NOAA HURRICANE FORECAST IMPROVEMENT PROJECT

Welcome
Project Overview

HFIP Annual Meeting

November 18-19, 2015

Purpose of Meeting

- HFIP Project Review
  - Accomplishments and Progress
- Review Status of FY15 Funded Activities
- Priorities and Planning for FY16
- Jet Computing Resources
- Discuss possible Team Lead changes

HFIP Charter and Leadership

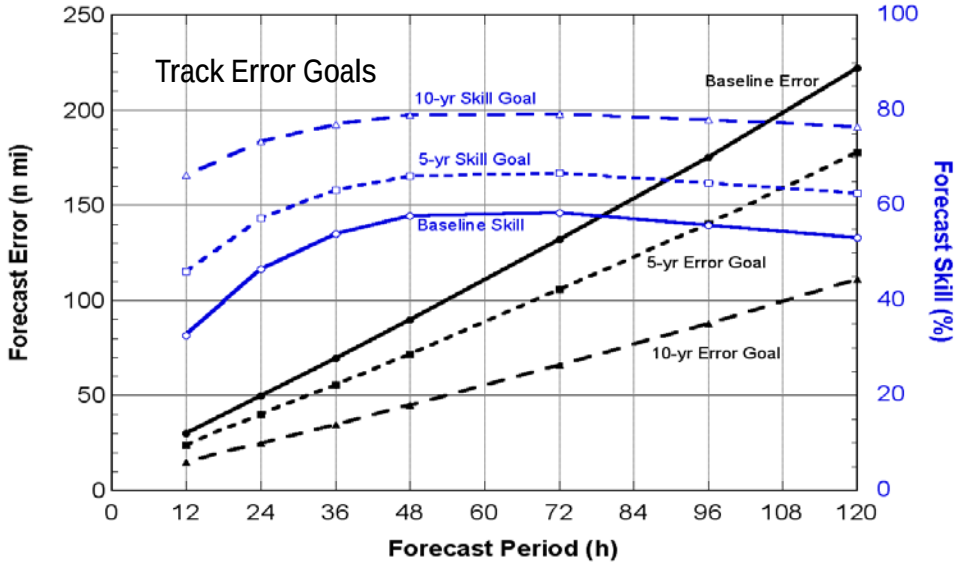
- **HFIP Charter signed August 1, 2007**
- **Hurricane Executive Oversight Board**
  - Jointly chaired by AA for National Weather Services and AA for Oceanic and Atmospheric Research
  - Cross-NOAA Membership
- **HFIP Management**
  - Project Manager: Fred Toepfer, NWS/OSTI
  - Development Managers:
    - Vijay Tallapragada, NWS/NCEP/EMC
    - Sundararaman Gopalakrishnan, OAR/AOML/HRD
  - Research Lead: Frank Marks, OAR/AOML/HRD
  - Operations Lead: Ed Rappaport, NWS/NCEP/NHC

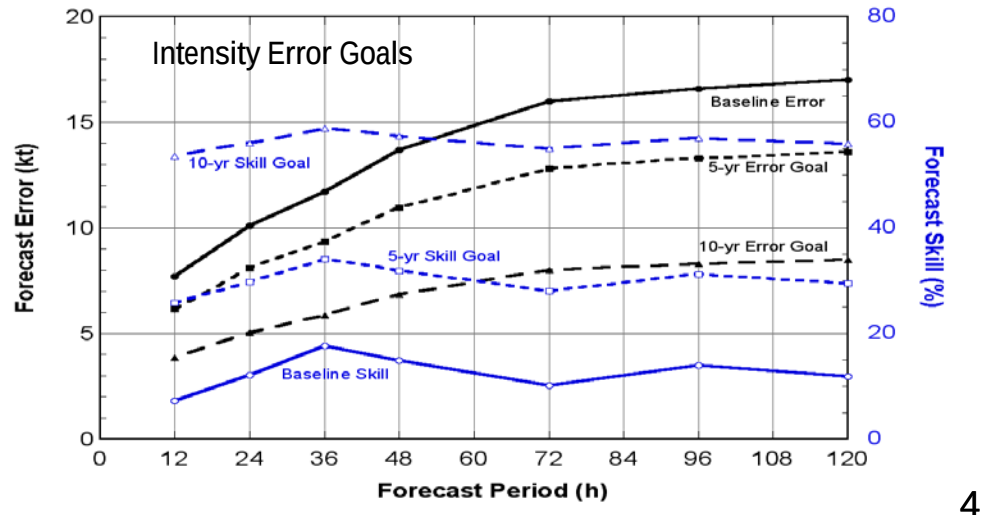
The HFIP Project Vision/Goals

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 at day 1 to 90% and 60% at day 5



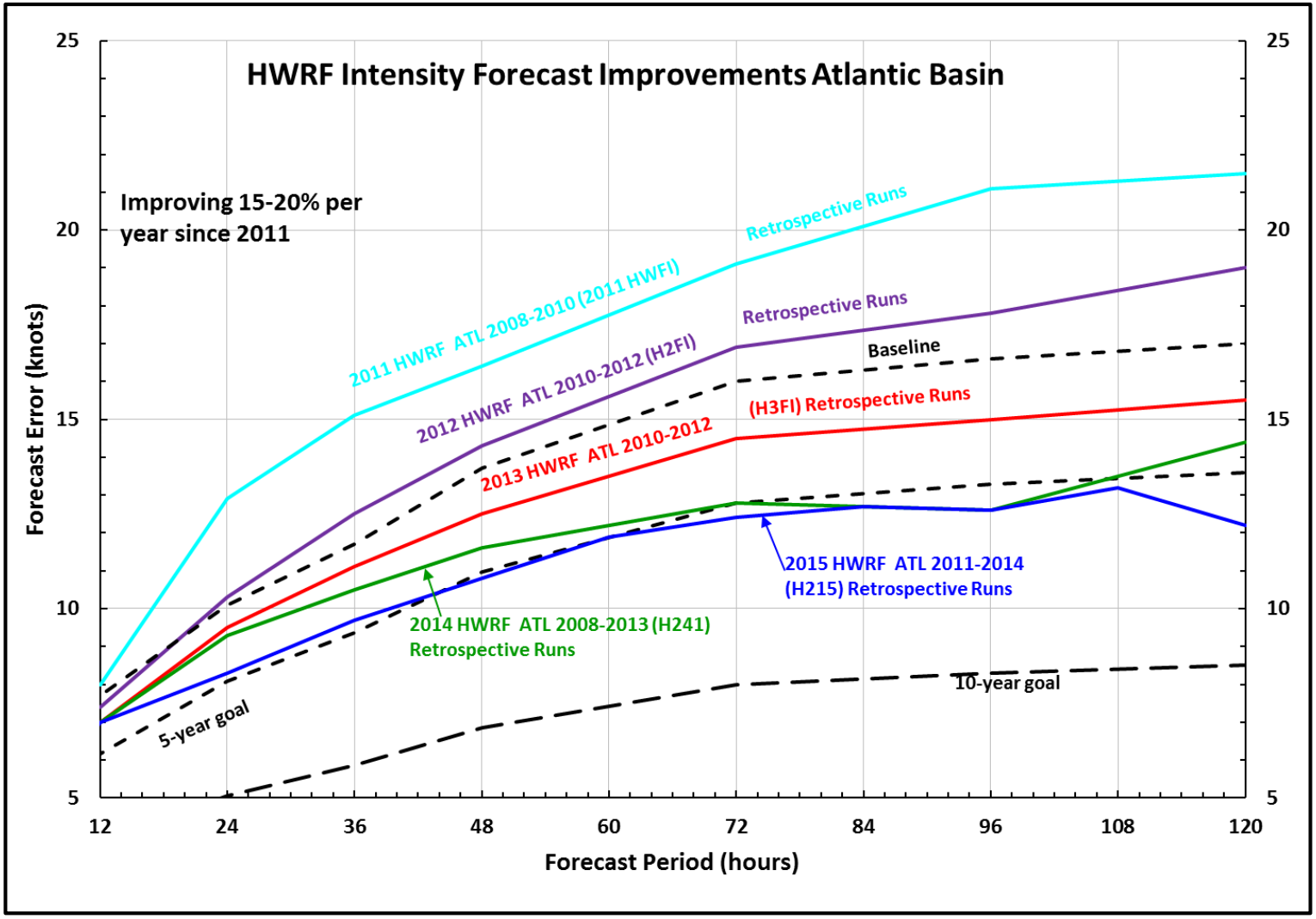


Highlights for 2015

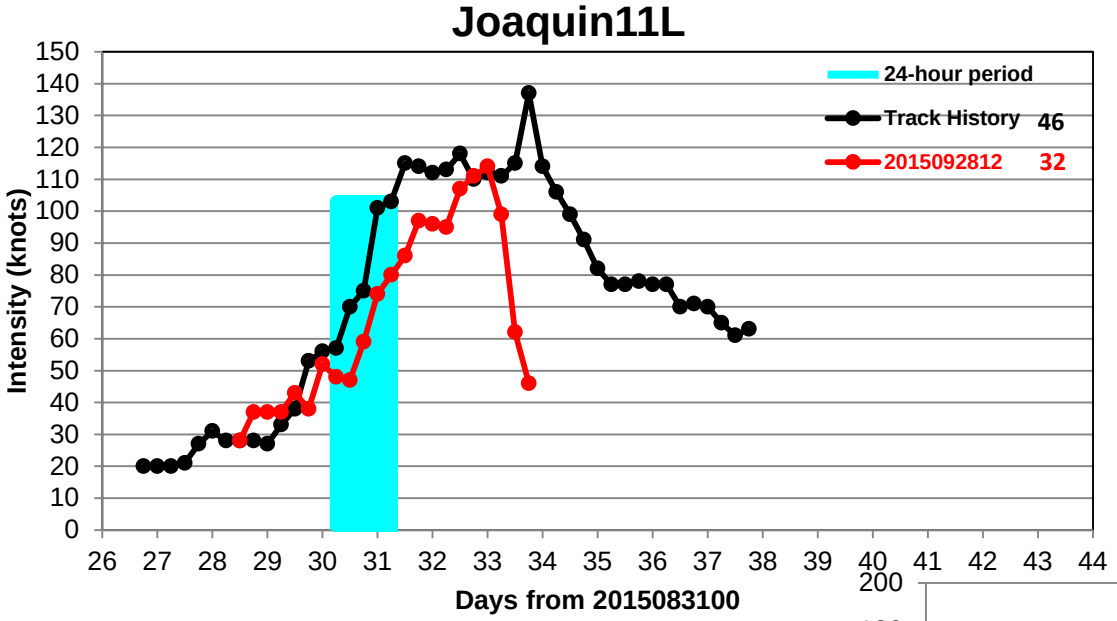
- 2015 HWRF operational implementation
  - Increase the horizontal resolution for all domains from 27/9/3 to 18/6/2 km
  - Continued improvement of nest tracking, more advanced vortex initialization, and advanced diagnostic products
- Transitioning HWRF into NMM-B (convert E-grid to B-grid) underway planned for implementation in 2017
- Basin-Scale HWRF
  - Prototype demonstrated on Jet in real-time during the 2015 hurricane season supporting multi-nested regional to global scale models
- Demonstrated multi-model regional ensemble (HWRF/COAMPS/GFDL)
  - 40 member ensemble run on Jet in Real-time for the 2015 hurricane season
  - Developed high-resolution probabilistic products
- Expand HWRF capabilities to all global (including WP/SH/IO) basins through 7-storm capability in operations to run year long
- HWRF WPAC demonstrated promising results for RI guidance
- ADCIRC coupled with operational HWRF 20mbr ensemble
- Improved forecaster display products at NHC

HWRF Intensity Error Improvements Atlantic Basin (2011-2015)

4 years of continuous improvements in intensity forecasts

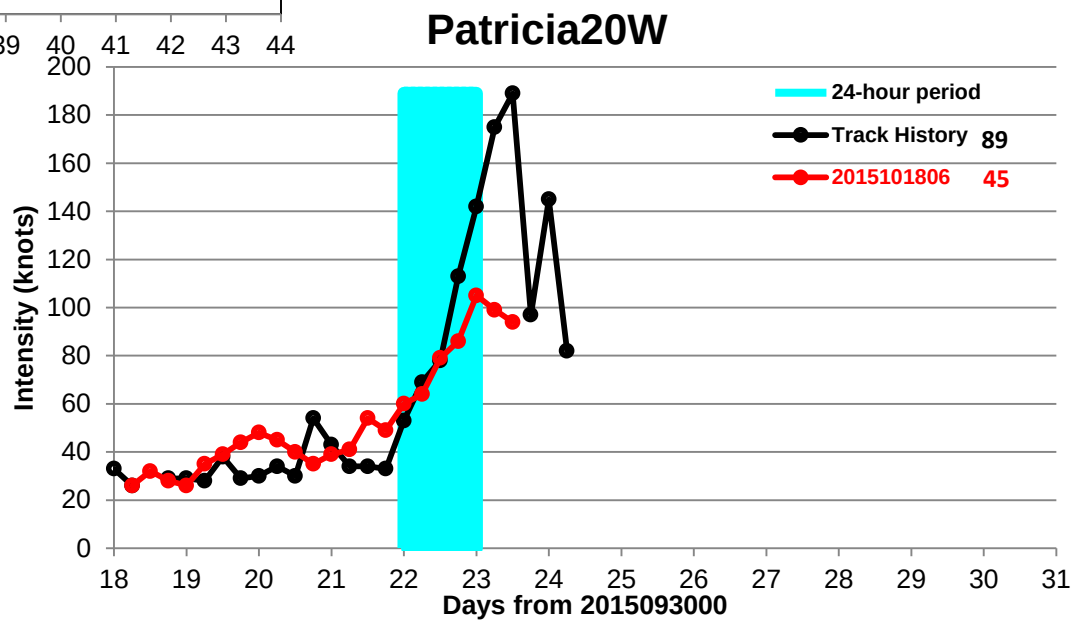


Promising RI Cases



Intensity forecast for Joaquin - RI prediction 36hrs after Invest before becoming a named storm

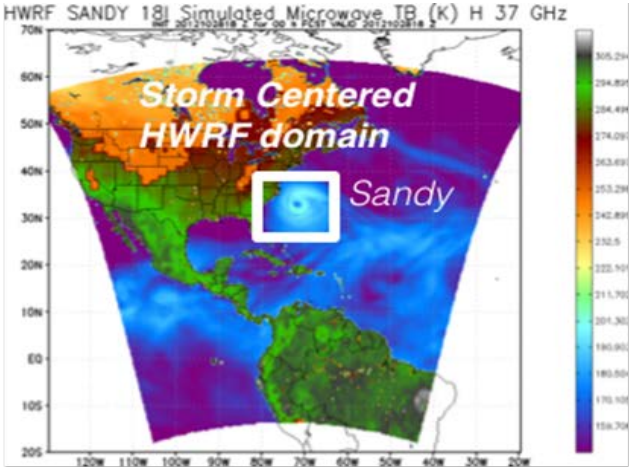
Intensity forecast for Patricia - RI prediction 6hrs after Invest and 3 days before being named



Next: Basin-Scale HWRF in NEMS

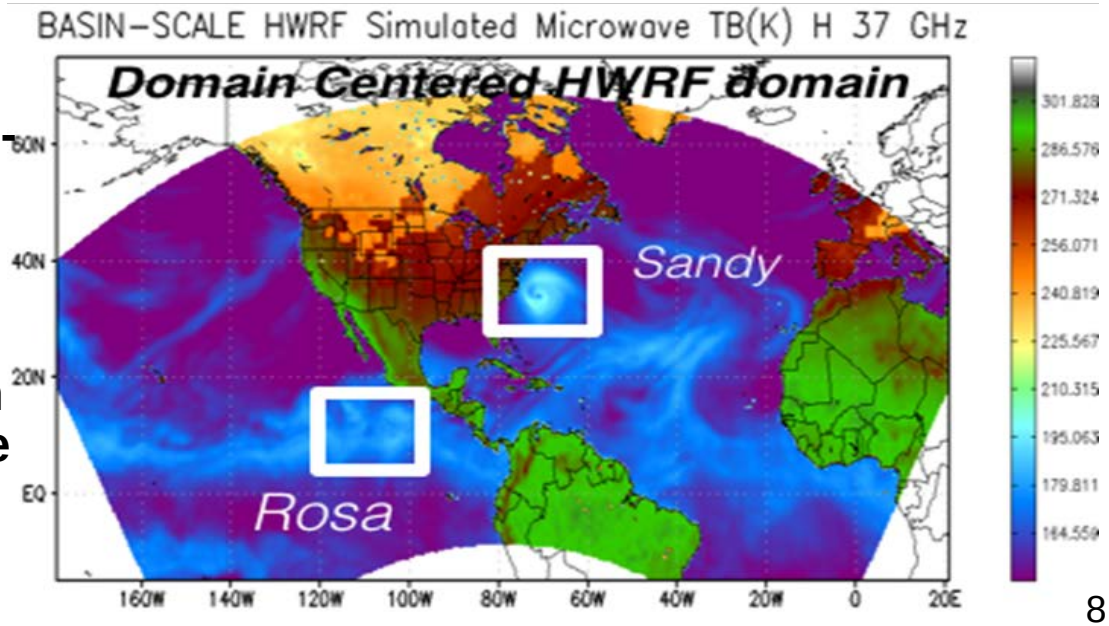
Storm Centric -VS- Domain Centric Forecasts

- Tropical Prediction System (Extended predictions)
- Improved storm-storm & multi-scale interactions
- Landfall and post landfall (storm surge & rainfall)
- Genesis; Regional ensembles; Data assimilation

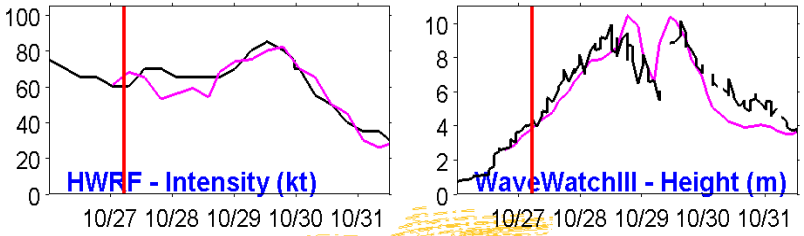


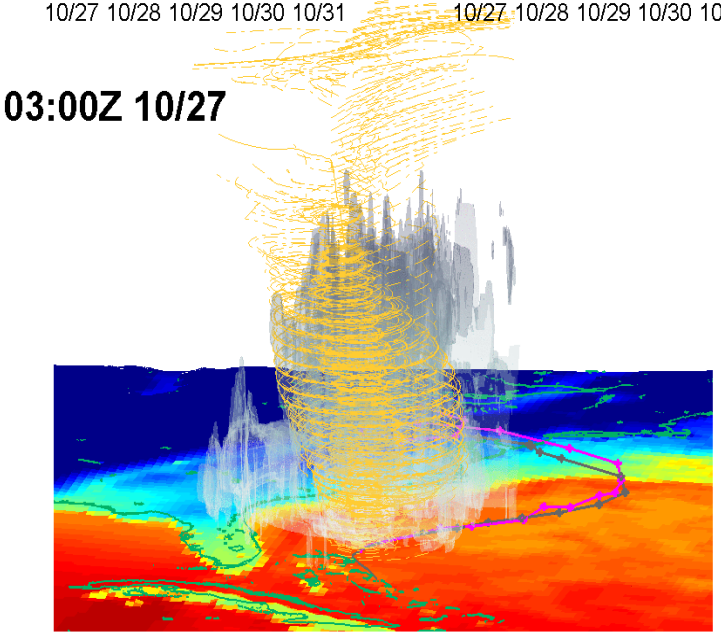
Transition HWRF into NMMB/ NEMS framework for Unified High-Resolution Mesoscale Modeling Suite at NCEP

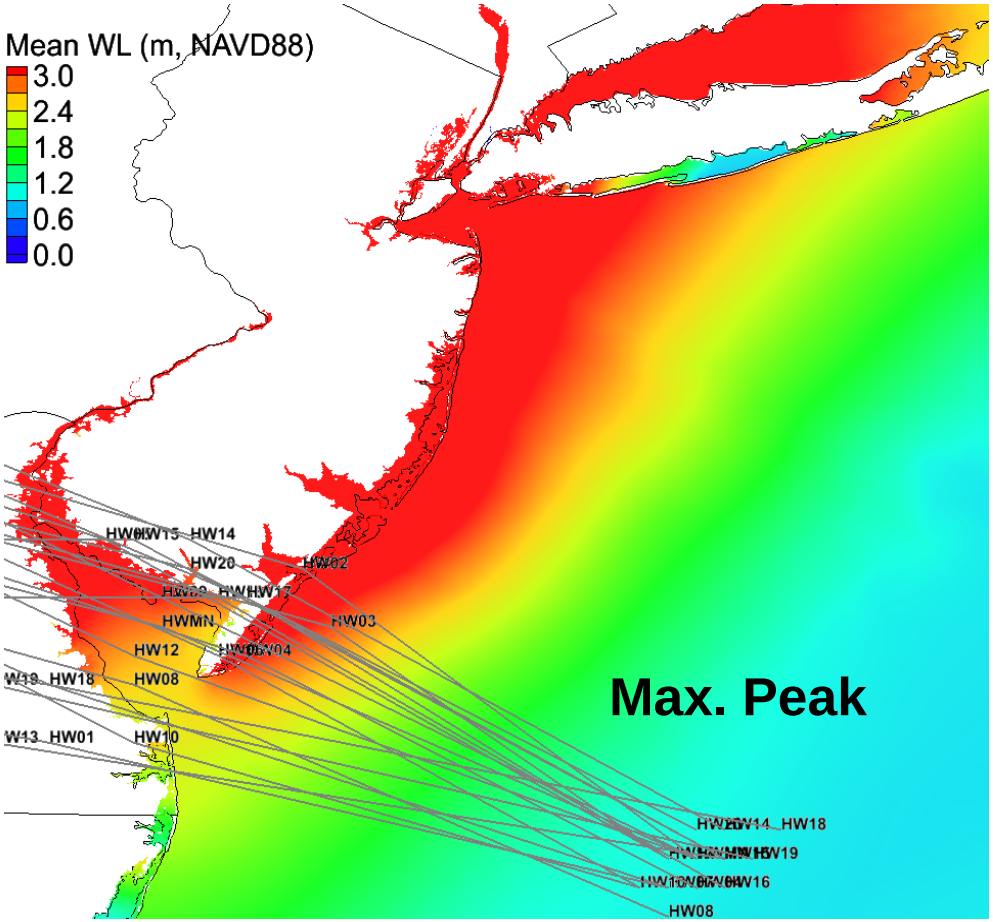
Future non-hydrostatic global models to include high-resolution moveable nests for more accurate predictions of significant weather events



Advanced Storm Surge and Wave Products from Operational HWRF Coupled to ADCIRC and WaveWatch III

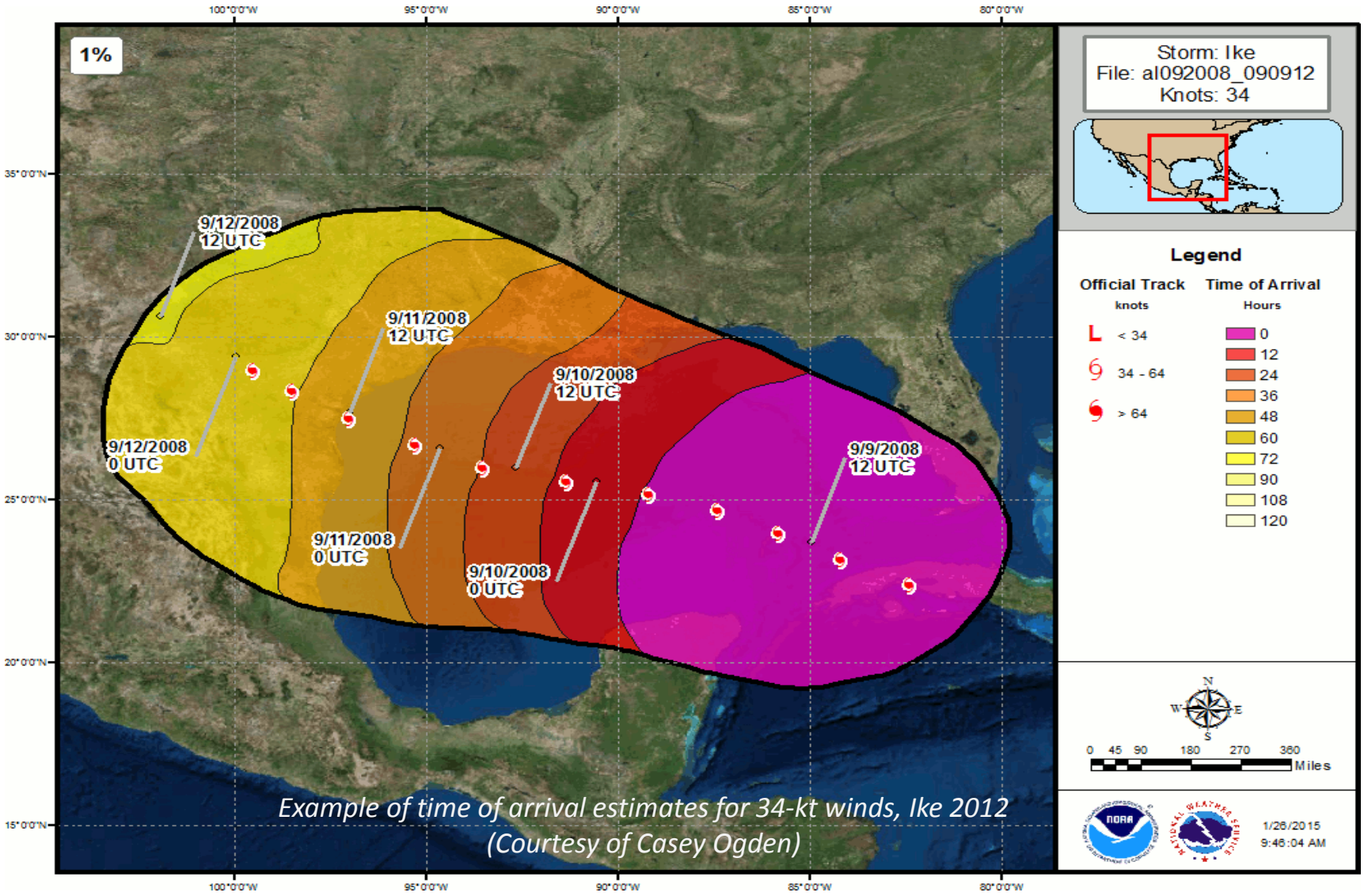






Courtesy of Vijay Tallapragada

Upgrade Wind Speed Probability Product



Example of time of arrival estimates for 34-kt winds, Ike 2012
(Courtesy of Casey Ogden)

Outreach and Community Participation

- 31st Conference on Hurricanes and Tropical Meteorology
  - 4 HFIP focused sessions
  - 41 papers (7) NCAR,(5)EMC,(4)HRD,(1)GFDL,(1)ESRL,(1)NRL,(1)IIT),(10)Univ.
- International Partnerships
  - India, China, Vietnam, Taiwan, Oman, and Korea
- Providing JTWC forecast guidance from HWRF
- 13 Grants awarded to University PI's (2nd Round)

Upcoming Opportunities

- Next round Announcement of Opportunity to be published early December (Funding Opportunity Number: NOAA-NWS-NWSPO-2016-2004713)
  - Letters of Intent due 19 January 2016
  - Application deadline is 29 February 2016
  - Expected award date for selected proposals 1 Sep 2016
- 32nd Conference on Hurricanes and Tropical Meteorology, 17-22 April 2016, San Juan, PR
  - Request 2nd round award recipients to register under HFIP session

Appropriation History
(2009-2016)

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16
WCOSS PAC (HFIP	6.000M	3.000M	3.000M	2.000M	2.000M	4.000M	4.000M	4.000M
NWS ORF	*15.040M	*14.040M	*14.044M	*14.044M 8.540M Due to NWS reprogram	**13.004M 1.999M Due to NWS reprogram	13.004M 3.2M due to reprogram of Sandy	4.500M	4.500M
Sandy Supplement					10.066M	3.600M Use for FY14 R2O Enhancement		
OAR ORF	6.100M	6.100M	6.100M	6.000M	5.800M	5.800M	5.800M	5.800M
TOTAL	*$27.140M	*$23.140M	*$23.144M	*$18.540M	*$22.737M	*$22.804M	$14.300M	$14.300M

*Includes $1,040K in NCEP Base allocation for HWRF and SLOSH O&M
** OMB Restored NOAA and DOC proposed reductions

Near-Term Priorities under 2015 Budget Reduction

- Leverage NGGPS resources to maintain cross-NOAA and external community involvement
- Operational Partnership for Multi-Model Ensembles in all Basins
- Focus on improvements of model physics (scale aware), vortex initialization and data assimilation
- Evolution of Hurricane Forecast System includes:
  - global-to-local scale predictions with emphasis on multi-scale interactions
  - Improved forecasts for land falling storms and downstream applications
  - Precipitation after land fall
  - Development of Nesting Technology
- Continued focus on high-resolution ensembles, advanced air-sea-wave-land-hydrology coupled systems
- Improved products to the forecasters

We Will Achieve Long Term Goals – just will take little longer!

R&D HPC
Configuration of Jet System

	Install Date	Total Cores	Performance (Tflops)	Storage (TB)
Phase 1 (Njet)	Aug 2009	3184	35.6	350
Phase 2 (Tjet)	Aug 2010	10600	113.0	416
Phase 3 (Ujet)	Oct 2011	16648	182.0	1166
Phase 4 (Sjet)	Aug 2012	22088	272.0	1613
Phase 5 (Vjet)	Aug 2014	24456	340.26	3261
Phase 6 (Xjet)	Oct 2015	32250	576	3773

New users must obtain NACI background investigation including fingerprinting through NOAA Office of Security to run on Jet or any RDHPC

- 2-3 months to process for US Citizens
- 6-8 months to process for Foreign Nationals and must have a Fed sponsor to renew annually

Real-time Experiments during 2015 Hurricane Season

- ARW Ensemble DA (Penn State Univ.): **S-Jet**
- FIM *global-scale* Deterministic, and 10-member FIM 40-km Global Ensembles: **N-Jet**
- HWRF *Vortex-Scale* Hybrid DA (Univ. of Oklahoma): **S-Jet**
- Non-hydrostatic Modeling System (NMS) Ensemble Hurricane Forecasts (UWI-Madison/CIMSS): **S-Jet**
- 12-member GFDL ensembles: **U-Jet**
- GFDL Deterministic runs for West Pacific in support of JTWC: **T-Jet**
- 20-member HWRF ensembles and HWRF-HYCOM and HWRF Physics Experiments: **T-Jet**
- HWRF Basin-Scale Multi-Storm Configuration AOML/HRD: **T-Jet**
- HEDAS Analysis and Forecast AOML/HRD: **T-Jet**
- ADCIRC Storm Surge: **T-Jet**
- ARW High Res Deterministic Experiments – Univ. Miami and FSU: **X-Jet**
- HWRF Satellite DA Experiments (FSU, NESDIS, U. Wisconsin) : X-Jet
- HWRF-POM ocean coupled Basin-Scale Multi-Storm Configuration (HRD/AOML) : **X-Jet**

Technical Team Leadership (2014)

FY 2014 Strategic Planning Teams

FY 2014 Teams	FY 2014 Team Leads
1. HFIP Model Strategy/Model Physics	Vijay Tallapragada (EMC), Jian-Wen Bao (ESRL), Stan Benjamin (ESRL)
2. Data Assimilation/Initialization/Ensemble Development	Jeff Whitaker (ESRL), Xuguang.Wang (OU), Jiayi Peng (EMC)
3. Post Processing and Verification Development Team	Mark DeMaria (NHC), David Zelinski (NHC), Tim Marchok (GFDL)
4. Socio-economic Impacts	Jennifer Sprague (NWS/OASST), Rick Knabb (NHC)

FY 2014 Tiger Teams

FY 2014 Teams	Strategic Team	FY2014 Team Leads
1. Web Page Design	3	Paula McCaslin (ESRL), Laurie Carson (NCAR), Thiago Quirino (AOML)
2. Satellite Data Impact	2	Jeff Whitaker (ESRL), Xiaolei Zou (UMD)
3. High Resolution Physics	1	
4 Recon Data Impact	1	James Franklin (NHC), Vijay Tallapragada (EMC)
5. Ocean Model Impact	1	Hyun-Sook Kim (EMC), George Halliwell (AOML)

Are these Teams still relevant for 2016? Do we need new Team Leads?

Questions?

Back-up / Misc

HFIP Scope

- Improve hurricane forecast system/global forecast system to reduce error in intensity and track
- Make better use of existing observing systems; define requirements for future systems to enhance research and operations capabilities and impacts
  - Does not include acquisition or operation of operational observing systems
- Expand and improve forecaster tools and applications to add value to model guidance

Priorities from 2014 Annual Meeting

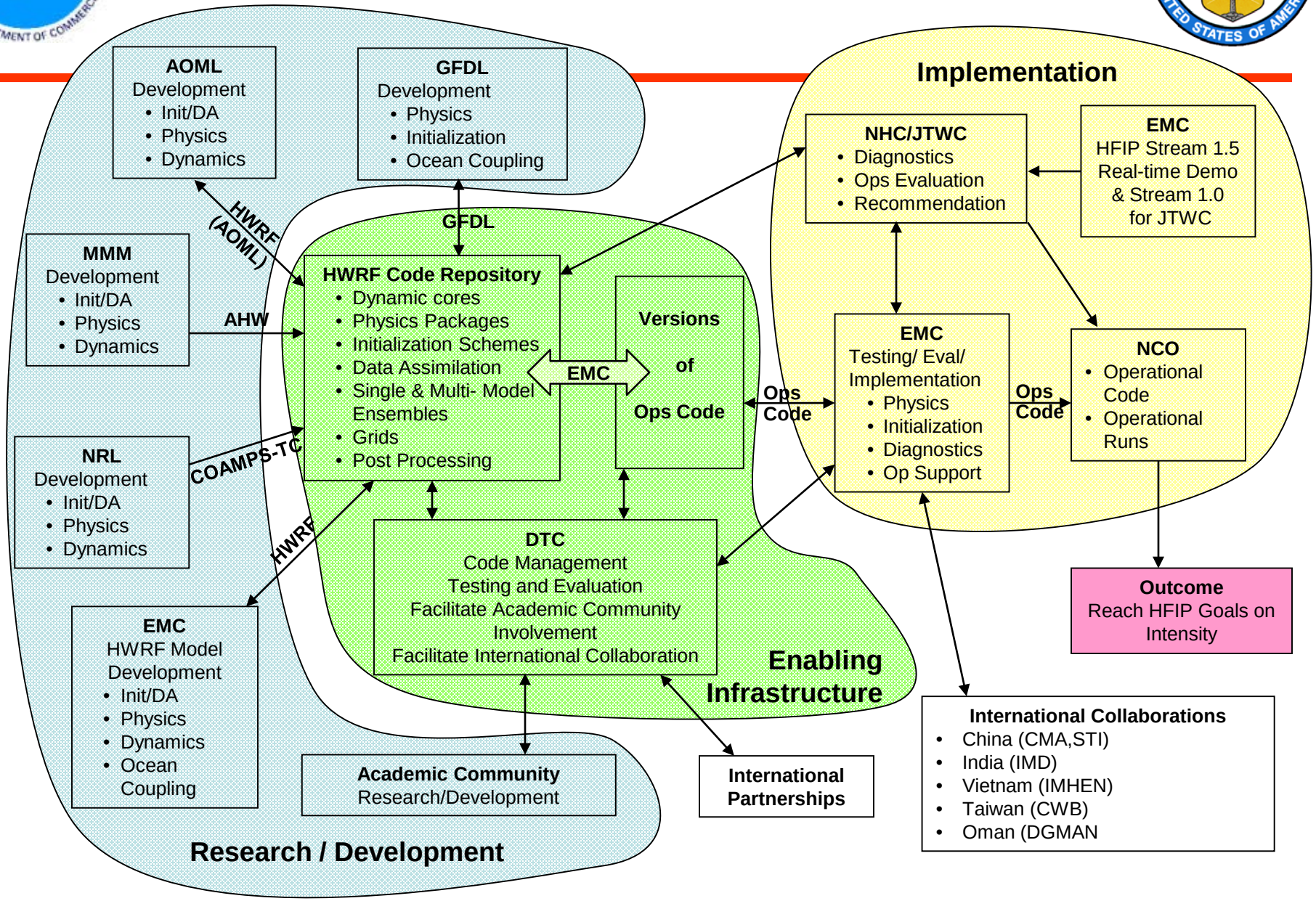
Summary of Recommended Priorities

- Focus resources on addressing
  - Initialization problem
  - Improving intensity & RI forecasts
  - Physics advancements
  - Data assimilation techniques
  - Regional ensemble development

Reduction Recommendations

- Reduce HFIP funding for global model and ensemble development
- Eliminate the formal Stream 1.5 process for delivering real-time experimental guidance to NHC (TCMT effort)
  - Continue Real-time Demo on Jet (requires defining new process)

Operational Hurricane Modeling System Development



HFIP Motivation
Reduced Evacuation Costs

- **Executive Office of President, Statement of Administration Policy, Oct 5, 2008**:
  - "… the administration urges the Congress … to support accelerated improvement of hurricane track and intensity forecasts, which will help to prevent unnecessary and costly evacuations."
- **Improved forecasts**
  - Increased forecast accuracy at longer lead times, especially during periods of rapid intensity changes; raise confidence levels for all forecast periods
  - Reduced over-warning
- **More effective emergency management response**
  - Reduced Evacuations
  - Overall reduction in preventable economic losses
  - Hundreds of millions of dollars saved annually

Overall Strategy

- Use global models at as high a resolution as possible to forecast track out to 7 days
- Use regional models at 1-3 km resolution to predict inner core structure to meet intensity goals out to 5 days including rapid intensification
- Hybrid DA for both regional and global using as much satellite and aircraft data as possible
- Both regional and global models run as an ensemble
- Statistical post processing of model output to further increase forecast skill

Accelerating Research to Operations

Key Steps Implemented to Include Broader Community and Accelerate Research to Operations:

- aligned research efforts within NOAA and with interagency and academic partners by establishing focused cross-collaborative development teams of subject matter experts from the research and operations communities
- established a process to leverage outside research capabilities in support of project objectives (Federally funded grantees working within a community code repository);
- defined and implemented a solution (the seasonal, real-time experimental forecast system) to accelerate research into operational products; and
- established a high performance computing infrastructure and attendant protocols to support research-to-operations activities.

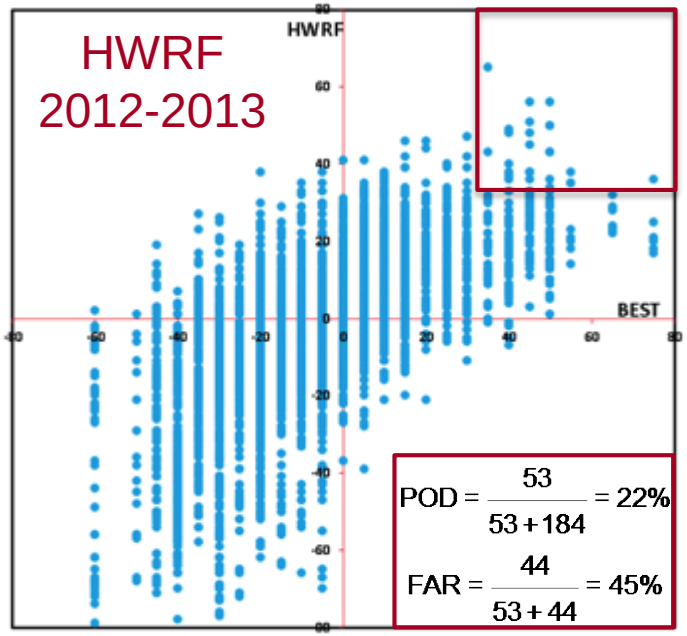
HFIP Strategic Teams

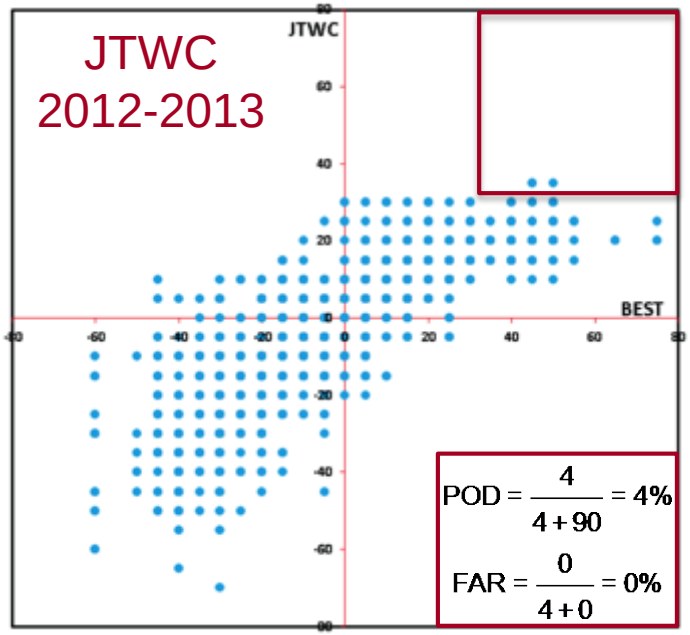
HFIP Teams	Contributions for Research Transitioned to Operations
Model and Physics Strategy Team	Strategic design of annual upgrade implementation plans Establish infrastructure and support for community model development Engage research community in advancing research and development for hurricane modeling techniques and physics
Data Assimilation / Ensemble Strategy Team	Develop advanced vortex scale data assimilation techniques: Ensemble based hybrid EnKF-3DVAR DA, self-cycled high-resolution EnKF based ensembles for DA, cloudy radiance assimilation using innovative microphysics independent techniques Impact assessment of aircraft data, GOES AMVs, microwave derived temperature anomalies and other cloud impacted satellite radiance data
Post-Processing and Verification	Advanced synthetic satellite imagery; high-frequency model output for track, intensity and structure; hurricane related tornado genesis products, ensemble based probabilistic products for genesis, wind and precipitation; statistical predictors for intensity using consensus of global and regional models (SPICE); advanced model diagnostics tools and verification techniques
Socio-economic Team	Determine best ways to convey tropical cyclone risk and uncertainty and present NHC products, information and services

HFIP Tiger Teams

HFIP Tiger Teams	Contributions for Research Transitioned to Operations
HiRes Physics *(components in bold transitioned to ops)*	Test most promising alternate physics packages ((2011-2012-2013) ***NOAH LSM, RRTMG Radiation; Observations based GFS PBL and GFDL Surface Physics; GFS Shallow Convection;*** MYJ PBL; Thompson MP, Meso-SAS convection etc.
Radar Data Impact	Test and evaluate impact of Aircraft Reconnaissance Data assimilation. (2012-2013-2014): ***One-way hybrid DA for TDR and dropsonde data outside the inner core; 40-member warm start HWRF ensemble based DA with all inner core data including GH/UAV sondes.***
Satellite Data Impact	Regional hybrid system for testing and assessing the impacts of satellite data assimilated in hurricane models (2013-2014-2015): AMSU temperature anomalies, high-res GOES AMVs, ***clear-sky radiance***
Ocean Model Impact	Document the importance of ocean model impacts on hurricane intensity prediction: (2014-2015): Design and develop new and ***improved ocean initialization techniques*** and physics at air-sea interactions using observations
HFIP Website	Test and evaluate most promising techniques evaluated by NHC and products displayed on HFIP website

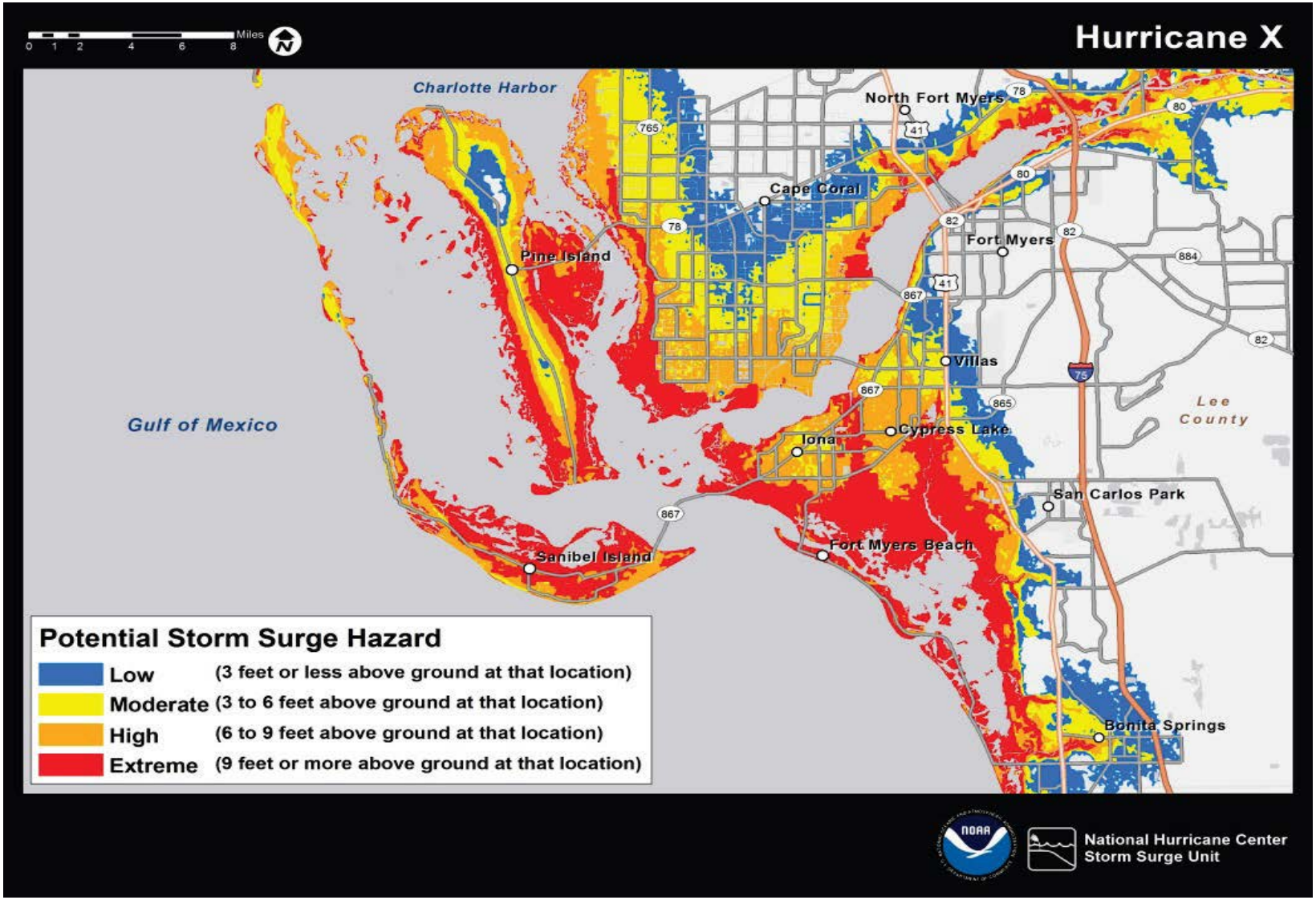
HWRF RI in WPAC





- If RI event defined as >30 kt/24 h, HWRF RI POD skill is ~ 22% and has much higher POD compared to operations and other models **(previous analysis of RI for WPAC in 2012 showed <10% skill)**.

Potential Advisory Product



Mission-Oriented Research University 2yr Grants ($3.78M)

Research Topic	University	PI
GSI-based hybrid ensemble-variational data assimilation system for airborne hurricane observations in HWRF	University of Oklahoma	Xuguang Wang
Dependence of all-sky nearly-simultaneous radiances from on atmospheric variables for assimilation into WRF	University of California, Los Angeles	Haddad
Addressing Deficiencies in Forecasting Tropical Cyclone Rapid Intensification in HWRF	University of Miami, RSMAS	J. Zhang
Assessing the Predictability of Tropical Cyclone Intensity using HWRF	State University of New York	Torn
HWRF Prediction System with Advancements in the Ocean Model Component and Air-Sea-Wave Coupling	University of Rhode Island	Yablonsky
Probabilistic Prediction of Hurricane Intensity with an Analog Ensemble	University of Wisconsin	Rozoff
Intrinsic Hurricane Predictability	University of Washington	Hakim
0-5 day prediction of tropical cyclogenesis incorporating HWRFwithin the marsupial framework and new Lagrangian flow tec	Naval Postgraduate School	Montgomery
Improved Satellite Data Assimilation and Vortex Initialization HWRF	University of Maryland	Zou
Improving Hurricane Intensity Forecasts using the Multi-model Superensemble and a Suite of Mesoscale Models	Florida State University	T.N Krish
Improving Vortex Initialization in HWRF Multiple-level Nested Domains with GSI Hybrid Data Assimilation	University of Utah	Pu
Sub-grid Scale Physics in HRWF and Inner-core Structure	Florida International University	Ping Zhu
Evaluating HWRF Parameterization Schemes Using Satellite Brightness Temperatures	University of Wisconsin	Otkin