Geophysical Research Abstracts
Vol. 18, EGU2016-5086, 2016
EGU General Assembly 2016

Using Causal Effect Networks to analyze different Arctic drivers of mid-latitude winter circulation

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In the past years, the northern hemisphere mid-latitudes have suffered from severe winters like the extreme 2013/2014 winter in the eastern USA. These cold spells were linked to a meandering upper tropospheric jet stream pattern and a negative Arctic Oscillation Index (AO). However, the nature of the drivers behind these circulation patterns remains controversial. Various studies have proposed different mechanisms related to changes in the Arctic, most of them referring to a reduction in sea ice concentrations or increasing Eurasian snow cover. Here we introduce a novel type of time series analysis, called Causal Effect Networks (CEN) based on graphical models to assess causal relationships and their time-delays between different processes. We present the effect of different Arctic actors on winter circulation on weekly to monthly time-scales. Barents and Kara sea ice concentrations are detected to be important external drivers in the context of mid-latitude circulation, influencing winter AO via tropospheric mechanisms and through processes involving the Stratosphere. Eurasia snow cover is also detected to have a causal effect on sea level pressure in Asia, but its exact role on AO remains unclear. The CEN approach overcomes some difficulties in interpreting correlation analyses, complements model experiments for testing hypotheses involving teleconnections, and can be used to assess their validity.