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Intensified warming of the Arctic: Causes and impacts on middle latitudes

John E. Walsh *

International Arctic Research Center, University of Alaska, Fairbanks, AK, USA

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ABSTRACT

Over the past half century, the Arctic has warmed at about twice the global rate. The reduction of sea ice and snow cover has contributed to the high-latitude warming, as the maximum of the amplification during autumn is a fingerprint of the ice-albedo feedback. There is evidence that atmospheric water vapor, a greenhouse gas, has increased in the Arctic over the past several decades. Ocean heat fluxes into the Arctic from the North Atlantic and North Pacific have also contributed to the Arctic warming through a reduction of sea ice. Observational and modeling studies suggest that reduced sea ice cover and a warmer Arctic in autumn may affect the middle latitudes by weakening the west-to-east wind speeds in the upper atmosphere, by increasing the frequency of wintertime blocking events that in turn lead to persistence or slower propagation of anomalous temperatures in middle latitudes, and by increasing continental snow cover that can in turn influence the atmospheric circulation. While these effects on middle latitudes have been suggested by some analyses, natural variability has thus far precluded a conclusive demonstration of an impact of the Arctic on mid-latitude weather and climate.

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1. Introduction

Several decades ago, the Arctic was an afterthought in climate change research. Today it is at the forefront. The recent acceleration of research on Arctic climate, together with widespread coverage by the media and interest by the public, has come in response to rapid changes in the Arctic over the past few decades. By some measures, these changes are unprecedented. While the changes are driven by warming of the ocean and atmosphere, they are manifested in sea ice, glaciers, ice sheets, permafrost and other components of the Arctic system. The Arctic changes are even more intriguing because they are expected to play, and may already be playing, a role in further changes that impact middle latitudes and the rest of the globe. As evidence of the increased public awareness of this topic, Hamilton and Lemcke-Stampone (2013) have recently reported results showing that a clear majority (60%) of surveyed members of the public now accepts that there is a connection

* International Arctic Research Center, University of Alaska, 930 Koyukuk Drive, Fairbanks, AK 99775, USA.
E-mail address: jwalsh@iarc.uaf.edu.

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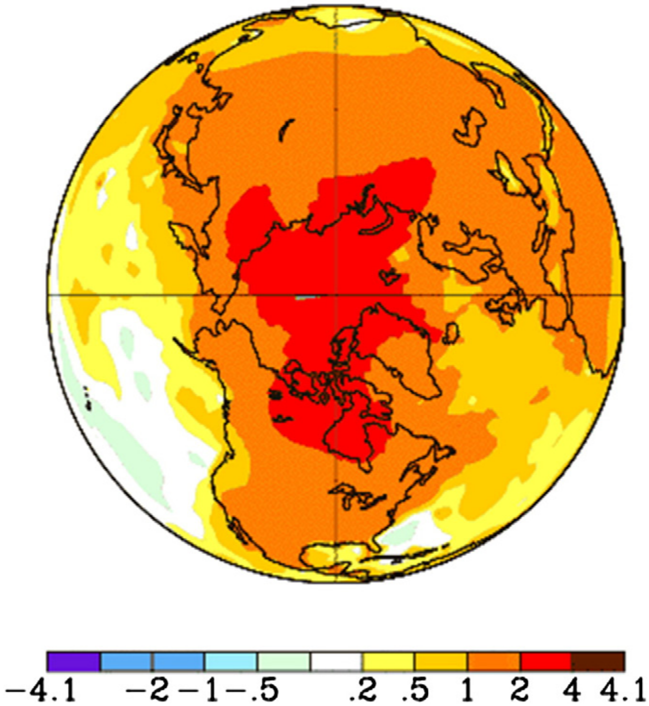

Fig. 1. Change of annual surface air temperatures (°C) over the 50-year period, 1963–2012. Plotted values are differences between initial and final points of linear regression trend line for each location. Source: NASA Goddard Institute for Space Studies, http://data.giss.nasa.gov/gistemp/maps/.

between Arctic warming and mid-latitude weather. Is such acceptance justified? This question motivates the present paper, which has two main objectives. The first is an assessment of our present understanding of the causes of the recent changes in the Arctic, with an emphasis on the warming that has contributed to changes in various other components of the Arctic system. Because such an assessment requires consideration of some other system components that may have amplified the recent changes, linkages with the global climate system will be prominent in the discussion. A second related objective is a synthesis of our current understanding of the impacts of Arctic change on middle latitudes. While this understanding is rapidly evolving, we will assess emerging evidence that the Arctic is already impacting mid-latitude climate over monthly to multiyear timescales. Section 2 provides information on the recent Arctic warming, while Sections 3 and 4 address the paper's two main objectives by assessing the causes and impacts, respectively. Some concluding thoughts on the future trajectory of Arctic climate are presented in Section 5.

2. The recent warming

Fig. 1 shows the change of annual mean temperature over the extratropical Northern Hemisphere during the past 50 years, 1963–2012. Warming dominates and increases poleward, consistent with the notion of polar amplification. The warming in Fig. 1 is strongest over the Arctic Ocean, where it ranges from 2 to 4 °C. In middle latitudes, the warming is generally greater over land than over the ocean. It should be noted that polar amplification also characterizes cooling episodes, such as occurred over the Northern Hemisphere from the 1940s through the 1970s (e.g., Serreze et al., 2009).

The Arctic warming of the past half-century appears to be unique in the past 2000 years, at least during the summer season. Kaufman et al. (2009) provided a reconstruction of pan-Arctic temperatures based on various types of proxy information, including lake sediments, pollen records, diatoms and tree rings. According to this reconstruction, the Arctic showed a slow cooling trend for most of the past 2000 years, consistent with variations of the Earth–Sun orbital parameters. However, the recent warming has taken Arctic temperatures outside the range of the previous 2000 years of temperature variations. It should be emphasized, however, that the information used in this reconstruction was indicative primarily of summer temperatures.

The recent Arctic warming has been accompanied by a rapid loss of sea ice, especially during the warm season. September sea ice extent in 2012 fell to approximately 50% of the mean for the 1979–2000 period (Figs. 2 and 3). (Consistent measurements by satellite passive microwave sensors began in 1979). The recent decline is unprecedented in the satellite record and in paleo reconstructions spanning more than 1400 years (Kinnard et al., 2011).

As shown in Fig. 4, extreme sea ice retreats have characterized Arctic sea ice from 2007 onward; these retreats appear in Fig. 4 as large negative departures from the previous means in the summer and autumn seasons. It is apparent from Fig. 2 as well as Fig. 4 that the recent reduction of sea ice has been much less in winter and spring than in summer and autumn, resulting in a sea ice cover that is largely seasonal. The

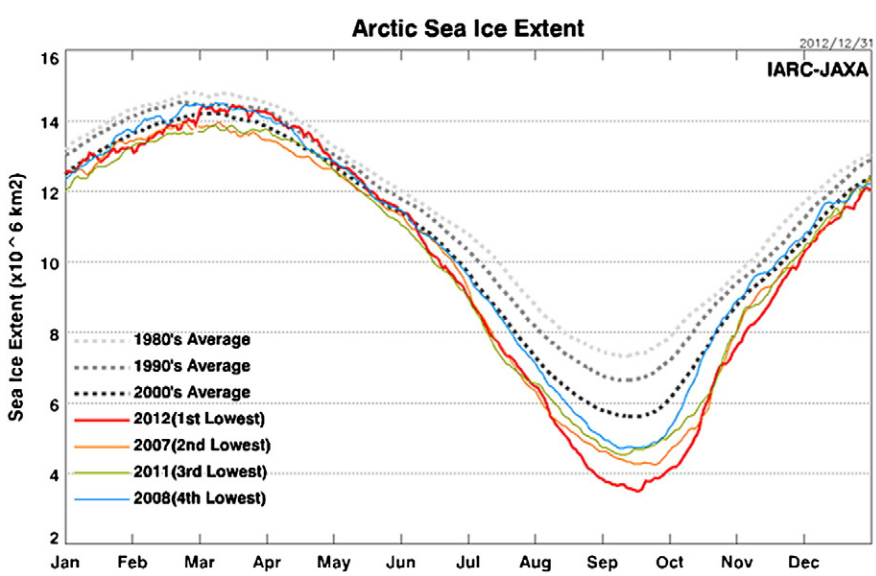

Fig. 2. Annual cycle of Arctic sea ice extent for 2012 (red), 2007 (orange), 2011 (green) and 2008 (blue). Dashed lines show decadal means for the 2000s (black dashes), 1990s (gray dashes) and 1980s (light gray dashes). Source: IARC/JAXA Sea Ice Monitor, http://www.ijis.iarc.uaf.edu/en/home/seaice_extent.htm.