

An aerial photograph of a dry, cracked riverbed. The ground is light brown and heavily fissured with a network of dark, winding cracks. A small, narrow stream of clear water flows through the center of the riverbed, creating a dark blue line that contrasts with the dry earth. The overall scene suggests a severe drought or arid climate.

# Near-future changes in Greenland climate in the CESM Large Ensemble

Jennifer Kay, Chris Cox

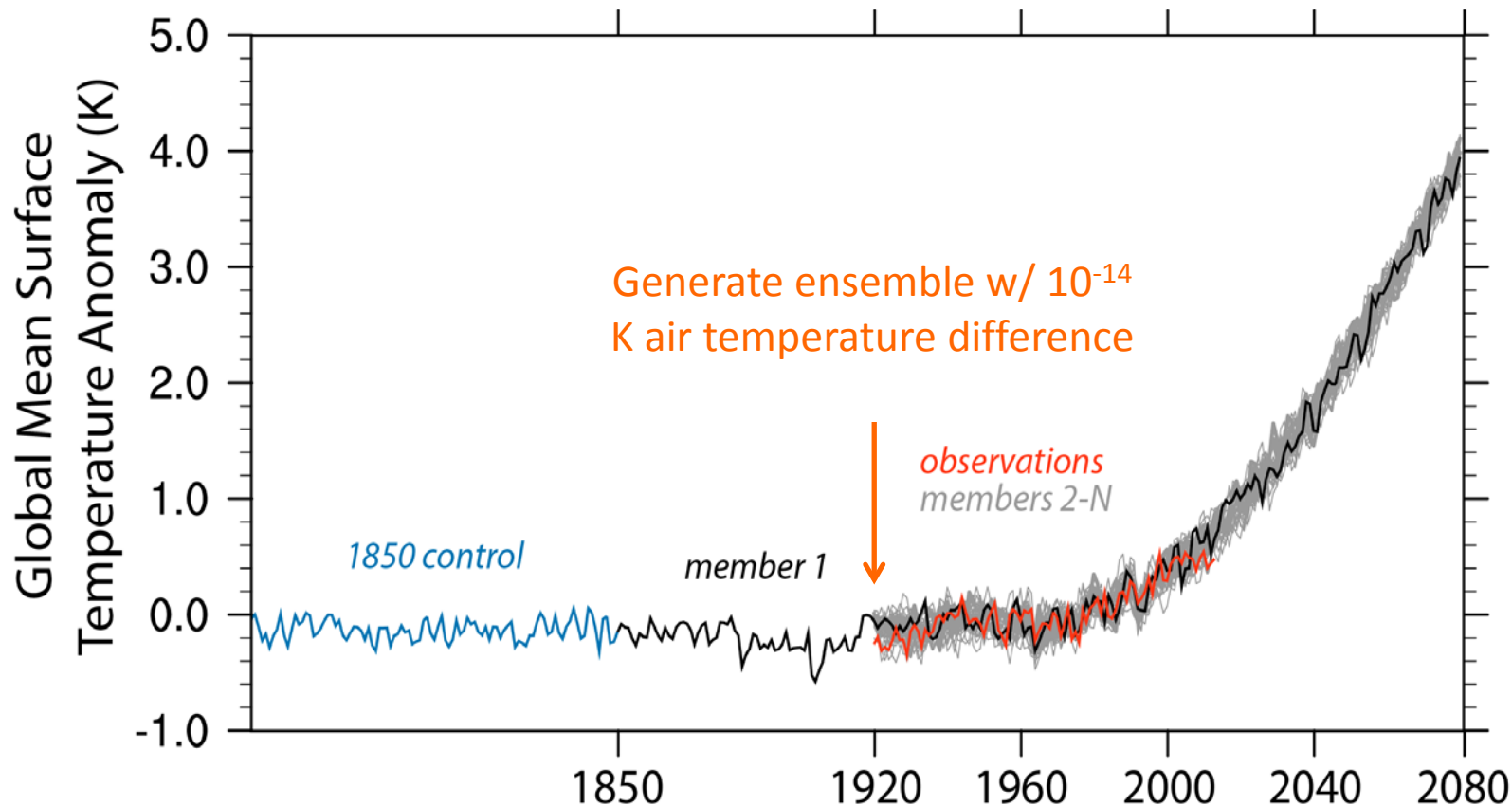
University of Colorado

Miren Vizcaino

TU-Delft

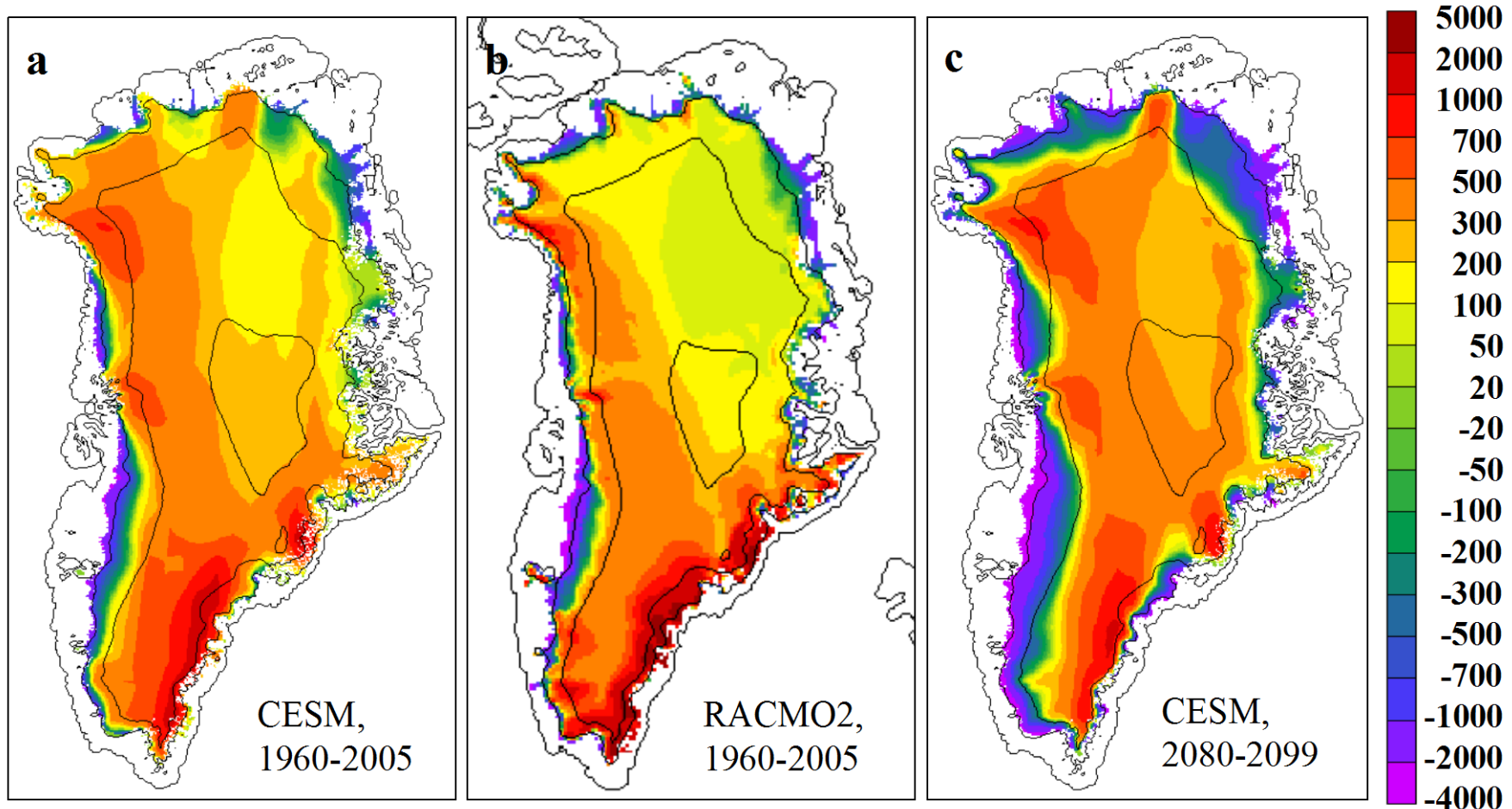
# CESM-CAM5 Large Ensemble

Data at [www.earthsystemgrid.org](http://www.earthsystemgrid.org)



CESM-LE Experimental Design (Kay et al. submitted).  
Historical and RCP8.5 forcing, 1920-2080

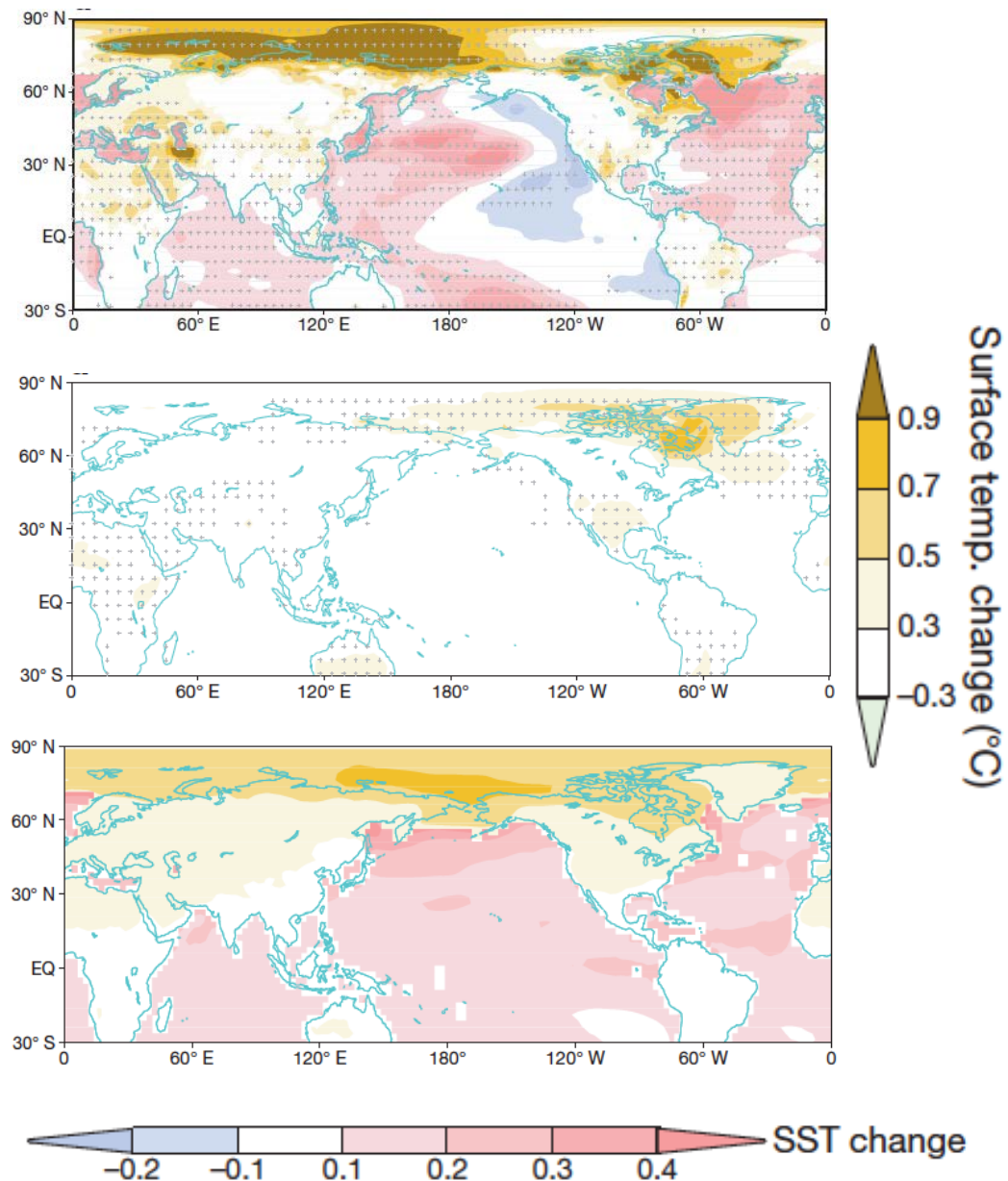
# Why Greenland?



Present-day and end-of-the-century simulations of the Greenland Ice Sheet Surface Mass Balance ( $\text{kg m}^{-2} \text{yr}^{-1}$ ) from CSM, and comparison with a high-resolution regional climate model RACMO2 (Vizcaino et al., 2013, 2014).

# Why Greenland?

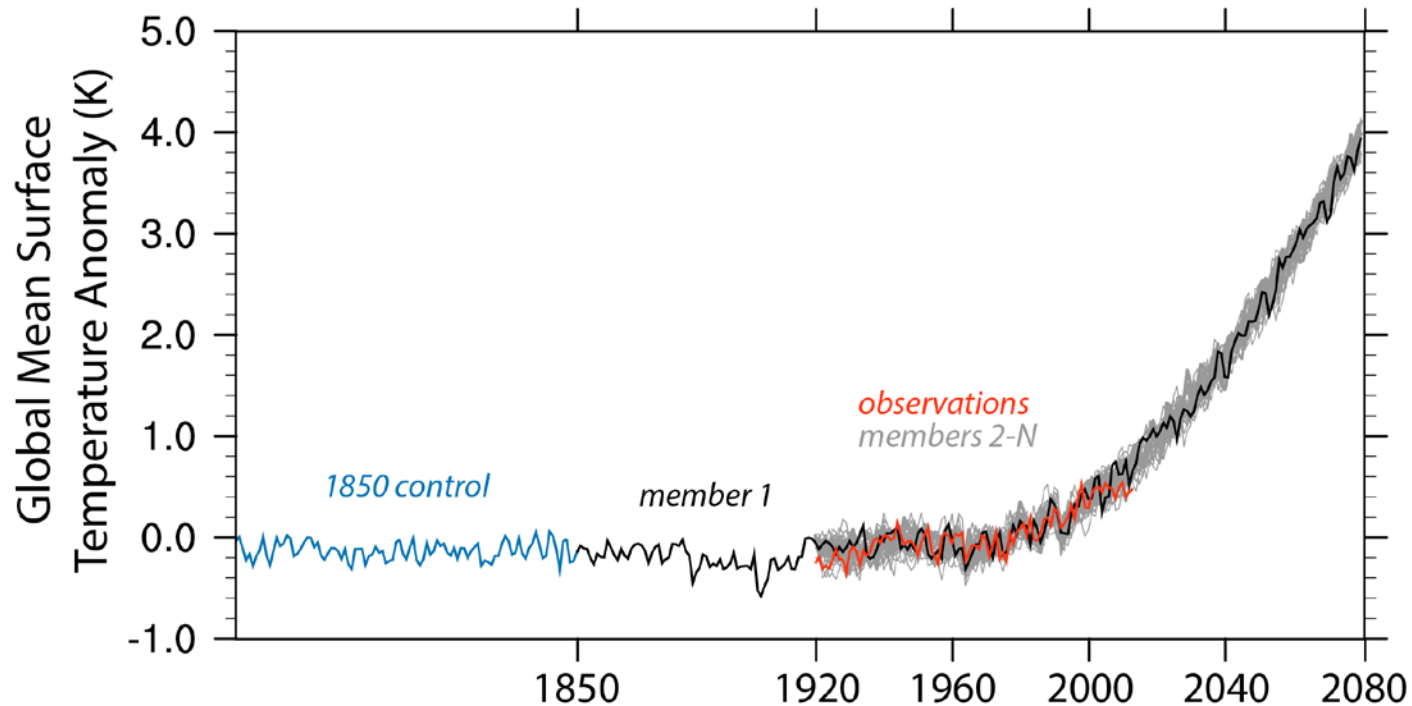
e.g., Ding et al. 2014:  
>50% of 1979-2012  
Greenland warming  
arose from unforced  
natural variability



Annual mean trends: Observed 1979-2012 (top), ECHAM forced by observed Tropical SST 1979-2012 (middle), CMIP5 mean response to historical forcing 1979-2004 (bottom)

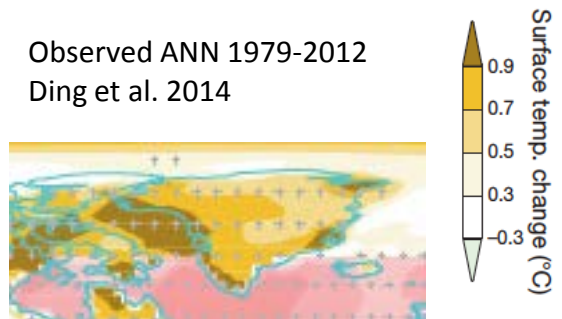
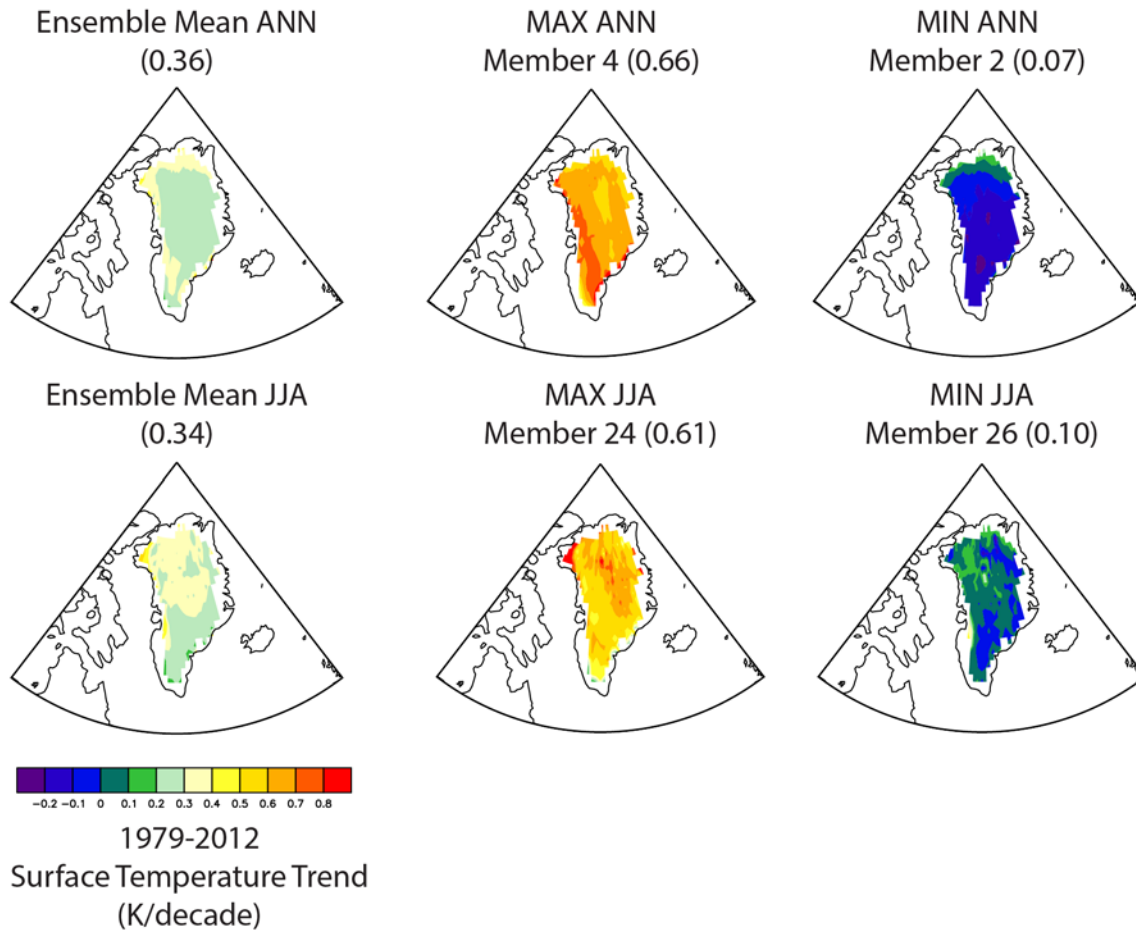
# Today:

- Greenland in the CESM Large Ensemble (CESM-LE)
- Focus on ice sheet surface mass balance (summer surface temperature, annual precipitation)



CESM-LE Experimental Design (Kay et al. submitted).  
Historical and RCP8.5 forcing, 1920-2080

# Historic surface temperature changes

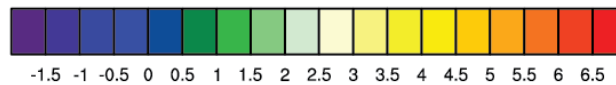
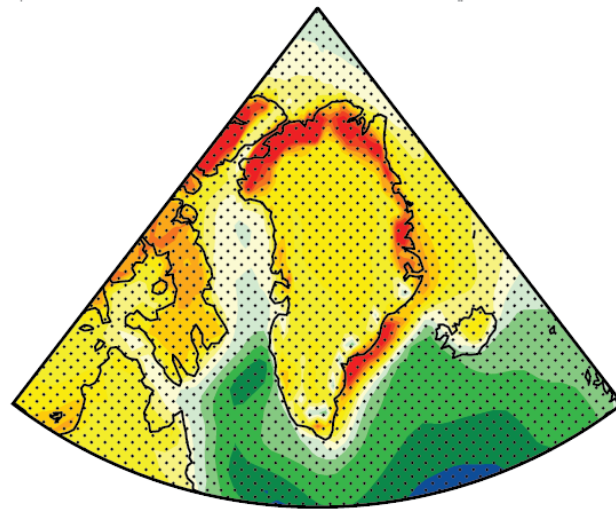


CESM-LE suggests observed Greenland 1979-2012 surface warming enhanced by internal variability, consistent with Ding et al. 2014.

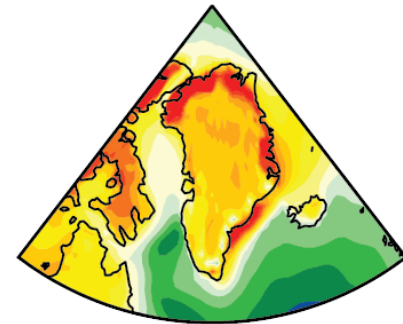


# Robust future summer surface warming

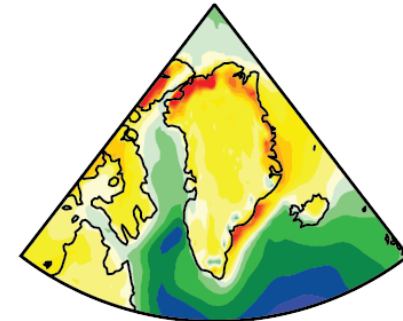
avg(2061-80)-avg(2005-24)



CESM-LE member 5

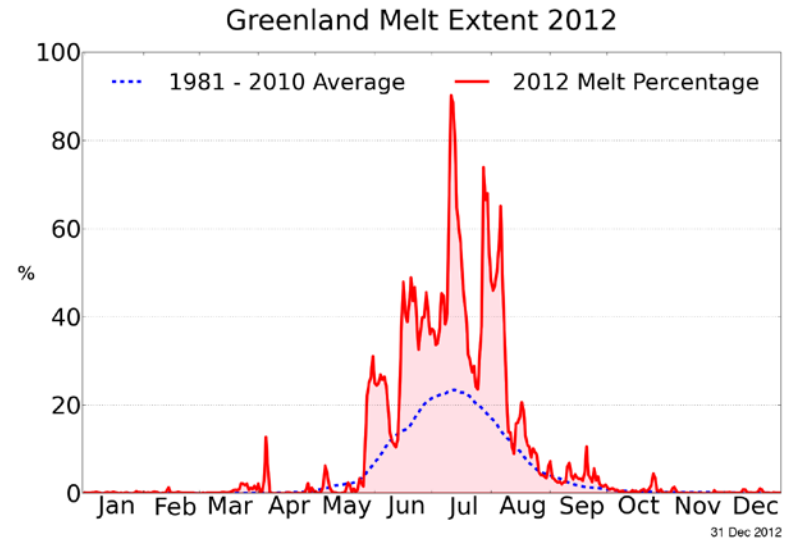
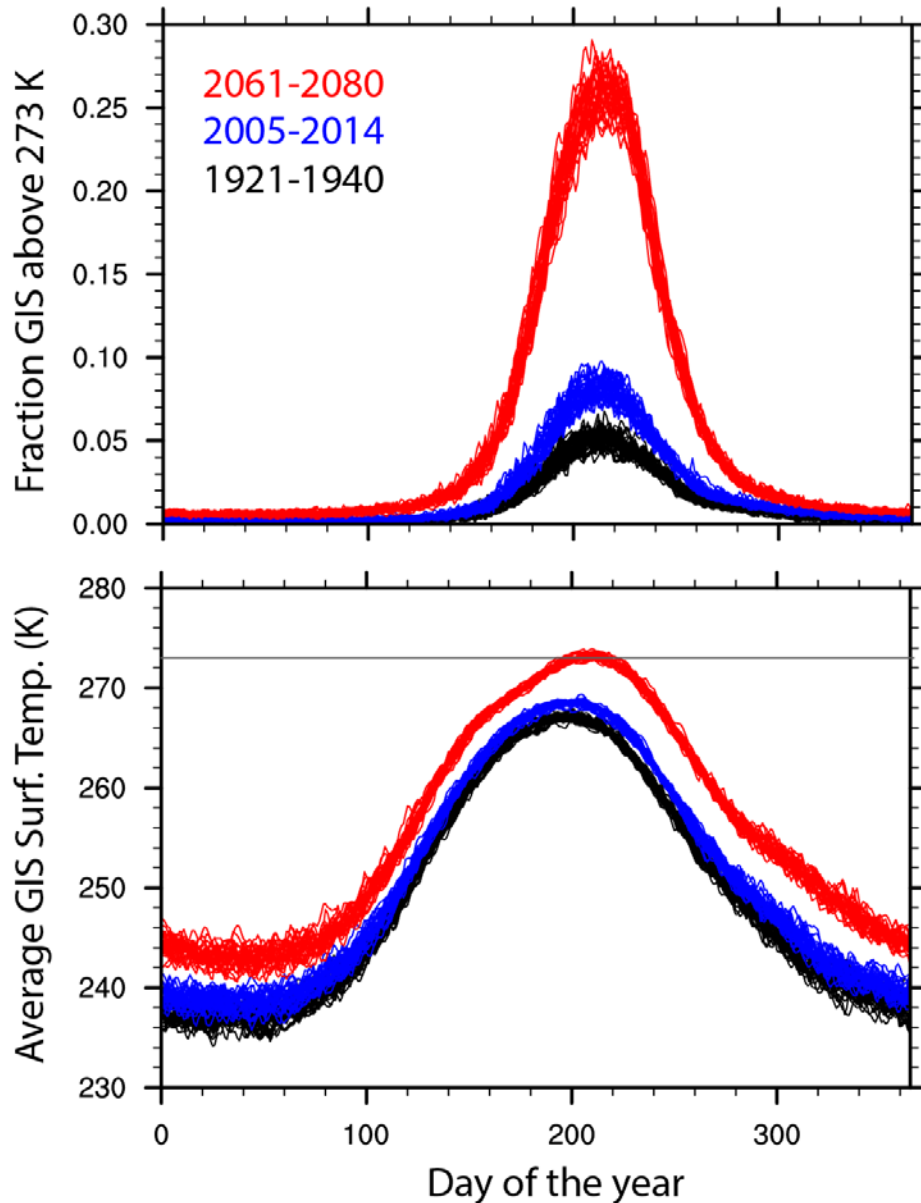


CESM-LE member 8



Inescapable Greenland Ice Sheet Warming: AVG: +4.5 K, MAX: +5.1 K, MIN: +4.5 K

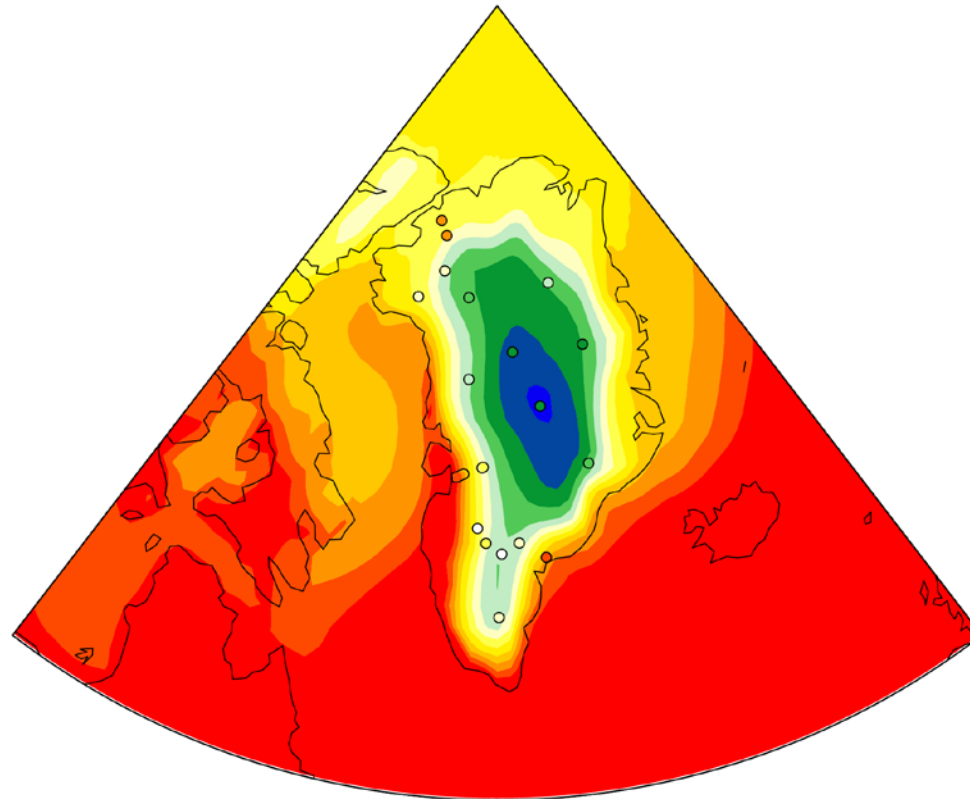
# Increasing Greenland melt extent



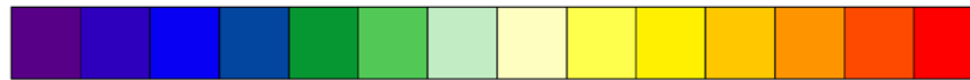
But present-day melt fraction  
in CESM-LE less than observed (?)



# CESM-LE Greenland too cold



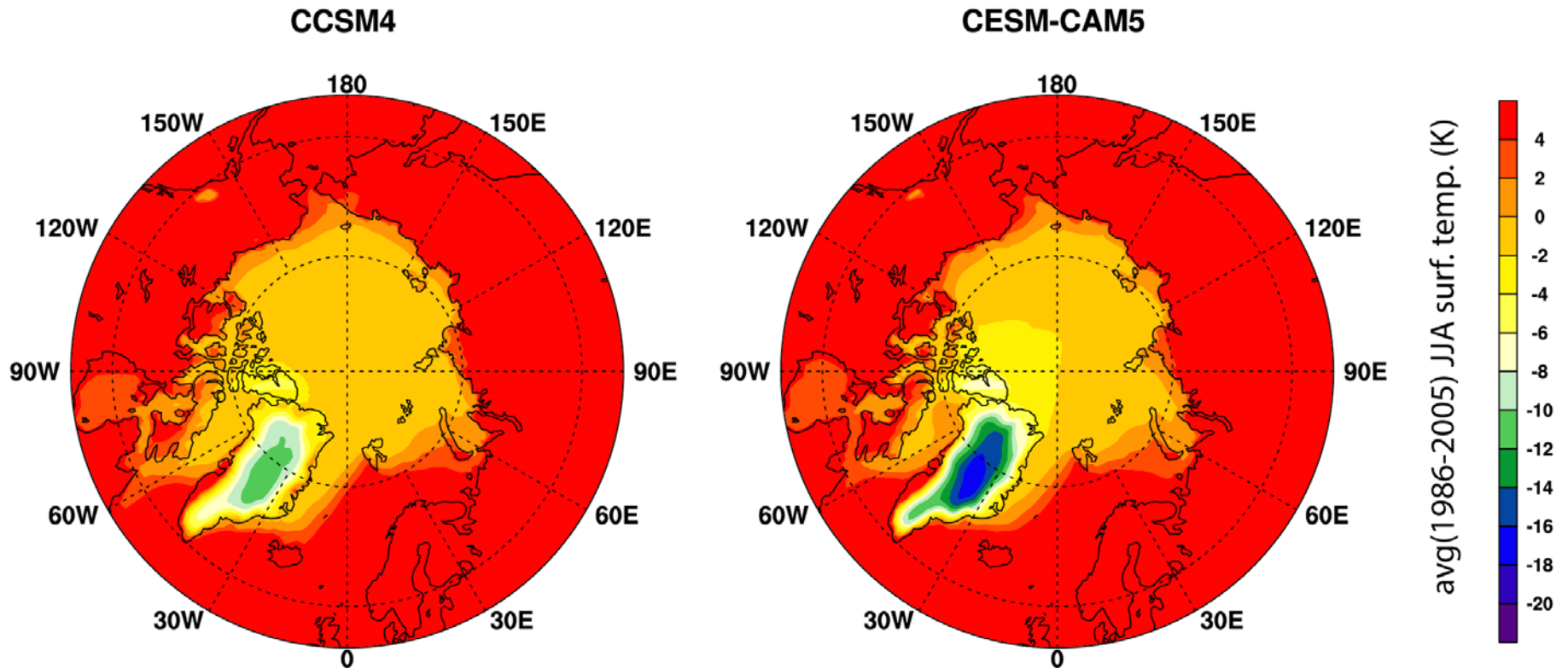
Summer Air Temperatures (1996-2013), degrees C



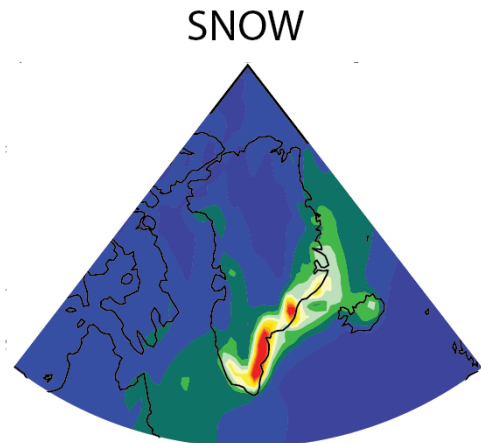
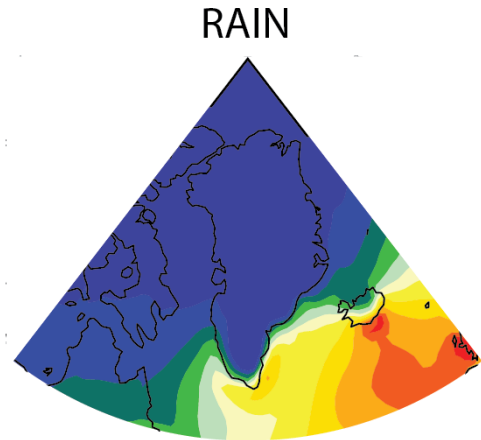
-20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4

GC-Net Observations: Steffen, K., and J.E. Box, Surface climatology of the Greenland ice sheet: Greenland climate network 1995-1999, *J. Geophys. Res.*, 106(D24), 33,951-33,964, 2001. (Thanks Anne-Katrine Faber!).

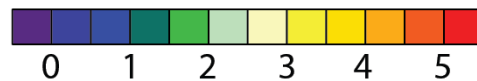
# CESM-LE (CAM5) colder than CCSM4 (CAM4)



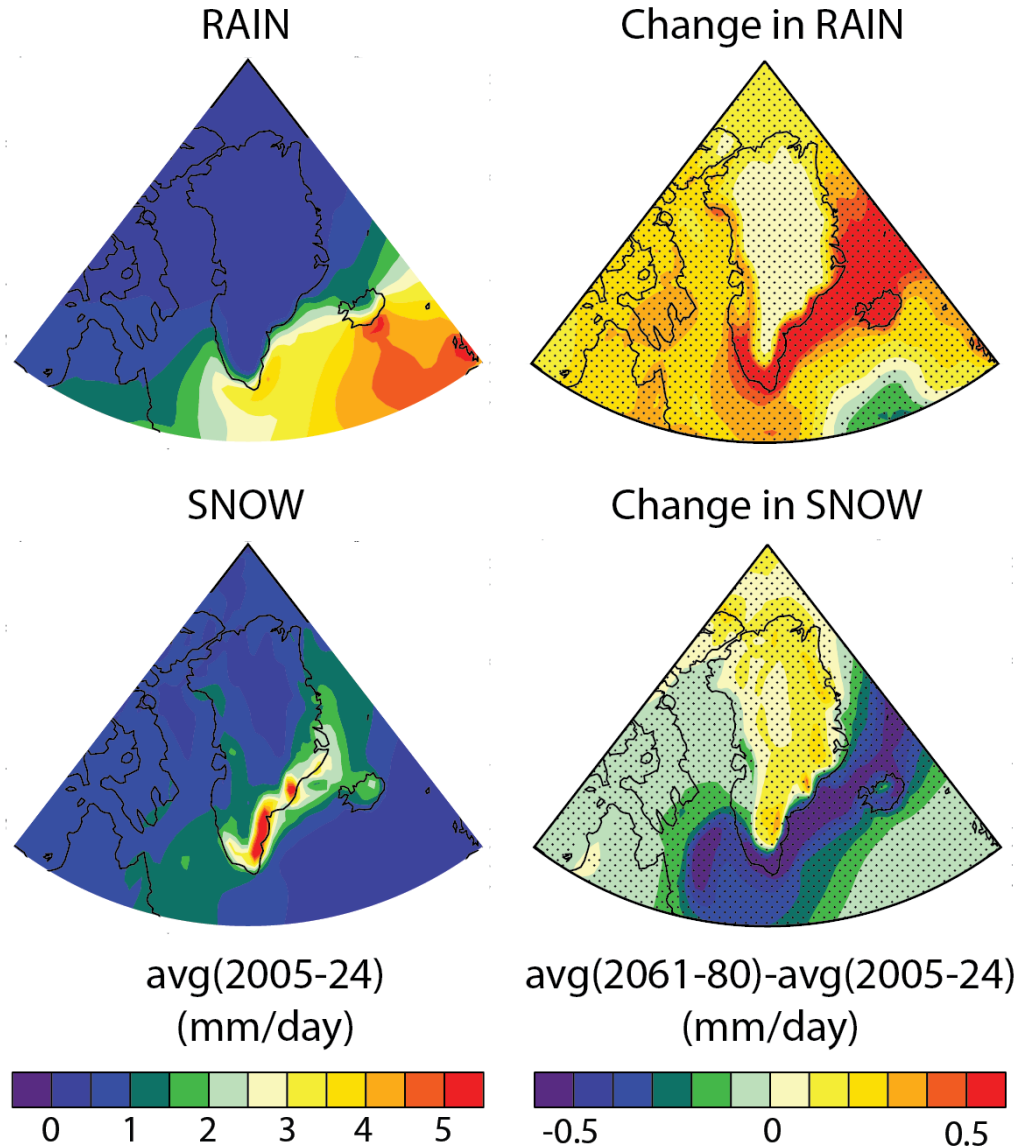
# Greenland Precipitation in CESM-LE



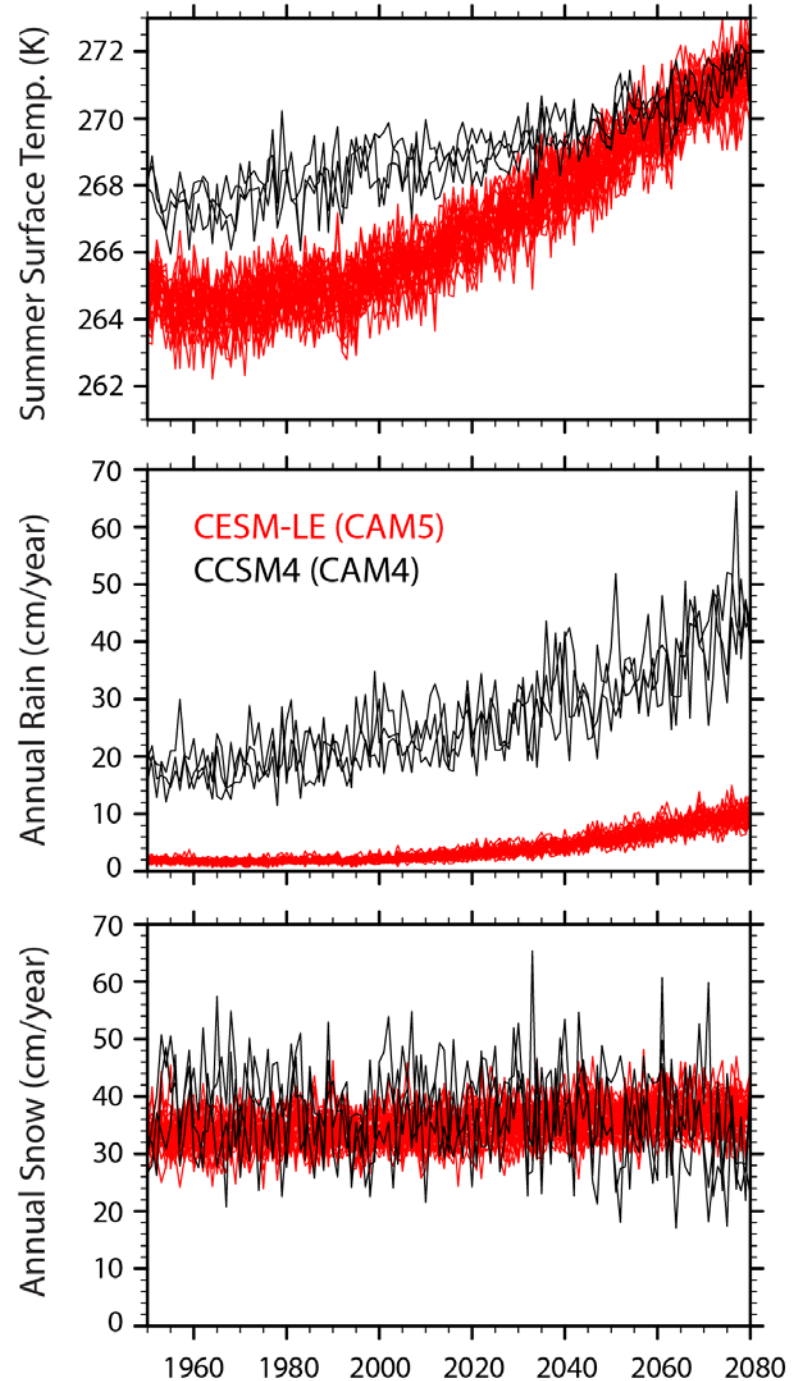
avg(2005-24)  
(mm/day)



# Future precipitation changes



# Greenland climate different with CAM5 than with CAM4 – implications for ice sheet modeling?



A photograph of a large iceberg floating in the ocean. The iceberg is white and jagged, with a large peak. The water is dark blue, and the sky is a lighter blue with some clouds. The iceberg is partially submerged, with the water level clearly visible.

## Summary:

- 1. 1979-2012 Greenland surface warming enhanced by internal climate variability (Ding et al. 2014, CESM-LE)**
- 2. Warmer and wetter late 21<sup>st</sup> century for Greenland in CESM-LE**
- 3. Greenland climate differences between CAM4 and CAM5 (CAM5 too cold now) -- implications for ice sheet modeling?**