Understanding Dynamical Links relevant for Extremes using Complex Networks and Machine Learning Algorithms

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Extreme Weather & Large-scale Circulation

Extreme weather is often linked to **anomalous large-scale circulation patterns** in the atmosphere. Extreme cold events in Europe or the US are often related to a breakdown of normally strong high-altitude winds circulating the North Pole (i.e. the **stratospheric polar vortex, PoV**), which causes cold air from the Arctic to move southwards. Such processes occur on multi-week timescales, potentially providing long-range **predictability**. Current atmosphere models often poorly capture such dynamical processes substantially contributing to the large uncertainties in future projections of regional climate.

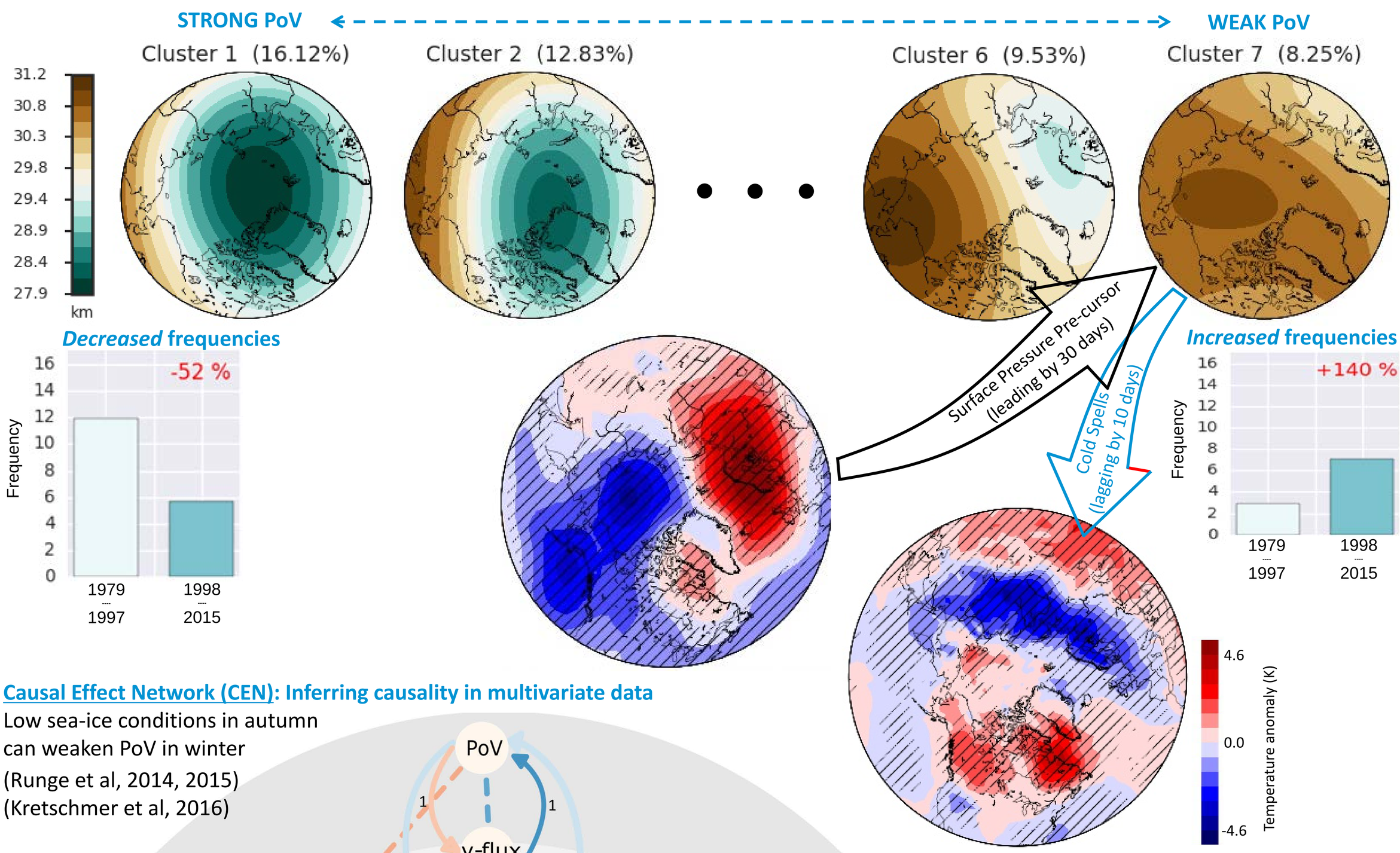
Machine Learning: Hierarchical Clustering and Causal Discovery Algorithms

Machine learning present promising tools to push our understanding in large-scale dynamical processes associated with extreme weather. Here we identify the **dominant polar vortex clusters** and show that **weak-states have become more common** in recent winters, accompanied by mid-latitude **cold spells**. Using causal discovery algorithms we show that weak states in late winter can be **causally linked to low Arctic sea-ice** concentrations in early winter/late autumn. This indicates that **rapid warming of the Arctic** and associated enhanced sea-ice melt likely increased the frequency of polar vortex breakdowns and thereby late winter cold spells.

Next steps

We will systematically apply these and similar machine learning tools to both the observed and modeled atmosphere (also as part of the recently funded project GOTHAM). Combining these methods with targeted simulations of **state-of-the-art atmosphere models**, will likely be fruitful in gaining fundamental insights, improving seasonal forecasts and reducing uncertainty in regional climate projections.

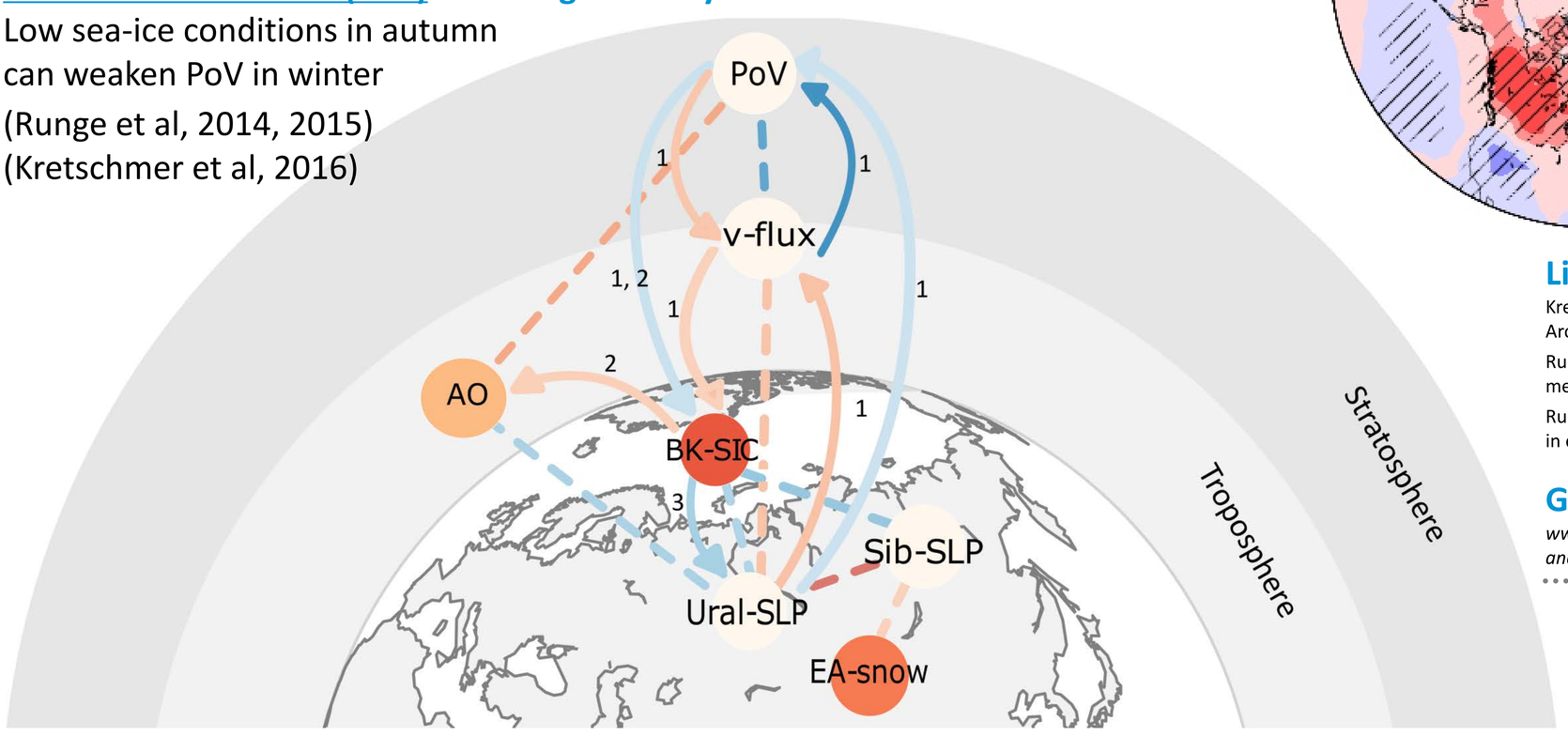
Hierarchical Clustering: 7 dominant patterns of Stratospheric Polar Vortex (PoV)



Causal Effect Network (CEN): Inferring causality in multivariate data

Low sea-ice conditions in autumn can weaken PoV in winter

(Runge et al, 2014, 2015)
(Kretschmer et al, 2016)



Literature

Kretschmer, Coumou, Donges, Runge, Using Causal Effect Networks to Analyze Different Arctic Drivers of Mid-latitude Winter Circulation, *J. Clim* (2016)

Runge, Heitzig, Marwan, Kurths , Quantifying causal coupling strength: A lag-specific measure for multivariate time series related to transfer entropy. *Phys. Rev.* (2012)

Runge et al. Identifying causal gateways and mediators in complex spatio-temporal systems. *Nat. Commun* (2015)

GOTHAM

www.belmontforum.org/funded-projects/gotham-globally-observed-teleconnections-and-their-role-and-representation

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