Atmospheric responses to Arctic sea ice loss in a high-top atmospheric general circulation model

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Abstract

Rapid Arctic warming and sea ice decline in recent decades might have profound impacts on midlatitude weather and climate. This study uses a high-top atmospheric general circulation model - Whole Atmosphere Community Climate Model version 6 (WACCM6) - to investigate the atmospheric responses to the Arctic sea ice reduction, including impacts on mid-latitude blocking and cyclones. The high-top configuration (top layer at about 100 km or 0.001 hPa) together with the finer vertical resolution (70 layers) in WACCM6 allow more realistic representation of stratosphere-troposphere interactions. The sea ice impact during 1979-2015 is obtained by comparing ensemble simulations forced by daily observational sea ice concentration (SIC) and sea surface temperature (SST) to simulations where the time-varying SIC is replaced by a daily SIC climatology. A series of SIC-SST adjustments are performed to minimize unrealistic SIC and SST forcings used in the simulations. Each ensemble consists of 30 members with slightly different atmospheric initial conditions in order to separate forced atmospheric responses from internal model spread.

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1. Introduction and model description

Rapid Arctic warming and sea-ice decline in recent decades might have profound impacts on midlatitude weather and climate. This study uses Whole Atmosphere Community Climate Model version 6 (WACCM6) to investigate the atmospheric responses to the Arctic sea-ice reduction. The high-top configuration and finer vertical resolution of WACCM6 allow more realistic representation of stratosphere-troposphere interactions.

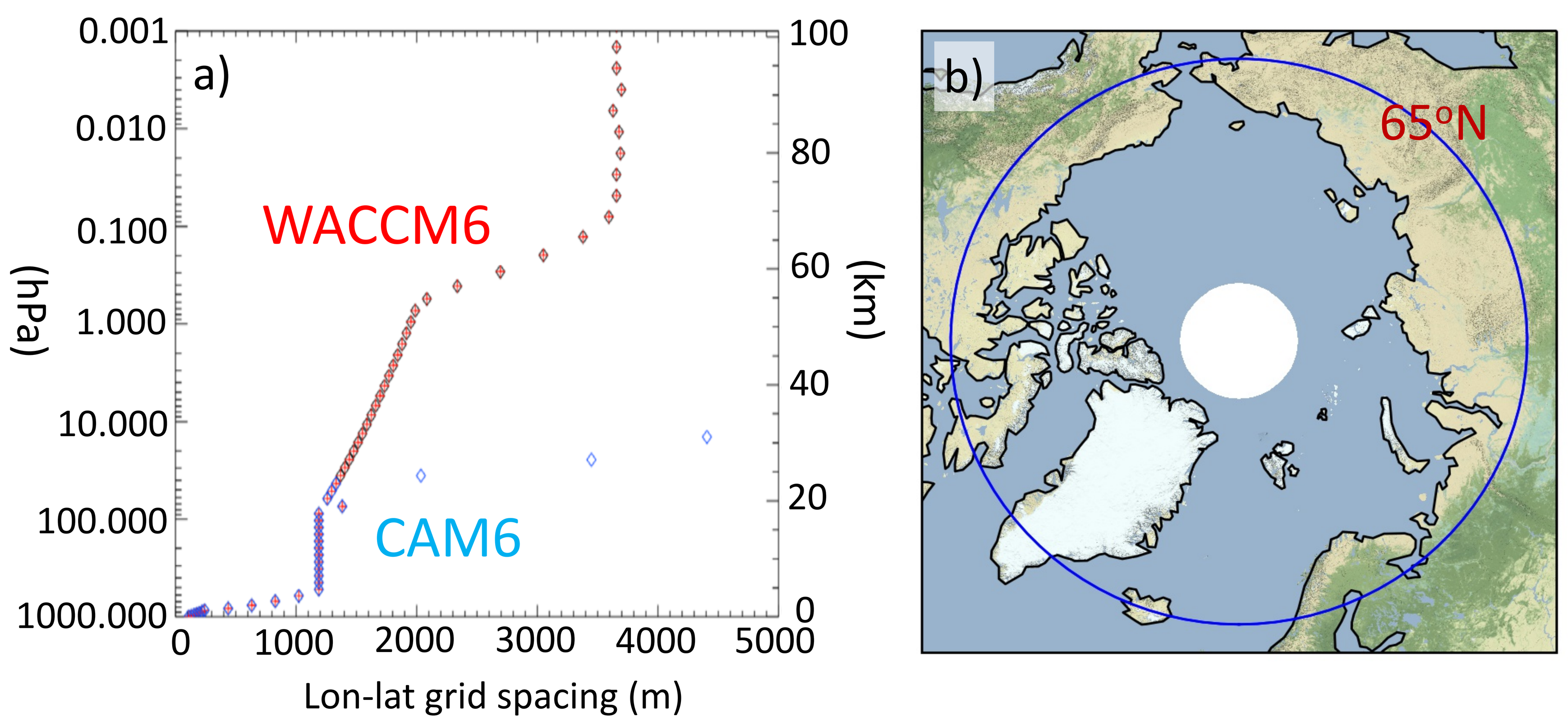

Fig 1. (a) Vertical and horizontal grids of WACCM6 (CAM6) adopted from J. Richter's presentation at NCAR. (b) The Arctic geographic domain.

2. Experiment design

EXP1	EXP2
Time-varying Arctic SIC	*Climatology Arctic SIC*
Time-varying Global SST	*Time-varying Global SST*

- 1979-2014 AMIP-type simulations forced with daily sea-ice concentration (SIC) and sea surface temperature (SST) from Met Office Hadley Centre, with GHG concentration and aerosol given by CMIP6.
- 12 members for EXP1 and 7 members for EXP2.
- **Response to Arctic Sea-ice decline = EXP1 minus EXP2**

3. ~60% of the annual-mean Arctic warming trend can be attributed to the sea-ice decline.

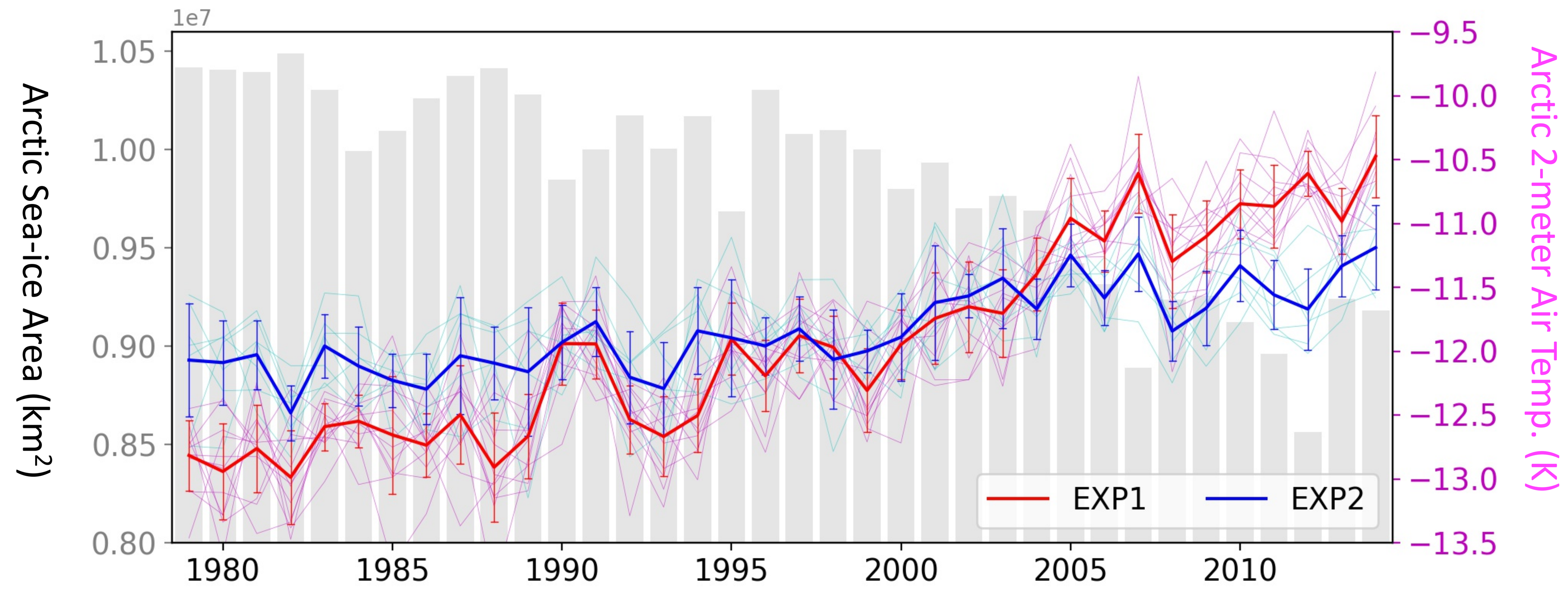

Fig 2. Annual-mean Arctic sea-ice and 2-meter air temperature time series.

	Sea-Ice Area (km²)	2-meter Air Temp. (K)	Surface Heat Fluxes (W/m², "+" upward)	
Linear Trend (units per year)	-43177	0.068 ± 0.0041	0.020 ± 0.034	← EXP1
	0	0.026 ± 0.0046	-0.076 ± 0.018	← EXP2
Standard Deviation (without trend)	231425	0.40 ± 0.039	2.722 ± 0.280	← EXP1
	0	0.36 ± 0.037	2.742 ± 0.294	← EXP2

4. Zonal-mean temperature responses to Arctic sea-ice decline are primarily confined in lower troposphere.

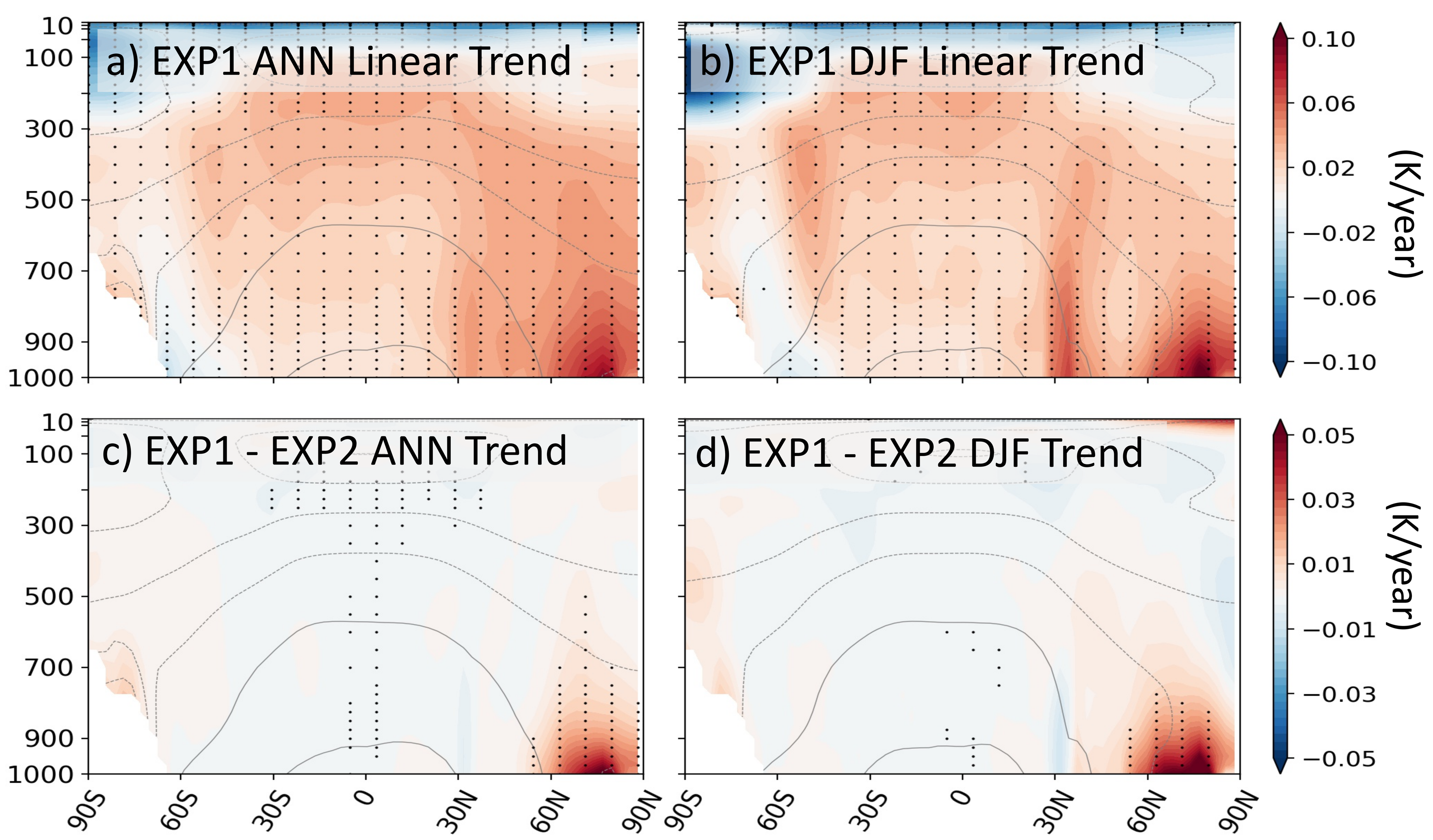

Fig 3. (a), (b) ANN and DJF zonal-mean temperature linear trends. (c), (d) Responses to sea-ice decline in ANN and DJF. Dots: significance at 5%

5. The warm Arctic-cold continent pattern in surface air temperature trends is not robust.

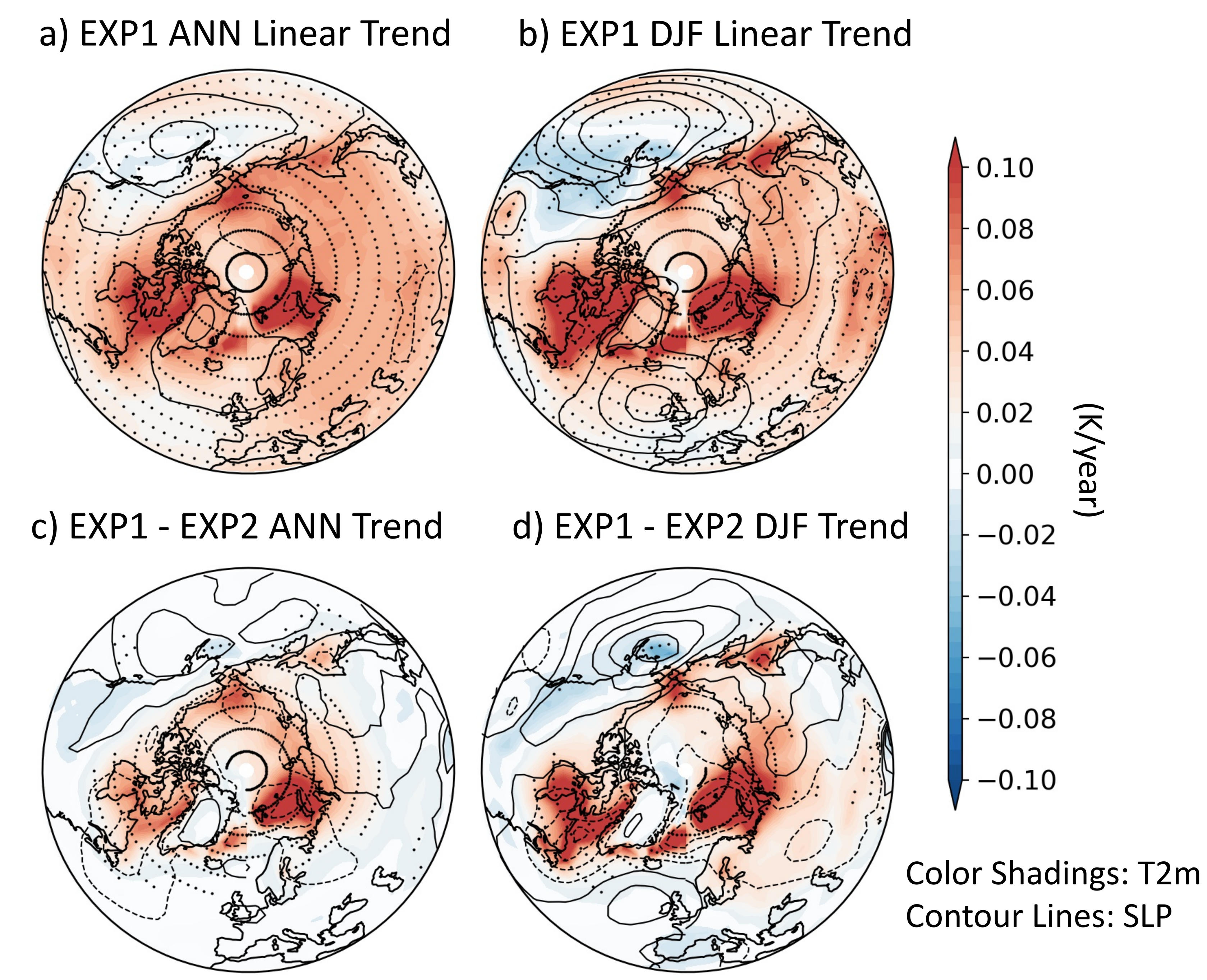

Fig 4. (a), (b) ANN and DJF lon-lat 2-meter temperature trend maps. (c), (d) Responses to sea-ice decline in ANN and DJF. Dots: significance at 5%

6. Summary

- ~60% of the Arctic near-surface warming trend in 1979-2014 can be attributed to sea-ice reduction and associated surface heat flux changes.
- The remote impacts of Arctic sea-ice reduction reach to Eurasia, where warmer air temperatures appear in lower troposphere.
- This pan-Eurasian warming pattern is distinct from the so-called warm Arctic-cold continent pattern.

7. Acknowledgements

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