The combined influence of Southern Ocean clouds and sea ice on top-of-atmosphere albedo in observations and CESM

Jen Kay

Fellow, Cooperative Institute for Research in Environmental Science

Assistant Professor, Dept. Atmospheric and Oceanic Sciences

University of Colorado-Boulder

Be Boulder.

University of Colorado Boulder

Journal of Geophysical Research: Atmospheres

The Combined Influence of Observed Southern Ocean Clouds and Sea Ice on Top-of-Atmosphere Albedo

W. R. Frey[1,2], A. L. Morrison[1,2], J. E. Kay[1,2], R. Guzman[3], and H. Chepfer[4]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO, USA, [2]Atmospheric and Oceanic Sciences, University of Colorado Boulder, Boulder, CO, USA, [3]LMD/IPSL, CNRS, Ecole Polytechnique, Palaiseau, France, [4]Sorbonne Université, École polytechnique, École normale supérieure, PSL Research University, CNRS, Paris, France

Key Points:

- Southern Ocean low cloud cover is unchanged in summer and slightly higher in spring over open water compared to sea ice
- In spring and summer, Southern Ocean cloud opacity increases over open water compared to sea ice
- Despite the cloud response, top-of-atmosphere albedo is lower and more shortwave radiation is absorbed over open water than over sea ice

CALIPSO Spaceborne Lidar Observations

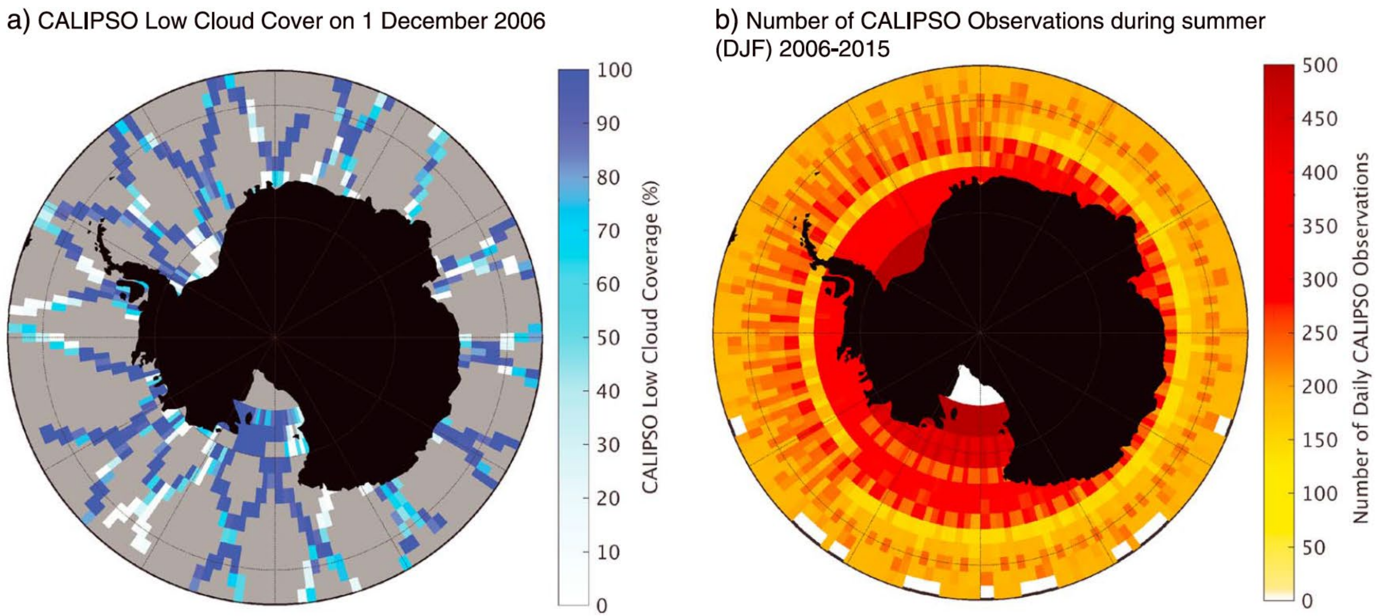
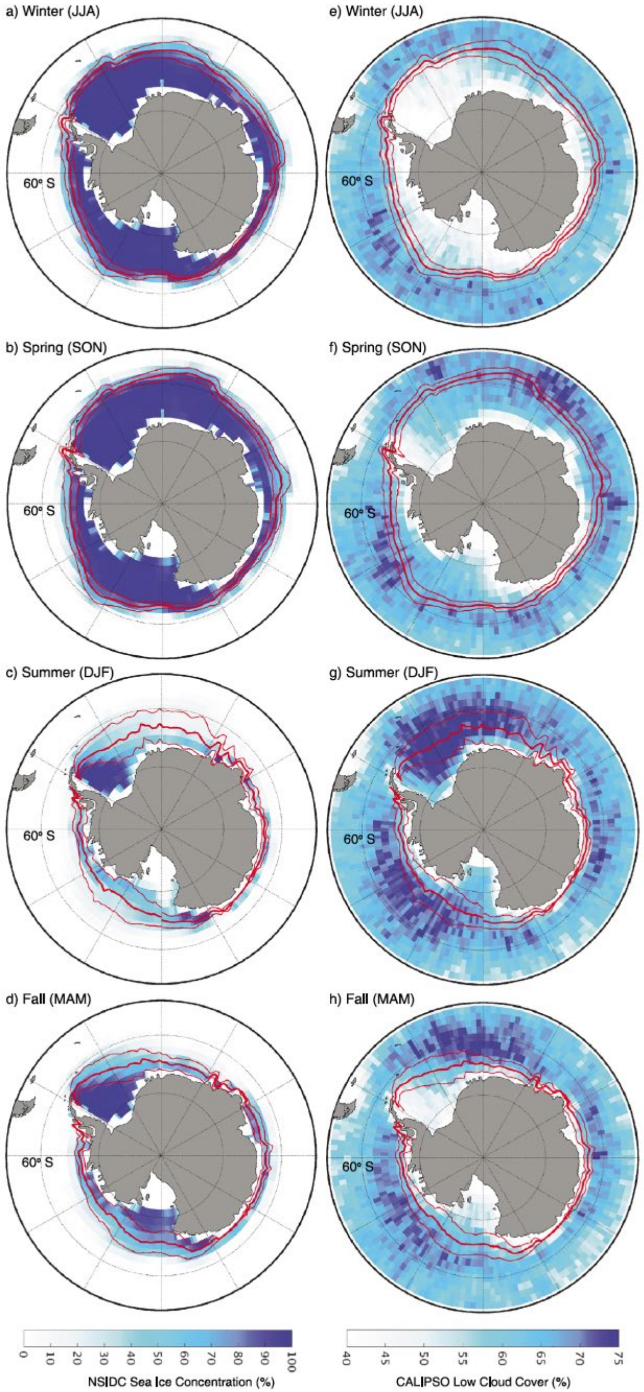


Figure 1. CALIPSO-GOCCP data demonstration. (a) A single day (1 December 2006) of CALIPSO low cloud cover data on the 2 × 2° GOCCP output grid (Chepfer et al., 2010). (b) Number of daily CALIPSO low cloud cover observations in each grid cell for summer (December, January, and February [DJF]) during our study period (2006–2015). Gray area in (a) shows grid cells with no CALIPSO data on 1 December 2006.

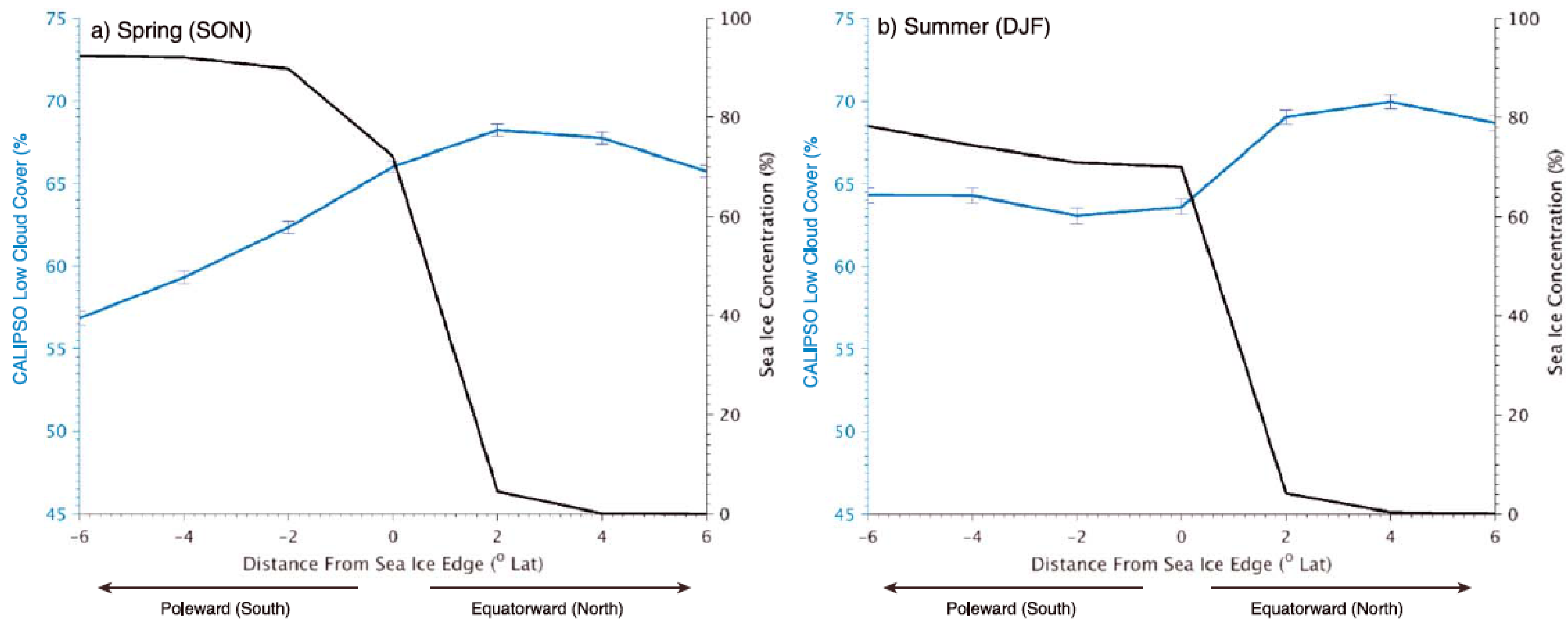
Figure 1, Frey et al. 2018



Observed seasonal mean Antarctic sea ice and cloud cover (2006-2015)

Figure 2, Frey et al. 2018

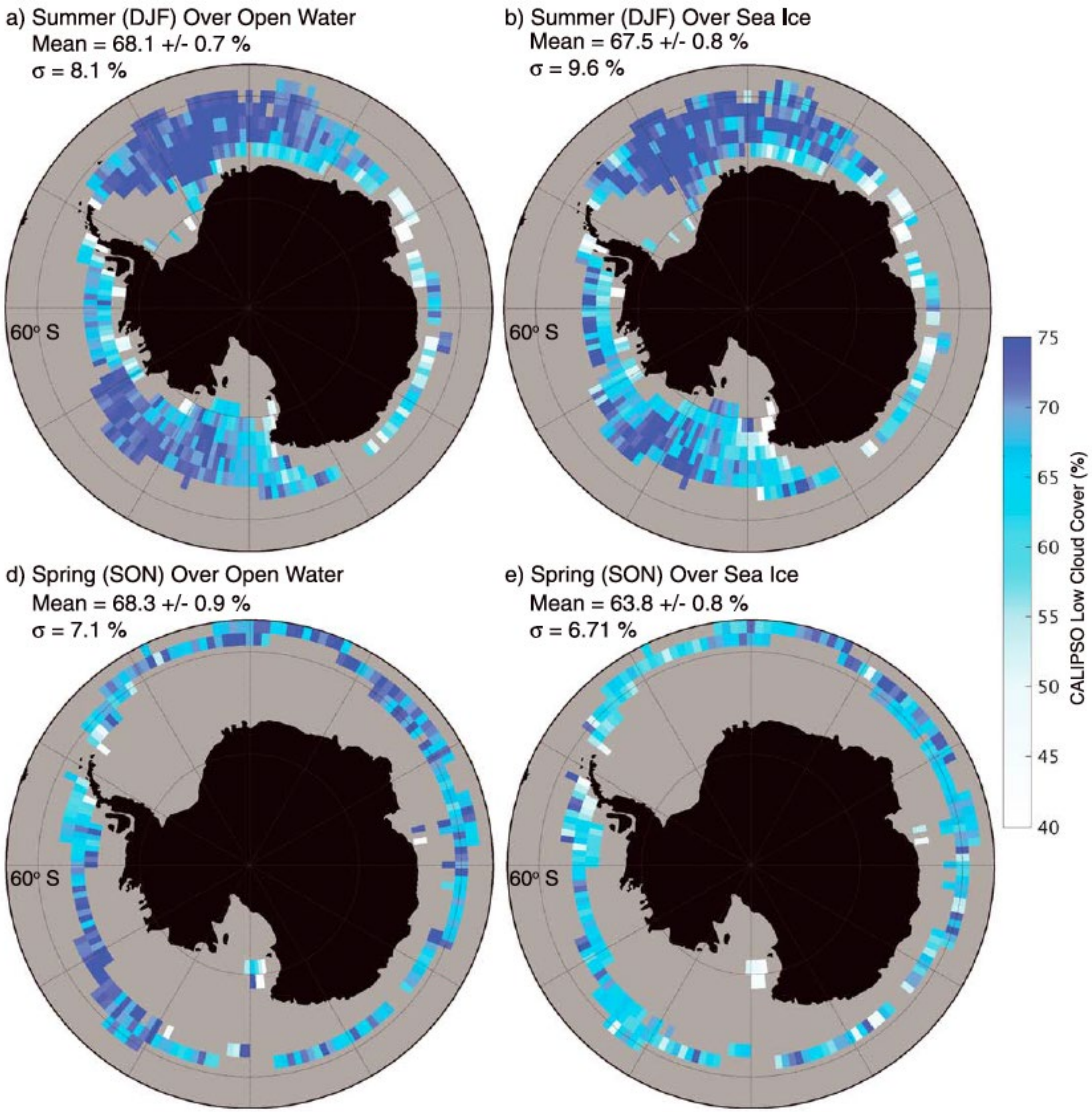
Clouds composited across the sea ice edge during Spring and Summer



Concern: This compositing approach is influenced by latitudinal variations in clouds unrelated to sea ice (e.g., location of the storm tracks)…

Figure 3, Frey et al. 2018

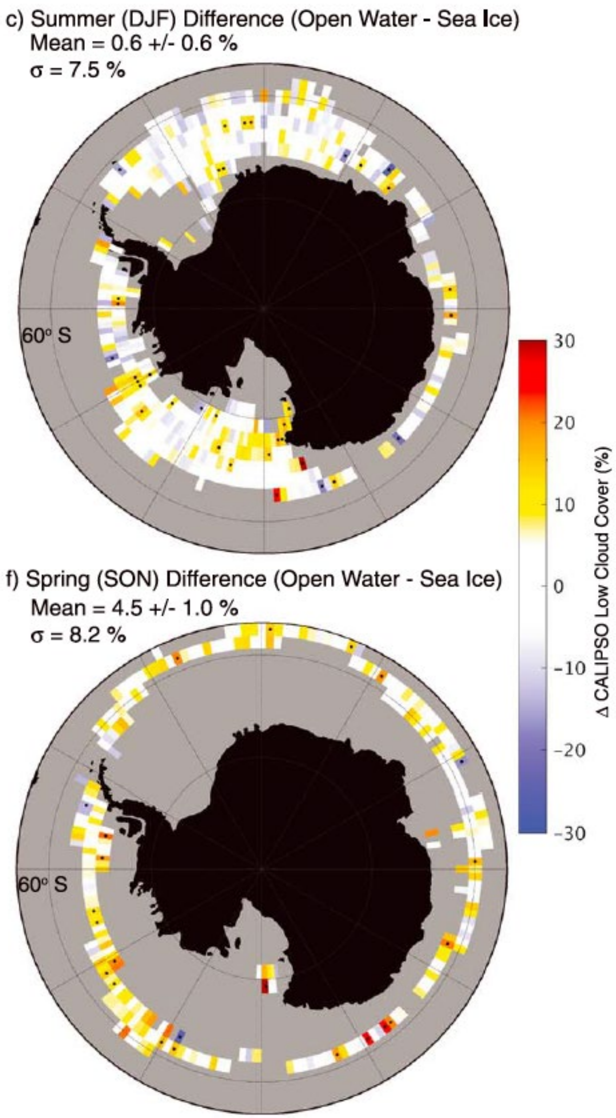
Intermittent Mask Approach



Cloud cover over open water (left) and over sea ice (right)

Figure 4, Frey et al. 2018

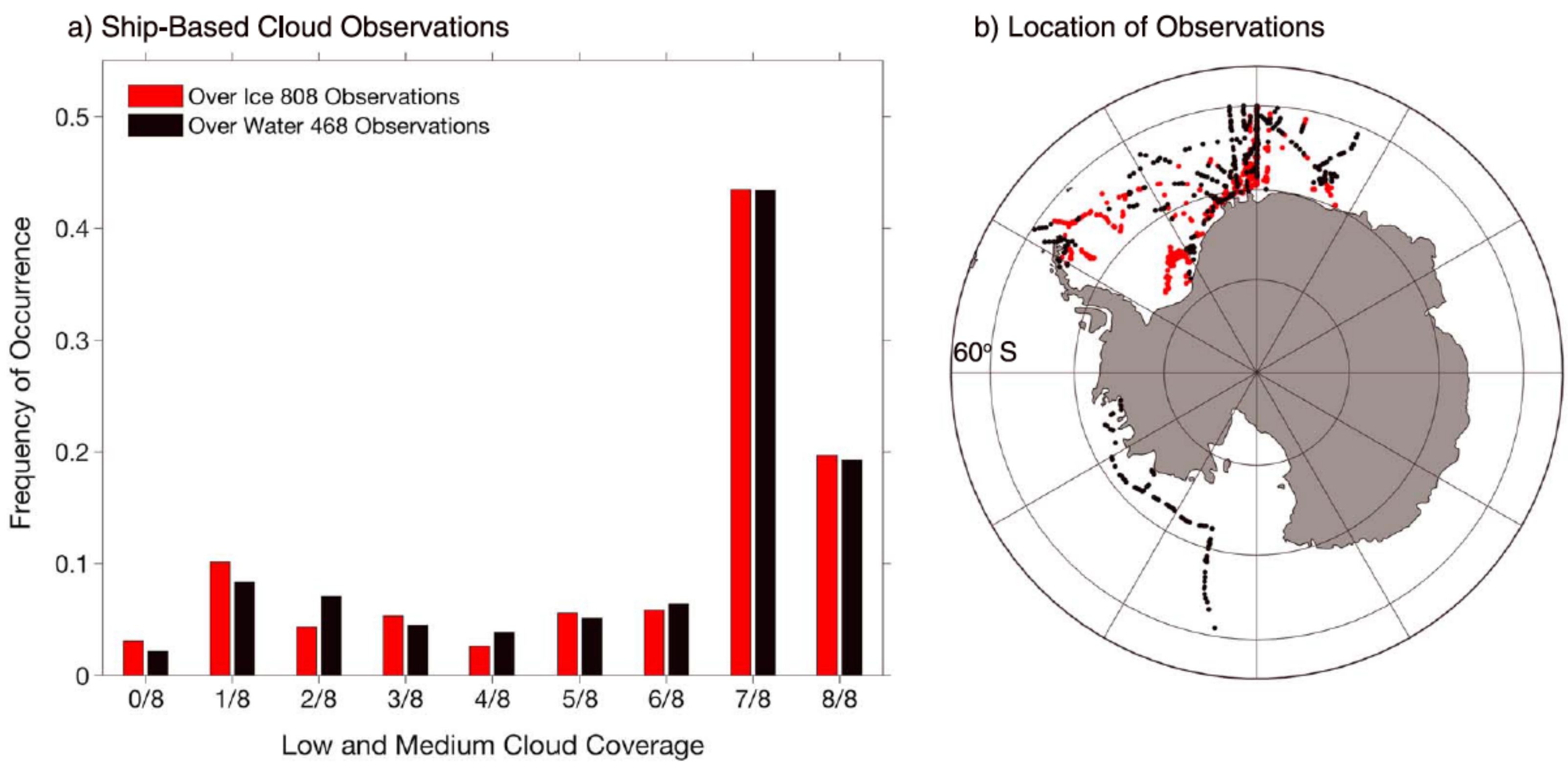
Cloud response to sea ice variability



Cloud cover response to sea ice variability negligible in summer; small in spring

Figure 4, Frey et al. 2018

Do the satellite observations match ship-based observations? Yes.

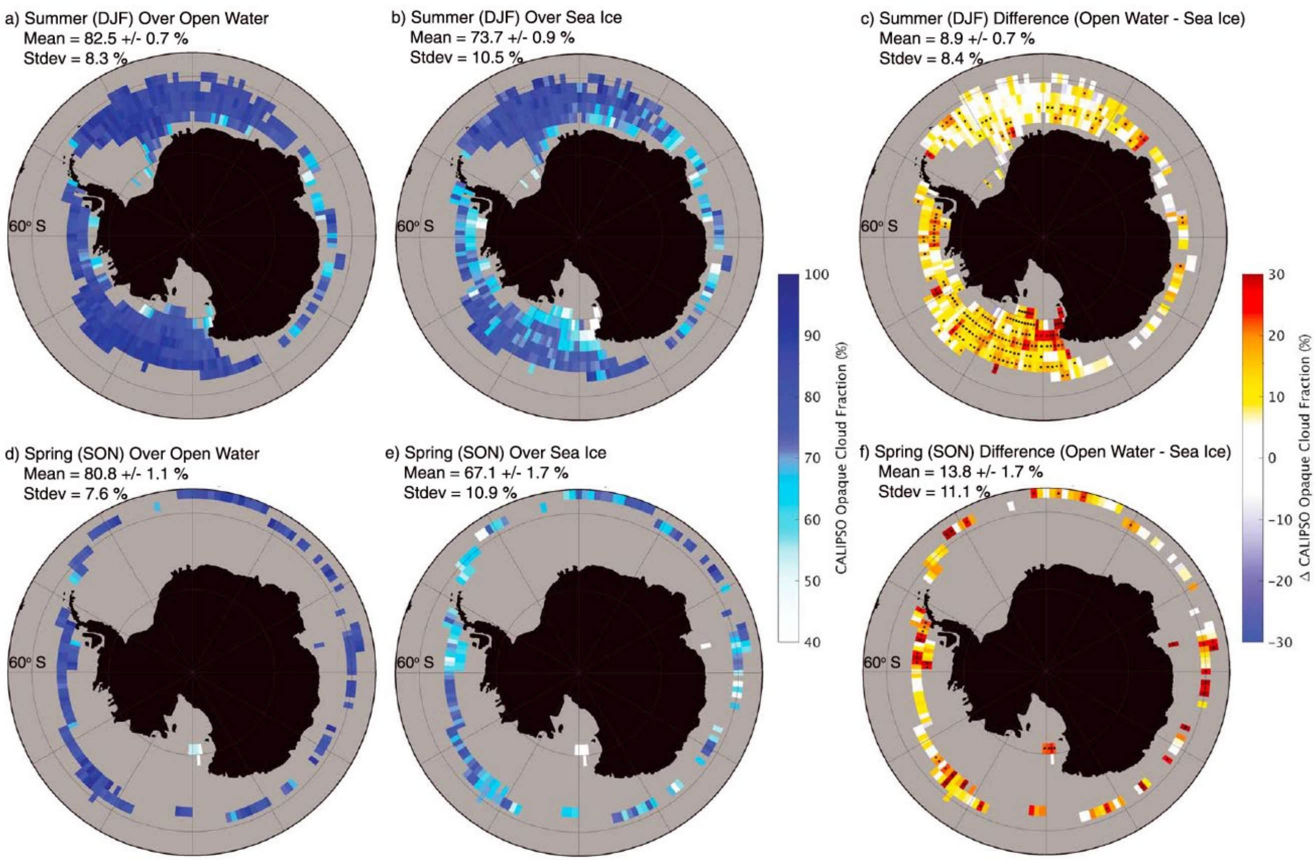


Two independent datasets show that the cloud cover response to sea ice variability is negligible in summer.

Figure 5, Frey et al. 2018

What about opaque cloud cover?

Note: Opaque clouds fully attenuate the lidar beam (optical depth >3)



Cloud cover over open water (left), over sea ice (middle), their difference (right)

Figure 7, Frey et al. 2018

It’s warmer and moister over the open water than over sea ice but not because of coupling to the surface…

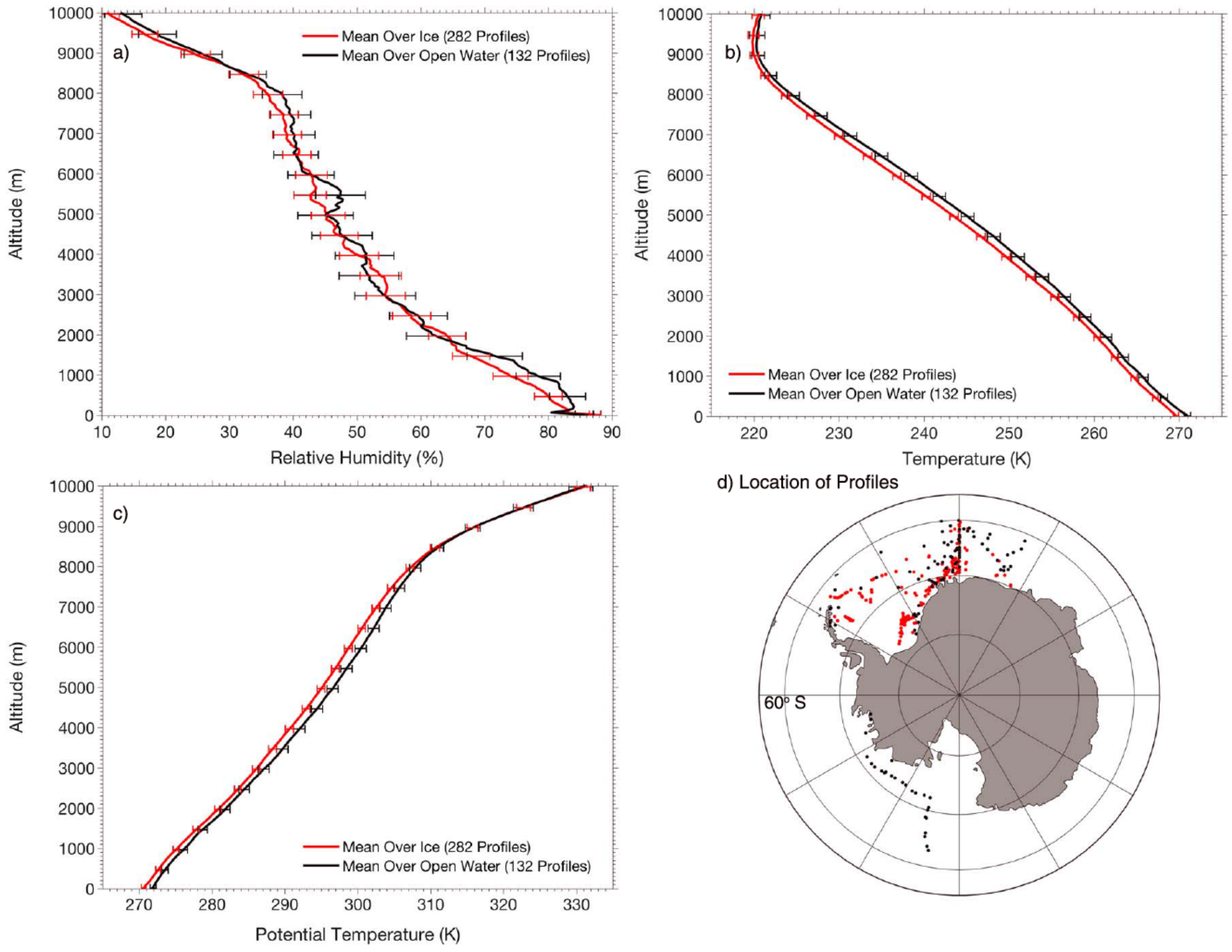
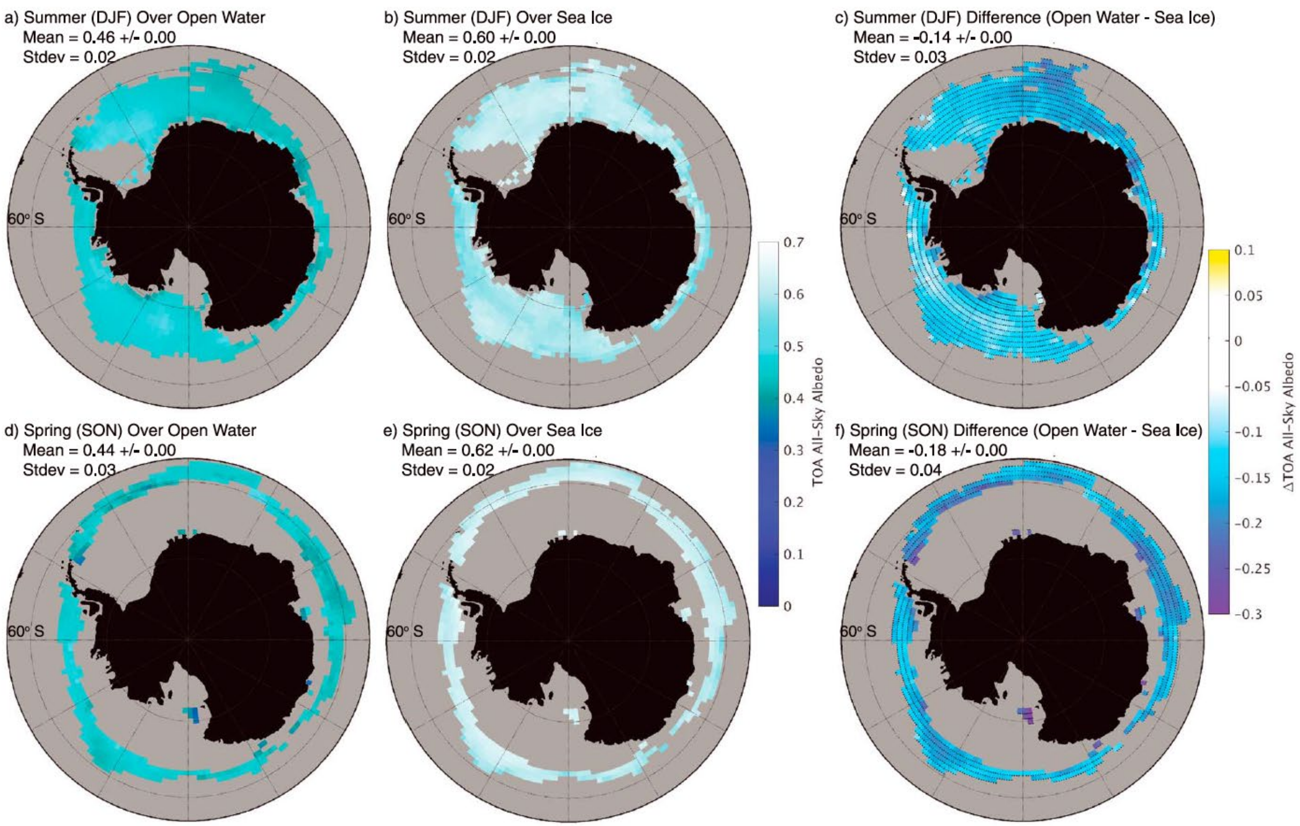


Figure 6, Frey et al. 2018

Top of atmosphere albedo lower over open water than over sea ice.



TOA Albedo over open water (left), over sea ice (middle), their difference (right)

Figure 9, Frey et al. 2018

Summary – Frey et al. 2018 JGR

RESEARCH ARTICLE

10.1029/2018JD028505

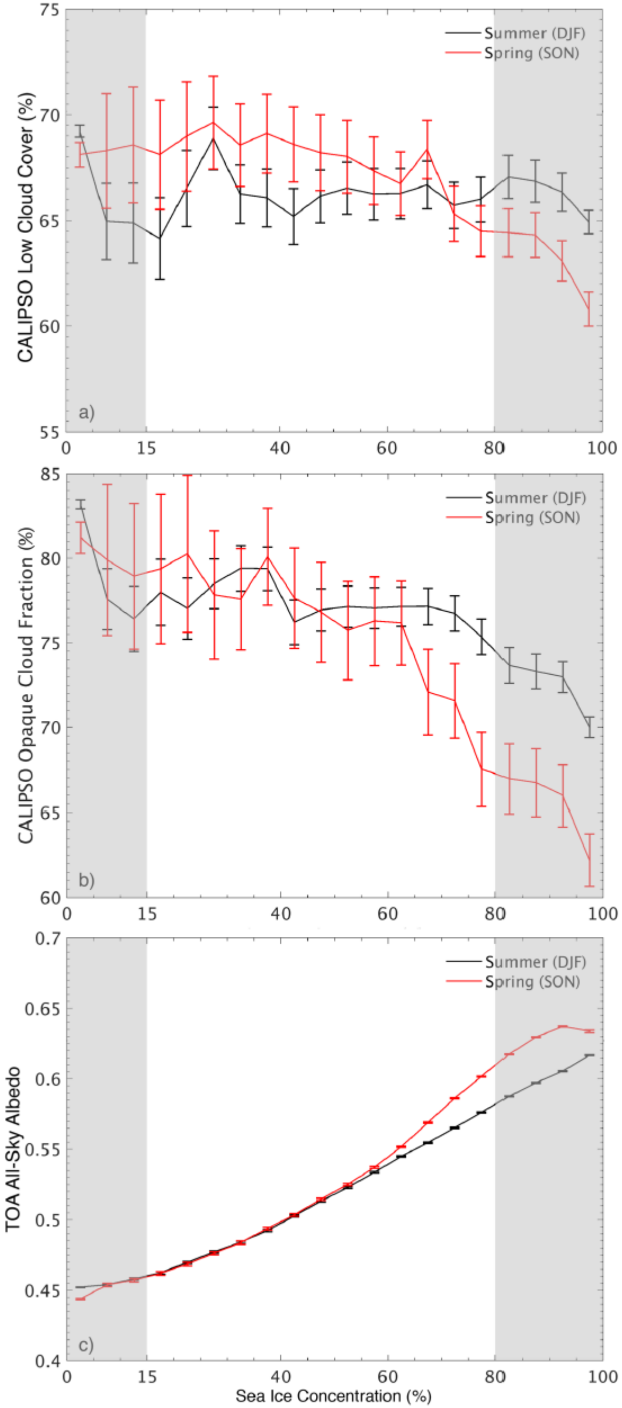
Key Points:

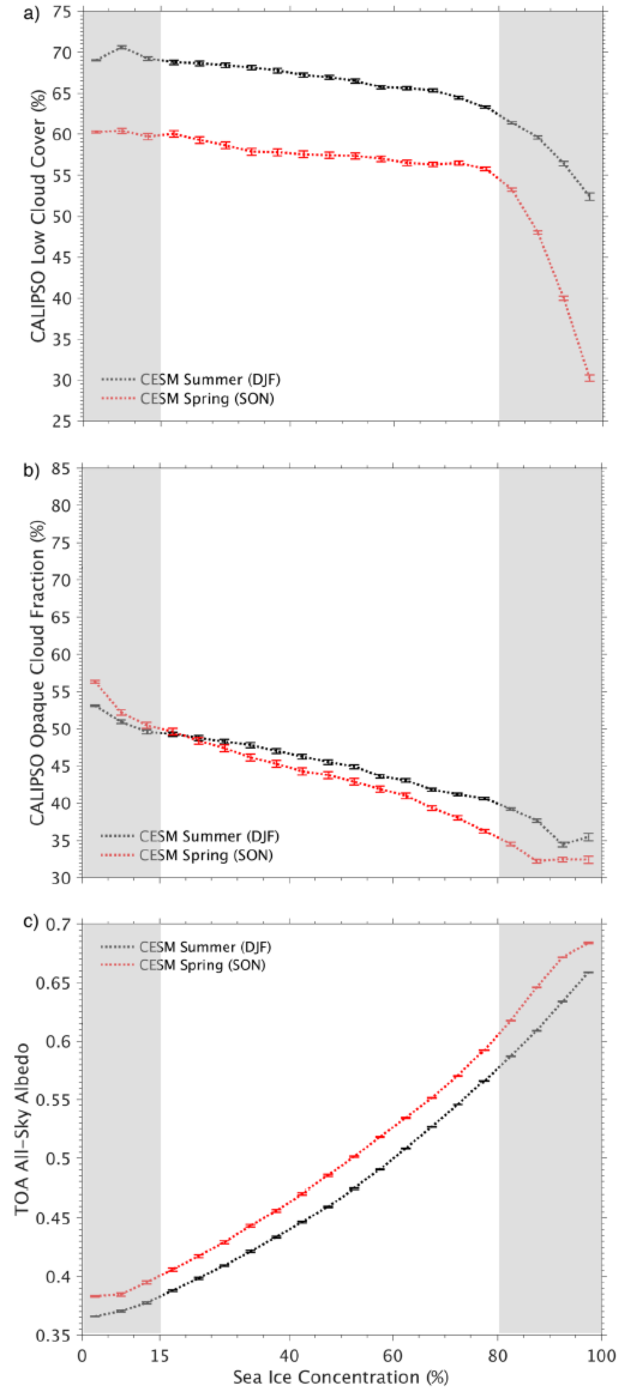
- Southern Ocean low cloud cover is unchanged in summer and slightly higher in spring over open water compared to sea ice
- In spring and summer, Southern Ocean cloud opacity increases over open water compared to sea ice
- Despite the cloud response, top-of-atmosphere albedo is lower and more shortwave radiation is absorbed over open water than over sea ice

Repeat Intermittent Mask methodology with lidar simulator within CESM1

…

Can CESM1 reproduce observed Antarctic cloud-sea ice-albedo relationship?





Even though CESM has large cloud biases (e.g., insufficient opaque cloud cover), the cloud and top-of-atmosphere albedo response to sea ice variability in CESM has the <u>same sign</u> as the observed response.

Figure 4.10 and 5.1 from Frey 2018 Ph.D. Dissertation