Nonlinear atmospheric response to Arctic sea-ice loss under different sea ice scenarios

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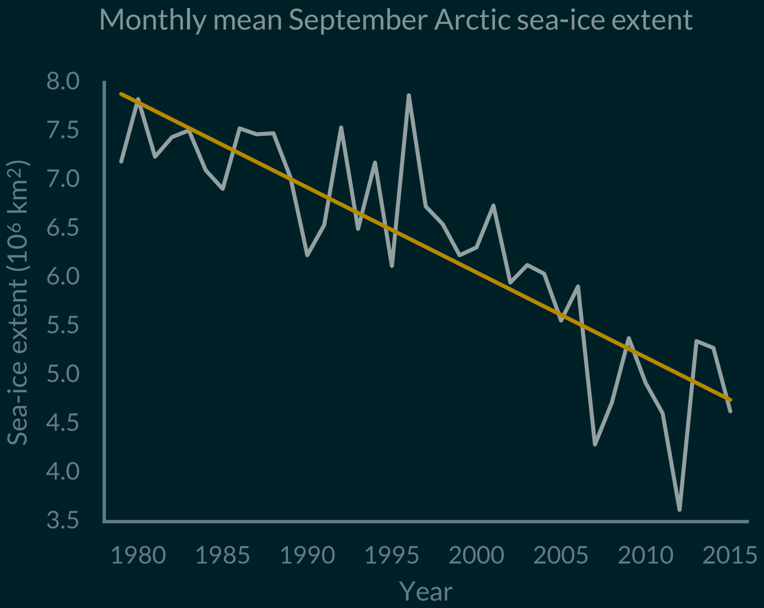
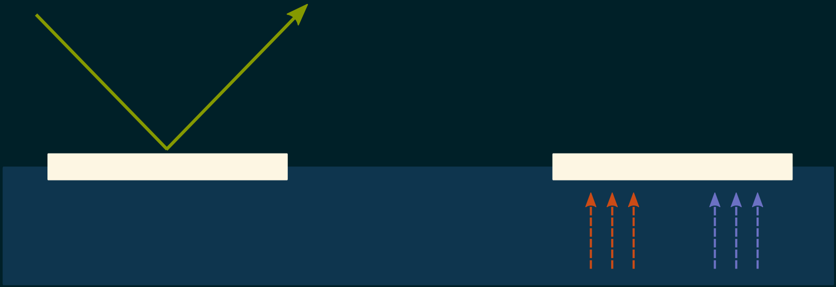
Advanced Data Assimilation and Predictability Techniques
The Pennsylvania State University

Arctic sea ice is rapidly declining



Sea ice plays a key role in the climate system



As a mirror
Reflects more solar radiation
than the underlying ocean

As an insulator
Reduces heat and moisture
fluxes to the atmosphere

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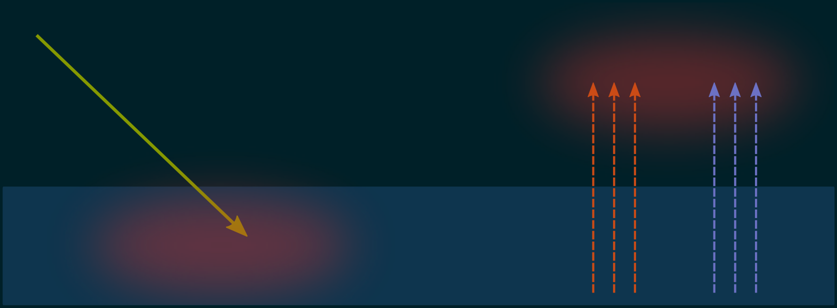

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Sea-ice loss may impact mid-latitude weather

Photo by Edward Stojakovic

Arctic sea-ice loss has been linked to more frequent extreme weather in the mid-latitudes, including extreme cold events

"...research on these linkages is still in its infancy, making it difficult to draw conclusions regarding their existence or their mechanisms"
— National Research Council, 2014

Approaching the challenge of sea-ice loss impacts

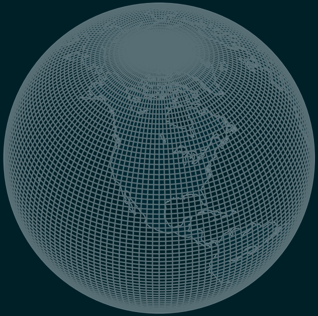
Objective

Quantify the atmospheric responses to Arctic sea-ice loss under varying sea-ice conditions

Approach

Model: NCAR Community Atmosphere Model 5.3

10 sea ice scenarios, each with 55 one-year simulations, yielding a 550-year realization of the climate

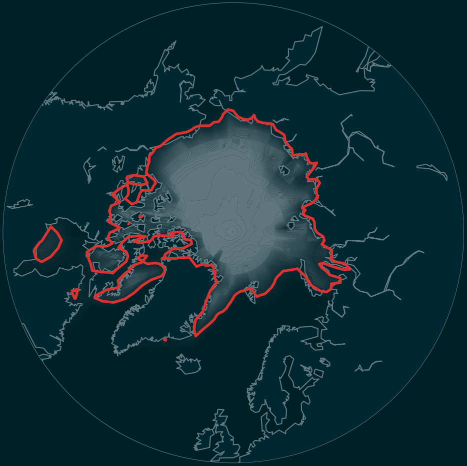


Horizontal resolution of $1.9^\circ \times 2.5^\circ$ and 30 vertical levels

Sea ice scenarios with gradually decreasing sea ice

-3 corresponds to September 2012 sea-ice conditions

Smaller $\alpha \Rightarrow$ less sea ice



September sea ice concentration

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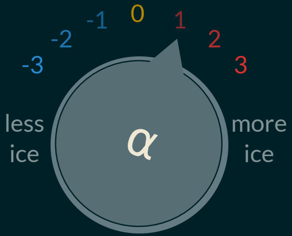

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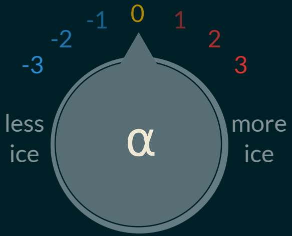

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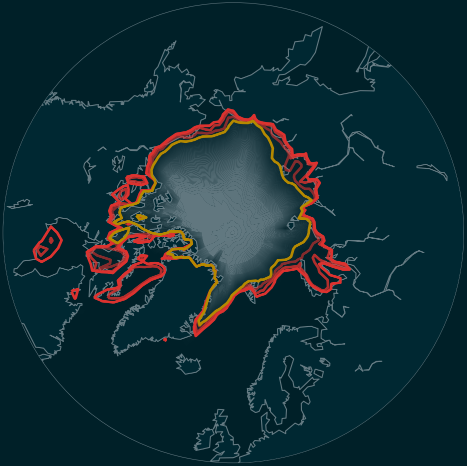

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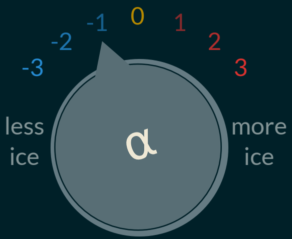

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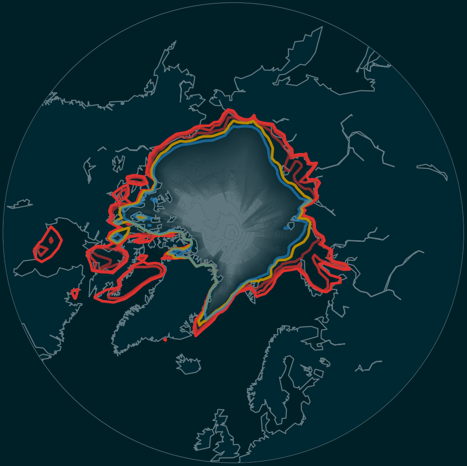

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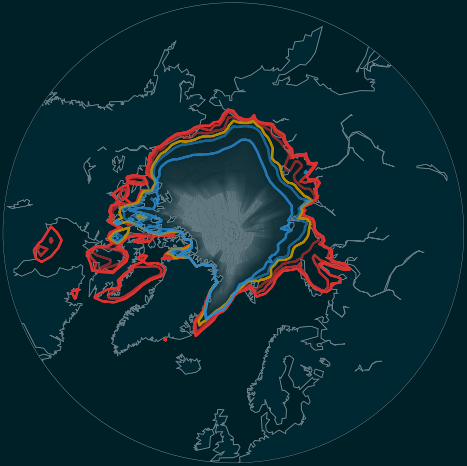

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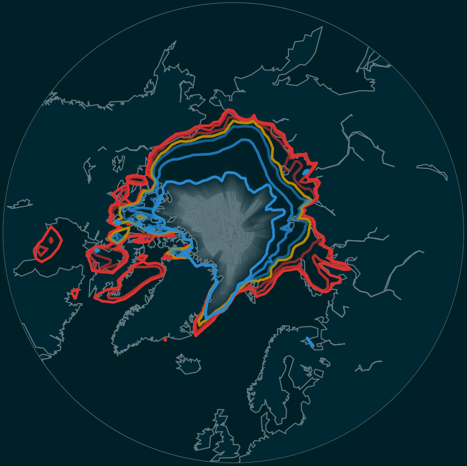
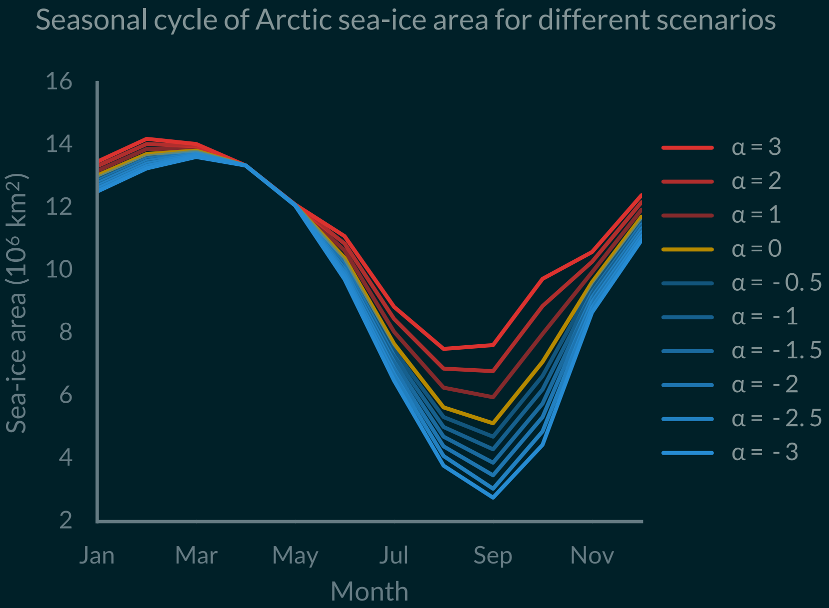
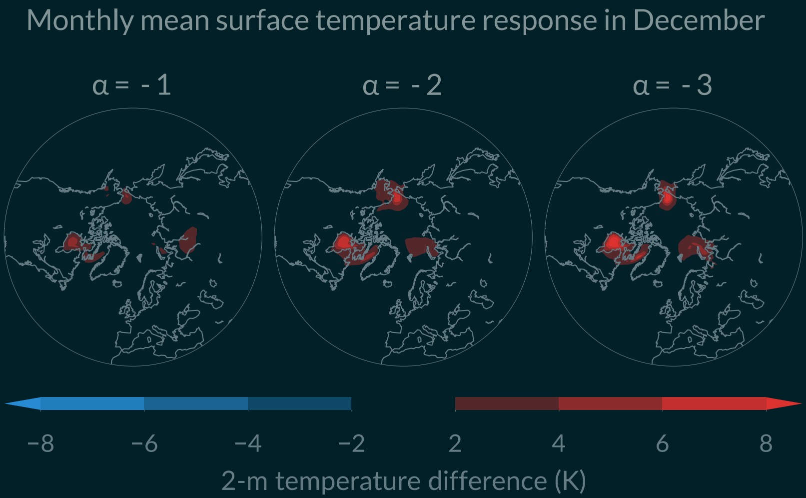


September sea ice concentration

A smooth transition to the perturbed state



Large warming over the Arctic



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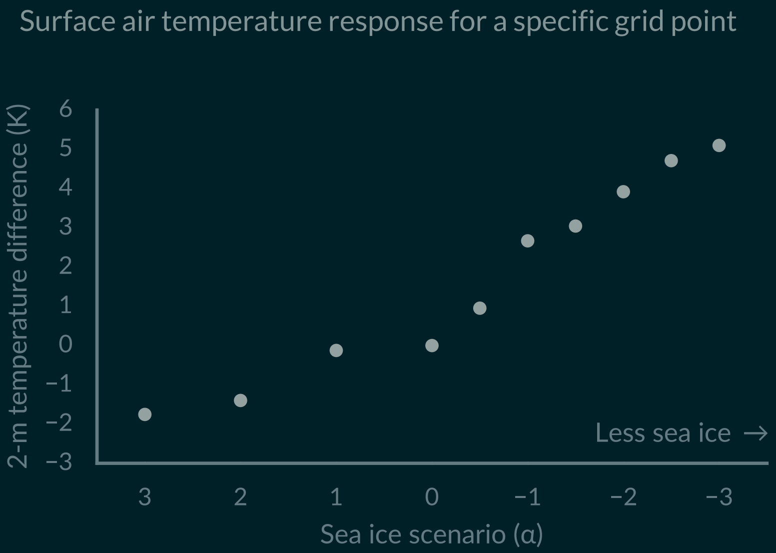

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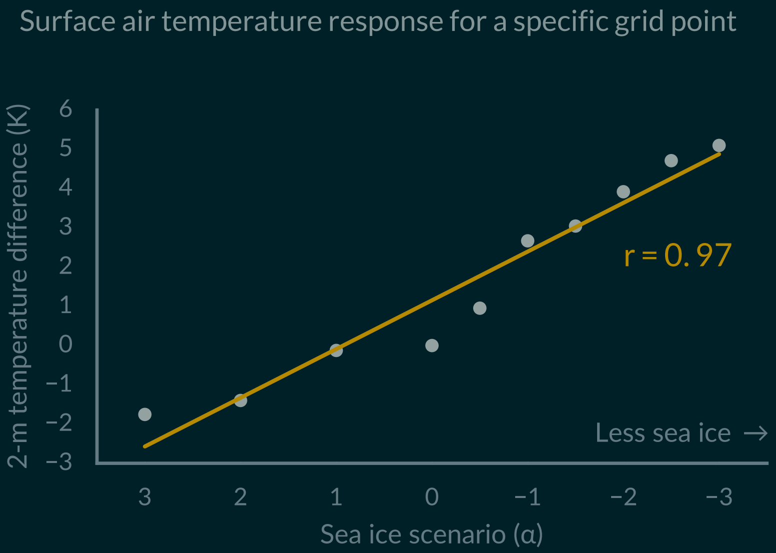
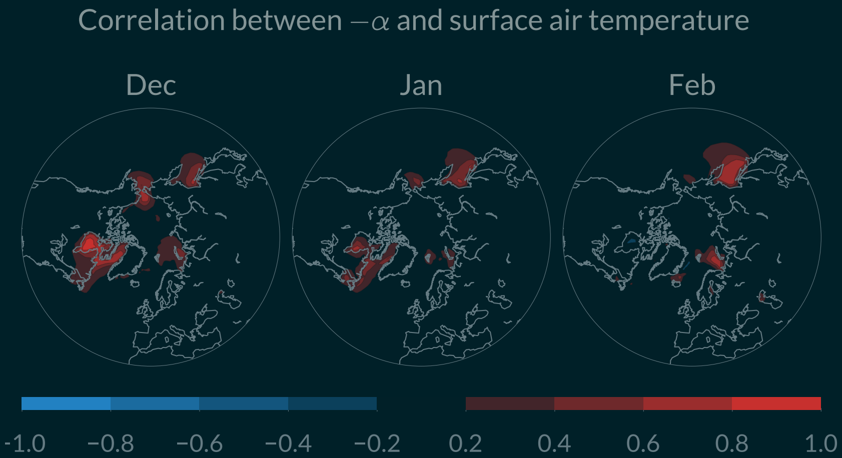
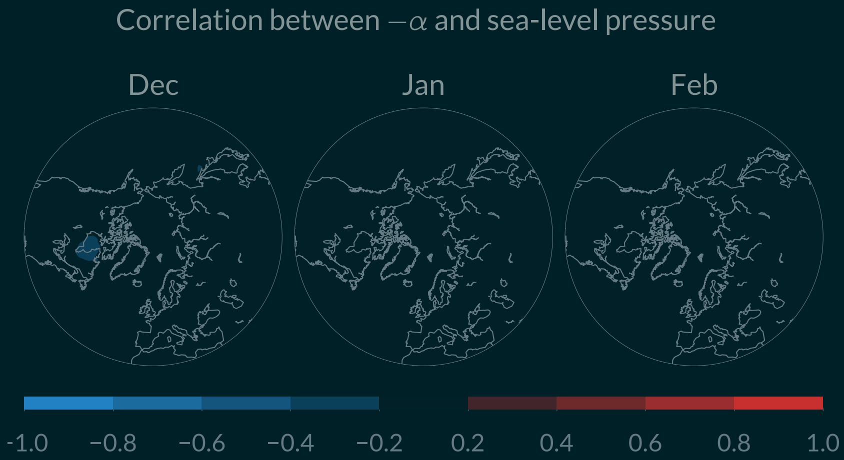


Strong correlation with temperature locally



Weak correlation with atmospheric circulation

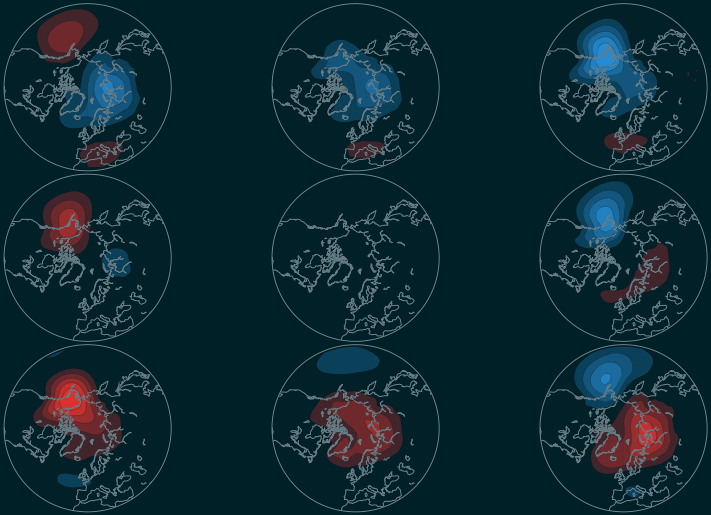


Daily data ⇒ a large amount of information

And 49,476 more...

Clustering of daily circulation anomaly pattens

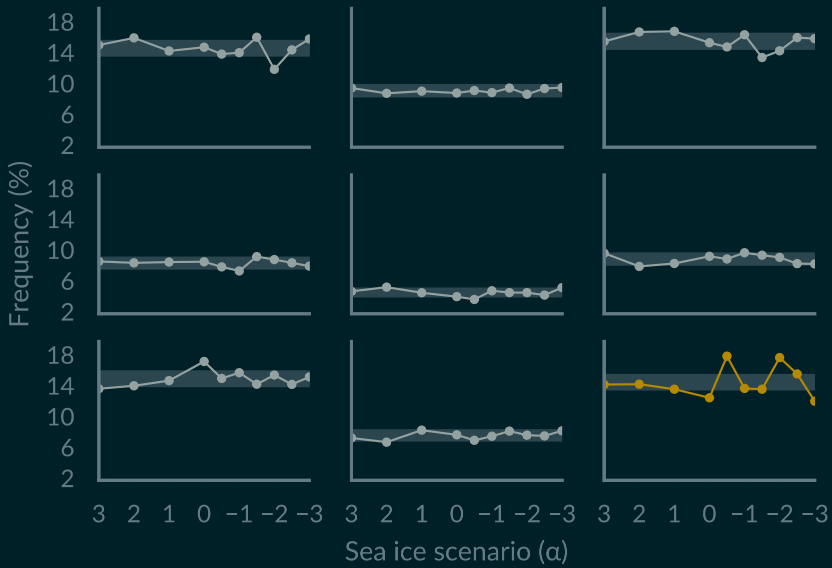
Use a self-organizing map to find 9 representative clusters



Sea-level pressure contoured every 2 hPa

Significant changes in some circulation patterns

Occurrence of circulation patterns for different scenarios



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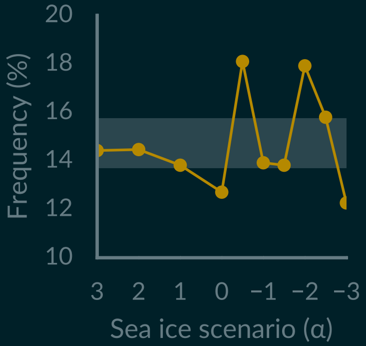
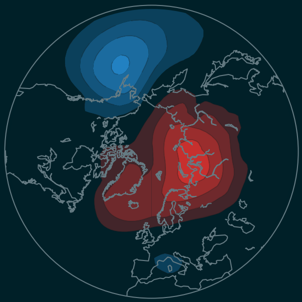
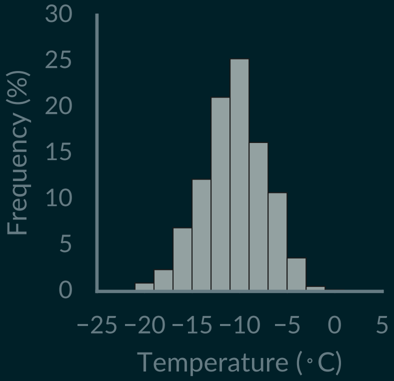
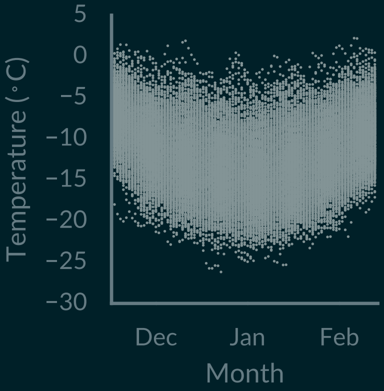




Increased frequency of a pattern that resembles the negative Arctic Oscillation associated with Arctic sea-ice loss, but the changes are highly nonlinear

Definition of extreme cold events





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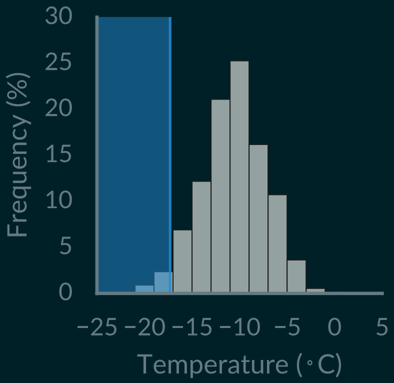
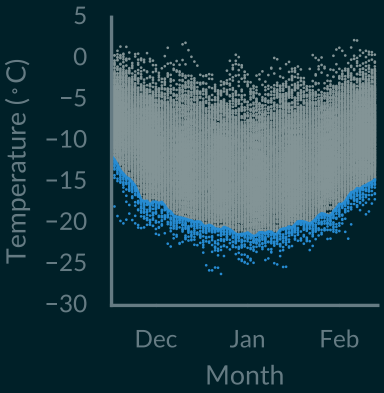
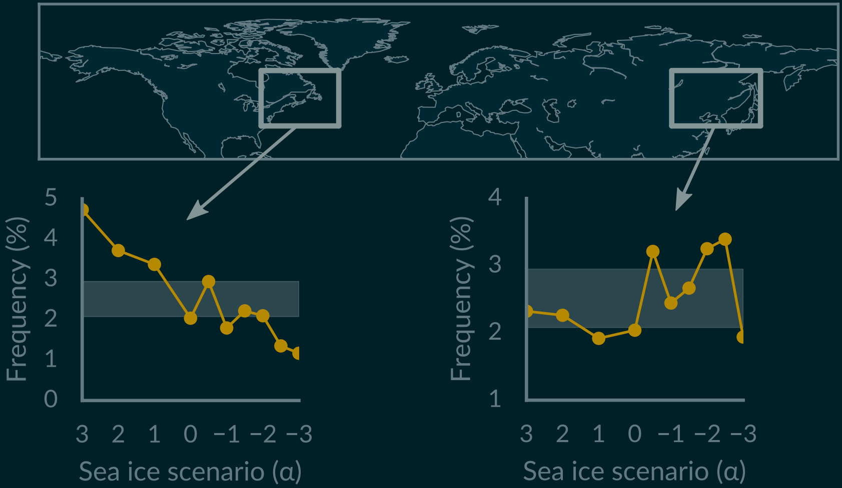




An extreme cold event is defined as a winter day when the average temperature falls below the 2.5th percentile of all ensemble members

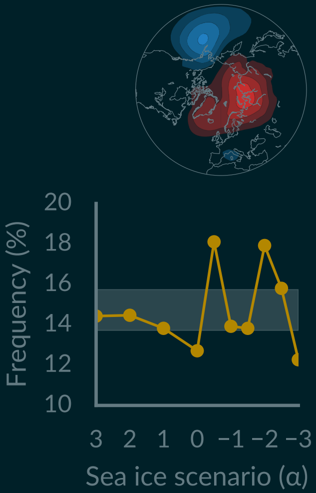
Linear and nonlinear changes in extreme cold events

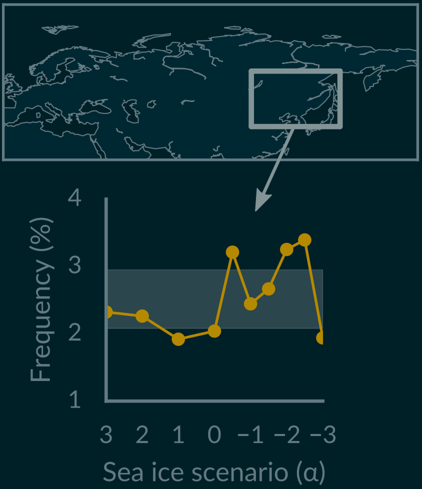


Linear decrease of extreme cold events in eastern North America

Nonlinear increase of extreme cold events in east Asia

Linear and nonlinear changes in extreme cold events

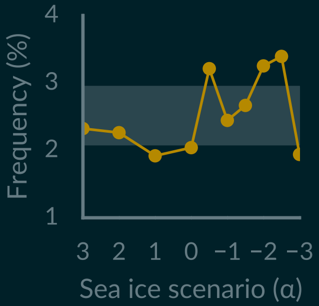




Changes in east Asia linked to more frequent negative AO

Nonlinear increase of extreme cold events in east Asia

Conclusions



Linear response

Warming of the Arctic

Decreased frequency of extreme cold events in eastern North America

Nonlinear response

More frequent negative AO pattern

Increased frequency of extreme cold events in east Asia

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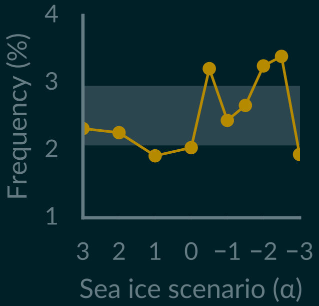
Conclusions



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Take-home message:

Important to consider nonlinearity of climate system when assessing future climate risks and impacts

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