The influence of clouds on Arctic Warming and Amplification

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Thin (40 cm) first-year ice, clouds, and a seal near Barrow, Alaska – June 2016

Be Boulder.
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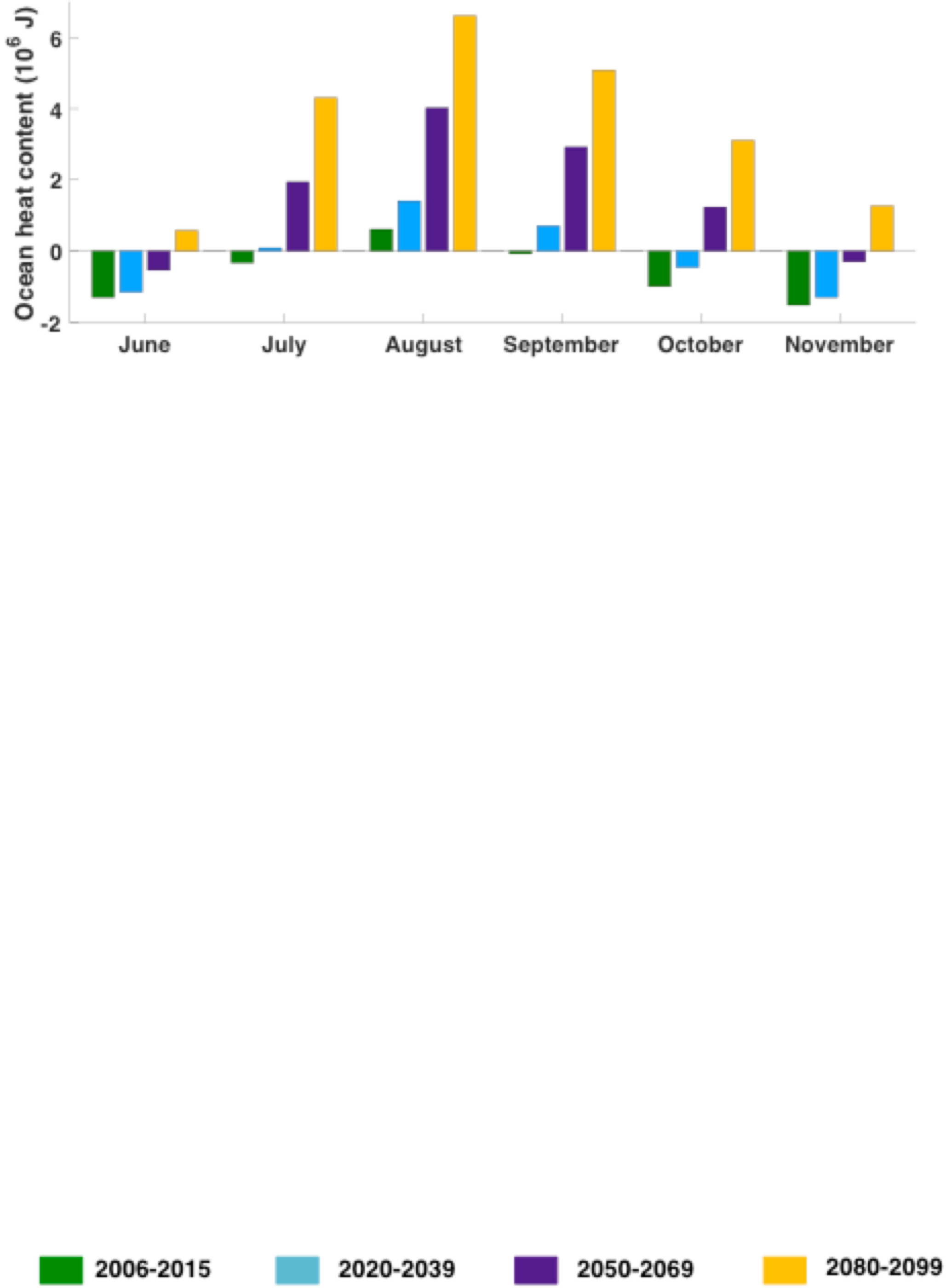
Observed Arctic sea ice loss and greater-than-global Arctic warming predicted decades ago….

Manabe and Stouffer (1980): "The CO_2-induced warming of the surface air is particularly large in high latitudes. "

"supercomputer" (1970s)
0.5 MB of memory

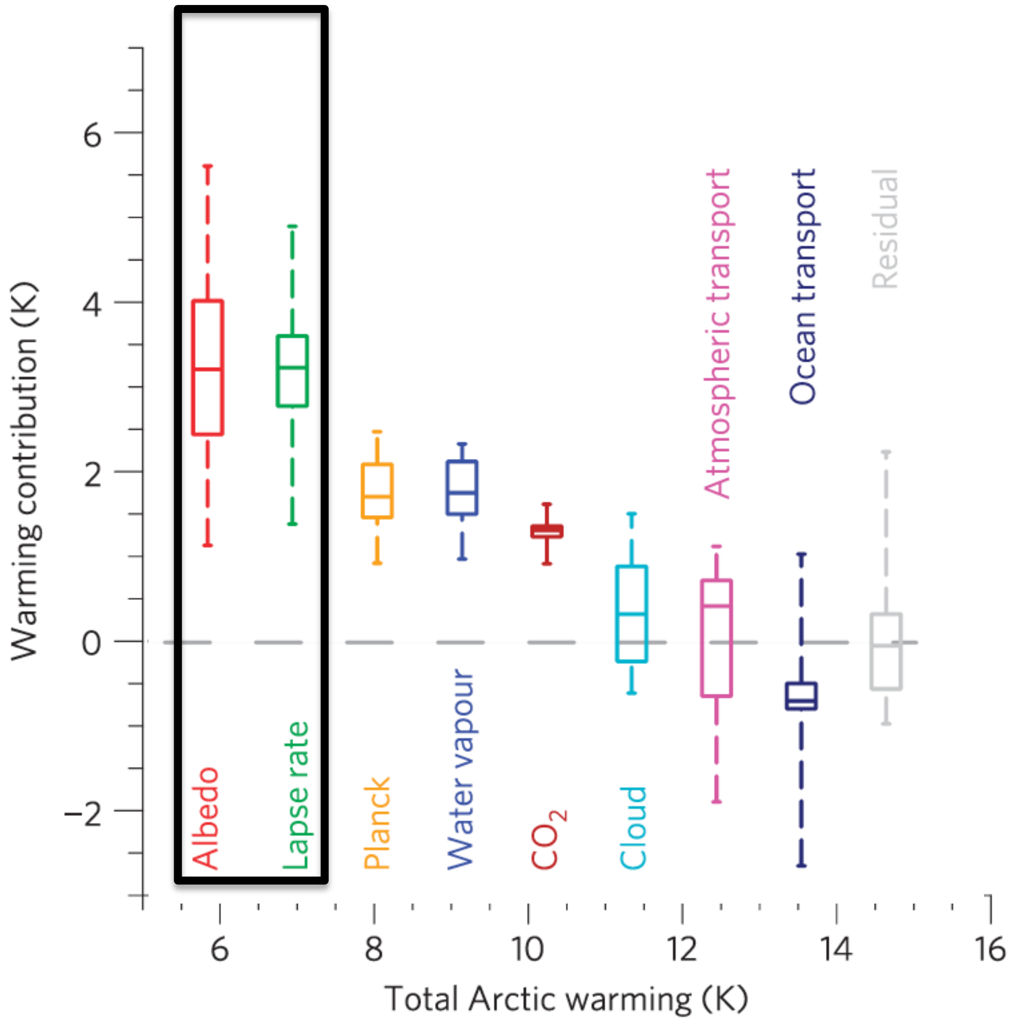
Similar to Manabe and Stouffer (1980), modern climate models show:

1) During Summer, shortwave radiation is absorbed in the surface ocean fueling a **positive surface albedo feedback**.
2) During Fall, accumulated ocean heat is fluxed to the lower atmosphere, the lower atmosphere warms, and atmospheric stability decreases fueling a **positive lapse rate feedback**.



Morrison et al. JGR (2018b)

Interconnected Positive Surface Albedo Feedback and Positive Lapse Rate explain Arctic Warming



Adapted from Pithan et al. 2014

While the representation of clouds in climate models has become more sophisticated, the vertical and seasonal fingerprints of Arctic greenhouse warming have not changed.

Do the clouds matter?

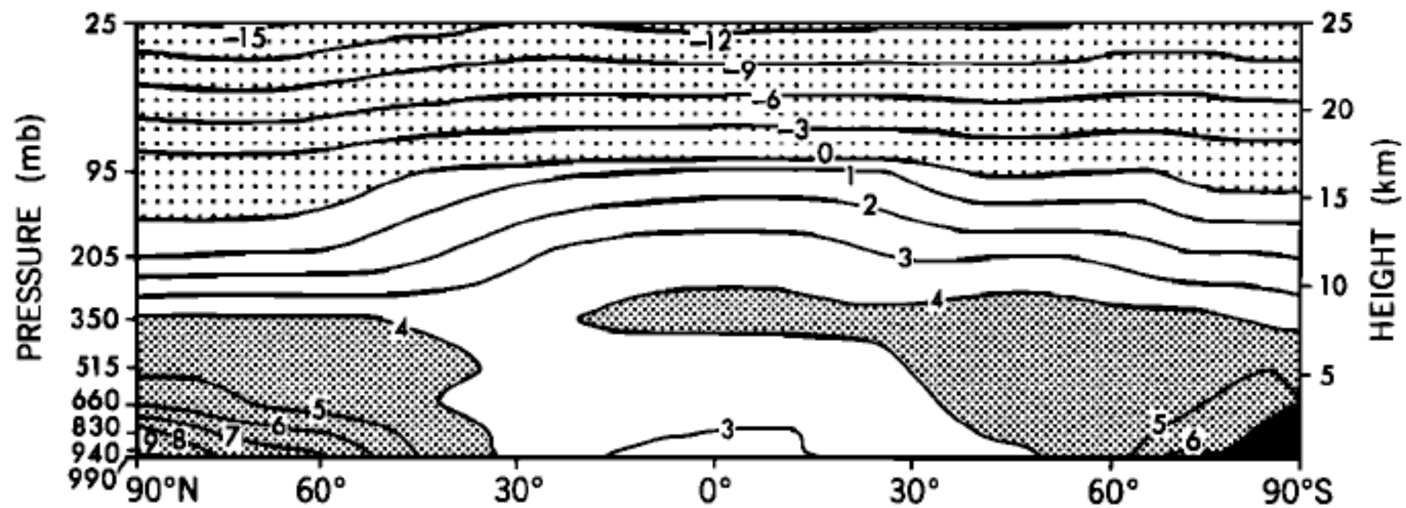


Fig. 14. Latitude height distribution of the zonal mean difference in annual mean temperature (degrees Kelvin) of the model atmosphere between the 4 × CO_2 and 1 × CO_2 experiment.

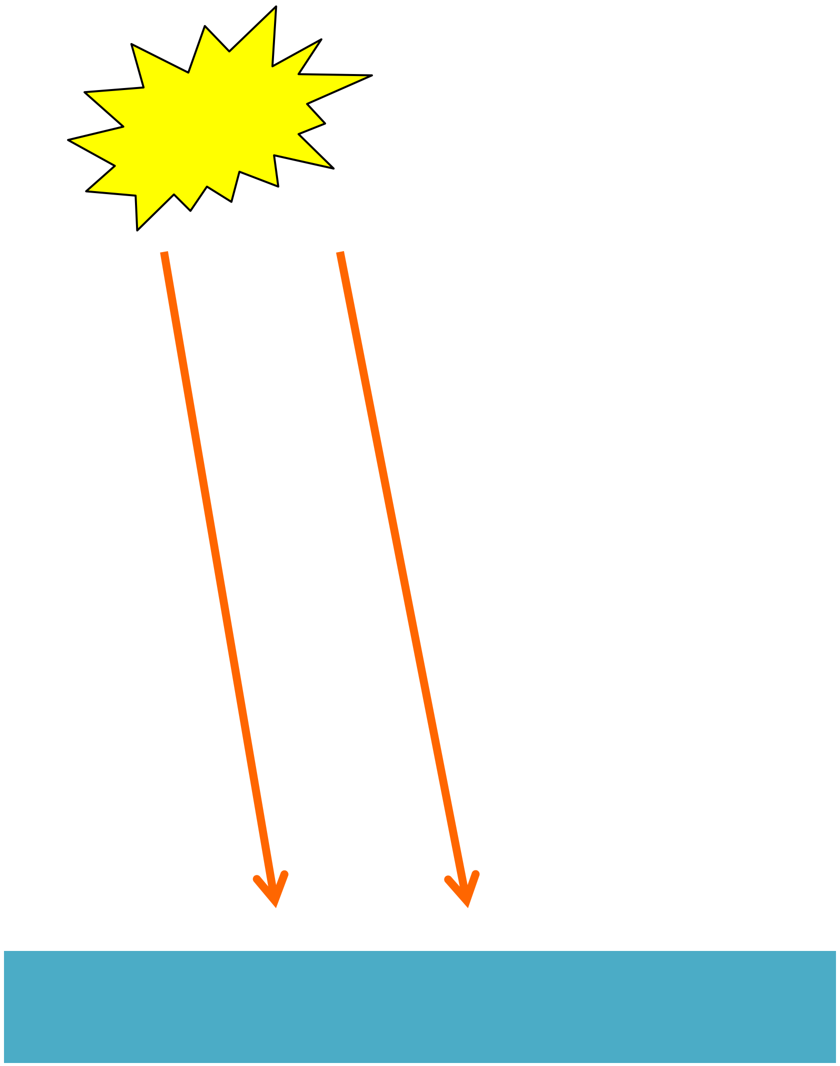
Manabe and Stouffer, 1980

Why might clouds matter for Arctic Warming and Amplification?

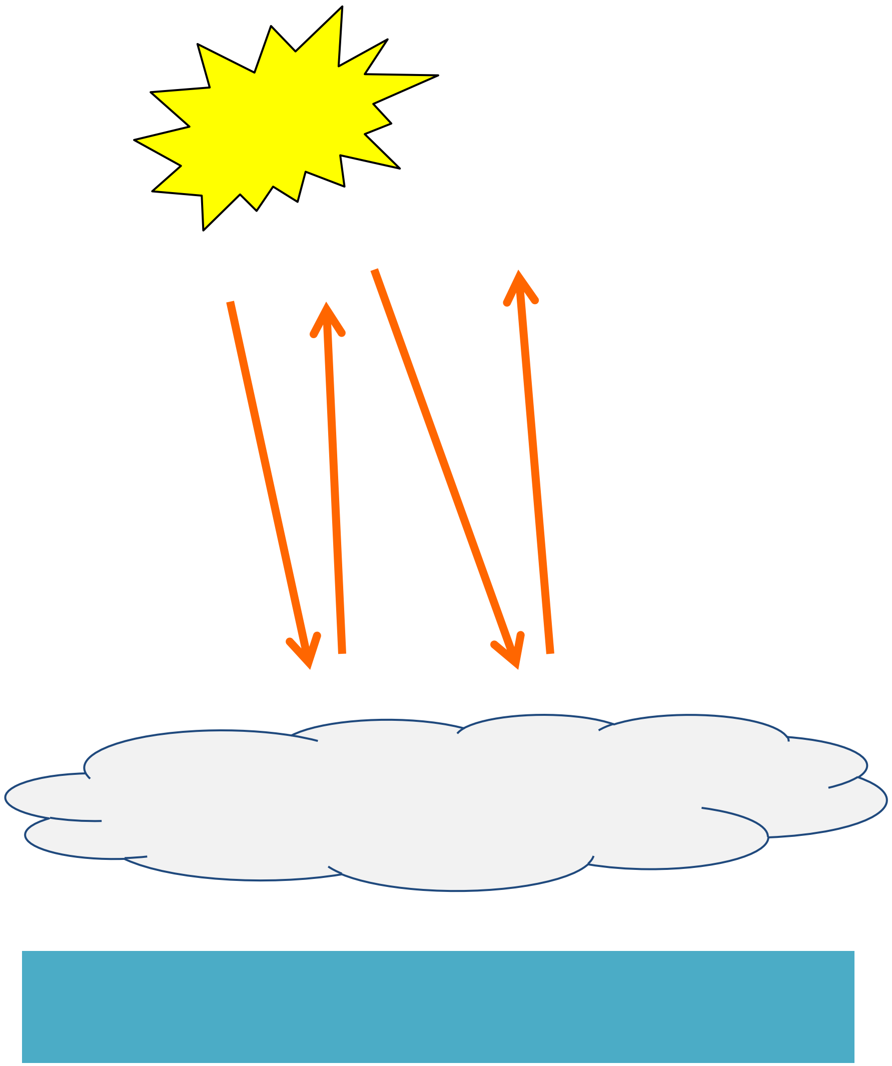
1) **Cloud Masking** – clouds reflect incoming shortwave radiation back to space

2) **Cloud Feedbacks** – clouds change with warming, which then influences the warming

Surface albedo feedback strength regulated by "cloud masking"

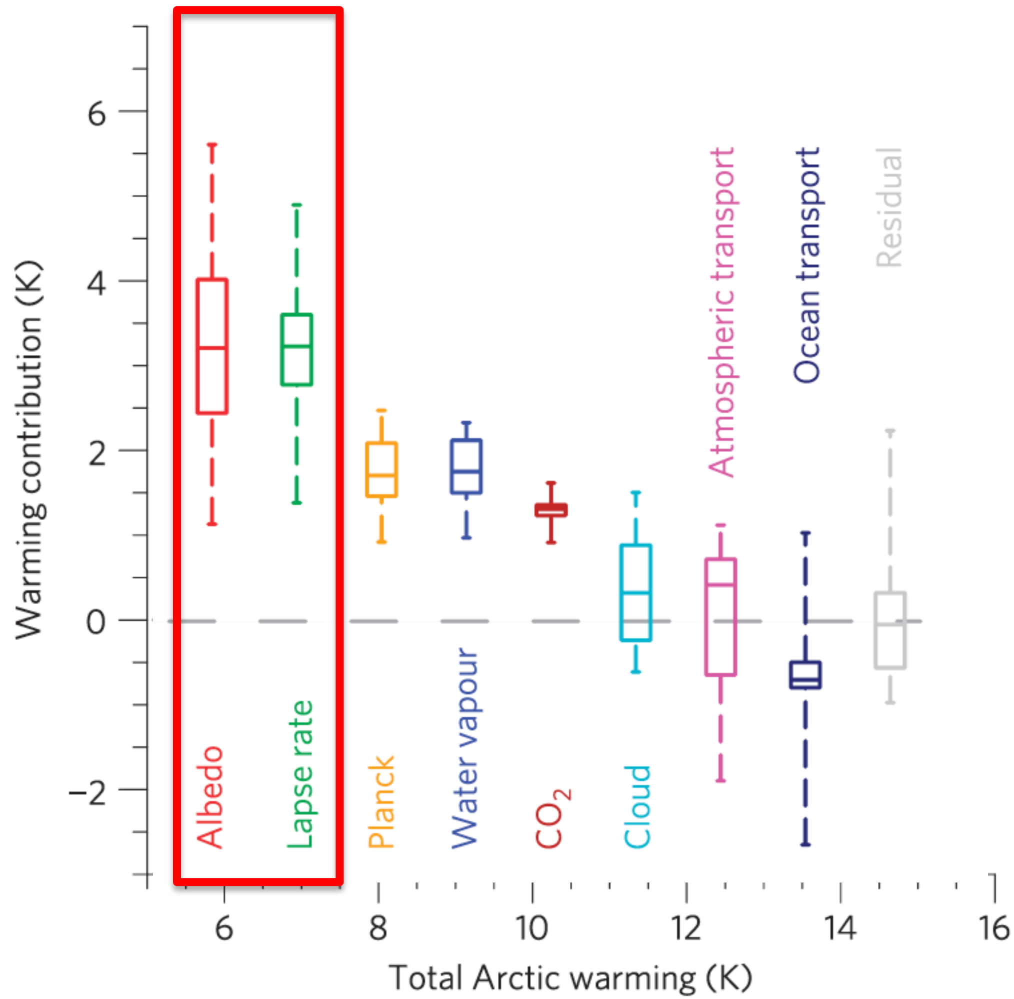


Maximum albedo feedback



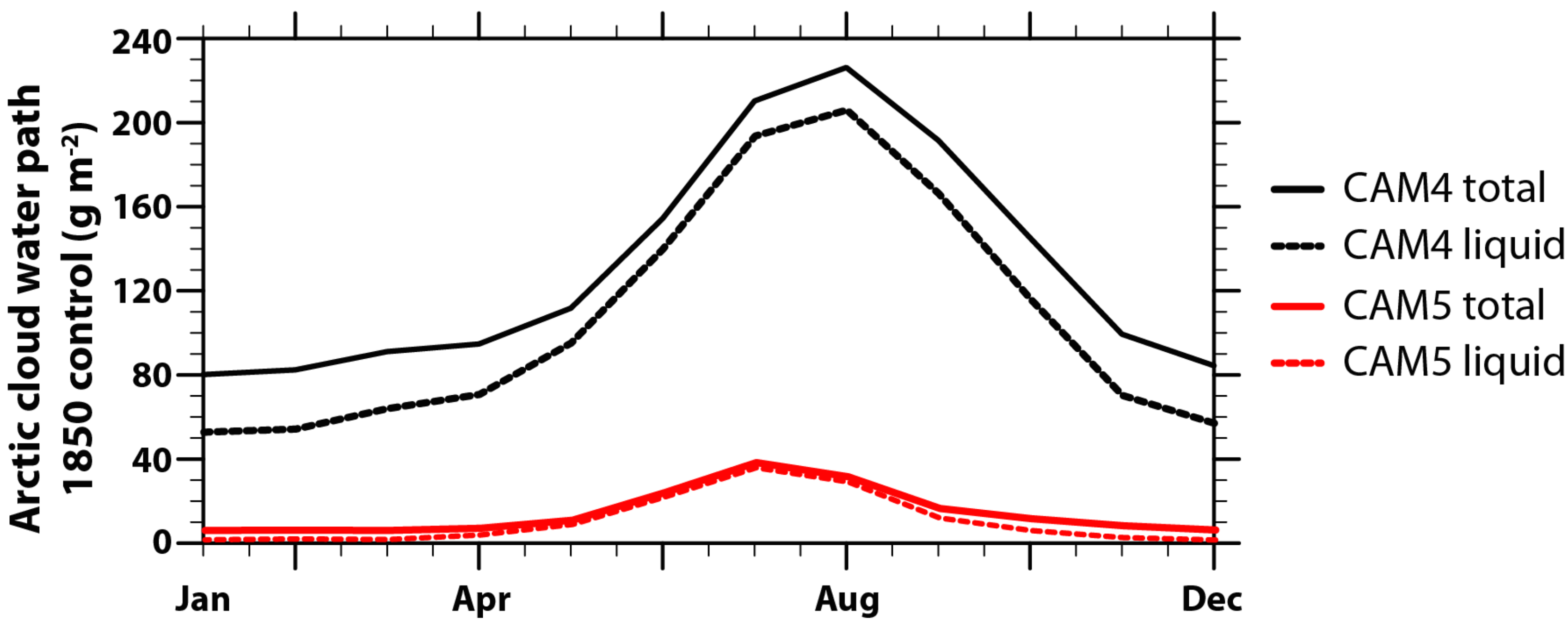
No albedo feedback

Clouds regulate the strength of the most important positive feedbacks in the Arctic: the interrelated albedo and lapse rate feedbacks!



Adapted from Pithan et al. 2014

Let's consider two models… CAM4 and CAM5. Which one when coupled to the rest of the climate system will produce more Arctic warming?

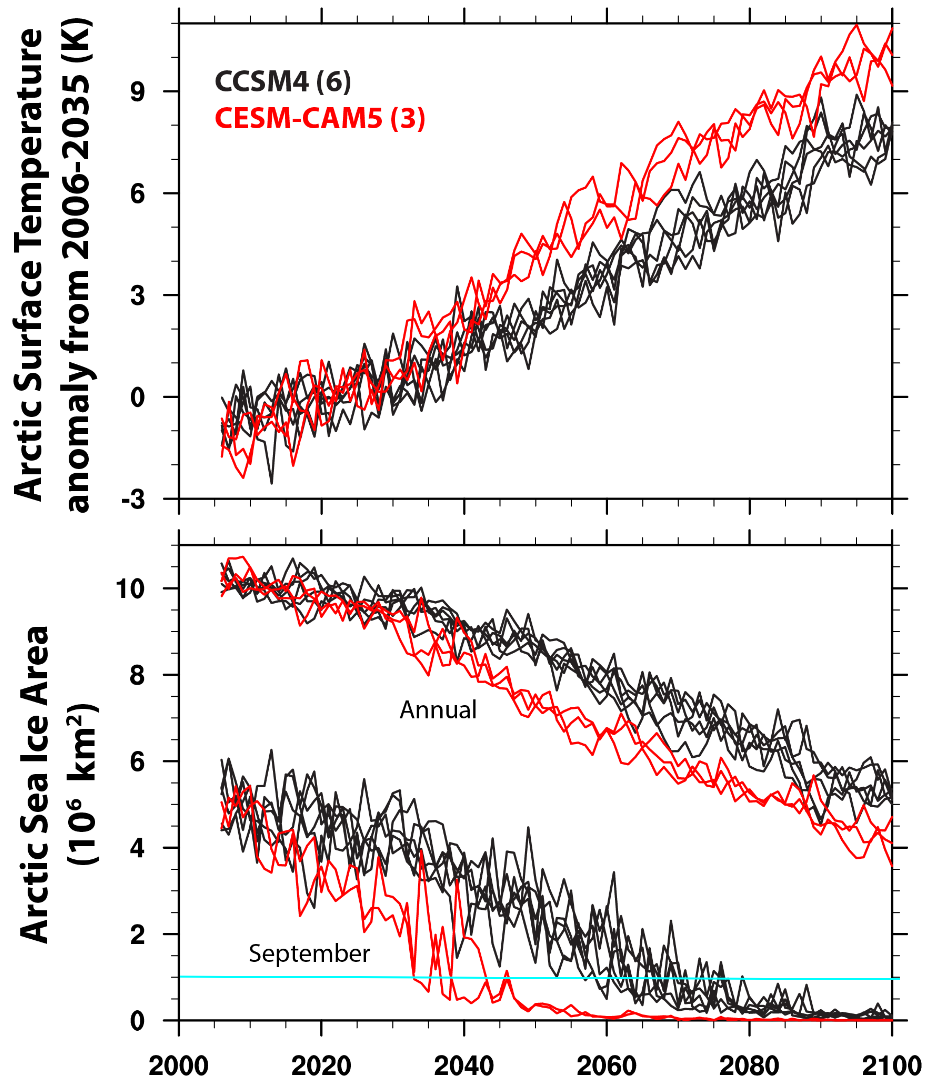


Kay et al. 2012

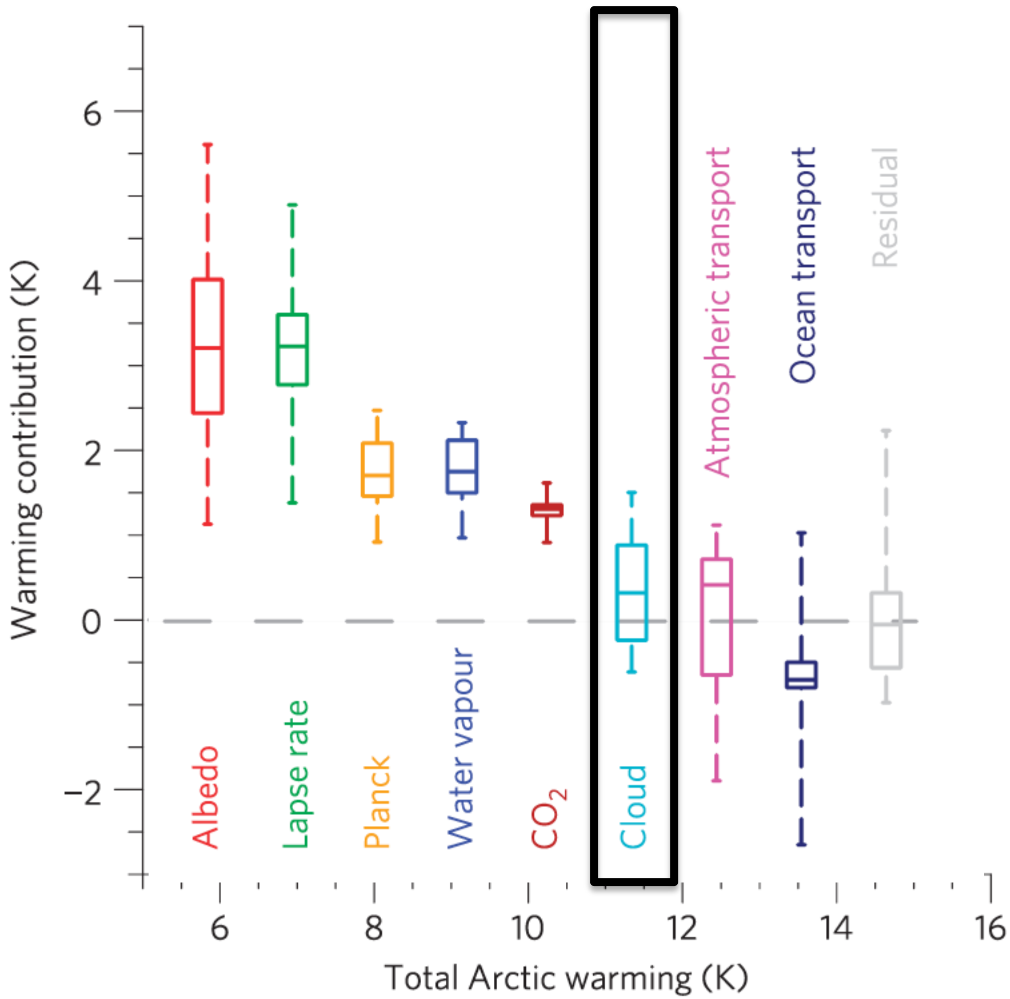
Evidence that cloud masking matters…. E.g.,

Shortwave feedback differences explain why fully coupled model with CAM5 (CESM-CAM5) goes ice free ~2 decades earlier than the fully coupled model with CAM4 (CCSM4).

Meehl et al. 2013



Modeled Arctic cloud feedbacks uncertain but small contribution to total Arctic warming



Adapted from Pithan et al. 2014

MIDDLEMAS ET AL. (IN PREP)

AMS100

ABSTRACT

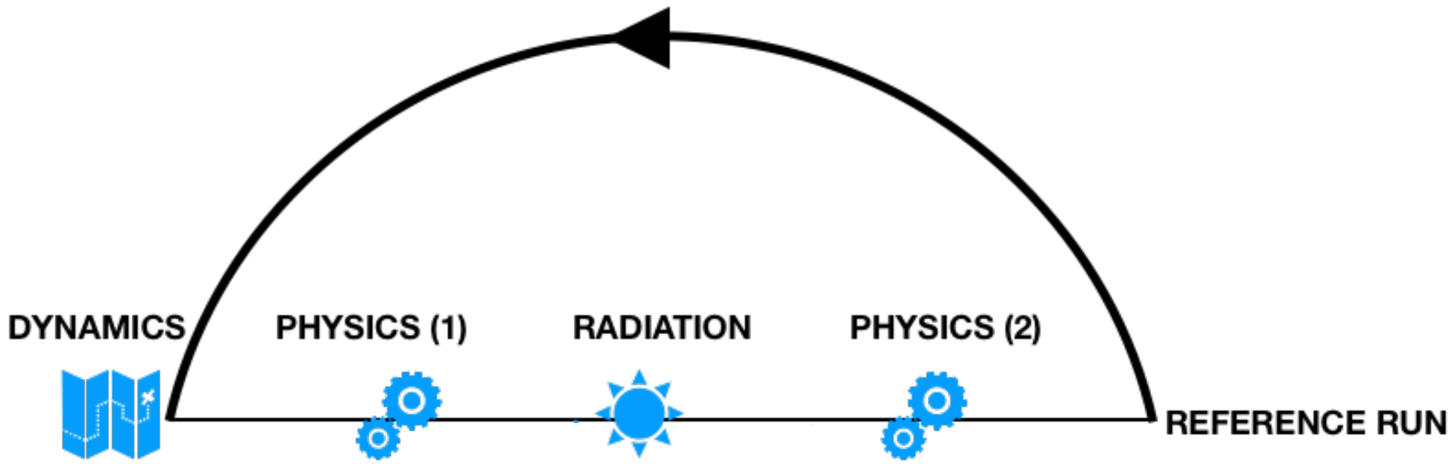
8B.4: Isolating the Influence of Cloud Radiative Feedbacks on Arctic Amplification through Cloud-Locking

Tuesday, May 21, 2019 **04:15 PM - 04:30 PM**

Williams Village Conference Center - Room B

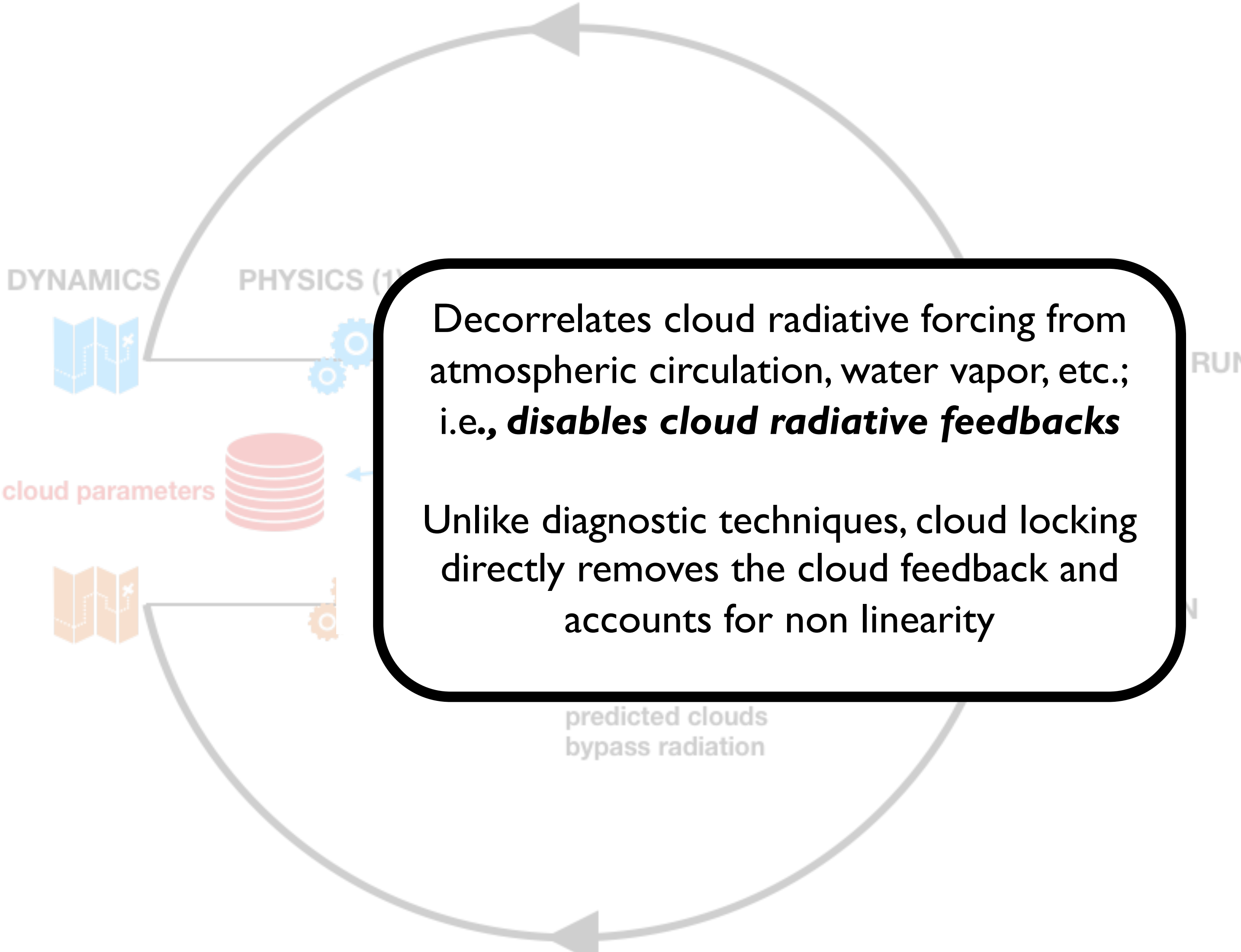
Satellite observations show increased cloud cover during non-summer months associated with Arctic sea ice loss, but no cloud response to summer sea ice loss (Morrison et al. 2018a; Kay et al. 2016). These observed non-summer cloud increases can increase surface-based Arctic amplification by generating a positive longwave cloud radiative feedback. Some climate models can reproduce observed present-day cloud-sea ice relationships. For example, CESM1 captures the physical mechanisms controlling seasonal changes in the cloud response to sea ice (Morrison et al. 2018b). Yet, it remains challenging to diagnose cloud influence on Arctic amplification in climate models because diagnostic techniques used to quantify cloud feedbacks struggle to account for nonlinearity among radiative feedbacks. Here, we utilize a technique called “cloud-locking” to isolate the influence of cloud radiative feedbacks on Arctic amplification within CESM1. Specifically, we disable Arctic cloud radiative feedbacks by prescribing one year of cloud fields recurrently in the model’s radiative transfer calculations from 70N poleward. By analyzing surface temperatures in response to a CO_2 doubling both with and without cloud radiative feedbacks in the Arctic, we separate the influence of cloud radiative feedbacks on Arctic amplification. Because CESM replicates observed Arctic cloud-sea ice relationships but has insufficient opaque cloud, we anticipate a small influence of cloud radiative feedbacks on Arctic amplification. The novelty of this experiment, though, lies in the fact that we are effectively isolating the role of cloud radiative feedbacks in a state-of-the-art model while accounting for the nonlinearity in the feedbacks between cloud radiative effects and the Arctic climate system.

CLOUD-LOCKING METHODOLOGY



Schematic by Brian Medeiros & Jim Benedict

CLOUD-LOCKING METHODOLOGY

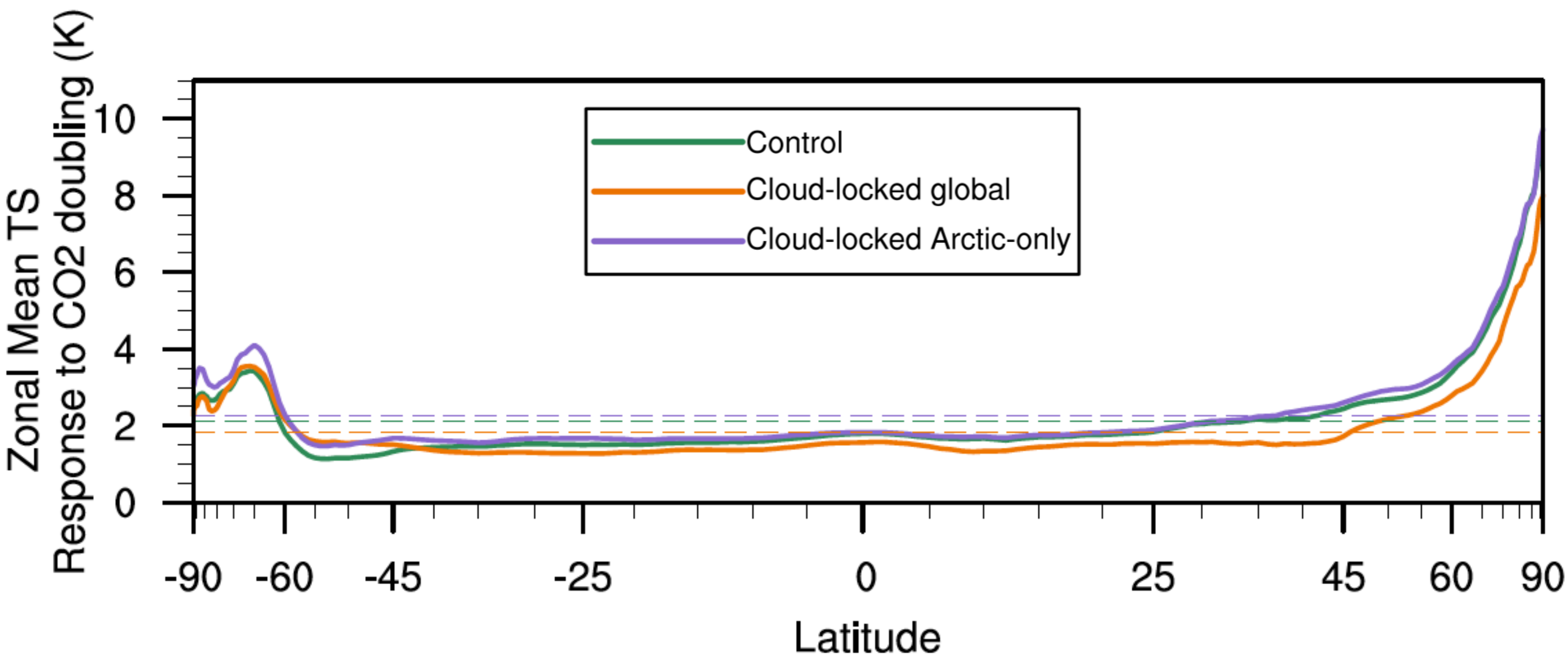


Decorrelates cloud radiative forcing from atmospheric circulation, water vapor, etc.; i.e., ***disables cloud radiative feedbacks***

Unlike diagnostic techniques, cloud locking directly removes the cloud feedback and accounts for non linearity

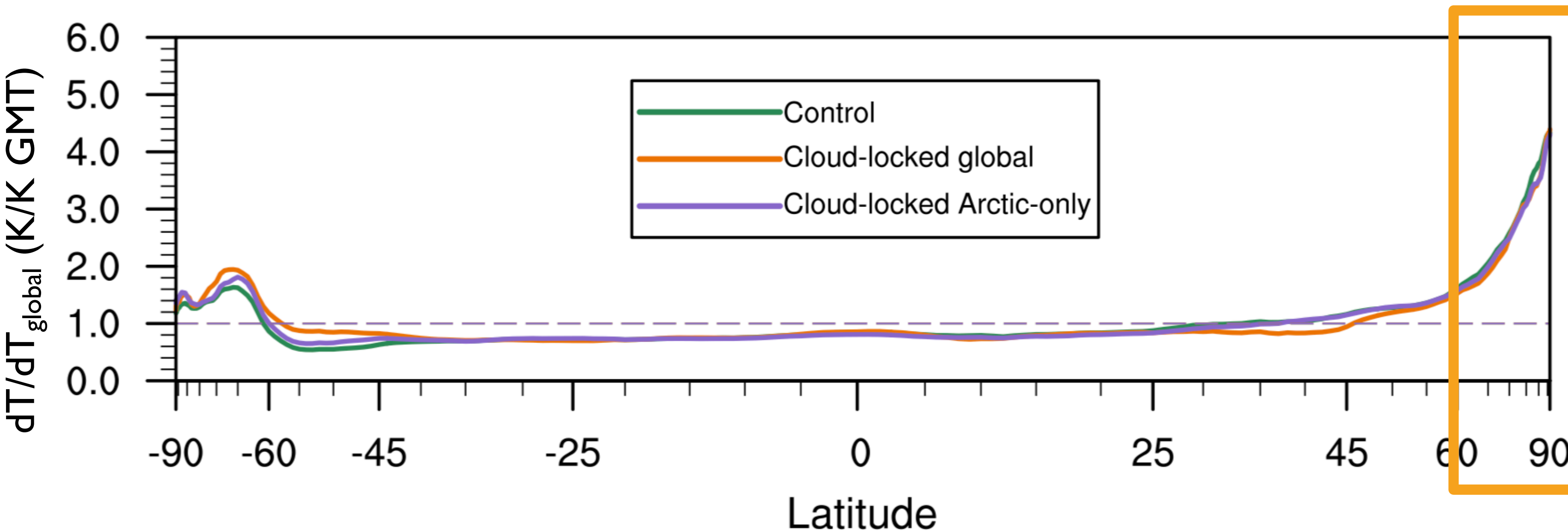
Schematic by Brian Medeiros & Jim Benedict

RESULT: ZONAL MEAN WARMING WITH AND WITHOUT CLOUD FEEDBACKS



Middlemas et al. *in prep*

RESULT: ARCTIC SURFACE AMPLIFICATION IN RESPONSE TO 2XCO_2 UNAFFECTED BY CLOUD FEEDBACKS



Middlemas et al. *in prep*

Summary: Are Arctic clouds important for Arctic Warming/Amplification? Yes and No.

1) YES. Cloud masking controls the strength of the inter-related positive albedo and lapse rate feedbacks that explain Arctic Amplification.

2) NO. Models (*and observations, ask me at the break – see Kay et al. 2016 review paper)* so far suggest Arctic cloud feedbacks are a weak influence on Arctic warming and Amplification.