Attribution of Recent Changes in Autumn Cyclone Associated Precipitation in the Arctic

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Introduction

Since 1979, the Arctic has been rapidly losing its summer sea ice cover [e.g. *Stroeve et al.,* 2008]. Currently the September trend stands at -11.2%/decade. Recent years have seen extreme seasonal sea ice minima (**Figure 1**).

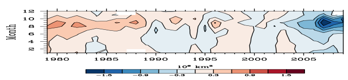


Figure 1. Sea ice extent anomalies by year and month from January 1979 to October 2009. Anomalies are computed relative to the 1979-2008 mean.

Larger expanses of open water in September lead to strong warming of the overlying atmosphere in autumn [*Serreze et al.*, 2009]. Through influences on vertical stability, the moisture holding capacity of the atmosphere and regional baroclinicity, it is reasonable to expect that this warming will have impacts on local and regional precipitation. A moister atmosphere may affect the intensity and precipitation efficiency of extratropical cyclones that generate much of the high latitude precipitation.

Based on data from the JRA-25 Reanalysis [*Onogi et al*., 2007], *Simmonds and Keay* [2009] argue for a link between the downward trend in September sea ice extent and stronger September cyclones due to an increase in enthalpy fluxes associated with more open water. Our analysis of the JRA-25 precipitation data, in conjunction with output from the cyclone tracking algorithm of *Serreze et al.,* [1997] reveals an increase in cyclone-associated precipitation (CAP) in recent years during autumn (**Figure 2**).

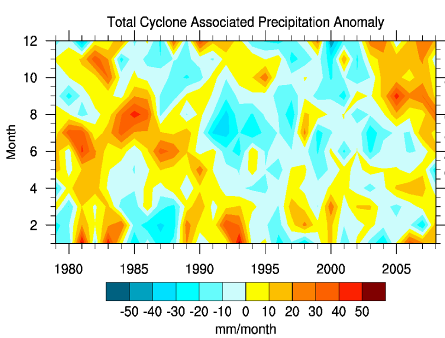


Figure 2. CAP anomalies for all regions north of 60°N by month and year. Anomalies are computed relative to the 1979-2008 mean.

Onogi, K., Tsutsui, J., Koide, H., Sakamoto, M., Kobayashi, S., Hatsushika, H., Matsumoto, T., Yamazaki, S., Kamahori, H., Takahashi, K., Kadokura, S., Wada, K., Kato, K., Oyama, R., Ose, T., Mannoji, N., and Taira, R., 2007. The JRA-25 reanalysis, *J. Met. Soc. Japan*, 85, 369-432.

Serreze, M.C., F. Carse, R.G. Barry, and J.C. Rogers, 1997. Icelandic Low cyclone activity: Climatological features, linkages with the NAO, and relationships with recent changes in the Northern Hemisphere circulation. *J. Climate,* 10, 453-464.

Serreze, M.C., A.P. Barrett, J.C. Stroeve, D.N. Kindig and M.M. Holland, 2009. The emergence of surface-based Arctic amplification, *The Cryosphere*, 3, 11-19.

Simmonds, I., and K.Keay, 2009. Extraordinary September Arctic sea ice reductions and their relationships with storm behavior over 1979-2008, *Geophys. Res. Lett*., 36, L19715, doi:10.1029/2009GL039810.

Stroeve, J., M. Serreze, S. Drobot, S. Gearheard, M. Holland, J. Maslanik, W. Meier, T. Scambos, 2008. Arctic sea ice extent plummets in 2007, *EOS Trans., AGU*, 89(2), 13-14.

Factors behind Increased Autumn Cyclone Associated Precipitation

Cyclone Associated Precipitation Anomalies

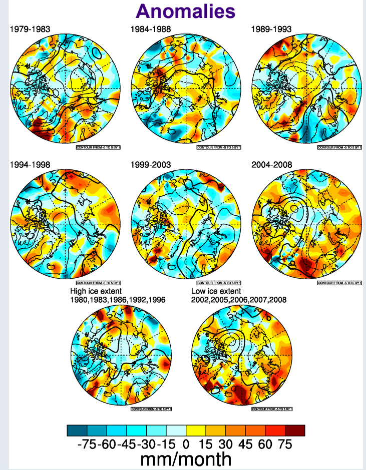


Figure 3. Autumn mean CAP anomalies for pentads and for years of high and low September ice extent. Isolines of SLP anomalies are also shown (dotted for negative, solid for positive).

Cyclone Central Pressure Anomalies

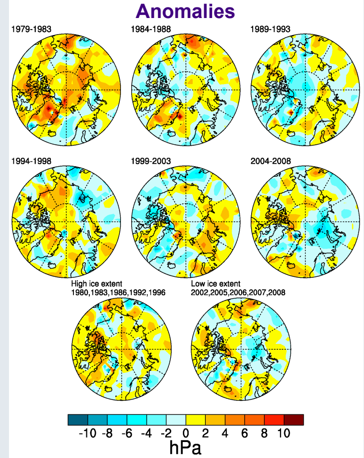


Figure 4. Autumn mean cyclone central pressure anomalies for pentads and following Septembers with high and low ice extent.

Cyclone Intensity (Laplacian of SLP) Anomalies

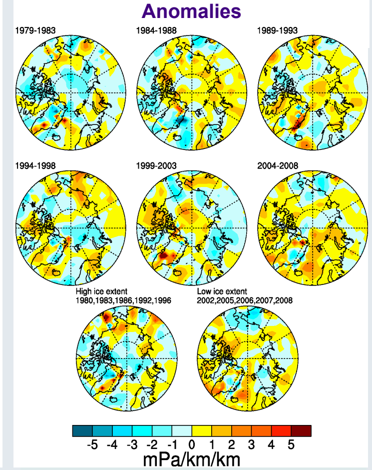


Figure 5. Autumn mean cyclone intensity anomalies for pentads and following Septembers with high and low ice extent.

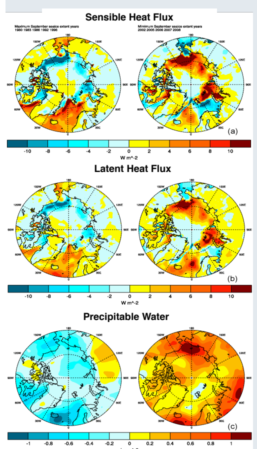
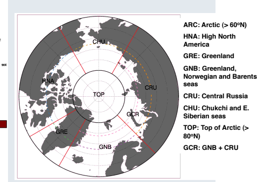


Figure 7. Autumn sensible heat flux (a), latent heat flux (b) and precipitable water (c) anomalies following Septembers with low (right) and high (left) ice extent.



Difference in autumn CAP due to a change in mean cyclone output or frequency

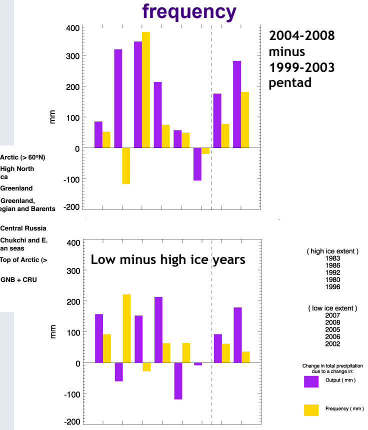


Figure 6. Differences in autumn CAP (mm) between the last two pentads (top) and between years with low and high September ice extent (bottom). Results are given for both mean cyclone output and cyclone frequency.

Conclusions

•Difference in CAP between the 2004-2008 and 1999-2003 pentads is clearly linked to a shift in atmospheric circulation, towards more frequent and more intense cyclones in the Atlantic sector of the Arctic (**Figures 3-5**).

•While the most pronounced open water anomalies in September in recent years have been north of Alaska and eastern Siberia, positive precipitation anomalies have been largest in the Barents and Kara seas.

•We are unable at this time to clearly demonstrate a causal link between decreased sea ice extent and precipitation in recent years.