CLOUD RADIATIVE FEEDBACKS' INFLUENCE ON ARCTIC CLIMATE CHANGE & PREDICTABILITY

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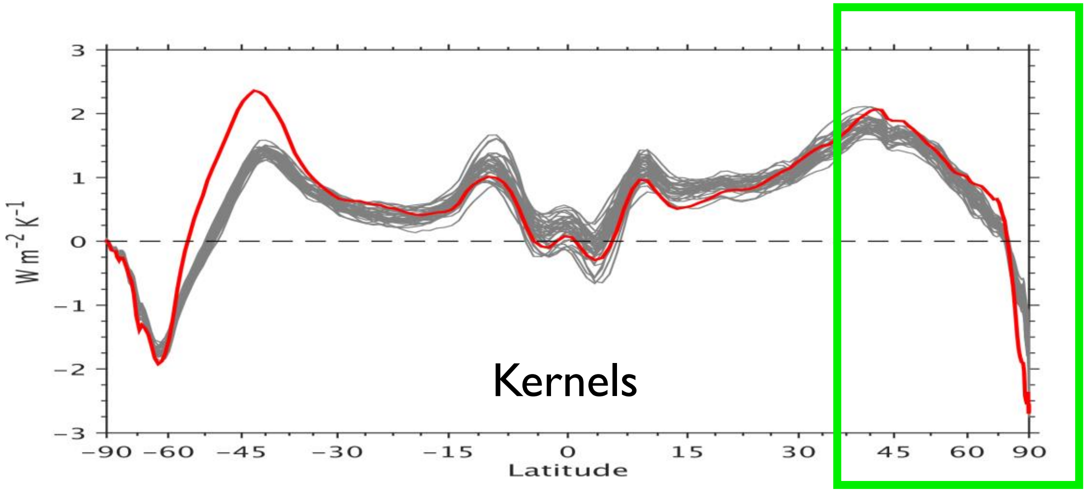
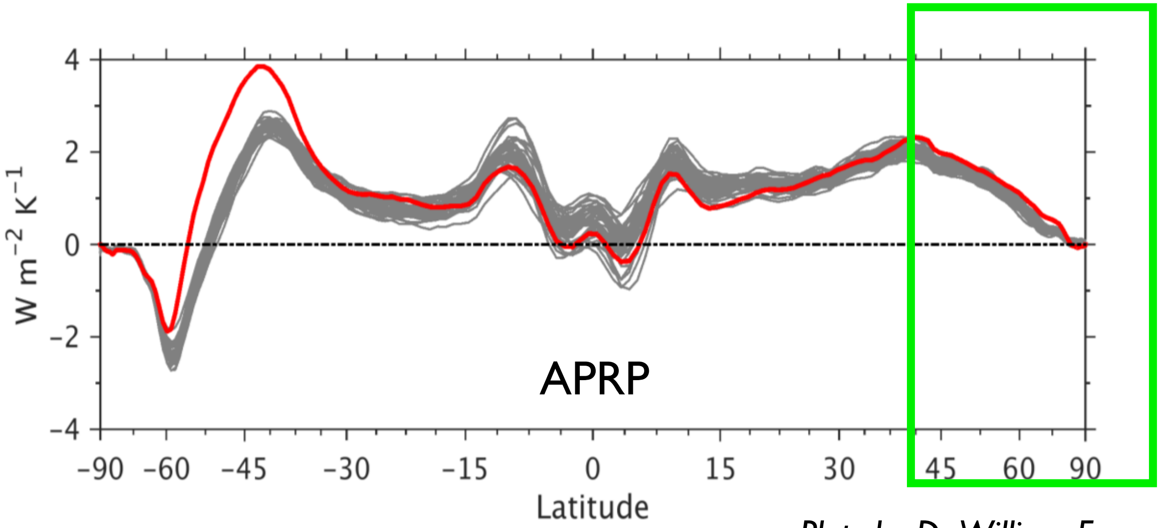
Detecting cloud radiative feedbacks' influence on the Arctic surface

Zonal mean SW Cloud Radiative Feedback in CESMLE (gray) & Observations (red)



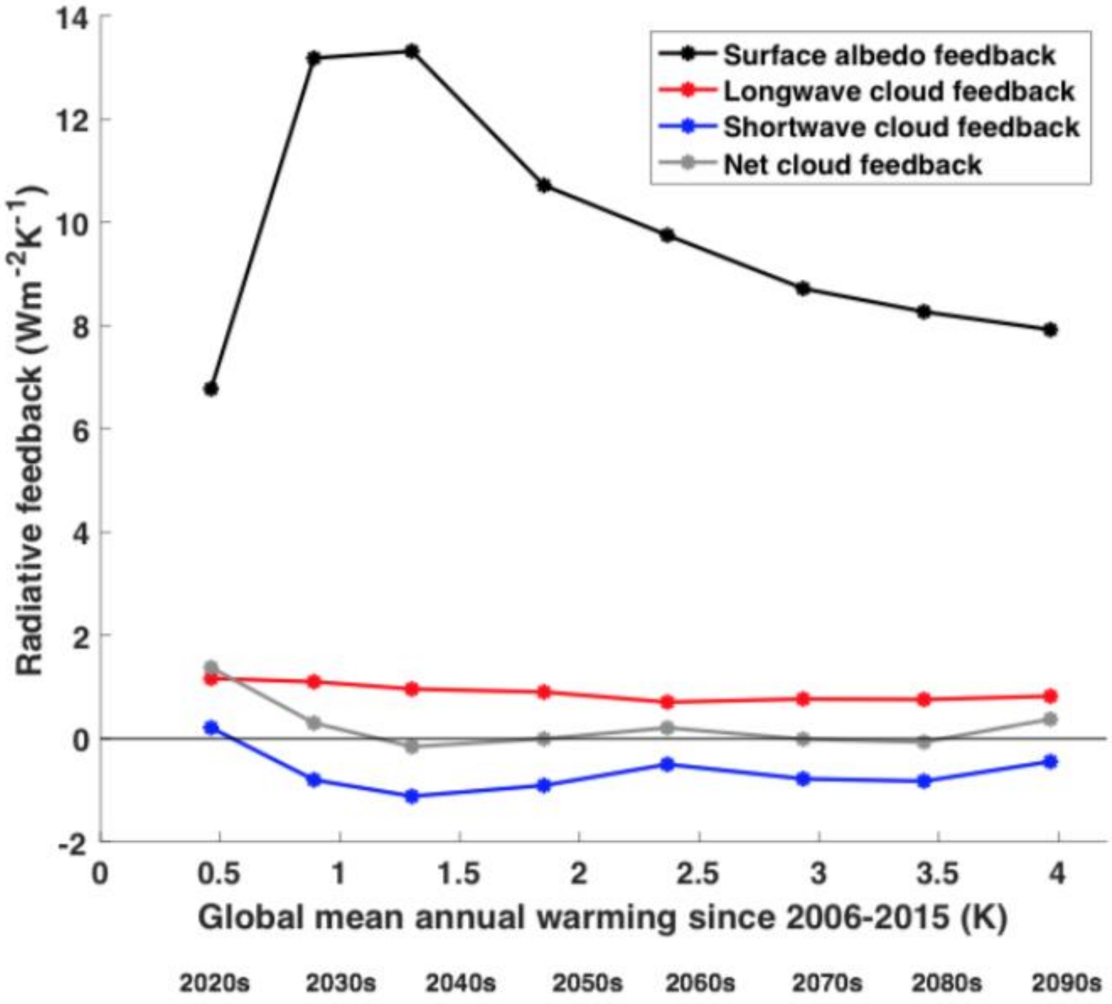


Plots by Dr.William Frey

- Radiative kernel technique:
  - Zelinka et al. (2012) detected an overall negative cloud radiative feedback (CRFB) in the Arctic across CMIP5 models
  - Pithan and Mauritsen (2014) measured a slightly positive CRFB, but models didn't agree on sign
  - Problems with calculating CRFB along sea ice edge (Pendergrass et al. 2018)
- APRP (approximate partial radiative perturbation) technique:
  - Explicitly calculates sea ice radiation

APRP in CESM1

- Shows consistency with observations in regards to cloud radiative feedback (Morrison et al. 2018)
- Though still does not account for correlation between clouds and other variables



Morrison et al. 2018, JGR

APRP in CESM

- Shows consistenc
  observations in r
  radiative feedbacl
  2018)
- Though still does
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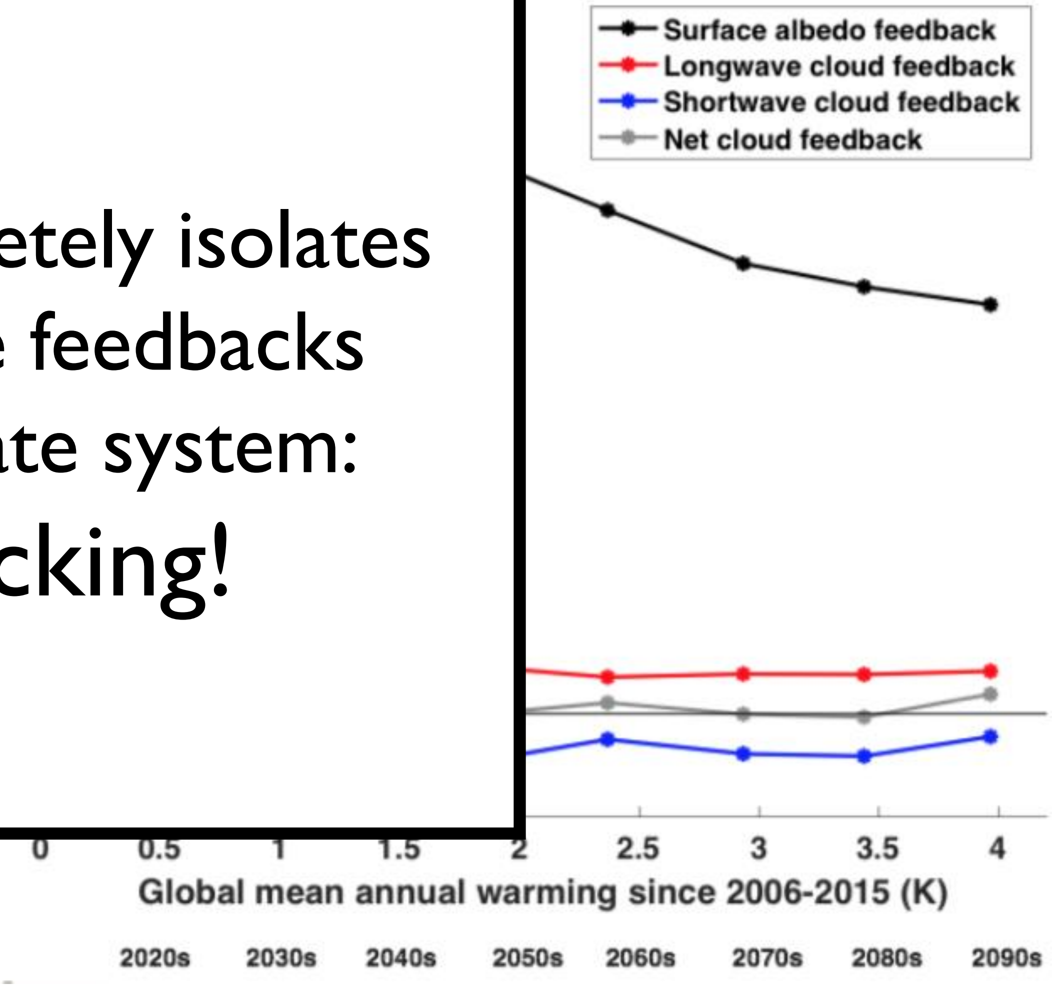
  other variables

One tool completely isolates cloud radiative feedbacks from the climate system:

cloud-locking!



Morrison et al. 2018, JGR

Experimental design

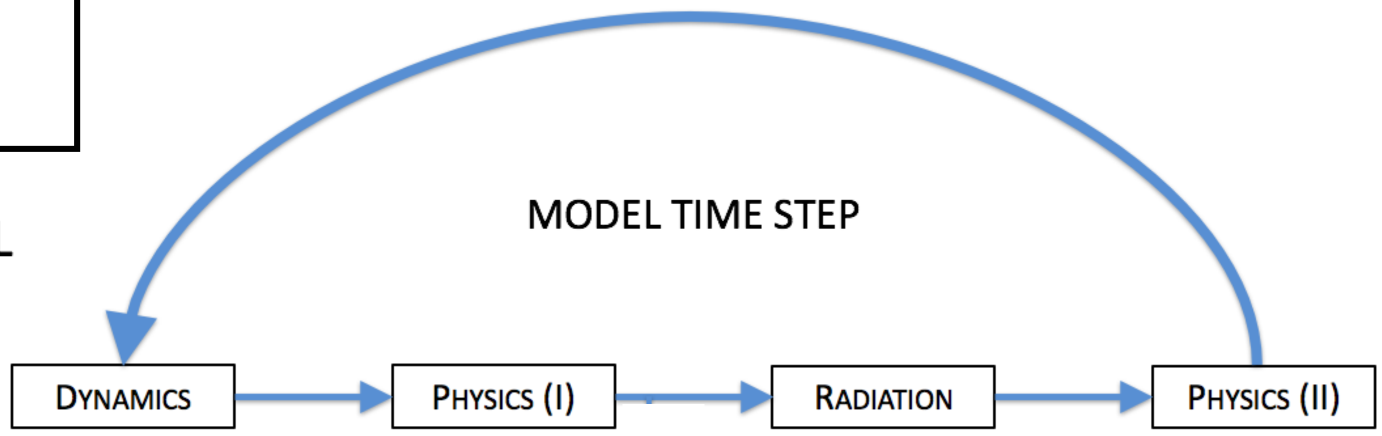
- Compare two fully-coupled CESM1 simulations:
  - One with cloud radiative feedback ("control"), one without ("cloud-locked")
  - Control is the long preindustrial simulation from the CESM Large Ensemble
  - Cloud-locked also has preindustrial control forcing

- Cloud-locked simulation is 134 years in length; first 30 years are omitted

- Control simulation is analyzed in 134-year chunks

Cloud-locking method

CONTROL



- Before radiation module is called in *control*:
  - Output cloud every 2 hours for 1 year
  - ***9 cloud parameters****
- In the radiation module of *experiment*:
  - cloud parameters are used instead of predicted cloud parameters
  - 1 year of cloud is repeated throughout duration of experiment

*cloud amount (1)

*liquid water, snow, and ice paths (3)

*effective radius of snow and ice (2)

*microphysical parameters dictating the size distribution of rain droplets (2)

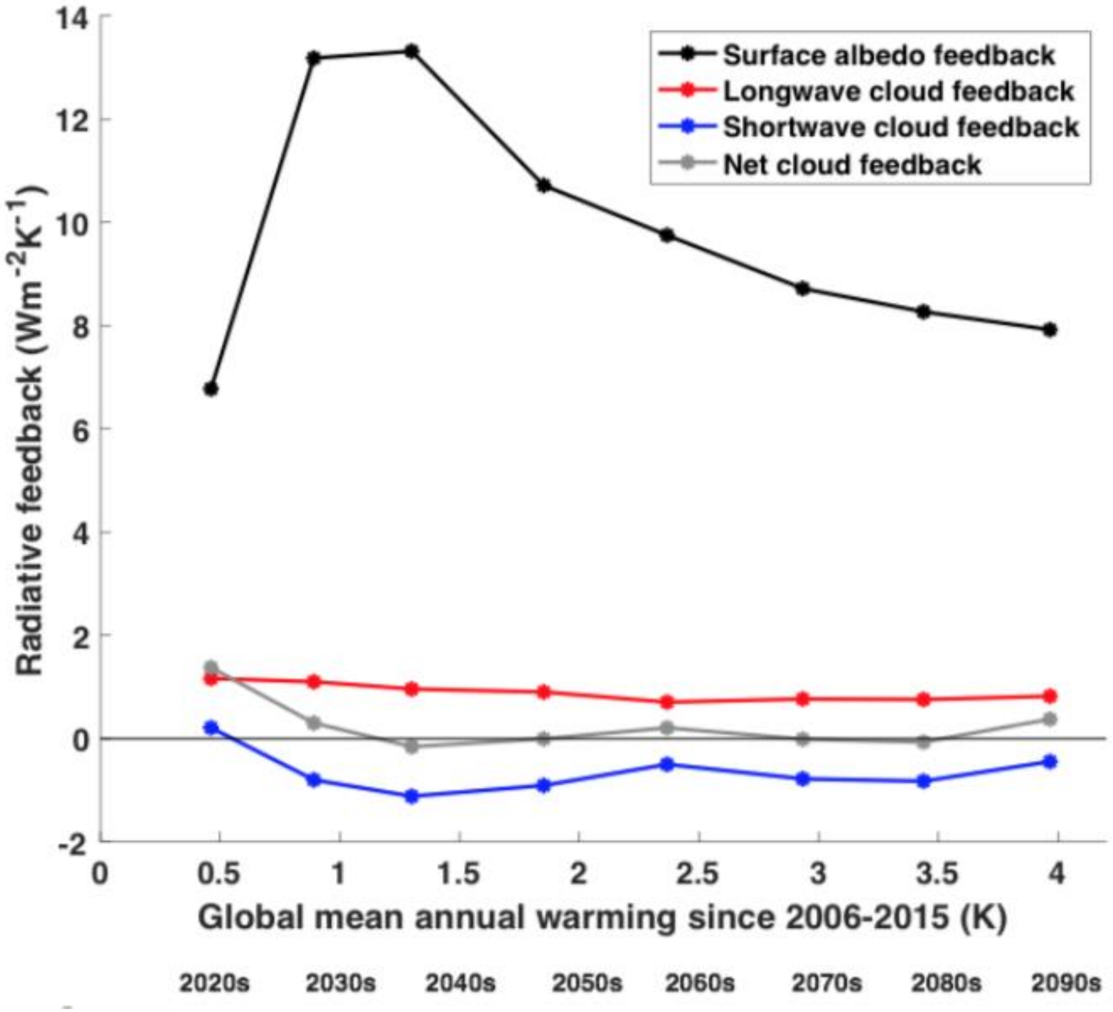
*effect of falling snow (1)

Hypothesis: how will the Arctic respond to locking clouds?

Cloud-locking experiments will show that cloud radiative feedbacks ***will not*** impact the predictability or variability of Arctic surface temperature & sea ice

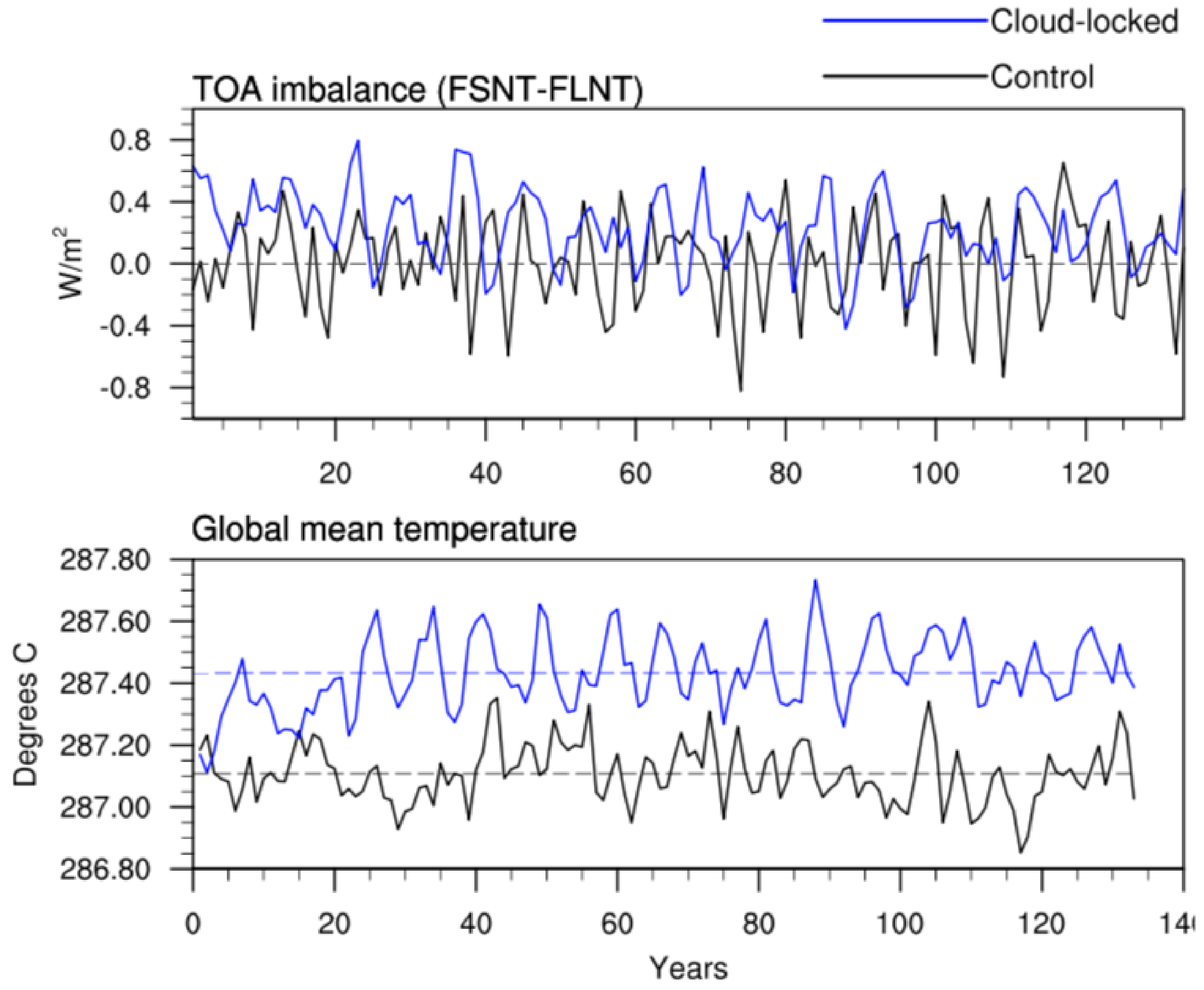
(At least in CESM…)*

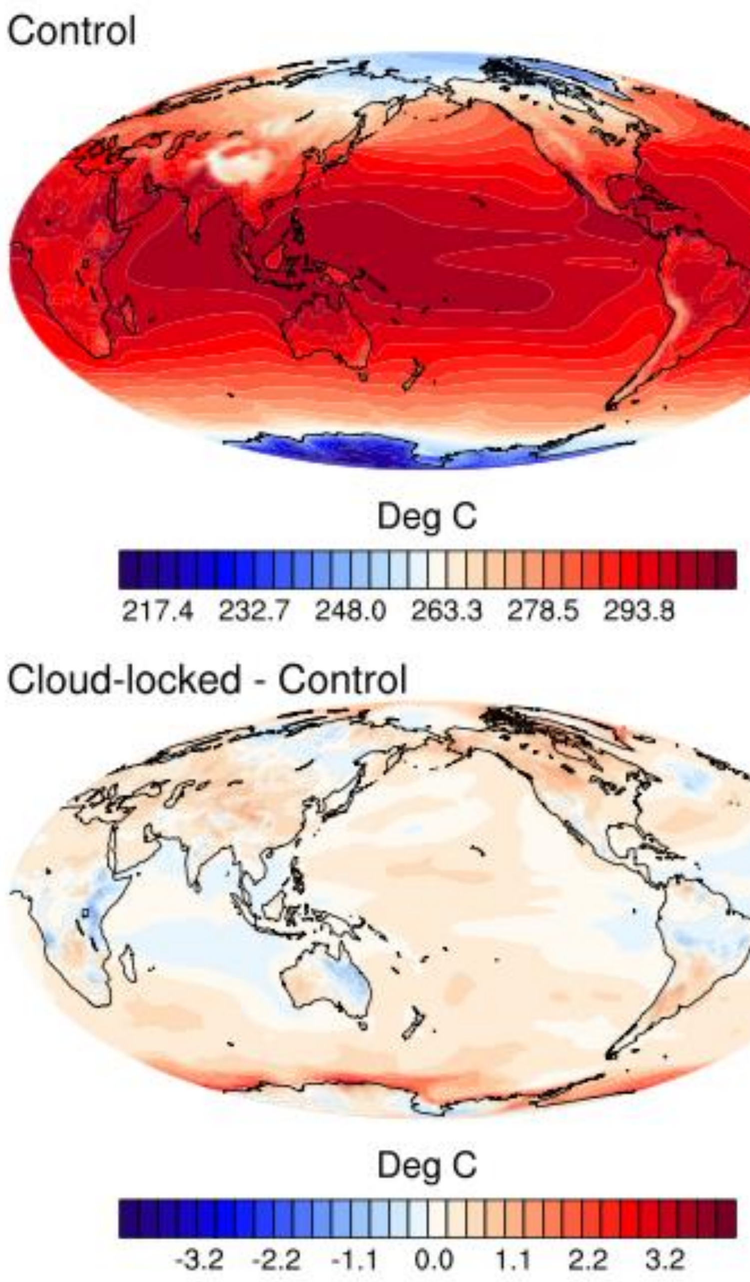
**based on Morrison et al. (2018) & our physical understanding, this looks realistic…*



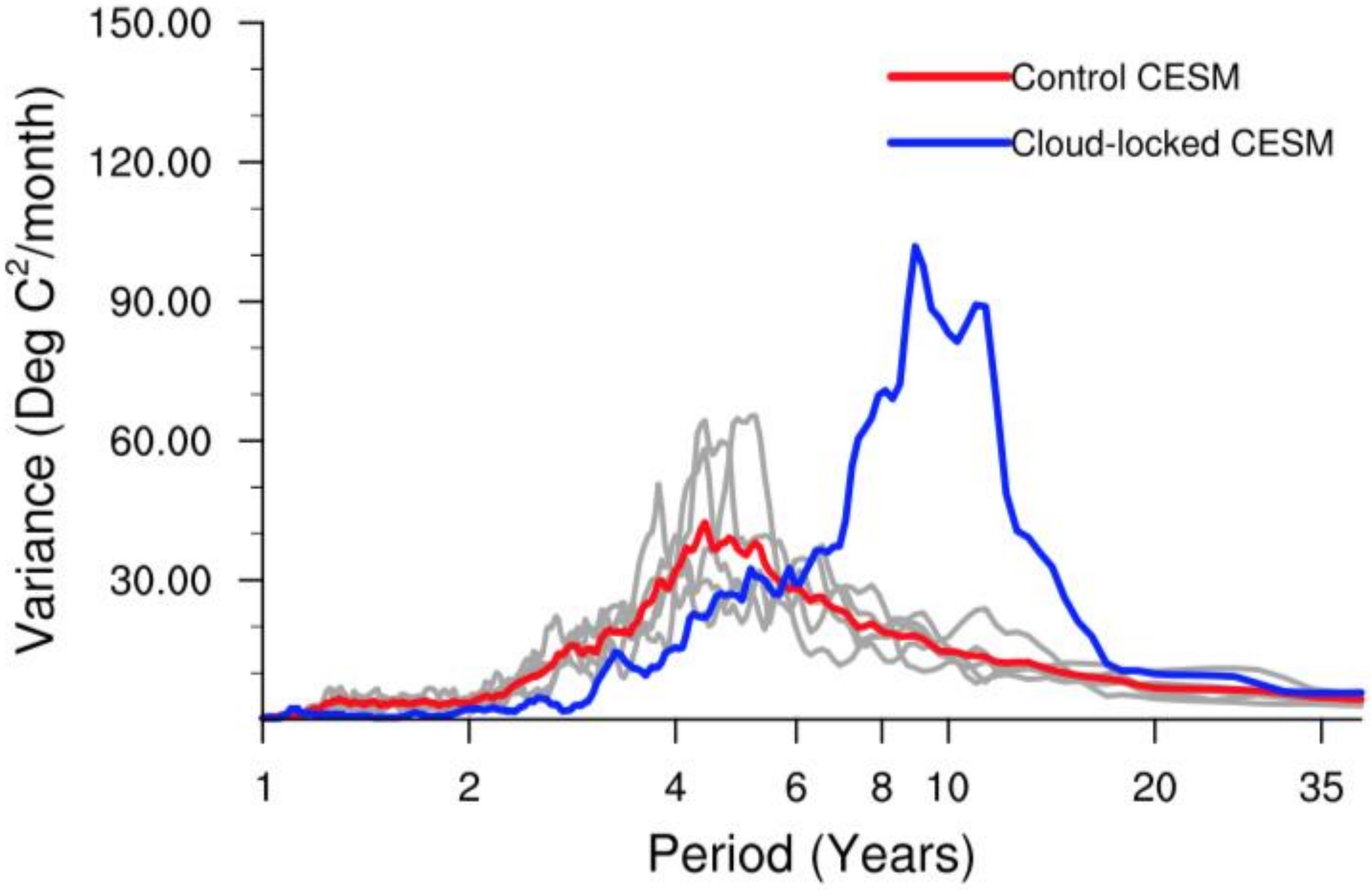
Morrison et al. 2018, JGR

Cloud-locking results in a new, stable equilibrium



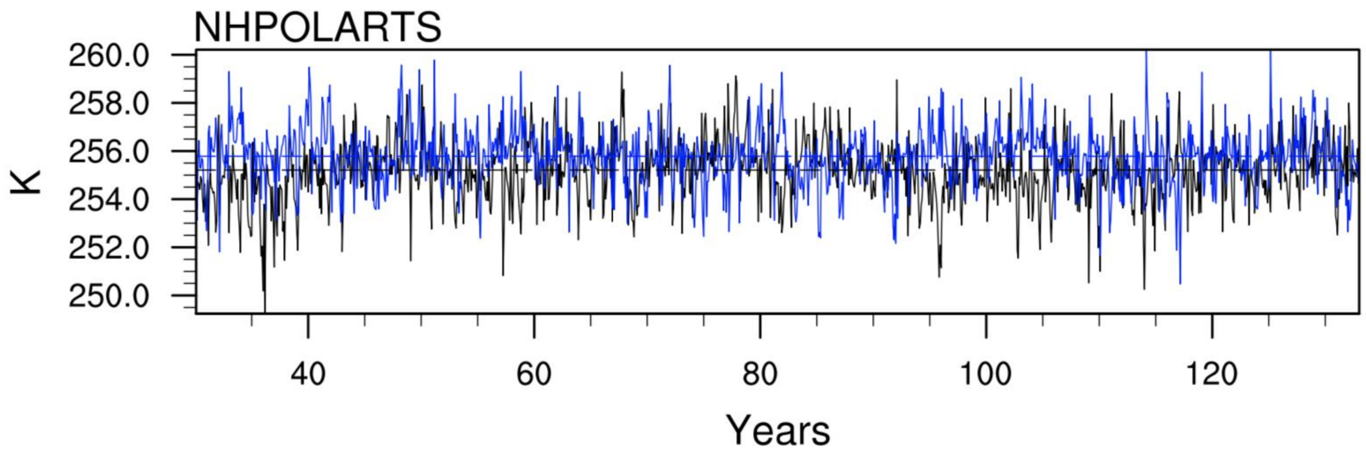


*Teaser: ENSO response-- power spectra of Niño3.4 index

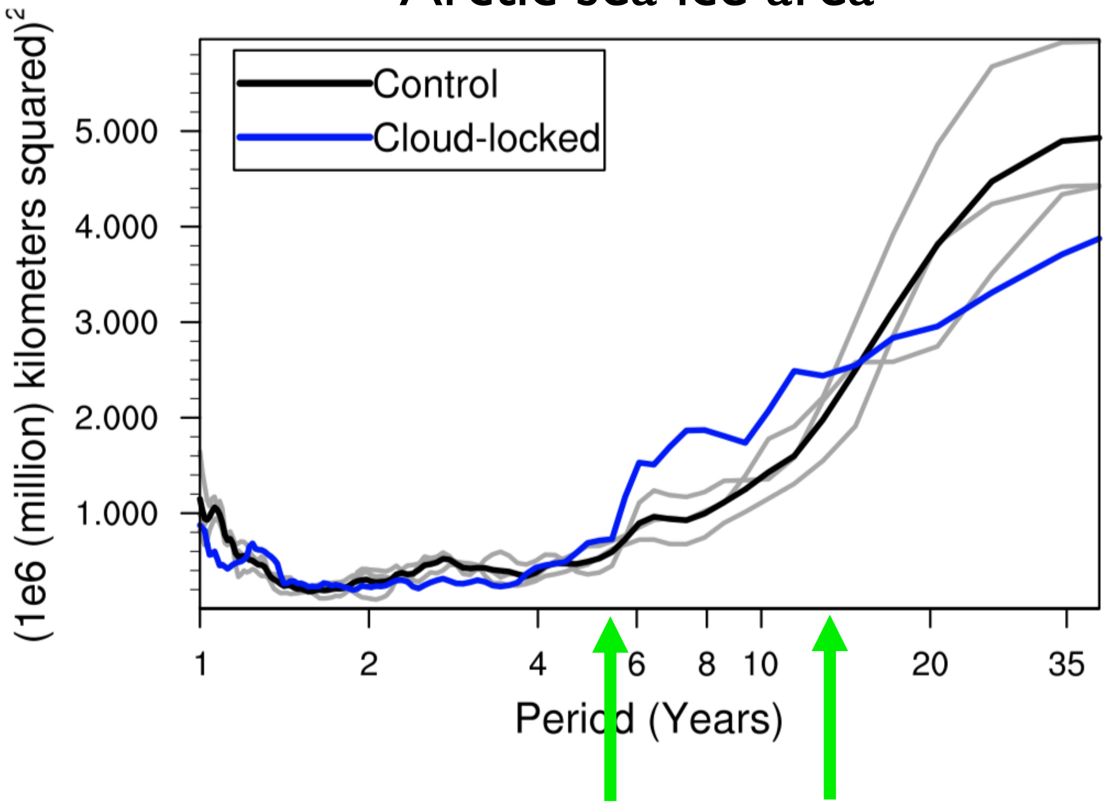


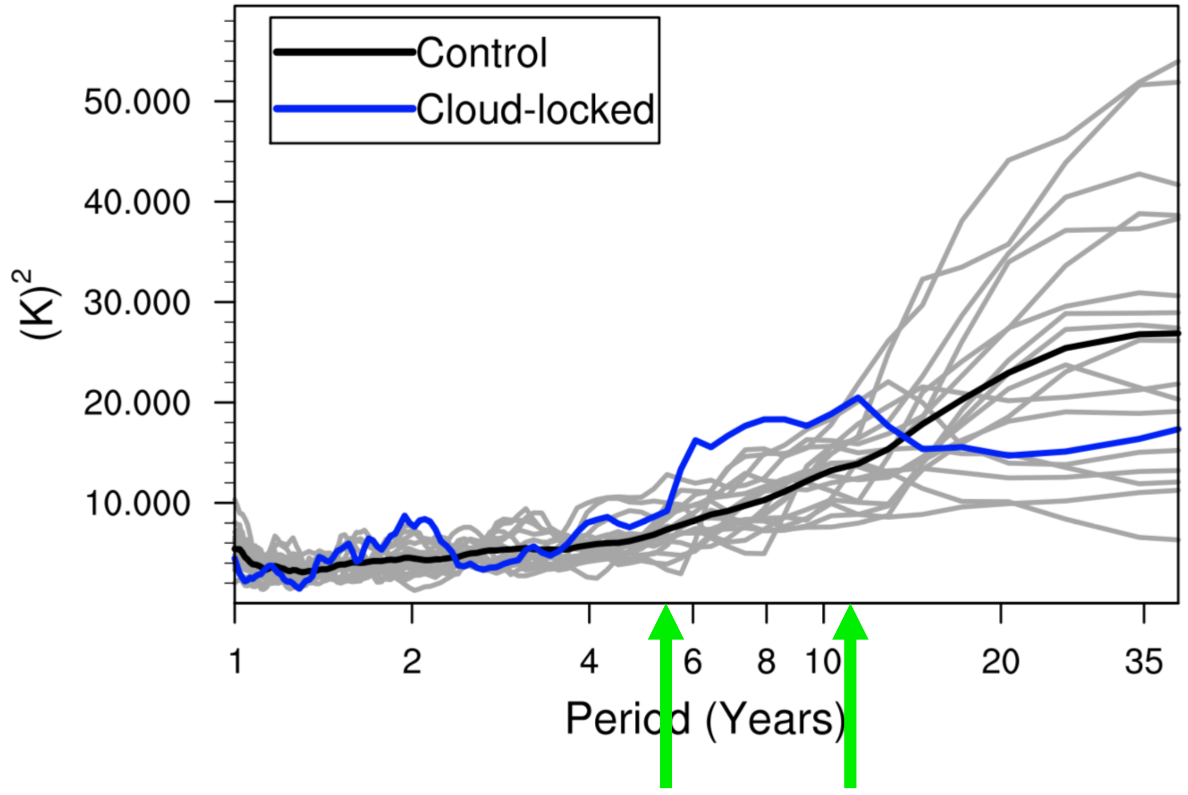
Middlemas et al. 2019, in revision, J. Clim

Changes in Arctic temperature

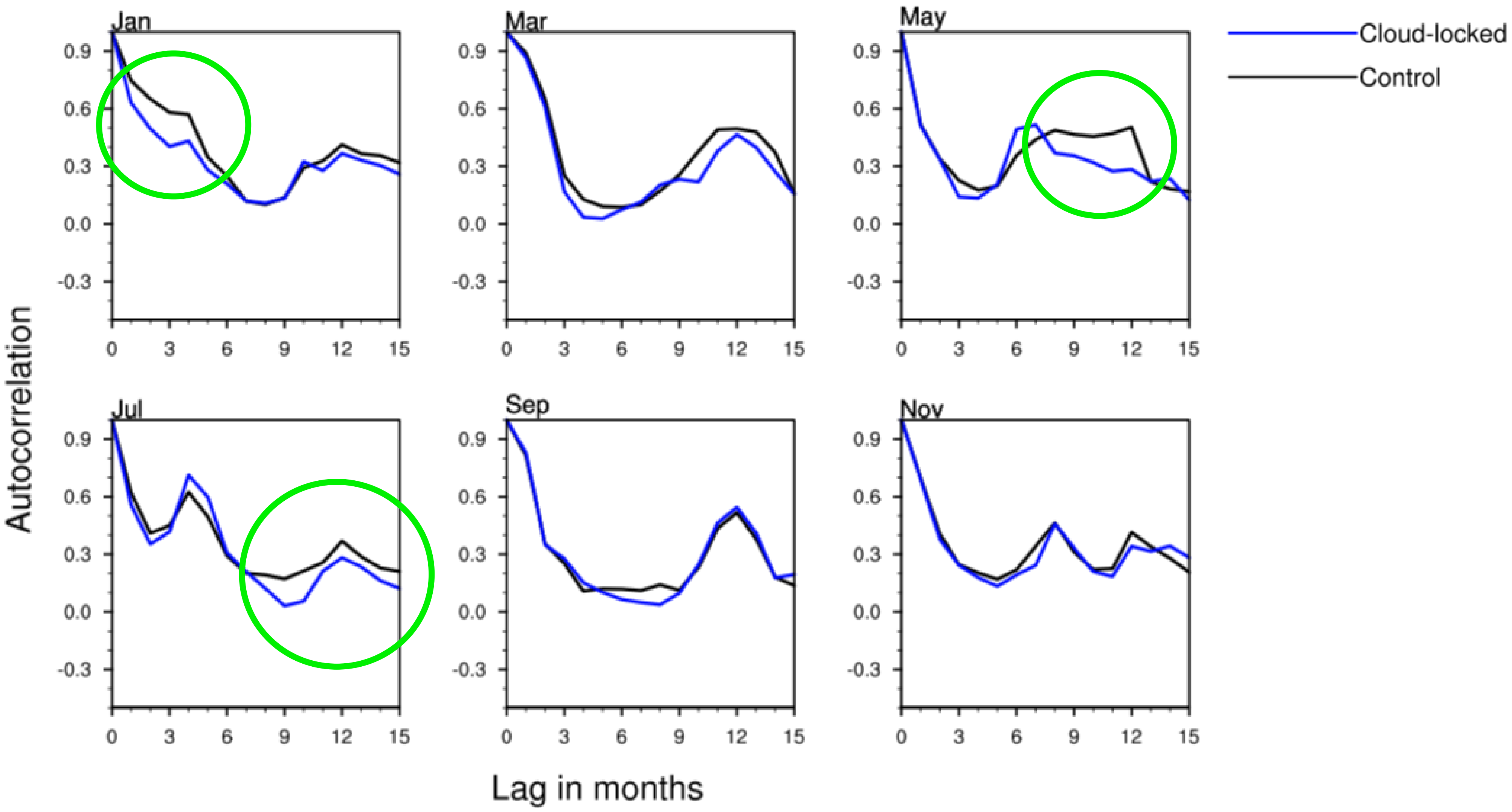


Arctic sea ice area



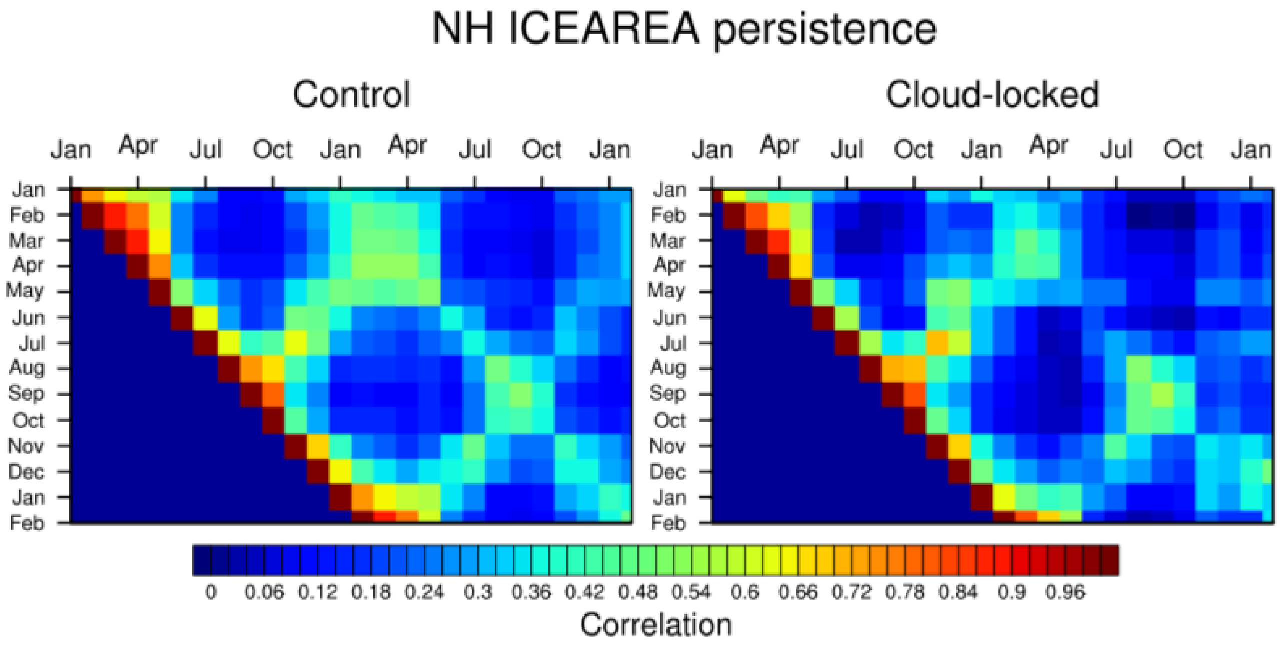


Change in the persistence of sea ice area



Change in the persistence of sea ice area

- Following Blanchard-Wrigglesworth et al. 2011 analysis
- Cloud radiative feedbacks enhance persistence of sea ice area:
  - From winter to following months
  - From spring/summer to next spring/summer



SST re-emergence?

Enhanced sea ice thickness?

Conclusions

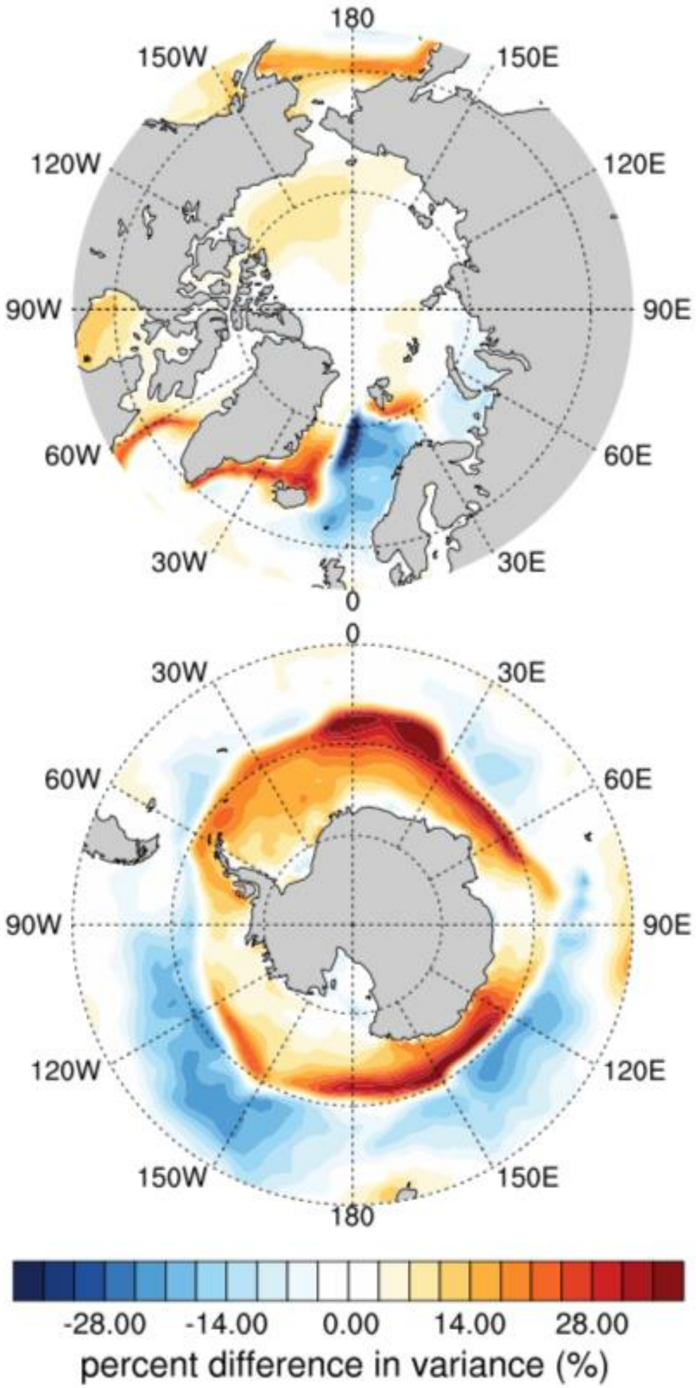
- Locking cloud radiative feedbacks in a fully-coupled climate model with preindustrial control forcing….
  - Leads to a new stable climate with little change in the Arctic mean state
  - But also small changes in Arctic sea ice & temperature variability & predictability
    - ENSO-related changes?
  - Longer experiment needed to assess statistical significance

Future experiments

- Perform cloud-locking in 2xCO_2 experiments to isolate impact of cloud radiative feedbacks on Arctic amplification
- Locking clouds only in the Arctic to disentangle teleconnections from ENSO response
- Seasonal perfect model forecasting experiments? (Blanchard-Wrigglesworth & Ding 2019, submitted)

Thank you!
Questions?

Changes in SST variance



Niño3.4 index response to cloud-locking