Arctic sea ice loss weakens Northern Hemisphere summertime storminess but not until the late 21st century

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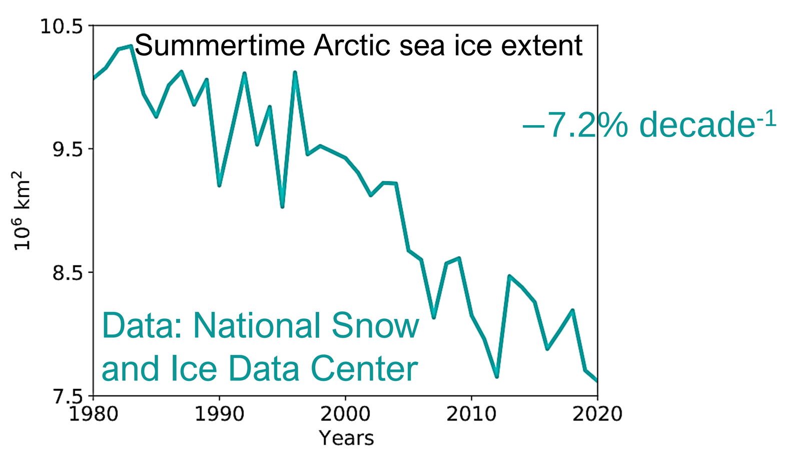
Link to paper Kang et al. (2023) GRL

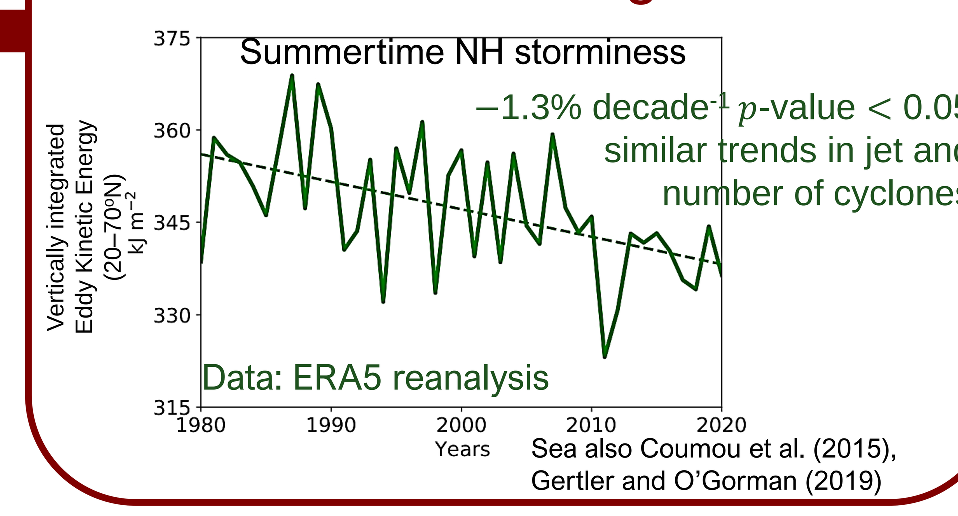
How Arctic sea ice loss and summertime storminess are connected is currently unclear

Summertime Arctic sea ice is declining rapidly



- Previous work mostly focused on wintertime circulation response to Arctic sea ice loss but not summer (e.g., Screen et al. 2018, *Nat. Geosci*.).
- Previous work hypothesized the weakening is related to Arctic Amplification (Coumou et al. 2018, *Nat. Comms*.), but its connection to Arctic sea ice loss is not quantified.

Summertime NH circulation is weakening



See also Coumou et al. (2015), Gertler and O'Gorman (2019)

Key Questions

1. Does Arctic sea ice loss significantly contribute to the present-day weakening of summertime storminess?
2. How does future Arctic sea ice loss impact summertime storminess?

1. Present-day Arctic sea ice loss and Arctic Amplification has not contributed significantly to the present-day weakening of summertime storminess

- **Approach**

-To quantify the time-evolving impact of Arctic sea ice loss on summertime circulation, **transient** Arctic sea ice loss simulation is used (Sun et al. 2018).

	Ensemble	Years	Radiative Forcing	Arctic sea ice	
RCP	5 members	1970–2090	RCP8.5	Freely evolving	Impact of anthropogenic forcing
RCP_ICE1990	5 members	1990–2090	RCP8.5	Fixed at 1990	Impact of anthropogenic forcing without Arctic sea ice loss
ΔICE (RCP – RCP_ICE1990)	5 members	1990–2090		Freely evolving	Impact of Arctic sea ice loss

Summertime NH storminess is quantified in the transient simulations

-RCP simulation captures observed Arctic sea ice loss

- **Present-day Arctic sea ice loss does not contribute to summertime storminess weakening**

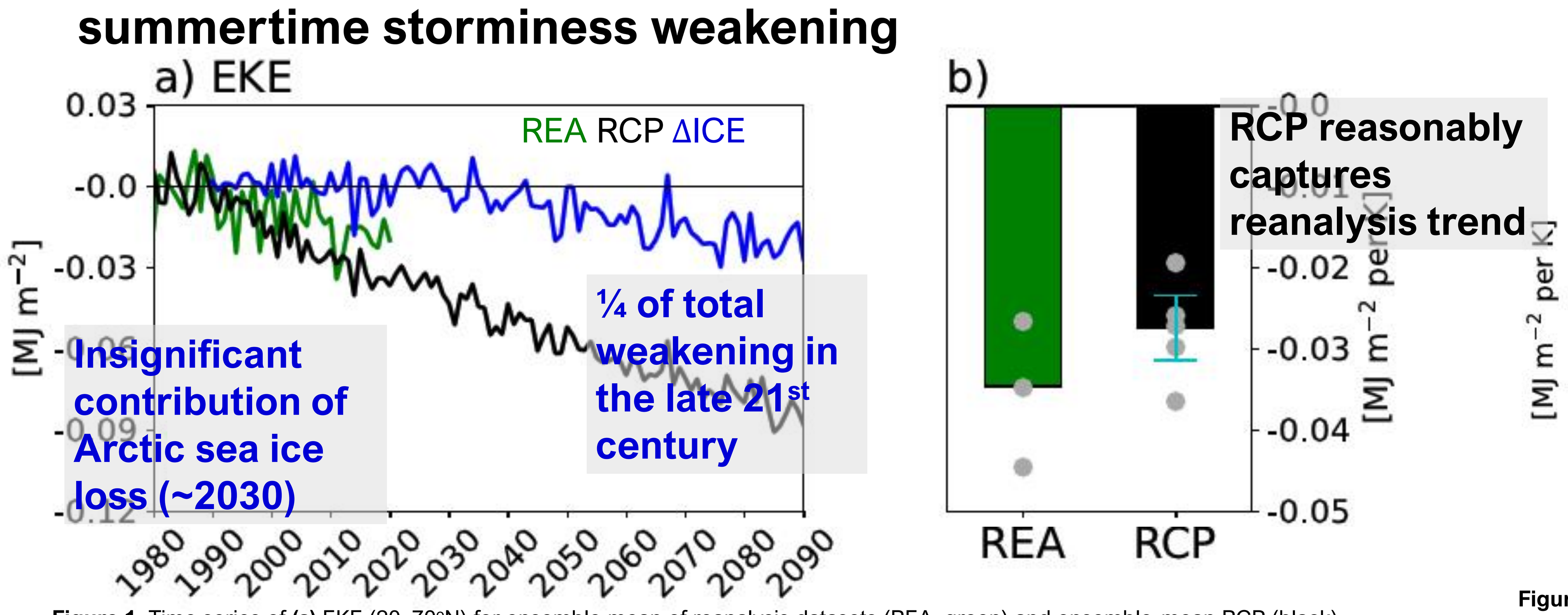


Figure 1. Time series of **(a)** EKE (20–70°N) for ensemble mean of reanalysis datasets (REA, green) and ensemble-mean RCP (black) and ΔICE (blue) simulations with respect to the 1980–90 climatology. **(b)** Linear trends from 1980 to 2020 per degree K of global-mean warming for EKE for ensemble mean of reanalysis datasets (REA, green) and ensemble mean of RCP simulations (black). Statistically significant trends at the 95% confidence level for individual reanalysis datasets and RCP simulation ensemble members are shown in filled gray circles. The error bars indicate the 95% confidence interval for the ensemble-mean trend.

- **Present-day summertime storminess weakening is not impacted by Arctic Amplification**

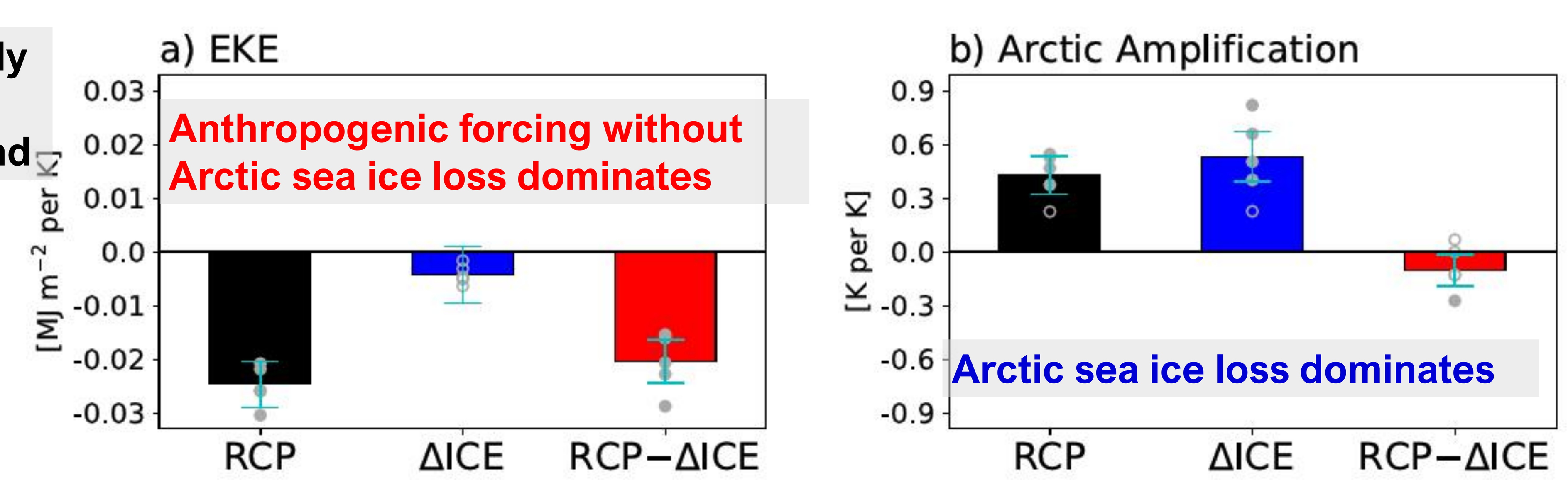


Figure 2. Linear ensemble-mean trends from 1990 to 2020 per degree K of global-mean warming of **(a)** EKE (20–70°N) and **(b)** Arctic Amplification defined as the difference between Arctic (65–90°N) and NH (0–90°N) near-surface temperature following (Blackport & Screen, 2020) for RCP (black), ΔICE (blue), and RCP−ΔICE (red) simulations. Statistically significant trends at the 95% confidence level for individual ensemble members are shown in filled gray circles. The error bars indicate the 95% confidence interval for the ensemble-mean trend.

2. Future Arctic sea ice loss weakens summertime storminess in the presence of ocean coupling

- **Approach**

-In the annual-mean, sea ice loss weakens equator-to-pole energy gradient due to surface turbulent flux changes following polar albedo reduction.
-To test whether similar mechanism operates in NH summer, **equilibrium** Arctic sea ice loss simulations **with and without ocean coupling** is used.

	Sea ice loss	Sea ice	SST
5 Coupled simulations	Mid-to-late 21st century	Controlled	Coupled
8 Uncoupled simulations	Mid-to-late 21st century	Prescribed	Prescribed

Summertime NH storminess is quantified for coupled and uncoupled model ensembles

Simulations details
Coupled
WACCM4 (Ghost flux)
Blackport and Kushner (2017), *J. Clim.* (Albedo)
Sun et al. (2018), *J. Clim.* (Ghost flux)
England et al. (2020), *Nat. Geosci.* (Ghost flux)
Uncoupled
Sun et al. (2015), *J. Clim.*
PAMIP Smith et al. (2019), *GMD*
AWI-CM-1-1-MR, CESM2, CanESM5, IPSL-CM6A-LR, HadGEM3-GC31-MM, MIROC6, TaiESM1

- **Summertime storminess weaken significantly in response to future Arctic sea ice loss only in the coupled simulations**

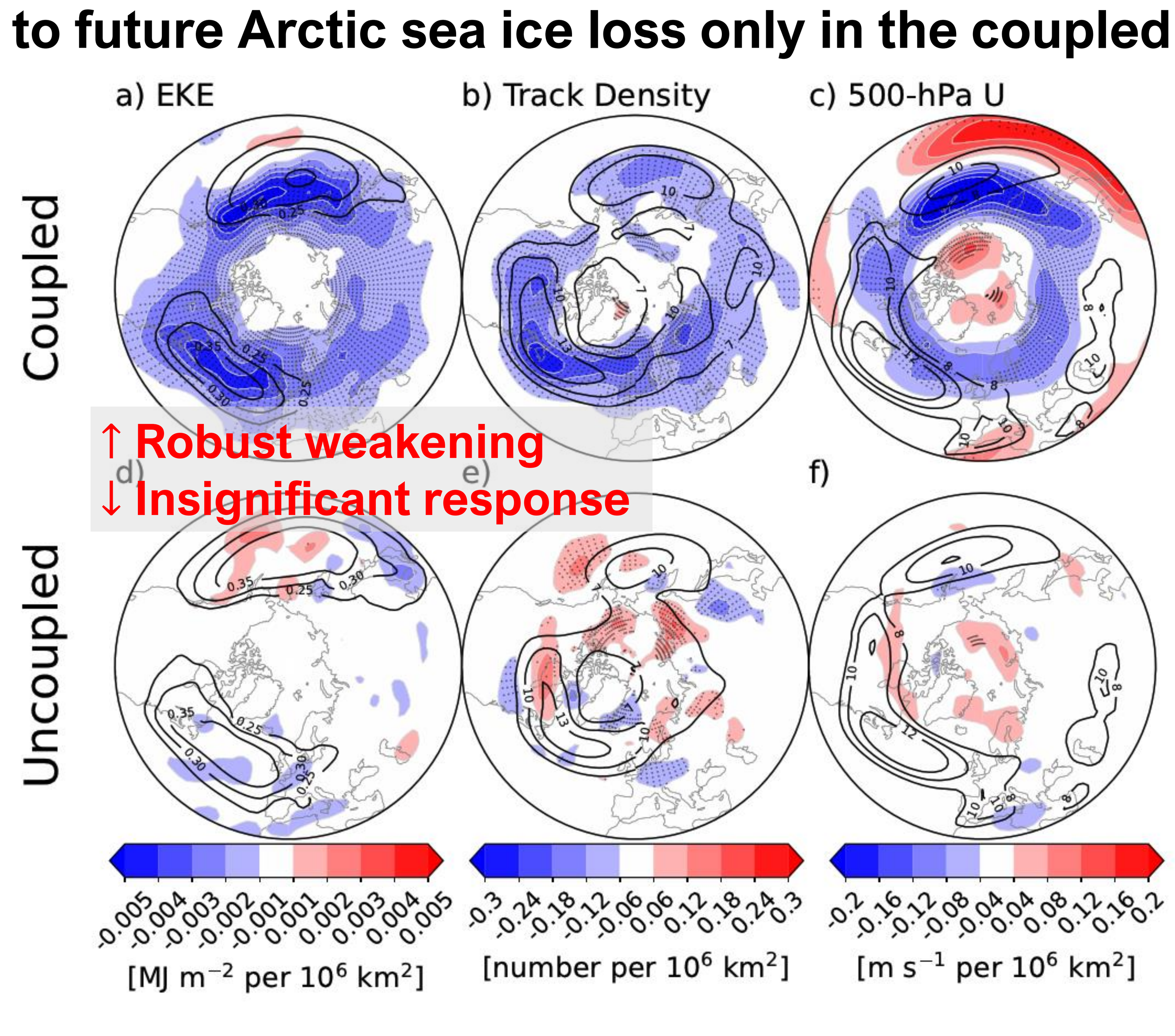


Figure 3. Response of summertime **(a,d)** vertically-integrated EKE, **(b,e)** track density, and **(c,f)** 500-hPa zonal wind to future Arctic sea ice loss in **(a–c)** coupled and **(d–f)** uncoupled climate model simulations. In all panels but **(b)**, stipples indicate where all models agree in the sign of the response. In **(b)**, stipples represent statistically significant responses at the 95% confidence level using a two-sided Student's t-test as track density response is calculated from a single model (CM3: 2061–90). The summertime climatology is shown in black contours in units of **(a,d)** MJ m^{-2}, **(b,e)** number, and **(c,f)** m s^{-1}.

- **Equator-to-pole energy and temperature gradient weaken significantly in response to future Arctic sea ice loss only in the coupled simulations**

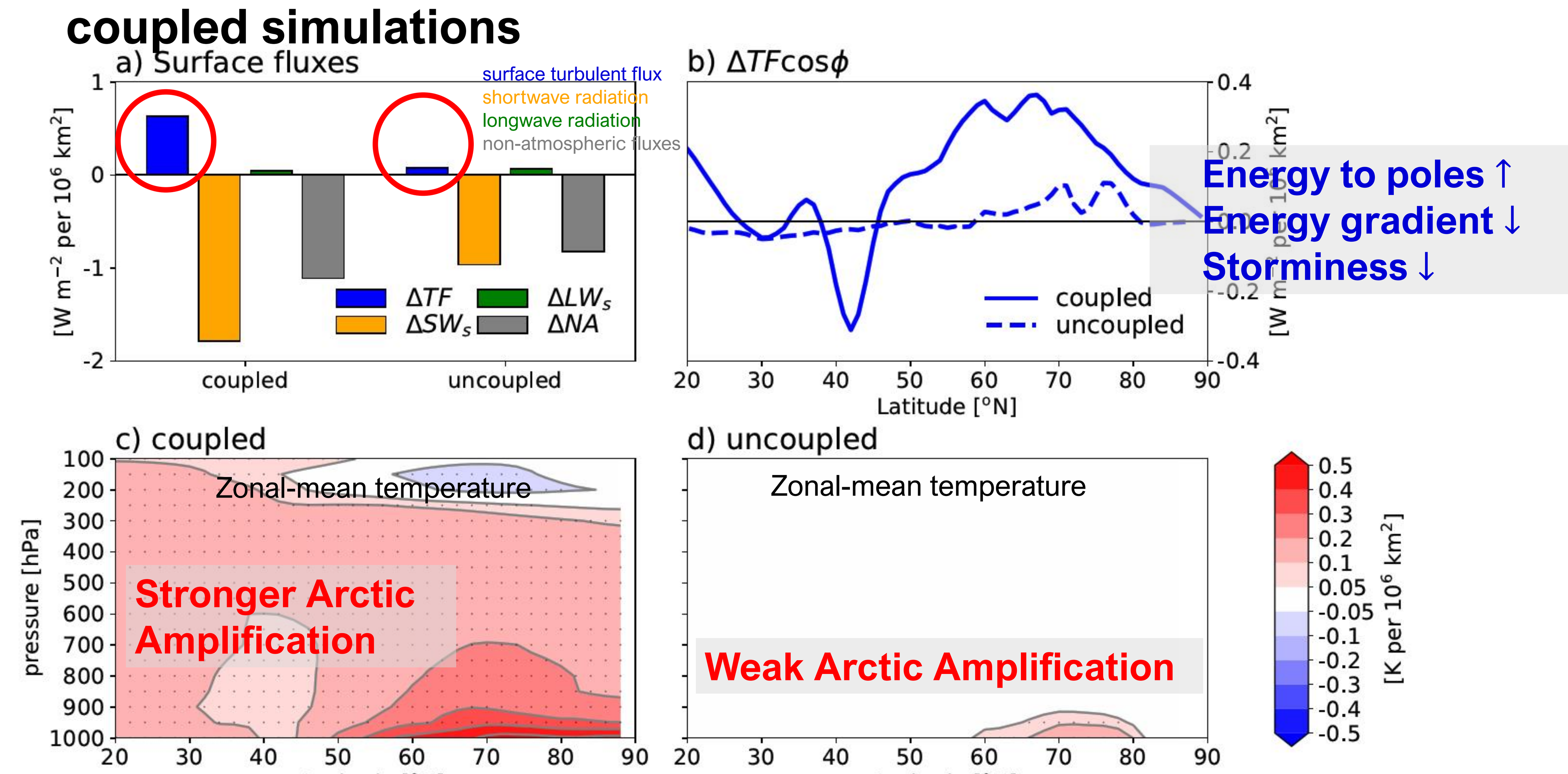


Figure 4. Response of summertime **(a)** high-latitude (50–90°N) surface energy flux (defined as positive upward), **(b)** zonal-mean surface turbulent flux (multiplied by the cosine of latitude), and **(c,d)** zonal-mean temperature to Arctic sea ice loss in the coupled and uncoupled climate model simulations. In **(c,d)**, stipples indicate where all models agree in the sign of the response.