Large-scale dynamical mechanisms of Arctic–mid-latitude linkages

D01

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1. Summary

Research questions

Q1 How sensitive is the simulated Arctic climate to changes of surface-related and gravity wave parameterizations?

Q2 How does a better representation of Arctic processes in a global climate model impact the representation of Arctic–mid-latitude linkages under present day climate?

Q3 Will a better representation of Arctic processes in a global climate model lead to significant changes in Arctic-mid-latitude linkages under future climate conditions?

D01 will substantially contribute to CCA2, SQ1, SQ2, & SQ3.

2. Achievements phase II

Studies of Arctic–mid-latitude linkages with global ICON model

- ICON sensitivity experiments with sea ice cover (SIC)/ sea surface temperature (SST)/ greenhouse gas concentrations (GHG) changes over **recent past**.
- Meridional energy transport and its changes are well represented in ICON (Fig. 1).
- Stratospheric pathway is well represented in ICON late-early sensitivity (Fig. 2).
- All forcings contribute to Arctic temperature change and stratospheric pathway (Fig. 2).

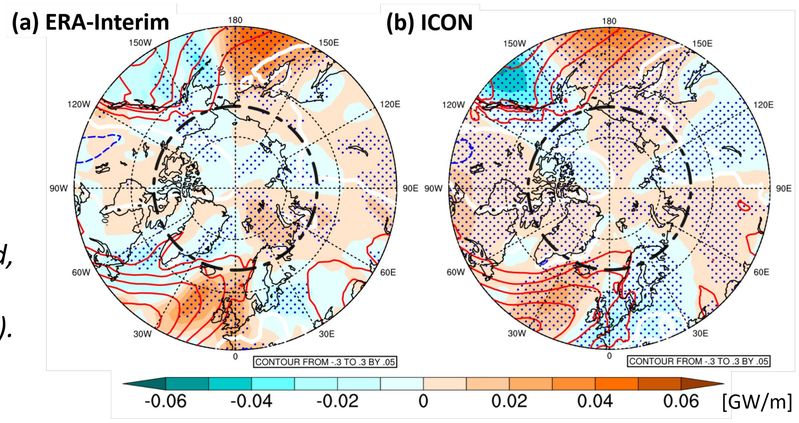


Fig. 1: Vertically integrated horizontal latent energy transport in winter (DJFM). Isolines: Climatology. Shading: Differences between (a) ERA-Interim late minus early period, (b) ICON late-early sensitivity, poleward (red), equatorward (blue).

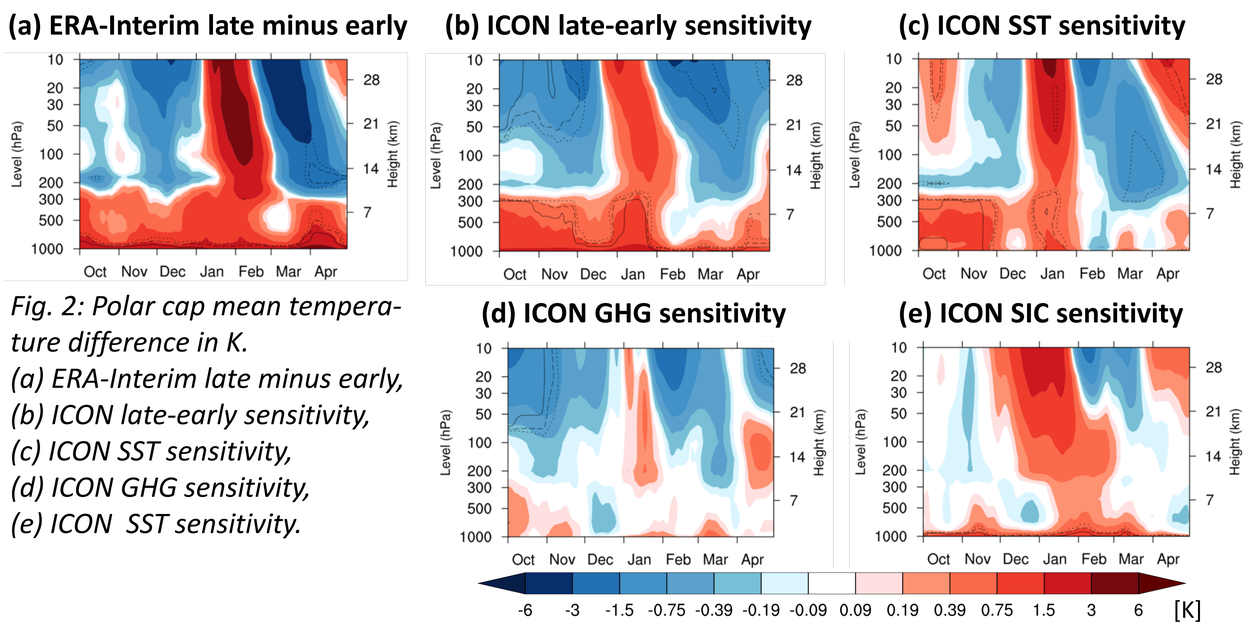


Fig. 2: Polar cap mean temperature difference in K. (a) ERA-Interim late minus early, (b) ICON late-early sensitivity, (c) ICON SST sensitivity, (d) ICON GHG sensitivity, (e) ICON SST sensitivity.

Machine learning based analysis of radiative forcing impact

- MPI-ESM experiment (E) with locally reduced forcing over Europe vs. control run (C).
- Clustering based on a physics-informed deep learning algorithm.
- Reduced local forcing favors NAO+ like pattern in later winter/spring and reduces frequency of Scandinavian blocking in fall.

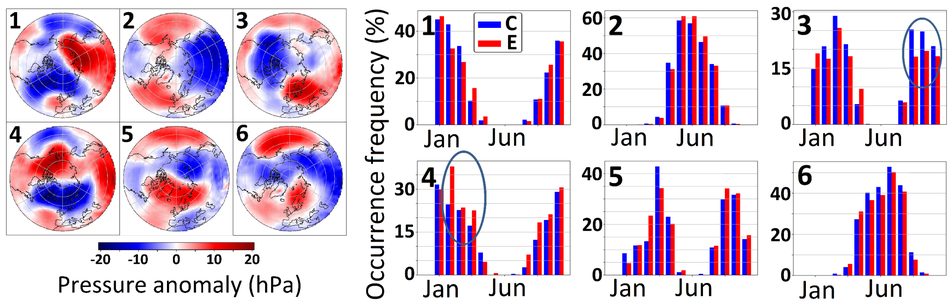


Fig. 3: Sea level pressure anomaly patterns (left) and occurrence frequencies for experiment (E) and control (C) run (right).

Hypothesis

Advanced representations of Arctic processes in a global climate model improve the representation of Arctic–mid-latitude linkages

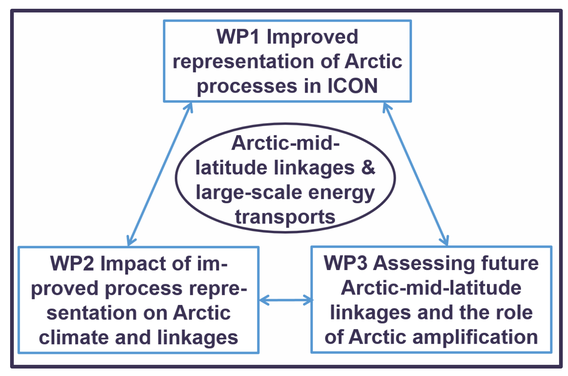
3. Research plan phase III

WP1 Improved representation of Arctic processes in the ICON model

- Implementation of surface related parameterizations developed within CCA2.
- Implementation of improved gravity wave drag parameterizations.
- Ensemble sensitivity simulations for present-day and future climate conditions.

WP2 Parameterization evaluation and impact analysis

- Process-based analysis of the impact of improved parameterizations in ICON on Arctic climate and Arctic–mid-latitude linkages.
- Quantification of the relative importance of improved parameterizations, and recommendations for an ICON version with improved representation of Arctic processes.



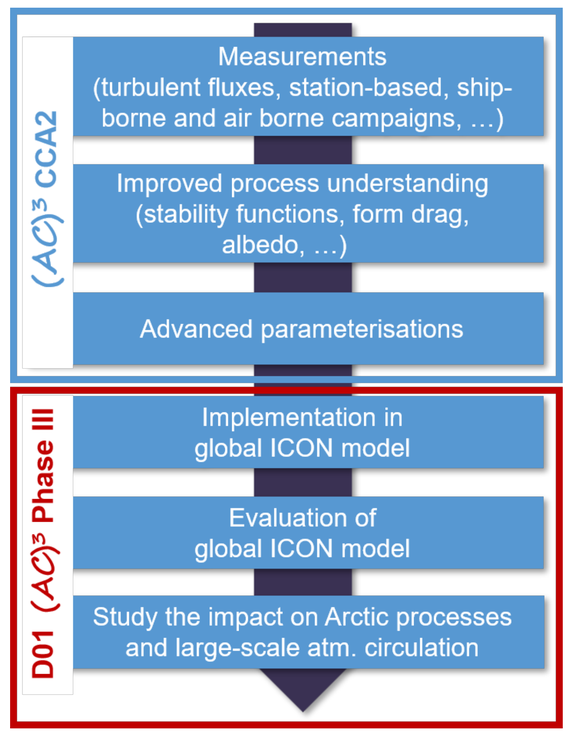
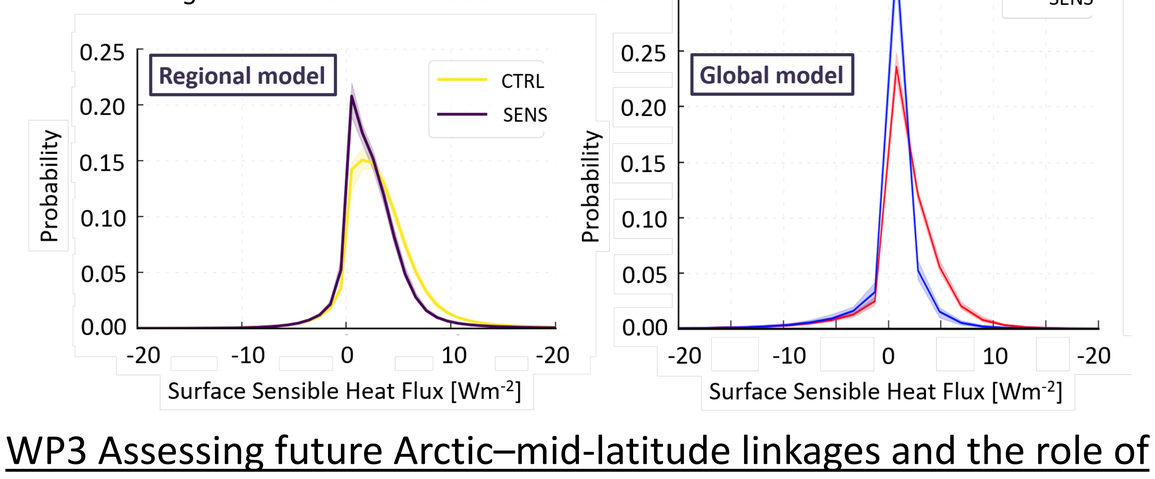


Fig. 4: Process-based boundary layer analysis. Change in PDF for sensible heat flux over sea ice and clear sky conditions in winter with different parametrizations for turbulent fluxes under stable stratification. Left: Regional Arctic model HIRHAM5. Right: Global climate model ECHAM6.



WP3 Assessing future Arctic–mid-latitude linkages and the role of Arctic amplification

- Analysis of the sensitivity of future Arctic climate and Arctic amplification changes to improved parameterizations in ICON.
- Quantifying changes in future Arctic–mid-latitude linkages due to improved Arctic parameterizations.
- Characterizing the range of future changes of pathways relevant for Arctic–mid-latitude linkages including CMIP6.

4. Legacy & Major expected results

Project Legacy

- Evaluated ICON version with improved representation of Arctic processes.
- Sensitivity runs and long-term runs for community use.

Major expected results within phase III

- Quantitative estimates of impact of new parametrizations on simulated Arctic climate change.
- Changes in future Arctic–mid-latitude linkage.
- Estimates for the range of future changes of pathways relevant for Arctic–mid-latitude linkages.

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