# Arctic Climate Feedback Response to Local Sea-Ice Concentration and Remote Sea Surface Temperature Changes in PAMIP Simulations


Matthew T. Jenkins[1], Aiguo Dai[1], Clara Deser[2]

[1]Department of Atmospheric and Environmental Sciences, University at Albany, Albany, NY USA
[2]National Center for Atmospheric Research, Boulder, CO USA

Contact: mtjenkins@albany.edu



Jenkins MT, Dai A, Deser C (2023) Arctic climate feedback response to local sea-ice concentration and remote sea surface temperature changes in PAMIP simulations. *Clim. Dyn.*, under review.


## I. Background and Motivation

**Arctic Amplification (AA)** refers to greater warming in the Arctic region relative to the rest of the globe under increased greenhouse gases.

**Proposed Causes of AA** include sea-ice loss, positive climate feedbacks (e.g., surface albedo and/or lapse rate feedback), and enhanced poleward energy transport.

**Sea-ice loss** exposes water surfaces that are warmer than the overlying atmosphere during Arctic autumn and winter, resulting in increased oceanic energy release and thus enhanced Arctic warming.

**Motivation:** The warming effects of sea-ice loss, poleward energy transport, and climate feedbacks are entangled in fully-coupled model runs. This motivates us to separate the warming effects of local sea-ice loss from remote processes on AA and climate feedback processes.

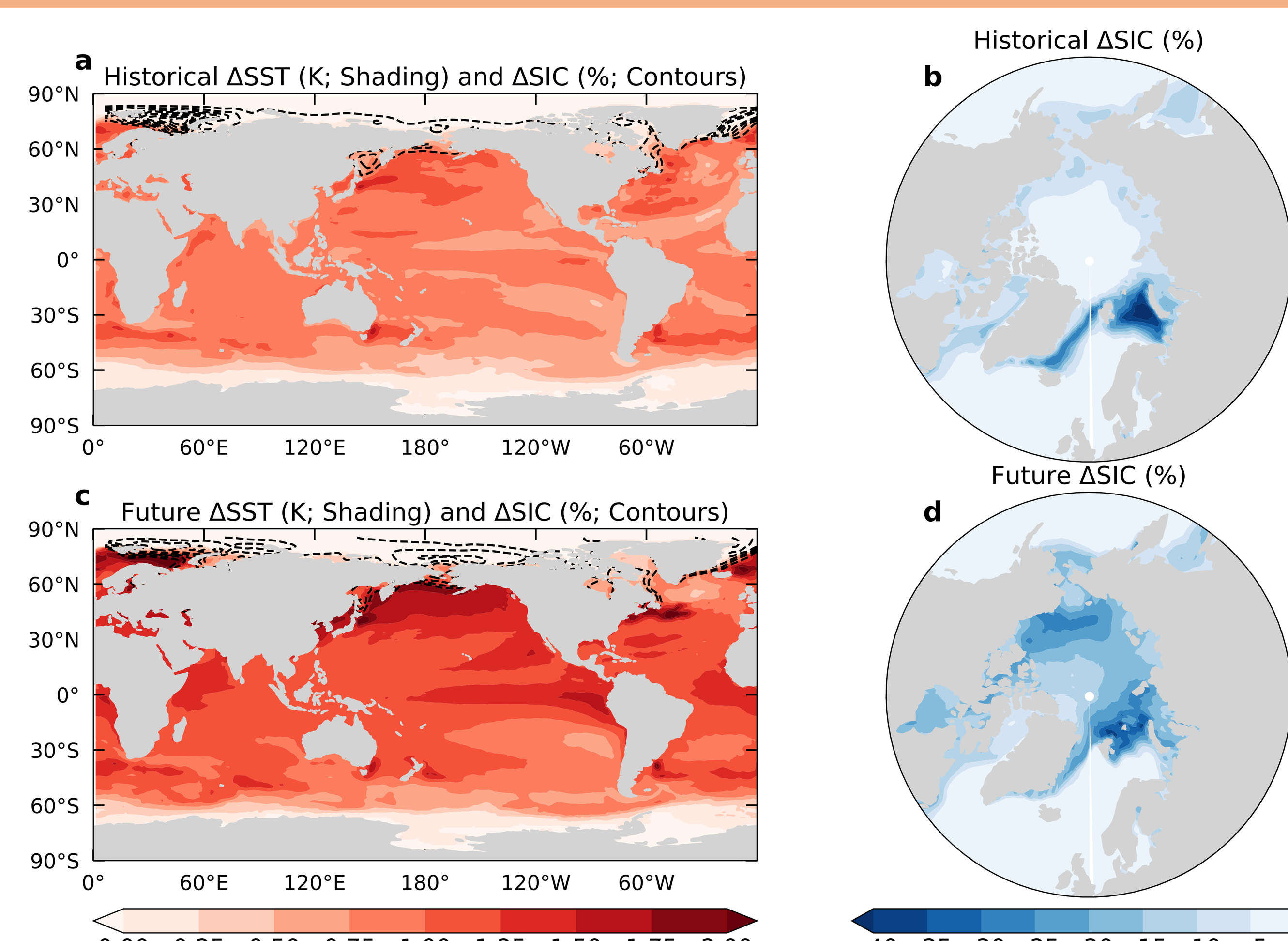
## II. PAMIP Model Simulations

### Polar Amplification Model Intercomparison Project (PAMIP)

**Atmosphere-only** simulations analyzed from **five** models.

We focus on the **ensemble-mean** of **100 ensemble runs** for each model and experiment with varied initial conditions.

We analyze simulations with either perturbed global SST and fixed polar SIC or fixed global SST and perturbed Arctic SIC (see table below).




**Historical**

Present-day MINUS Preindustrial

**Future**

Future MINUS Present-day

Fig. 1. (a, c) Annual mean changes in SST (K; shading) and Arctic SIC (%; contours; interval 5%) for the (a) historical (present-day minus preindustrial) and (c) future warming (future minus present-day) cases. Changes in SIC for the (b) historical and (d) future cases are shown as shading in (b) and (d) for clarity.

| Model Simulation | Full Name | Description |
|---|---|---|
| **1.1 pdSST-pdSIC*** | Present day sea surface temperature<br>Present-day sea-ice concentration | Year 2000 global SST and polar SIC; GHG fixed at year 2000 concentrations.<br>***Control run; experiments 1.2-1.6 compared to experiment 1.1.** |
| **1.3 piSST-pdSIC** | Preindustrial sea surface temperature<br>Present-day sea-ice concentration | Historical (1.3) and future (1.4) global SST with polar SIC fixed at year 2000 conditions; GHG fixed at year 2000 concentrations. |
| **1.4 futSST-pdSIC** | Future sea surface temperature<br>Present-day sea-ice concentration | Assesses role of background warming without sea-ice feedback. |
| **1.5 pdSST-piArcSIC** | Present-day sea surface temperature<br>Preindustrial sea-ice concentration | Historical (1.5) and future (1.6) Arctic SIC with global SST fixed at year 2000 conditions; GHG fixed at year 2000 concentrations. |
| **1.6 pdSST-futArcSIC** | Present-day sea surface temperature<br>Future sea ice concentration | Assesses role of Arctic sea-ice feedback without background warming. |

## III. Surface Warming Response

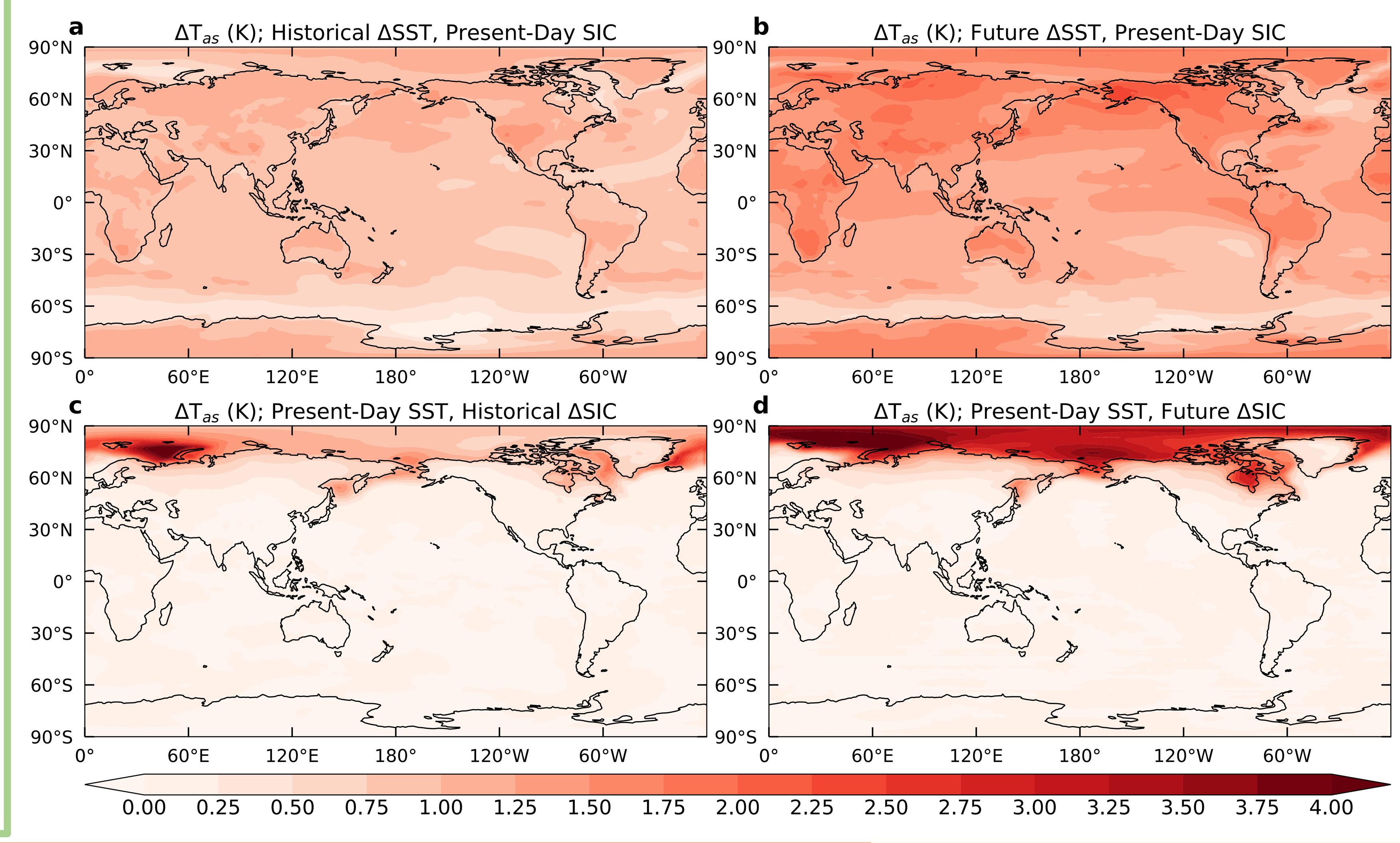



**Fig. 2.** Multi-model ensemble mean changes in annual-mean surface air temperature ($\Delta T_{as}$) in response to (a, c) historical and (b, d) future (a, b) SST and (c, d) SIC changes shown in Fig. 1.

- **Changed SST, Fixed Polar SIC (TOP):** Produces roughly uniform global warming with weak AA.
- **Fixed SST, Changed Arctic SIC (BOTTOM):** Produces strong AA with negligible warming in the lower latitudes.
- **Future** case produces stronger warming than historical case.

## IV. Climate Feedbacks

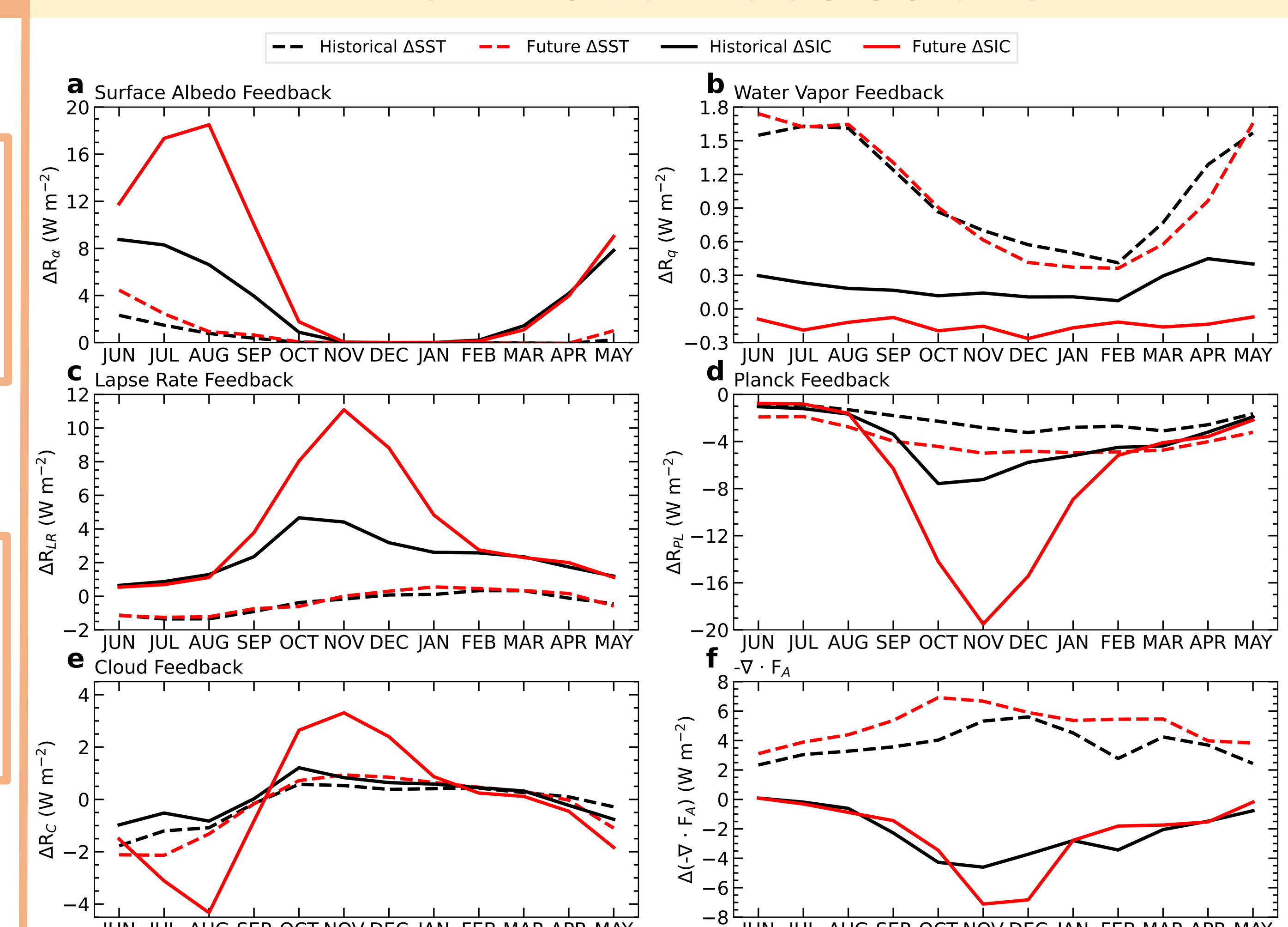



**Fig. 3.** Arctic (67°-90°N; land surfaces excluded) multi-model, ensemble mean seasonal cycle of the (a) surface albedo, (b) water vapor, (c) lapse rate, (d) Planck, and (e) cloud feedbacks, and (f) changes in atmospheric energy convergence (in W m$^{-2}$) in response to historical (black lines) and future (red lines) SST (dashed lines) and SIC (solid lines) changes. *Feedbacks estimated with radiative kernels.

## V. Lapse Rate Feedback Maps

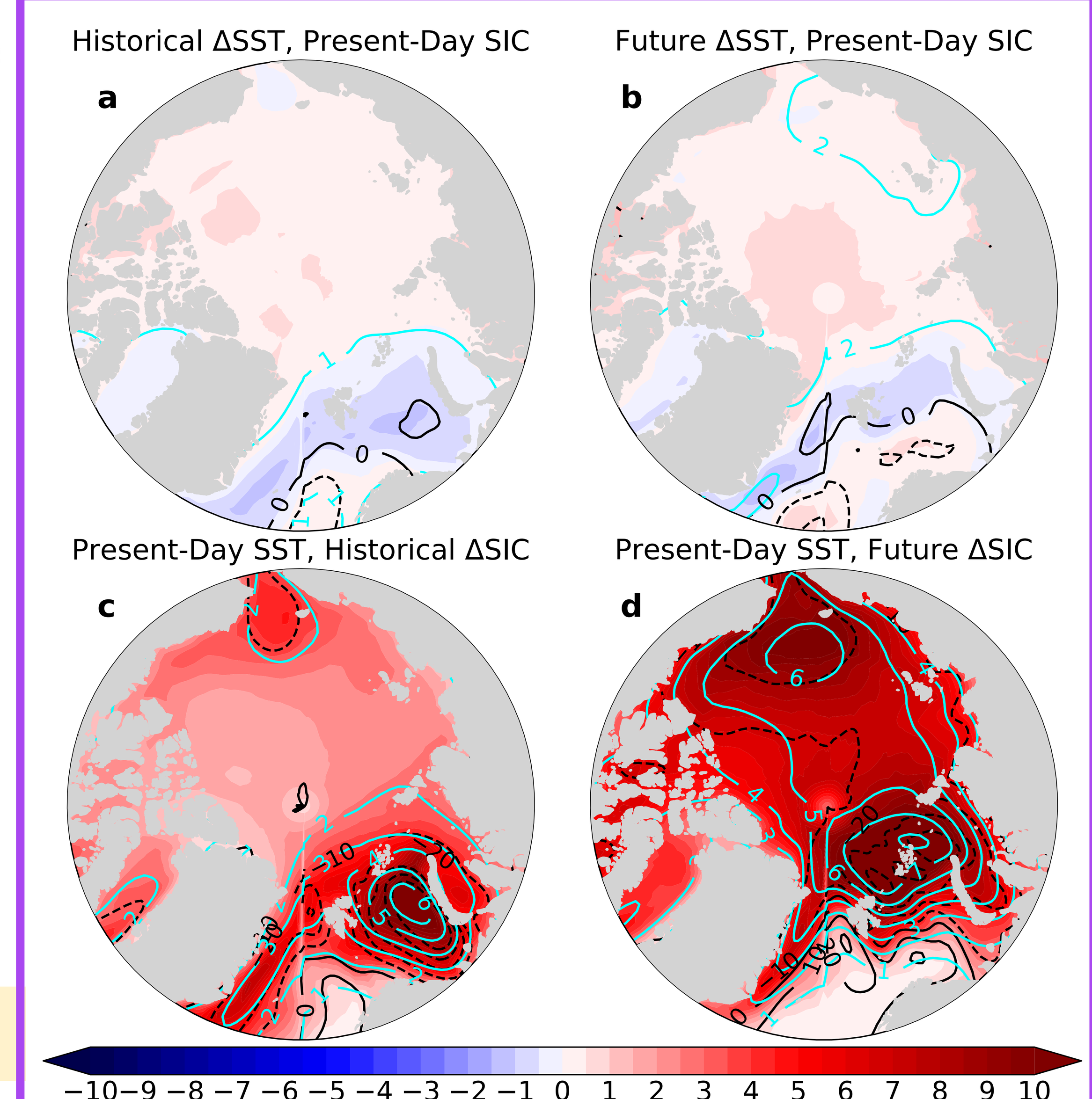



**Fig. 4.** Multi-model, ensemble mean TOA radiative flux change due to the lapse rate feedback (shading; in W m$^{-2}$), changes in oceanic heat uptake (black contours; in W m$^{-2}$; positive downward), and changes in surface air temperature (cyan contours; in K) averaged over October-March in response to (a, c) historical and (b, d) future (a, b) SST and (c, d) SIC changes.

## VI. Atmos. Energy Transport

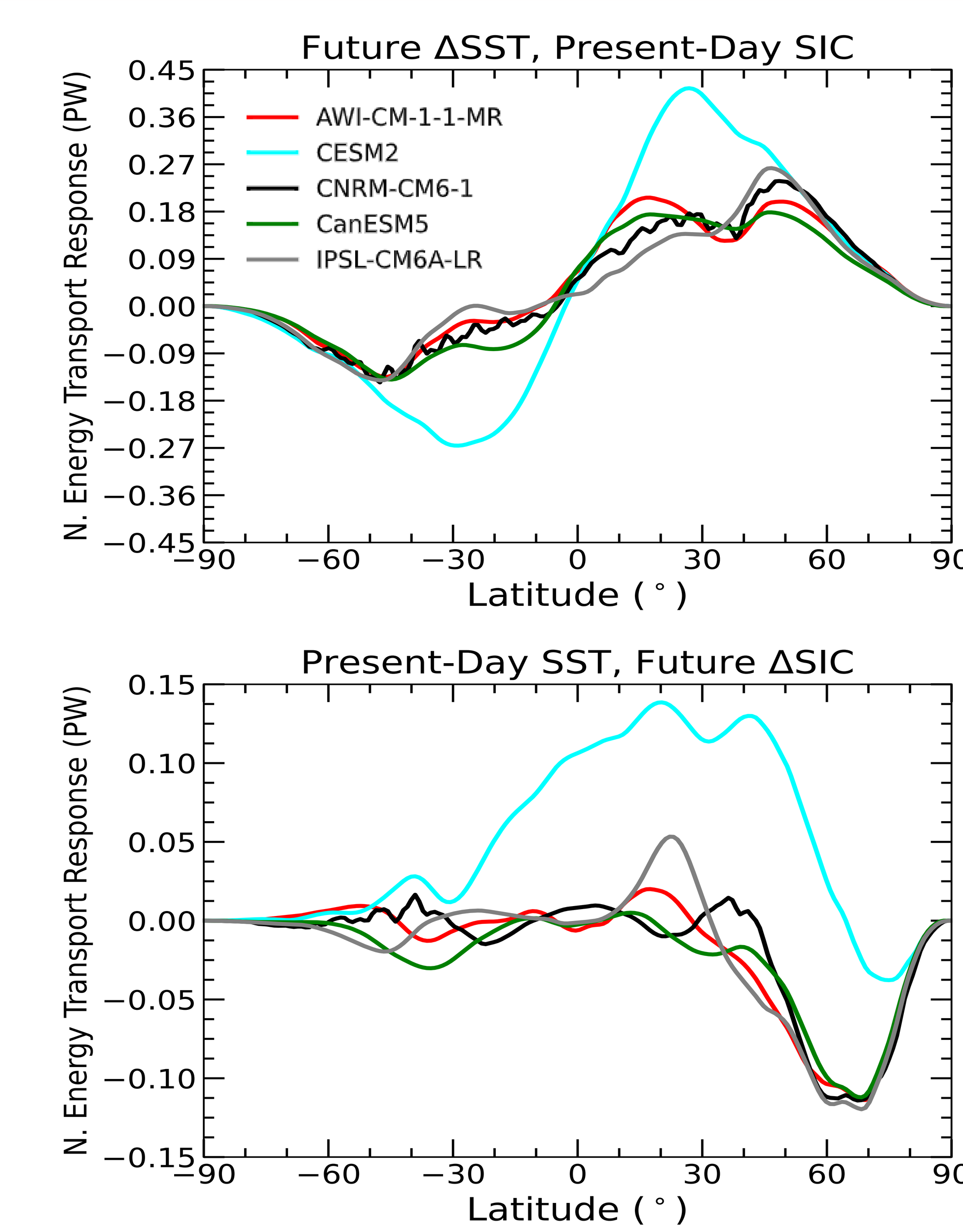



**Fig. 5.** October-March Arctic northward energy transport in response to future (TOP) SST and (BOTTOM) Arctic SIC changes.

## VII. Summary

- **Warmer global SSTs** enhance **atmospheric energy convergence into the Arctic** and trigger Arctic **water vapor feedback**.
- **Reduced Arctic SIC** and **increased oceanic heat release** enhances cold-season positive **lapse rate** and **cloud** feedbacks and reduces **atmospheric energy convergence into the Arctic**.
- **Lapse rate feedback** strongest in areas with **large oceanic heat release** and **surface warming** in response to Arctic SIC loss.