Causal pathways of Arctic-midlatitude interaction

D06

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1. Summary

Research questions

This project will quantify the causal influence of Arctic amplification on midlatitude weather and climate and assess related risks in the face of global warming.

Q1 What are the causal pathways through which Arctic sea ice loss affects midlatitude weather?

Q2 How strong are the relative contributions of the different pathways in the observations and in state-of-the art climate models?

Q3 Which plausible effects of a changing Arctic on midlatitude weather can we expect in the future?

Contribution to CCA4, SQ2 and SQ3.

2. Research rationale

State-of-the-art

Controversial debate to what extent Arctic amplification influences midlatitude weather and climate:

- Observational studies suggest a strong influence
- Climate model simulations partly provide diverging results

Quantifying the causal effects of Arctic amplification on midlatitude circulation is difficult:

- Only short observational record
- Not clear to what extent climate models realistically represent the two-way Arctic-midlatitude interactions
- Lack of understanding of the underlying causal mechanisms with non-stationarities likely playing a role (also see Fig. 1)

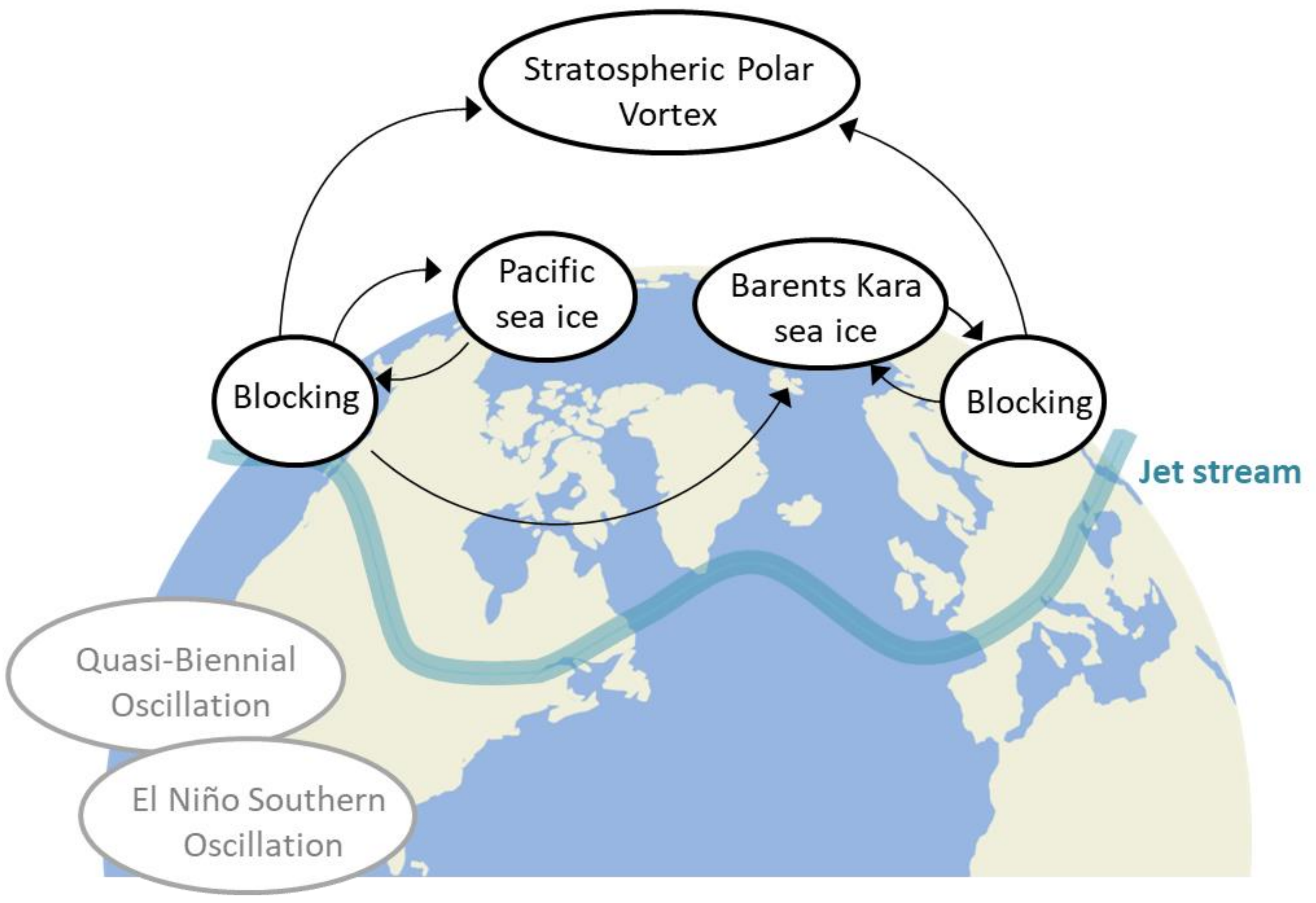

Fig. 1: Example of a causal network, showing the complex, partly two-way interactions between Arctic sea ice and large-scale atmospheric circulation in winter.

Preliminary work

- Causal-inference framework to analyse teleconnections
- Observational evidence for an influence of Barents and Kara sea ice loss on midlatitude circulation
- Evidence for a small causal effect of Barents and Kara sea ice in CMIP5 models
- Given the dramatic amount of expected sea ice loss, a small causal effect can have large implications with projected BK sea ice loss explaining the CMIP5 ensemble-mean change and the different signed polar vortex response

Hypothesis

Identifying and quantifying non-stationary Arctic-midlatitude linkages will help to reconcile model and observation studies and to constrain future projections of midlatitude climate.

3. Research plan phase III

Research focus

D06 will focus on two critical areas of Arctic-midlatitude interactions:

- The potential non-stationarity of the stratospheric pathway linked to the Quasi Biennial Oscillation (QBO) and El Niño Southern Oscillation (ENSO)
- Influence of Atlantic and Pacific-sector sea ice losses on high-latitude atmospheric blocking in both summer and winter

Data & Methods

- Observation and reanalysis data
- Use of large model ensembles (e.g. SMILES, CMIP6, PAMIP) to account for uncertainties
- Causal inference to isolate causal effects from data

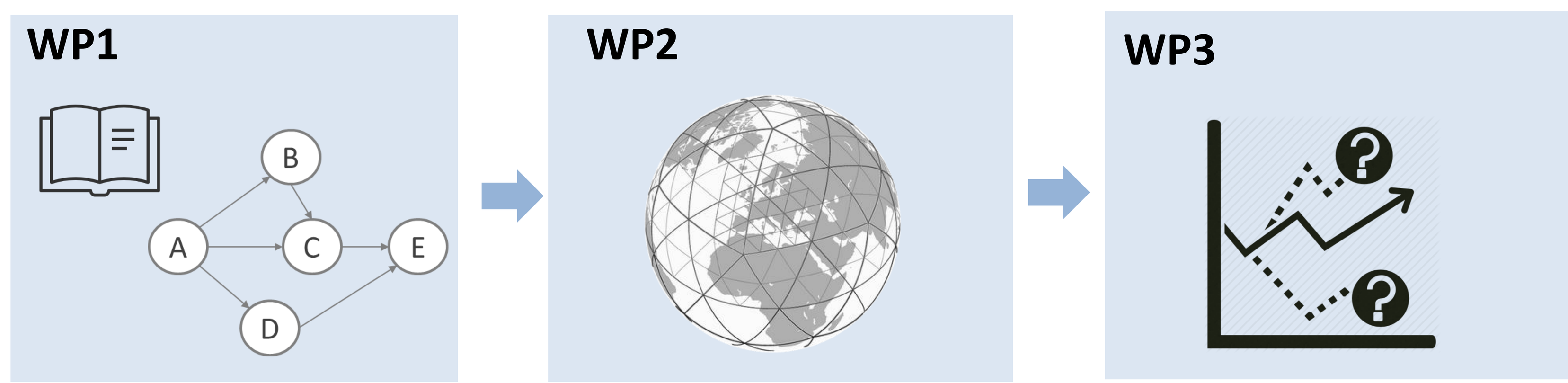

Fig. 2: Schematic representation of the workflow.

WP1 Possible causal pathways

Different hypotheses will be collected, synthesized and developed (→ **Q1**).

- Collect pathways based on literature and discussions with experts
- Establish causal networks of pathways

WP2 Quantifying causal effects in models and observation

The effects on midlatitude weather is quantified and uncertainties are estimated using large-ensemble climate model simulations (→ **Q2**).

- Identify causal effect based on network structure
- Quantify causal effects using linear and non-linear approaches

WP3 Assessing plausible futures

A range of statistical approaches are applied to assess plausible future effects of Arctic sea ice loss on midlatitude circulation (→ **Q3**).

- Constrain projections (e.g. through emergent constraints)
- Derive storylines (e.g. of drivers and of different effect sizes)

Project D06 will closely collaborate with Mercator Fellow **Judah Cohen**.

4. Major expected results

Advancing the understanding of Arctic-midlatitude linkages

- Robust process-based quantification of the contributions of sea ice changes on midlatitude weather and climate extremes in different seasons
- Identification and attribution of differences between model and observation studies
- Assessment of possible risks of Arctic amplification for future midlatitude weather and climate

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