# HFIP ENSEMBLE TEAM UPDATE

**Carolyn Reynolds (NRL) carolyn.reynolds@nrlmry.navy.mil**
**Zoltan Toth (ESRL) zoltan.toth@noaa.gov**
**Sim Aberson (HRD) Sim.Aberson@noaa.gov**
**Tom Hamill (ESRL) tom.hamill@noaa.gov**
**Jeff Whitaker (ESRL) Jeffrey.S.Whitaker@noaa.gov**
**Fuqing Zhang (PSU) fzhang@psu.edu**
**Yuejian Zhu (EMC) Yuejian.Zhu@noaa.gov**
**Jun Du (EMC) Jun.Du@noaa.gov**
**Mike Brennan (NHC) Michael.J.Brennan@noaa.gov**
**Mrinal K Biswas (FSU) Mrinal.K.Biswas@noaa.gov**
**Krish (FSU) tkrishnamurti@fsu.edu**

•Develop more reliable and useful automated probabilistic numerical guidance for hurricane track, intensity, structure, rainfall, storm surge, and other associated weather elements through improved ensemble forecasting systems and improved post-processing methods

•Work closely with HFIP ***Data Assimilation Team*** on development and use of ensemble-based data assimilation techniques for initializing ensemble predictions

•Work with ***Verification Team*** on developing and using ensemble/probabilistic measures

•Work with ***Applications/DiagnosticsTeam*** to develop ensemble/probabilistic products

# Major Milestones & Accomplishments

- **Real-time global ensembles: GSI/ENKF, EMC, other groups**
- **Real-time regional ensembles: Several ensemble DA efforts, some ensemble forecast efforts**
- **Ensemble design: Ensemble DA efforts, model uncertainty, initial condition uncertainty**
- **Collaborative development of HFIP regional EFS: Effort has started, more from B. Etherton, M. DeMaria**
- **Post-processing: Examples for wind probabilities, intensity, genesis**

# Next Global Ensemble Forecast System

Yuejian Zhu,
Dingchen Hou, Richard Wobus, Mozheng Wei,
Jessie Ma, Bo Cui, Jiayi Peng and Shrinivas Moorthi

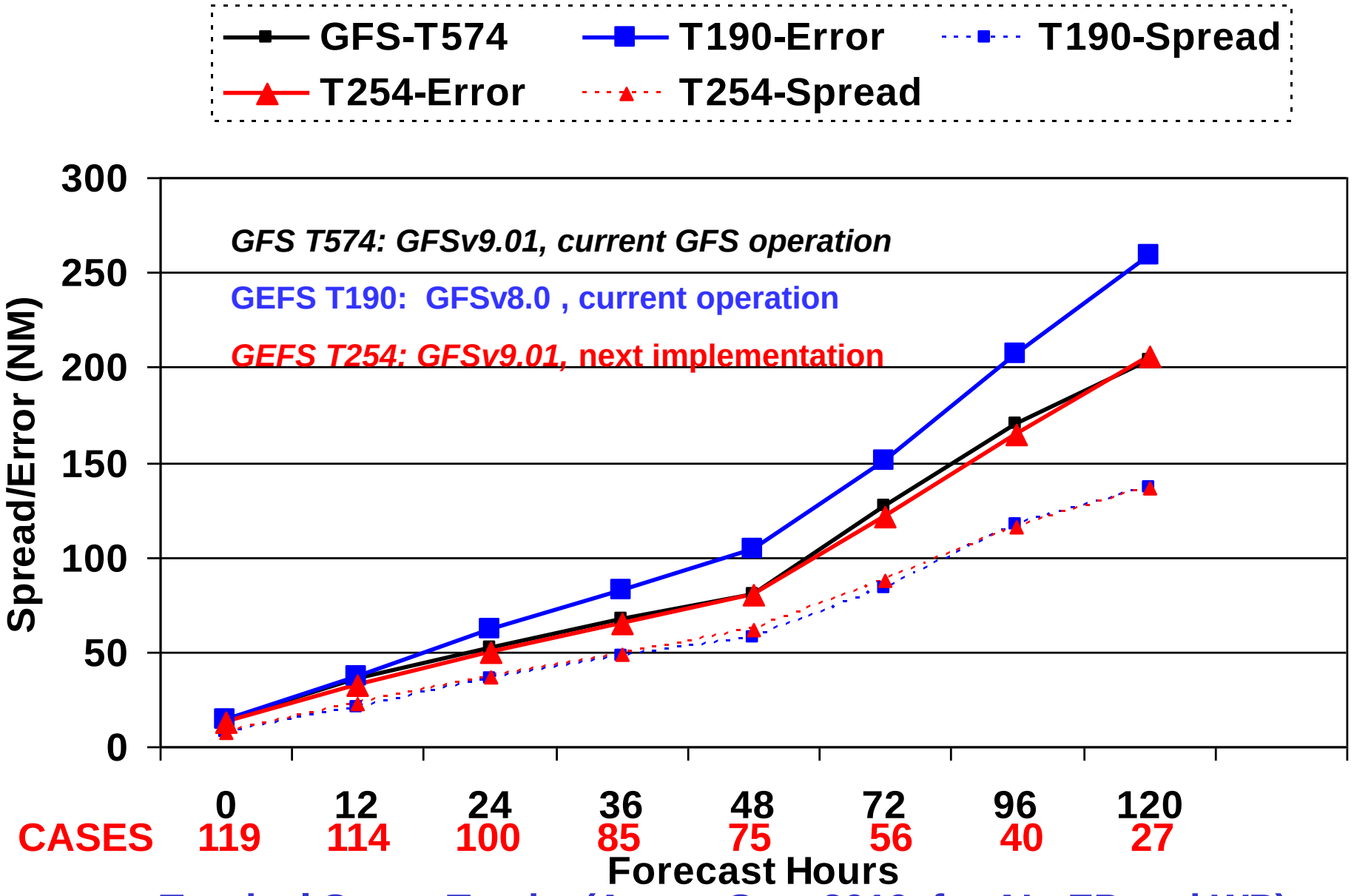
Acknowledgements:
Julia Zhu, Weiyu Yang, Malaquias Pena, Yucheng Song, Yan Luo and Jun Du

Ensemble Team

http://wwwt.emc.ncep.noaa.gov/gmb/yzhu/html/imp/201109_imp.html

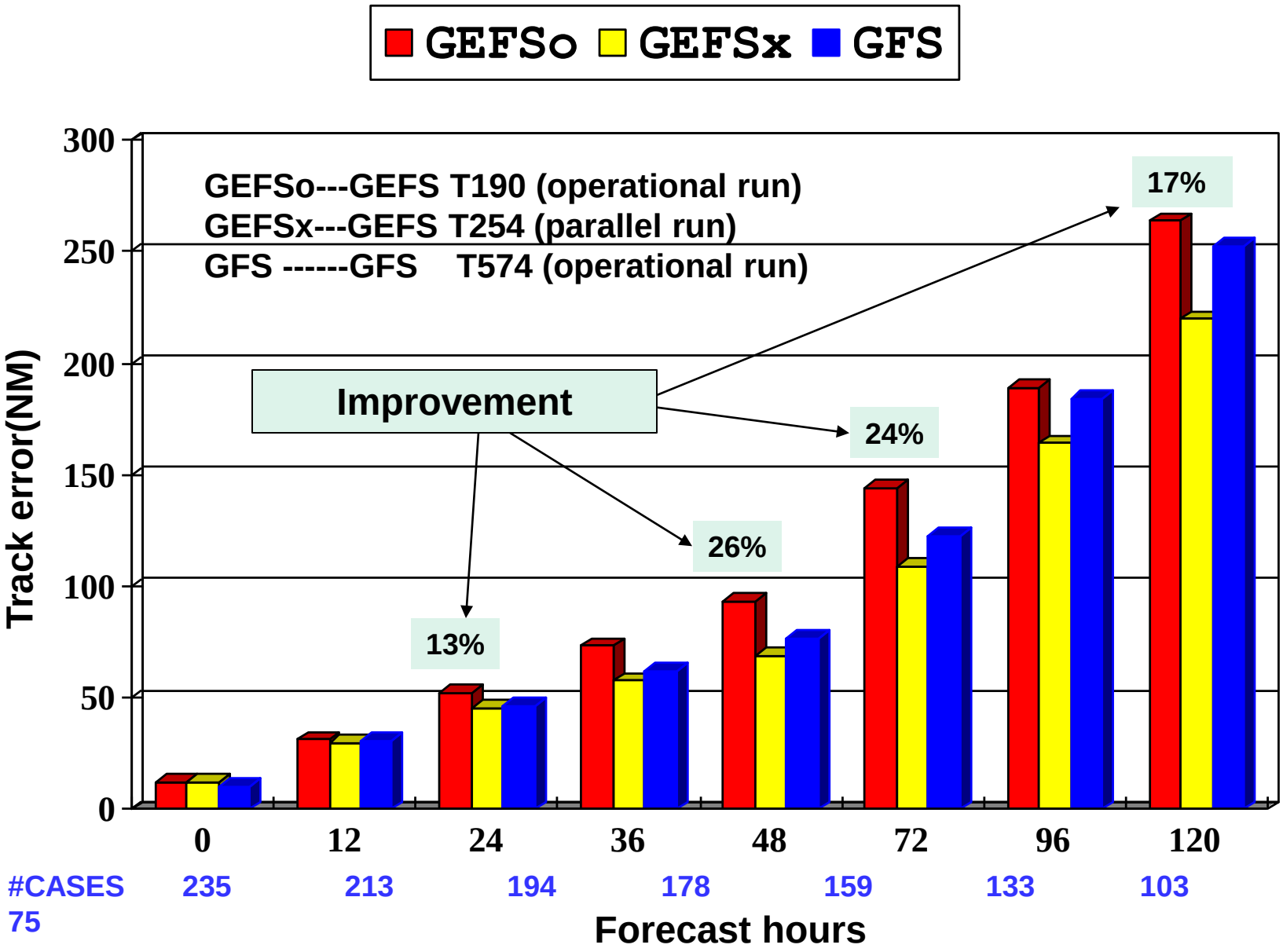
- **Model and initialization**
  - **Using GFS V9.01 (current operational GFS) instead of GFS V8.00**
  - **Improved Ensemble Transform with Rescaling (ETR) initialization**
  - **Improved Stochastic Total Tendency Perturbation (STTP)**
- **Configurations**
  - **T254 (55km) horizontal resolution for 0-192 hours (from T190 – 70km)**
  - **T190 (70km horizontal resolution for 192-384 hours (same as current opr)**
  - **L42 vertical levels for 0-384 hours (from L28)**
- **Upgrade scheduled for January 2012**

# GEFS-T254 (January 2012)



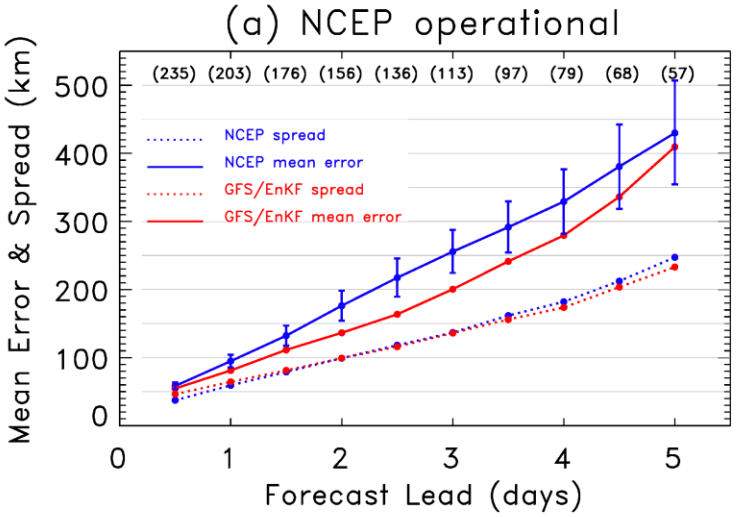

Tropical Storm Tracks (Aug. – Sep. 2010, for AL, EP and WP)

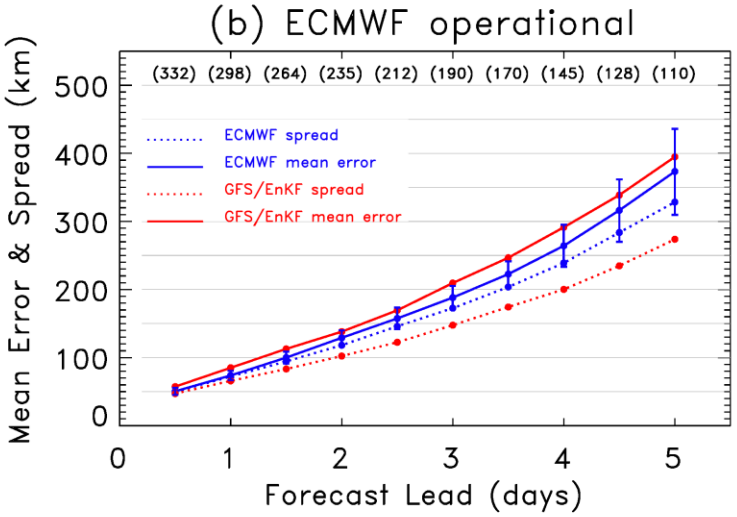
# Atlantic, AL01~17 (06/01~09/30/2011)

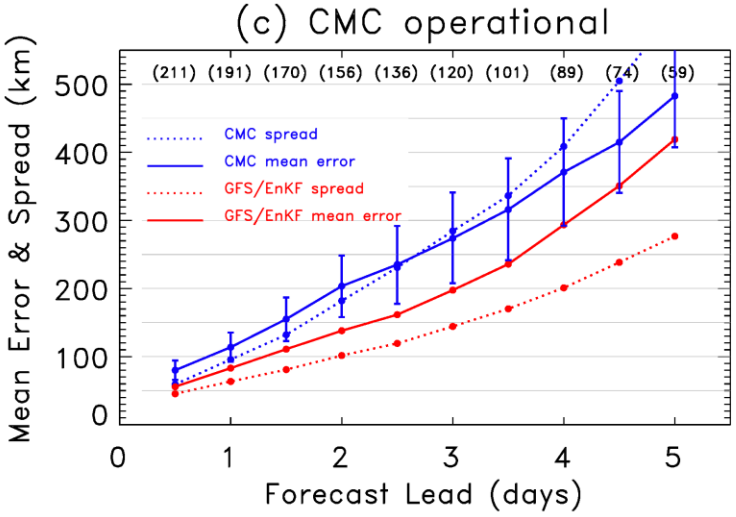


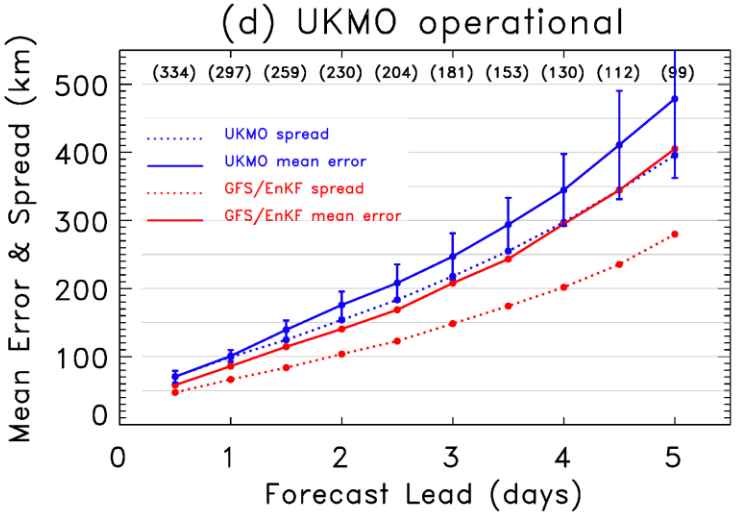
# GFS/ENKF (J. Whitaker, D. Kleist, T. Hamill)

## Hurricane track errors, 2011(through early Oct)



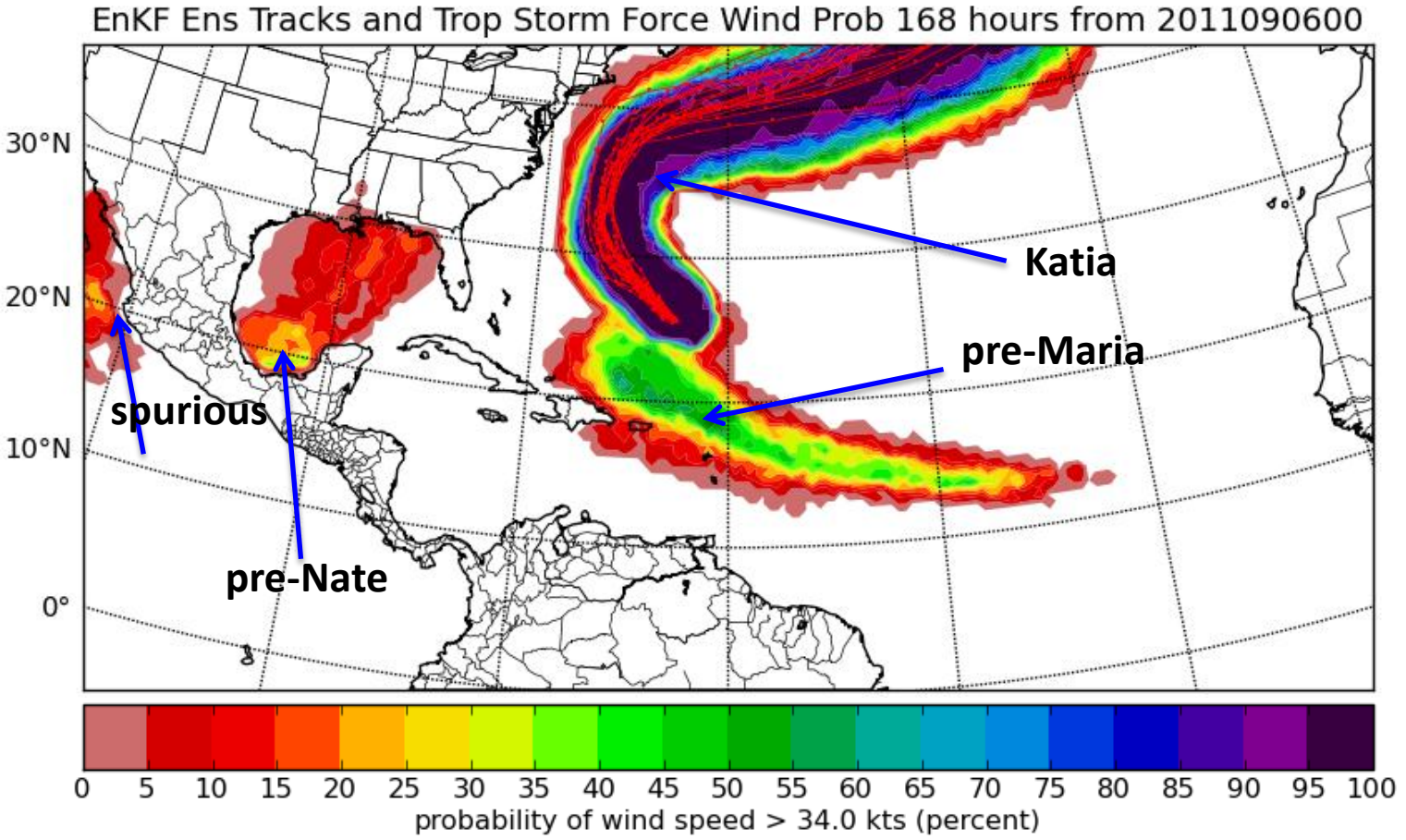




**EnKF has less consistency between spread and error in 2011, possibly due in part to the limited resolution (T254)**

# New GFS/EnKF Ensemble TC Wind Prob Product
# ESRL-PSD HFIP Team

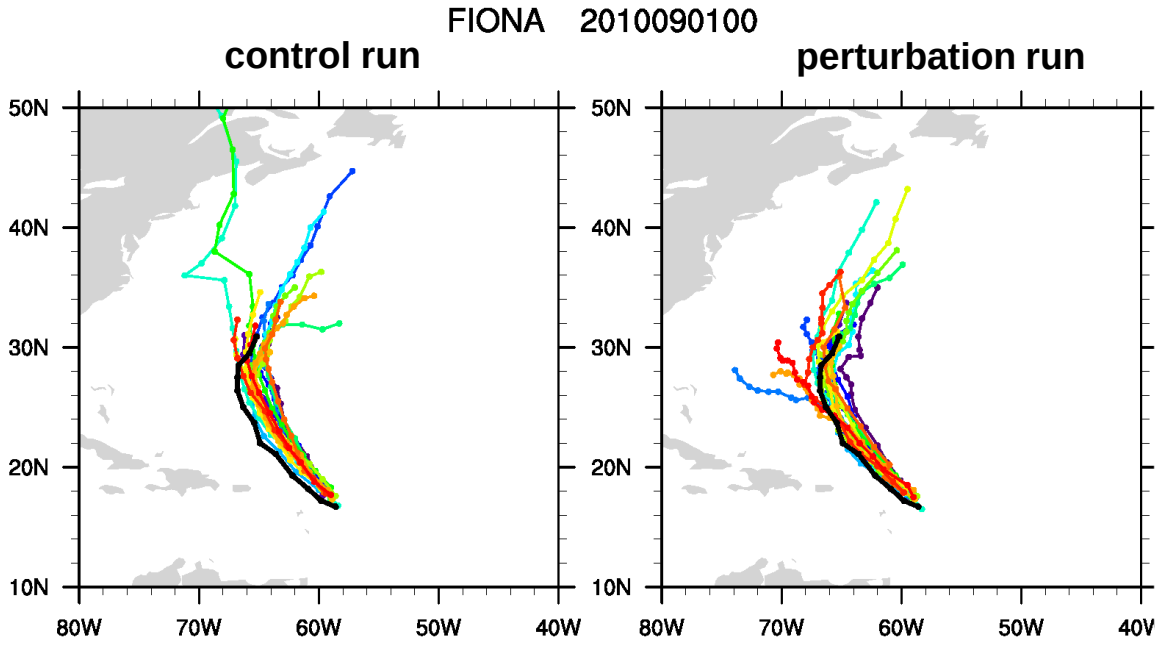


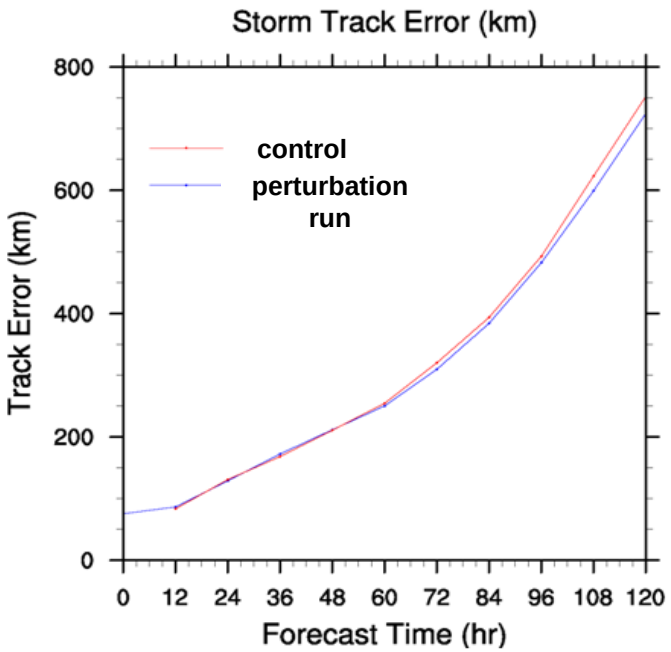

- TS wind cumulative prob contoured (computed from 20 GFS members).
- Tracks for storms (not invests) present at initial time shown as red lines.
- Prob “swaths” not associated with tracks are new storms (TC genesis).
- Will be verifying probabilities for tracked and untracked (genesis) probs separately.

# Accounting for Physics Uncertainties in the GFS Based Ensemble Track Prediction

J.-W. Bao, E. D. Grell, J. S. Whitaker, G. A. Grell, T. Hamill
NOAA/ESRL, Boulder, Colorado

**Increased ensemble spread and decreased ensemble-mean error with Grell-Devenyi convection scheme permutations**

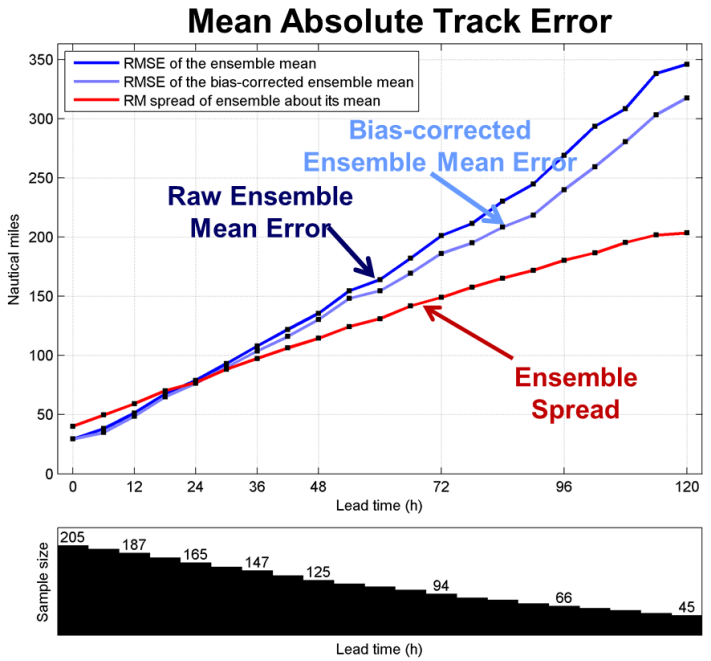


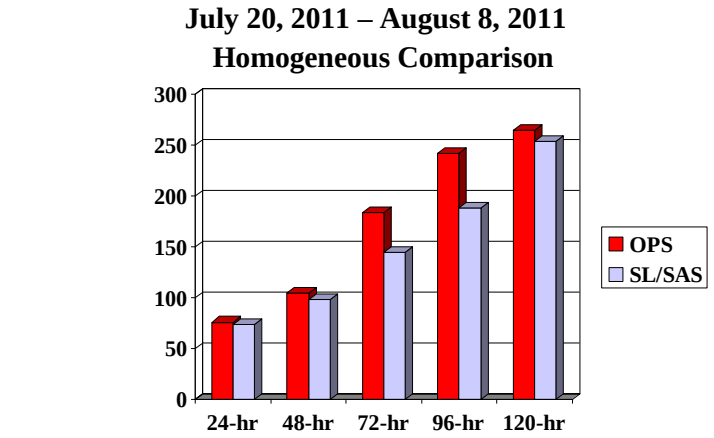
# NRL Global Ensemble Upgrades

C. Reynolds, J. McLay, J. Moskaitis, E. Serra

- **Sept 2011: Upgrade NOGAPS ensemble from T119 to T159.**
- **2010 high-resolution experiments: ET formulation and stochastic forcing impact spread, not mean.**
- **Track improvements from (in sample) bias correction.**




- **FY2012: Navy Global Environmental Model (NAVGEM)**
  - **Semi-Lagrangian advection for higher resolution**
  - **Improved physical parameterizations**
  - **Currently in pre-operational testing at FNMOC**
  - **Planned for ensemble at T239**



# NRL COAMPS-TC Forecast Ensemble

A. Reinecke, J. Moskaitis, J. Doyle

DA and forecast for Atlantic, EastPac, and WestPac basins

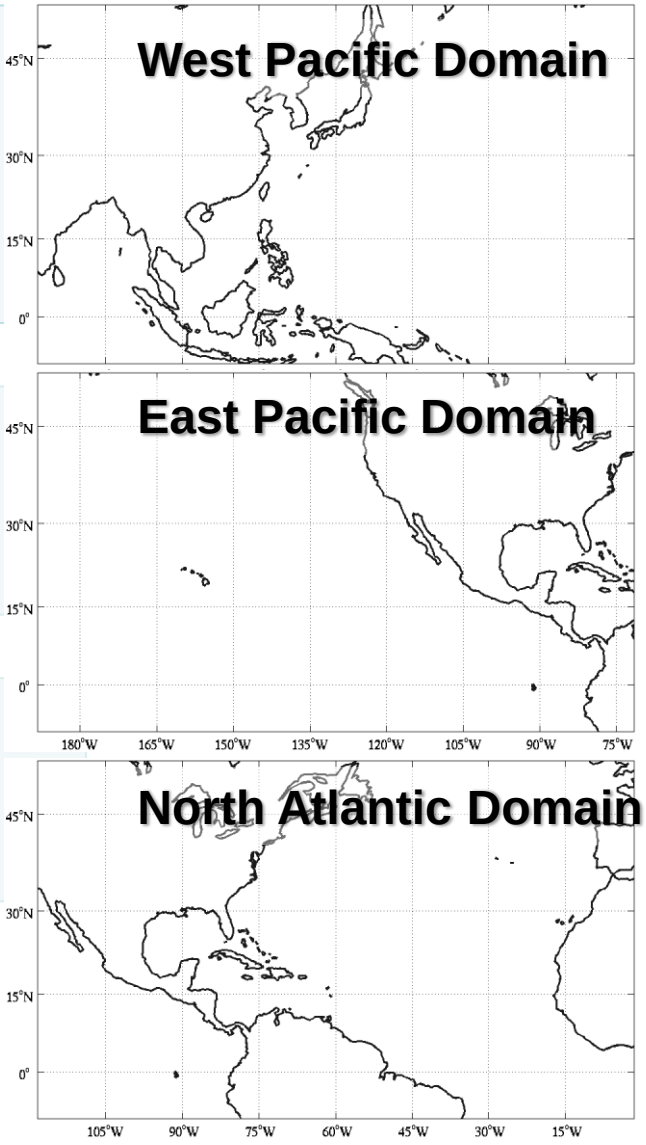
- Fixed 45-km mesh for each basin
- Imbedded 15- and 5-km moving nests
- 80-member serial EnKF for data assimilation (DART)
- For each storm mesh is initialized once with GFS-EnKF analysis fields

10-members (option to run 20-members)

- 120-h lead time twice daily (00 and 12 UTC)
- GFS-EnKF lateral boundary conditions
- Real-time forecasts available by +5:30

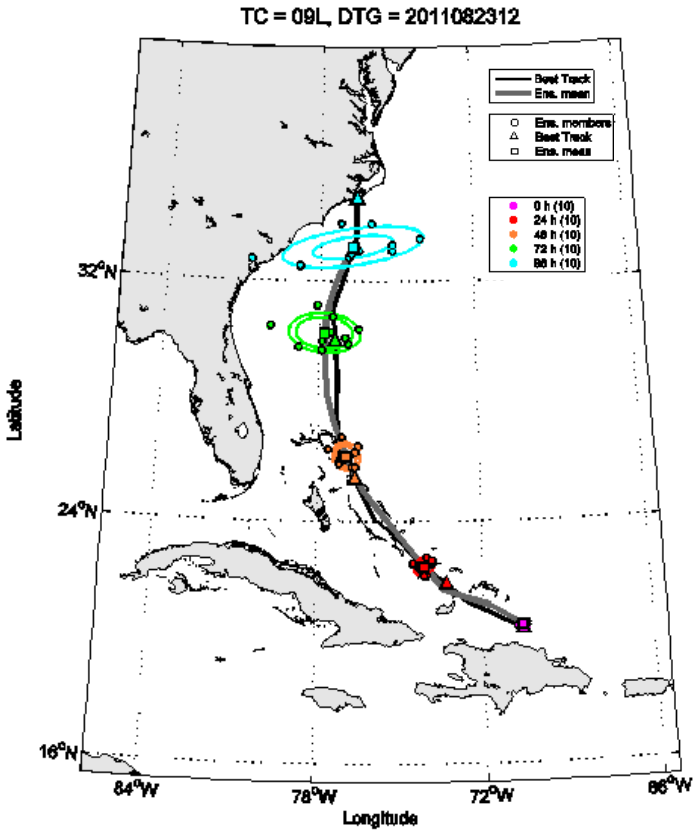
Perturbations

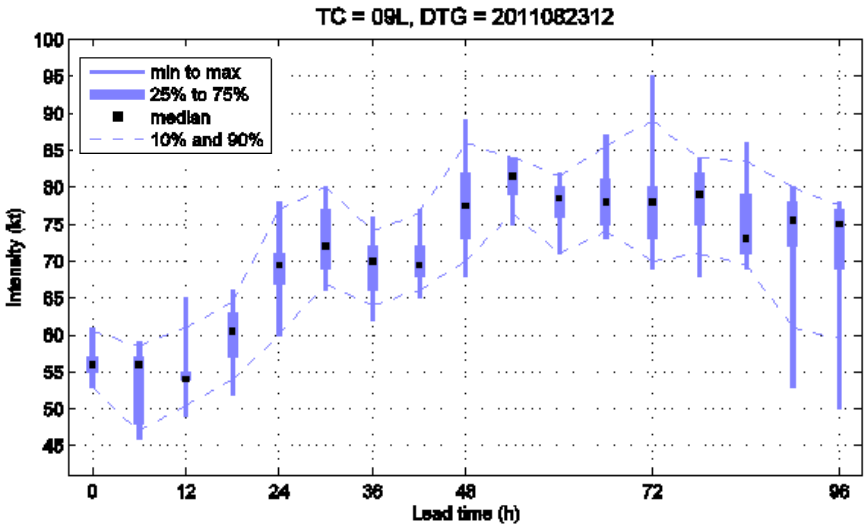
- IC perturbations from member 1-10 of the 80 member DA ensemble
- No perturbations to model dynamics or parameterizations



# COAMPS-TC Ensembles

## Web Graphics Output




**TC position from individual ensemble members every 24 h and ellipses that encompass the 1/3 and 2/3 ensemble distributions.**

**Median, minimum, maximum, and 10% and 90% distributions are shown**

**Products from COAMPS-TC Ensemble System were on the web available by +7:20**

# HFIP Regional Ensemble Forecast Working Group

1. **Accelerate progress in HFIP regional multi-model ensemble development by enhancing communication and collaboration.**

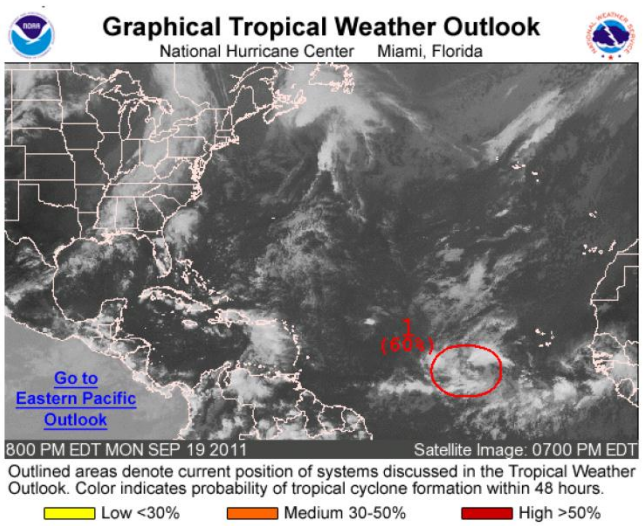
2. **Develop a community prototype regional ensemble forecast system offering a common platform for the testing and comparison of new methods both for the generation of ensemble forecasts and derived products.**

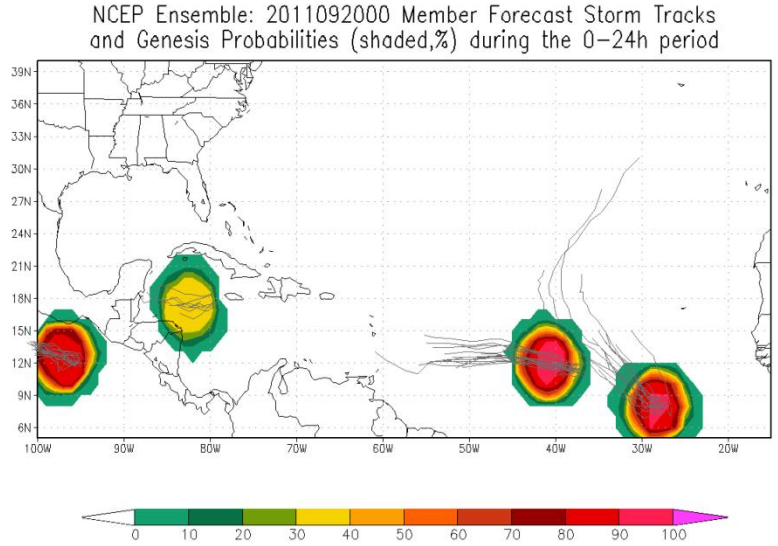
3. **Using the most promising techniques and based on a consensus approach prepare and test in real time a regional hurricane ensemble forecast system suitable for transition to NCEP operations.**

**Subgroup 1 (Brian Etherton): prototype ensemble design and generation.**
**Subgroup 2 (Mark DeMaria): ensemble product development.**
**Subgroup 3 (Paula McCaslin and Thiago Quirino): web-based collaborative tools (telecons with subgroup 2).**

# Examples of Ensemble Genesis Products (T. Marchok)

Ensemble track-based probabilistic genesis guidance




Probability is simply the percentage of members indicating genesis in a given lead time window (here, 0-24h).

# Probabilistic Tropical Storm Position Forecasts

Wesley Smith, Paula McCaslin, & Zoltan Toth

NOAA/ESRL/Global Systems Divison/Forecast Applications Branch

Funded by the Hurricane Forecast Improvement Program (HFIP)

September 14th, 2011

## Verification Results (2010, GEFS)

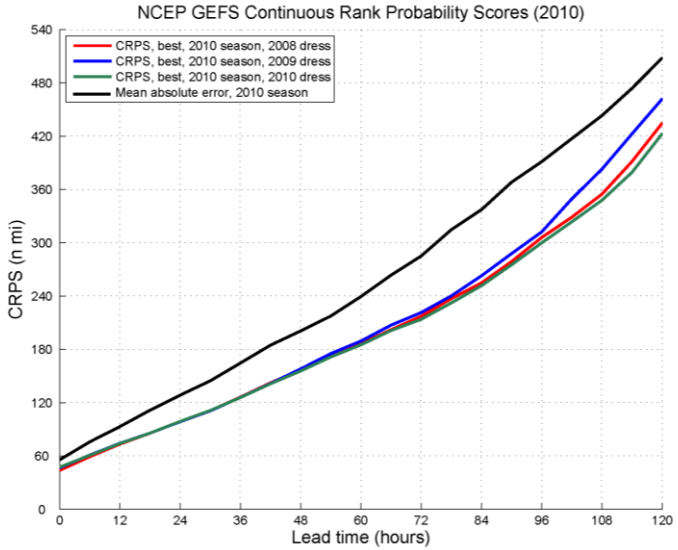



Figure: CRPS for storm position pdf forecasts in the Atlantic during the 2010 season, created with the 20-member GEFS global ensemble.

## Algorithm Overview

1. **Aggregate recent position error statistics.** For each case:
   1. Determine the best member of the ensemble.
   2. Decompose the best member errors into along-track and cross-track components.
   3. Fit bivariate Gaussian kernels to the aggregated errors at each lead time.
   4. In a multi-model ensemble, seperate kernels are derived for each member.
2. **Produce a calibrated storm position PDF (SPPDF).** The SPPDF is a mixture of the determined kernels, located at corresponding forecast positions. This "dresses" the ensemble with historical best member error statistics.
3. **Calculate storm position probability.** Integrate the SPPDF over a specified region to obtain the probability that the storm center is located within that region.

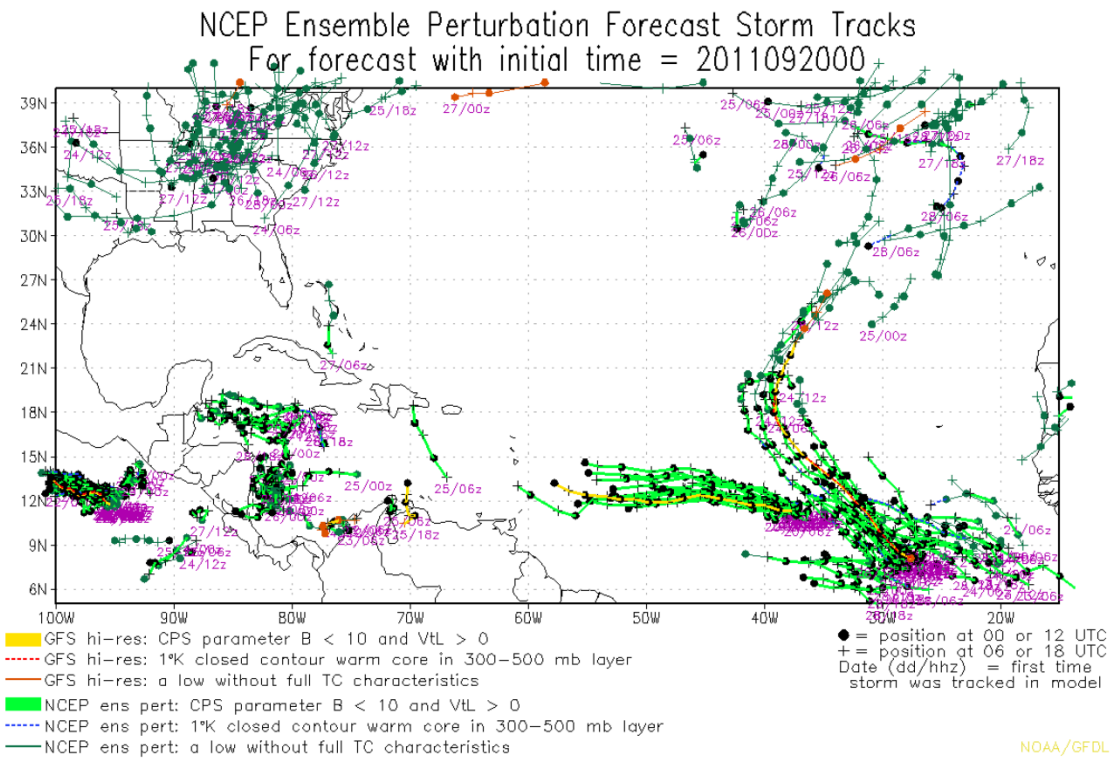
# Priorities and Challenges

- Probabilistic product development and validation.
- Regional multi-model ensemble forecasts.
- Understanding predictability of hurricane intensity.
- Accounting for model uncertainty properly in ensemble predictions of TCs.
- Advanced data assimilation methods.
- Value of statistical post-processing using reforecasts; new GEFS reforecast data set available to study. Train LGEM on reforecast data?

# NCEP/EMC Extra Slides

# Examples of Ensemble Genesis Products (T. Marchok)

## 2. Track-based guidance

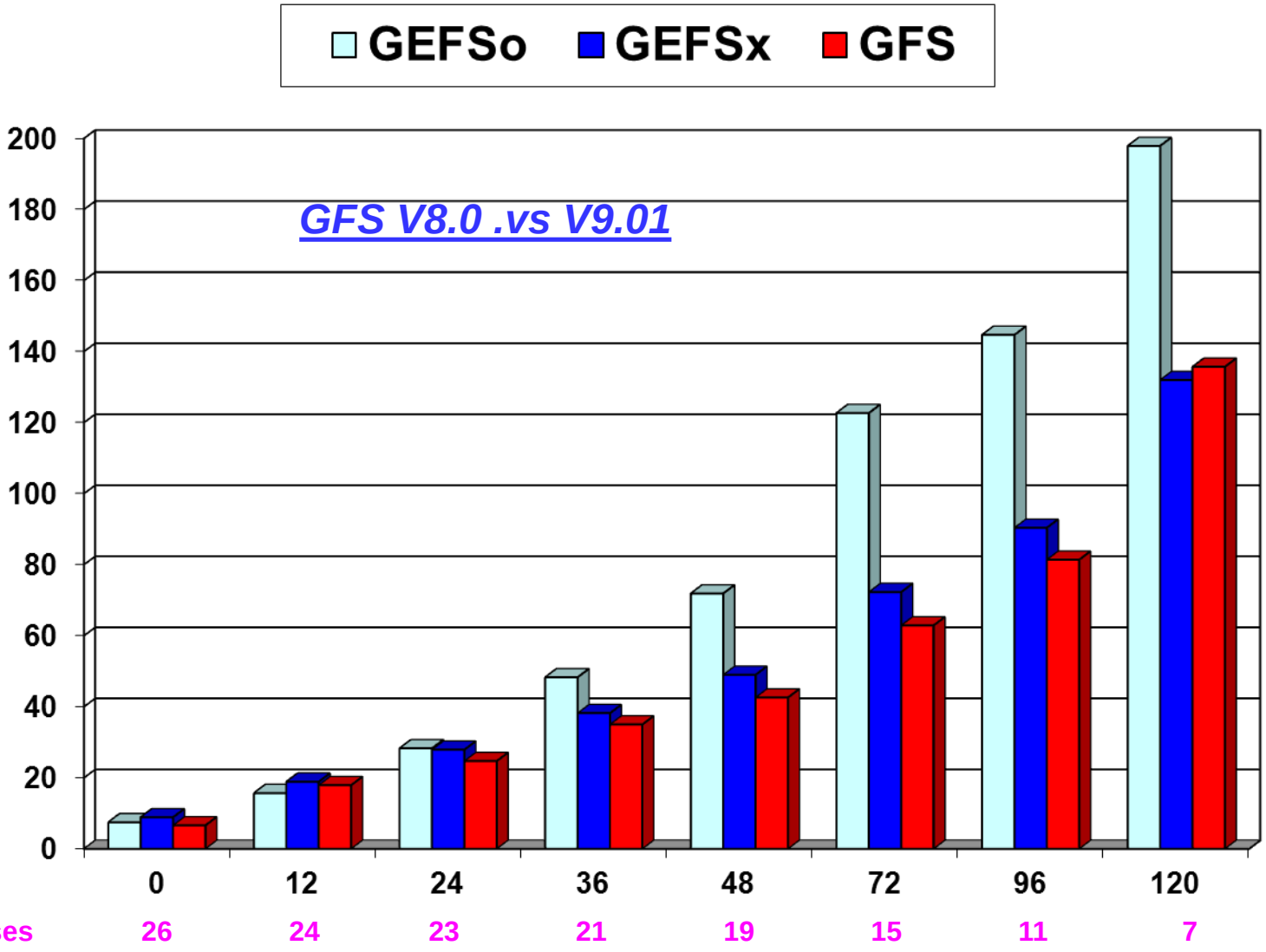



http://www.emc.ncep.noaa.gov/gmb/tpm/emchurr/tcgen

A few critical criteria for tracking and TC / non-TC determination

- At least one closed mslp contour
- Azimuthally averaged 850 mb $V_T$ must exceed threshold
- Cyclone phase space & simple warm core checks used for TC / non-TC determination
- Forecast storm must last at least 24h

# Track forecast error for Hurricane Irene (2011)

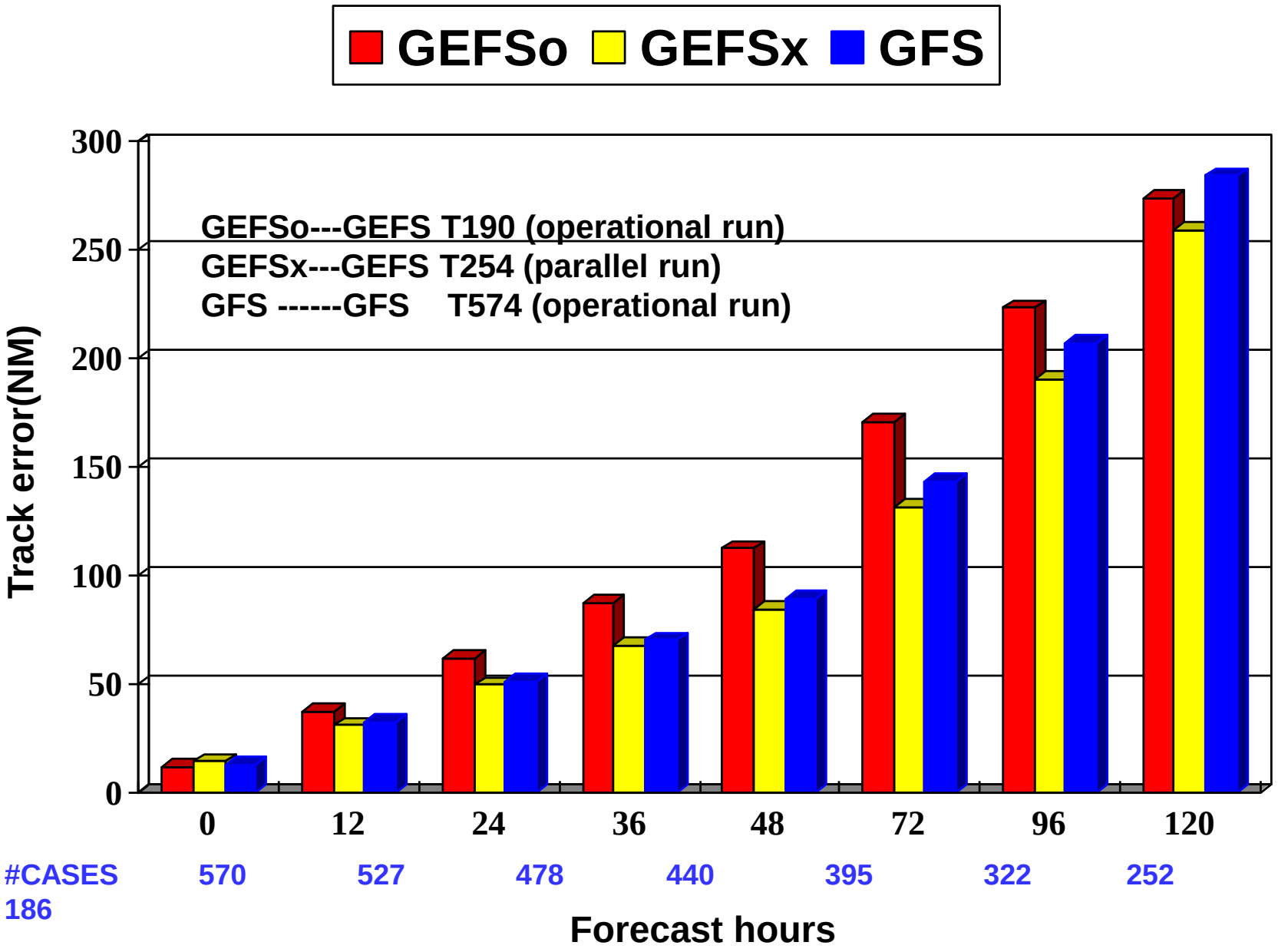



**Period: 08/20 – 08/27/2011**

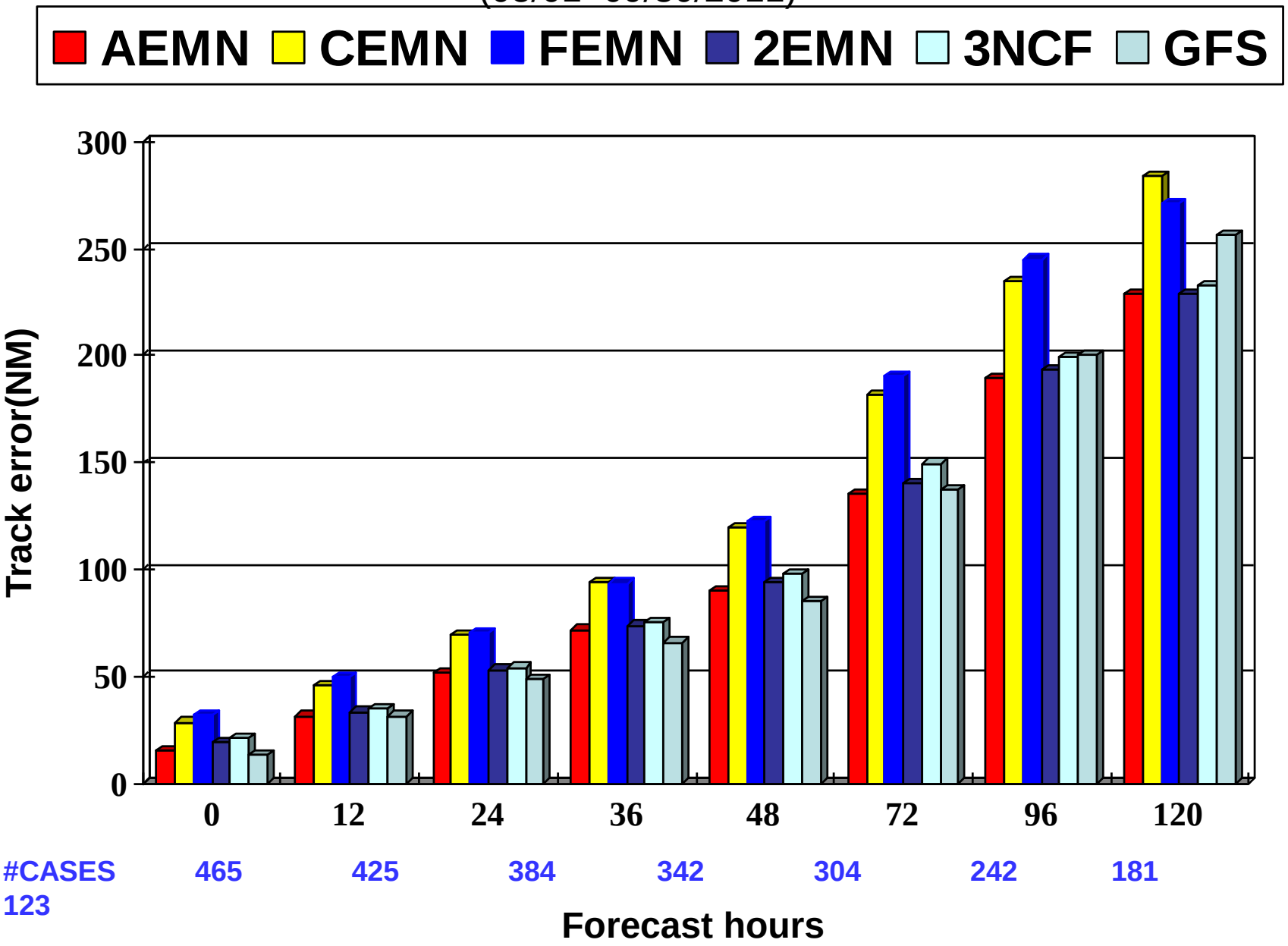


Contributed by Dr. Jiayi Peng (EMC/NCEP)

**Atlantic, East and West Pacific, AL01~17, EP01~09,WP05~22 (06/01~09/30/2011)**



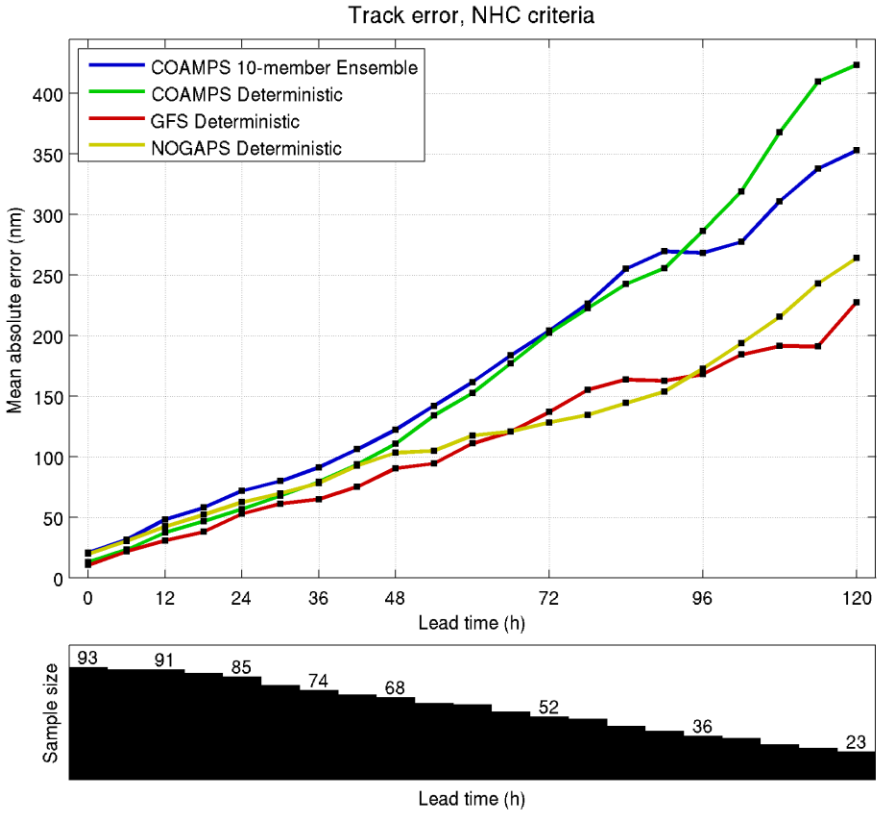
Atlantic, East and West Pacific, AL01~17, EP01~09,WP03~22
(05/01~09/30/2011)

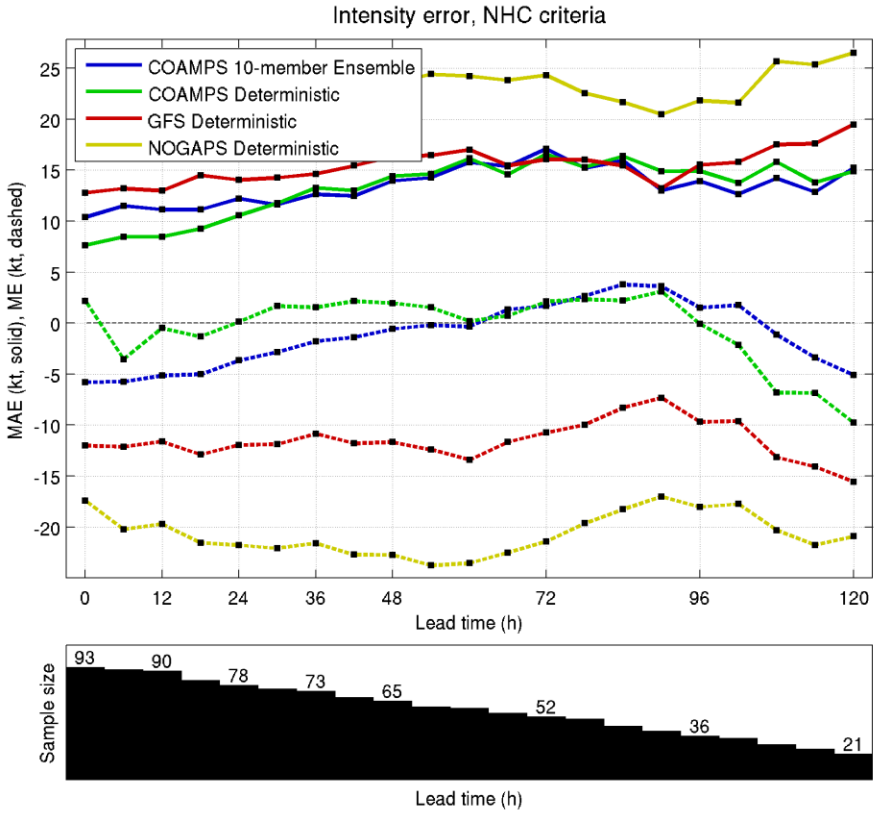


# NRL Extra Slides

# Track and Intensity Errors

## Homogeneous Comparison -- 2011

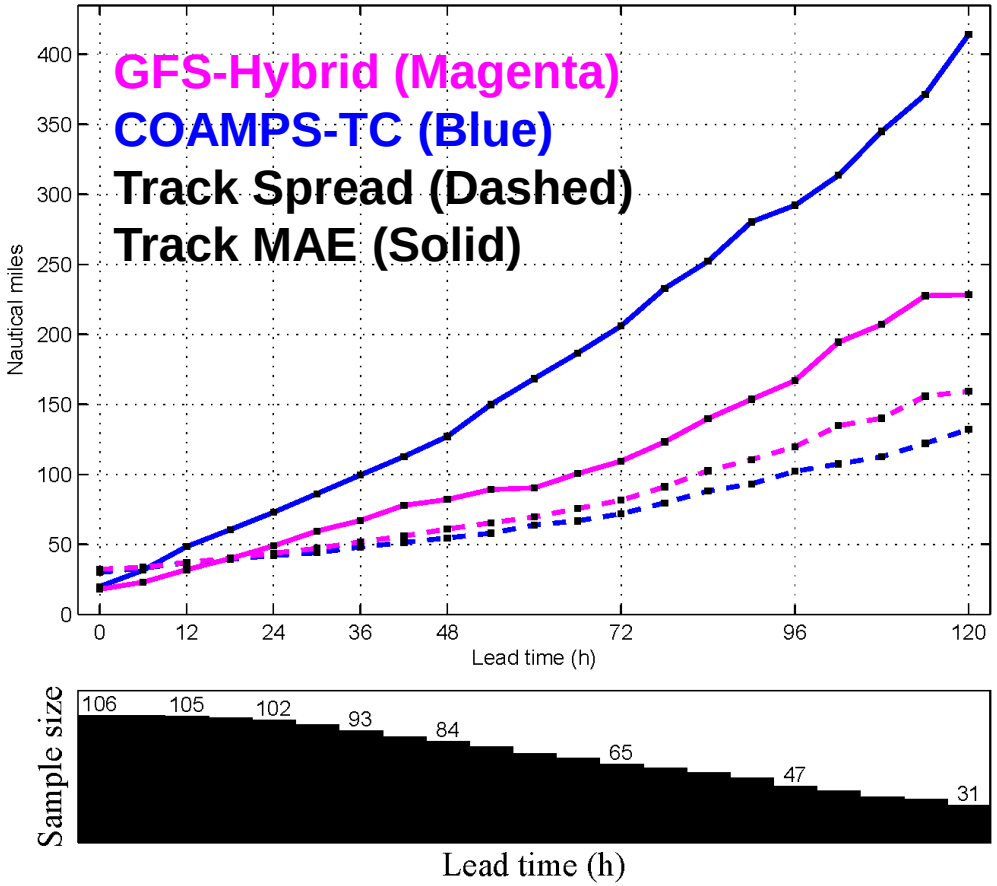



- **COAMPS (det. & ens.) track forecast worse than global models, intensity is better.**
- **Ensemble system track forecast are better than deterministic system beyond 72 hours.**
- **Low wind speed bias for ensemble system from 0 to 48 hours.**

# Track Spread-Skill Relationship

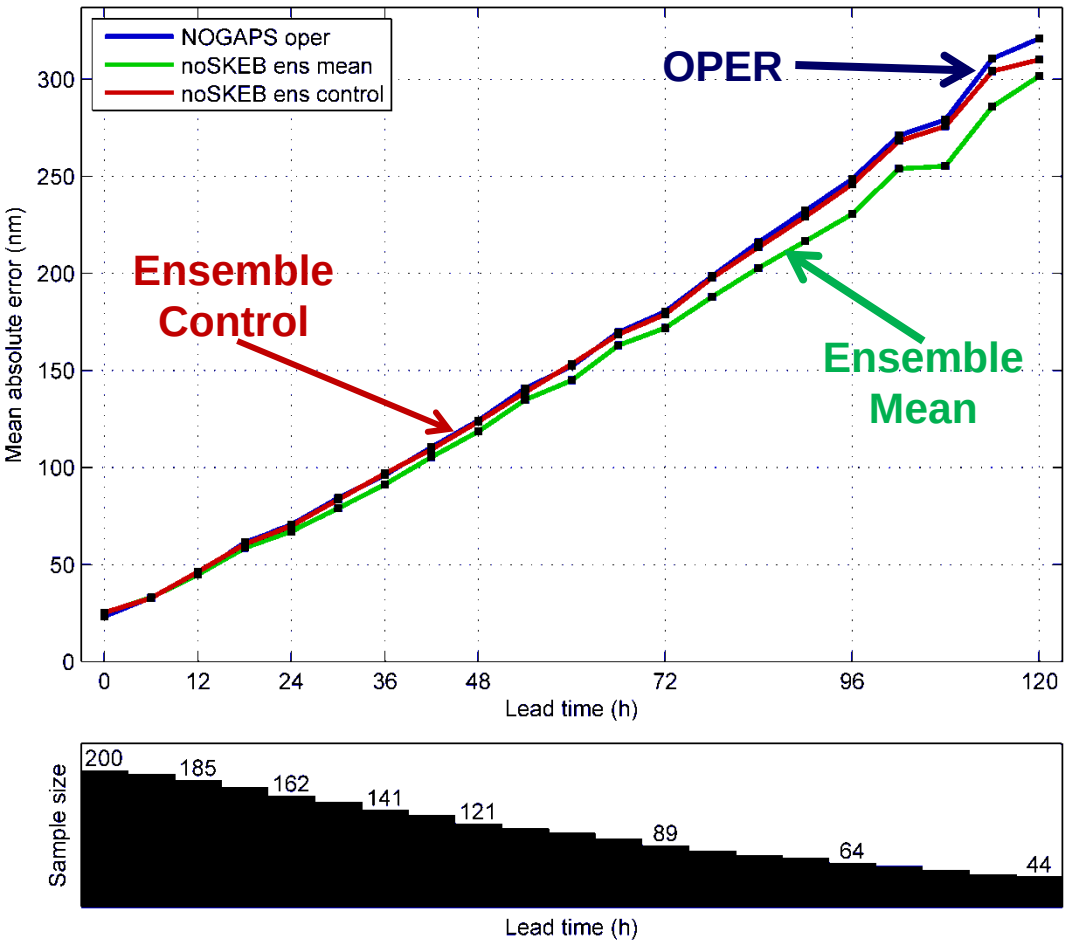
## Homogeneous comparison to GFS-Hybrid



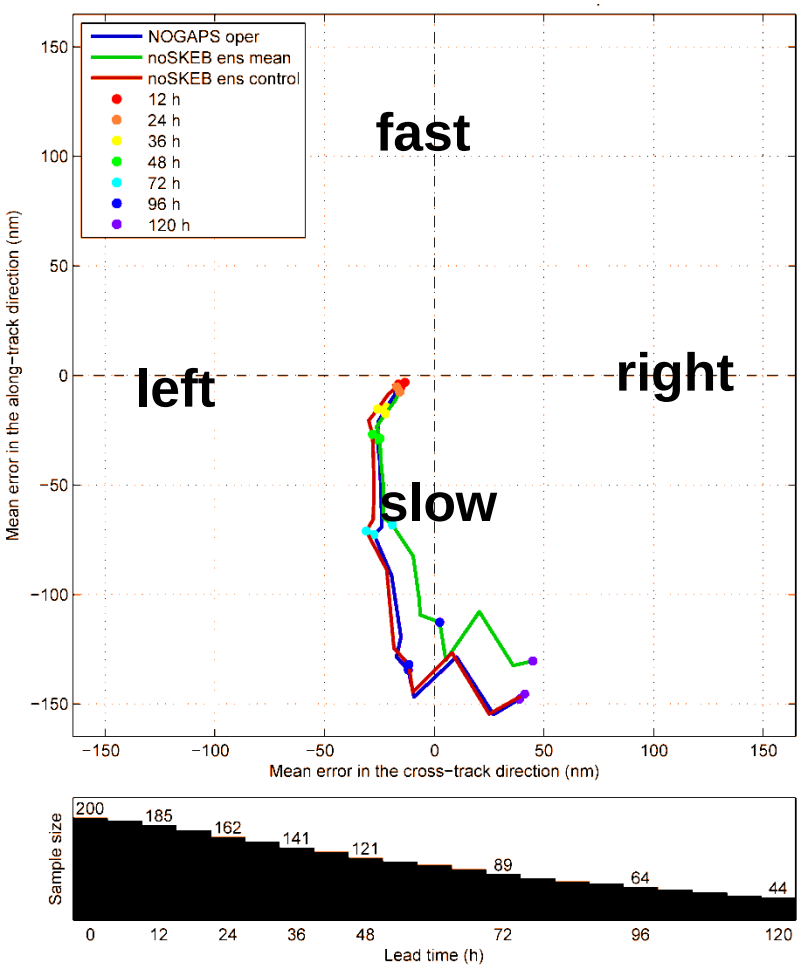

- **Track spread is comparable to HFIP GFS-Hybrid system**
- **Large track errors are similar to deterministic COAMPS-TC system**
- **On average spread-skill good at analysis time**

# High-resolution Real-time Ensembles

## Mean Absolute Track Error



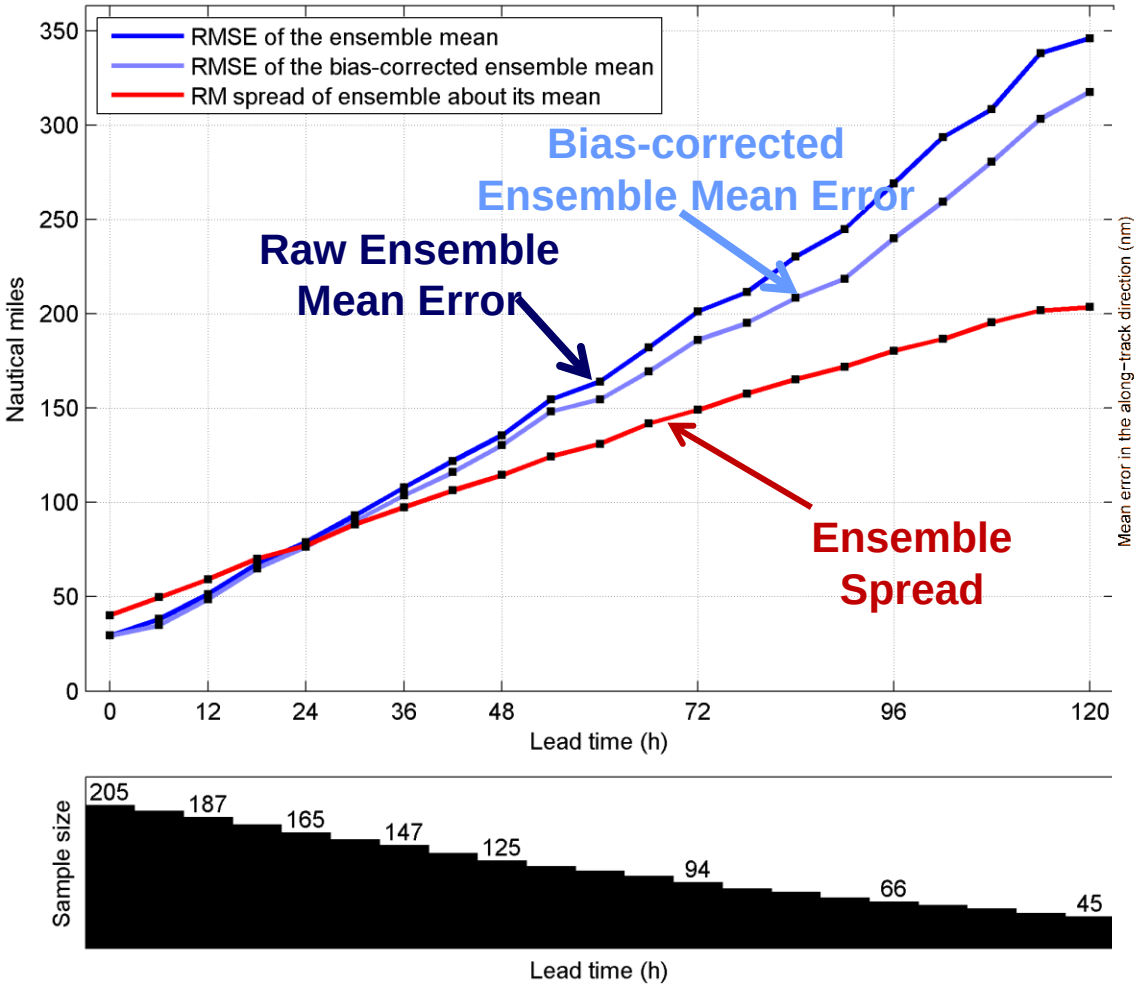

## Track Bias



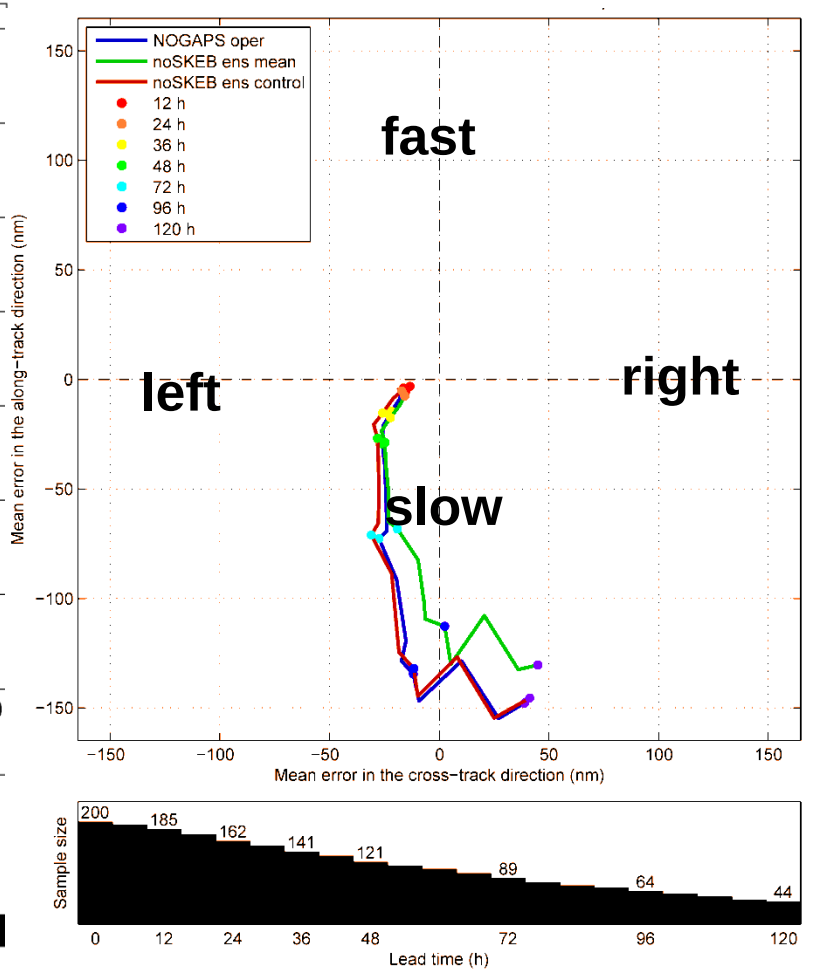

**Ensemble mean slightly better than control member and operational forecast. All forecasts are slow.**

# High-resolution Real-time Ensembles

## Mean Absolute Track Error




## Track Bias




**After 24 hours, ensembles are under-dispersive (ensemble spread less than ensemble mean error). Removing the cross and along-track biases reduces track error.**

# ESRL Extra Slides

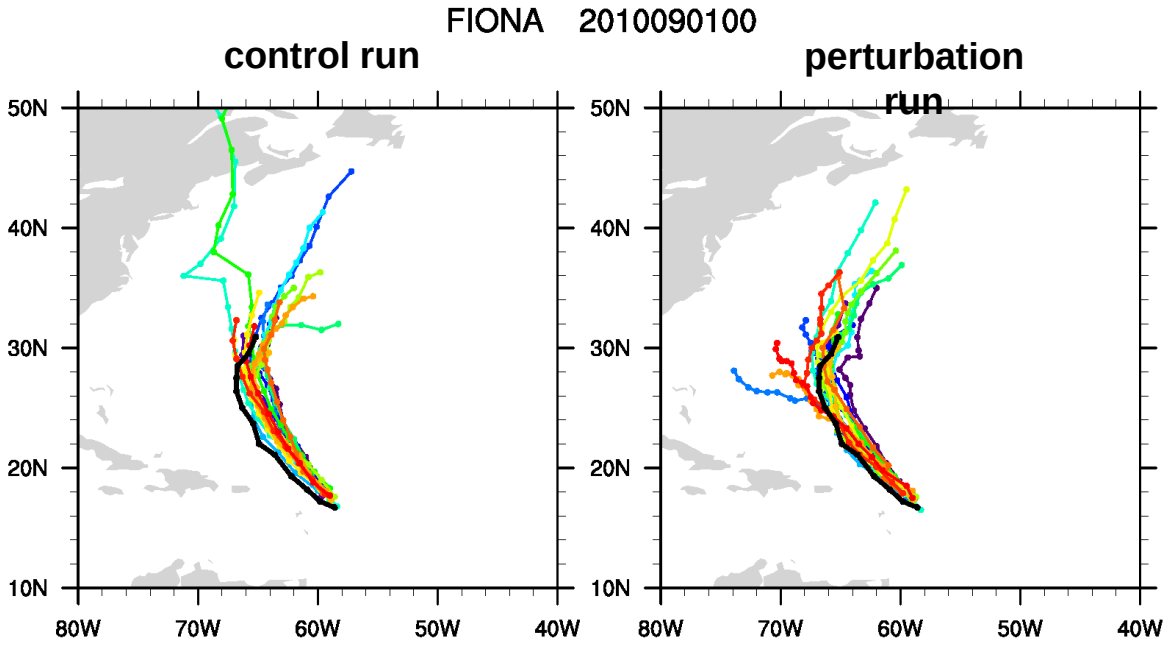
# Accounting for Physics Uncertainties in the GFS Based Ensemble Track Prediction

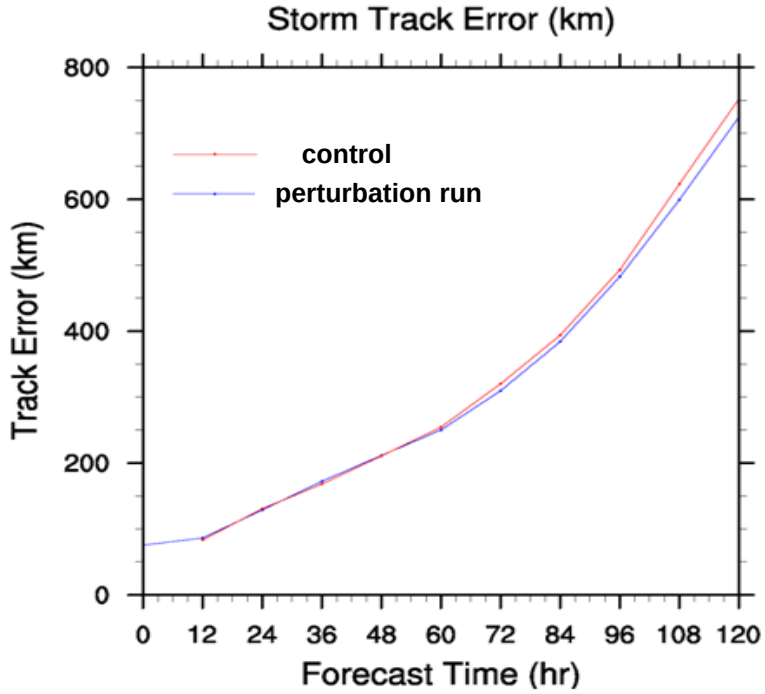
**J.-W. Bao, E. D. Grell, J. S. Whitaker, G. A. Grell, T. Hamill**
**NOAA/ESRL, Boulder, Colorado**

**Objective:** Improve ensemble spread in the tropics by perturbing the parameterization scheme of subgrid convection

**Method:** Use various permutations of the Grell-Devenyi (2002) convective parameterization in the GFS model, including variations to the cloud base mass-flux closure assumptions and to the updraft and downdraft parameter settings.

**Preliminary Experiment:** 20 ensemble members derived from 20 different initial conditions; each member is run with one of 5 different mass-flux closure assumptions × 4 combinations of parameter variations; the GFS The model was initialized every 12 h and run for 120h, for the 21-day period from 20 August 2010 to 9 September 2010 (a total of 39 forecasts).




**Top Panels: Impact of the perturbation of the convection scheme on one forecast of Fiona initialized at 20090100. Colored lines: ensemble members. Black line: the best track.**

**Left Panel: Track error averaged over 5 Atlantic TCs for the 21-day period from 20 August 2010 to 9 September 2010. The perturbed convective parameterization scheme has a discernable positive impact on the ensemble track ensemble prediction.**

# Problems and Challenges (T. Hamill)

- Understanding predictability of hurricane intensity. Controled by inner-core features, by environment? How long are rapid fluctuations of intensity predictable? HFIP workshop to discuss (Doyle, Hamill, Snyder)?
- Accounting for model uncertainty properly in ensemble predictions of TCs. Need *physically based* stochastic parameterizations of convection, microphysics, sea spray, etc. See **http://tinyurl.com/3mh49xk**.
- Advanced data assimilation methods.
  - Hybrid EnKF/GSI ported to HWRF and run with global hybrid.
  - Methods to account for mislocations of TCs in prior ensembles, e.g., field alignment: **http://tinyurl.com/6xmf74p.** Some preliminary experimentation going on at NCAR (Auligne) in conjunction with AER (Nehrkorn) and MIT (Ravela).
- Value of statistical post-processing using reforecasts; new GEFS reforecast data set available to study. Improve intensity when statistical models like LGEM trained on reforecast data?