

HFIP Joint HWRF/COAMPS-TC/GFDL Multi-Model Regional Ensemble System

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Weiguo Wang, Vijay Tallapragada

NRL: Jon Moskaitis, Alex Reinecke, Jim Doyle

GFDL: Matthew Morin, Timothy Marchok
Morris Bender

Outline

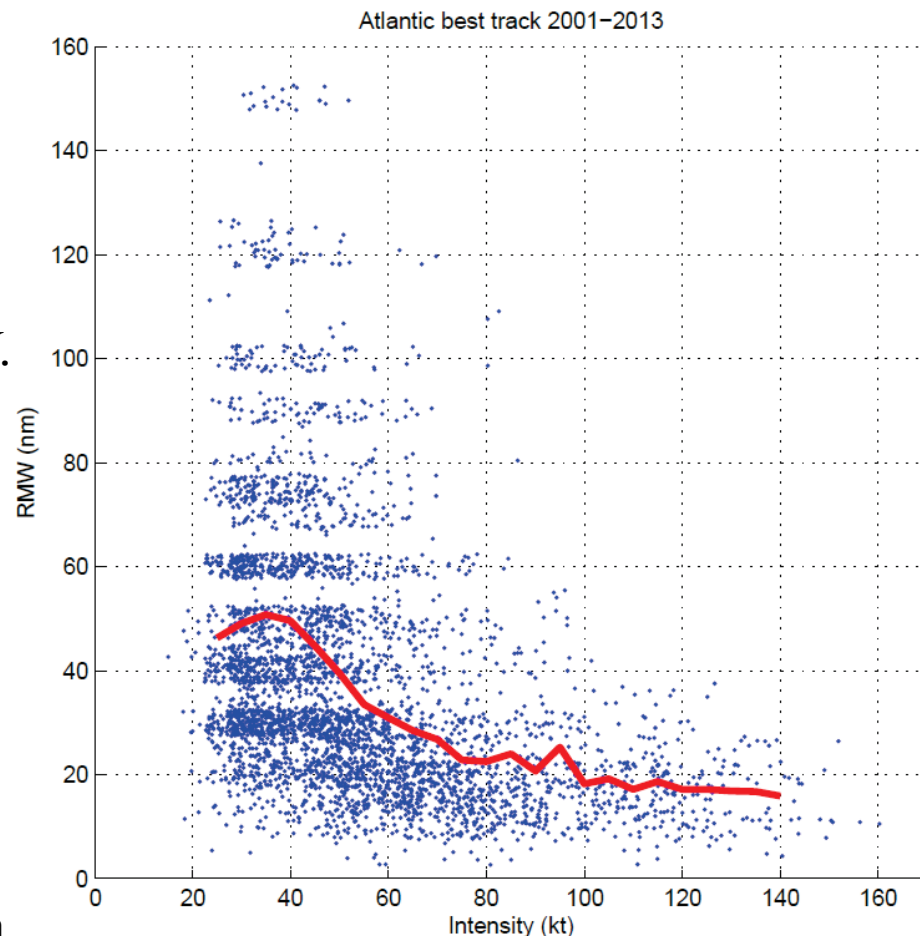
- Motivations and Goals;
- Introduction to Three-model High-resolution Regional Ensemble System;
- Verification Results from Retrospective experiments;
- Real Time Ensemble Forecast Products.

Motivations and Goals

- Increase number of ensemble members to take into account more uncertainties in:
 - Large scale environment flows, IC/BC;
 - Vortex intensity and structures at the model initial time;
 - Model physics and dynamics.
- Provide improved and reliable real time storm track/intensity forecasts and probabilistic forecasts (real time tier₁ products will be submitted to TCMT for verification);
- Develop more ensemble probabilistic forecast products based on multi-model ensembles.

2014 COAMPS-TC ensemble Configuration

- Synoptic perturbations:
 - Perturbation drawn from a static covariance
 - Perturb the boundaries
 - Use WRFVAR cv3
- Vortex scale perturbations:
 - Vortex position, max wind, and RMW.
 - Perturbation variance from:
 - Torn and Snyder 2012
 - Landsea and Franklin 2013
 - Max wind and RMW covariance derived from 2001-2013 best track data.
 - Variance's and covariance's depend on TC-vital max wind speed.



2014 GFDL ensemble Configuration

GP00: Control forecast (based on NCEP's 2014 implementation of the GFDL hurricane model)

GP01: Opposite vortex bogussing method of the ensemble control model (i.e., runs unbogussed when the control runs bogussed, and vice versa)

GP02: Increase NHC-observed Vmax 10%, 34-kt radii 25%, 50-kt radii 40%, ROCI 25%

GP03: Decrease NHC-observed Vmax 10%, 34-kt radii 25%, 50-kt radii 40%, ROCI 25%

GP04: Increase inner-core moisture by a max of 10%

GP05: Decrease inner-core moisture by a max of 10%

GP06: Increase SSTs by a max of 2°C within the initial extent of the TC

GP07: Decrease SSTs by a max of 2°C within the initial extent of the TC

GP08: Surface physics modification: GFDL 2011 operational formulation of CD & CH (surface drag and enthalpy exchange coefficients)

GP09: Surface physics modification: HWRF 2014 operational formulation of CH (surface enthalpy exchange coefficient)

GPMN: Ensemble mean computed at each lead time where the member availability is at least 4 members (40% threshold)

2014 HWRF ensemble Configuration

- Use 2014 operational deterministic HWRF model except for
 - Less vertical resolution: L43 vs. L61;
 - Smaller D02, D03 domains, same as H213;
 - No GSI due to lack of GDAS data;
- IC/BC Perturbations (large scale): 20 member GEFS.
- Model Physics Perturbations (vortex scale):
 - Stochastic Convective Trigger in SAS: -50hPa to + 50hPa white noise ;
 - Stochastic boundary layer height perturbations in PBL scheme, -20% to +20%;
 - Stochastic initial wind speed perturbations with zero mean and 7% standard deviation, Gaussian distribution.

Retrospective Runs from HWRF/COAMPS-TC/GFDL Ensembles

Models	Number of Cycles	Number of Storms
HWRF	520 cycles, 2011-2013, AL and EP	54
COAMPS-TC	210 cycles, 2010-2013, AL	10
GFDL	716 cycles, 2011-2013, AL	43

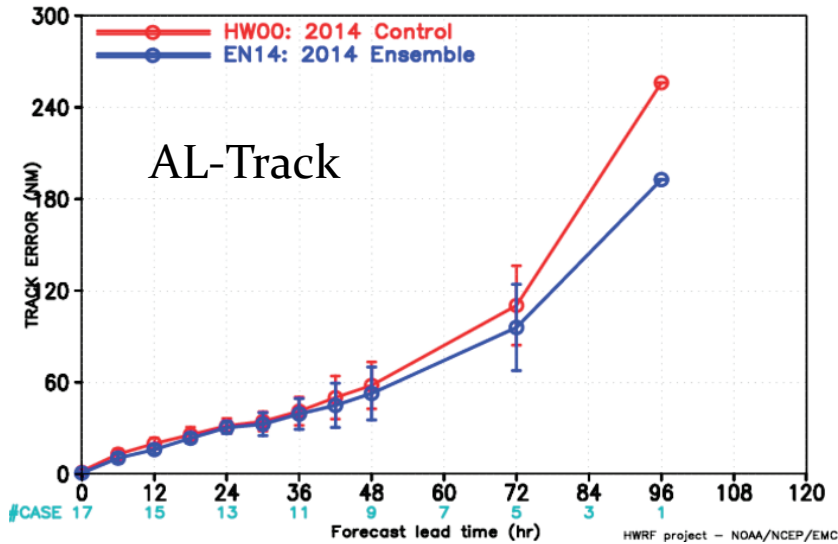
Homogeneous Samples:
(133 Cycles, 8 TC)

- (1) Irene, 2011/09L
- (2) Katia, 2011/12L
- (3) Ernesto, 2012/05L
- (4) Isaac, 2012/09L
- (5) Nadine, 2012/14L
- (6) Sandy, 2012/18L
- (7) Gabrielle, 2013/07L
- (8) Humberto, 2013/09L

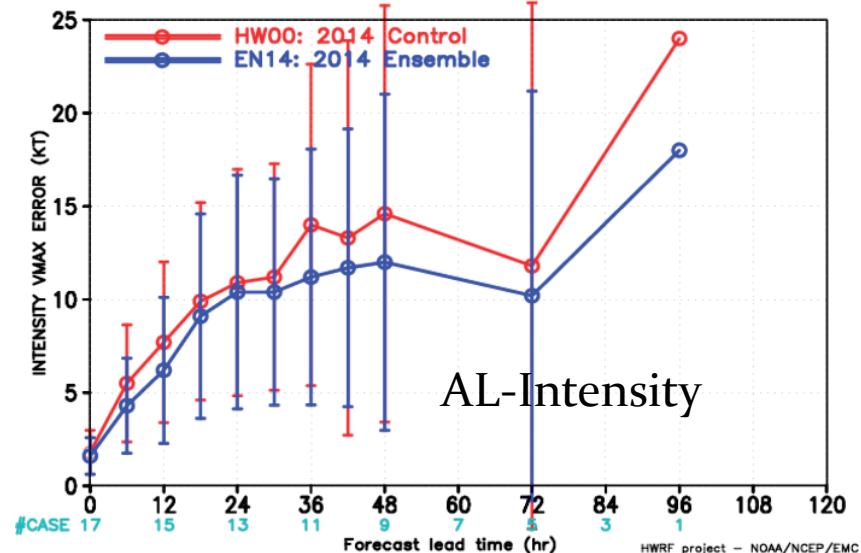
Ensemble mean is computed when the forecasts available from 40% of the total ensemble members.

HWRF-EPS vs. HWRF-deterministic (2014 Real time)

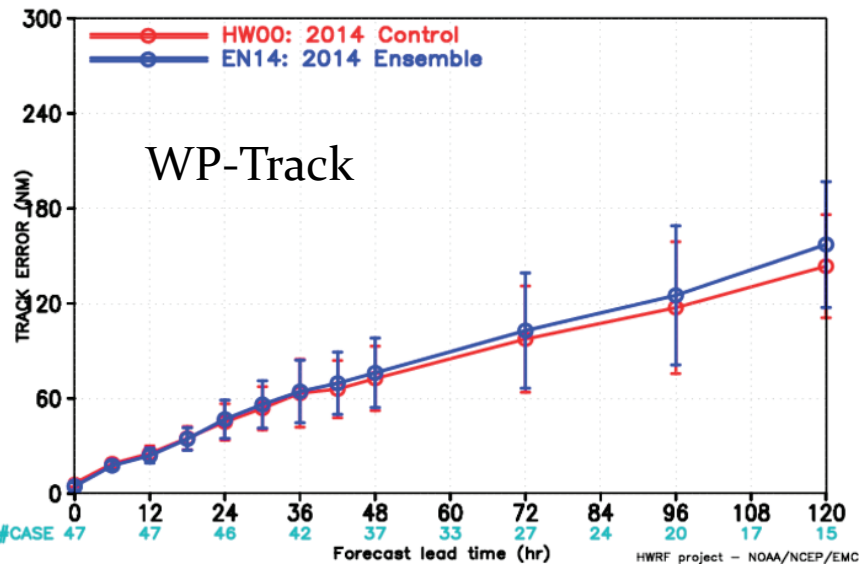
HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION 2014 Ensemble against HWRF ATL 2014



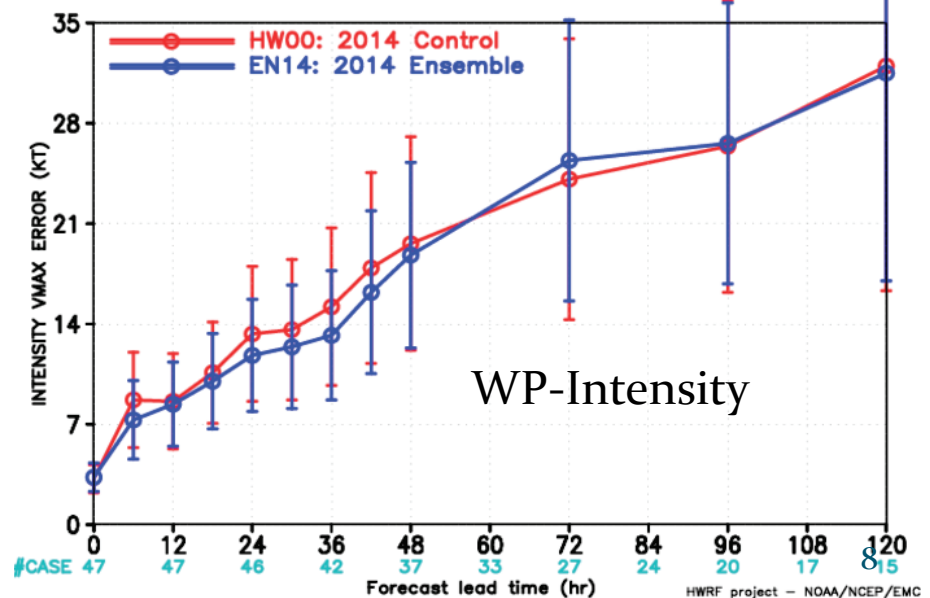
HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION 2014 Ensemble against HWRF ATL 2014



HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION 2014 Ensemble against Control for W-PAC 2014

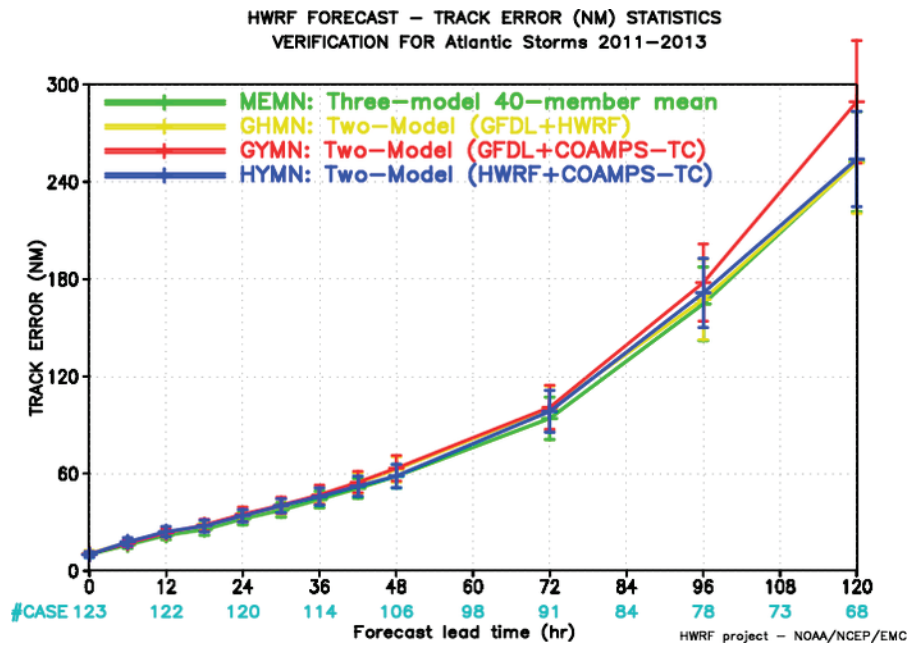


HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION 2014 Ensemble against Control for W-PAC 2014

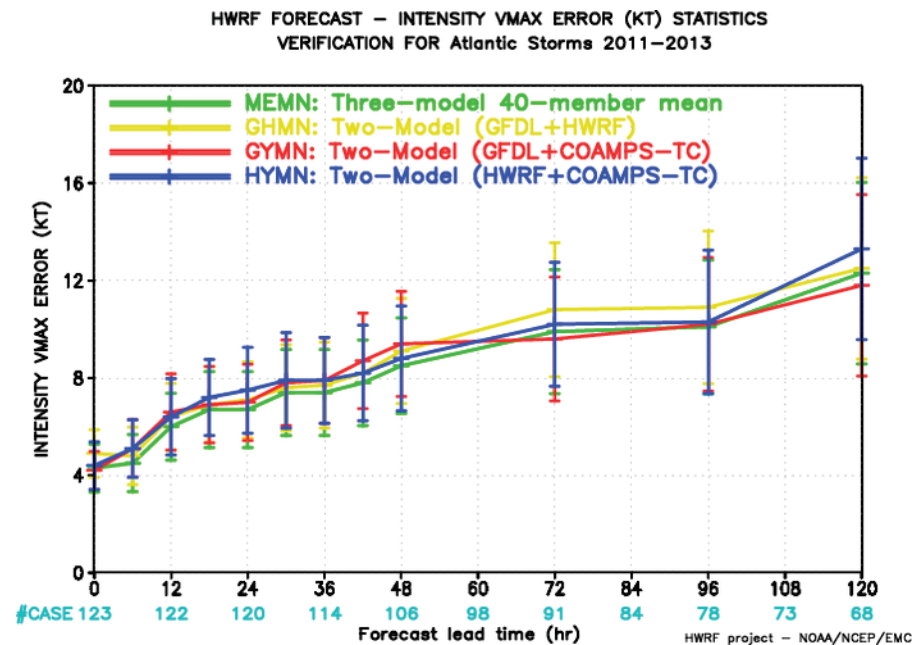


Three Model Ensembles vs. Two-model Ensembles

Track



Intensity

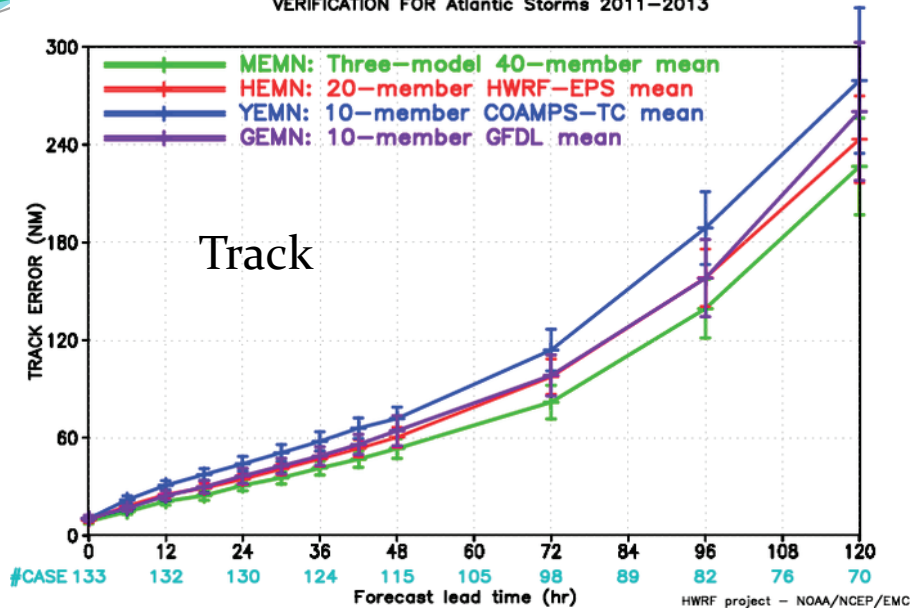


Three-model ensemble is generally better than Two-model ensemble in terms of both track and intensity forecasts at all forecast hours.

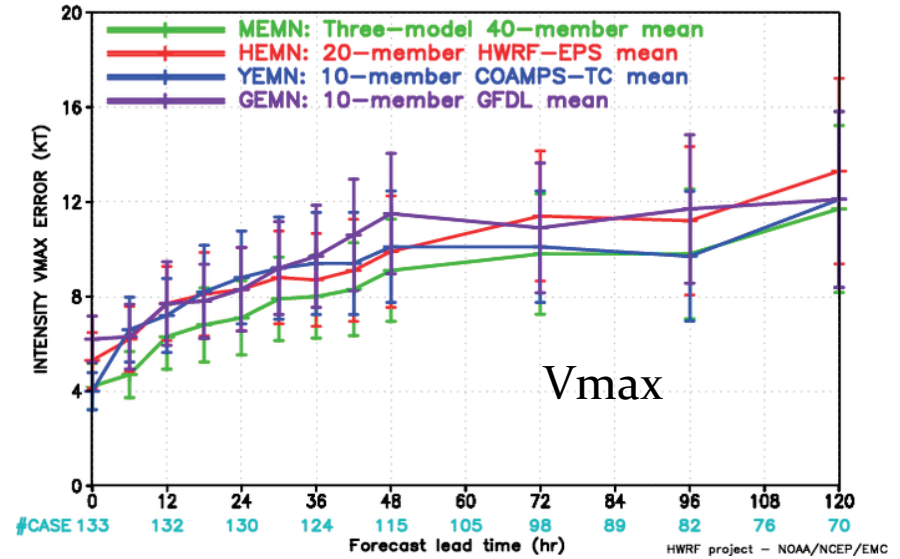
Multi-Model Ensemble Verification

(Retrospective runs 2011-2013)

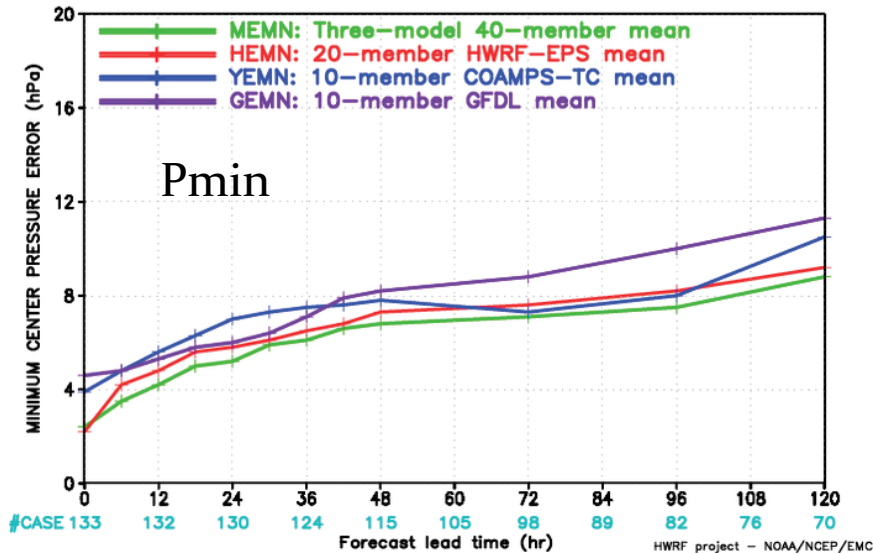
HWRF FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR Atlantic Storms 2011–2013



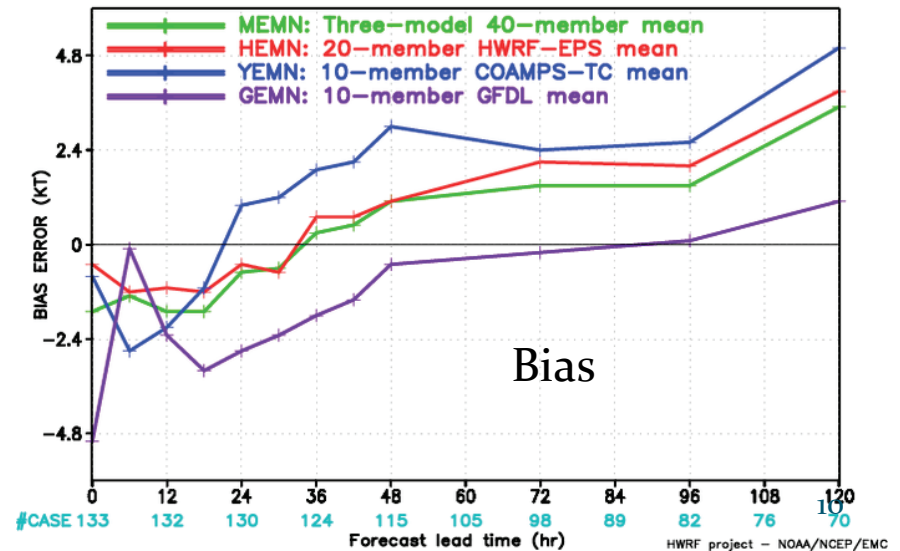
HWRF FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR Atlantic Storms 2011–2013



HWRF FORECAST – MINIMUM CENTER PRESSURE ERROR (hPa) STATISTICS
VERIFICATION FOR Atlantic Storms 2011–2013

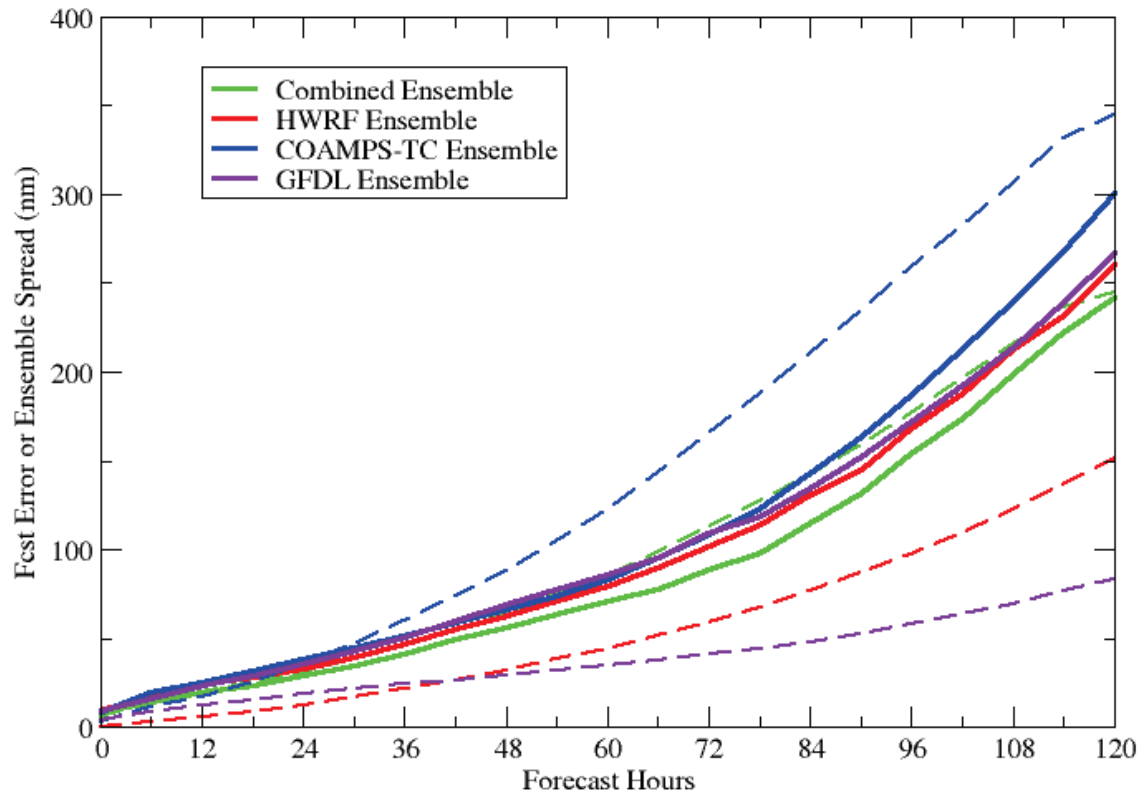


HWRF FORECAST – BIAS ERROR (KT) STATISTICS
VERIFICATION FOR Atlantic Storms 2011–2013



Comparisons of Track Forecast Error and Ensemble Spread

Solid: Forecast Error, Dash: Ensemble Spread

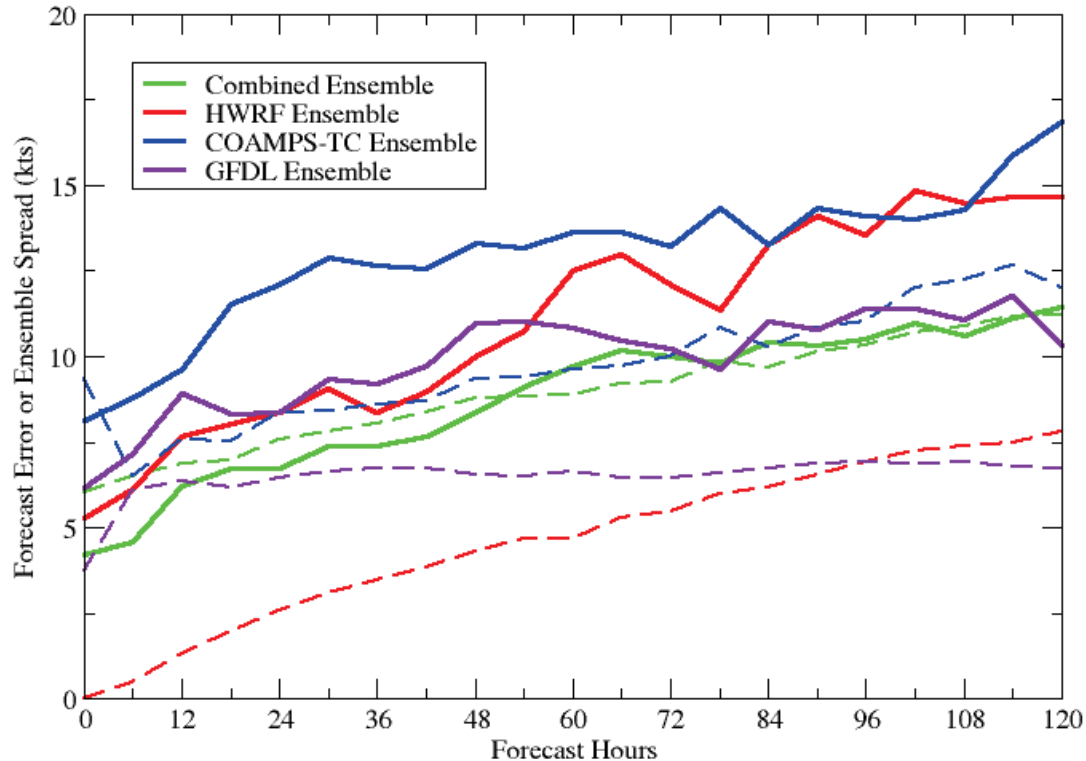


Combined ensemble track forecasts have:

1. lowest track forecast errors;
2. adequate ensemble track spread.

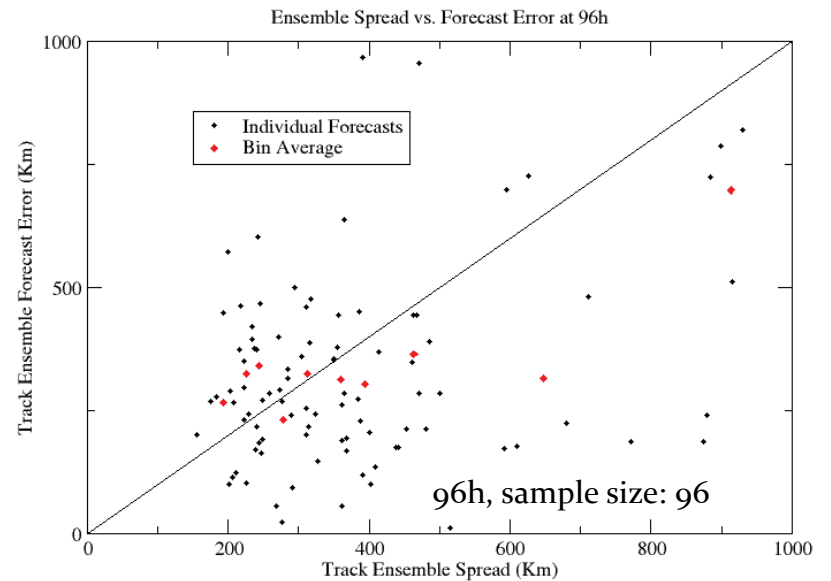
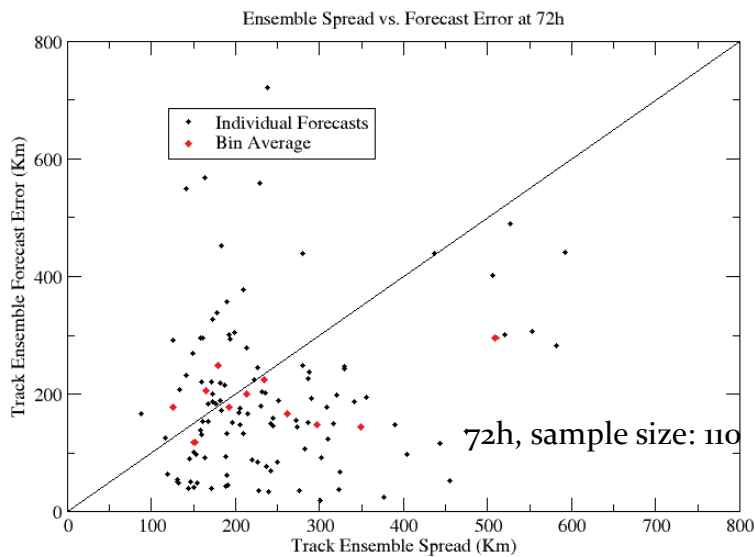
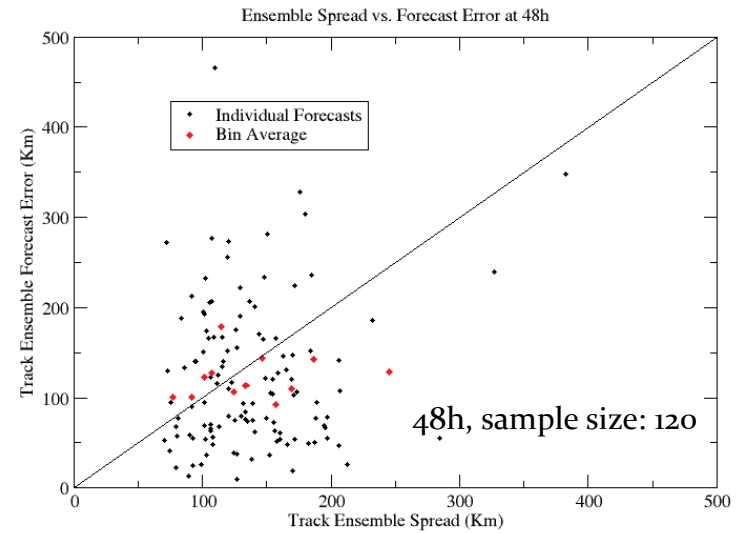
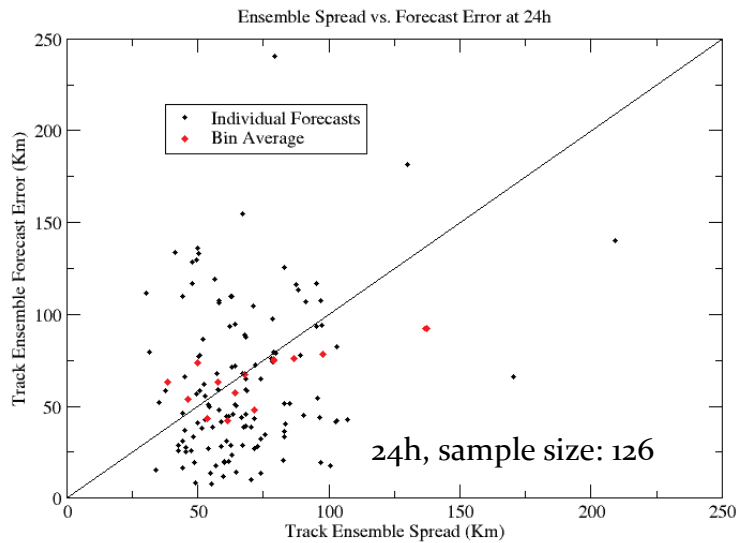
Comparisons of Intensity Forecast Error and Ensemble Spread

Solid: Forecast Error; Dash: Ensemble Spread

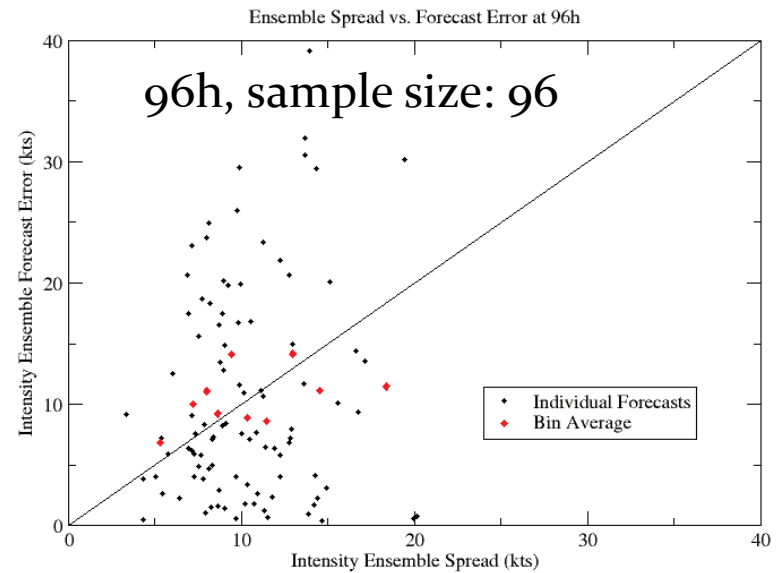
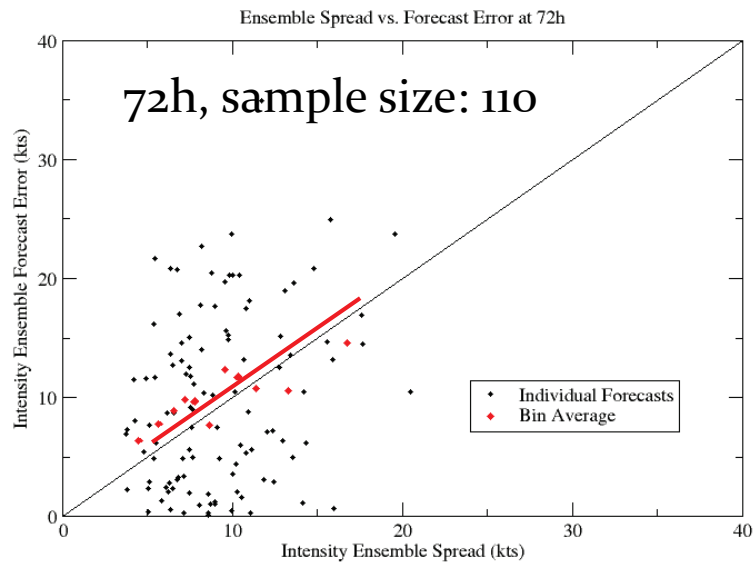
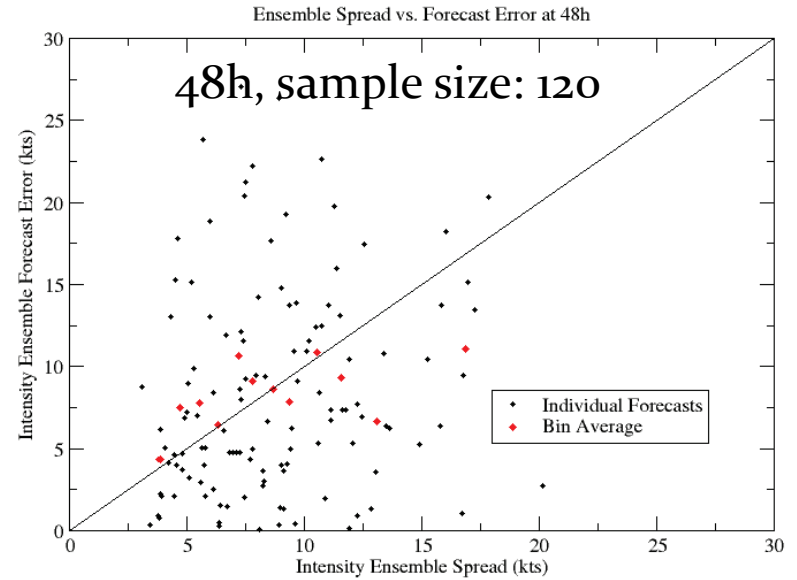
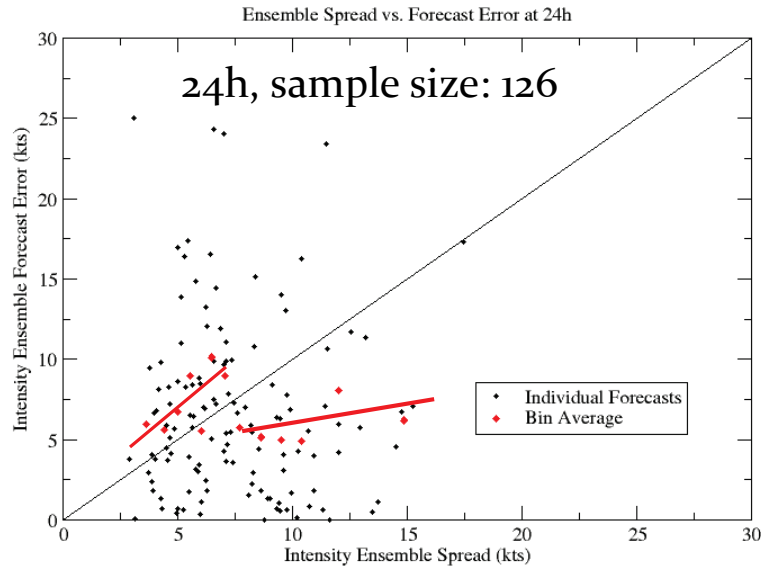


1. Even though HWRF ensemble spread has fast growth rate, it is much smaller than its forecast error because of zero spread at the initial time. This is corrected by adding intensity uncertainties at initial time now.
2. Combined forecast errors are close to the combined ensemble spread.

Relationship between Forecast Error and Ensemble Spread (Track)

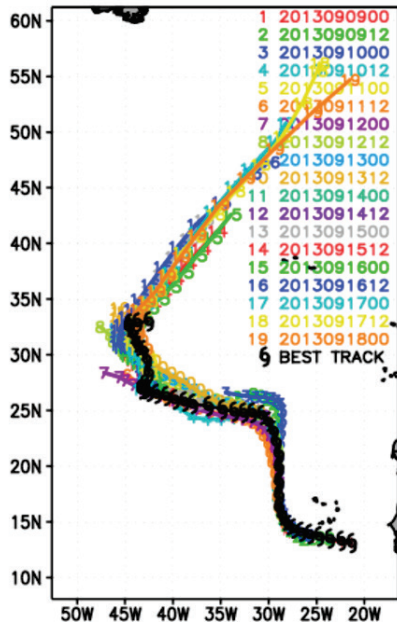


Relationship between Forecast Error and Ensemble Spread (Intensity)

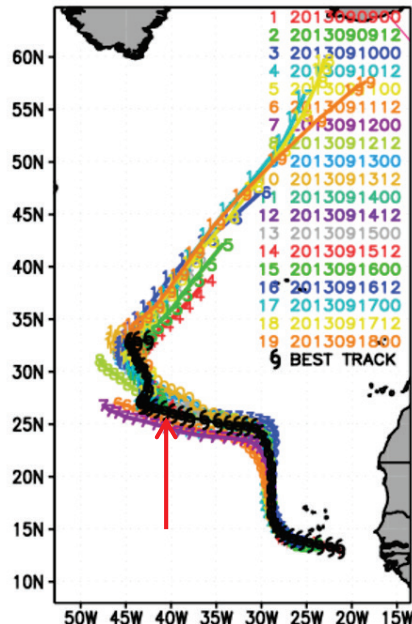


Composite track forecasts for Humberto 09L, 2013

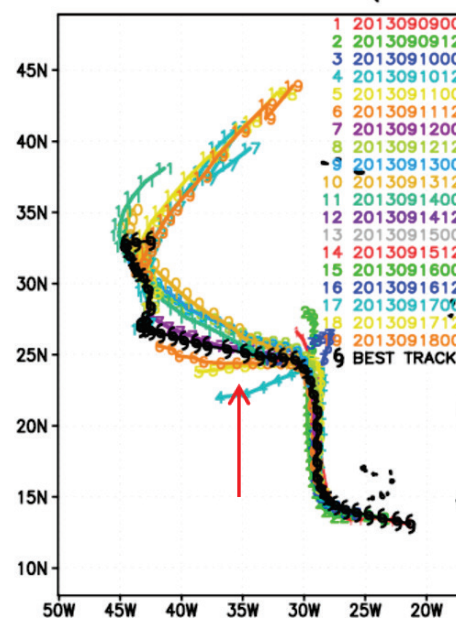
MEMN forecast: HUMBERTO (a1092013) HEMN forecast: HUMBERTO (a1092013) YEMN forecast: HUMBERTO (a1092013) GEMN forecast: HUMBERTO (a1092013)



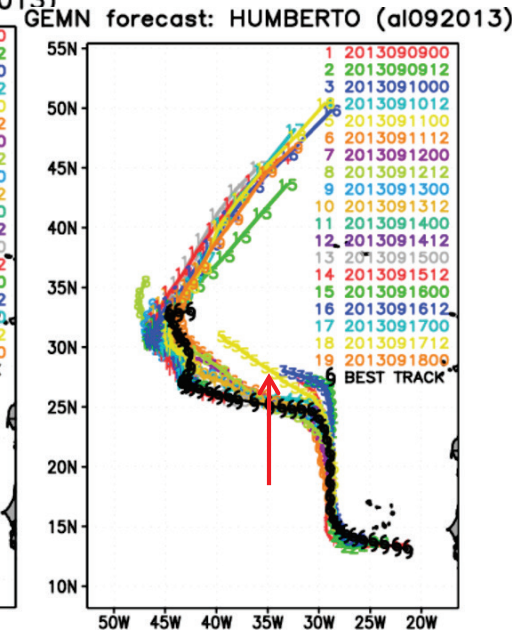
MEMN



HWRf-EPS



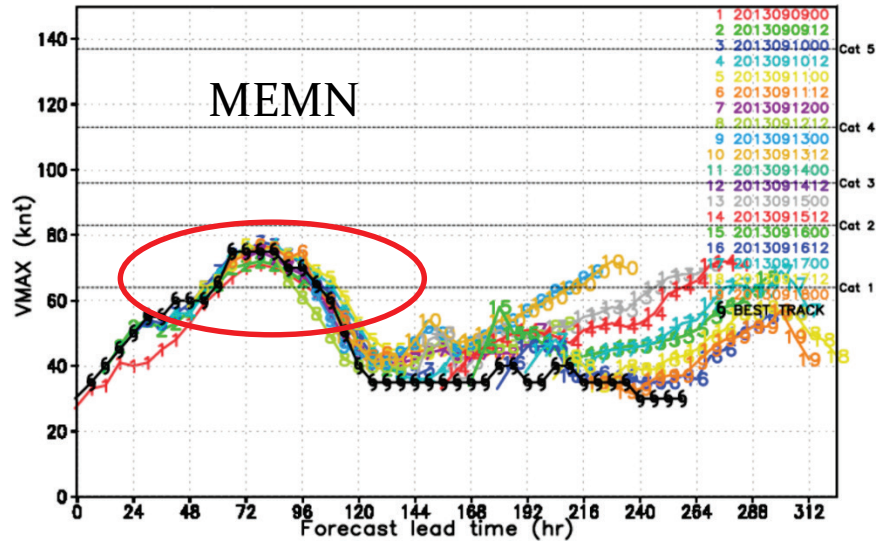
COAMPSTC-EPS



GFDL-EPS

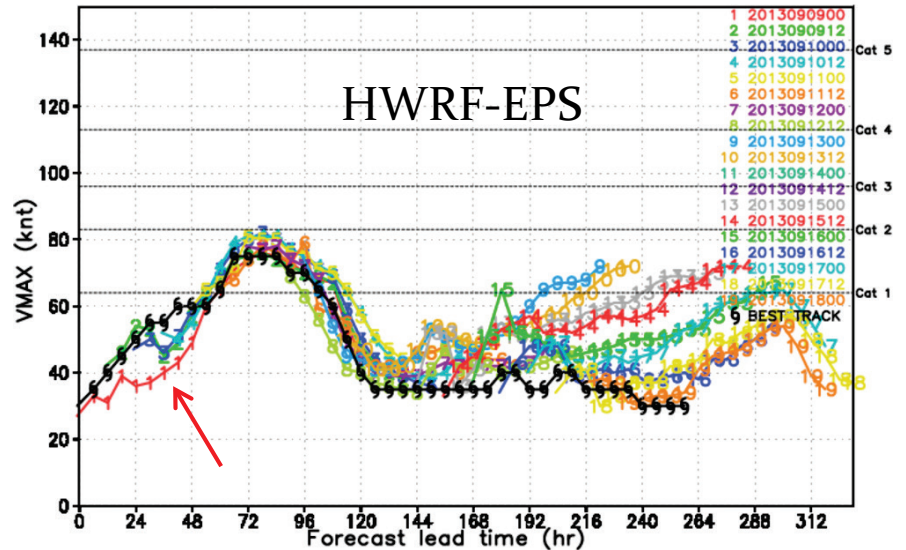
Composite intensity forecasts for Humberto 09L, 2013

MEMN forecast: HUMBERTO (aI092013)
Maximum 10-m wind time series

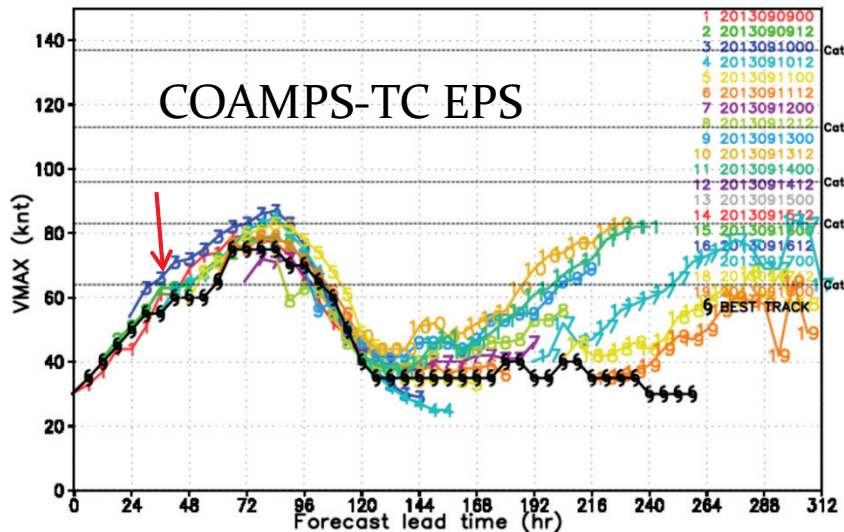


2013

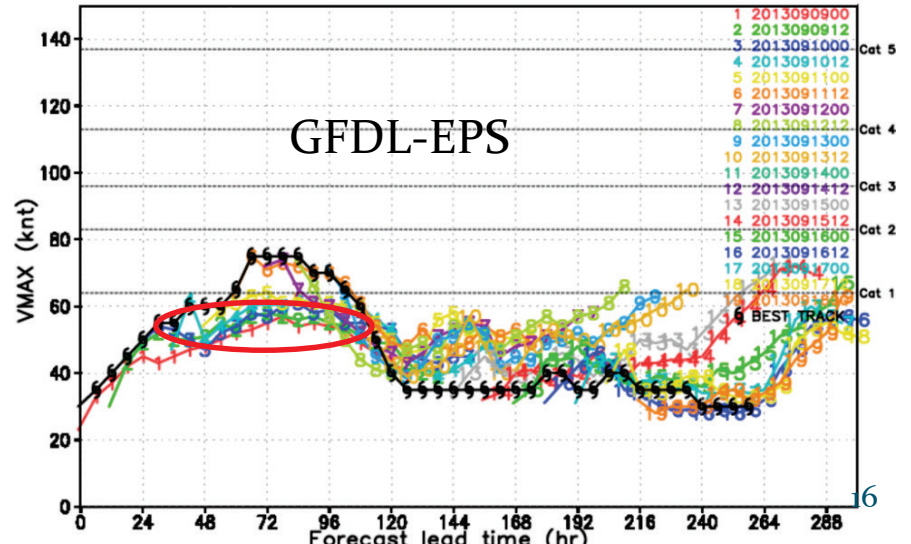
HEMN forecast: HUMBERTO (aI092013)
Maximum 10-m wind time series



YEMN forecast: HUMBERTO (aI092013)
Maximum 10-m wind time series

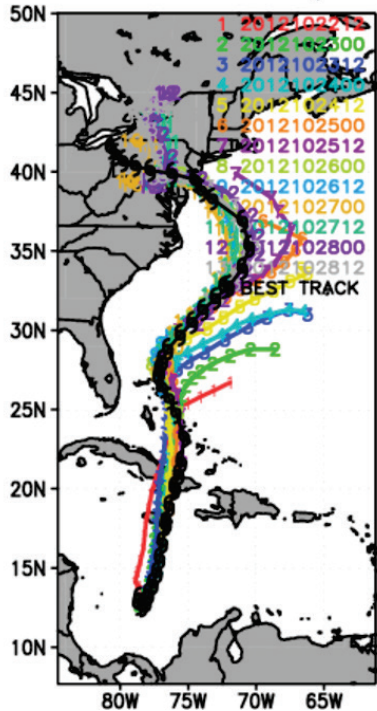


GEMN forecast: HUMBERTO (aI092013)
Maximum 10-m wind time series

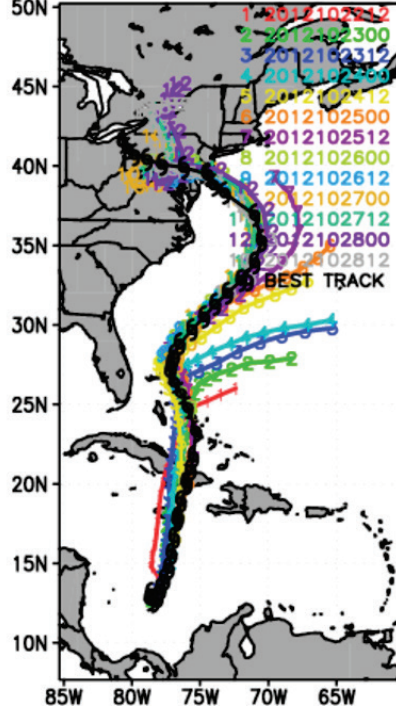


Composite track forecasts for Sandy 18L, 2012

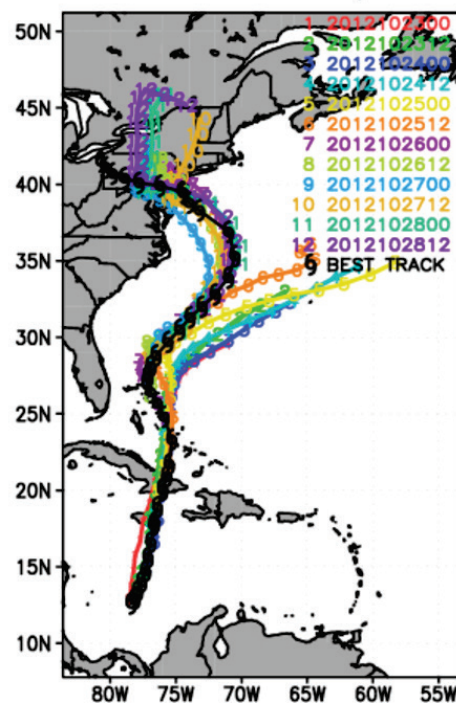
MEMN forecast: SANDY (a182012) HEMN forecast: SANDY (a182012) MEMN forecast: SANDY (a182012) GEMN forecast: SANDY (a182012)



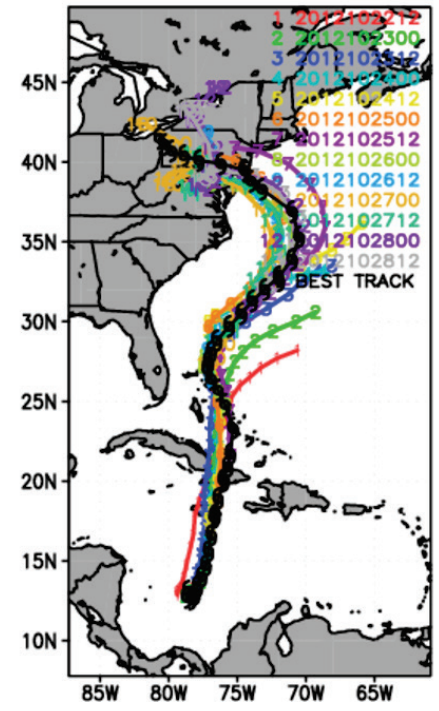
HEMN



HWRF-EPS



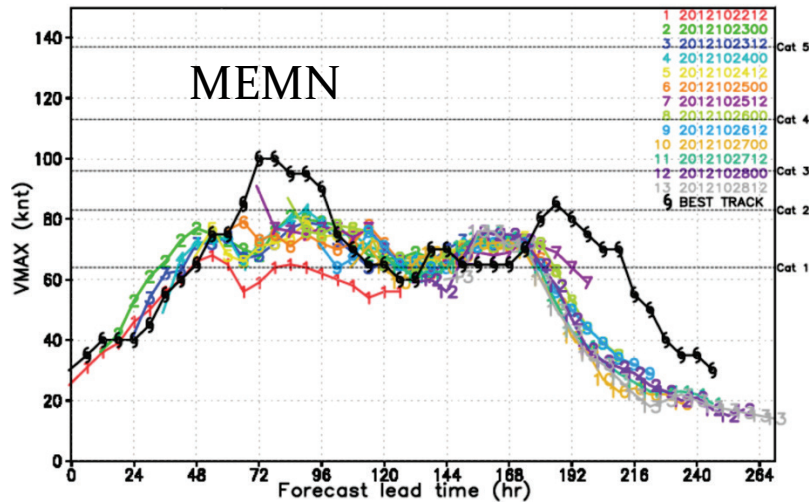
COAMPS-TC EPS



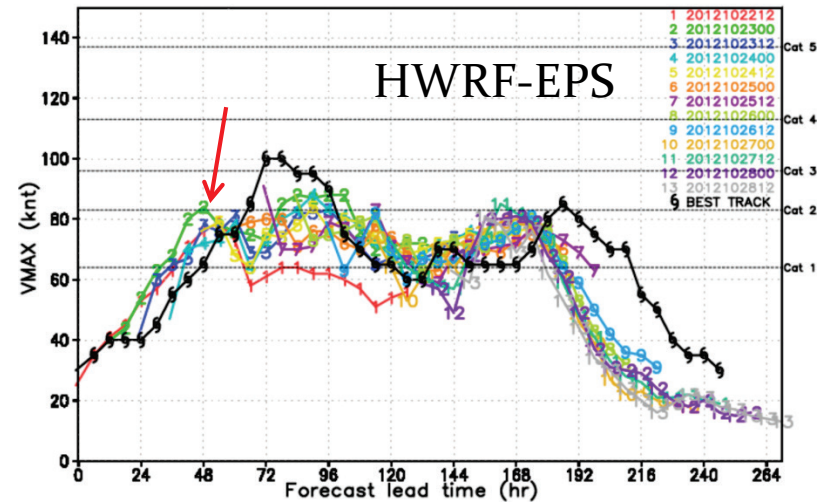
GFDL EPS

Composite intensity forecasts for Sandy 18L, 2012

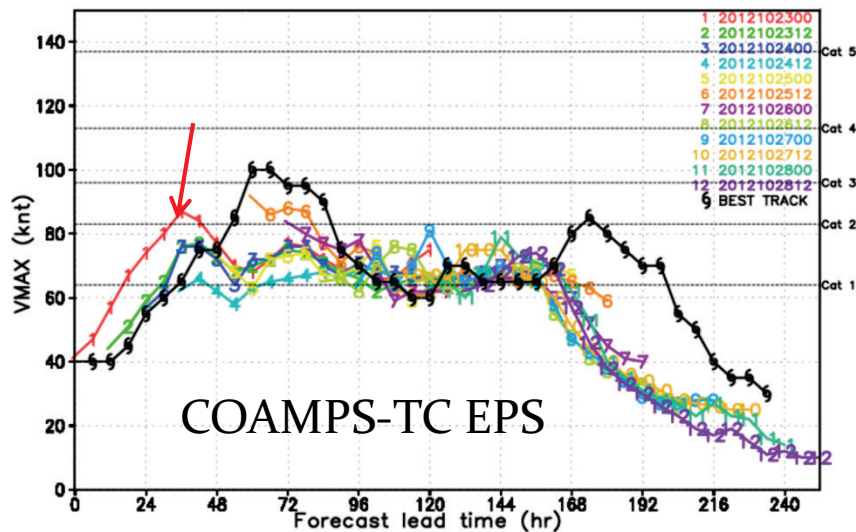
MEMN forecast: SANDY (a182012)
Maximum 10-m wind time series



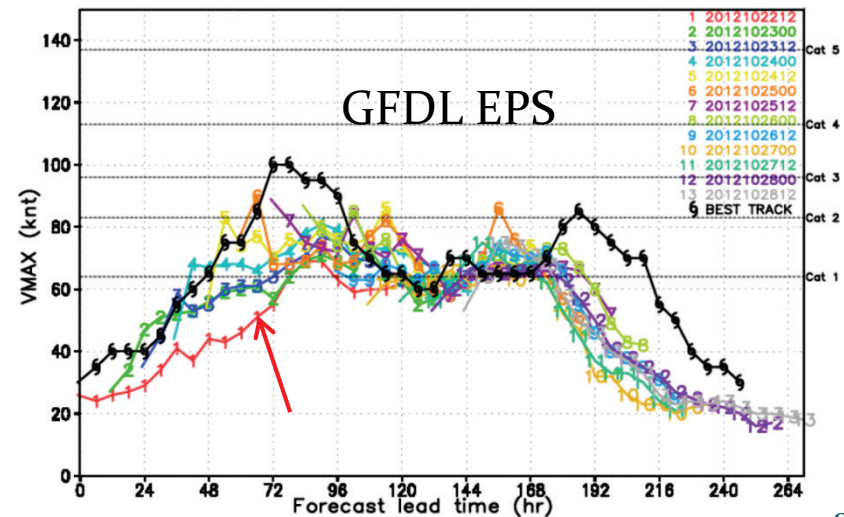
HEMN forecast: SANDY (a182012)
Maximum 10-m wind time series



YEMN forecast: SANDY (a182012)
Maximum 10-m wind time series



GEMN forecast: SANDY (a182012)
Maximum 10-m wind time series





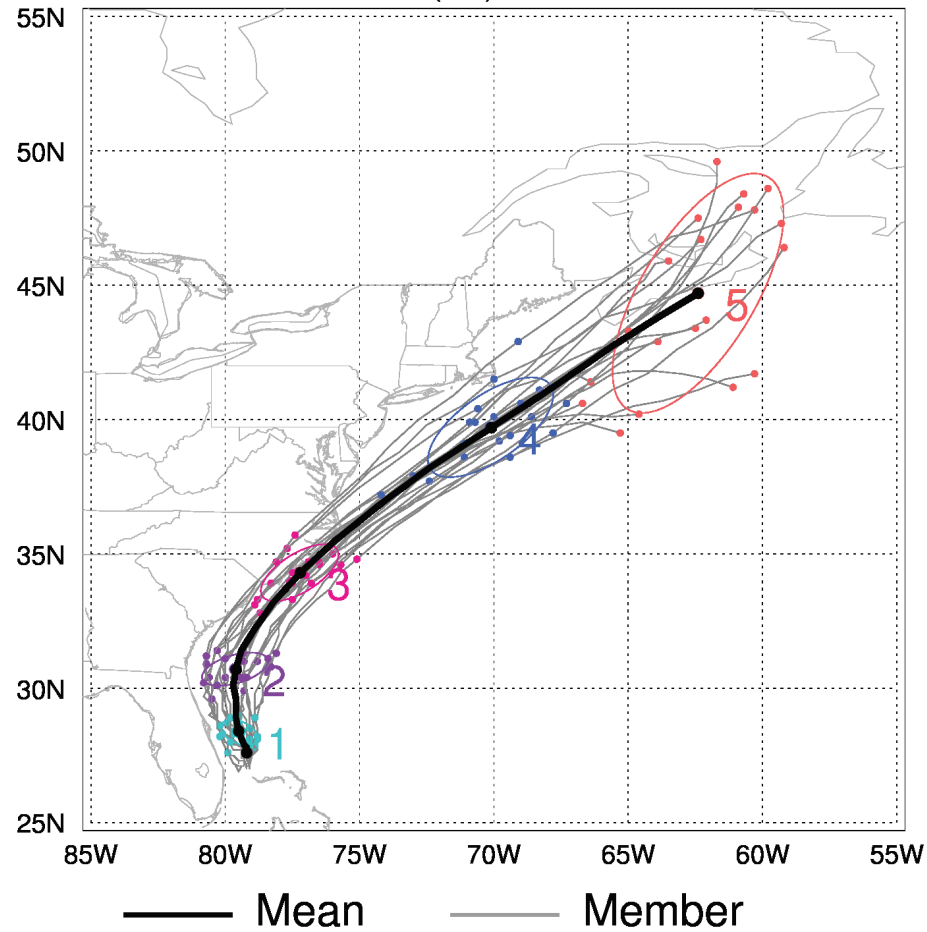
HWRF Ensemble Products

Track Forecasts

Arthur, 2014070106

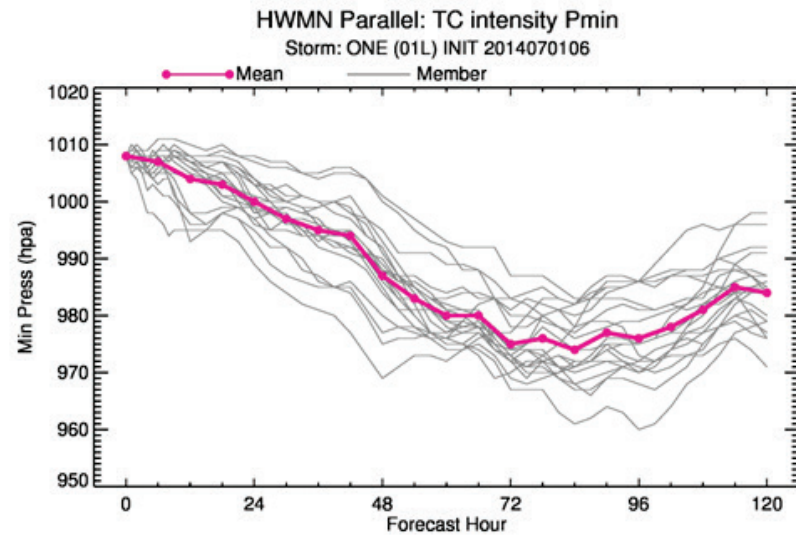
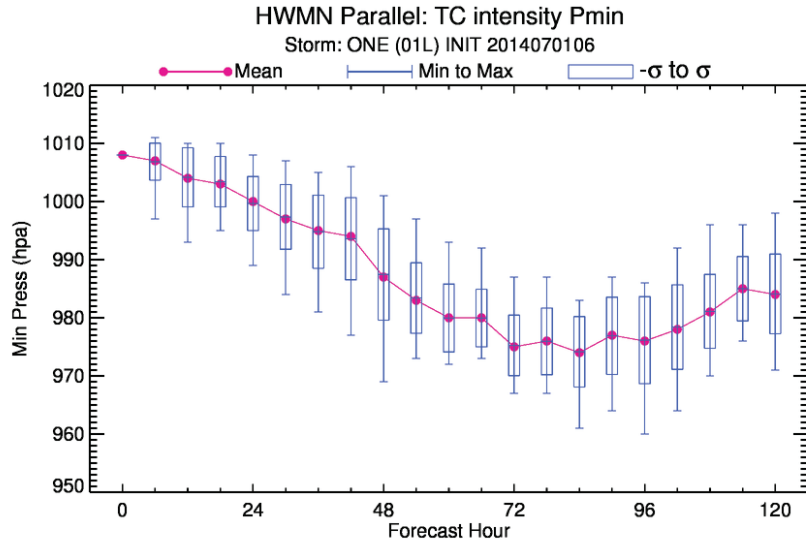
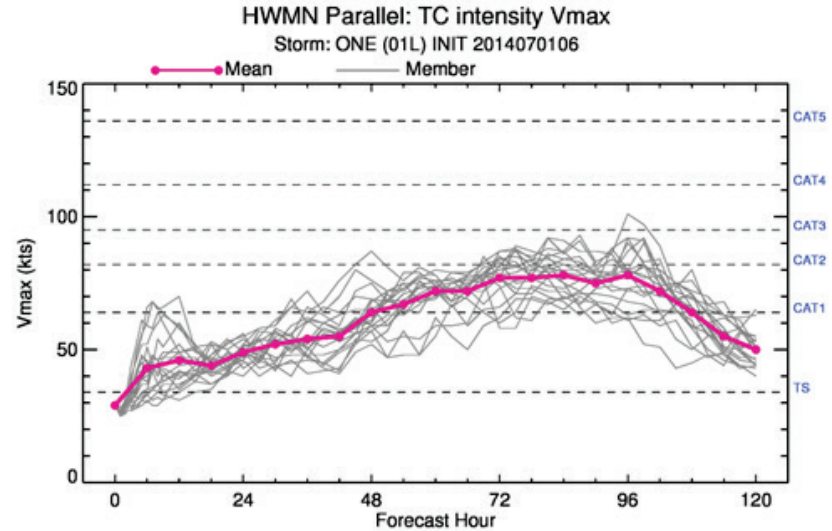
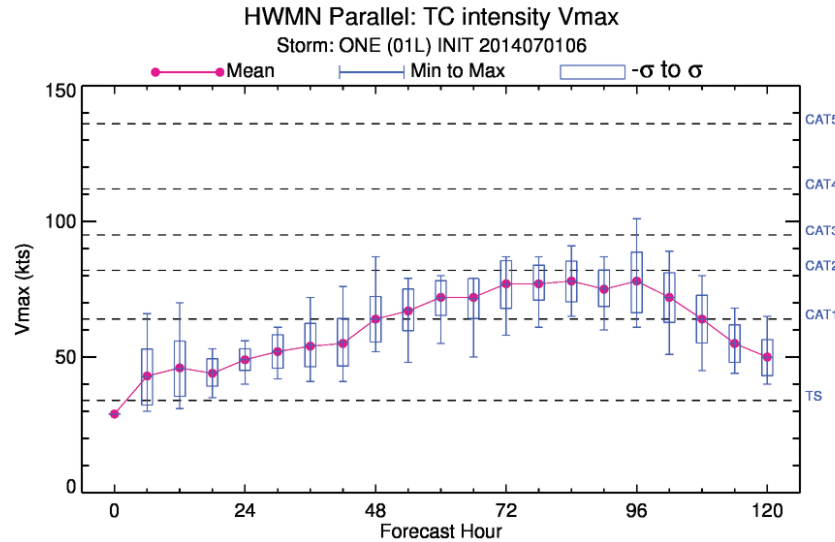
HWMN Parallel: TC Tracks

Storm: ONE (01L) INIT 2014070106



Can be extended to multi-model ensemble products.

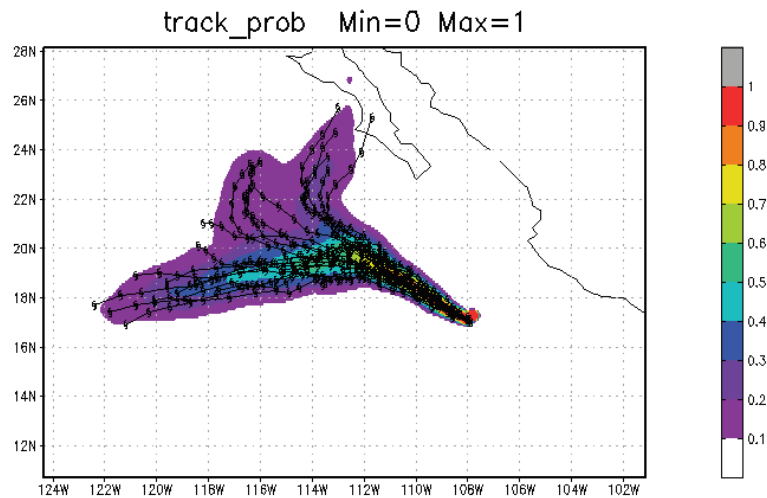
Intensity Forecasts



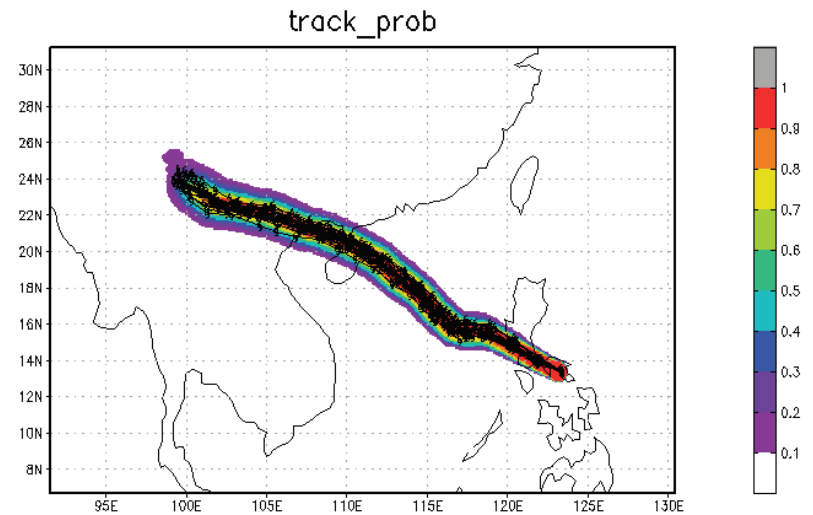
Can be extended to multi-model ensemble products.

Track Probability Forecast based on HWRF-EPS and Deterministic HWRF Forecast Errors

Cristina 03E, 2014061300



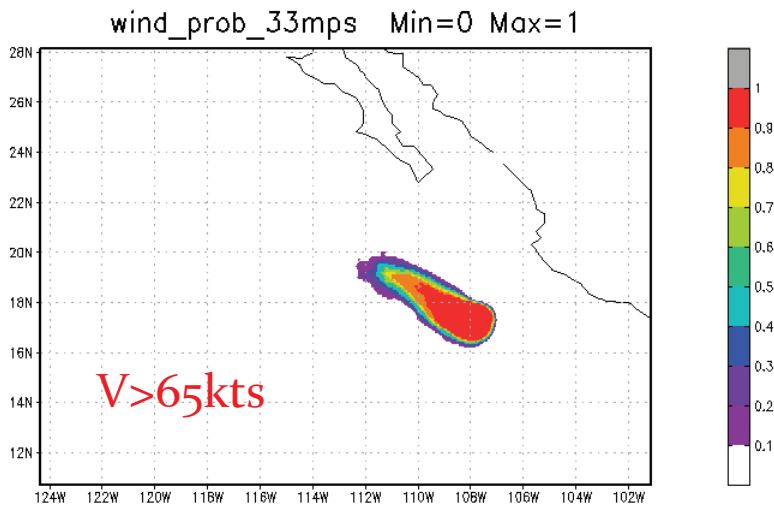
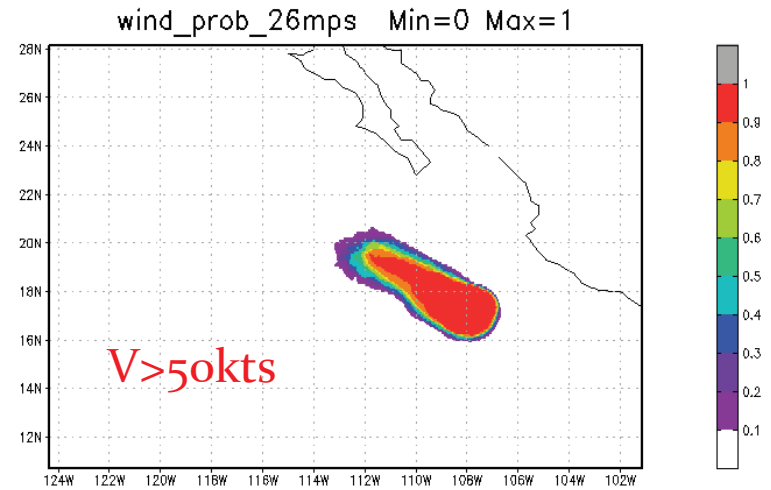
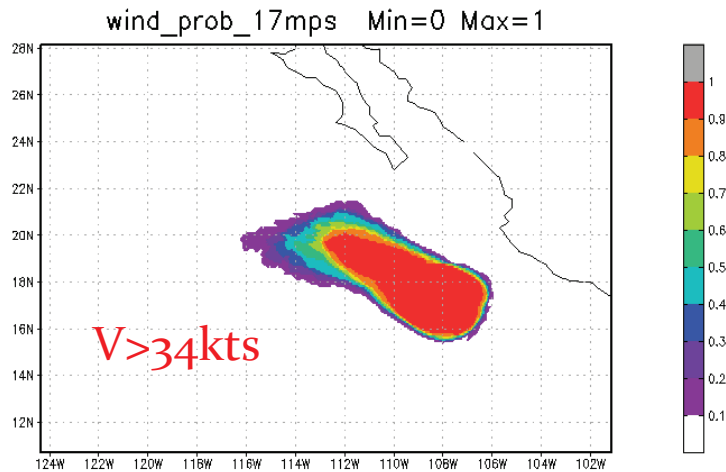
Rammasun 09W, 2014071512



Can be extended to multi-model ensemble products.

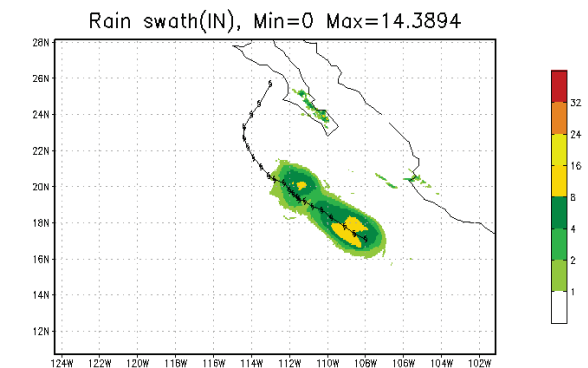
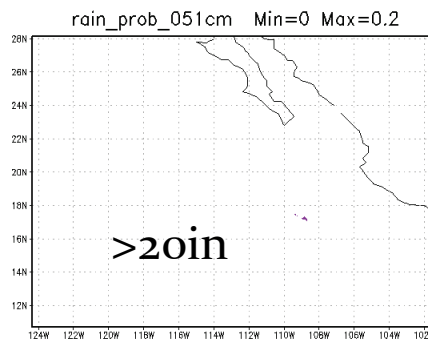
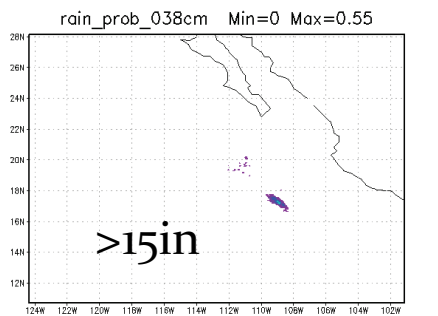
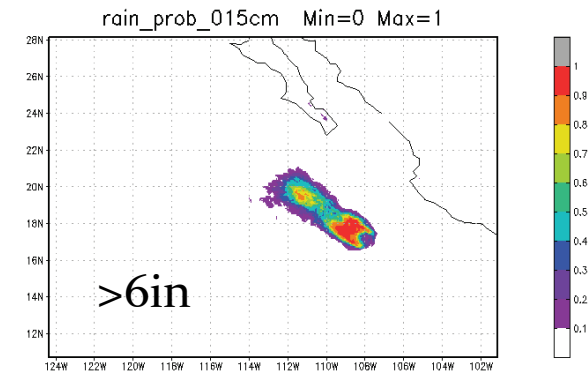
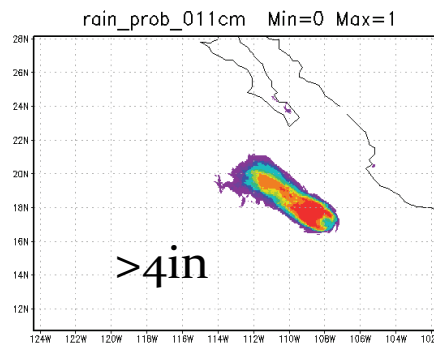
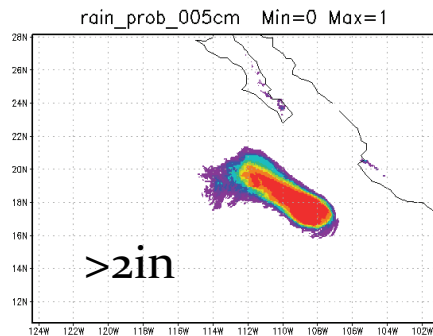
Credited to Sam Trahan

Wind Probability Forecasts based on HWRF-EPS at different Thresholds



Cristina 03E, 2014061300

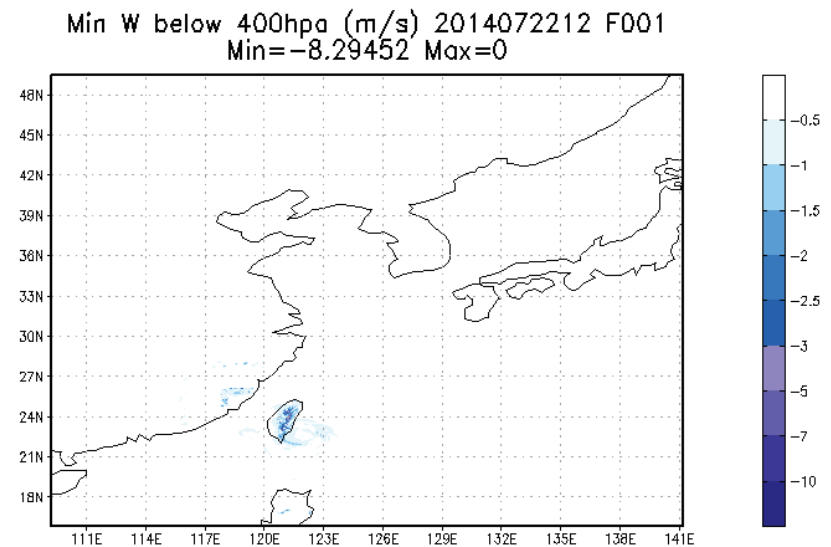
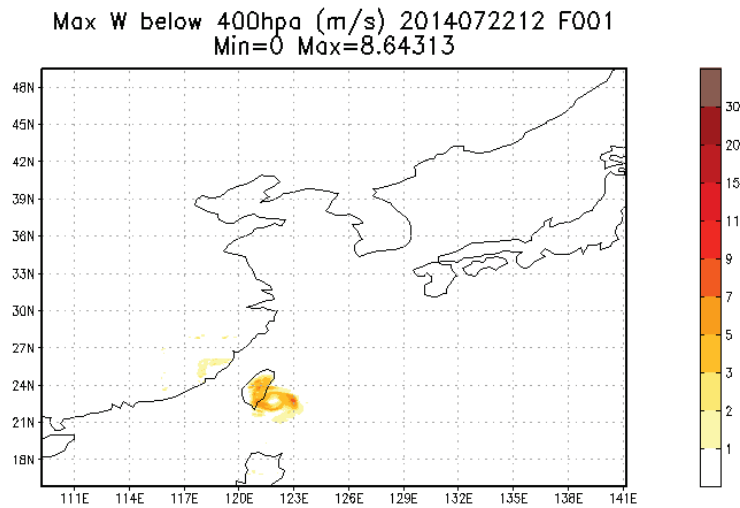
Rainfall Probability Forecast based on HWRF-EPS at different Thresholds



Cristina 03E, 2014061300

Credited to Sam Trahan

Hourly Ensemble Max/Min Vertical Velocity (m/s)



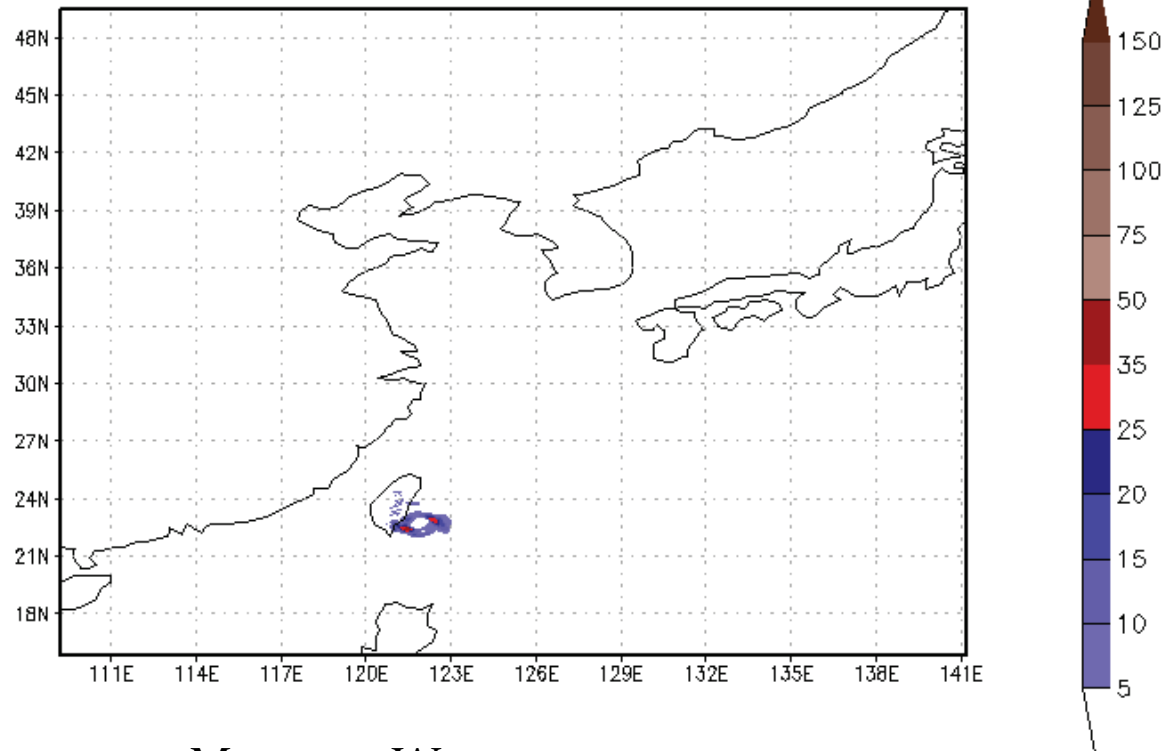
Matmo 10W, 2014072212

Useful for tornado forecast guidance for
landfalling storms

Credited to Sam Trahan

Hourly Ensemble Updraft Helicity (m^2/s^2)

Max 2–5km updraft Helicity (m^2/s^2) 2014072212 F001
Min=0 Max=42.6099



Matmo 10W, 2014072212

Useful for tornado forecast guidance for
landfalling storms

Credited to Sam Trahan

Summary

- Combined HWRF/COAMPS-TC/GFDL ensemble system takes into account most of uncertainties that are important to model hurricane track/intensity forecasts;
- Combined ensemble system provided improved track/intensity forecasts, compared to the forecasts from each individual ensemble system;
- Combined ensemble system has adequate forecast error and ensemble spread relationship;
- More ensemble products can be developed based on the combined ensemble system.



COAMPS-TC
Slides provided separately



GFDL Ensemble Products

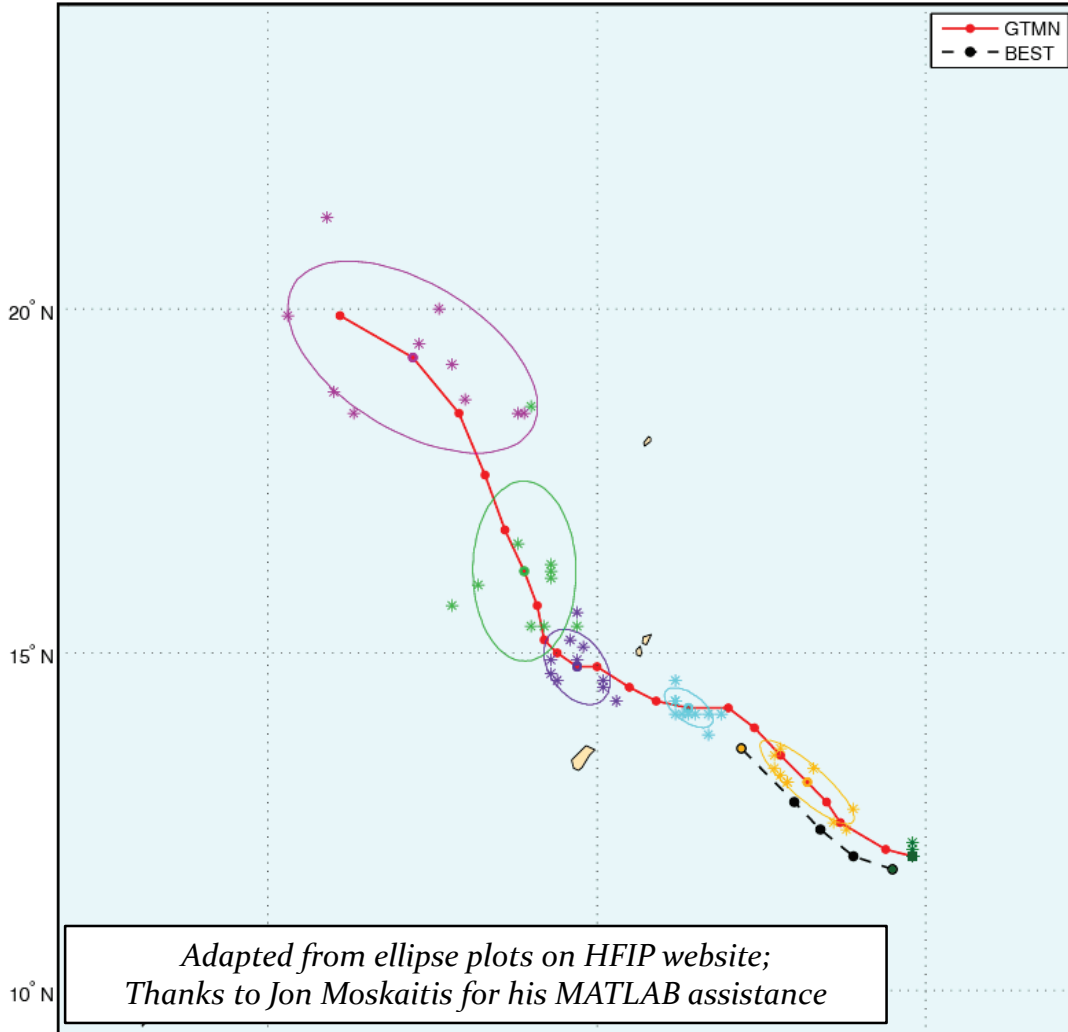
Track Forecasts

GFDL Ensemble Track Forecasts

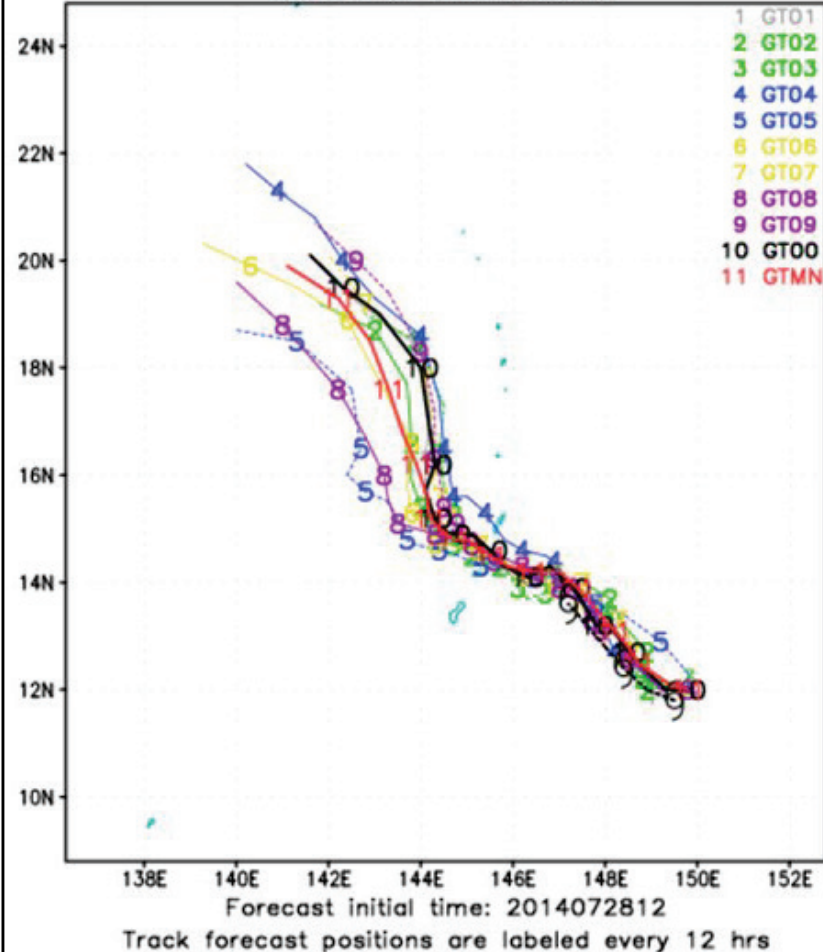
Storm: ELEVEN11W

Valid: 07/28/2014 12 UTC

140° E 145° E 150° E



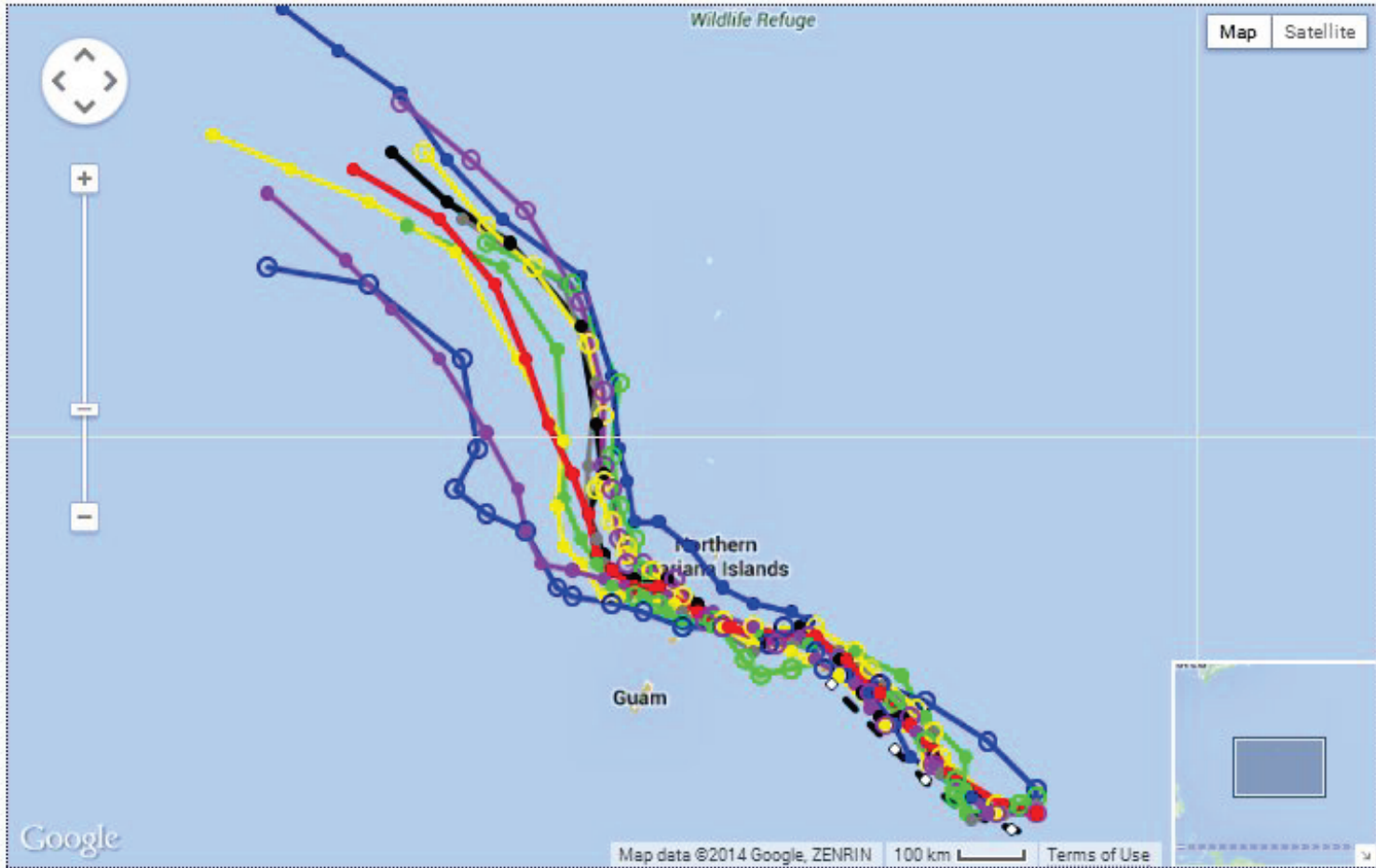
GFDL Ensemble Track Forecasts Storm: WP1114 (eleven)



Mean track forecast position marked every 6 hrs
Ensemble track positions and ellipses color-coded for days 0, 1, 2, 3, 4, and 5.
GFDL Hurricane Dynamics Group

Track Forecasts

Check to enable Google Maps API



Forecast initial time: 2014072812

Track forecast positions are labeled every 6 hrs (hover over points to see member ID and forecast hour)

Lat, Lon: 14.84937990914623, 149.12918038666248

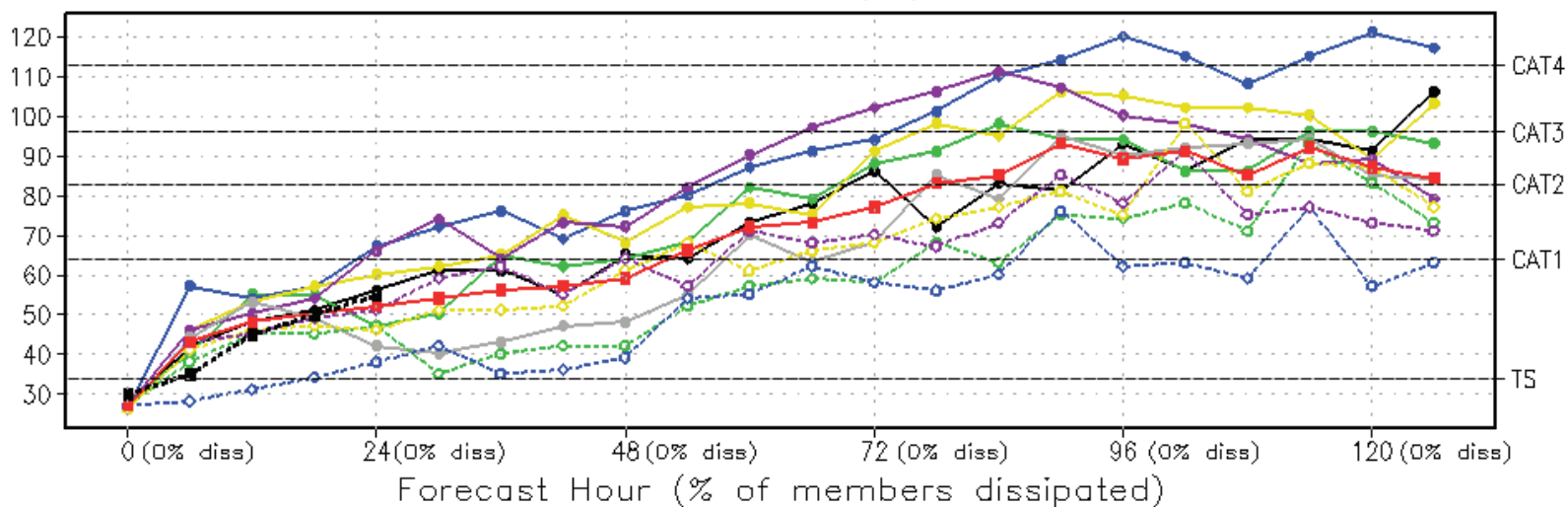
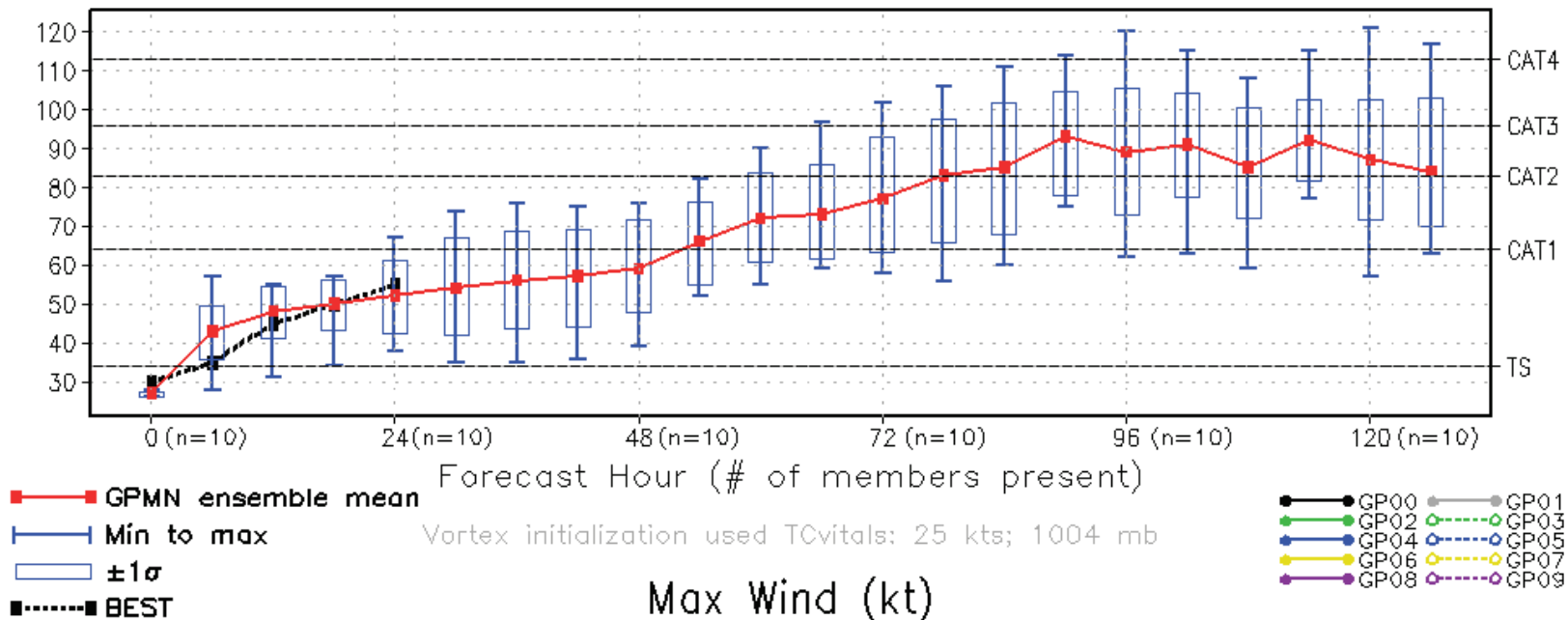
Lat, Lon on click: 16.741721000434605, 147.35015831887722

Map zoom options:

(1) Use mouse scroll wheel, (2) double left-click to zoom-in, double right-click to zoom-out, or (3) use "+/-" slider control

Intensity Forecasts

GFDL Ensemble Forecast for ELEVEN11W from 12Z28JUL2014
Max Wind (kt)




Missing members (out of 10) at t=0: None

GFDL Hurricane Dynamics Group

Wind Probability Forecasts Based on GFDL-EPS

GFDL ensemble forecast for ELEVEN11W on 2014072812

Max wind speed probabilities and swaths 

Click the tabs below to view each product

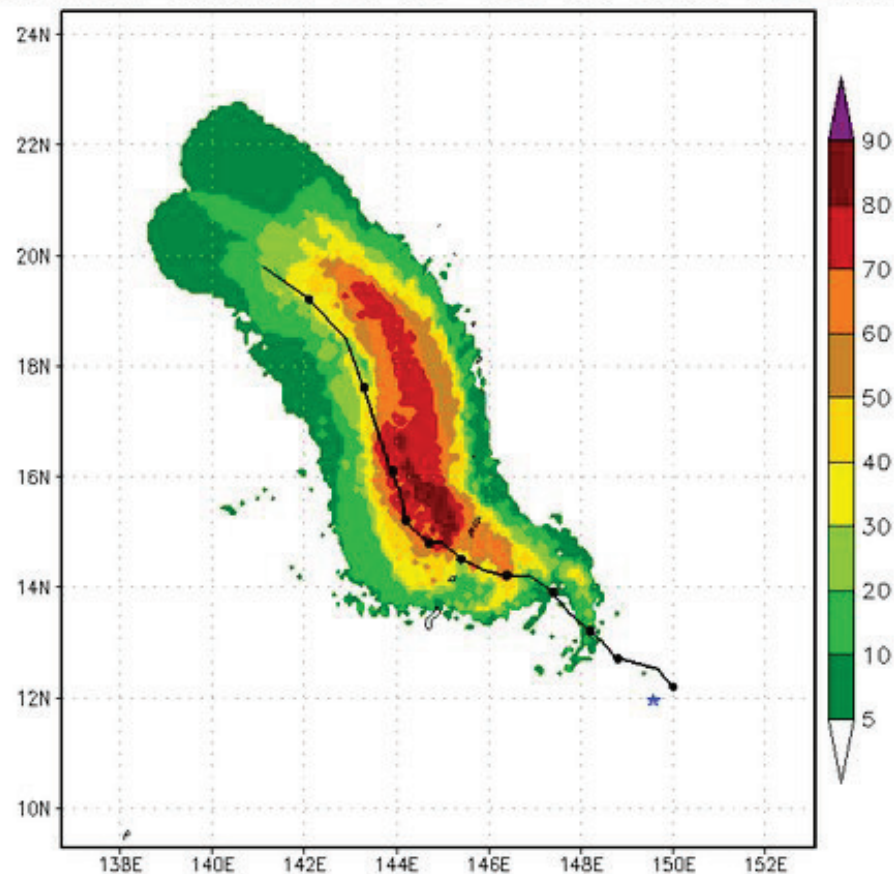
34-kt wind speed probability

50-kt wind speed probability

64-kt wind speed probability

Max 10-m winds swaths

Hurricane Force Wind Speed Probabilities (%) for ELEVEN11W
GFDL Ensemble forecast for the 126 hrs from 12Z28JUL2014



of missing members (out of 10) at t=0: 0

★ indicates ELEVEN11W observed center at initial time

GPMN forecasted track marked every 12 hrs

GFDL Hurricane Dynamics Group

Rainfall Probability Forecast Based on GFDL-EPS

GFDL ensemble forecast for ELEVEN11W on 2014072812

Precipitation probabilities and swaths



Click the tabs below to view each product

Probability of precip > 1.00"

Probability of precip > 4.00"

Probability of precip > 8.00"

Probability of precip > 16.00"

Precipitation swaths

0-120hr

0-24hr

12-36hr

24-48hr

36-60hr

48-72hr

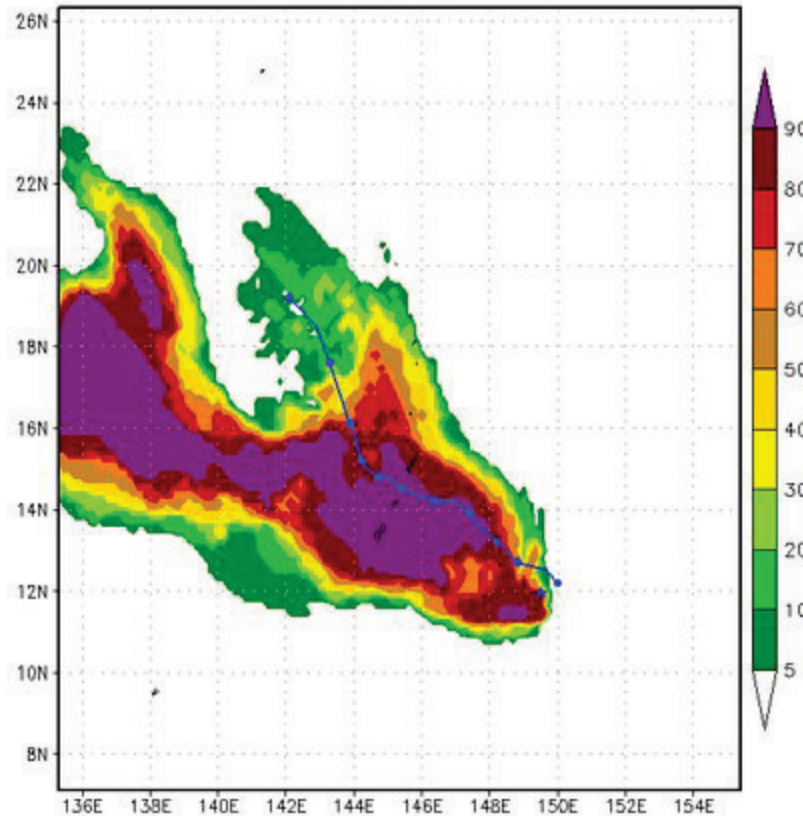
60-84hr

72-96hr

84-108hr

96-120hr

Probability (%) of 120-hr Total Precipitation > 8.00"
ELEVEN11W Init:2014072812 Valid:12Z28JUL2014



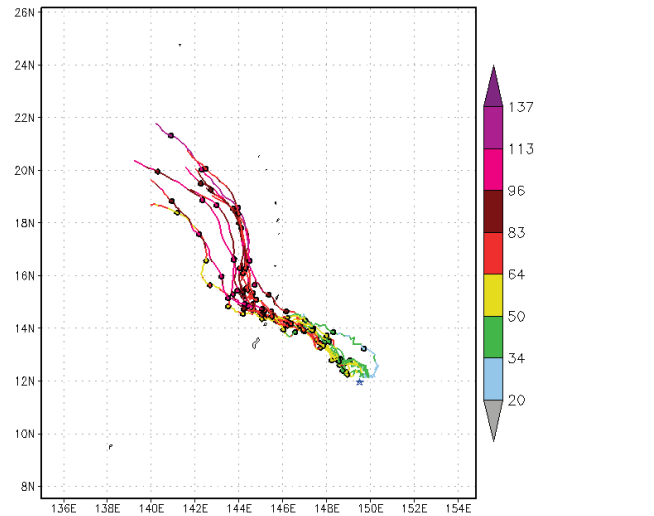
* indicates ELEVEN11W observed center at initial time

GPMN forecasted track marked every 12 hrs

GFDL Hurricane Dynamics Group

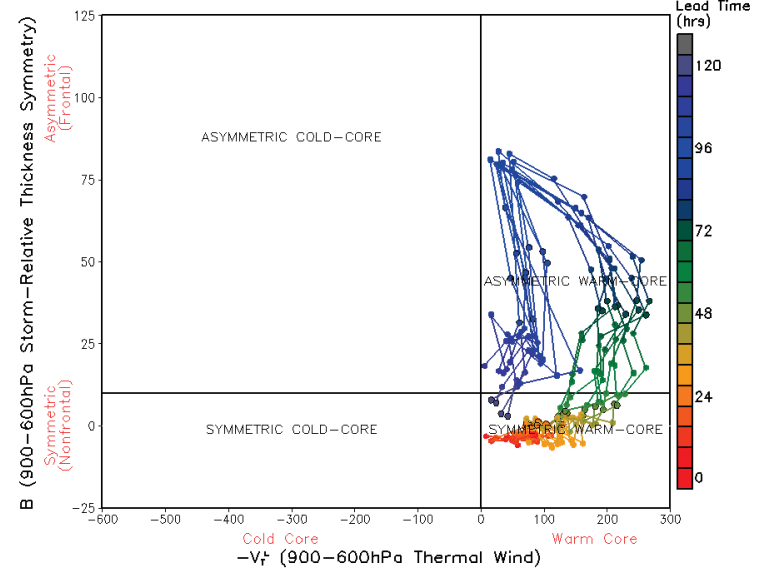
Other GFDL-EPS Products

Hourly Track and Intensity (kt) for ELEVEN11W
GFDL ensemble forecast for the 126 hrs from 12Z28JUL2014



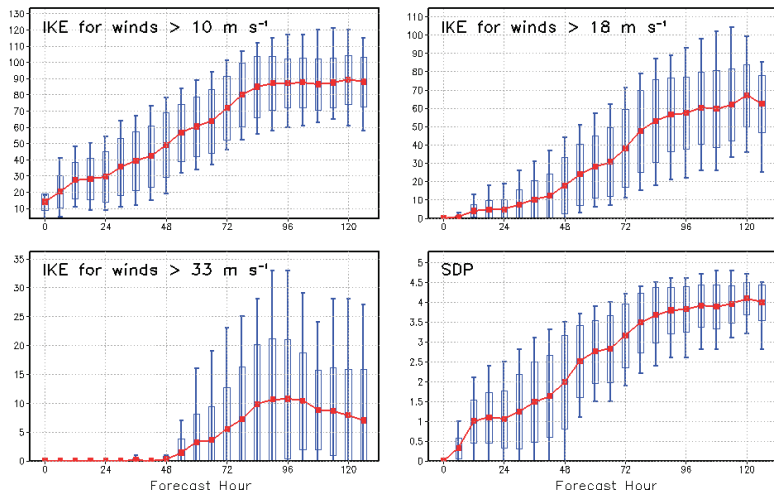
of missing members (out of 10) at t=0: 0
* indicates ELEVEN11W observed center at initial time
Track forecast positions are marked every 12 hrs
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GFDL Ensemble Forecast for ARTHUR01L: Cyclone Phase Space
Initial time: 00Z02JUL2014



Missing members (out of 10) at t=0: None
GFDL Hurricane Dynamics Group

Integrated Kinetic Energy (TJ) and Surge Destructive Potential



GFDL Ensemble Forecast for ELEVEN11W
Initial time: 12Z28JUL2014

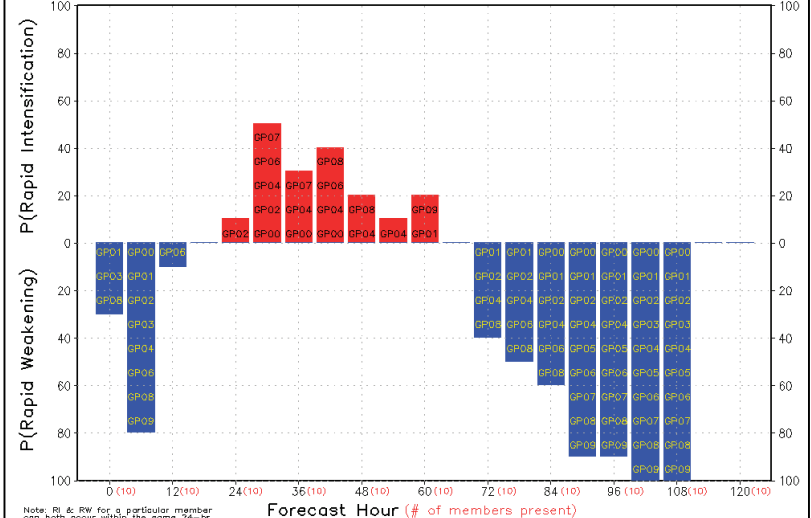
R ≤ 400 km

— Ensemble mean
— Min to max
— ±1σ

Missing members (out of 10) at t=0: None

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GFDL Ensemble Forecast for RAMMASUN09W from 00Z15JUL2014
24-hr Probability of Rapid Intensification/Weakening (%; $|\Delta V_{max}| \geq 30$ kts)



Note: RI & RW for a particular member can both occur within the same 24-hr interval and thus be plotted together.

Missing members (out of 10) at t=0: None

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