How to Chase the Signal of a Model Parameterization Change in a Global Climate Model

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MOTIVATION

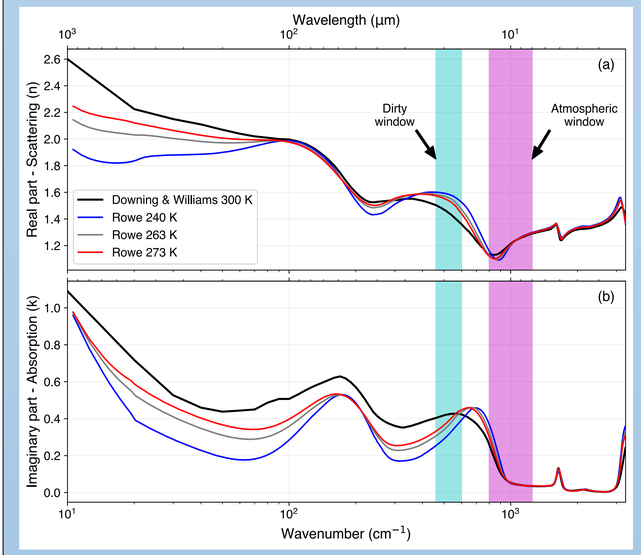

Figure 1. Complex refractive index of water with the (a) real part and (b) imaginary part between 10 and 3000 cm^{-1} for four CRI at different temperatures (240 K, 263 K, 273 K, 300 K). The highlighted regions are the dirty (blue) and atmospheric windows (pink).

- We propose a novel **model hierarchy** for assessing the **importance** of a **cloud optics change** to the **climate**
- The **cloud optics change** we test in this study is **temperature-dependent liquid water optics**
- A **case study** found these temperature-dependent optics **increase the longwave flux** emitted by **supercooled liquid clouds**
- Given the prevalence of **supercooled liquid** in **Arctic clouds**, we test the importance of these optics there

QUESTIONS

- Are the effects of temperature-dependent liquid water optics on longwave radiation substantial?
- How can we assess their importance?

CONCLUSIONS

- The effect from the temperature-dependent optics is not substantial relative to climate variability
- The temperature-dependent optics are not a first priority for model radiation parameterization development
- More broadly, the model hierarchy assessed the model physics change across a range of model complexities and time and spatial scales, enabling us to make recommendations for model development

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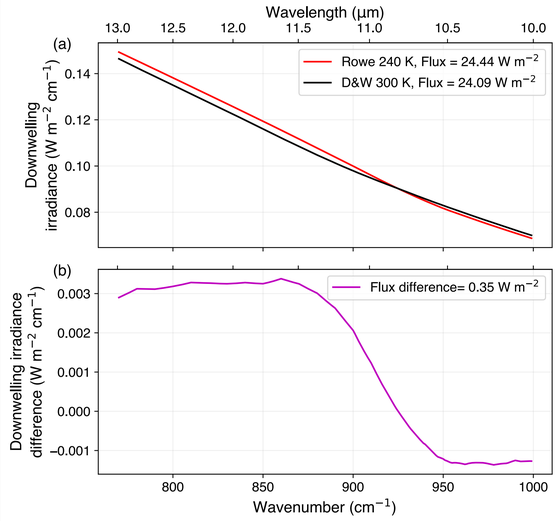
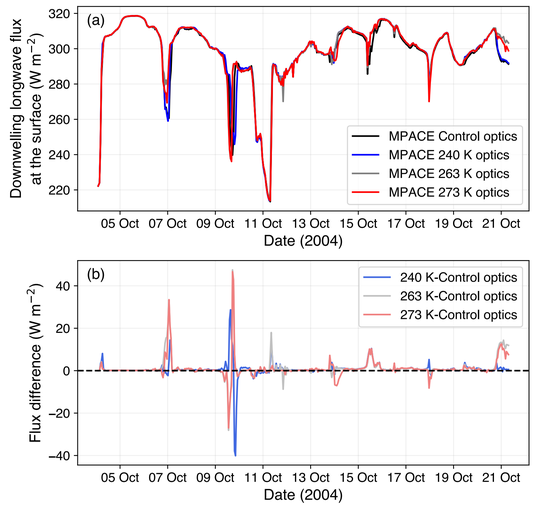
1) Two-stream radiative transfer model



Do we see an effect with a conceptual model on a spectral scale? Yes, on the order of 0.35 W m^{-2}

Figure 2. (a) Downwelling irradiance spectra of a 240 K supercooled liquid cloud modeled using a two-stream radiative transfer model between 770 and 1000 cm^{-1}. The spectra was modeled with both 240 K optics (red) and 300 K optics (black). (b) The difference in irradiance between the spectra modeled with 240 K optics and 300 K optics.

2) Single-column atmospheric model (CESM2-SCAM)



Do we see an effect with an atmospheric model at a single location on a daily time scale? Considering only supercooled liquid clouds, yes, on the order of 0.11-41 W m^{-2}

Figure 3. (a) Downwelling longwave flux at the surface modeled by SCAM for the MPACE field study with four different sets of optics: Control – 298 K (black), 240 K (blue), 263 K (gray), and 273 K (red). (b) The difference in flux between all three sets of temperature-dependent optics and the control optics.

3) Freely-evolving global climate model (CESM2)

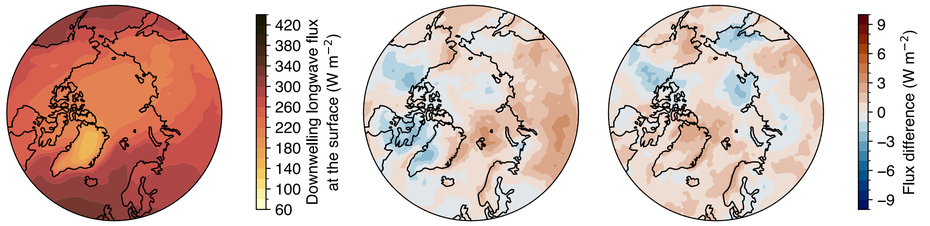


Figure 4. (a) The 20 year mean downwelling longwave flux at the surface from the freely-evolving pre-industrial climate run with control optics. Flux differences in the 20 year averages between (b) the 240 K and control optics runs and (c) the 273 K and control optics runs.

Do we see an effect with a global climate model over the entire Arctic on a decadal time scale? Yes, on the order of 1-3 W m^{-2}, but it is not statistically significant

4) Wind-nudged global climate model (CESM2)

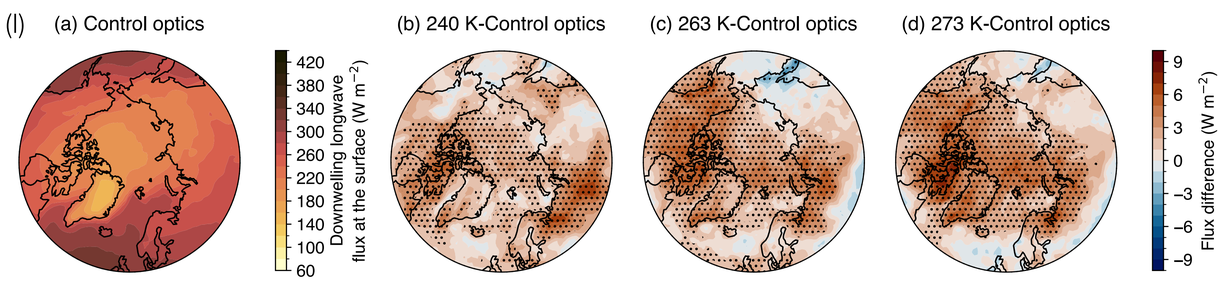


Figure 5. (a) The 1 year ensemble mean downwelling longwave flux at the surface from the wind-nudged, 10 member ensemble, pre-industrial climate run with control optics. Flux differences in the 1 year ensemble averages between (b) the 240 K and control optics runs, (c) the 263 K and control optics runs, and (d) the 273 K and control optics runs. Stippling indicates the differences are statistically significant at the 95 % level.

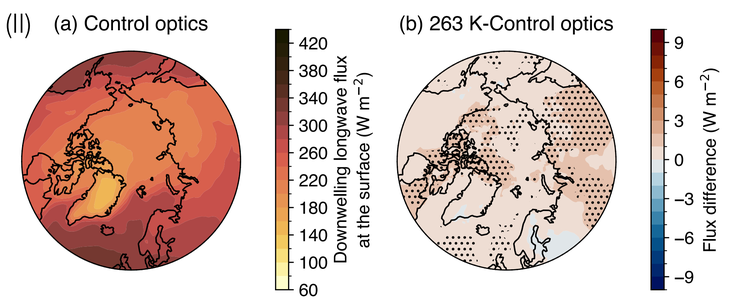


Figure 6. (a) The 39 year ensemble mean downwelling longwave flux at the surface from the wind-nudged, 3 member ensemble, pre-industrial climate run with control optics. Flux differences in the 39 year ensemble averages between (b) the 263 K and control optics runs. Stippling indicates the differences are statistically significant at the 95 % level.

Do we see an effect with a dynamically constrained global climate model over the entire Arctic on (I) 1 year and (II) decadal time scales? (I) Yes, on the order of 1-5 W m^{-2} and it is statistically significant. (II) Yes, on the order of 1-3 W m^{-2} and it is statistically significant