Isolating the Influence of Temperature-dependent Cloud Optics on Infrared Radiation within a Model Hierarchy

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MOTIVATION

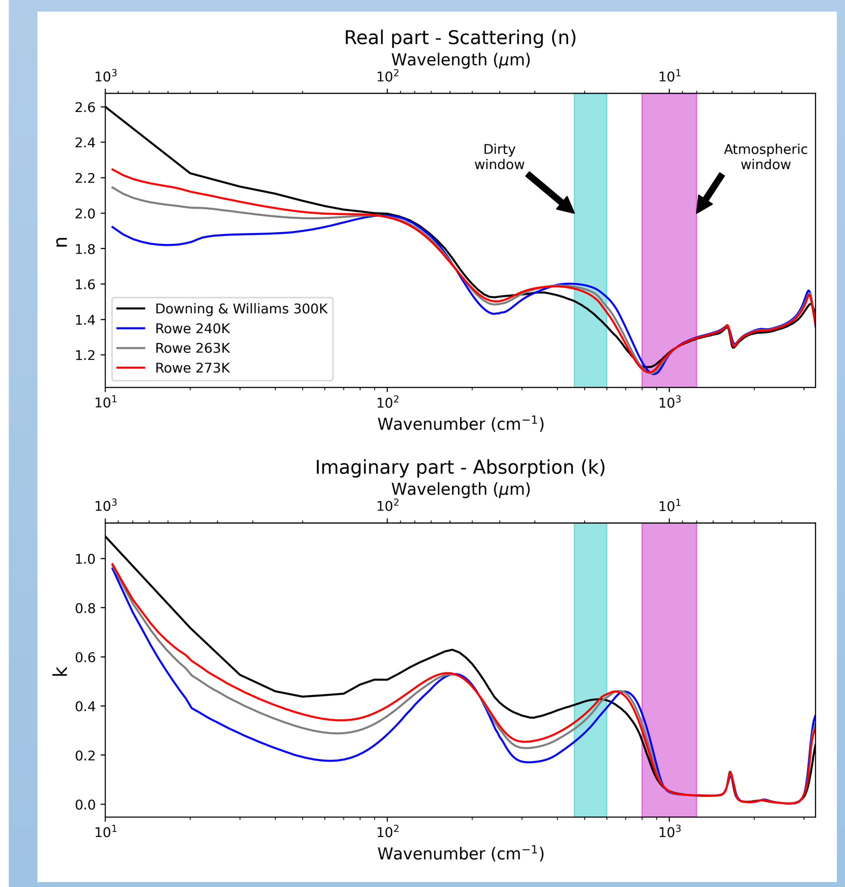


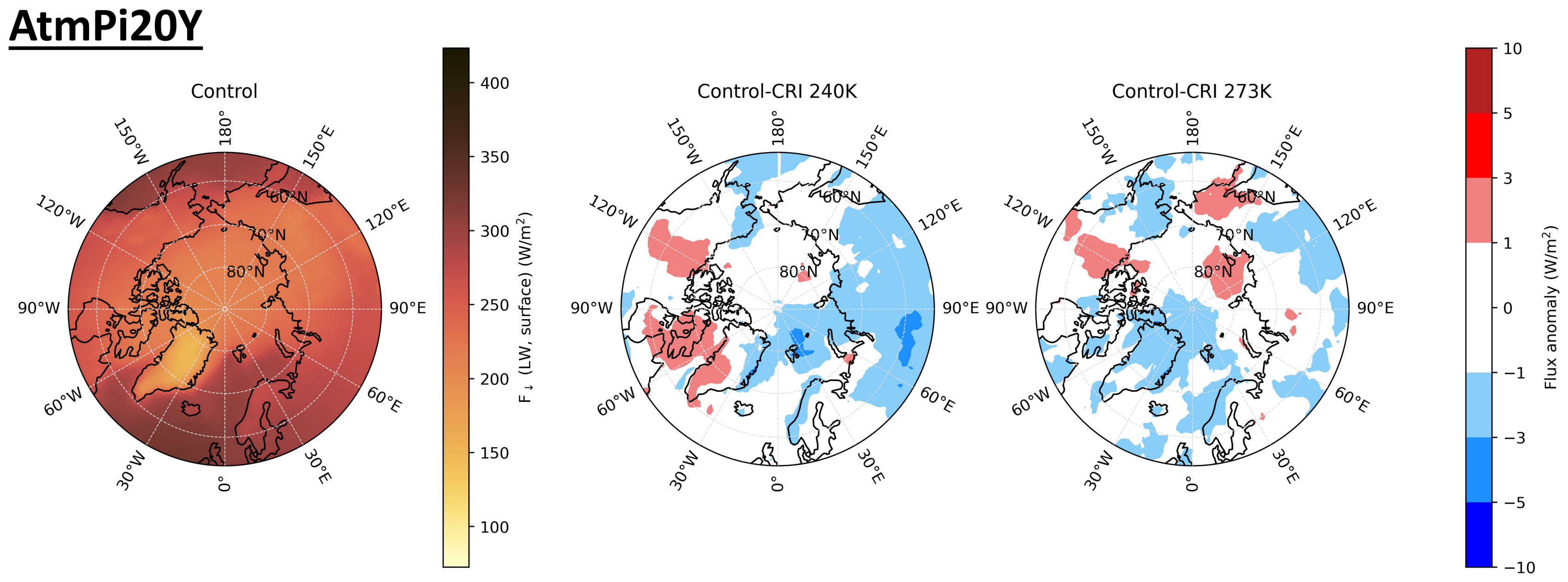
Figure 1. Complex refractive index of water (real part – top graph, imaginary part – bottom graph) between 10 and 3000 cm^{-1} for four CRI at different temperatures (240K, 273K, 263K, 300K). The highlighted regions are the dirty (blue) and atmospheric windows (pink).

- The **complex refractive index** (CRI) for water has a **temperature dependence for supercooled liquid water**
- Case studies from the Antarctic showed that accounting for the temperature dependence **increased downwelling longwave flux at the surface**
- This **temperature dependence** for liquid water CRI is **unaccounted for in global climate models**
- Given the prevalence of **supercooled liquid water in Arctic clouds**, this temperature dependence may **bias the modeled long-term Arctic radiation**

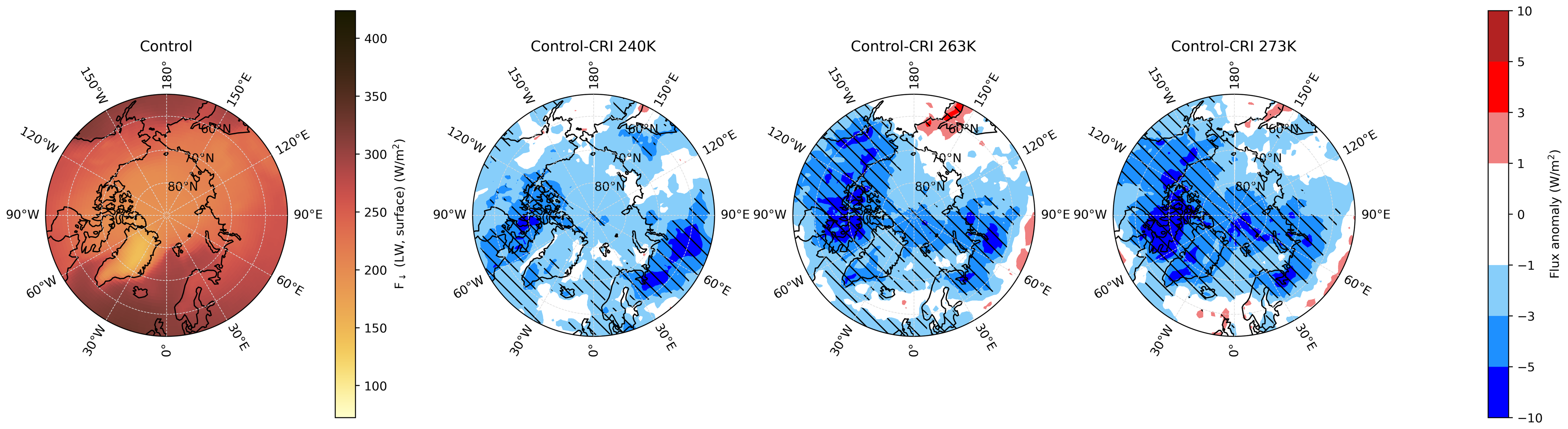
Questions: How do temperature dependent liquid water optical properties affect long-term Arctic radiation? **Do we need to update liquid water optical properties in global climate models?**

RESULTS

AtmPi20Y



AtmPiWN1Y10em



AtmPiWN39Y3em

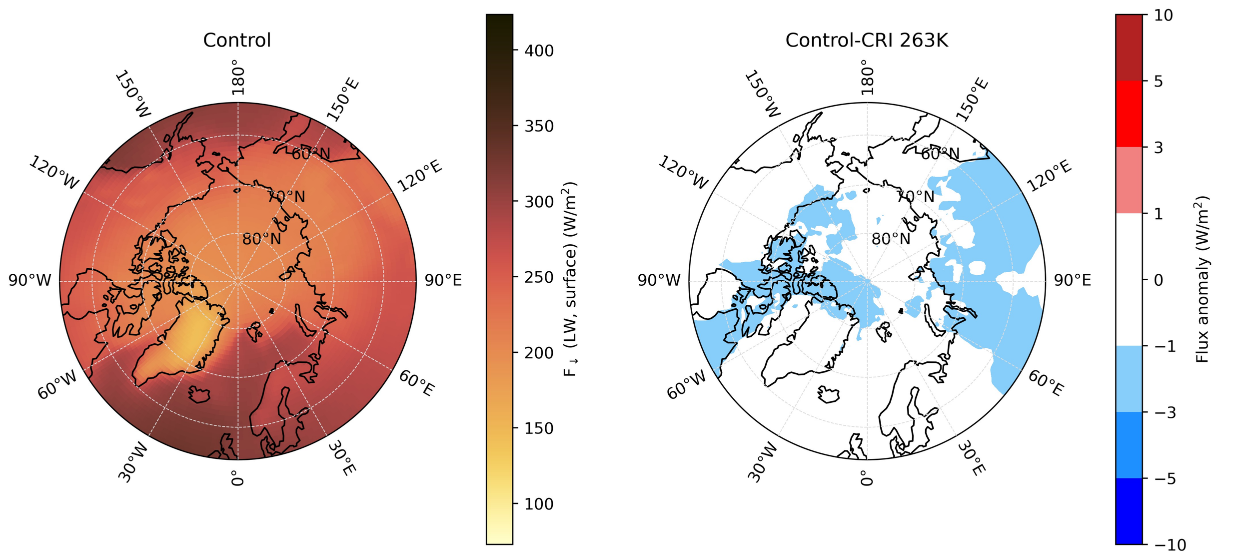


Figure 3. All graphs above show the downwelling LW flux at the surface from CESM2.2, atmosphere-only, pre-industrial simulations. Hatching indicates a statistically significant difference between a control and supercooled CRI at the 5% level. (top row) 20-year mean from **AtmPi20Y** – atmosphere-only, pre-industrial, freely-evolving atmosphere, 20-years long simulation. (middle row) 1-year ensemble mean from **AtmPiWN1Y10em** – atmosphere-only, pre-industrial, nudged winds in the Arctic, 1-year long, 10 ensemble member simulation. (bottom row) 39-year ensemble mean from **AtmPiWN39Y3em** – atmosphere-only, pre-industrial, nudged winds in the Arctic, 39-years long, 3 ensemble member simulation.

CONCLUSIONS

- We found a **detectable** but **not statistically significant difference** in **downwelling longwave flux (1-5 W/m²)** in **20-year CESM simulations** from the temperature dependent optics
- We found a **detectable** and **statistically significant difference** in **downwelling longwave flux (1-10 W/m²)** in **1-year 10-member wind-nudged CESM simulations** from the temperature dependent optics
- We found a **detectable** but **not statistically significant difference** in **downwelling longwave flux (1-3 W/m²)** in **39-year 3-member wind-nudged CESM simulations** from the temperature dependent optics
- Through this model hierarchy, we also **developed** a **process for detecting a physics change**

Key takeaway: Using a hierarchy of modeling experiments, we find that the temperature dependence of liquid water optical properties has no significant impact on long-term modeled Arctic radiation. **We do not need to update liquid water optical properties in global climate models.**

METHODS

1) **2-stream radiative transfer model simulations**
2) **Single-Column Atmospheric Model (SCAM) simulations from the Mixed-Phase Arctic Cloud Experiment (MPACE) case**
3) **Community Earth System Model (CESM2) simulations – freely evolving**
4) **CESM2 simulations – wind nudging in the Arctic**

Increasing model complexity

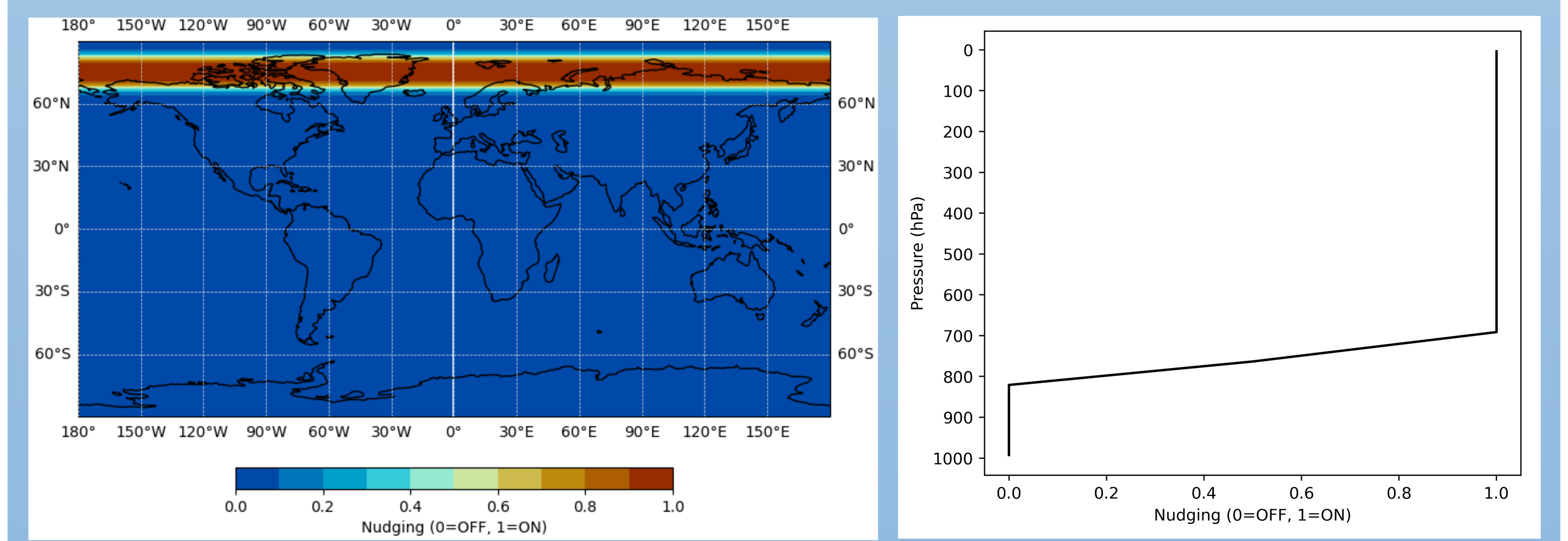
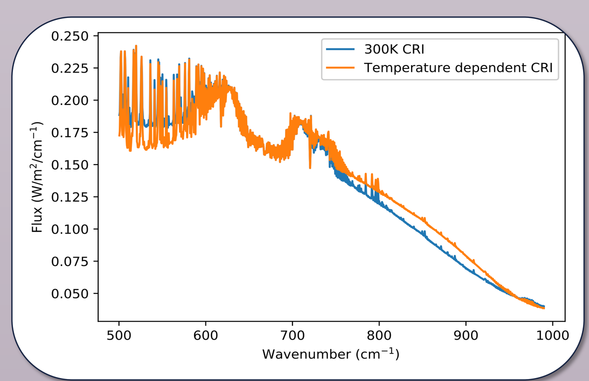


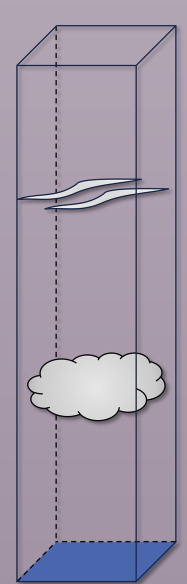
Figure 2. (left) Horizontal wind nudging window (nudging on between 67.5-82.5°N). (right) Vertical wind nudging window (nudging on above 850 hPa). Where wind nudging is enabled, the model nudges **u** & **v** wind components towards ERA-I reanalysis wind values.

PHYSICS CHANGE DETECTION PROCESS

1) Conceptual model – is there a difference at the simplest level?

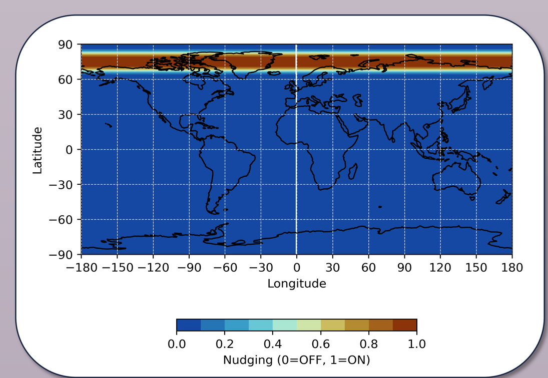


2) Single-column model – is there a difference using a simplistic climate model?



3) Multi-decadal climate model run – is there a difference at long timescales and large spatial scales?

4) Wind nudging climate model run - is there a difference when dynamics no longer contributes to the variability?



NEXT PROJECT

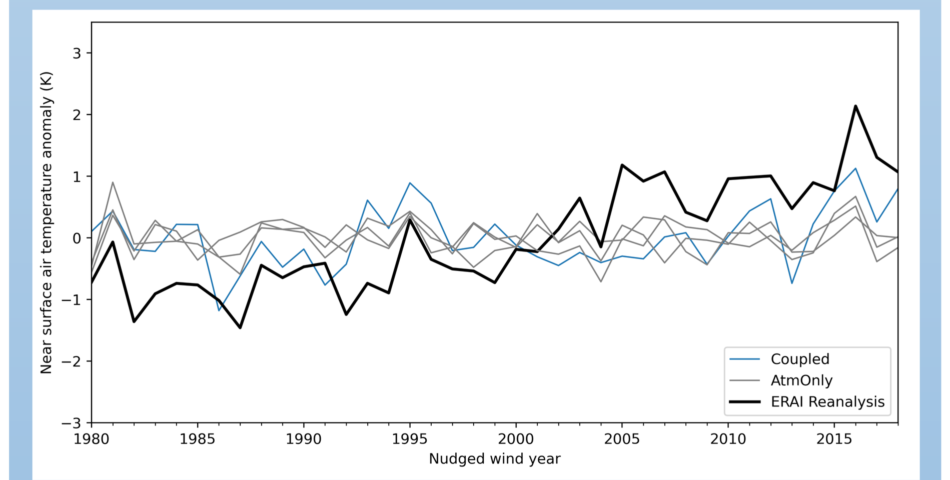


Figure 4. Near surface Arctic yearly temperature for ERA-I data (black) and four 39-year wind nudged pre-industrial runs – three are atmosphere-only (gray) and one is coupled (blue).

Question: What is the breakdown of the Arctic warming trend in models?

- Initial results show that **wind-nudged atmosphere-only** and **coupled** simulations can **reproduce observed internal variability**, but **not the trend**

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