Arctic Amplification, Temperature Inversions, and Sea-Ice Spread in CMIP6 Models

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Background

Proposed mechanisms of polar amplification include sea-ice thermodynamics, changes in heat transport, and radiative feedbacks associated with changes in surface albedo and atmospheric lapse rate (Taylor et al. 2022, Boeke et al. 2021). The lapse-rate feedback, wherein the wintertime temperature inversion is eroded as warming is surface amplified, is thought to play a leading role in polar amplified warming (e.g., Hahn et al. 2021).

The inter-model spread in polar amplification is less well understood (Taylor et al. 2022). Here we investigate whether the magnitude of Arctic surface warming is related to the strength of the climatological wintertime temperature inversions, which in turn may set the strength of the lapse-rate feedback.

Key Points + Future Work

We find:

- Large inter-model spread in climatological sea-ice concentration, surface albedo, and temperature inversions across CMIP6 models
- Similar spatial patterns of inter-model spread in climatological sea-ice concentration, surface albedo, and temperature inversions
- Yet no relationship between wintertime climatological inversion strength and Arctic amplification in CMIP6 models.
- A simple model coupling radiative-advective equilibrium (Cronin and Jansen 2016), sea-ice thermodynamics, and ocean-heat storage could potentially inform which of the above GCM variables are biasing the rest

Data and Methods

Data

Output from 18 pre-industrial control (piControl) and abrupt quadrupling of carbon dioxide (abrupt 4xCO_2) simulations participating in the Sixth Coupled Model Intercomparison Project was used. All data was bilinearly regridded to the GFDL-CM4 default grid.

Methods

We calculate climatological means as 40-year averages from piControl simulations for:

- Surface temperature inversion strength
- Surface albedo
- Sea-ice concentration

Changes in each of these variables under abrupt quadrupling of CO_2 are calculated by subtracting the climatological mean from the 20-year average of the end of each abrupt-4xCO_2 simulation.

Inversion Strength (IS) is calculated as:

$$IS = T_{850} - T_{sfc}$$

Arctic Amplification Factor (AA) is calculated as:

$$AA = \frac{T_{sfc,70^\circ-90^\circ N}}{T_{sfc,global}}$$

Results

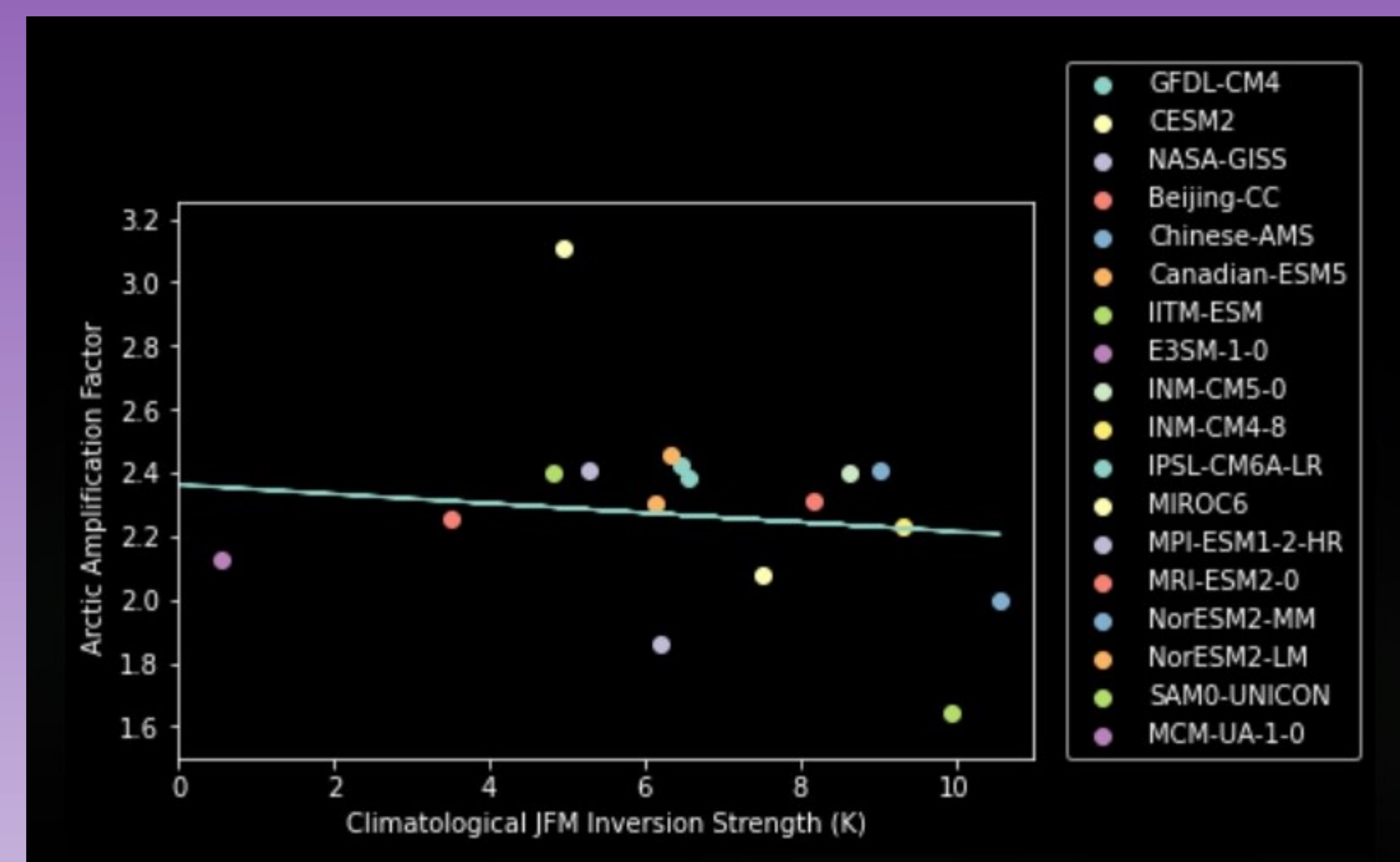

Figure 1: Measure of Arctic Amplification across 18 CMIP6 models vs mean climatological wintertime inversion strength. The mean-state inversion is not a good predictor of expected Arctic warming. Note the large spread in inversions across models.

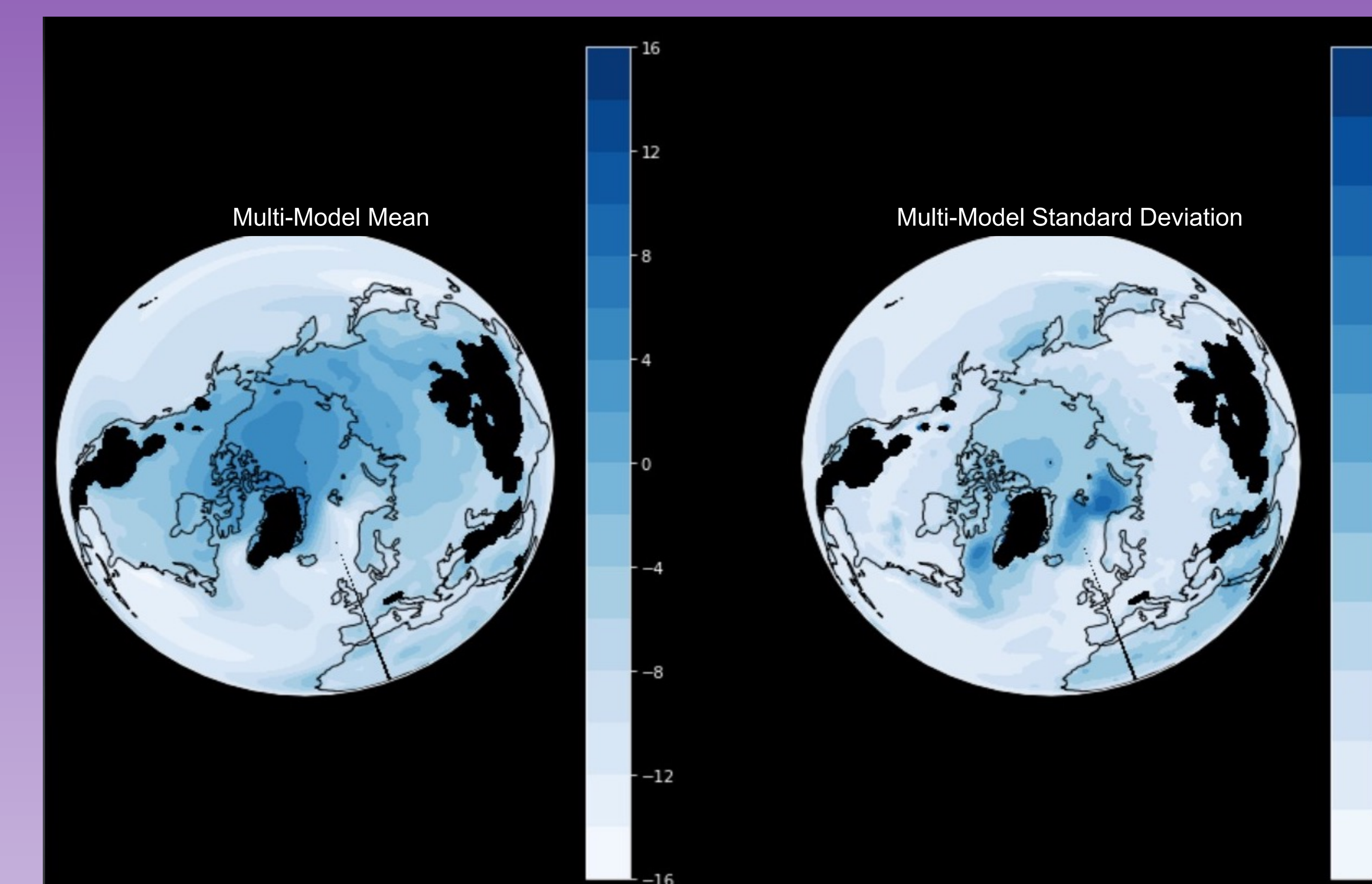

Figure 2: Multi-model mean and standard deviation of climatological inversion strength, measured in Kelvin. Regions of large disagreement are also regions of large sea-ice loss in models.

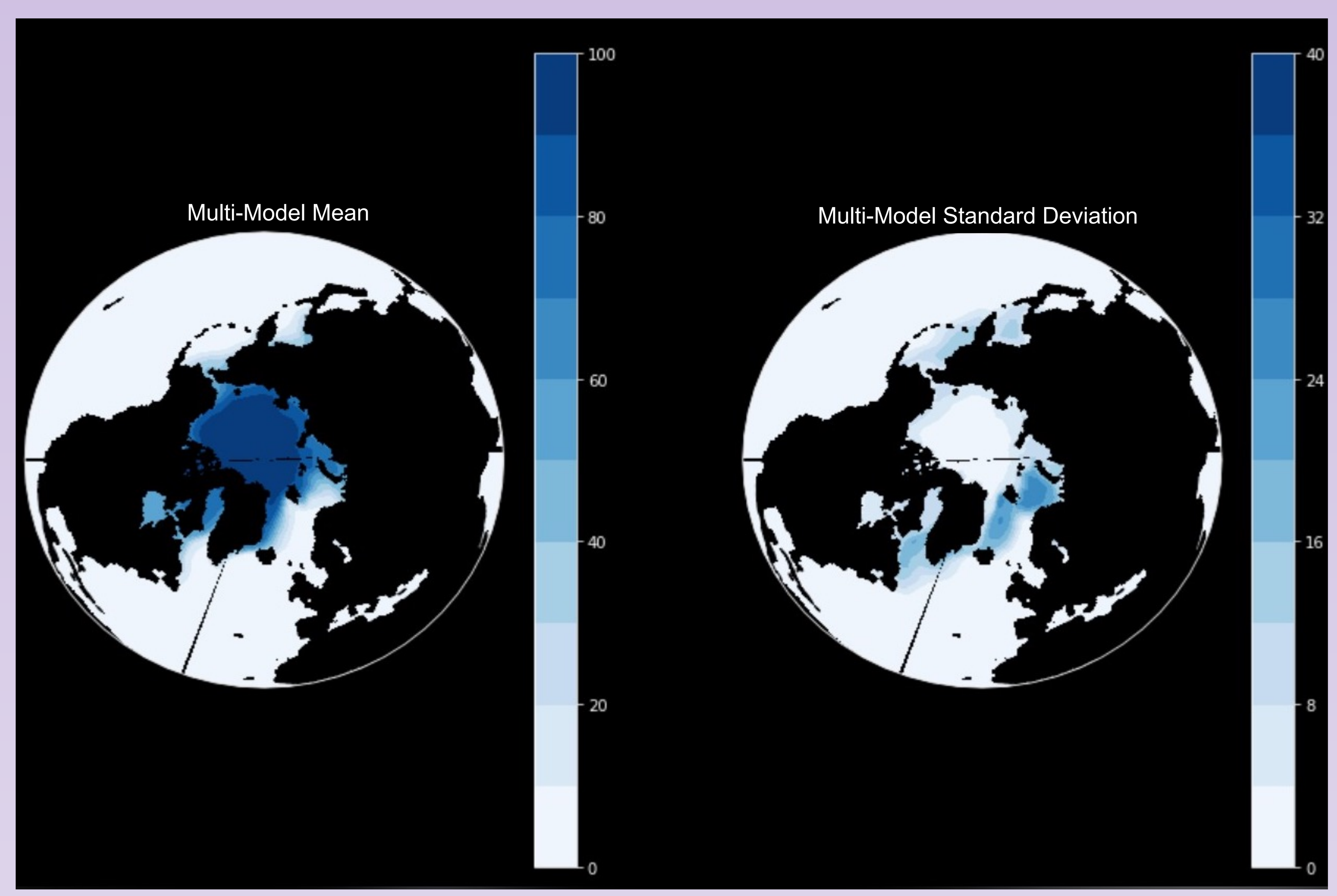

Figure 3: Multi-model mean and standard deviation of climatological sea-ice concentration as a percentage of area cover. As expected, regions of spread in sea-ice concentration correlate well with spread in inversion strength.

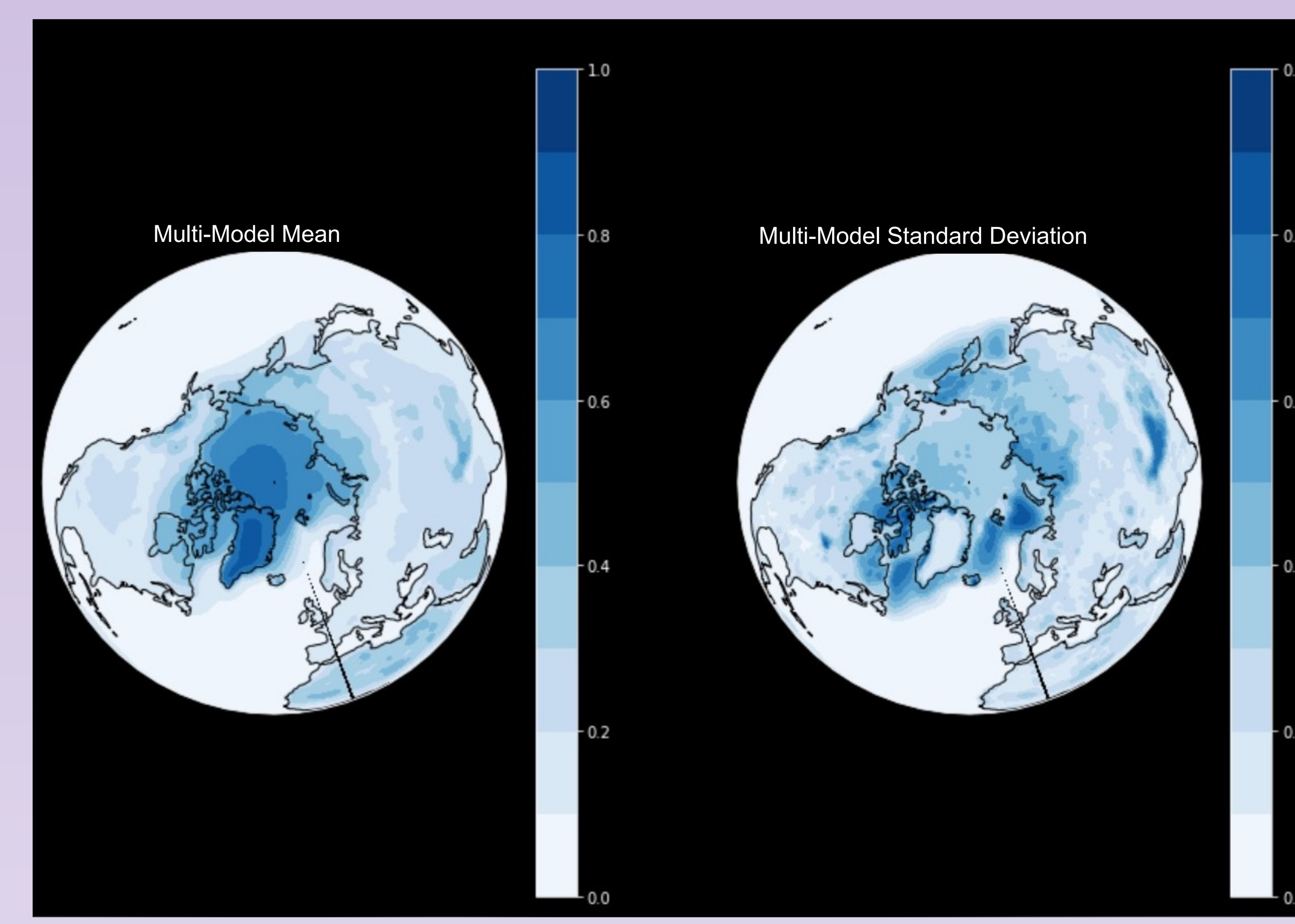

Figure 4: Multi-model mean and standard deviation of climatological surface albedo. Large spread correlates with sea-ice and inversion strength. There is also a ± 0.1 spread in albedo in regions of no spread in sea-ice concentration.

References

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- Cronin, T. W., and M. F. Jansen (2016), Analytic radiative-advective equilibrium as a model for high-latitude climate, *Geophys. Res. Lett.*, 43, 449–457