

# A 21st century warming threshold for irreversible Greenland ice sheet mass loss

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LIWG winter meeting 2020



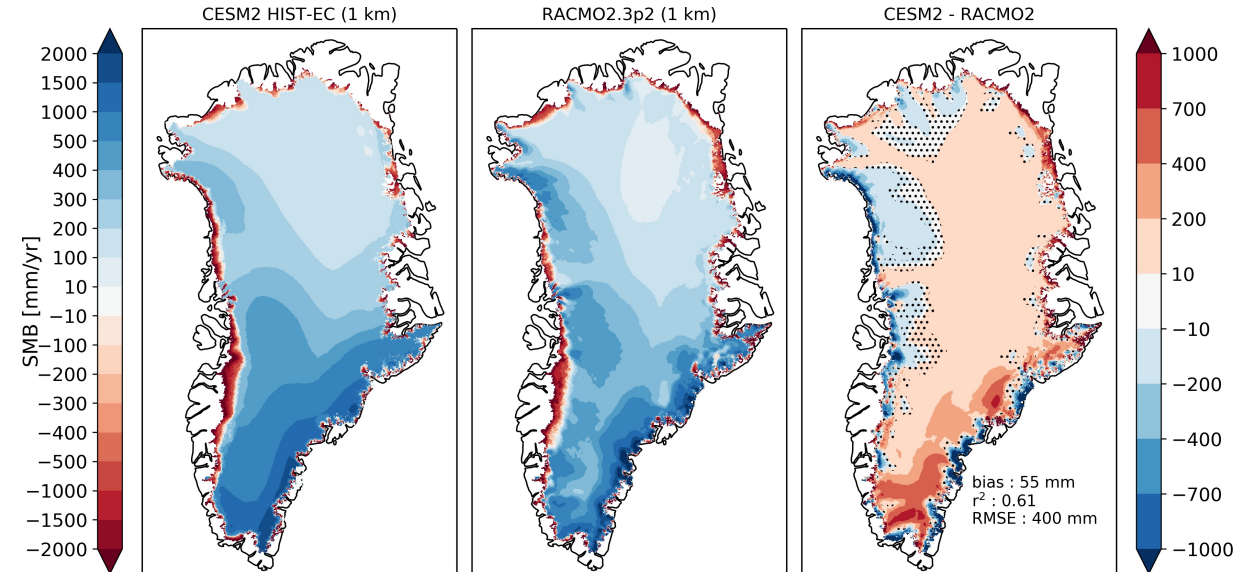
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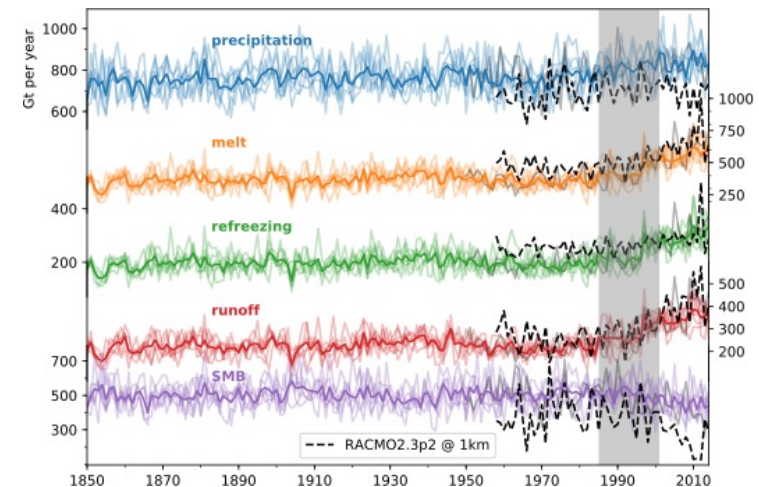
# Greenland SMB in CESM2

- paper accepted in JGR Earth Surface  
<https://doi.org/10.1029/2019JF005318>
- surface energy balance
- surface mass balance
- downscaled using elevation classes



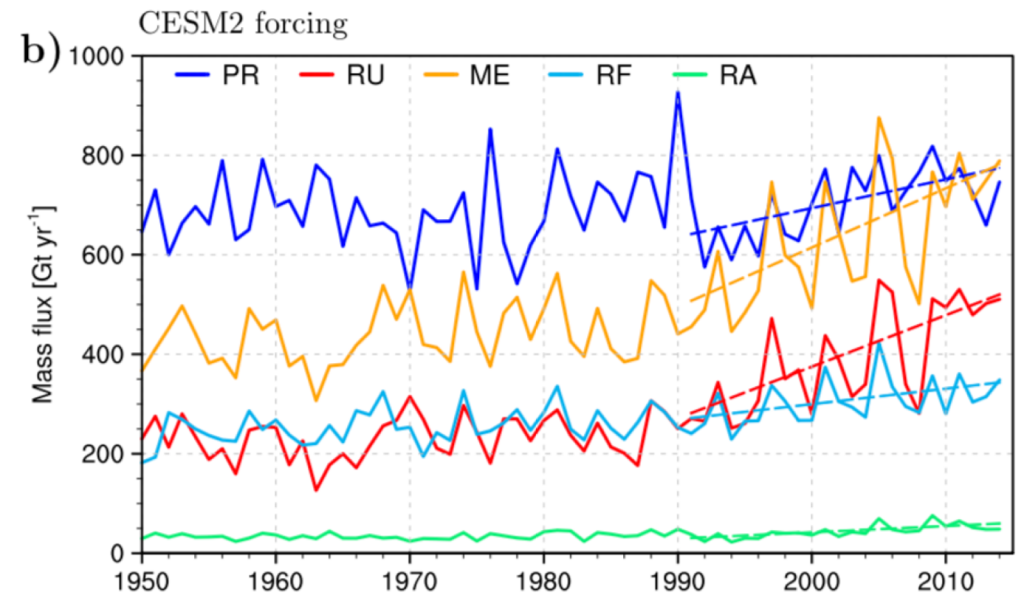
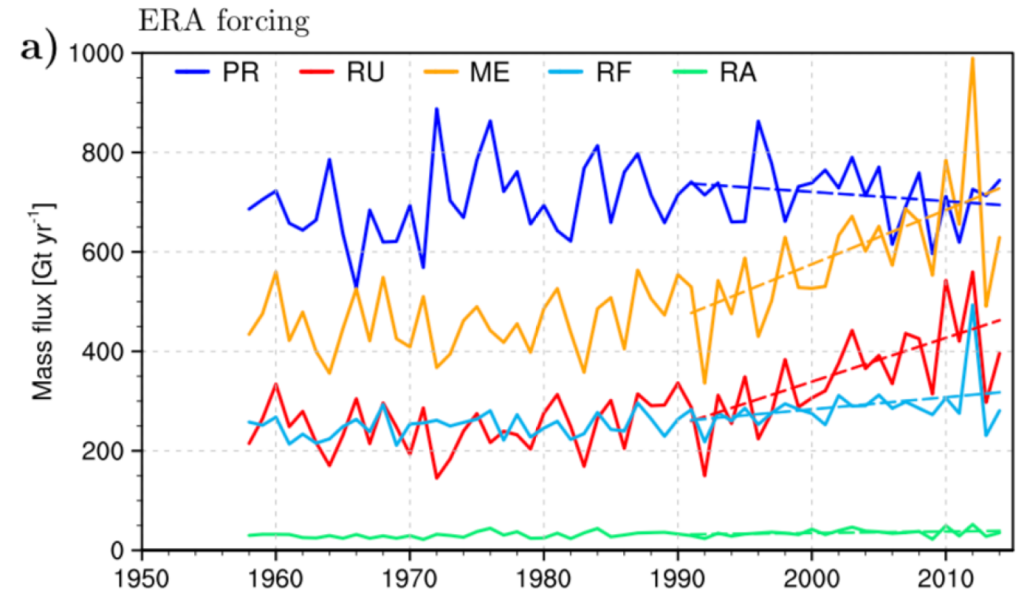
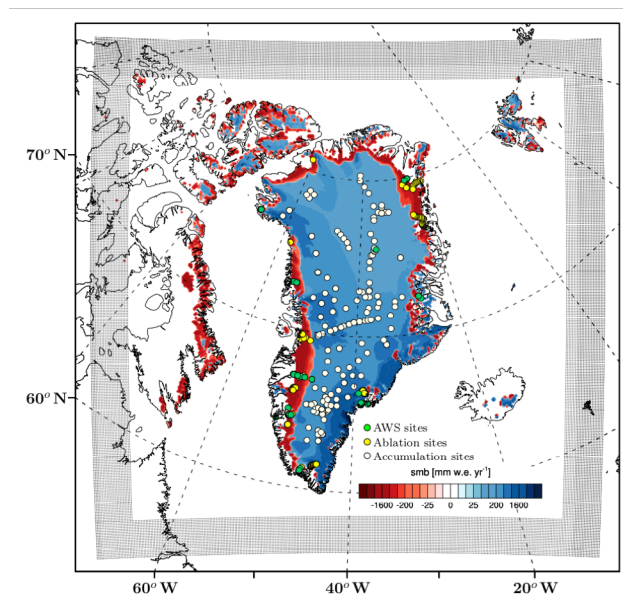
key points

- The simulation of GrIS climate and SMB in CESM2 compares well to reanalyses and RACMO2 data
- GrIS-integrated melt, runoff, and refreezing in CESM2 are bracketed by RACMO2 estimates at 11 and 1 km
- A break point in SMB is identified at year  $1993 \pm 8$ , driven by increased melt and runoff



# downscaling with RACMO

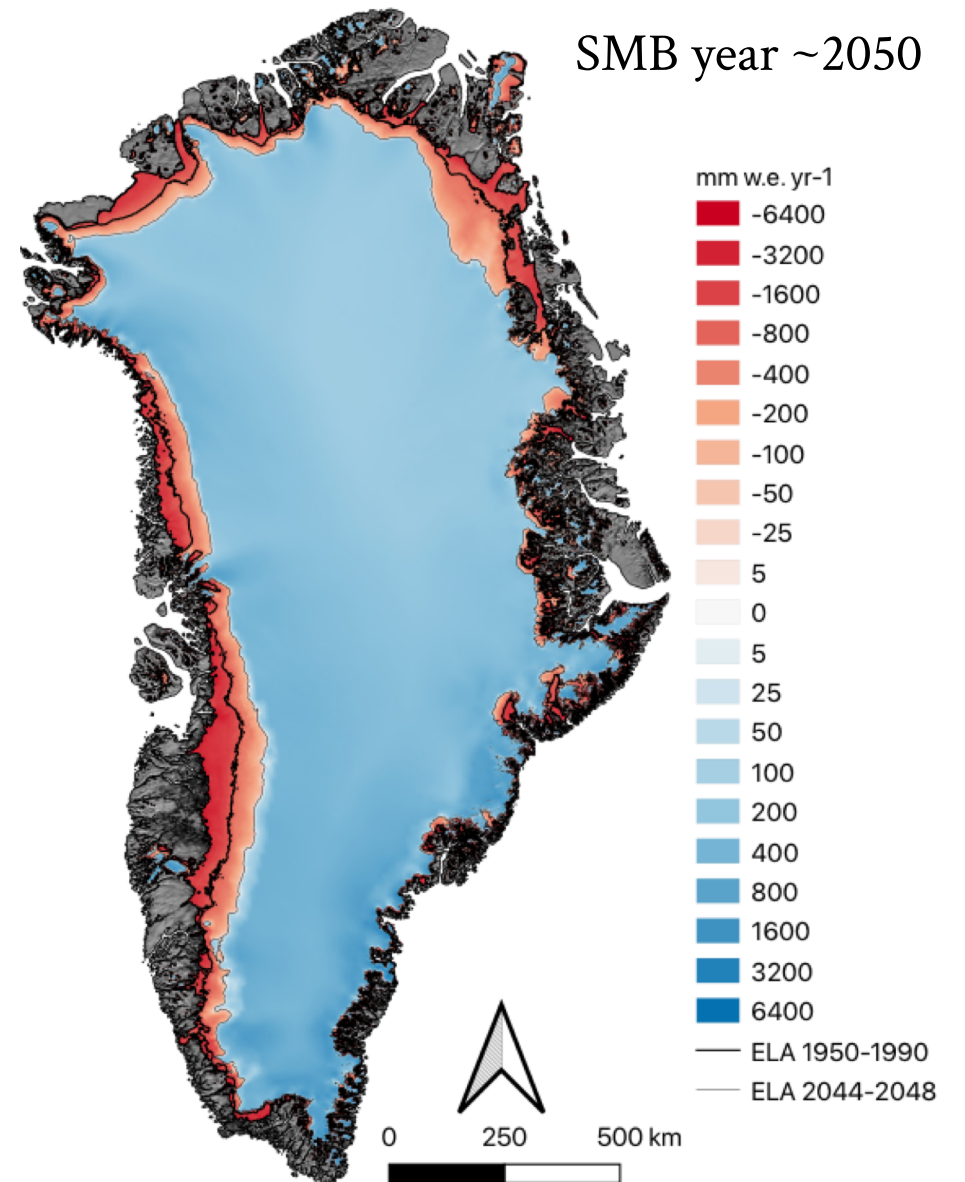
- paper led by Brice Noël in TCD  
<https://www.the-cryosphere-discuss.net/tc-2019-209/>
- 11 km resolution
- statistical downscaling to 1 km
- remarkable match in recent past trends



# RACMO future simulation 2015-2100

- high emission scenario, SSP5-85
- single run (computational constraints)
- research question:

Can we identify a **tipping point** for irreversible mass loss?





# “irreversible” GrIS mass loss threshold

- $SMB = 0$  in 5 year running mean
- $MB = SMB - D$  with  $D \geq 0$ , so  $MB \leq 0$



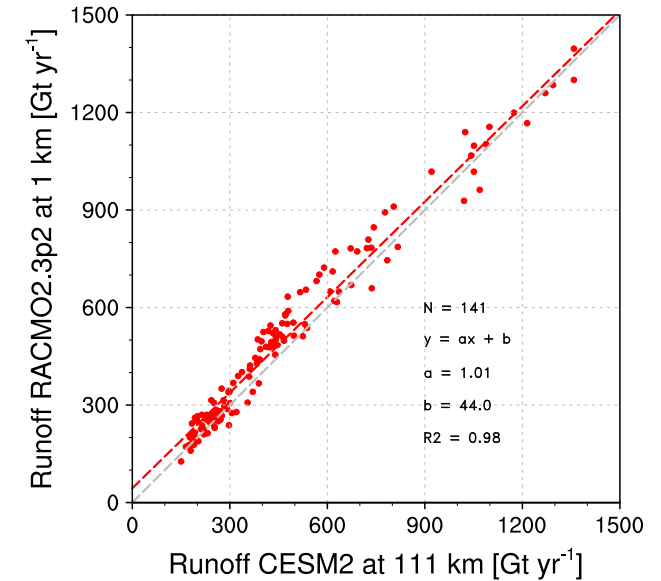
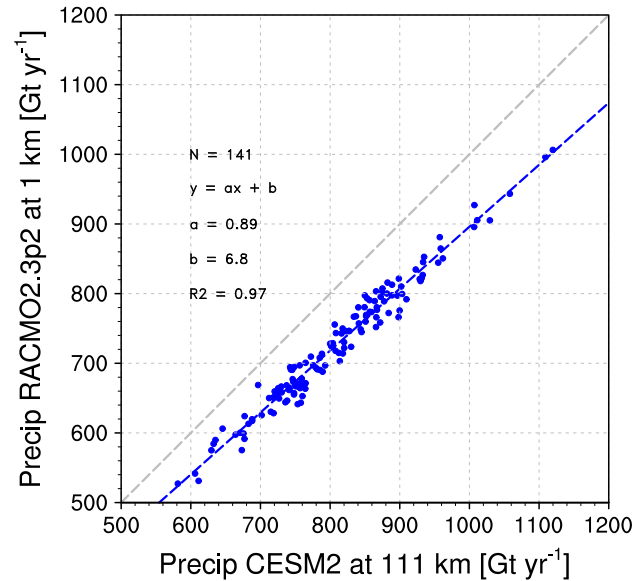
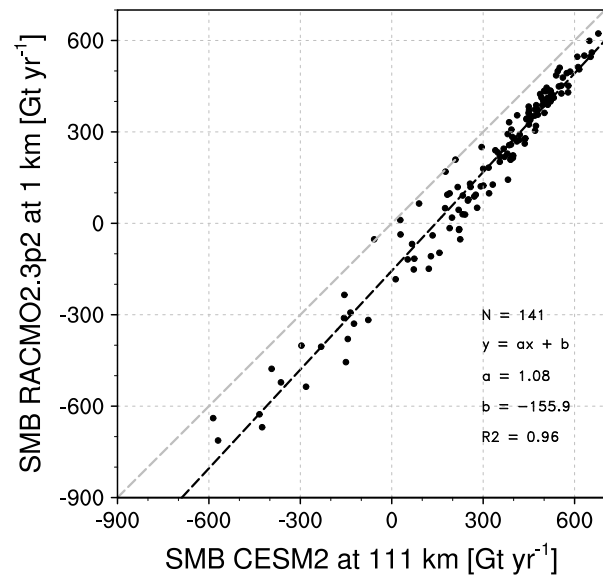
SMB



D

# 'correction method' based on SSP5-85 run

- per SMB component
- largest correction in precipitation

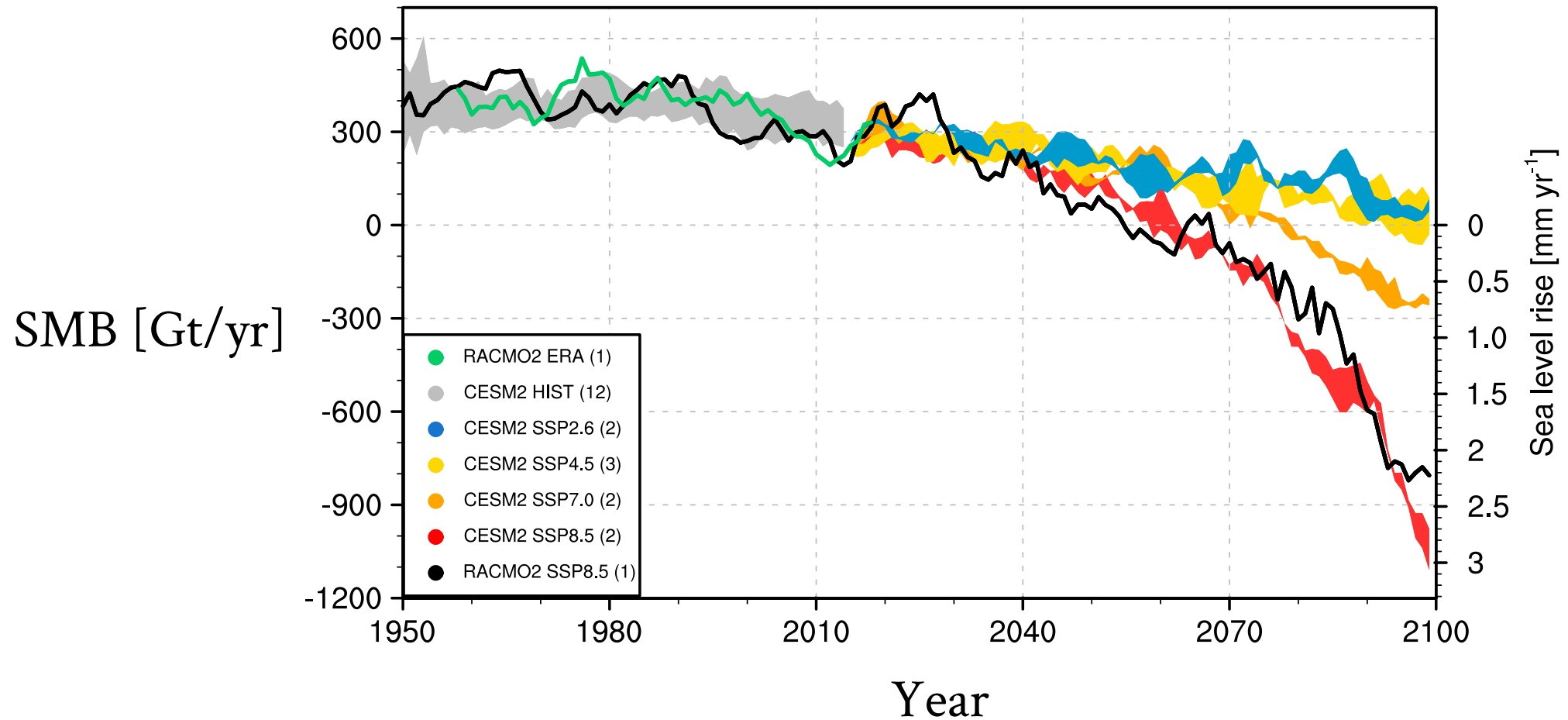




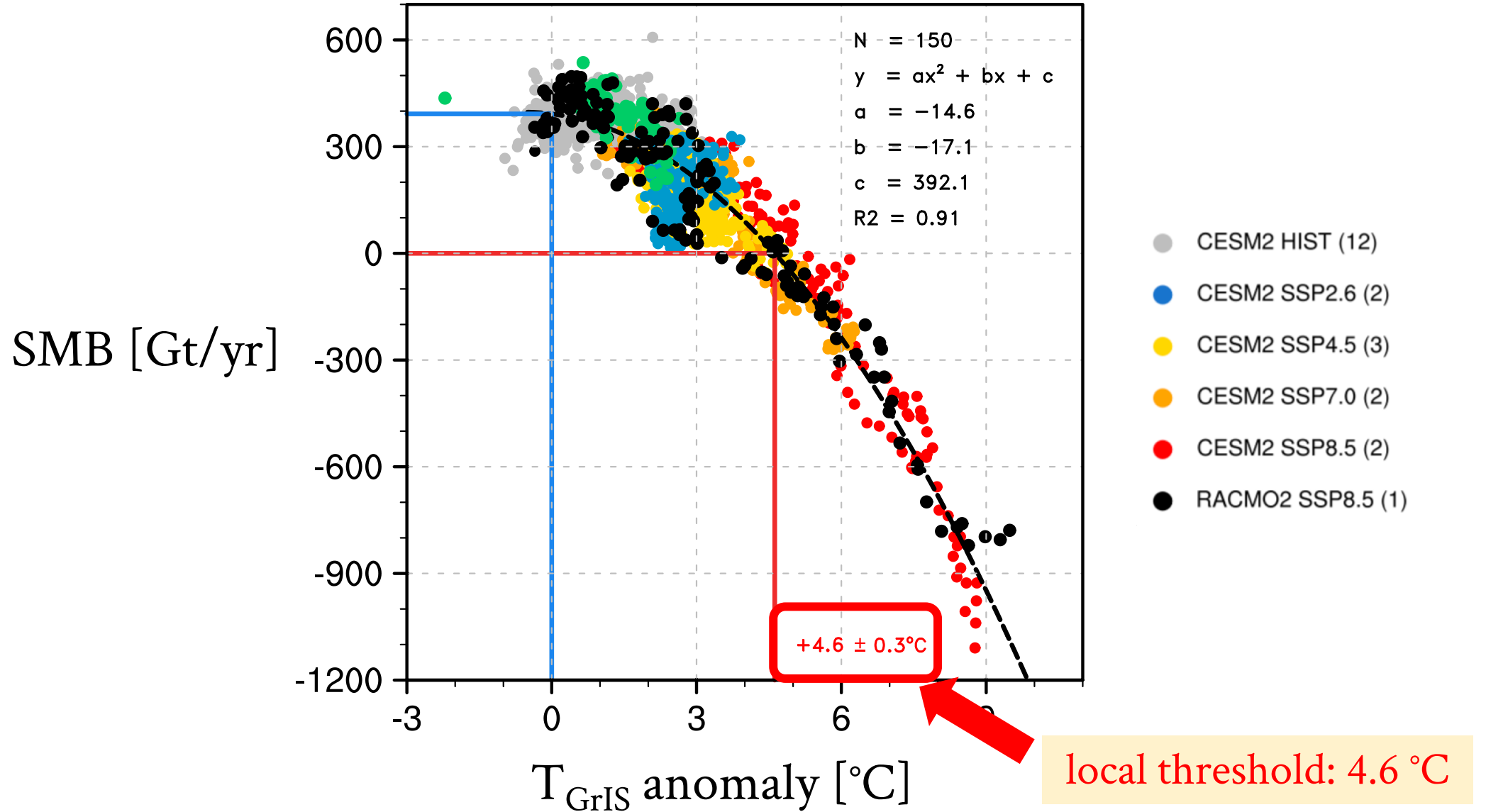
# RCM-corrected time series

with the correction method of previous slide

$$\text{SMB} = \text{PR}_{\text{corr}} - \text{RU}_{\text{corr}} - \text{SU}_{\text{corr}}$$

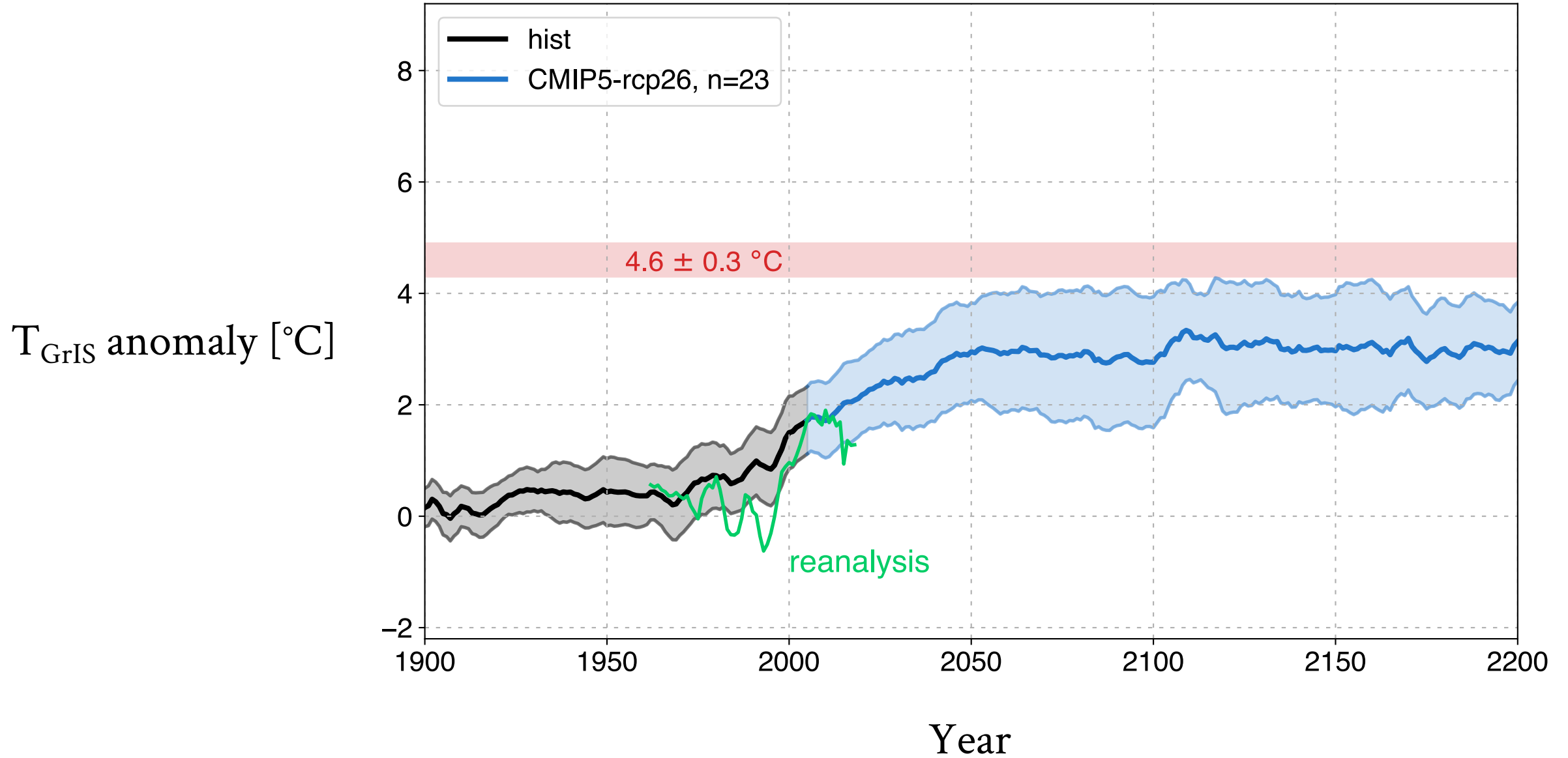


# regression to local temperature relative to 1850-1899

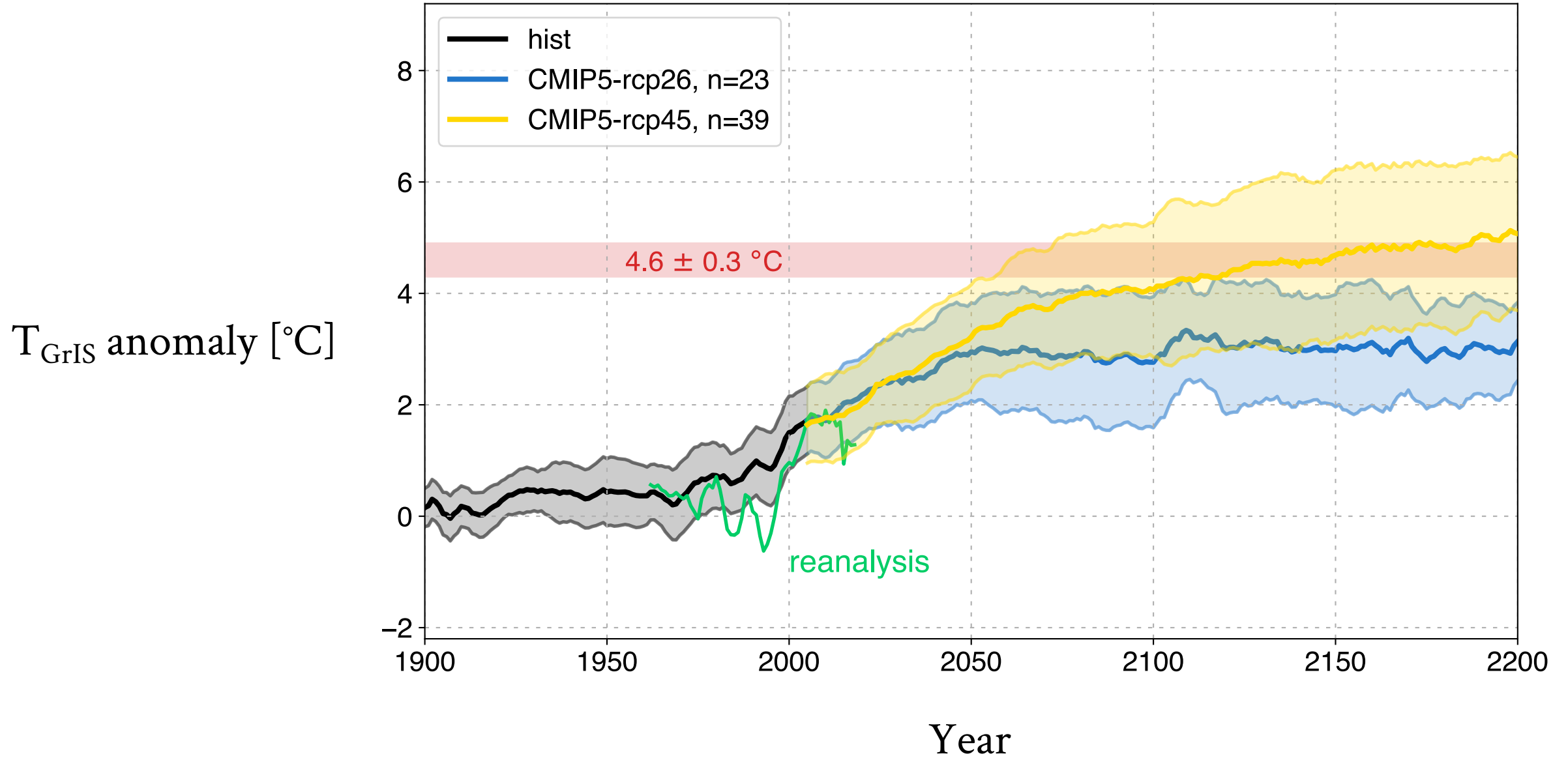




# CMIP5

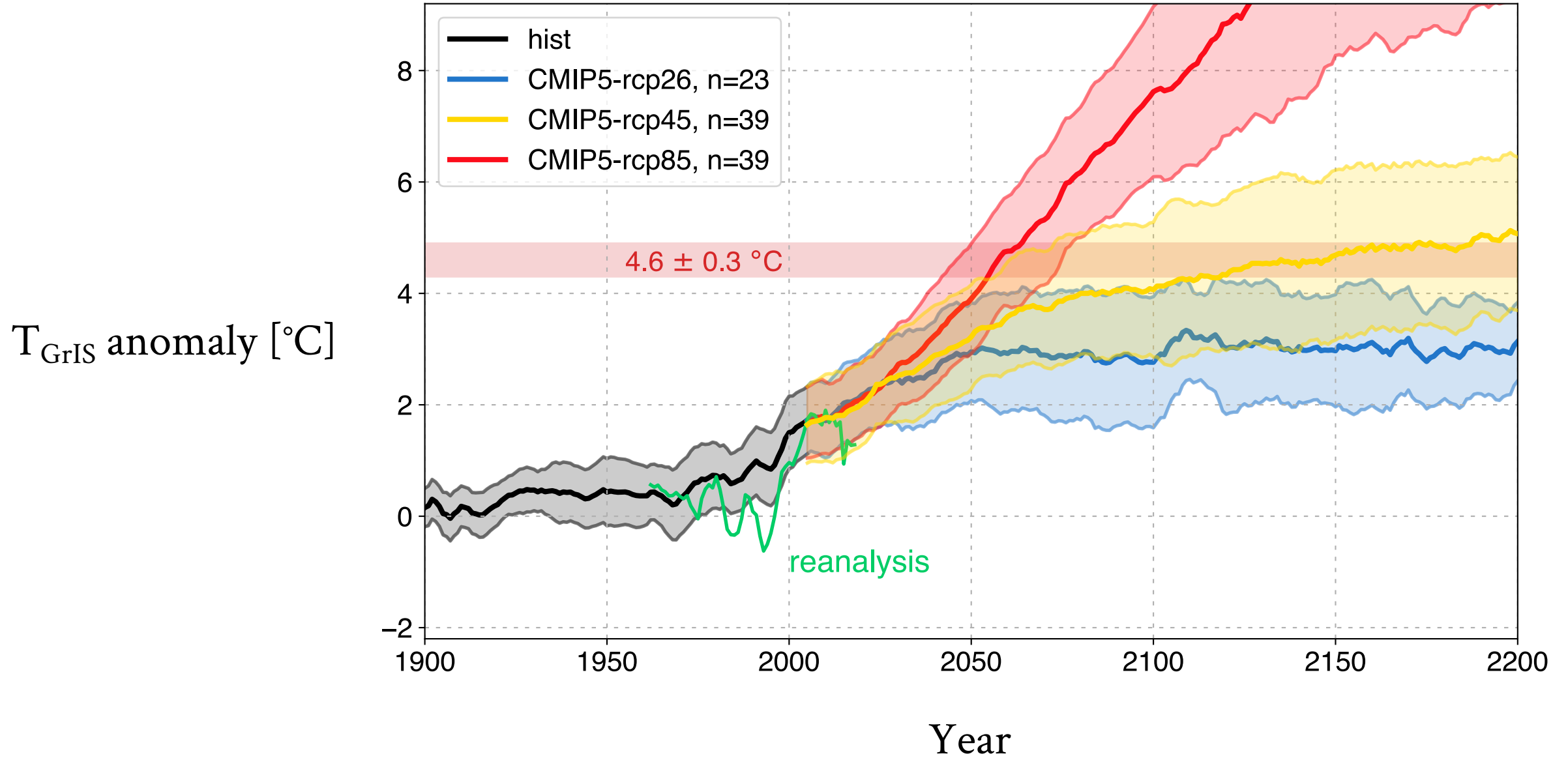


# CMIP5

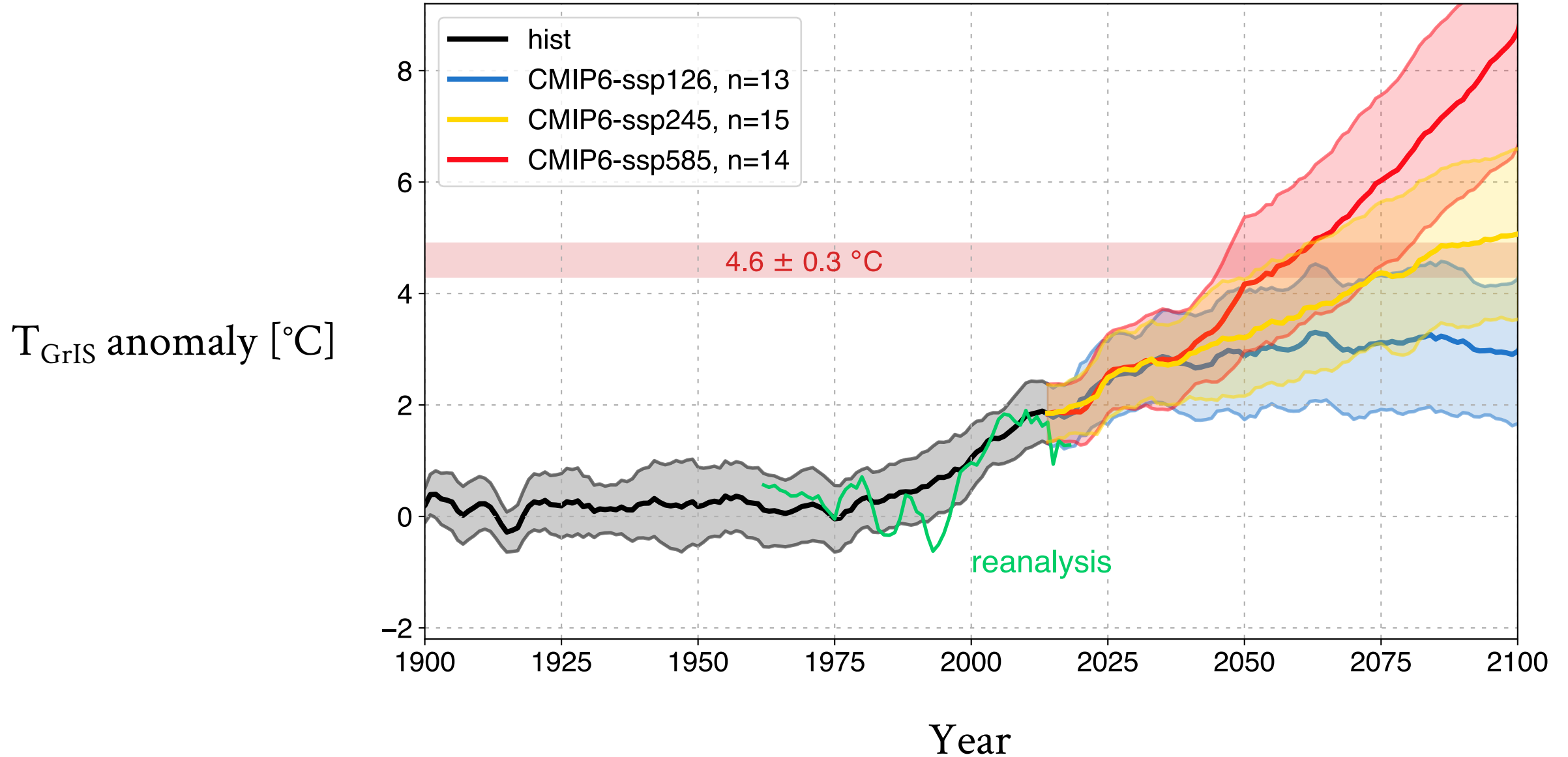




# CMIP5



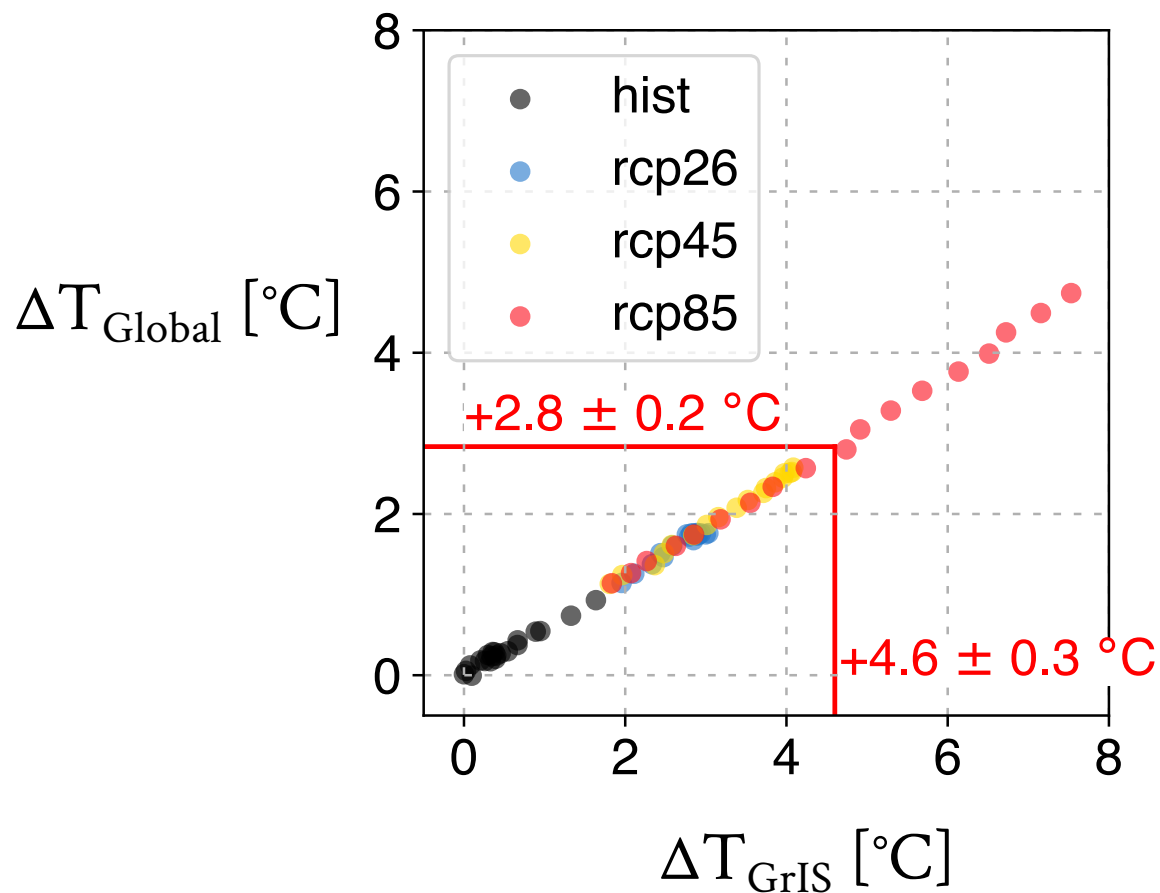
# CMIP6 only until 2100



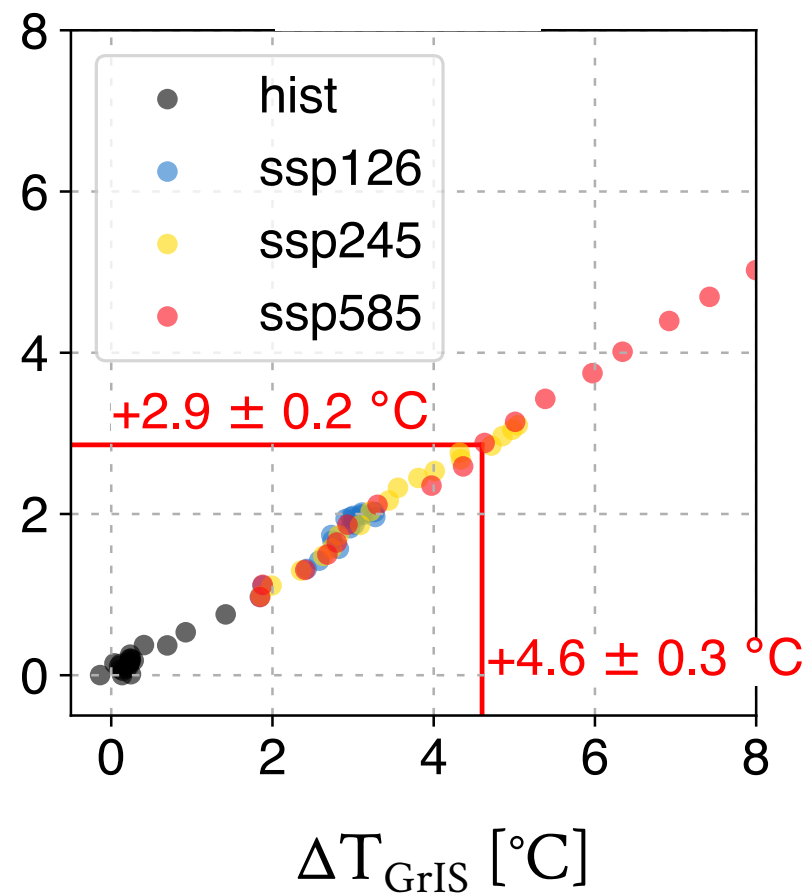
# 2.8 °C

## global temperature threshold

### CMIP5

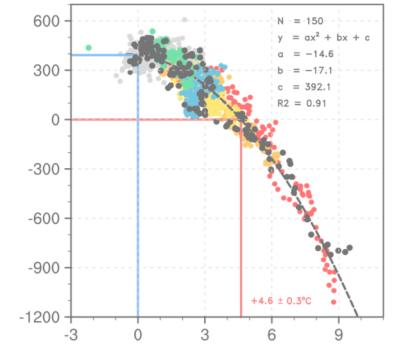


### CMIP6



# reconstructed SMB for all CMIP models

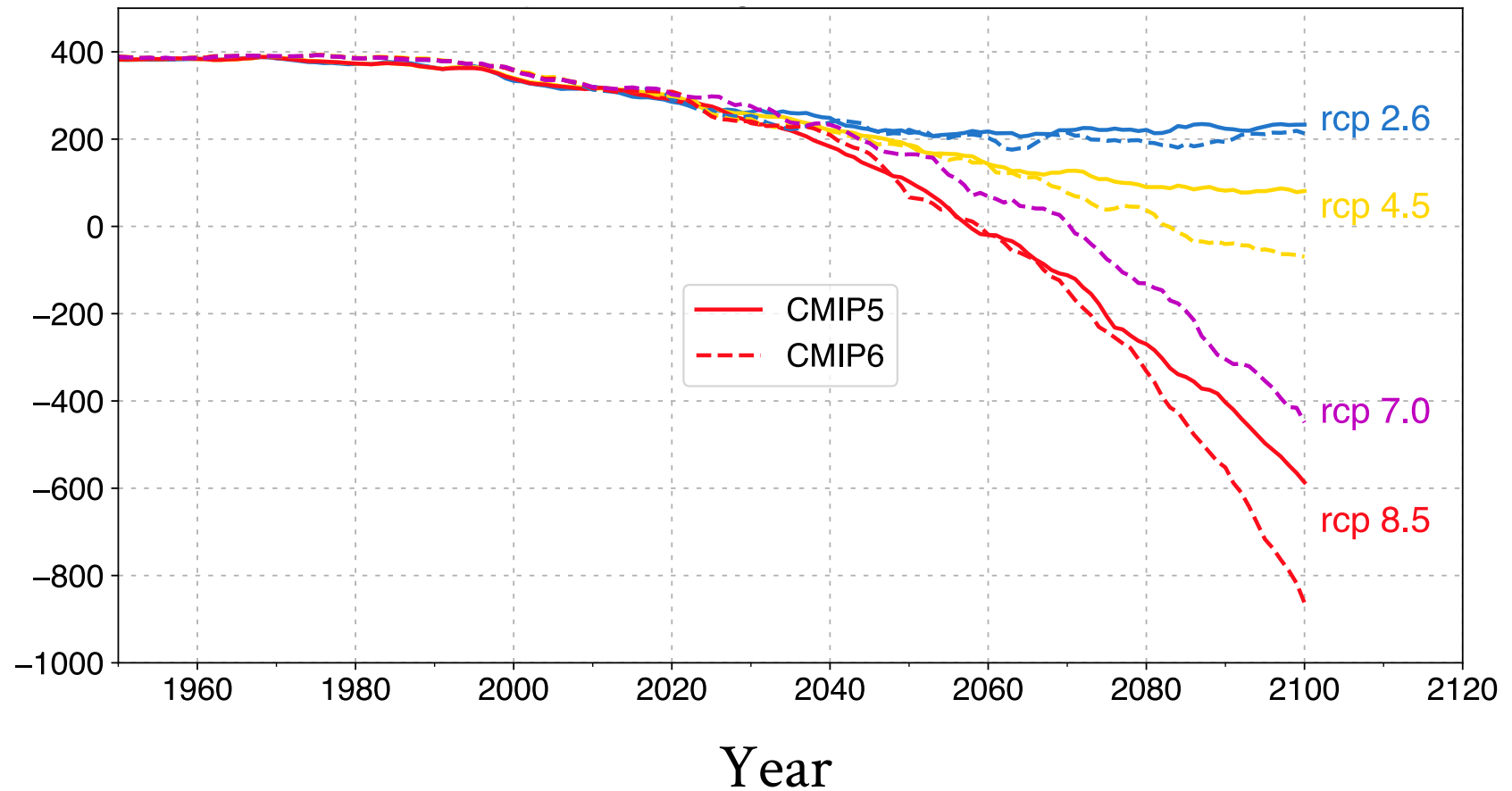
using the quadratic relationship from earlier



$$\text{SMB} = a \cdot x^2 + b \cdot x + c$$

with  $x = \Delta T_{GrIS}$

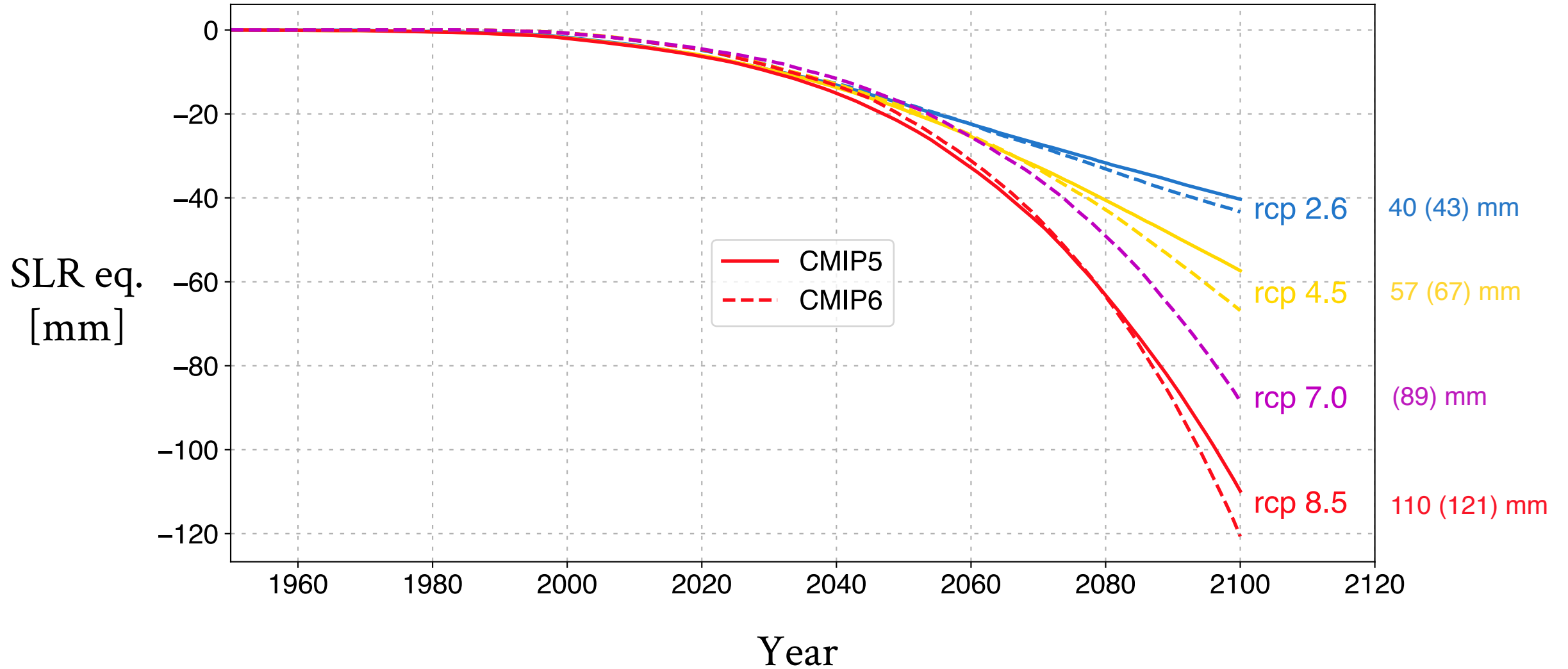
SMB  
[Gt year<sup>-1</sup>]





# sea level rise contribution

## GrIS SMB only



# sea level rise contribution

## GrIS SMB only

scenario	IPCC AR5 table 13.5	our study CMIP5	our study CMIP6
rcp 2.6	30 [10-70]	35	36
rcp 4.5	40 [20-90]	48	55
rcp 8.5	70 [30-170]	85	90

in mm  
2081–2100 relative to 1986–2005

# pros / cons



- SMB from state-of-the-art RCM
- “correction method” to improve temporal sampling
- year of crossing is independent of CESM2 model (uses CMIP)
- idem for sea level rise
- simple



- no height feedback
- single transient RCP 8.5 run to inform “correction method”
- CMIP ensemble is unweighted
- added uncertainty from CMIP ensemble spread (needs work)
- **conservative estimate**; likely, irreversible mass loss is reached sooner than SMB=0

# summary

1. method to determine “irreversible mass loss” SMB = 0
2. CESM2 – RACMO transient (RCP 8.5)
  - “correction method” → all CESM2 ScenarioMIP simulations
  - $T_{\text{GrIS}}$  threshold 4.6 °C picked from quadratic fit (figure)
3. CMIP archives to compute:
  - timing
  - global threshold 2.8 °C
  - sea level rise equivalent
4. conservative estimate (no dynamics)

