Nudging the Arctic ocean to quantify sea-ice feedbacks

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1. OBJECTIVES
- The Arctic sea-ice feedback is challenging to quantify, but it is a large source of uncertainty in climate models.
- We will quantify the Arctic Ocean sea-ice feedback using a novel nudging technique.

2. METHOD & MODEL
- Create nudging procedure to obtain a climate with present-day (PD) Arctic sea ice state under CO2 perturbation.
- Compare 2xCO2 perturbed climate with melting Arctic sea-ice: run 2xCO2 to a 2xCO2 perturbed climate with Arctic sea-ice kept as in present day (PD): run 2xCO2+nudge.

Fully coupled global climate model: EC-Earth V2.3

3. Nudging leads to present day sea-ice?

BELOW: Column-integrated annual mean nudge energy due to temperature damping in final integration year (2050) in W m².

3.1. STRONG NUDGING TECHNIQUE:
- Nudge to PD temp. mean & PD salinity minimum. Restore time = 20¹ day.
- Nudge whole Arctic ocean column where there was sea-ice in PD control run.
- Quantify nudge energy (E).

3.2. TAKE HOME MESSAGE
- Successfully nudged the Arctic Ocean to maintain present-day Arctic sea-ice area under a 2xCO2 perturbation.
- In EC-Earth, the estimated Arctic sea-ice feedback \( \approx -0.68 \) W m⁻² K⁻¹.
- The energy loss due to nudging \( \sim 0.7 \) W m⁻², small compared to radiative forcing.

4. Quantifying feedbacks
The method Gregory et al. (2004) does not require to run until equilibrium to estimate climate sensitivity. Computing the slope of the regression between global annual mean top net radiation change (ΔTNR) and 2 meter temperature change yields the climate feedback parameter Y:

\[ \Delta \text{TNR} = \text{RF} - Y \Delta T. \]

- run CO₂ is in equilibrium when: \( \Delta \text{TNR} = 0. \)
- run CO₂+nudge is in equilibrium when \( \Delta \text{TNR} = -dE. \)

4.1. The difference in slopes is between the experiments is \( -0.68 \) W m⁻² K⁻¹.

4.2. This yields an estimate of the Arctic sea-ice feedback. (albedo, insulation, clouds).

- The run CO₂+nudge leads to lower equilibrium temperature because of the absence of the sea-ice feedback in the Arctic.