HWRF-GEFS Hurricane Ensemble System

-- Uncertainty in Initial Large-Scale Flow

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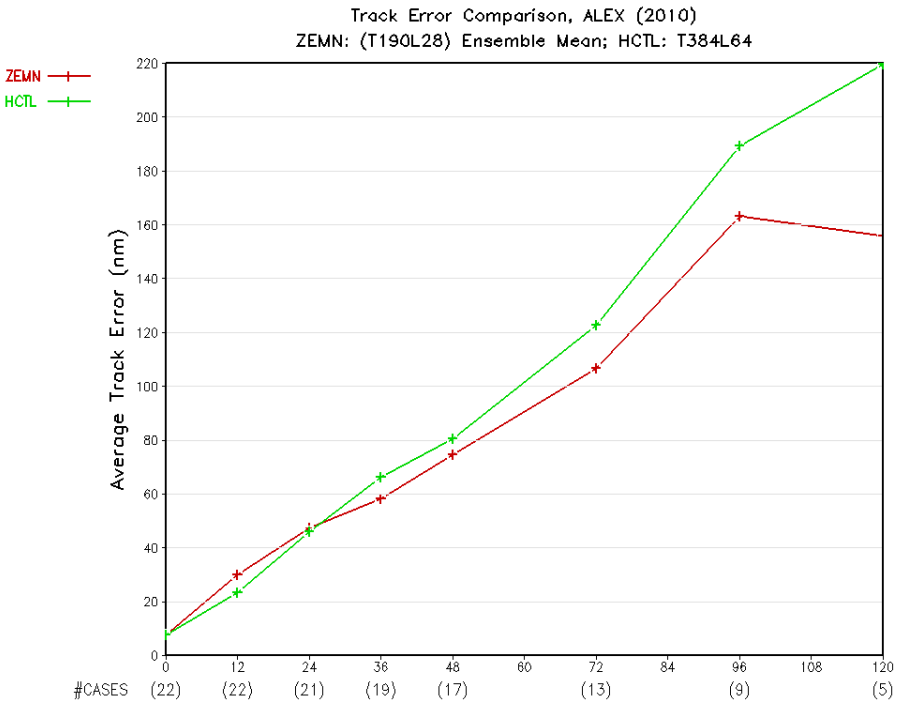
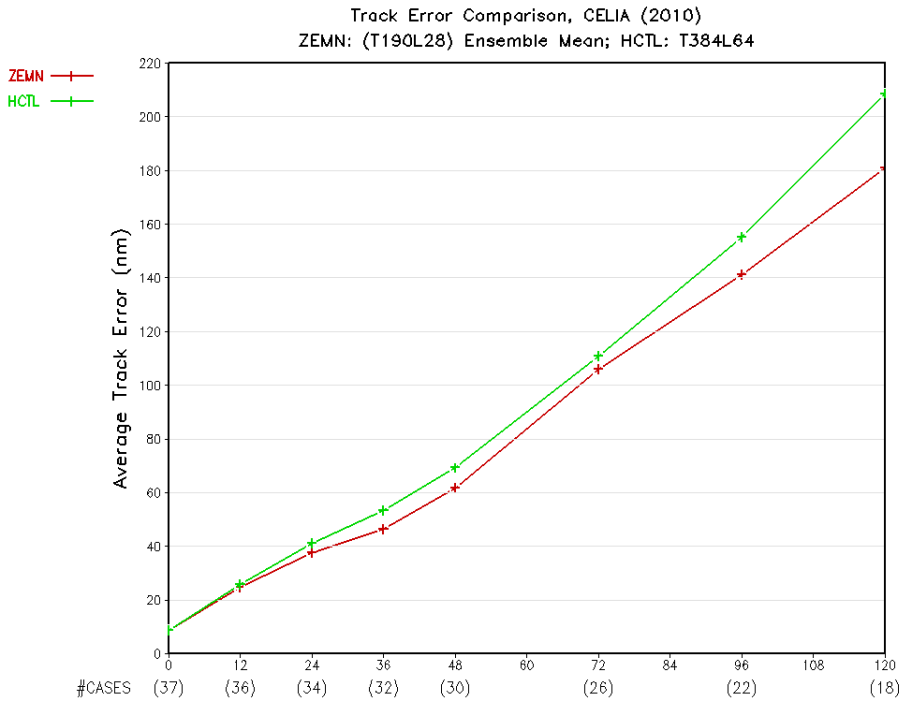
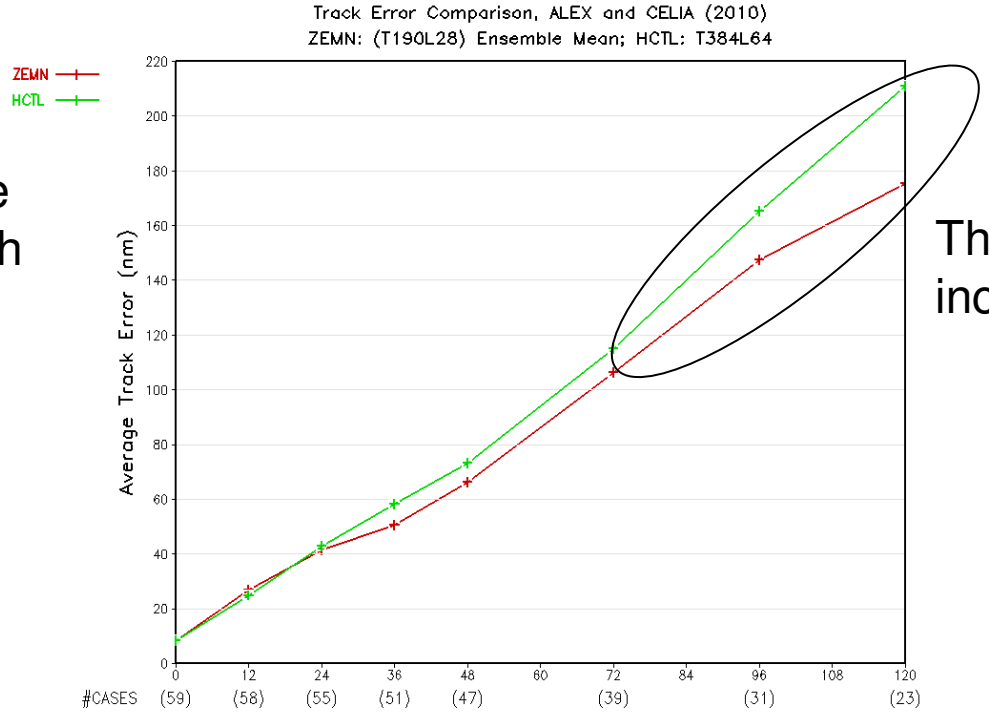
Experiment Design

- HCTL: Control run, GFS input (T382L64), HWRF V3.2 (R2);
- ZPxx: Ensemble runs, GEFS input (T190L28), HWRF V3.2 (R2); 20+1 members;
- ZEMN: Ensemble mean from ZPxx;
- HWRF: GFS input, with current operational HWRF (H210 version).
- Two 2010 hurricanes: Alex (AL) and Celia (EP)

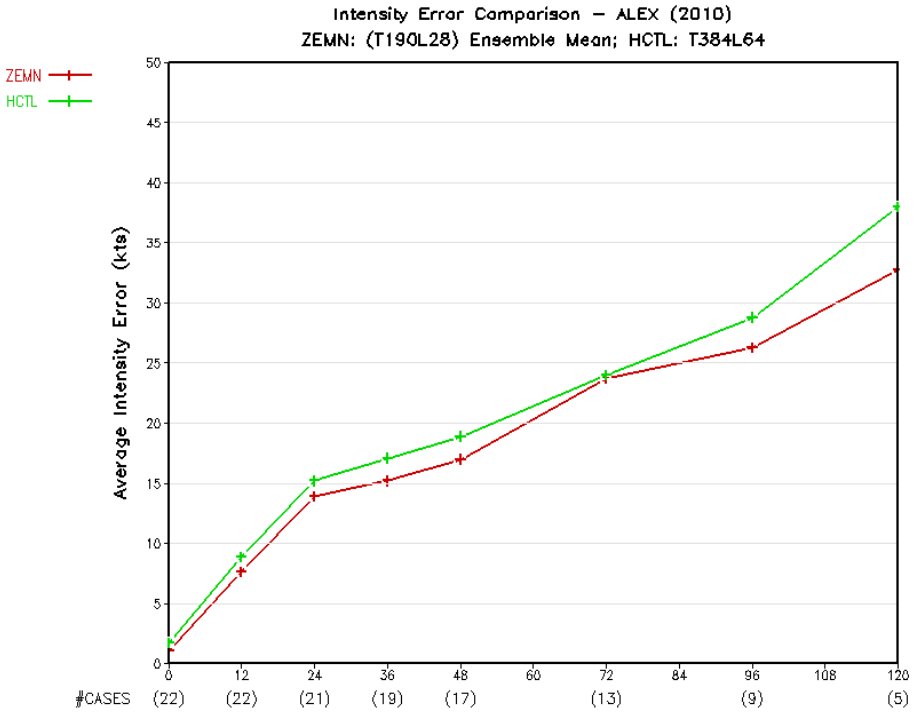


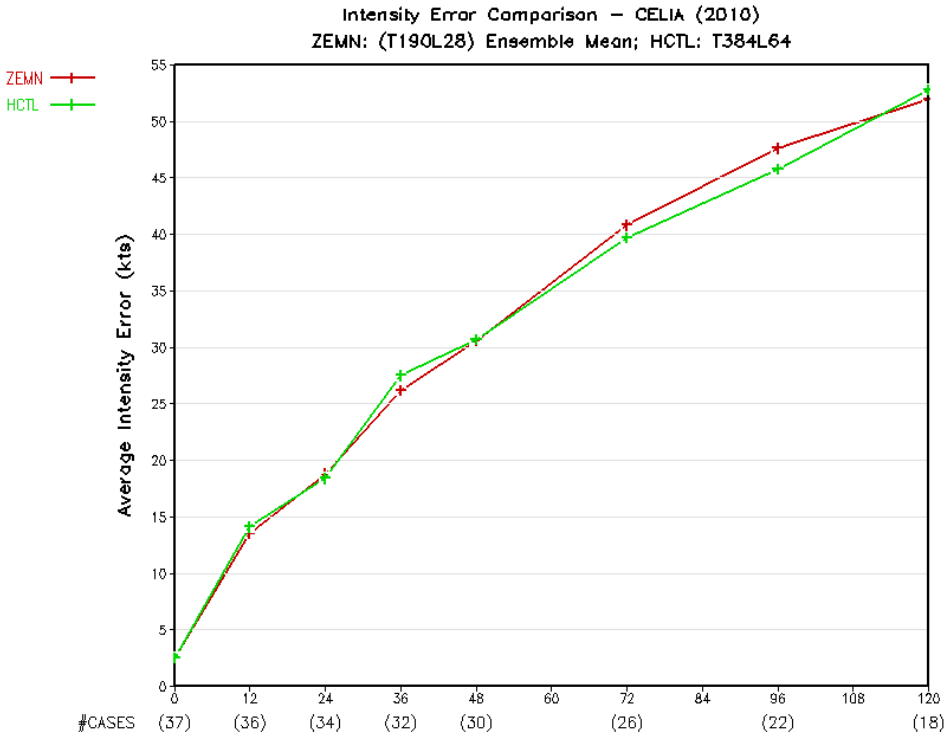


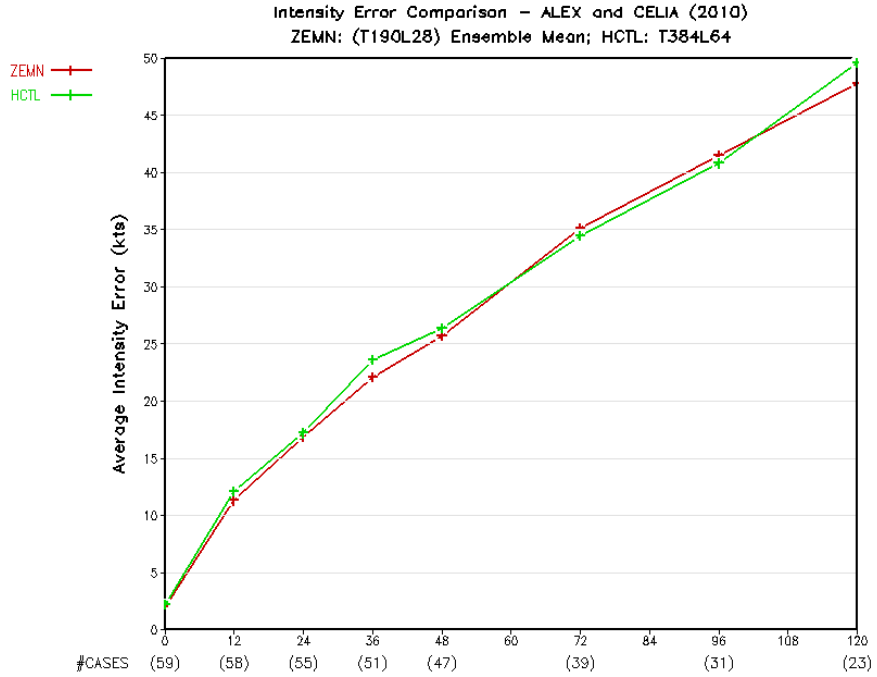


Forecast skills are improved from 24h to 120h.

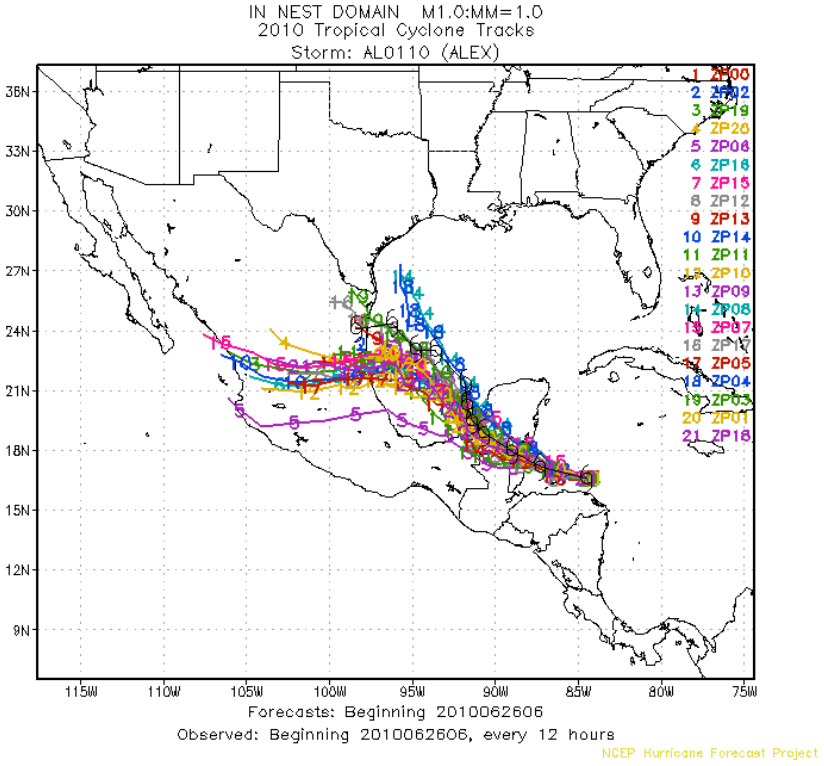
The skill improvement increases with time.

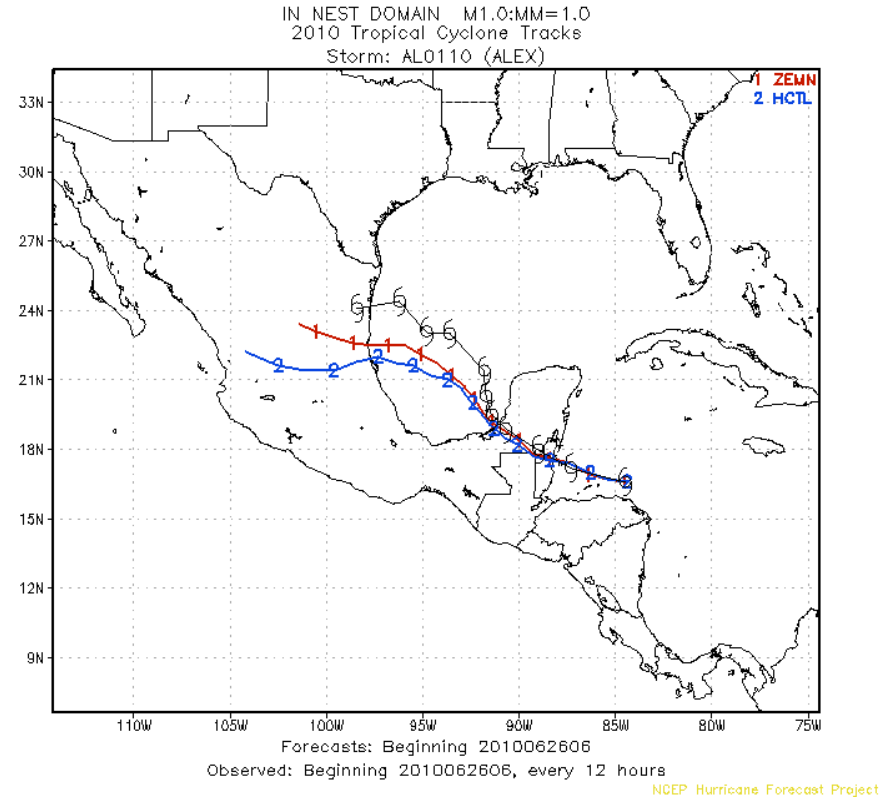

Intensity Error Comparison – ALEX (2010)
ZEMN: (T190L28) Ensemble Mean; HCTL: T384L64
ZEMN
HCTL
Average Intensity Error (kts)
0 5 10 15 20 25 30 35 40 45 50
0 12 24 36 48 60 72 84 96 108 120
#CASES (22) (22) (21) (19) (17) (13) (9) (5)

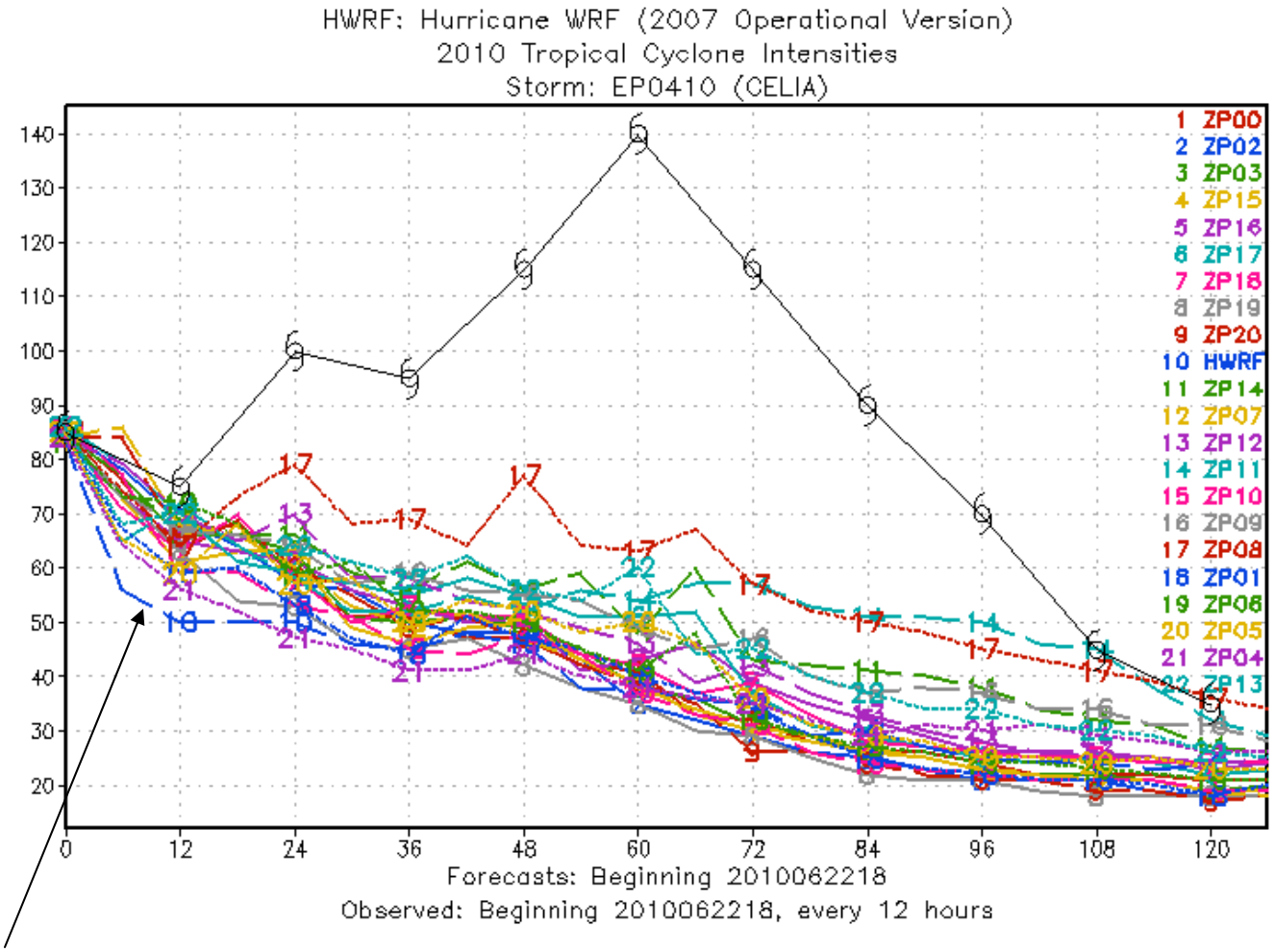

Intensity Error Comparison – CELIA (2010)
ZEMN: (T190L28) Ensemble Mean; HCTL: T384L64
ZEMN
HCTL
Average Intensity Error (kts)
0 5 10 15 20 25 30 35 40 45 50 55
0 12 24 36 48 60 72 84 96 108 120
#CASES (37) (36) (34) (32) (30) (26) (22) (18)


Intensity Error Comparison – ALEX and CELIA (2010)
ZEMN: (T190L28) Ensemble Mean; HCTL: T384L64
ZEMN
HCTL
Average Intensity Error (kts)
0 5 10 15 20 25 30 35 40 45 50
0 12 24 36 48 60 72 84 96 108 120
#CASES (59) (58) (55) (51) (47) (39) (31) (23)

Ensemble Track Forecasts, Hurricane Alex, 2010062606





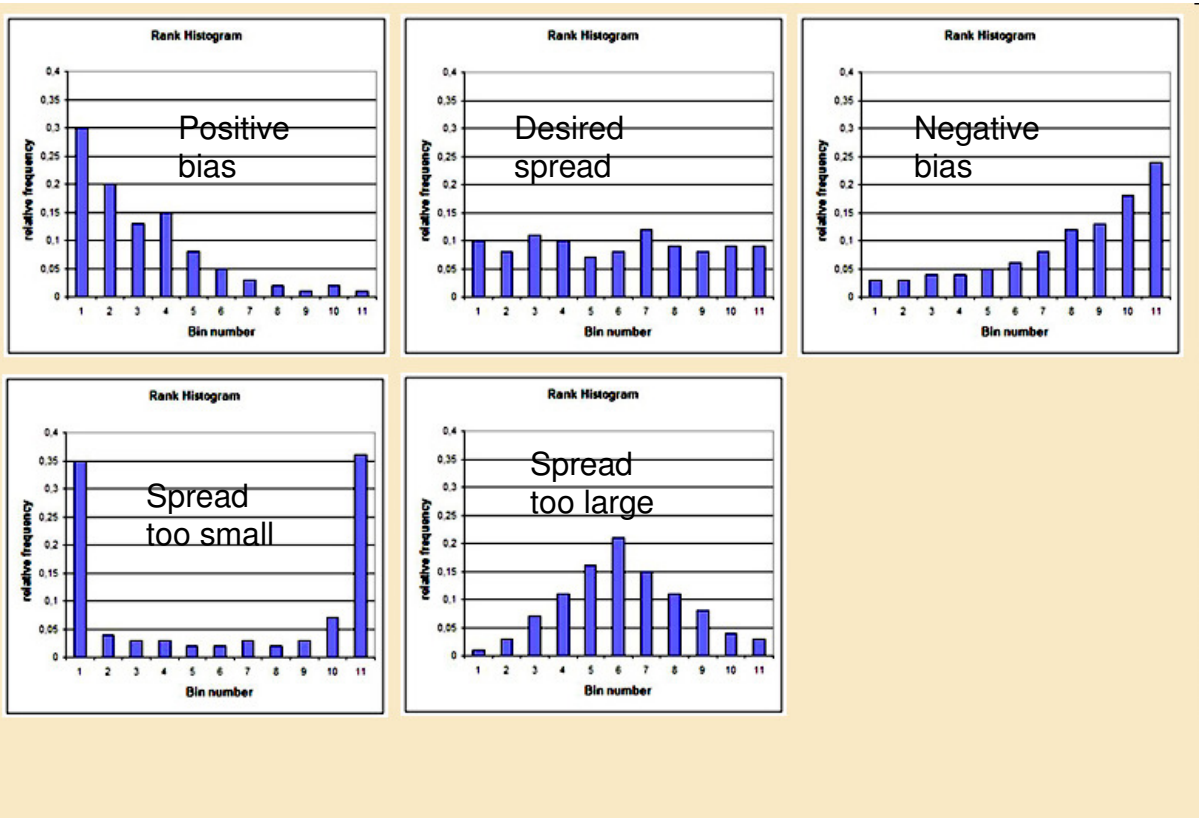


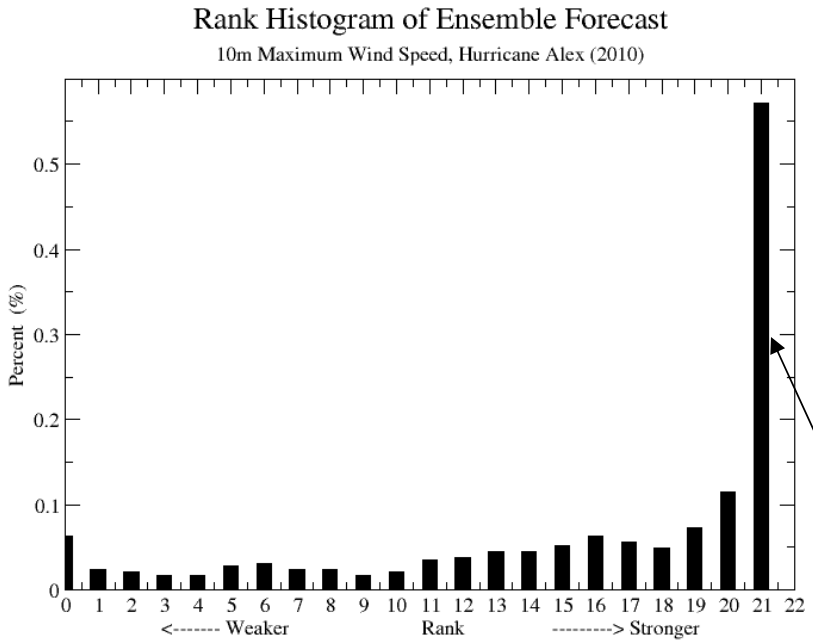
HWRF is the outlier

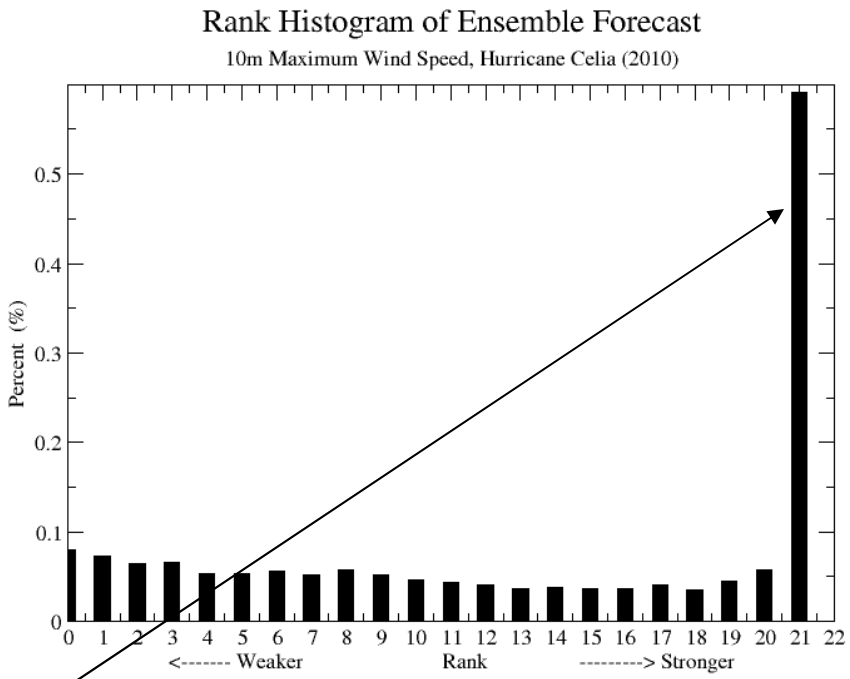
Ensemble Spread Verification

- Does the ensemble spread represent the uncertainty in the initial large scale flow? Or the track improvement is due to biases in the ensemble perturbations?
- The rank histogram evaluates if the ensemble has desired spread, so that the probability of occurrence of the observation within each bin is equal.

For each specific forecast, the bins are determined by ranking the ensemble member forecasts from lowest to highest. The interval between each pair of ranked values forms a bin. If there are N ensemble members, then there will be N+1 bins. The outer bins, lowest and highest – valued, are open-ended.



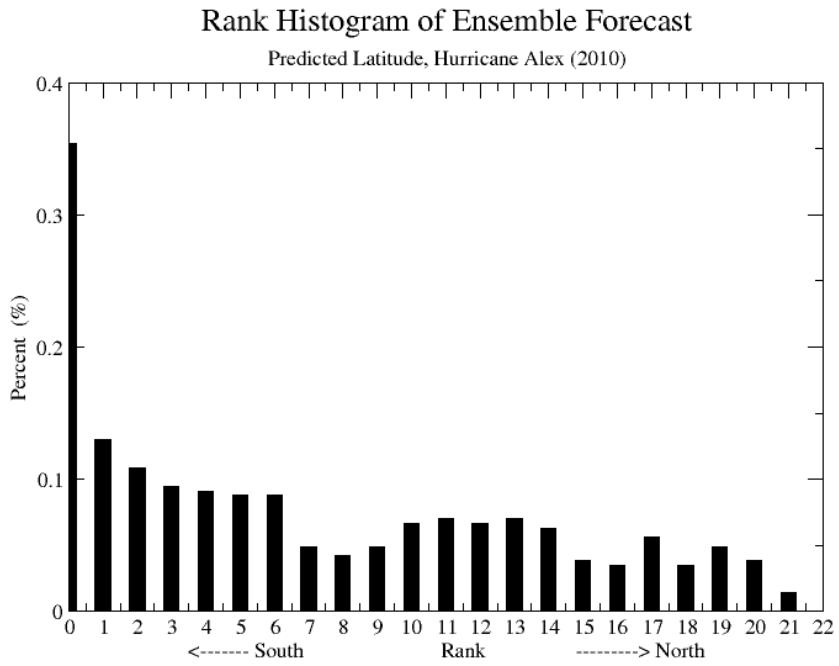


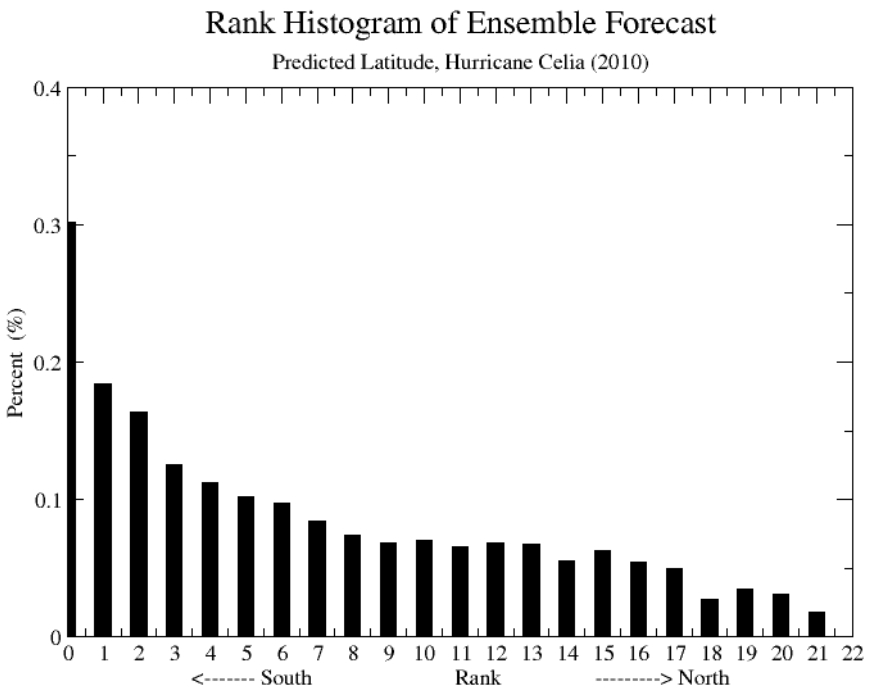


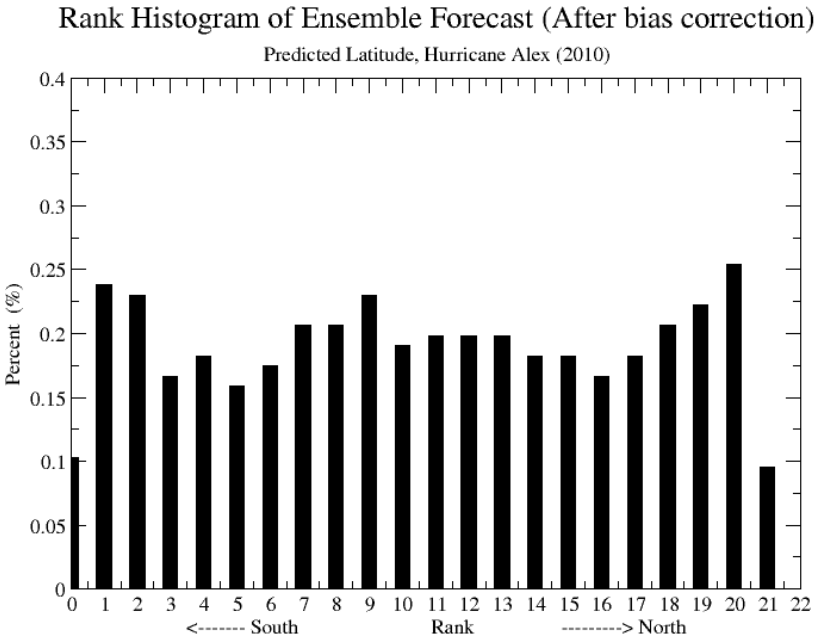
Negative intensity bias

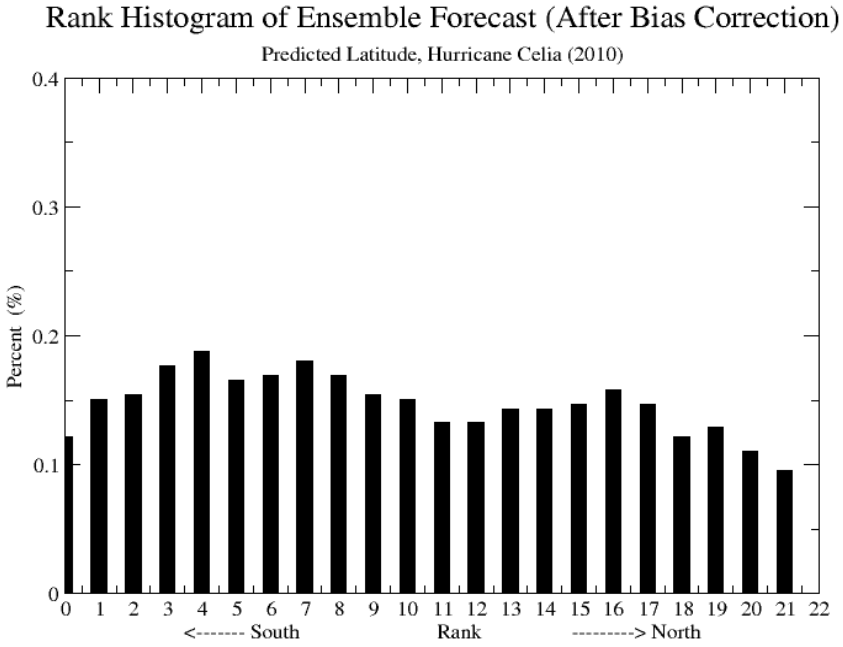
Average HWRF Model Intensity Bias (Kt)

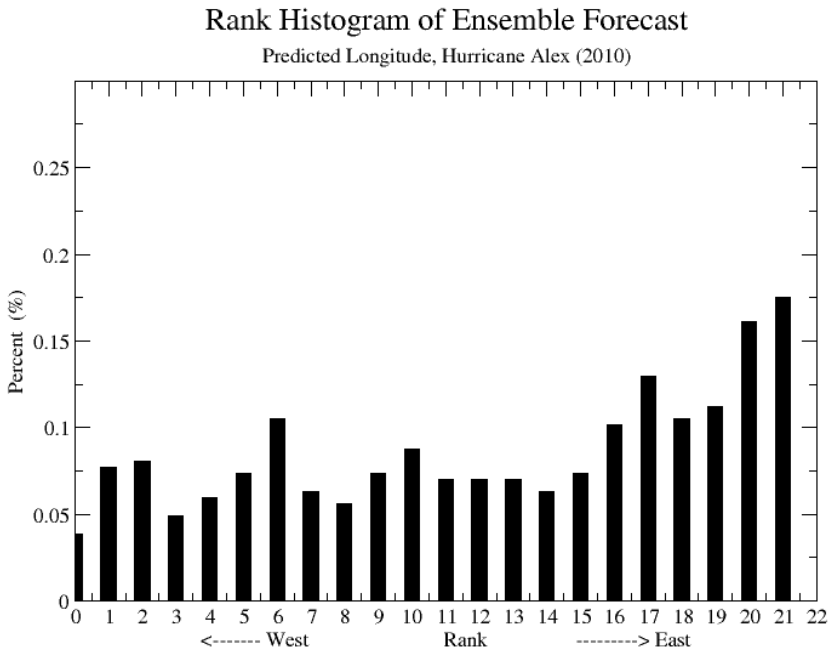
	00h	12h	24h	36h	48h	72h	96h	120h
Alex	0.1	-4.3	-8.2	-14.5	-17.0	-22.9	-26.3	-32.8
Celia	0.1	-12.2	-18.3	-24.7	-28.4	-38.9	-47.5	-51.9


Rank Histogram of Ensemble Forecast
Predicted Latitude, Hurricane Alex (2010)
Percent (%)
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
<------- South
Rank
---------> North


Rank Histogram of Ensemble Forecast
Predicted Latitude, Hurricane Celia (2010)
Percent (%)
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
<------- South
Rank
---------> North

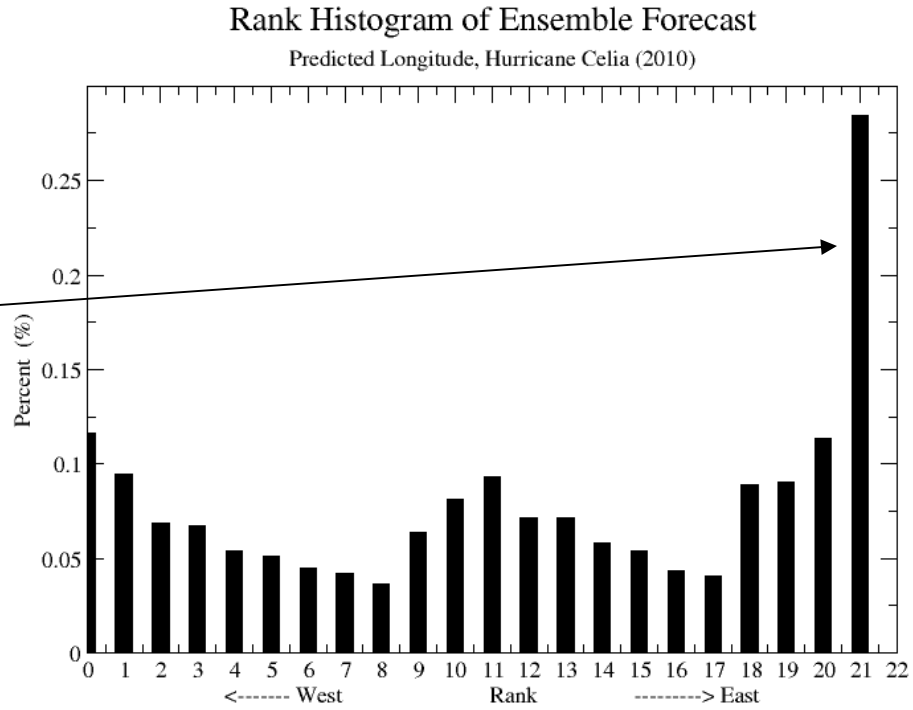

Rank Histogram of Ensemble Forecast (After bias correction)
Predicted Latitude, Hurricane Alex (2010)
Percent (%)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
<------- South
Rank
---------> North

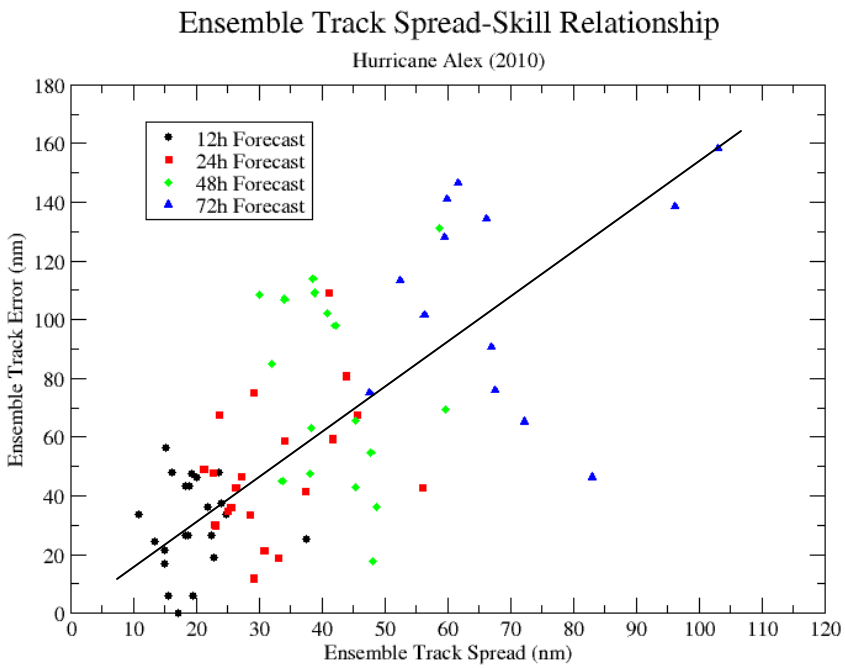

Rank Histogram of Ensemble Forecast (After Bias Correction)
Predicted Latitude, Hurricane Celia (2010)
Percent (%)
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
<------- South
Rank
---------> North

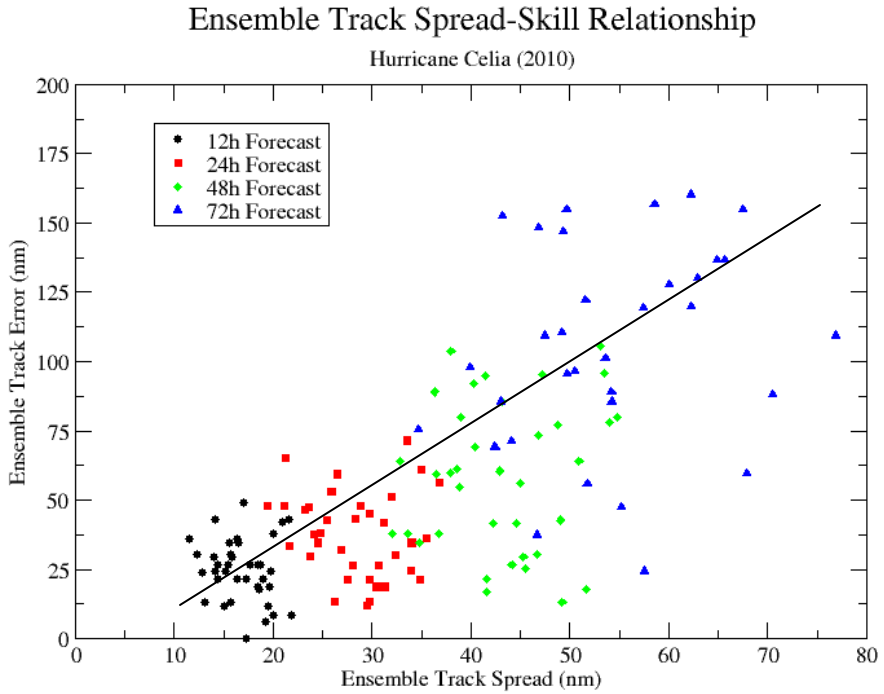


Slightly west bias for Alex.

Strong west bias for Celia. Moving faster than observed.

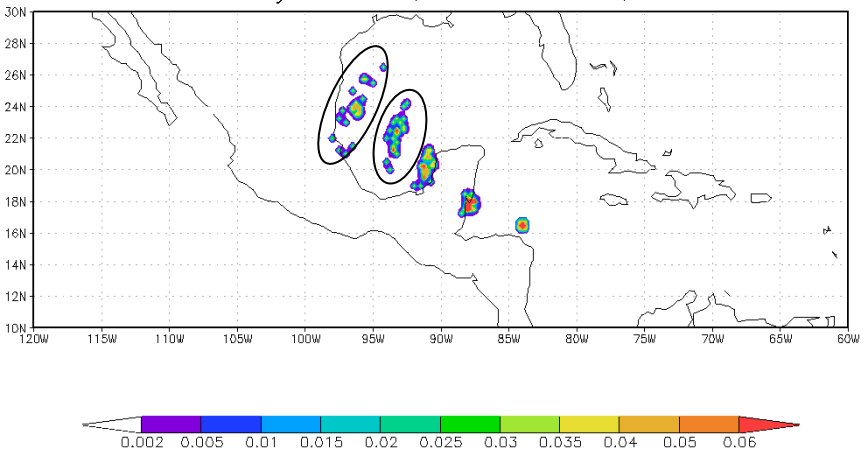



Ensemble Track Spread-Skill Relationship
Hurricane Alex (2010)
12h Forecast
24h Forecast
48h Forecast
72h Forecast
Ensemble Track Error (nm)
Ensemble Track Spread (nm)
0
20
40
60
80
100
120
140
160
180
0
10
20
30
40
50
60
70
80
90
100
110
120

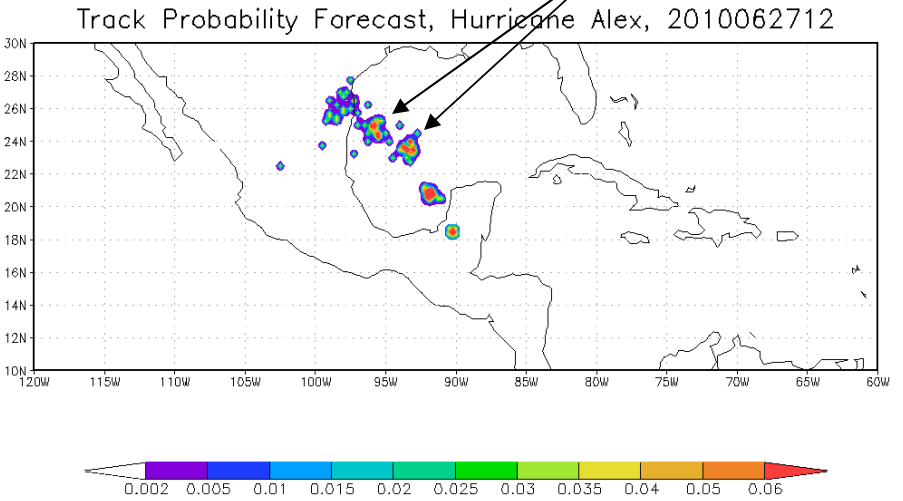

Ensemble Track Spread-Skill Relationship
Hurricane Celia (2010)
12h Forecast
24h Forecast
48h Forecast
72h Forecast
Ensemble Track Error (nm)
Ensemble Track Spread (nm)
0
25
50
75
100
125
150
175
200
0
10
20
30
40
50
60
70
80

Multiple centers

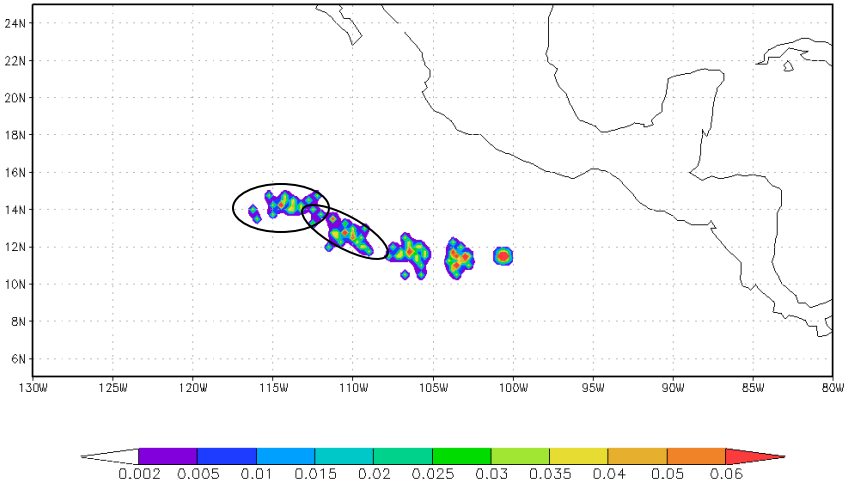
Track Probability Forecast, Hurricane Alex, 2010062600



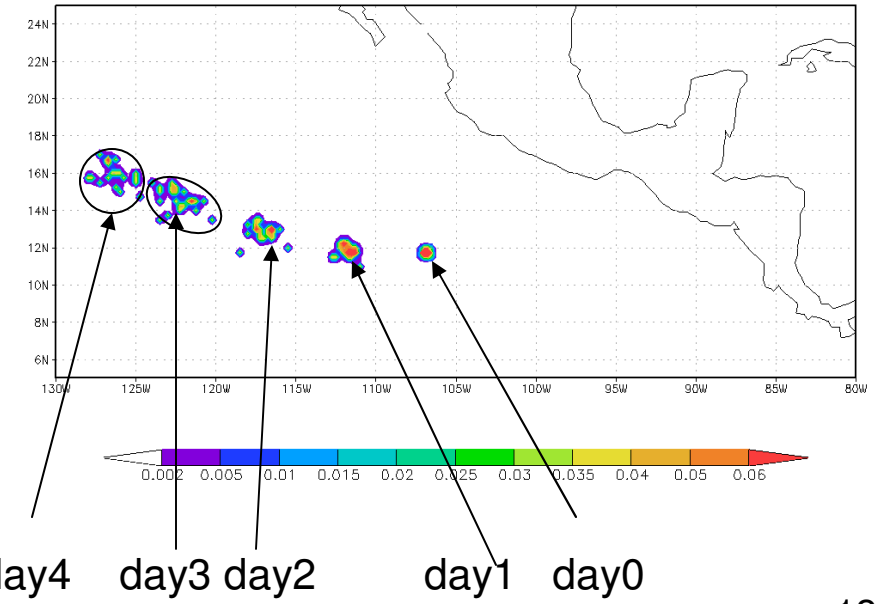
Track Probability Forecast, Hurricane Alex, 2010062712



Track Probability Forecast, Hurricane Celia, 2010062100



Track Probability Forecast, Hurricane Celia, 2010062300



Summary and Future Plan

- HWRF V3.2 (R2) is tested using GEFS input (ZPxx). The results of ensemble mean (ZEMN) are compared with single model run (HCTL);
- Hurricane track forecast skills are improved using HWRF-GEFS ensemble system (both Alex and Celia);
- Hurricane intensity forecast skills remained unchanged between ZEMN and HCTL;
- The uncertainties in initial large-scale flow are well represented in GEFS perturbations;
- Combine GEFS perturbations with physics-based perturbations;
- Flow-dependent initial position perturbations.