Basin-wide HWRF Modeling System with Multiple Movable Nests

--A pathway toward operational implementation

Xuejin Zhang (UM/CIMAS)
Thiago Quirino (AOML/HRD)

Collaborators:
AOML/HRD modeling group
NCEP/EMC HWRF Team
Da-lin Zhang UMD/AOSC

Acknowledgement:
This research funded by NOAA/HFIP (NOAA Award: NA12NWS4680007)

Prepared for HFIP AO annual review, 5 June 2013

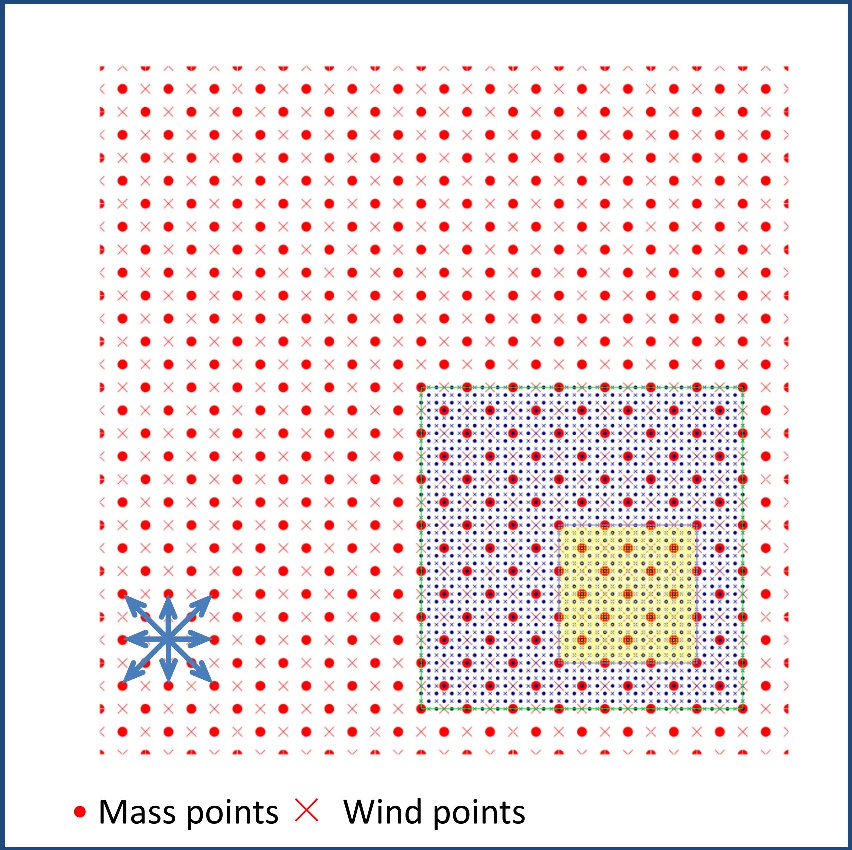
Objectives

- Improve both TC track and intensity predictions within the scope of the HWRF operational system for seamless transition to operation
- Enhance structure and rainfall predictions critical to landfall and post-landfall application
- Improve storm-storm/multi-scale interactions
- Provide an alternative pathway for storm-oriented satellite and vortex data assimilation within HWRF system
- Explore application for extended TC track and intensity forecasts (up to 7 days) and genesis

Approaches

- Develop multiple movable nested system to follow multiple storms within HWRF model
- Initialize each storm independently with common environmental circulation (localized vortex initialization)
- Explore storm-oriented parallel integration

Current Operational HWRF



Single Moving Nest

• Mediate domain follows the inner most domain
• Nest following centroid MSLP/dynamic pressure minima

Modeling system

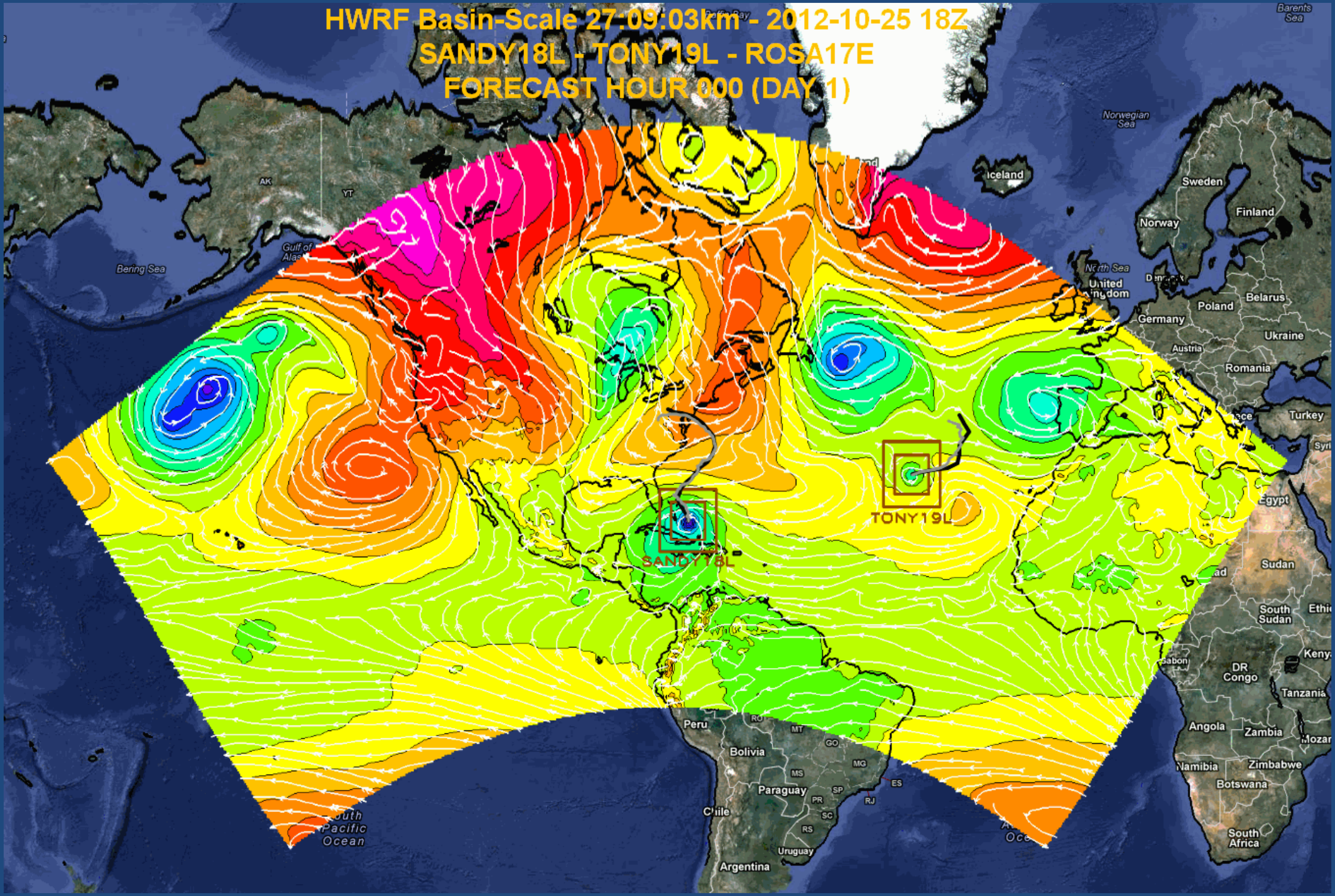
• Real and idealized case framework
• Flexible physics configuration
• Nest Initialization
• DA

Operational implementation

• Dynamic setup for forecast domain based storm position
• Single storm forecast
• Partial cycling (vortex cycling only)
• One-way hybrid DA

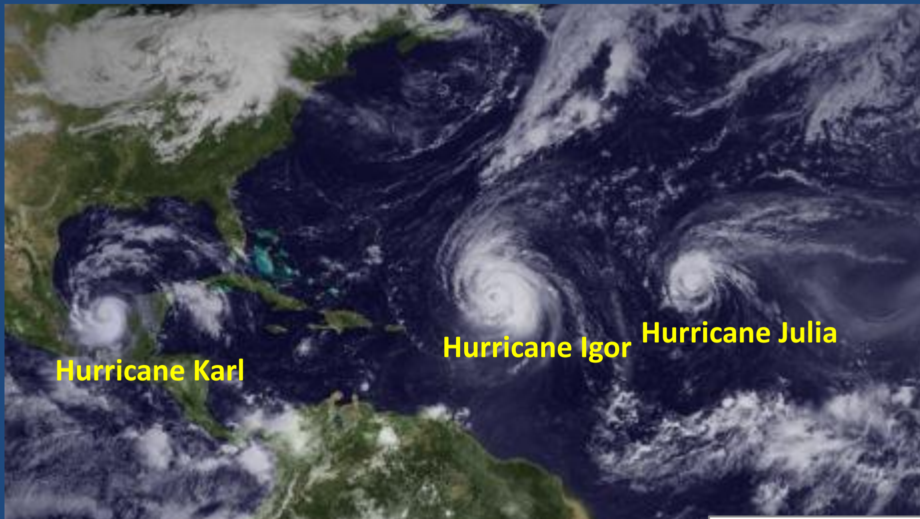
Research and operational communities now successfully share common repository and directly work together under HFIP

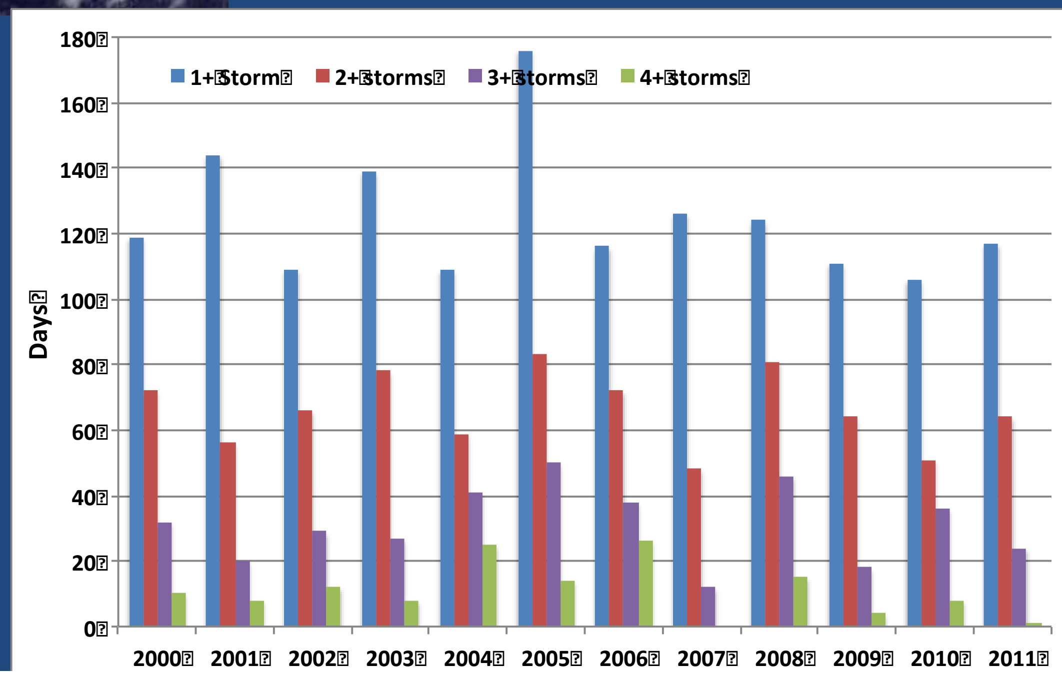
New Functionality



Multiple movable, two-way interactive nests following multiple storms in the upgraded HWRF system

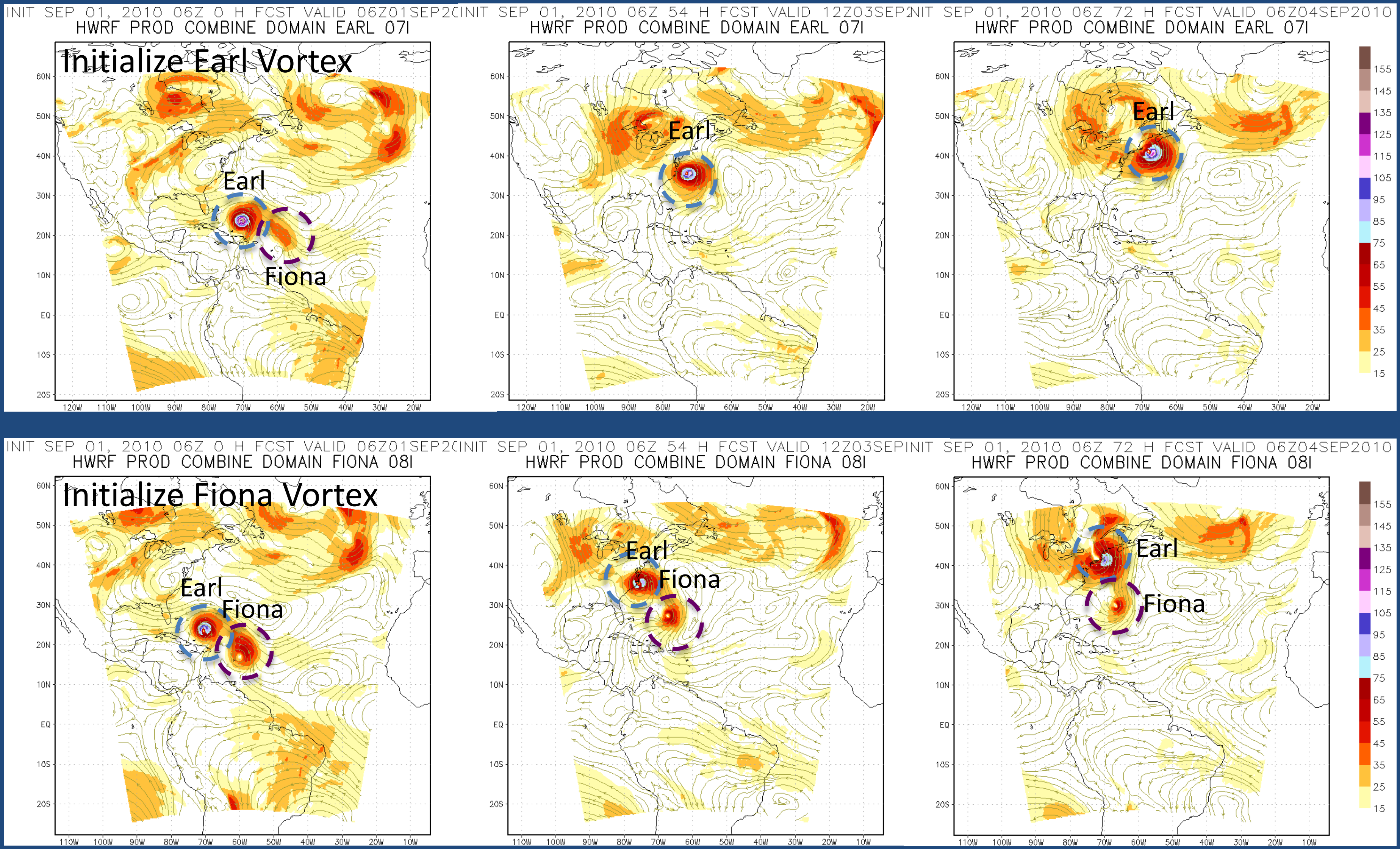
Problem: busy day in tropics





	1+ storm days	2+ storm days	3+ storm days	4+ storm days	Total storm days
ATL	87.4(57.6%)	31.3(35.8%)	9.6(11.1%)	1.4(1.6%)	151.8
EP	77.8(48.0%)	25.5(32.8%)	5.4(6.2%)	0.3(0.4%)	161.9
ATL+EP	124.7(65.1%)	66.2(53.1%)	31.1(35.6%)	10.9(8.8%)	191.6

Forecast Problem



850hPa Streamlines and Isotachs (kts)

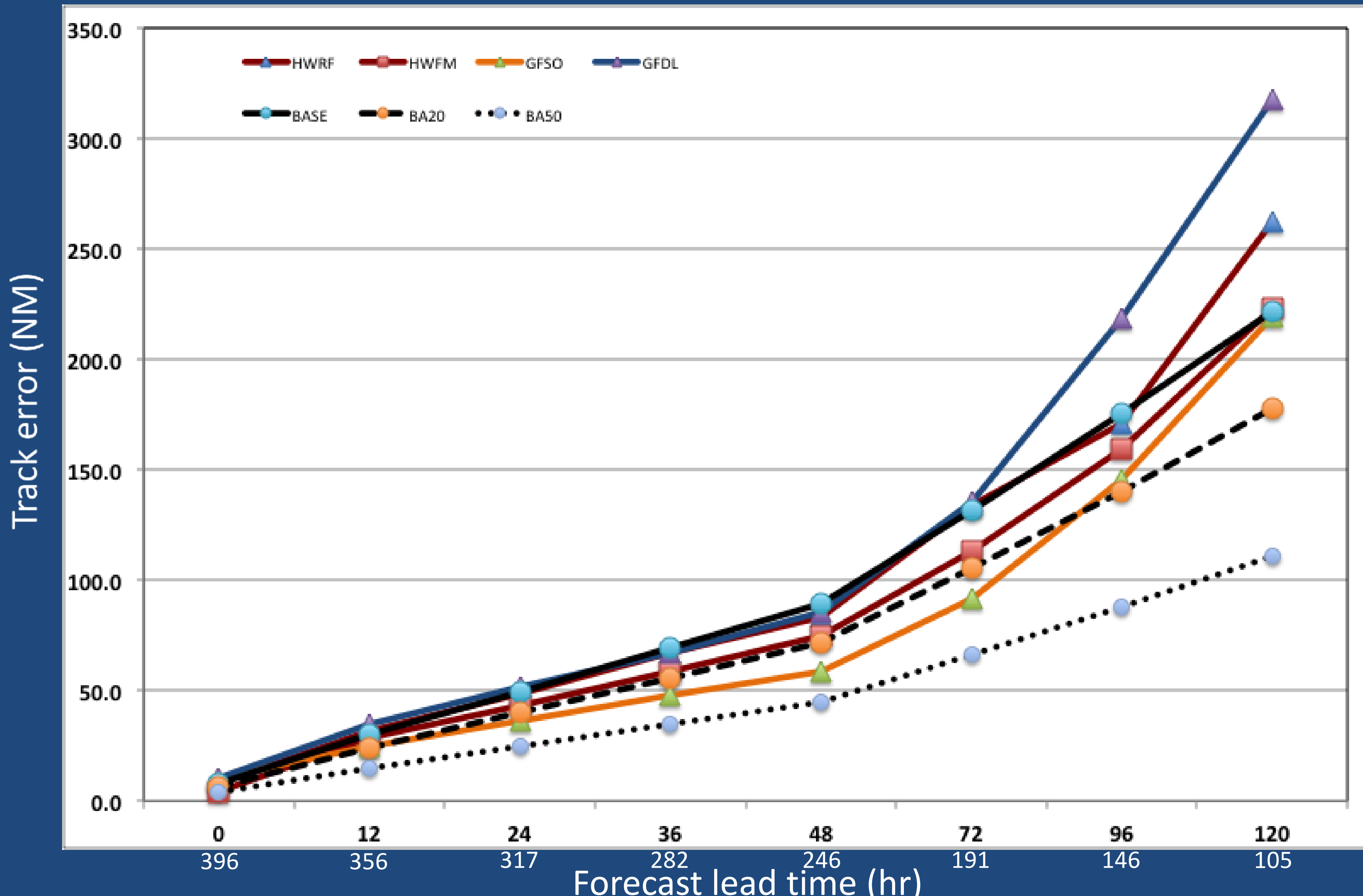
Credit to EMC HWRF webpage http://www.emc.ncep.noaa.gov/gc_wmb/vxt

Retrospective & Real-time Forecasts

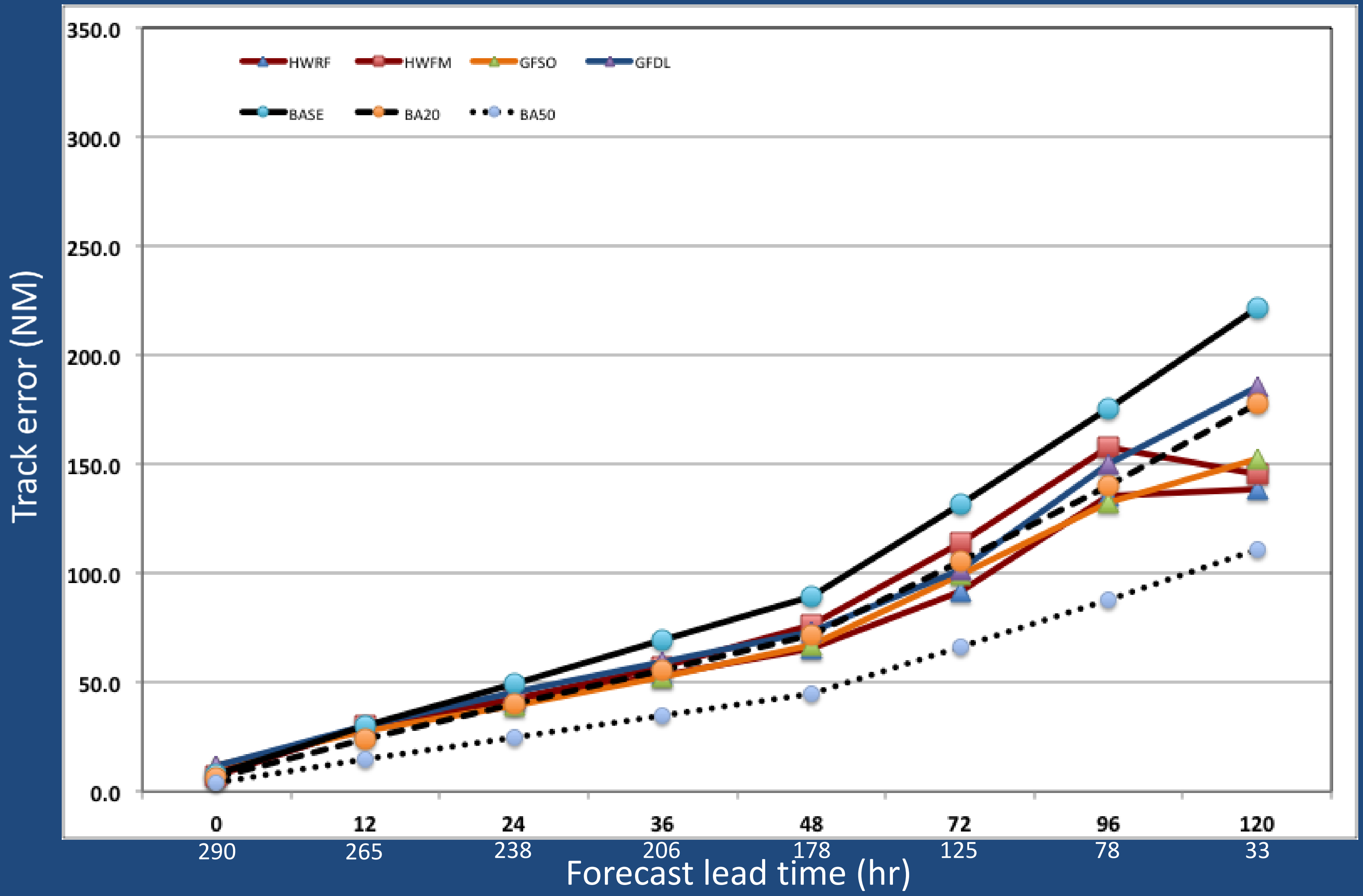
- Cycles start from 00Z 05/19/2012 to 00Z 11/04/2012
- Real-time test: Isaac (37 cycles); Sandy (33 cycles)
- Web products:
  - 3 categories (27km environment; 3km moving nest; multi-model)
  - 20 products

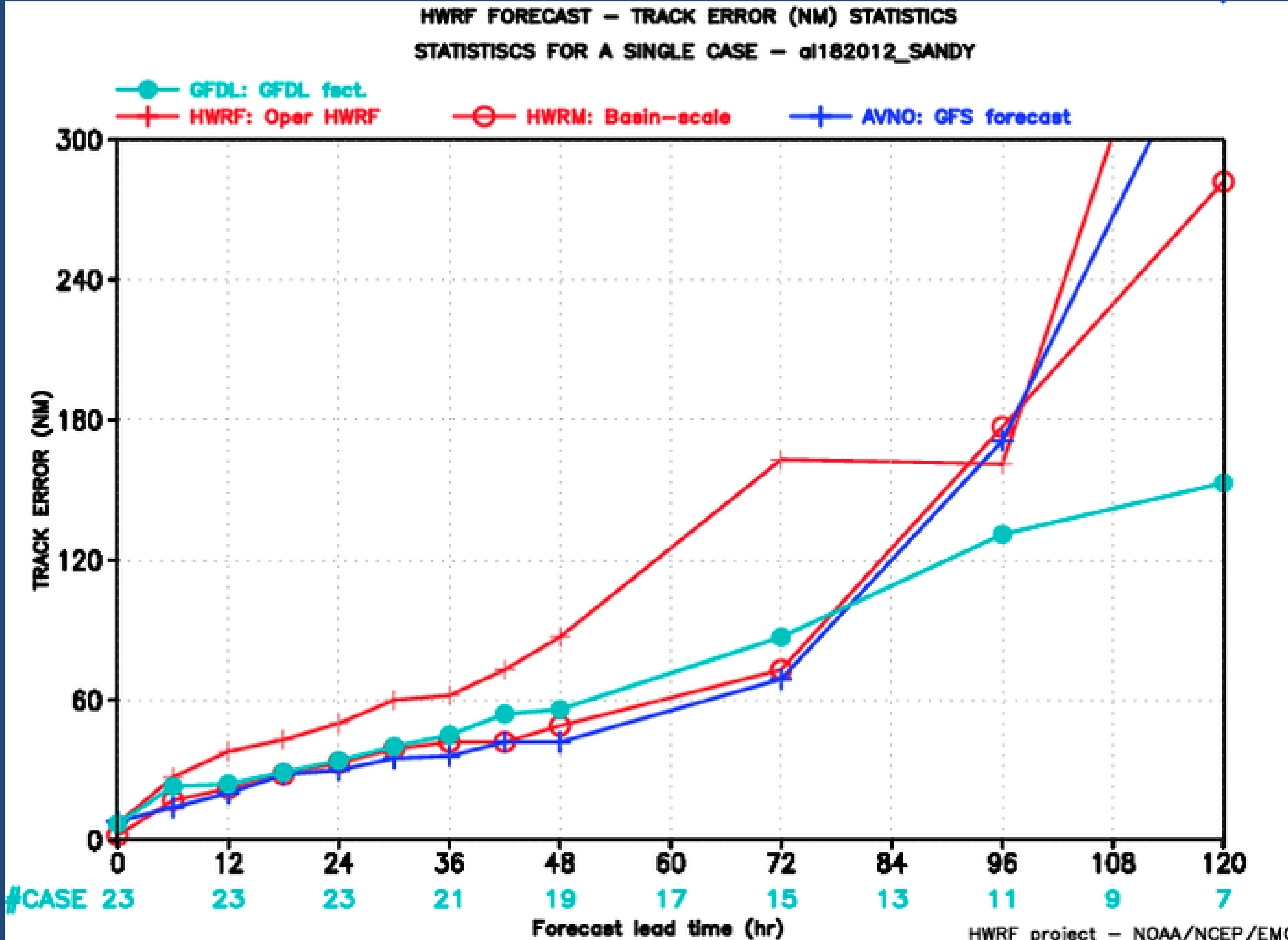
https://storm.aoml.noaa.gov/basin

Track error (Atlantic 01-19)



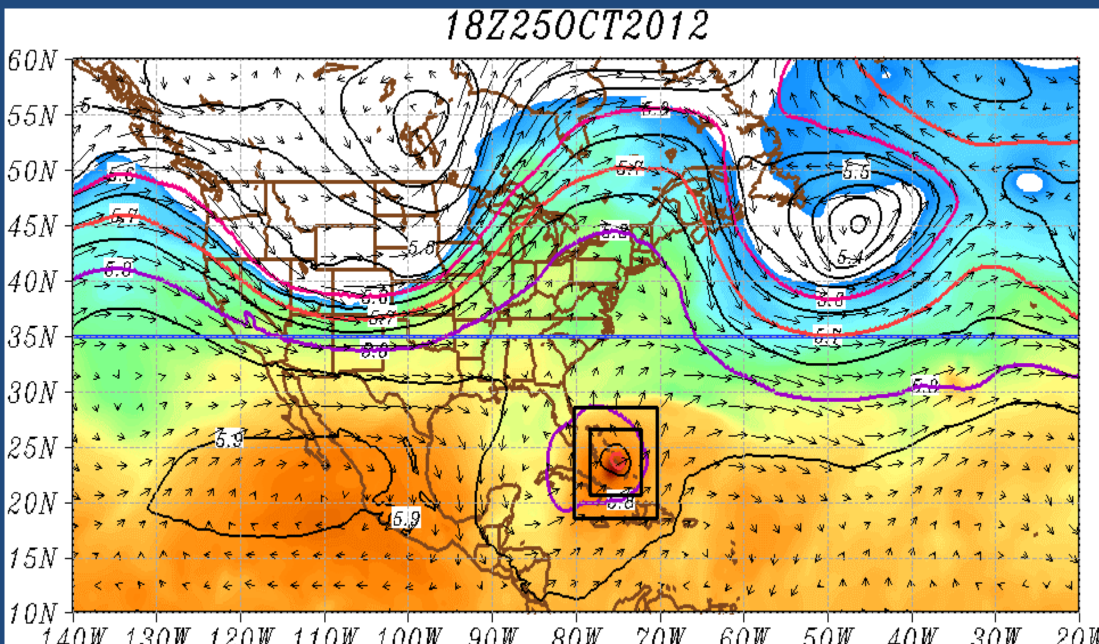
Track error (East Pacific 01-17)



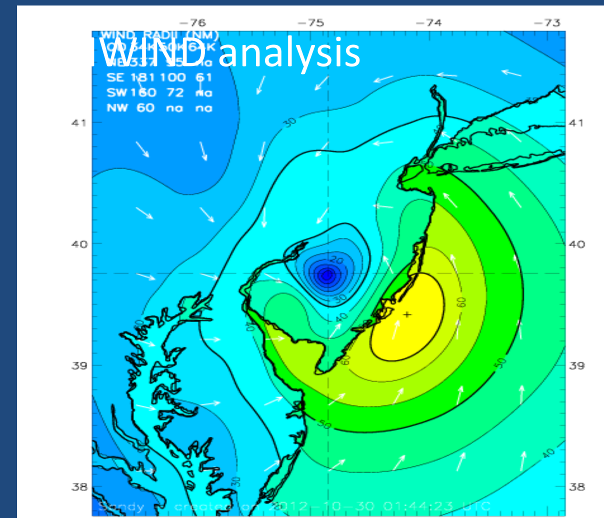

HWRF FORECAST – TRACK ERROR (NM) STATISTICS
STATISTISCS FOR A SINGLE CASE – al182012_SANDY
GFDL: GFDL fcst.
HWRF: Oper HWRF
HWRM: Basin-scale
AVNO: GFS forecast
TRACK ERROR (NM)
300
240
180
120
60
0
0 12 24 36 48 60 72 84 96 108 120
#CASE 23 23 23 21 19 17 15 13 11 9 7
Forecast lead time (hr)
HWRF project – NOAA/NCEP/EMC

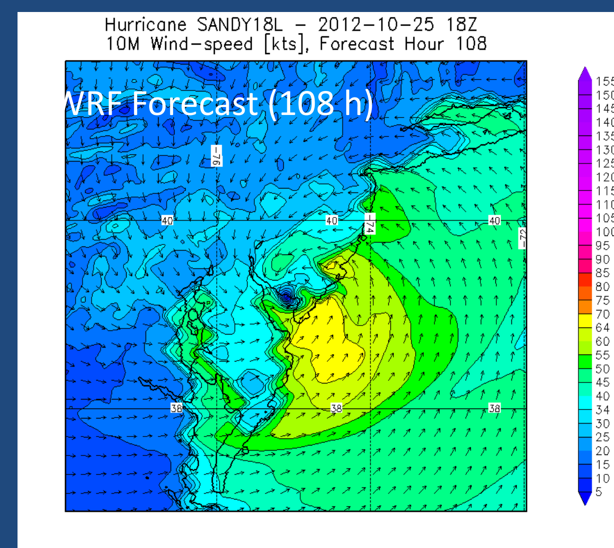
Basin Scale HWRF: Hurricane Sandy Prediction

Improved Scale Interactions
and Improved Track and
Size Forecasts (25/18Z prediction)



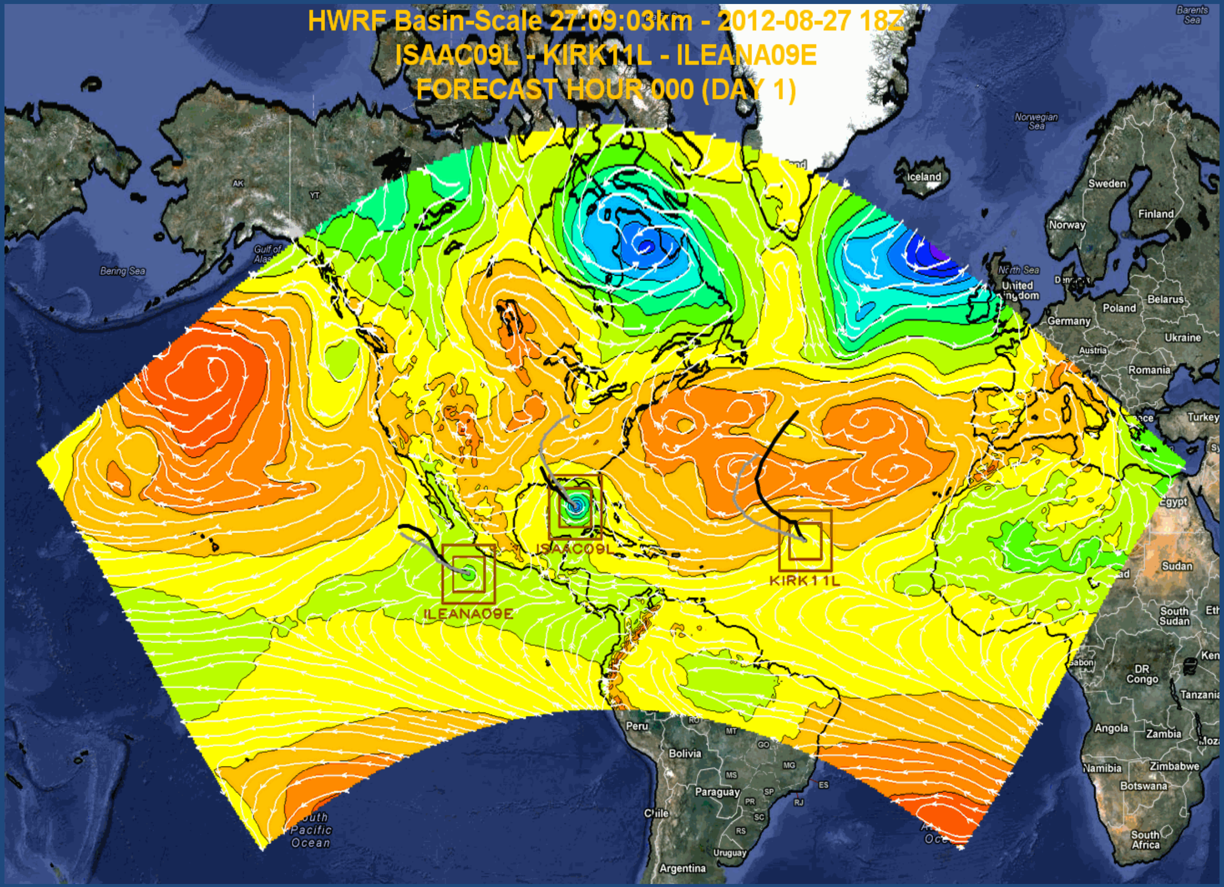
Shading: T at 500 hPa; Contour: GHT at 500 hPa
Vector: Flow averaged between 500 hPa and 200 hPa
(credits to Dr.Hua Chen, AOML/HRD/NRC)



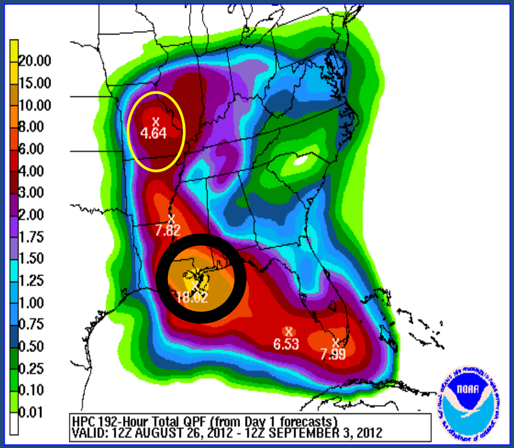


Basin Scale HWRF: Isaac-Ileana-Kirk real-time 3-km predictions

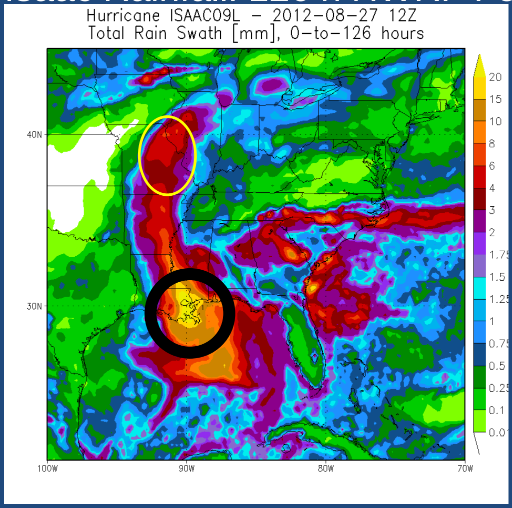
Improved tracks and
structure, improved rainfall predictions



Isaac Rainfall:192 h QPF forecast

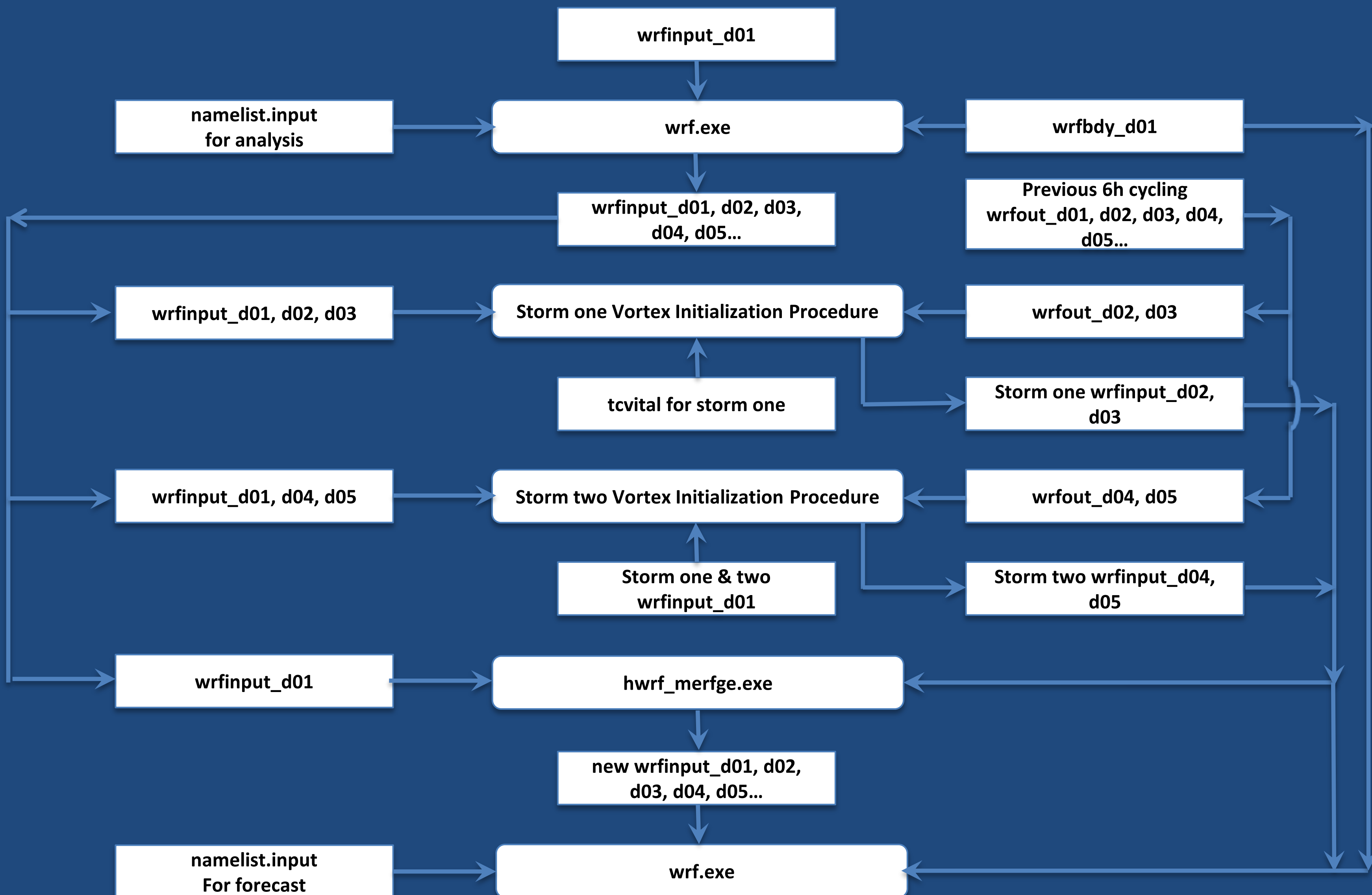


Isaac Rainfall: 126 h HWRF Foreca



Progress Report 2

Flowchart for HWRF Vortex Initialization Implementation



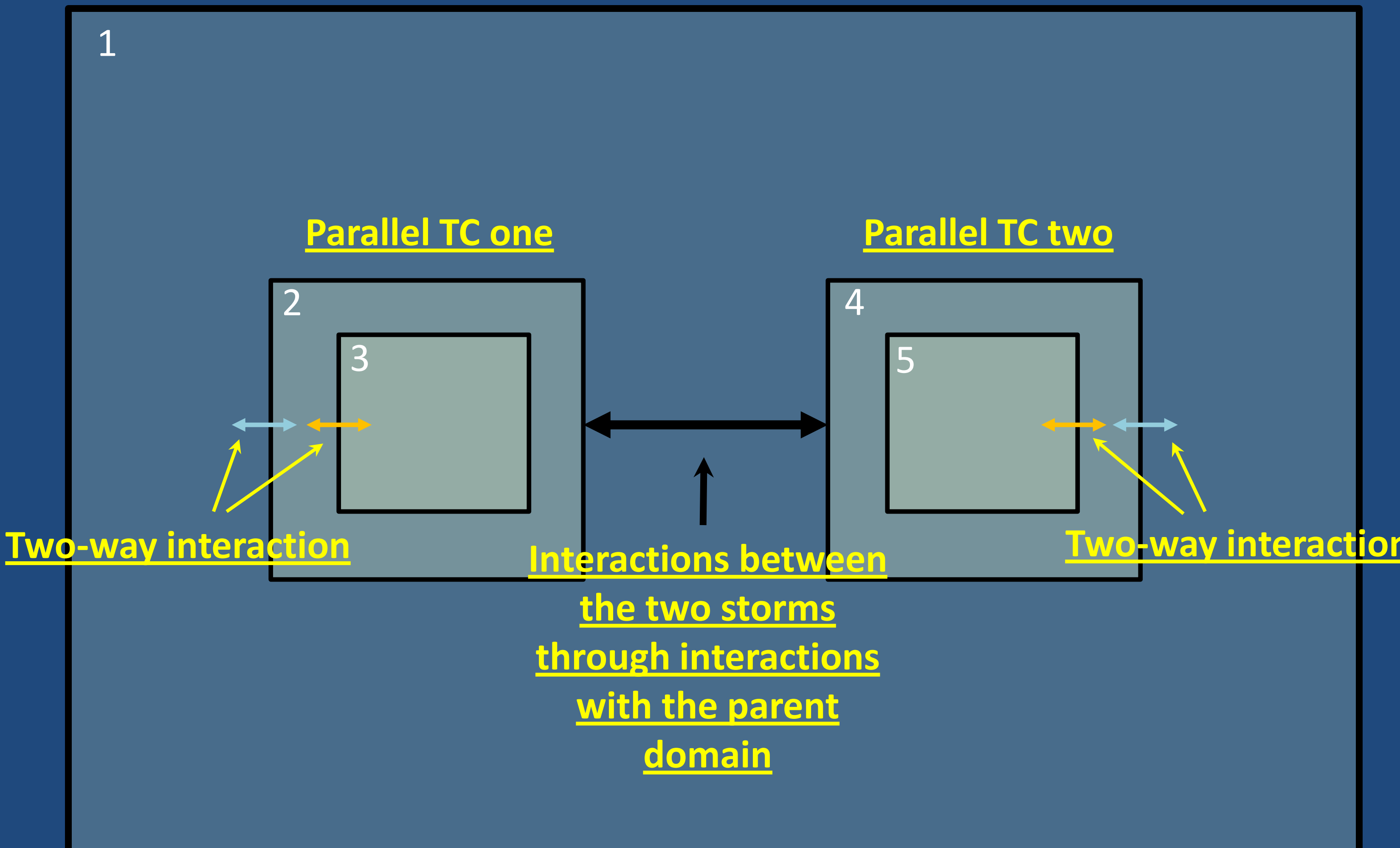
Trigger mechanism

- Decide forecast configuration from tcvital
  - Number of storms
  - Priority storm if number of storms more than four
  - Forecast length (Need genesis forecast product)
- Set up domain location
- Prepare vortex initialization domains
- Allocate resources (disk space, CPUs, running time, and post-processing resource)

Parallel Basin-scale HWRF

- Issues
  - Sequential integration of multiple high-resolution nests (Slow)
  - Limited scalability
- Solutions
  - Parallel high-resolution nests of each storm
- Technical roadmap
  - Use P-threads to integrate multiple nest-pairs in parallel
    - Free OpenMP to be used to further speed up model code
  - Make integration related routines and MPI calls thread-safe
  - Make RSL thread safe to support parallel halo updates by multiple domains
  - Synchronize/sequentialize access by multiple domains to non-thread safe code:
    - Avoid bottlenecks imposed by existing multi-threaded MPI implementations
    - Provides a mechanism for progressive code parallelization without the need to modify every routine in the model to achieve any speed gains
      - Example: Synchronized access to I/O, forcing, and feedback routines

The basin-scale HWRF system



Basin-scale HWRF Configuration Test

	Number of Nest Domains	Wall Clock Time (original)	Wall Clock Time (New)	CPUs
27 km	No	~50 mins		196
27-9-3 km	2 (1 storm)	~137 mins	~137 mins	196
27-9-3 km	4 (2 storms)	~256 mins	~213 mins	196
27-9-3 km	4 (2 storms)	Not scalable	~150 mins	376
27-9-3 km	6 (3 storms)	~363 mins		196
27-9-3 km	8 (4 storms)	~430 mins		196

Current code is scalable and shows huge potential for transition to operation. More resource is required for further speed-up and testing.

Basin-scale Model Configurations

	2013 HWRF Operational	Basin-scale Model (Stream 2)
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°
Vortex Initialization	Modified Vortex Initialization at 3 KM and Hybrid DA	Modified Vortex Initialization at 3 KM and GSI DA
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
GWD	Yes(27km); No(9-3km)	Yes(27km); No(9-3km)

Summary of work accomplished

- Completed movable nests for multiple storms
- Implemented 2013 HWRF upgrade to basin-scale modeling system
- Implemented localized vortex initialization for multiple storms and cycling
- Accelerated code efficiency

Ongoing work

- Integrated system testing through retrospective cases (2012 season)
- Implement new parallel algorithm to 2013 HWRF model
- Efficiency and scalability testing
- Run system in real-time for 2013 season (Stream 2 advancement)
- Production and dissemination

Challenges

- Further optimize the code to meet the operational time requirements
- Urgent need of computing resource during the season to demonstrate on-going advancements

Conclusion

- Development of the integrated modeling system is completed and the system is showing great promise for transitions
- Intensity and structure verifications are on going for the retrospective runs
- Forecast efficiency will be critical to the pathway toward operational implementation