Clouds in CESM1.5: An initial evaluation of the mean state using simulators

Jen Kay (CU-Boulder)

Thanks to:
Andrew Gettelman (NCAR)
Cecile Hannay (NCAR)

What are best practice methods for evaluating cloud biases in climate models?

"TOP 10" for Clouds and Radiation to be assessed in 5+ year long runs (Kay, Klein, Pincus, Hillman)

1) TOA SWCF compared to CERES EBAF (Loeb et al. 2009)
2) TOA Absorbed shortwave compared to CERES EBAF
3) TOA LWCF compared to CERES EBAF
4) "total cloud fraction" (CLDTOT > 1.3) compared to ISCCP/MISR/MODIS
5) "thin cloud fraction" (CLDTOT 9.4 > tau > 1.3) compared to ISCCP/MISR/MODIS
6) "thick cloud fraction" (CLDTOT tau > 9.4) compared to ISCCP/MISR/MODIS
7) Total Grid Box Cloud Liquid Water Path over ocean only compared to SSM/I U.Wisc Climatology (O'Dell et al. 2008).
8) CLDLOW compared to CALIOP GOCCP (Chepfer et al. 2010)
9) CLDMED compared to CALIOP GOCCP
10) CLDHGH compared to CALIOP GOCCP

(blue means using simulators contained in COSP, COSP1.4 is ready for CMIP6!)

20th C AMIP: Global Cloud Fraction

CAM5 improved "too few too bright"

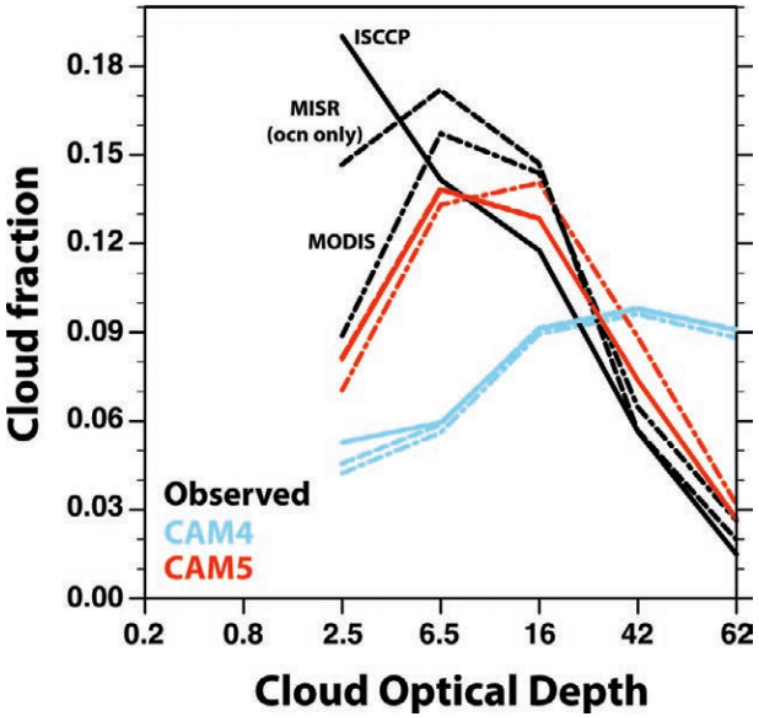
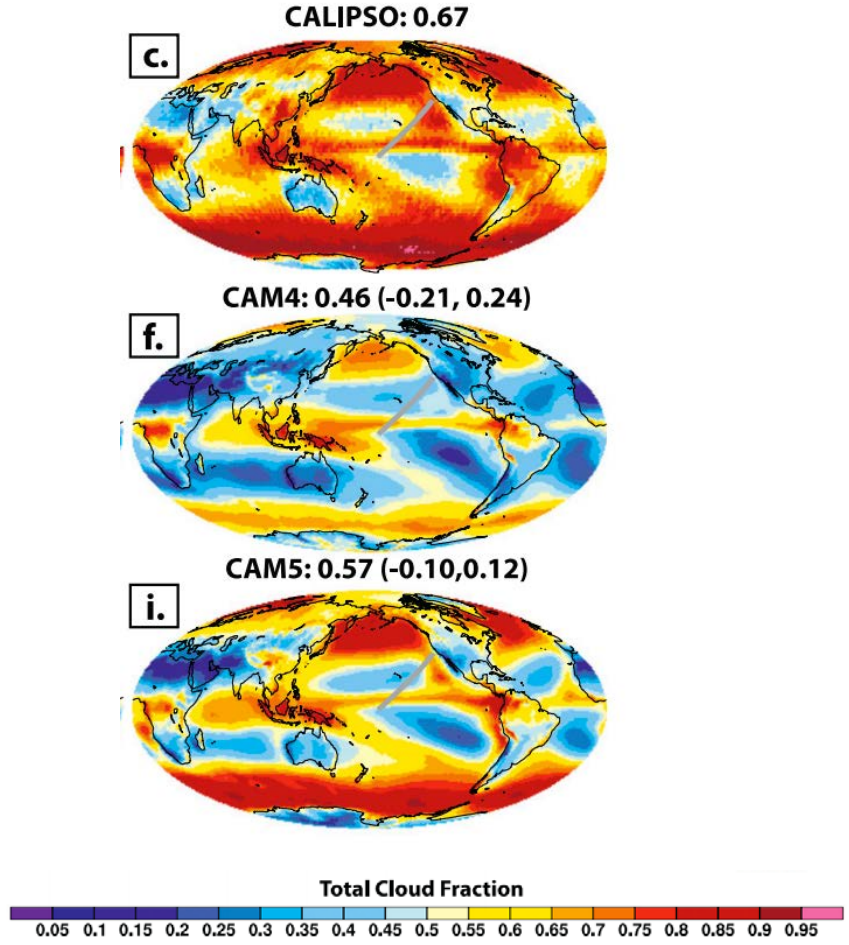


FIG. 3. Global column-integrated cloud optical depth distributions from three satellite observations and their corresponding CAM4 and CAM5 outputs from instrument simulators (Bodas-Salcedo et al. 2011). Comparisons use International Satellite Cloud Climatology Project (ISCCP), the Multiangle Imaging SpectroRadiometer (MISR), and the Moderate Resolution Imaging Spectroradiometer (MODIS) observations. (Adapted from Kay et al. 2012a.)



Figures from Kay et al. 2012; Hurrell et al. 2013

20th C AMIP: Global Cloud Phase

CAM5 has too much ice, not enough liquid.

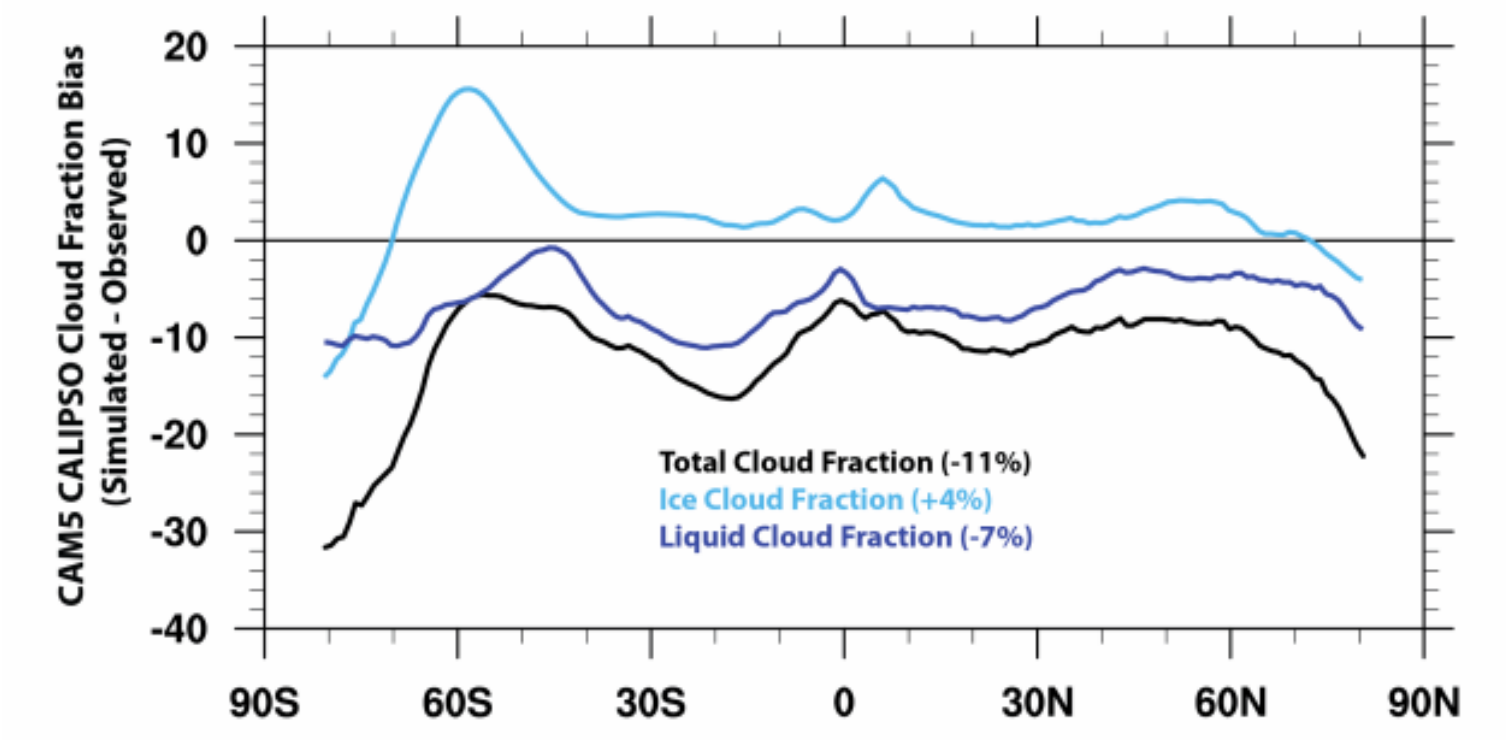
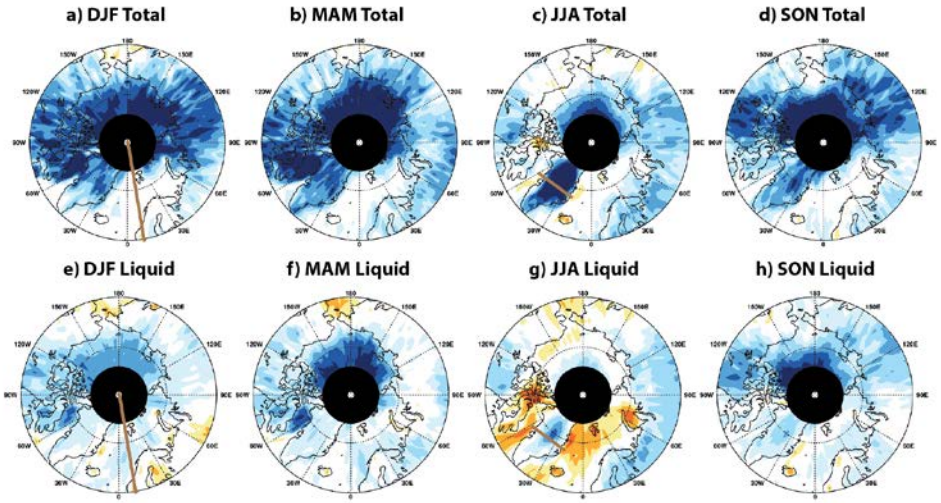


Figure 1. Zonal annual mean CAM5 CALIPSO Cloud Fraction bias (CAM5 simulated – observed). Global mean values are indicated in parenthesis.

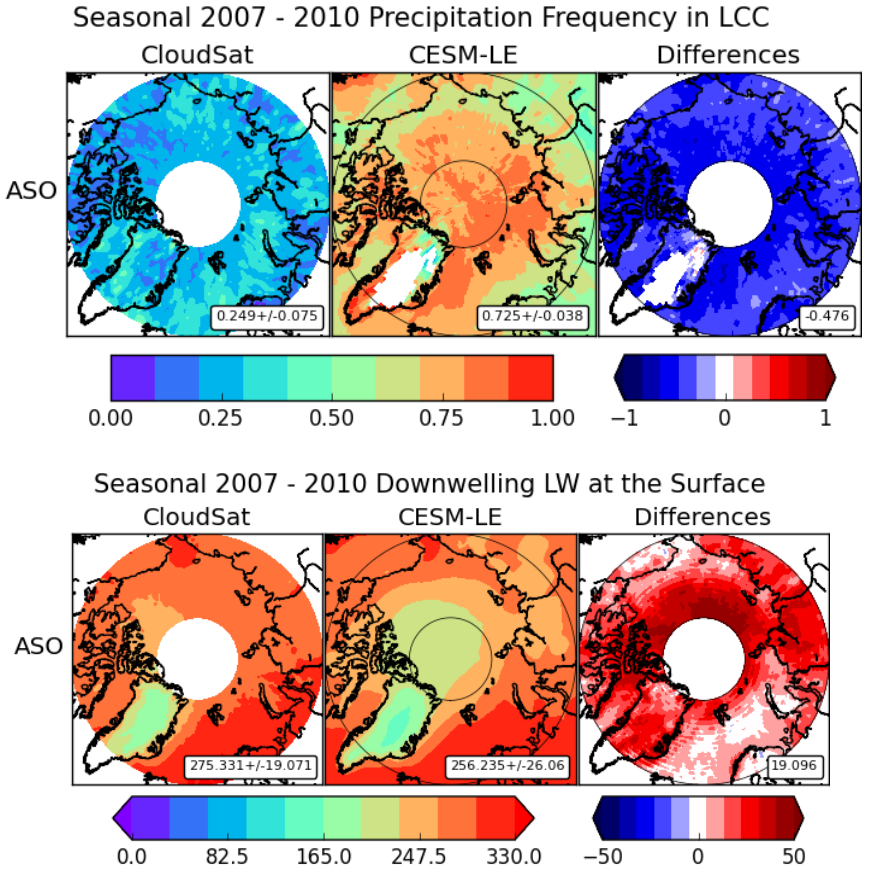
Figure from Kay et al. (minor revisions)

20th C AMIP: Arctic Clouds/Precipitation

CAM5 has insufficient liquid cloud, too much snow, and insufficient downwelling longwave radiation.



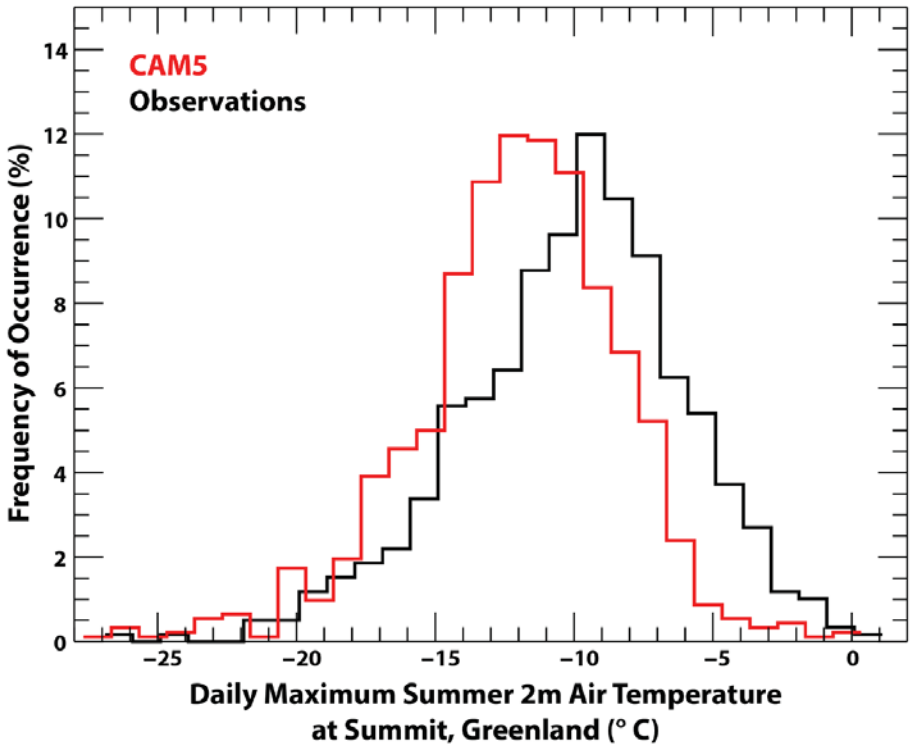
Kay et al. (minor revisions)

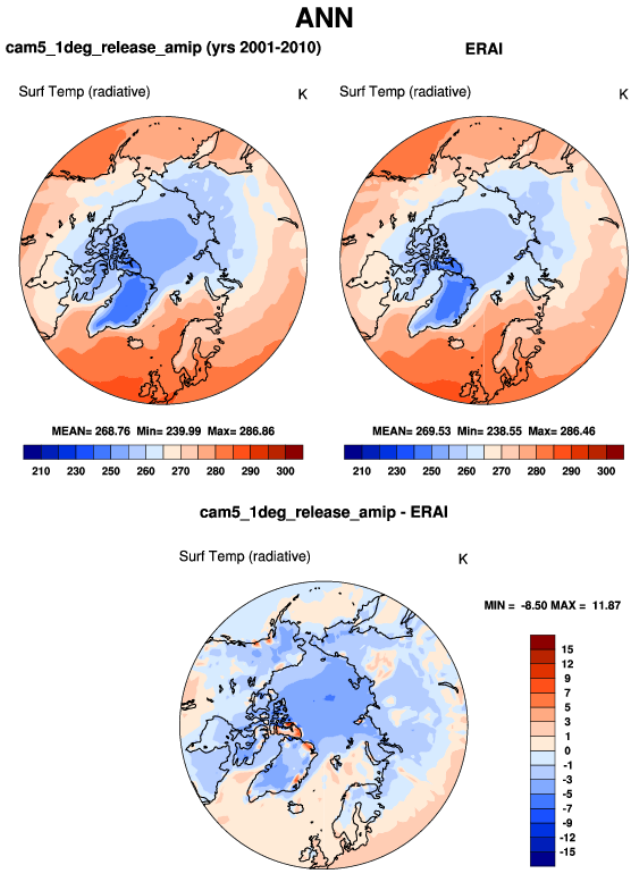


Courtesy Elin McIlhattan

20th C AMIP: Arctic Temperature

CAM5 is too cold (due to insufficient liquid cloud)





Kay et al. (minor revisions)

How is CAM5.5 (“28”) looking compared to CAM5?

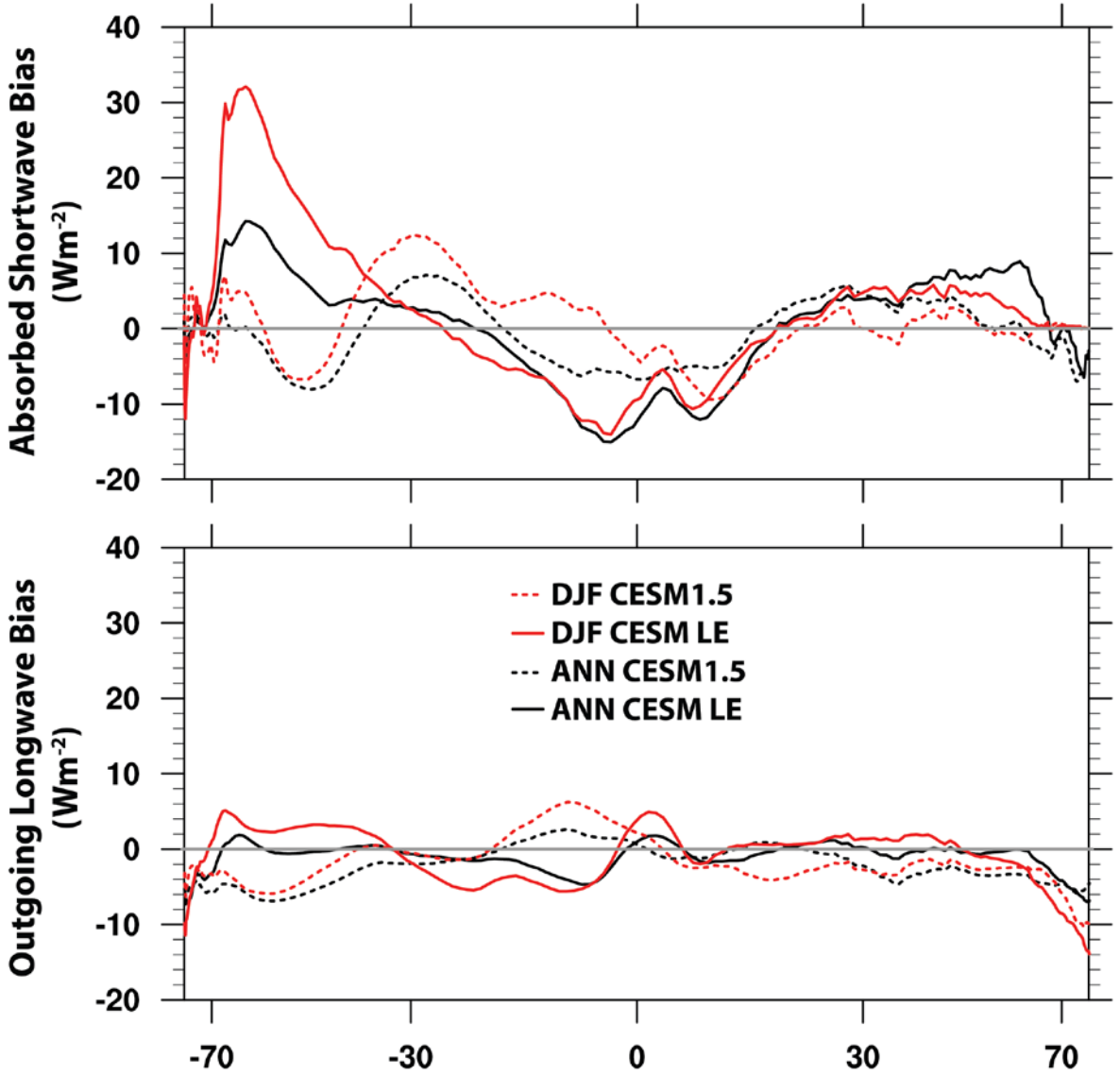
CAUTION:

Preliminary Results Rough Plots

Short 7-year AMIP run (but results presented checked with 1850 fully coupled runs)

1850 Fully Coupled Radiation vs. CERES-EBAF:

CESM1.5 bias <10 Wm^{-2} at all latitudes!



20th C AMIP Radiation vs. CERES-EBAF

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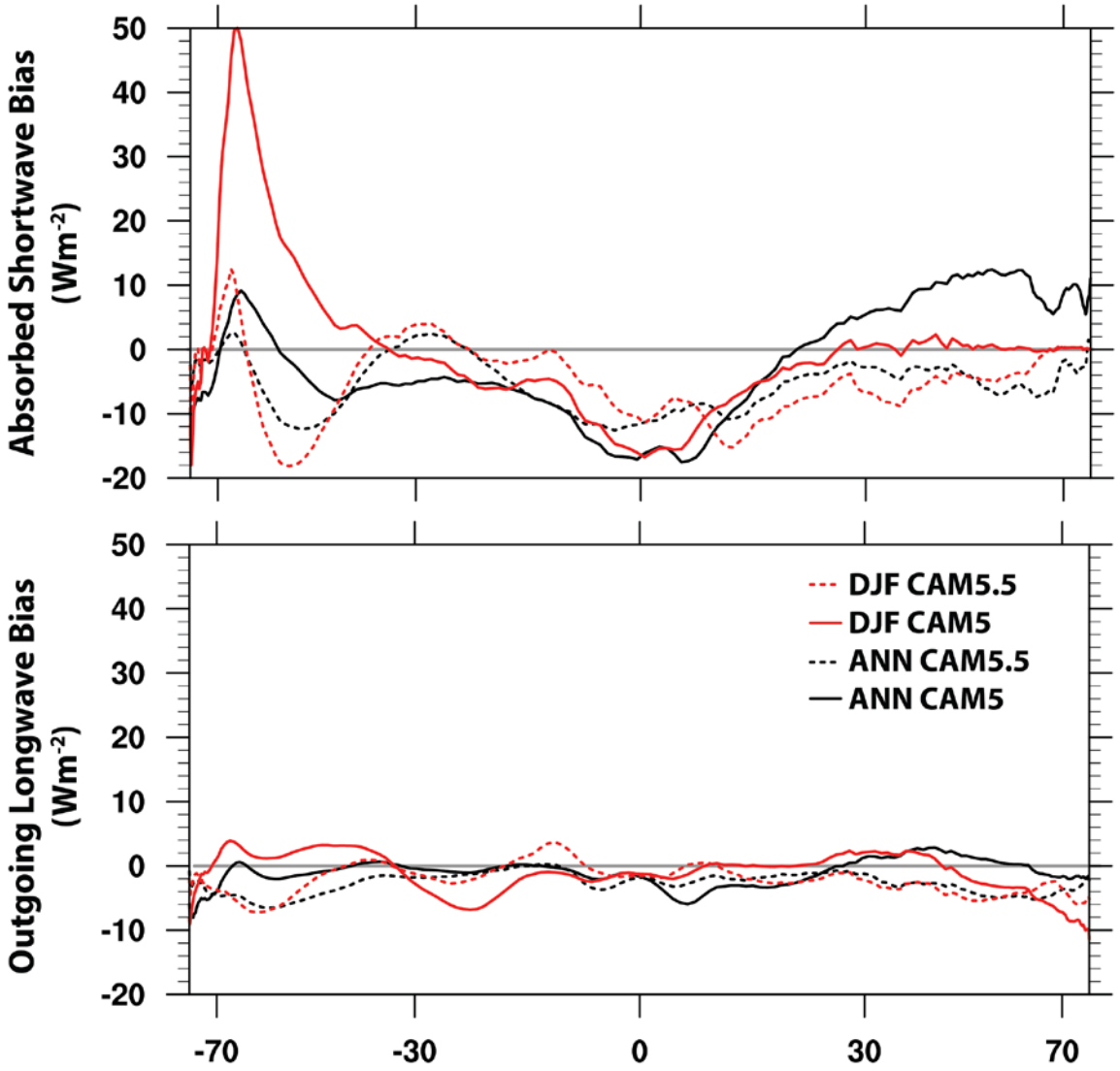
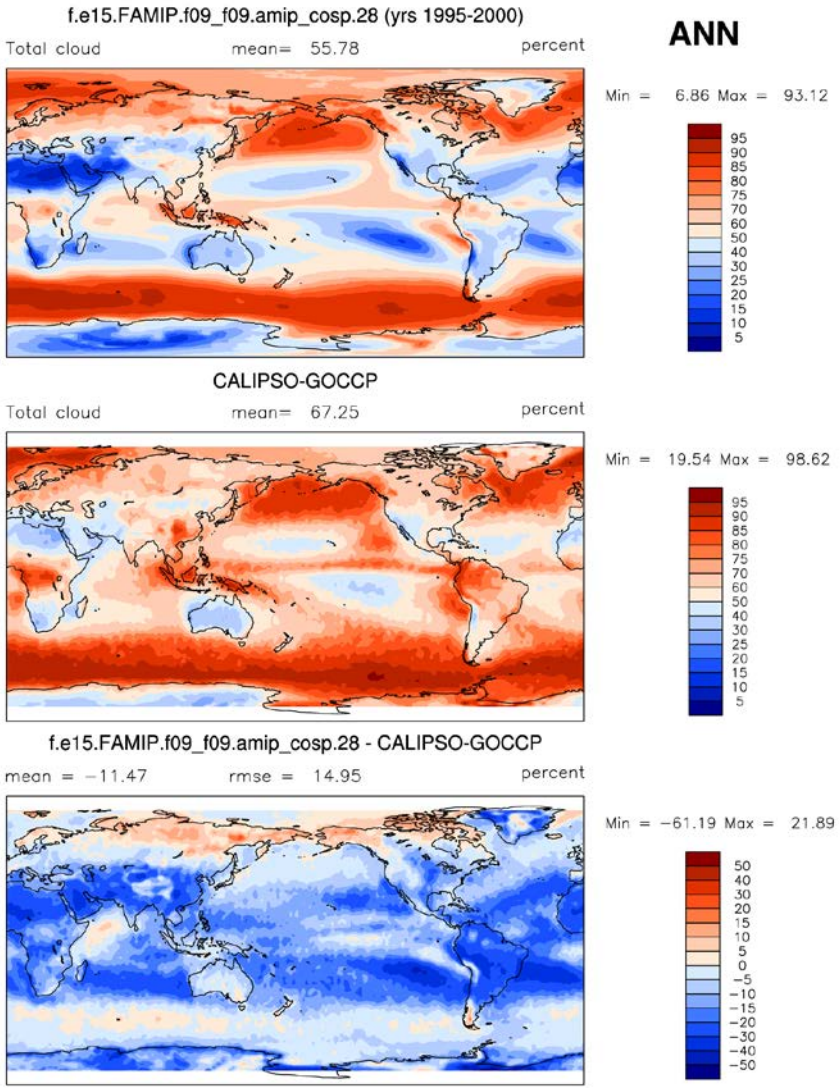
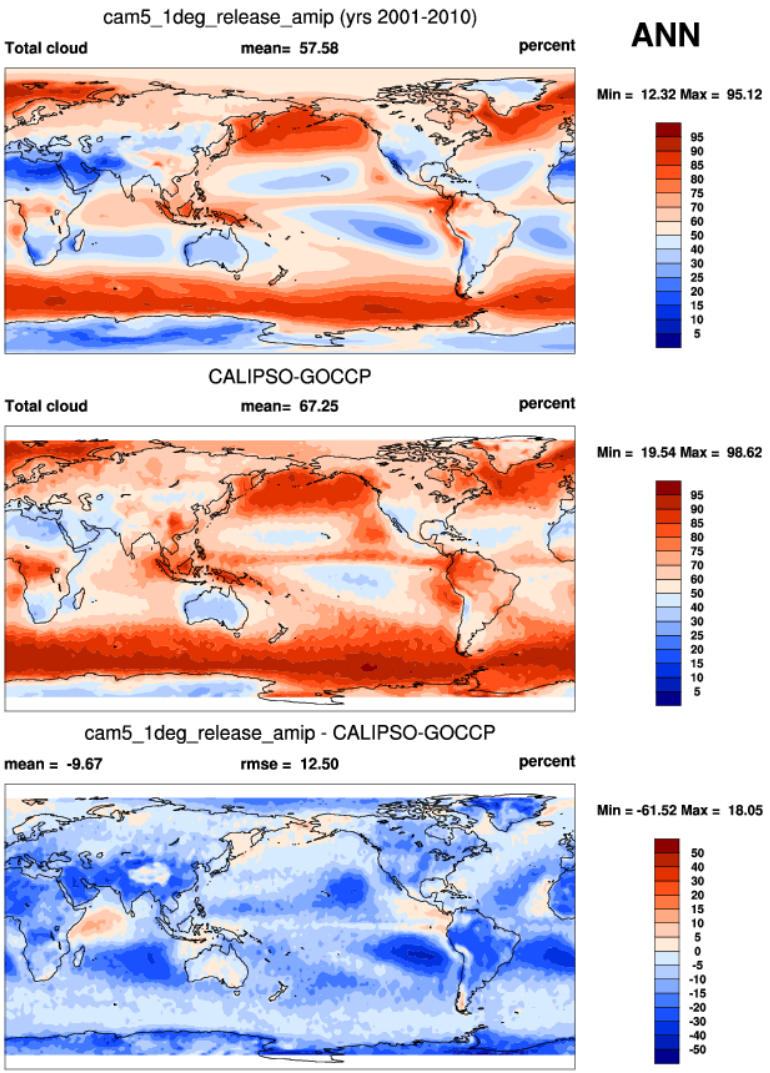


20th C AMIP: CALIPSO Total Cloud

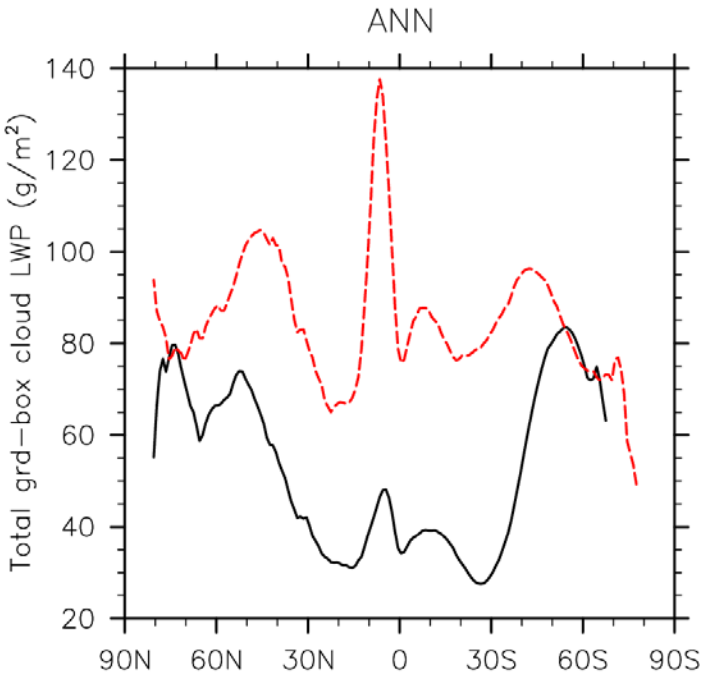
CAM5.5 not enough total cloud (like CAM5)

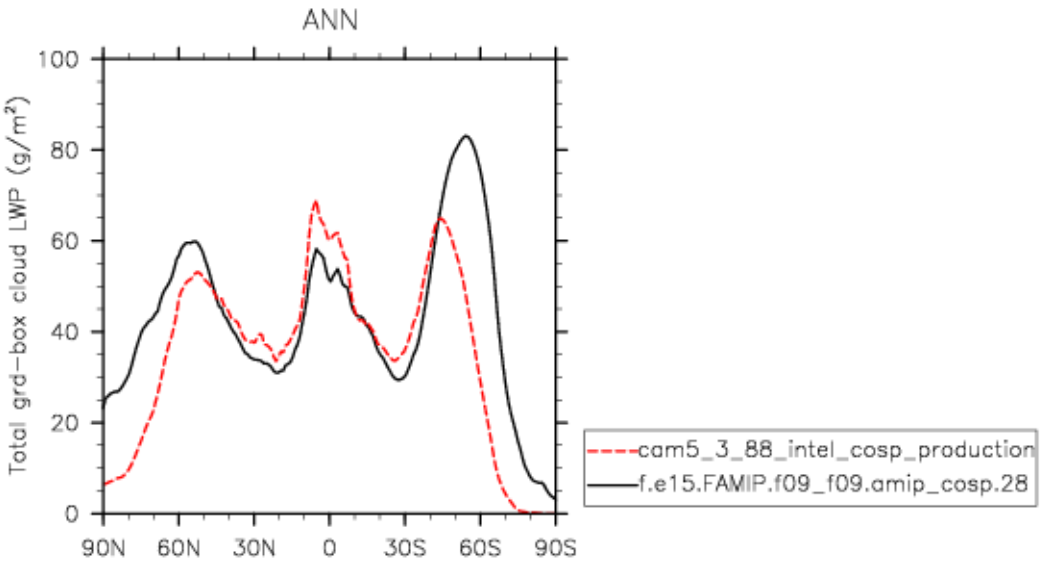




20th C AMIP: Liquid Water Path

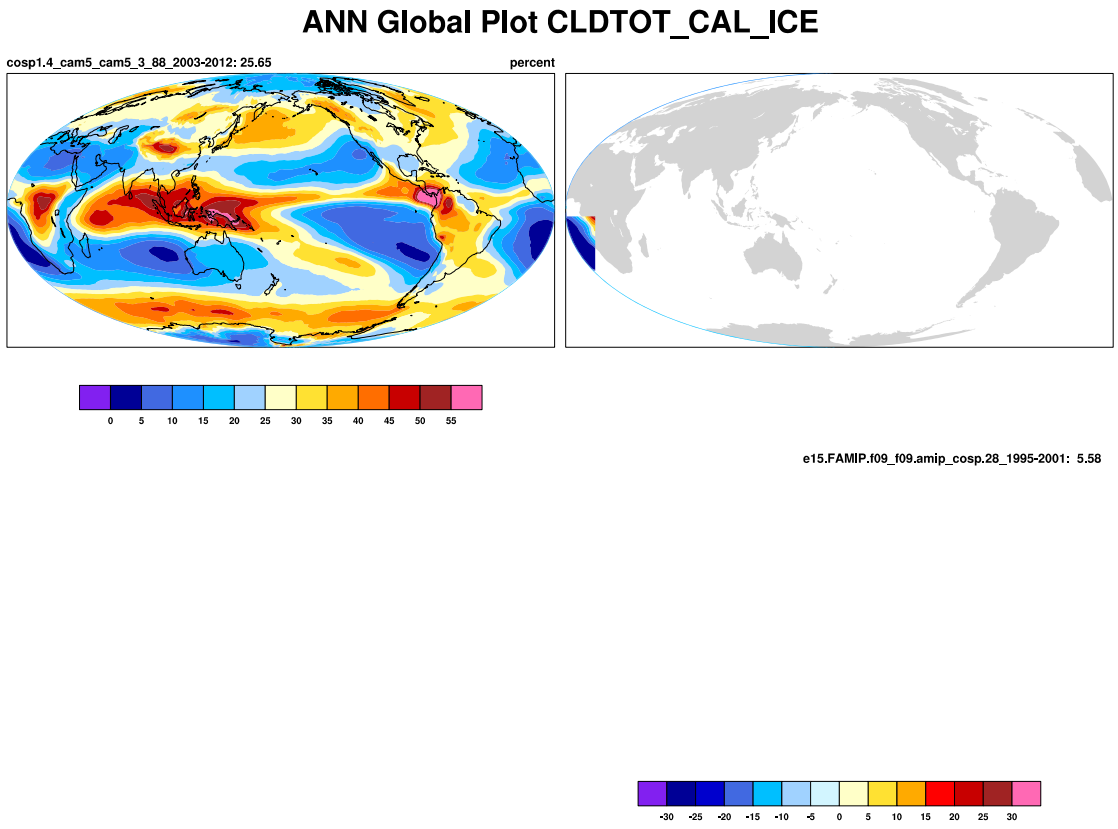
CAM5.5 still not enough liquid (left), more supercooled liquid in polar regions than CAM5 (right)





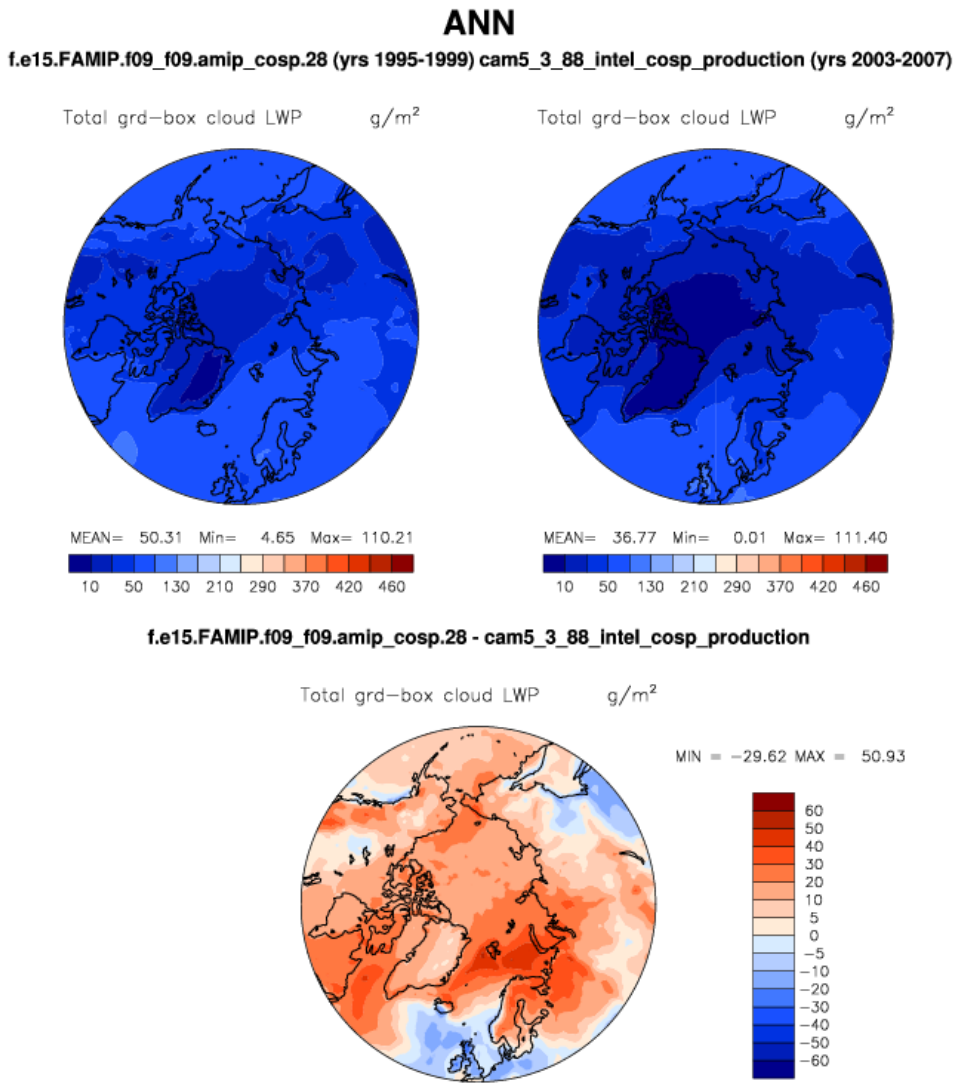
20th C AMIP: Global Cloud Fraction

Less Ice Cloud over mid-latitude stormtracks (explain reduced Southern Ocean ASR bias?)



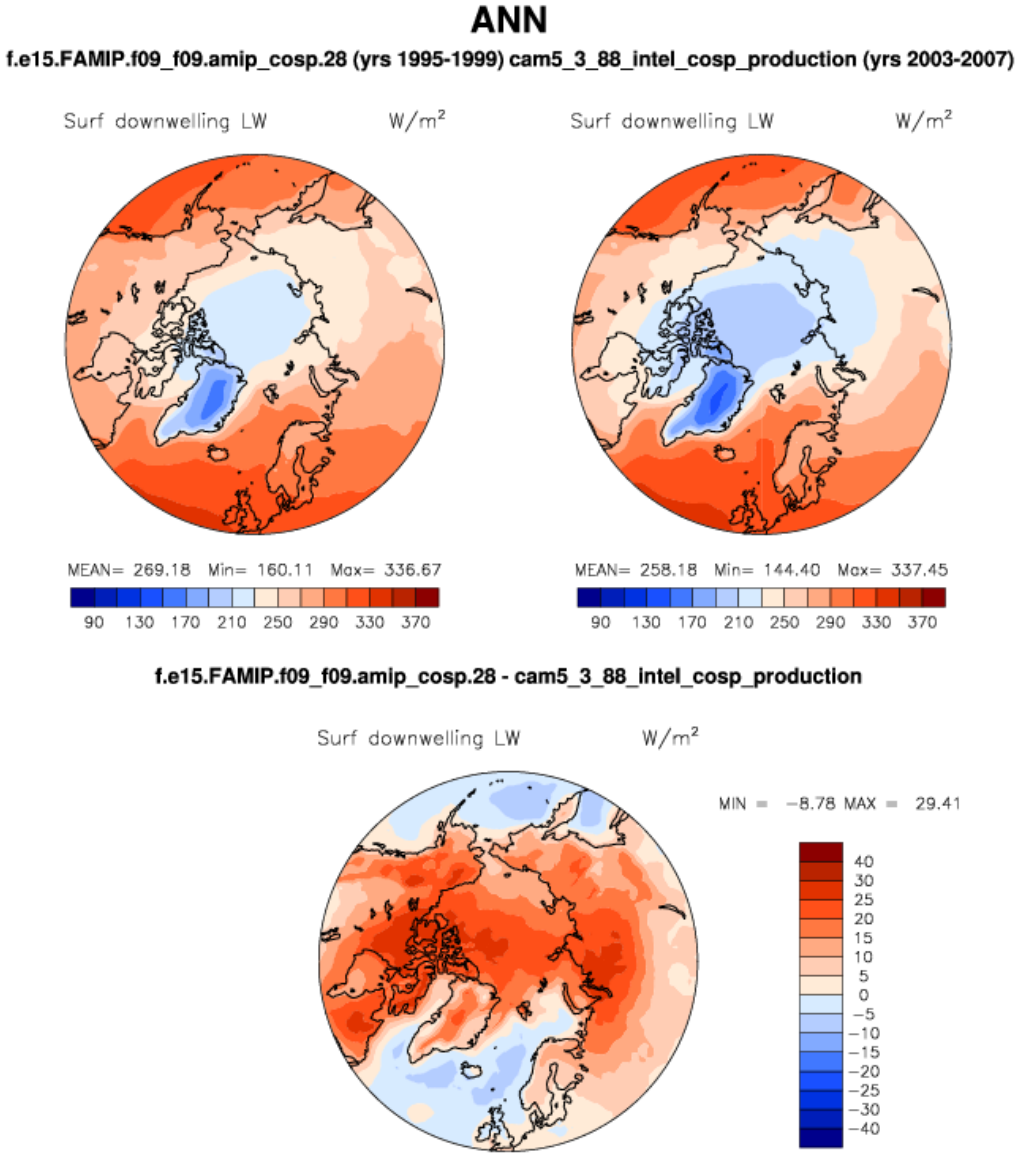
Arctic Map Liquid Water Path

Improved (more!) cloud liquid in CAM5.5



20th C AMIP: Arctic

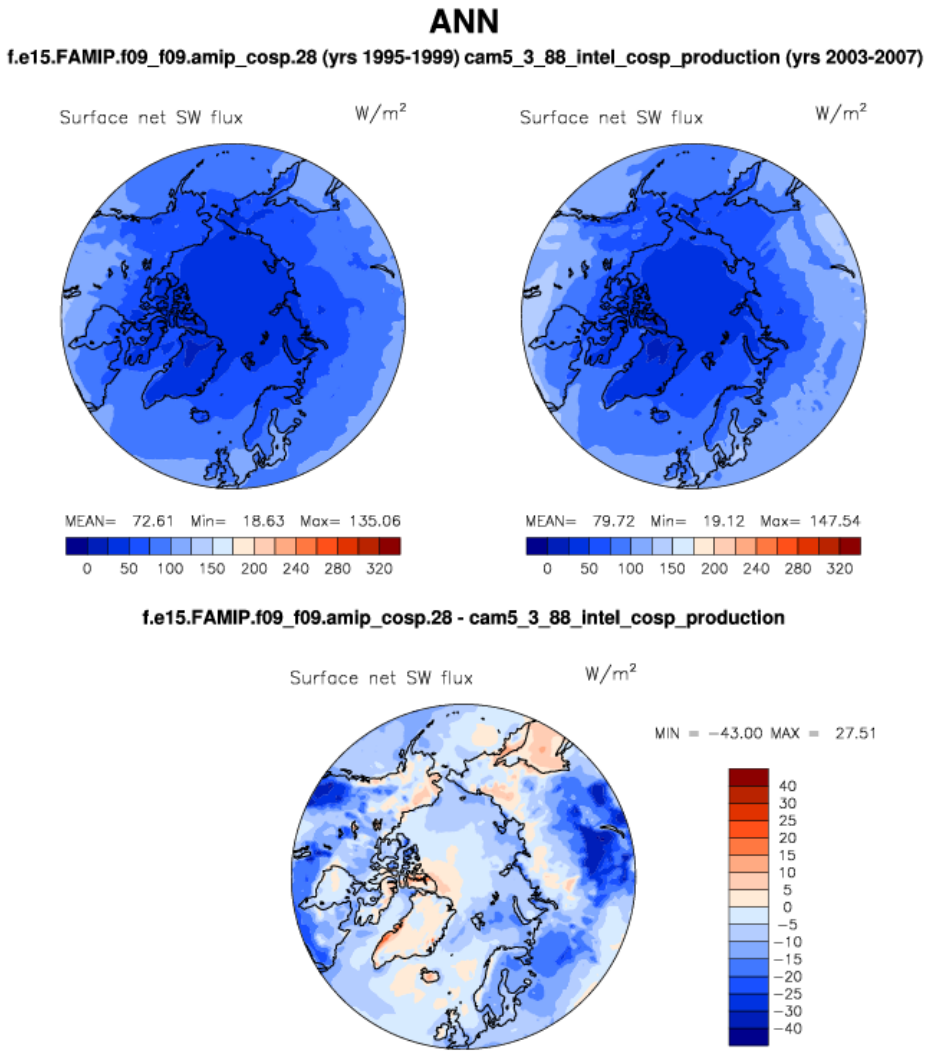
more cloud liquid = more longwave down



20th C AMIP: Arctic Net Shortwave

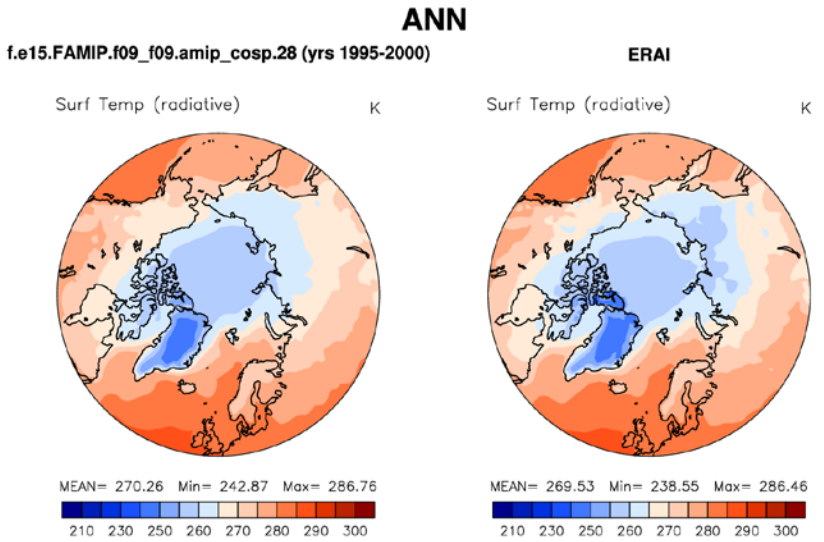
more cloud liquid, less snow

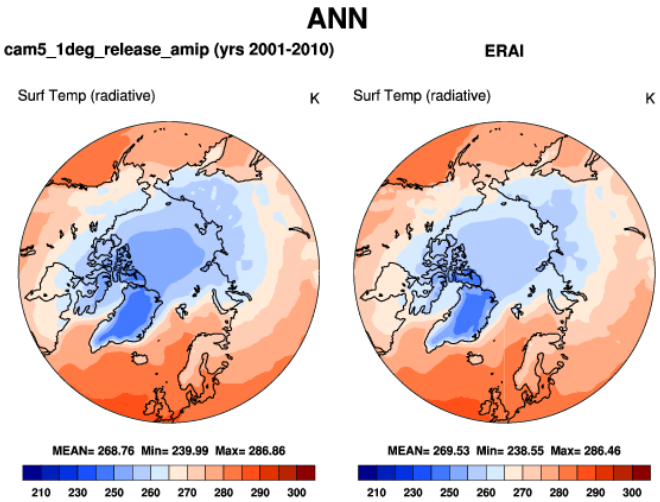
less net shortwave in CAM5.5 than in CAM5

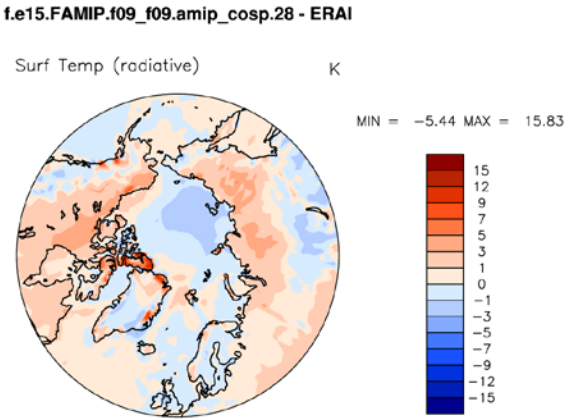


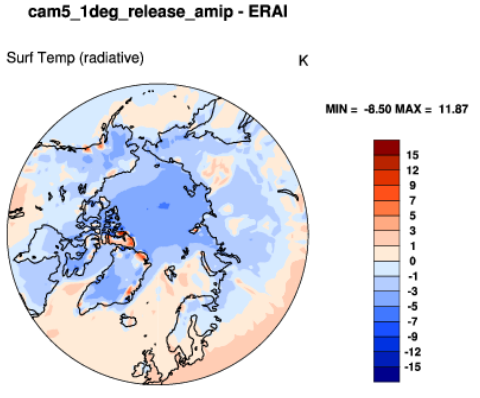
20th C AMIP: Arctic Temperature

CAM5 is too cold. CAM5.5 is warmer (an improvement), explained by more cloud liquid and more downwelling longwave radiation









Two Arctic cloud biases we have improved in CESM1.5?

More supercooled cloud liquid and Less snow = competing effects on net shortwave

More supercooled liquid =
More downwelling longwave radiation, warmer Arctic

What are the impacts on feedbacks?
(Cecile and Marika's talks yesterday)

Summary

1) There are strong observational constraints both on clouds and on radiation. Cloud-climate feedbacks depend on an accurate mean state. Even though we can "tune" clouds – there are observational constraints.

2) In general, CAM5.5 total cloud fractions and liquid water path are smaller than observed (similar to CAM5).

3) Arctic clouds (more liquid, less snow) and surface temperature improved in CAM5.5 over CAM5. Should do our best to retain these changes, while not compromising Arctic sea ice thickness.

20th C AMIP CAM5 : Global Cloud Fraction vs. CALIOP observations

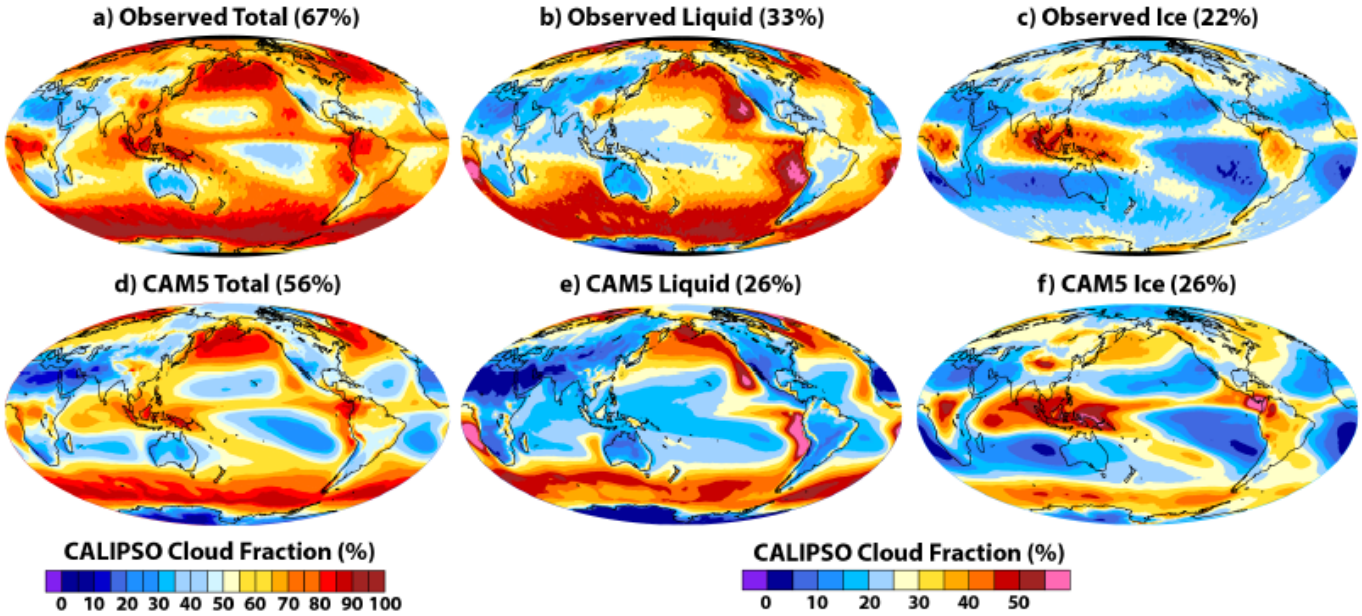
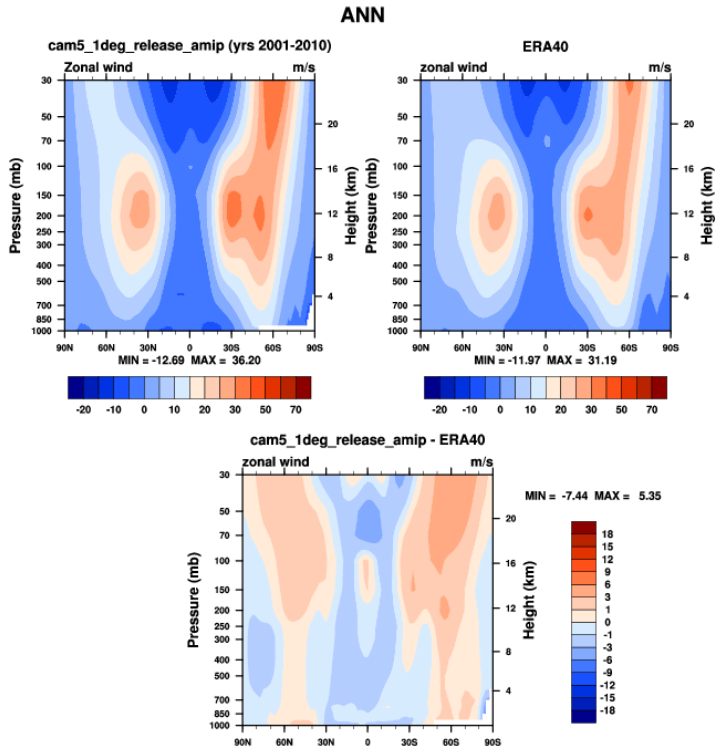
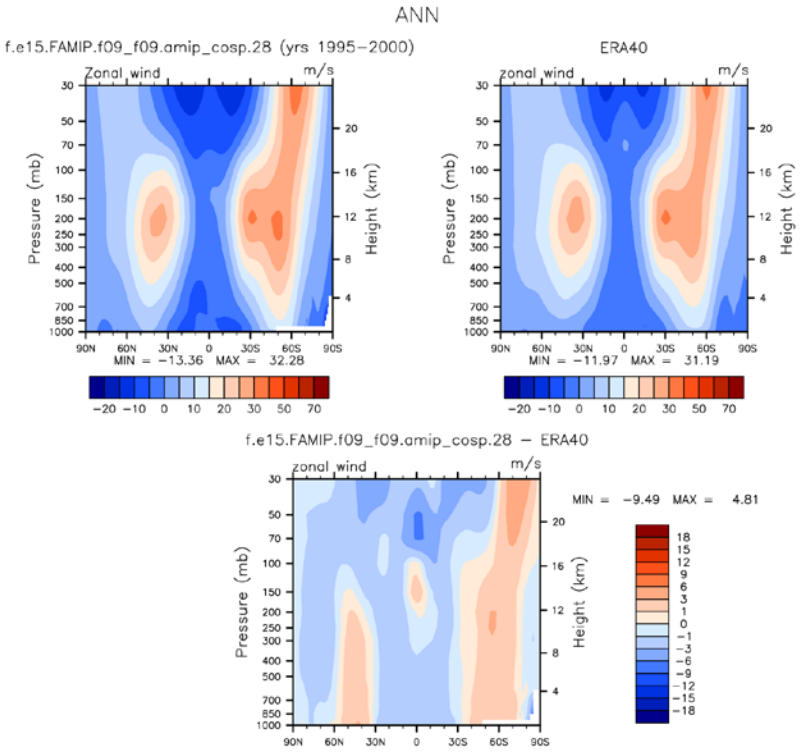


Figure 2. Global maps of CALIPSO cloud fraction: a) Observed Total, b) Observed Liquid, c) Observed Ice, d) CAM5 Total, e) CAM5 Liquid, f) CAM5 Ice. Global mean values are indicated in parenthesis.

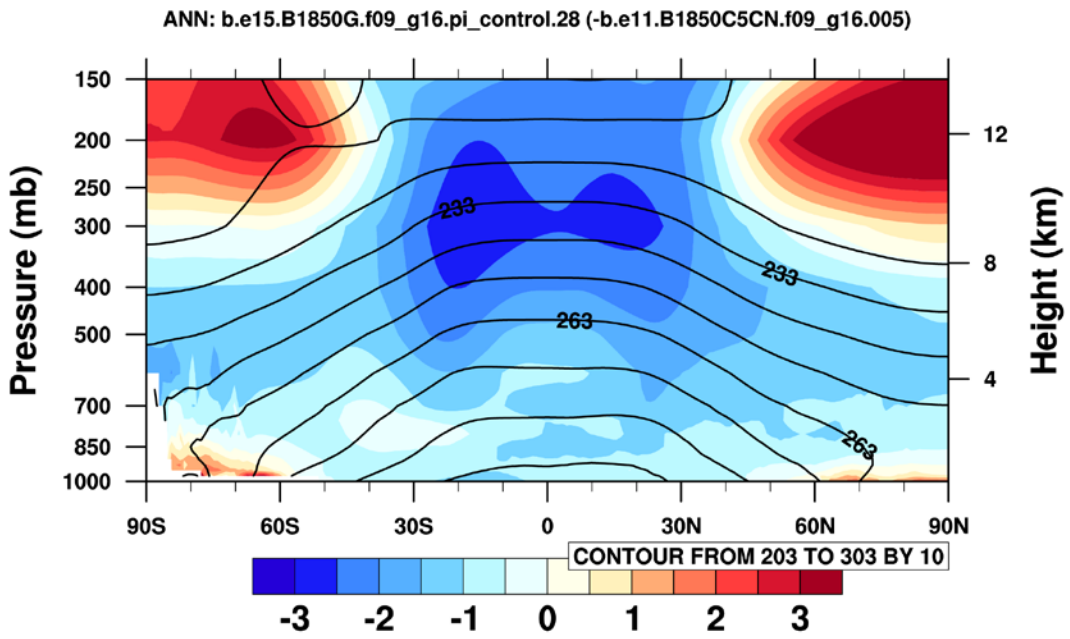
Figure from Kay et al. submitted

1850 Fully Coupled: Zonal Mean Atmospheric Circulation (CAM5 vs. CAM5dev vs. obs.)

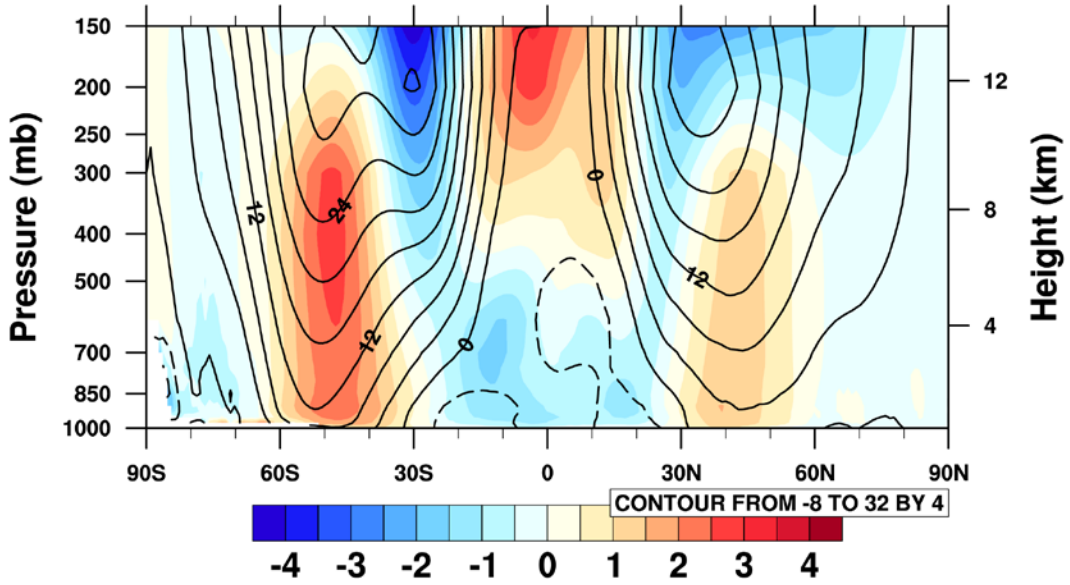




1850 Fully Coupled Atm. Circulation



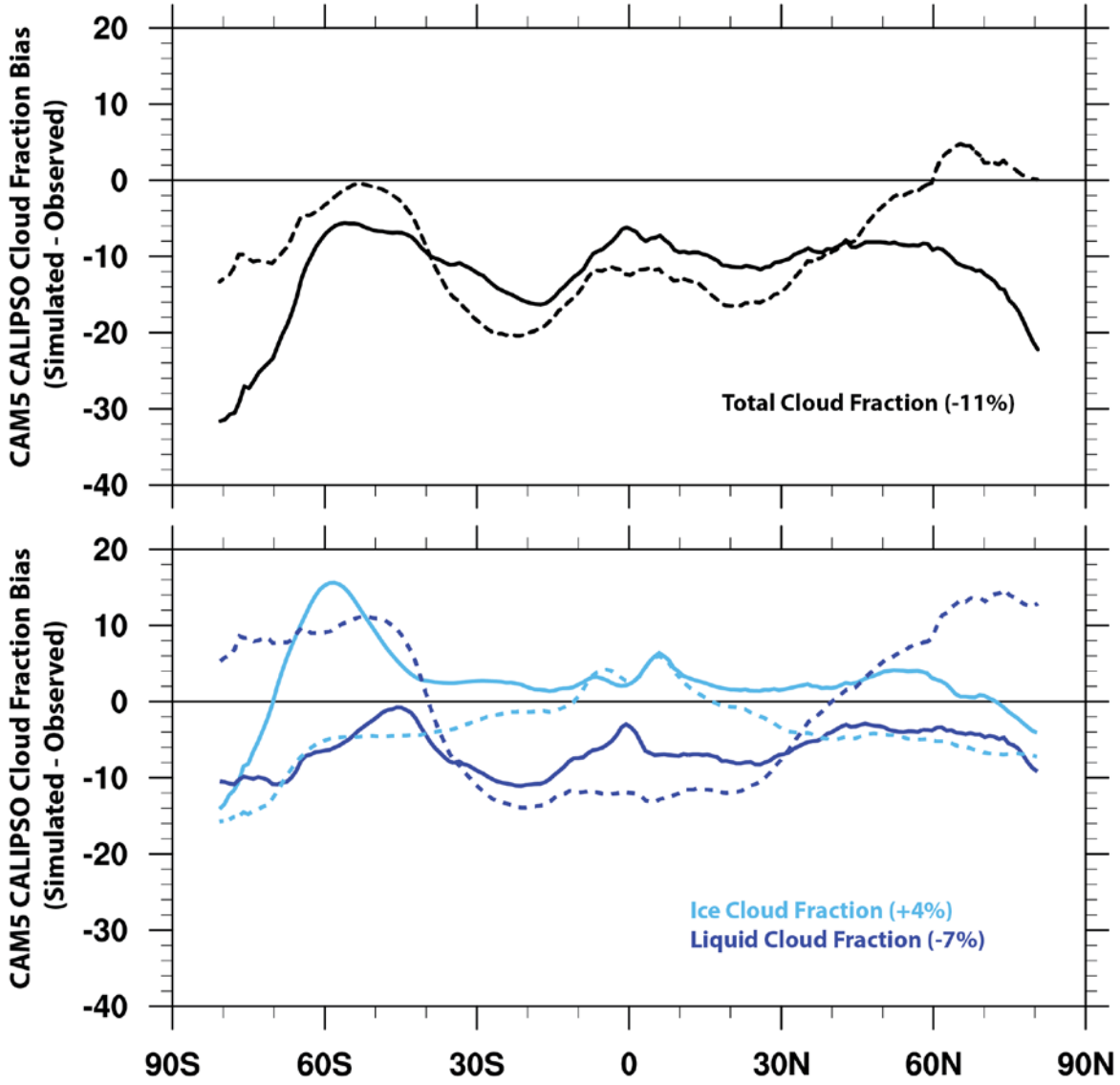
Temperatures aloft:
Cooler tropics; warmer poles



Zonal mean winds:
STRONGER JETS,
Especially Southern Hemisphere

20th C AMIP: Global Cloud Fraction

different cloud phase biases



Simulations

- **1850 control runs**

-CESM-LE (b.e11.B1850C5CN.f09_g16.005 ,yrs 400-600)

-CESM1.5 (b.e15.B1850G.f09_g16.pi_control.28, yrs 1-100)

- **Present-day AMIP runs (with COSP1.4)**

-CAM5 (cam5_3_88_intel_cosp_production, 2003-2012)

-CMIP5 CAM5 (cam5_1deg_release_amip)

Note: CAM5/CMIP5 CAM5 cloud differences small

-CAM5.5 (f.e15.FAMIP.f09_f09.amip_cosp.28, 1995-2001)

1850: Arctic Map Liquid Water Path

Improved (more!) cloud liquid in CAM5.5