Disentangling Causal Pathways of the Stratospheric Polar Vortex
A Machine Learning Approach

Marlene Kretschmer

Abstract

With ongoing anthropogenic climate change, some types of weather and climate extremes are becoming more frequent and thus a proper understanding of their underlying mechanisms and their representation in climate models is critical. While the observed rise in heat-waves was anticipated, the occurrence of severe winter cold spells in the mid-latitudes over the past years was unexpected. Parts of Europe, Asia and the United States (US) have even experienced a cooling tendency in mean winter temperature, in sharp contrast to the overall global warming trend and the even-faster warming Arctic in particular. The underlying mechanisms behind this so-called warm Arctic - cold continents pattern are, however, not well understood. One major source of uncertainty is the limited understanding of dynamical atmospheric processes linked to cold-spells including their representation in climate models. Another compounding factor is the difficulty to assess cause-effect relationships with conventional statistical techniques.

This thesis aims to improve our understanding of winter circulation associated with midlatitudinal cold-air outbreaks by using novel data-driven techniques to find causal pathways. In particular, the role of the stratospheric polar vortex which denotes the strong circumpolar westerly flow in the winter-time Arctic stratosphere is addressed. In this context, novel machine learning approaches based on causal discovery algorithms and clustering techniques are applied and further developed to overcome common methodological limitations frequently faced in climate science.