HFIP Real-Time Forecast System for 2012

2012 Interdepartmental Hurricane Conference

Charleston, SC

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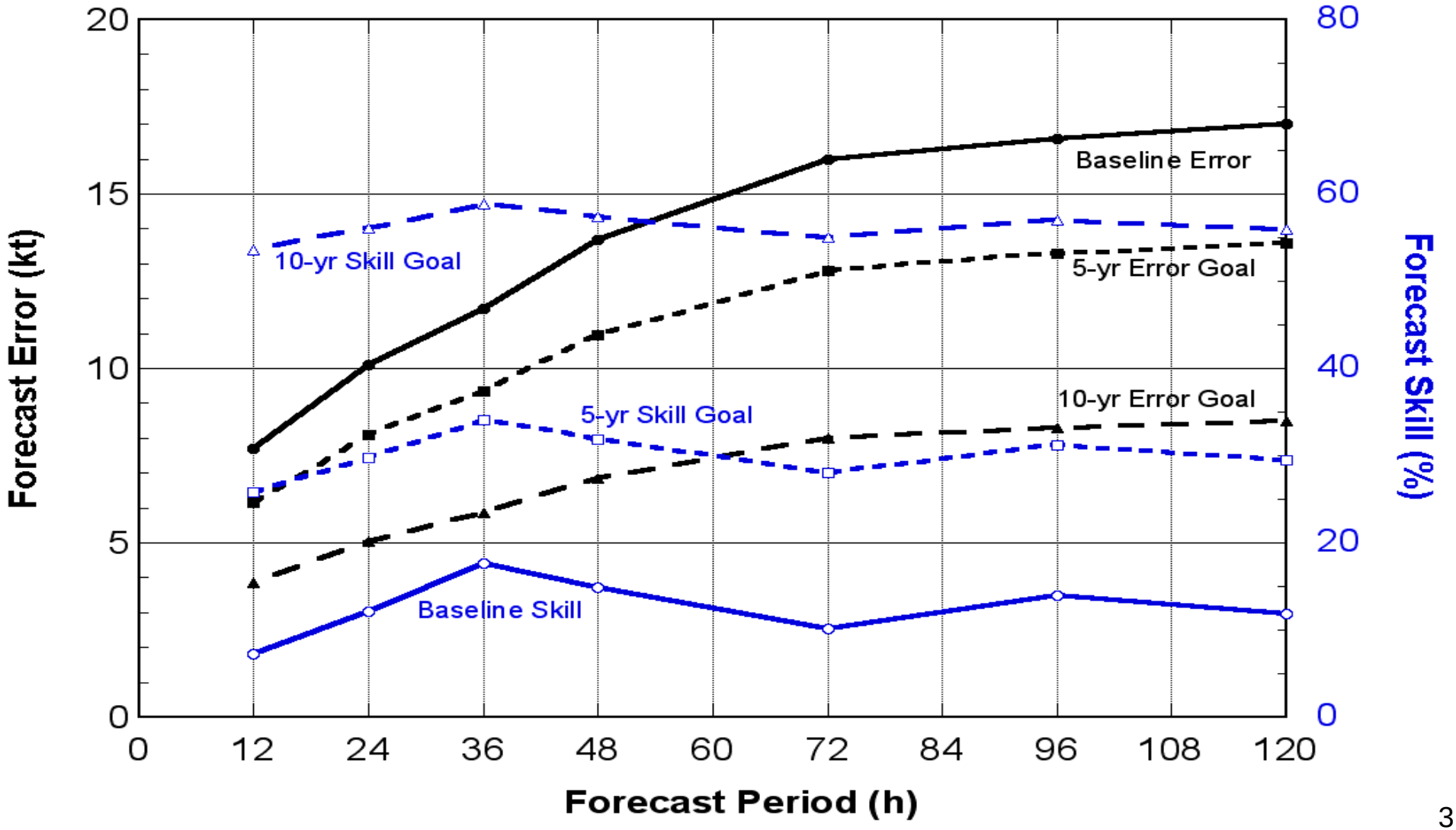
The HFIP Project Vision/Goals

- 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 forecasts to 7 days
  - Increase probability of detecting rapid intensification at day 1 to 90% and 60% at day 5

HFIP Baselines and Goals: Intensity



HFIP 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

Success in Organizing the Community

- External Universities are making significant contributions; Navy/ONR HFIP co-funding external collaborators
  - PSU first to demonstrate the impact of aircraft radar data
  - FSU showing impressive results using a regional multi-model approach
- NCAR/DTC is now the repository for all HWRF codes
  - Both research and operational communities drawing from this repository
  - Greatly streamlines research transitions to operations
- NOAA OAR labs strongly engaged in developing future operational systems
  - ESRL in demonstrating value of advanced data assimilation methods in hurricane track forecasts
  - AOML is working closely with EMC on HWRF development and demonstrating future HWRF DA and model systems
- Strong collaboration with NRL on global/regional model, data assimilation and ensemble development

HFIP Success to Date

- HFIP recognized for successfully aligning and focusing research efforts within NOAA and its interagency partners

- HFIP has defined a solution for transitioning research into ops
  - Stream 1.5 “experimental operations” products being made available to NHC forecasters in real-time

- HFIP is making significant progress – 5yr performance goals within reach
  - Global ENKF ensembles providing 20% improvement in track guidance
  - Improved hurricane model initialization and higher resolution models – along with inner core data - showing significant (20-40%) improvement in intensity
  - Demonstration of Skill for track at 7 days underway
  - 3-5 day lead-time hurricane genesis potential product with potentially acceptable POD’s and FAR’s in development
  - Still uncertain progress toward goal for POD/FAR of rapid intensification of 90%/10% at day 1 and 60%/40% at day 5.

Plans for 2012 Hurricane Season

- Establish an Experimental Numerical Forecast System (Stream 1.5) for the Hurricane Seasons using NOAA's R&D computing acquired by HFIP
- Include global and regional ensembles, advanced DA and advanced statistical models
- Use R&D computing to demonstrate reaching the HFIP 5 year intensity and track goals
- Deliver experimental guidance to NHC in real-time
  - NHC defines real-time guidance for the selecting product suite

Potential Real-time Forecast System for FY12

- Global Hybrid DA system using GFS at T-574 (80 members)
- Global Ensemble (GFS, FIM) 10 members each, T-574 (27 km)
- Global FIM Deterministic model at 15 km
- Multi model Regional ensemble (all 3-5 km)
  - HWRF (27-9-3) with HEDAS for all aircraft data (WC-130 and P-3), parallel run (10 members?)
  - ARW (4 km) (EnKF DA on outer domain 10 members?)
  - TC-COAMPS (5 km) (navy initialization system 10 members)
  - Wisconsin Model (4 km) (bogus vortex initialization 10 members?)
  - PSU model (4.5 km) (pseudo hybrid DA 10 members?)
  - GFDL ensemble (7.5 km) 16 members
- Basin Scale HWRF (27 km, +multiple 9 km moving nests) with Hybrid-GSI
- NESDIS statistical Prediction ensemble (SPICE, using stream 1.5 systems) and FSU MME?

NHC's Stream 1.5 Selection Schedule

Activity	Deadline
Retrospective cases identified	**Complete**
List of Stream 1.5 participants and their intended model characteristics finalized	Jan 30 – in progress 75% complete
Major ATCF upgrades completed	Early April^{+}
Completed retro runs submitted in A-deck format	April 9
TCMT/DTC assessment of retrospective tests completed	May 15^{+}
NHC decision on prospective projects	May 31^{+}
Sample model output sent from each approved model sent from TCMT to NHC	June 6^{+}
Technical preparations by model teams and NHC	Jun 1-Jul 14^{+}
Stream 1.5 Test/shake down for 2012	Jul 15
Stream 1.5 Live Activities	Aug 1 – Oct 31

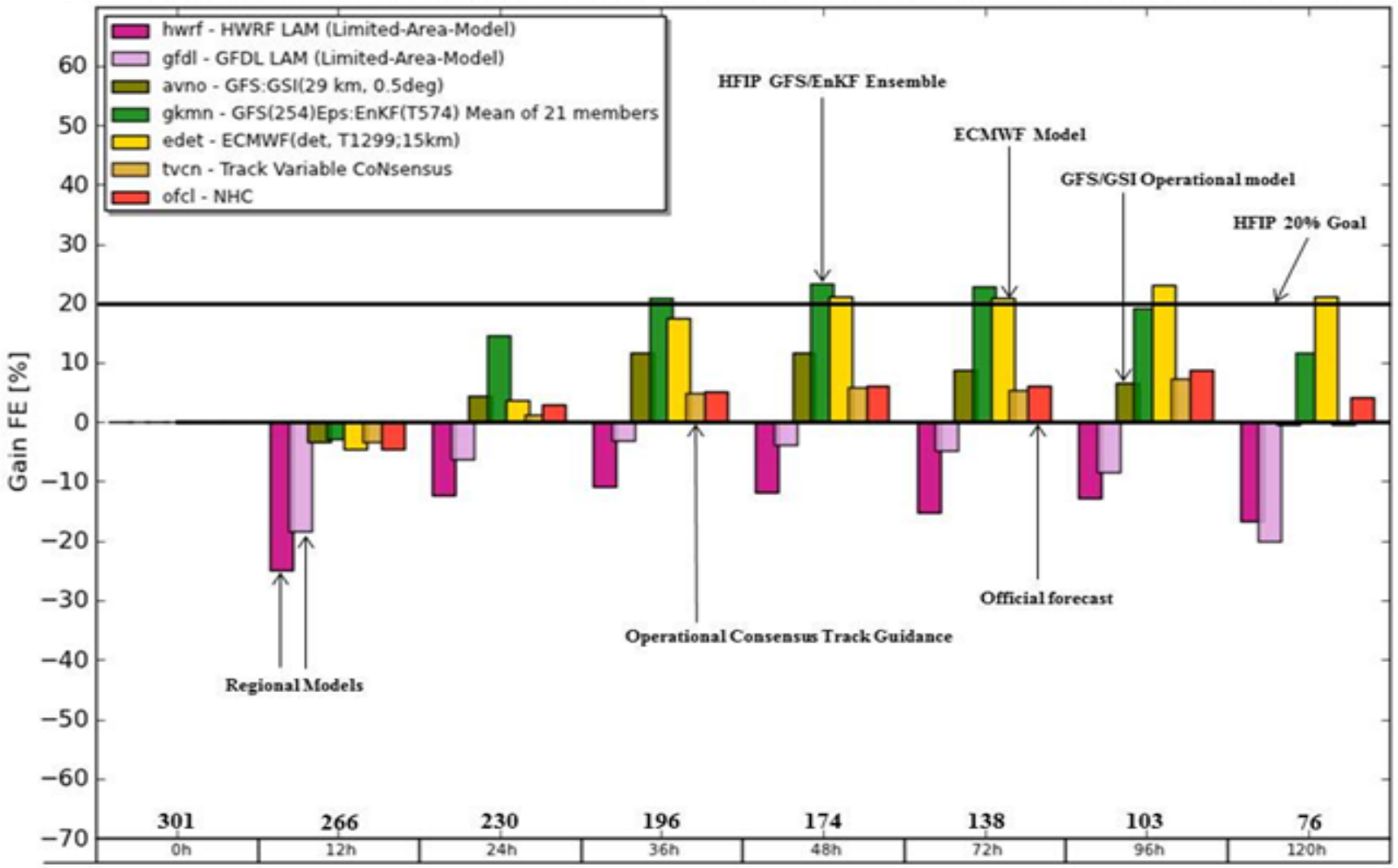
$^{+}$ Hard deadline

Reaching Track Goals:
Global Models

- Use Global models with advanced Data Assimilation System (Hybrid system eg: 3DVAR+Ensemble background error)

  - Global models outperform regional models on track
  - Forecast problem basically becomes a global problem after a couple of days.
  - Global models are necessary for genesis forecasts particularly at the longer lead times
    - Many storms last less than 5 days so 7 day forecast require skill at forecasting genesis

Track Error of Models (2010-2011)
(% Improvement over HFIP baseline)

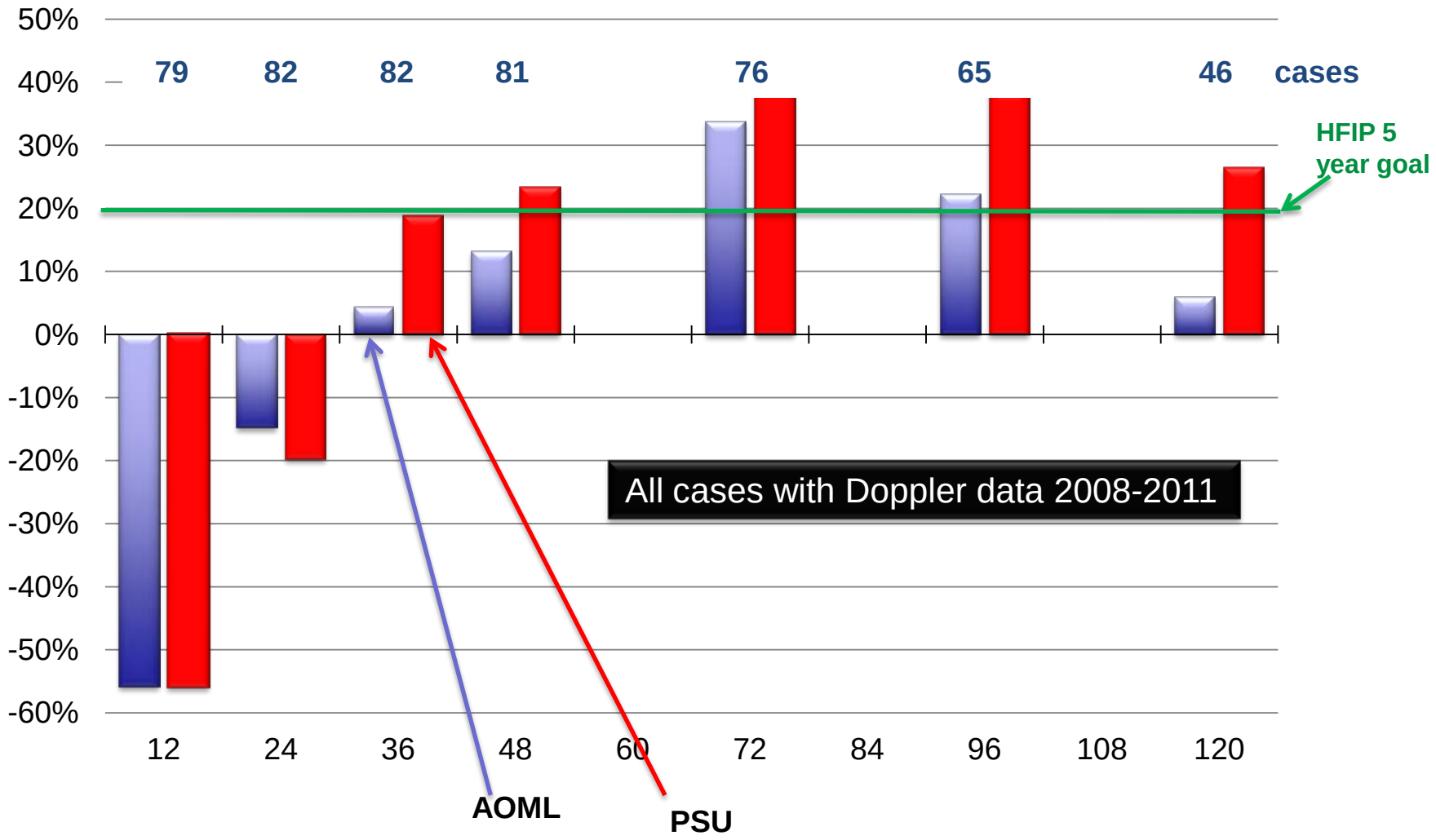


Reaching Intensity Goals:
Regional Models

- Use Regional models at high resolution (1-3 km)
  - This resolution necessary to capture inner core processes.
  - Won’t be achievable with global models especially when run as ensembles.
  - Need to use high resolution inner core data taken by aircraft and/or satellites

Impact of Aircraft Radar Data

% Improvement over HFIP baseline



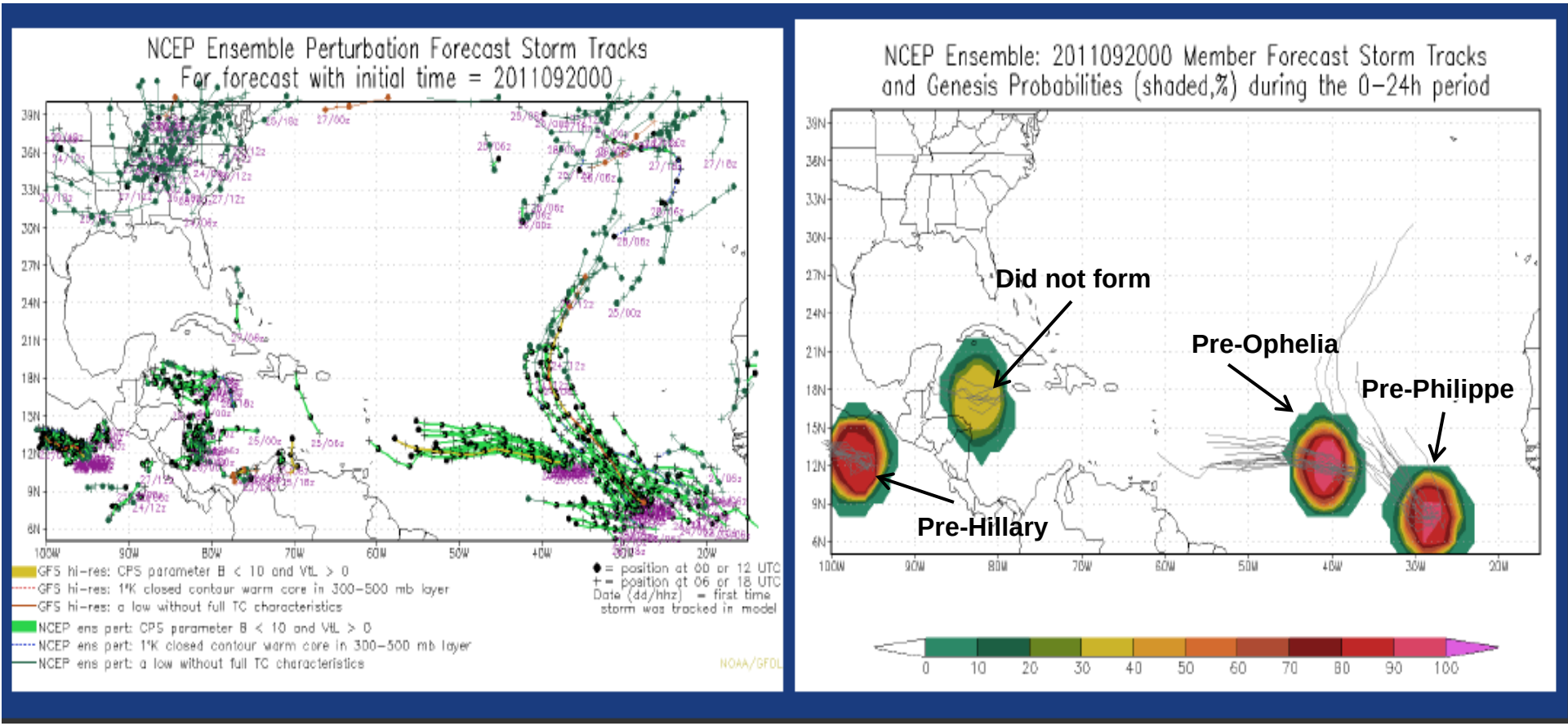
Hurricane Genesis

- Many hurricanes last less that 5 days
  - Genesis is important for forecasting out to 7 days
  - Especially important for hurricanes making landfall toward the end of the forecast period

- The HFIP global ensemble appears to be doing an excellent job of forecasting genesis even out 7 days lead time

GFDL Automatic Genesis Tracker

Probability of Genesis in first 24 hours of forecast period



NCEP Operational Ensemble

Initial time: 20 September 2011—7 day forecasts

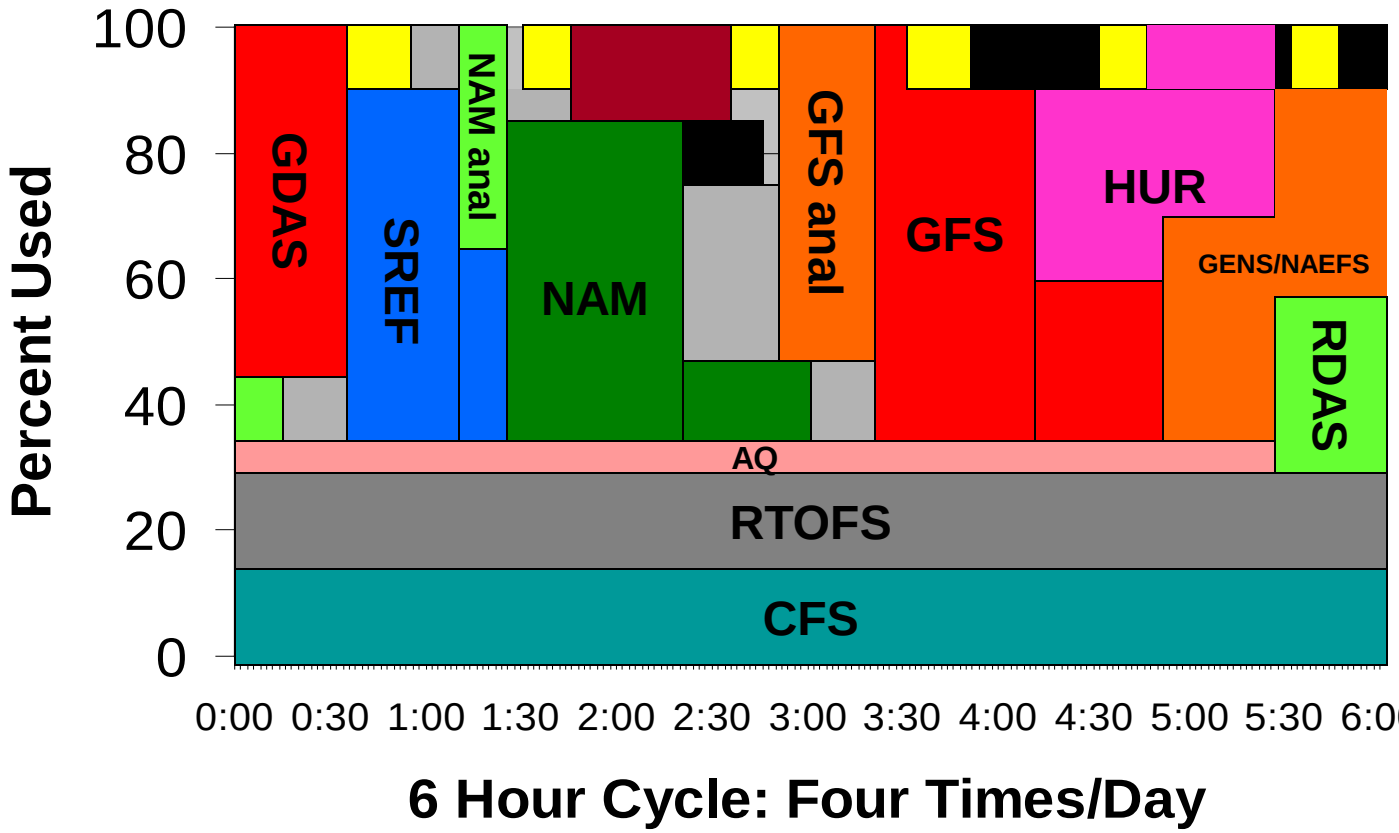
HFIP dedicated HPC
NOAA Jet system

	Install Date	Cores	Performance (Tflops)	Storage (Tbytes)
Phase 1 (Njet)	Aug 2009	3184	35.6	350
Phase 2 (Tjet)	Sep 2010	10600	113.0	416
Phase 3 (Ujet)	Nov 2011	16648	182.0	1166
Phase 4 (Sjet)	June 2012	est: ~23050	~ 250.0	~1500

- "Jet" system performance in 2011 is estimated at 182 Tflops
- Current Operations Computing peaks at 73.6 Tflops

NCEP Production Suite
Weather, Ocean, Land & Climate Forecast Systems

Current



Total Computing for Hurricane Runs: 26.5%

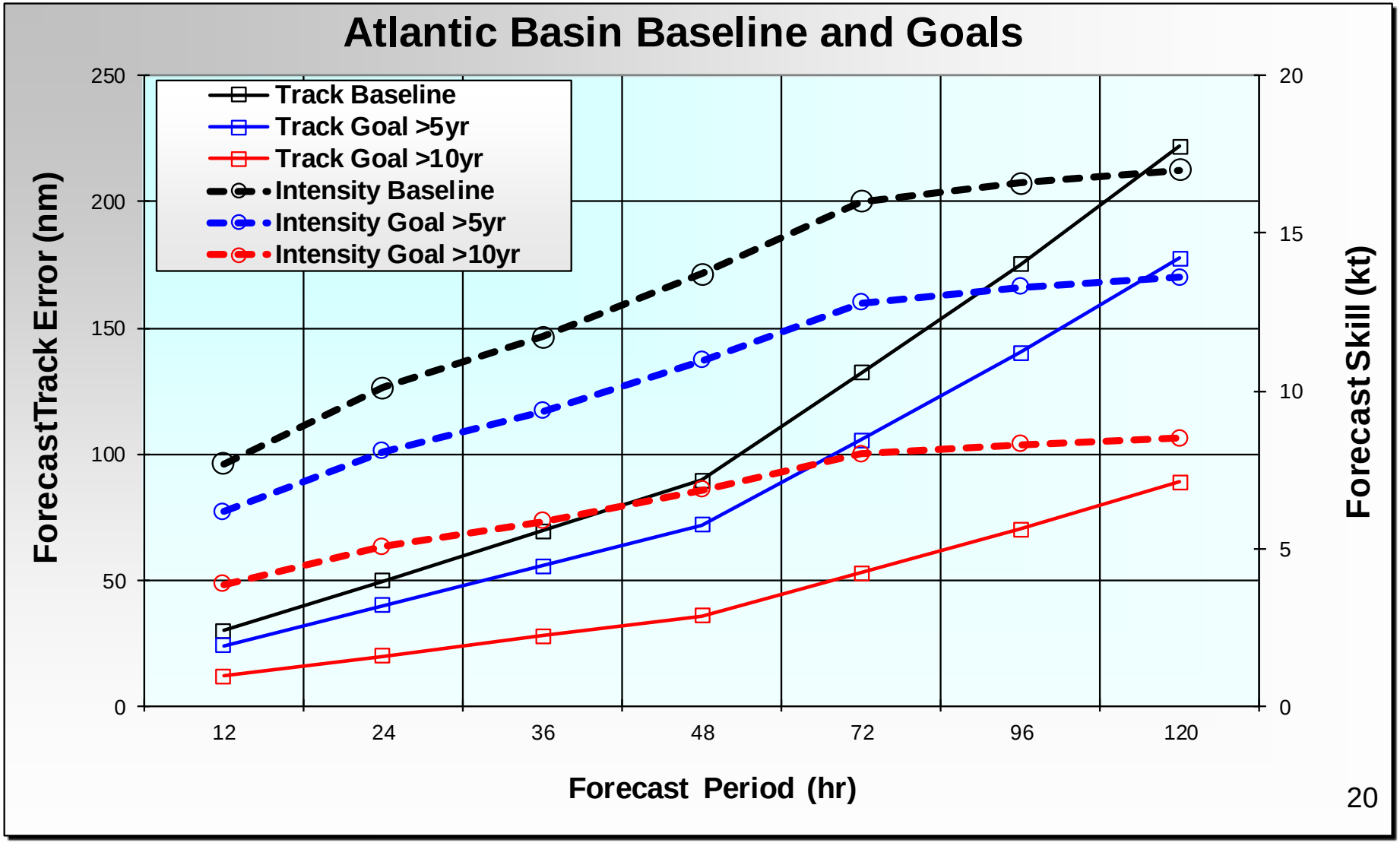
- GFS analysis and fcst: 15%
- GDAS: 5%
- HWRF: 6.5%

Questions?

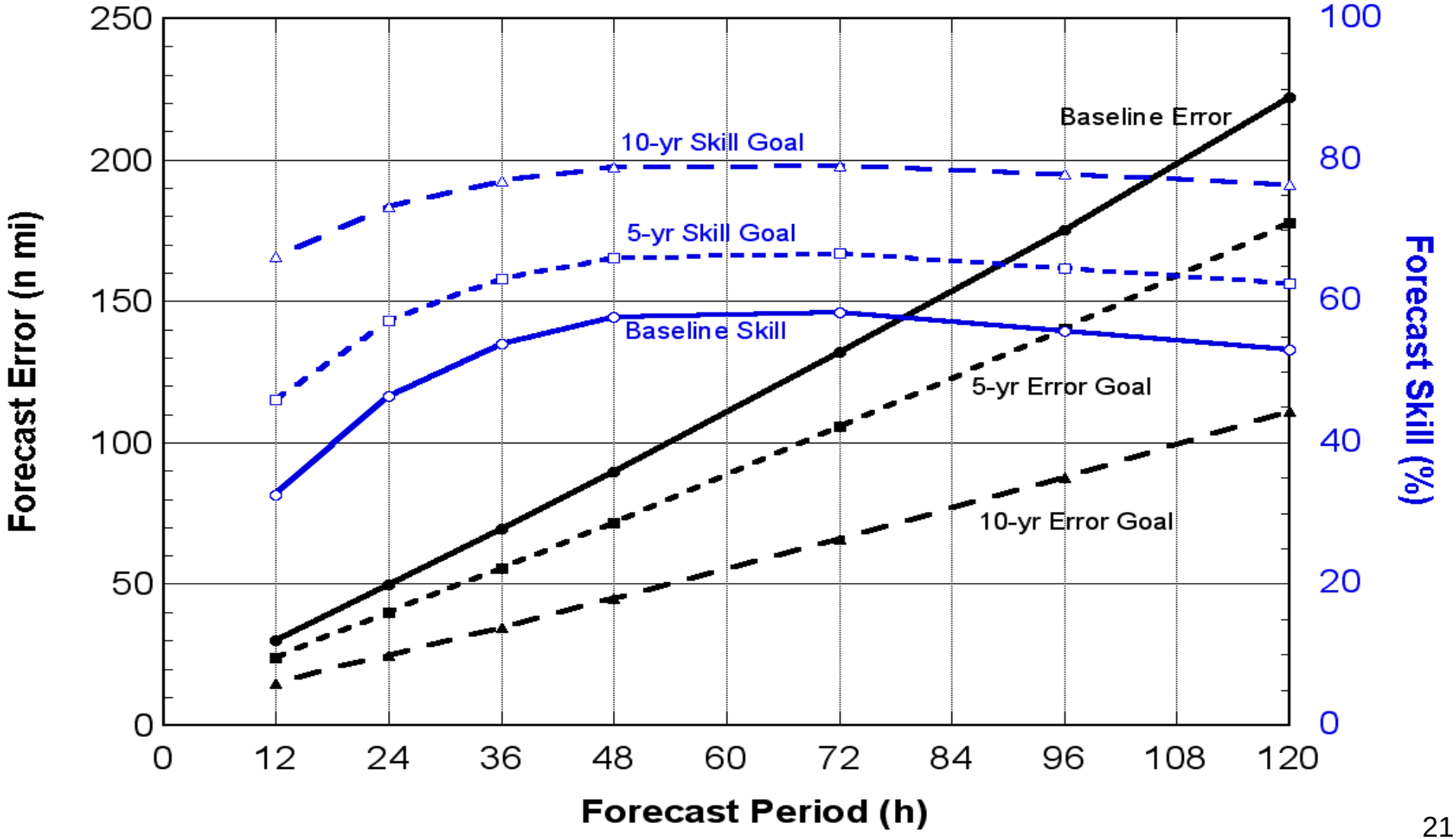
Back Up

HFIP Baselines and Goals

Absolute Error



HFIP Baselines and Goals: Track



Overall Computing Objective

- Several years before NOAA operational computer can run numerical model system necessary to meet the HFIP goals
- HFIP's alternate strategy is building a supercomputer in Boulder for use as an experimental "operational" forecast system during the hurricane season
- System will have 23000 cores for 2012 hurricane season
  - Preliminary version of final experimental "operational" system
  - Demonstration of reaching HFIPs 5yr goal – 20% improvement
- Expected target system will need on the order of 50K cores/ 3K nodes to run fully operational

HFIP 5-year Target Numerical Forecast System

- Global model ensemble with Hybrid Data Assimilation
  - 20 members at 20 km
  - Multi Model (at least two—eg: FIM, GFS, NMMB, Cubed Sphere)
  - National Unified Operational Prediction System – multi-Agency multi-model Operational Ensemble system

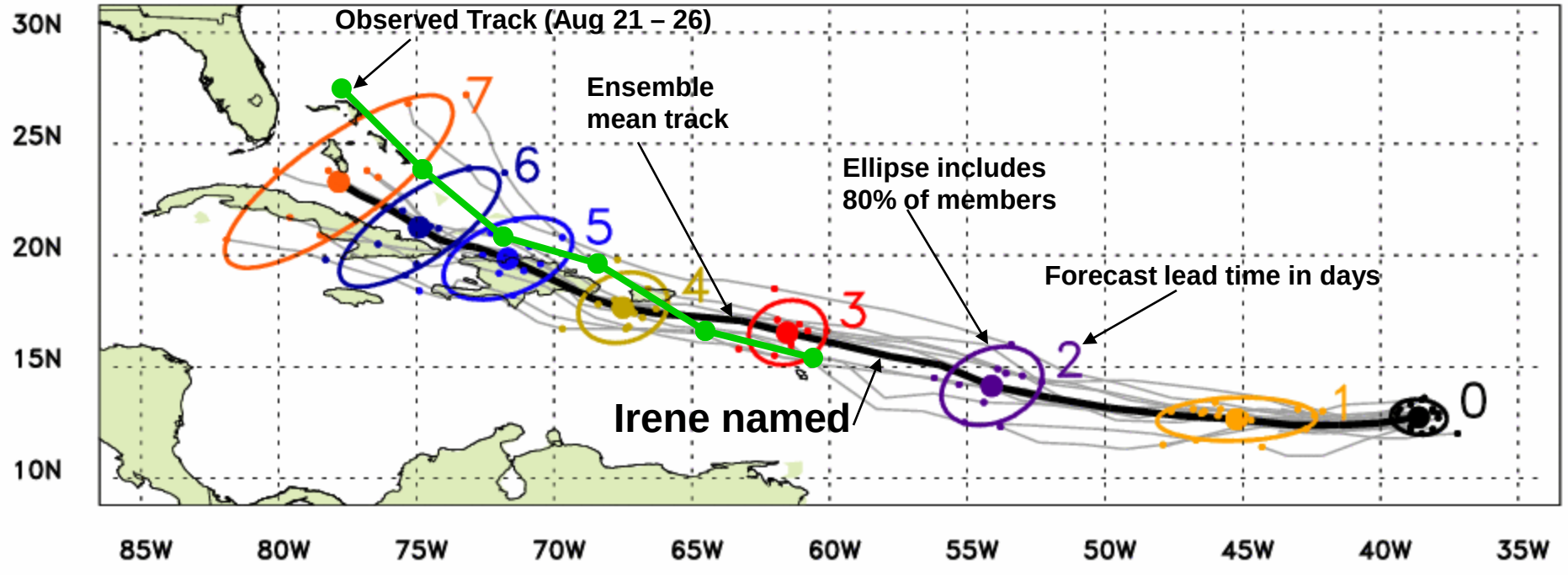
- Regional model ensemble
  - 20 members at 3 km
  - Multi model (at least two—eg: HWRF, AHW, TC-COAMPS)
  - Using all available aircraft and satellite data in core and near environment of hurricane

- Statistical Post processing
  - Bias correction, CBC,LGEM, SHIPS…

Ongoing Challenges
to meet the HFIP 5 and 10 year goals

- Operational high performance computing resources – capacities and capabilities to meet HFIP goals
- Appropriate physics packages, initialization for high resolution (1-3km) regional models
- Improved observing strategies for hurricane core and near storm environment –
  - Better use of satellite data at resolutions appropriate for the hurricane
  - Aircraft/UAV data

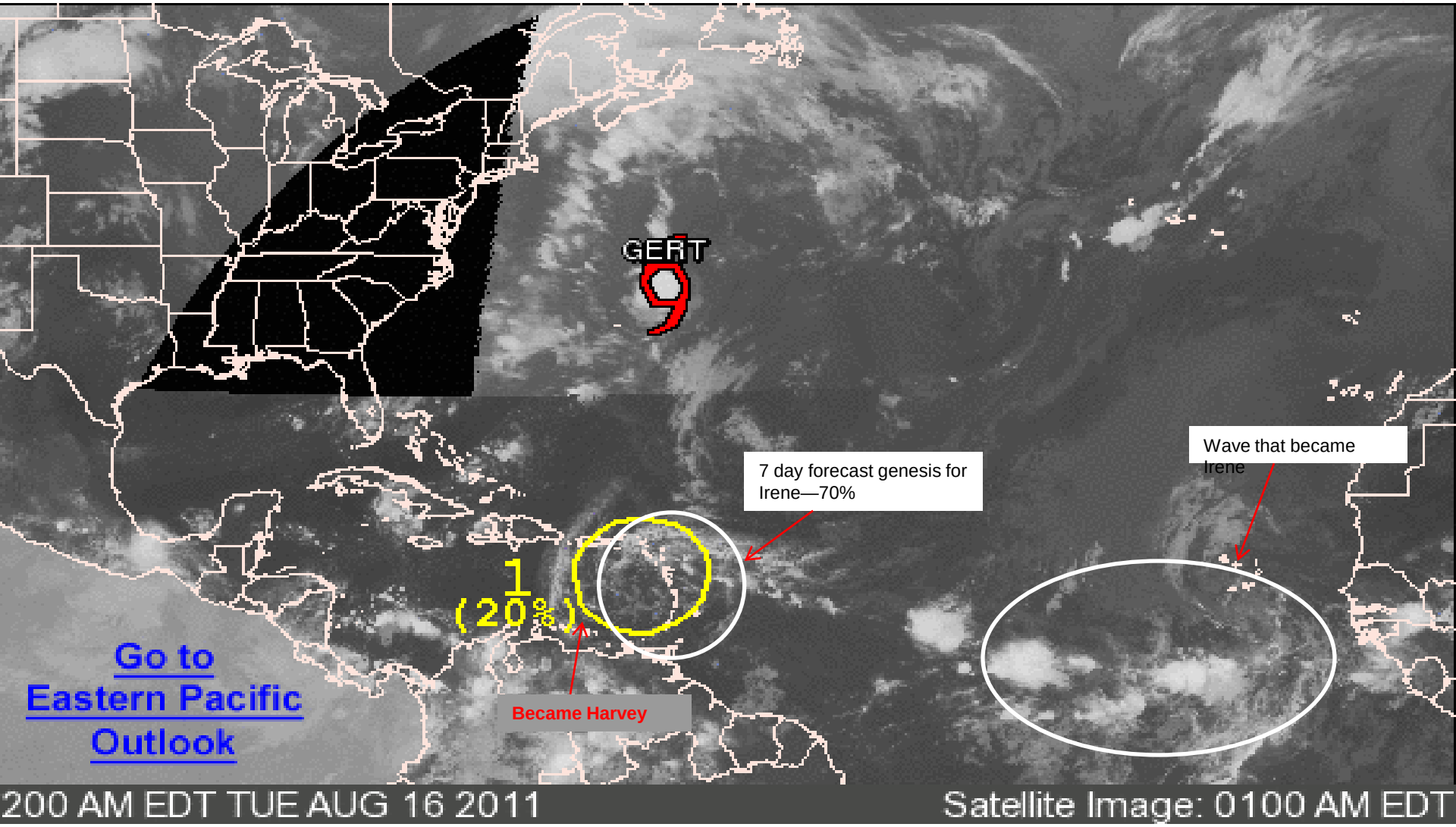
HFIP Global Ensemble Forecast for Irene Starting at 1200Z **August 18, 2011**



- Irene declared an investigation area at 1200Z on August 18, 2011
- Irene named at 0000Z August 21, 2011
- Initial indication of the formation of Irene from ensemble at **00Z August 16, 2011**
  - 2 days before it was declared an investigation area
  - 5 days before it was named

Graphical Tropical Weather Outlook

National Hurricane Center Miami, Florida



Outlined areas denote current position of systems discussed in the Tropical Weather Outlook. Color indicates probability of tropical cyclone formation within 48 hours.

Low <30% Medium 30-50% High >50%

HFIP Configuration

	Install Date	Cores	Performance (Tflops)	Storage (Tbytes)
Phase 1	Aug 2009	3184	35.6	350
Phase 2	Sep 2010	10600	113.0	416
Phase 3*	July 2011	~16,000	~175	~770

- Combining HFIP with additional 3112 cores from other projects
  - Measured Linpack result is 126.5 Tflops
  - This puts it as 50th on the November 2010 Top 500 list
- Current system is 10128 cores on tJet and 472 cores on nJet
  - Sharing of infrastructure and resources allowed for a bigger single system (tjet)

* Estimates based on anticipated FY11 Funds

Timeline

- 2011 set up a preliminary version of the eventual experimental system
  - Included tentative components of 2012 system
  - 10,000 cores
- 2012: Full Experimental system
  - Hopefully ~23,000 cores
- 2013: Full system with modifications as suggested by previous year
  - 23,000 cores
- 2014-? As long as t-jet remains available
  - Replaced by the operational system?

Relative Performance

System	Relative Perfor-mance	Workload comparison	Power Consumption
HFIP	1	10600	340 KW
Power 6	1.07	9138	1600 KW
Cray XT6	0.66	17660	382 kW

- Relative Performance – Comparison to 1024 core WRF job
  - Similar computationally to HWRF and other atmospheric codes
- Workload Comparison – How many cores it would take to match the performance of the HFIP system
- Power Consumption – Power necessary for the comparative system