Fall Arctic synoptic changes and sea ice reductions

Ian Simmonds and Kevin Keay

School of Earth Sciences, The University of Melbourne, Victoria, 3010, Australia
simmonds@unimelb.edu.au

Many aspects of changes in Arctic climate have been documented recently (Stroeve et al. 2007, Simmonds et al. 2008). Synoptic activity and sea ice coverage interact in numerous complex ways, so it is logical to explore the extent to which recent changes in Arctic storm activity and in sea ice coverage are linked. We identified all September Arctic MSLP cyclones over the period 1979-2008 using the JRA-25 global reanalysis (Onogi et al. 2007). For this we used The University of Melbourne cyclone tracking scheme (Simmonds et al. 2003), which diagnoses many key features of cyclone structure, including Depth and Radius. The Sea Ice Extent (SIE) data was sourced from NSIDC.

The greatly reduced September Arctic sea ice coverage in recent years is shown in Fig. 1. The time series of September Arctic SIE is presented in the top panel of Fig. 2. It exhibits a significant decline over the last three decades ($p < 0.001$) of 0.728 x 10^6 km^2 decade^{-1}. Noteworthy variations in September synoptic activity have also occurred in the Arctic basin over the period. The mean number of cyclone displays no significant trend (Fig. 2b). By contrast there are strong and significant positive trends in mean cyclone Depth (1.58 hPa century^{-1}, $p = 0.037$) and Radius (0.70 ^{o}latitude century^{-1}, $p = 0.001$) (parts c, d), and the last few years have witnessed extreme values of these cyclone characteristics. These basin-wide trends hint at links between SIE and cyclone vigour rather than frequency. The other panels in Fig. 2 show the variability of other key climate indicators. Of especial interest is the latent heat flux which has shown a significant upward trend (7.02 Wm^{-2} century^{-1}, $p = 0.066$), and has displayed large values since 2002, representing a potential increase in energy available to cyclones.

Fig. 2 suggests that years of low September Arctic SIE are associated with stronger and larger cyclones. We quantify this by correlating the raw time series of SIE with those of the cyclone properties displayed in Fig. 2. The mean September Depth is correlated with SIE with a coefficient (r) of -0.52 ($p = 0.003$), while $r = -0.65$ ($p = 0.001$) for the monthly mean Radius. (There is no significant correlation between SIE and cyclone frequency.) There is also a significant, albeit smaller, negative association between the SIE and the latent heat flux of -0.37 ($p = 0.046$).

The findings, discussed more fully in Simmonds and Keay (2009), reinforce suggestions that the decline in the extent and thickness of Arctic ice has started to render it particularly vulnerable to future anomalous cyclonic activity and atmospheric forcing.

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Simmonds, I., and Coauthors, 2008: Arctic climate change as manifest in cyclone behavior. *J. Climate,* **21,** 5777-5796.

Stroeve, J., and Coauthors, 2007: Arctic sea ice decline: Faster than forecast. *Geophys. Res. Lett.,* **34,** L09501, doi:10.1029/2007GL029703.

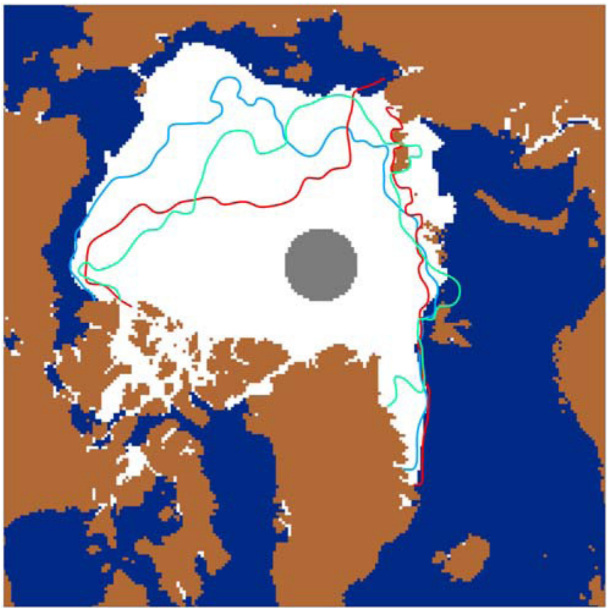

Figure 1: September Arctic sea ice coverage. The median ice cover (for 1979–2000) is presented in solid white. The blue, green, and red lines indicate the ice edges in 2005, 2008, and 2007, respectively.

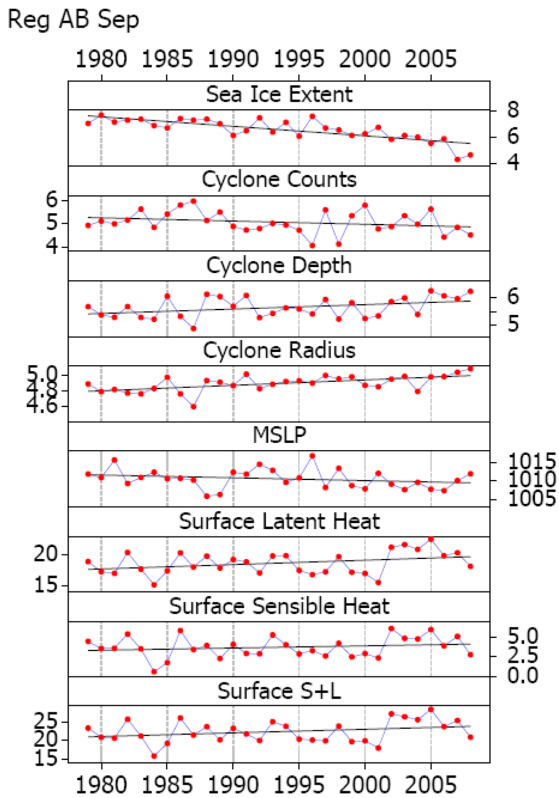

Figure 2: September Arctic basin mean time series 1979-2008. (a) Sea ice extent (in 10^6 km^2), (b) cyclone counts per analysis, (c) cyclone Depth (hPa), (d) cyclone Radius (^{o}latitude), (e) MSLP (hPa), (f) surface latent heat flux (Wm^{-2}), (g) surface sensible heat flux (Wm^{-2}), and (h) the sum of the last two (Wm^{-2}). The solid lines denote the line of best fit (least squares).