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Warmer Arctic weakens vegetation

Ana Bastos

Abstract: Warm conditions in the Arctic Ocean have been linked to cold mid-latitude winters. Observations and simulations suggest that warm Arctic anomalies lead to a dip in CO₂ uptake capacity in North American ecosystems and to low crop productivity.

The amount of CO₂ taken up by terrestrial ecosystems has been increasing over the past decades. The global terrestrial CO₂ sink is highly variable and is responsible for most of the interannual variability of the atmospheric CO₂ growth-rate¹. In North America, the terrestrial biosphere currently absorbs more than 30% of the region's CO₂ emissions from fossil fuels. Although the trend in terrestrial CO₂ uptake is well understood, a clear picture of the causes of interannual variability in the terrestrial sink is still missing. Ocean–atmosphere variability patterns are known to induce changes in terrestrial CO₂ balance, as is the case of the widely studied El Niño. Warm years in the Arctic Ocean have been linked to cooler winters and springs in North America.

Writing in *Nature Geoscience*, Kim *et al.* now show how warmer-than-average years in the Arctic trigger cooler winters and springs in North America, resulting in reduced vegetation growth and lower CO₂ uptake capacity in North American ecosystems.

Over the past several decades, the Arctic has warmed at a much faster pace than the rest of the globe. One result of this warming has been enhanced terrestrial productivity at high latitudes. Arctic warming has also been linked to changes to the climate in North America through teleconnections. Specifically, reductions in autumn sea ice have led to warmer-than-average winter temperatures over the Arctic, which in turn produced a characteristic circulation pattern that has been associated with harsher

cold winters in North America

Kim *et al.*⁵ use an Arctic climate index along with simulations and observations to show that warmer sea surface temperatures in winter over the Bering Strait impose harsher spring conditions over North America. They further demonstrate that these colder temperatures result in a decrease in the CO₂ uptake capacity of ecosystems.

Understanding the impacts of these remote climatic influences can be tricky. At interannual timescales, ecosystems do not respond to variations in temperature only. Instead, they respond to combinations of anomalies in a wide range of intertwined climatic variables, possibly with opposing effects, such as cloudiness and rainfall. And often the response of ecosystems is delayed, such as when winter snow cover affects

summer soil water availability.

Kim *et al.*⁵ rely on a simple index derived from the sea surface temperature over the Bering Sea during late winter/early spring to evaluate the response of North American ecosystems to the mid-latitude anomalies imposed by the warmer-than-average Arctic. Consistent with previous studies, they find severe cooling over most of northern North America and drying in the central south regions, associated with the anomalous advection of cold and dry air from the Arctic. Using observation-based data and Earth system model simulations over the past decades, Kim *et al.* link warm Arctic anomalies to a loss in gross primary productivity in North American ecosystems of about 0.3 PgC yr⁻¹. They associate this decrease with spring cooling, and possibly foliar damage, in temperature-limited regions and drying in water-limited regions. They estimate that Arctic warming anomalies cause a decrease in the net North American CO₂ sink of 0.1 PgC yr⁻¹, which corresponds to about 14% of the average North American sink.

This impact represents only a small fraction of the North American CO₂ sink. But autumn sea ice has been decreasing steadily, and warm Arctic/cold continent events may become more frequent. Kim *et al.* find that terrestrial models simulate a decrease in vegetation photosynthesis in response to warm Arctic anomalies, although large differences between models are found. The response of gross primary productivity to Arctic temperature anomalies also appears to be reproduced to some extent in future climate simulations from the fifth Coupled Model Intercomparison Project (CMIP5), and Kim *et al.* suggest that Arctic-related gross primary productivity anomalies may be amplified in the future.

Whether the relationship found implies a decreasing carbon sink capacity of North American ecosystems in the coming decades is unclear. In particular, the differentiated responses of phenology, photosynthesis and respiration to spring cooling, superimposed on the long-term warming trend, need to

be more thoroughly examined. For example, an earlier onset of the growing season due to the warming trend, combined with more frequent cold spells linked to Arctic warming could imply more frequent early spring plant damage. Since the increasing trend in the global CO₂ sink is mainly dominated by northern ecosystems², it is also worth evaluating whether mid-latitude ecosystems in Eurasia respond similarly to Arctic warming, possibly creating a hemisphere-scale decrease in CO₂ uptake capacity in response to Arctic warming.

Interestingly, Kim *et al.* also find significant variations in certain crop yields in the United States in response to winter Arctic warming, as a result of changes in precipitation in some regions and colder winters and springs in others. Irrigation could be used in water-limited regions to counter the drying effects, but spring frost may be harder to manage after sowing, and may impose heavy losses. Given that these events appear to be linked to variations in Arctic sea-ice extent during the previous autumn, the results by

Kim *et al.* may allow farmers to anticipate spring weather and manage their crops accordingly. The link found between Arctic warming and continental cooling is probably not a simple cause-effect mechanism. It is likely to vary between seasons, regions and the warming versus cooling states, and nonlinear effects or additional factors must be taken into account. A deeper look at the differences between the different land-surface and Earth system models may help better constrain the response of mid-latitude ecosystems to climate variability. Long-term warming trends in the Arctic have increased carbon uptake in the Northern Hemisphere. Kim *et al.* have now demonstrated that interannual variability in Arctic temperatures can also affect productivity in far-removed regions of North America, possibly countering the long-term trend.

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