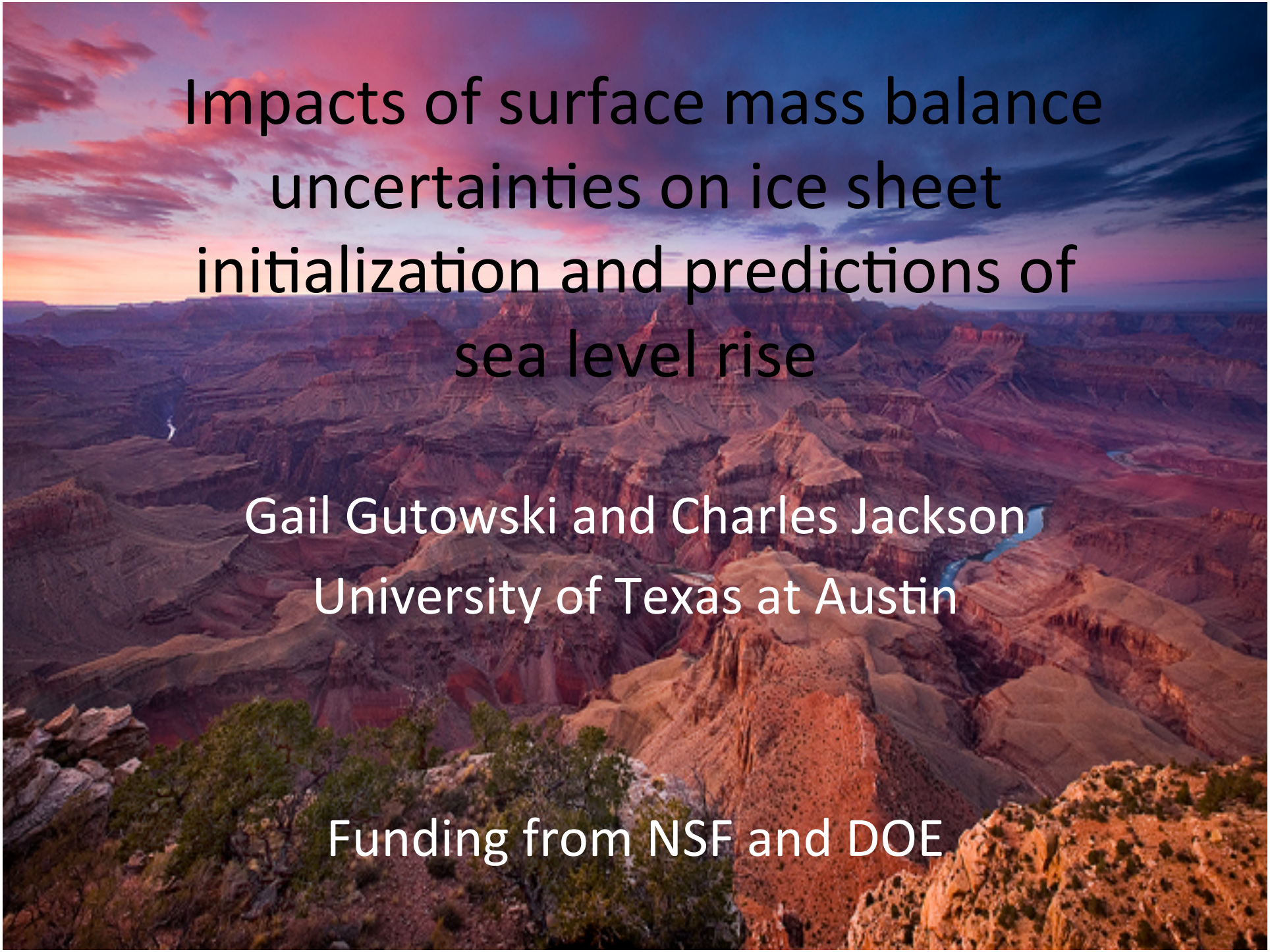

Impacts of surface mass balance uncertainties on ice sheet initialization and predictions of sea level rise

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- Jeremy Fyke (LANL)
- Bill Lipscomb (LANL)
- Nan Rosenbloom (NCAR)
- Bill Sacks (NCAR)

Motivation

- If you are going to test model validity (against observational data), one needs to represent errors in forcings or boundary conditions that will be used in modeling experiments to know what level of model-data agreement is “good enough”.

- Uncertainties in predictions of ice sheet contribution to future sea level rise will depend on compensating errors that exist in the initialization of an ice sheet.

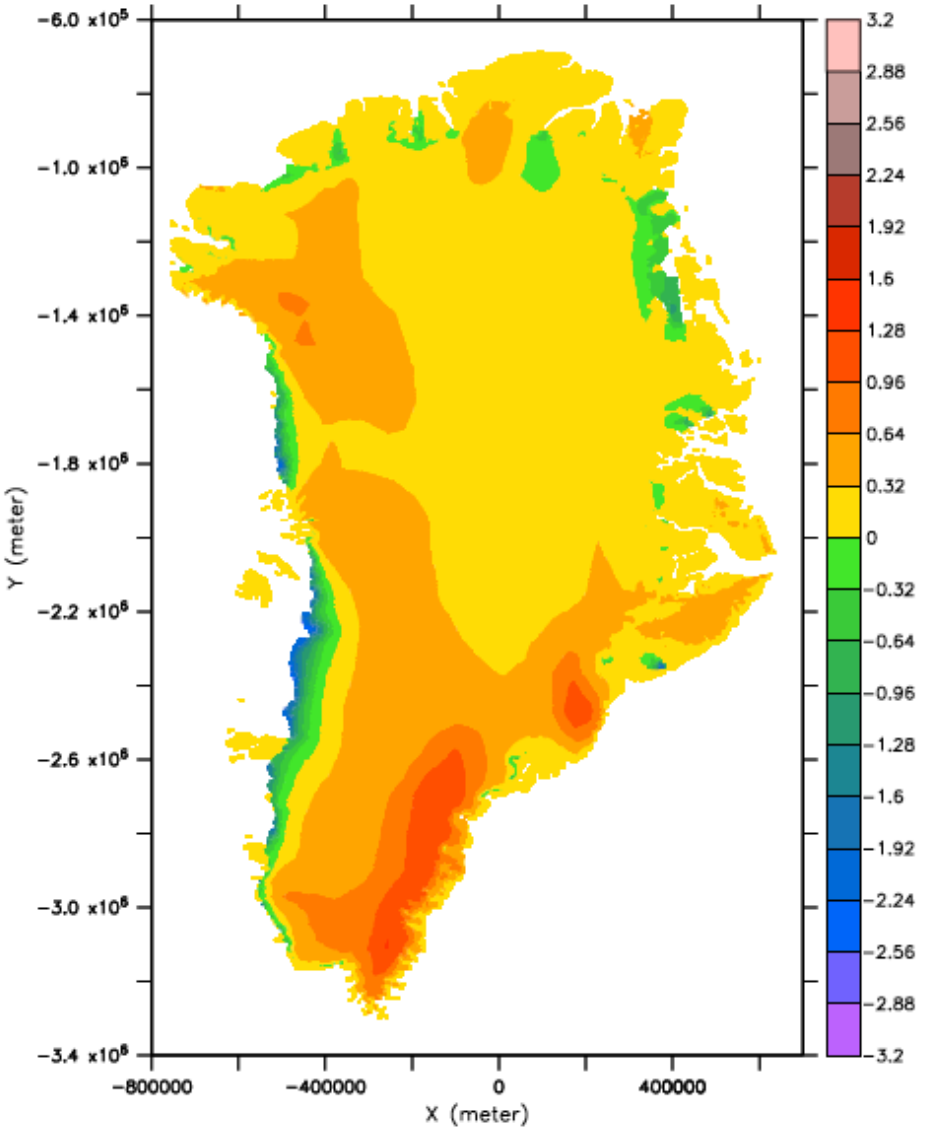
Surface Mass Balance (SMB)

- Unique formulation in CESM based on an energy balance and use of “elevation classes” to compensate for lack of atmospheric model resolution.
- SMB depends on
  - Snow and bare ice albedo
  - Temperature
  - Lapse rate (fixed in our case)
  - Turbulent exchange with atmosphere

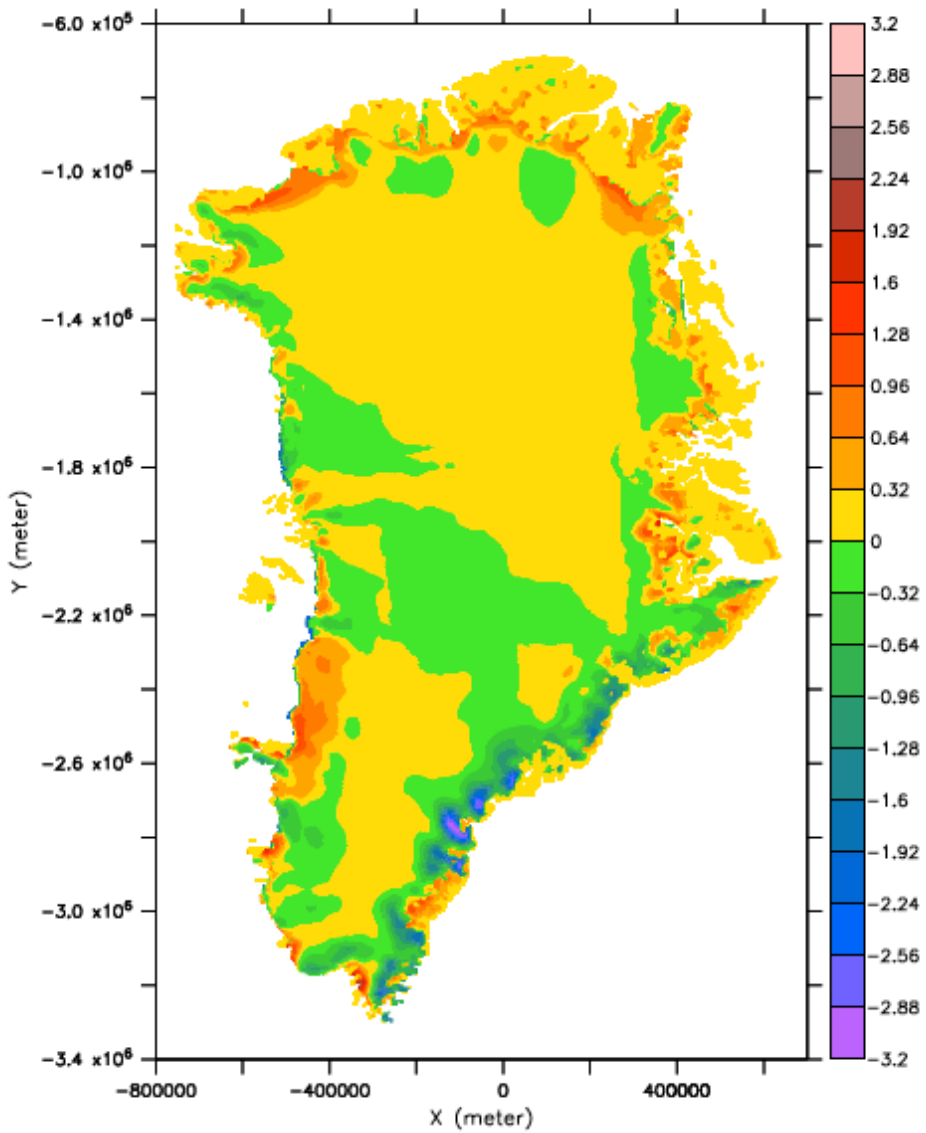
Specific steps

- Obtain 156 years of 3 hourly coupler output from a pre-industrial “MOAR” CCSM4 at 1 degree resolution “FV” CAM4. ~1.5 TB of data.
- Obtain another 250 years of 20th and 21st century CCSM4 output to estimate historical and future SMB. ~2.5 TB of data.
- Run IG compset twice (CLM with glacier land units turned “on” + data atmosphere for 312 model years) to generate equilibrated SMB at 1850. 11,000 cpu hours
- Run TG compset for 10000 years to equilibrate CISM to SMB forcing. 10 cpu hours (cheap!)
- Run IG compset from 1850 to 2100 for another 9000 cpu hours.
- Run TG compset from 1850 to 2100 to get future sea level change, priceless.

Surface Mass Balance within CESM



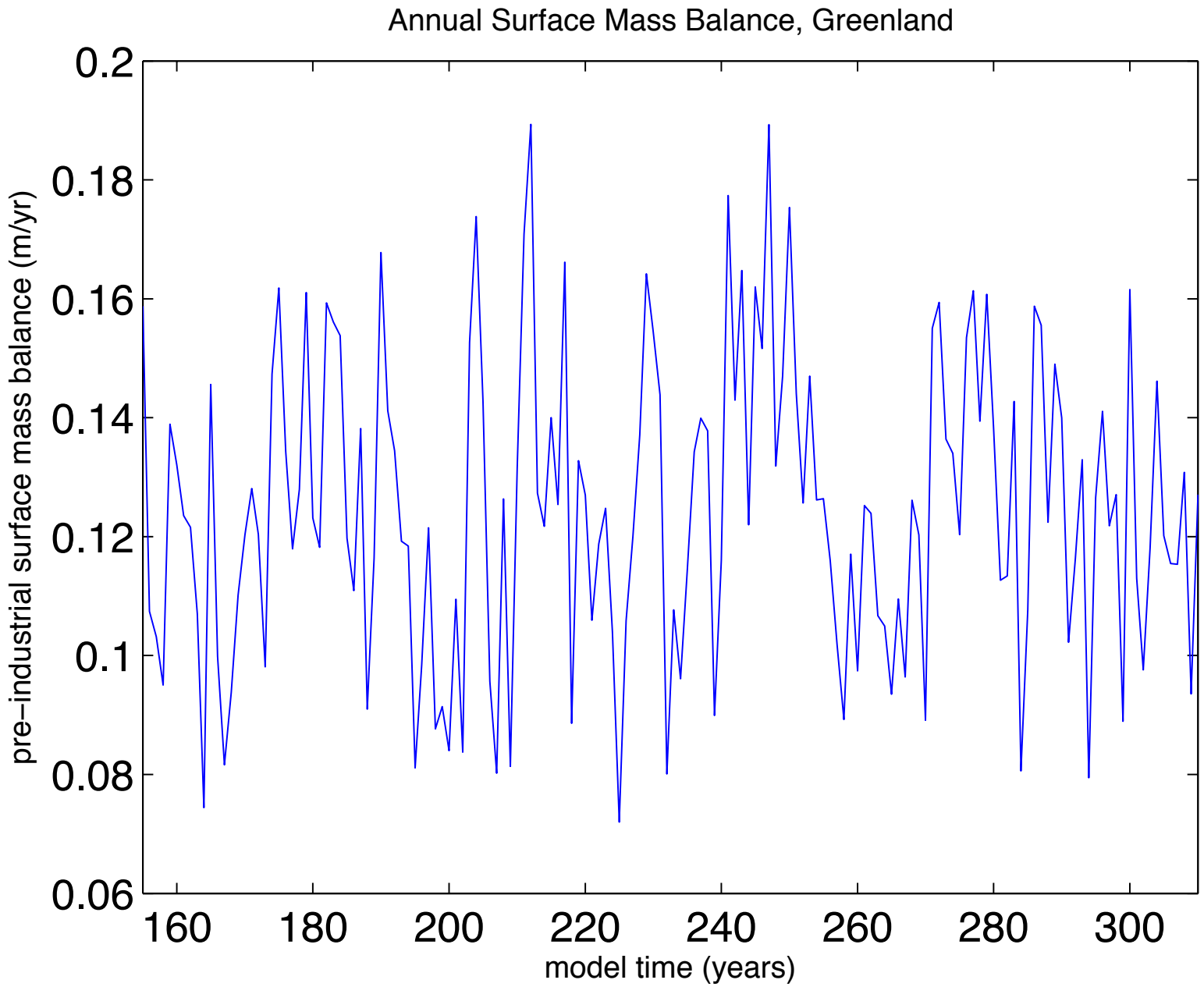
Difference to RACMO target

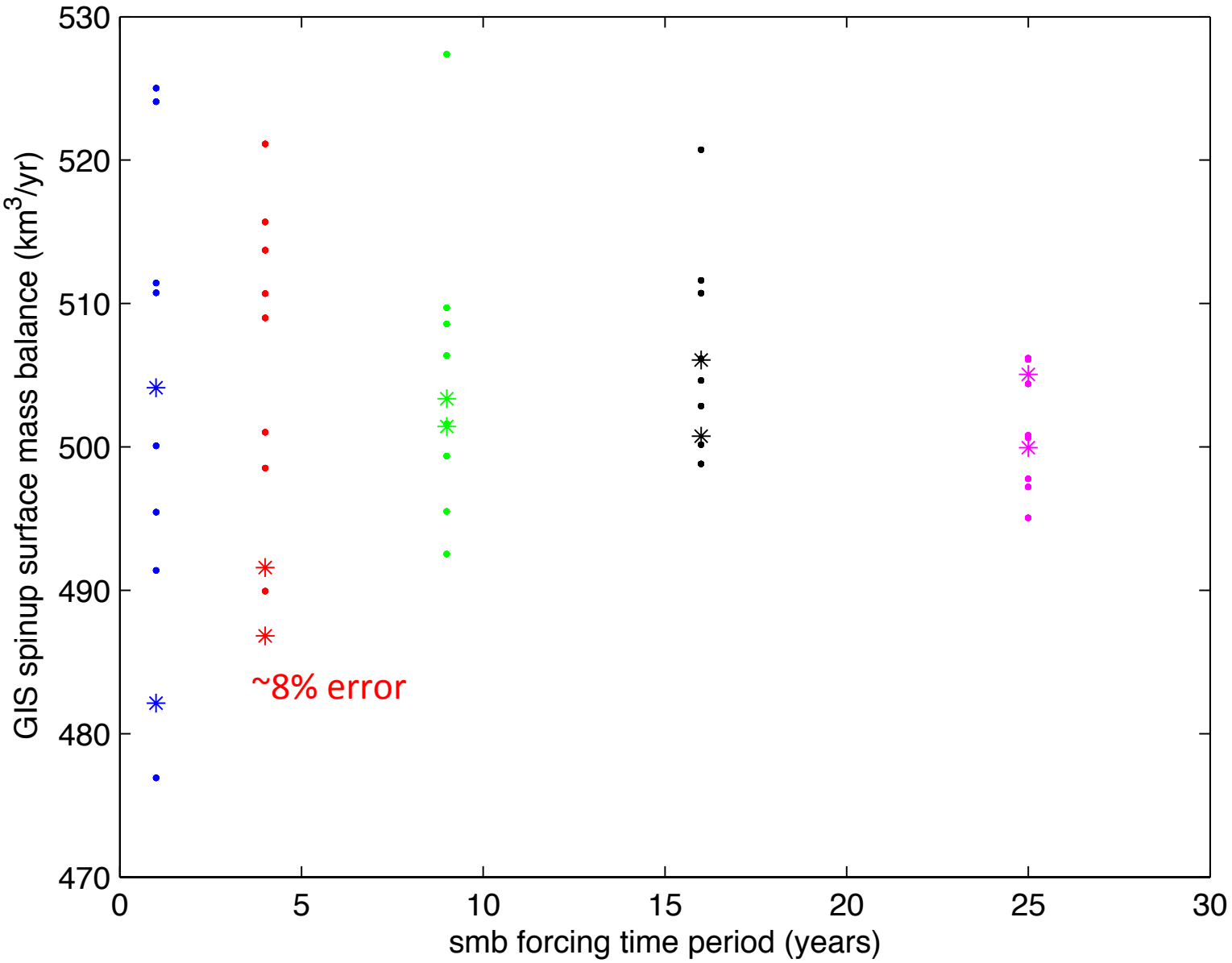


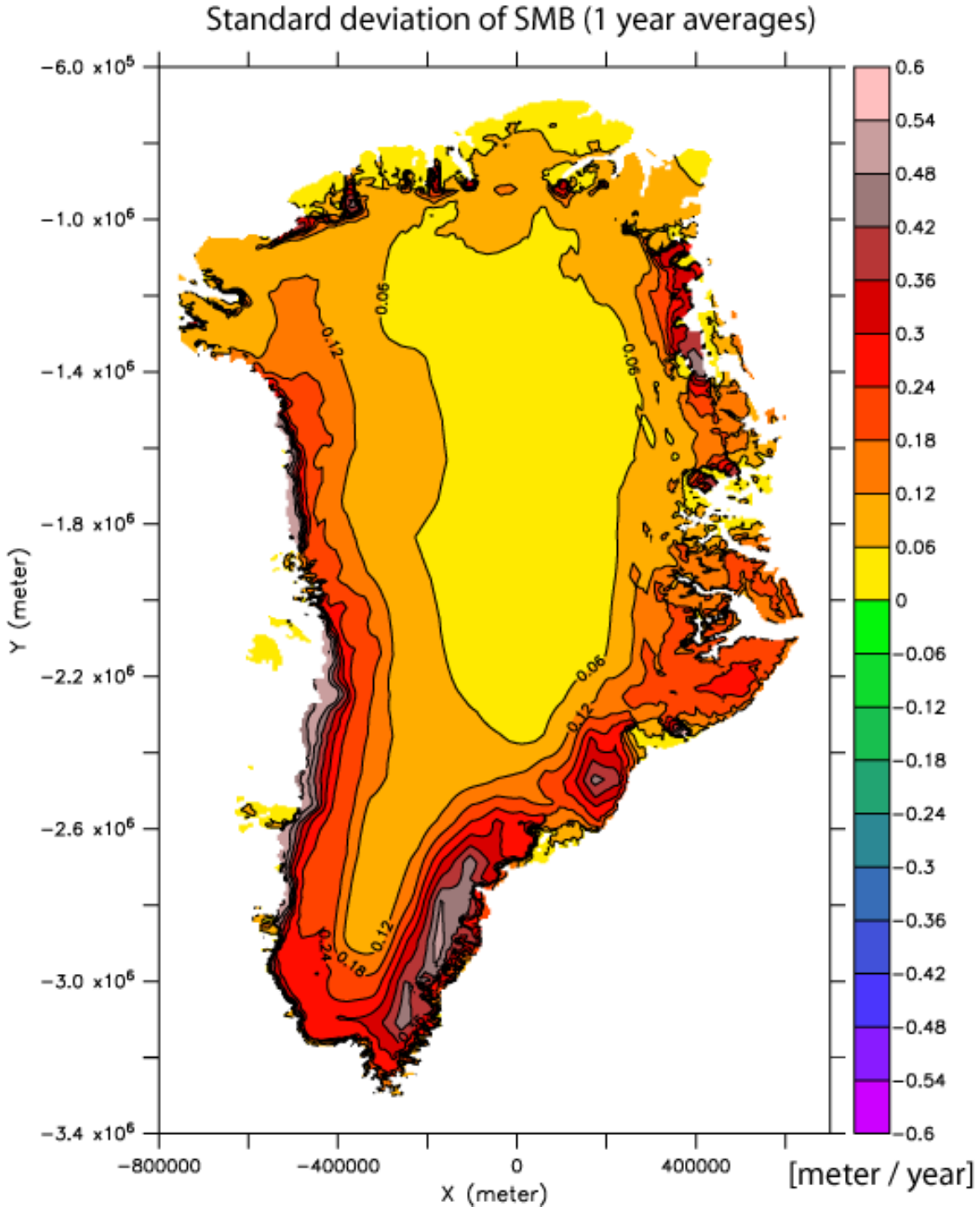
Regionally CESM is has surface mass balance errors on the order of 1 meter/year

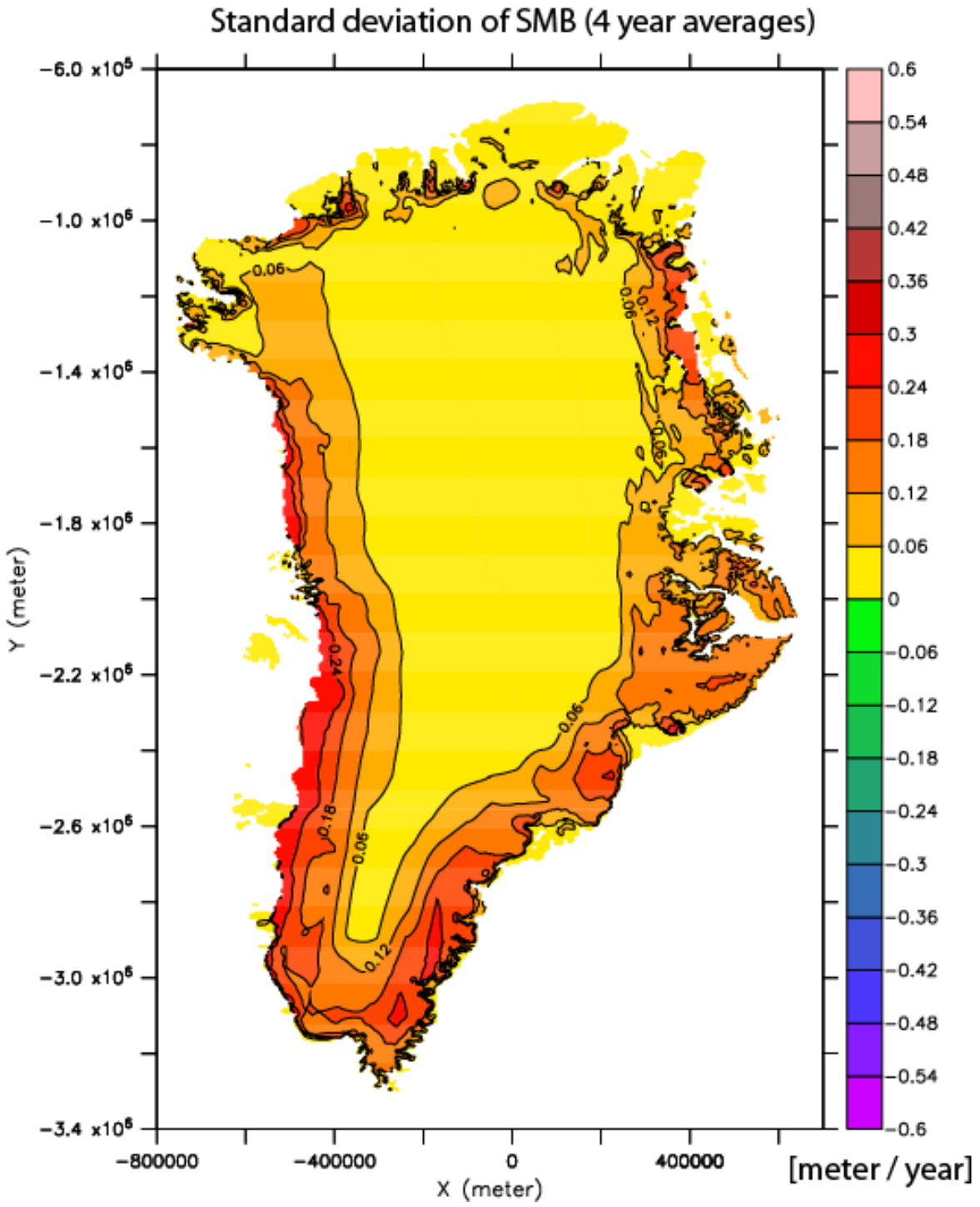
What level of error matters?

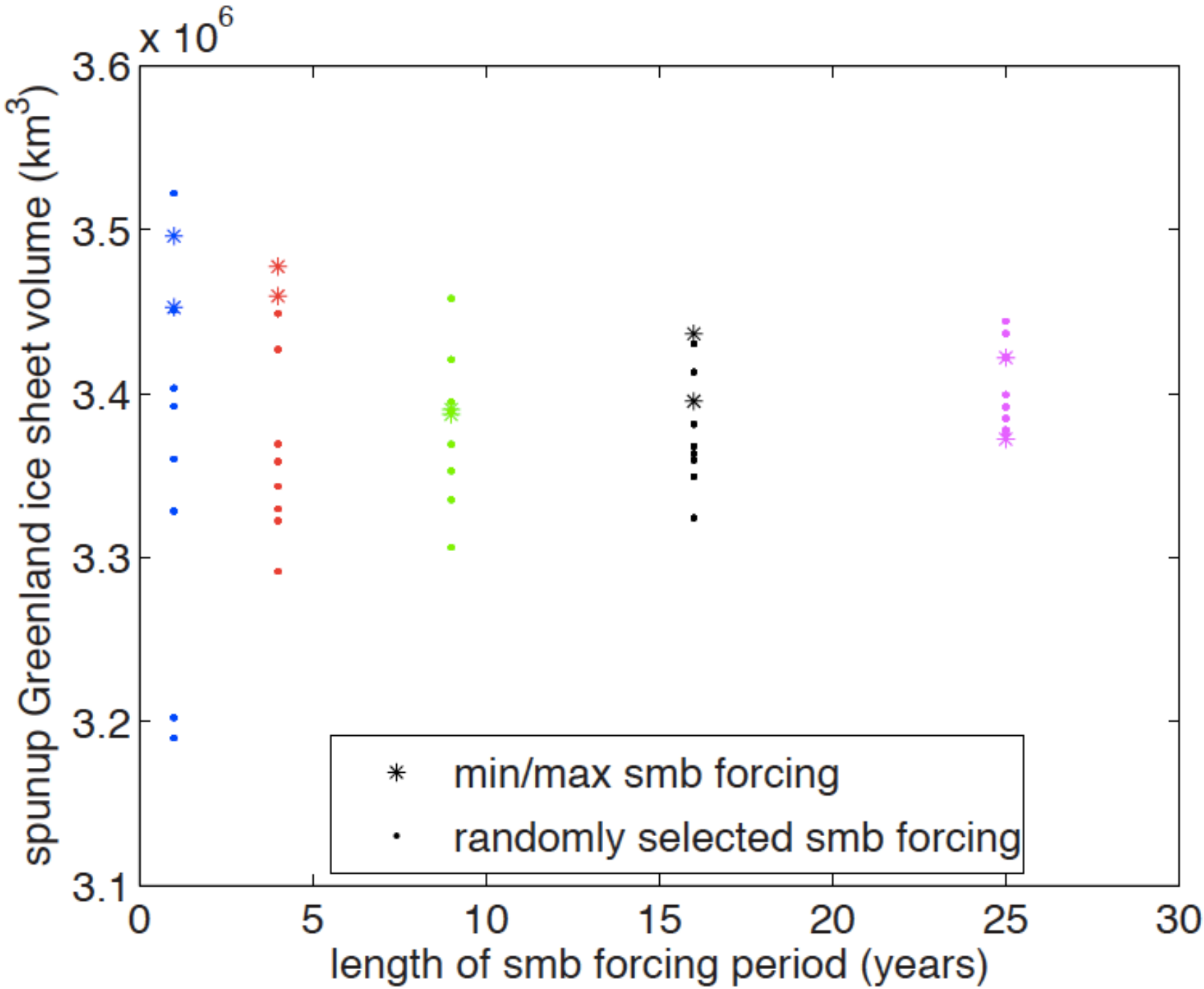
- Simulate errors in SMB by using different length averages (e.g. 1, 4, 8, 16, 25 years). 10 samples of each.
- Find the equilibrated ice sheet to each SMB field (10kyr run of CISM)
- Force with projected climate change forcing (RCP 8.5)


Annual Surface Mass Balance, Greenland
pre−industrial surface mass balance (m/yr)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
160
180
200
220
240
260
280
300
model time (years)

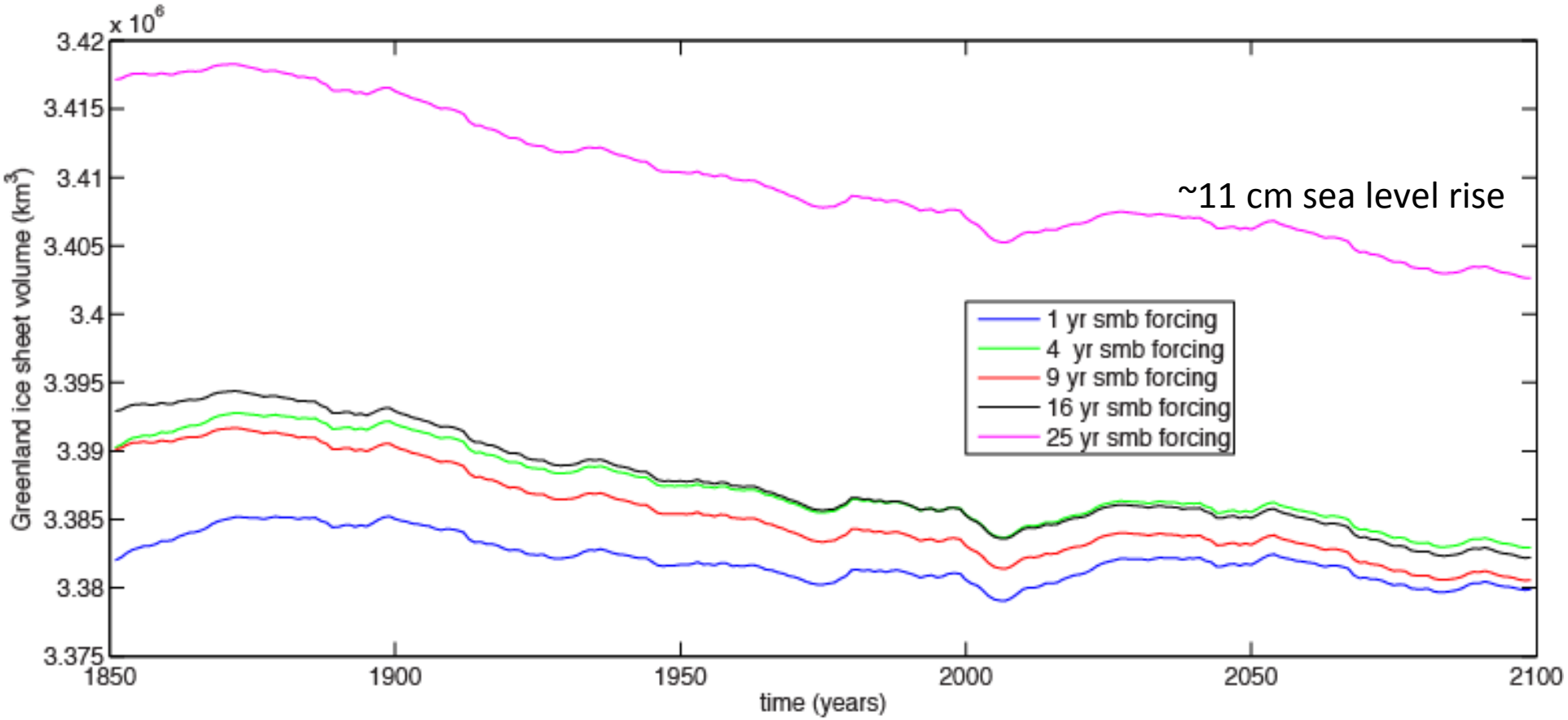

530
520
510
500
490
480
470
0
5
10
15
20
25
30
GIS spinup surface mass balance (km3/yr)
smb forcing time period (years)
~8% error


Standard deviation of SMB (1 year averages)
−6.0 x10^5
−1.0 x10^6
−1.4 x10^6
−1.8 x10^6
−2.2 x10^6
−2.6 x10^6
−3.0 x10^6
−3.4 x10^6
Y (meter)
−800000
−400000
0
400000
X (meter)
0.6
0.54
0.48
0.42
0.36
0.3
0.24
0.18
0.12
0.06
0
−0.06
−0.12
−0.18
−0.24
−0.3
−0.36
−0.42
−0.48
−0.54
−0.6
[meter / year]

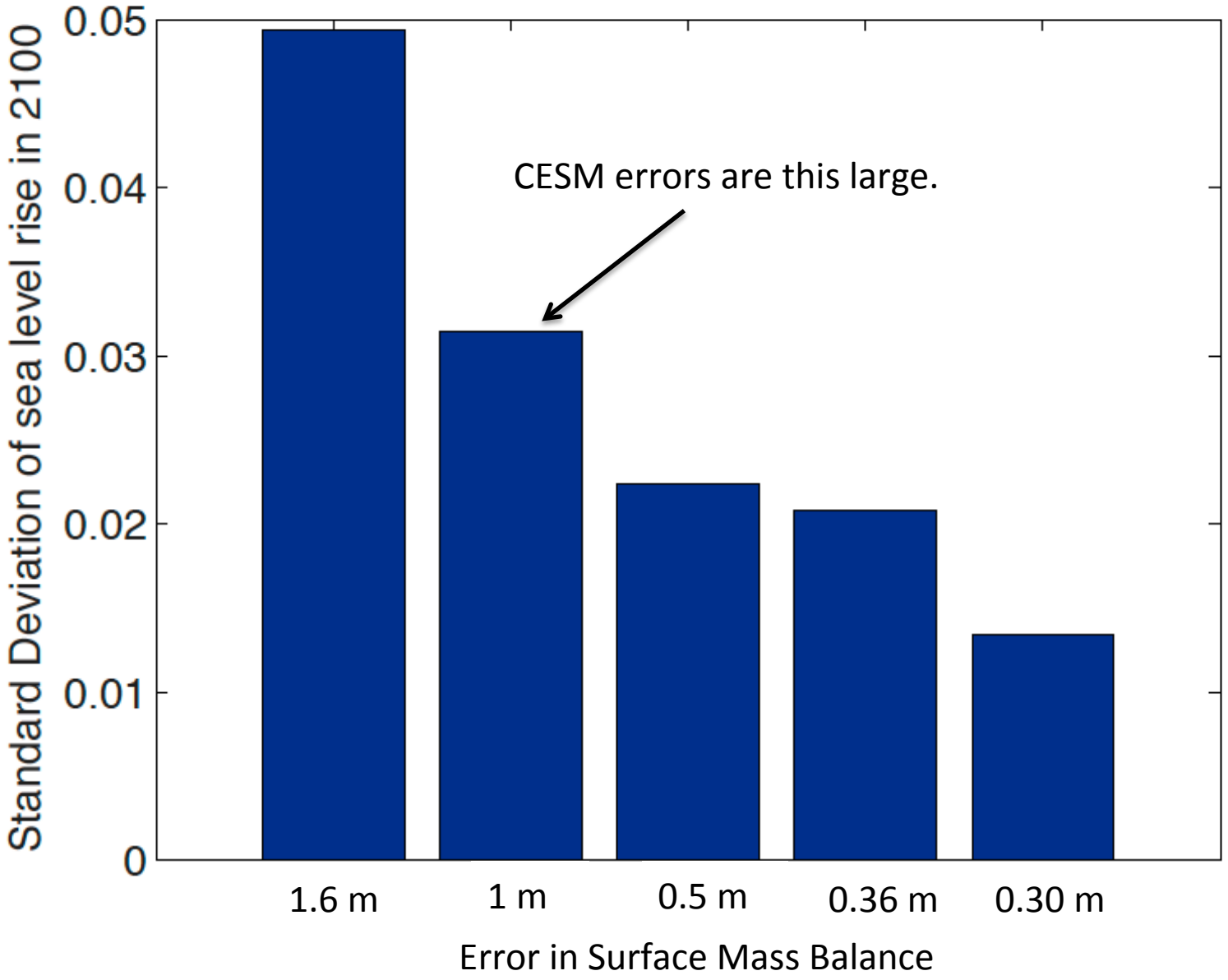

Standard deviation of SMB (4 year averages)
−6.0 x10^5
−1.0 x10^5
−1.4 x10^5
−1.8 x10^5
−2.2 x10^5
−2.6 x10^5
−3.0 x10^5
−3.4 x10^5
Y (meter)
−800000
−400000
0
400000
X (meter)
0.6
0.54
0.48
0.42
0.36
0.3
0.24
0.18
0.12
0.06
0
−0.06
−0.12
−0.18
−0.24
−0.3
−0.36
−0.42
−0.48
−0.54
−0.6
[meter / year]


x 10^6
3.6
3.5
3.4
3.3
3.2
3.1
spunup Greenland ice sheet volume (km^3)
0
5
10
15
20
25
30
length of smb forcing period (years)
min/max smb forcing
randomly selected smb forcing

Evolution of Greenland ice sheet volume



Errors in surface mass balance produce >100% uncertainty in Greenland contribution to sea level at 2100.



conclusions

Differences between CESM surface mass balance and RACMO “observations” are about 1 m/year. We estimate an 11 cm Greenland contribution to sea level given the RCP8.5 forcing. There is a 2-sigma uncertainty of plus or minus 6 cm.