# Arctic warming and the trend from snowfall to rain

James A. Screen and Ian Simmonds

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

We are exploring some of the mechanisms responsible for ‘Arctic amplification’ of the global warming signal (Arctic warming is observed in all months (Screen and Simmonds 2010).) One of this is potentially associated with a warmer polar environment more likely to produce rainfall rather than snow. In such a scenario, the surface albedo decreases and encourages more absorption of solar radiation.

To investigate this we have made use of the ERA-Interim reanalyses for the 1989-2009 period. The proportion of precipitation occurring as snow can be expressed by the snowfall-to-precipitation ratio (SPR); i.e.,

$$SPR = \frac{S_{we}}{P}$$

where $S_{we}$ is the daily total snowfall water equivalent (mm-we day$^{-1}$) and $P$ is the daily total precipitation (mm day$^{-1}$). Days with no precipitation are not considered. We calculate the Arctic-mean SPR as:

$$SPR_{arctic} = \frac{\overline{S_{we}}}{\overline{P}}$$

where the overbar denotes the area-average north of 70°N.

Fig. 1 which shows the mean annual cycles of SPR and surface temperature averaged over the Arctic. We have calculated the ERA-Interim Arctic-mean trends in these precipitation quantities (Fig. 2). The largest seasonal-mean Arctic-mean changes in SPR are in summer, when the proportion of precipitation falling as snow has significantly decreased. A smaller, but still statistically significant, decrease in SPR is depicted in autumn. However, these two seasons show contrasting changes in snowfall and total precipitation. In summer, there has been a decrease in snowfall and total precipitation. The decline of snowfall exceeds the total precipitation decrease resulting in the decrease in SPR. Given that the majority of precipitation in summer falls as rain one would expect a decrease in total precipitation to be associated with a decrease in rainfall. That rainfall has increased and not decreased, when the total precipitation has decreased, reflects the decrease in the SPR. Had SPR remained constant, rainfall would have decreased in line with decreasing precipitation. In autumn, there is a large increase in total precipitation and only a small increase in snowfall. This increase in snowfall cannot be related to changes in precipitation form as SPR has decreased and must be related to the increase in total precipitation. This additional precipitation has disproportionately fallen as rain rather than snow, as reflected by the decrease in SPR and the large increase in rainfall.

Further details may be found in Screen and Simmonds (2012).

Screen, J. A., and I. Simmonds, 2010: Increasing fall-winter energy loss from the Arctic Ocean and its role in Arctic temperature amplification. *Geophys. Res. Lett.*, **37**, L16707, doi:10.1029/2010GL044136.

Screen, J. A., and I. Simmonds, 2012: Declining summer snowfall in the Arctic: Causes, impacts and feedbacks. *Climate Dyn.*, doi: 10.1007/s00382-011-1105-2.

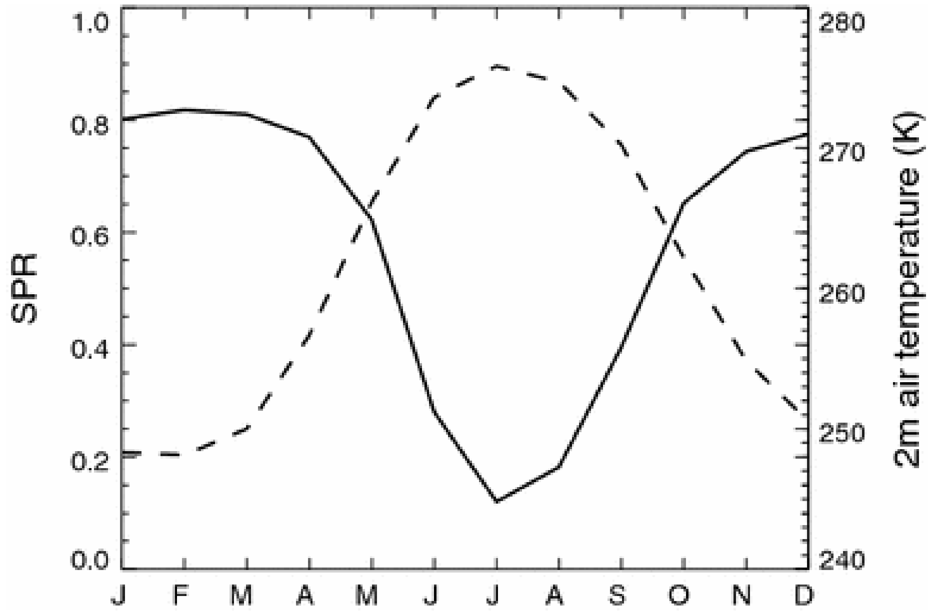


**Figure 1:** Monthly climatologies of the Arctic-mean (north of 70°N) SPR (*solid*) and surface air temperature (*dashed*) in ERA-Interim, 1989-2009

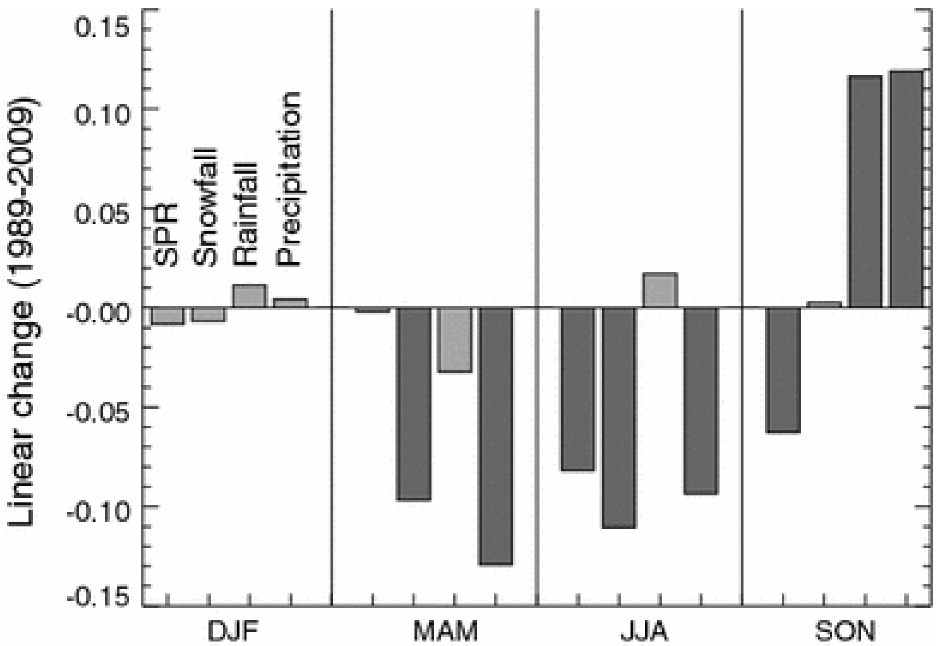


**Figure 2:** Linear changes from 1989 to 2009 in seasonal-mean Arctic-mean SPR, daily snowfall (mm-we day$^{-1}$), daily rainfall (mm day$^{-1}$) and daily total precipitation (mm day$^{-1}$) in ERA-Interim. *Darker bars* denote linear changes that are statistically significant ( $p < 0.10$).