

Effects of a warming Arctic

Article

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1 Perspective, aag2349

2 Are cold winters connected to the warming Arctic?

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4 *One of the most controversial areas of climate science is the extent to which the*
5 *warming Arctic might be affecting climate and weather extremes at lower latitudes.*

6 Recent years have seen a series of anomalously cold winters in northern
7 midlatitudes, including the eastern US where they have been accompanied by
8 extremely heavy snowfalls. Some atmospheric scientists have argued that such cold
9 events may be associated with climate change, specifically with the rapid warming
10 of the Arctic that has been observed over recent decades and is manifested in the
11 precipitous decline of Arctic sea-ice extent since the early 1990s. Others have
12 argued precisely the opposite: that the cold events merely reflect the chaotic
13 variability of the climate system and are in fact becoming less likely under climate
14 change. Unlike most scientific debates about climate change, which are limited to
15 specialist fora, this one has exploded into the public domain. How can different
16 atmospheric scientists come to such different conclusions from the same data?

17 On basic thermodynamic grounds, climate change is expected to warm wintertime
18 surface temperatures over land, with an amplified warming in the Arctic. This is
19 what is seen in observations over sufficiently long periods (Fig. 1a). All else being
20 equal, this would lead not only to fewer cold events, but also to less variability in
21 surface temperature due to the reduced latitudinal temperature gradient. (However
22 heavy snowfalls could increase due to the moister atmosphere¹.) Arguments for
23 more frequent cold events thus rely on a change in atmospheric dynamics, and here
24 the scientific understanding is very poor². Various mechanisms have been proposed,
25 but they represent hypotheses rather than predictive theories³.

26 The climatological transport of heat from middle to high latitudes is mainly
27 accomplished by atmospheric weather systems during the winter season, and varies
28 from year-to-year through natural climate variability. Some years are characterized
29 by a strong tropospheric polar vortex which inhibits the Arctic-midlatitude
30 exchange of air masses, and other years by a weaker and wavier polar vortex which
31 enhances the exchange, leading to midlatitude cold spells and to a warmer Arctic
32 (Fig. 2). The difference between these two states shows up as a cold-
33 continents/warm-Arctic pattern, although North America and Eurasia can vary
34 independently. The observed changes over recent decades (Fig. 1b) align with this
35 pattern, with a cooling tendency over the eastern US and especially central Asia, and
36 an accelerated warming of the Arctic compared with that seen in Fig. 1a.

37 Given the uncertainties surrounding dynamical aspects of climate change, a
38 reasonable null hypothesis would be that climate change is dominated by its
39 thermodynamic aspects, and that the anomalous behaviour seen in recent decades
40 (e.g. the difference between Figs. 1a and 1b) reflects natural variability. The
41 contrary hypothesis is that the accelerated warming of the Arctic is part of the

42 climate-change signal, and has changed the weather patterns in midlatitudes
43 through changes in the tropospheric polar vortex. Such a hypothesis is not as far-
44 fetched as it may sound, as there are general grounds for expecting that the
45 dynamical response to climate change will project onto the modes of internal
46 variability⁴. Unfortunately this makes it difficult to separate the signal from the
47 noise as they will have similar spatial patterns.

48 One aspect of the scientific debate has focused on whether the observed changes
49 associated with particular hypotheses are statistically significant. This is rather
50 beside the point since the definition of statistical significance is arbitrary⁵, a lack of
51 statistical significance does not mean the effect is not there, and a positive finding
52 does not imply any attribution to climate change. It is also extremely challenging to
53 accurately characterize the low-frequency noise from the limited observational
54 record. A deeper difficulty in any such analysis is that correlation does not imply
55 causality. A recent study⁶ has used the concept of causal effect networks to
56 overcome this limitation; importantly, it finds that a loss of Barents/Kara sea ice
57 (which induces local warming) can indeed be considered a causal driver of a
58 weakened tropospheric polar vortex.

59 Another aspect of the debate has focused on what numerical models predict. Many
60 studies have attempted to model the midlatitude circulation response to Arctic
61 warming, usually induced through reduced sea-ice extent. The results have
62 generally been all over the map, showing only that the answer depends sensitively
63 on details of the model set-up. The one result that does seem to consistently emerge
64 is a cooling in central Asia (much as seen in Fig. 1b) resulting from loss of
65 Barents/Kara sea ice⁷, which can be understood in terms of the circulation response
66 to a local warming. This matches the observationally determined causal
67 relationship⁶, and could account for the observed attribution of an increase in cold
68 extremes in central Asia to circulation changes⁸.

69 Comprehensive climate models do not provide any indication of increased
70 wintertime cold events in northern midlatitudes in response to climate change,
71 suggesting that any such tendency arising from Arctic warming (if it exists) is
72 overwhelmed by other factors. However, one can question whether these models
73 represent the relevant physical processes in a sufficiently accurate way for this to be
74 considered a definitive answer. Interestingly, the models with stronger Arctic
75 warming have a tendency towards surface pressure increases over northern
76 Eurasia⁹, which is broadly consistent with the above-mentioned studies.

77 To the extent we trust the current generation of climate models, and given the
78 impossibility of ruling out natural variability as the explanation for the observed
79 behaviour in recent decades, the null hypothesis is certainly a scientifically
80 defensible position¹⁰. However there are multiple lines of evidence supporting the
81 hypothesis of an Arctic-midlatitude connection in central Asia — though not, it must
82 be said, in the eastern US. Moreover the either/or dichotomy between forced
83 response to climate change and natural variability is overly simplistic. For example,
84 the meanders in the tropospheric polar vortex induced by teleconnections from

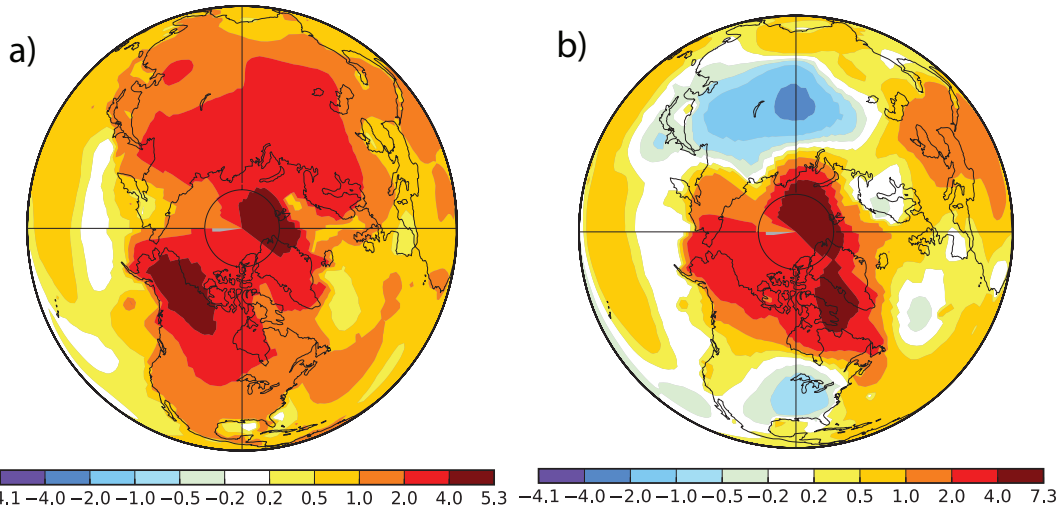
85 Pacific sea-surface temperature variations can be expected to be larger if the vortex
86 was weaker. Thus it is easy to imagine variability and the forced response acting
87 together to affect extreme weather.

88 The question is not whether Arctic changes are affecting midlatitudes, but rather
89 how and by how much. Framing studies in this way will avoid polarization and aid
90 progress. It is already encouraging to see scientists from what might be considered
91 'opposing' camps collaborating¹¹; this sort of productive interaction will move the
92 science, and with it the public discourse, forward.

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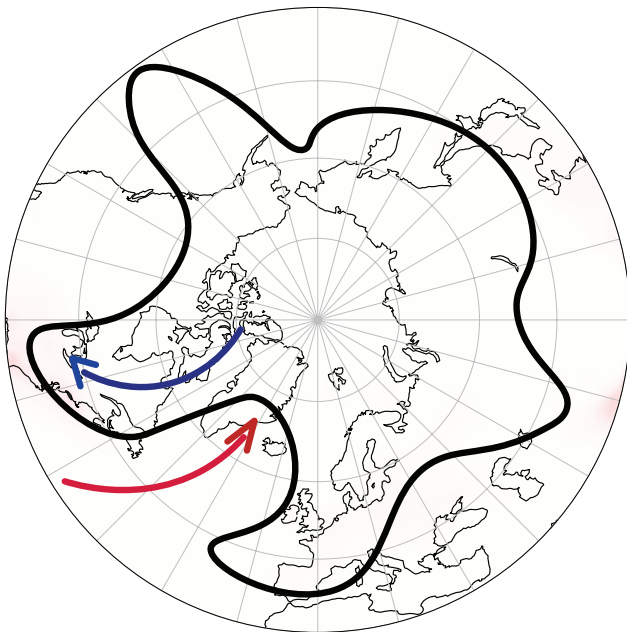
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113 **Figure 1.** Change in average temperature (in °C) during the winter season
 114 December-January-February over (a) the last 50 years (1966-2016) and (b) over the
 115 last 25 years (1991-2016) during which Arctic sea ice extent has declined
 116 precipitously. Data from GISTEMP, NASA Goddard Institute for Space Studies¹².



117

118 **Figure 2.** Schematic of the weather situation on January 26, 2015, when Winter
 119 Storm Juno hit Boston. The black line depicts the edge of the tropospheric polar
 120 vortex, which lies within the core of the jet stream and represents a boundary
 121 between cold Arctic air and warmer midlatitude air. The vortex is deformed by
 122 Rossby waves which generally move eastward but can sometimes stall. The blue
 123 arrow depicts transport of cold air to the eastern US, and the red arrow transport of
 124 warm air into the Arctic. Figure courtesy of Dr. Michaela Hegglin.