The boundary layer response to Arctic Sea Ice Loss

(and other tales of using A-train satellites to understand the New Arctic…)

Jen Kay
University of Colorado

And many but especially Ariel Morrison (CU), Tristan L'Ecuyer (U. Wisconsin) and Helene Chepfer (LMD France)

Be Boulder.
University of Colorado **Boulder**

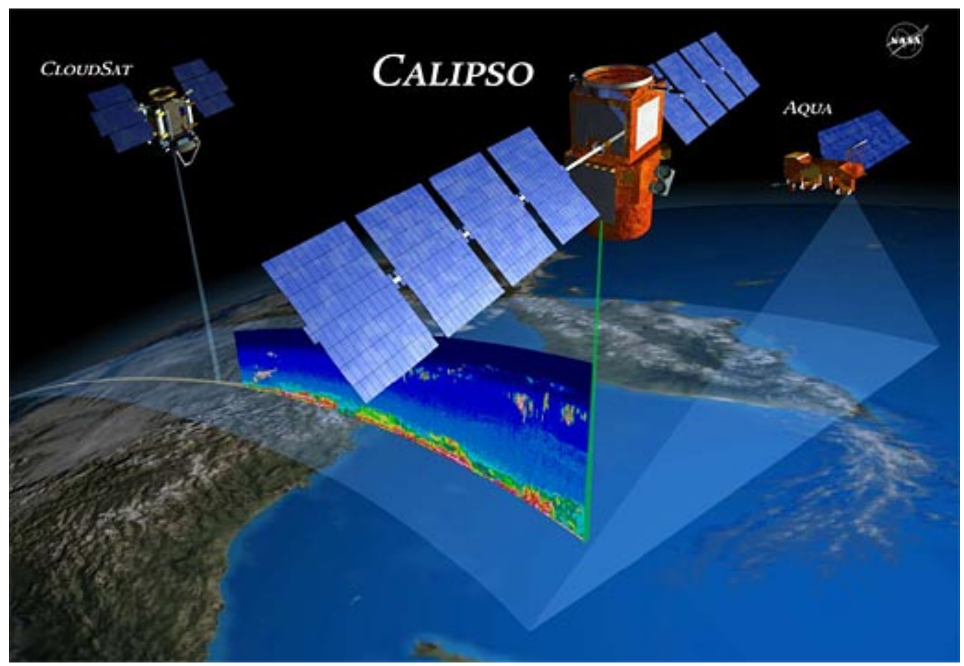
Barrow, Alaska coastline - May 2016

Challenge of Observing Arctic Clouds and Precipitation From Space

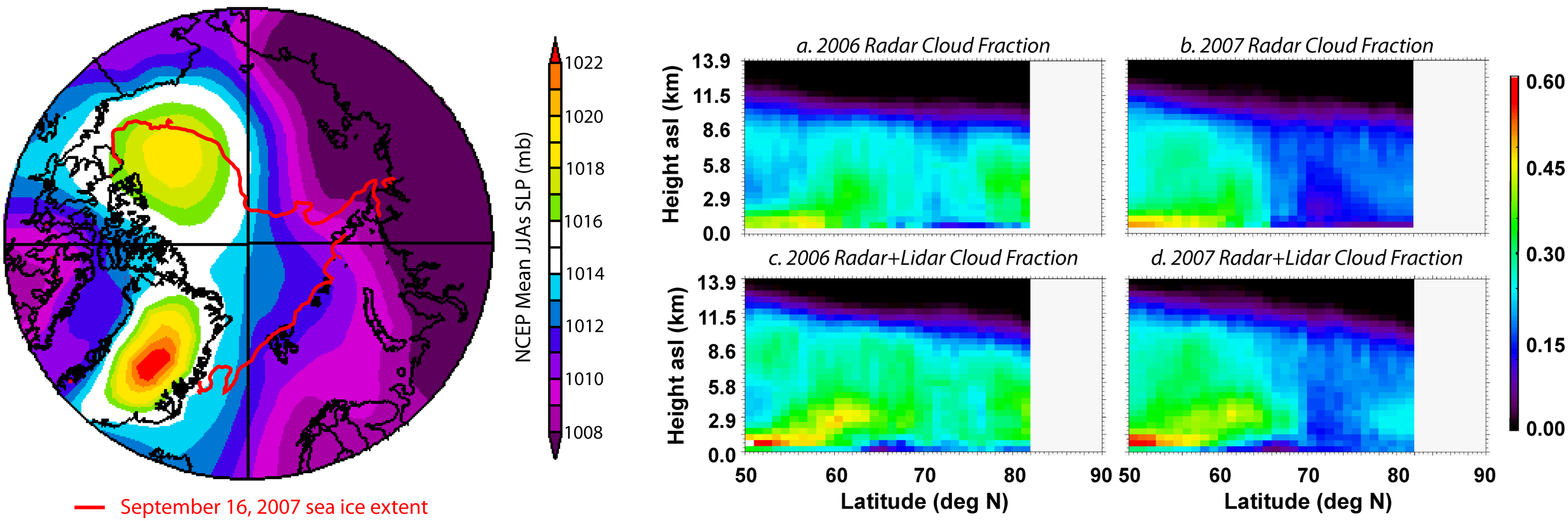
1) optically thin
2) phase is not well known
3) cover surfaces with highly variable albedos

"Scientific discoveries occur when one can associate oneself with new observations of what appear to be prominent yet unexplored or poorly understood features of Earth"

Jack Oliver

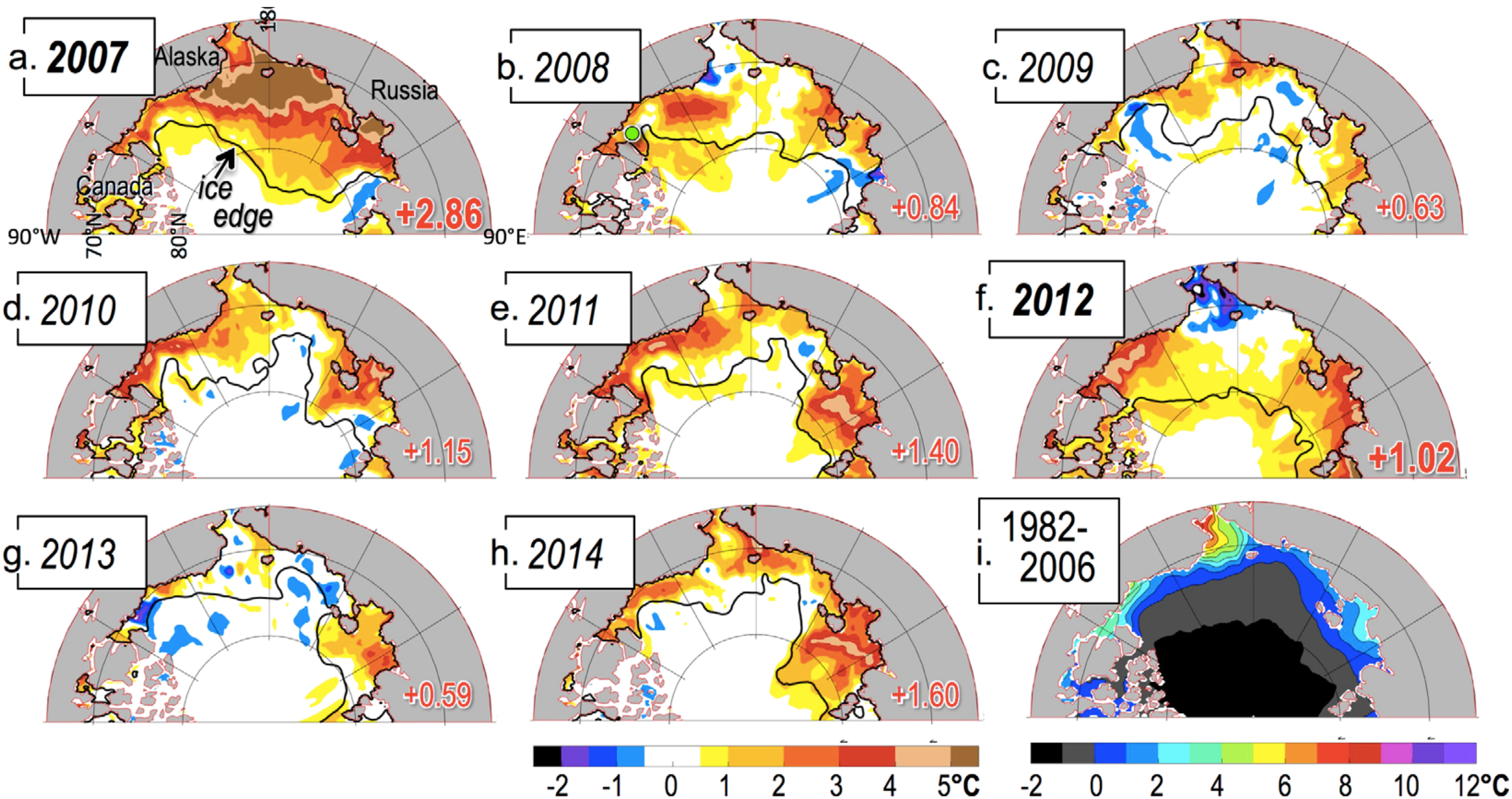


Arctic clouds can influence extreme events



e.g., Cloud reductions associated with high pressure contribute to extreme 2007 Arctic sea ice loss (Kay et al. 2008)

Warmest sea surface anomalies in 2007 (not 2012)

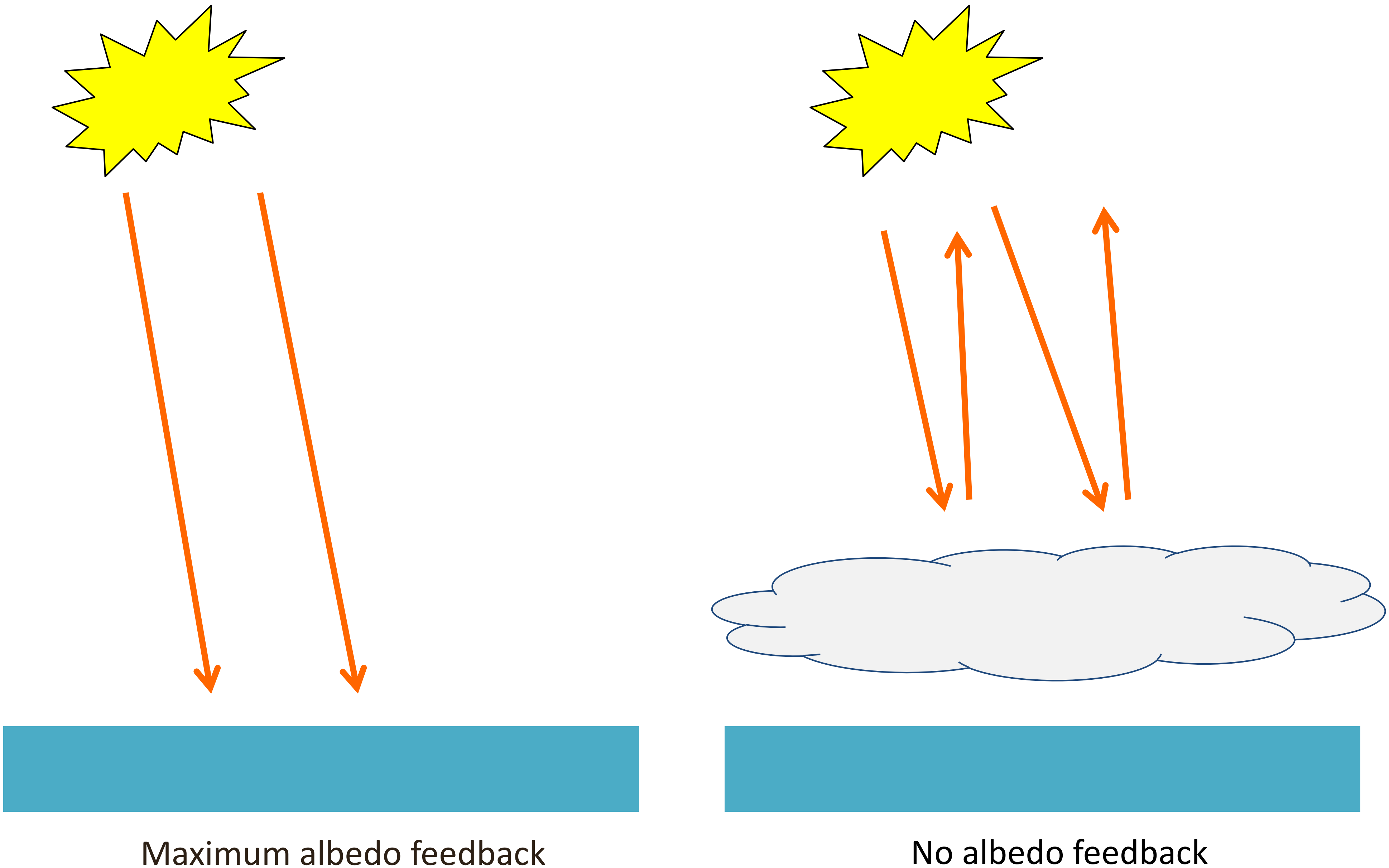


SST: Aug/Sept dOISST (AVHRR only)

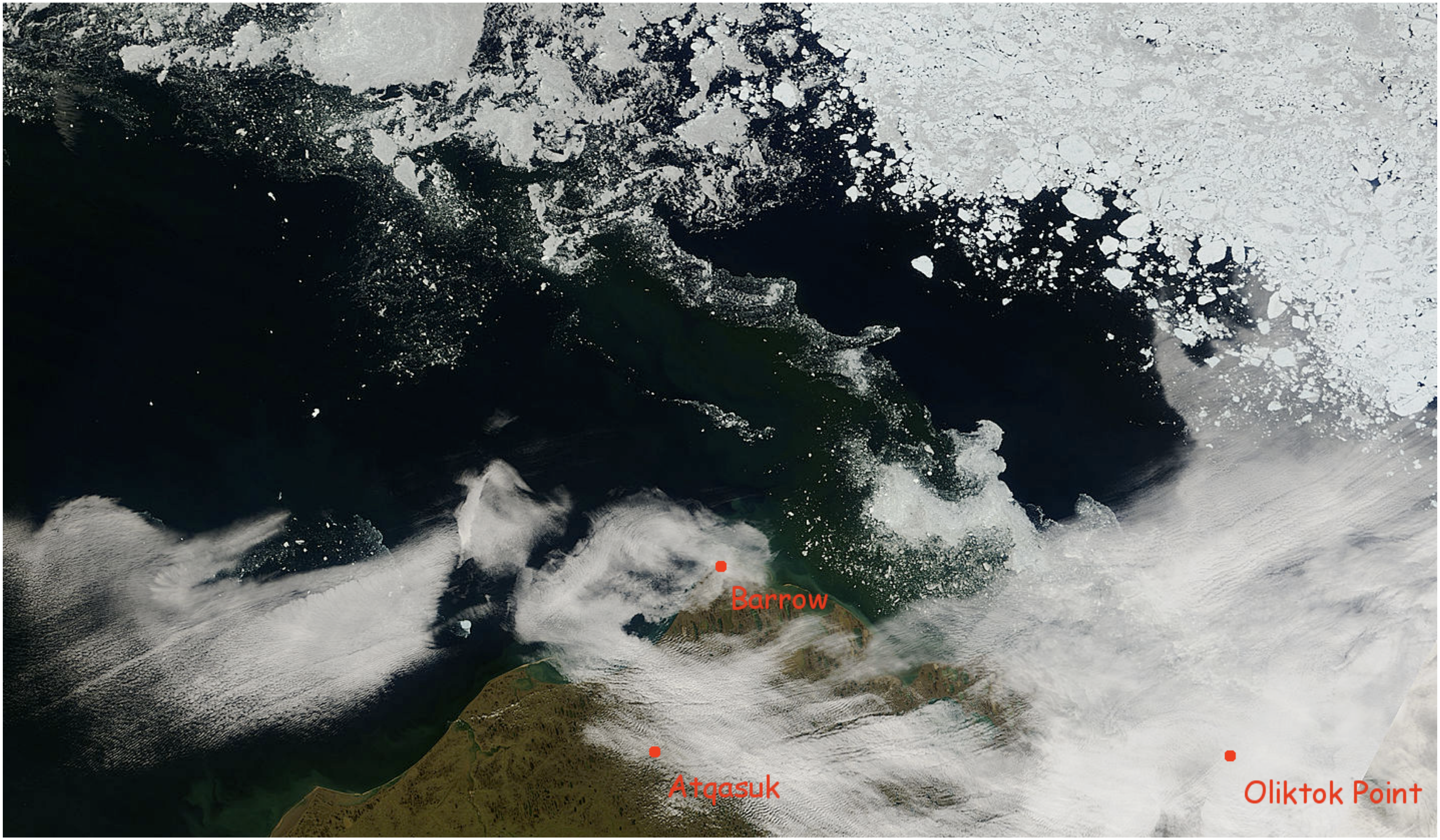
Ice edge: 15% concentration (NASA Team1)

Steele & Dickinson (JGR, 2016)

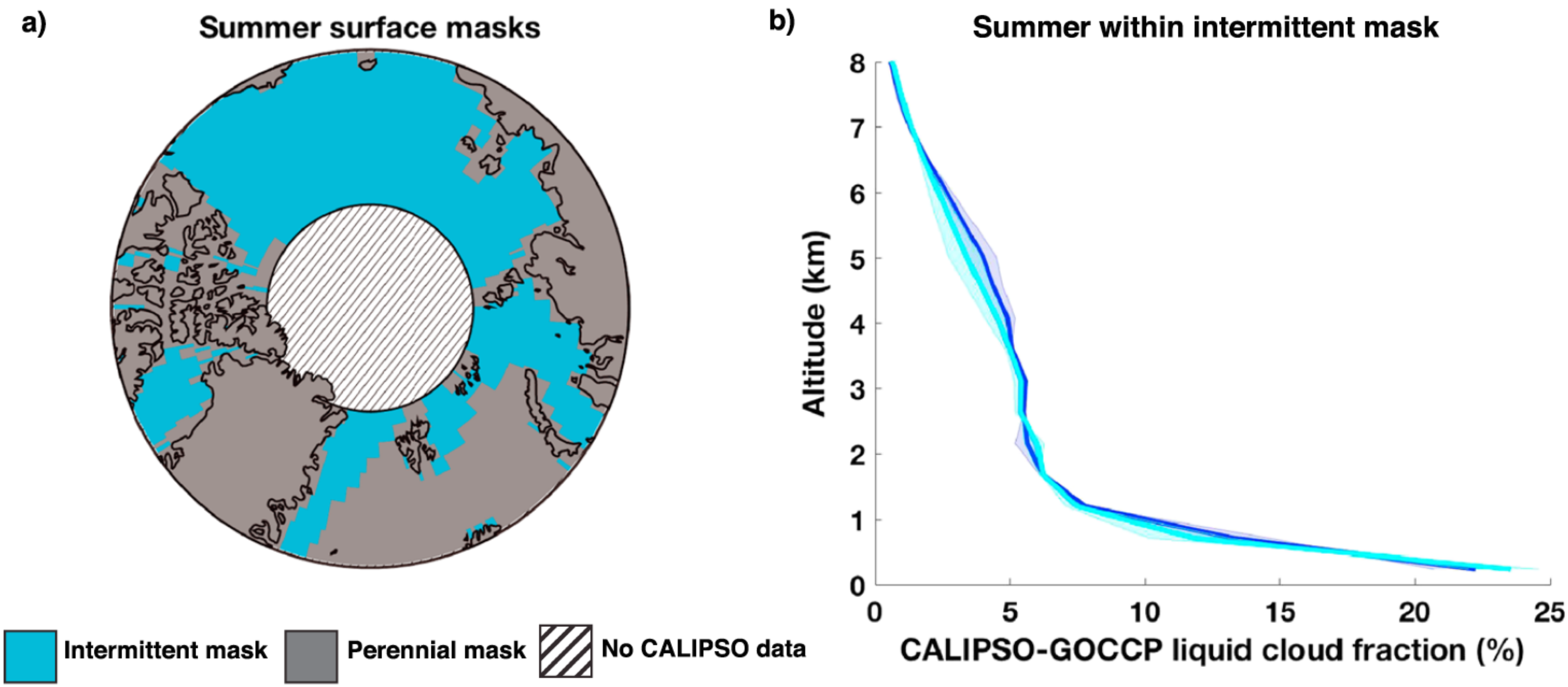
Thinking about the end-members helps
Surface albedo feedback strength depends on clouds



MODIS Visible Image July 23, 2007



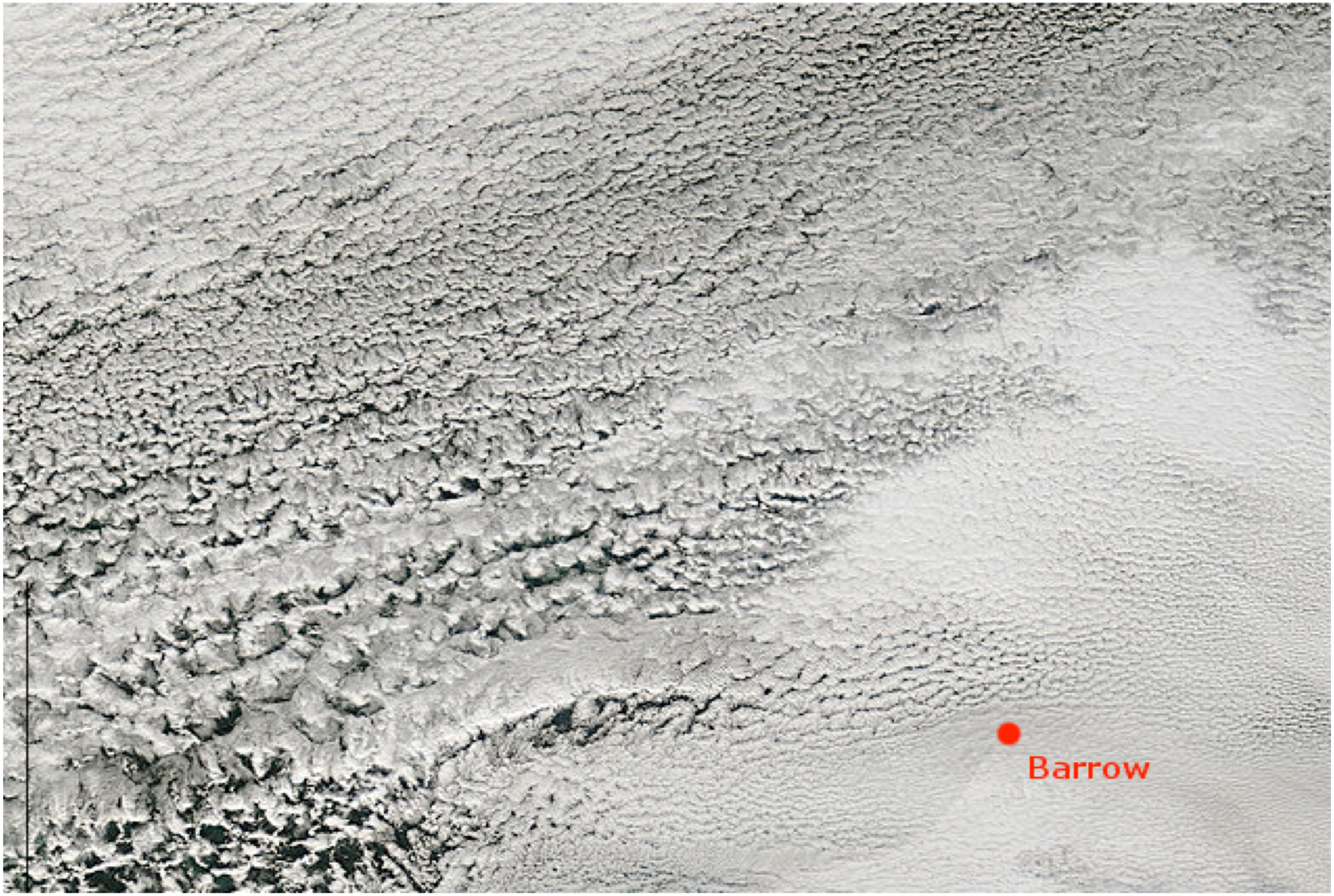
No observational evidence for a summer cloud-sea ice feedback



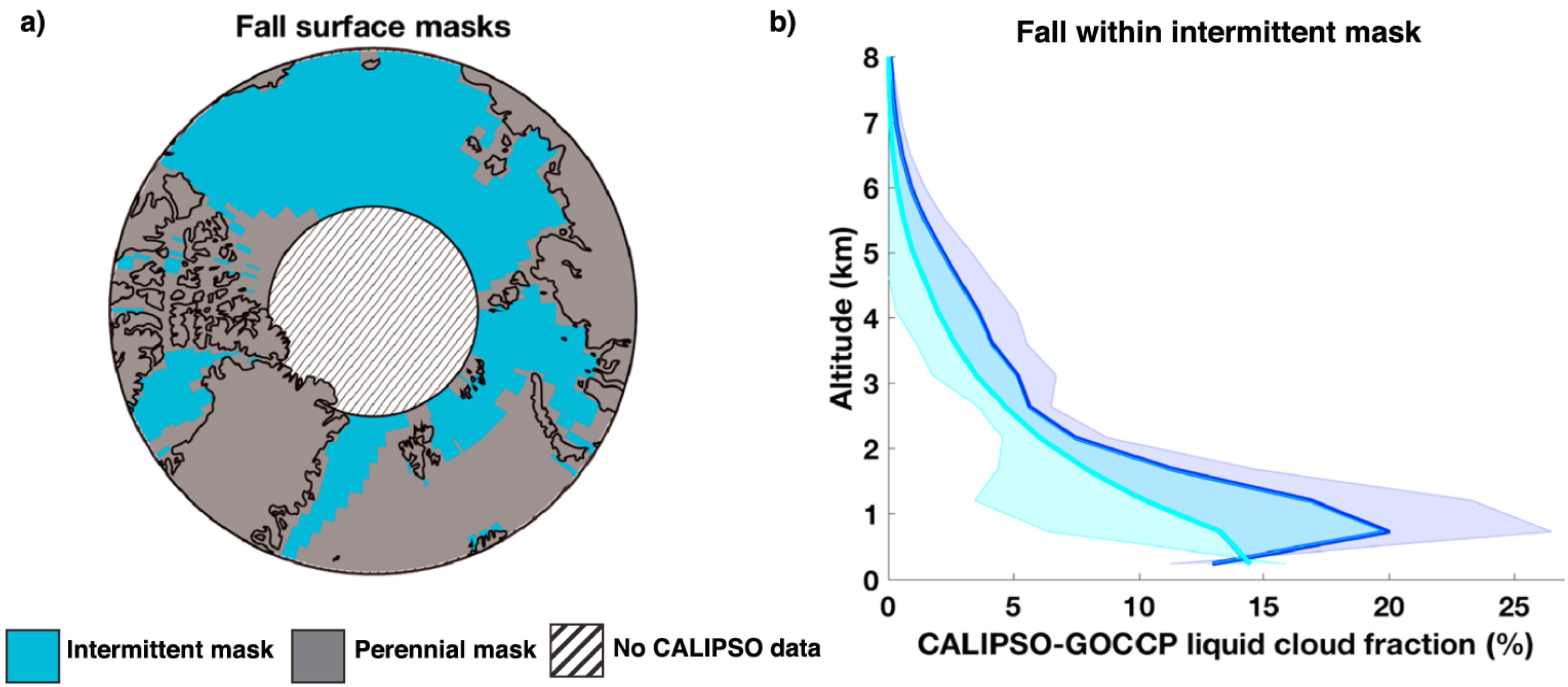
IMPORTANT: We'll use cloud profiles only from regions where sea ice cover varies ("intermittent mask")!

Morrison et al. 2018

MODIS Visible Image September 30, 2007



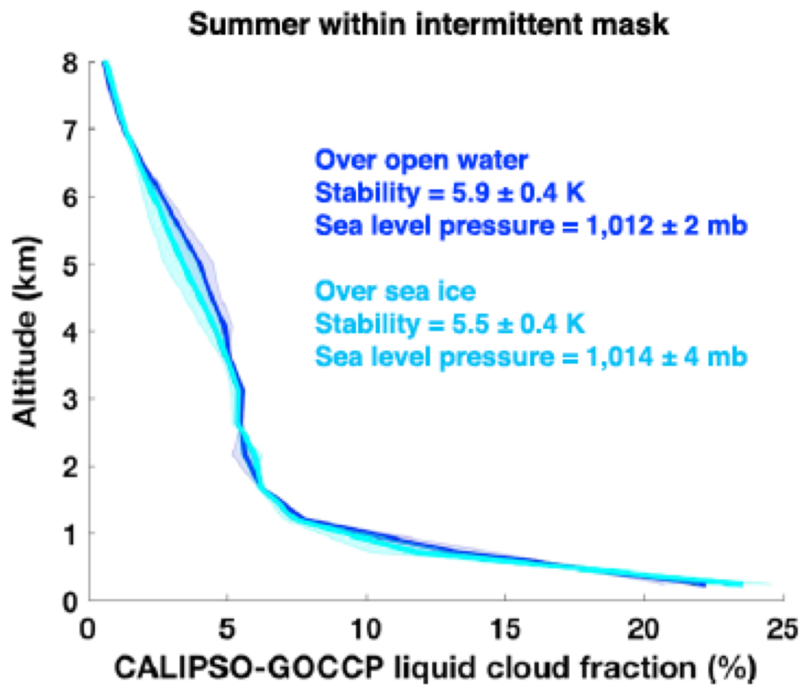
More low-level liquid cloud observed over newly open water during Fall

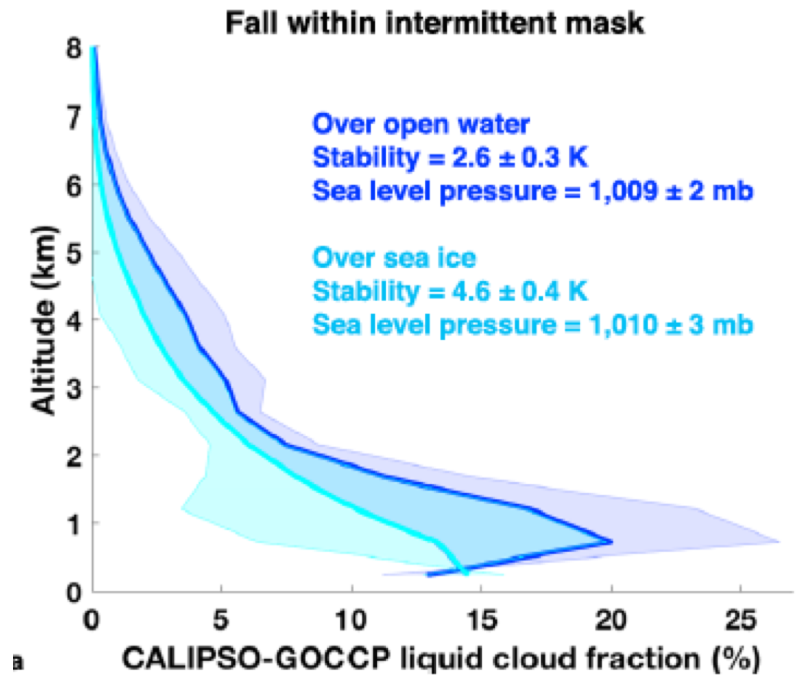


IMPORTANT: Cloud profiles only from regions where sea ice cover varies ("intermittent mask")!

Morrison et al. 2018

Evidence so far suggests small impact of cloud-sea ice feedbacks on observed warming





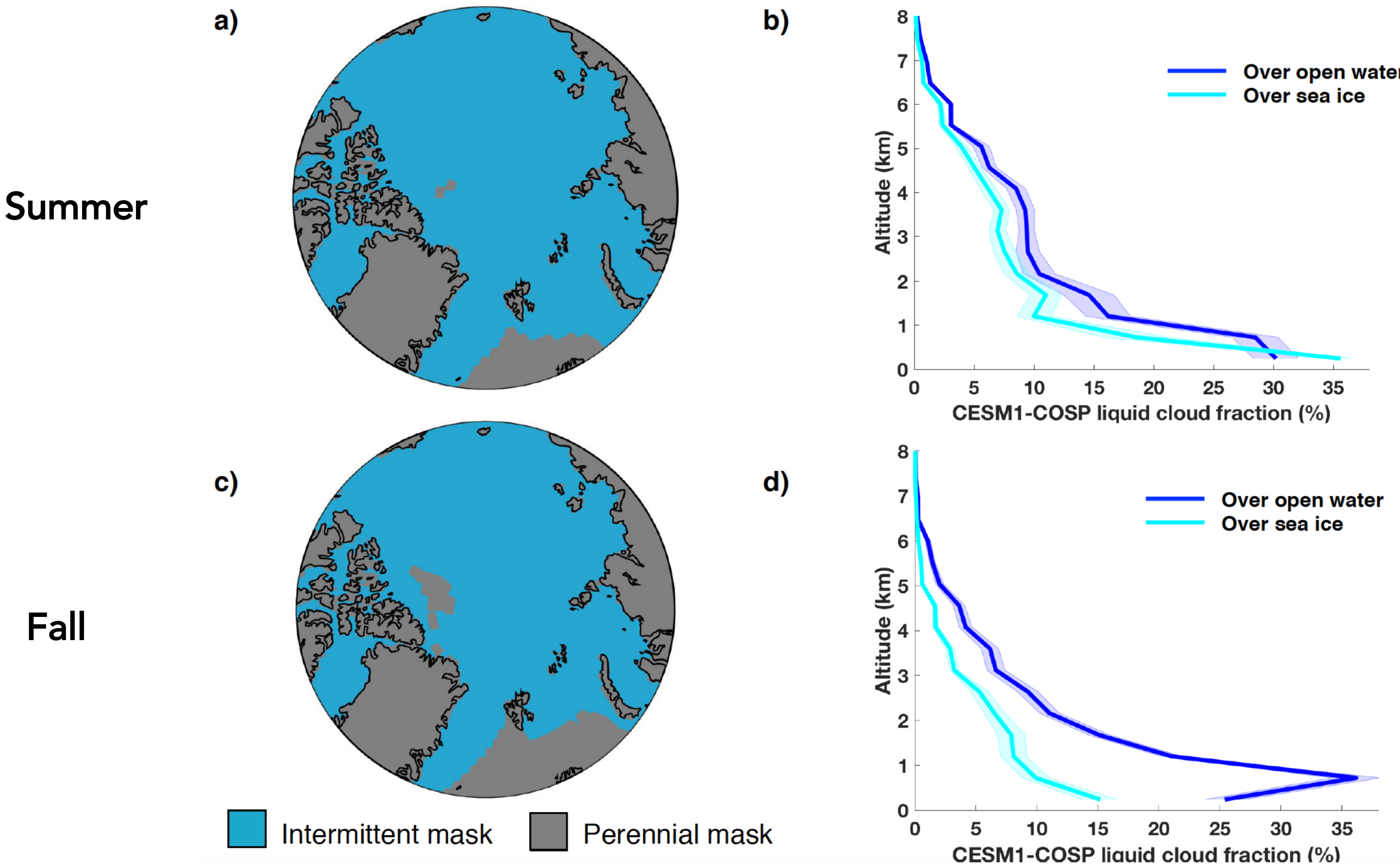
No evidence for summer cloud-sea ice feedback

Weak cloud-sea ice feedback in Fall – shortwave and longwave compensate.

Morrison et al. 2018 - JGR

Can climate models reproduce observed Arctic sea ice-cloud relationships?

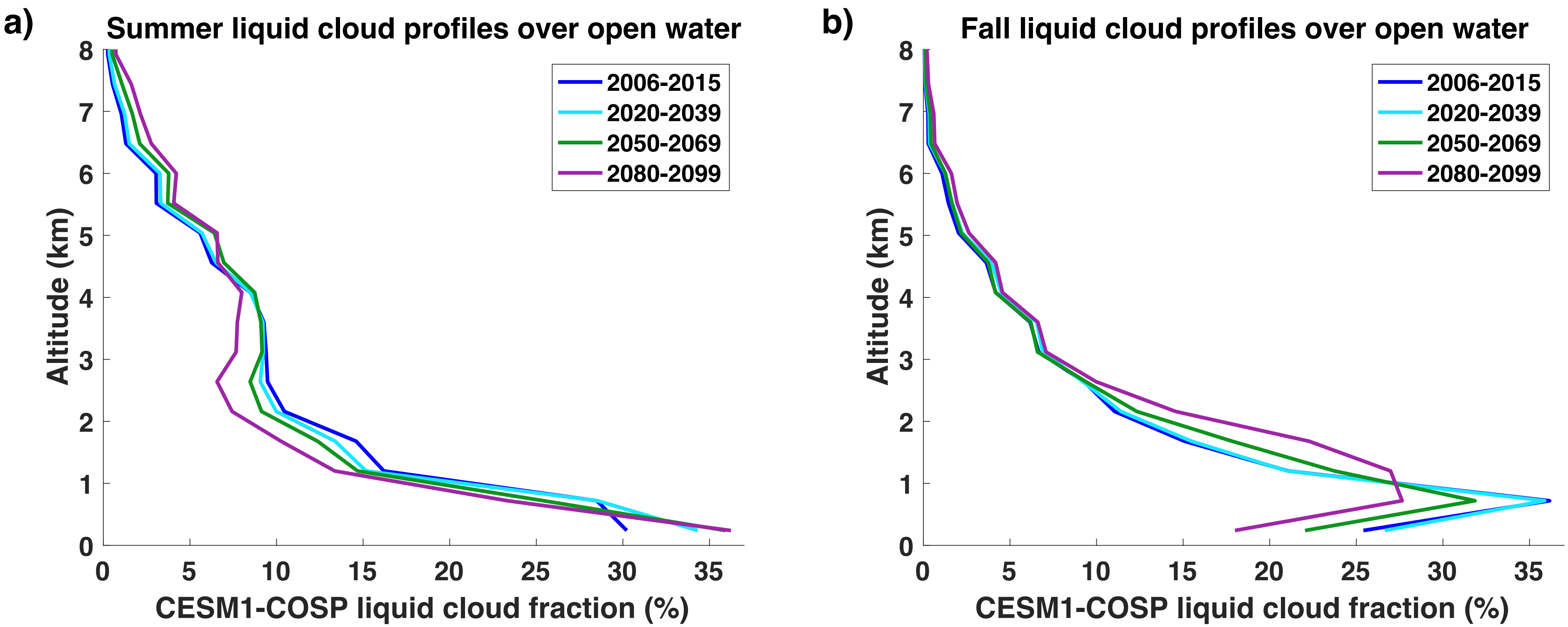
CESM1 matches observations: no change in summer, more clouds over open water than over sea ice in fall



Morrison et al. (in prep)

Does the present-day CESM1 cloud response to sea ice variability explain future cloud-sea ice feedbacks?

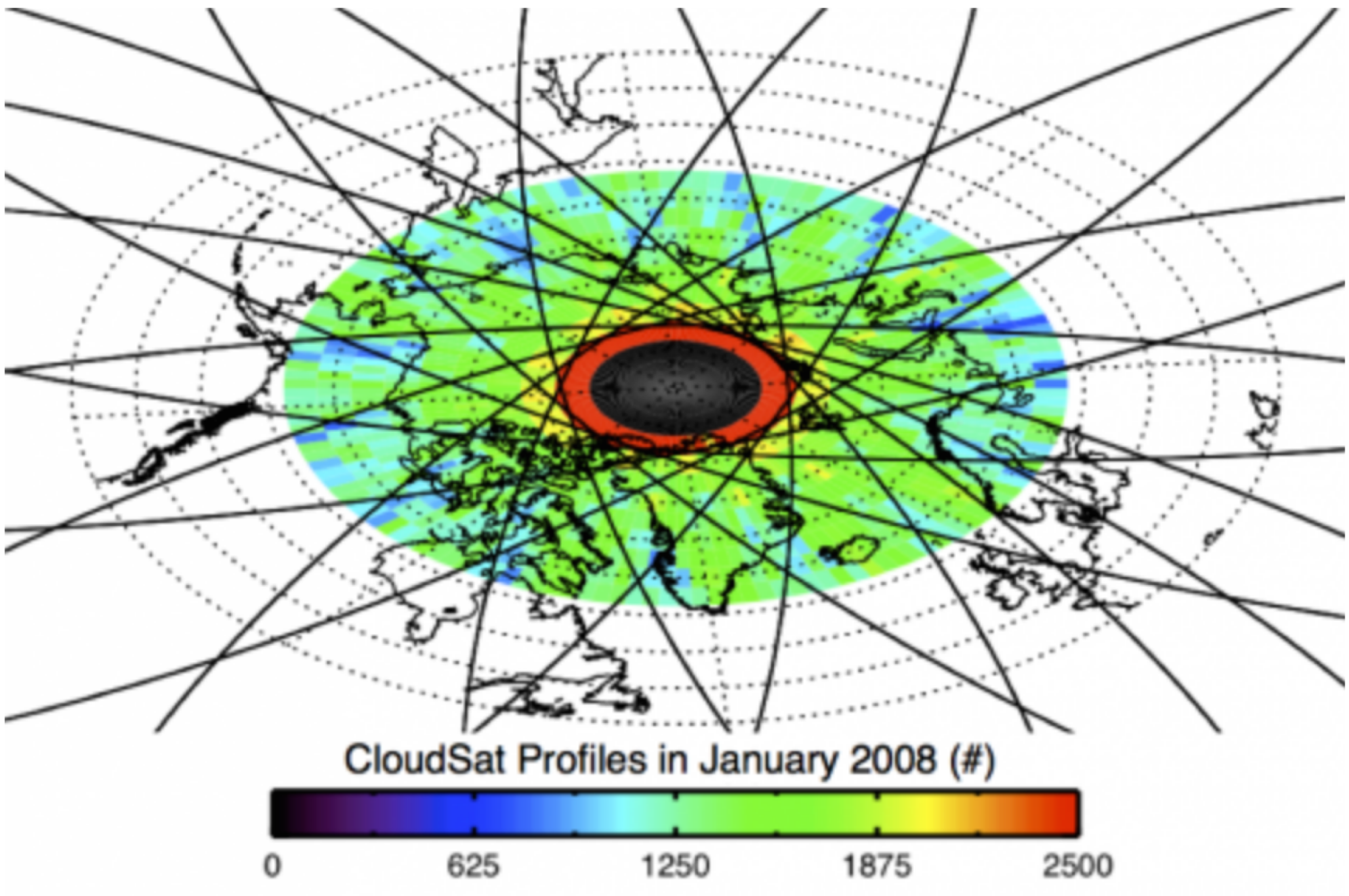
Future clouds in CESM1: no change to summer cloud profiles, boundary layer deepens in fall and lidar attenuation increases



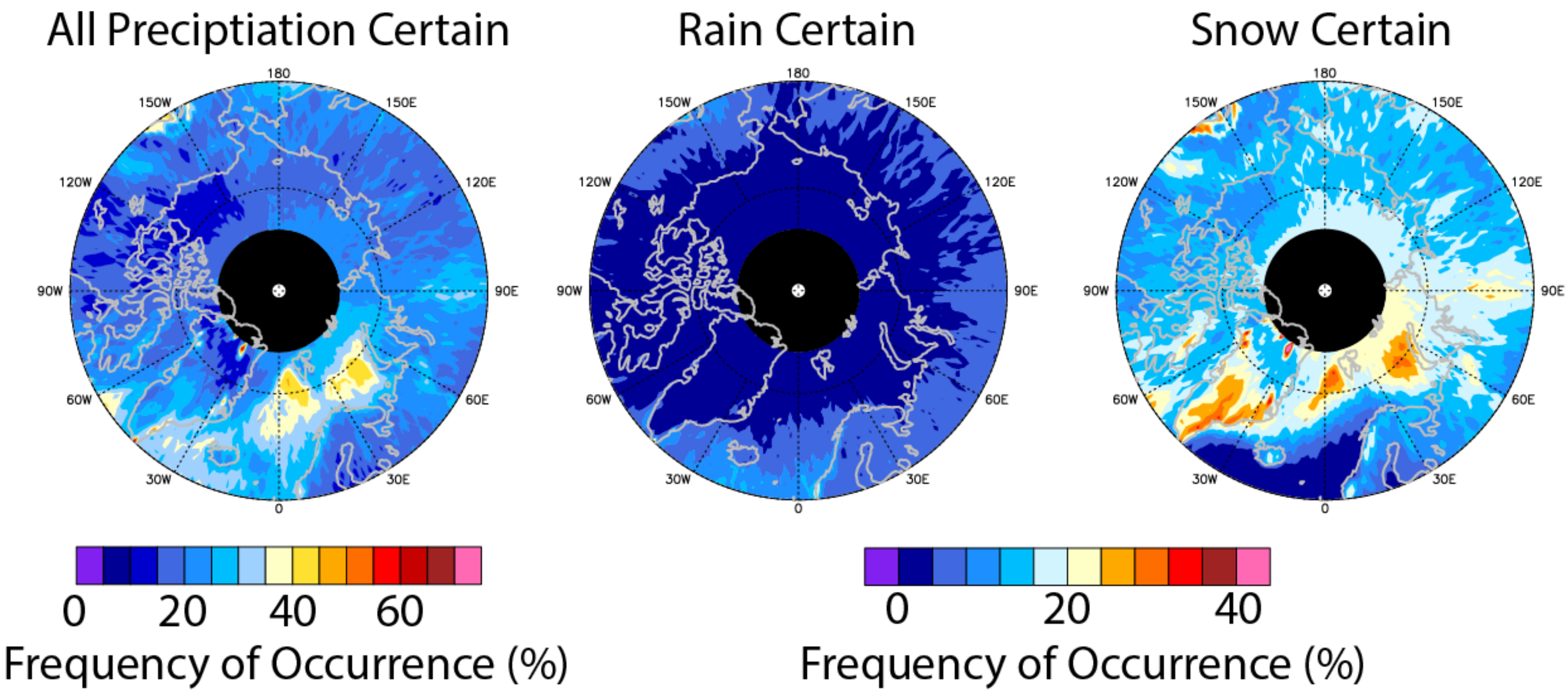
FUTURE

Morrison et al. (in prep)

Global (including Arctic) precipitation from CloudSat radar



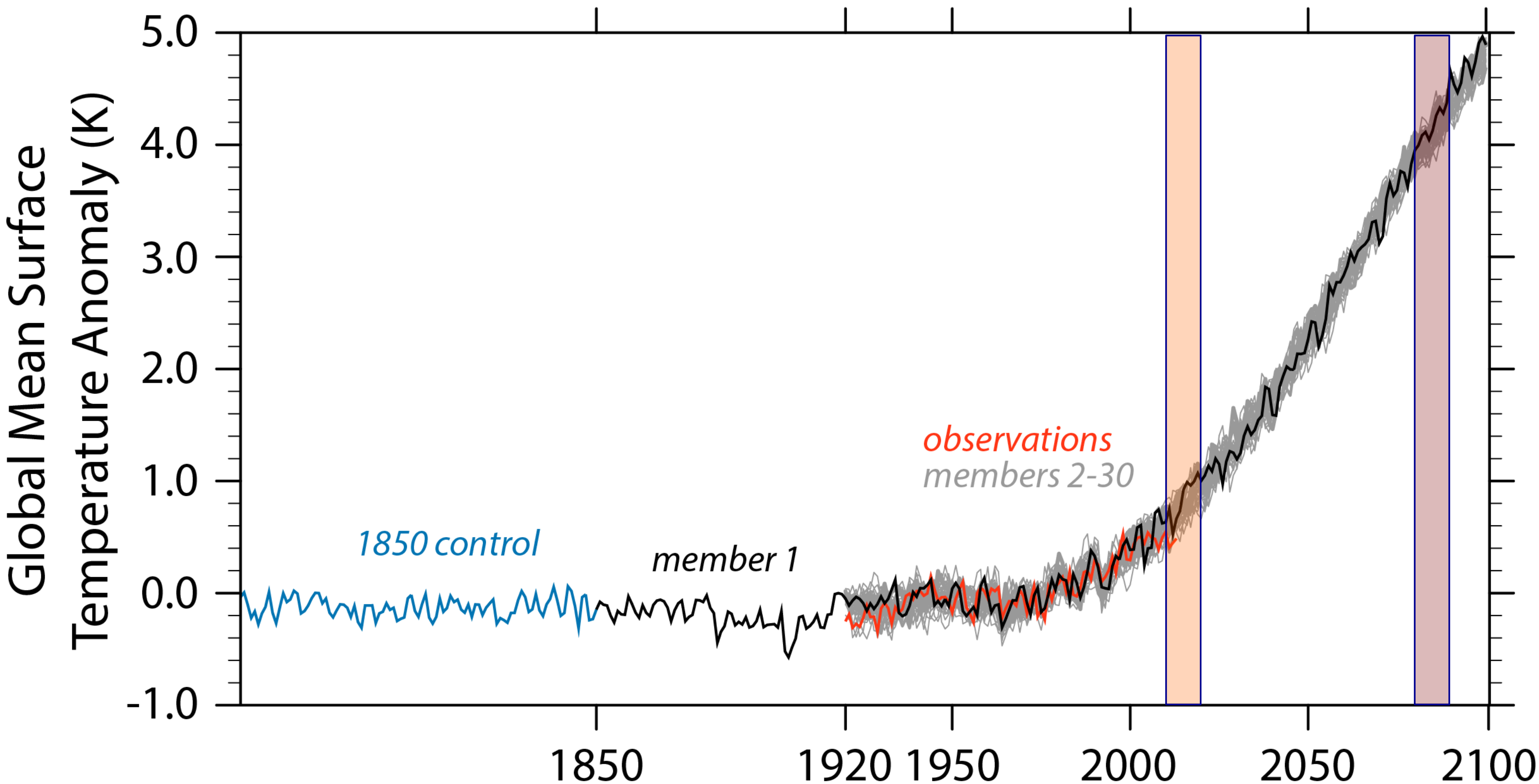
Arctic Observed Precipitation Frequency



Data from Tristan L'Ecuyer (University of Wisconsin)

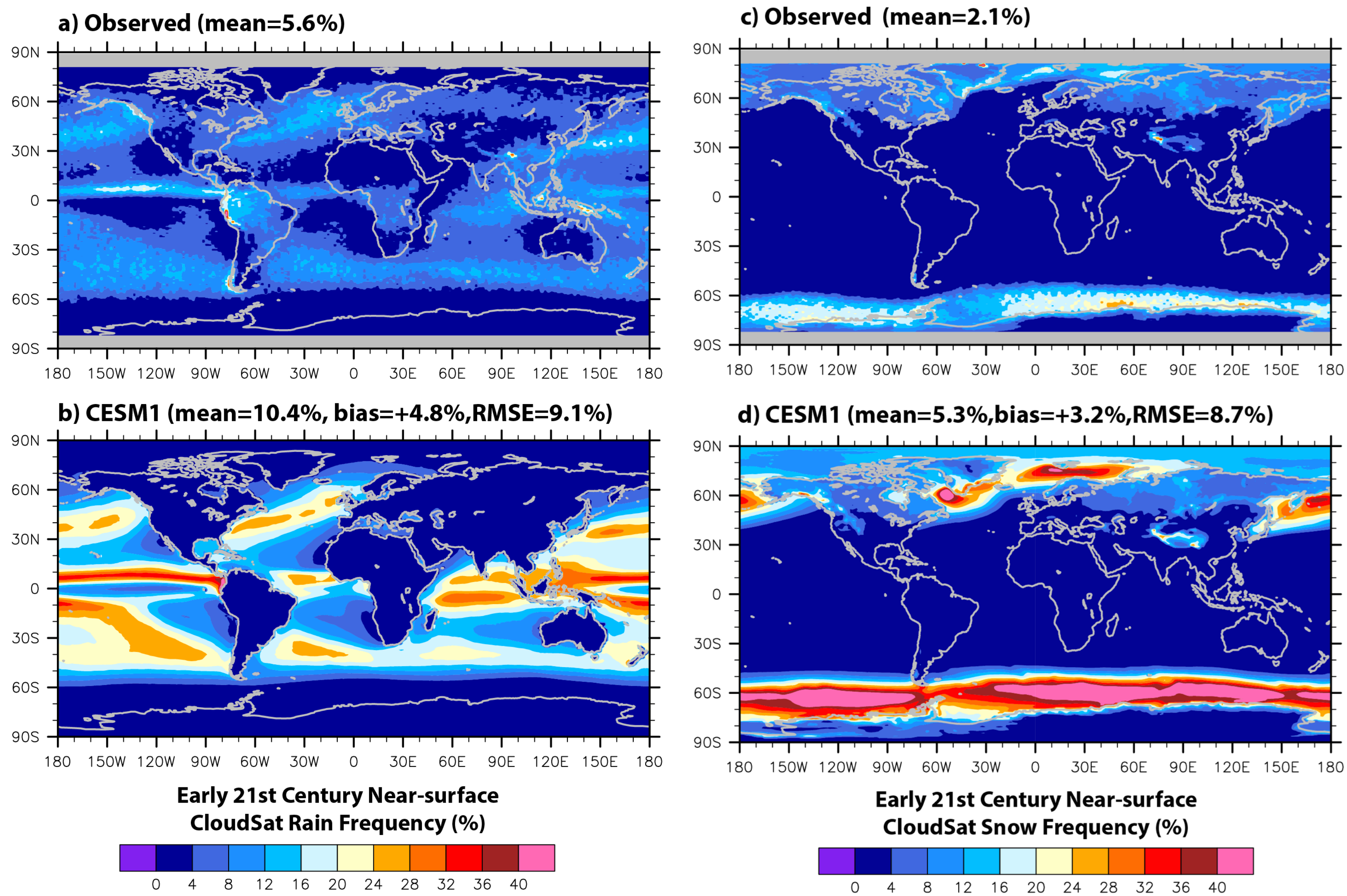
What precipitation would CloudSat detect within CESM1?

Let's compare 2010s with 2080s!



CESM1 Large Ensemble, (Kay et al. 2015)

The present-day "dreary state of models": it rains and snows too frequently in CESM1…



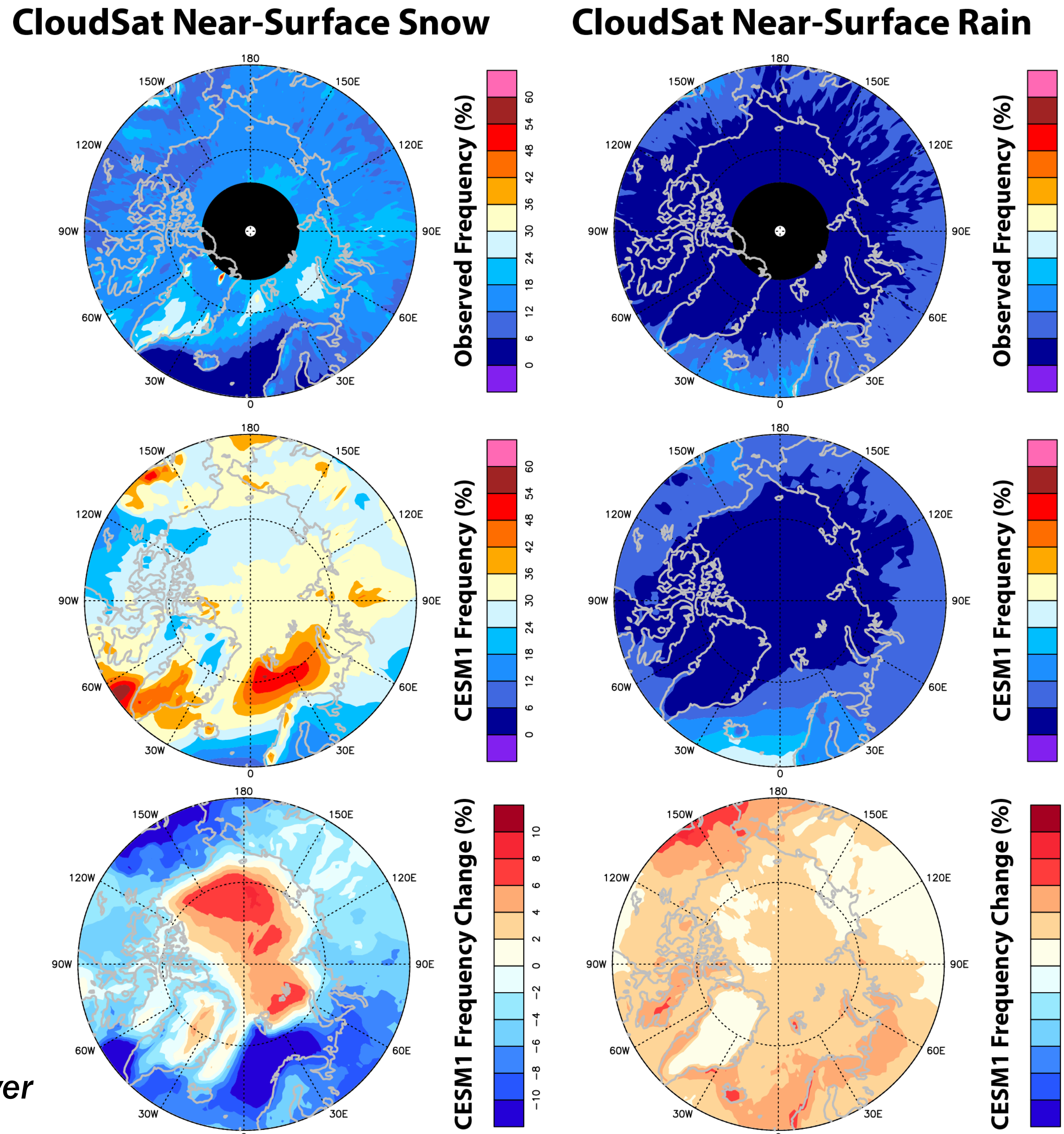
Kay, L'Ecuyer et al. JGR (2018)
DOI:10.1002/2017JD028213

Arctic Snow and Rain Frequency Maps

CESM1-projected 21st century changes:

1) More Snow in High Arctic and Over Greenland
2) More Rain Except over Greenland and Central Russia

Camron, Lenearts, Kay, L'Ecuyer (in prep)



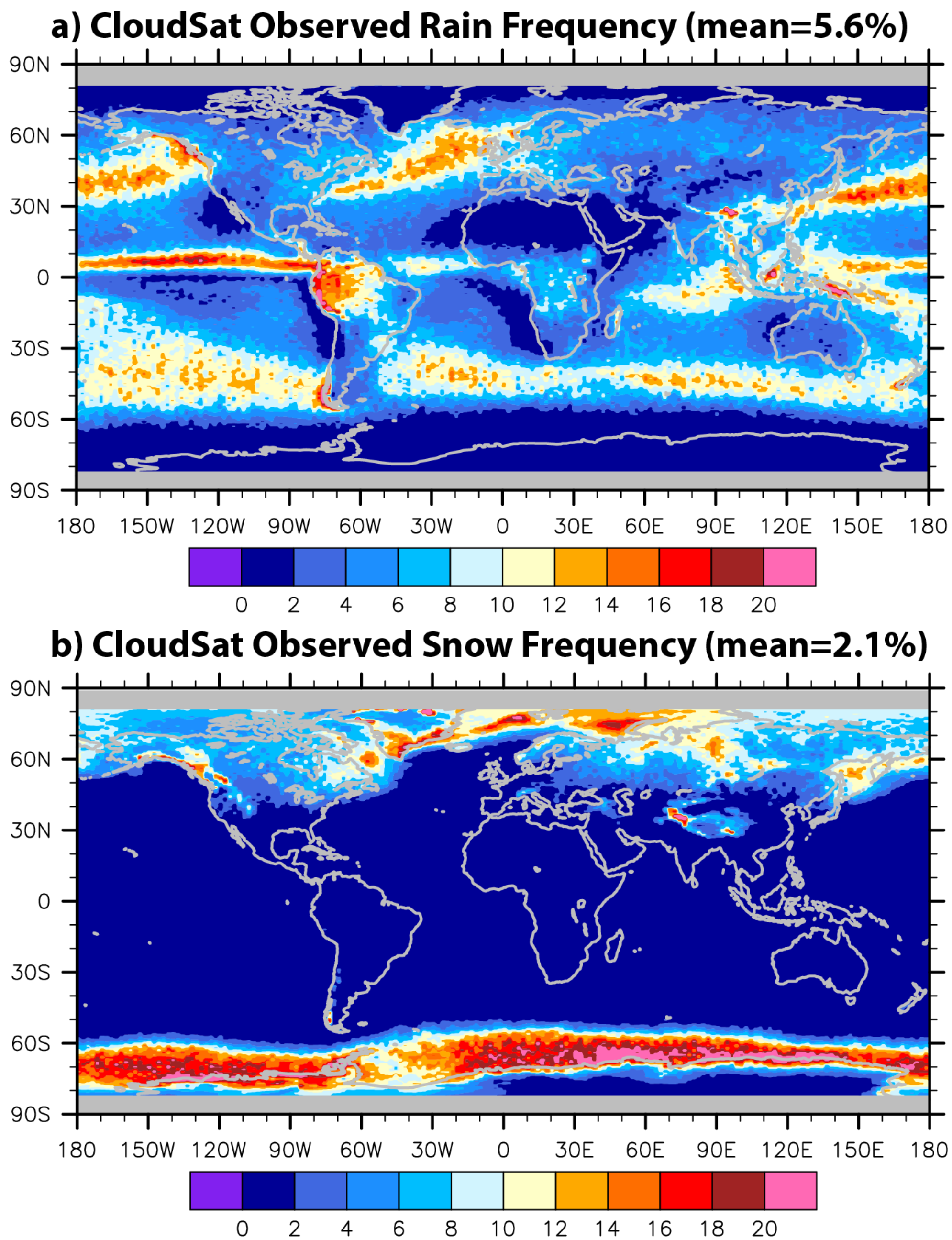
Summary

1) Reliable Arctic Cloud Observations suggest sea ice loss is affecting fall clouds but not summer clouds. Implication is a weak present-day cloud-sea ice feedback.

2) CESM1 can reproduce observed cloud-sea ice relationships and provide insights into future feedbacks. Positive longwave feedback in winter but no influence of summer sea ice loss on summer clouds.

3) CloudSat provides global observations of precipitation (including the Arctic!). Let’s discuss!!

Global Observed Snow and Rain Frequency



Kay, L'Ecuyer et al. JGR (2018)
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Goal: Use CloudSat to make definition-aware and scale-aware precipitation frequency comparisons with climate models. *But **how**? And what is **new**?*

vs.

Model Gridbox Profiles

1) "Down-scale" using sub-column generator (COSP1.4)

Model Sub-Column Profiles

2) Apply satellite forward model (COSP1.4)

Model Sub-Column CloudSat dBZ

Model Near-Surface Precipitation Frequency

3) Apply 2C-PRECIP-COLUMN algorithm (Haynes et al.. 2009)

vs.

Observed Near-Surface Precipitation Frequency

4) Apply 2C-PRECIP-COLUMN algorithm (Haynes et al.. 2009)

Kay, L'Ecuyer et al. JGR (2018)
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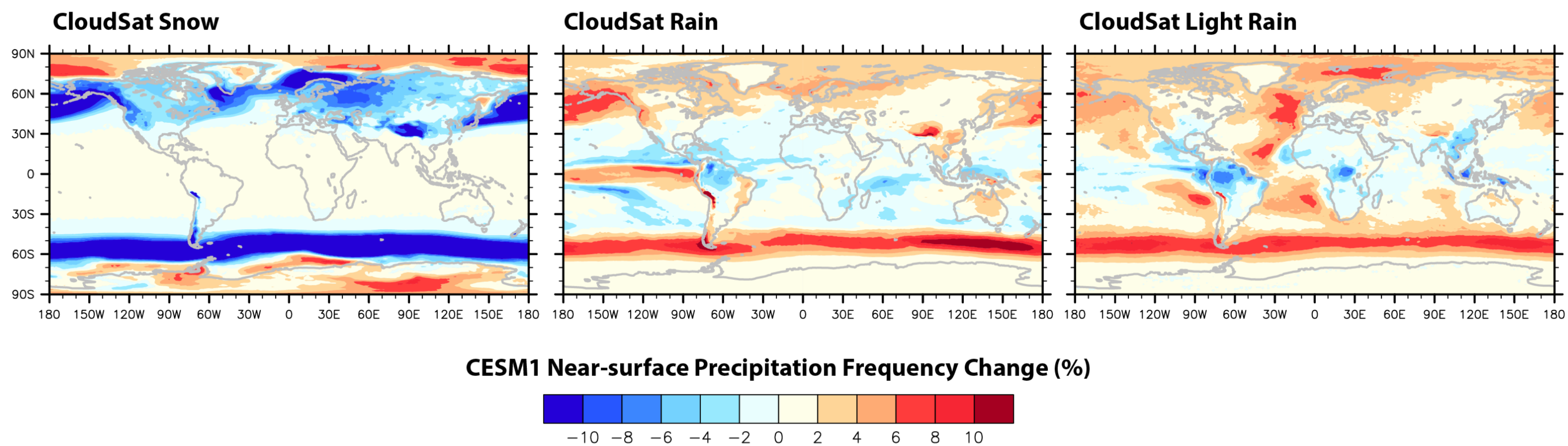
CESM1-Projected 21st Century Change: What would CloudSat Observe?



Three CESM1-projected Changes:

1) Snow becoming Rain (esp. in mid-latitude storm tracks)
2) Less Off-Equatorial Rain, More Equatorial Rain (esp. in Pacific)
3) Increase in Sub-tropical Light Rain Frequency

Kay et al. (2018)