A Comparison of the Predictability of Arctic and Atlantic Basin Cyclones

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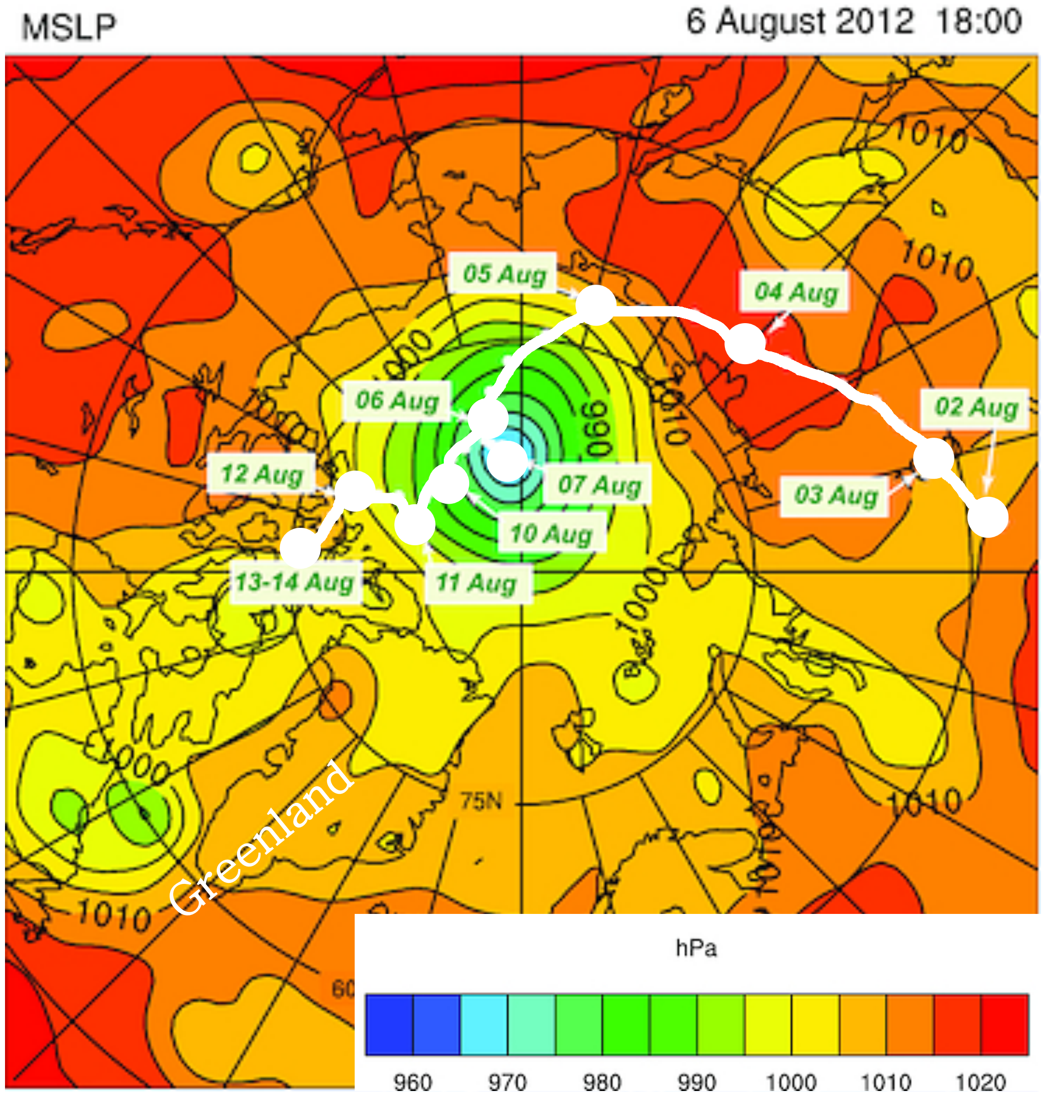
Background

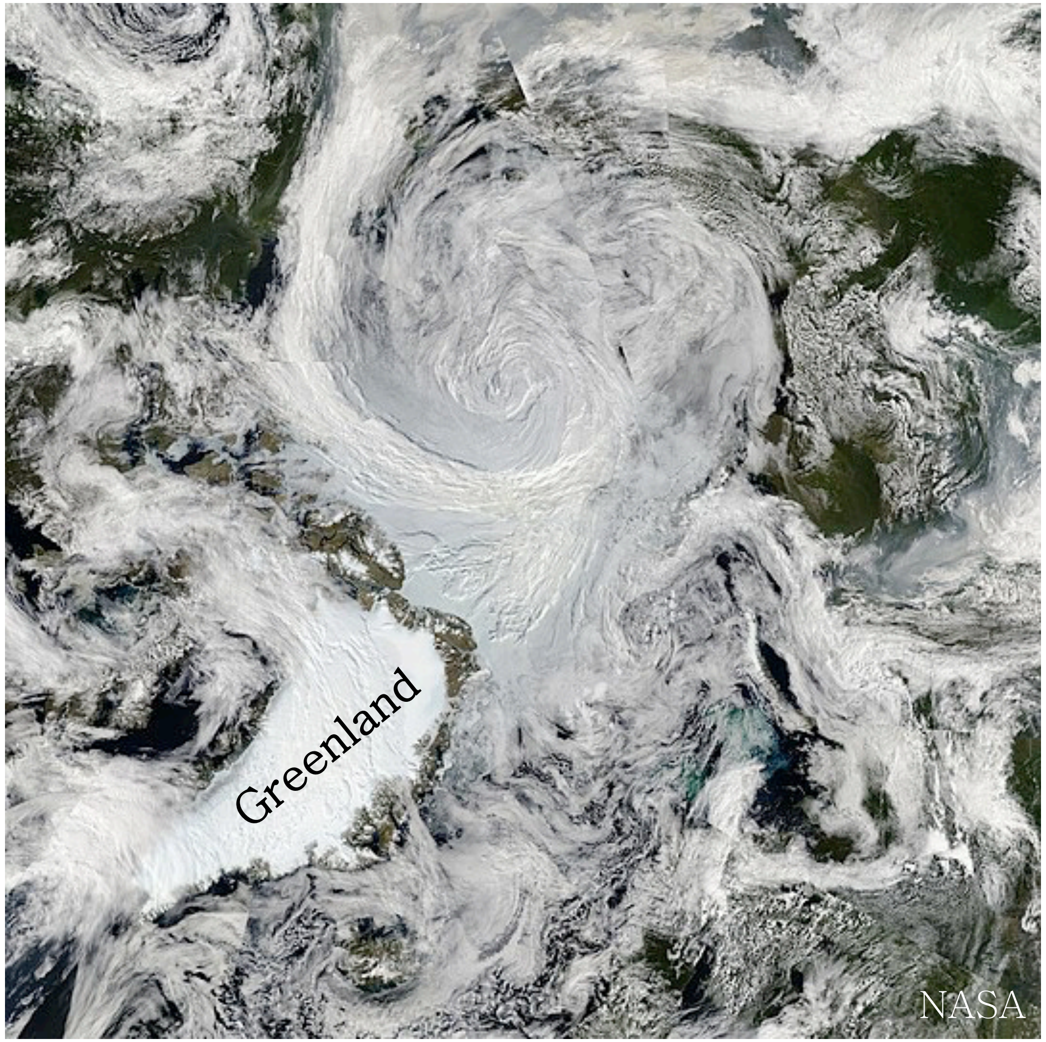
- **Arctic Cyclones** are synoptic-scale cyclones that may be responsible for transporting warm, moist air into the Arctic region, leading to warming and sea-ice depletion during the summer months (Zhang et al. 2013)

- Crawford and Serreze (2016) demonstrate that Arctic cyclones tend to originate over Eurasia during the summer – possibly due to a reduction is static stability

- **Motivation:** Shrinking sea-ice opens the possibility for ocean vessels to travel through the Northwest passage

Great Arctic Cyclone (GAC) of 2012

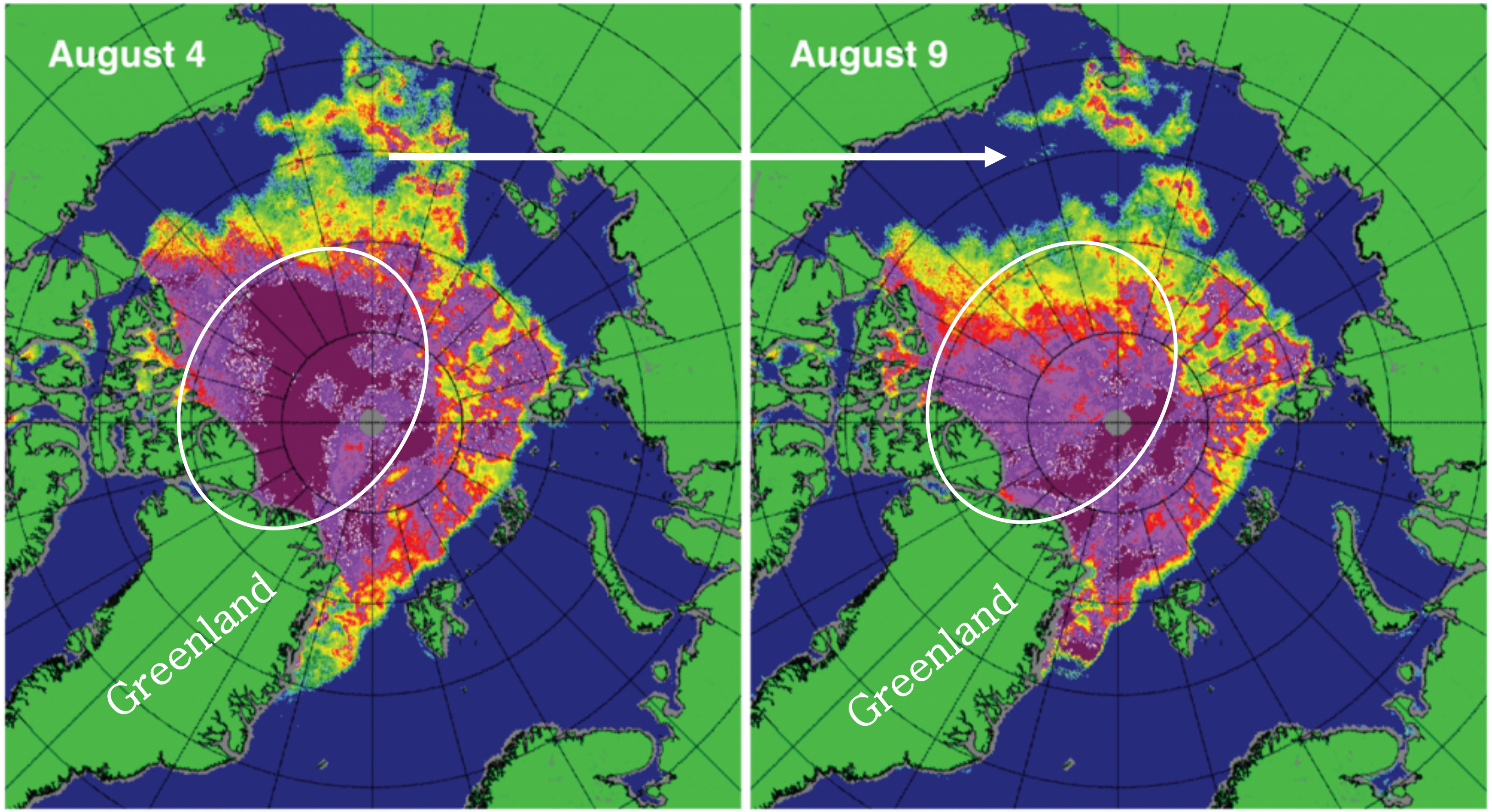




Simmonds and Rudeva (2012)

GAC of 2012 (cont.)

Sea-ice extent: loss of ~200,000 square kilometers



Research Outline

- **Goal:** Compare the predictability of Arctic Cyclones (ACs) to the predictability of Atlantic Basin Cyclones (ABCs), since midlatitude cyclones are much better understood
  - **First:** Identify strong cyclones in midlatitudes (Atlantic Basin) and the Arctic region
  - **Second:** Create methodology for an ensemble tracking algorithm that is versatile for both region
  - **Third:** Examine mean cyclone position and intensity standard deviation for Arctic cyclones vs. Atlantic Basin as a function of time

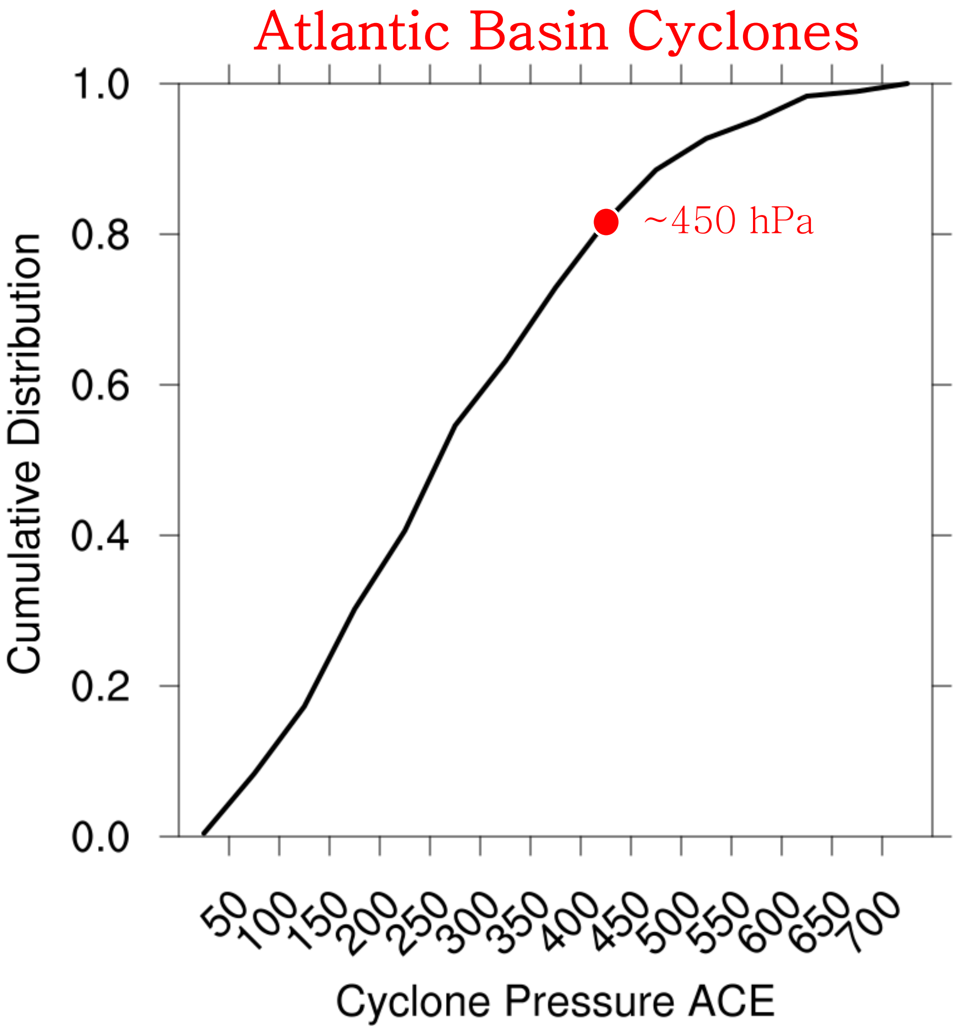
Criteria for Selecting Cyclones

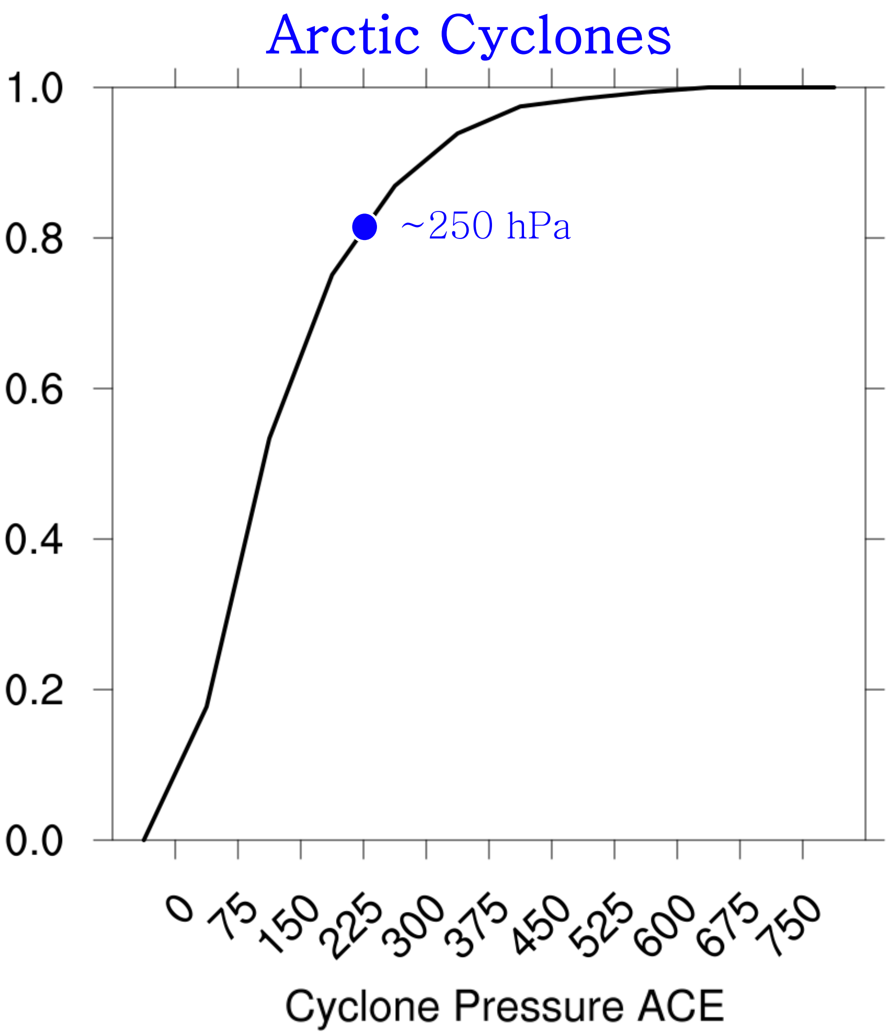
- Using **Sprenger et al. (2017)** Climatology (6-hourly data) – ERA Interim data
  - 32-year climatology (1985-2016)
  - Winter months (Nov-Mar) for Atlantic Basin
  - Summer months (Jun - Aug) for the Arctic
  - Duration of at least 3 days (12 six-hourly periods)
  - ABCs: must undergo cyclogenesis off the East coast of the United States
  - ACs: North of 70 degrees North for at least 80% of life cycle
- To determine intense cyclones:
  - **Pressure difference** = last closed contour – pressure center

$$\text{Accumulated Pressure Difference} = \sum (pressure\ differences)$$

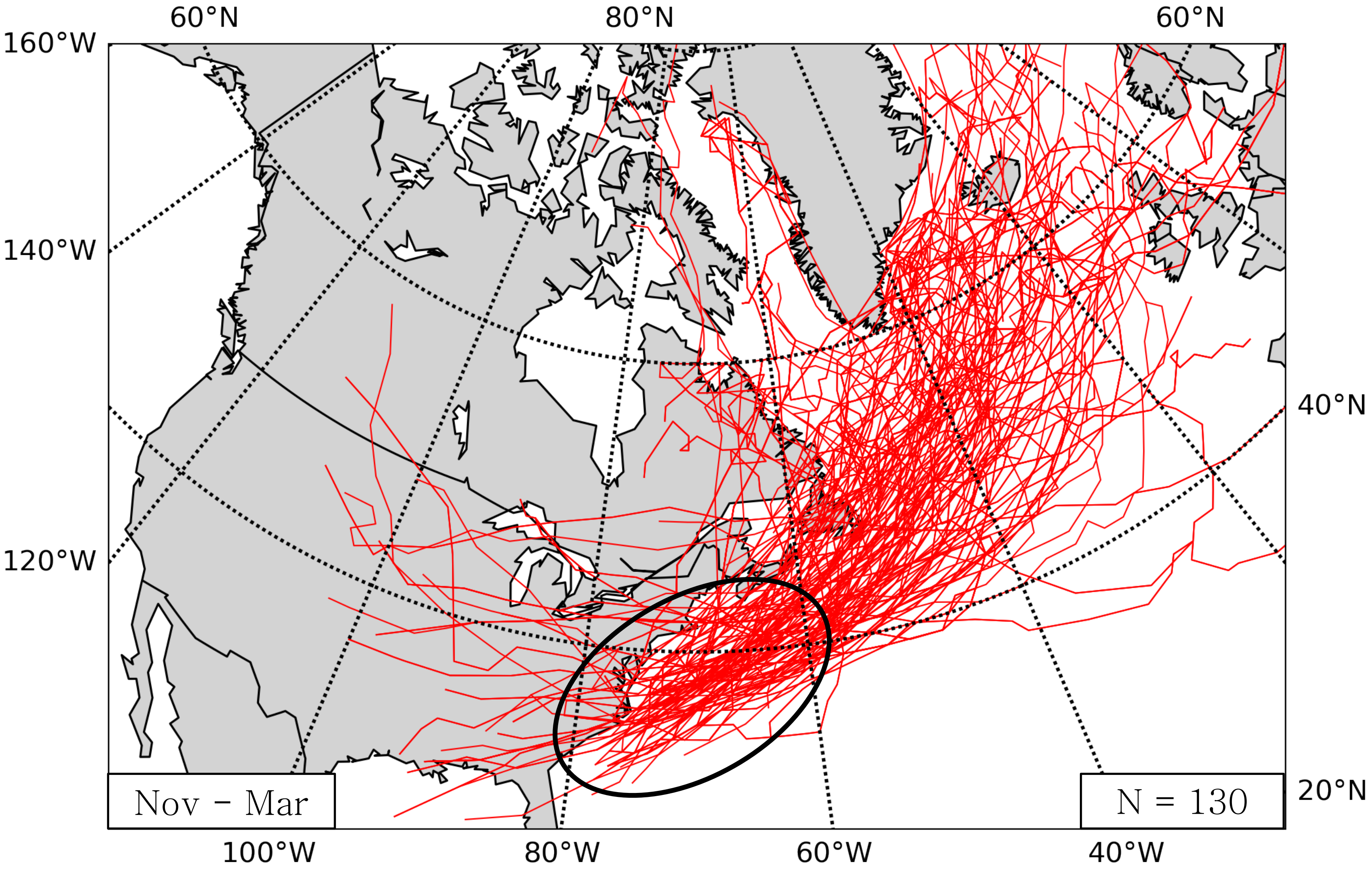
(similar to **ACE** (Accumulated Cyclone Energy) but using pressure difference)

Accumulated Pressure Difference

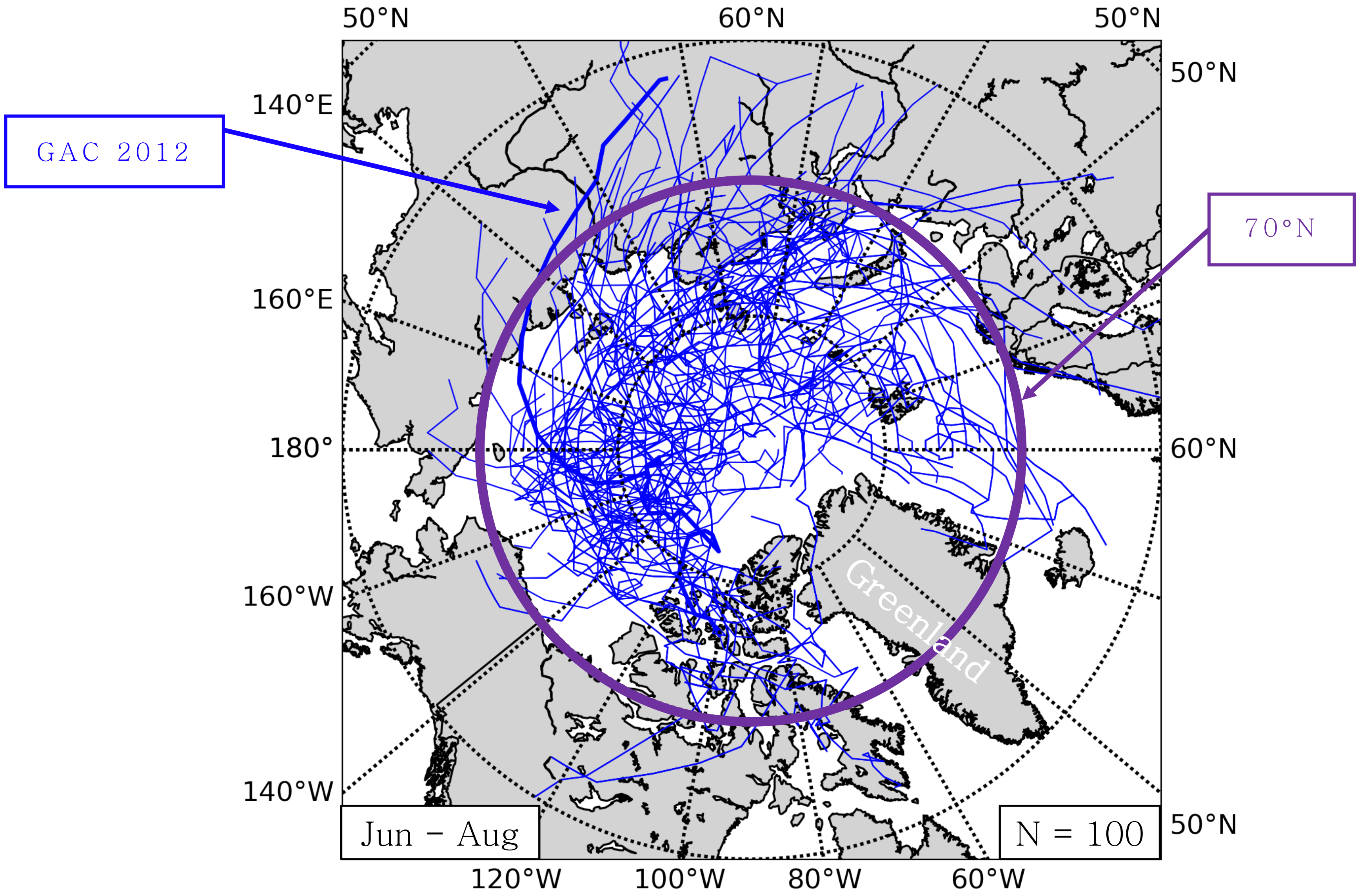




Atlantic Track Density



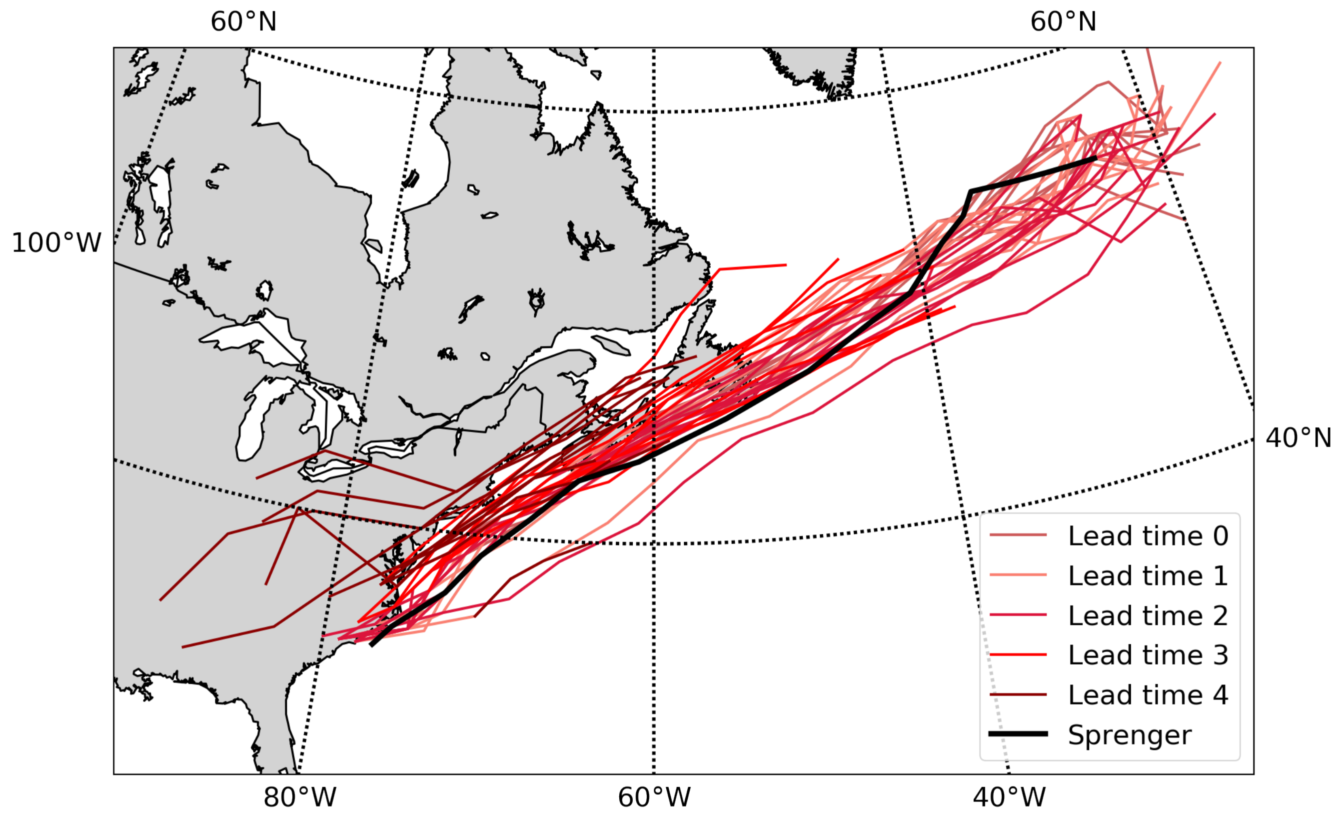
Arctic Track Density



Ensemble Tracking Methodology

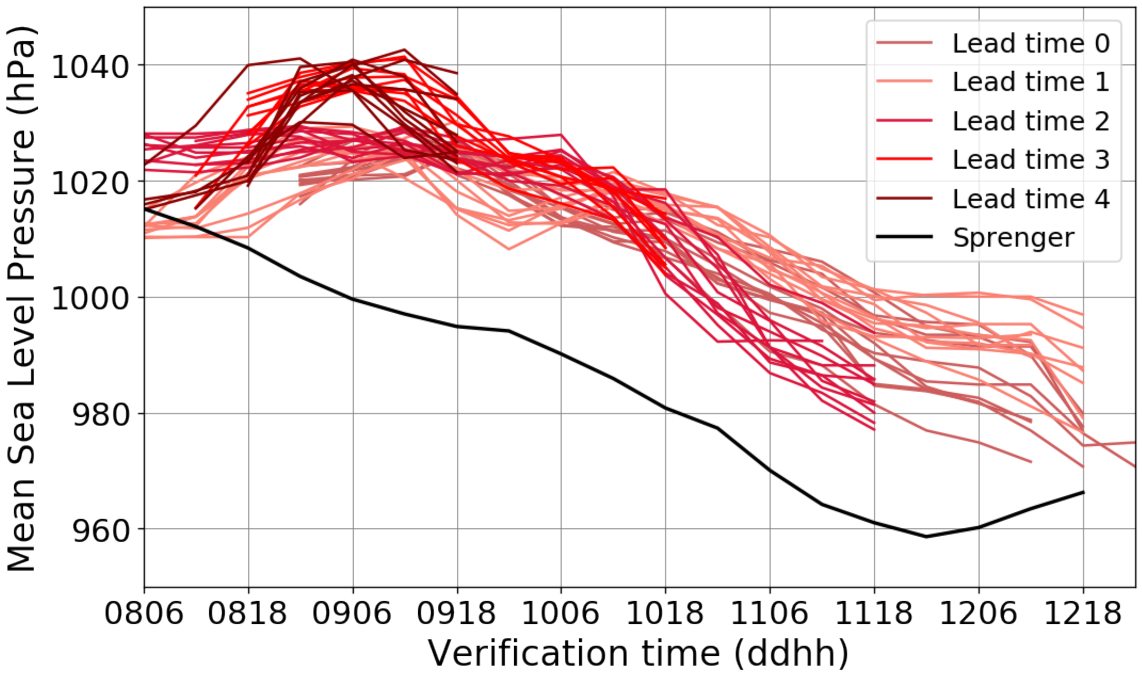
- **NCEP Global Ensemble Forecasting System** (GEFS) Reforecast Data:
  - **Consistent** modeling system for a long period of time
  - **11 ensemble members** (control + 10 perturbed members)
  - Initialized each day at **0000 UTC** over same period
  - Cyclones tracked via **925-hPa area-averaged vorticity**
  - Initialization time: first timestep that **pressure difference >= 12-hPa**
  - **120 hours forecast time** (5 days)

Atlantic Basin Case Study



Jan. 2, 1988 06Z – Jan. 12, 1988 18Z

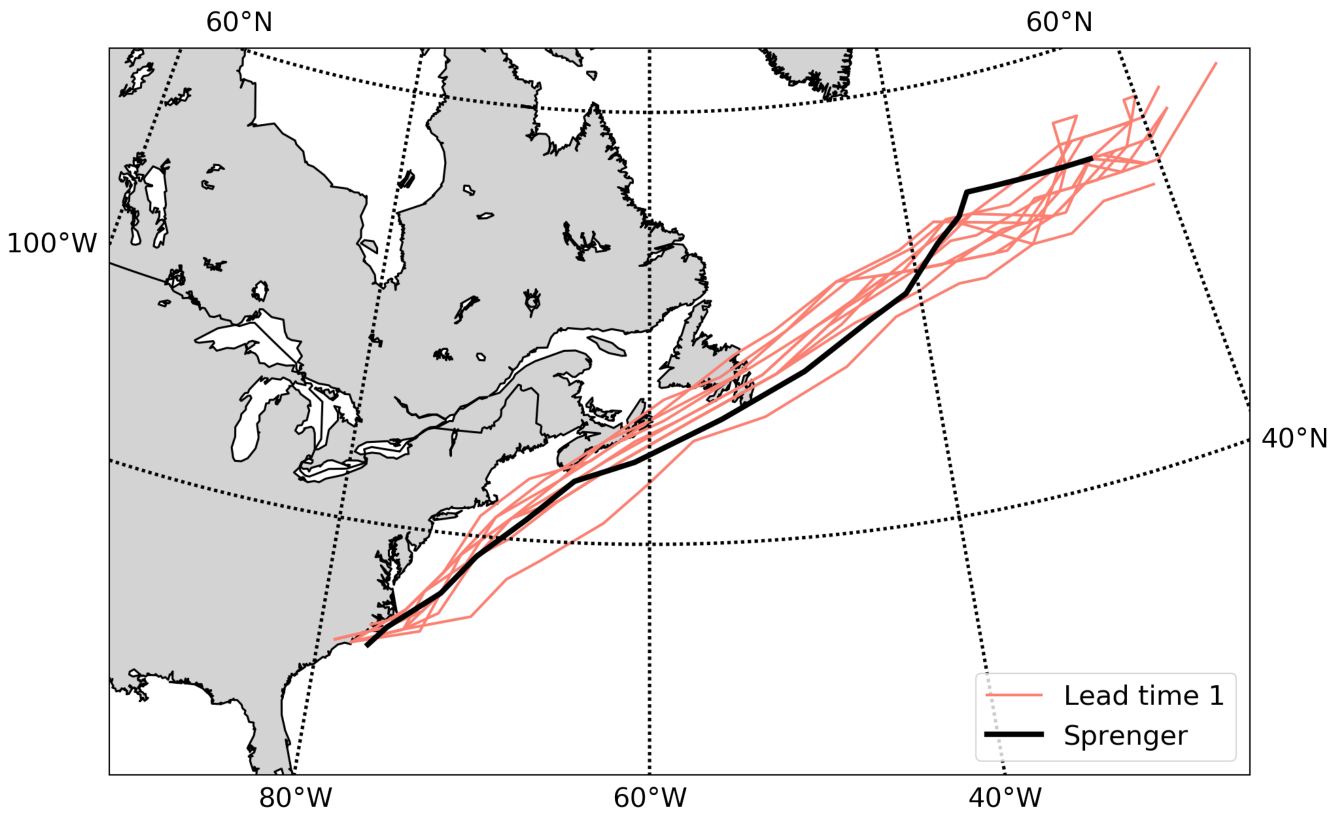
All Lead times

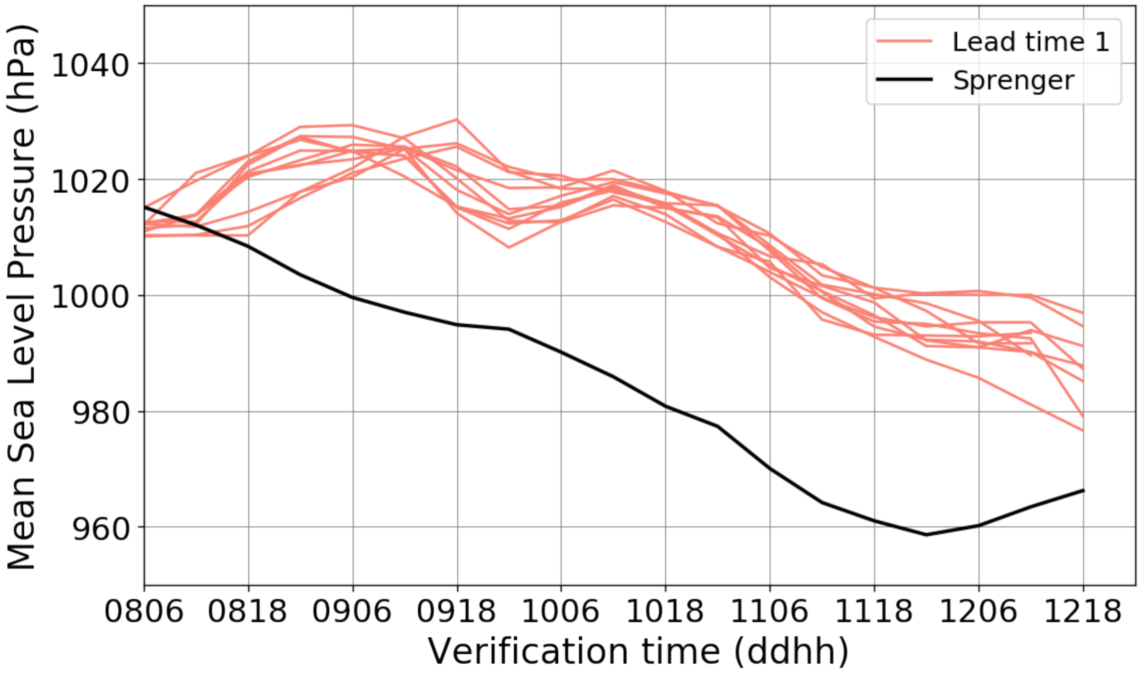


Atlantic Basin Case Study

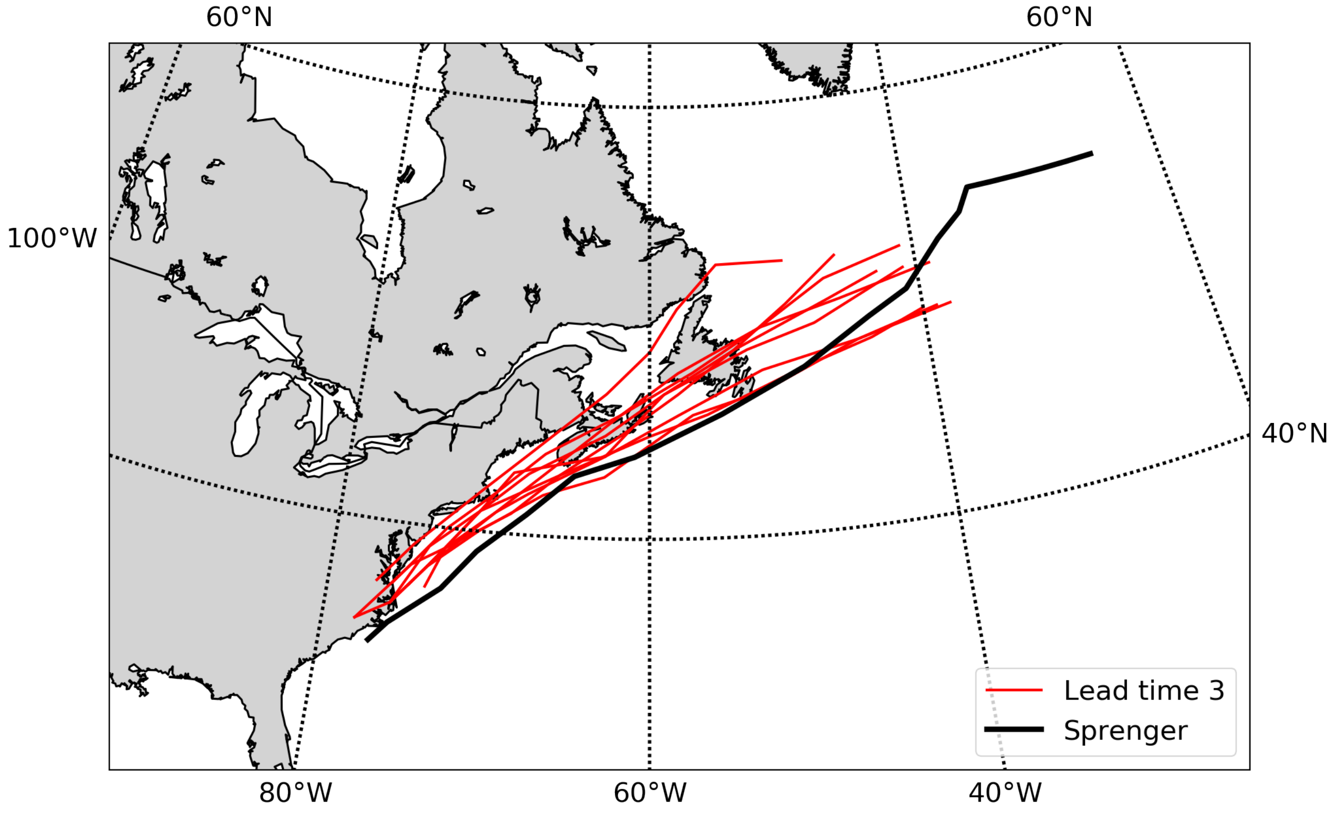
Jan. 2, 1988 06Z – Jan. 12, 1988 18Z

Lead time 1





Atlantic Basin Case Study



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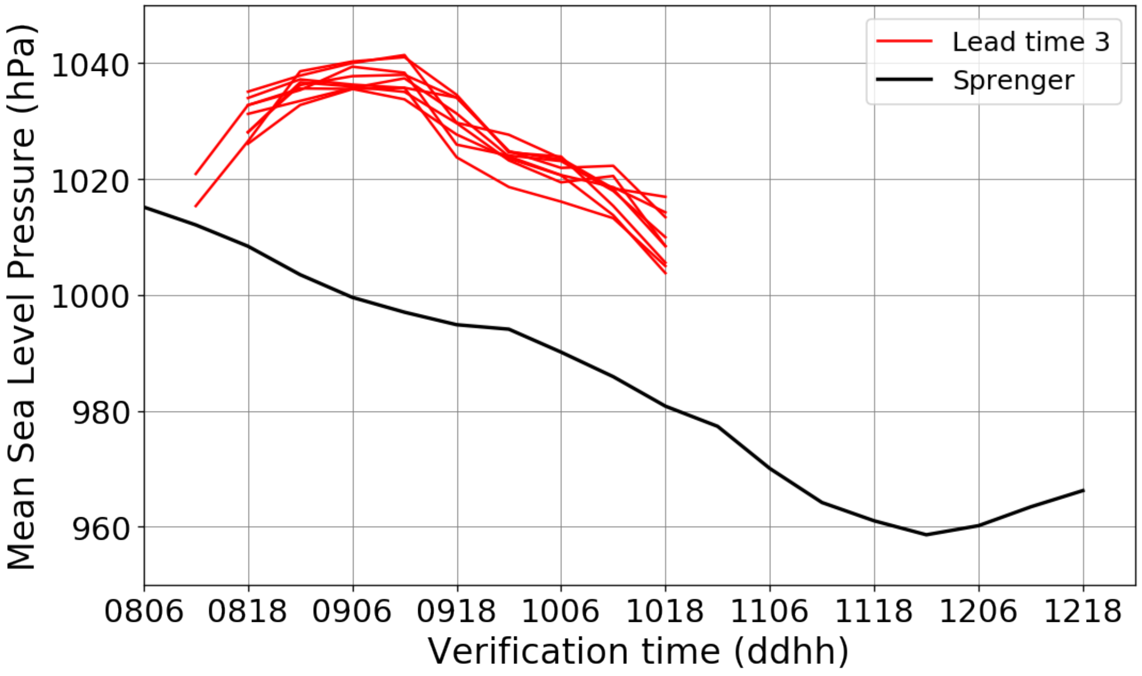
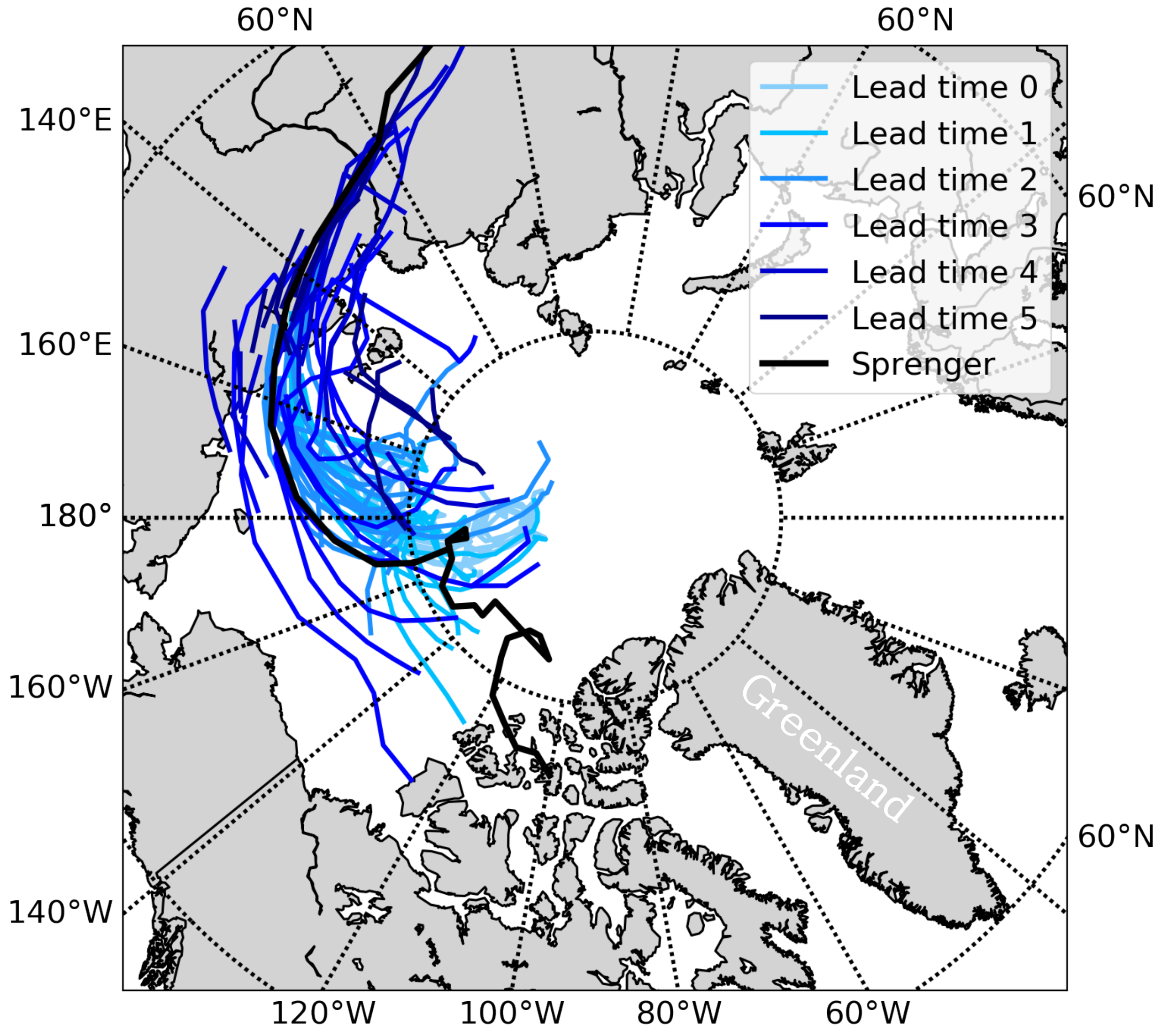
Lead time 3

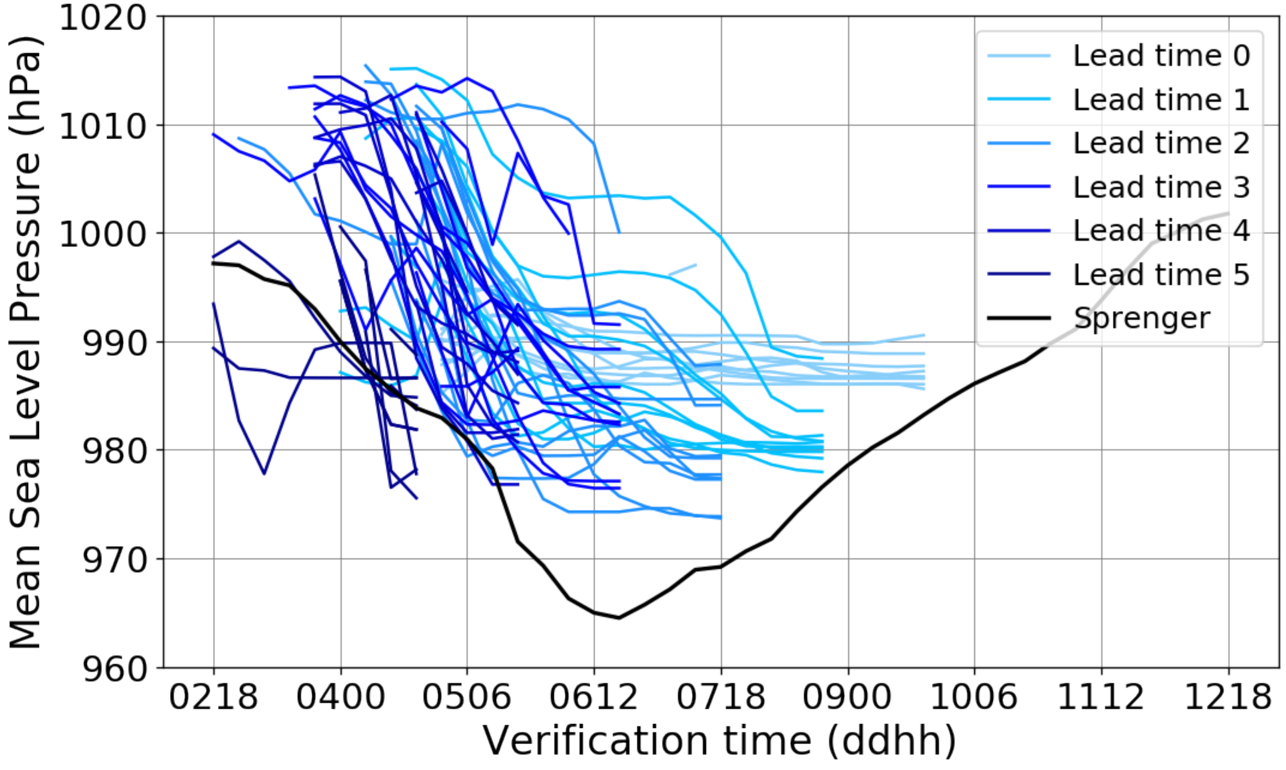


Great Arctic Cyclone Case Study

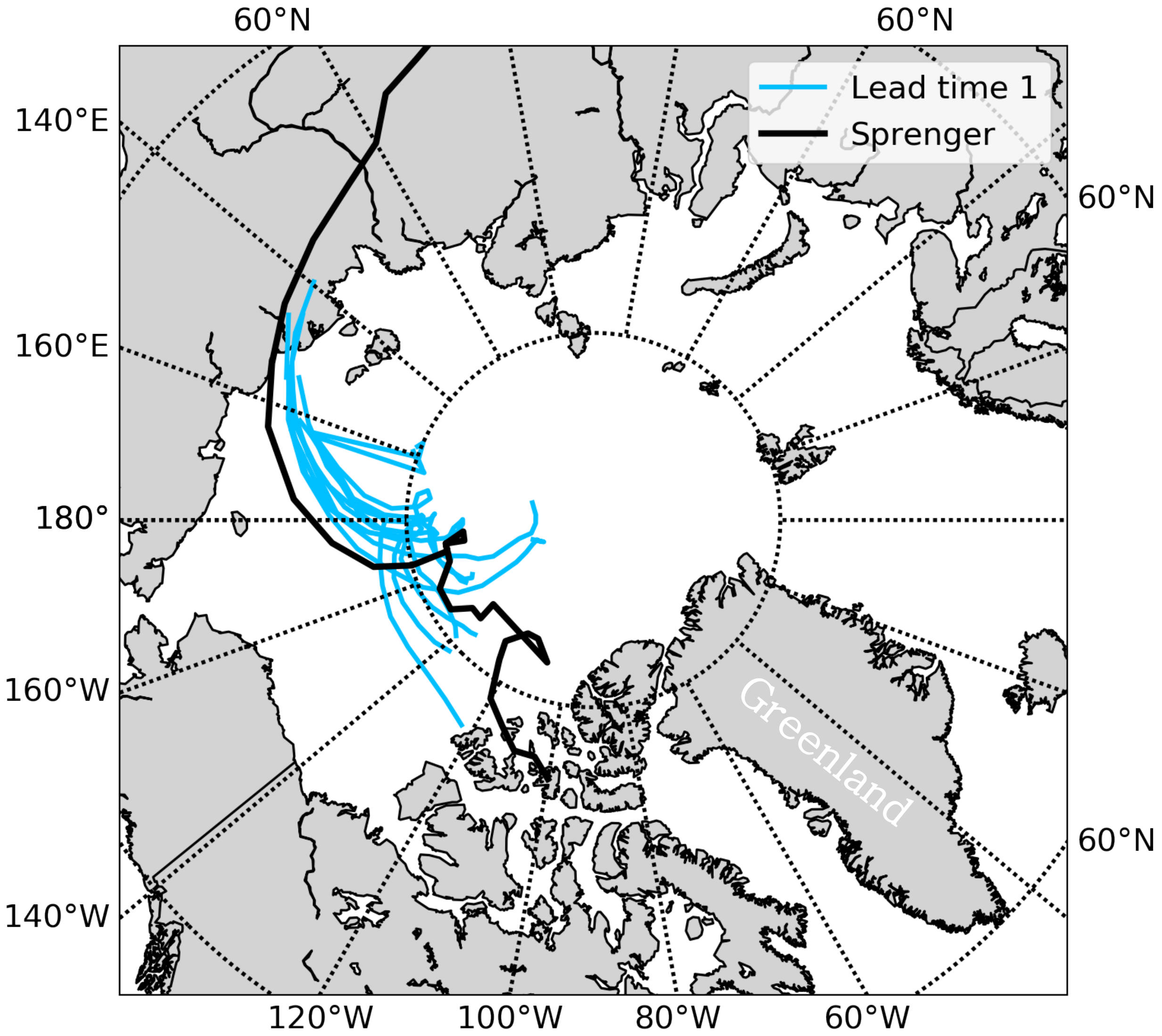


Aug. 2, 2012 18Z – Aug. 12, 2012 18Z

All Lead times

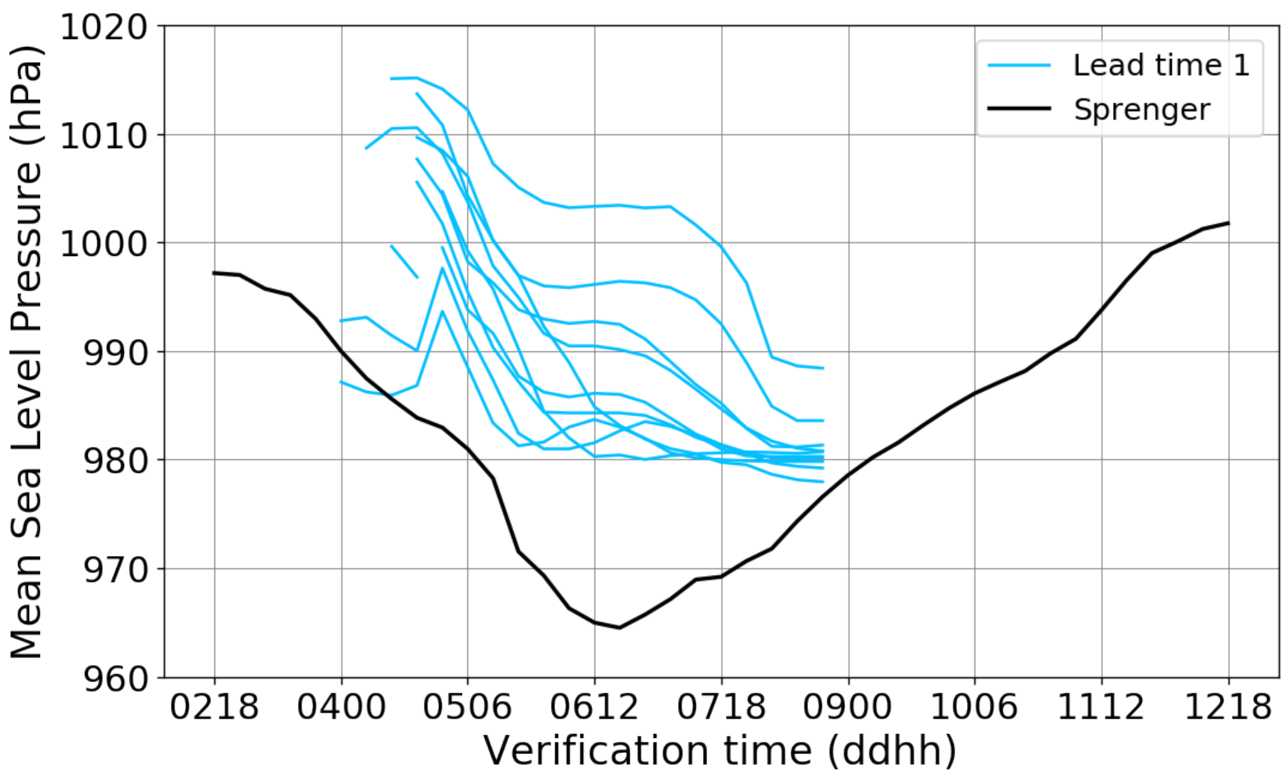


Great Arctic Cyclone Case Study



Aug. 2, 2012 18Z – Aug. 12, 2012 18Z

Lead time 1



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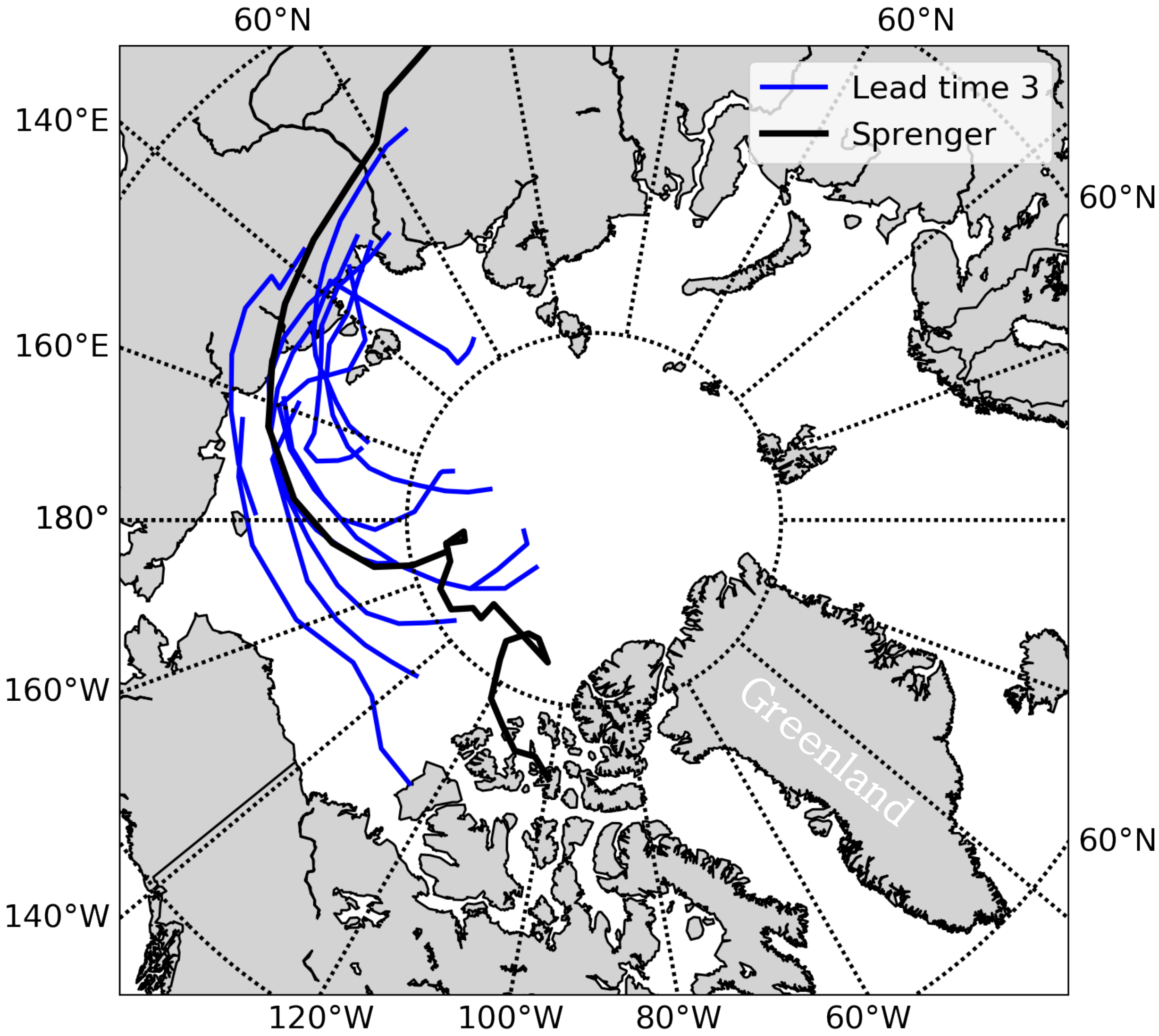

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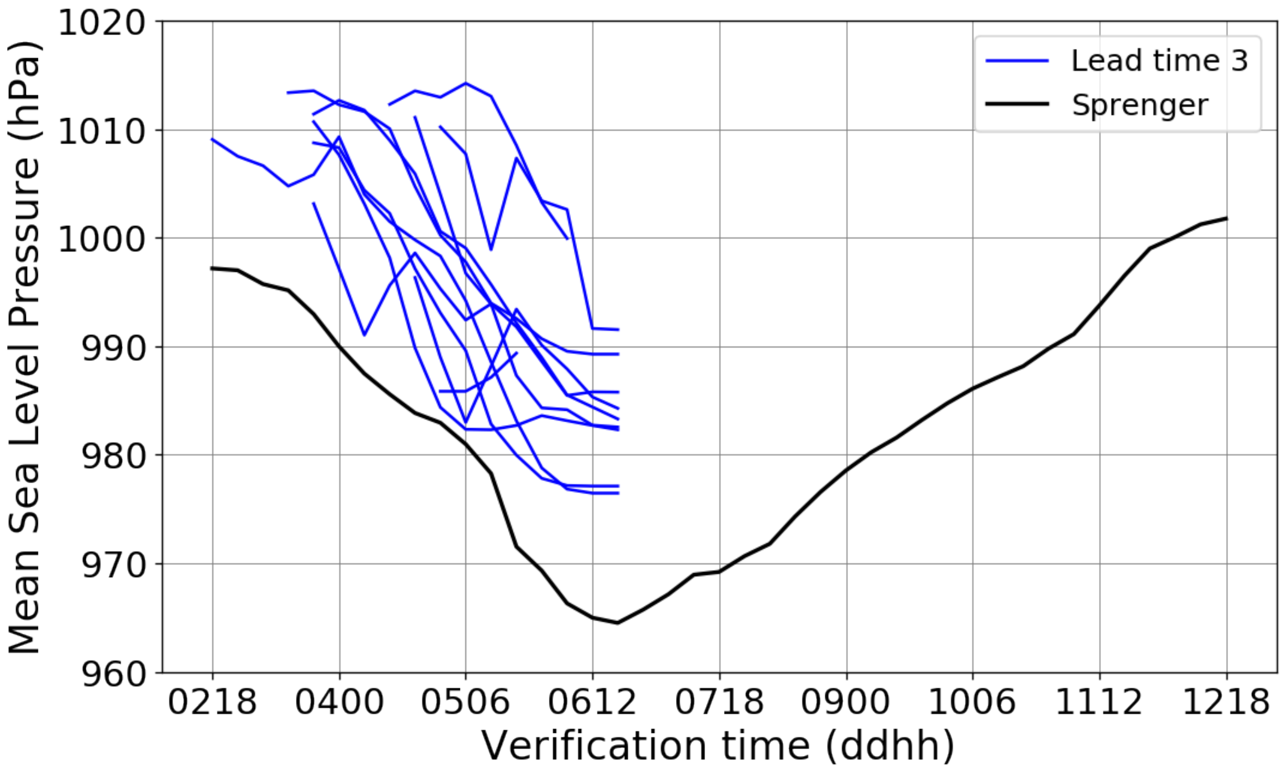
Lead time 3



Ensemble Spread

In order to examine the ensemble spread:

- **Intensity – standard deviation**
  - Used mean sea level pressure (MSLP)
  - Calculated standard deviation for each lead time (if available):

$$\sigma = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}}$$

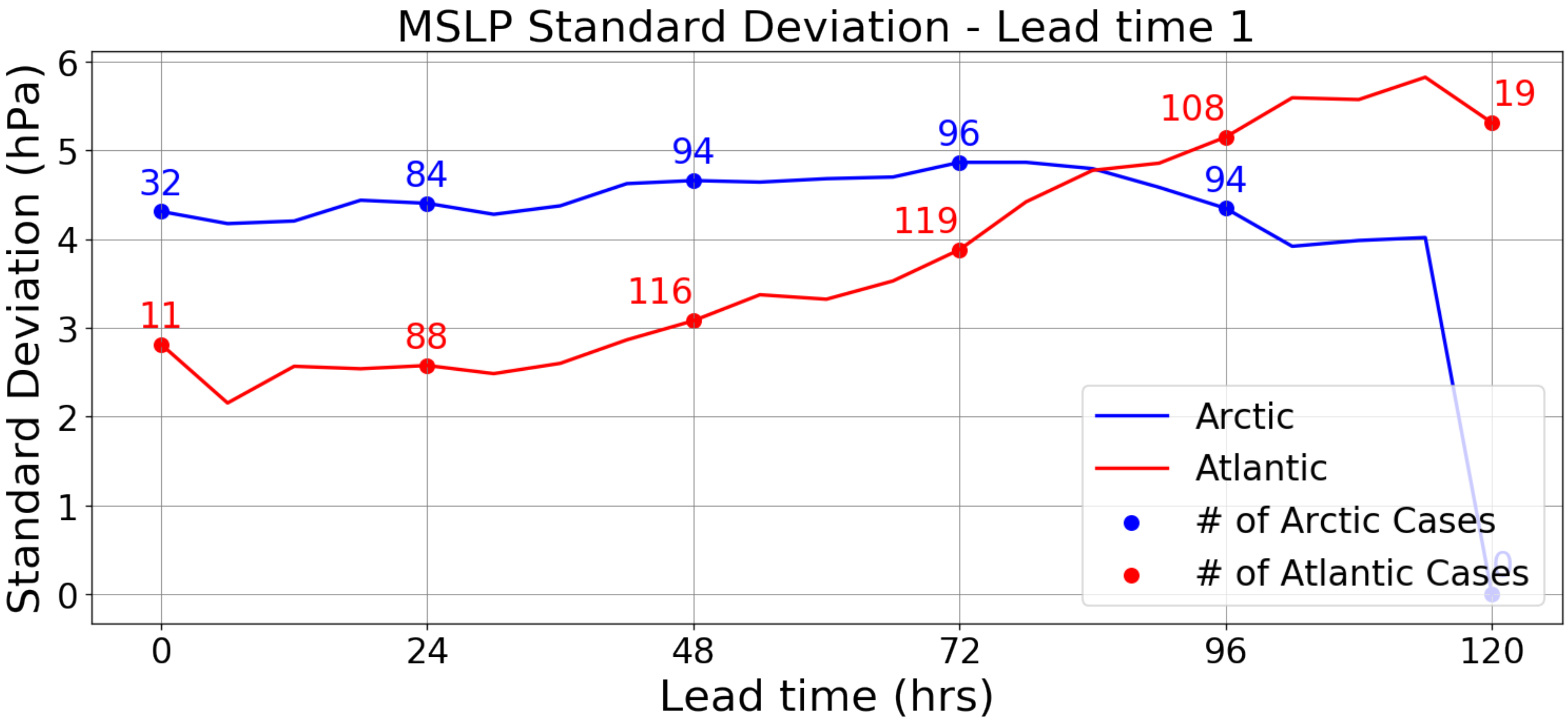
where X is MSLP and n is the number of ensemble members

- **Position – root mean square**
  - Used latitude and longitude
  - Calculated great circle distance between ensemble and mean
  - Took root mean square of distances:

$$RMS = \sqrt{\frac{x_1^2+x_2^2+\cdots+x_N^2}{N}}$$

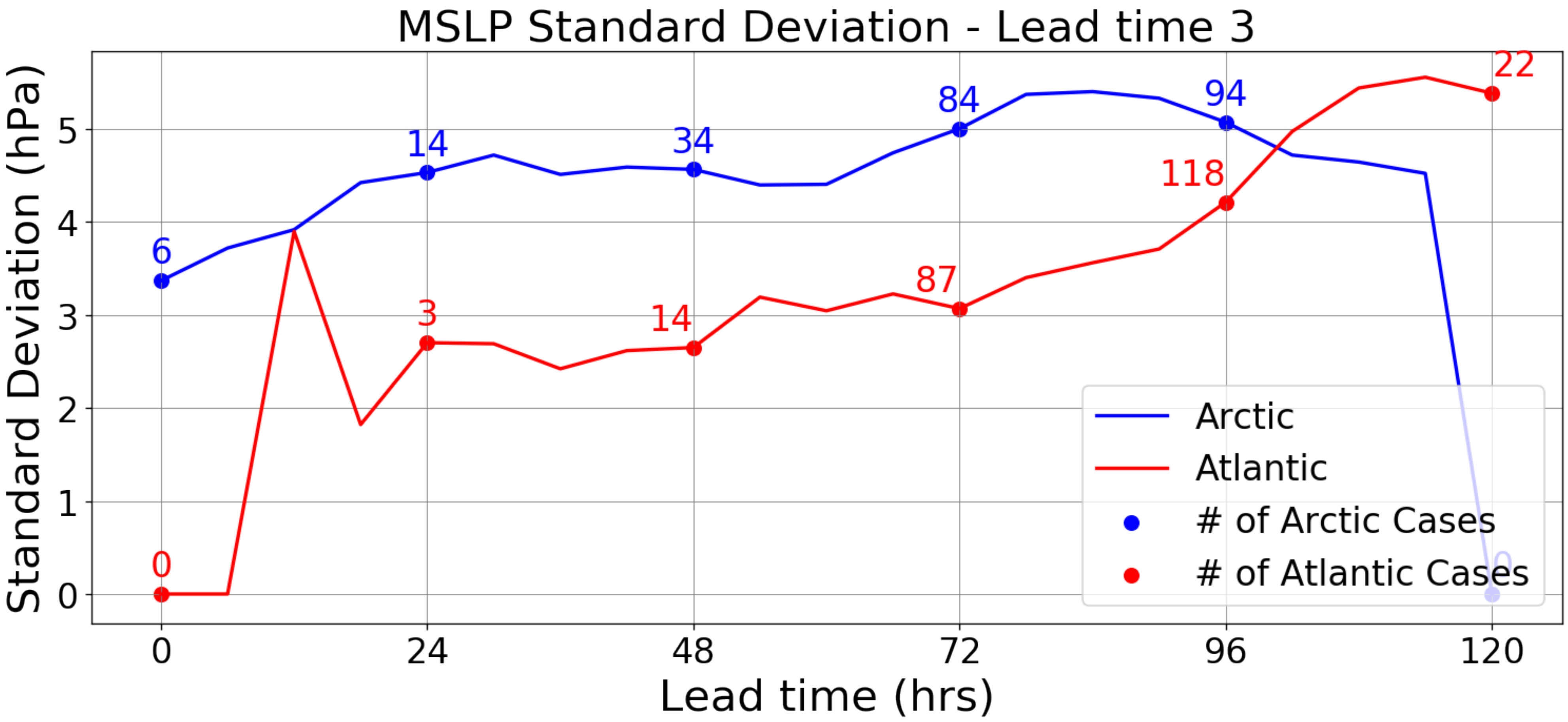
where x is great circle distance and N is number of ensemble members

Intensity Variability



ACs = 100 Total Cases
ABCs = 130 Total Cases

Intensity Variability



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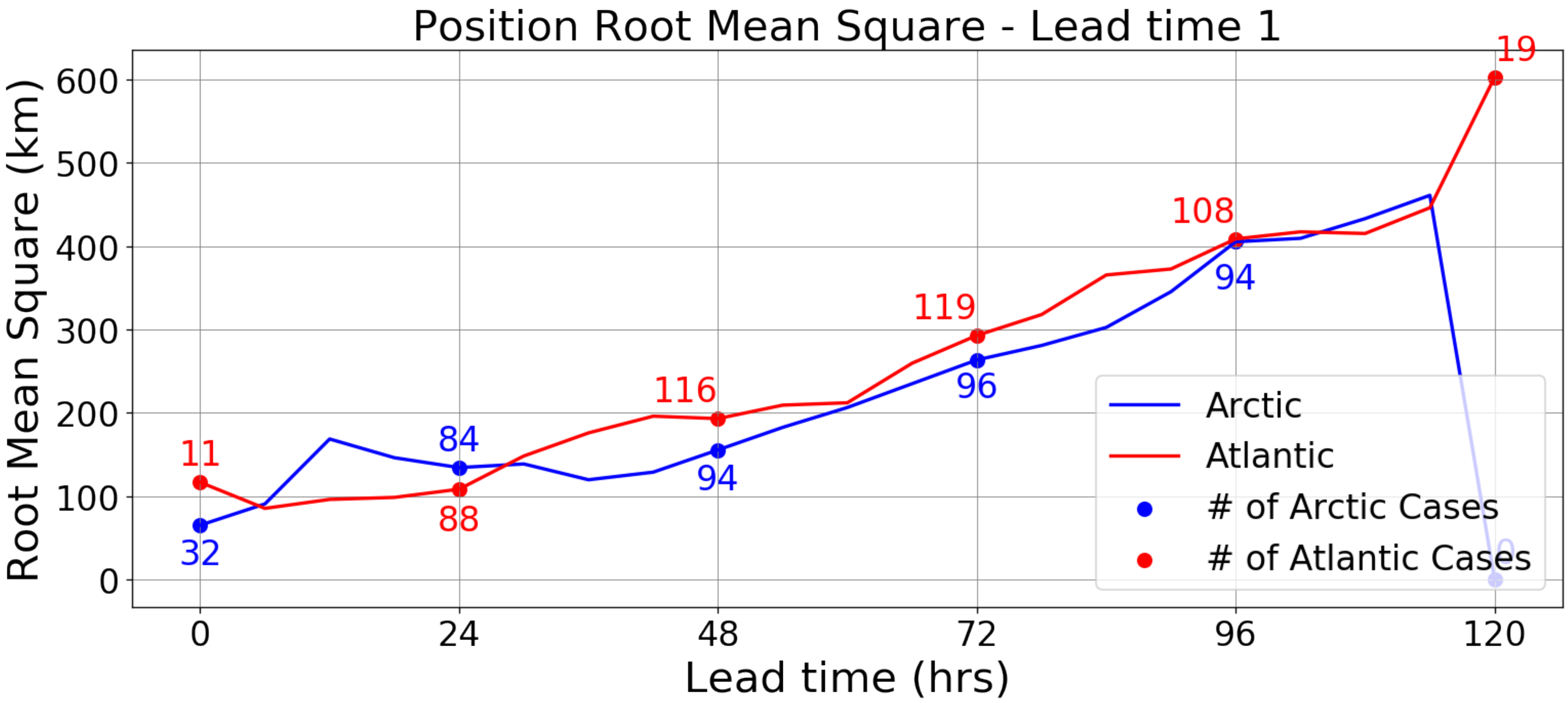
ABCs = 130 Total Cases

Position Variability



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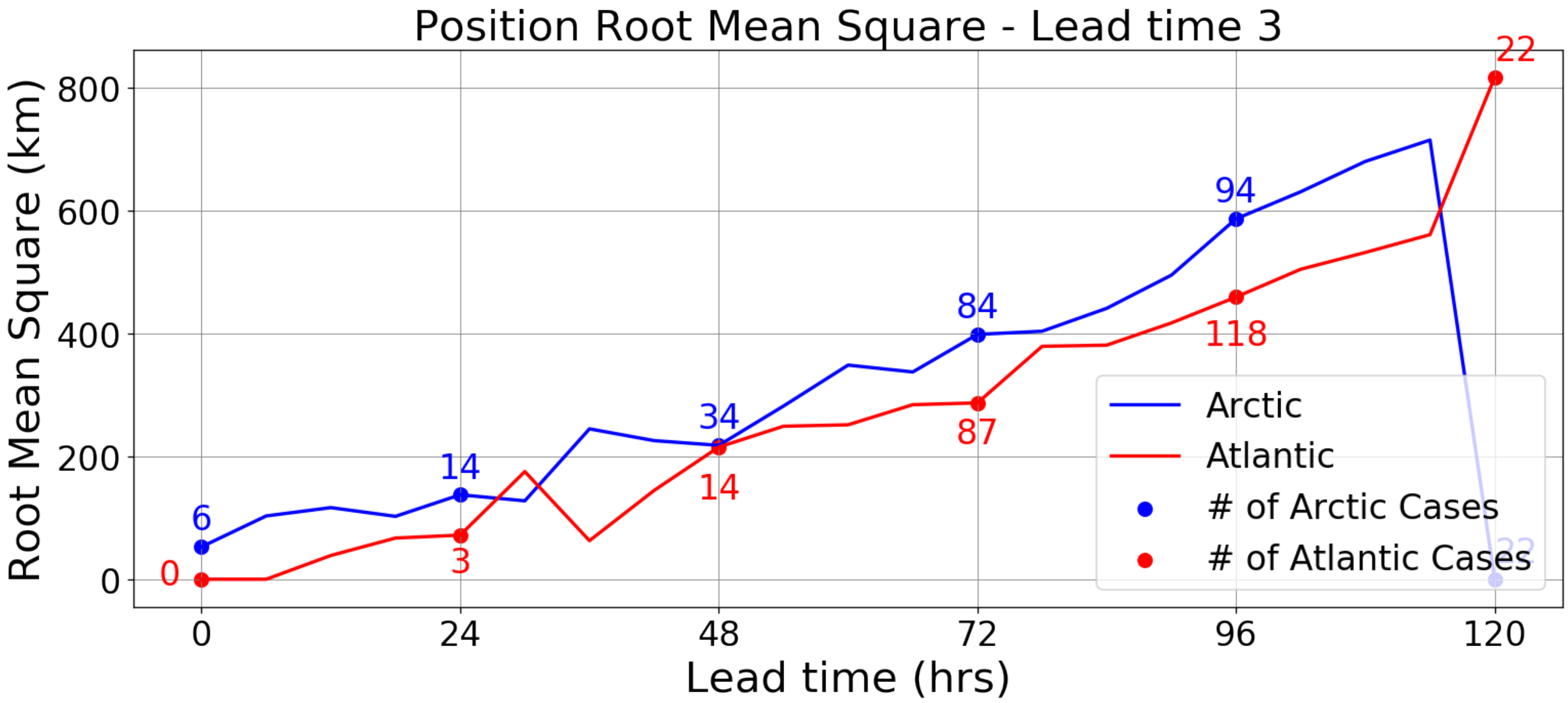
Position Variability



ACs = 100 Total Cases
ABCs = 130 Total Cases

Summary and Conclusions

- By using our selected criteria, we found 100 Arctic cyclones and 130 Atlantic Basin cyclones
- Forecast variability increases as a function of lead time for both the Arctic and Atlantic Basins
- On average, Arctic cyclone intensity standard deviation is higher compared to the Atlantic Basin cyclones
- By contrast, the average position standard deviation is similar for Arctic and Atlantic Basin cyclones at most lead times

Future Work

- Finish examining all lead times for mean cyclone position and intensity standard deviation for Arctic cyclones vs. Atlantic Basin

- Longer term: Use an ensemble-based sensitivity method to analyze what processes limit Arctic cyclone predictability for cases that are characterized by larger position or intensity uncertainty

References

Crawford, A., and M. Serreze, 2016: Does the summer Arctic frontal zone influence Arctic Ocean cyclone activity? *J. Climate,* **29**, 4977-4993.

Simmons, I and I. Rudeva, 2012: The great Arctic cyclones of August 2012. *Geophys. Res. Lett., **39.*** https://doi.org/10.1029/2012GL054259

Sprenger, M., G. Fragkoulidis, H. Binder, M. Croci-Maspoli, P. Graf, C.M. Grams, P. Knippertz, E. Madonna, S. Schemm, B. Škerlak, and H. Wernli, 2017: Global Climatologies of Eulerian and Lagrangian Flow Features based on ERA-Interim. *Bull. Amer. Meteor. Soc.,* **98**, 1739–1748, https://doi.org/10.1175/BAMS-D-15-00299.1

Zhang, J., R. Lindsay, A. Schweiger, and M. Steele, 2013: The impact of an intense summer cyclone on 2012 Arctic sea ice retreat. *Geophys. Res. Lett.,* **40,** 720–726.

NASA: http://www.climatecentral.org/news/last-summers-great-arctic-cyclone-unprecedented-says-new-study-15415

National Snow & Ice Data Center: http://nsidc.org/arcticseaicenews/2012/08/a-summer-storm-in-the-arctic/

Extra Slides

Atlantic domain of cyclogenesis