Warm Arctic – Cold Continents: A reconsideration allowing for ozone feedbacks

Evaluation of the stratospheric pathway of the Arctic-midlatitude linkage with the Chemistry Climate Model EMAC

***F. Schmidt, U. Langematz**, Institute of Meteorology, Freie Universität Berlin*

In Short

- The Arctic region is undergoing an enhanced warming since two decades, but more cold weather extremes in winter occured over the continents.
- Does the Arctic warming can have a remote impact on the circulation in midlatitudes?
- We address this question with a Chemistry Climate Model and put emphasis on the role of the stratosphere and ozone feedbacks.

The continuously rising greenhouse gas (GHG) emissions are known to force a warming of the earth's atmosphere almost worldwide. In that respect, the Arctic region stands out because an accelerated warming has been observed accompanied by a dramatic sea ice decline. The average warming in the Arctic is about twice as high as for the rest of the globe. This phenomenon is known as Arctic Amplification (AA). On the contrary, the winter land temperatures in the Northern Hemisphere (NH), especially over eastern Eurasia, do not show a warming or even tend to have more cold weather extremes in winter [1]. These opposing trends since the 1990s raised the question whether the accelerated warming in the Arctic can have a remote impact on the circulation in the NH and the winter weather in midlatitudes.

Early studies focused on tropospheric processes regarding the changes in storm tracks mainly in the North Atlantic sector and changes in the characteristics in the jet stream. However, given the many still unresolved questions of the AA-midlatitude linkage, the role of the stratosphere recently attracted more and more attention [2]. A schematic of possible responses of AA is given in Figure [1]. Accounting for the stratospheric pathway in model studies we need a realistic presentation of the stratosphere. In particular, a model top at least in the mesosphere is required and stratospheric features such as the quasi-biennial oscillation (QBO) and ozone should be represented.

Ozone concentrations can be calculated by models with interactive chemistry but this is computationally demanding. On the other hand, a set of

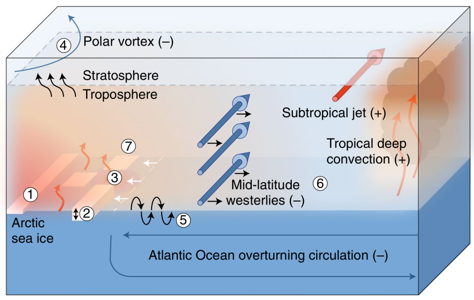

***Figure 1:** Schematic representation of the potential climate response to Arctic sea-ice loss from [3]. An illustrative cross-section from the North Pole to the Equator. Major atmospheric and oceanic circulation features that are weakened by Arctic sea-ice loss are shown by blue arrows and labelled with minus signs, and those that are strengthened by Arctic sea-ice loss are shown by red arrows and labelled with plus signs. Red/orange shading indicates regions of greatest warming in response to sea-ice loss. Circled numbers indicate sources of disagreement in model experiments (see [3] for more details). Not drawn to scale.*

ensemble simulations is required to attribute a circulation anomaly to Arctic sea ice change, because the signal is very weak compared to the internal variability. A lively debate about the existence of the proposed connection is still ongoing in the scientific community. The question arises whether the diverging results of the numerous model studies in the past result from a missing or incorrect representation of physical processes in the models [3]. So far, a comprehensive study of the stratospheric pathway of the Arctic-midlatitude linkage has not been performed with a chemistry-climate model (CCM) including interactive chemistry. Against this background, this project is focused on the questions:

1. How important is the integration of ozone chemistry in model studies? May neglecting important stratospheric processes have led to the controversial results in the past?
2. Is the observed response of midlatitude circulation change a significant response to AA or just internal variability?

The aim of this project is to obtain an improved understanding of key stratospheric dynamical processes in the Arctic-midlatitude linkages. Emphasis will be put on the mechanisms underlying the stratospheric pathway and how interactive stratospheric ozone chemistry may impact the identified mechanisms. First, we want to verify if the relation between the warm Arctic and the cold continents in winter emerges in a model with interactive chemistry. If that is the case, we will investigate what happens when the chemistry module is turned off and climatological ozone values are prescribed. As mentioned before, the signal is expected to be very weak compared to the interannual variability. Therefore, ensemble simulations are planned to determine the significance of the signal. Numerical model experiments are computed with the CCM EMAC (ECHAM/MESSy Atmospheric Chemistry) with and without interactive chemistry. There is much controversy about the relation of the AA and midlatitude weather and we intend to contribute with more insights specifically regarding the ozone feedback.

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https://www.geo.fu-berlin.de/met/

More Information

[1] Cohen, J., Screen, J., Furtado, J. et al. (2014). Recent Arctic amplification and extreme mid-latitude weather. *Nature Geoscience* **7**, 627–637. doi:10.1038/ngeo2234

[2] Cohen, J., Zhang, X., Francis, J. et al. (2020). Divergent consensuses on Arctic amplification influence on midlatitude severe winter weather. *Nat. Clim. Chang.* **10**, 20–29. doi:10.1038/s41558-019-0662-y

[3] Screen, J.A., Deser, C., Smith, D.M. et al. (2018). Consistency and discrepancy in the atmospheric response to Arctic sea-ice loss across climate models. *Nature Geosciience* **11**, 155–163. doi:10.1038/s41561-018-0059-y

Project Partners

D. Handorf from Alfred-Wegener-Institute (Potsdam), J. Ukita from Niigata University (Japan)