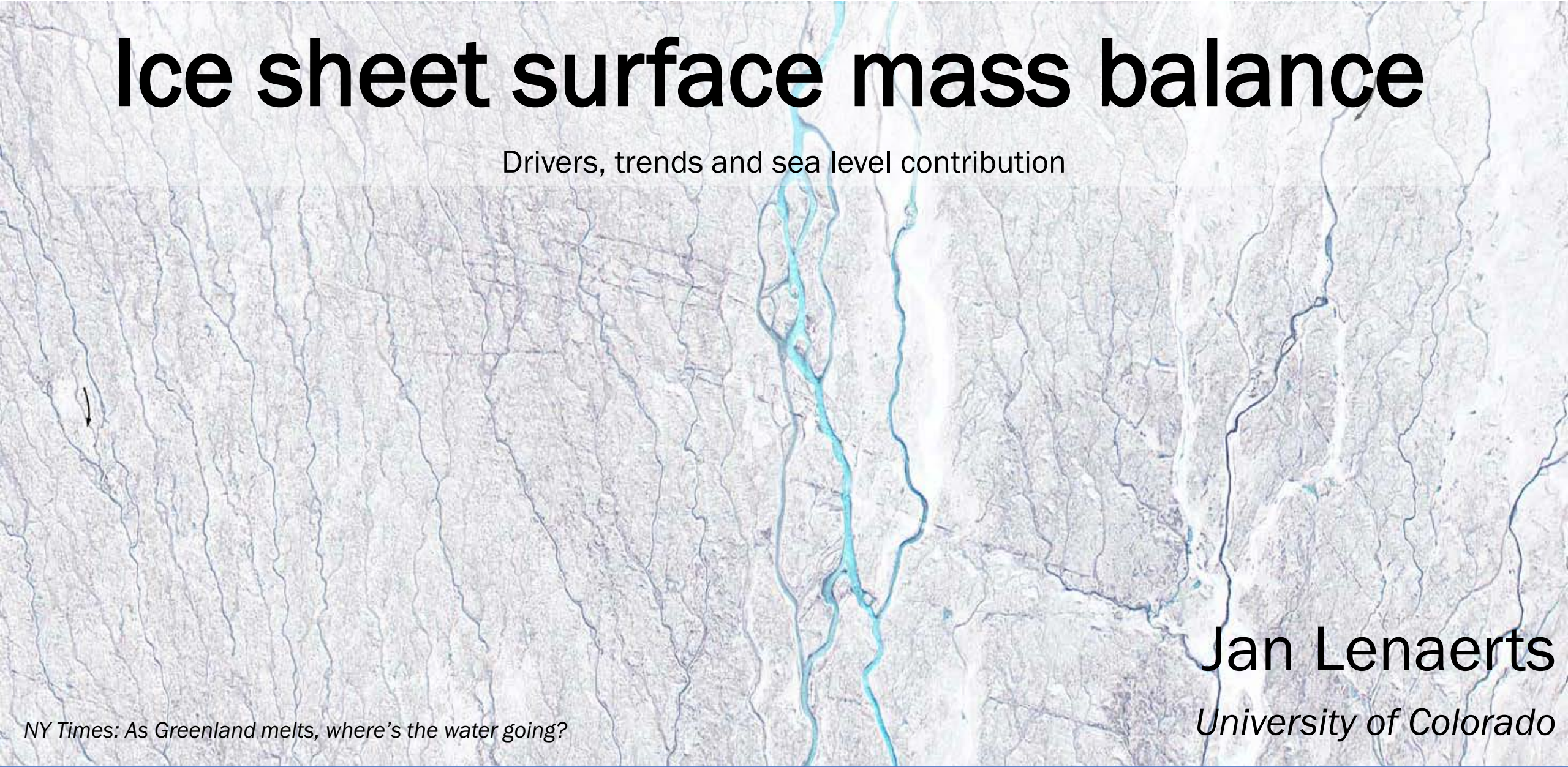


# Ice sheet surface mass balance

Drivers, trends and sea level contribution



Jan Lenaerts

*University of Colorado*

*NY Times: As Greenland melts, where's the water going?*



University of Colorado  
Boulder

CESM Sea Level Session – January 10, 2018

SMB = input (snowfall)...



...minus output (meltwater runoff)



# SMB and sea level

(based on regional climate modeling)



1 mm sea level equivalent

Per year:

*Greenlan*

Precipitation  
**(IN)**



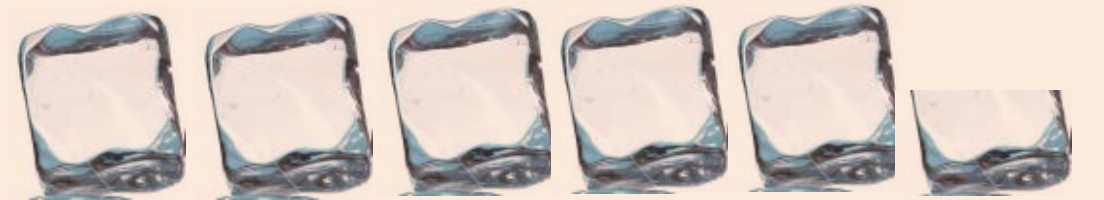
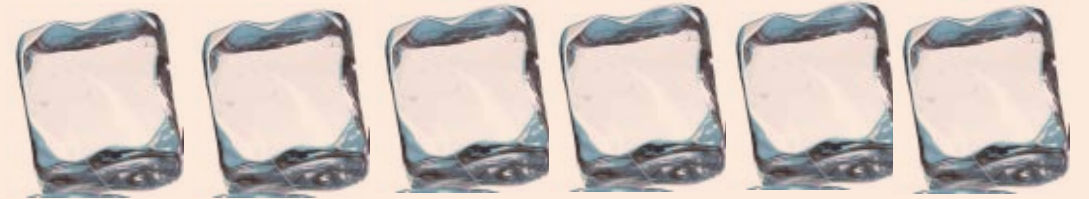
Runoff + Sublimation  
**(OUT)**



Surface mass balance  
**(IN-OUT)**



*Antarctica*







How much water has melted and refrozen?

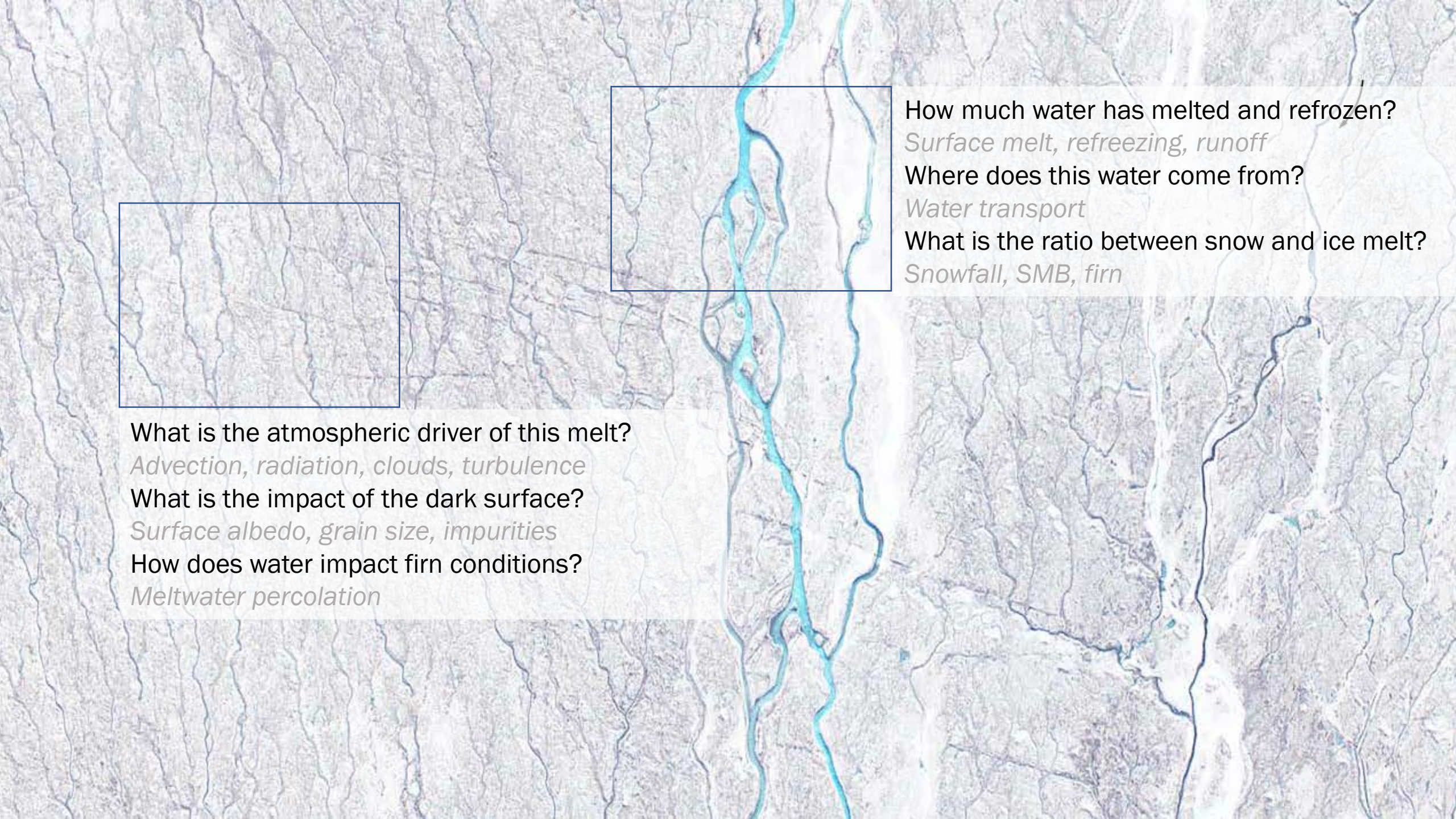
*Surface melt, refreezing, runoff*

Where does this water come from?

*Water transport*

What is the ratio between snow and ice melt?

*Snowfall, SMB, firn*



What is the atmospheric driver of this melt?

*Advection, radiation, clouds, turbulence*

What is the impact of the dark surface?

*Surface albedo, grain size, impurities*

How does water impact firn conditions?

*Meltwater percolation*



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***Ice sheet - climate coupling***





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**What is the ice sheet impact on climate?**

***Ice sheet - climate coupling***

**Climate models can complement observations in providing ice sheet wide fields and long-term time series of all these parameters**



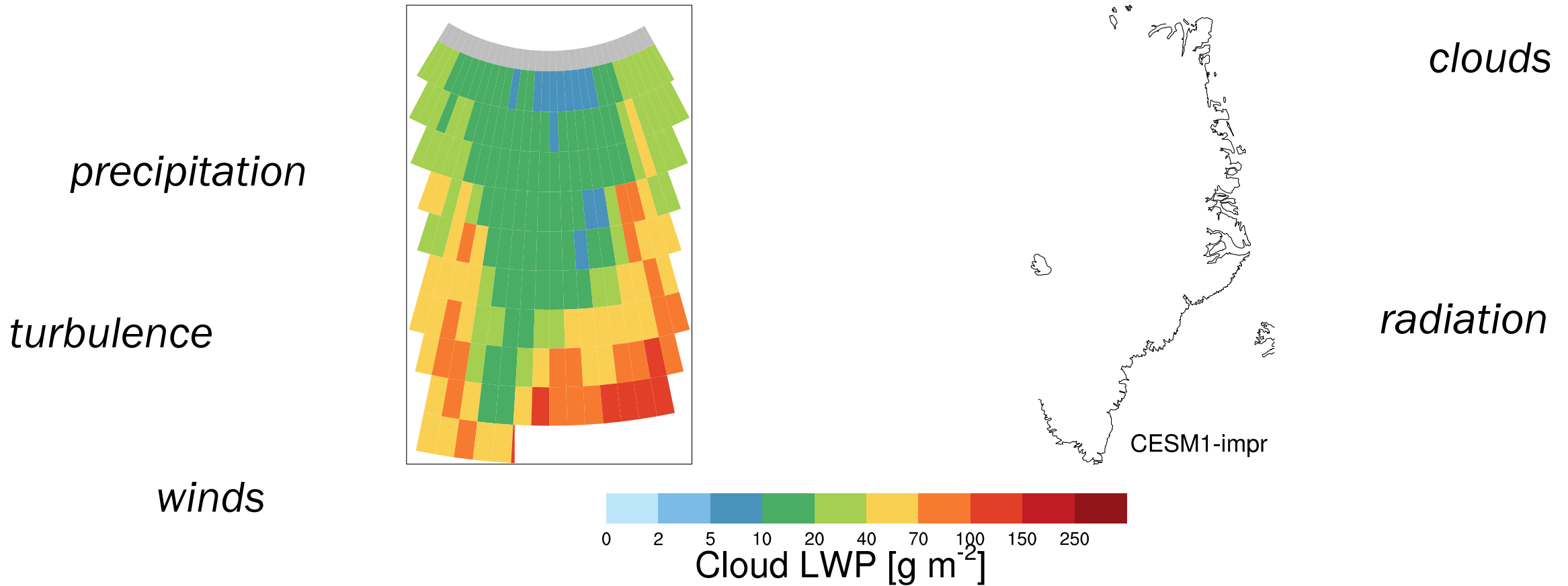
# Blame the weather

*CESM wind speed*  
Source: NCAR VisLab



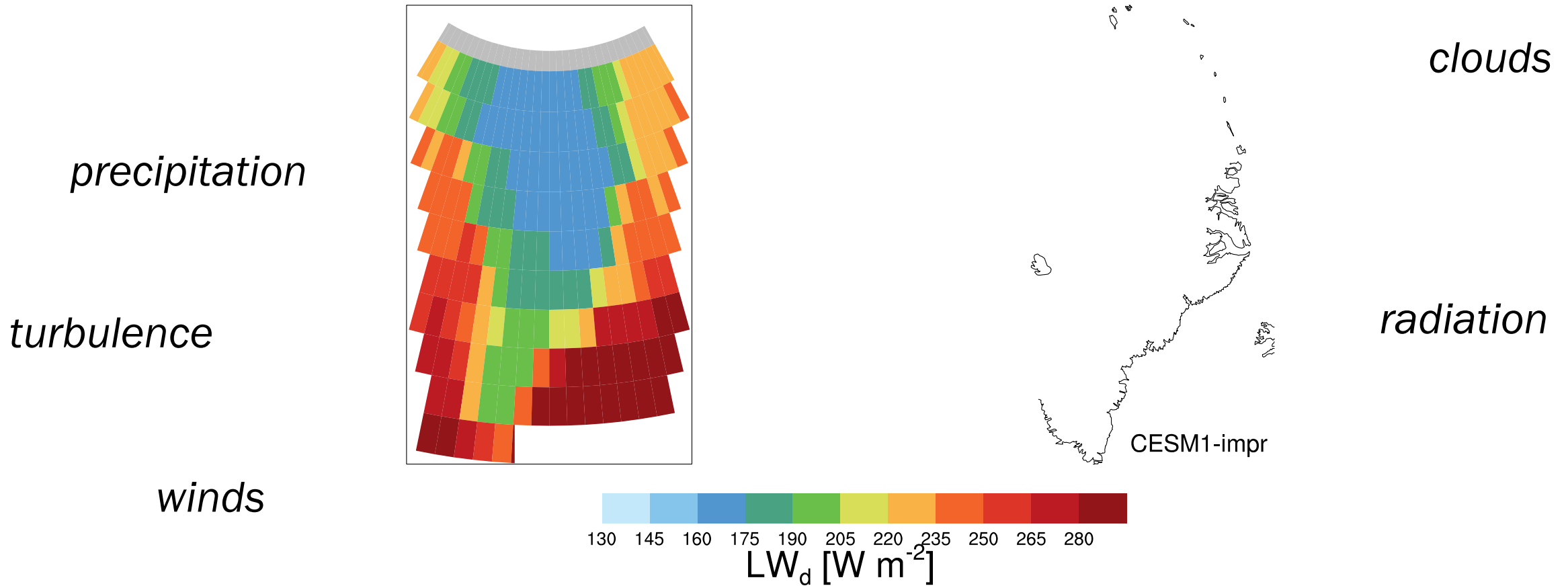
# Recipe for a delicious SMB

1. Start with a (good) atmospheric model  
Community Atmosphere Model (CAM)



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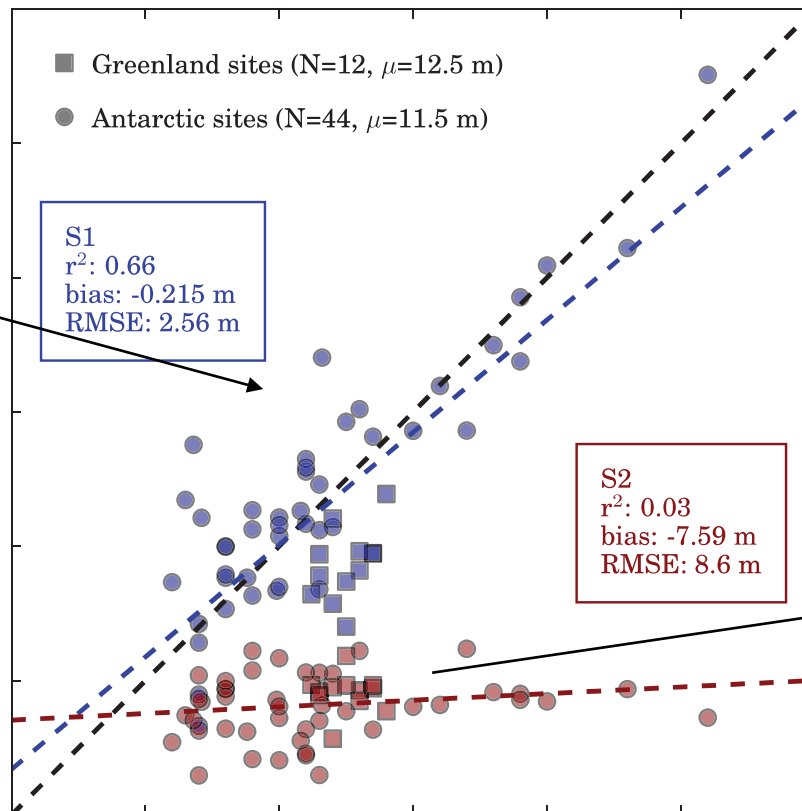
# Recipe for a delicious SMB

Original (CLM4)

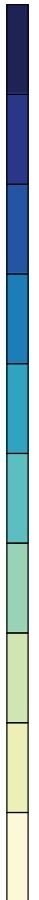
Improved (CLM5)

## 2. Develop and improve a snow and firn model Community Land Model (CLM)

Semi-empirical



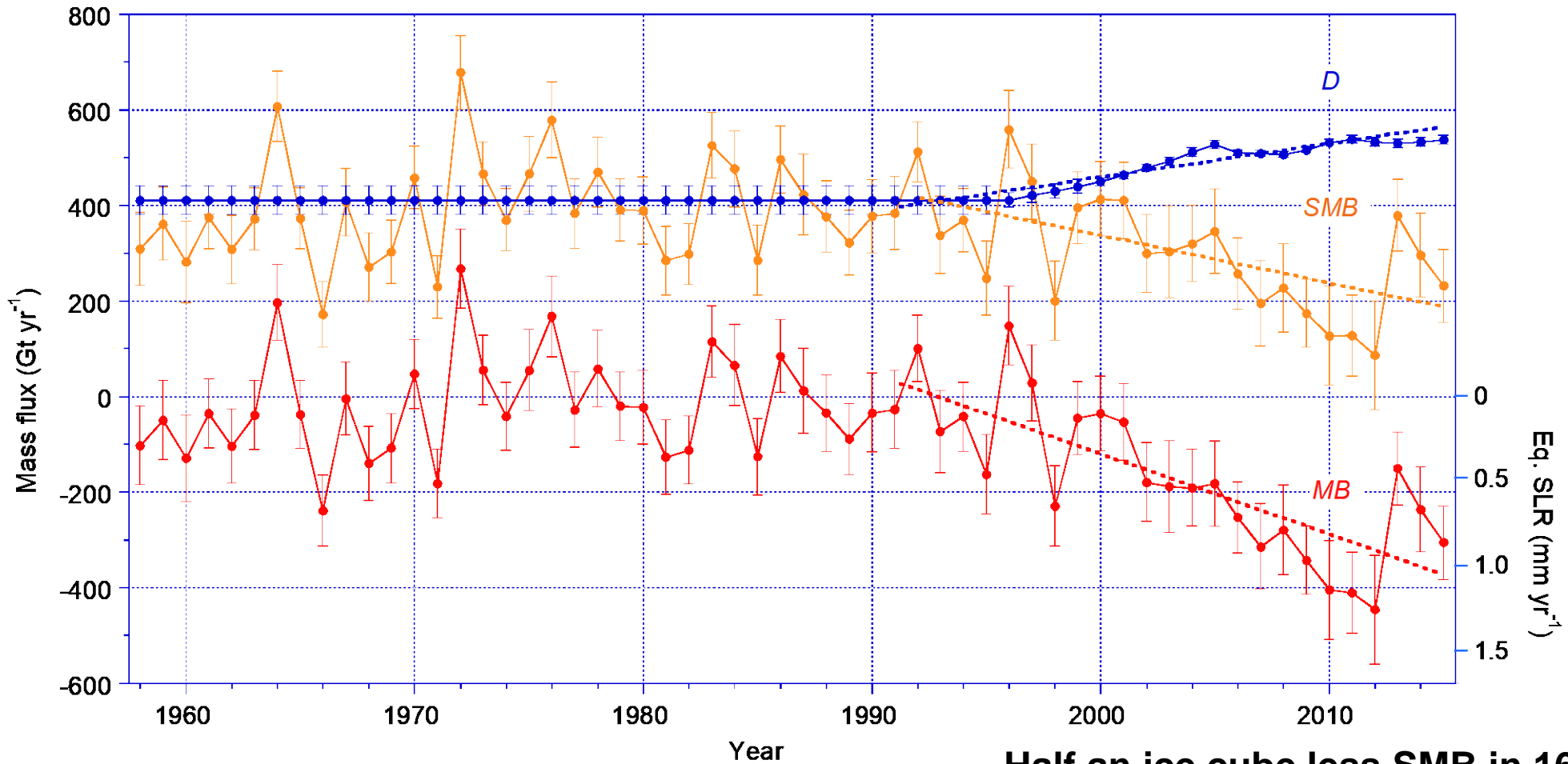
Original (CLM4)



Go see Leo's talk tomorrow for more details!

# Trends: Greenland

Van den Broeke et al., 2016




Half an ice cube less SMB in 16 years

*When do we reach threshold?*

D has increased until ~2005 but is leveling off

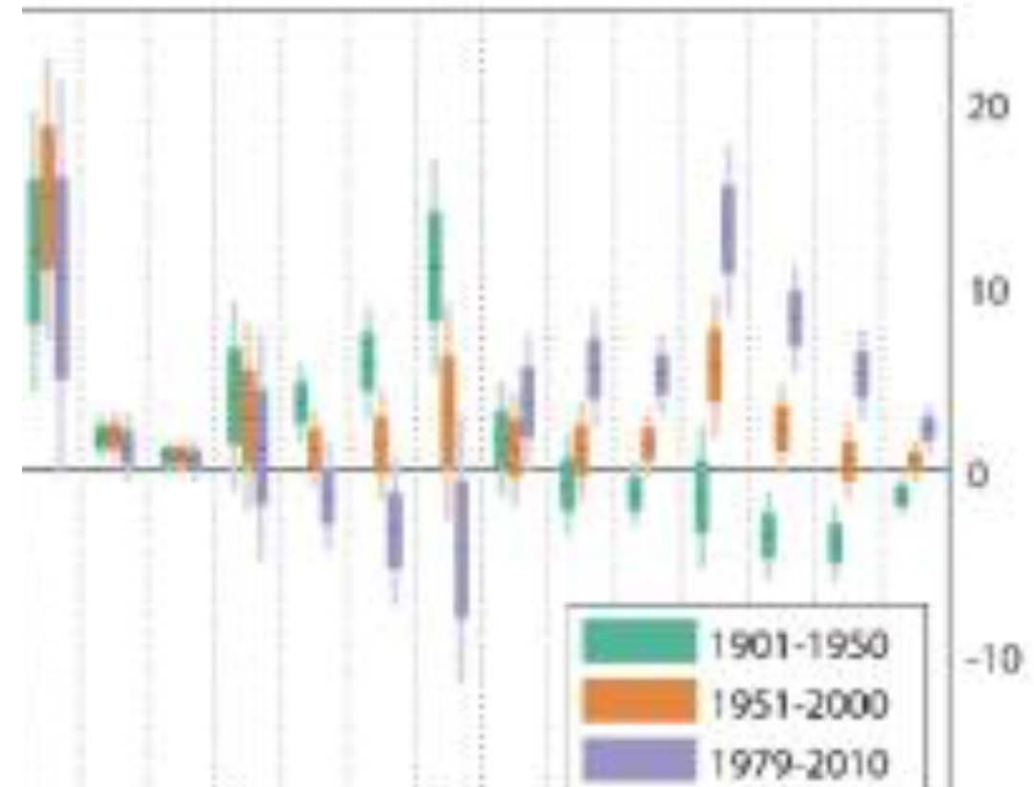
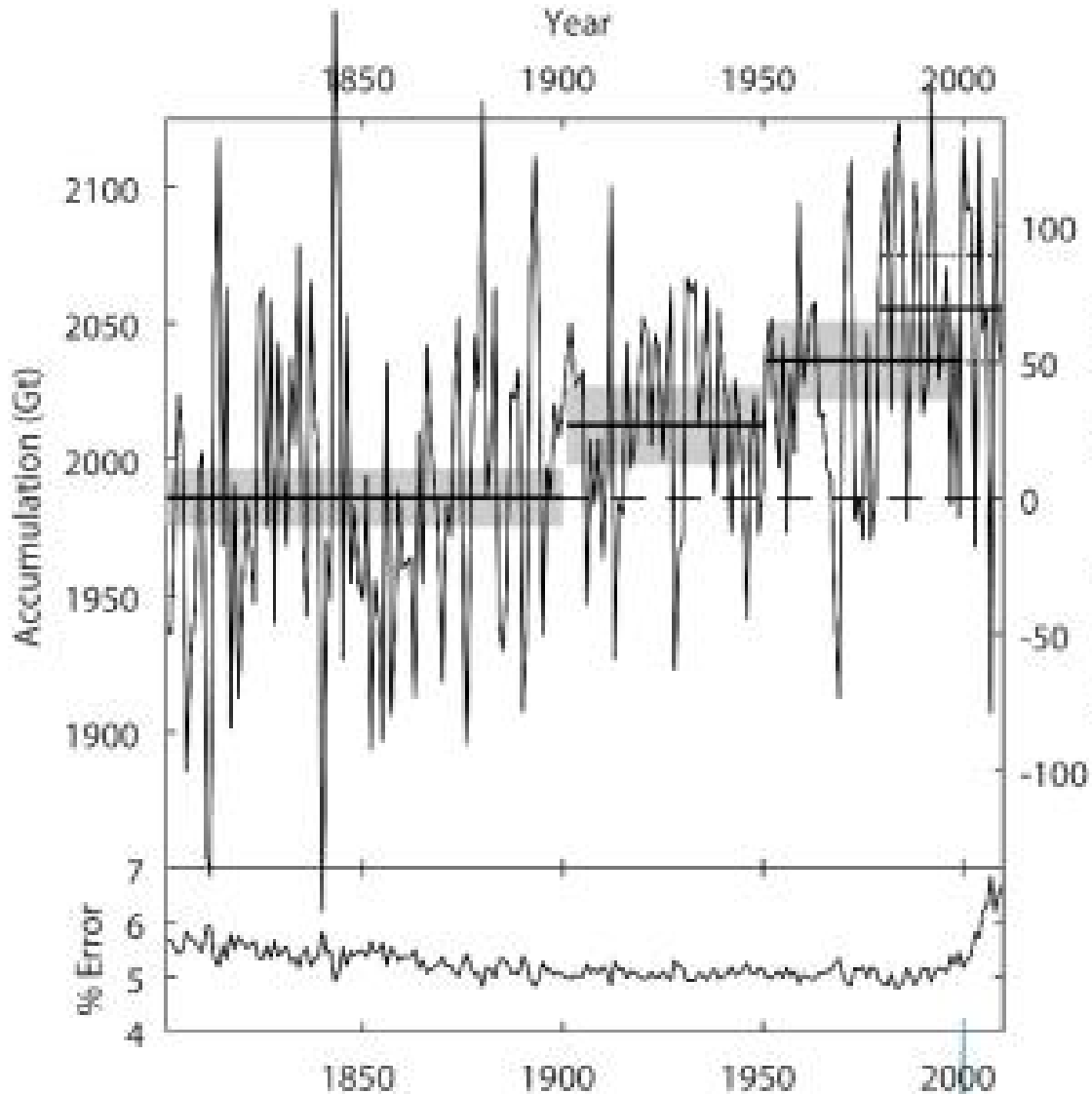


Summer 2012: 1000 Gt = 



# Trends: Antarctica

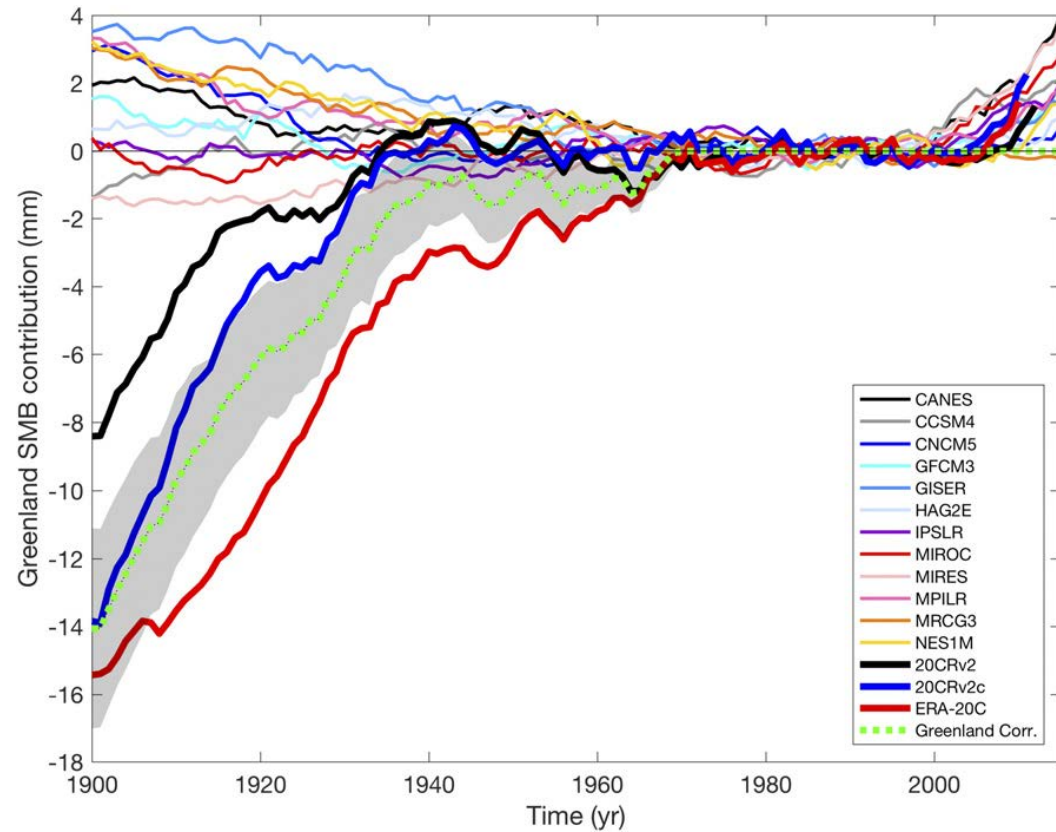
*Medley and Thomas, in review*



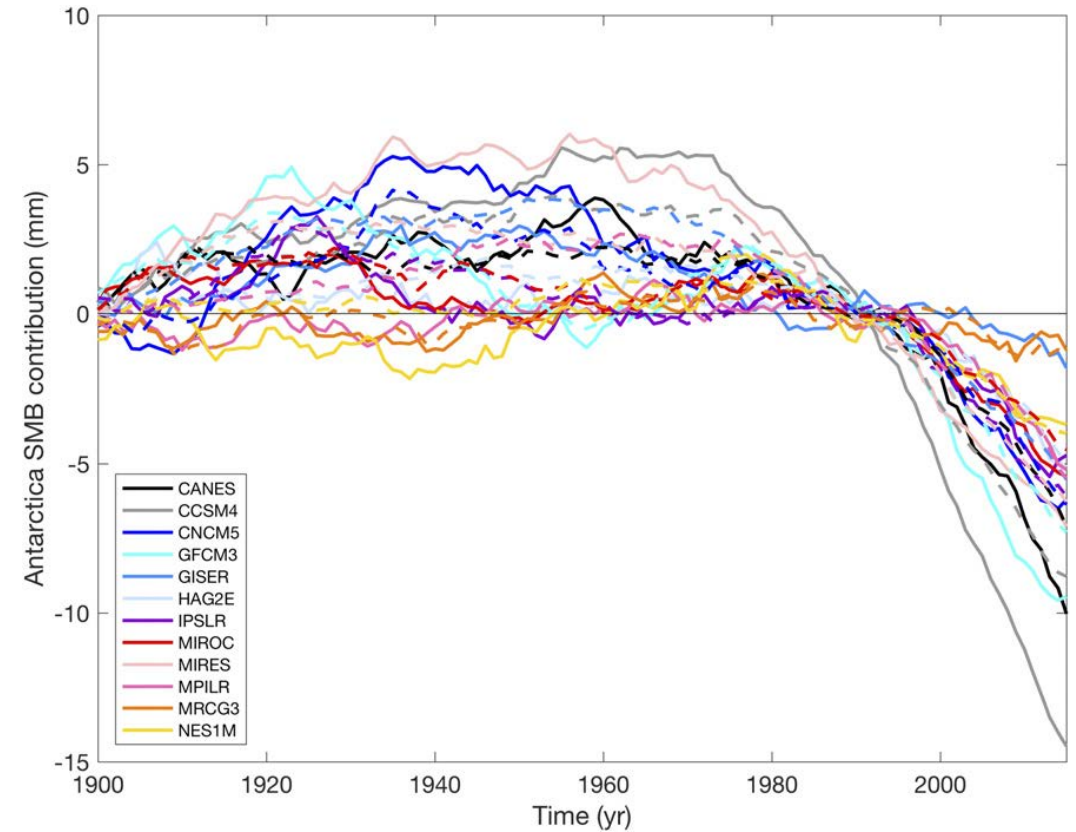
**Twelve ice cubes more SMB in last 110 years**  
**Go see Jeremy Fyke's talk tomorrow for more details**

# What about the climate models?

## Greenland

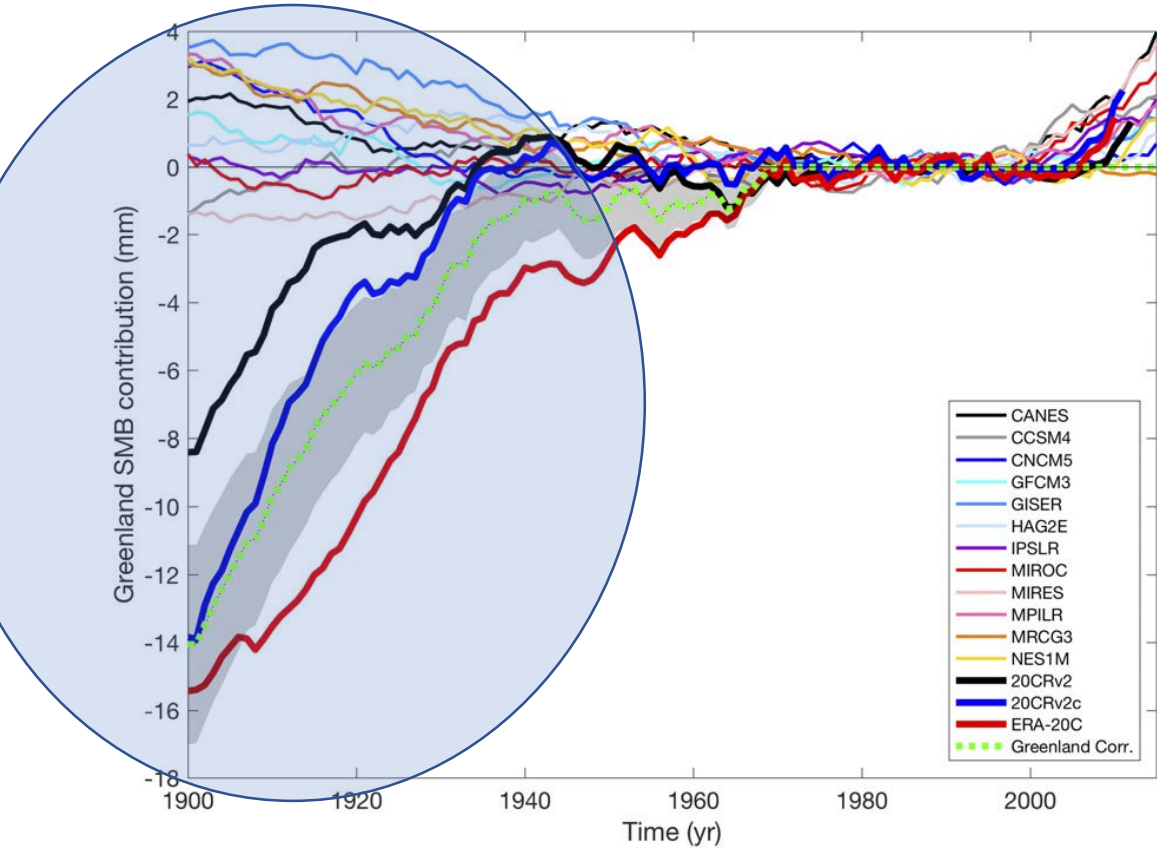


## Antarctica

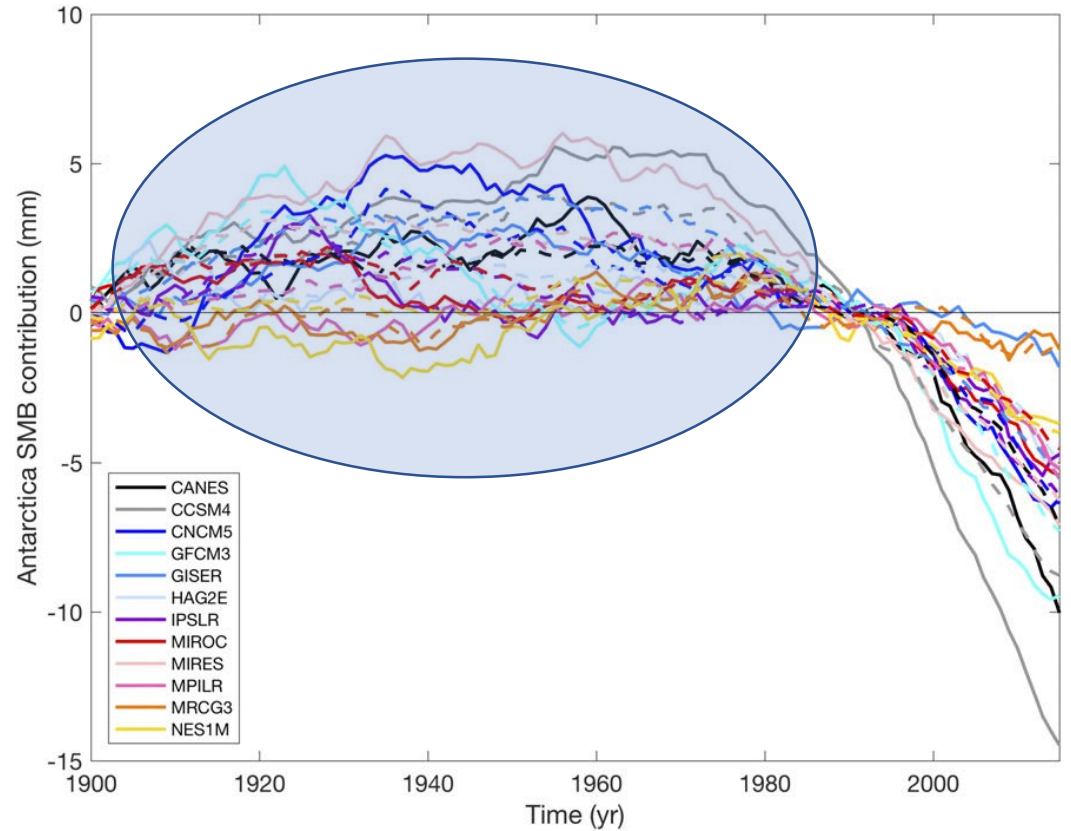


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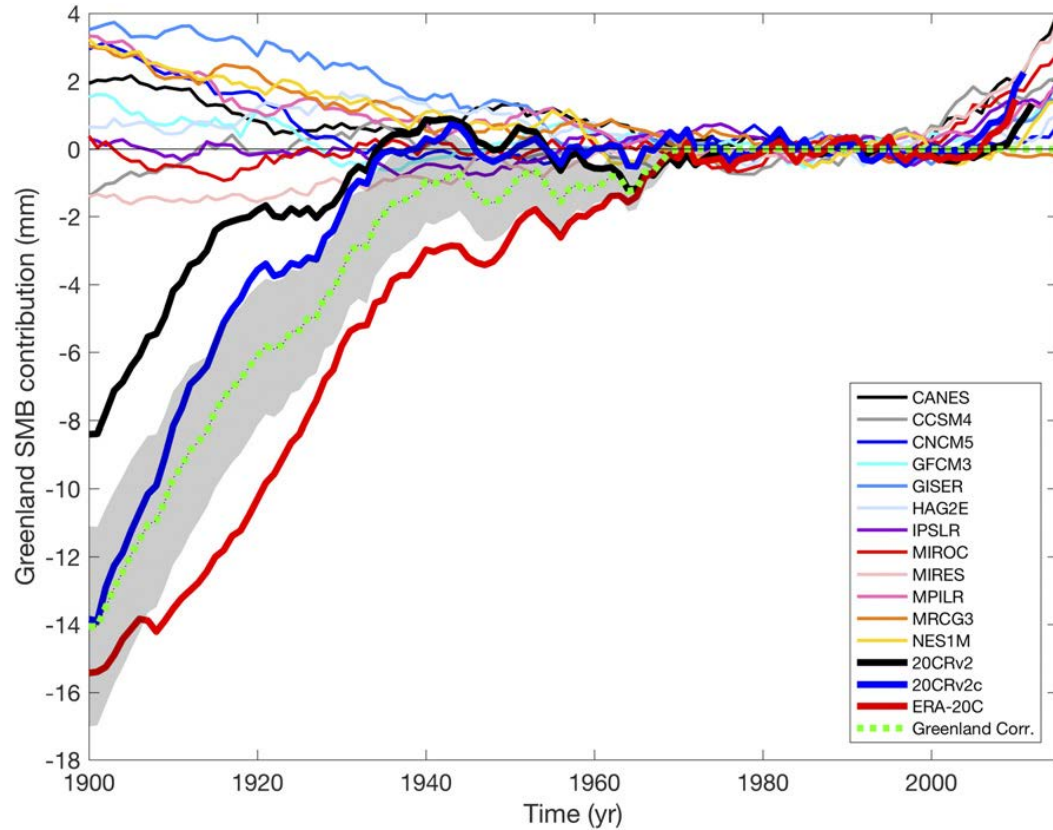
## Antarctica



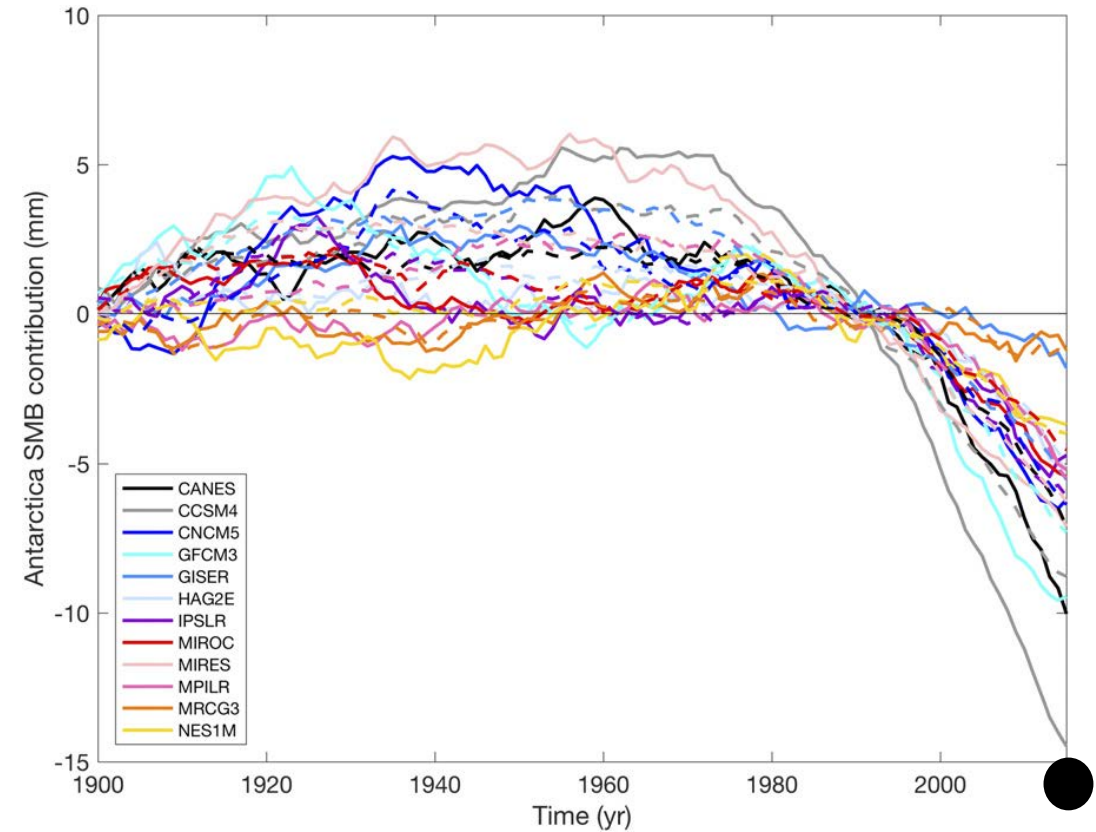
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Van den Broeke et al., 2016

## Greenland



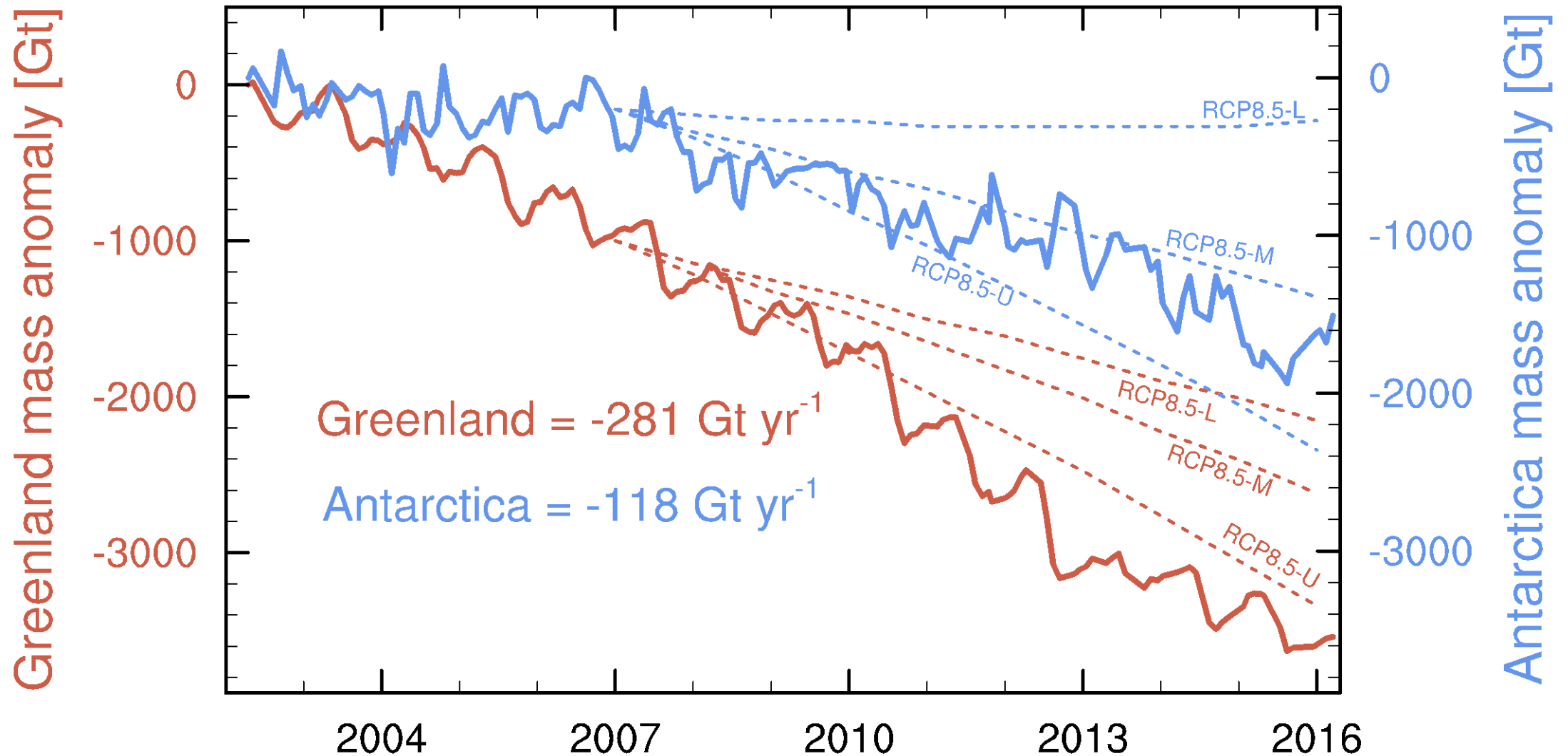
## Antarctica



Slangen et al., 2017

Medley and Thomas, in review

# IPCC AR5 ice sheet mass loss vs. GRACE



# Conclusions

- Ice sheet SMB is not constant in time or space (also not in the past)
- Greenland SMB decrease contributes to recent sea level rise, while Antarctic SMB increase mitigates it (a lot)
- This is a window into the future: Greenland zero SMB threshold and Antarctic SMB increase
- Models are not (yet) able to reproduce observed trends. That said, we need better (longer-term) reconstructions!