Progress on “Evaluating Hurricane Intensity Predictability using the Advanced Hurricane WRF”

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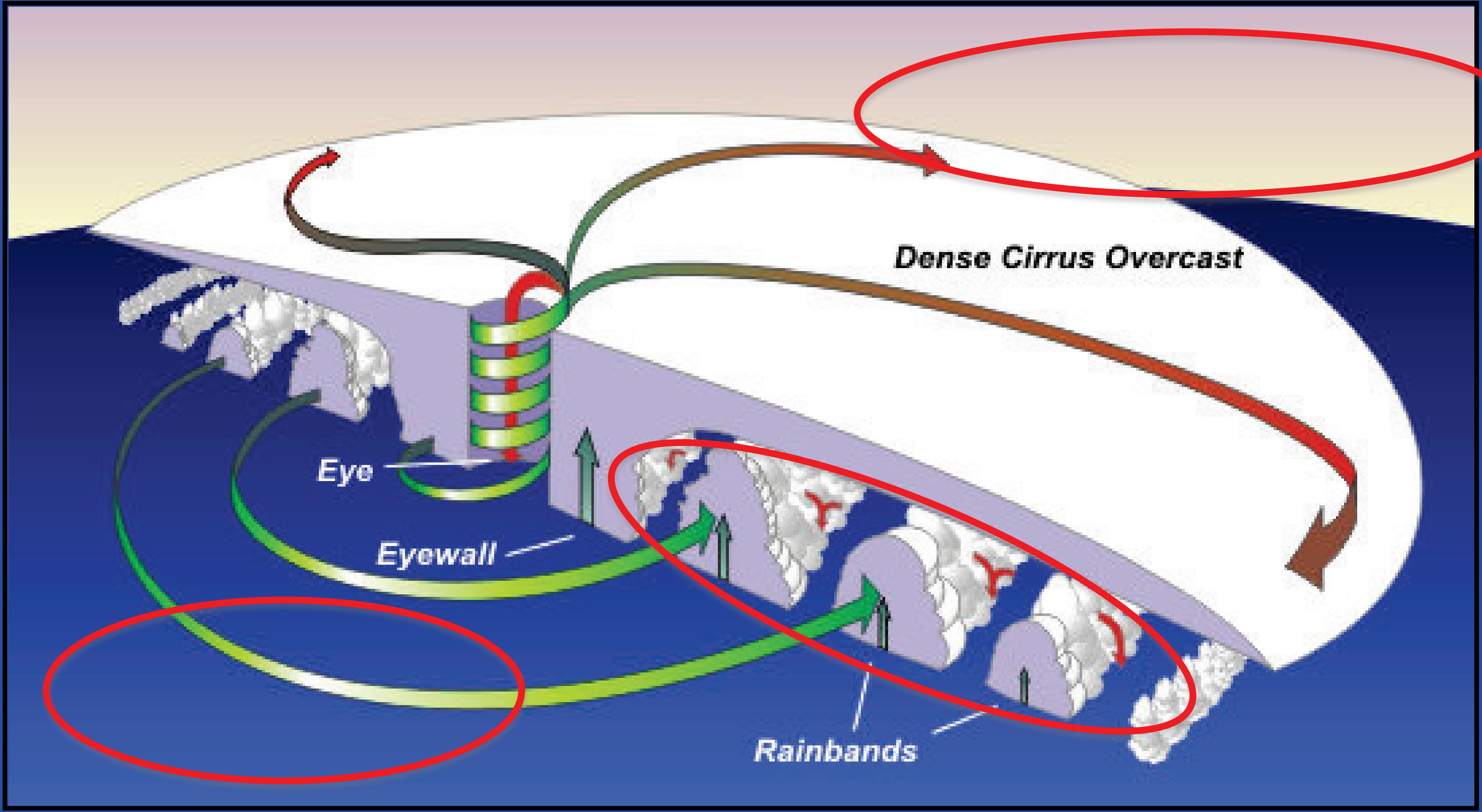
Motivation

- Forecasts from numerical prediction models suffer from errors in the initial conditions or formulation (resolution, parameterizations, etc.)
- Ultimate goal of this work is to understand how uncertainty (i.e., errors) in initial conditions translate into forecast intensity errors
- Has implications for how one might go about improving the forecast and optimal observation strategies

Intensity Factors

TC Environment



Courtesy National Hurricane Center

Surface Boundary

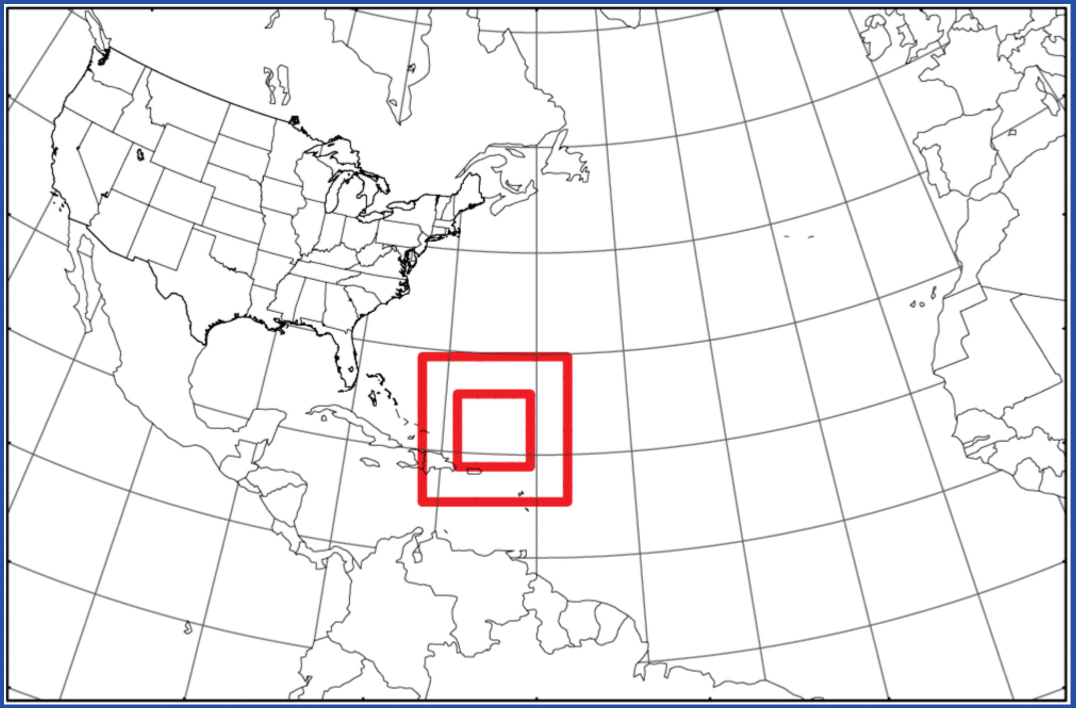
Internal Processes

Motivation

- Fundamental question of how predictable TC intensity forecasts are given errors in model initial condition and formulation
- Not clear whether atmospheric and oceanic errors are complimentary to each other or orthogonal
- Has implications for designing tropical cyclone ensemble prediction systems
- Explore this using high-resolution ensemble forecasts that are characterized by different sources of variability

Data

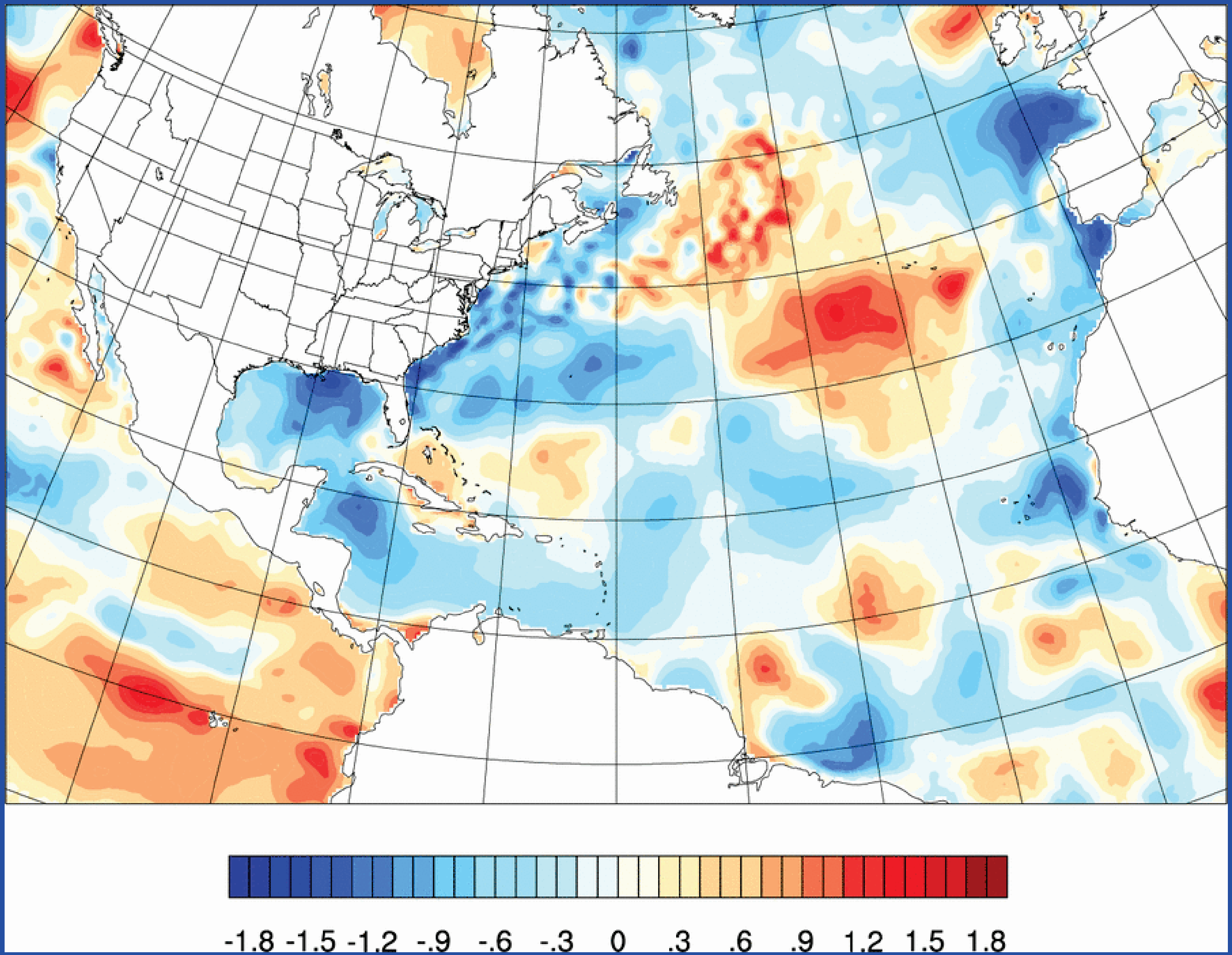
- Use Advanced Hurricane WRF (AHW), 2012 HFIP retrospective configuration (Davis et al. 2008, 2010)
  - Initial conditions obtained from cycling ensemble Kalman filter (EnKF) using Data Assim. Research Testbed (DART)
  - Assimilates conventional data + dropsondes
  - Forecast: 36/12/4 km resolution, 30 ensemble members
  - 1D column ocean model (Pollard 1973), NCEP SST, HYCOM MLD



Ensemble Experiments

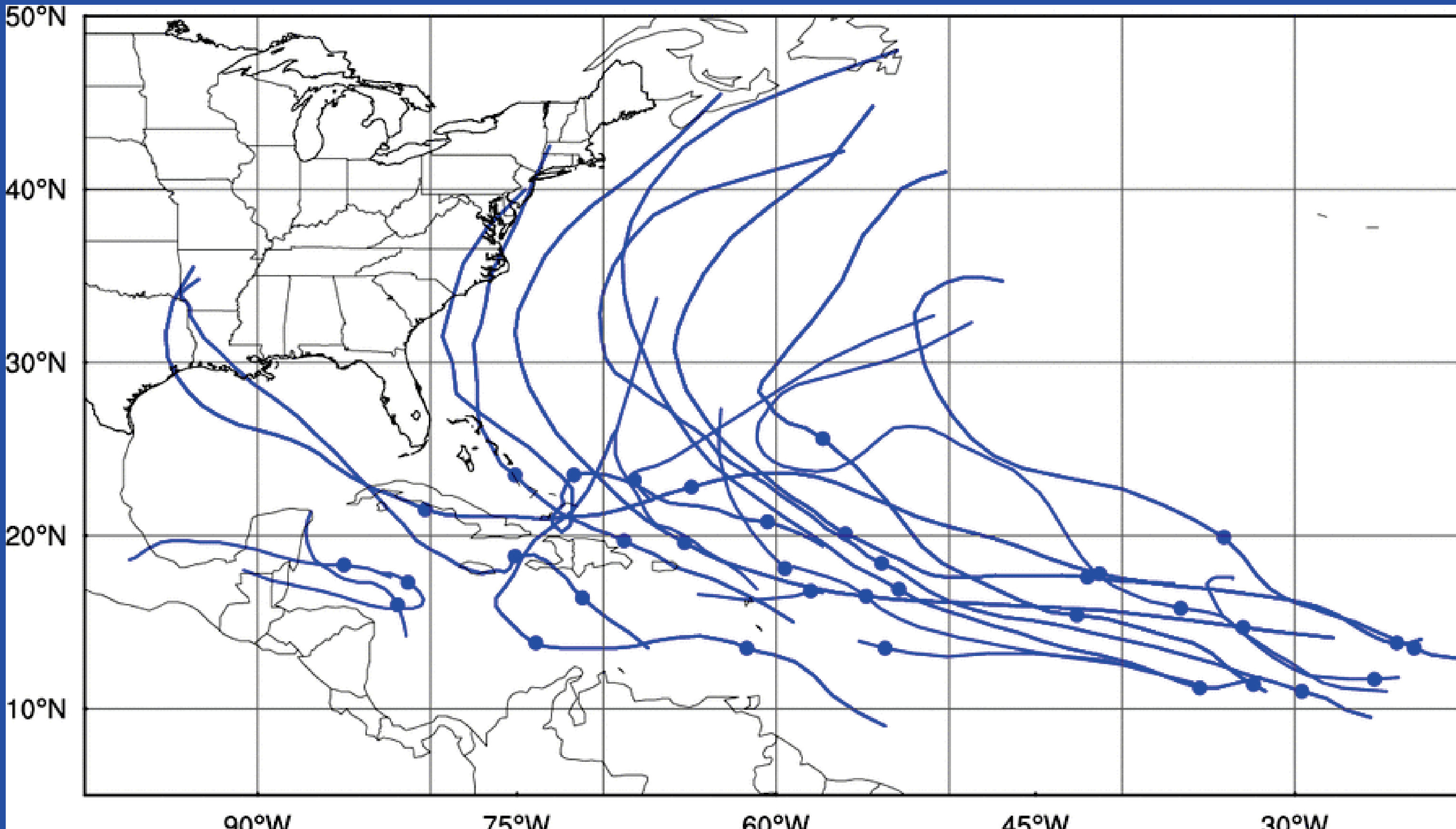
- Atmosphere Only:
  - Use 30 analysis members from ensemble data assimilation system for atmosphere
  - Same ocean state for each member
- Ocean Only:
  - Use atmospheric analysis used in deterministic AHW forecast
  - Ocean perturbations from climatology
- Atmosphere + Ocean
  - Use atmospheric states from Atmosphere Only
  - Use ocean states from Ocean Only

Ocean Perturbation



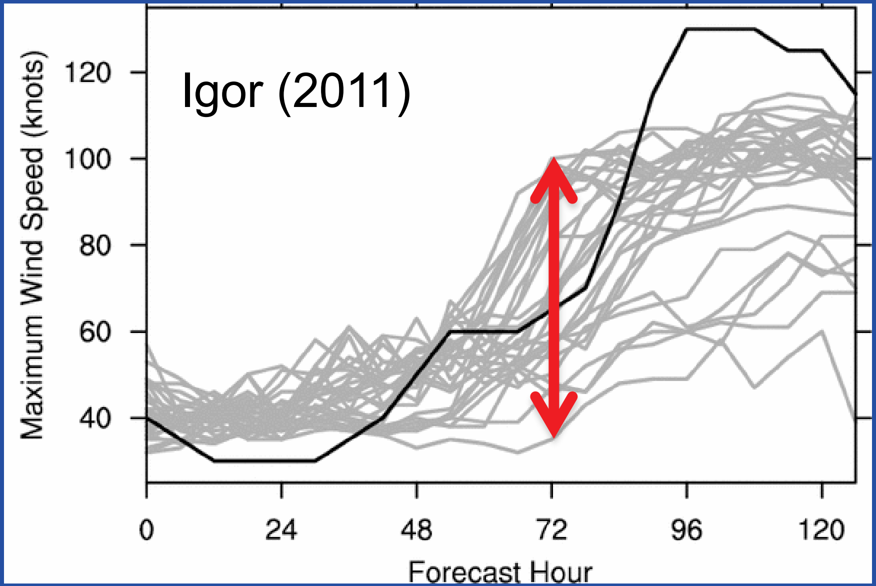
- Ensemble ocean initial conditions hard to come by
- Ensemble ocean perturbations obtained by sampling from a 2006-2011 climatology of SST and MLD fields
- Remove mean, scale SST so that individual locations have a 0.5 K standard deviation
- MLD values are scaled by the same value

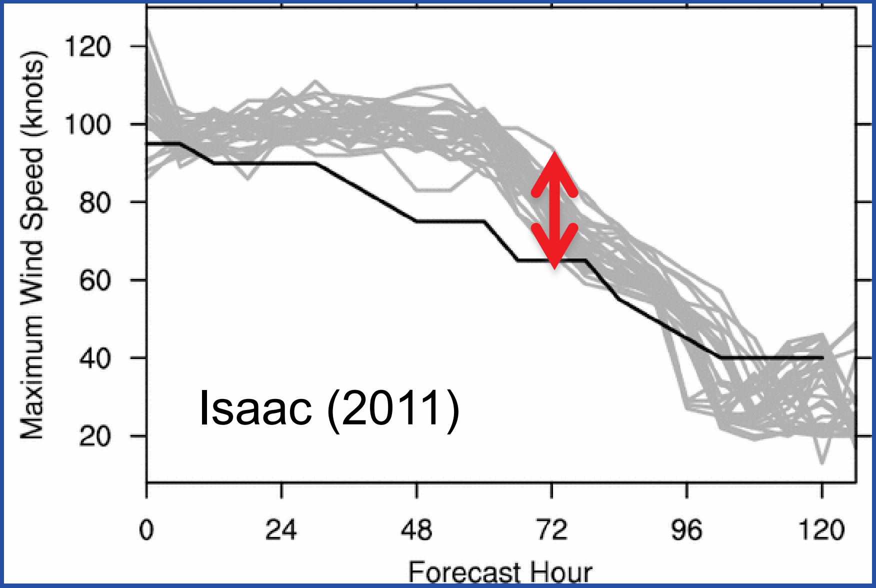
Cases



Gustav (2008; 2)	Erika (2009)	Igor (2010; 3)	Richard (2010)	Maria (2011)
Hanna (2008; 2)	Fred (2009)	Julia (2010; 2)	Tomas (2010; 2)	Ophelia (2011)
Ike (2009; 3)	Danielle (2010; 3)	Karl (2010)	Irene (2011; 2)	Philippe (2011)
Bill (2009; 2)	Earl (2010; 2)	Otto (2010)	Katia (2011; 2)	Rina (2011)

Example Forecasts



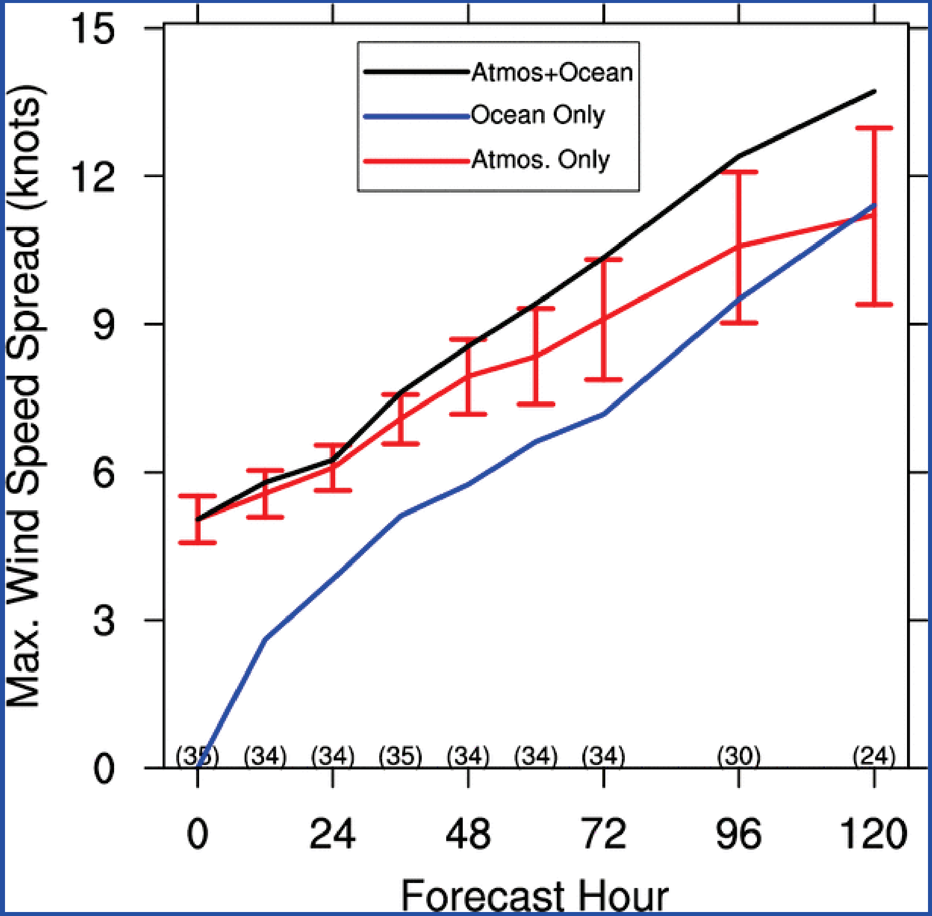


- Compute standard deviation of maximum wind as a function of forecast hour
- Significant case-by-case variability
- Can also compute an amplification or error growth factor based on ensemble forecasts

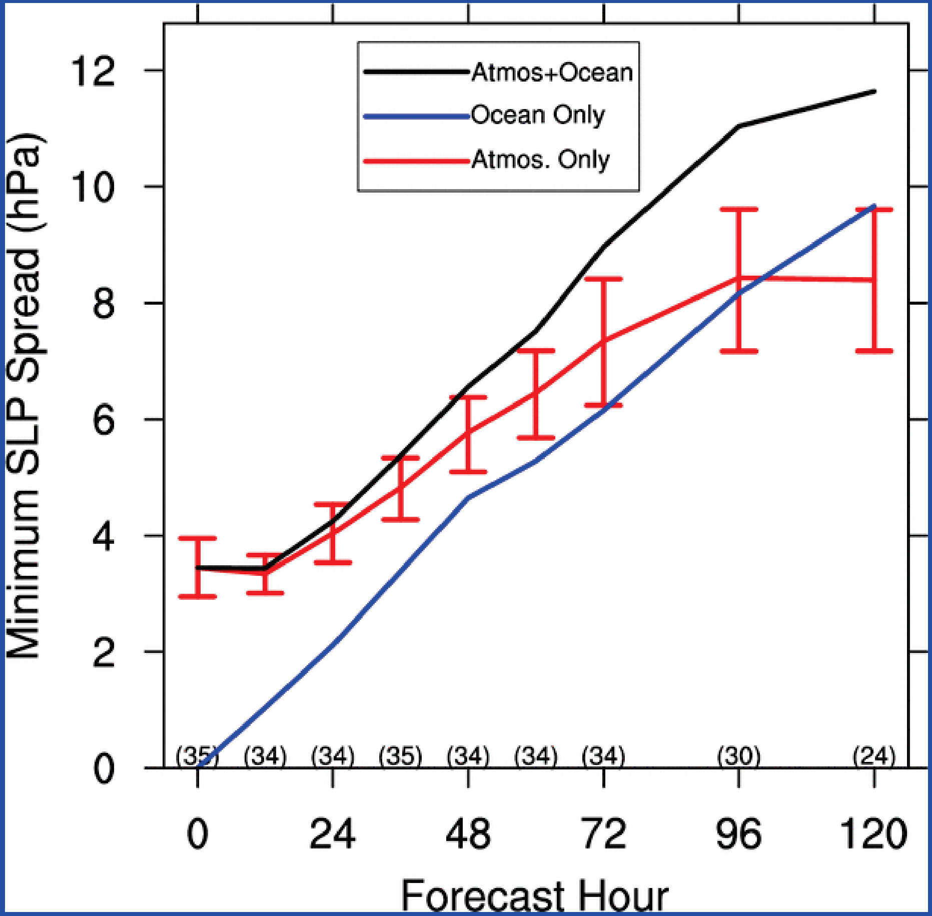
$$\mathcal{A} = \frac{\sigma_t}{\sigma_0}$$

Overall Statistics

Maximum Wind Speed

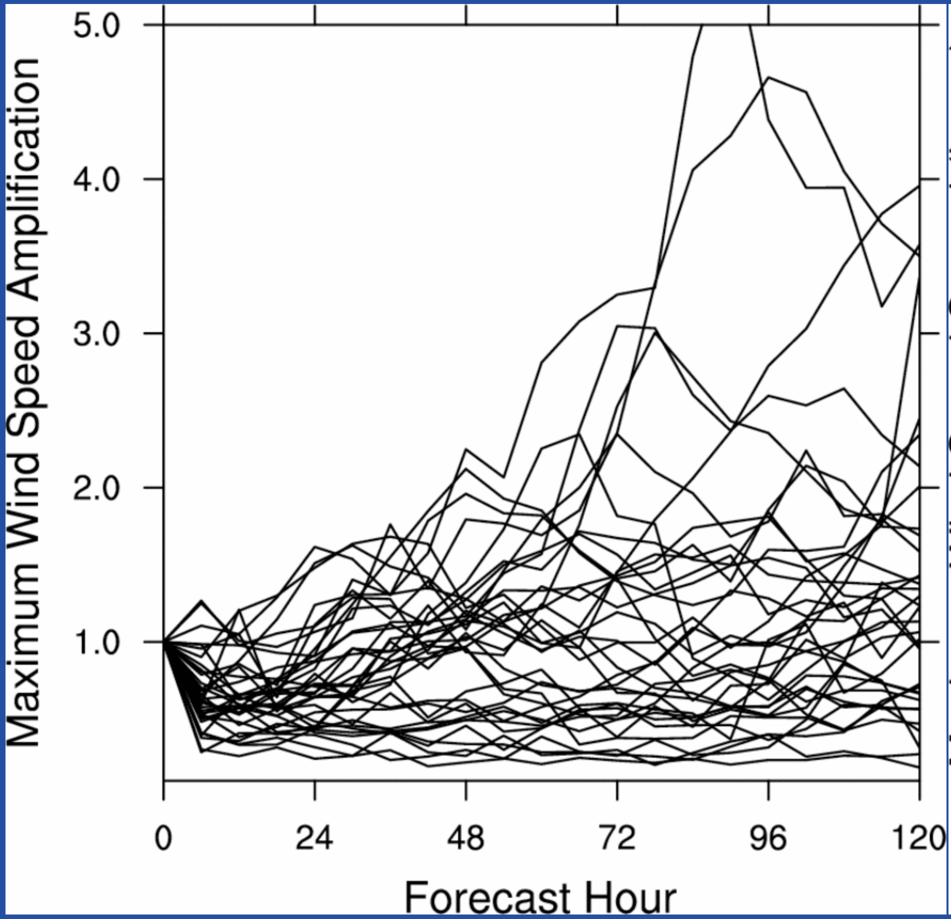


Minimum SLP

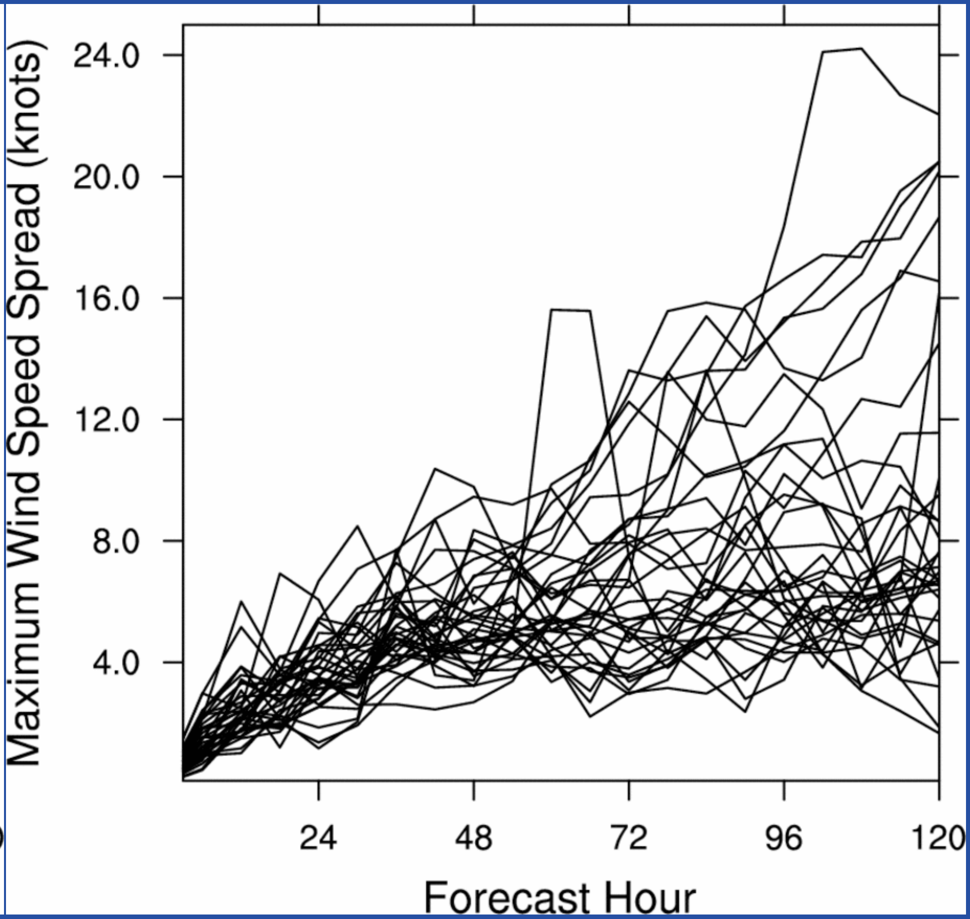


Amplification Factors

Atmosphere Only

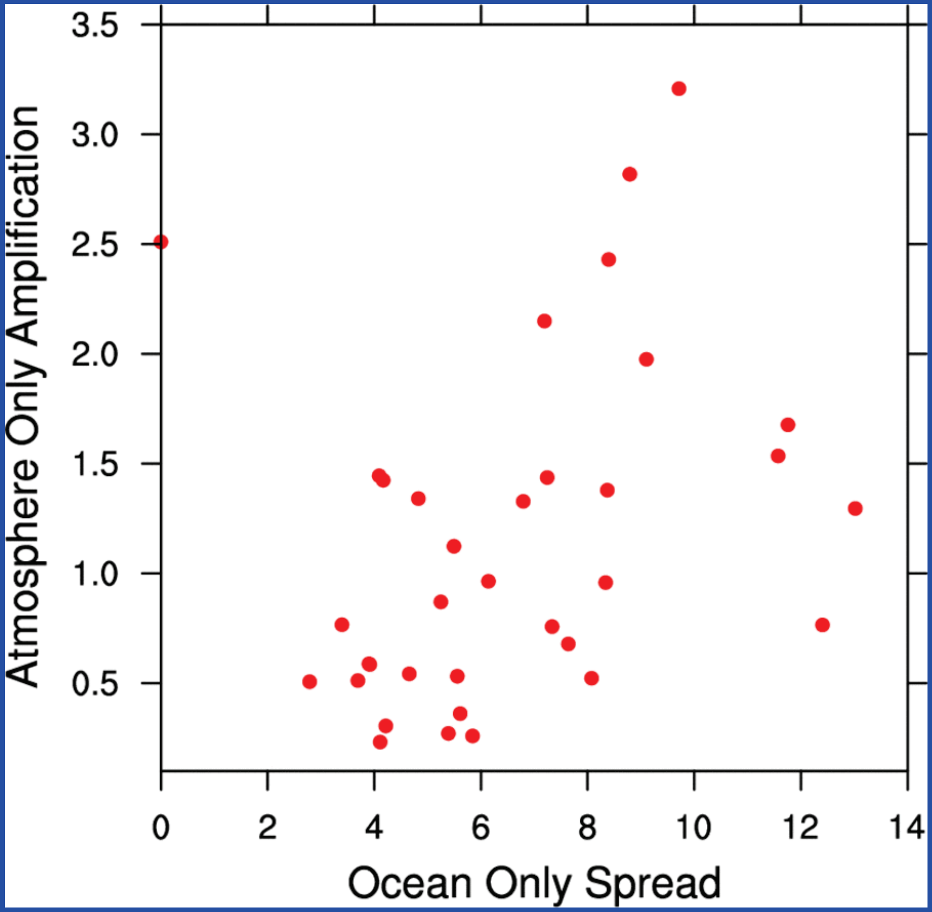


Ocean Only

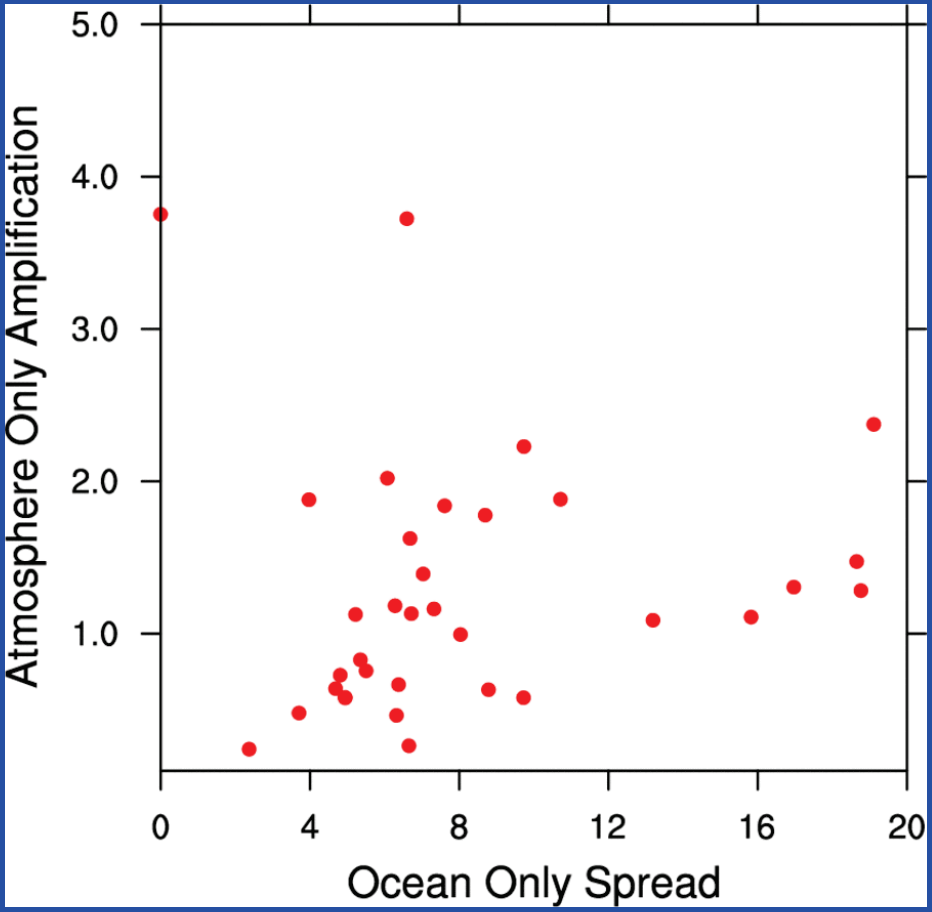


Atmosphere vs. Ocean Variance

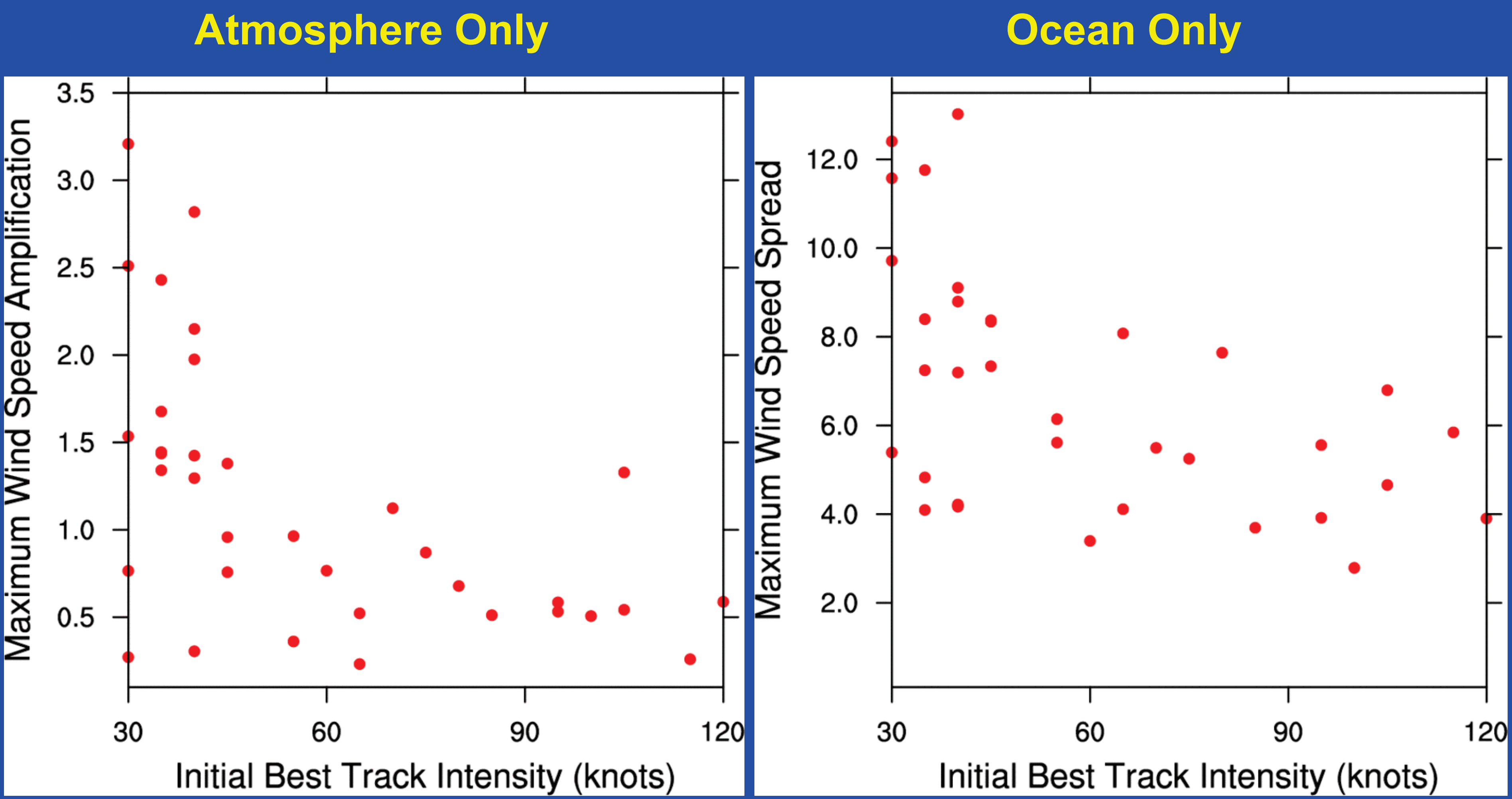
3-day Forecast



5-day Forecast



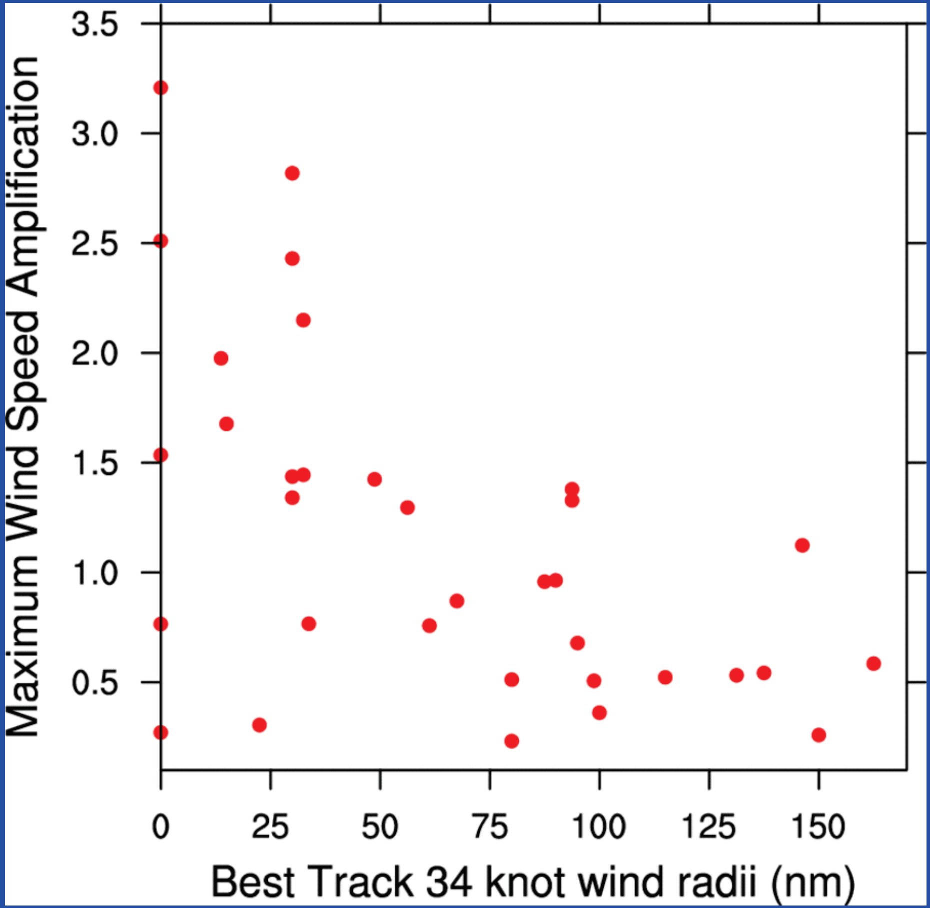
Case Comparison



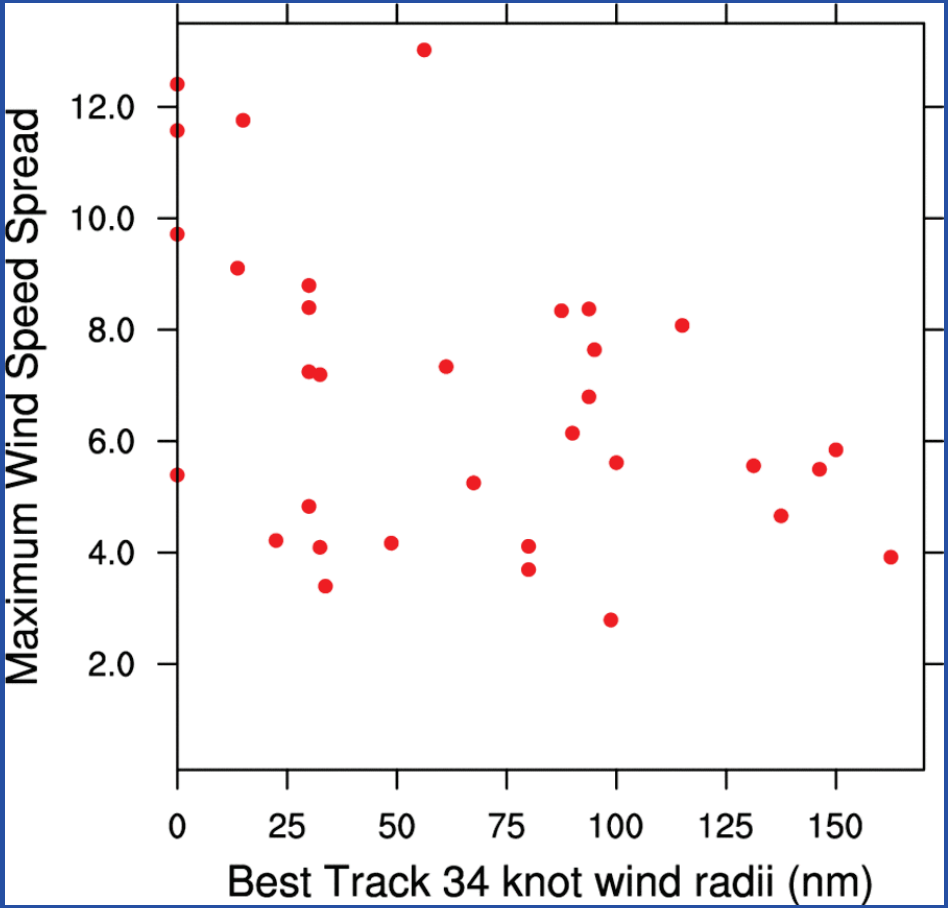
72 Hour Forecasts

Case Comparison

Atmosphere Only

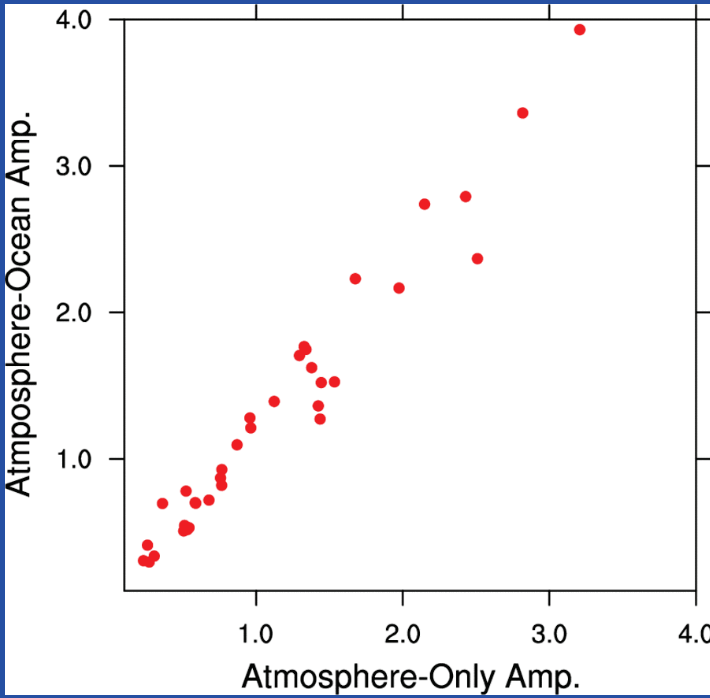


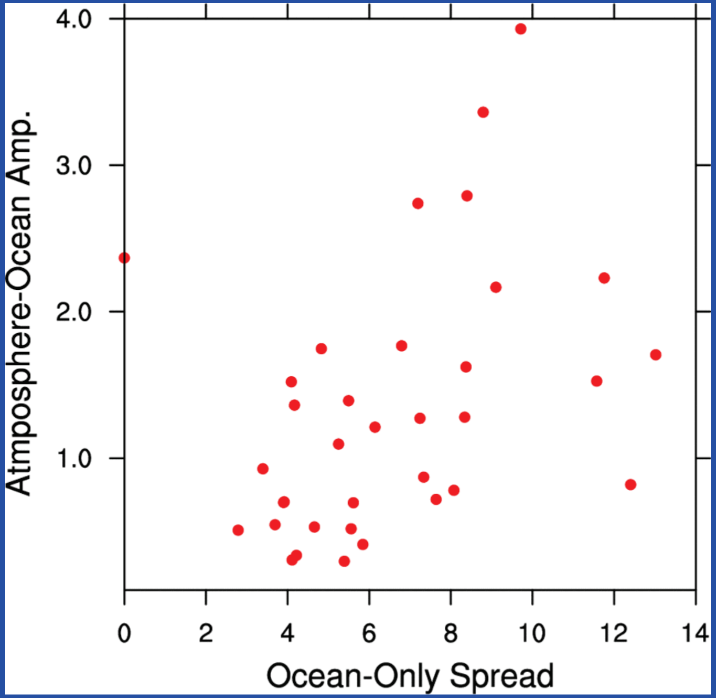
Ocean Only

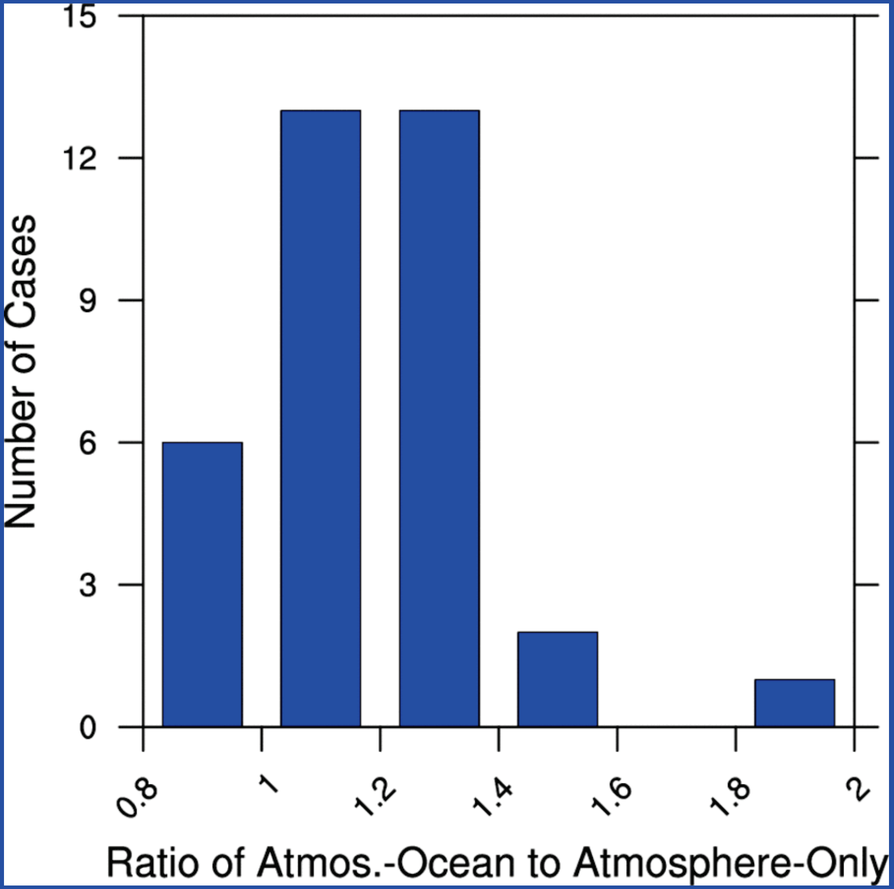


72 Hour Forecasts

72 h Atmos. and Ocean Contribution







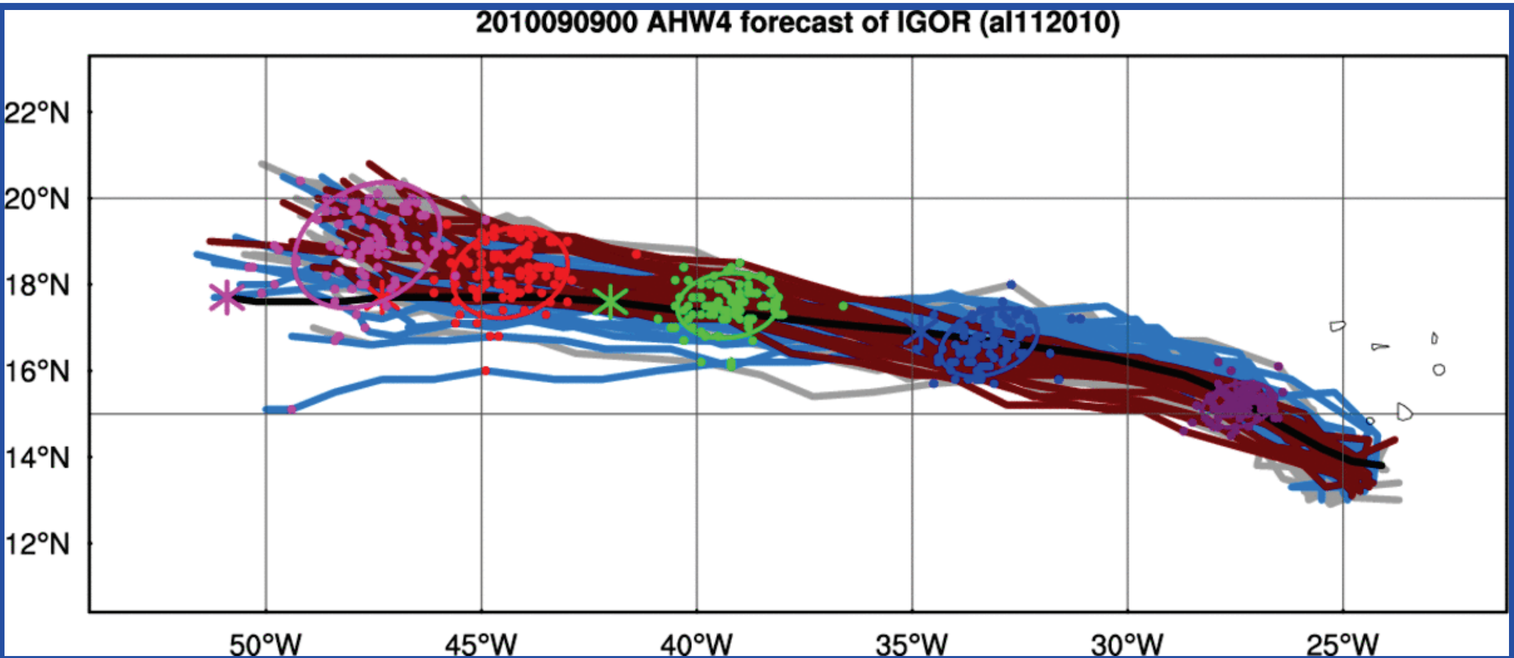
Ensemble Future Work

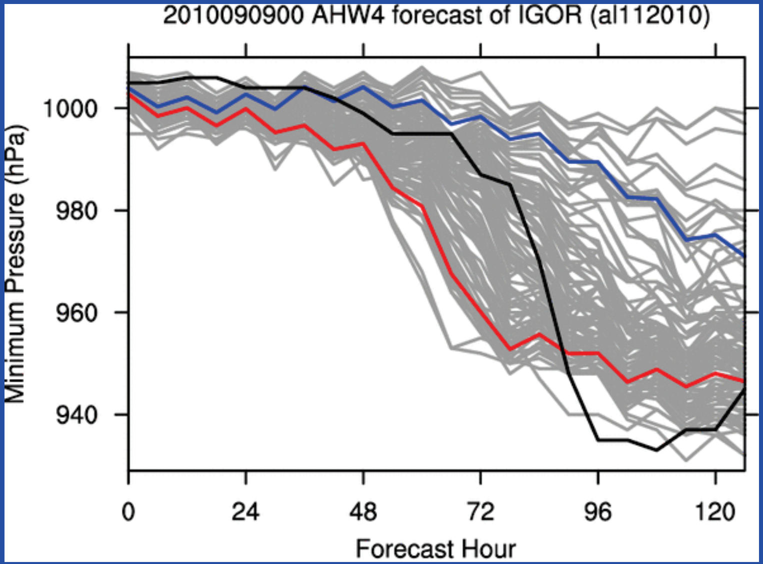
- Need to understand what is error growth mechanism for errors in the atmosphere vs. ocean (continued below)
- Compare these results with ensemble characterized by specific model errors (i.e., parameters that are uncertain)
- Operational Implications:
  - appears to be more important to account for uncertainty in atmosphere vs. ocean when designing ensemble predictions systems
  - Suggestion that smaller storms should be priority for targeted observations??

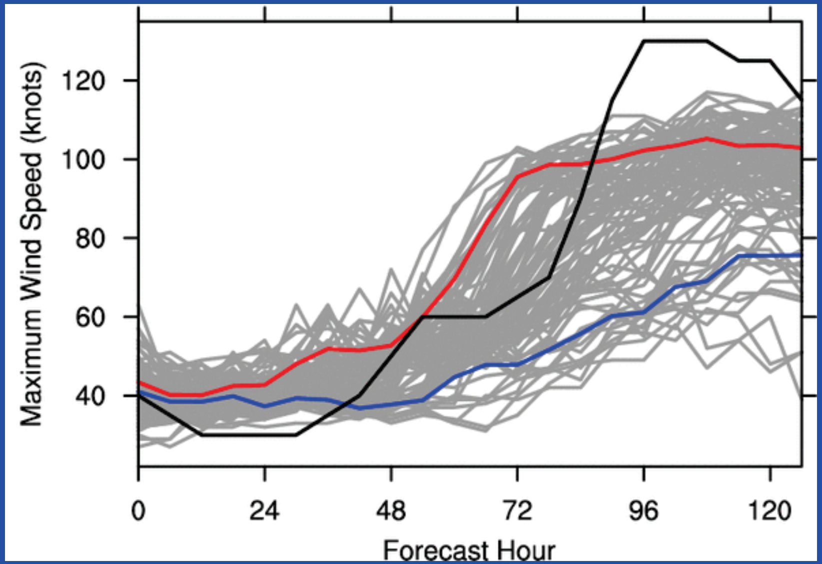
Sensitivity Analysis

- Previous results suggest certain forecasts can be very sensitive to initial conditions
- Important to understand what aspects of initial conditions are particularly sensitive
  - Suggests areas for model improvement
  - Suggests locations for observation targeting
- Will use ensemble-based sensitivity analysis to determine this
- Involves producing 96 member forecasts for select times

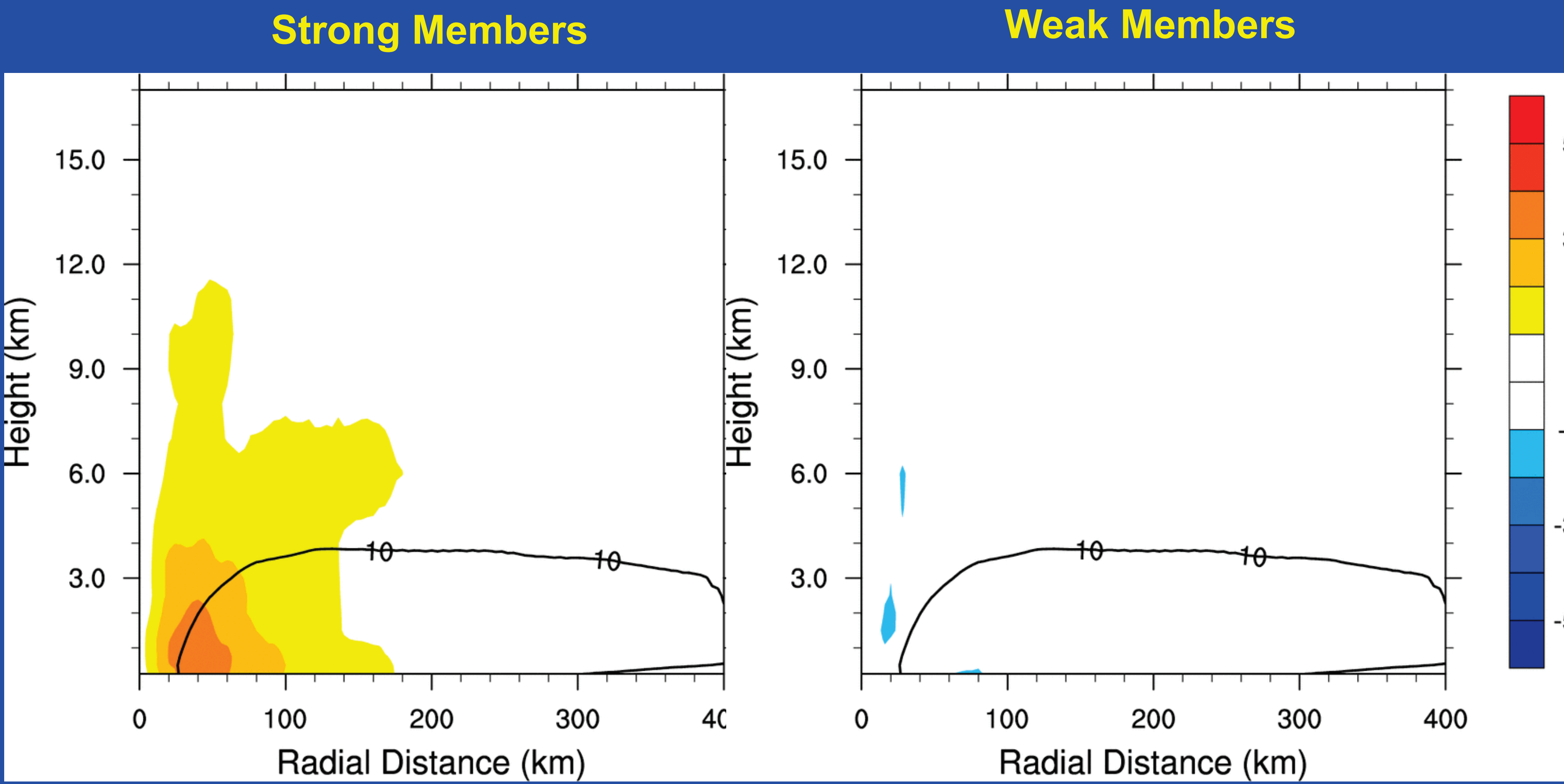
9 September Igor





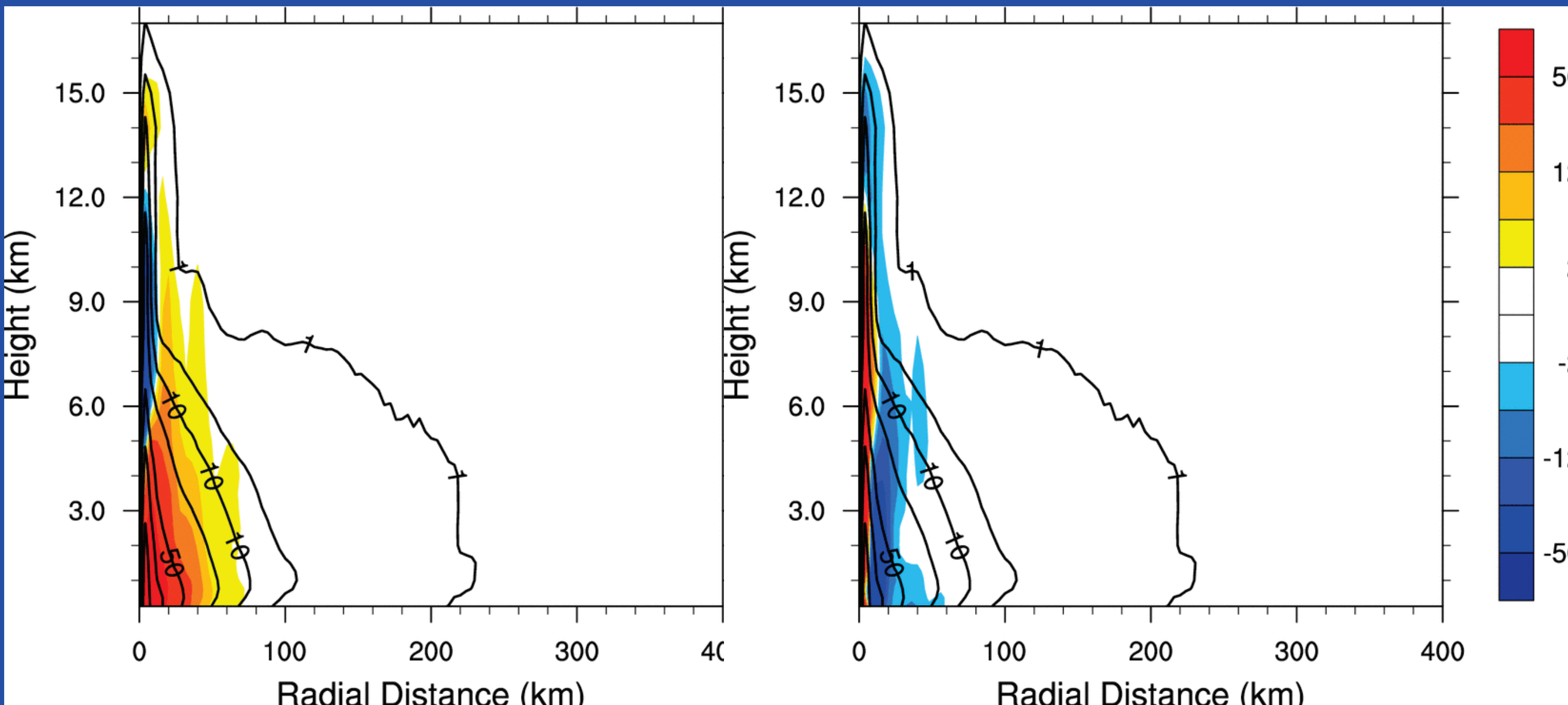


0 h Tangential Wind



0 h Member Comparision

Strong Members **Weak Members**



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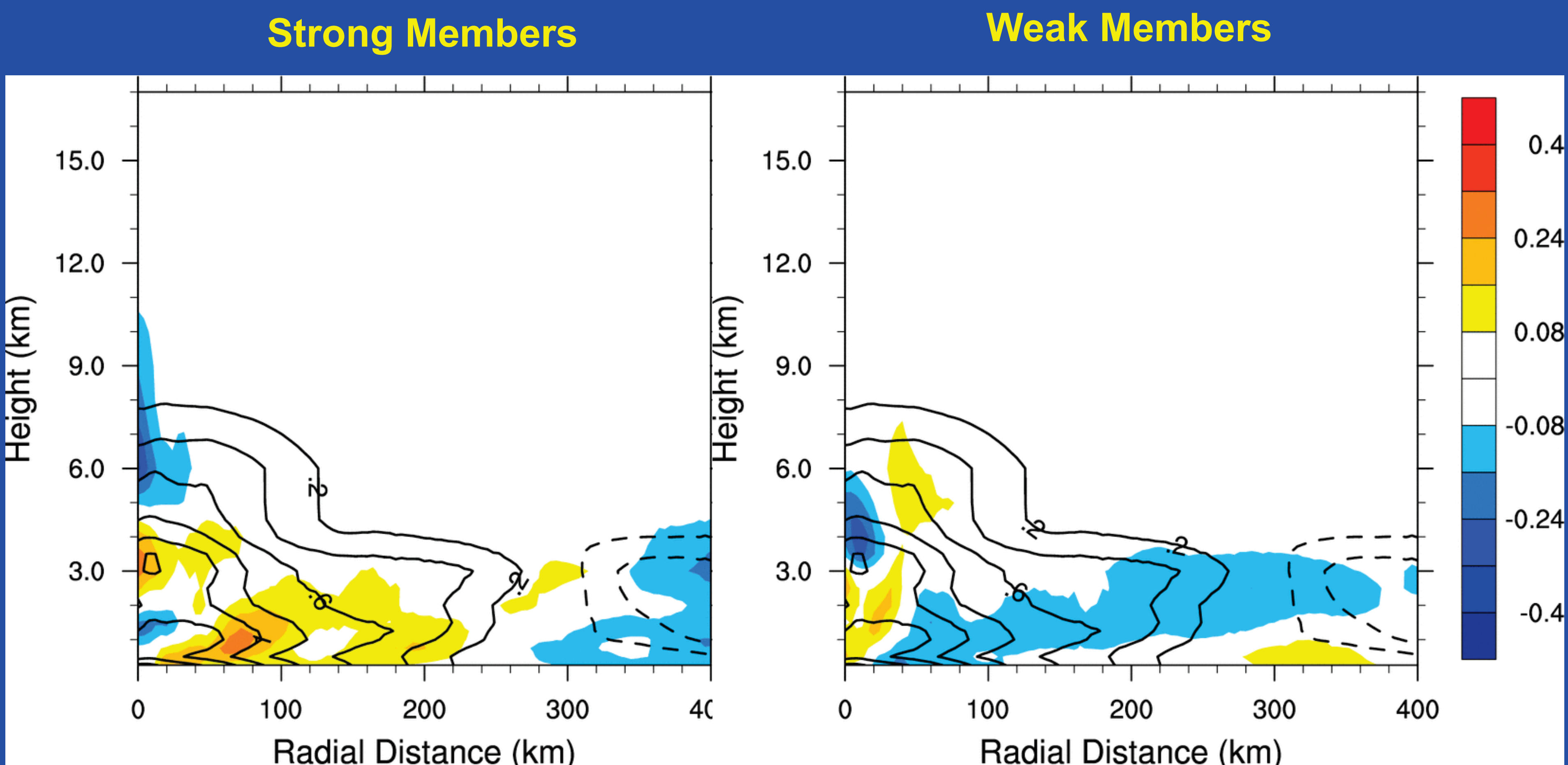
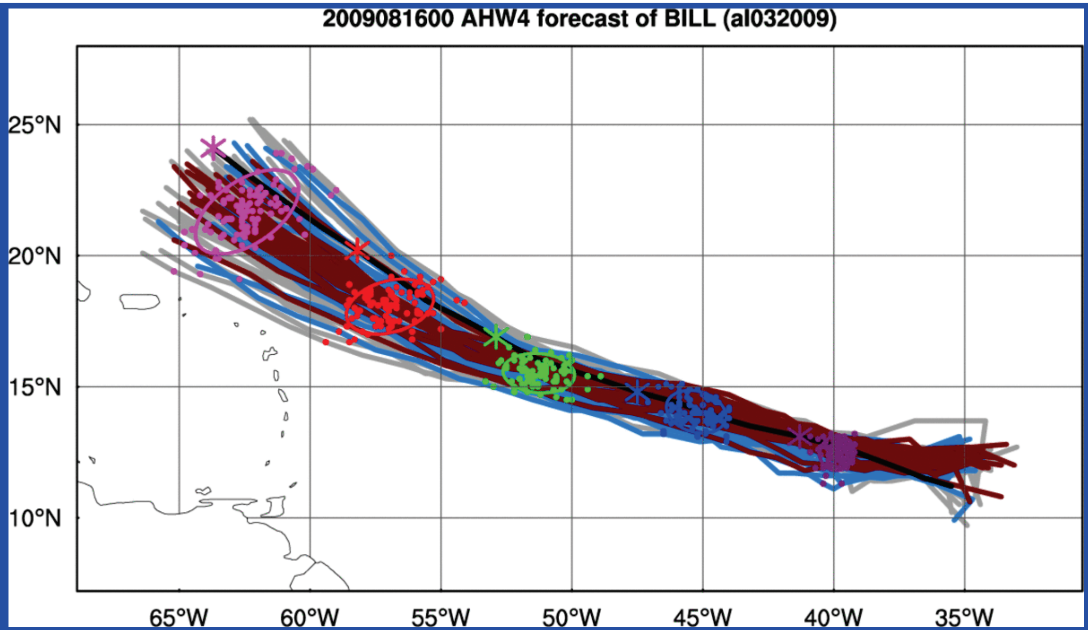
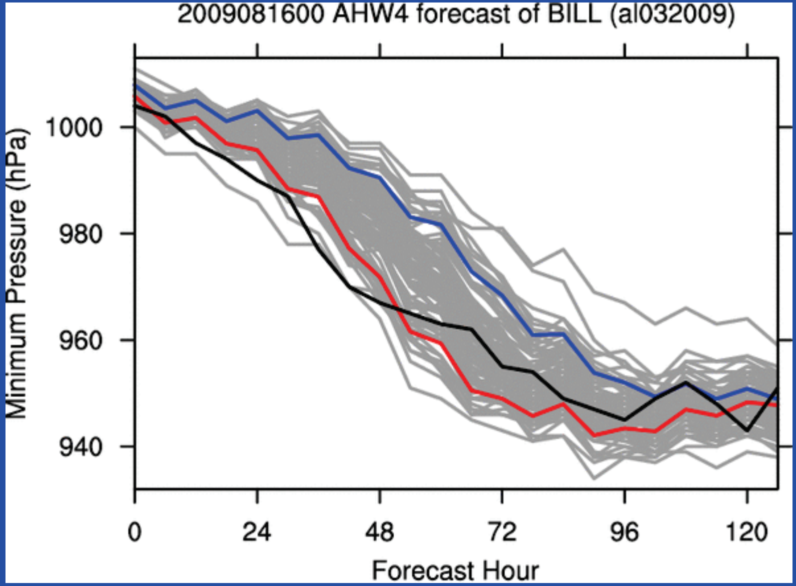
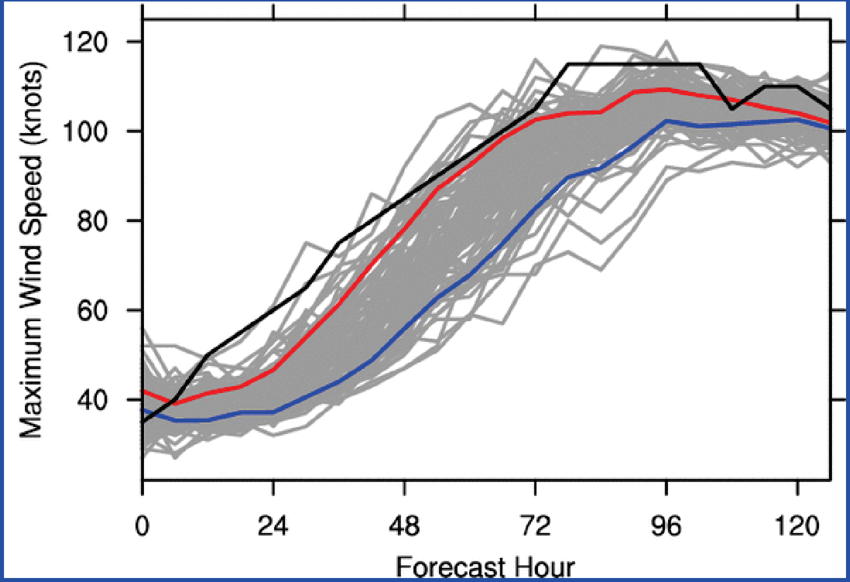


16 August Bill Forecast







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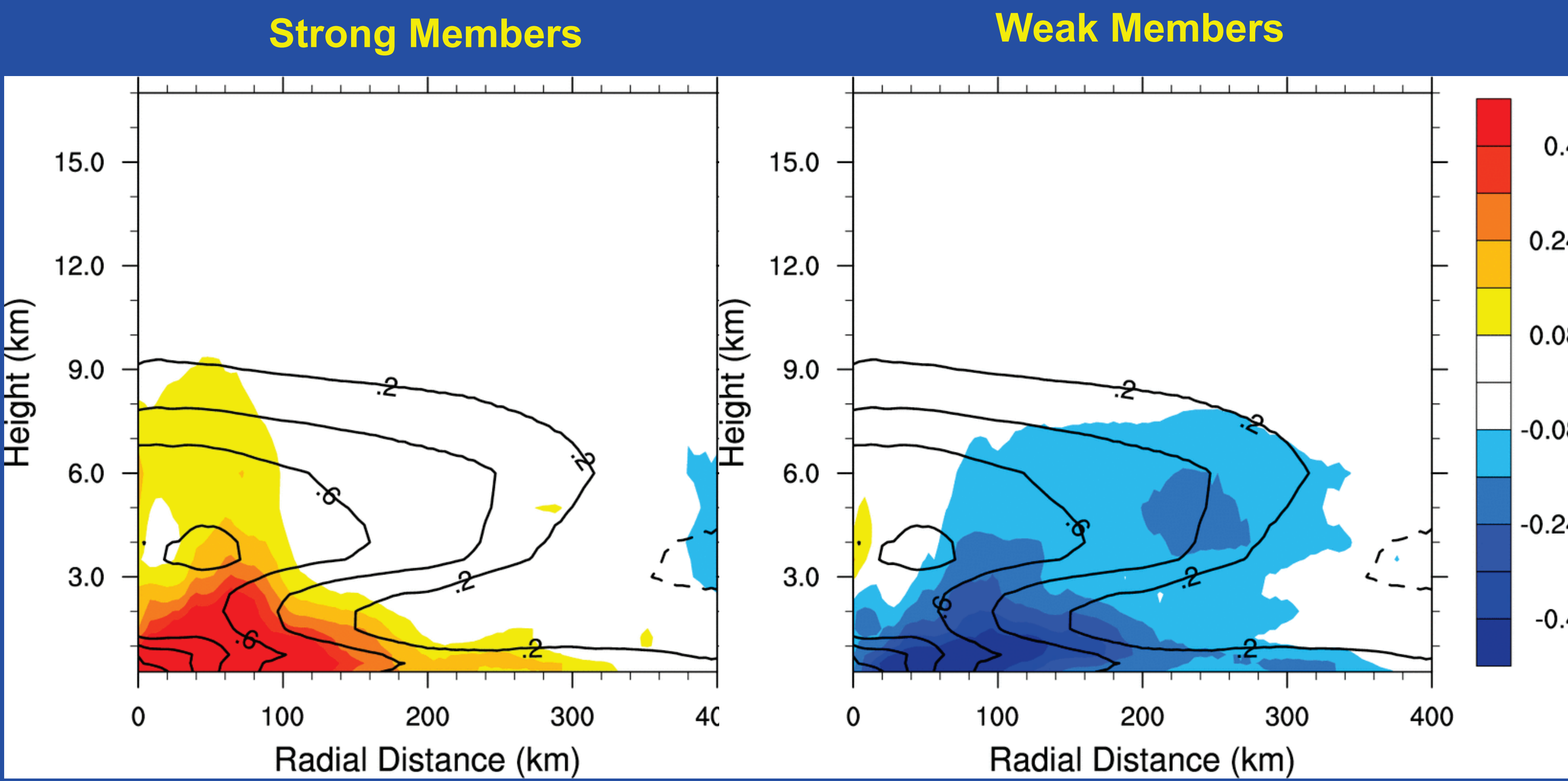
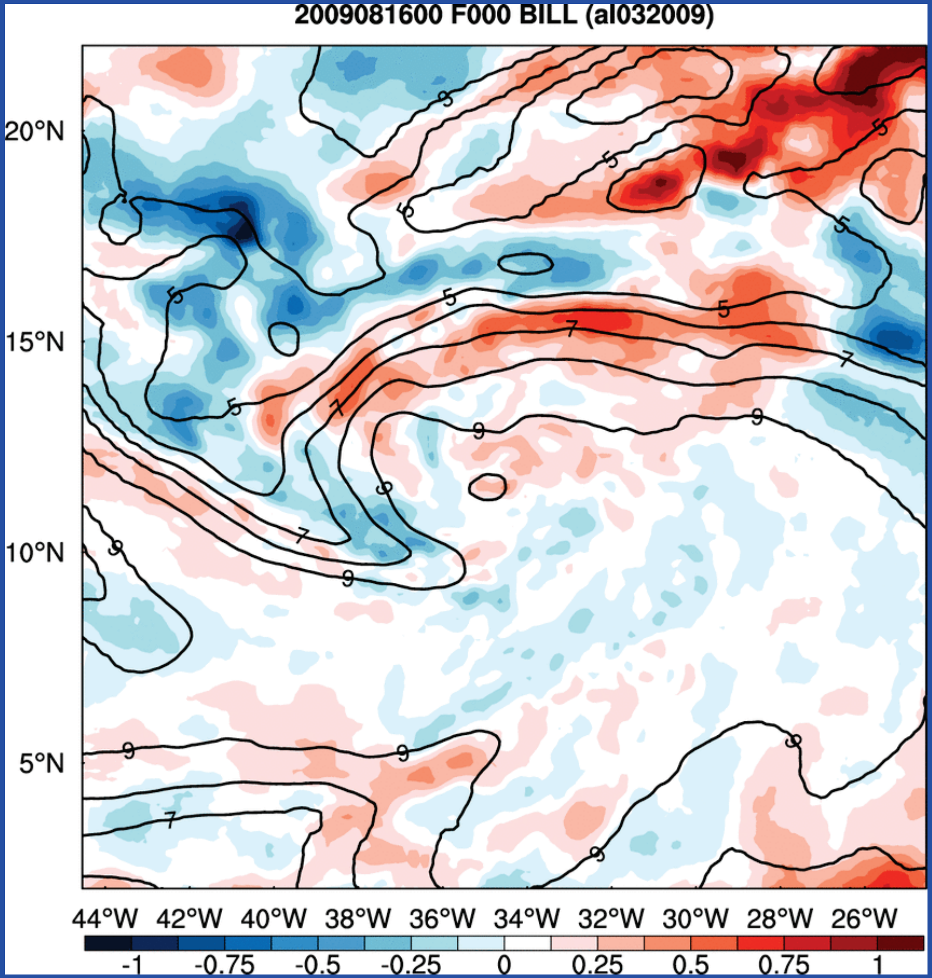
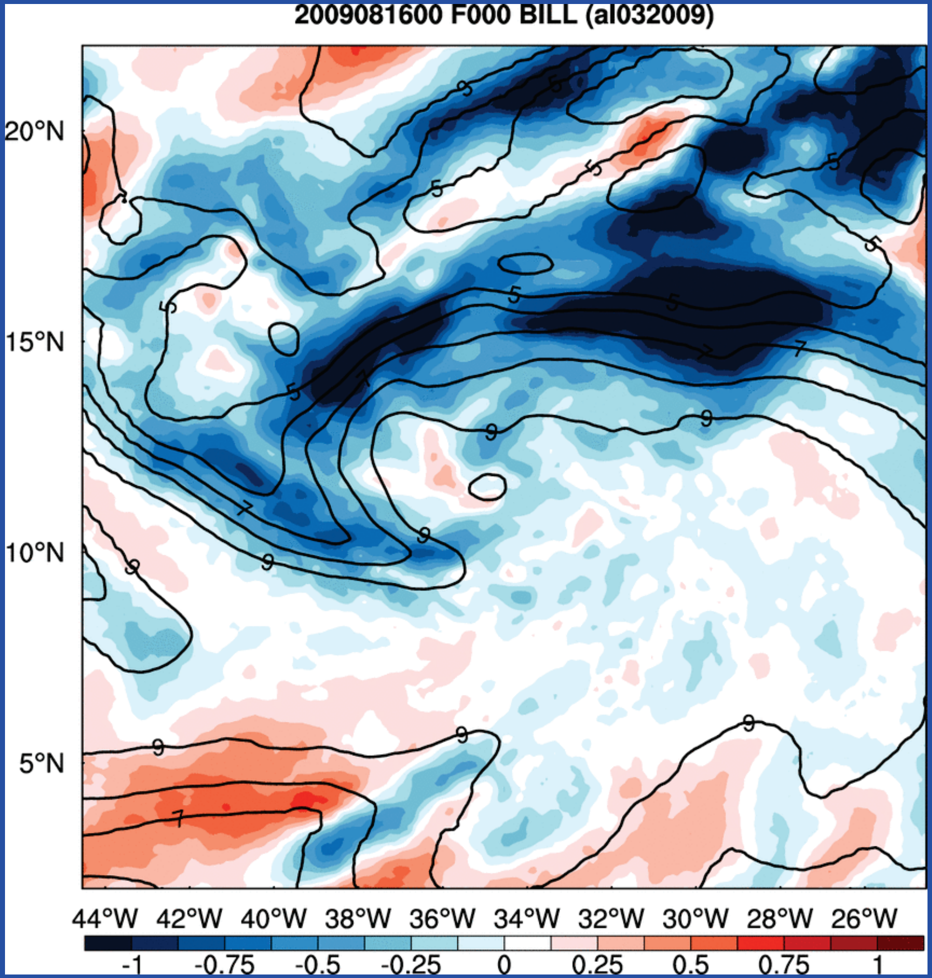


0 h Comparison

Strong Members



Weak Members



Summary and Future Work

- Initial condition errors in the atmosphere translate into larger intensity variability on short time scales, Initial condition errors for the ocean translate into comperable intensity variability over longer lead times (5 days)
- Atmospheric uncertainty translates into large intensity uncertainty for small, weak storms, ocean errors translate into comparable intensity uncertainty, regardless of intensity and size
- Minimal relationship between intensity variability for atmosphere and ocean, suggests error growth mechanism not the same (subject of future work)
- Some TCs characterized by sensitivity to wind structure, others to moisture in specific quadrants (future work)