HWRF based Ensemble Prediction System Using Perturbations from GEFS and Stochastic Convective Trigger Function

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Outline

- Introduction to HWRF-based EPS
  - Background and Motivation;
  - Methodology;
  - Verification: Ensemble vs. Deterministic;
  - Statistical Validation of HWRF EPS.
- Ensemble Ranking and Selection Method
  - Motivation;
  - Max Potential Forecast Skill;
  - Two Ensemble Member Selection Methods;
- Conclusion and Future Work.

Background and Motivation

- Convective Trigger function in Current HWRF Cumulus Parameterization Scheme (SAS: Simplified Arakawa-Schubert)

  P_{CSL}-P_{LFC} <= DP(w) Convection is triggered,

  P_{CSL}-P_{LFC} > DP(w) No sub-grid convection

  P_{CSL}: Parcel pressure at Convection Starting Level,

  P_{LFC}: Parcel pressure at Level of Free Convection

  DP(w): Convective Trigger, which is function of large scale vertical velocity w.

DP(w) is arbitrarily confined between 120hPa-180hPa

- Storm intensity (Max Wind Speed) is found very sensitive to the convective trigger function;
- Necessary to introduce fuzzy logic trigger to represent sub-grid features.

Methodology

- IC/BC Perturbations (Large scale):

20 member GEFS (ETR-based).

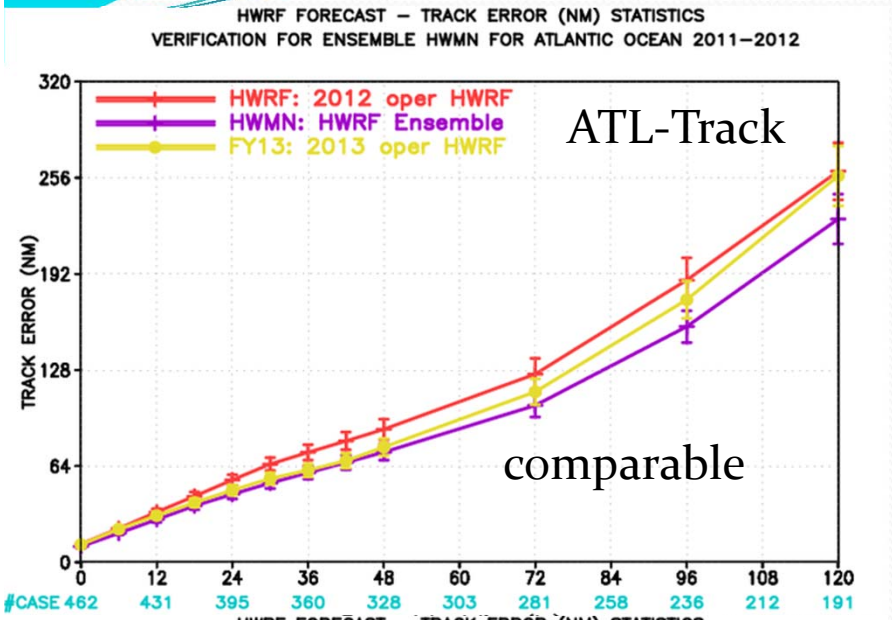
- Model Physics Perturbations (Sub-grid scale):

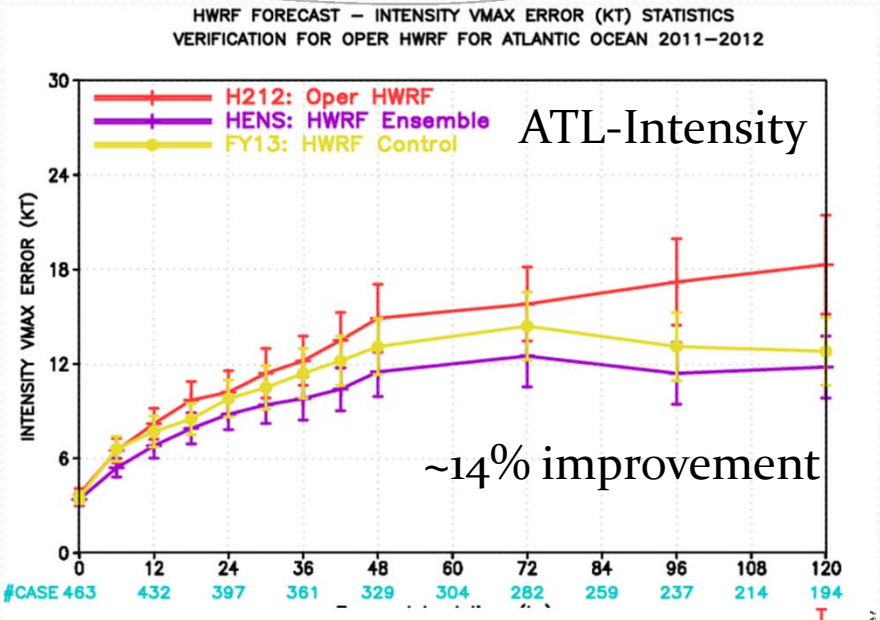
Stochastic Convective Trigger

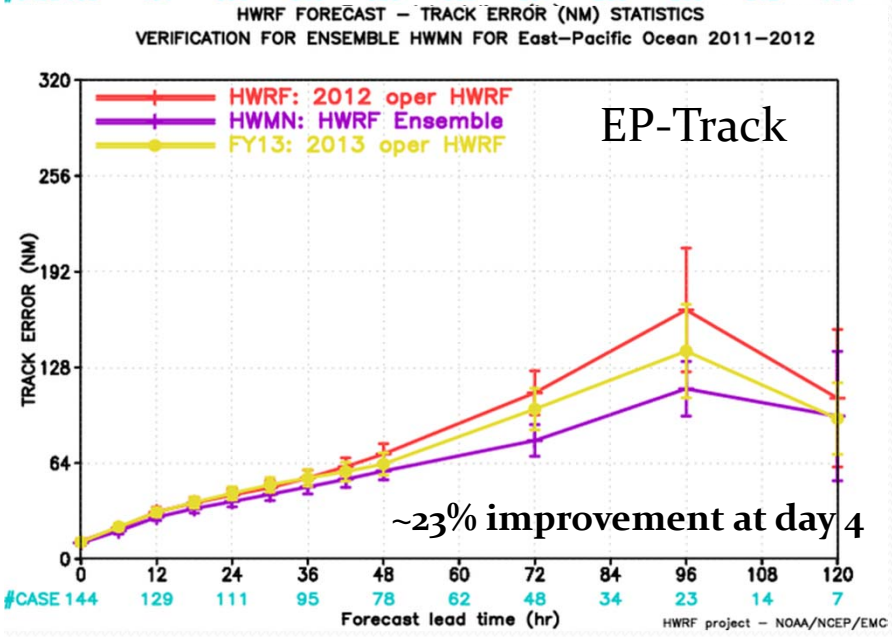
P_{CSL}-P_{LFC} <= DP(w) + Rr (n)

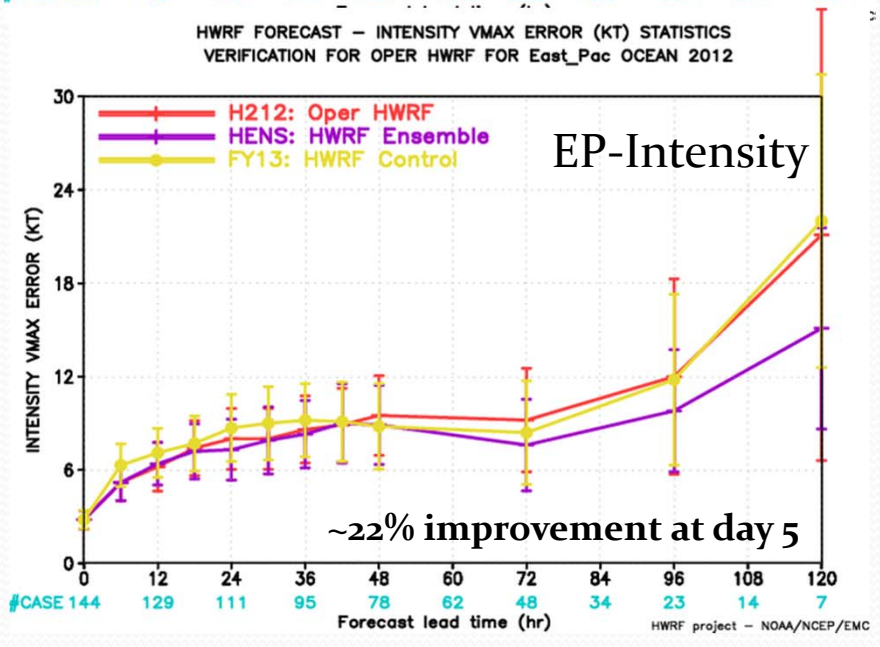
Rr is white noise, ranging from -50hPa to +50hPa, n is nth ensemble member, used as random seed. No spatial and temporal correlations

HWRF/EPS Verifications for 2011-2012 Storms

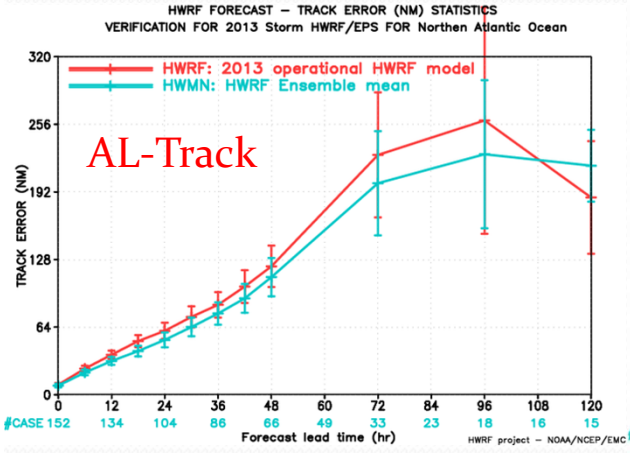


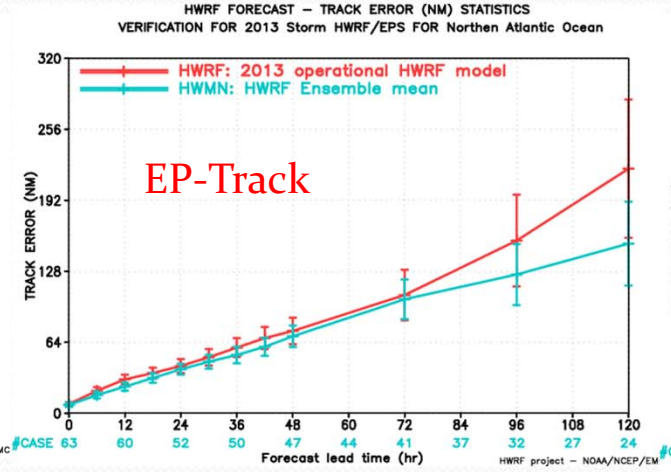


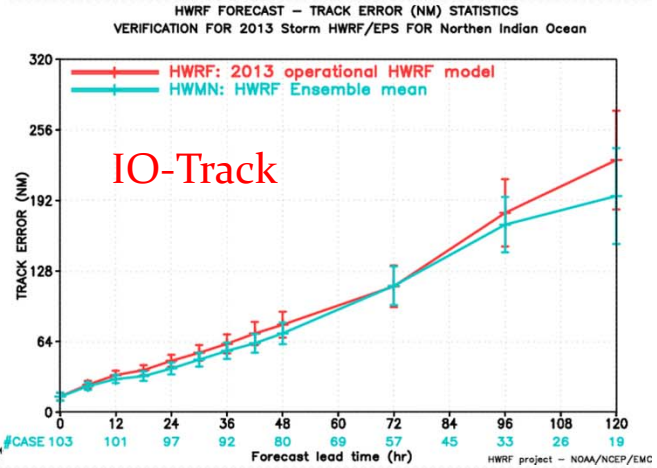


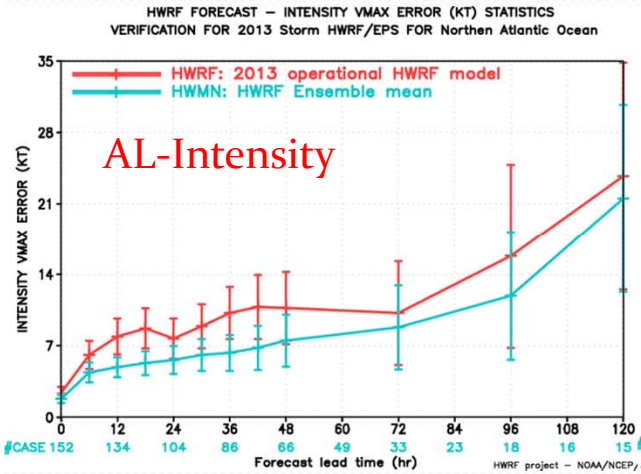


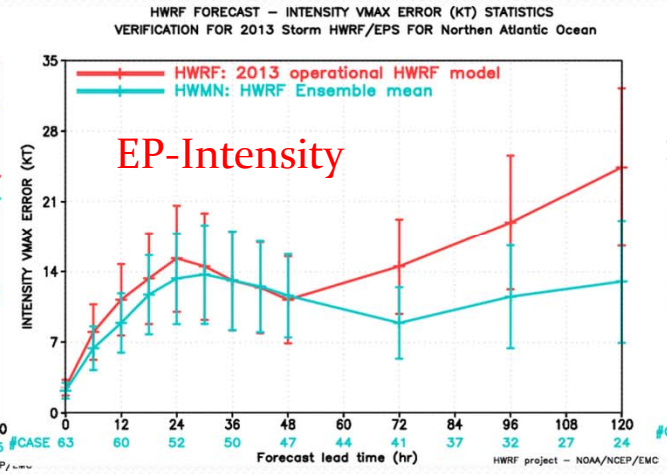
HWRF/EPS Verifications for 2013 Storms

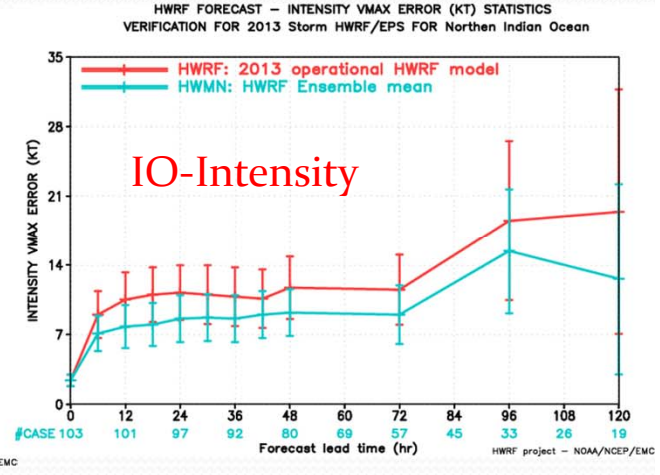








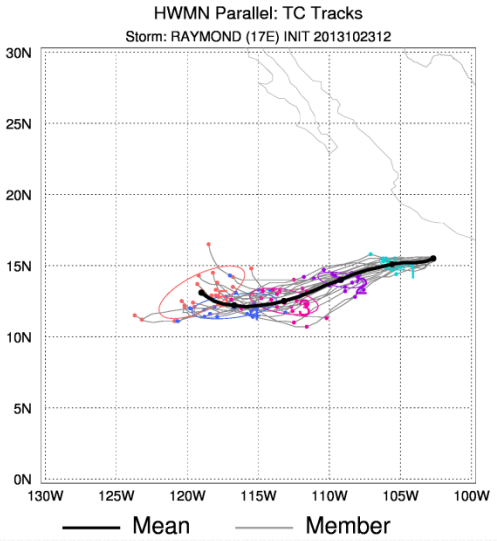


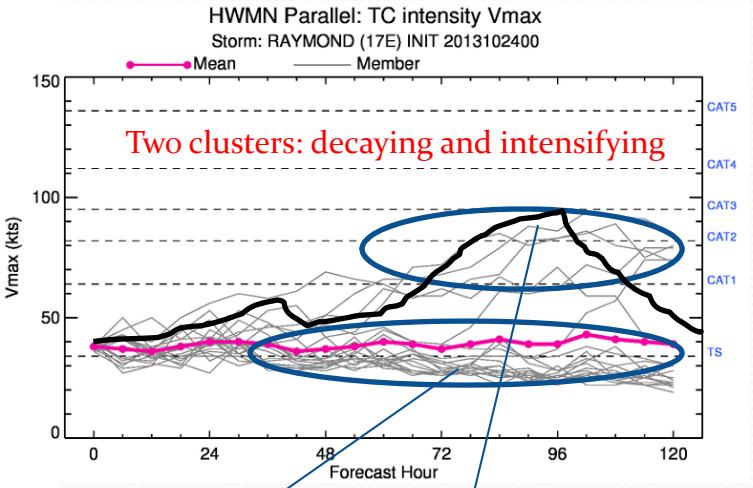


Prediction for Hurricane Raymond, 20131024 00Z

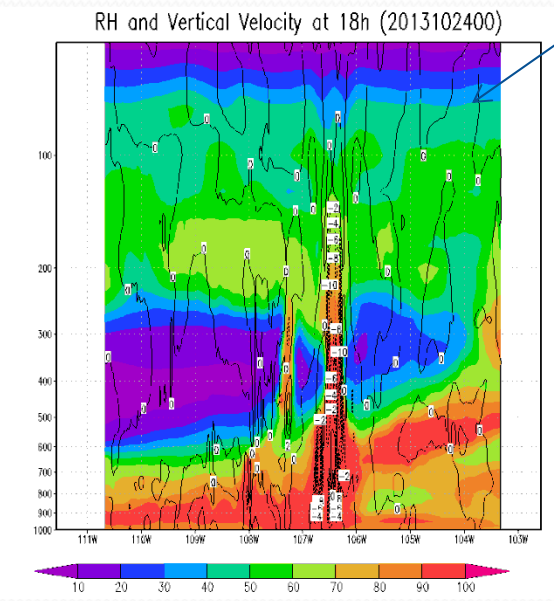
Large differences in predicted storm intensity due to sub-grid uncertainties in model physics: stochastically perturbed cumulus convection scheme in HWRF

Dry air at mid-level suppressed storm development in one member, while active convective cells overcome the dry air, storm intensified in anther member.

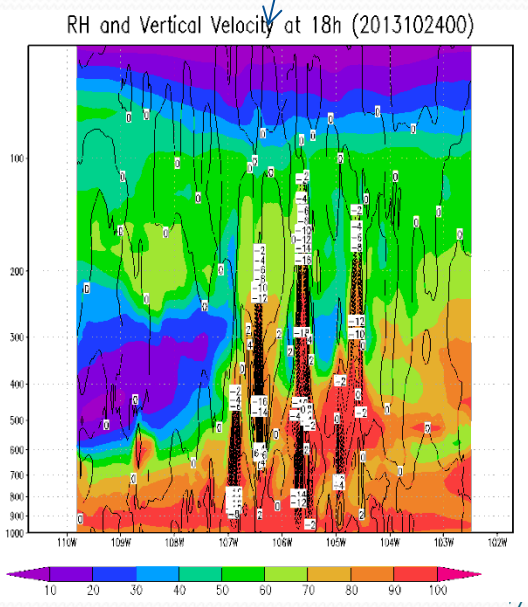




HW06

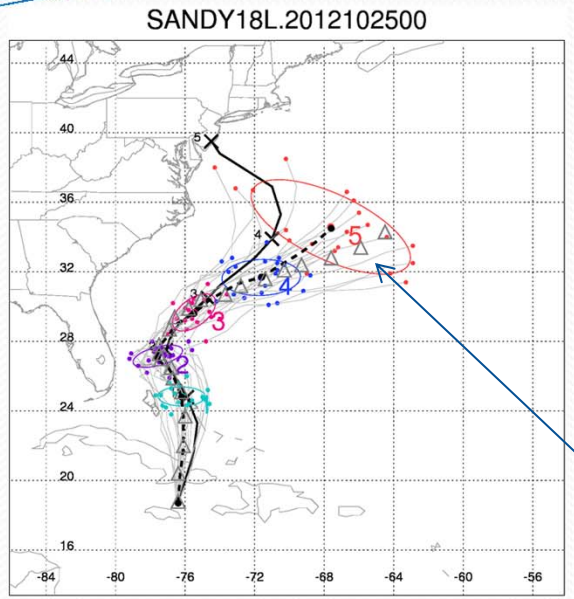


HW10

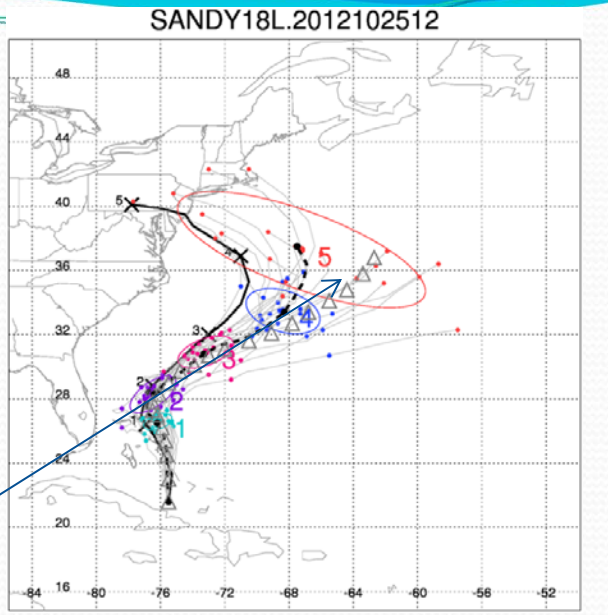


Track Probability Forecasts for Hurricane Sandy

Few members turned west

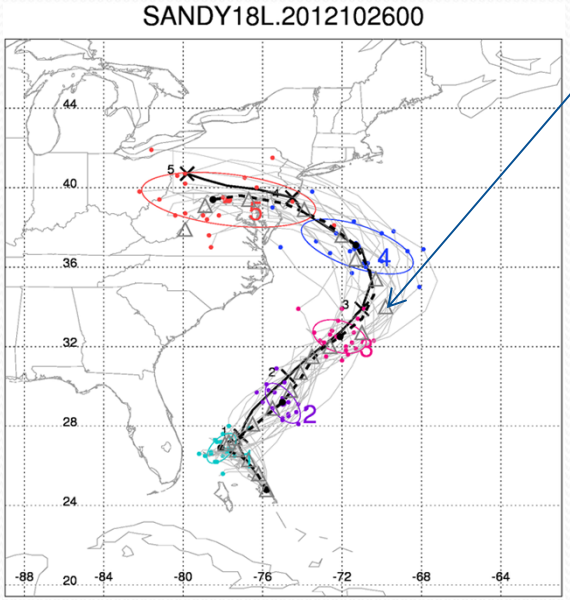


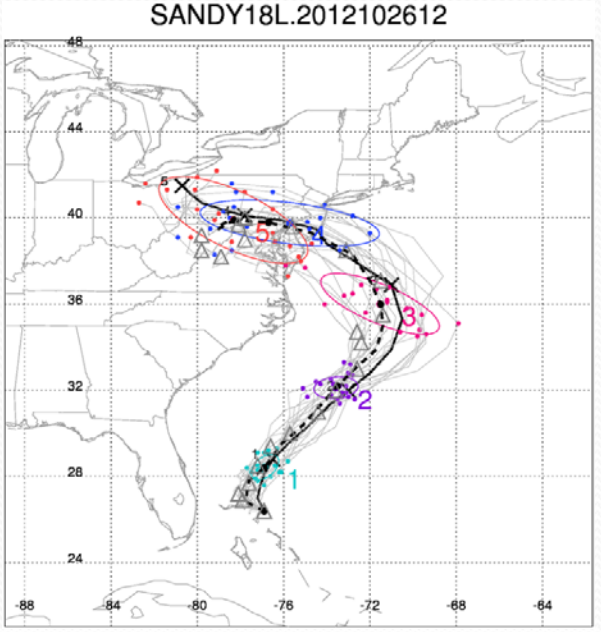
More members turned west



FY13

All members turned west

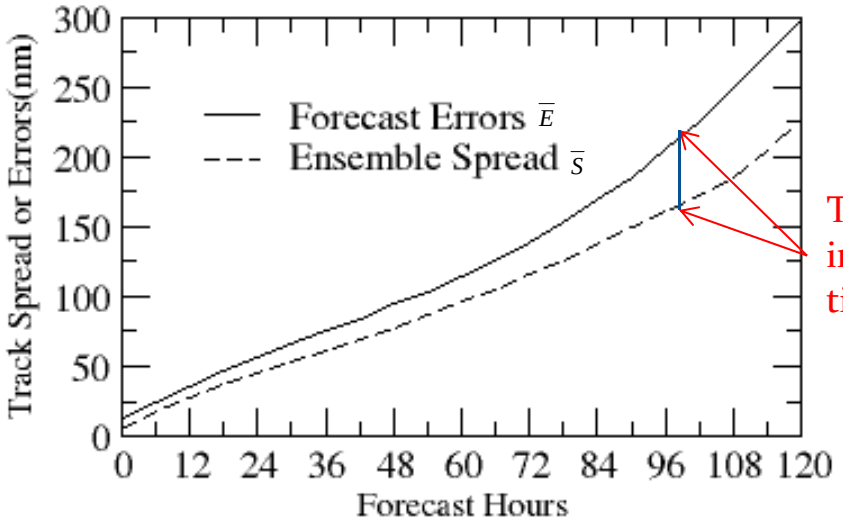




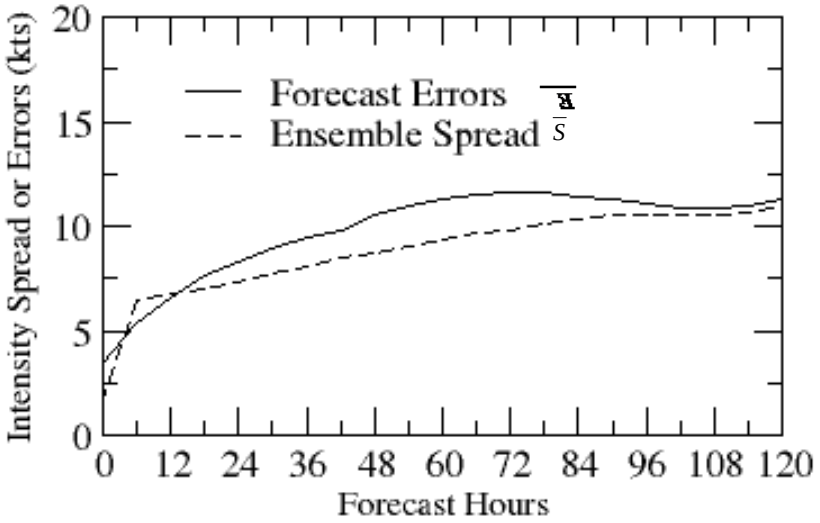
Statistical Validation of HWRF EPS

Forecast Errors and Ensemble Spread (Track and Intensity)

Averaged over all 2011-2012 storms



The under-dispersion increases with forecast lead time



1. The mean of ensemble spread is close to the mean of the forecast errors;
2. The difference between the two lines indicates the level of ensemble dispersion;

Ensemble Ranking and Selection Method

Selecting Individual Ensemble Member to Represent Ensemble Forecasts

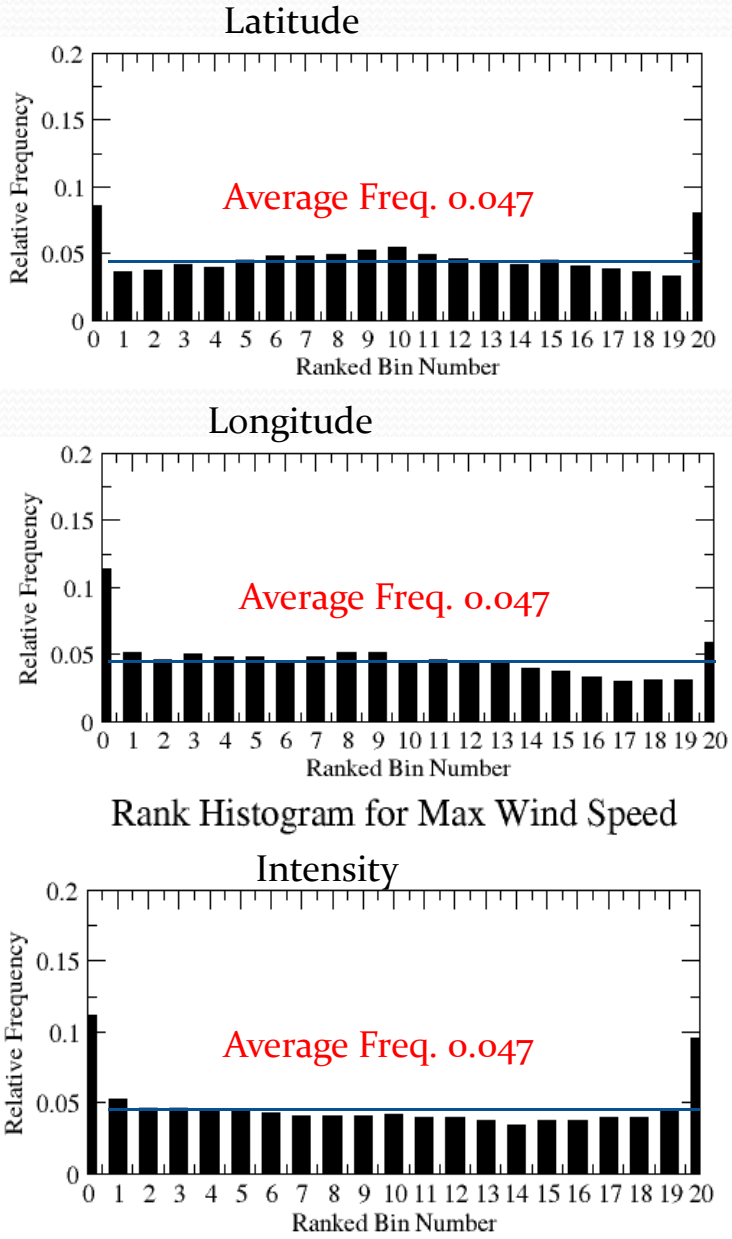
Motivation:

- The ensemble mean track/intensity forecasts are NOT associated with any 3-dimensional model forecast fields;
- Because of the phase diff. among the members, ensemble mean of 3D fields don't represent predicted storm structures.
- It is desirable to select one ensemble member to represent 3D ensemble forecast fields for diagnostic purpose, so we can further improve model physics.

Methodology:

- Although the performance of individual members statistically perform in an equally likely manner in a well designed EPS, the performance of individual member is certainly not equal in every single forecast event;
- It is desirable to know beforehand the performance of each member relative to other members;
- The optimal member selection will be based on ensemble mean of track/intensity forecasts.

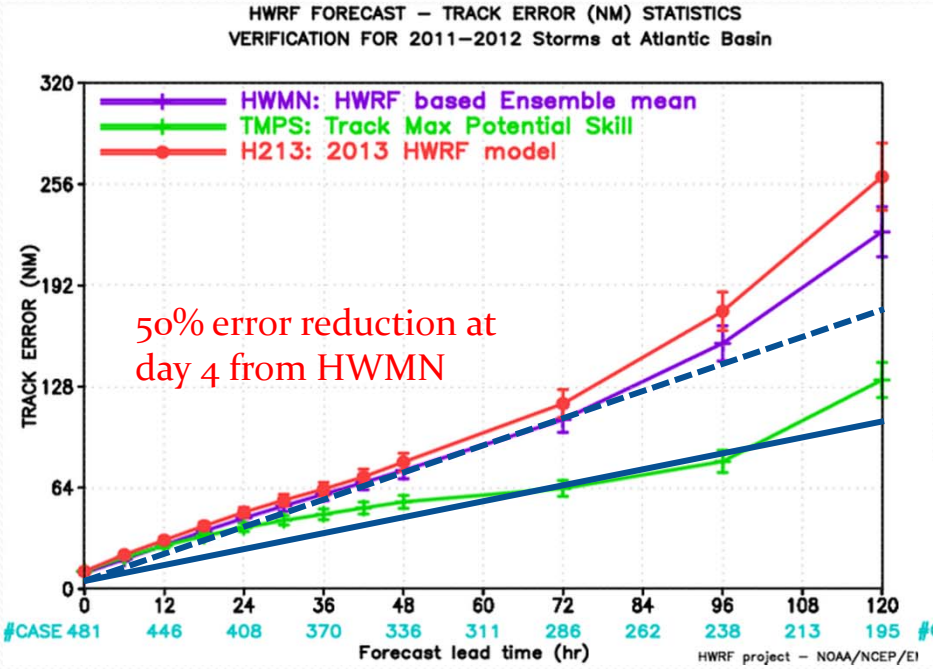
Analysis of Rank Histogram

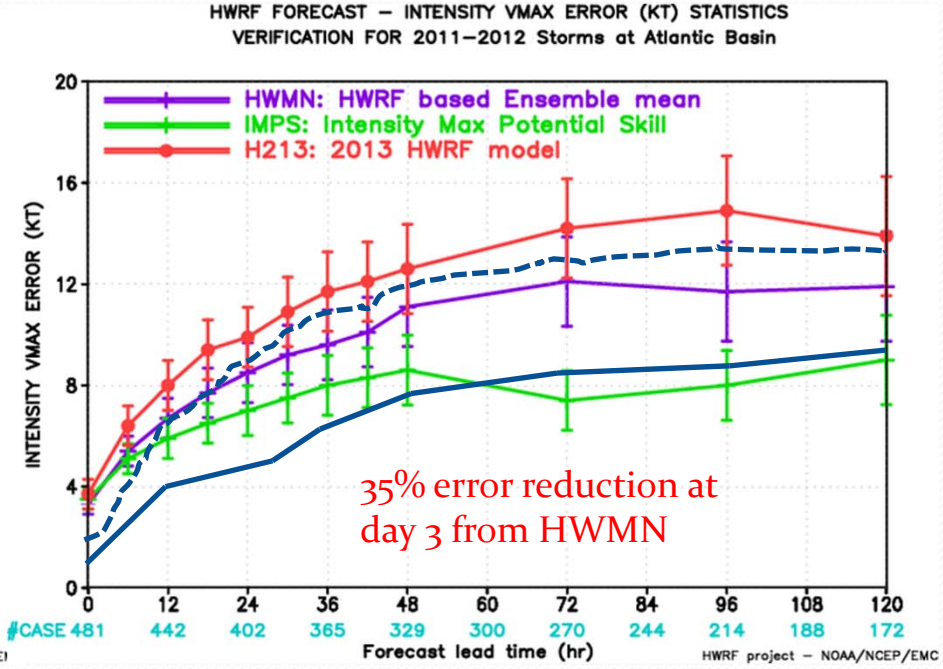


Max Potential Forecast Skill

- Max Potential Forecast Skill (MPFS) is defined as the track/intensity forecast skill by assuming we always make the right decision and select the ensemble member that is closest to the truth;
- Assume the best track info is known beforehand, the member whose track/intensity is closest to the obs. is selected as its final forecast;
- MPFS shows the forecast skill limit of the current HWRF EPS.

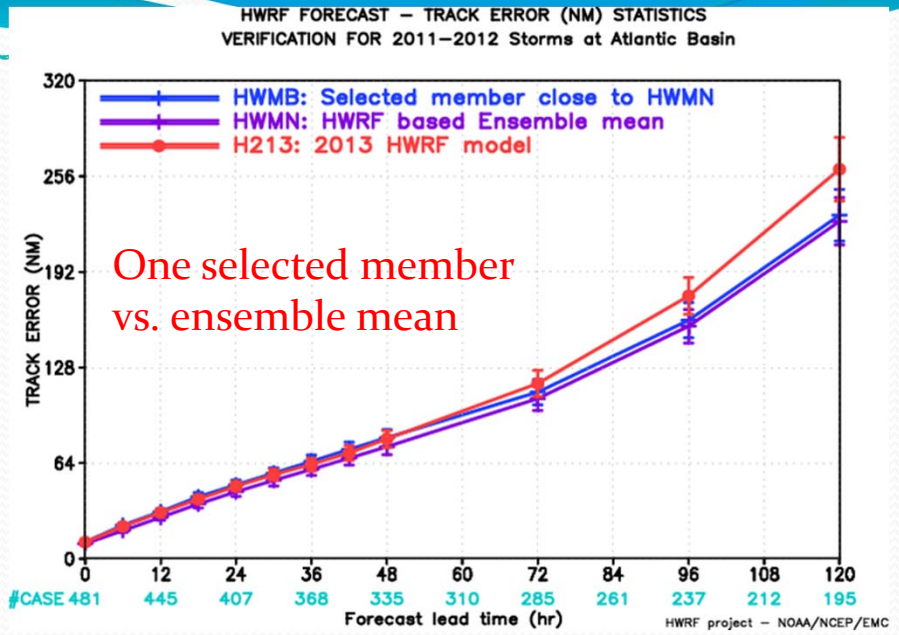
HFIP 5 year goal — HFIP 10 year goal

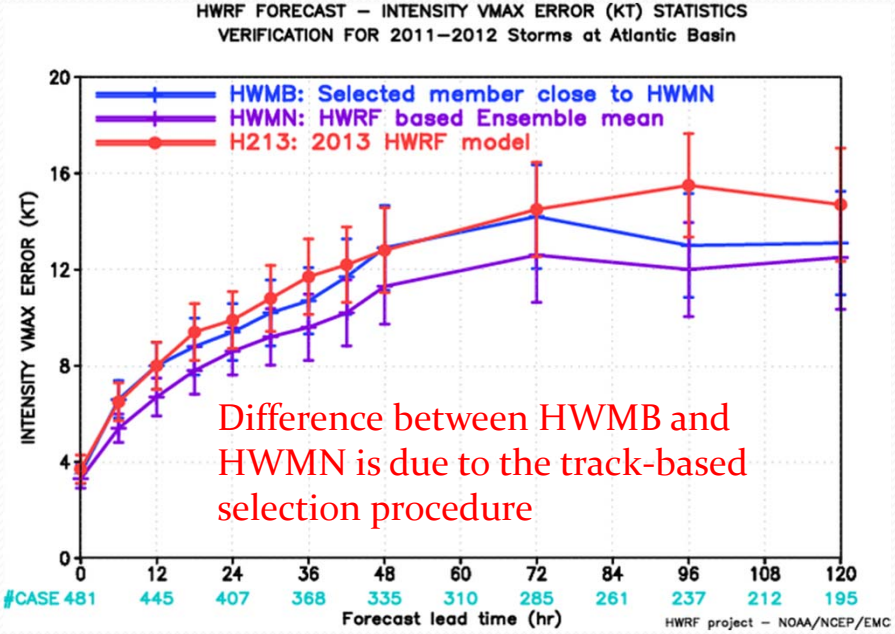


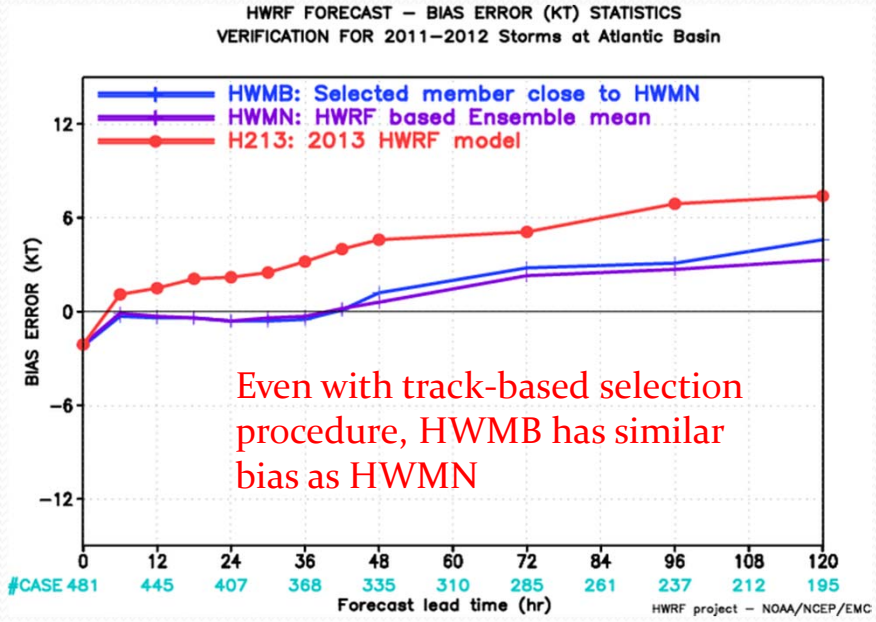


Ensemble Mean based selection method

It is natural to assume that the ensemble mean is a good estimation of the truth, so the member, whose track/intensity is closest to the ensemble mean (HWMN), is considered as the optimal member.





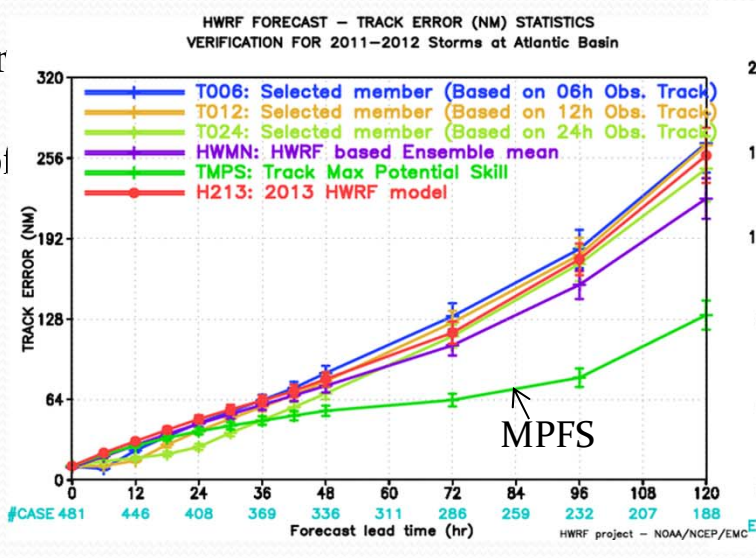


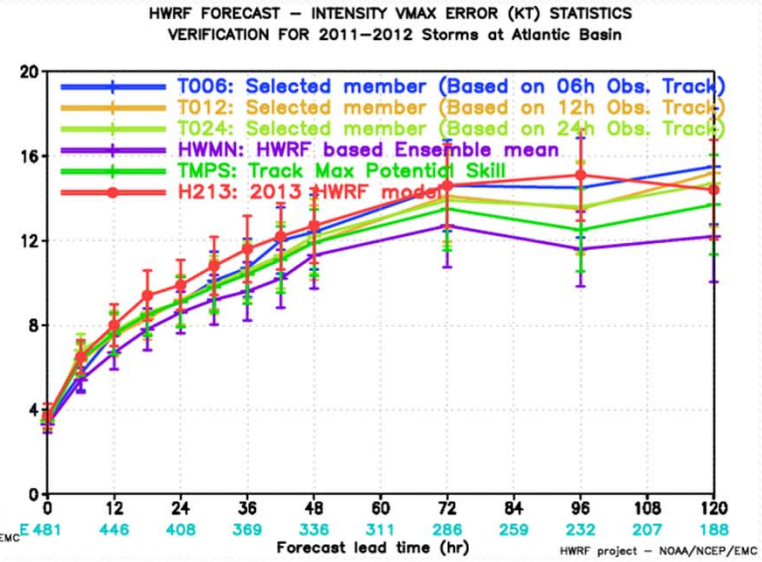
Observation based selection method

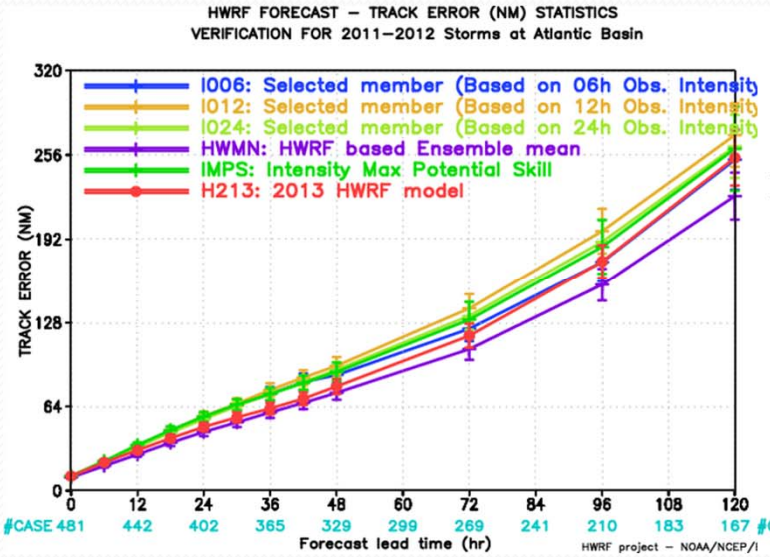
Assumption:
The best track info for certain period is available at the time of the forecast.

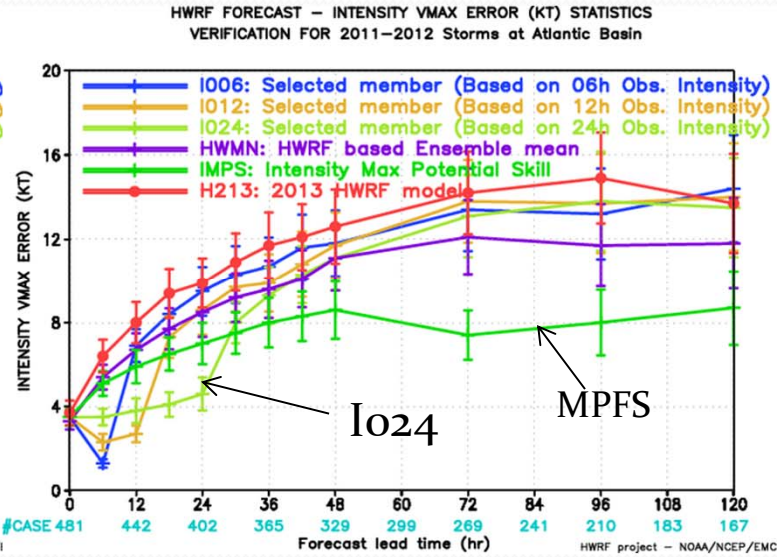
- 06h BT is avail.
- 12h BT is avail.
- 24h BT is avail.
- MPFS
- H213

Even though the forecast skills are improved initially, HWMN is better in general.
More info other than obs.
Track/intensity may be needed for this approach









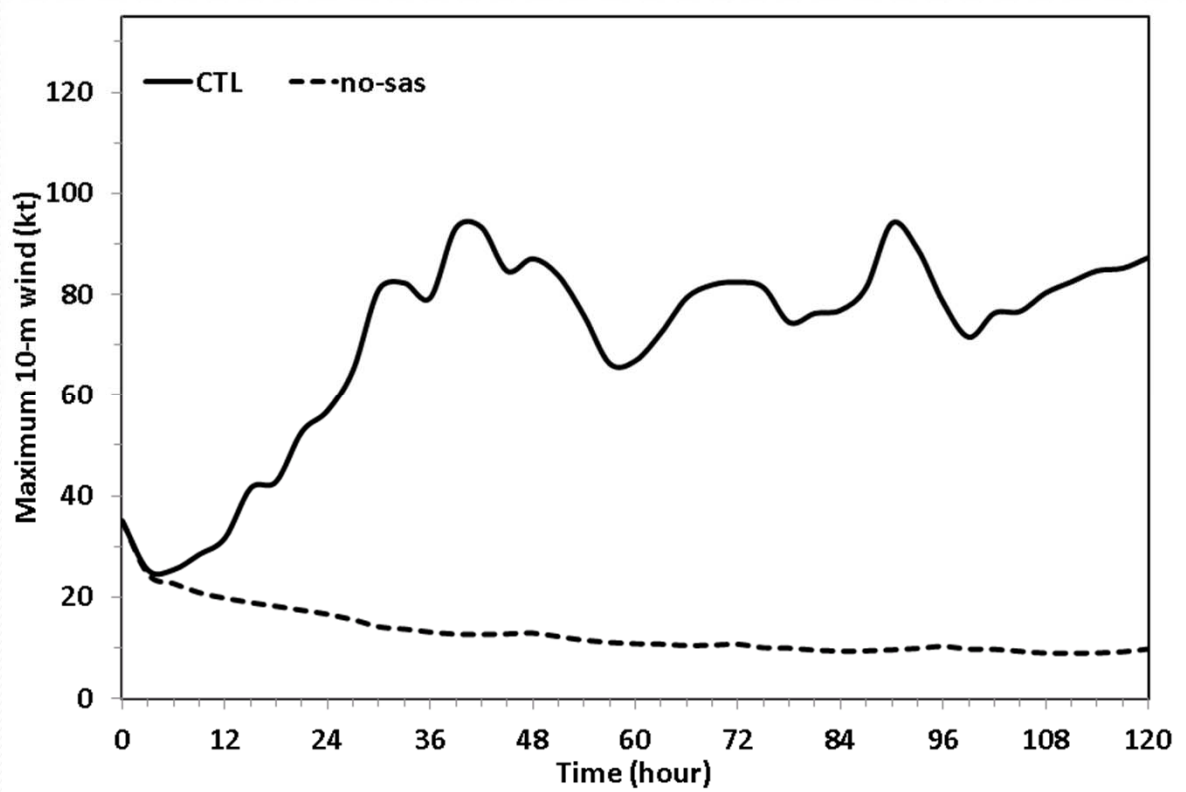
Summary

- HWRF-based EPS includes perturbations from large scale flows (GEFS) and sub-grid scales (physics-based SCT);
- Statistical characteristics shows that HWRF EPS introduces no bias but inherits some biases from the deterministic model in terms of track/intensity forecasts;
- Both HWMN track and intensity forecast skills are improved over its deterministic versions (H212 and FY13), with more improvements in intensity forecasts;
- MPFS and ensemble member selection procedure are discussed. Ensemble mean based selection method produced better forecast skills than observation based method.

Future work:

- Add more stochastic processes to model physics in HWRF EPS;
- Explore ensemble performance ranking method to select optimal member to present ensemble forecasts.

Impact of Cumulus Convection on Large Scale Flow
Idealized Experiment



Solid line: SAS in D01 and D02 (27km and 9km)
Dash line: no SAS in D01 and D02.
Sub-grid convection is explicitly expressed in D03 in both exps.
The model storm will not develop when SAS scheme is turned off in the 27- and 9-km domains even if the domain 3 (3km) resolution is high enough to resolve the convection scheme.