Ensemble-Based Data Assimilation and Hurricane Prediction

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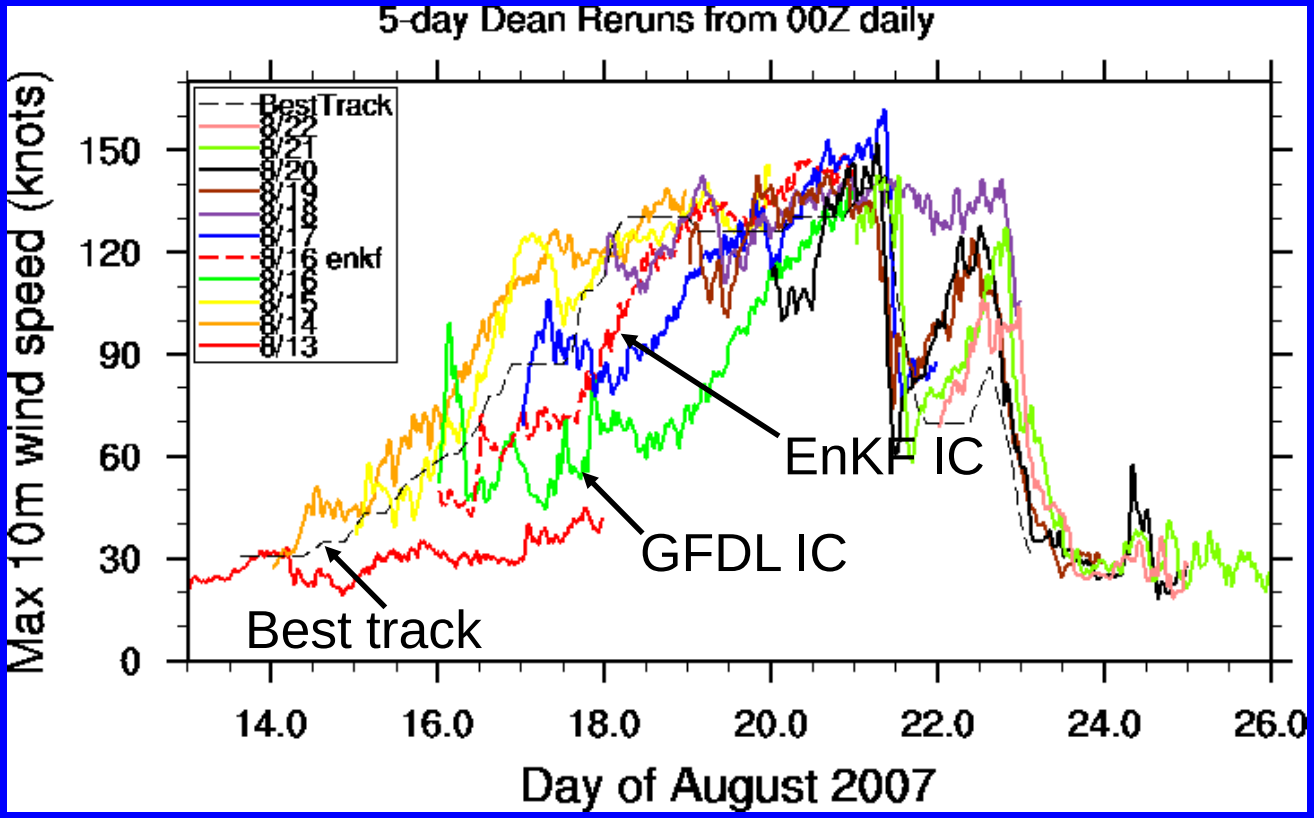
Background

- Observation “assimilation” in the vicinity of TC consists of:
  - Vortex bogusing (e.g., GFDL)
  - Vortex repositioning (e.g., NCEP)
  - Do nothing
- One reason for these special techniques is there are few good error statistic models for within or near a TC
- Ensemble assimilation systems offer promise for TC because error statistics are computed from ensemble, thus providing flow-dependent estimate of how to correct state

Background

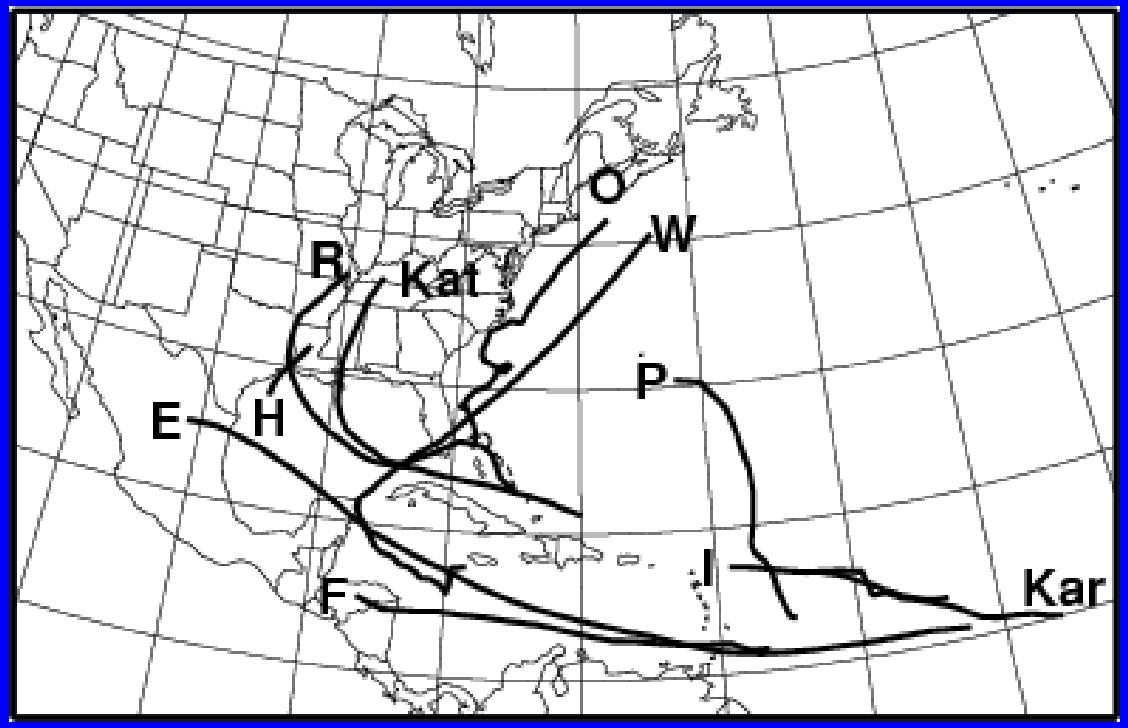
- Models need high spatial resolution to resolve important features within TC such as eyewall, rainbands, etc.
- Initializing from bogus vortex can be problematic:

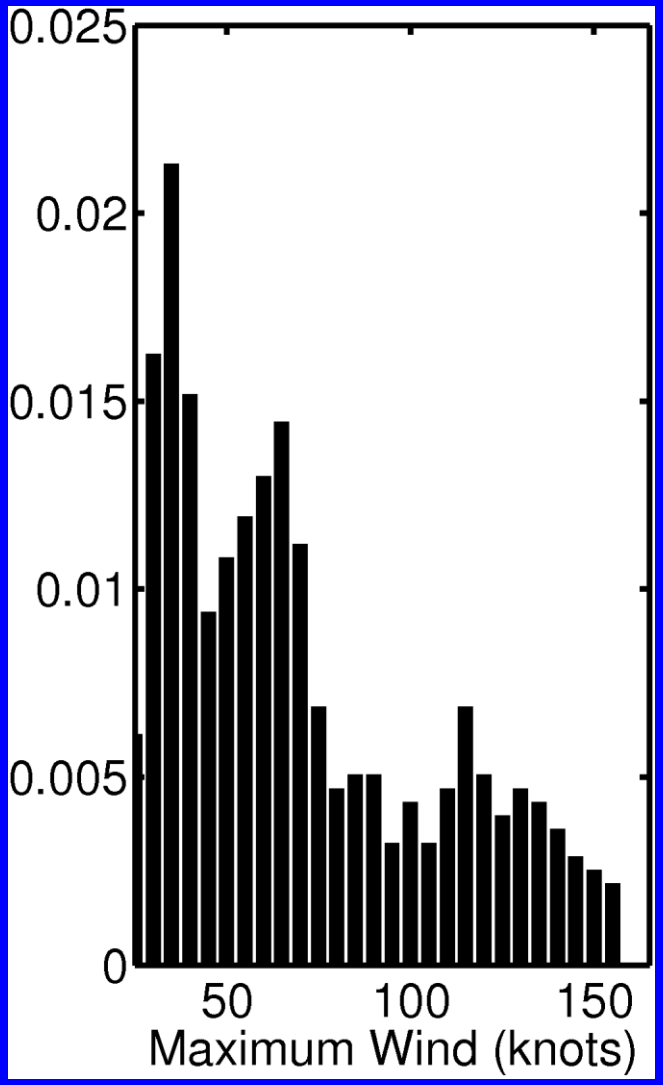


Overview

- For NCAR/MMM's participation in DTC HRH test, generated mesoscale initial conditions for the 10 different storms determined by NHC forecasters
- Goal was to generate initial conditions that:
  - Have a good estimate of environment
  - Have a "decent" estimate of TC structure
  - Does not lead to initialization problem
- Provides a good opportunity to evaluate value of ensemble assimilation system over wide range of storms

HRH Storms



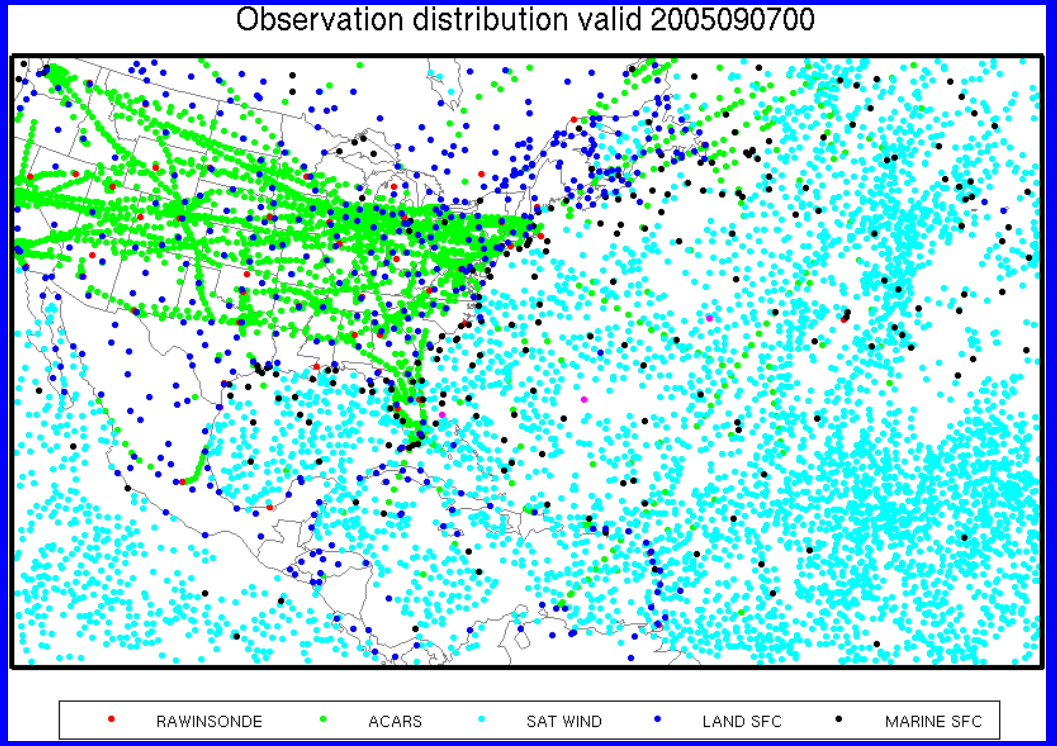


2005 – Emily, Katrina, Ophelia, Philippe, Rita, Wilma

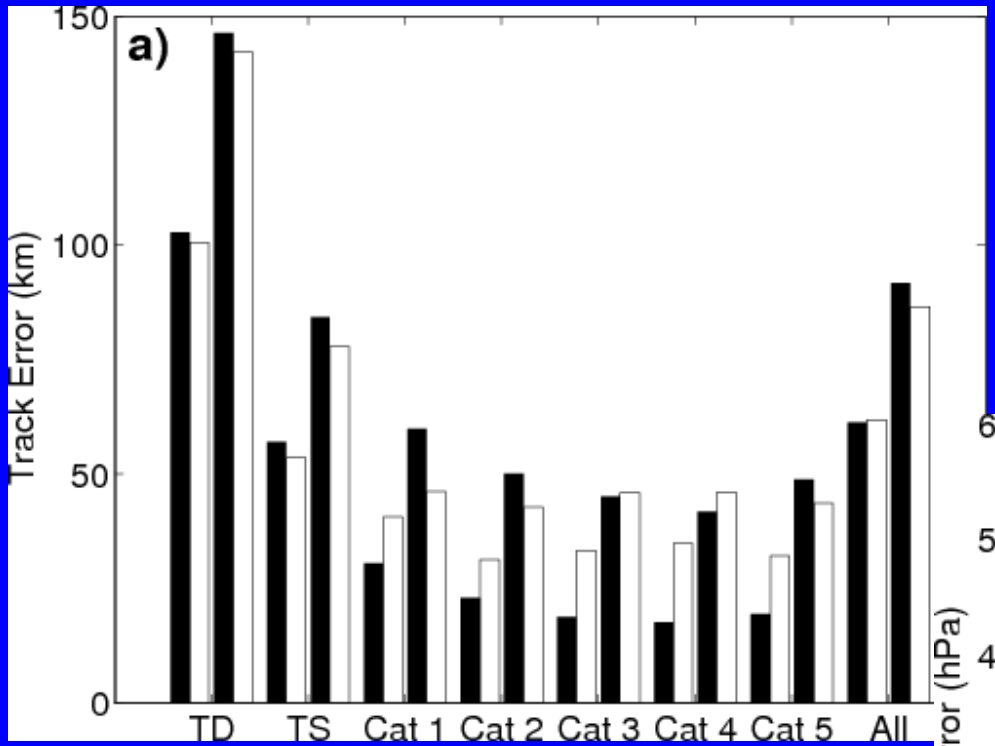
2007 – Felix, Humberto, Ingrid, Karen

Assimilation System

- WRF ARW (v2.2.1), 36 km horizontal resolution, 96 ensemble members
- Observations assimilated each six hours from surface and marine stations (P_{sfc}), rawinsondes, synoptic dropsondes, ACARS, sat. winds, TC position and minimum SLP
- Cycle system from 3-4 days prior to TD declaration to last TC time, 90 total days over six different periods.

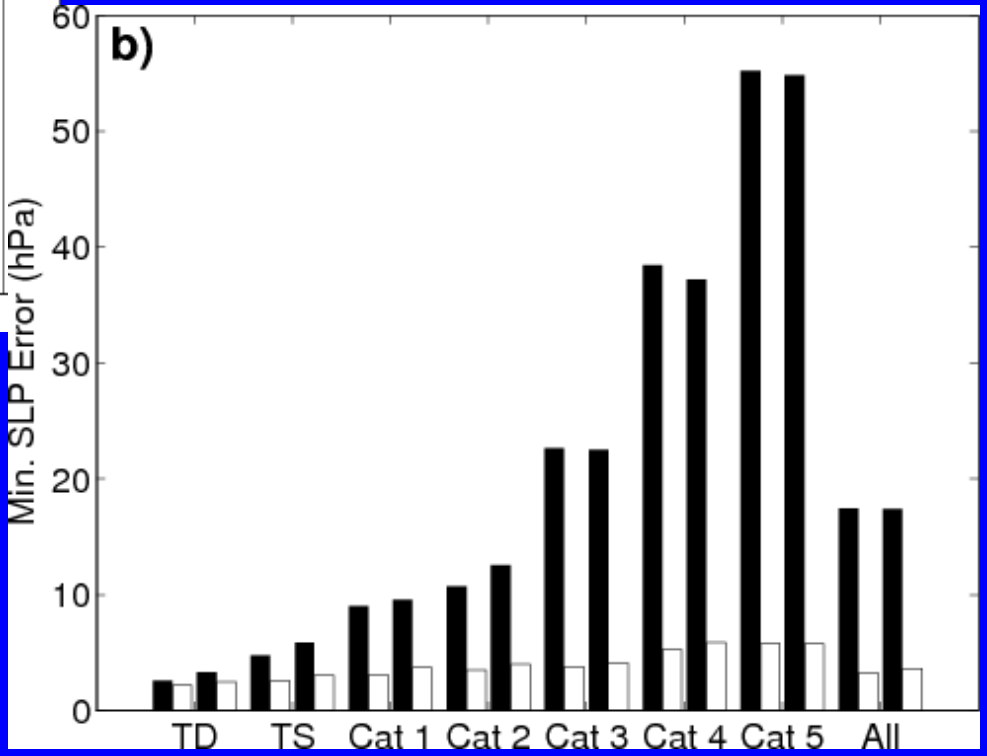


Cycling Errors

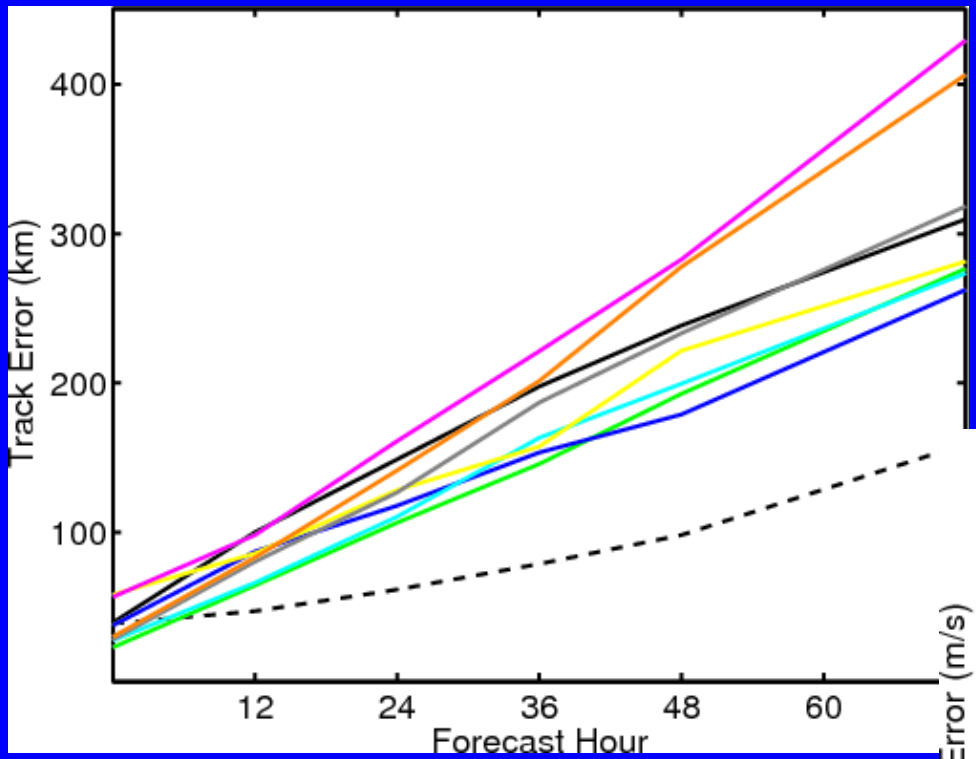


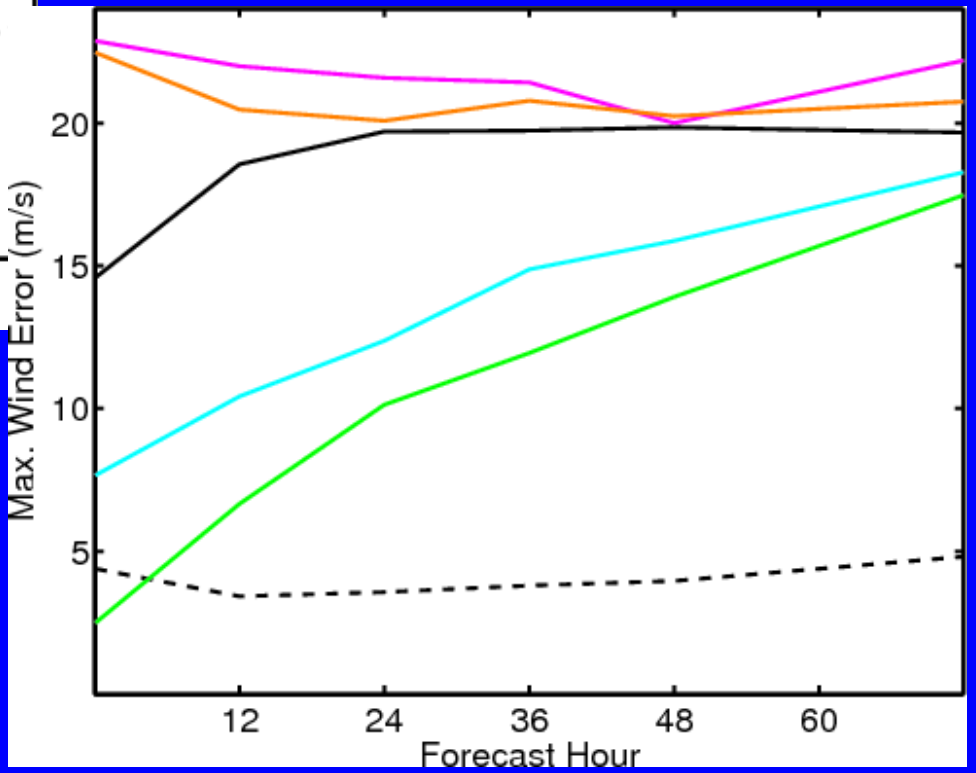
TC Position

TC Minimum SLP



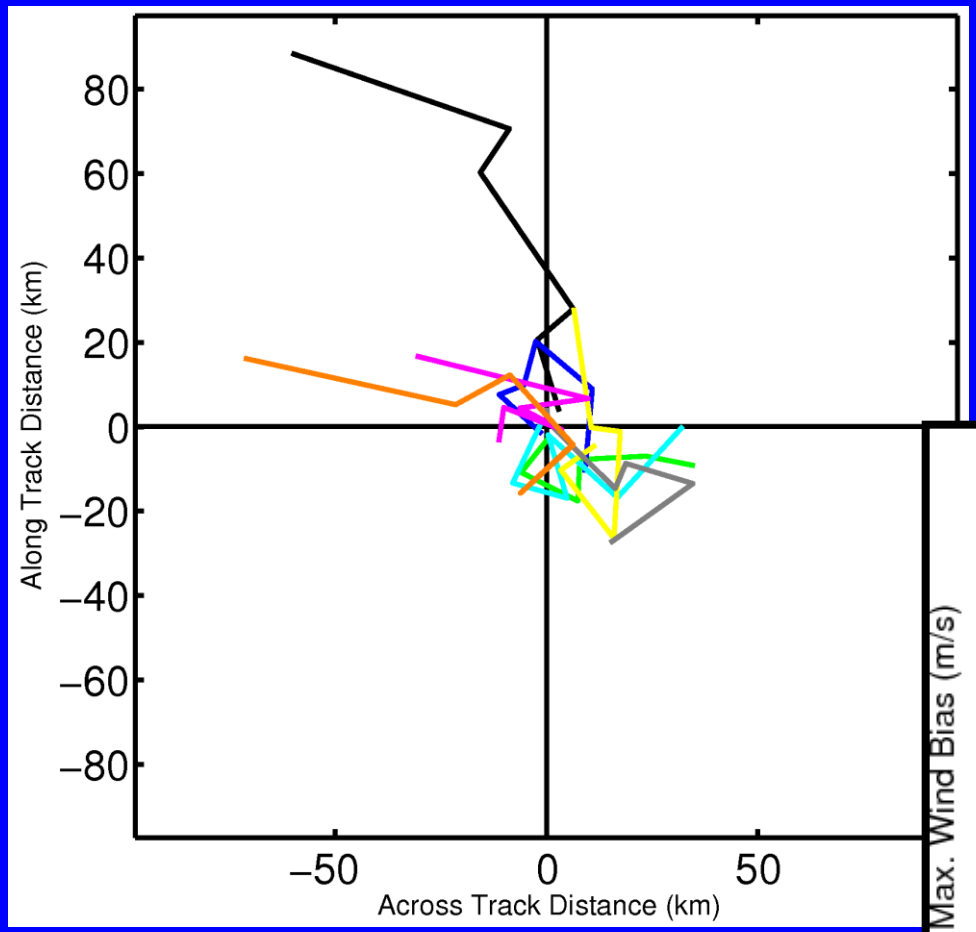
Forecast Errors

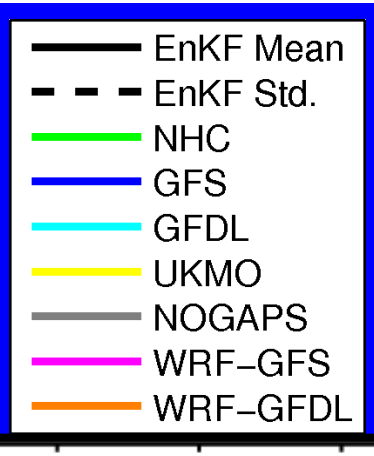


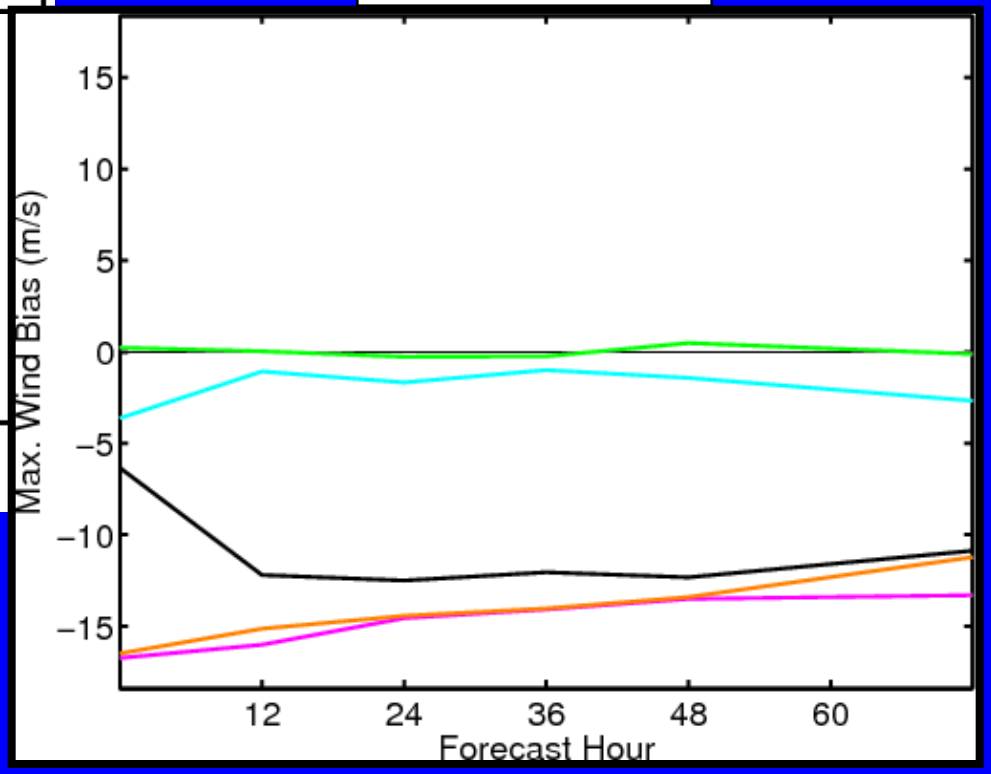


EnKF Mean
EnKF Std.
NHC
GFS
GFDL
UKMO
NOGAPS
WRF–GFS
WRF–GFDL

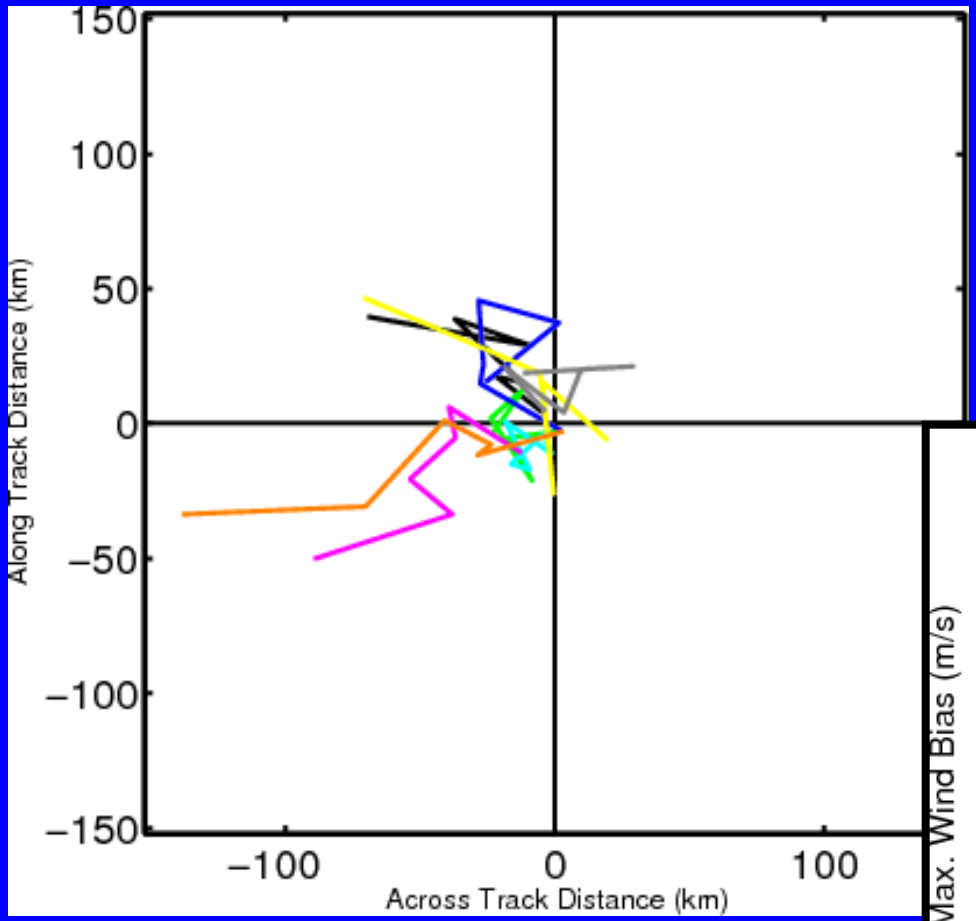
Forecast Biases

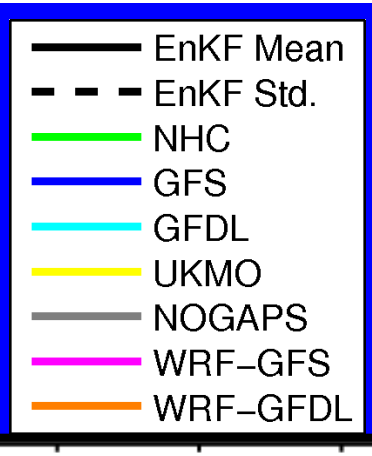


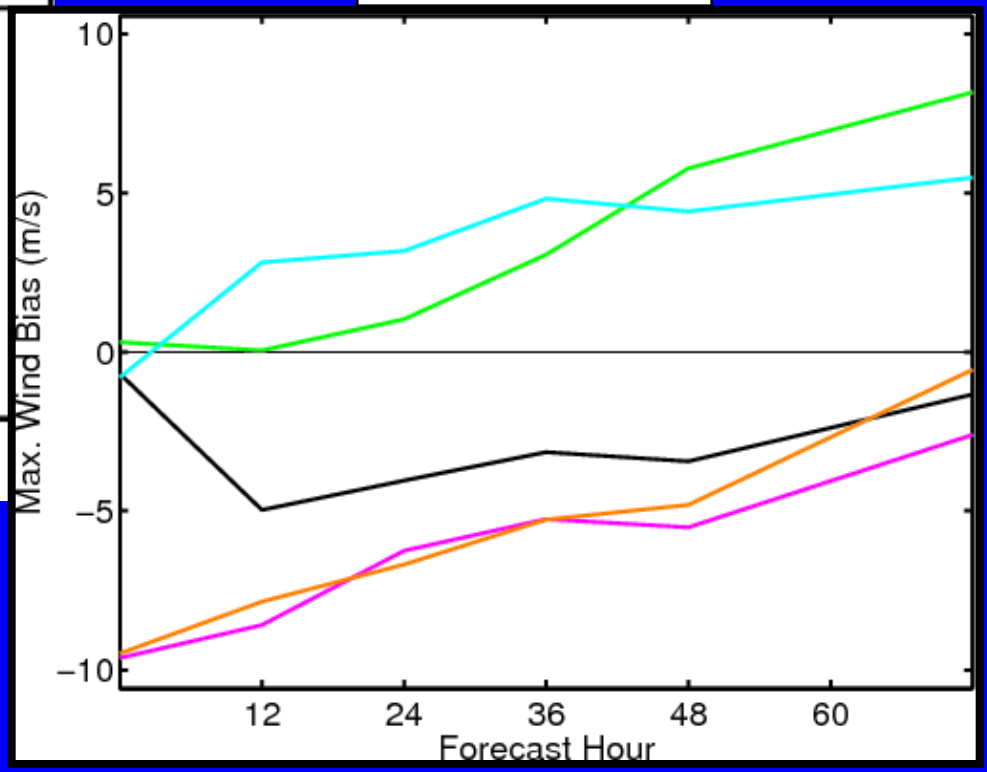




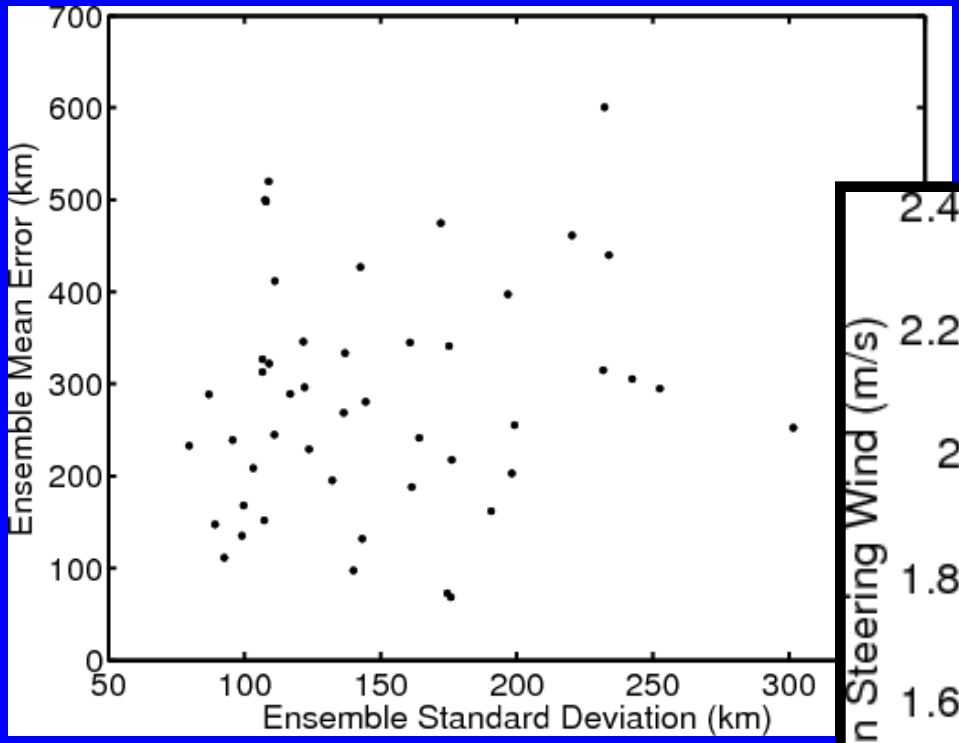
Forecast Biases





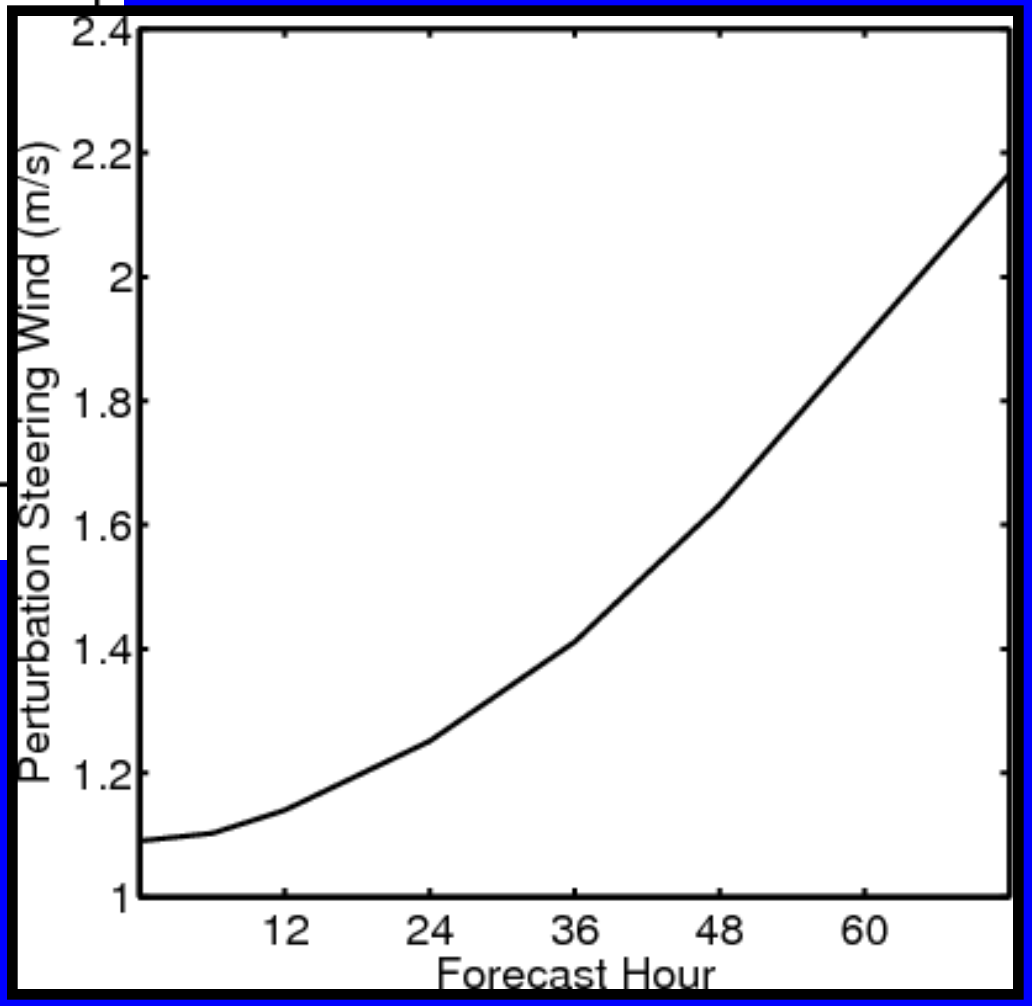


Track Error vs. Spread



Spread vs. Error

Asymmetric Wind Magnitude

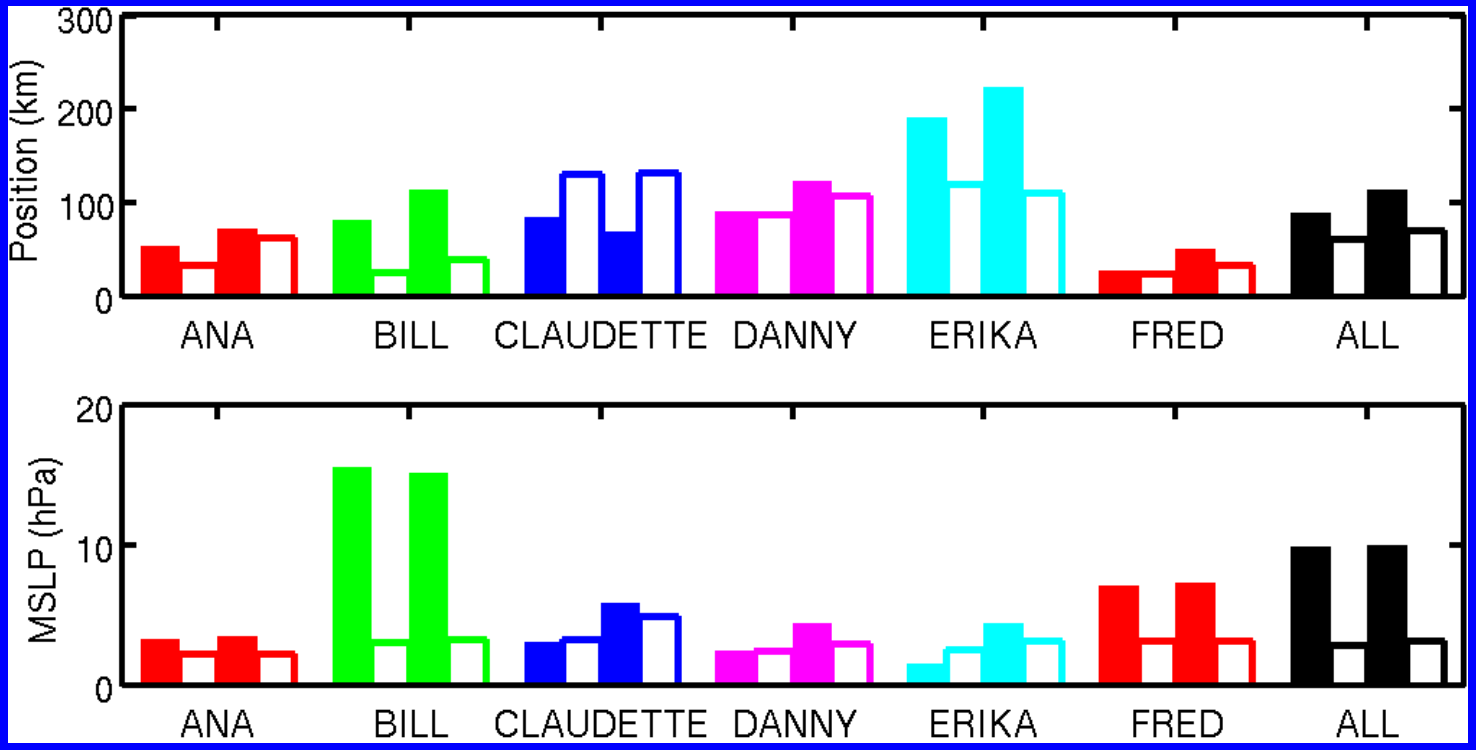


Towards Real-time

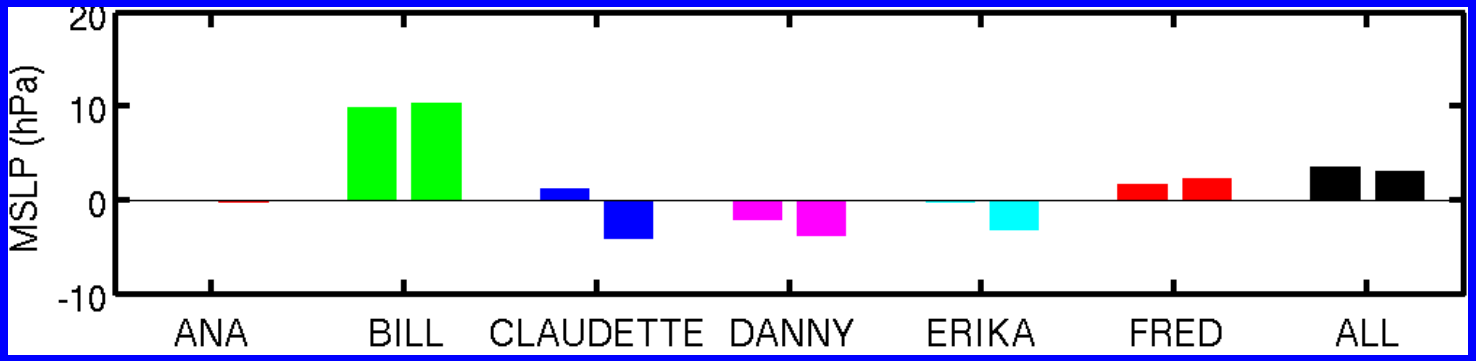
- Given the performance of the high-resolution forecasts, we decided to run a comparable system in real-time during 2009 (tested using 2008 period)
- Initialized on 0000 UTC 10 Aug., captured every storm thus far at genesis
- Run one high-resolution forecast using member that minimizes a cost function involving initial position and intensity

Cycling Errors

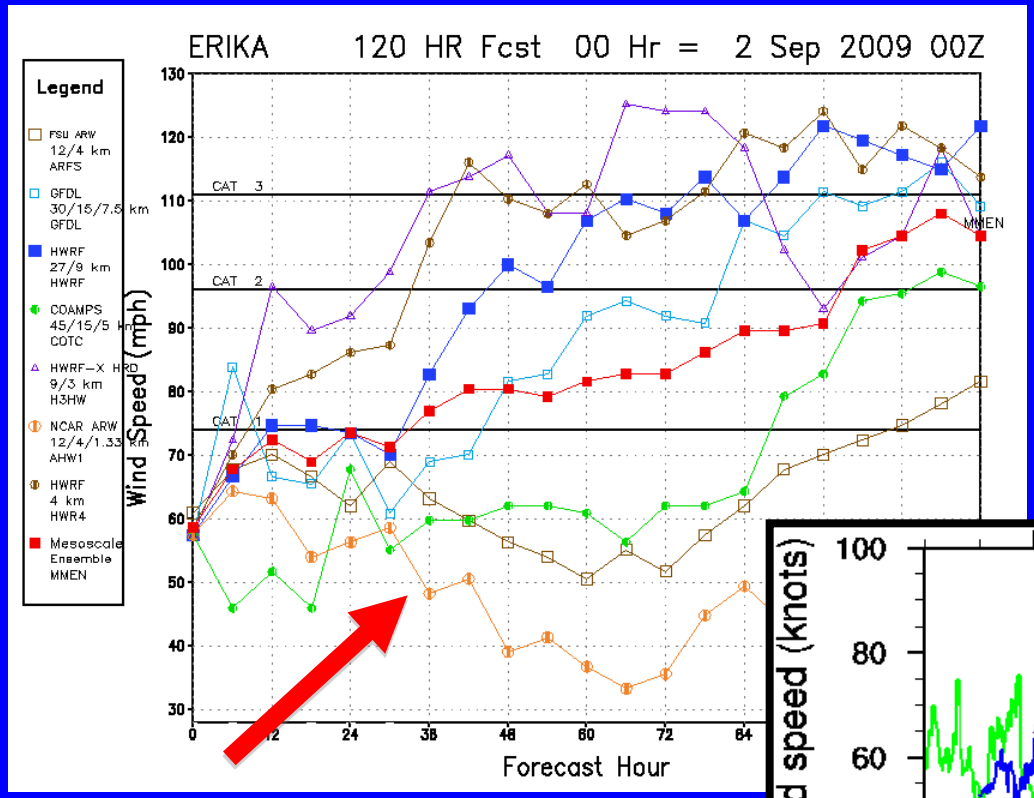
RMS Error

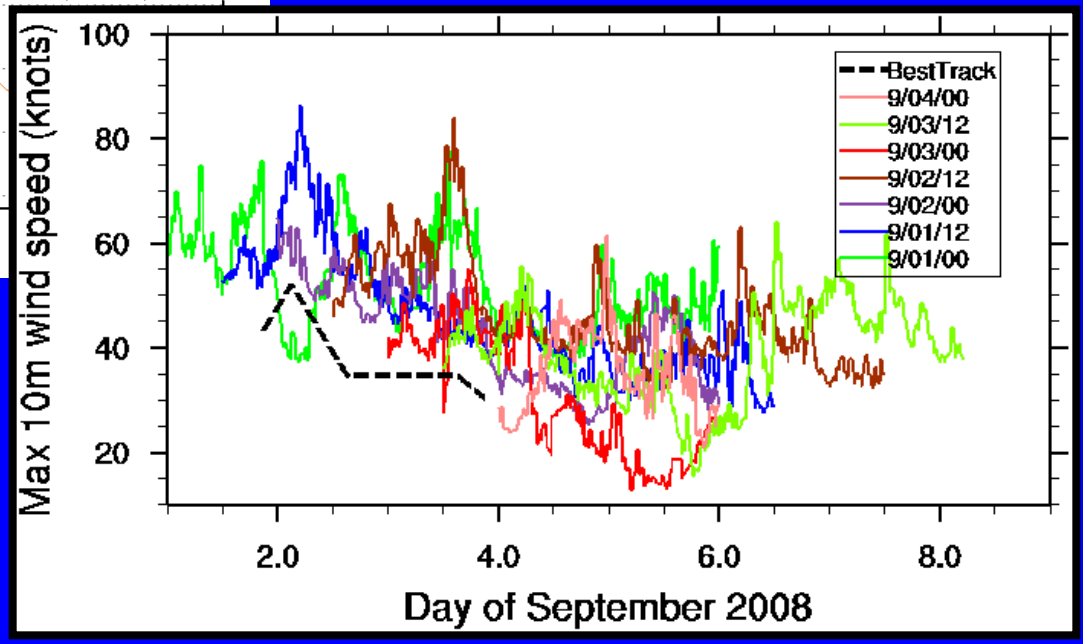


Bias



Erika Forecast

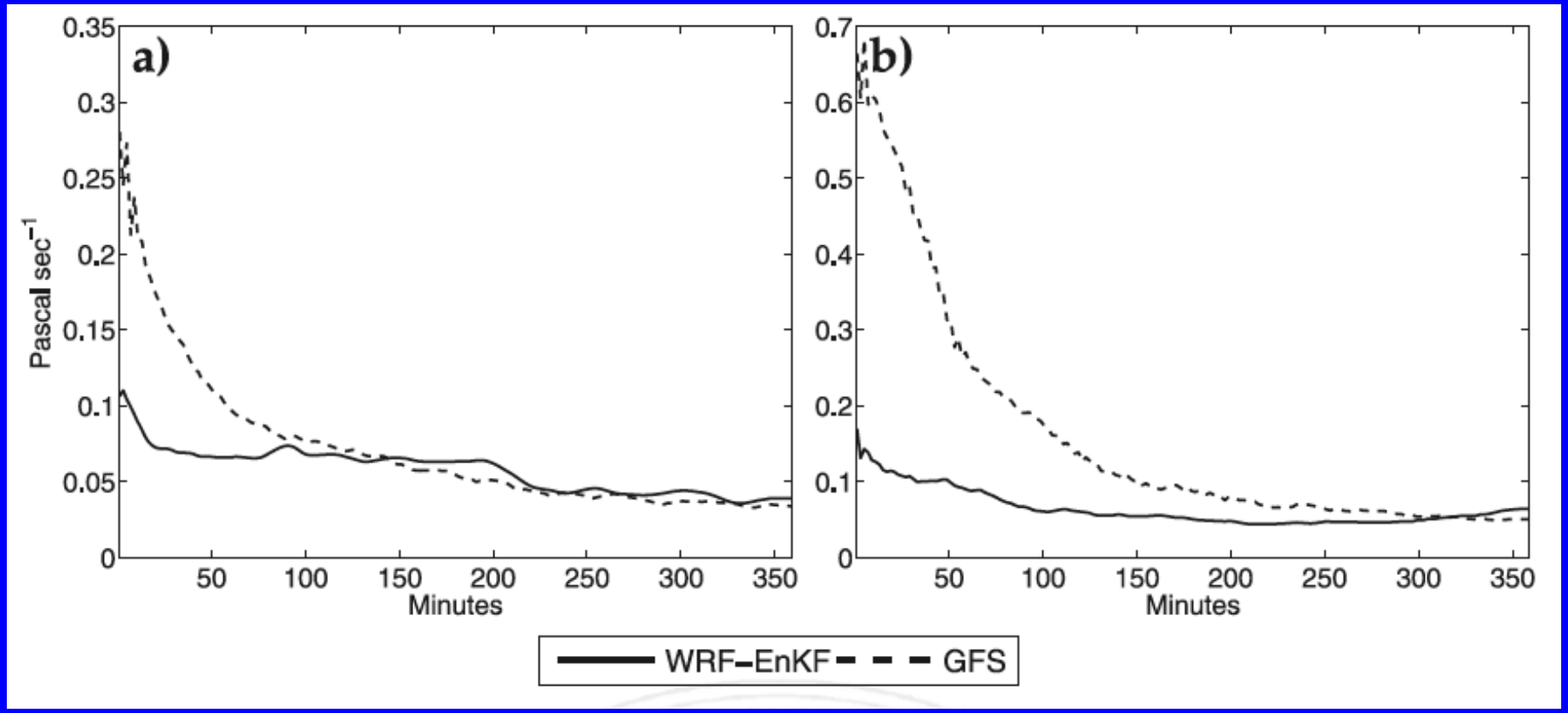




Summary

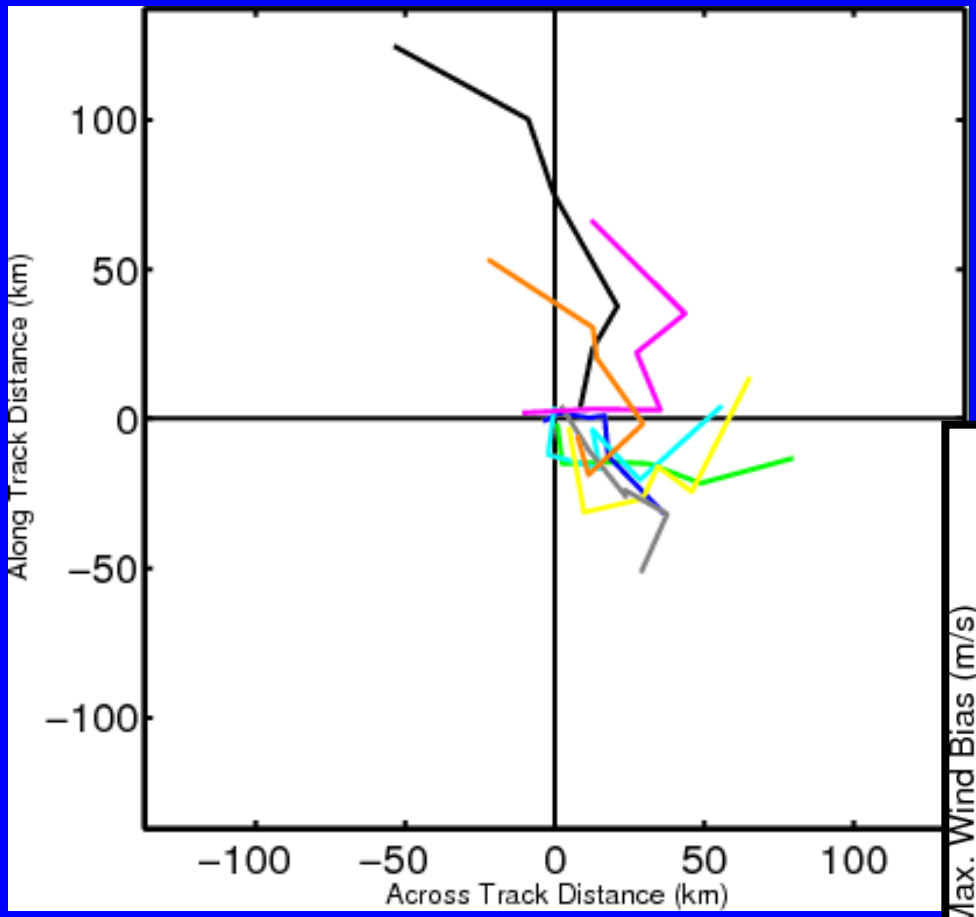
- Ran mesoscale ensemble assimilation system during DTC HRH tests. Focus on generating good analysis of environment, not storm structure
- Track and intensity errors slightly larger than operational models, comparable when statistics computed for weak storms
- Consistent growth in ensemble variance with time (track, intensity, steering wind), though too small
- Real-time convective-resolving forecasts appear to benefit from using EnKF analysis, especially for weak sheared storms (i.e., Ana, Danny, Erika)
- Analysis plots available from MMM WRF site

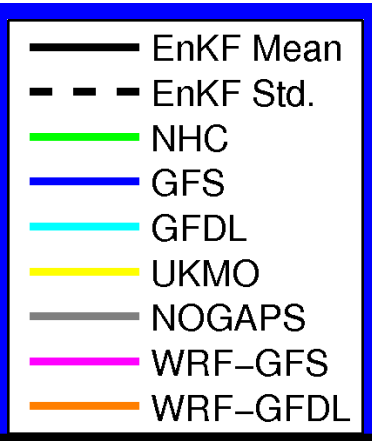
EnKF Initialization

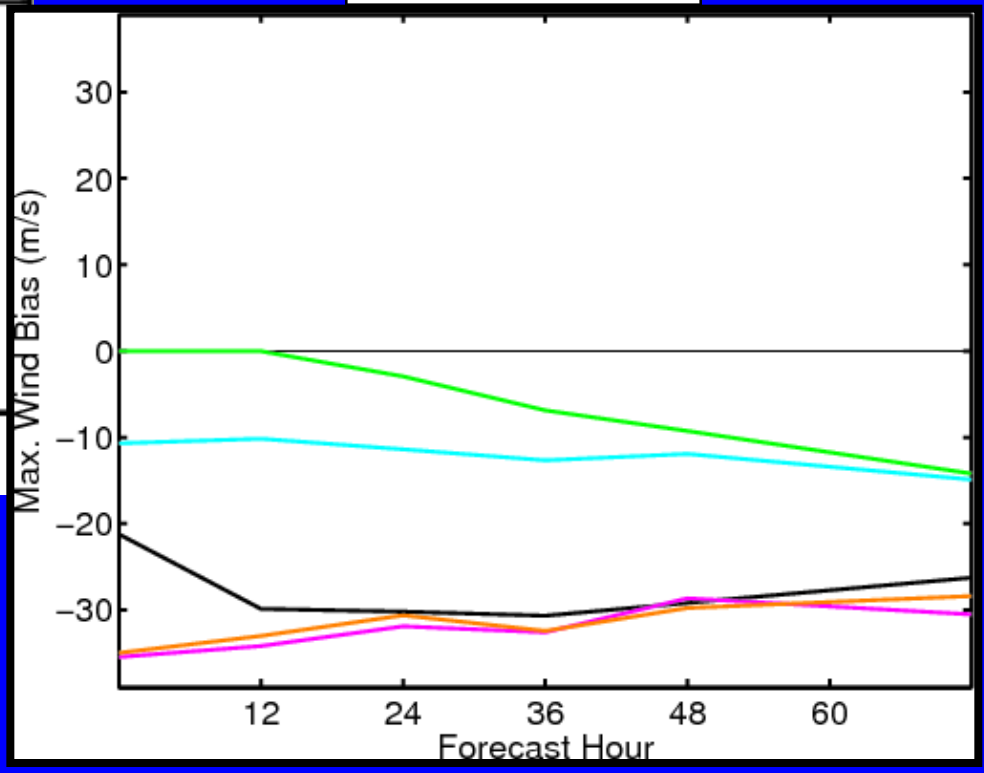


Torn and Hakim (2009) MWR

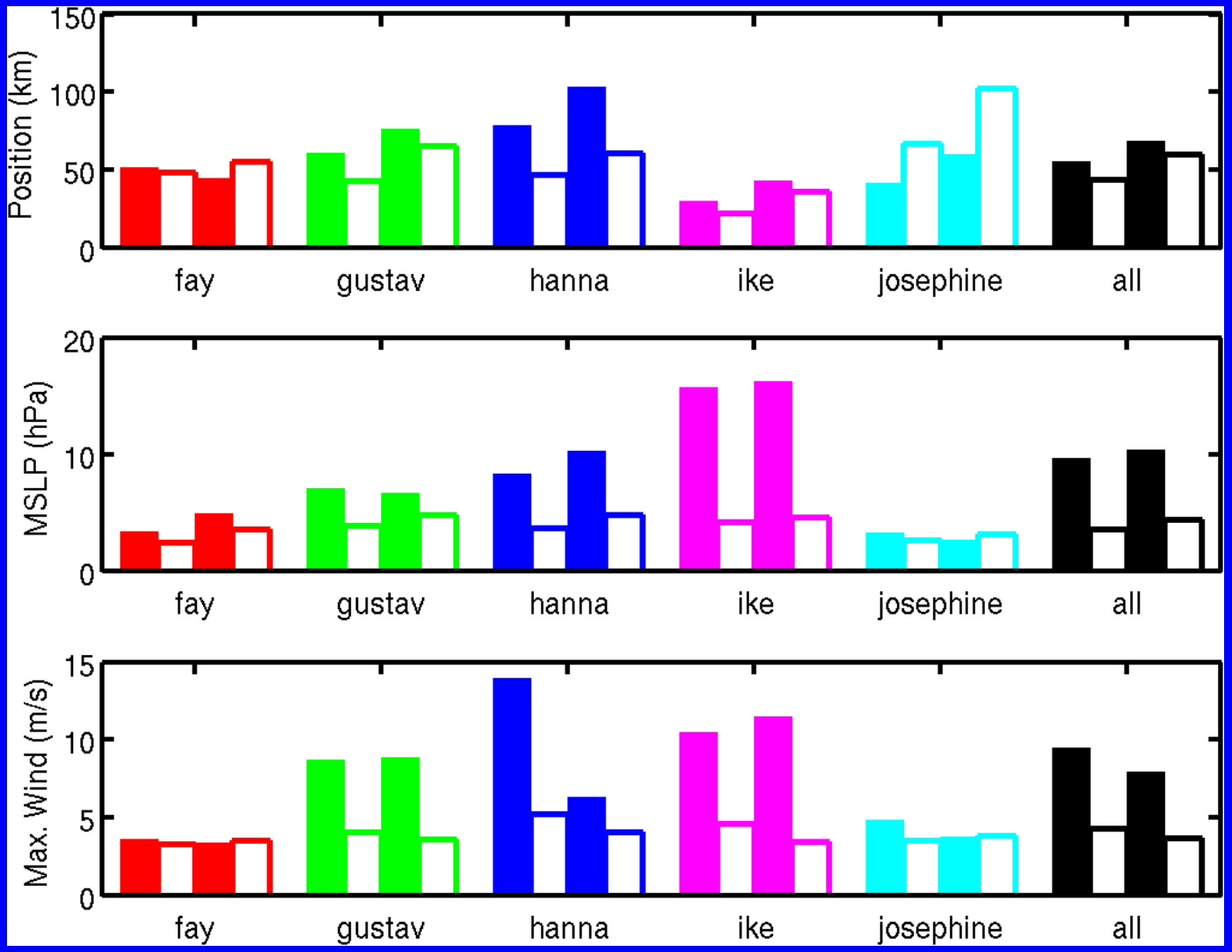
Forecast Biases







2008 Retrospective Errors



2008 Retrospective Biases