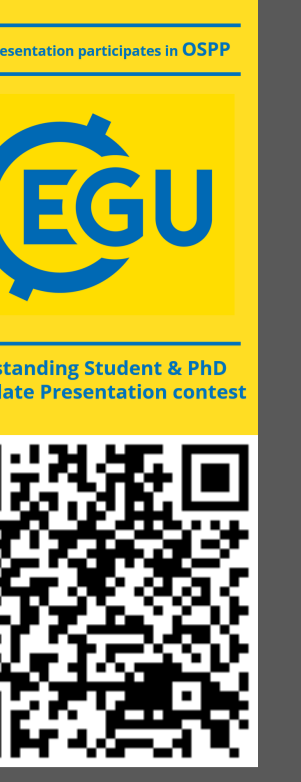


Greenland surface melt outweighs marine discharge over the next three centuries



Coupling framework

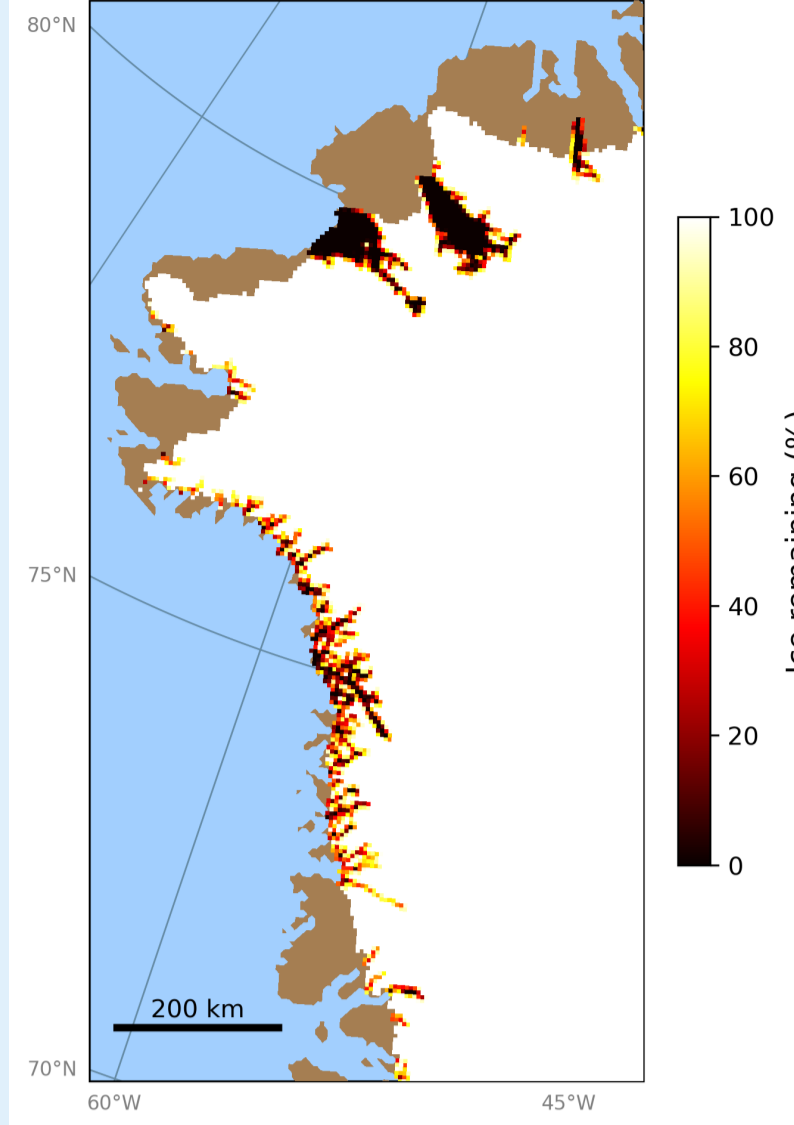
- Fully coupled ice sheet–regional climate model simulations until 2300 with the MAR and GISM models forced by IPSL-CM6A-LR under SSP5-8.5
- Outlet glacier retreat included through an empirical retreat parametrization (Slater et al., 2019)
- Simulations with both atmospheric and oceanic forcing vs single-forced experiments, to disentangle importance of surface mass balance versus marine discharge

Following Slater et al. (2019) retreat is calculated as:

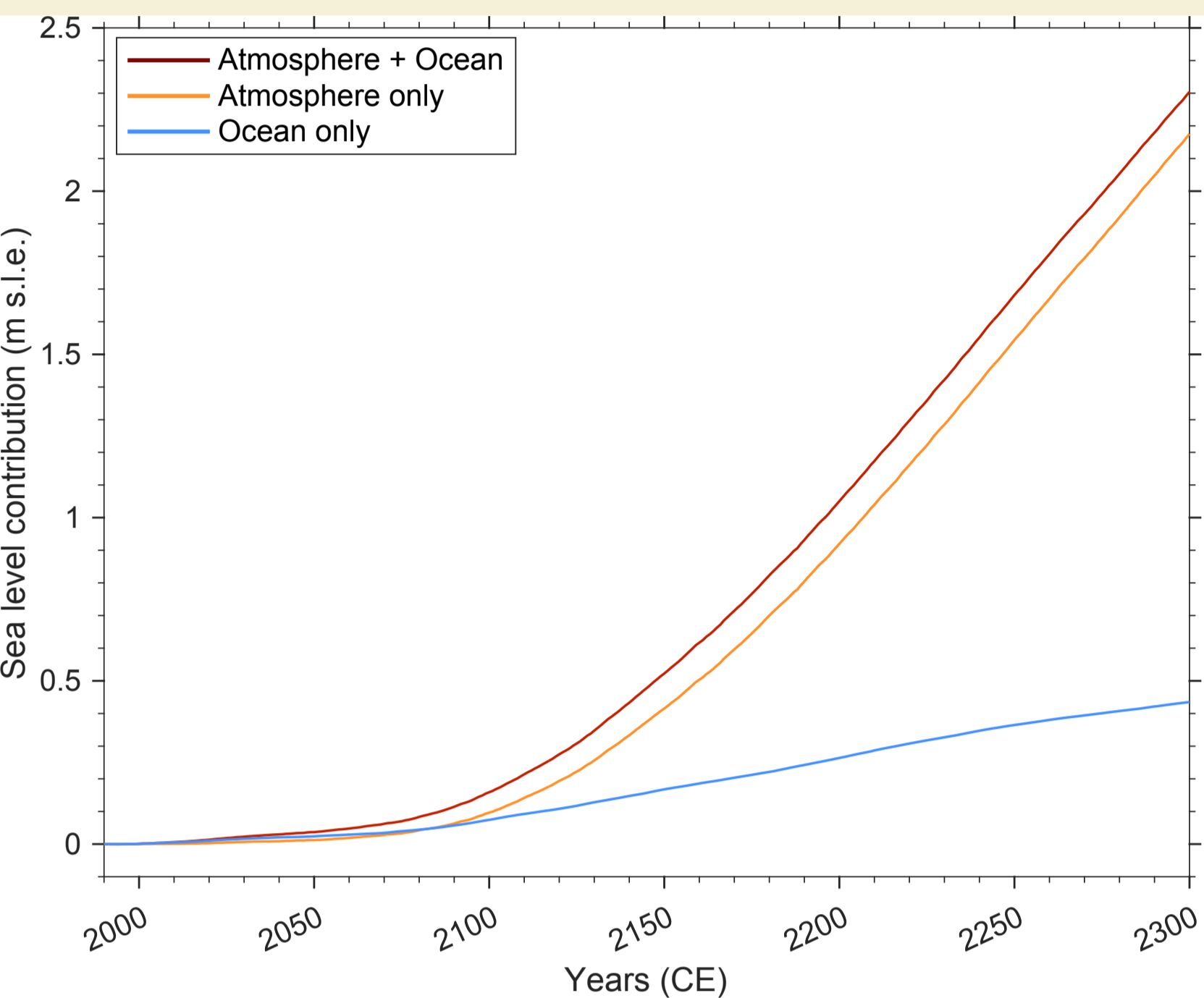
$$\Delta L = \kappa \Delta(Q^{0.4} TF)$$

ΔL = glacier front retreat
 κ = sensitivity parameter
 Q = subglacial discharge
 TF = ocean thermal forcing

resulting in retreat masks

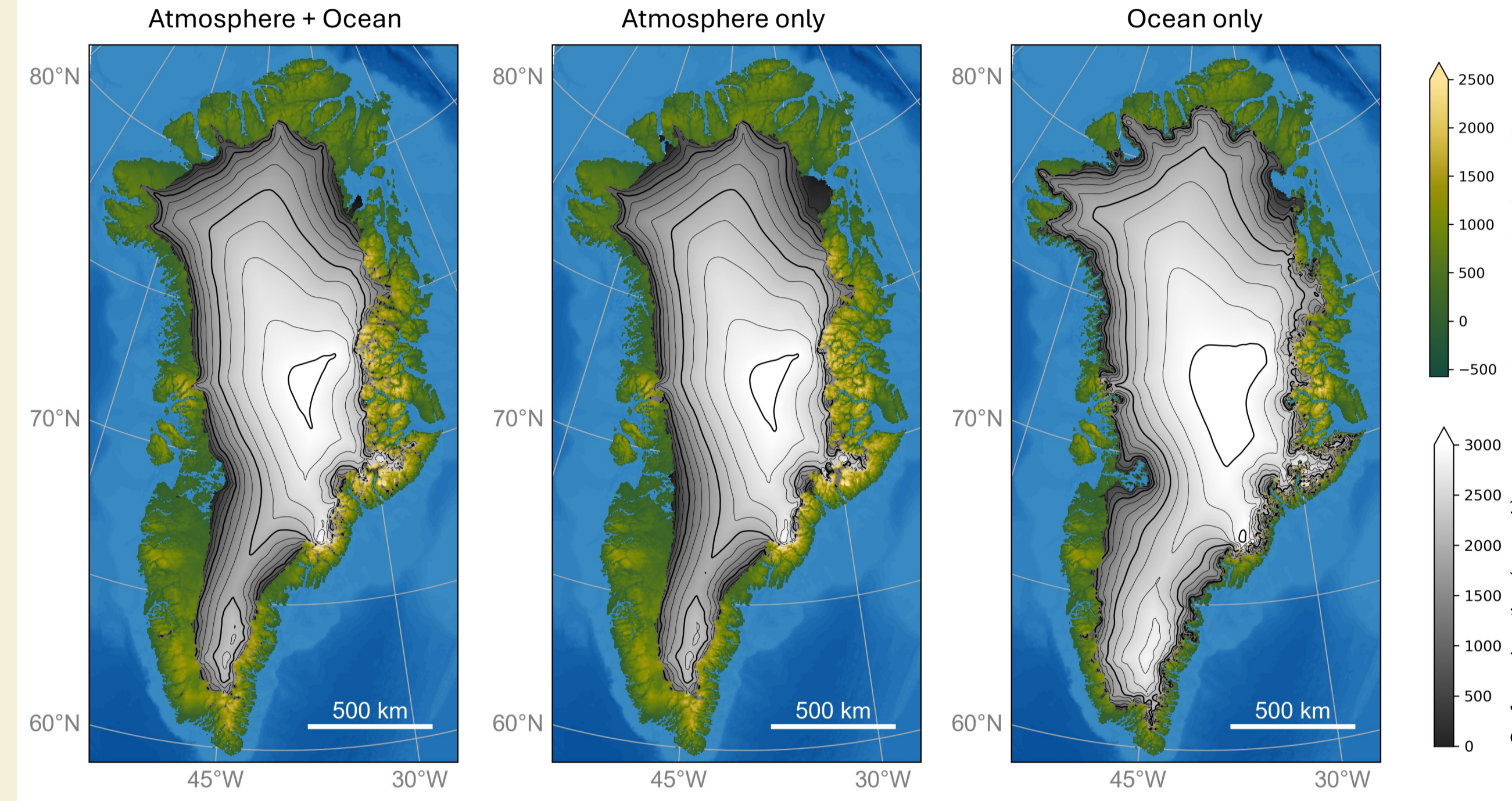


Atmospheric and Oceanic forcing are mutually competitive processes

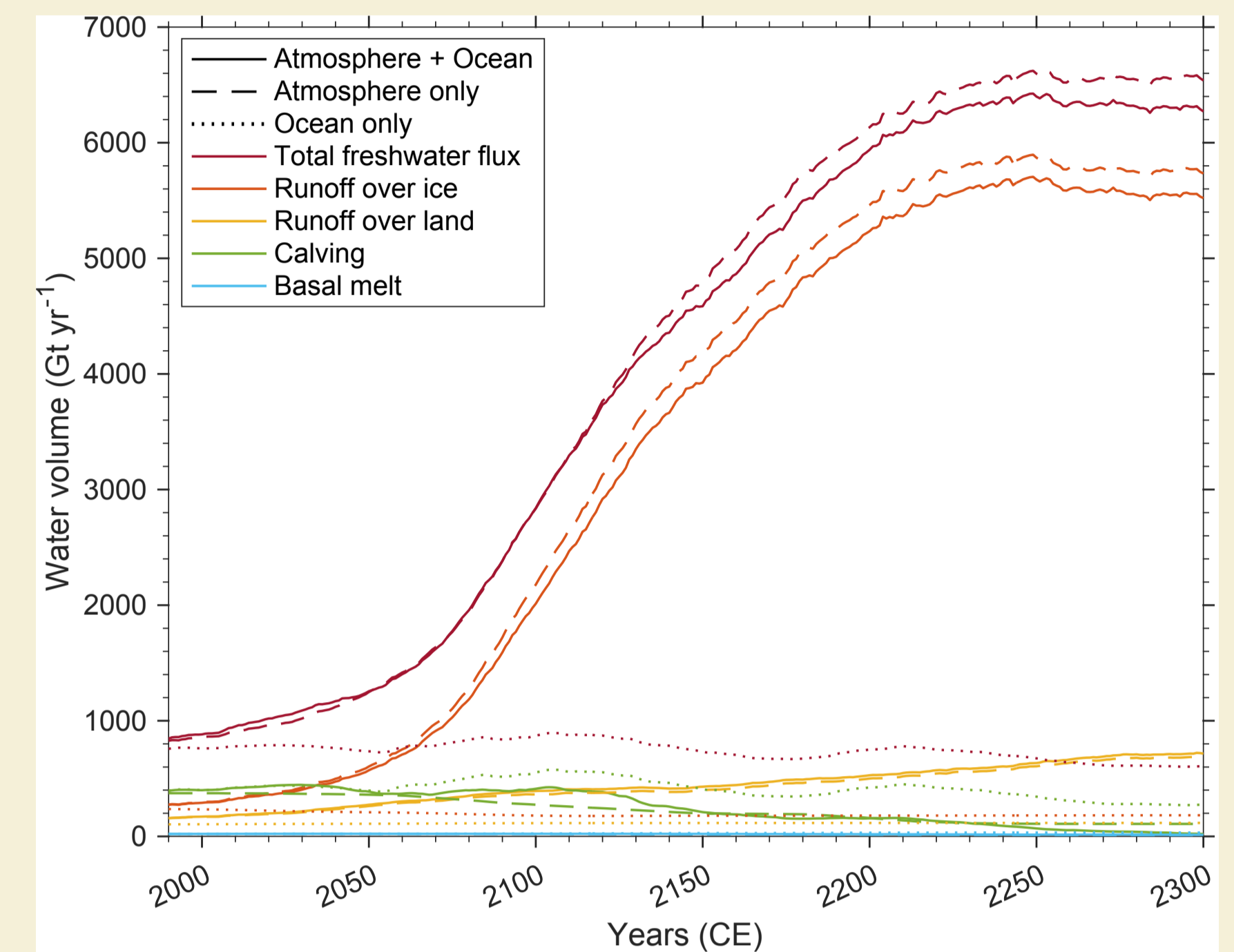


Contribution from atmosphere 5x larger by 2300 than from ocean forcing alone

But sum of single contributions does not add up: 13.3 % larger by 2300 compared to simultaneously forced experiment



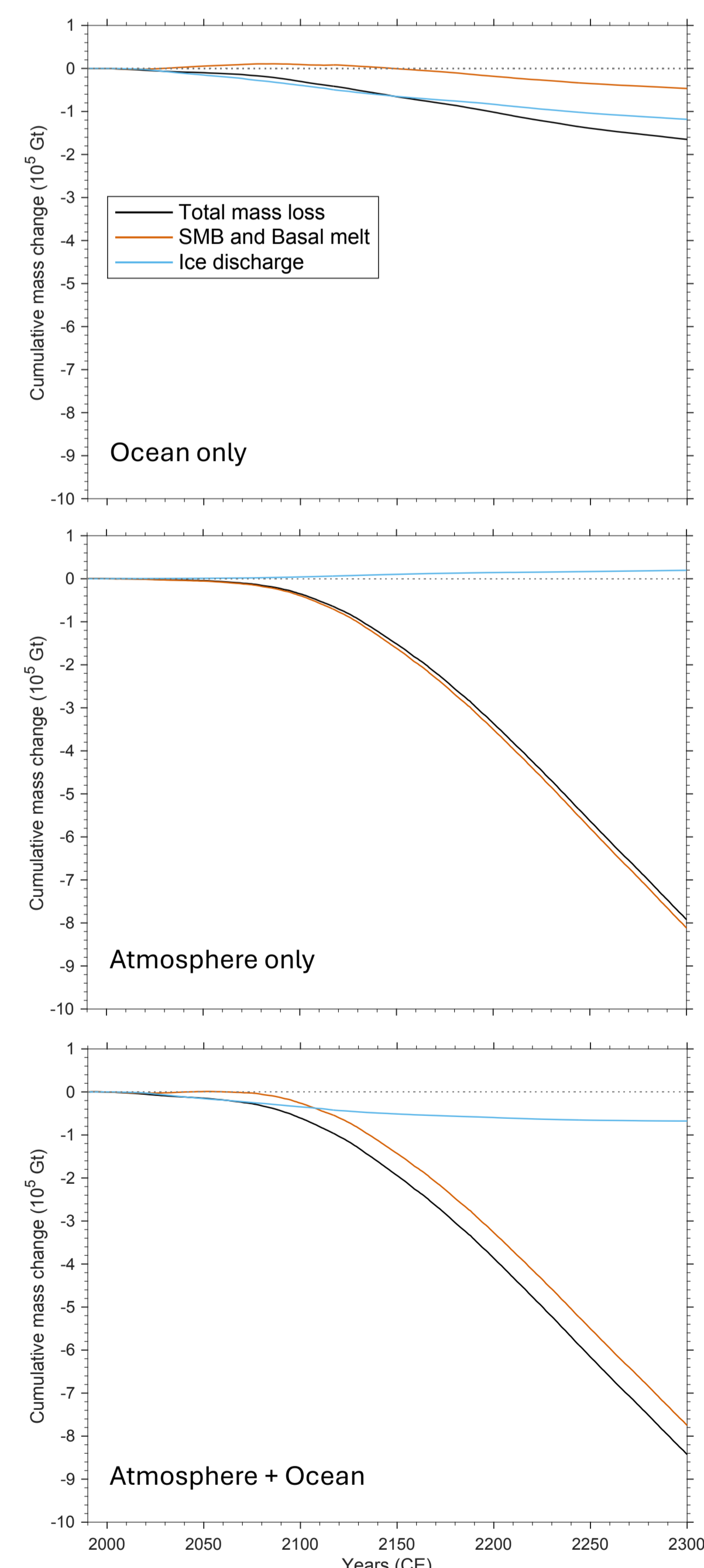
Surface melt removes ice before it reaches the calving front: with atmospheric forcing, ice – ocean contact area remains 55 – 58 % compared to ocean-only experiment



Ice removed by marine discharge is no longer subject to surface melt:

runoff over ice is 4 % larger when not applying ocean forcing

Attribution of mass loss is not straightforward



Cumulative anomalies

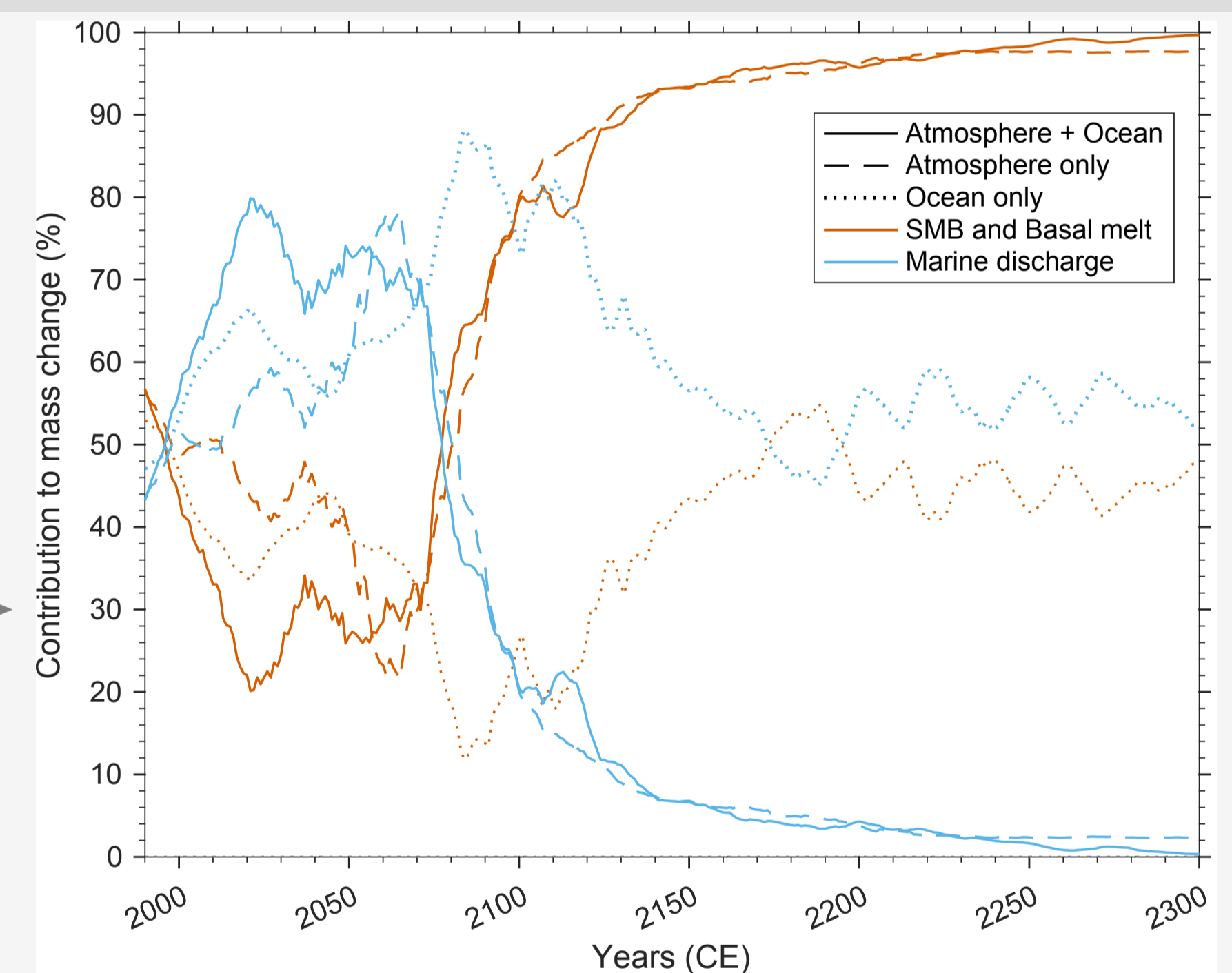
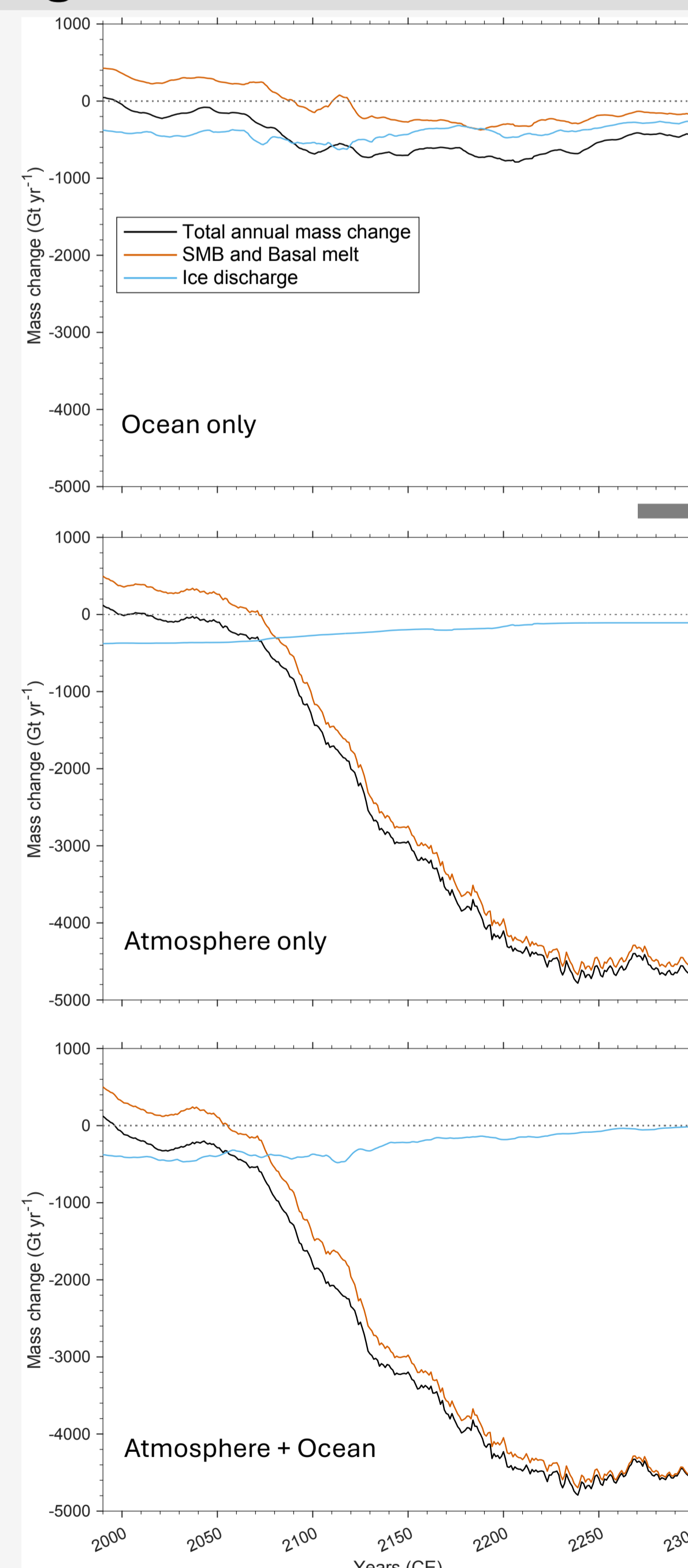
PROBLEM: assumes constant steady-state ice sheet geometry and ice flow

When rates fall below initial rates, anomalies become positive, and no longer translate in contribution to mass loss

Annual mass change rates

Marine discharge attenuates for all experiments

Counterintuitively, by 2300 annual SMB contribution is largest for simultaneously-forced experiment, due to faster reduction of ice – ocean contact area



Annual fractional contributions

Peak contribution from discharge occurs when SMB becomes near-zero

Contribution from SMB rises to 80 % by 2100, and > 97.5 % by 2300 for atmosphere-forced experiments

For ocean-only experiment contribution from discharge remains 45 to 59 %

Sensitivity to oceanic forcing attenuates relative to atmospheric forcing

- Additional sea level contribution from ocean forcing attenuates over time
- Contribution from high retreat scenario becomes disproportionately large because ever thicker ice is removed
- High retreat scenario becomes unrealistic over time

