On the dynamics and evolution of forecast uncertainty and forecast sensitivity

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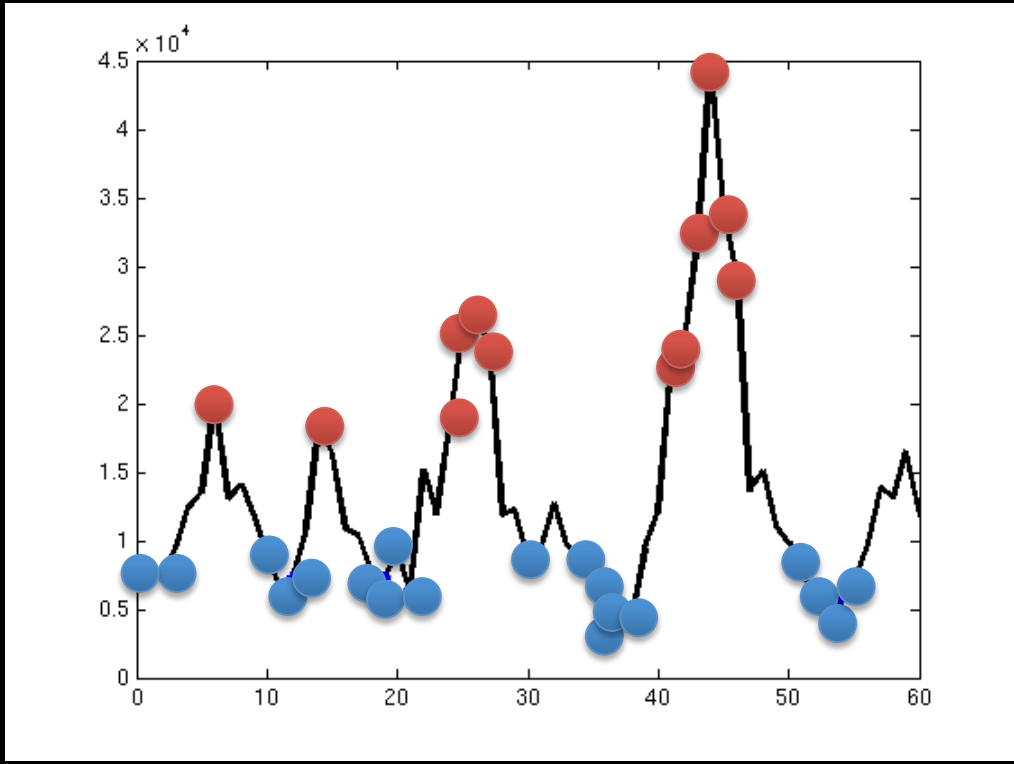
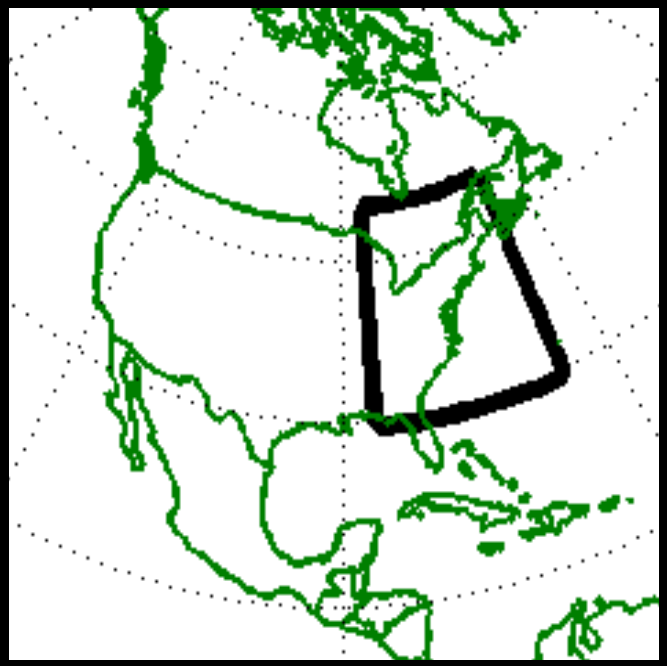
Introduction

- What relationship exists between forecast ensemble spread, model error and adjoint sensitivity?
- Is there a preferential synoptic configuration that leads to higher uncertainty/greater model error?



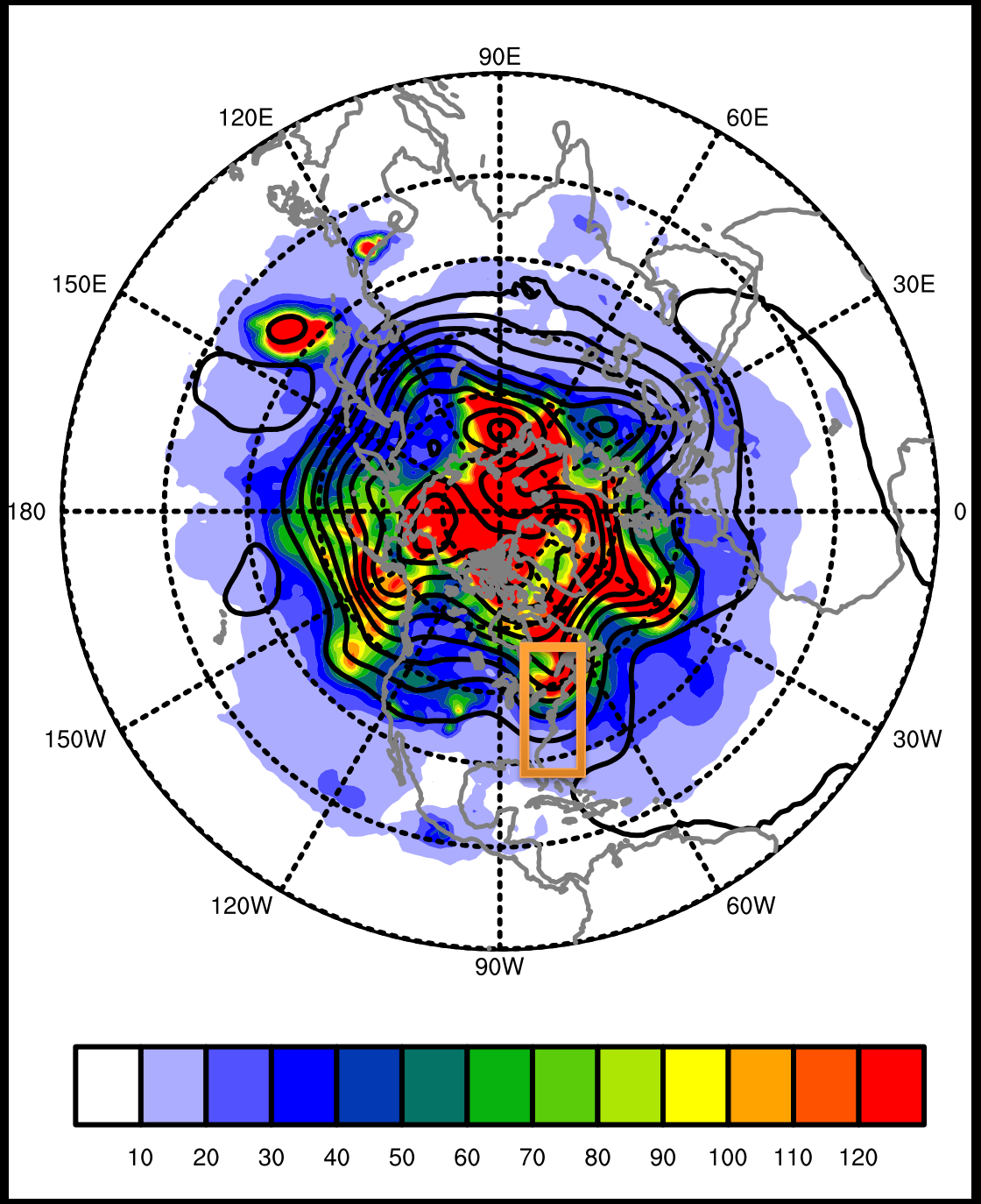
Above: September 2013 cumulative uncertainty time series. Blue dots denote days that fall one half standard deviation below the mean, red dots fall one half standard deviations above the mean.

Below: Verification Region over which ensemble spread (variance) for time series was summed.

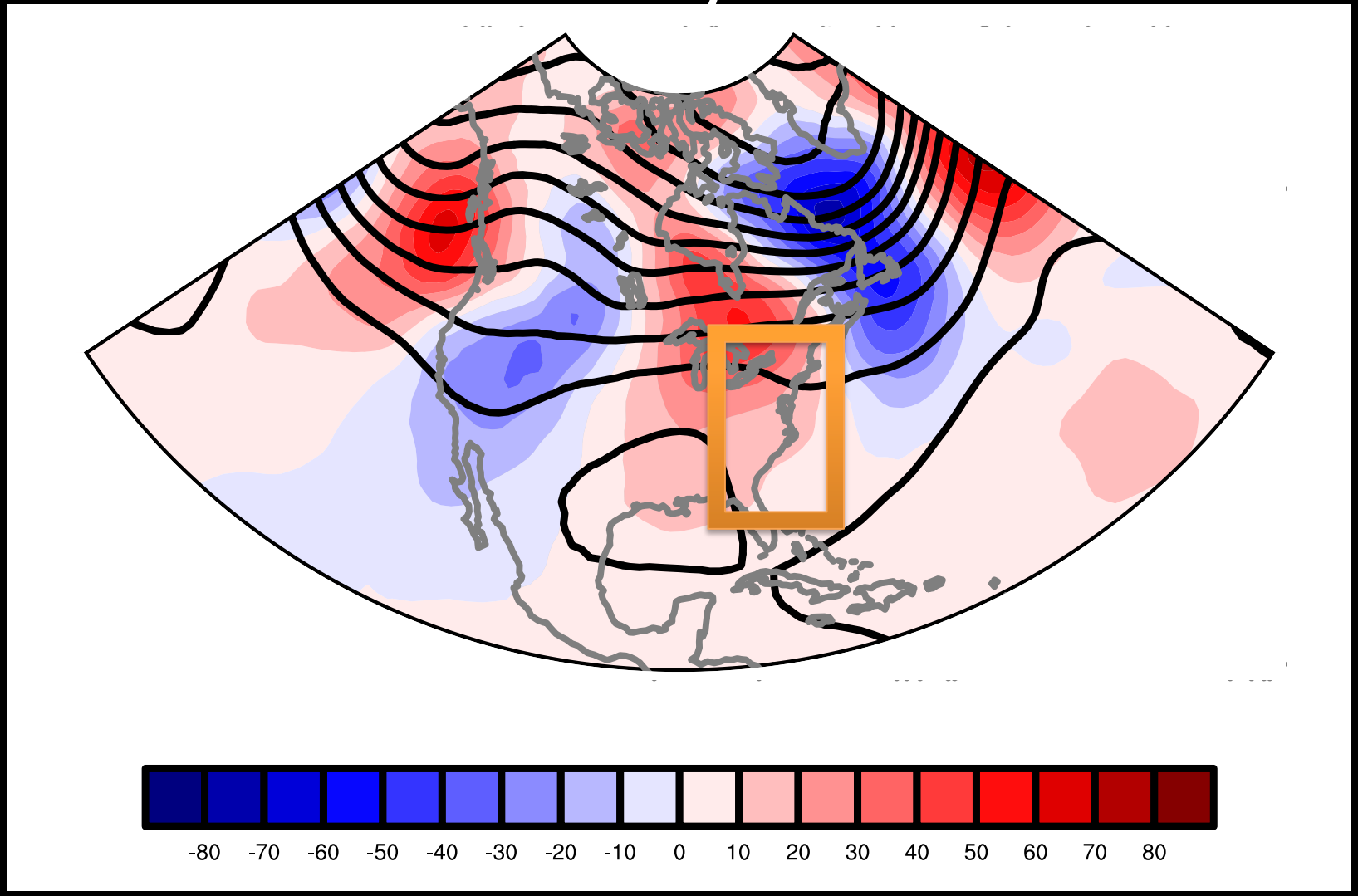


Example uncertainty plot. Model data was obtained from the TIGGE archive. Both GFS and ECMWF 1° Ensemble data was examined, although for the purposes of this talk only the GFS data will be considered.

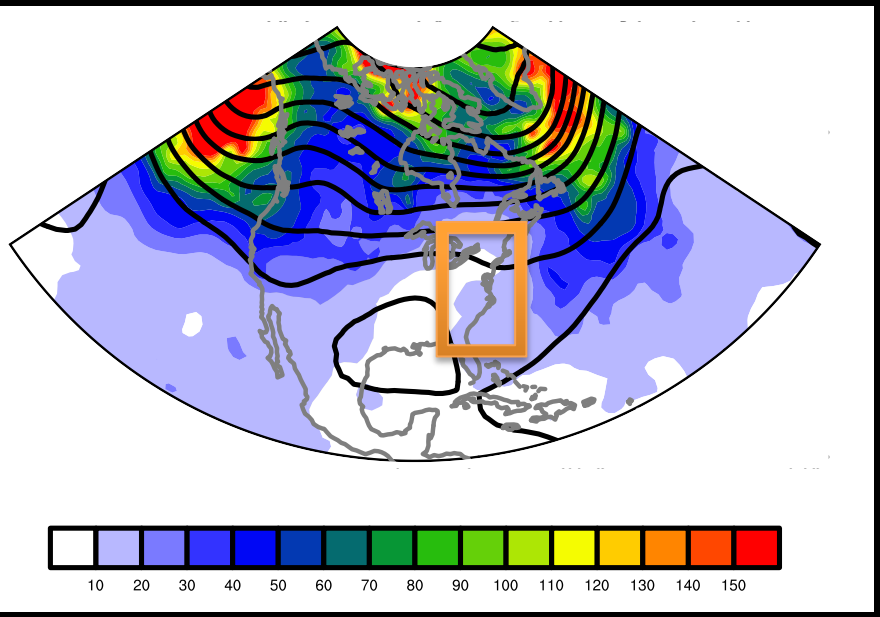
•Uncertainty – Ensemble variance of 500 hPa geopotential height.
•Error – difference between the ensemble forecast and ECMWF analysis.



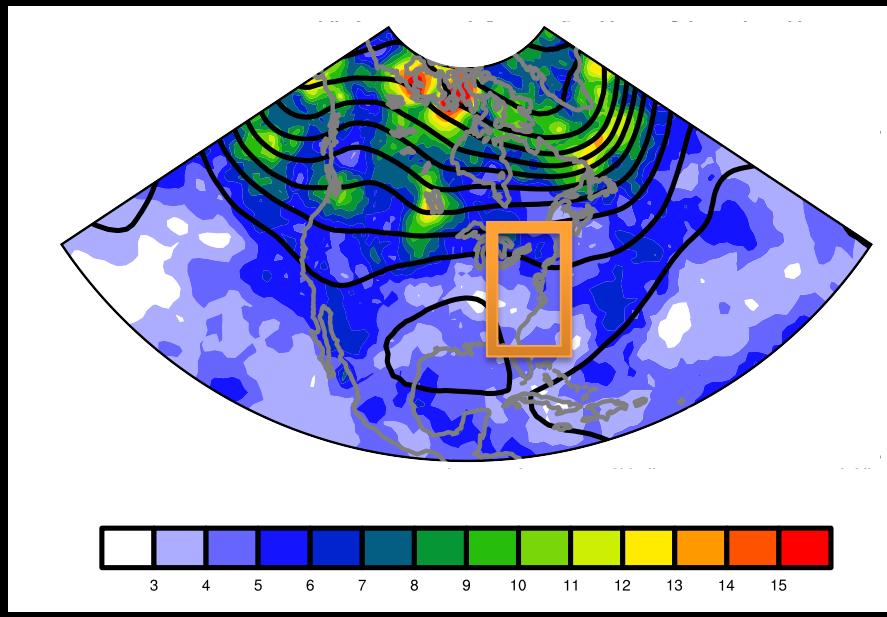
Low Uncertainty, -24 Hour Expected Analysis



Low Uncertainty

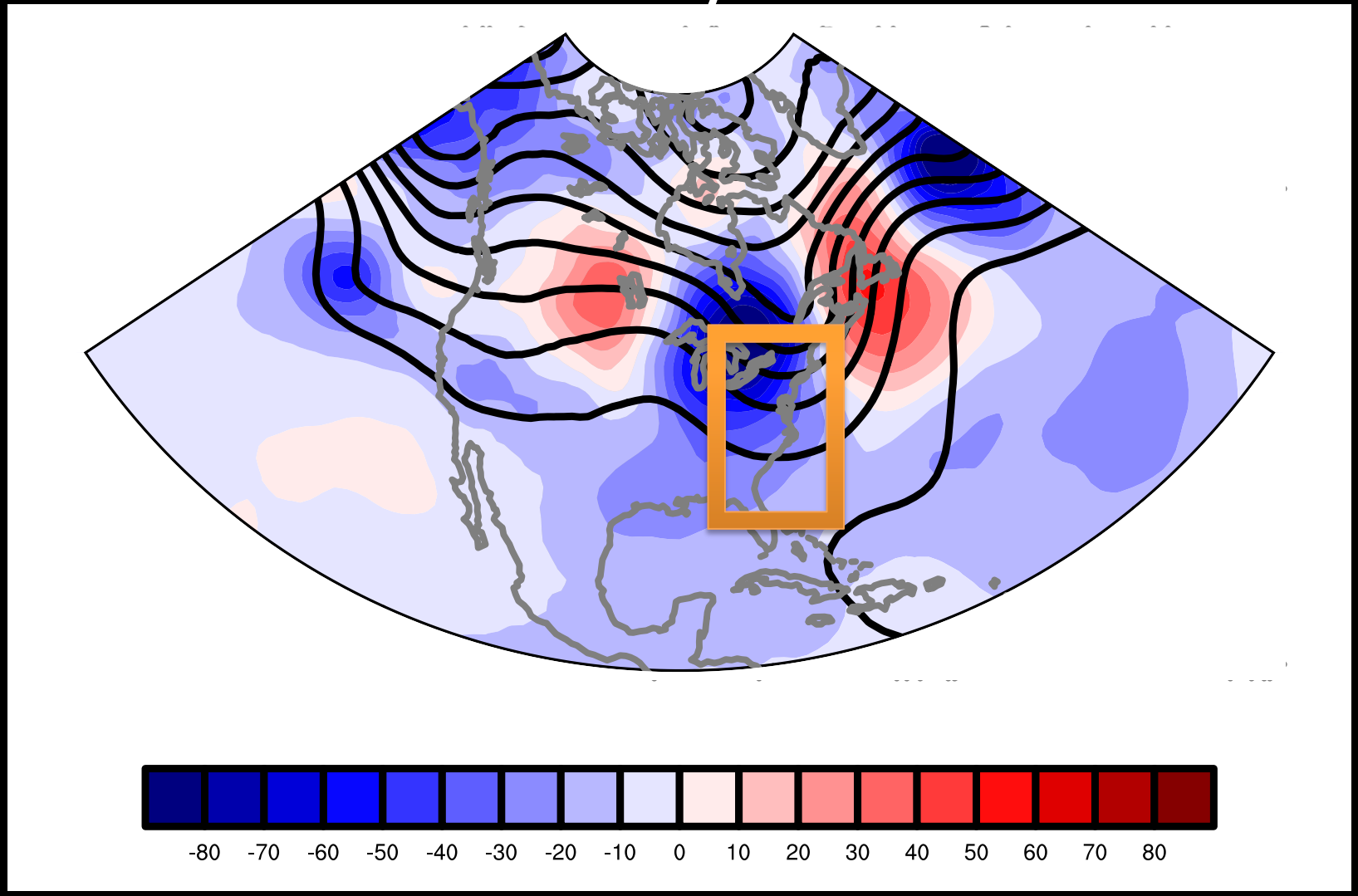


24 hour forecast uncertainty composite

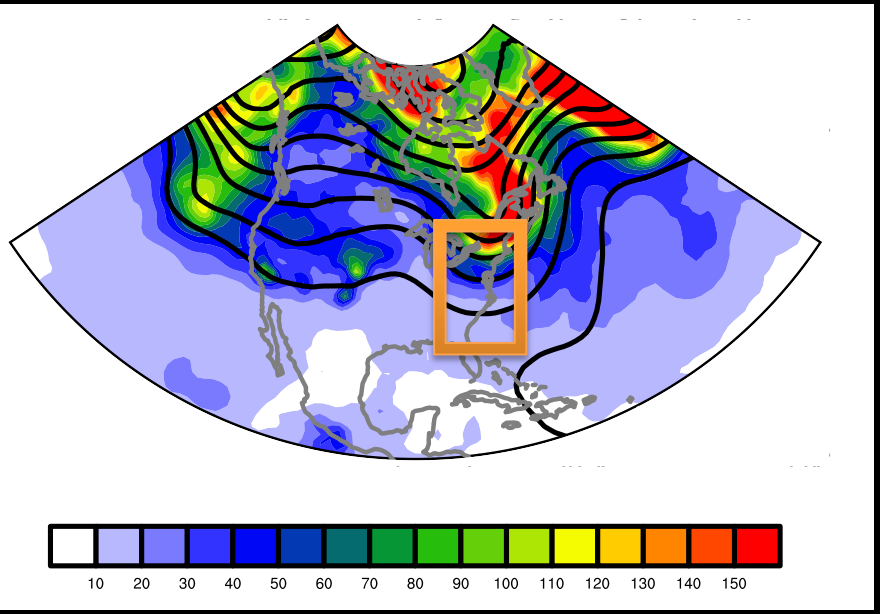


24 hour forecast error composite

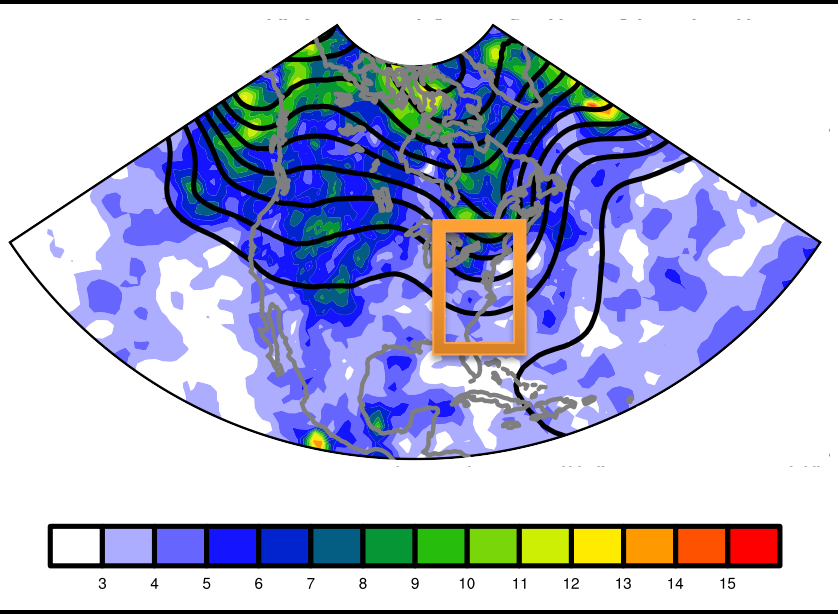
High Uncertainty, -24 Hour Expected Analysis



High Uncertainty



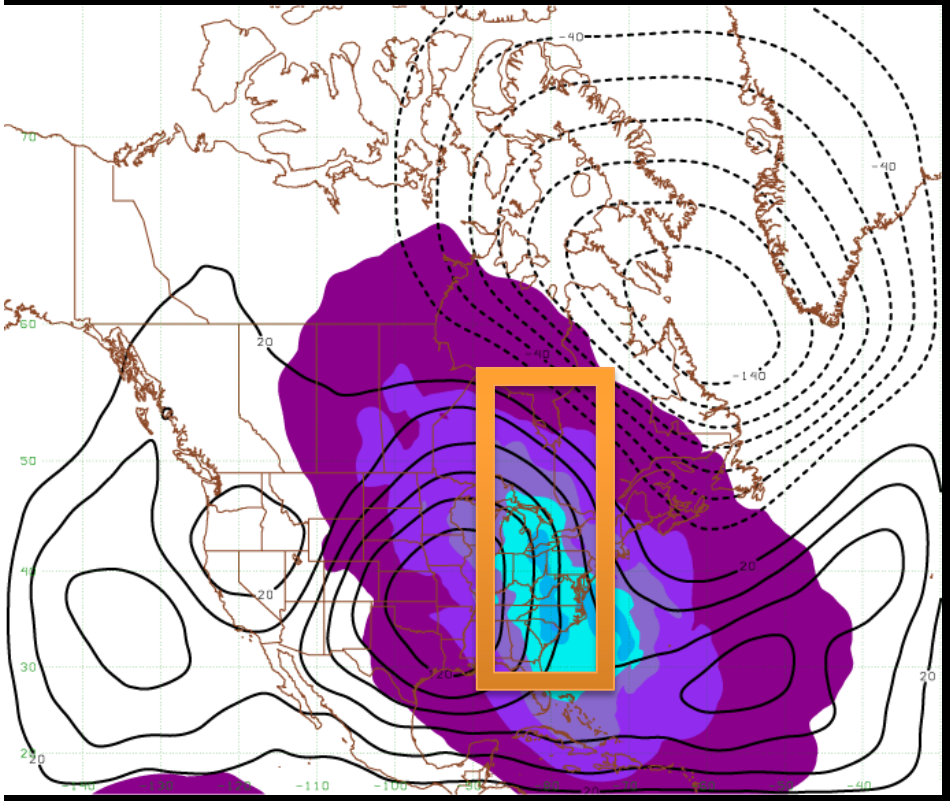
24 hour forecast uncertainty composite



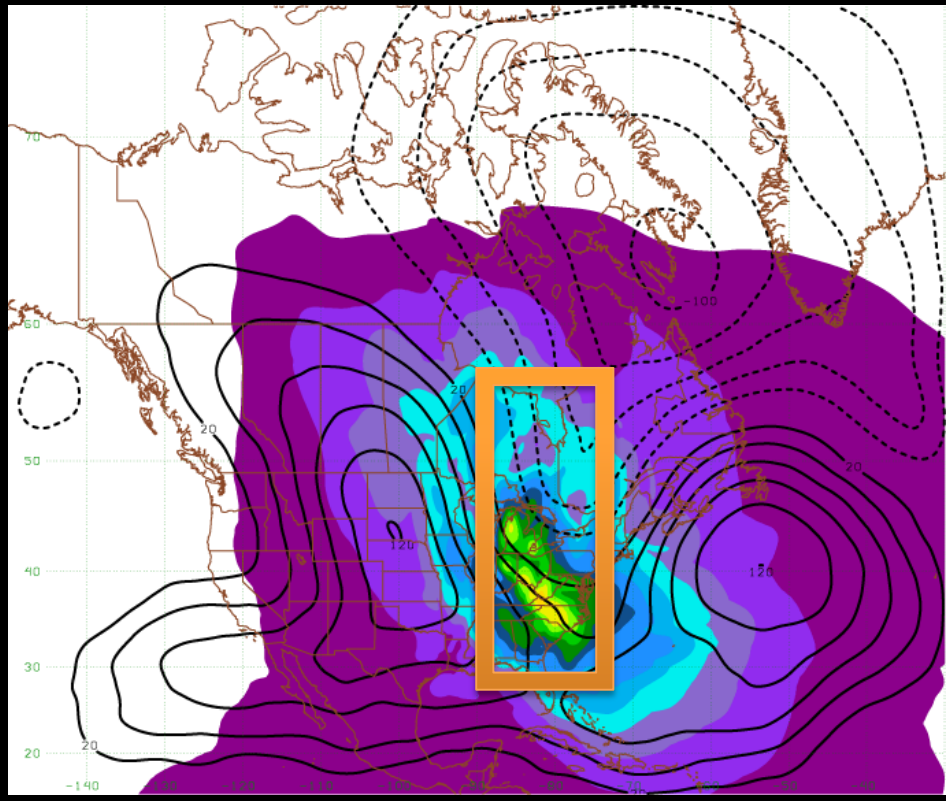
24 hour forecast error composite

NAVGEM Adjoint Sensitivity Structure

Low Uncertainty Sensitivity Composite

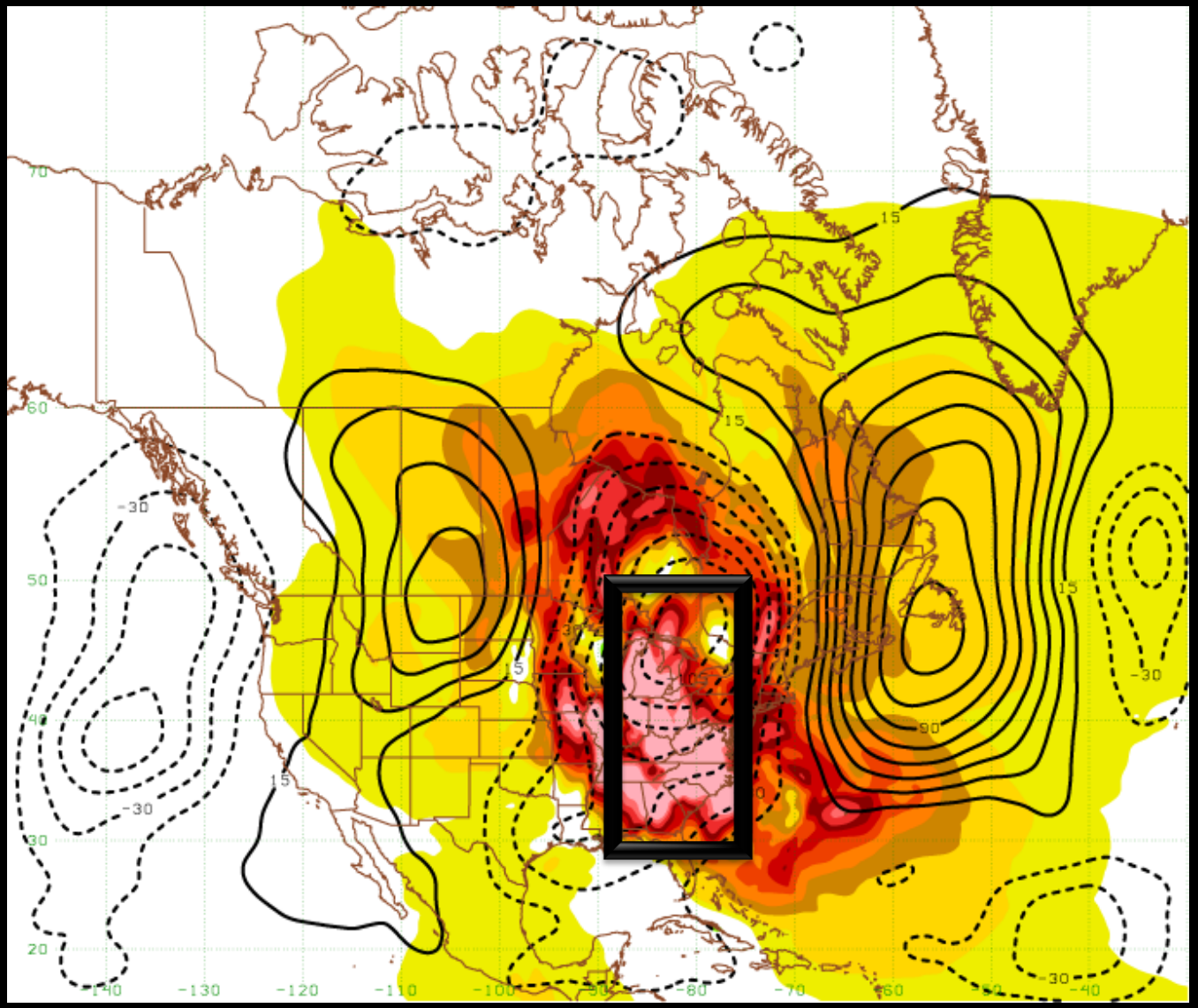


High Uncertainty Sensitivity Composite



- Sensitivity of error to initial condition 500 hPa Vorticity.
- 24 hr forecast for each 00/12 UTC analysis for September 2013.
- Error computed using energy based error norm.

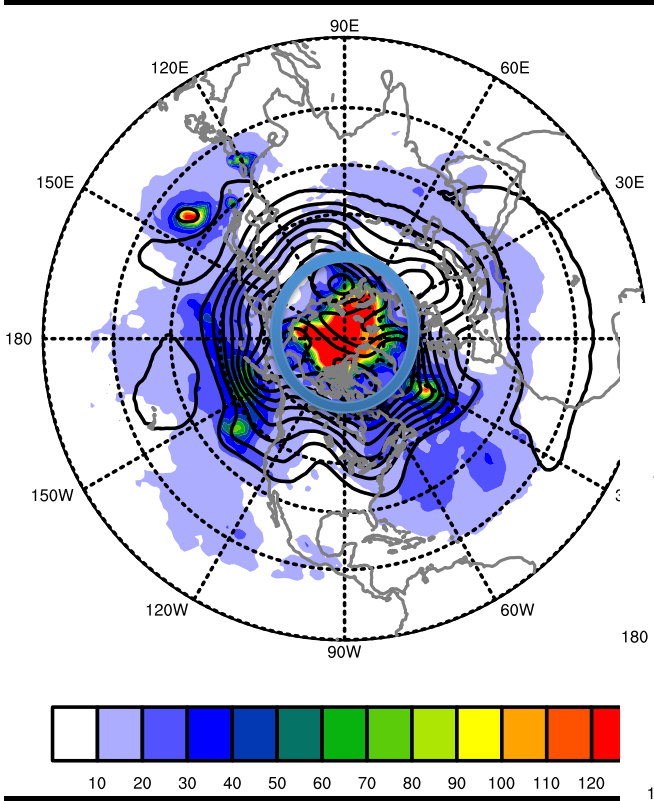
NAVGEM Adjoint Sensitivity Difference



High Latitude Influence

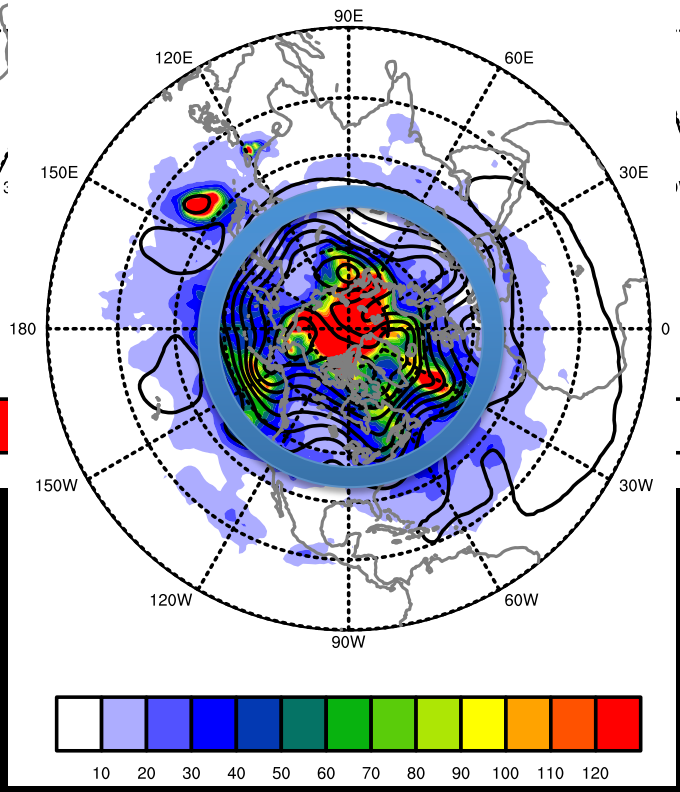
- Forecast uncertainty can be regarded as a Lagrangian "tracer", in that it appears to be characterized by both an Eulerian component and an advective component. The advective component however is more easily visualized using the normalized uncertainty metric to follow.
- Uncertainty sometimes "spills" down from the high latitudes and which *may* "pollute" the forecast. This is especially common in GFS ensemble forecasts, where the perturbation scheme used fosters the growth of a reservoir of uncertainty in the high latitudes.
- Adjoint sensitivity seems to at least partially mirror this, as channels between troughs/ridges seem to advect sensitivity from high latitudes to lower latitudes, similar to how uncertainty is advected.

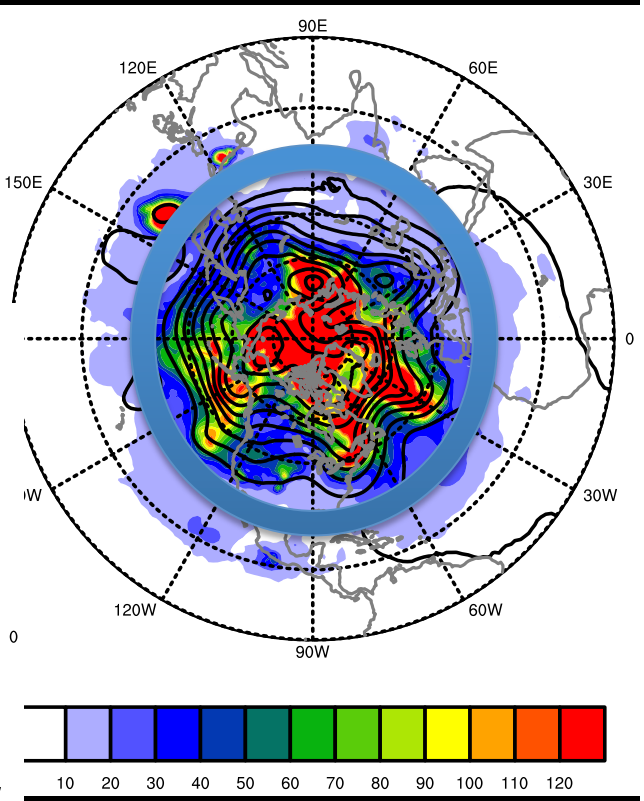
High Latitude Influence (Cont'd)



Analysis Time

12 Hour Forecast





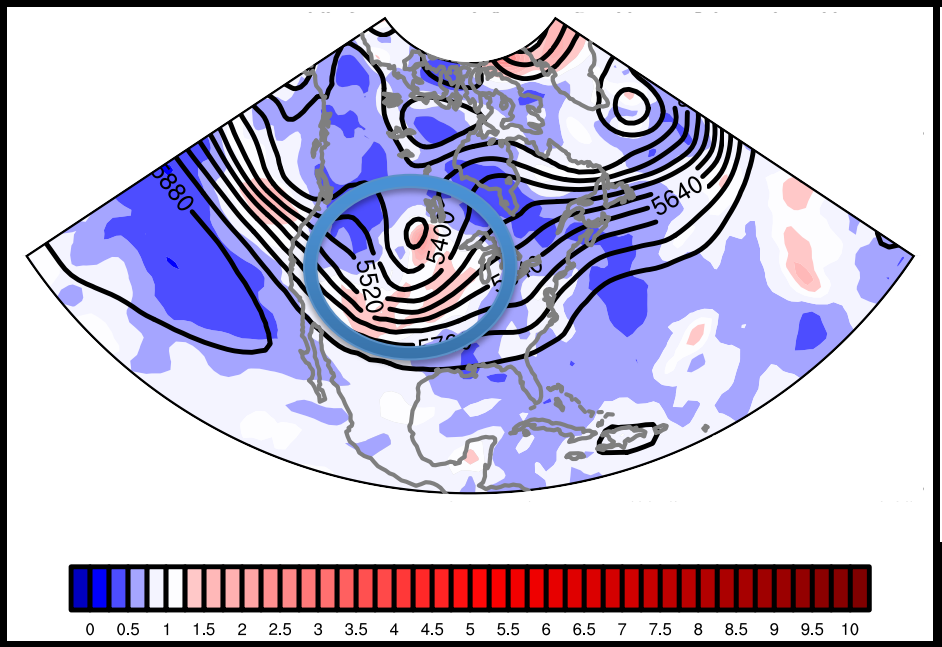
24 Hour Forecast

Normalized Uncertainty

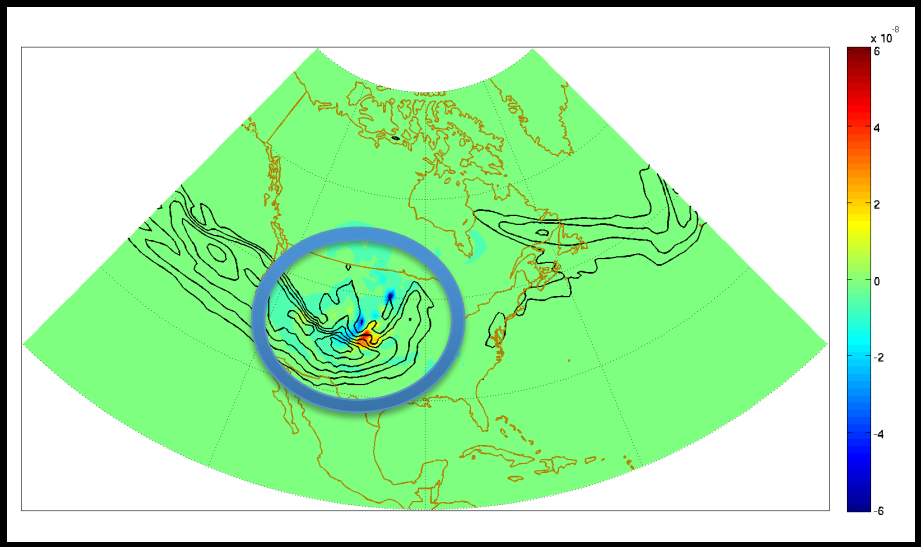
- Climatology assembled from eight years (length of TIGGE archive) of GFS and ECMWF ensemble uncertainty respectively.
- Individual forecasts are normalized to their respective forecast trajectory climatology, resulting in uncertainty anomalies.
- More easily visualizes advective nature of uncertainty than “bare” uncertainty.

Great Lakes "Hurricane" Case – October 26, 2010

24 Hour Uncertainty



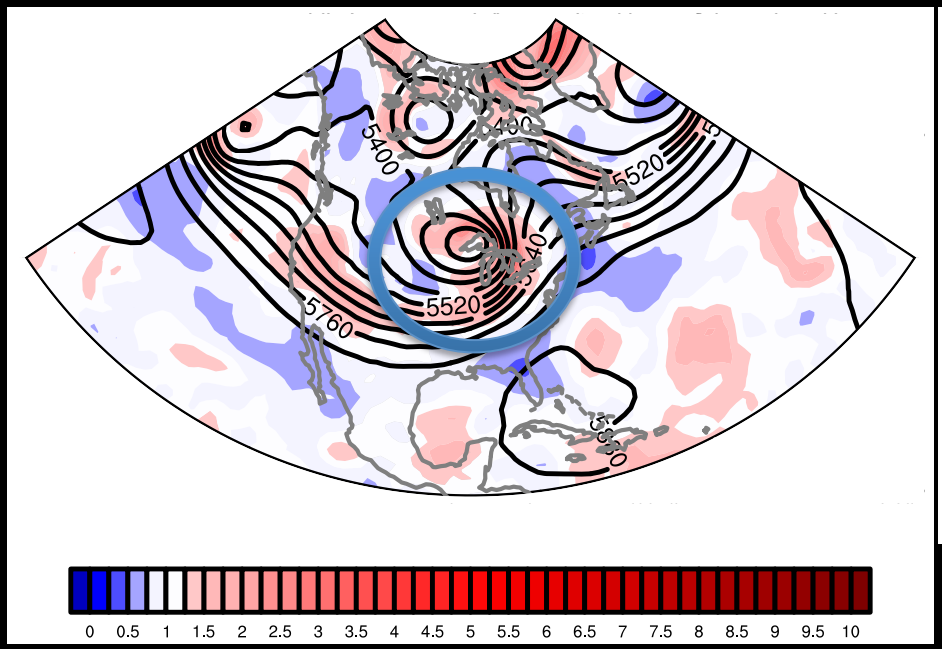
24 Hour Sensitivity to 500 hPa Temperature (GEOS-5)



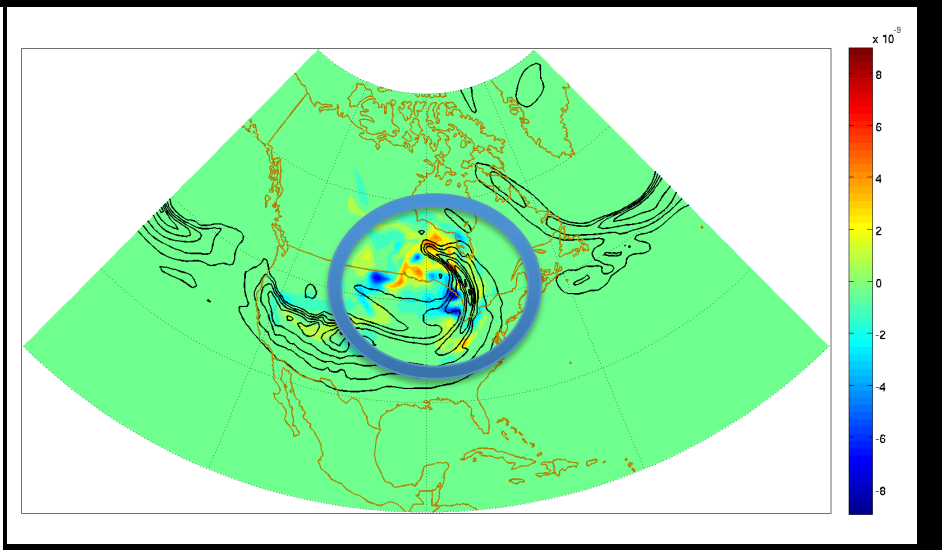
- 956 hPa SLP recorded near International Falls, MN
- 57 tornado reports; 339 high wind reports

Great Lakes “Hurricane” Case (Cont’d)

48 Hour Uncertainty



48 hour Sensitivity to 500 hPa Temperature (GEOS-5)



Conclusions

- High vs. low predictability seems predicated upon trough/ ridge placement.
- It is easy to “eyeball” a spatial relationship between areas characterized by high variance and non-zero error.
- Uncertainty and sensitivity exhibit structures that vary between high and low predictability cases, and both exhibit advective behavior.
- High uncertainty cases tend to have larger sensitivity near the verifying region, whereas low uncertainty cases tend to have smaller sensitivity near the verifying region.
- Depending on synoptic pattern, high latitudes can have a significant influence on forecast uncertainty and forecast error.