HFIP ENSEMBLE PLAN

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GOALS

• Develop more reliable and useful automated probabilistic numerical guidance for hurricane track, intensity, and associated weather elements based on ensemble forecast systems.

• Work closely with DA group on development of ensemble DA/Forecast system.

HFIP ENSEMBLE PLAN

Technical Approach:

- Design and use probabilistic measures of hurricane forecasts to evaluate value added in probabilistic HFIP R&D

- **Improve initial and model uncertainties in NOAA and Navy global ensemble forecast systems for improved track forecasts and LBCs for finer scale ensembles**

- **Evaluate potential of mesoscale ensemble forecasting using the NCEP SREF system for improved track, intensity, and structure forecasts**

- **Develop a fine-scale relocatable (storm-following) hurricane ensemble system to be used as an inner mesh within a mesoscale ensemble to represent initial state and model related forecast uncertainties**

- Interface with verification and diagnostics groups to ensure probabilistic measures are incorporated into standard diagnostic and verification packages

- Interface with DA team in ensemble-based DA efforts

- Interface with Numerical Modeling Team in exploring the use of various models for global ensemble TC forecasting

- Interface with post-processing/applications team in designing probabilistic forecast products for hurricane track, intensity and associated weather elements
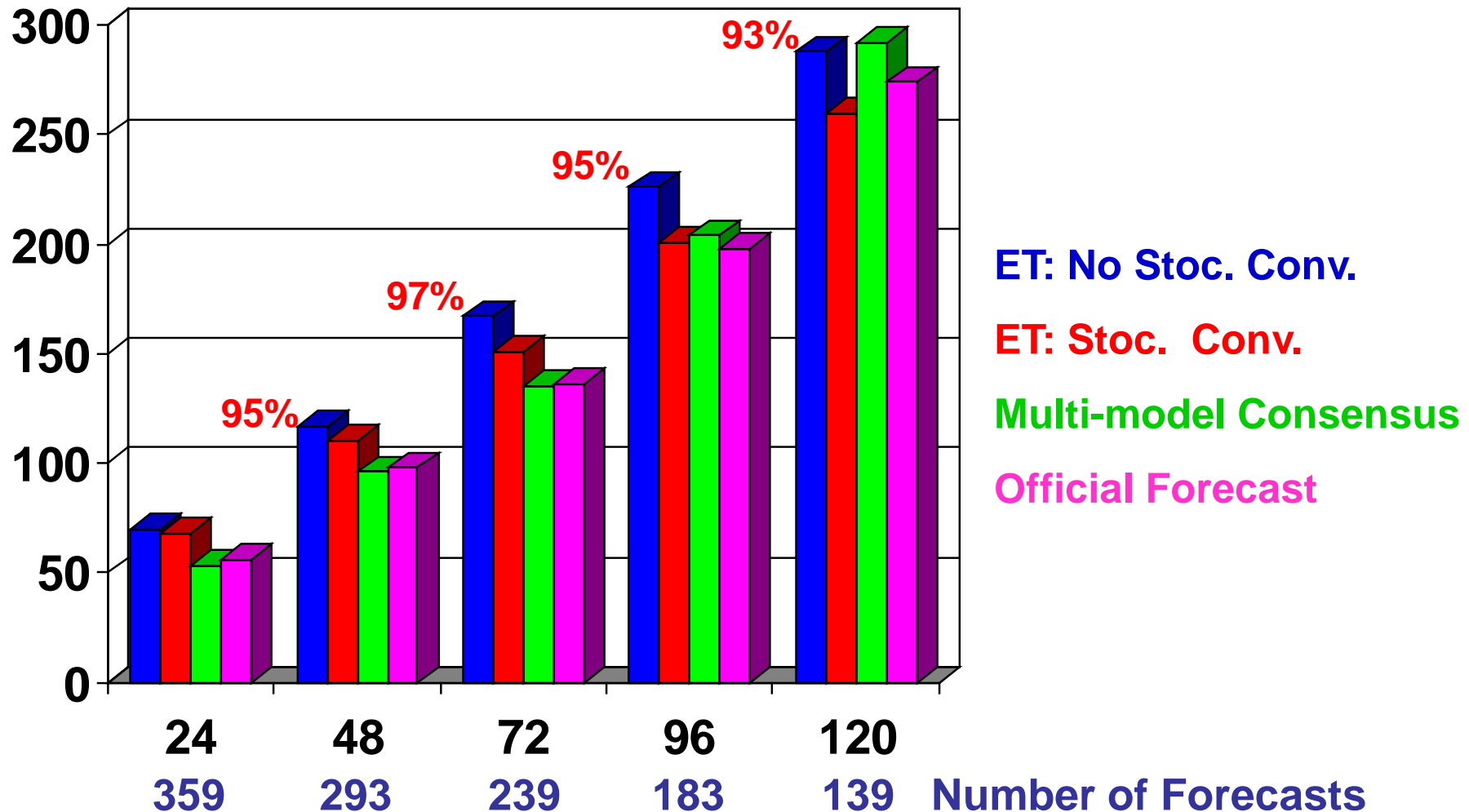
HFIP ENSEMBLE PLAN at NRL (Carolyn Raynolds)

NRL Ensemble Plans for FY09

- Global Ensembles:
  - NOGAPS ensembles will be run to examine member vs. resolution question for 2008 season
    - T119L30 32 member
    - T159L30 16 member
    - T239L30 8 member (resources permitting)
    - Tested with and without model uncertainty (stochastic convection)
    - Weighting scheme for multi-member/multi-model ensemble will be developed/tested

- Mesoscale Model:
  - COAMPS-TC, run down to 5km, will be part of the multi-model mesoscale ensemble

Atlantic 2005 (03L-26L)
Homogeneous TC Forecast Error (nm)

Stochastic Convection significantly improves NOGAPS ET performance

ET: No Stoc. Conv.

ET: Stoc. Conv.

Multi-model Consensus

Official Forecast

24	48	72	96	120	
359	293	239	183	139	**Number of Forecasts**

HFIP ENSEMBLE PLAN at ESRL (Tom Hamill and Jeff Whitaker)

<u>ESRL</u> Ensemble Plans for FY09

- Ensemble DA
  - Run quasi real-time ensemble data assimilation system using the FIM model at approximately 30 km grid spacing, ~40 members, full operational observational data stream
  - Provide LBCs alternative to operational NCEP system to partners wishing to run regional ensemble data assimilations

- Global Ensembles:
  - Conduct longer-lead ensemble forecasts, to perhaps 7 days.
  - Provide lateral boundary conditions alternative to operational NCEP system for regional ensemble forecasts

- Diagnostics
  - Adapt existing, and add new contributions to diagnostics package to generate and display ensemble statistics for the FIM assimilations and ensemble forecasts.

Ensemble Data Assimilation at ERSL for Hurricane Forecasts

Jeff Whitaker, Tom Hamill, Jian-Wen Bao & Tomi Vukicevic

NOAA/ESRL
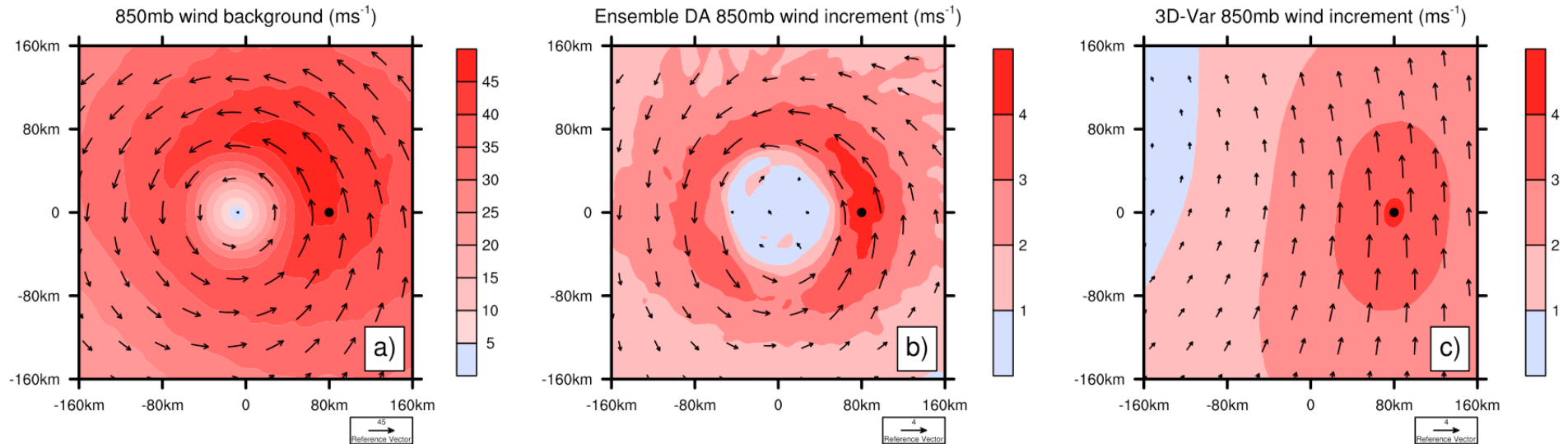
EnKF work with NCEP GFS

- Developed via a THORPEX funded collaboration.
  - Participants from U. of Maryland, ESRL, Colorado State, Naval Research Lab, NCEP
  - Have moved from tests with low-resolution toy models to T254 GFS, full observational data stream.

- Spinoff system for historical reanalysis being used for 20th Century Reanalysis (1892-present) at ESRL.

EnKF/GSI comparison
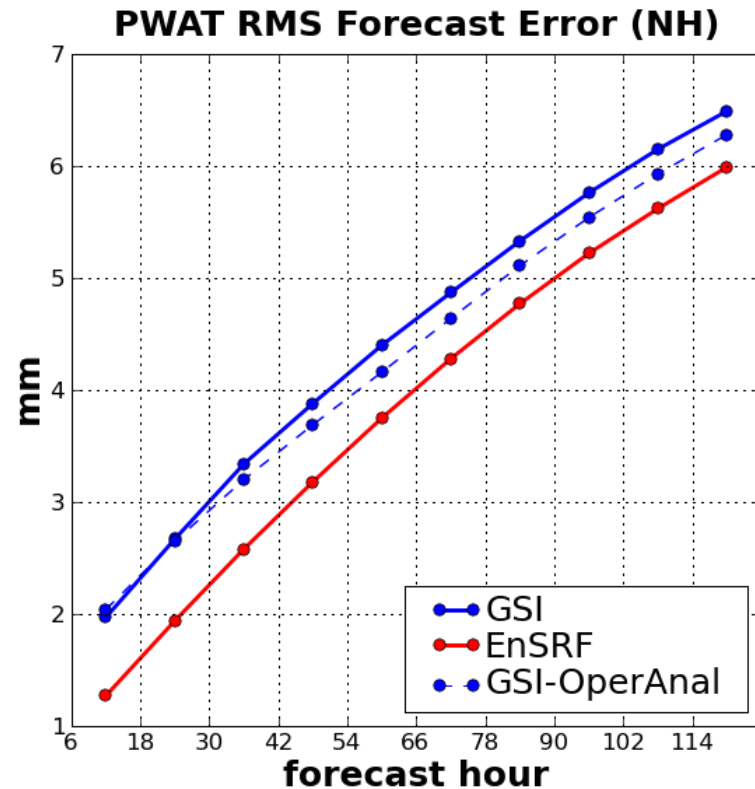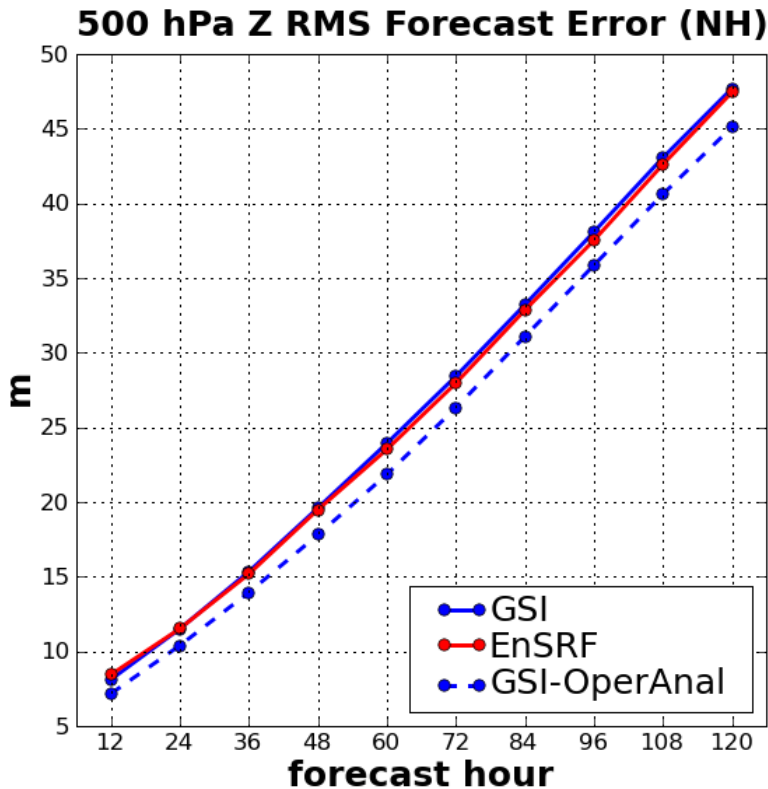
- Compared mean from T126L64 "EnSRF", T126L64 "GSI", T382L64 GSI ("OperAnal")
- GFS/EnKF similar for Z500; T126L64 forecast from T382L64 operational GSI analysis is slightly better than from EnKF analysis for Z500.
- EnKF has an ~ 12-h advantage for precipitable water forecast (PWAT). Advantage due to use of non-humidity observations (e.g., sea-level pressure) to make humidity increments. This doesn't happen in GSI.
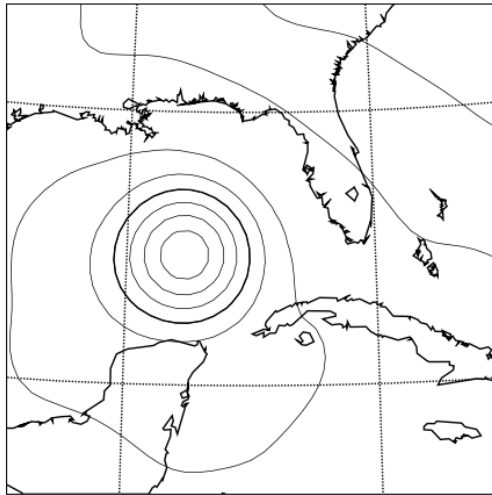
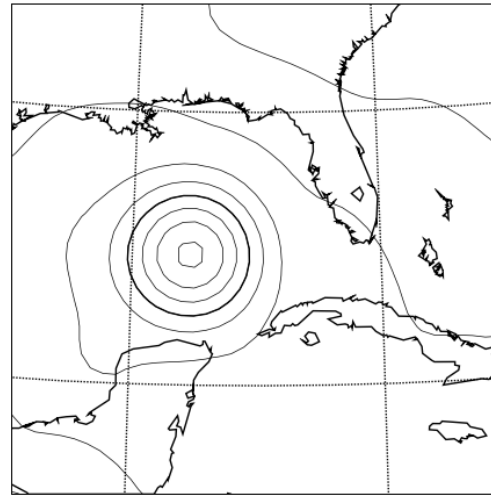# Takemasa Miyoshi's comparison of 4D-Var and EnKF at JMA
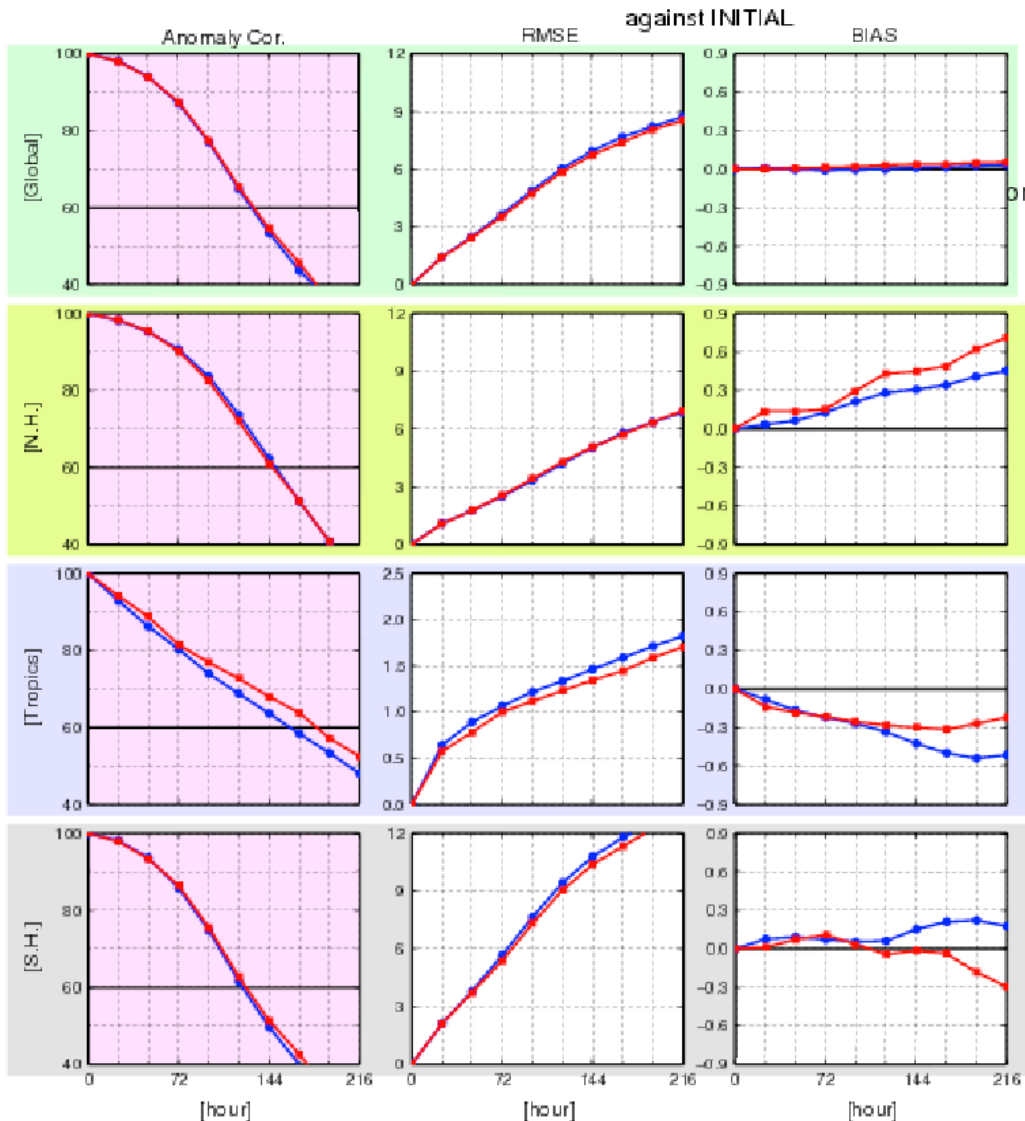
- Red: EnKF
- Blue: 4D-Var
- EnKF's positive impact especially noticeable in tropics.

GDAS and EnKF analyses, 06 UTC 22 September 2005 (SLP, 4 hPA contours, 1000 hPa thicker)
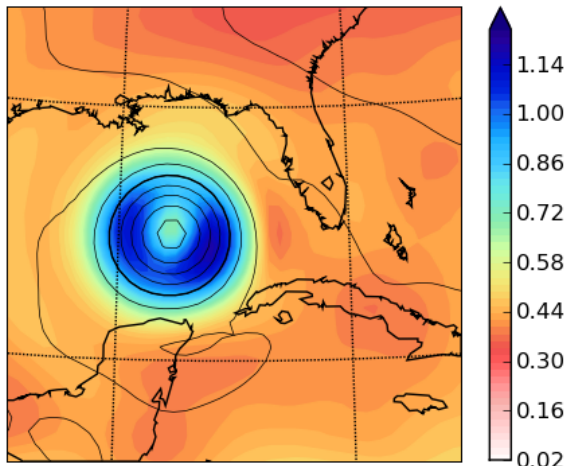

GDAS First-Guess 2005-09-22 06:00:00
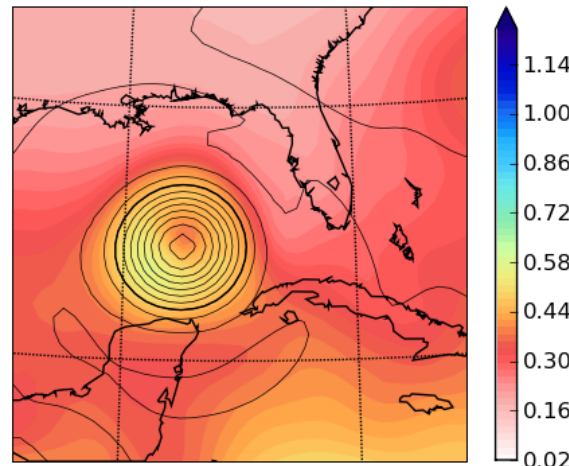

GDAS Analysis 2005-09-22 06:00:00

GDAS has less intense initial vortex, which is the first guess vortex relocated to the observed location, then updated with observed data

EnKF First-Guess with recon obs 2005-09-22 06:00:00

EnKF Analysis with recon obs 2005-09-22 06:00:00

EnKF has more intense analyzed vortex. Colors denote spread in the ensemble, larger around eye, where small change.

# HFIP ENSEMBLE PLAN at EMC/NCEP (Zoltan Toth and Jun Du)

<u>EMC</u> Ensemble Plans for FY10 (demonstration system)

3-tier fully consistent ensemble system initialized off operational analysis

- ***Global Ensembles***:
  - (a) T384 resolution, 20 members
  - (b) improved ET initial perturbations
  - (c) improved stochastic perturbations in physics

- ***Mesoscale Ensemble*** (under NEMS with various physics):
  - (a) 20km resolution, 21 members
  - (b) ET initial perturbations (consistent with GEFS)
  - (c) stochastic physics for convection
  - (d) possibly land surface perturbations (soil moisture, soil temperature etc.)
  - (e) 5-day integrations for case studies and possible experimental extension of operational SREF to 5-days for FY09 demo

- ***Storm-Following Hi-Res Ensemble***:
  - (a) nested within SREF (perturbed LBCs and ICs, two-way or one-way);
  - (b) 5km; membership (7-10?);
  - (c) ET initial perturbations (consistent with SREF);
  - (d) use various models available in NEMS and leverage WRF community research (Krishnamurti's work)

. ***Post-processing of hurricane-related forecasts***
  - (a) Decompose gridded forecast errors into phase and amplitude component;
  - (b) Evaluate, then correct bias for phase before amplitude corrections
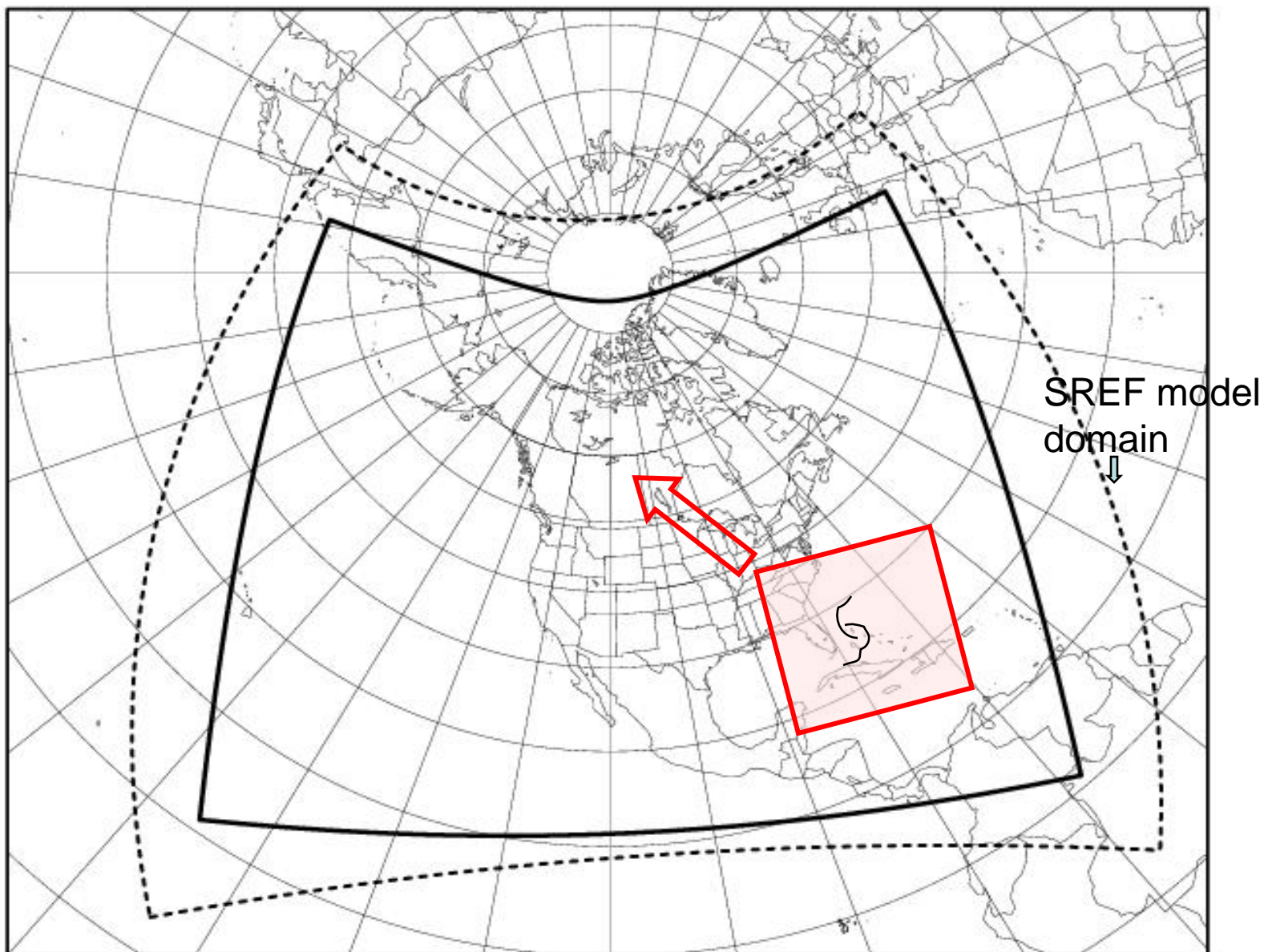
GEFS mean track forecast outperforms GFS forecast after 4 days. "Dural-resolution/hybrid emsembling" approach (combining GEFS and GFS) will be used to improve day1-4 performance.

Atlantic Basin 7-day track forecast verification
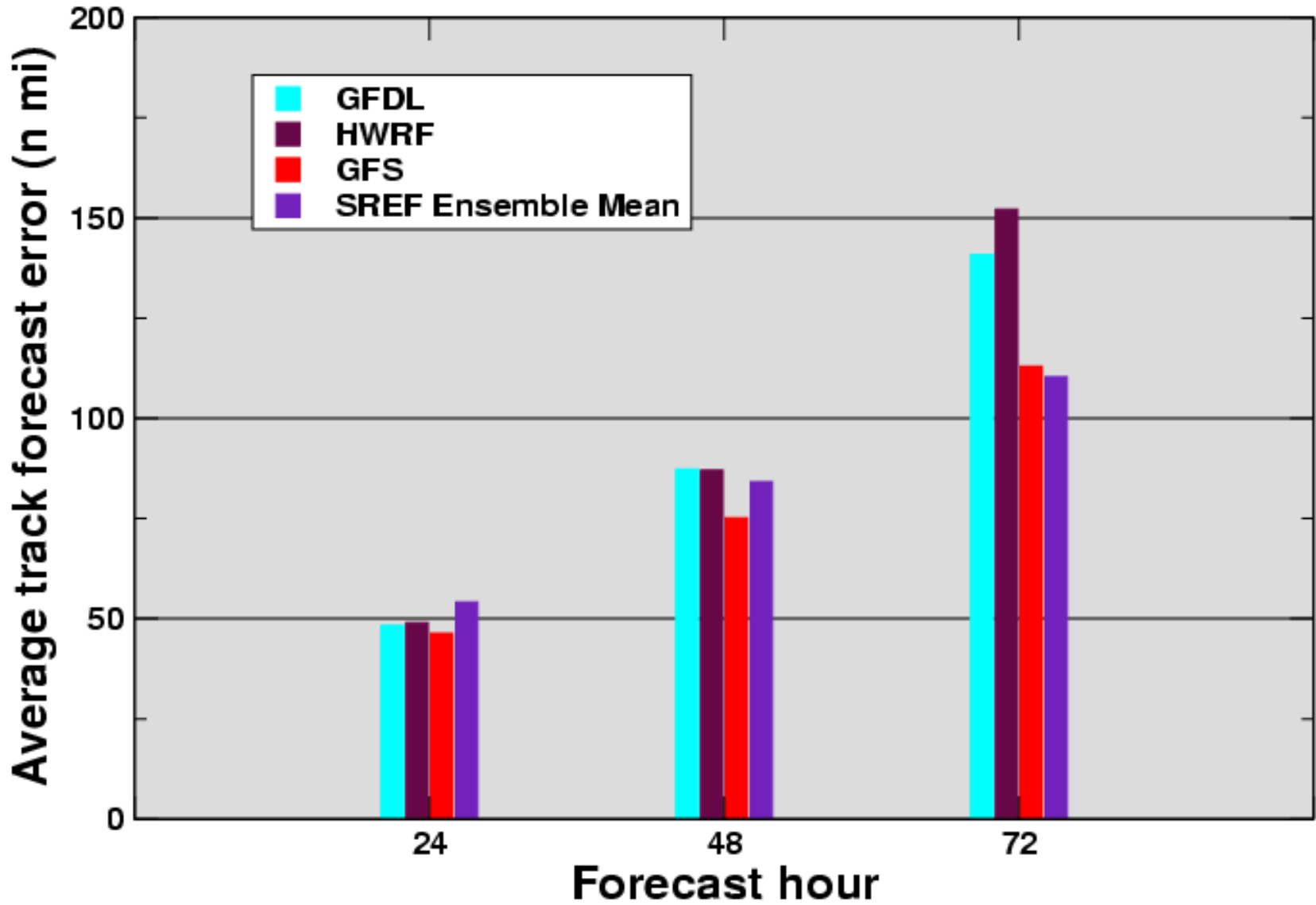### 2008 season (Late models) (Tim Marchok)
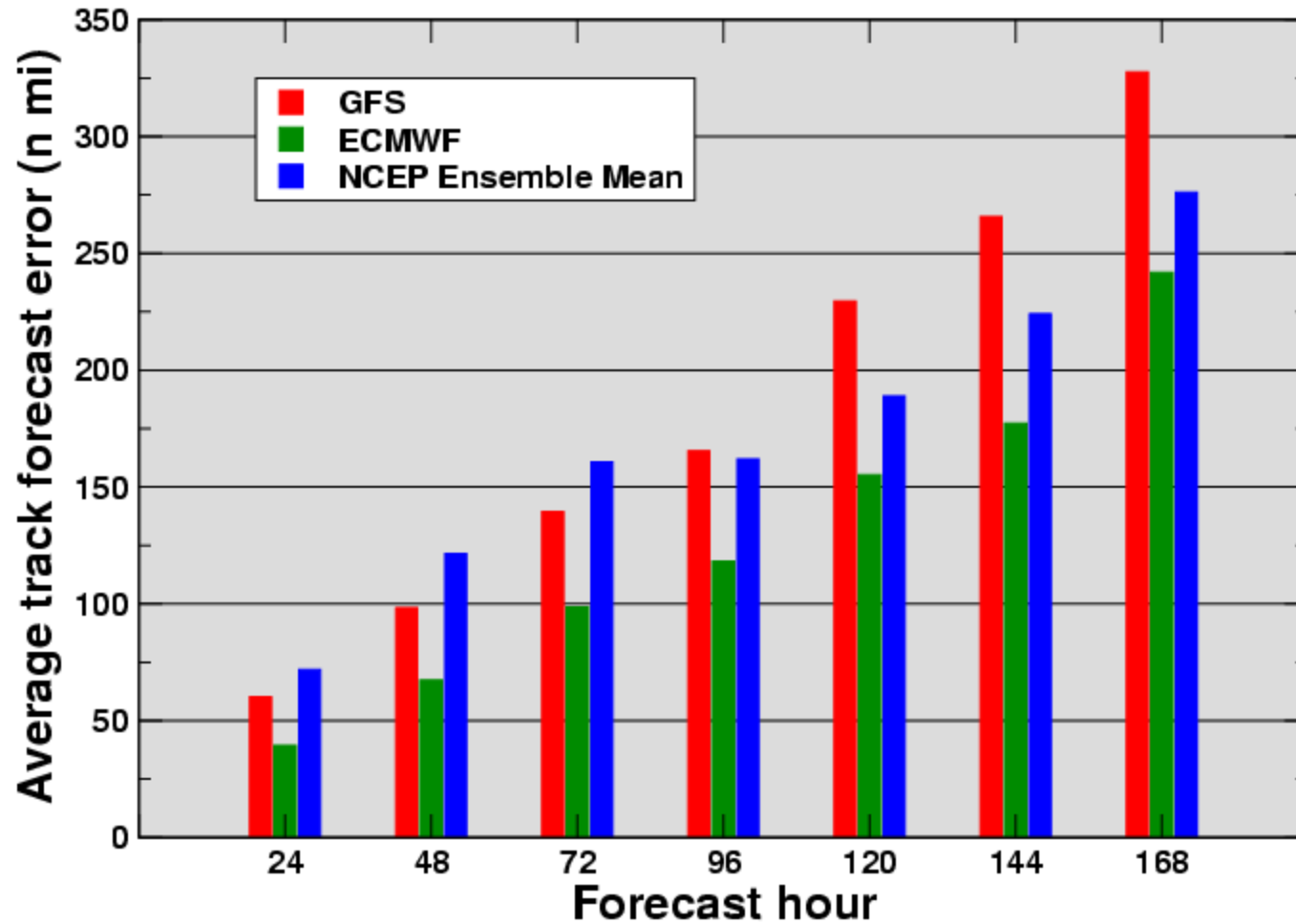
#CASES: 153   126   87   59   42   27   10

DASHED = EXPANDED NAM-12 ; SOLID = GRID 221

SREF model domain

Atlantic Basin 3-day track forecast verification
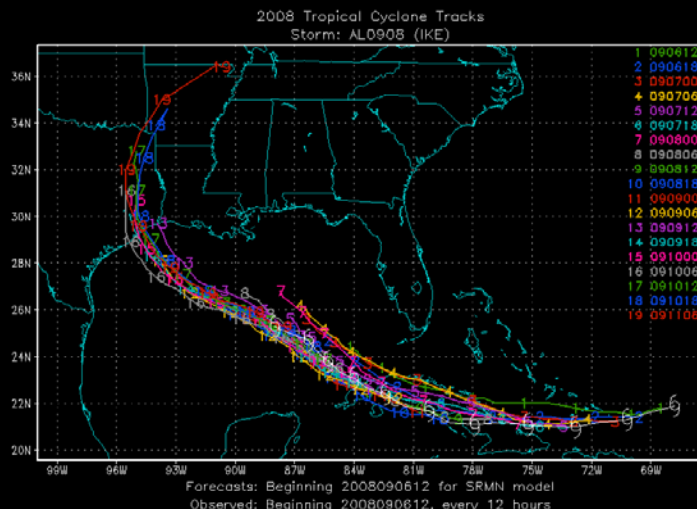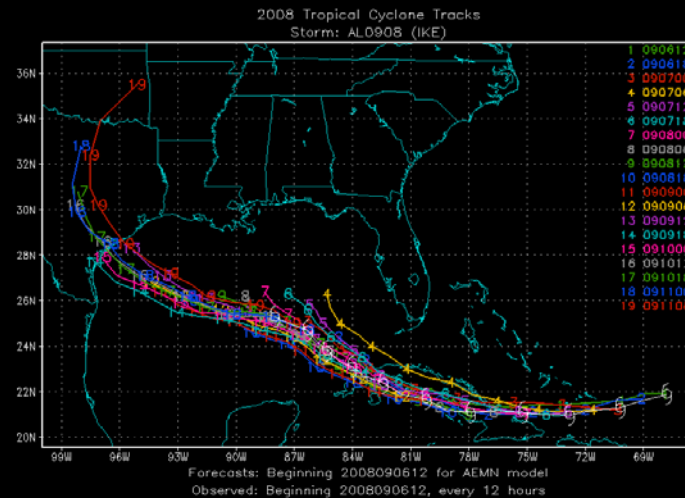2008 season (Late NCEP models) (Tim Marchok)

Hurricane IKE (Sept., 2008) Forecasts (Tim Marchok) which shows
(a) ensemble mean forecasts are more consistent from run to run;
(b) SREF mean predicted near-perfect landfall location while many other models
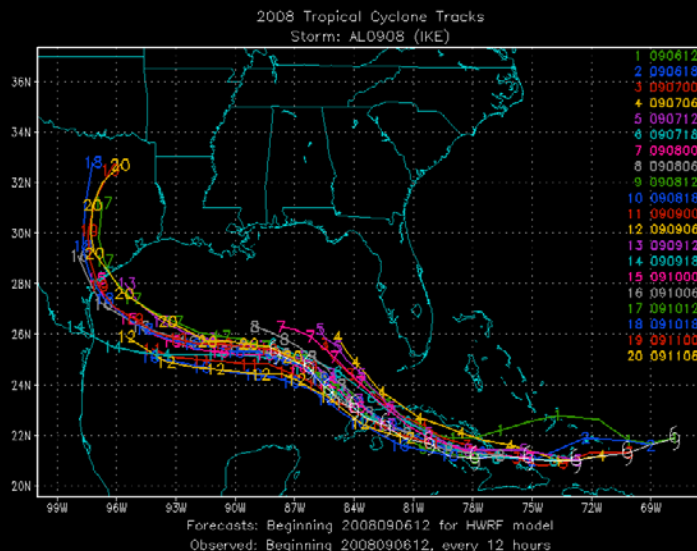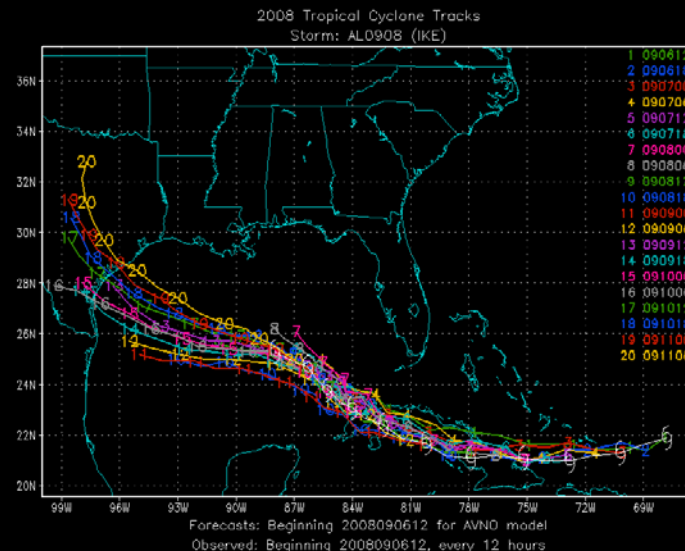showed substantial westward bias for this particular case.
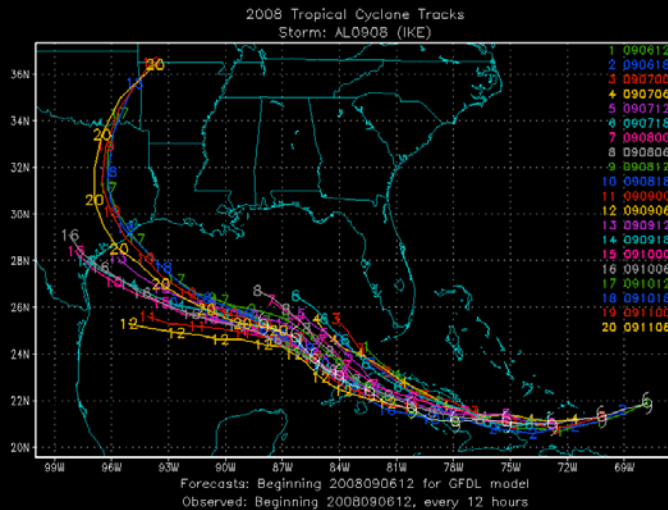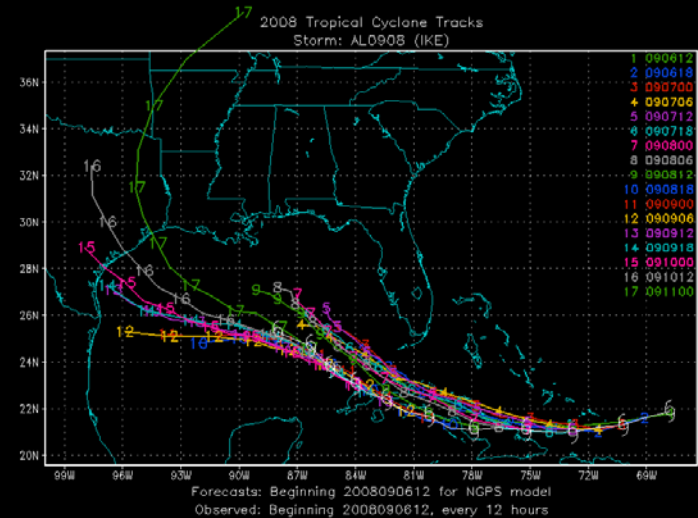
SREF

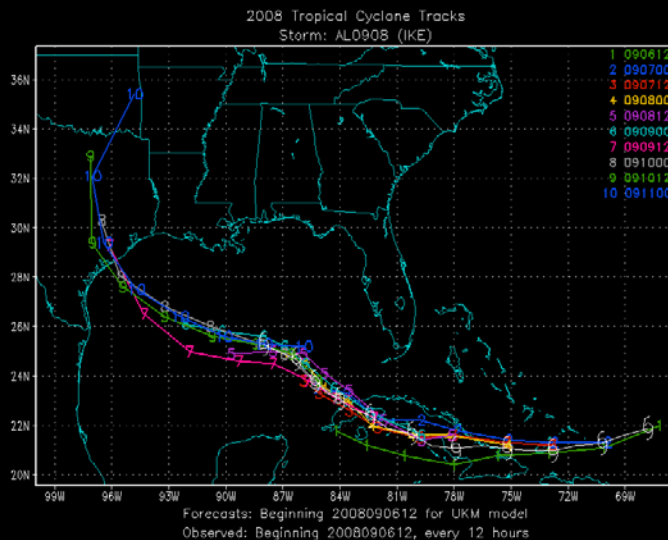GEFS

HWRF

GFS

Hurricane IKE (Sept. 2008) Forecasts (Tim Marchok)

GFDL

NGPS

UKMET

ECMWF
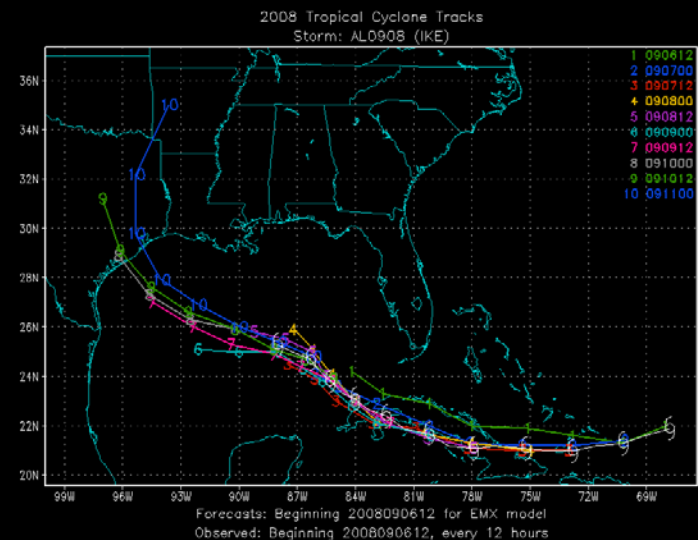
Resulted Difference in Precipitation FCST ("exp - ctl") after adding stochastic perturbations to a convective parameterized scheme

03h-apcp Diff (mm) 48H fcst from 09Z 11 SEP 2008
verified time: 09z, 09/13/2008
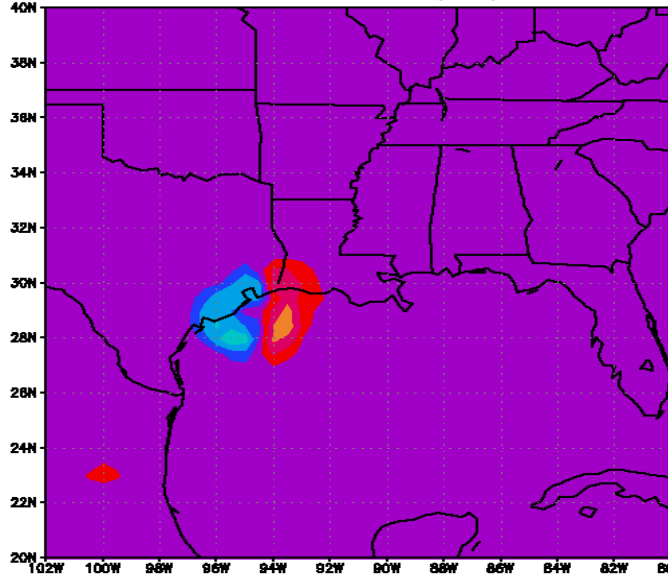
06h-apcp Diff (mm) 48H fcst from 09Z 11 SEP 2008 (mem 11)
verified time: 09z, 09/13/2008
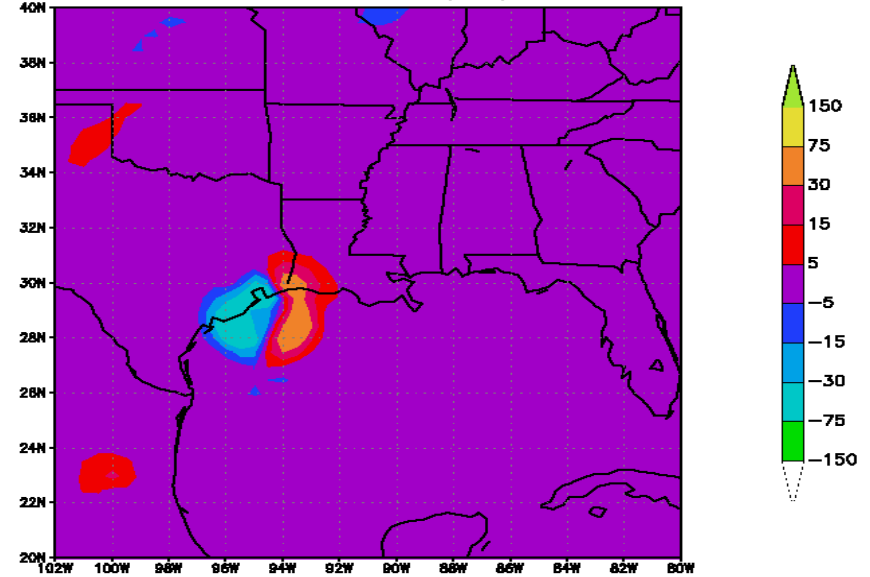
12h-apcp Diff (mm) 48H fcst from 09Z 11 SEP 2008
verified time: 09z, 09/13/2008
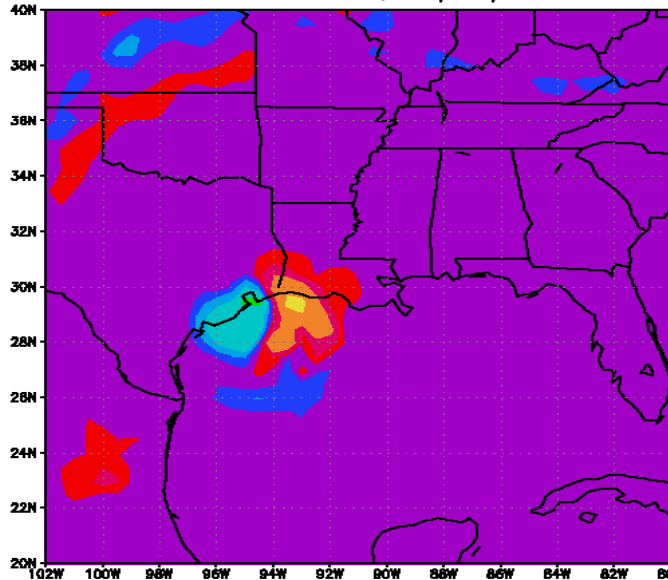
24h-apcp Diff (mm) 48H fcst from 09Z 11 SEP 2008 (mem 11)
verified time: 09z, 09/13/2008
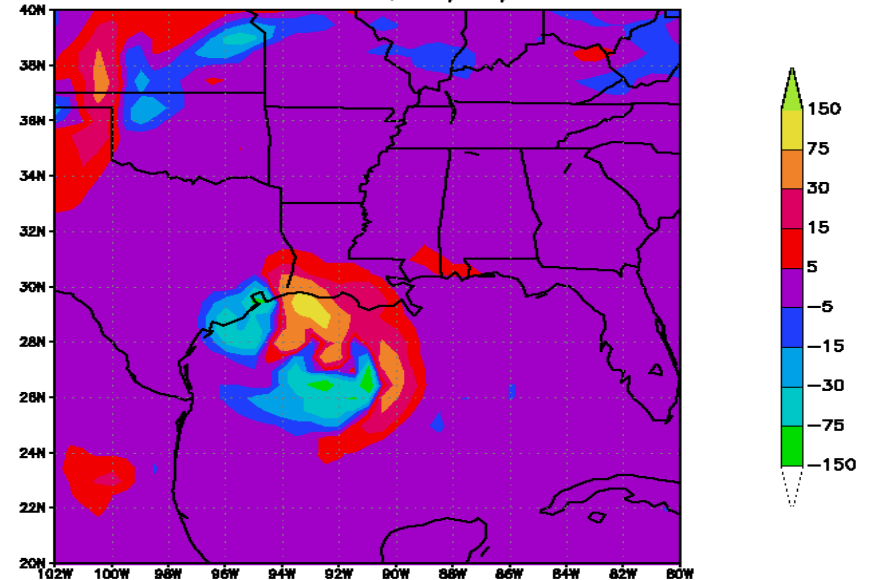
FSU Krish's post-processing work based on multiple mesoscale models' outputs (Krishnamurti)

Member Models
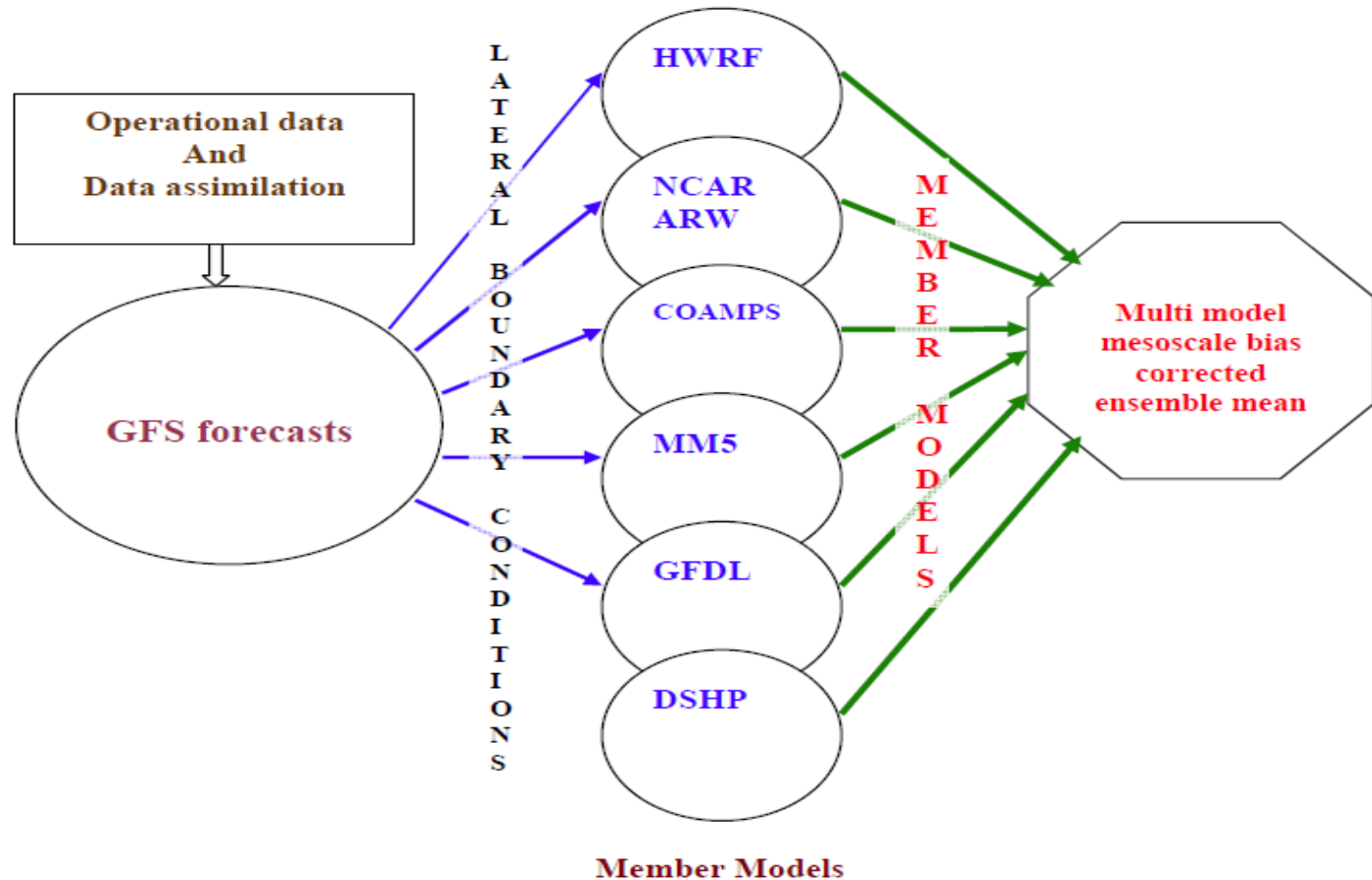
Benefit from mesoscale model over global model (Krish's multi-model work)

Comparison between Large scale, mesoscale and combined Track BCEM
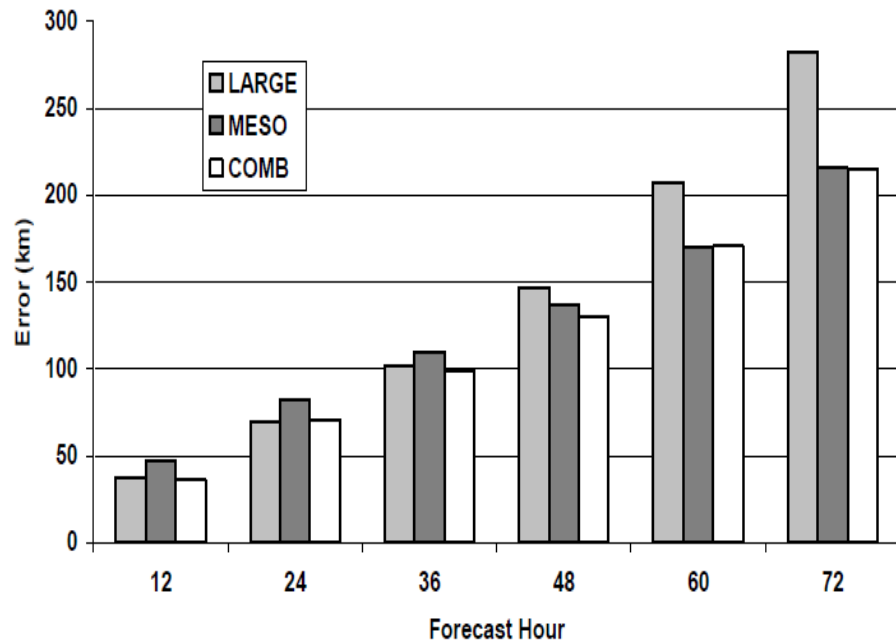
Comparison between large scale, mesoscale and combined Intensity BCEM
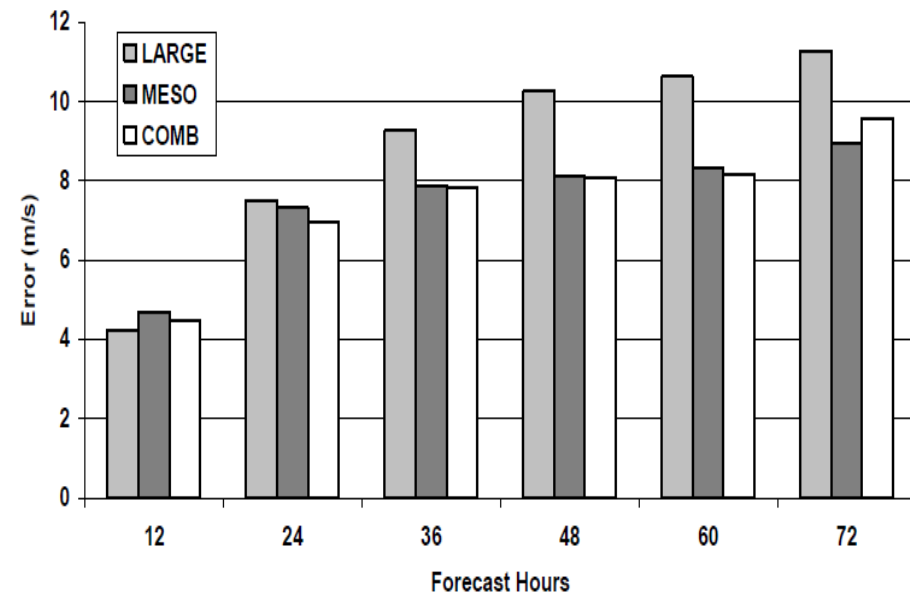
Track error and intensity error (from Krish's multi-mesoscale model work)

Mean Absolute track error for 2004, 2005 and 2006 (km)
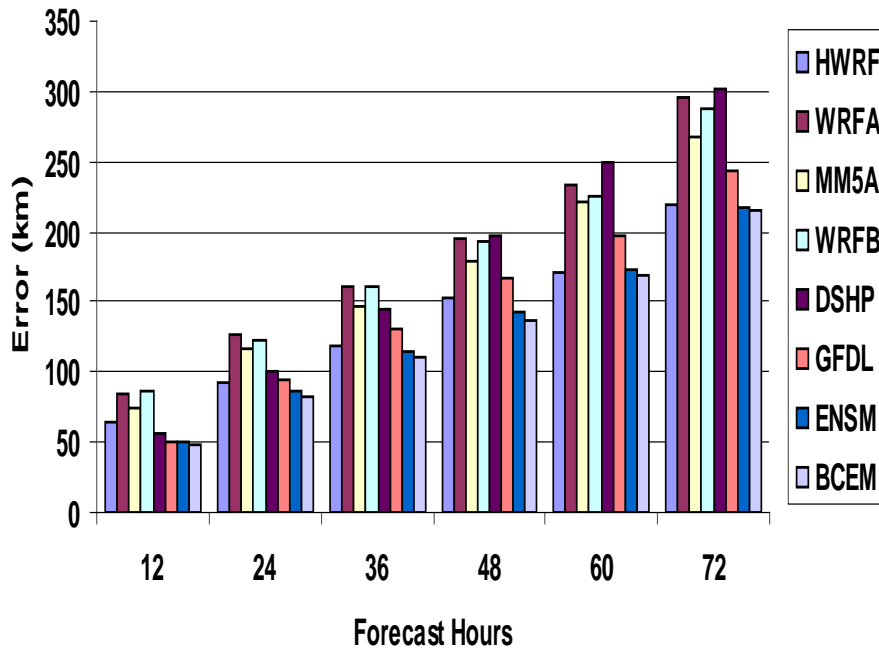
Mean Absolute intensity error for 2004, 2005 and 2006 (m/s)
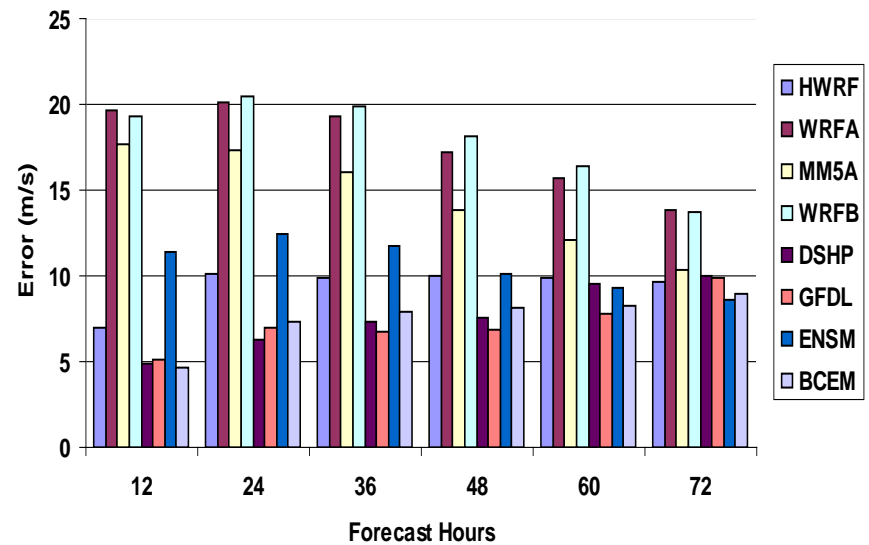
Appendix

- FY2009 tasks
- FY2010 tasks
- FY2011 tasks
- FY2012 tasks
- FY2013 tasks
- FY2009 milestones and deliverables
- FY2010 milestones and deliverables
- FY2011 milestones and deliverables
- FY2012 milestones and deliverables
- FY2013 milestones and deliverables

HFIP ENSEMBLE PLAN

FY09 TASKS:

- Evaluate TIGGE forecasts of hurricanes in 2009 to determine hurricane statistics for each model and for multi-model ensembles

- Define ensemble verification measures; share algorithms / software

- Test stochastic convective parameterizations with T254 GFS ensemble

- Determine optimal weights for single and multi-model ensembles track forecasts

- Compare NOGAPS T119M32 vs. T159M16 hindcasts

- Develop new methods in targeted observations using multi-center ensembles

- Test FNMOC & ECMWF ensembles into NAEFS for hurricanes

- Evaluate impact of running higher-resolution global ensemble (GFS & FIM)

- Evaluate potential skill of operational SREF ensemble; assess contribution to skill by NMM, ARW WRF, RSM, and ETA models

- Adapt field adjustment method to decompose positional and amplitude errors for use in hurricane verification and bias correction studies

- Adapt comprehensive probability distribution package from University of Virginia for use in NOAA for probabilistic and ensemble hurricane forecasting (including bias correction, product generation)

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FY10 TASKS:

- Evaluate hurricane statistics from ensemble forecasts initialized from global EnsDA using T254 GFS vs. T254 GFS with GSI control, ensemble transform perturbations (with DA).

- Define baseline ensemble verification suite for verification group "tool kit"

- Test stochastic backscatter in T254 GFS ensemble and perform NLR global ensemble tests with improved stochastic convection/parameter variations

- Provide initial and lateral boundary conditions from global ensemble data assimilation experiments to AOML for regional EnsDA experiments (with DA)

- Examine hurricane forecast performance from various resolutions of global ensemble data assimilation and ensemble forecasts

- Explore the combination of single-model and multi-model ensembles and determine optimal weights to produce superior intensity forecasts.

- Development and evaluation of COAMPS-TC ensembles with global (NOGAPS and or other, GFS) boundary conditions using historical cases

HFIP ENSEMBLE PLAN

FY11 TASKS:

- Implement stochastic convective parameterization and/or backscatter into NOAA global ensemble forecast models.

- Examine effect of coupled ocean vs. mixed layer vs. statistical methods on global hurricane ensemble forecasts (with ocean HFIP group)

- Implement improved method of initialization of global ensemble forecasts (perhaps EnsDA) into NOAA model(s).

- Implement NRL global ensembles with improved model uncertainty (stochastic and/or parameter variations) and examine impact on NRL-NOAA multi-model ensemble forecasts

- Begin real-time and retrospective tests of two-way (atmos-ocean) coupled COAMPS-TC ensembles

HFIP ENSEMBLE PLAN

FY12 TASKS:

- Reanalyses and ensemble reforecasts specific to hurricanes computed for updated NOAA global model/assimilation system

- Explore effects of perturbing ocean initial conditions, and/or parameters in ocean model, to determine if spread of hurricane simulations is realistically increased

- Begin NRL global ensemble tests with coupled model (if available)

- Development and testing of COAMPS-TC ensembles with stochastic forcing

- Testing of three-way (atmos-ocean-wave) coupled COAMPS-TC ensembles

HFIP ENSEMBLE PLAN

FY13 TASKS:

- Development of post-processed ensemble forecast products using NOAA global ensemble forecasts & reforecasts.

- Perform NRL global ensemble realtime tests with coupled model

- Continue testing of COAMPS-TC coupled ensembles with stochastic forcing

- Real-time three-way coupled COAMPS-TC ensembles as part of multi-model ensembles)

HFIP ENSEMBLE PLAN

FY09 Milestones and Deliverables:

- Single-model and multi-model ensemble weighting method for track forecasts (NRL).

- Initial assessment of value in international multicenter ensemble data provided by TIGGE / GIFS (ESRL, AOML)

- Determination of relative merits of high-res vs. high-member ensembles for track forecasts (NRL)

- Determination of the effects of stochastic convective parameterization in GFS ensemble (ESRL).

- Deliver best practices ensemble verification manual and library of basic verification routines to verification software "tool kit" (presumably maintained by HFIP verification group) (ESRL, AOML, NRL, EMC).

HFIP ENSEMBLE PLAN

FY10 Milestones and Deliverables:

- Determination of the effect of global EnsDA relative to existing GSI/ET technique for hurricane forecast performance (ESRL, HFIP DA).

- Determination of the effect of stochastic backscatter, stochastic parameterizations, parameter variations on global ensemble forecasts of hurricanes (ESRL, NRL, EMC)

- Evaluation of uncoupled COAMPS-TC ensemble performance (NRL)

- Delivery of ICs / LBCs to AOML for regional EnsDA/EF experiments (ESRL)

- Single-model and multi-model ensemble weighting method for intensity forecasts (NRL).

- Determination of effect of resolution in global EnsDA & forecasts (ESRL)

- Transition (if warranted) of higher resolution global ensemble into Navy operations (NRL)

- Deliver baseline ensemble verification suite to verification team (ESRL, AOML, NRL, EMC).

HFIP ENSEMBLE PLAN

FY11 Milestones and Deliverables:

- Evaluation of two-way (atmos-ocean) coupled COAMPS-TC ensembles (NRL)

- If warranted from experiments, operational implementation of stochastic convection/backscatter into operational global models (NRL, ESRL, EMC)

- Determination of whether fully coupled ocean model is required for hurricane global ensemble forecasts and whether simpler schemes are adequate replacements .

- If warranted by results, operational implementation of global ensemble data assimilation system or EnsDA/4D-Var hybrid in a NOAA global model (ESRL).

HFIP ENSEMBLE PLAN

FY12 Milestones and Deliverables:

- Evaluation of NRL global ensemble tests with coupled model (NRL)
- Evaluation of three-way (atmos-ocean-wave) coupled COAMPS-TC ensembles (NRL)
- Reanalyses and reforecast data set appropriate to hurricane problem (ESRL)
- Determination of whether perturbed ocean conditions and/or perturbed ocean physics improves ensemble hurricane forecasts (ESRL, NRL, EMC)

HFIP ENSEMBLE PLAN

FY13 Milestones and Deliverables:

- Experimental calibrated hurricane forecast products from global ensemble using reforecasts (ESRL)

- Evaluation and potential implementation of Navy global coupled ensembles (NRL)

- Evaluation and potential implementation of COAMPS-TC ensembles as part of multi-model ensembles (NRL)