Quantifying uncertainties in the land ice contribution to sea level from ISMIP6 and GlacierMIP

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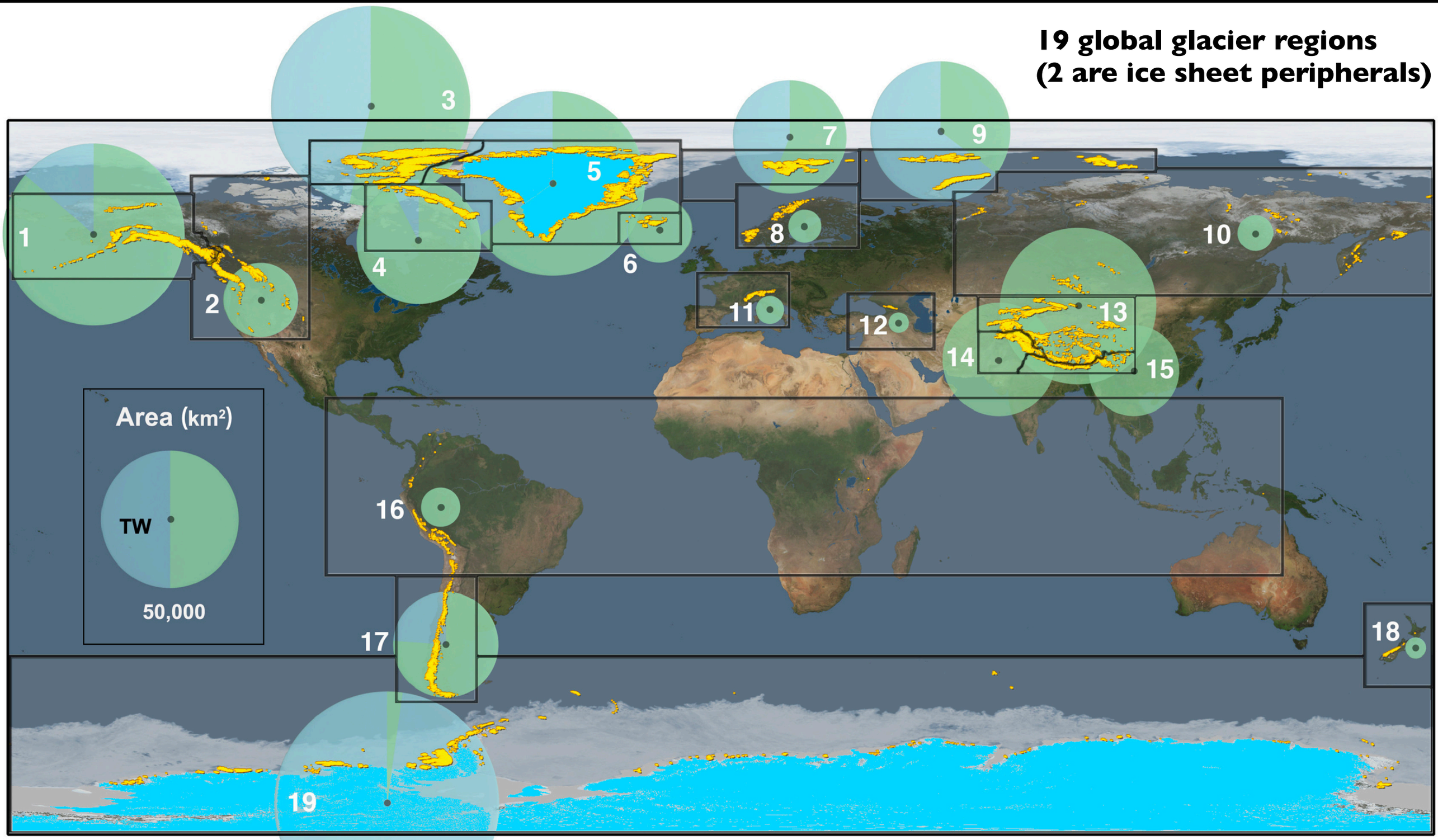
Huge thanks to Jonathan Rougier

Ice sheets and glaciers

Just under half of sea level rise since 1993

Fraction expected to increase



Bamber et al. (2018)

Major advances for IPCC AR6

ISMIP6 and GlacierMIP

Ice Sheet Model Intercomparison Project for AR6 (17 groups)

Glacier Model Intercomparison Project (11 groups)

Multiple climate models and ice-ocean parameter values

> 200 projections each

emissions -> concentrations -> climate -> ice

-> climate -> ice

-> climate -> ice

ice sheets: parameterisation of ice-ocean interface

Limitations

But still some limitations:

10 climate models

Mostly RCPs not SSPs (Shared Socioeconomic Pathways)

3-4 values of ice sheet-ocean parameters

Full design not completed

So fill in the gaps with "emulation" (just regression!)

Estimate input-output relationships from ensembles:

- Global temperature
- Sensitivity of ice sheets to ocean warming
- Antarctic ice shelf collapse

-> translate ANY values of **temperature** and **ice sheet/shelf sensitivity** into **sea level projections**

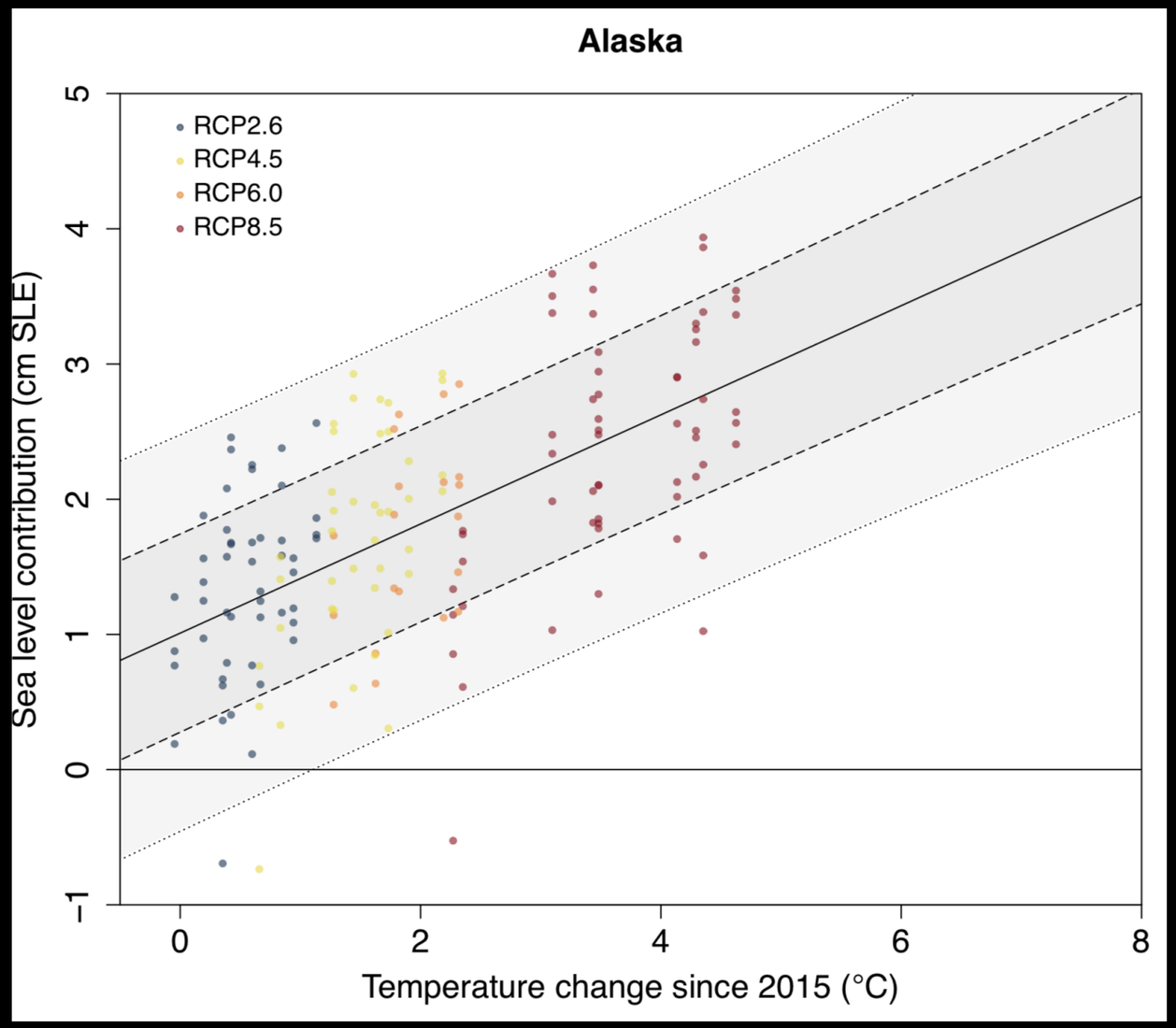
Temperature-dependence of glacier regions at 2100

Simulations: dots, RCP2.6; RCP4.5; RCP6.0; RCP8.5

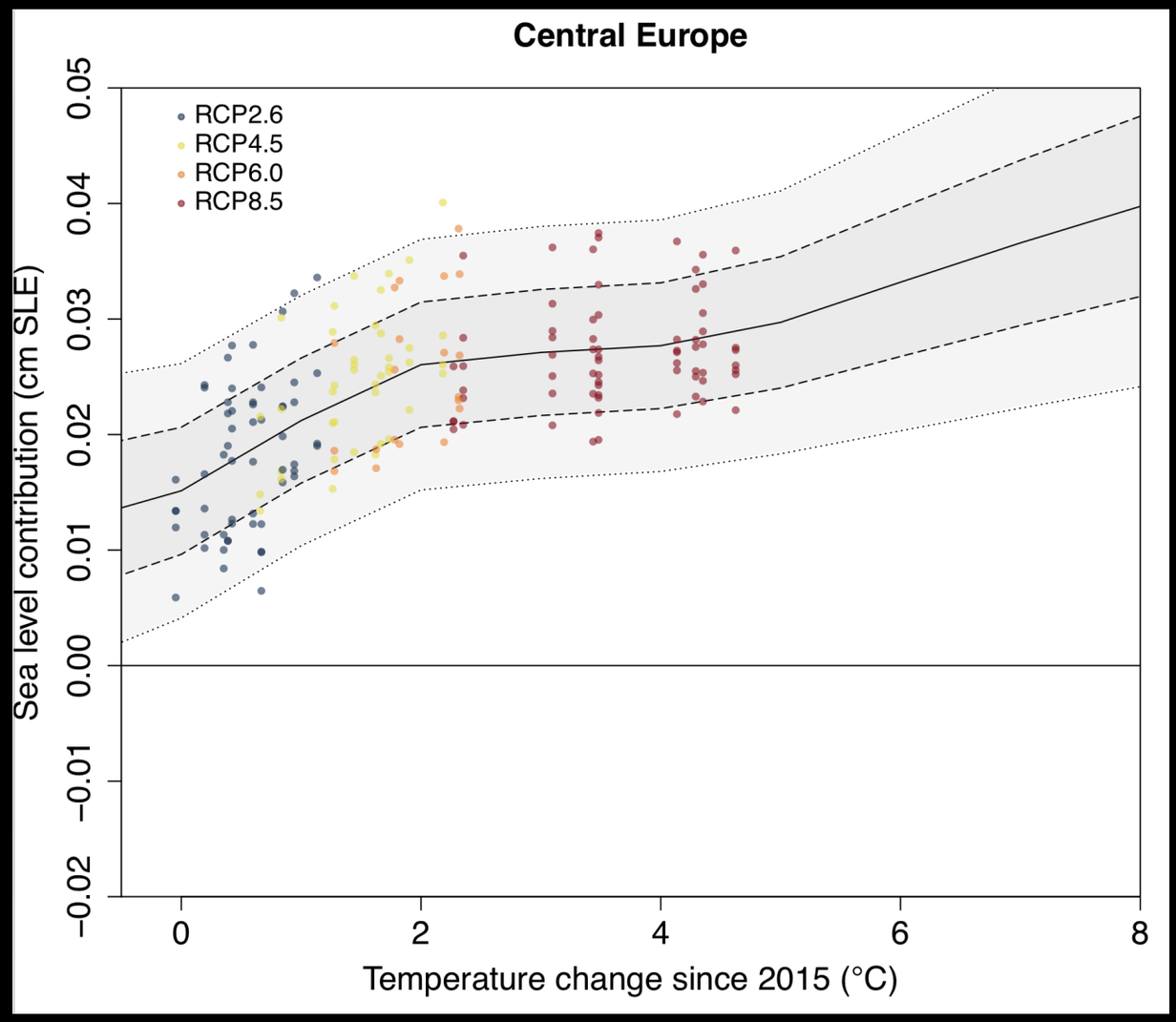
Emulator: lines, mean ± 1 s.d. and ± 2 s.d.

Emulate 18 of 19 regions (not Antarctic peripherals because not masked from ISMIP6)

Most regions fairly linear with global temperature



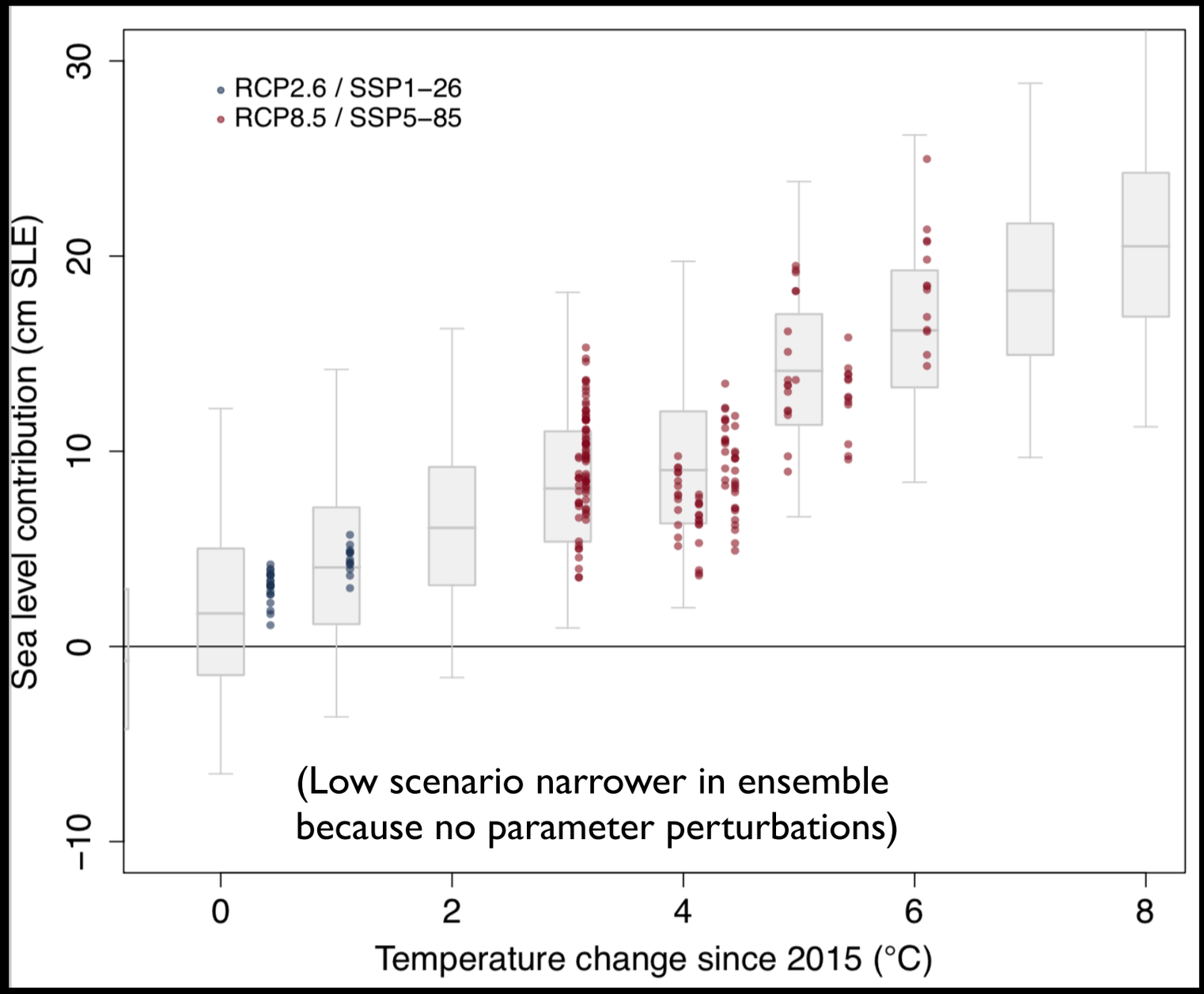
A few are non-linear



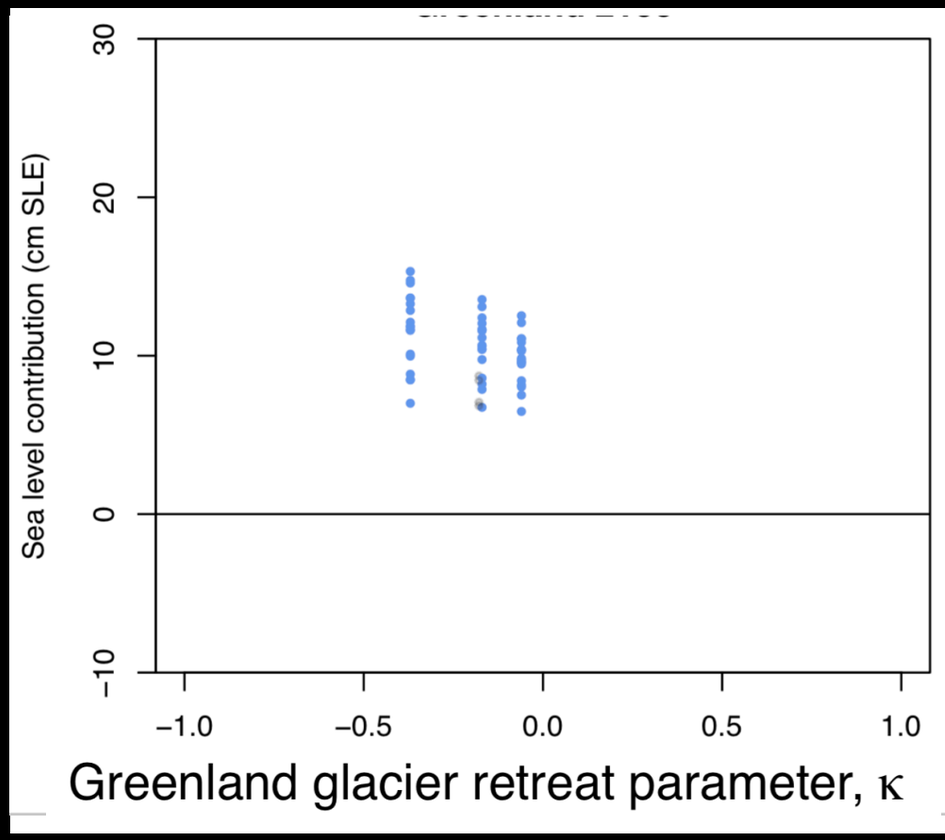
Temperature-dependence of Greenland at 2100

Simulations: dots, RCP2.6 / SSP1-26, RCP8.5 / SSP5-85
Emulator: box and whisker at 1 degree intervals

Fairly linear with global temperature

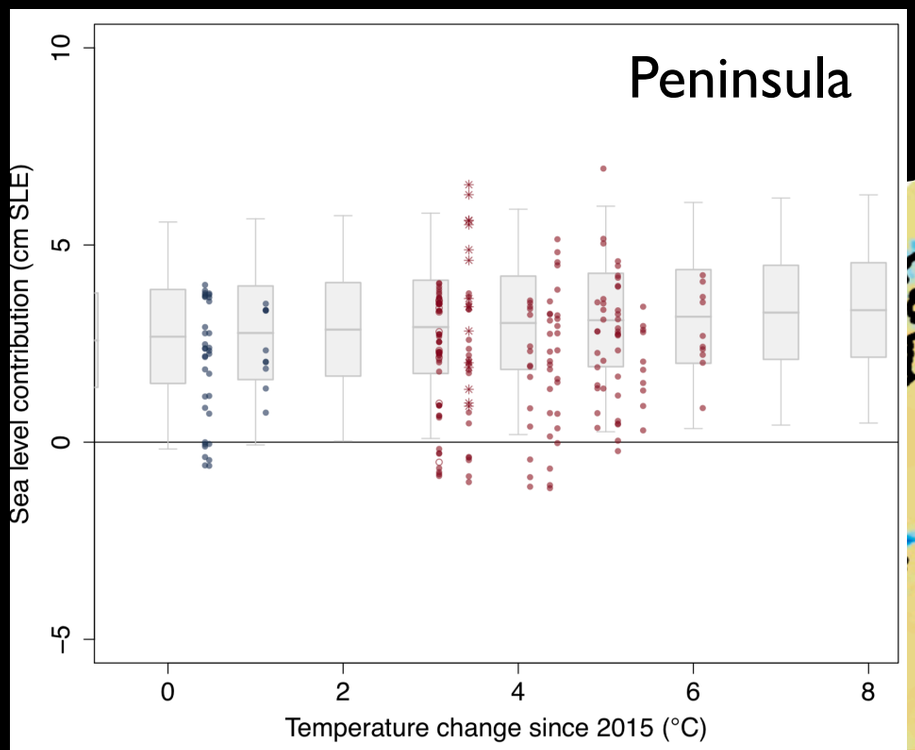


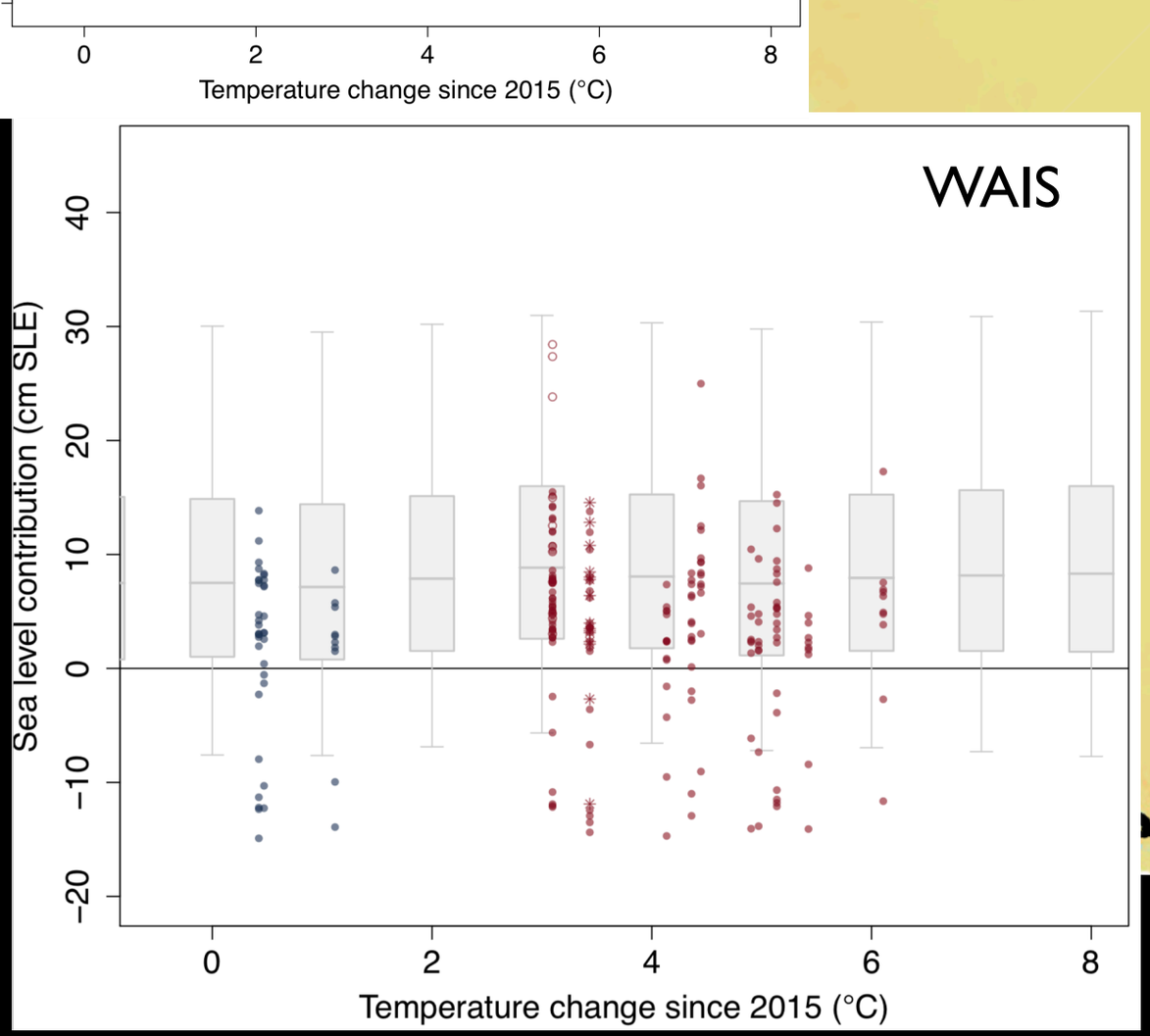
Also depends on
glacier retreat parameter:

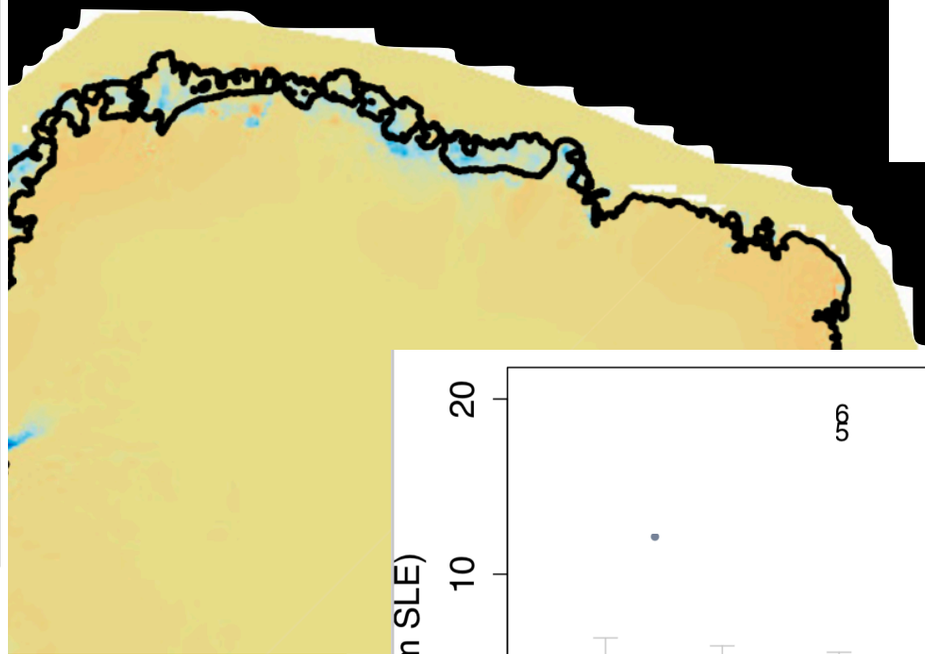


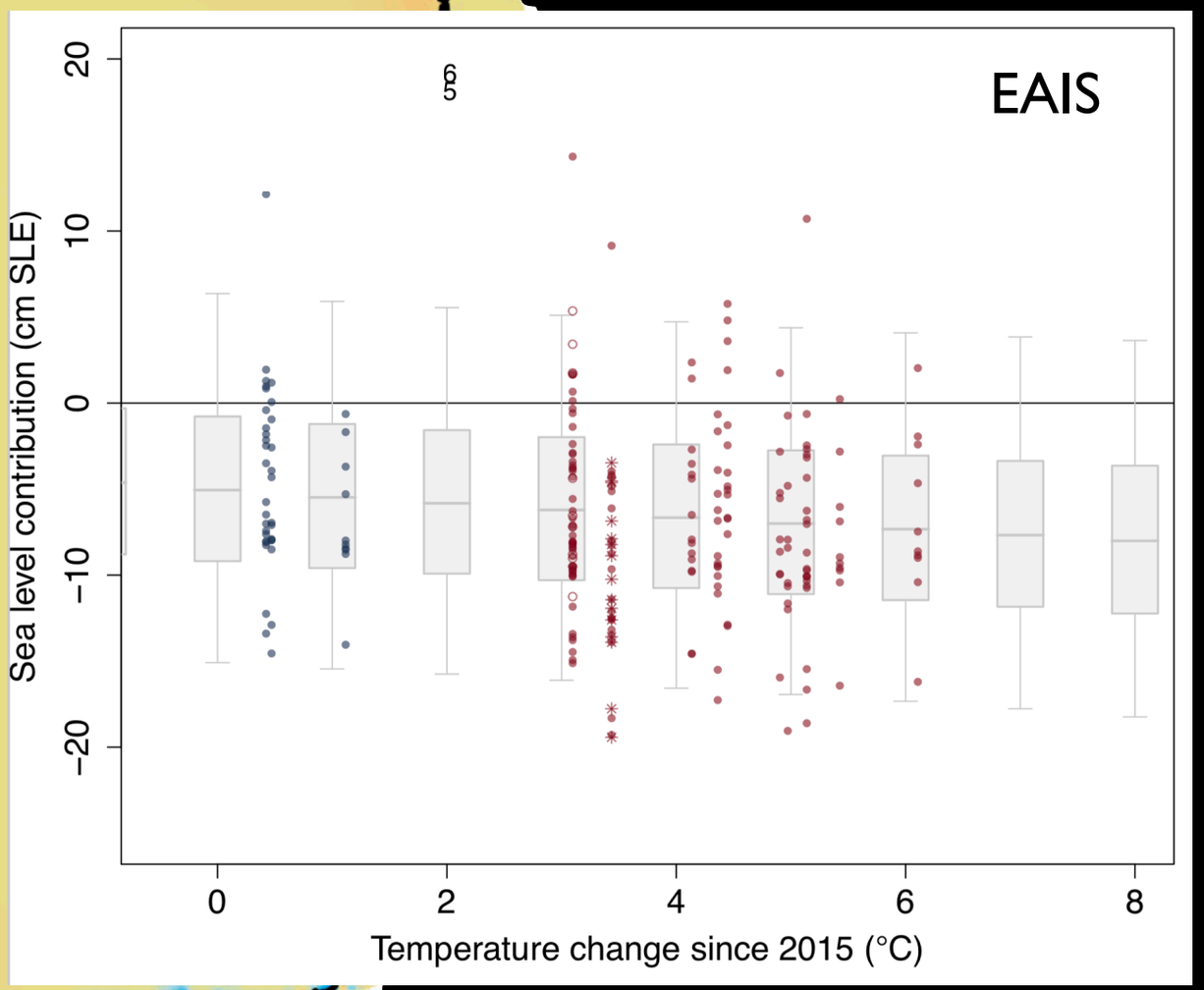
Glacier retreat parameterisation:
Slater et al. (2019)

Temperature-dependence of Antarctic regions at 2100









- RCP2.6 / SSP1–26
- RCP8.5 / SSP5–85

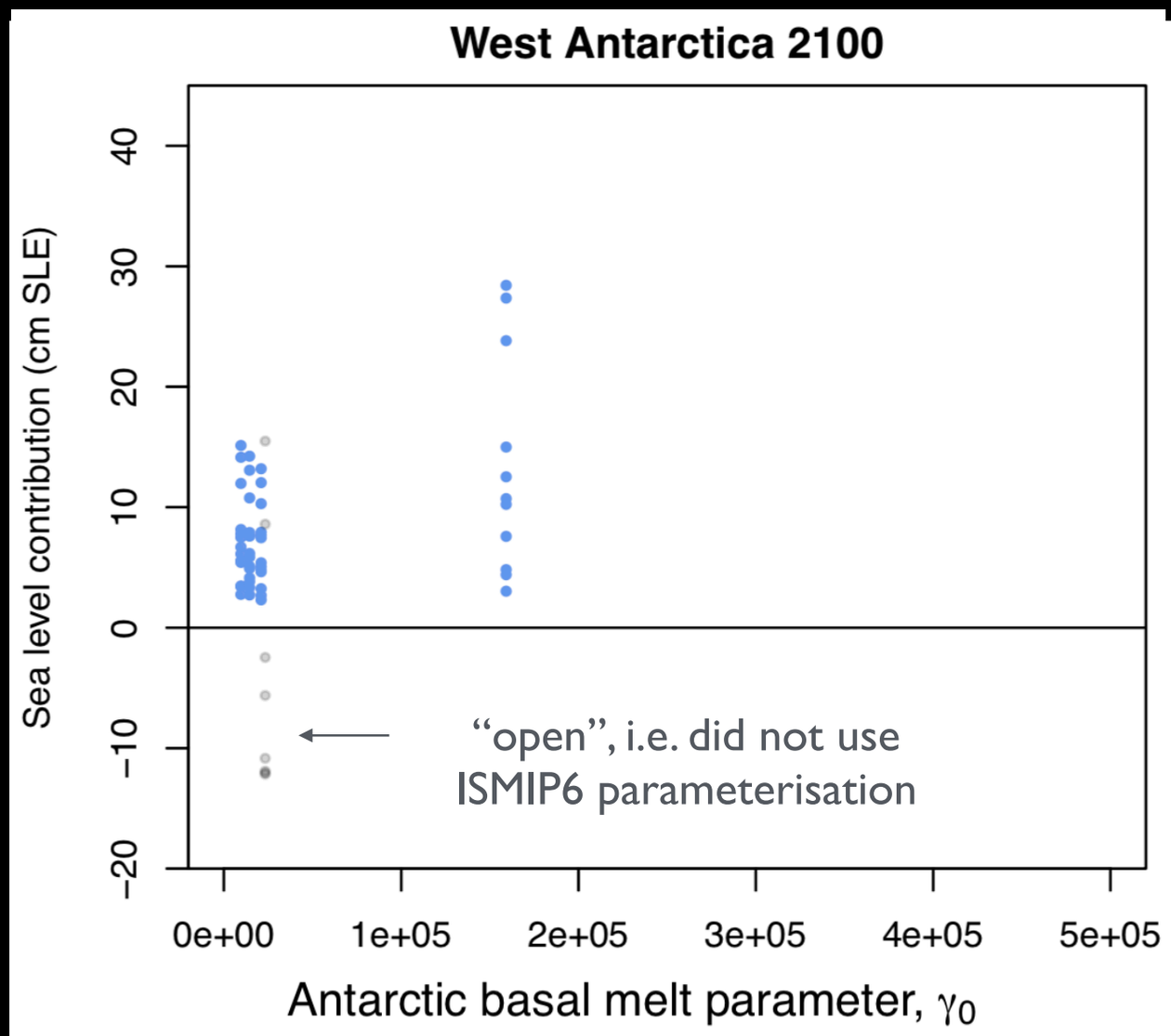
i.e. not much…

(Low scenario narrower in ensemble because no parameter perturbations)

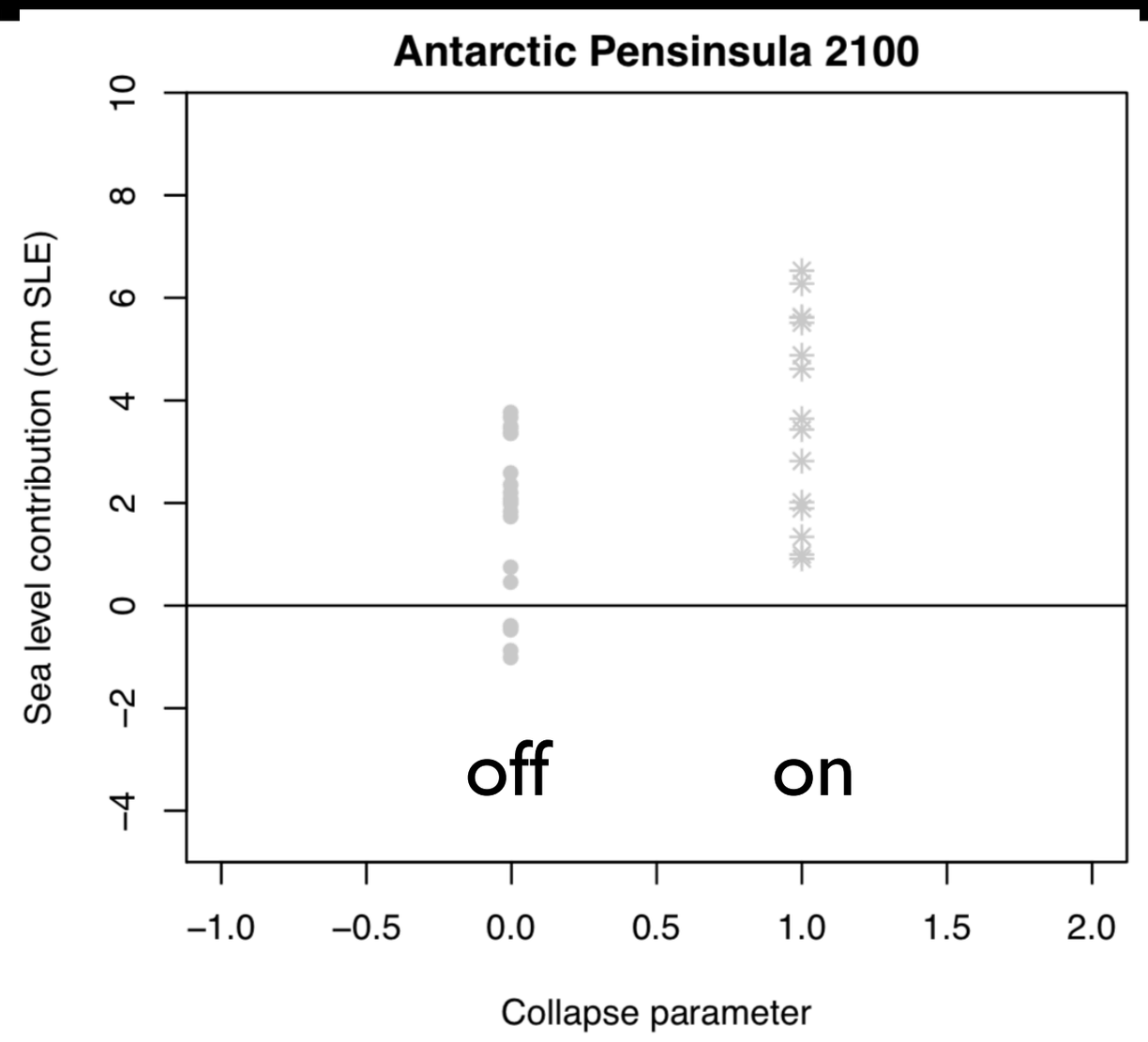
Also depends on ice-ocean parameters

Key impacts:

Basal melting increases
WAIS contribution



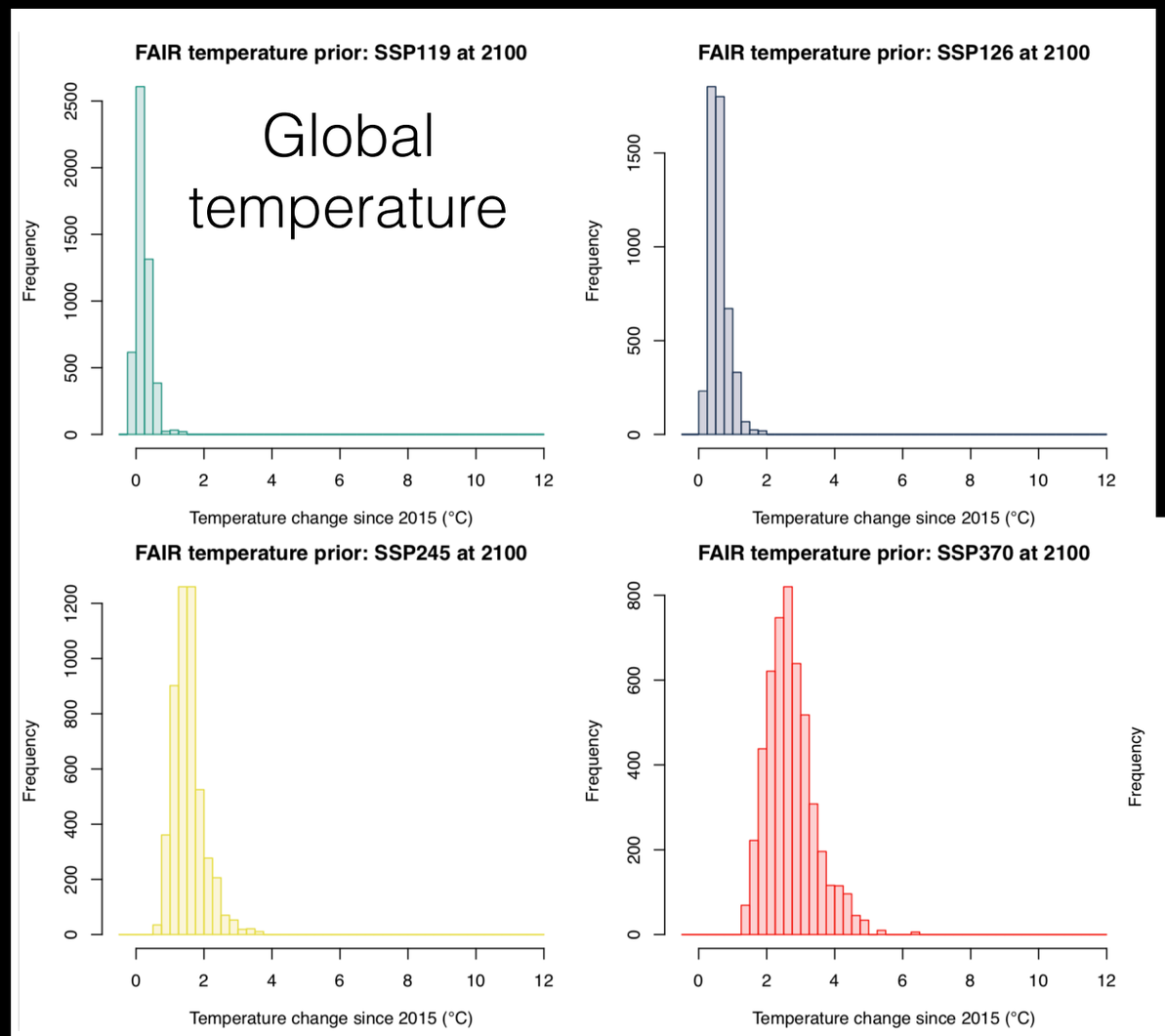
Ice shelf collapse increases
Peninsula contribution



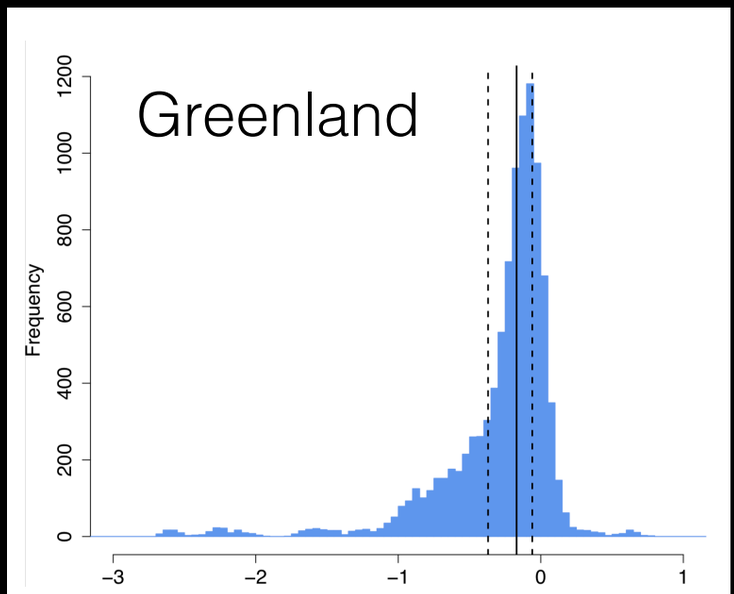
Basal melt parameterisation: Jourdain et al. (in review)
Ice shelf collapse parameterisation: Trusel et al. (2015)

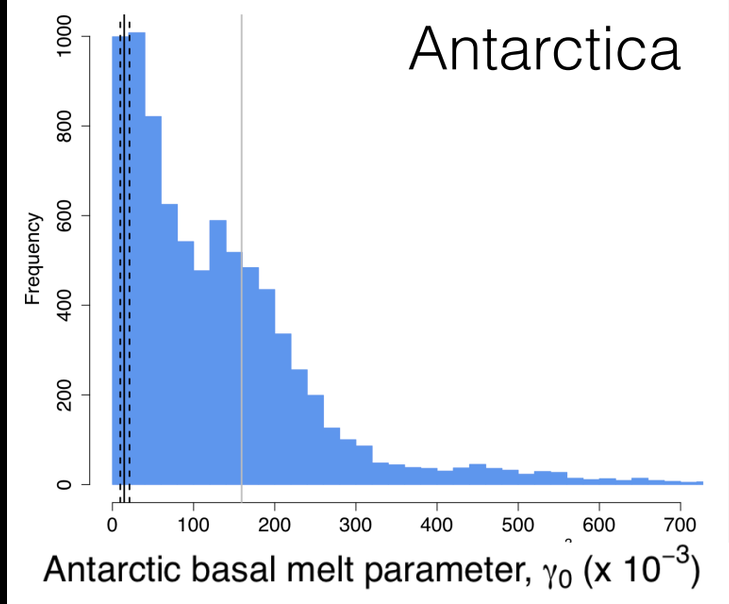
Emulation means we can use full input distributions

Global mean temperature change 2015-2100
ISMIP/GlacierMIP: N=10, mostly RCPs
Emulator: N=500, for 5 SSPs



Ice sheet parameters
ISMIP: N=3-4 (or open)
Emulator: N=5000



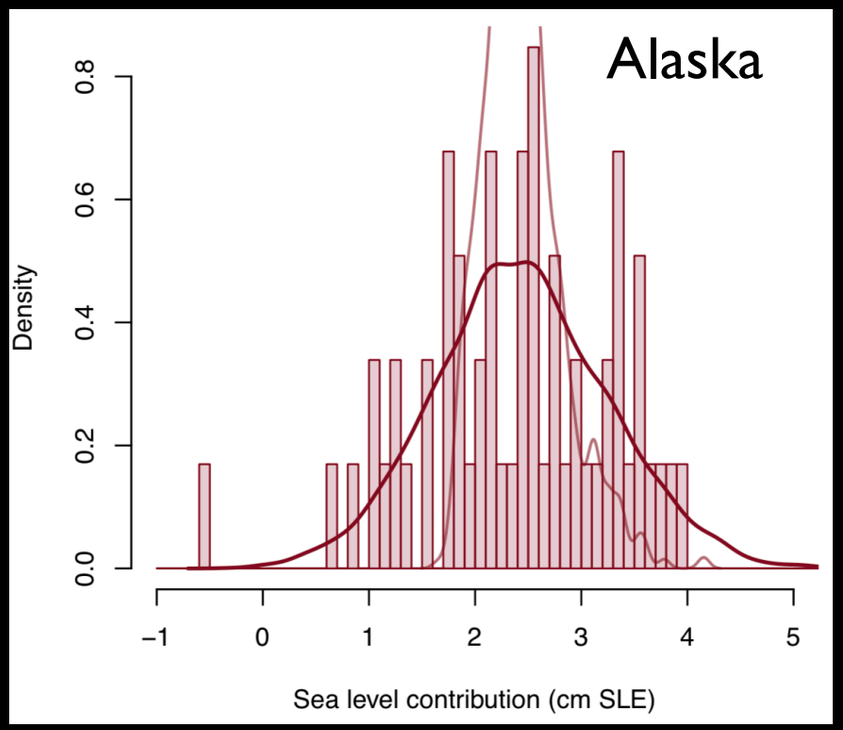


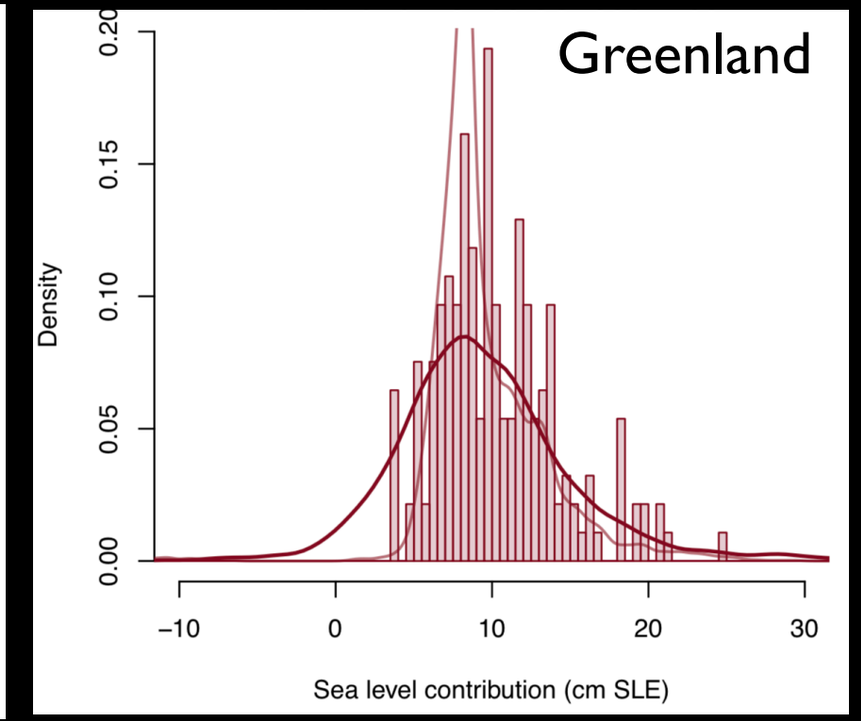
FaIR climate projections: Chris Smith
Ice sheet parameter distributions: Slater et al., Jourdain et al.

Emulated 2100 pdfs for SSP5-85

Histogram: models
Thick line: emulator

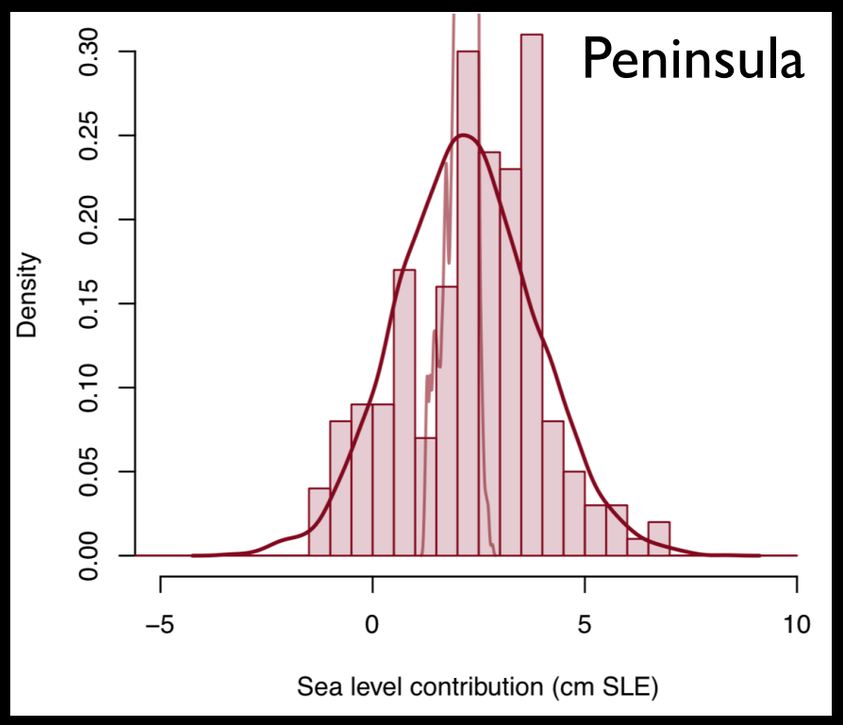
Other 17 glacier regions not shown

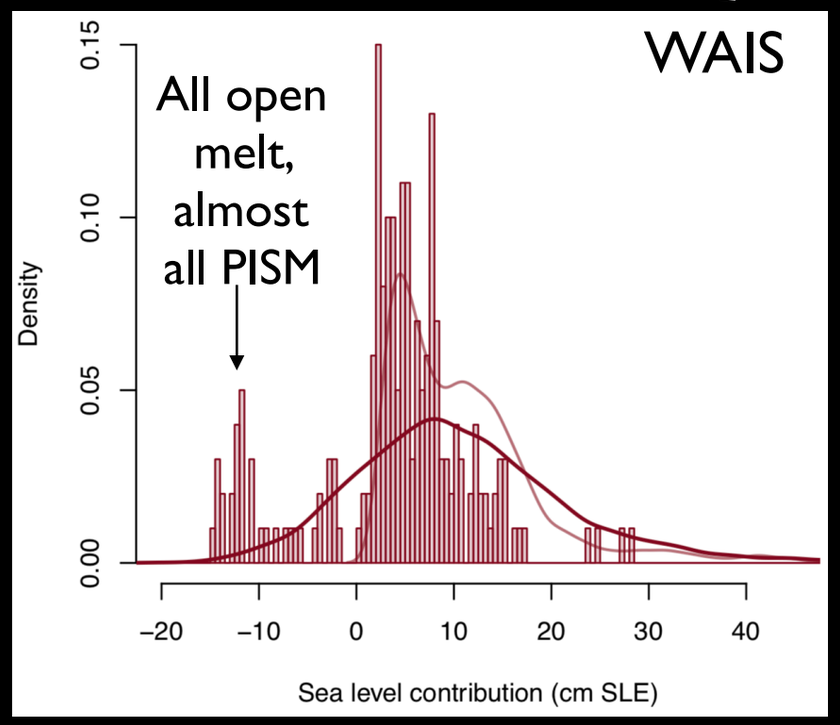


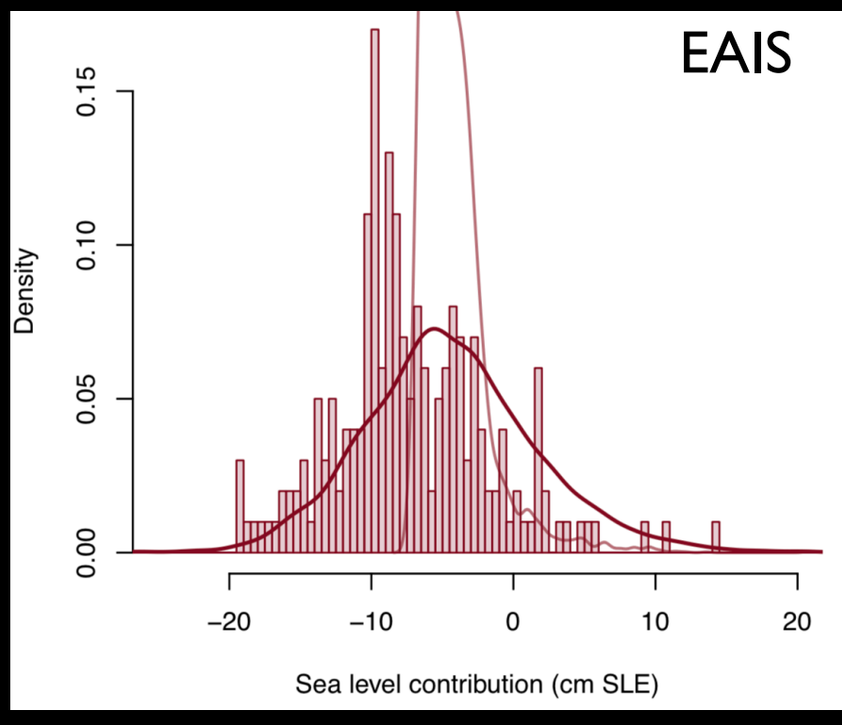


Wouldn't expect to be identical - different input temperature distribution

(Emulator can't reproduce low WAIS mode because it is not a function of inputs)





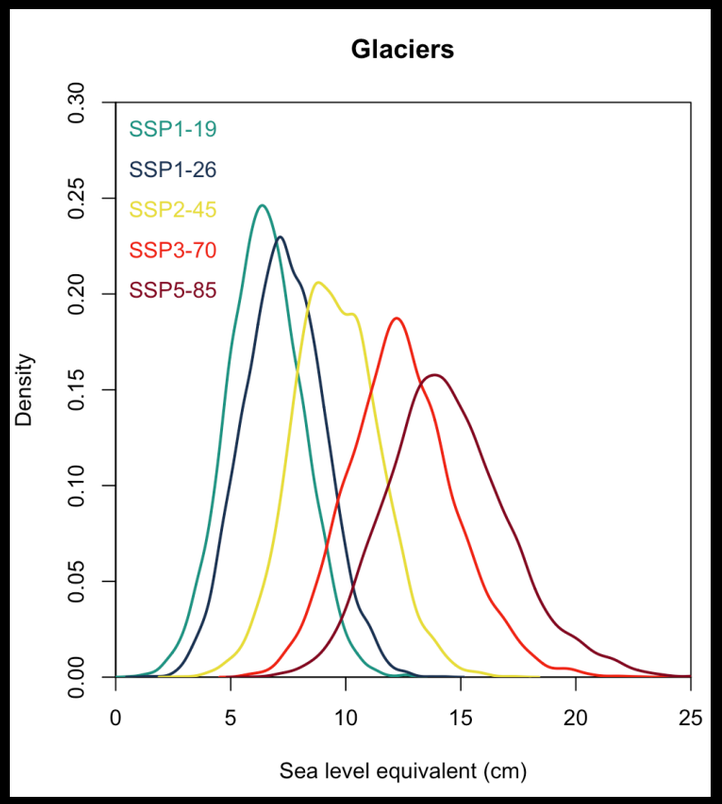


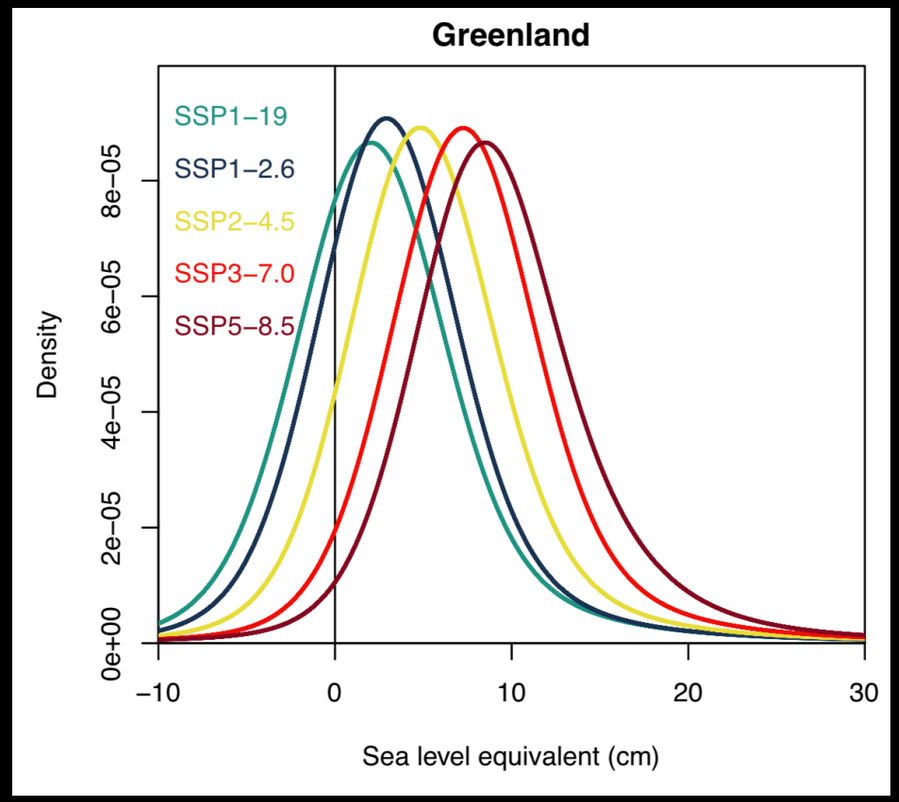
Emulated pdfs for glaciers & ice sheets

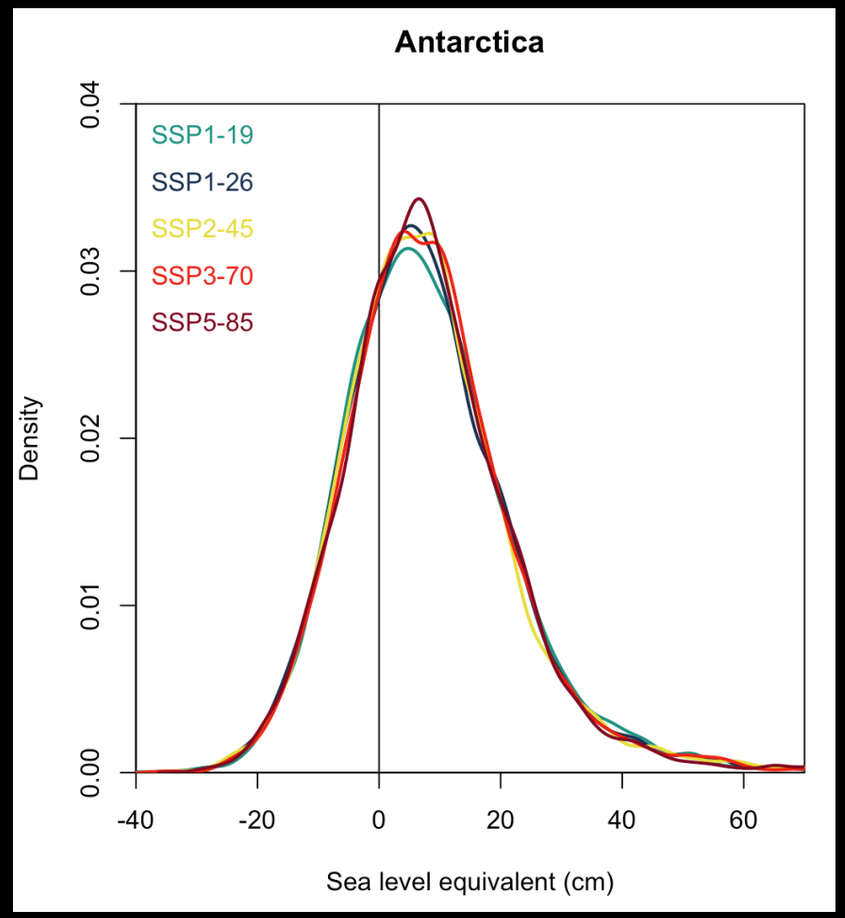
For 5 SSPs

Ice sheets: similarly large uncertainties for all scenarios

Adding new simulations might change this picture





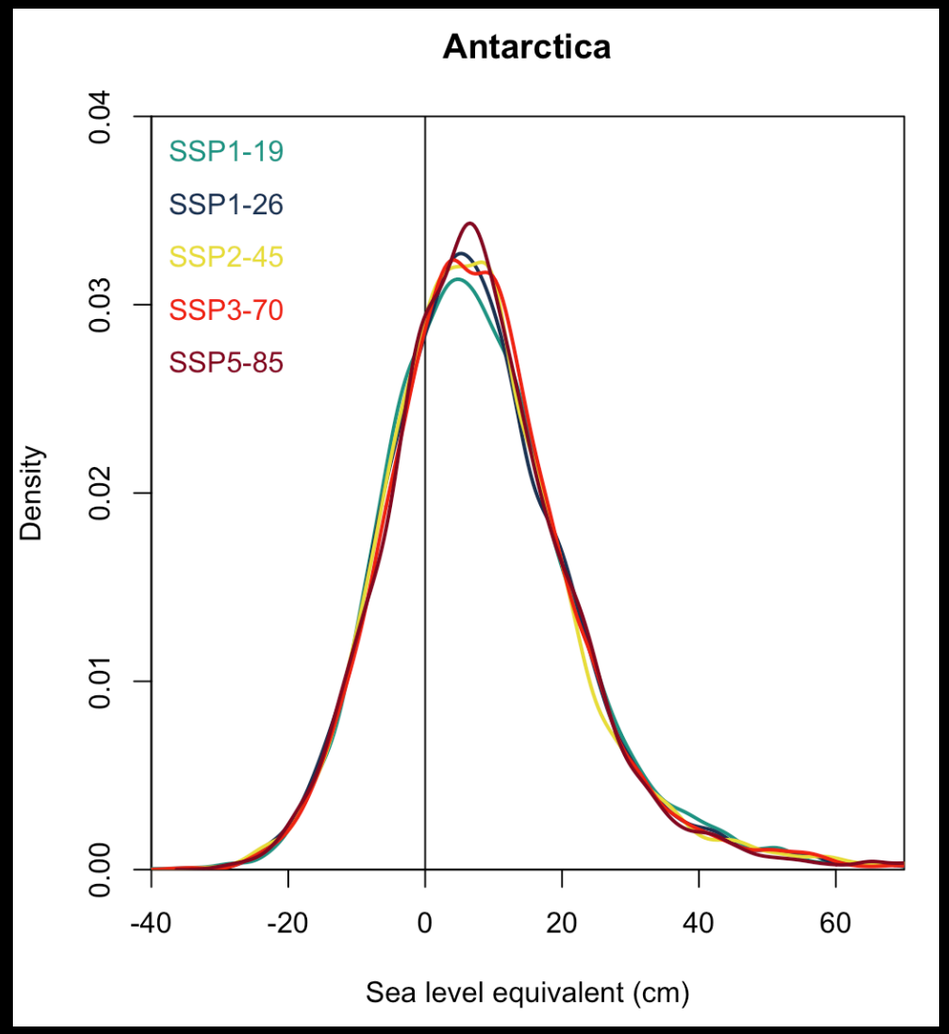


Antarctic sign uncertainty & scenario independence

Two opposite responses increasing with warming:
Ocean melting and increased snowfall

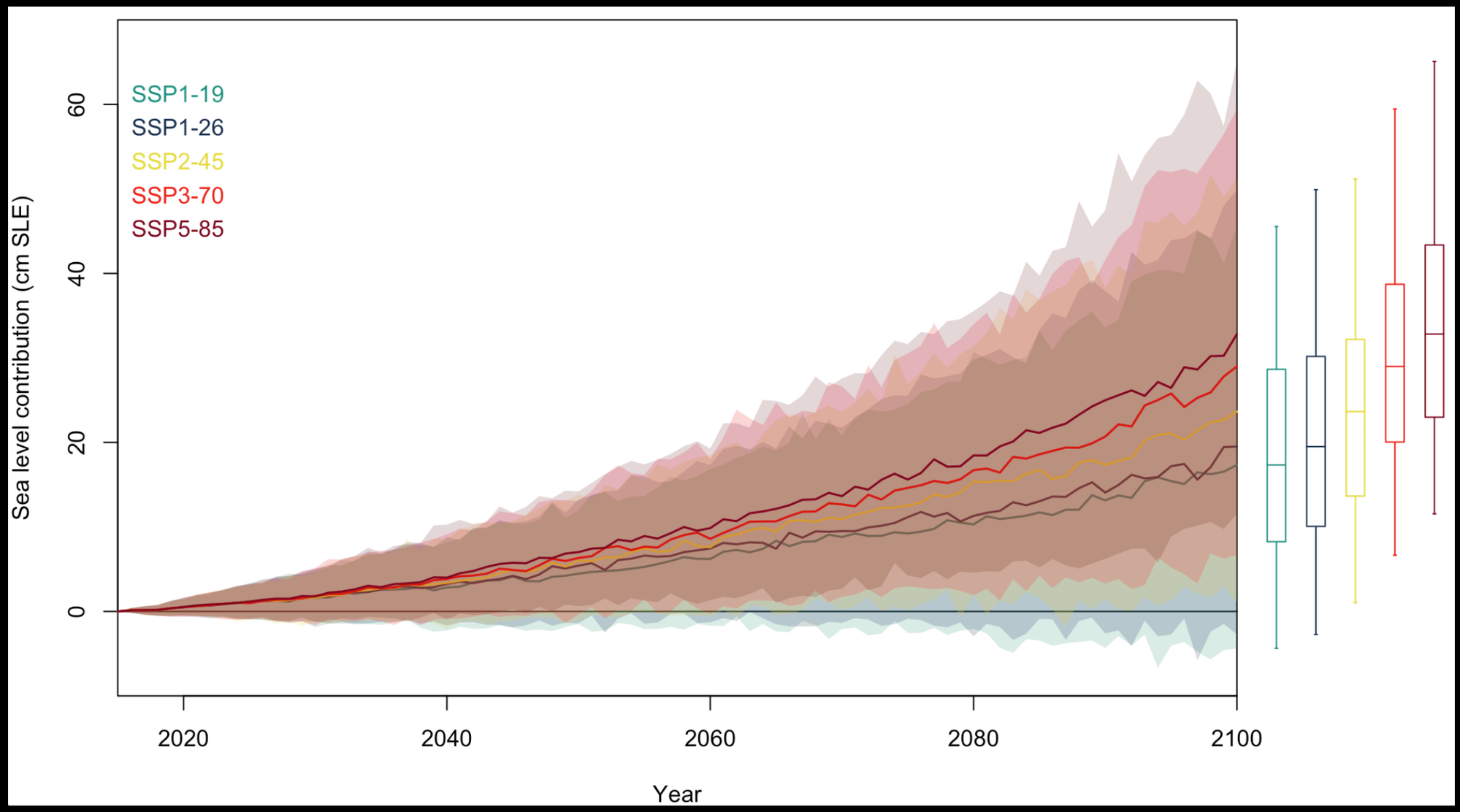
Net result:
Sign uncertainty
No scenario dependence (in ensemble or emulator)

Similar to IPCC (2013):
-3 to 14cm lowest scenario,
-6 to 12cm highest
But now more climate & ice sheet models
-> better sampling of uncertainty



Total land ice projections for 5 SSPs

Each ice sheet and glacier region forced by same global temperature
Greenland peripherals modelled explicitly (i.e. GlacierMIP);
Antarctic peripherals (partially) included in ice sheet (i.e. ISMIP)



Edwards et al. (in review)

Quantifying uncertainties in the land ice contribution to sea level rise this century

Summary

- More comprehensive modelling than ever before
  - Impressive effort and huge advance since IPCC (2013)
- Systematic design across climate forcings and ice sheet parameters
- But (inevitably) incomplete sampling
  - Emulate ensembles to interpolate and estimate uncertainties
- Key results:
  - Stronger temperature-dependence for glaciers than ice sheets, particularly Antarctica, because:
    - Parameter uncertainties are also explored for ice sheets
    - Antarctic climate and ice sheet model responses vary widely
  - Antarctica: we know ‘less’ than before (good! not over-confident)

Q. Why use global mean temperature not regional climate?

- Sacrifice some uncertainty in climate-ice response for:
  - Thorough and physically realistic sampling of climate uncertainty
    - Can use FaIR simple climate model
    - Otherwise limited to CMIP5/6 and/or expert judgement
  - Consistency across ice sheets and glacier regions
    - Same temperature forcing for all land ice projections
  - Consistency of sea level projections with rest of AR6
    - Can use AR6 assessments of global mean temperature projections