Exploring present and future Arctic CMIP5 biases

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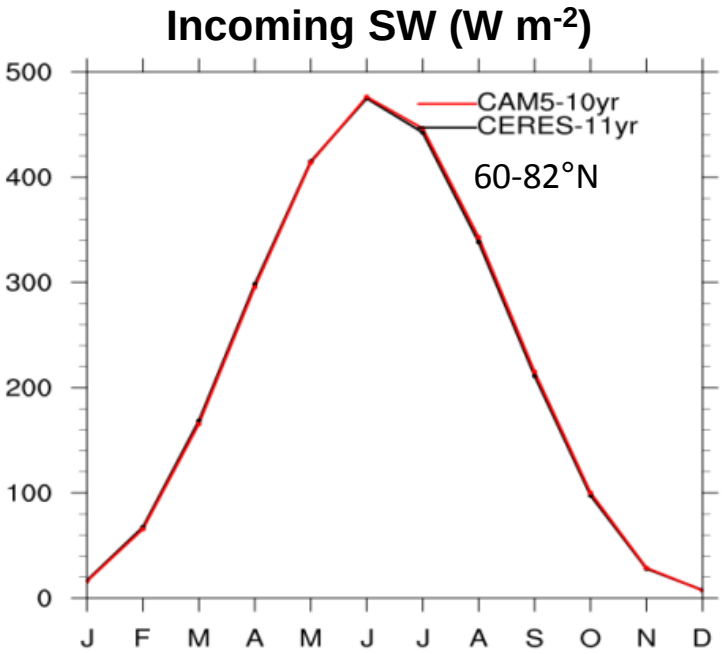
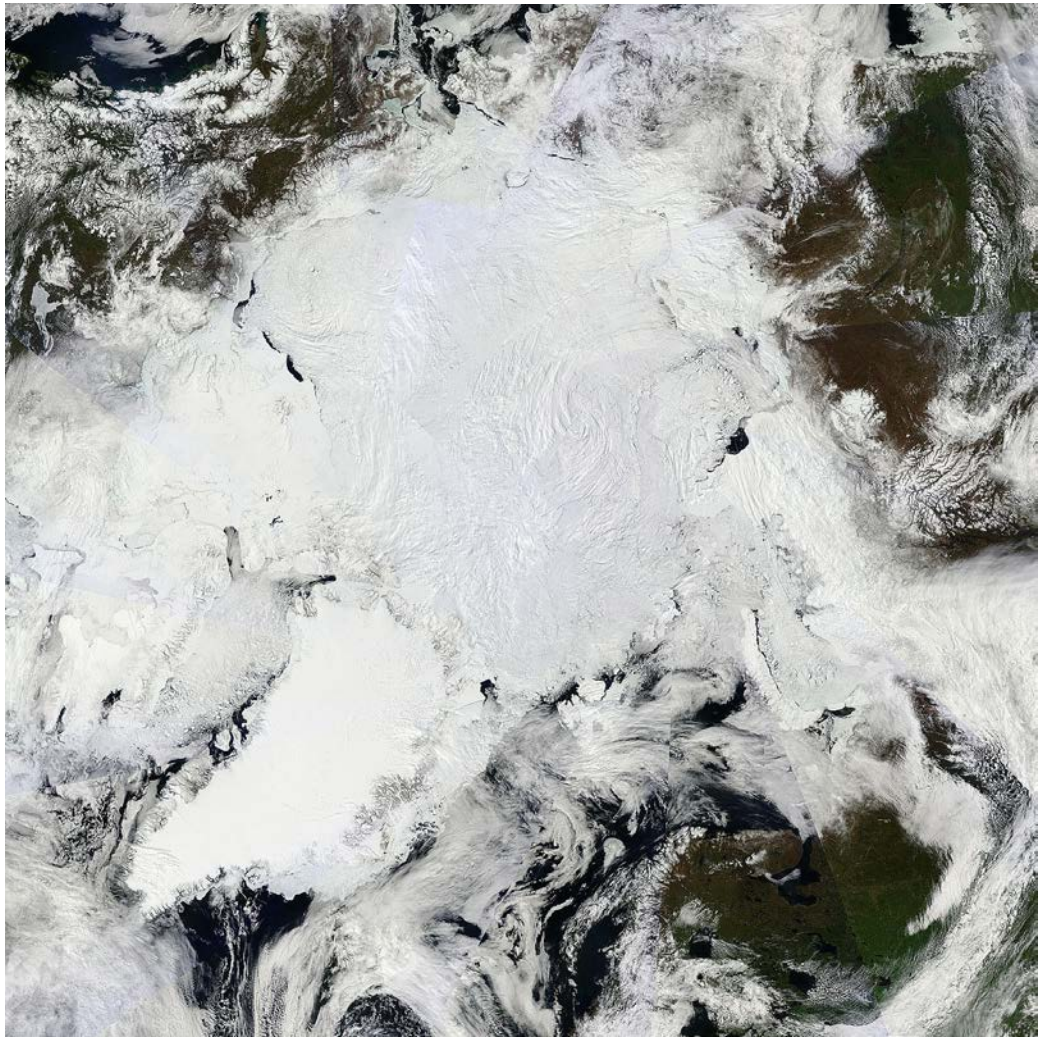
Thanks to Collaborators
Andrew Gettleman & Jen Kay

NASA MODIS image May 27, 2013

Arctic energy balance is strongly affected by clouds & surface albedo

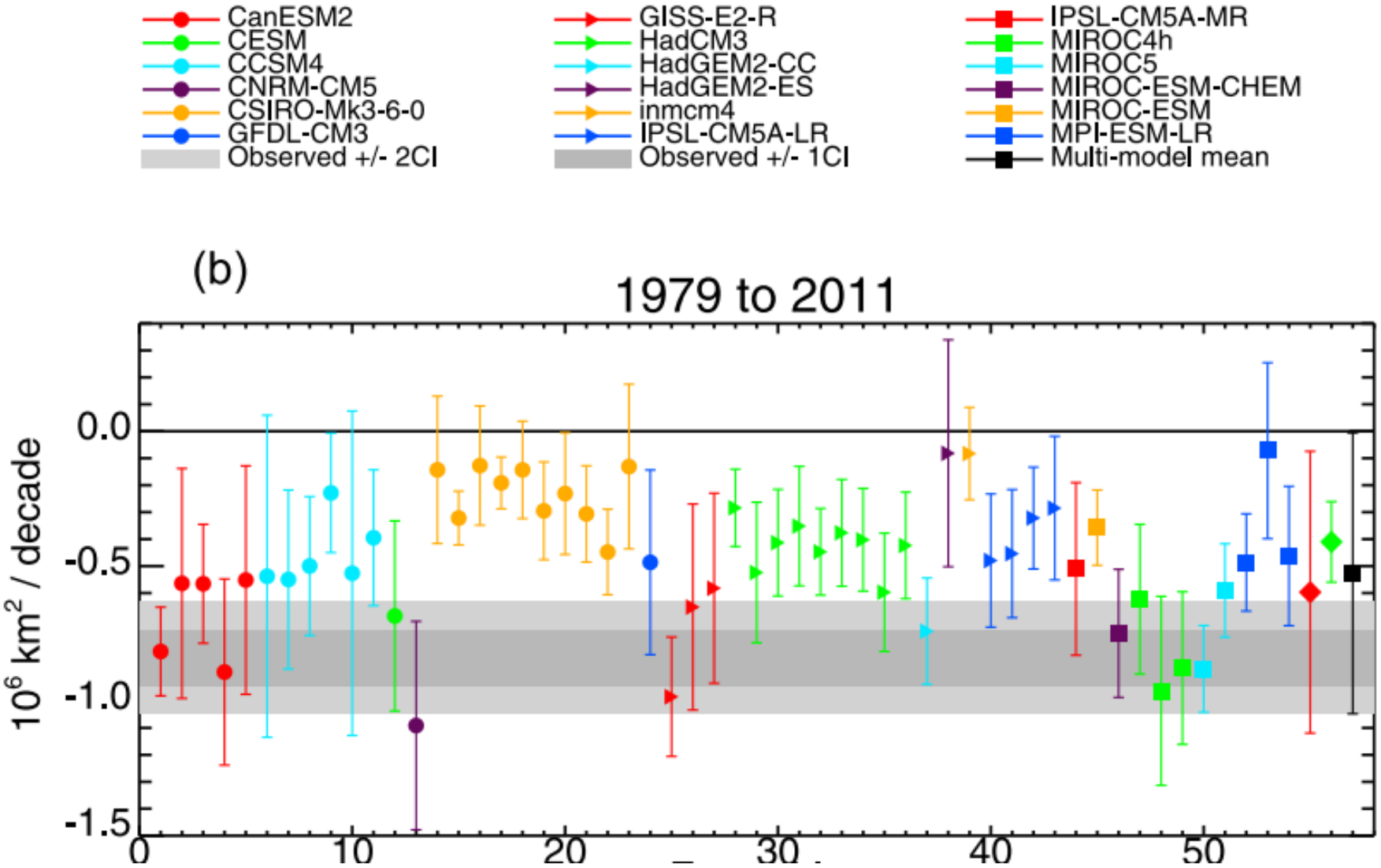


High albedo



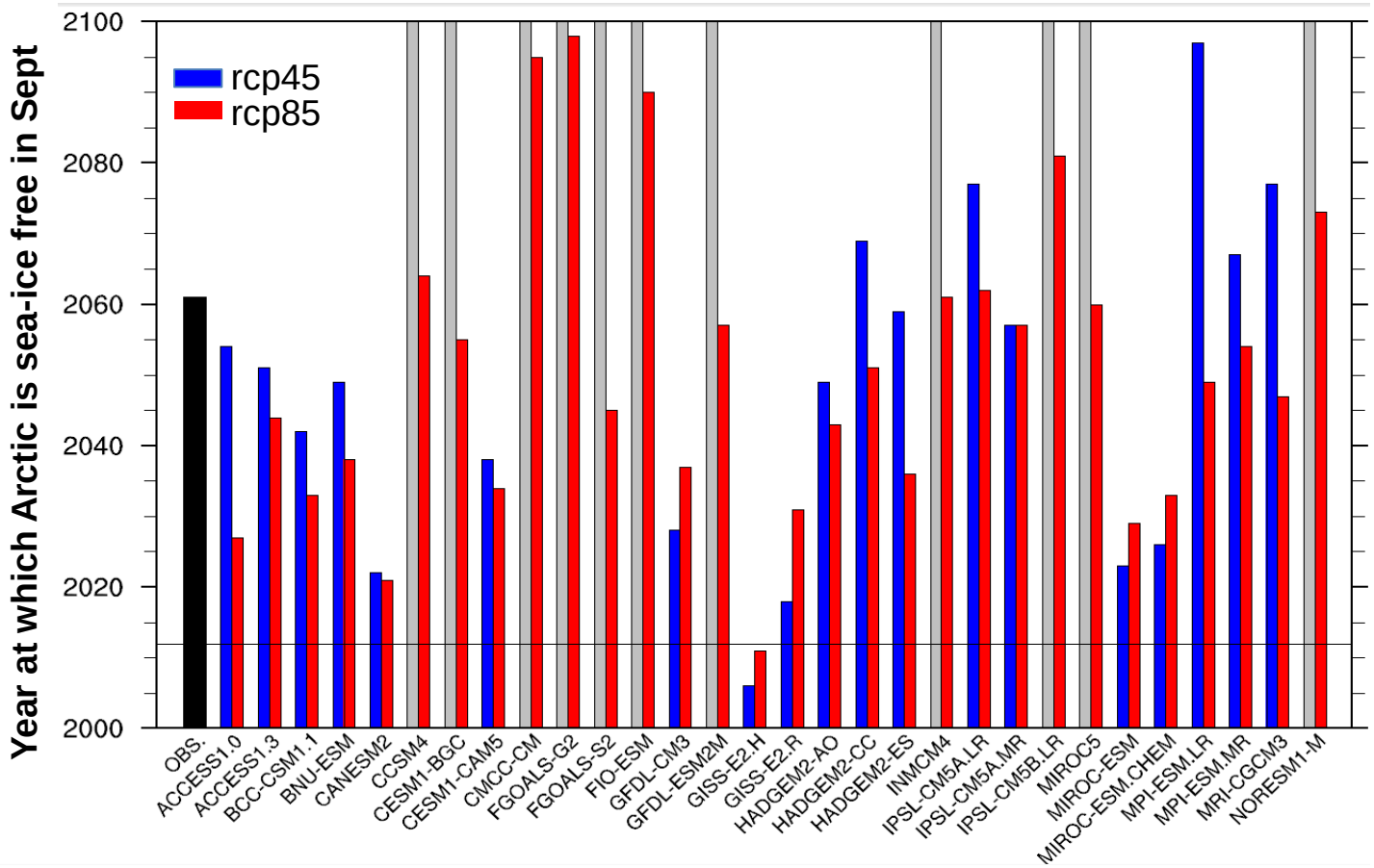
NASA MODIS image May 27, 2013

CMIP5 models underestimate observed recent sea ice loss



Stroeve et al 2012

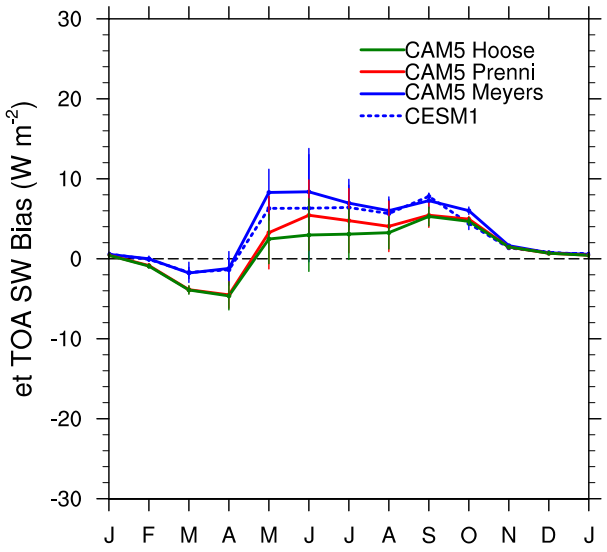
CMIP5 models disagree on rate of future sea ice loss

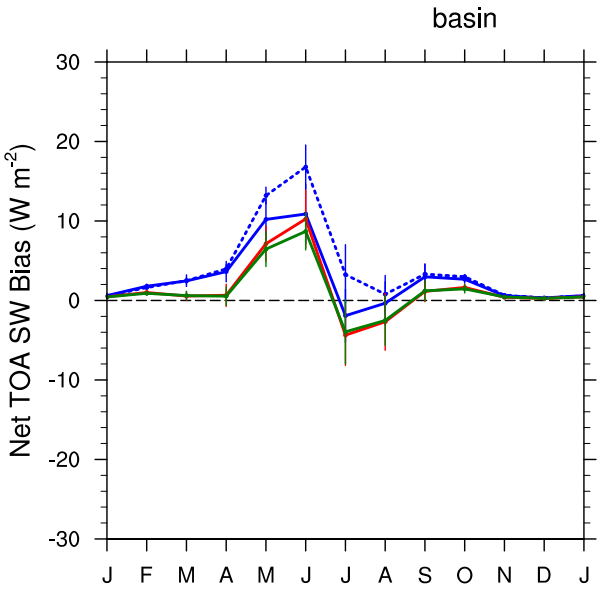


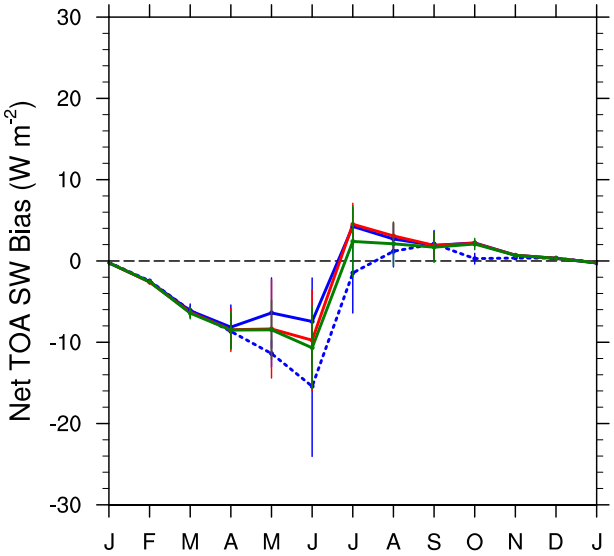
What are the contributions of clouds & radiation?
(as opposed to NHT, circulation)

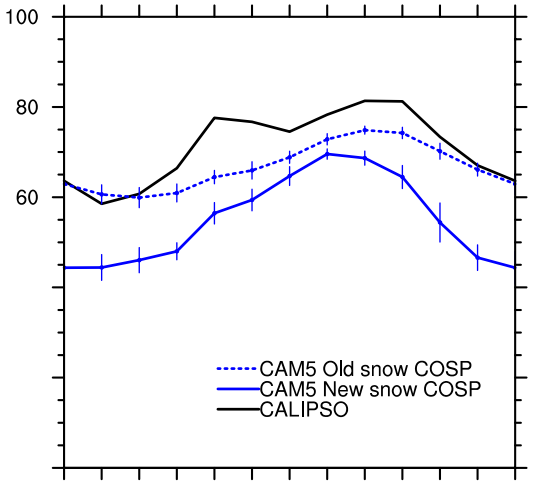
Liu et al. 2013

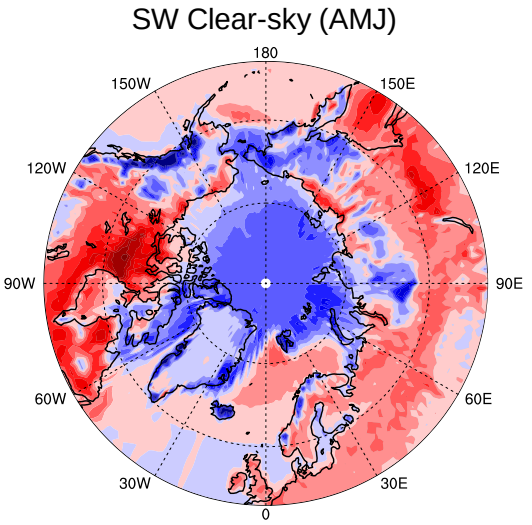
CESM/CAM5 SW cloud forcing biases (insufficient clouds) compensated by SW clearsky biases (snow albedo)











English et al., 2014, J Clim, in press

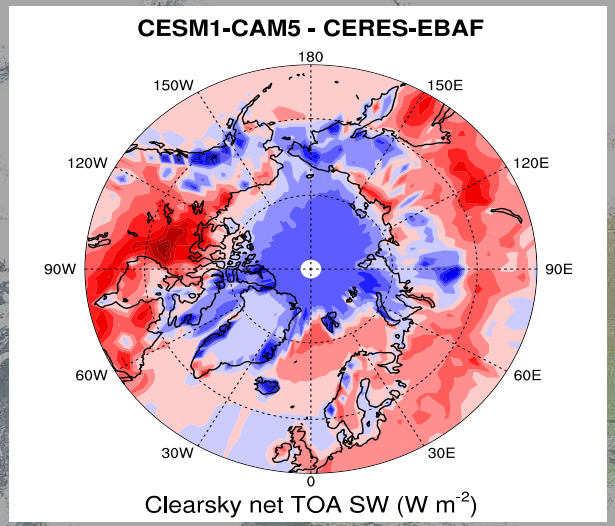
Science Questions

<u>Present climate (2000-2008):</u> How do CMIP5 TOA radiative fluxes compare to CERES-EBAF? What are the contributions of clouds and surface albedos to these biases?

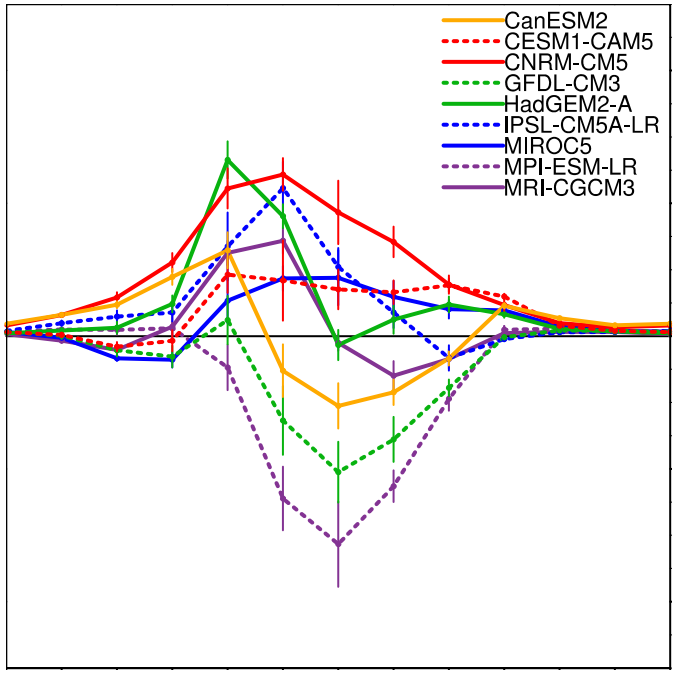
<u>Future climate (2080-2090):</u> What are the projected changes to net TOA forcing in the CMIP5 models? What are the contributions of clouds and surface albedos to these changes?

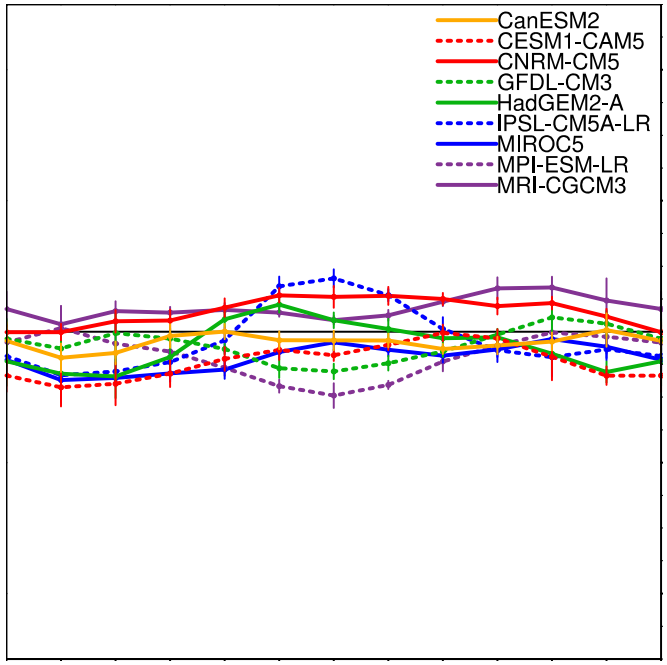
Approach

- **Compare CMIP5 to CERES-EBAF fluxes & CALIPSO cloud amount over different surface types:**
  - **Entire Arctic basin (60-82°N)**
  - **Sea ice**
  - **Open ocean**
  - **All land areas**
  - **Land areas w/snow**
  - **Land areas without snow**

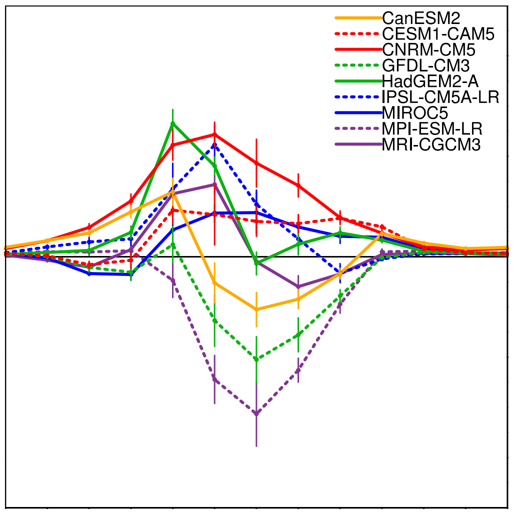


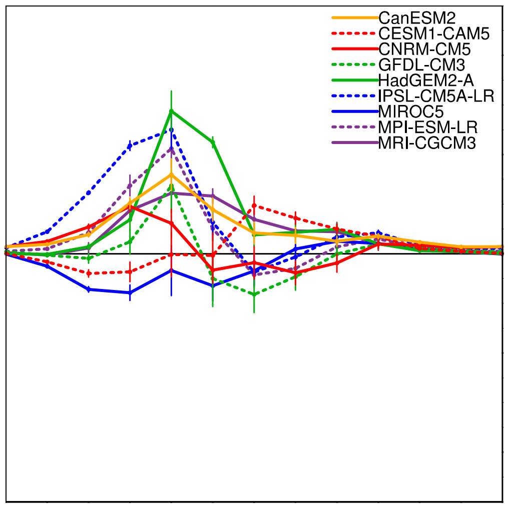
Current climate (AMIP 2000-2008): SW biases are larger than OLR biases

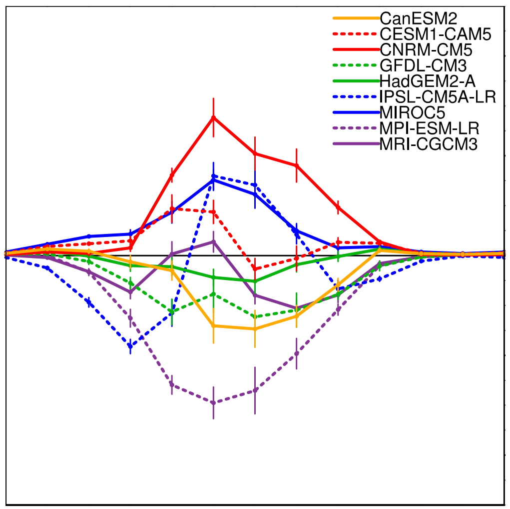




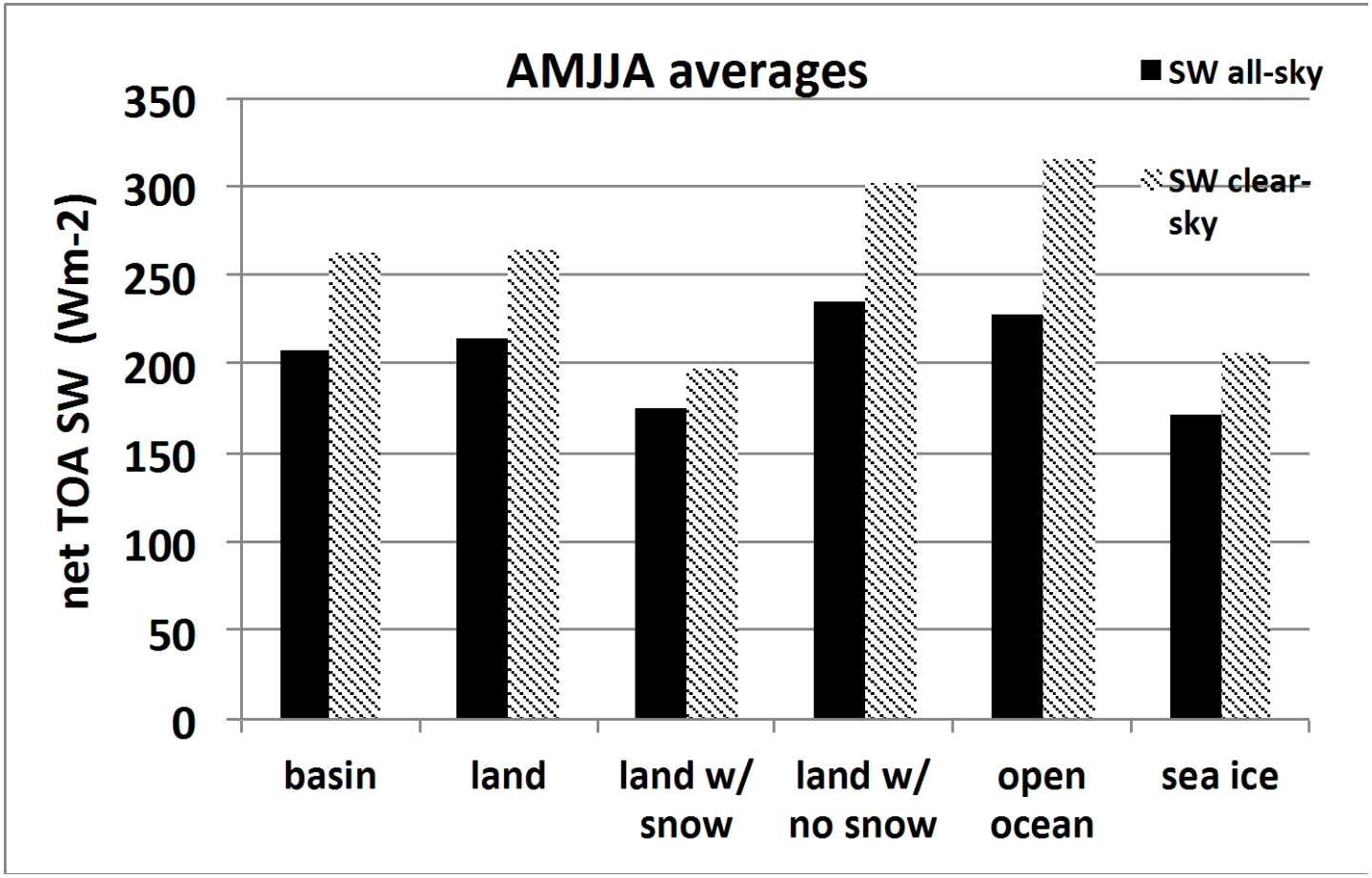
CMIP5 models have SW Clear-sky and cloud forcing biases



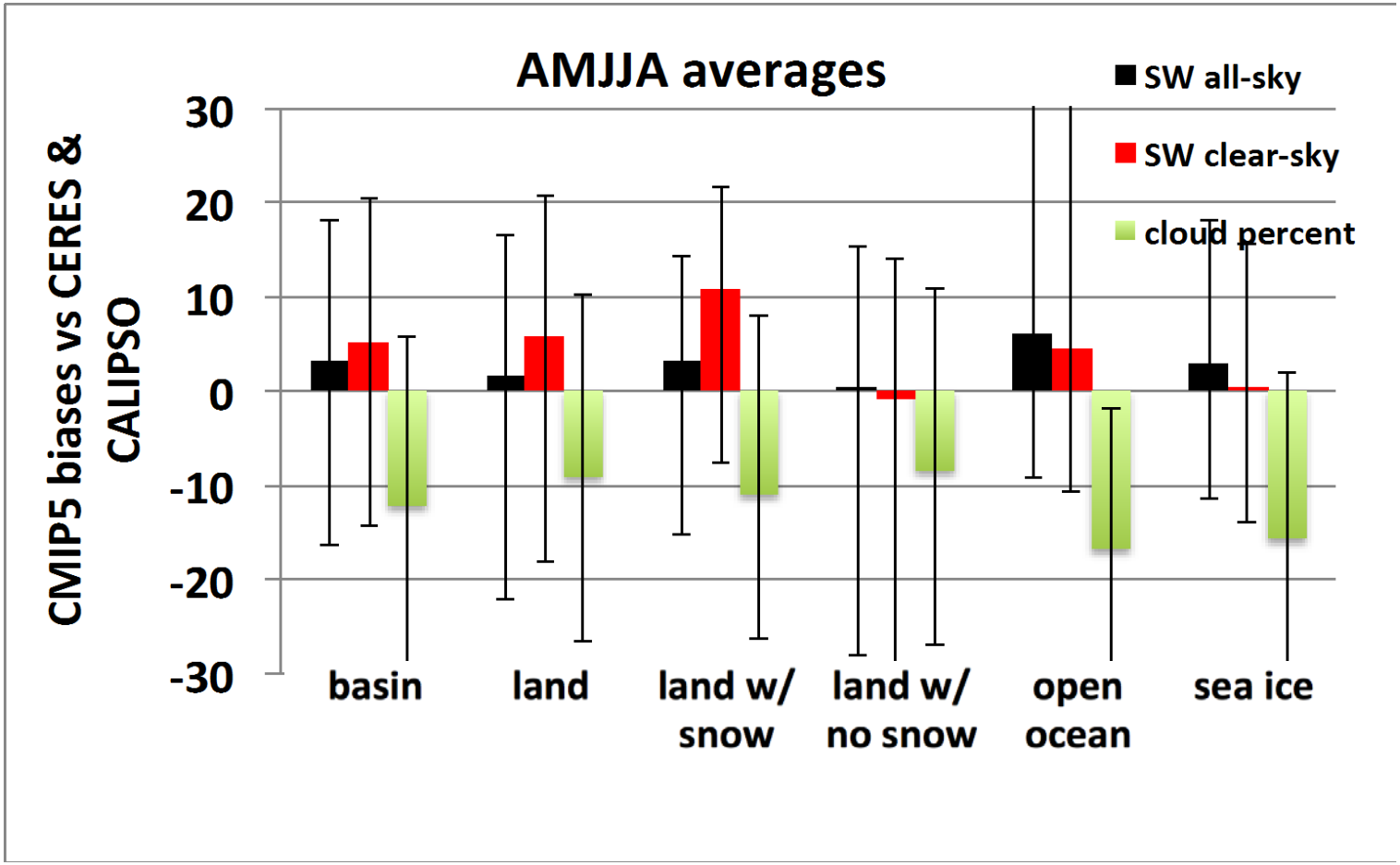




CERES-EBAF net TOA SW fluxes, and differences between all-sky and clear-sky fluxes, are lowest over land w/snow and sea ice, as expected

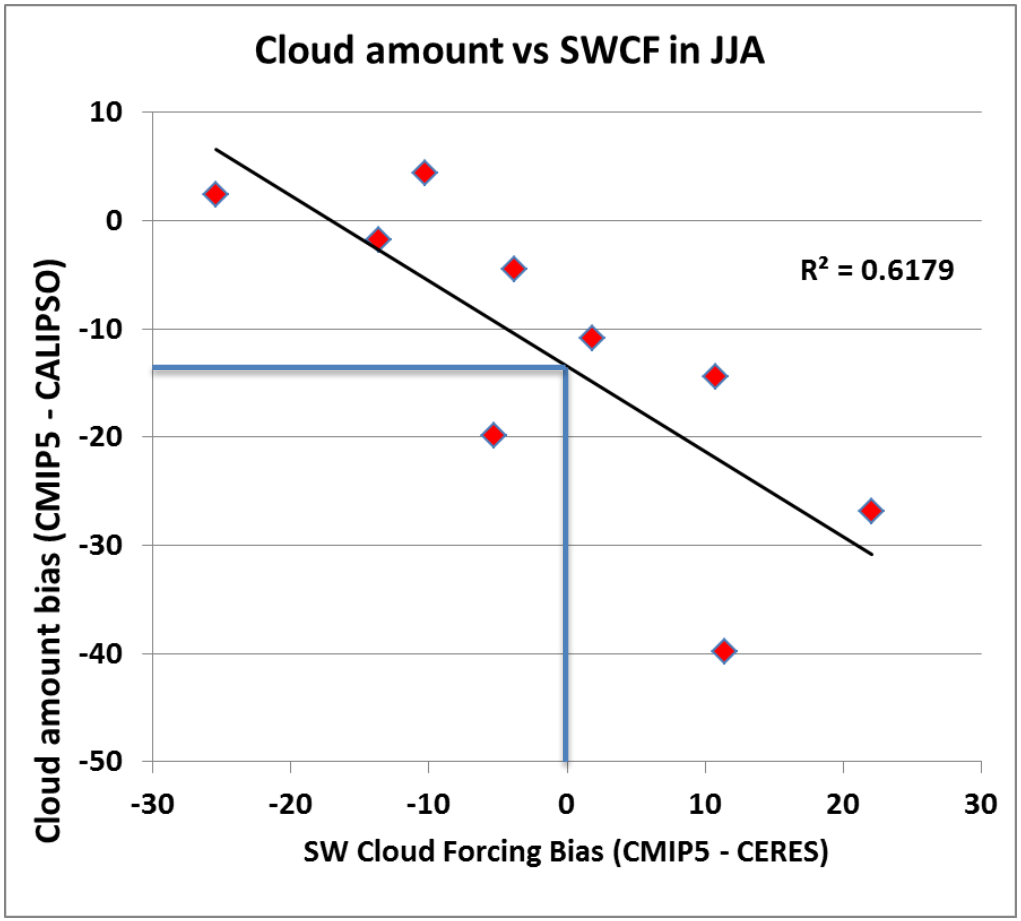


CMIP5 models span a large range of biases
CMIP5 fluxes too high except over land w/no snow
Cloud amount biases largest over sea ice & open ocean



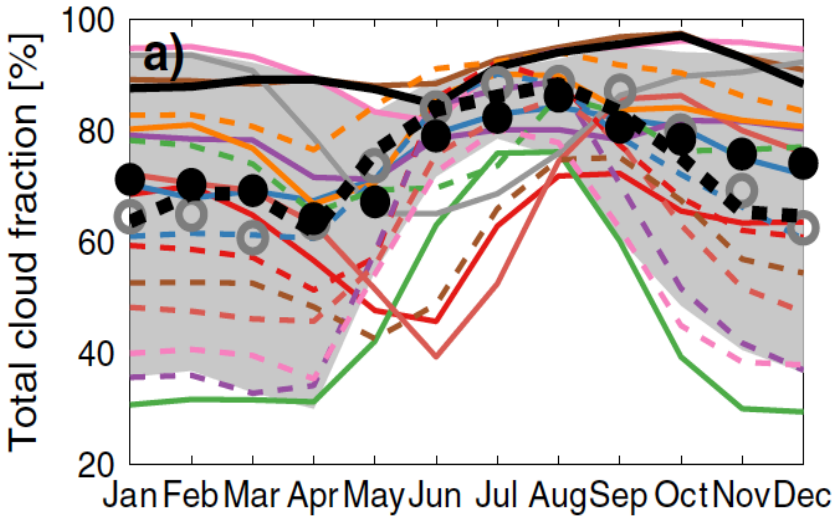
Two items to explore further: 1) land w/snow versus without 2) why clear-sky biases are higher despite insufficient clouds

CMIP5 SW cloud forcing biases correlated with CALIPSO cloud amount biases, but a 0 CERES bias corresponds to -15 CALIPSO



Possibly CERES clear-sky biases, cloud optical properties, or errors in surface albedo?

CMIP5 models have insufficient clouds, and their radiative effect is affected by sea-ice albedo



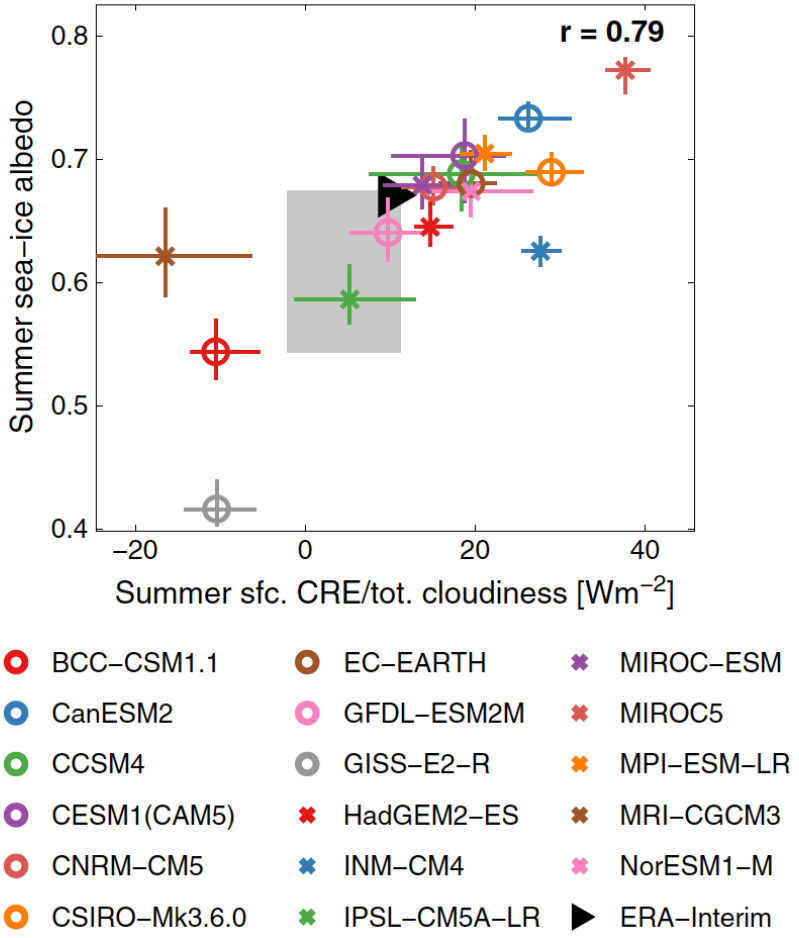
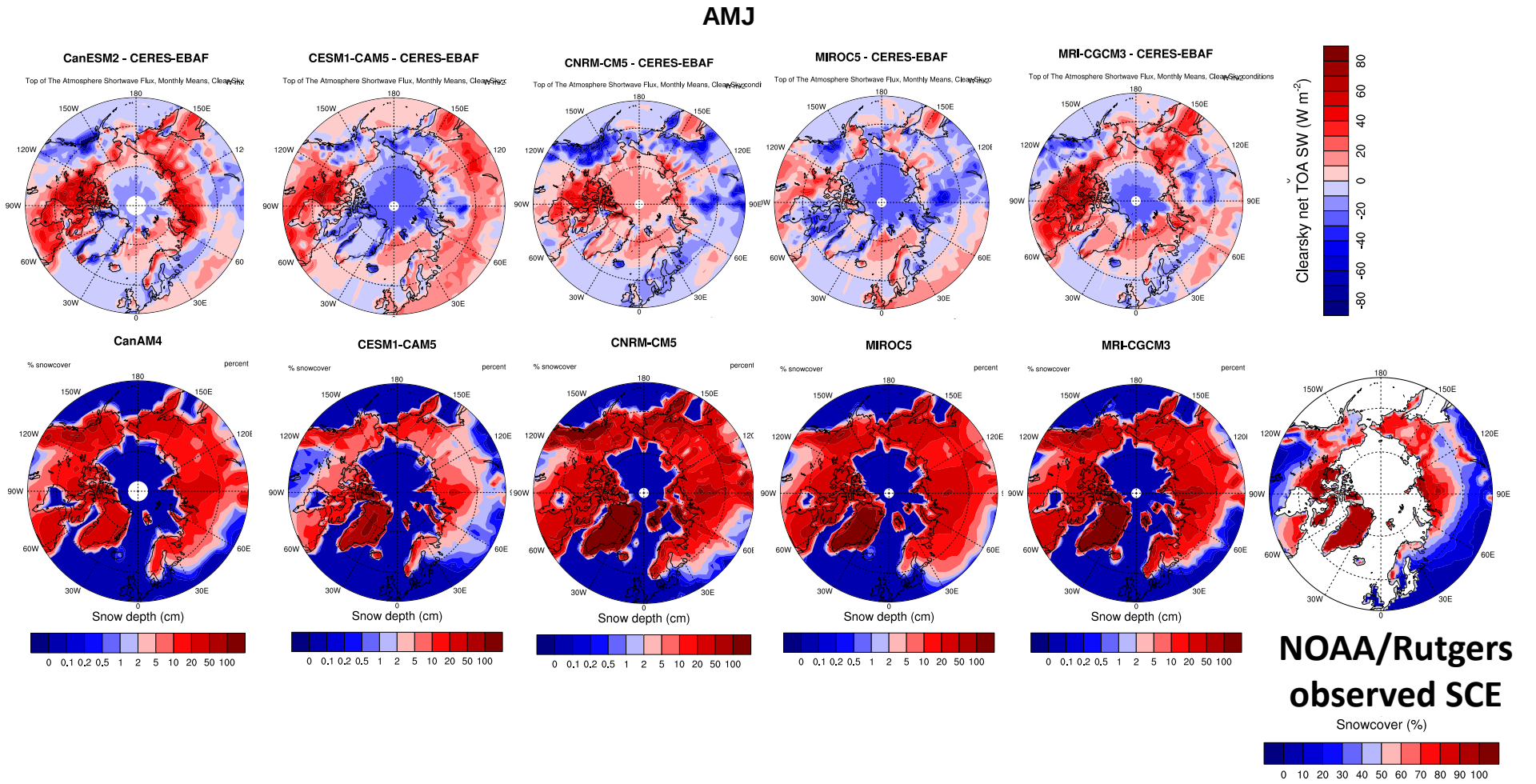


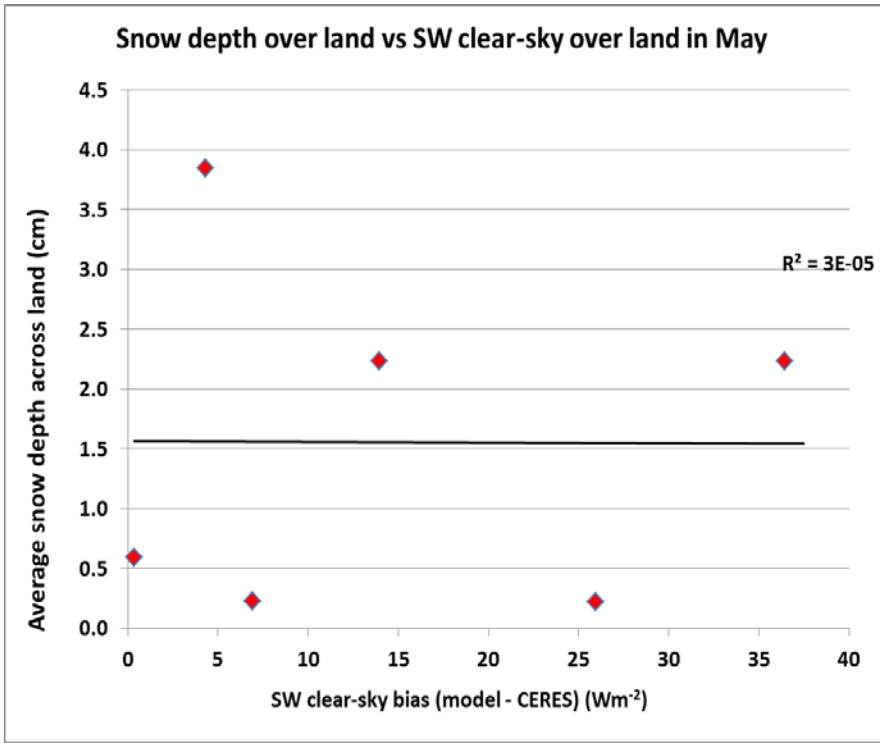
Figure 2. Simulated summer (MJJA) net surface cloud radiative effect normalized with total cloud fraction versus summer sea-ice albedo. The gray-shaded area indicates the observed interannual range of summer sea-ice albedo (CLARA-A1 and APP-x) and normalized surface CRE (APP-x).

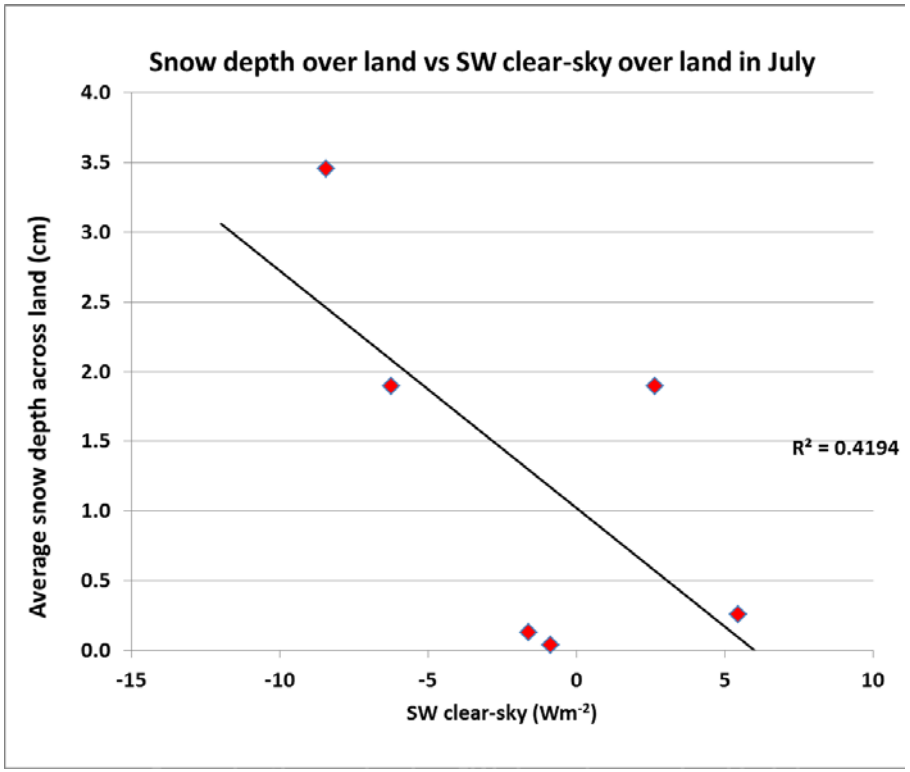
Karlsson and Svensson 2013

CMIP5 SW clear-sky biases in S Alaska explained by too much snow but not in N Canada. Why?



Snow depth does not fully explain spring clear-sky biases (due to interactions between trees & snow-cover)





Land surface albedo affected by complex interaction between trees and snow cover

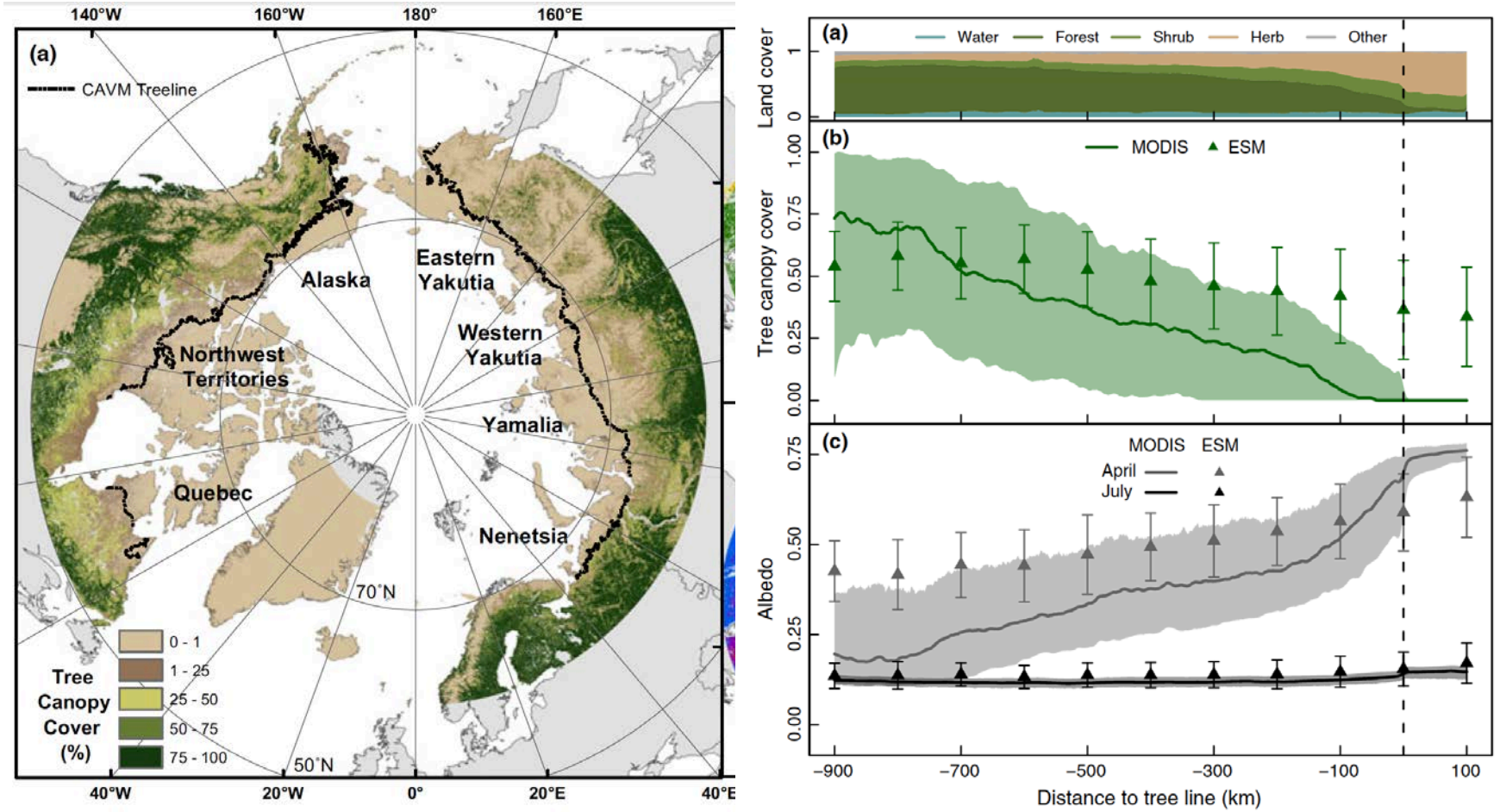
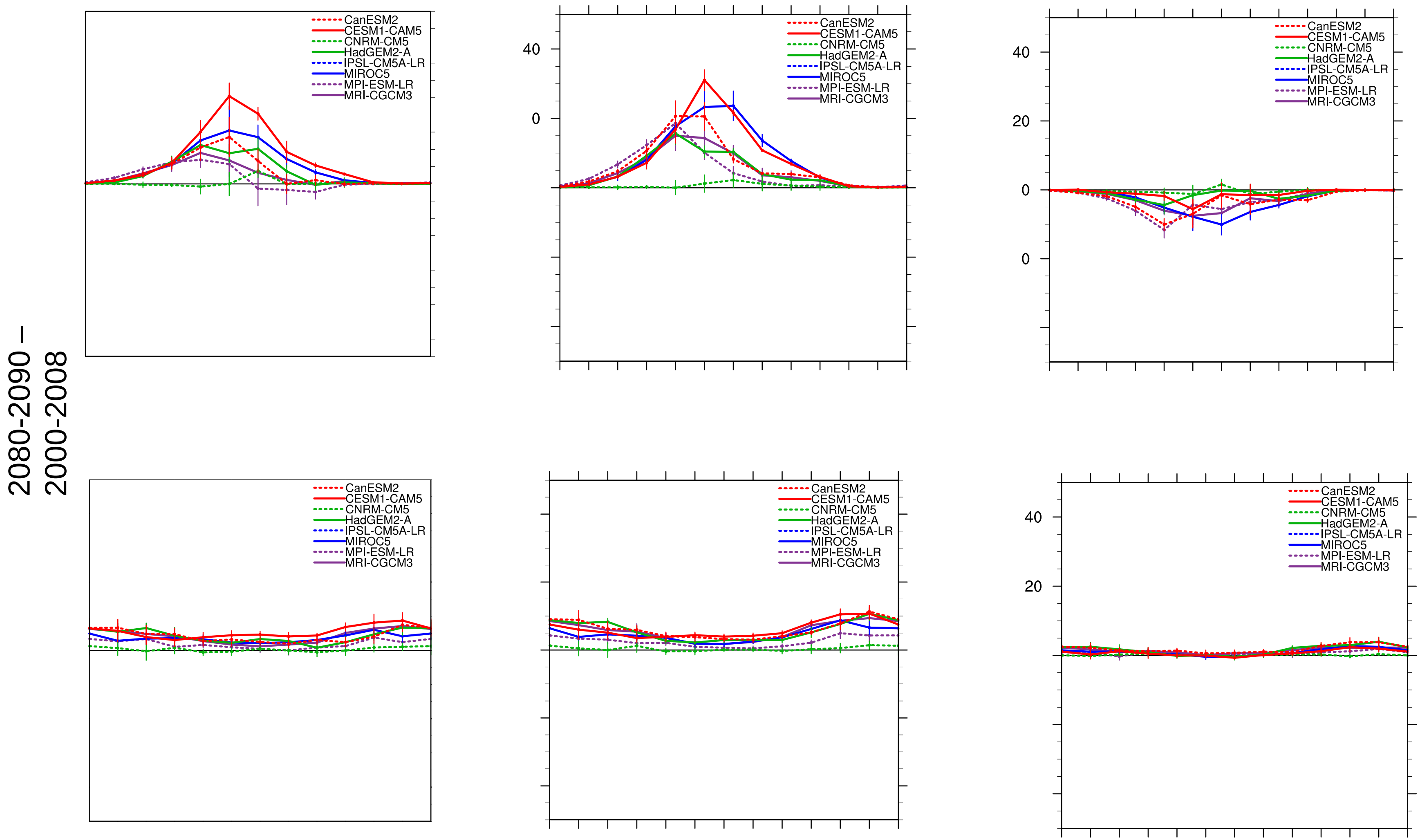


Fig. 1 Map of the study domain showing variability in MODIS tree cover (main panel), GLC-2000 plant functional type for boreal forest (upper right) and MODIS albedo for April 2006–2010 (lower right). A low pass filter was applied to the albedo data to improve visual interpretation. Forest types are as follows: deciduous broadleaf forest (DBF), deciduous needleleaf forest (DNF), evergreen needleleaf forest (ENF) and mixed-leaf forest (MIX).

Loranty et al., 2014

RCP4.5 projections: More net SW (due to snow/ice loss?) and more OLR due to higher T



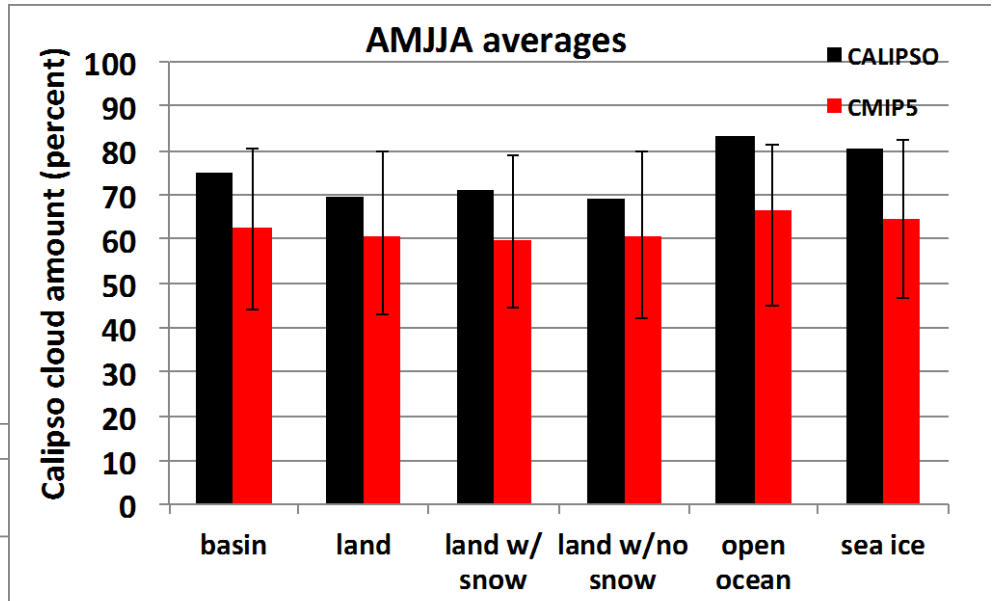
Summary

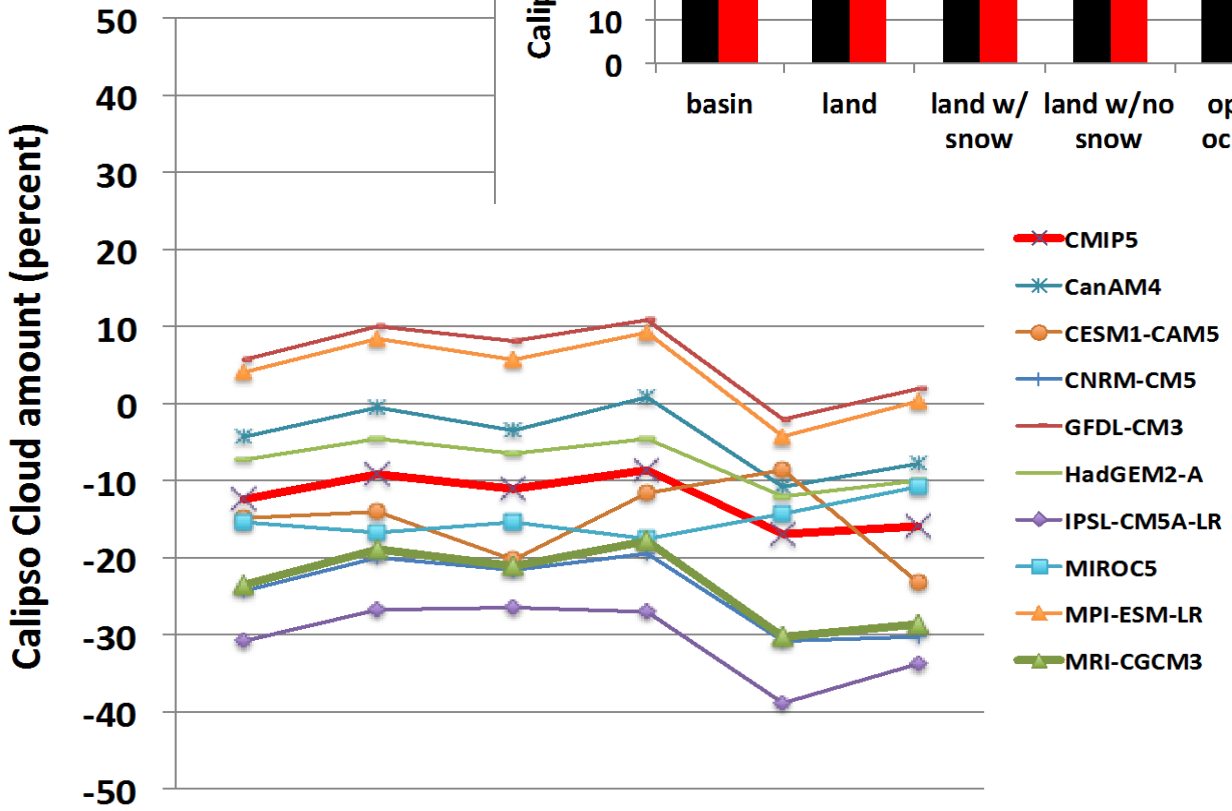
- CMIP5 models span a large range of net TOA SW fluxes and cloud amount
- CMIP5 net TOA SW is generally too high and varies significantly over different surface types (big difference over land w & w/o snow)
- CMIP5 net TOA SW biases due to insufficient clouds, and surface albedo errors (trees interacting with snow-cover; sea ice errors)
- CMIP5 models project more net SW and more OLR under RCP4.5

Next Steps

- Analyze individual CMIP5 model biases
- Look into separating into regions of land w/trees and land w/no trees
- Calculate total Watts over each surface type to compare energy
- Conduct a similar analysis on RCP4.5 scenario (how do TOA fluxes and cloud amount change over each surface type in the future)

EXTRA SLIDE





2000-2008
AMIP average