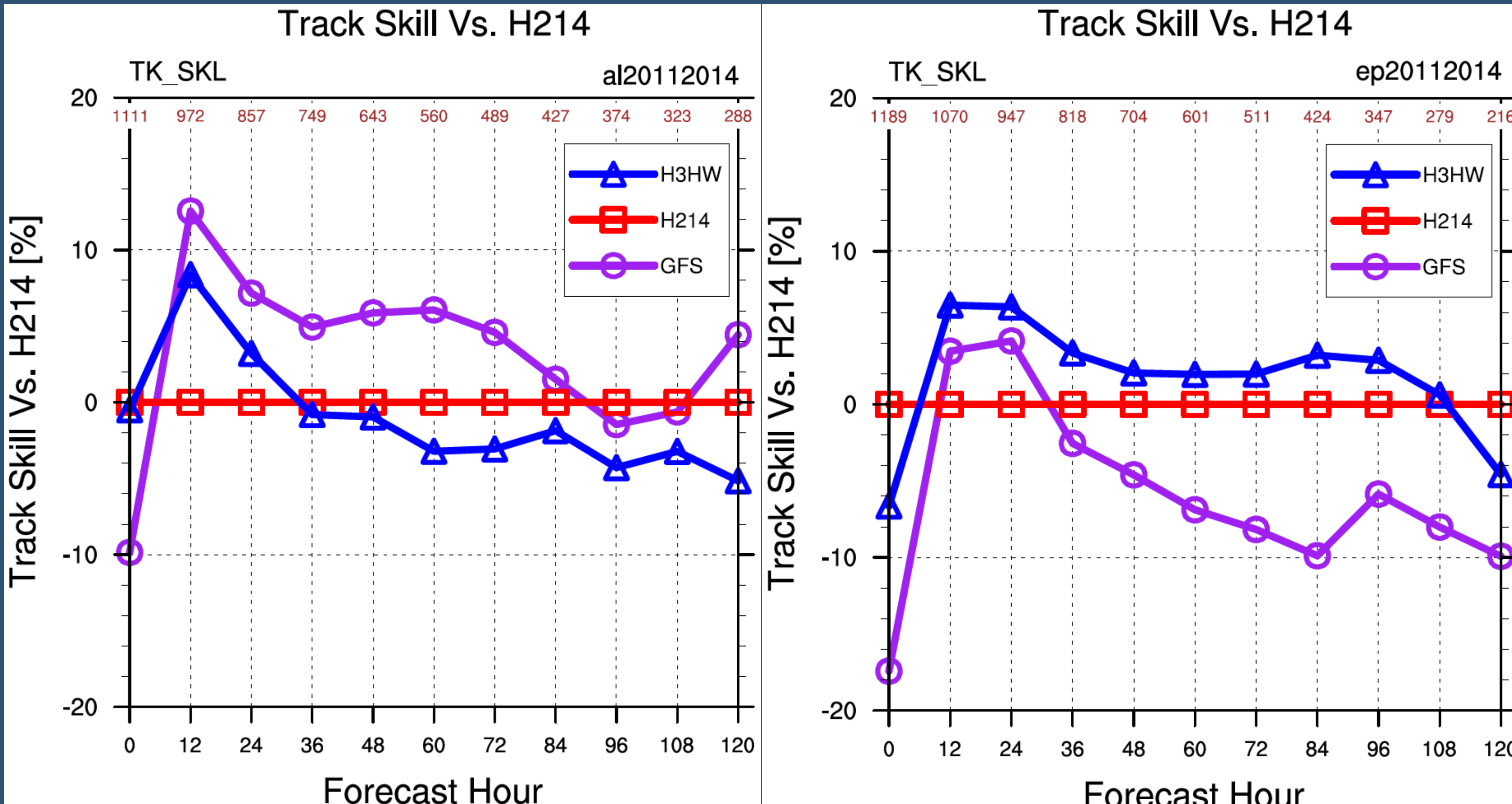
	2013 Opt. HWRF (H213)	2013 Basin-scale HWRF (H3HW)	2014 Opt. HWRF (H214)	2015 Opt. HWRF (H215)	2015 Basin-scale HWRF (H5HW)
Domain	27 KM: 77.6˚ X 77.6˚ 9 KM: 10.5˚ X 10.14˚ 3 KM: 7.18˚ X 6.46˚	27 KM: 213.6˚ X 113.6˚ 9 KM: 10.5˚ X 10.14˚ 3 KM: 7.18˚ X 6.46˚	27 KM: 77.6˚ X 77.6˚ 9 KM: 12.66˚ X 12.18˚ 3 KM: 7.9˚ X 7.06˚	18 KM: 77.6˚ X 77.6˚ 6 KM: 12.74˚ X 12.29˚ 2 KM: 7.94˚ X 7.07˚	27 KM: 213.6˚ X 113.6˚ 9 KM: 12.66˚ X 12.18˚ 3 KM: 7.9˚ X 7.06˚
Vertical Levels	42 levels	61 levels	61 levels	61 levels	61 levels
Model Top	50hPa	2hPa	2hPa	2hPa	2hPa
Vortex Initialization	at 3 KM	at 3 KM	at 3 KM	at 2 KM	at 3 KM
Data Assimilation	GSI	No GSI	Hybrid	Hybrid + Ensemble (TDR)	Hybrid
Cycling	Yes (9-3 km vortex)	Yes (9-3 km vortex)	Yes (9-3 km vortex)	Yes (9-3 km vortex)	Yes (9-3 km vortex)
Ocean Coupling	Yes	No	Yes	Yes	No
Multiple Storm	No	Yes	No	No	Yes
Physics schemes					
Microphysics	Modified Ferrier	**Modified Ferrier**	**Modified Ferrier**	**Modified Ferrier-Aligo**	**Modified Ferrier-Aligo**
Radiation	GFDL	**GFDL**	**GFDL**	**RRTMG**	**RRTMG**
Surface	GFDL	**GFDL**	**GFDL**	**GFDL(V215)**	**GFDL(V215)**
PBL Scheme	Modified GFS	**Modified GFS**	**Modified GFS**	**Modified GFS (V215)**	**Modified GFS (V215)**
Convection	SAS, No CP (3 KM)	**SAS, No CP (3 KM)**	**SAS, No CP (3 KM)**	**SAS, No CP (2 KM)**	**SAS, No CP (3 KM)**
Land Surface	GFDL Slab	**GFDL Slab**	**GFDL Slab**	**NOAH**	**NOAH**

Basin-scale HWRF vs. Operational HWRF (Parent domain)



Proving the value of the Basin-scale HWRF

Stratified verification (2011-14)

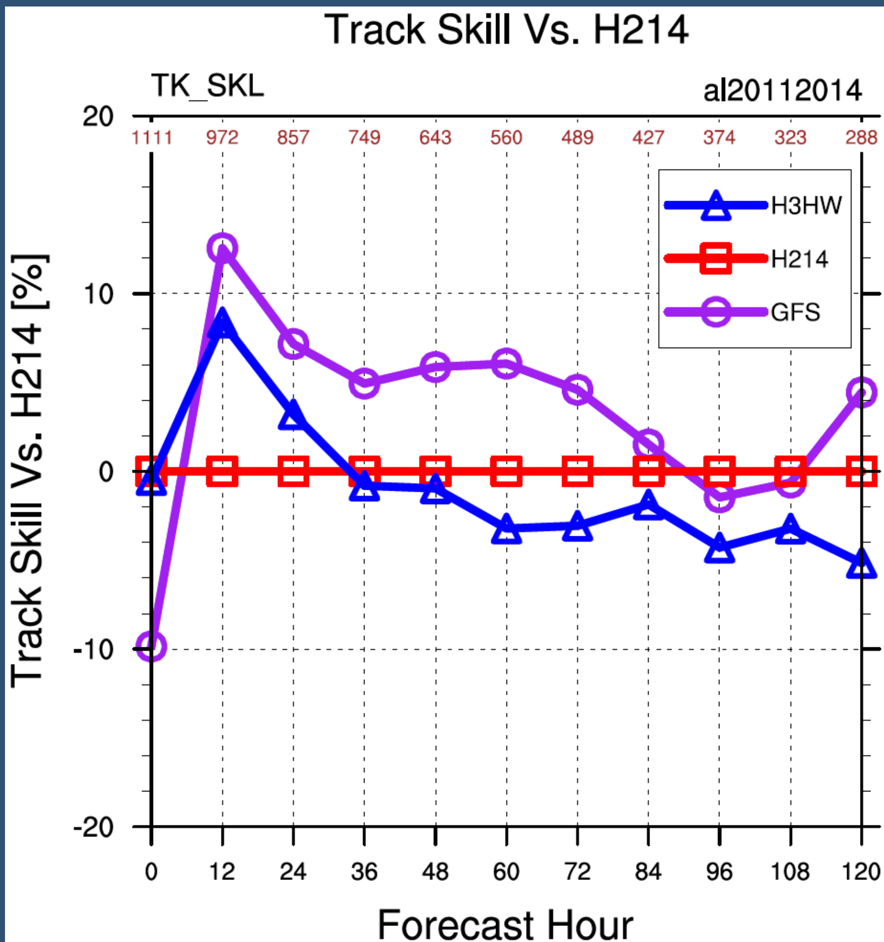


Full sample ATL

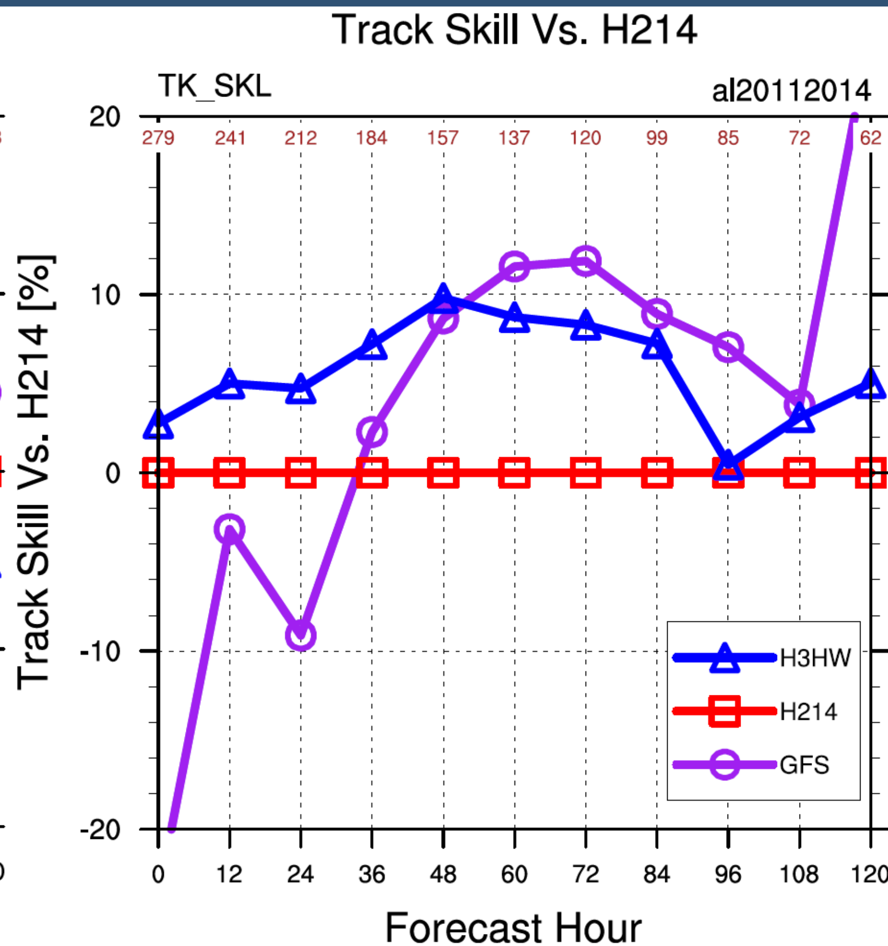
Full sample EP

Proving the value of the Basin-scale HWRF

Stratified verification (2011-14)



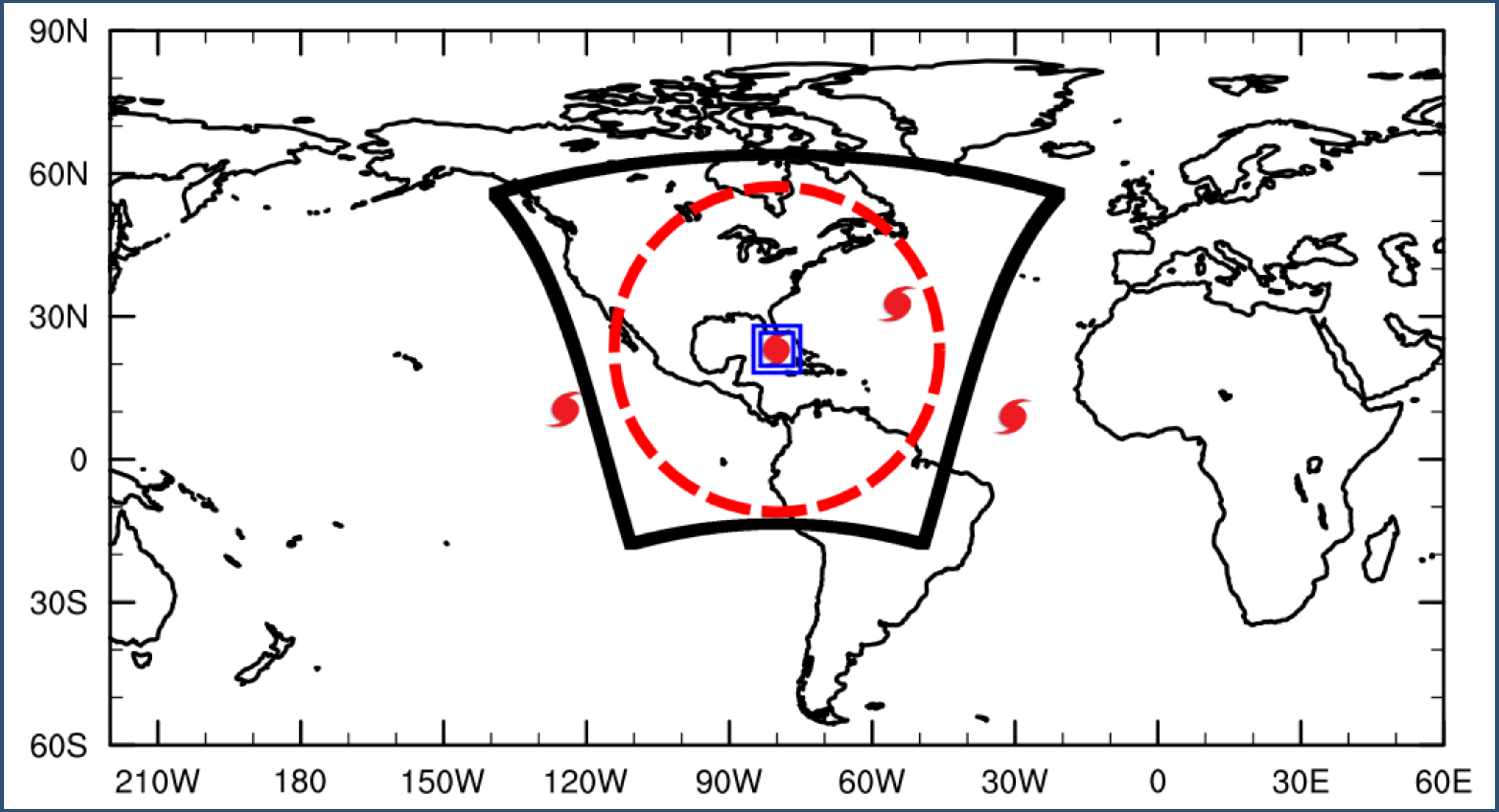
Full sample ATL



1 ATL storm with ≥1 EP storm

Proving the value of the Basin-scale HWRF

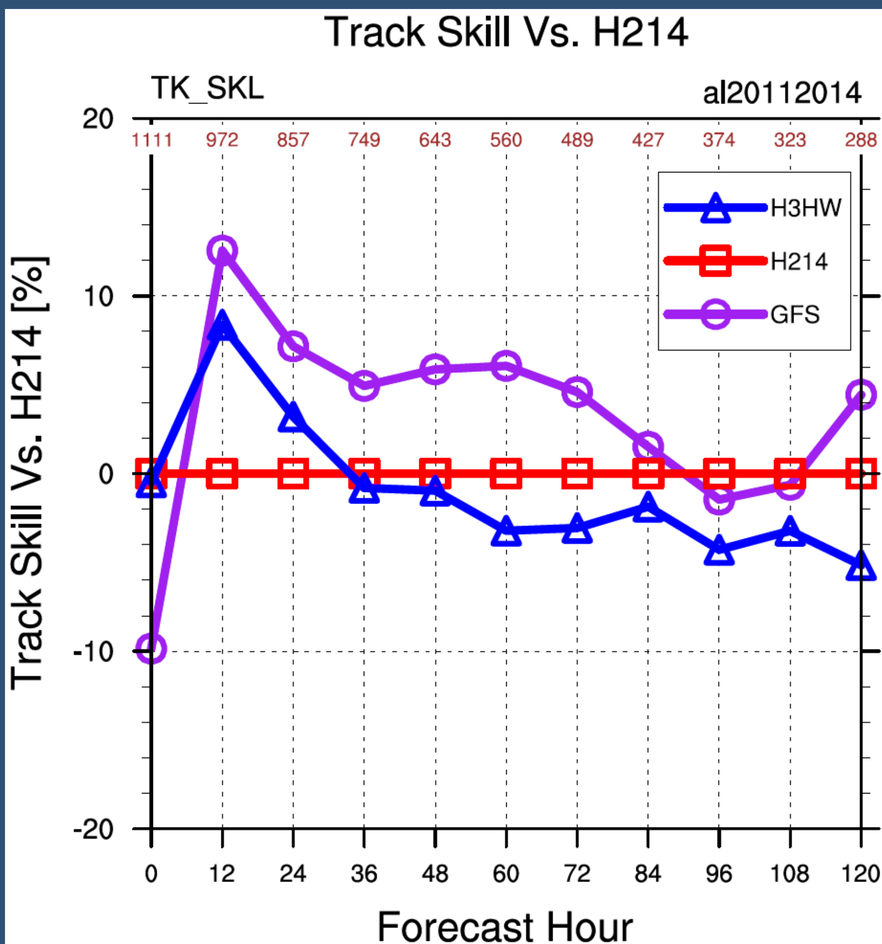
Stratified verification



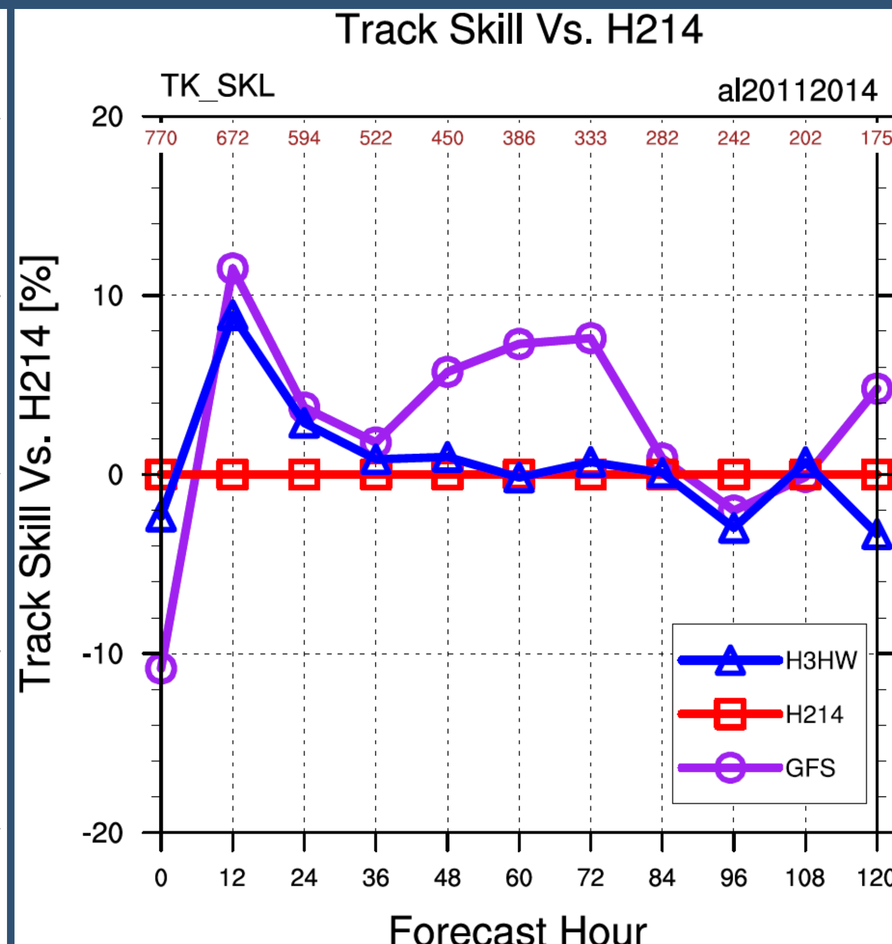
3500km verification radius

Proving the value of the Basin-scale HWRF

Stratified verification (2011-14)



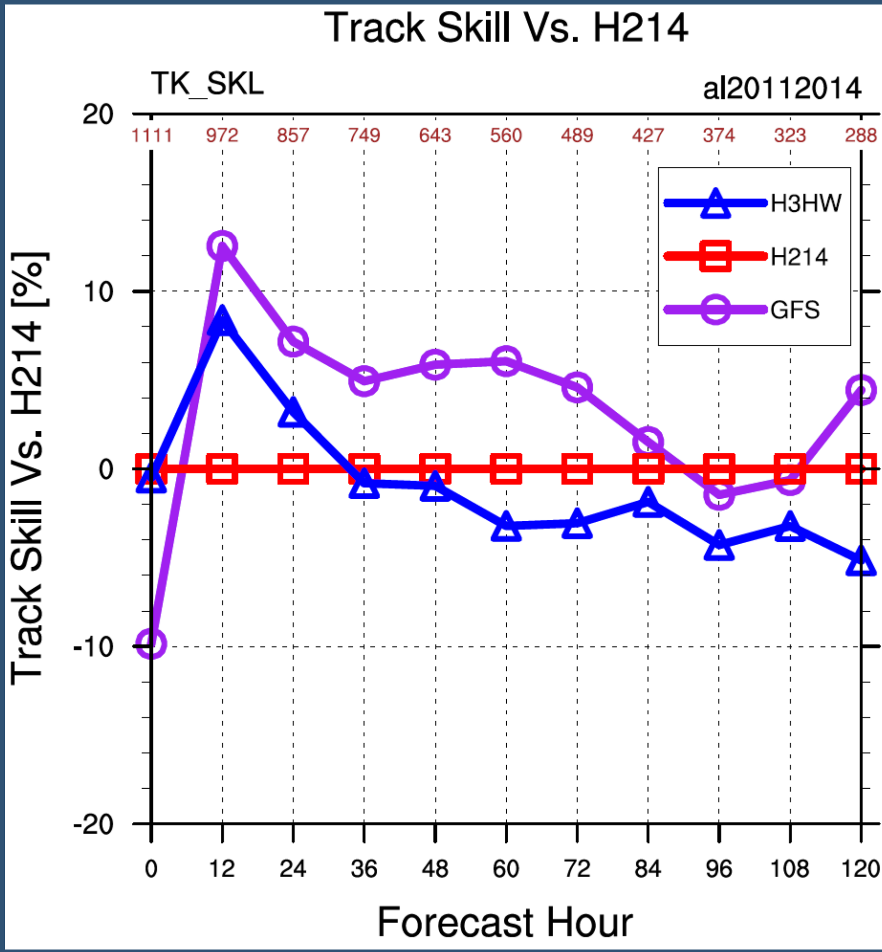
Full sample ATL



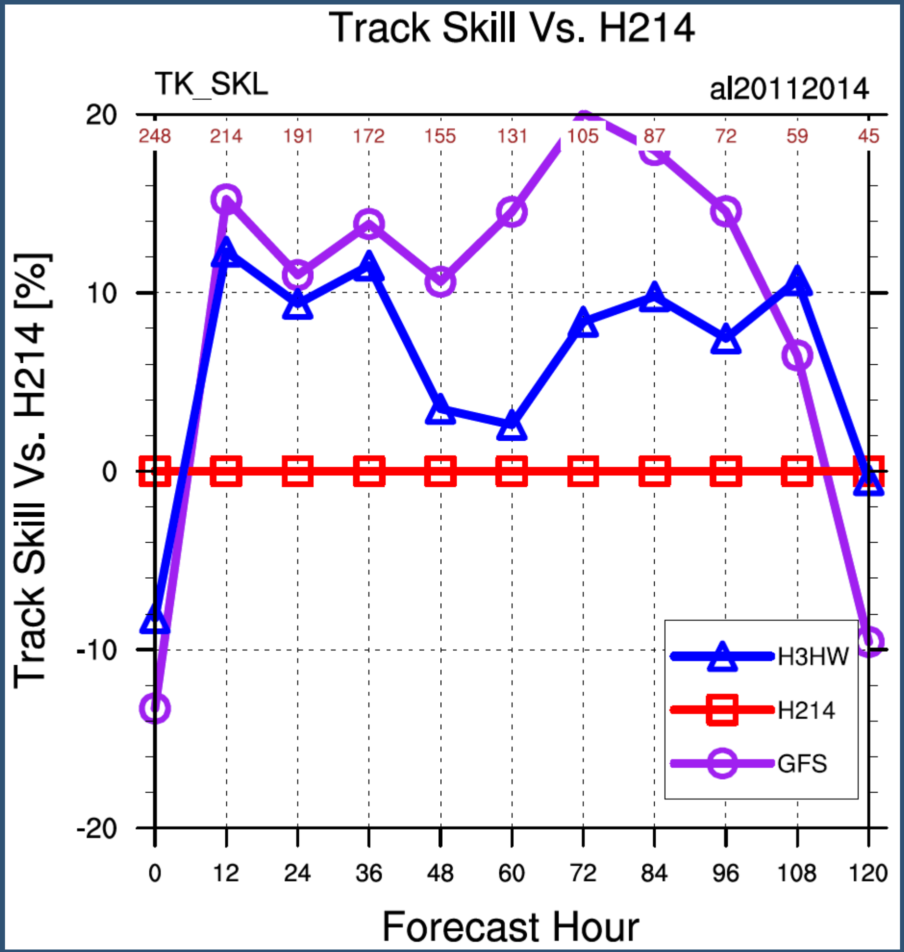
≥1 storm(s) outside 3500km radius

Proving the value of the Basin-scale HWRF

Stratified verification (2111-14)

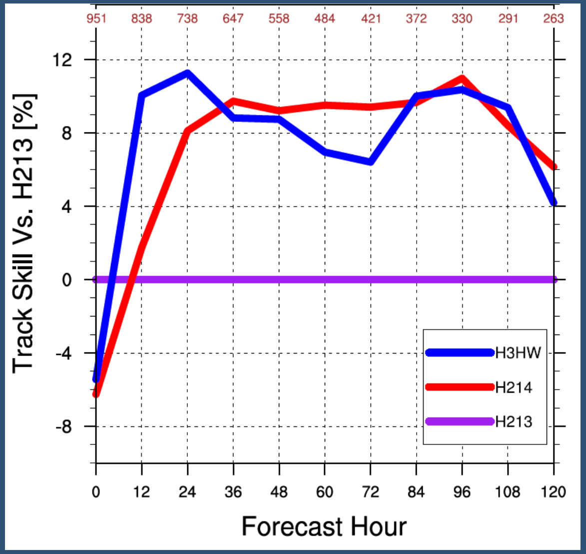


Full sample ATL



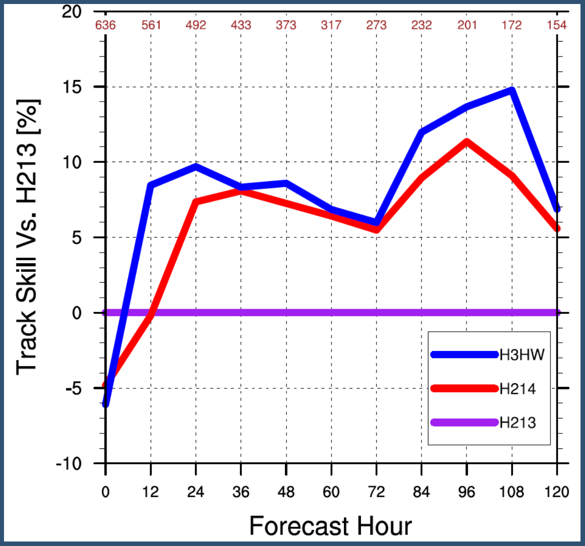
≥2 storm(s) outside 3500km radius

Multi-storm Interactions
Impacts of Far-Field TCs?

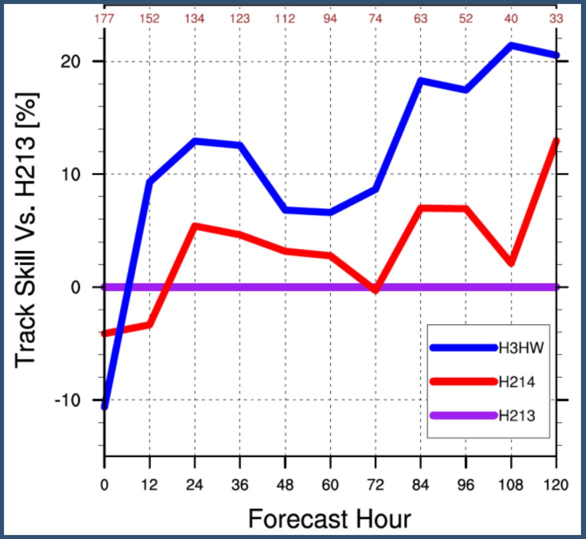


BASELINE

1+ Far-Field TC



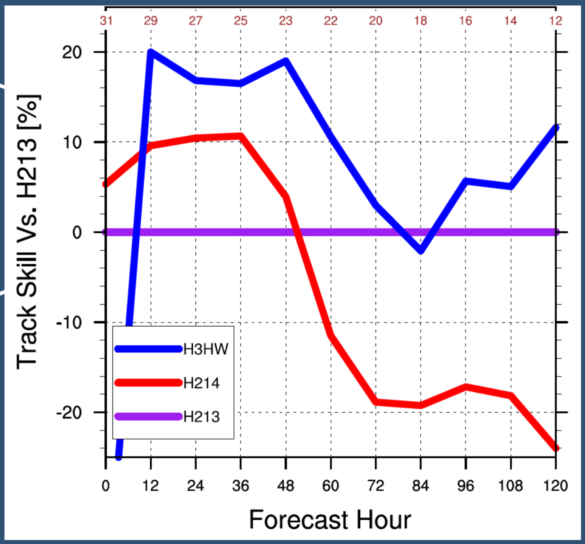
2+ Far-Field TC



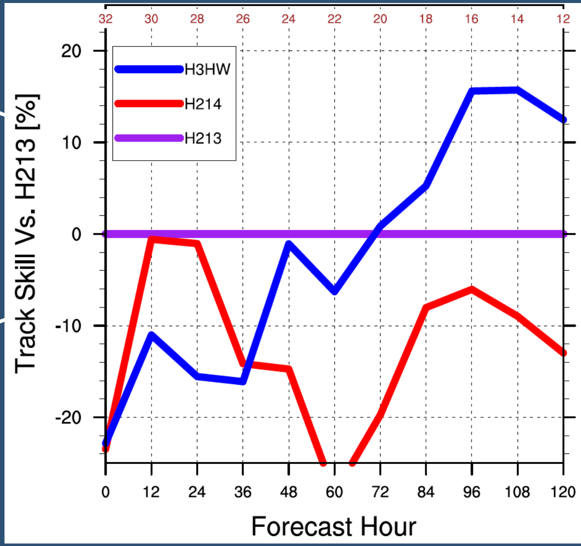
"Far-Field TC" is
> 3500 km away from
Local TC

Long-lived TCs in the Basin-scale HWRF

Michael (AL132012)

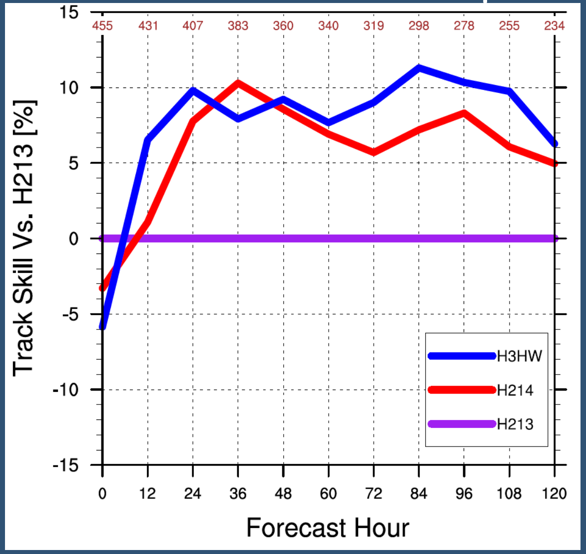


Irene (AL092011)

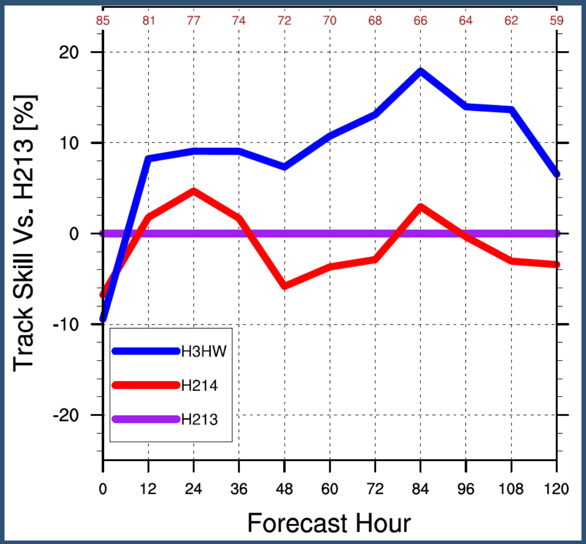


10 Longest lived TCs from 2011-2013

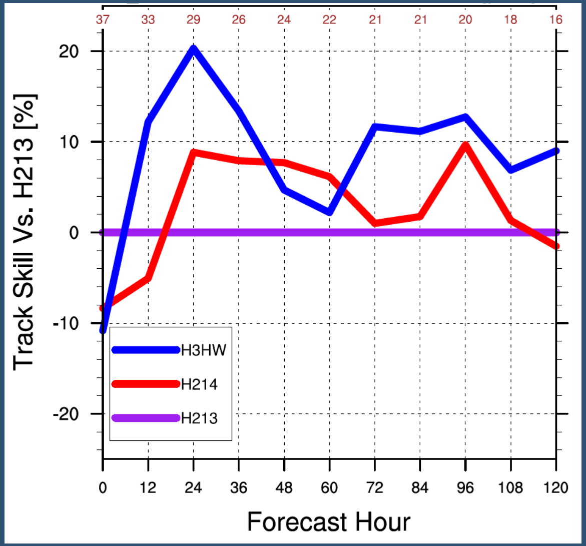
~48% of the total sample



Side panels show 4 individual TCs from the above sample.



Nadine (AL142012)



Maria (AL142011)

Storm-storm Interaction

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

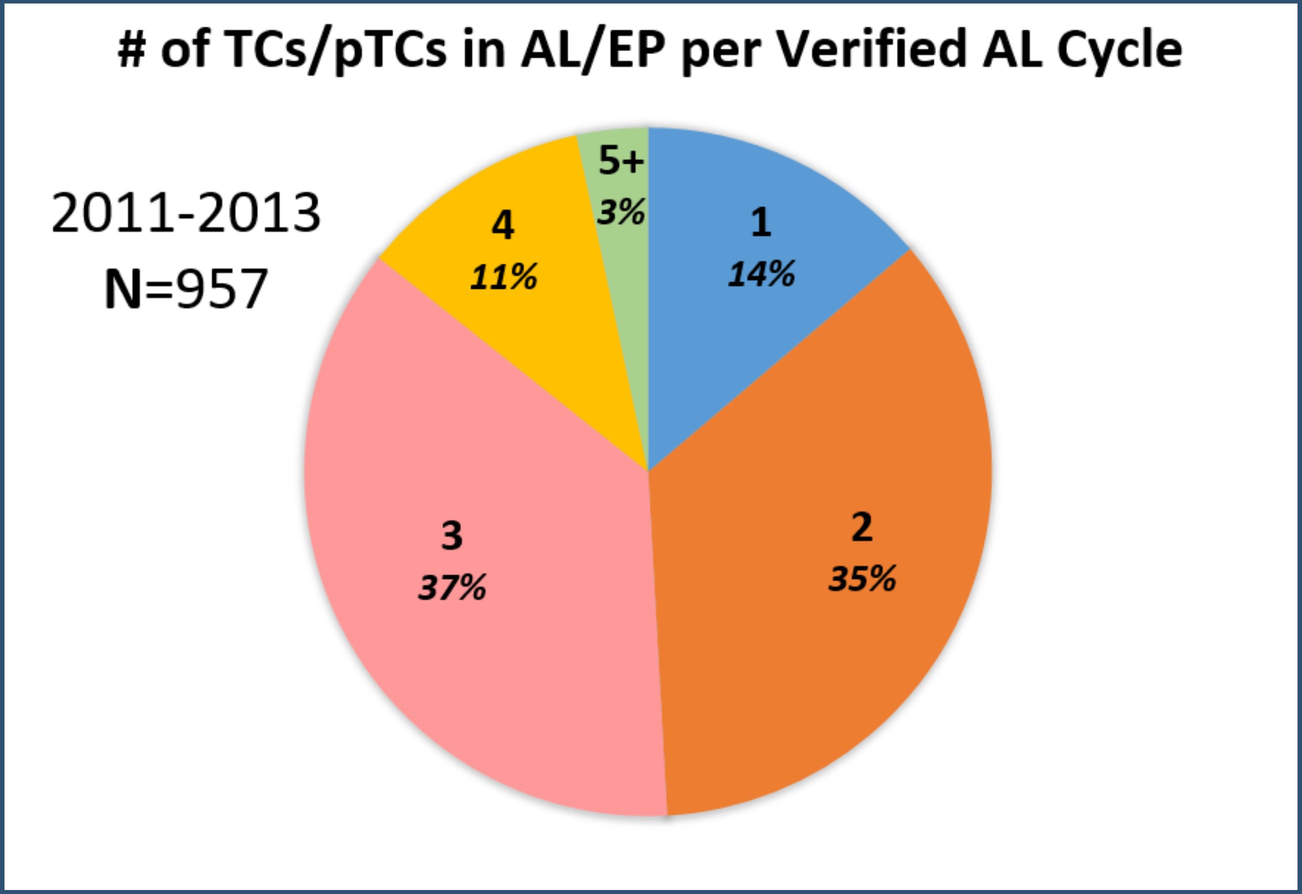
Global Storm Occurrence in All Basins

Number of Storms	Global	% of occurrence	NHC alone	JTWC alone
1+	15287	70	8300	12022
2+	9148	42	4632	4461
3+	4956	23	2260	987
4+	2521	12	864	155
5+	1081	5	243	14
6+	387	2	69	0
7+	99	0.5	4	0
8+	22	0.1	0	0
9+	0	0	0	0

Data: real-time TCVital during 2000-2014

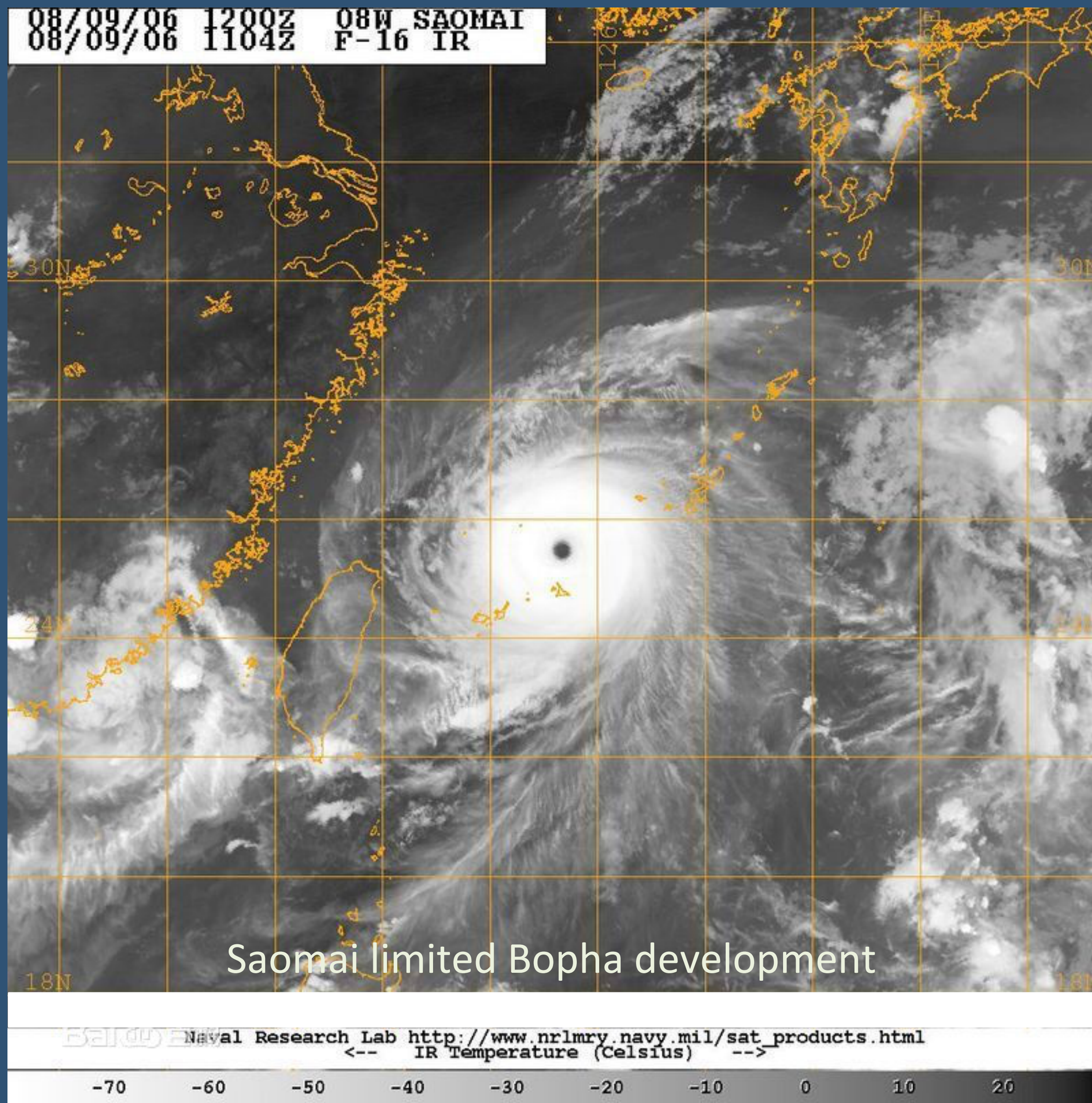
Tallapragada et al, 2014

Frequency of Multi-storm



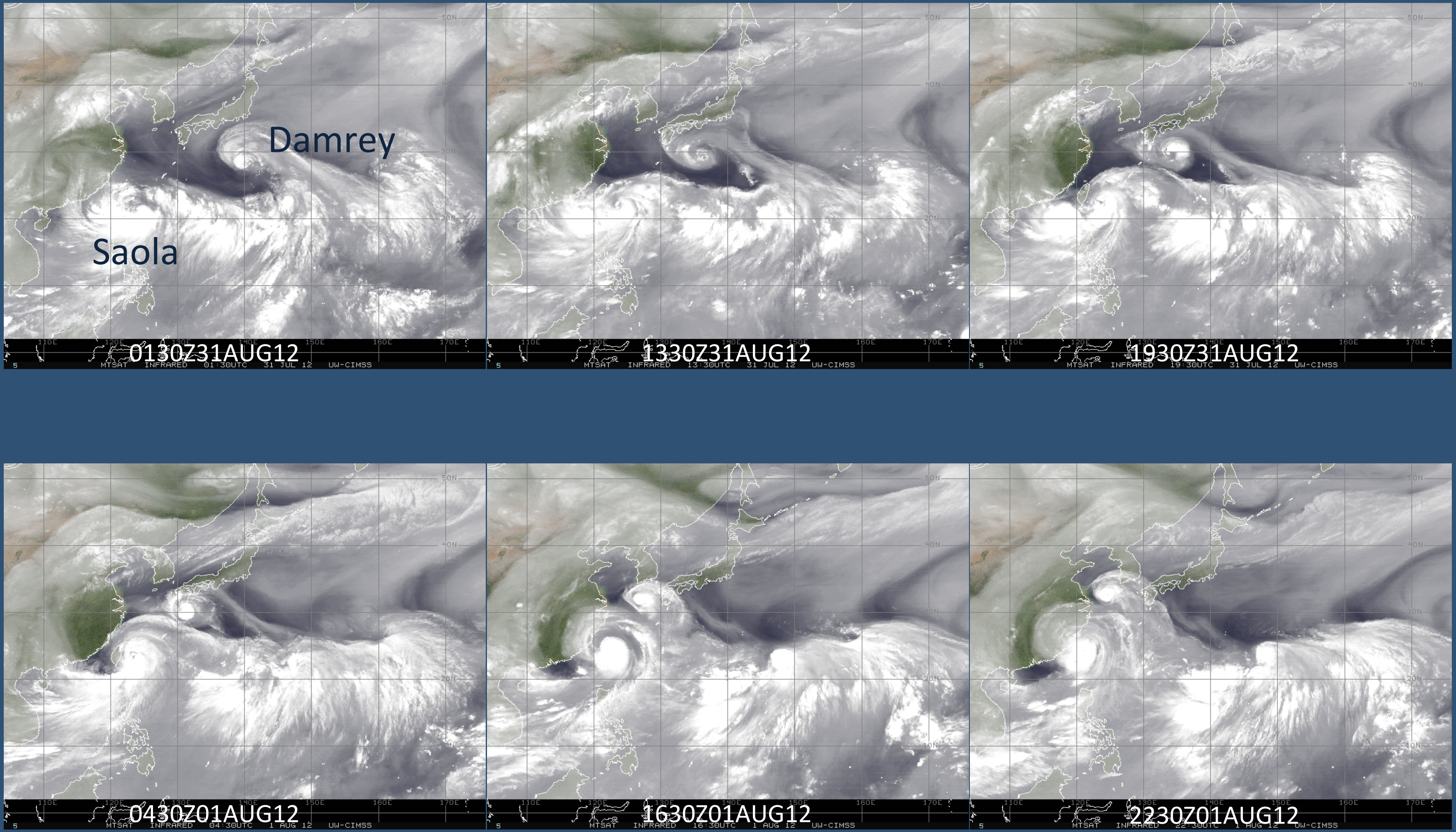
In 86% of verified Atlantic forecast cycles, at least 2 disturbances are present.

Forecast Implication



Saomai limited Bopha development

Example of Binary TC interaction

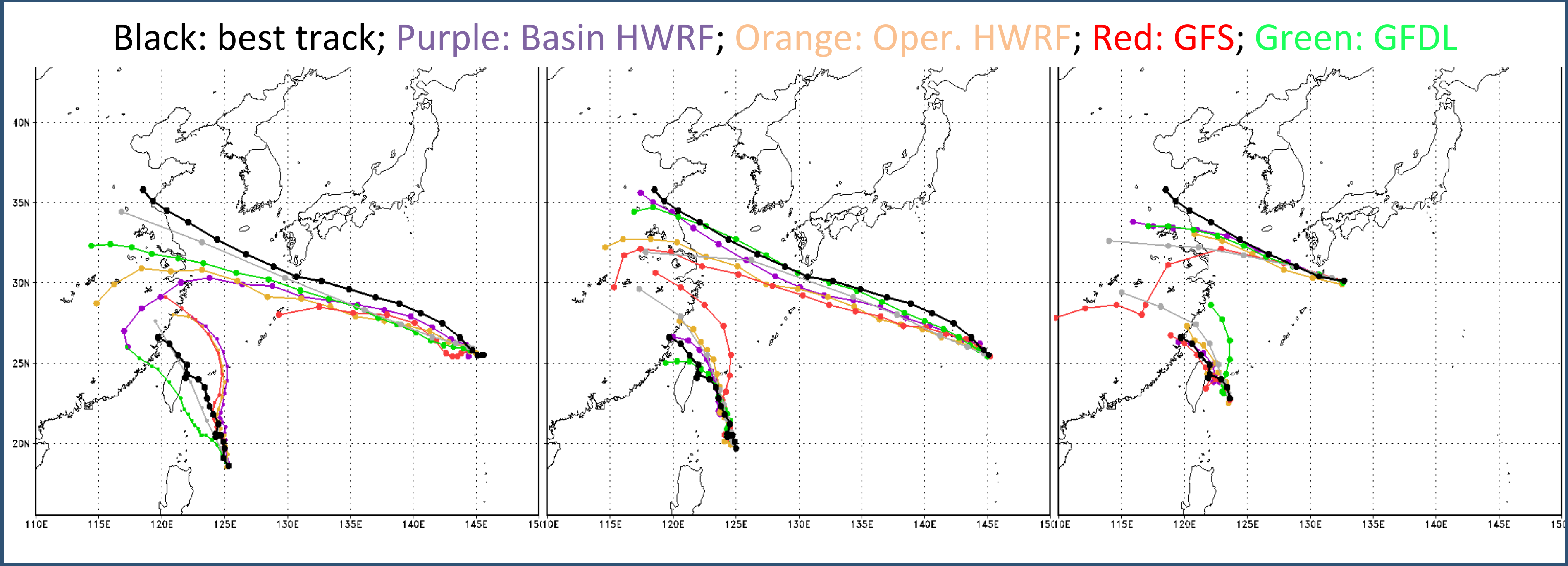


Damrey: 28 JUL-02 AUG

Saola: 28 JUL-03 AUG

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



Initial time 2012072912	Initial time 2012073000	Initial time 2012080100

Roadmap to Transitions

- Develop ocean coupling capability for basin-scale HWRF
- Develop parent domain data assimilation capability
- Scalability test
- Framework improvement for higher resolution
- Forecast products for basin-scale forecast applications and diagnostics

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 expand to any number of high-resolution movable nests centered on storms that may exist in the regional domain but current scripts allow for only 5 storms as it is currently limited in the HWRF code
- 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 be applied to various unique research on TCs, such as storm-storm interaction, model bias diagnostics, physical scheme evaluation and improvement, and localized multiple-vortex initialization and advanced data assimilation