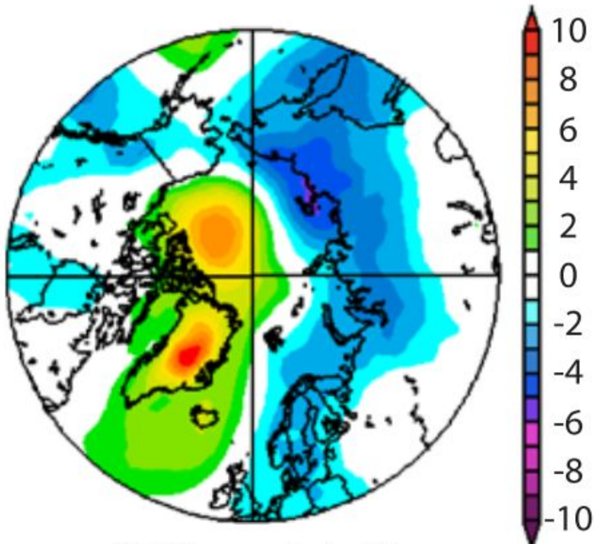
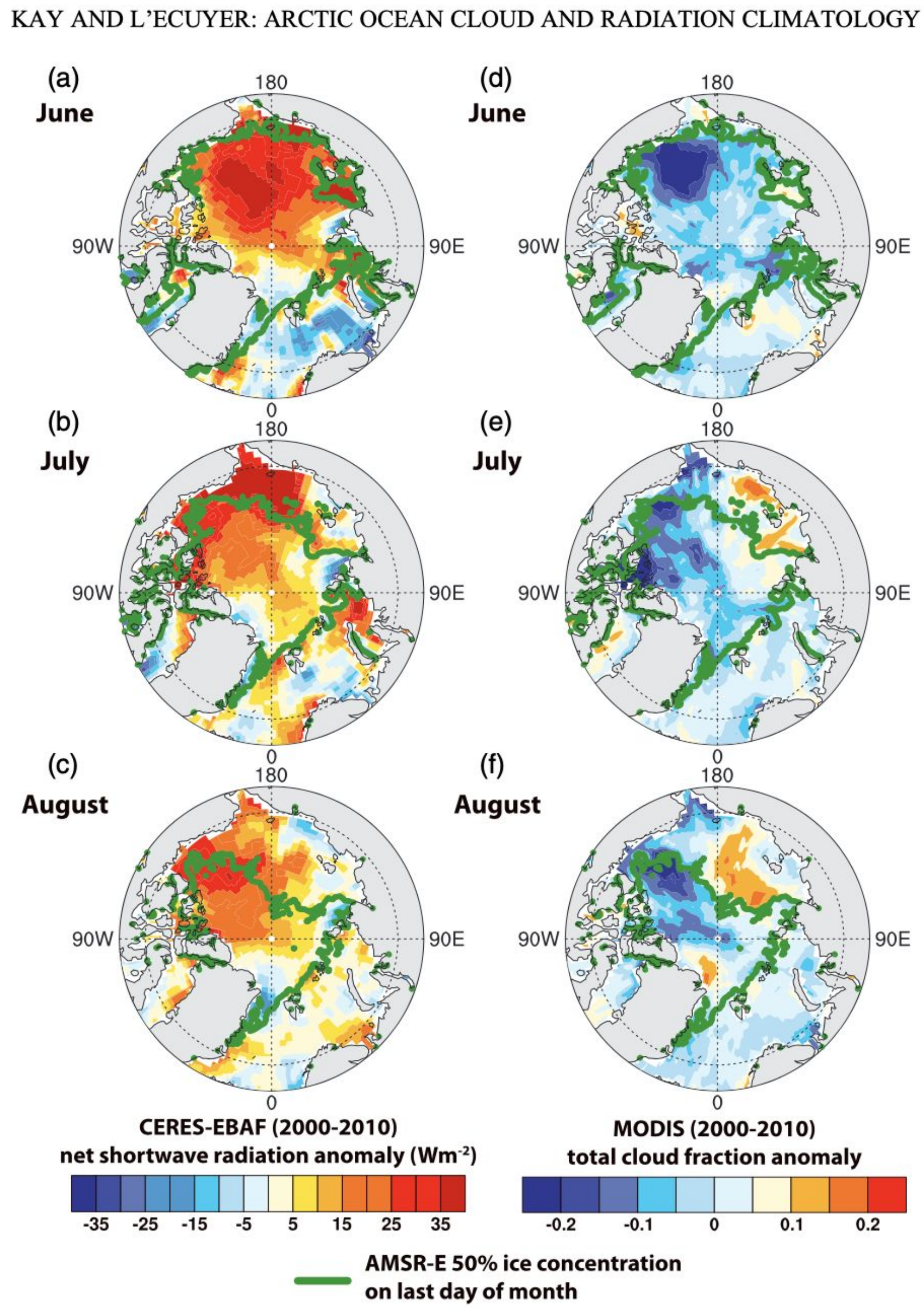


SLP Anomaly (mb)
JJAS 2007



Observations in Kay and L'Ecuyer 2013

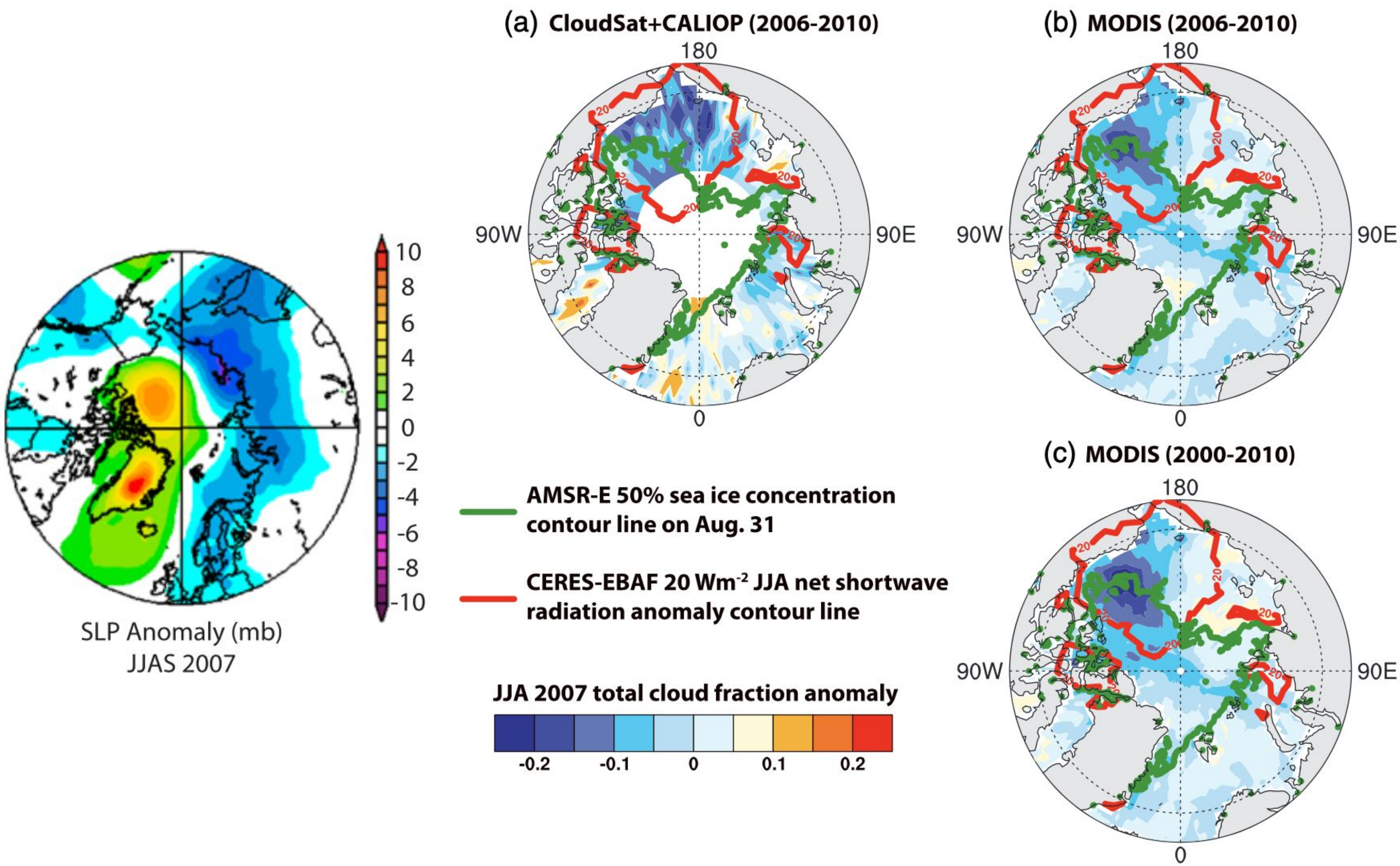


Figure 11. Summer (JJA) 2007 total cloud fraction anomalies: (a) CloudSat + CALIPSO 2007 anomaly from 2006 to 2010, (b) MODIS 2007 anomaly from 2006 to 2010, and (c) MODIS 2007 anomaly from 2000 to 2010. The figure uses CERES-EBAF data available from March 2000 to February 2011 (Table 1), CloudSat and CALIPSO data available from July 2006 to February 2011 (Table 1), and daily sea ice extents from AMSR-E observations [*Cavalieri et al.*, 2004].

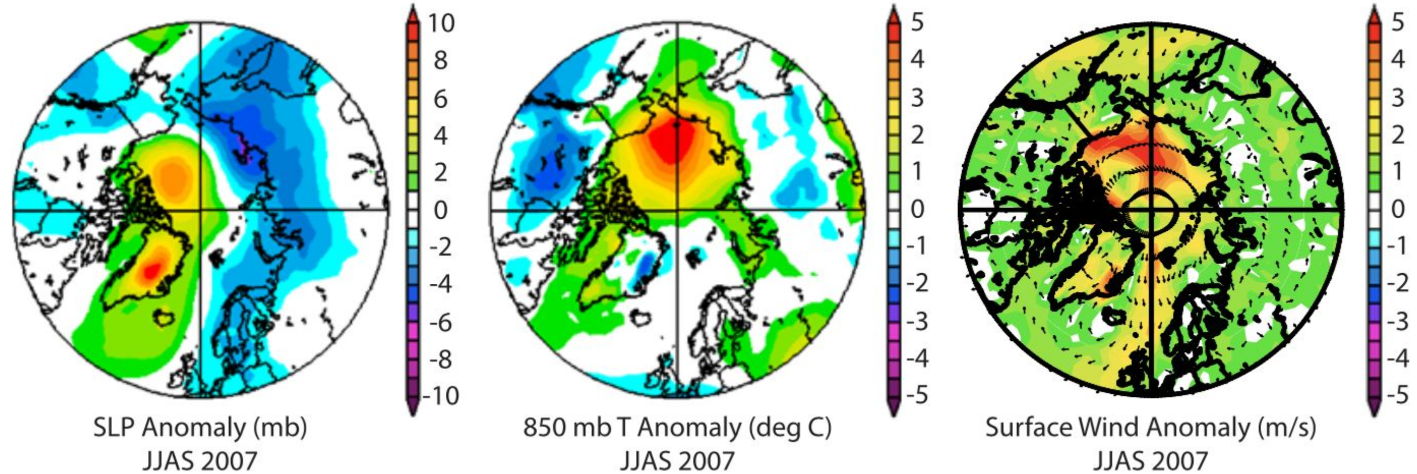


Figure 4. Sea level pressure (mb), 850 air temperature (deg C), and surface wind anomalies (m/s) from the NCEP reanalysis project.

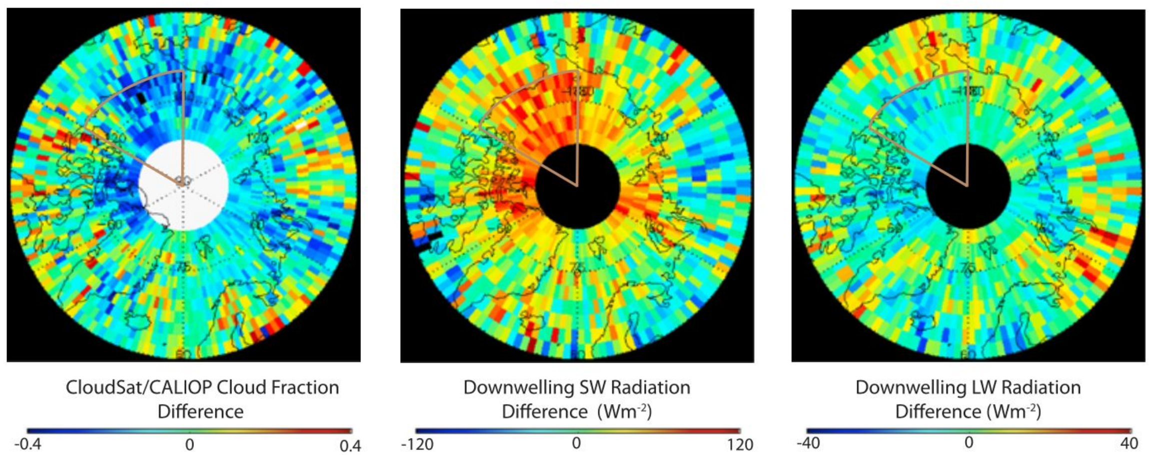


Figure 2. Clouds and downwelling radiation 2007–2006 differences (June 15–Sept 15). (left) Total cloud fraction differences based on radar and lidar data. (middle) Downwelling SW radiative flux difference. (right) Downwelling LW radiative flux difference. The Western Arctic Ocean is outlined in brown.

Observations in Kay et al. 2008

Arctic clouds and precipitation in the Community Earth System Model Version 2

Elin Mcilhattan[1], Jen Kay[2], Tristan L'Ecuyer[1]

[1]University of Wisconsin - Dept. Atmospheric and Oceanic Sciences

[2]Cooperative Institute for Research in Environmental Science, Dept. Atmospheric and Oceanic Sciences - University of Colorado-Boulder

AGU100 ADVANCING EARTH AND SPACE SCIENCE

JGR

Journal of Geophysical Research: Atmospheres

Arctic Clouds and Precipitation in the Community Earth System Model Version 2

Elin A. McIlhattan[1], **Jennifer E. Kay**[2], **Tristan S. L'Ecuyer**[1]

[1]Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA
[2]Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO, USA

Key Points:

- Arctic cloud liquid is five times greater in CESM2 relative to CESM1, resulting in large changes in surface downwelling radiation.
- The Arctic surface temperature is 4 K warmer in CESM2 than CESM1, in the annual mean.
- Rainfall in the Arctic is increased in CESM2 relative to CESM1, occurring year-round across the region in the new version.

Paper under review, Soon available at: http://www.cesm.ucar.edu/publications/

Using 1850 pre-industrial control runs with additional cloud/precip-relevant diagnostics (Table 1) – We ask:

- How has the frequency of Arctic LCCs changed in CESM2 relative to CESM1?
- How does the surface energy balance of the Arctic compare in the two versions?
- How has precipitation changed moving to CESM2, both in amount and spatial and temporal distribution?

McIlhattan et al. submitted

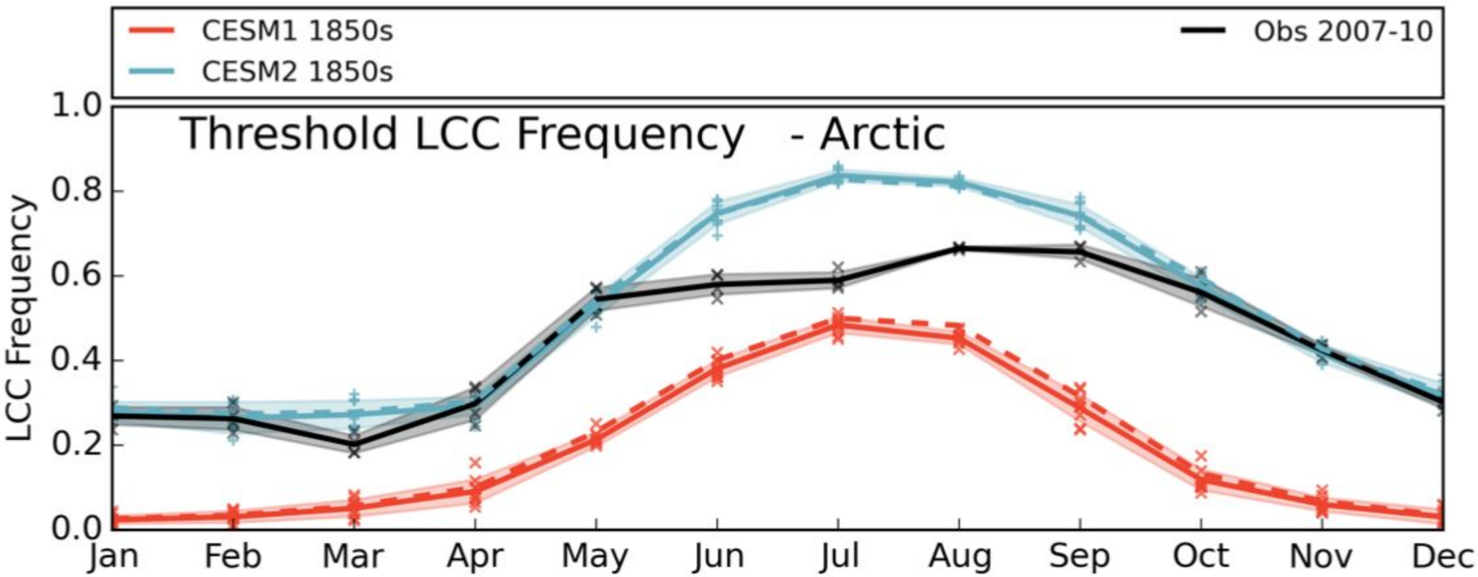


Figure 1. Annual cycle of liquid containing cloud (LCC) in the Arctic. The solid lines for CESM1 (red) and CESM2 (blue) illustrate the mean values for the monthly area weighted averages for all grid boxes between 66.91 and 90°N from the 10 year branch simulations of their respective 1850s control runs. The dashed lines are also for CESM1 and CESM2, but for for the area between 66.91 and 81.99° N, for comparison with observations. The blue line represent the average of 2007-10 CloudSat/CALIPSO observations. The markers surrounding the lines each depict a single year's monthly average. The shaded regions denote the standard deviation about the mean for the month, showing the inter-annual variability.

Figure 1, McIlhattan et al. submitted

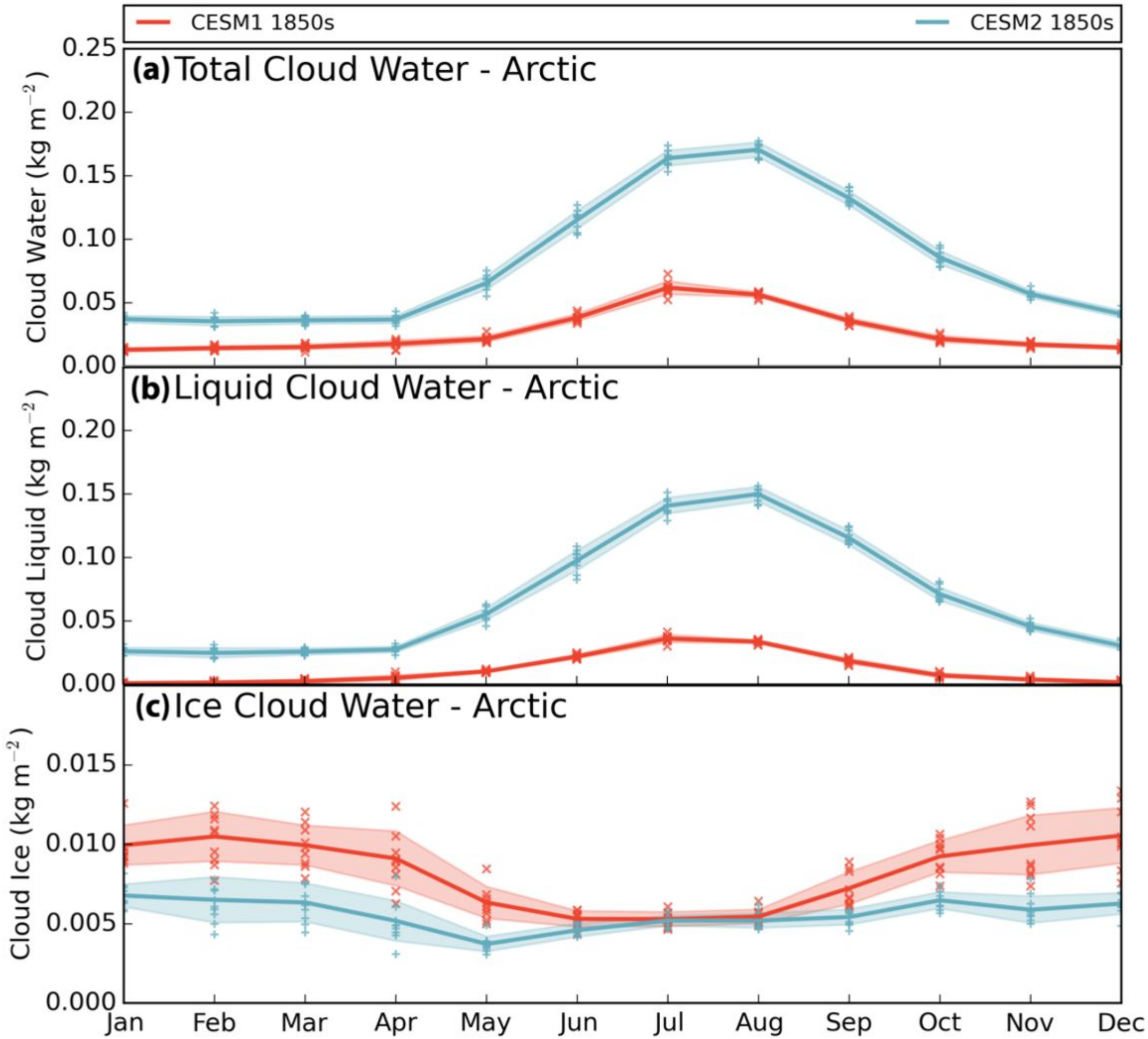
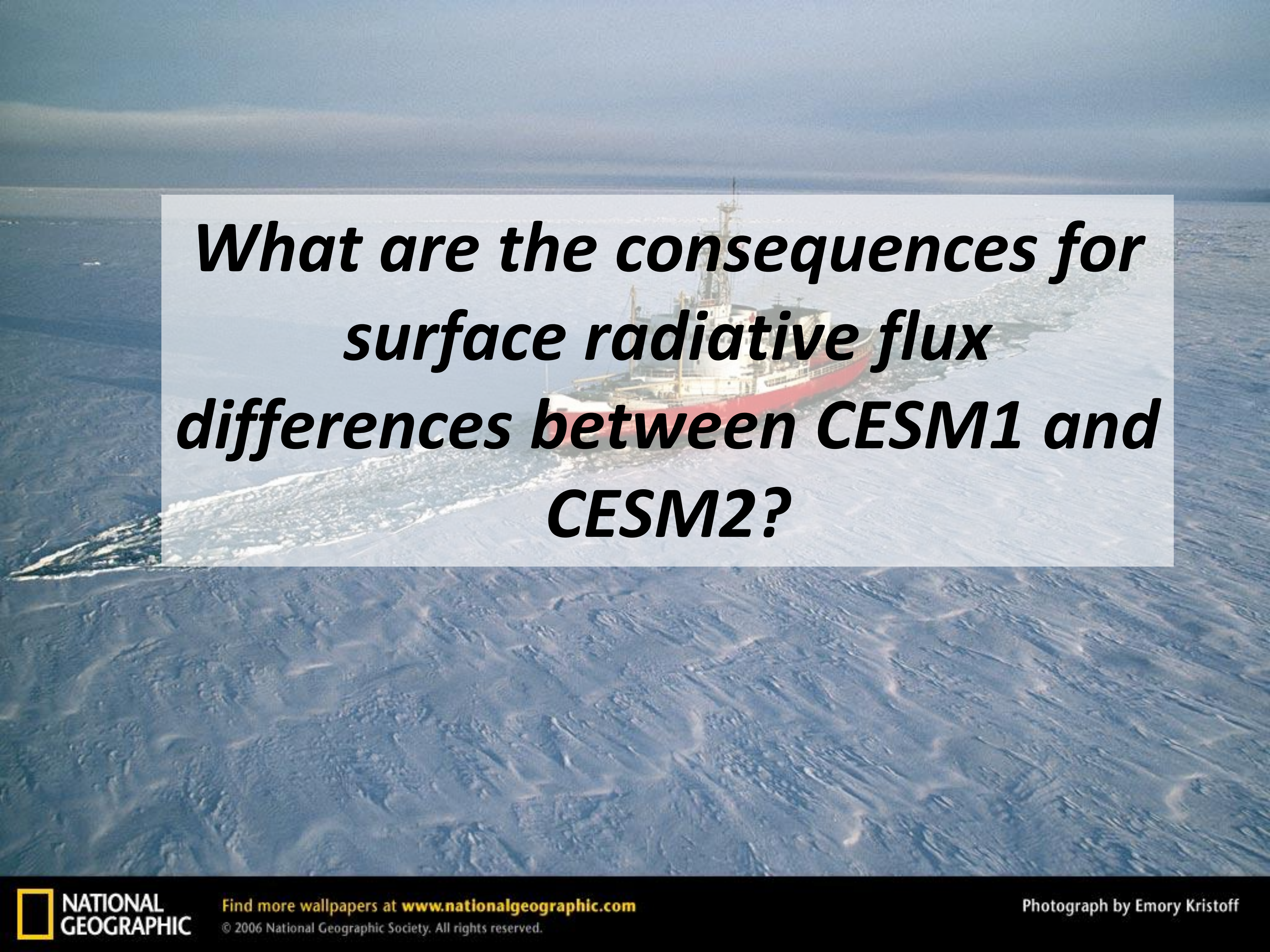


Figure 2. As in Fig 1 for the annual cycles of **(a)** total cloud water, **(b)** liquid cloud water, and **(c)** ice cloud water. Note the same y-axis is used in **(a)** and **(b)**, but **(c)** is reduced.

Figure 2, McIlhattan et al. submitted

What are the consequences for surface radiative flux differences between CESM1 and CESM2?



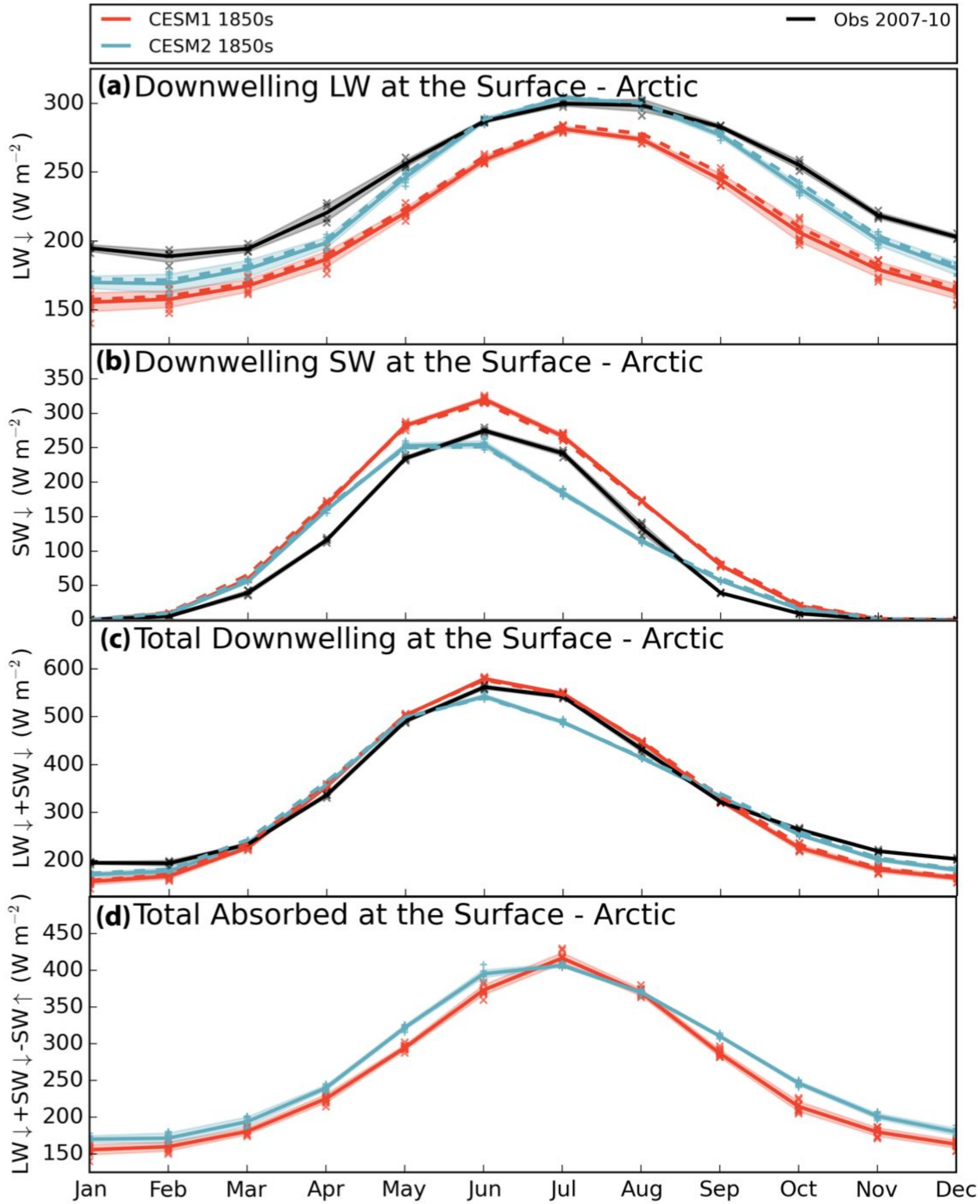


Figure 3. As in Fig 1 for the annual cycles of **(a)** downwelling LW at the surface, **(b)** downwelling SW at the surface, **(c)** total downwelling radiation at the surface (LW↓+SW↓), and **(d)** total absorbed radiation at the surface(LW↓+SW↓-SW↑). Note each y-axis different.

Figure 3, McIlhattan et al. submitted

What are the consequences for surface air temperatures differences between CESM1 and CESM2?

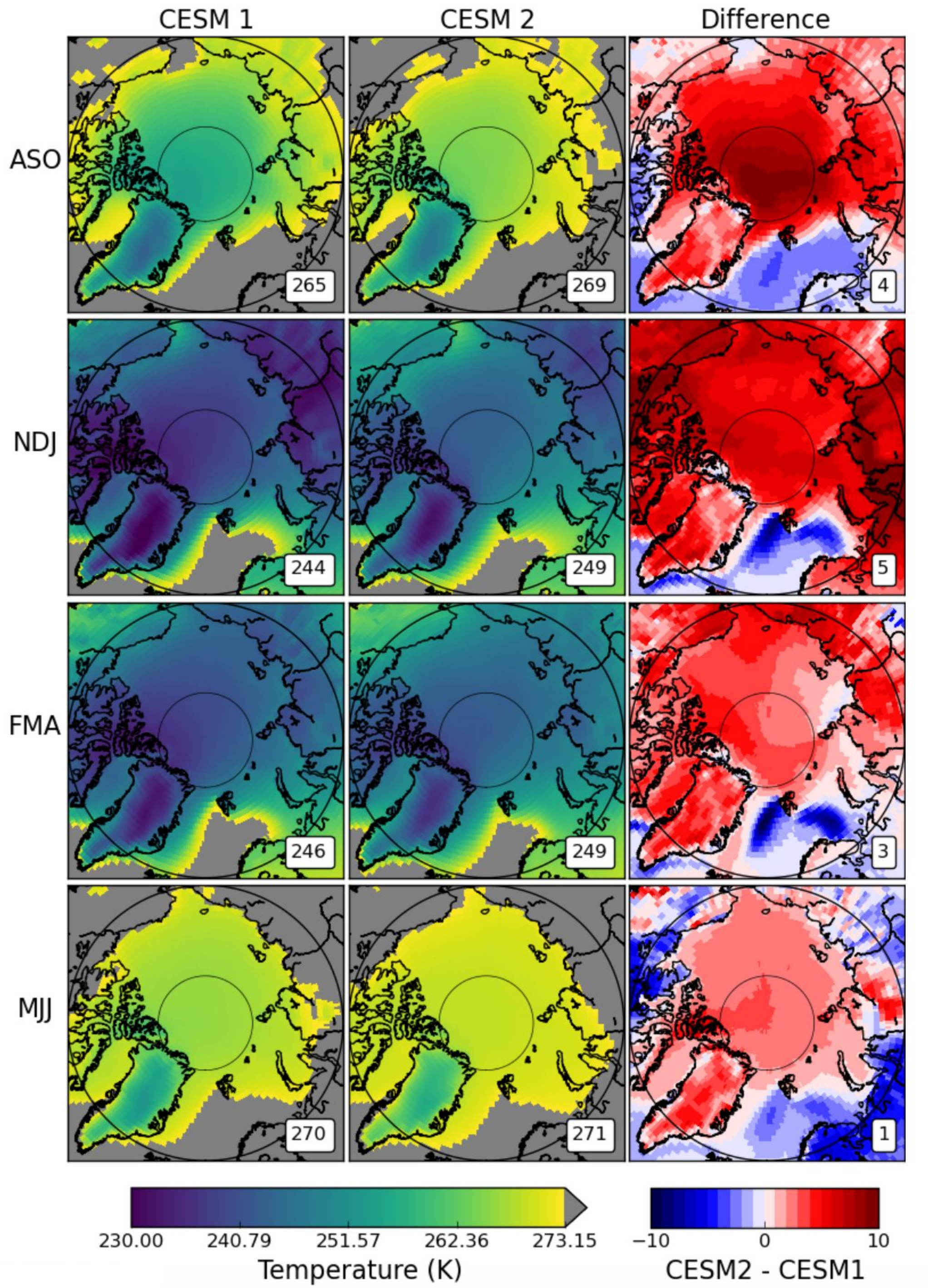
NATIONALGEOGRAPHIC.COM

Photograph by Bill Hatcher

The annual mean Arctic surface temperature is 4 K higher in CESM2 than in CESM1.

Dataset	Spatial Region	Time Period	Surface Temp (K)	Near Surface Air Temp (K)
CESM1	67-90° N	1850s Control	256 ± 13	257 ± 12
CESM2	67-90° N	1850s Control	260 ± 11	260 ± 11
CESM1	Global	1850s Control	287 ± 2	286 ± 1
CESM2	Global	1850s Control	288 ± 1	287 ± 1

Table 2, McIlhattan et al. submitted



Differences in surface air temperature CESM1 vs. CESM2

Figure 4, McIlhattan et al. submitted

How much does it rain and snow in CESM1 and CESM2?

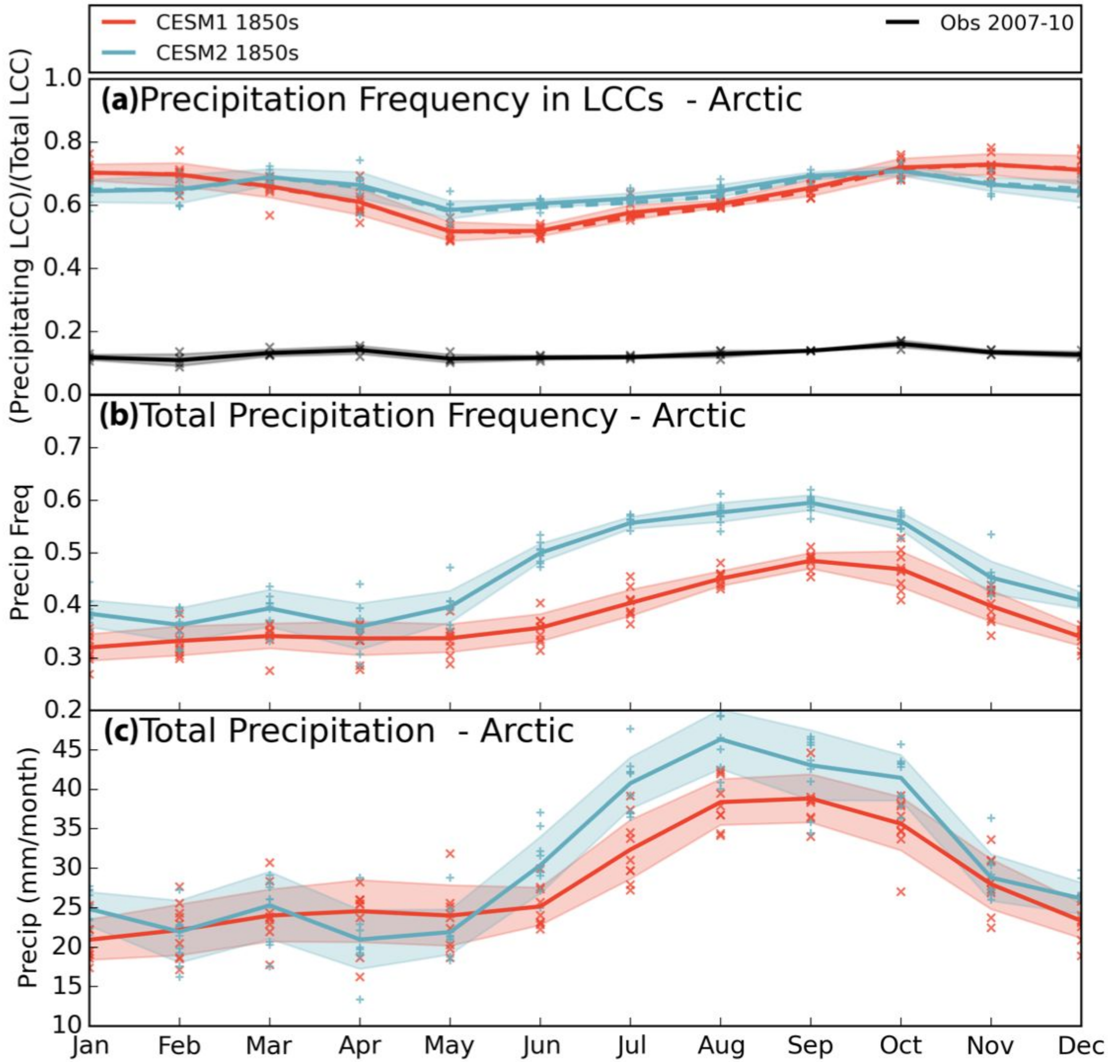


Figure 5. As in Fig 1 for the annual cycles of **(a)** precipitation frequency in LCCs, **(b)** total precipitation frequency, and **(c)** total precipitation. Note each y-axis different.

Figure 5, McIlhattan et al. submitted

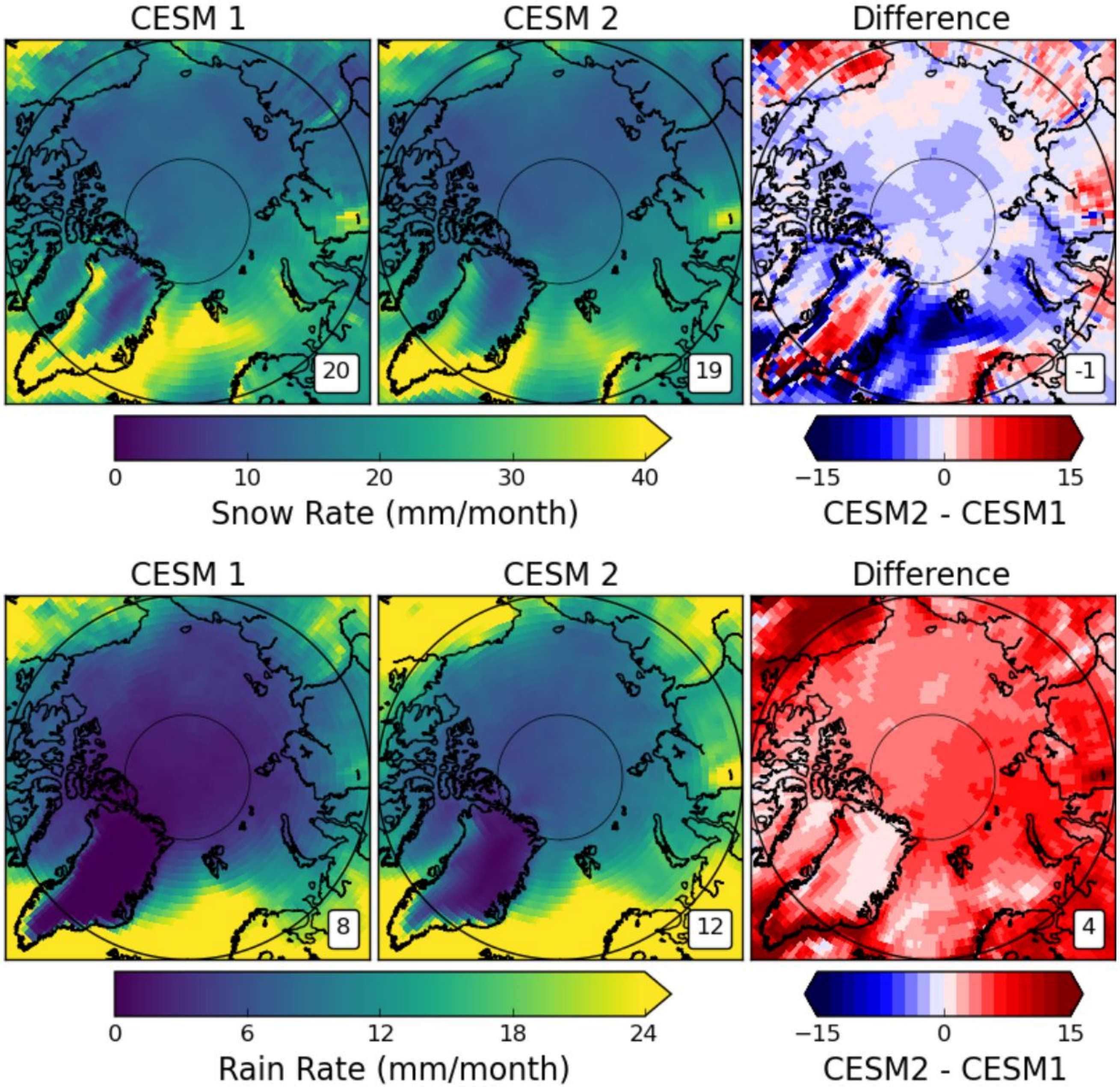
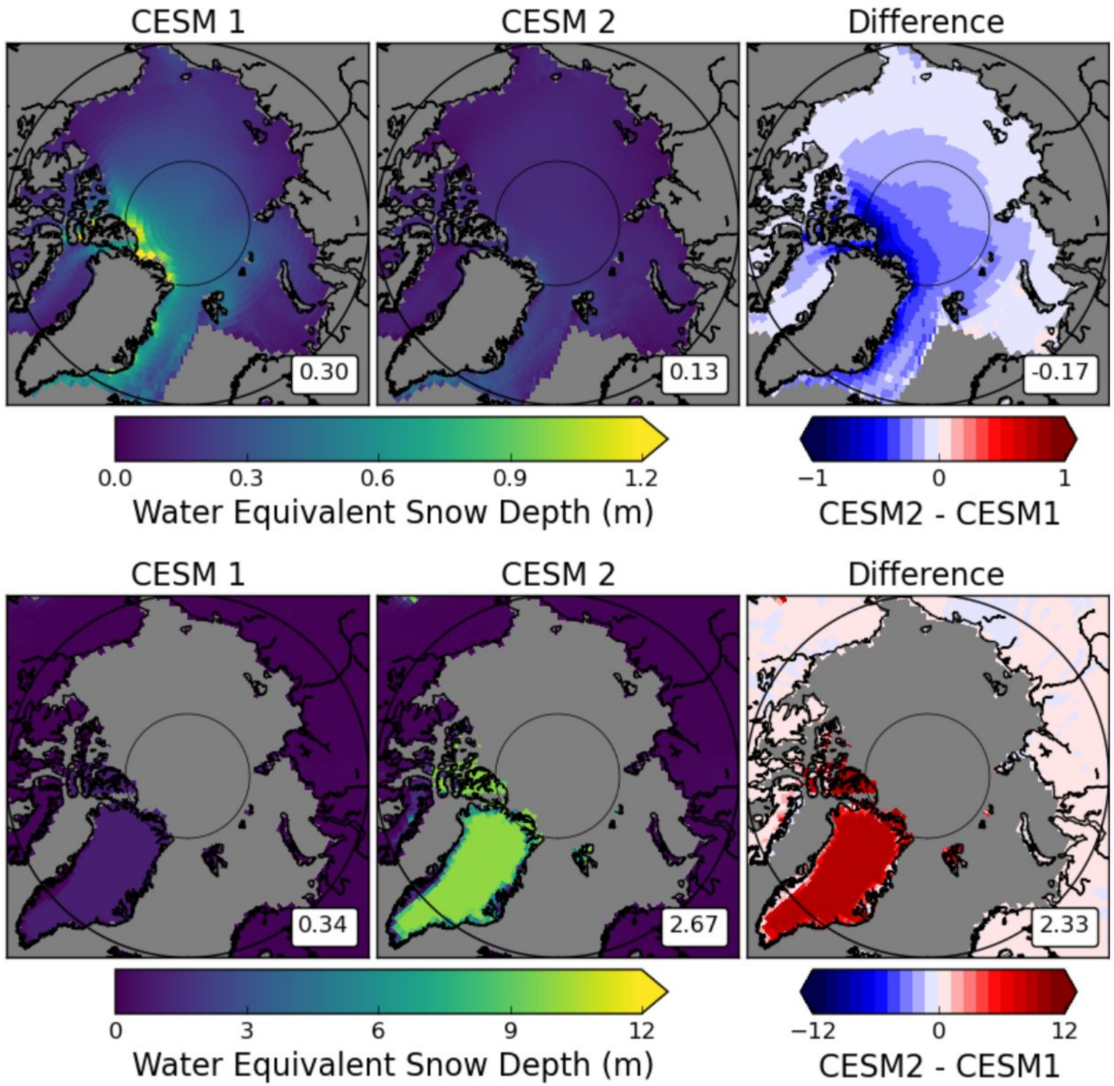


Figure 8. As in Fig. 6 for snow rate (top row) and rain rate (bottom row).

Figure 8, McIlhattan et al. submitted



Compared to CESM1, CESM2 has less snow in sea ice but more snow on land

Figure 6. Annual averages of water equivalent snow depth on sea ice (top row) and land (bottom row). The plots for CESM1 (left column) and CESM2 (center column) are means from the 10 year branch simulations of their respective 1850s control runs. The difference plots in the right column are CESM2 minus CESM1, with red (blue) values showing increases (decreases) in snow depth in CESM2 with respect to CESM1. The area weighted averages for the study area (66.91° N and 90° N) are shown in the lower right of each map.

Figure 7, McIlhattan et al. submitted

Why the CESM1->CESM2 changes?

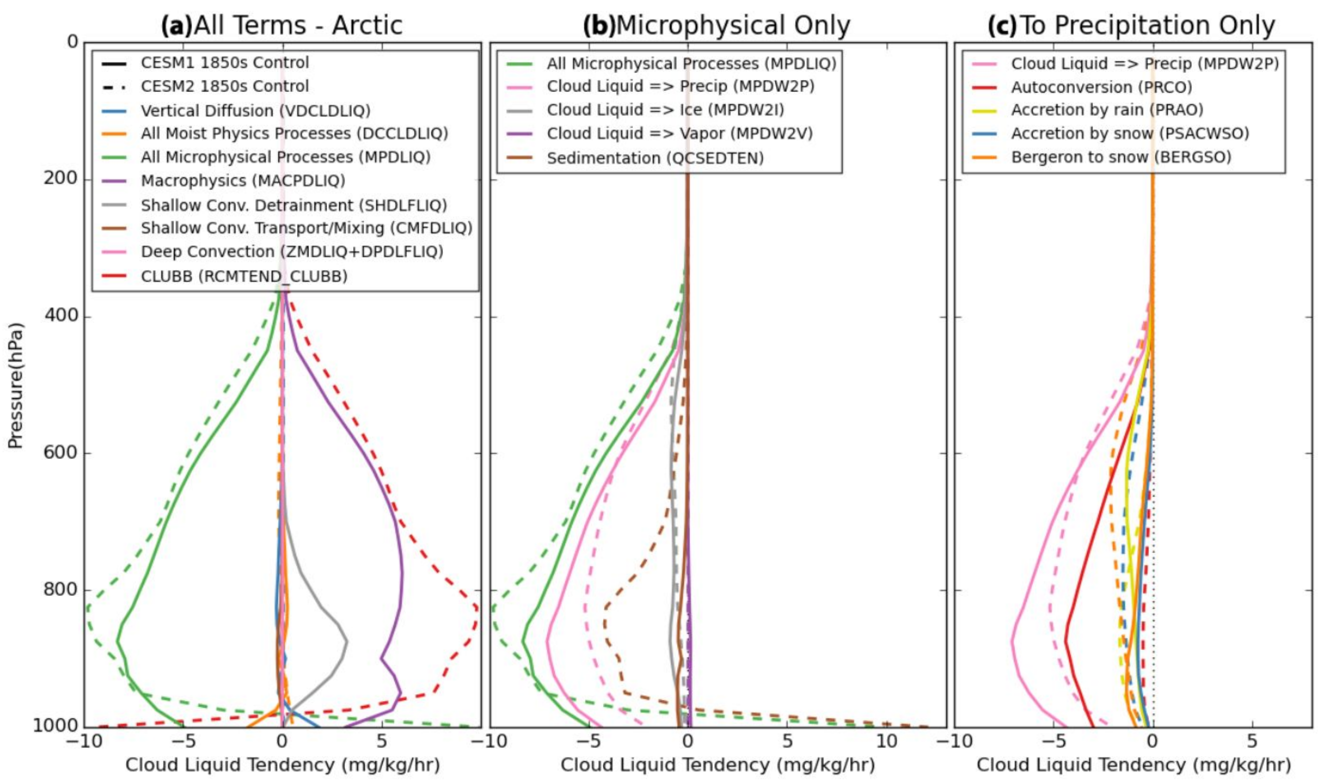


Figure 9, McIlhattan et al. submitted

The key results from the tendency terms presented in Fig 9 are: first, the direct conversion of Arctic cloud liquid to precipitation is reduced in CESM2 relative to CESM1, and thus the mean snowfall rate is also reduced; second, due to the increased sedimentation of Arctic cloud liquid in CESM2, the mean Arctic rainfall rate has also increased year round, despite sub-freezing temperatures.

Summary: McIlhattan et al. submitted

Arctic Clouds and Precipitation in the Community Earth System Model Version 2

Elin A. McIlhattan[1], **Jennifer E. Kay**[2], **Tristan S. L'Ecuyer**[1]

[1]Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA
[2]Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO, USA

Key Points:

- Arctic cloud liquid is five times greater in CESM2 relative to CESM1, resulting in large changes in surface downwelling radiation.
- The Arctic surface temperature is 4 K warmer in CESM2 than CESM1, in the annual mean.
- Rainfall in the Arctic is increased in CESM2 relative to CESM1, occurring year-round across the region in the new version.