Inferring interannual surface cloud microphysical feedbacks at the North Slope of Alaska

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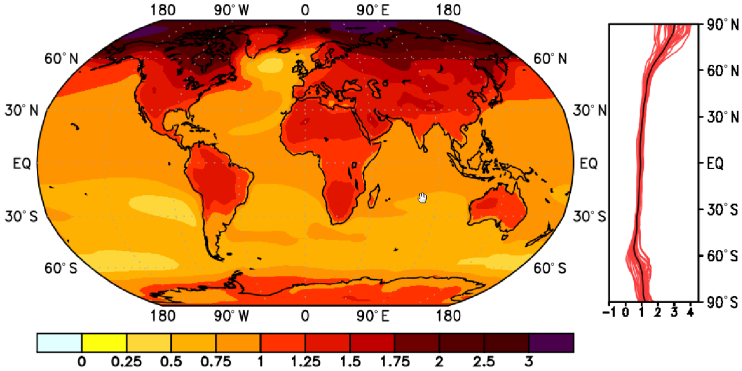
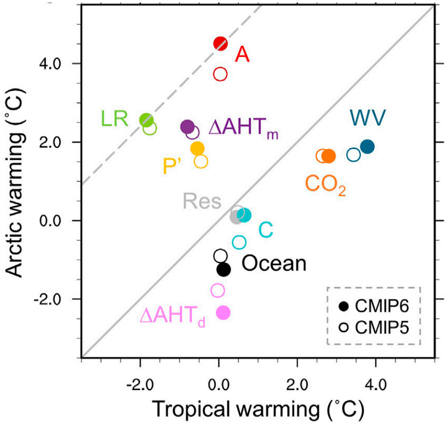
Arctic amplification

- There is a large spread in the degree of Arctic Amplification predicted by large-scale climate models



Smith et al. (2019)

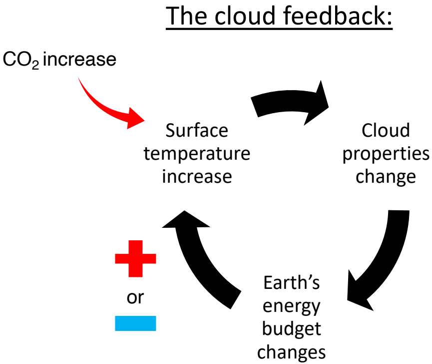
Role of cloud feedback



Hahn et al. (2021)

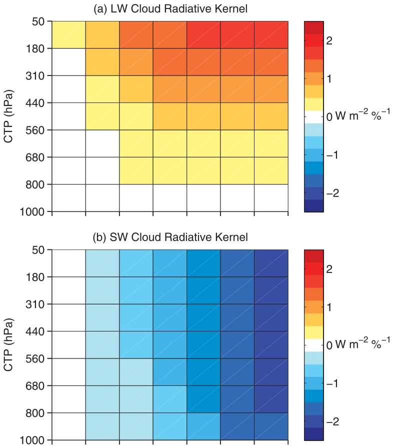
- A less negative cloud feedback and more positive albedo feedback cause more Arctic warming in CMIP6 models compared to CMIP5 models

Cloud feedback



- Changes in cloud properties in response to global warming
- Can be quantified from the perspective of the *top of the atmosphere* or *surface*

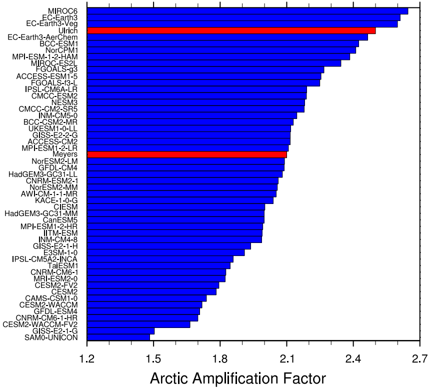
Cloud radiative kernels



Zelinka et al. (2012)

- Cloud radiative kernels are developed using an offline radiative transfer model to calculate the change in cloud radiative effect due to changing cloud properties
- Cloud properties are macroscopic:
    i. cloud-top pressure
    ii. cloud optical depth
    iii. cloud amount

Sensitivity of Arctic amplification to ice microphysical effects

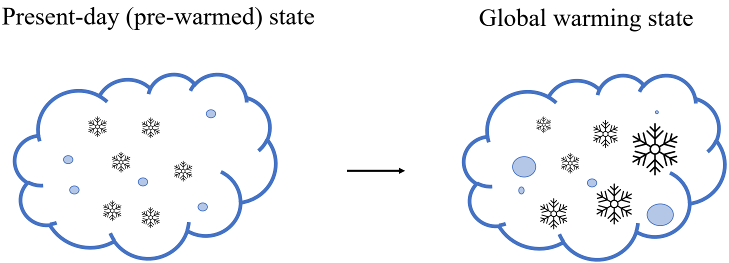


Tan et al. (2022)

- A change in the ice nucleation scheme of the GEOS-5 model resulted in a large difference in Arctic amplification in global climate model simulations relative to a number of CMIP6 models

Cloud particle size feedback

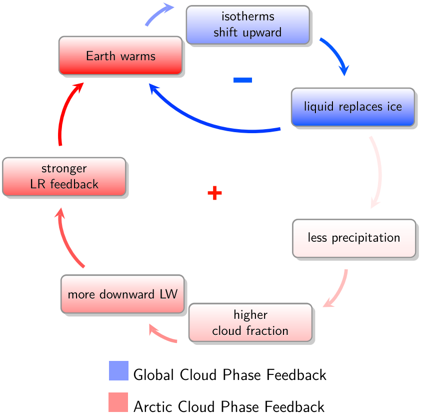
"Direct"



- E.g. as quantified by Zhu & Poulsen (2019) using the partial radiative perturbation method in a climate model

Cloud particle size feedback

"Indirect"

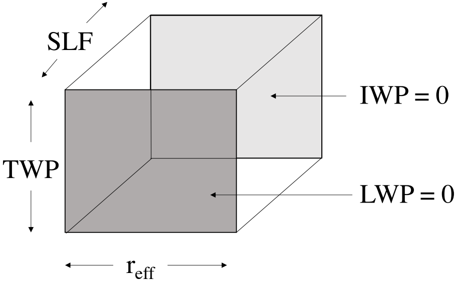


- Cloud particle size feedback also associated with cloud "lifetime" effect
- Basis: larger particles tend to precipitate out more efficiently
- This changes cloud **amount** in addition to cloud optical thickness
- Tan & Storlevmo (2019); Mulmendstadt et al. (2021)

Goals

- Use long-term ground-based **observations** at the NSA site to quantify the cloud particle size feedback in mixed-phase clouds from the perspective of the surface

Mixed-phase cloud radiative kernels (CRKs)



- Using RRTMG model, replace cloud optical depth with: TWP and effective radius (r_{eff})
- Supercooled liquid fraction (SLF) dimension accounts for mixed-phase clouds
- r_{eff} is weighted by the SLF

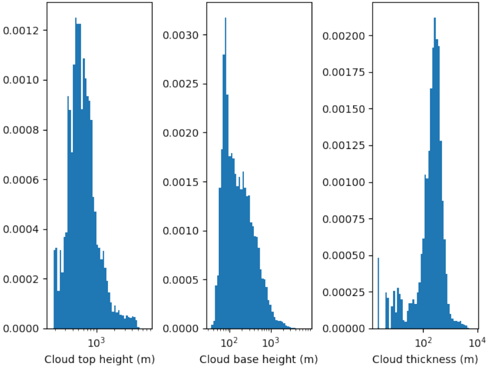
$$SLF = \frac{liquid}{liquid + ice}$$

$$r_{eff} = r_{liq} \times SLF + r_{ice} \times (1 - SLF)$$

Mixed-phase cloud radiative kernels (CRKs)

- Cloud feedback = Kernel $\times \Delta C \div \Delta T_s$
- The total cloud feedback can then be **decomposed** into contributions from the cloud particle size feedback
- We consider only **single-layer, stratiform** clouds

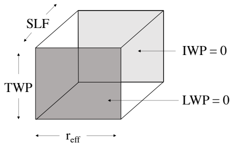
Mixed-phase cloud radiative kernels (CRKs)



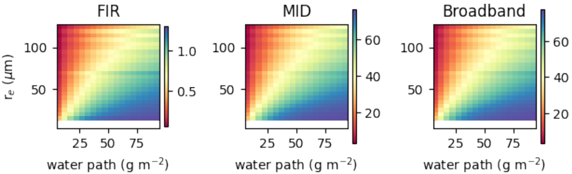
- Take three cloud-base heights: 30^{th}, 60^{th}, 90^{th} percentiles
- Take the cloud thickness to be the most commonly occurring value within each percentile range

Mixed-phase cloud radiative kernels (CRKs)

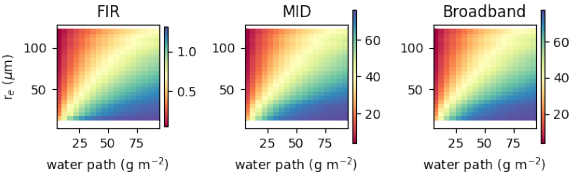
- Longwave cloud radiative effect at the surface



SLF = 0.1:

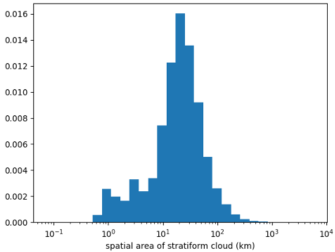


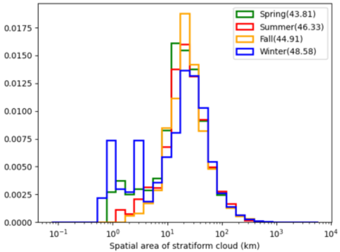
SLF = 0.2:



Mixed-phase cloud radiative kernels (CRKs)

- Median ≈50 km horizontal length of stratiform clouds over one hour
- Bimodal distribution with shorter horizontal cloud lengths in winter and spring





Summary

- Arctic mixed-phase CRKs have been built
- CRKs will be a PI product

Next steps:

- We will soon calculate the observed interannual total Arctic surface-based cloud feedback with these CRKs
- Decompose the total Arctic cloud feedback into contributions due to the cloud particle size feedback