# Greenland Ice Sheet cumulative carbon-based stability thresholds: quantification and relation to policy

Jeremy Fyke[1], Michael Eby[2], Nathan Urban[1], Lauren Vargo[3], Damon Matthews[4]

Los Alamos NATIONAL LABORATORY

University of Victoria

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI VICTORIA UNIVERSITY OF WELLINGTON

UNIVERSITÉ Concordia UNIVERSITY

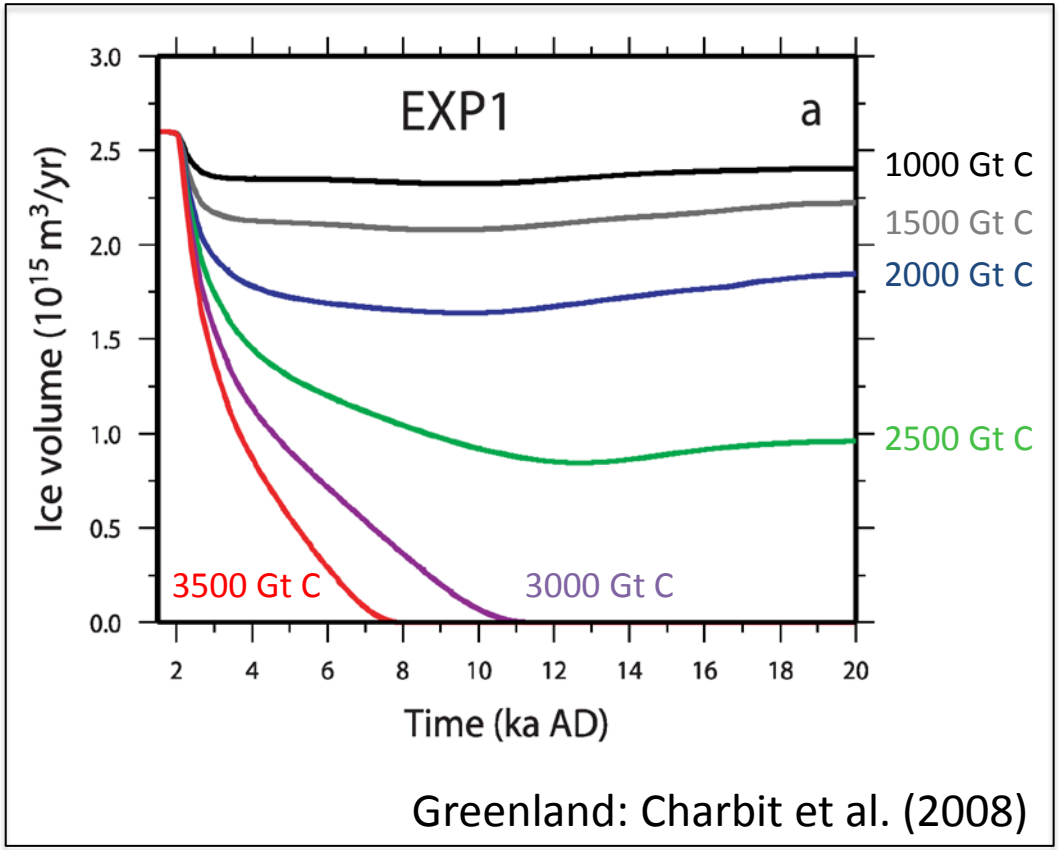
# Synopsis

- Why a cumulative carbon threshold on Greenland Ice Sheet stability?
- Coupled ice-sheet/carbon/climate modeling (*climate model: UVic ESCM, Fyke et al., 2011, GMD*)
- Cumulative emissions modeling (*IAM model: CEPM, Fyke and Matthews (2015)*)
- Can we tackle this problem with CESM?

# Why a cumulative carbon threshold on GrIS stability?

- Long-term ice sheet response are likely to depend on cumulative C emissions (via [$CO_2$] response)
  - Cumulative emissions are policy-tractable
  - Cumulative emissions threshold could be *'early warning'* for inevitable loss

# GrIS cumulative carbon threshold




Greenland: Charbit et al. (2008)

"…the climatic changes induced by anthropogenic activities operating on a few centuries will have large consequences for the surface of the Earth for ongoing millennia."

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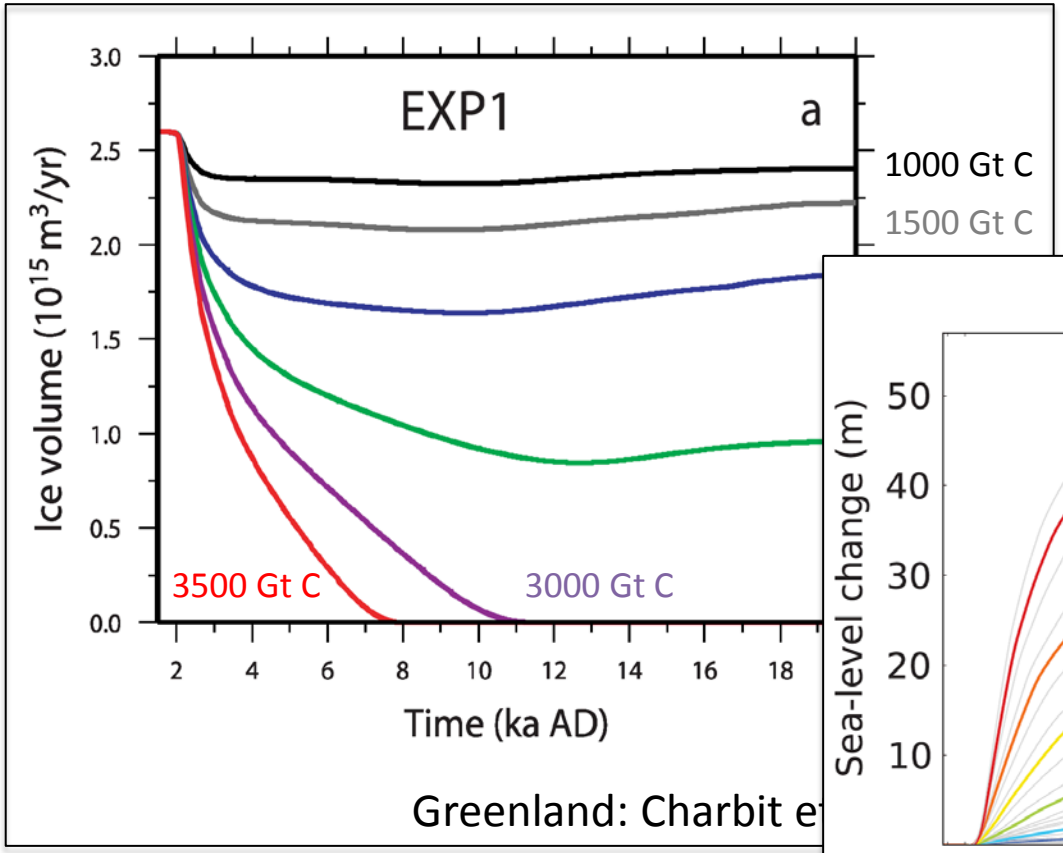
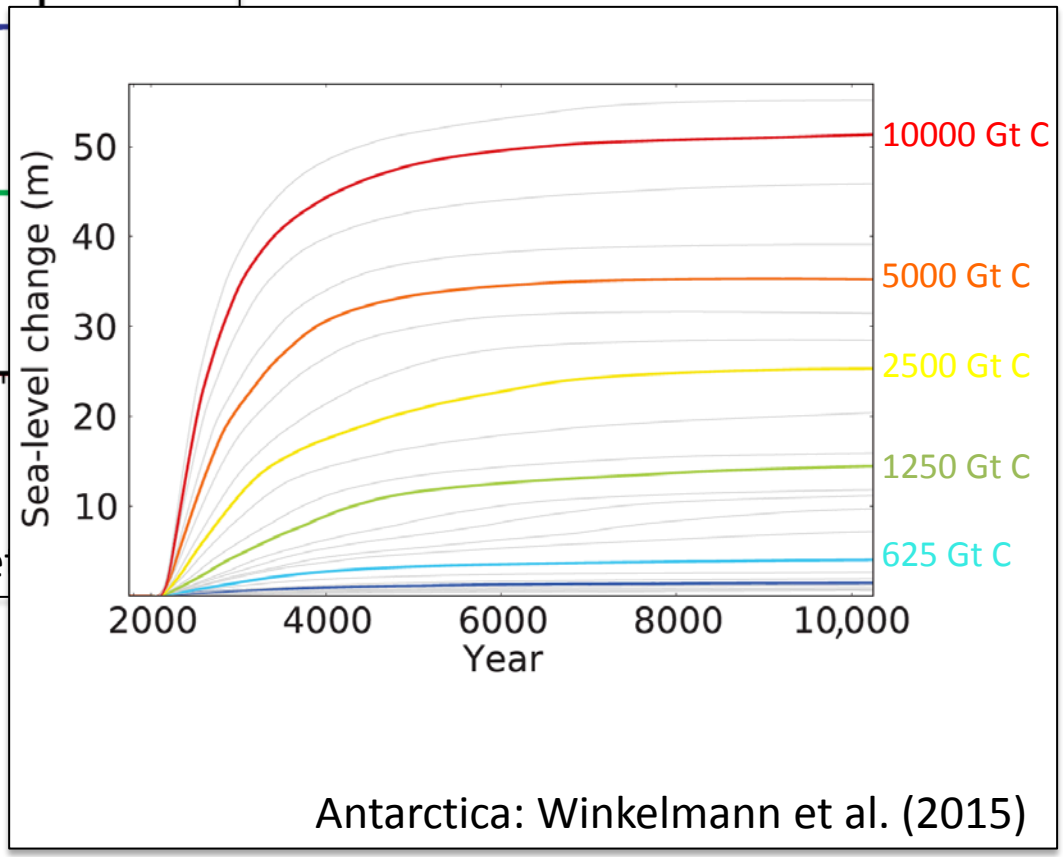



Greenland: Charbit et




Antarctica: Winkelmann et al. (2015)

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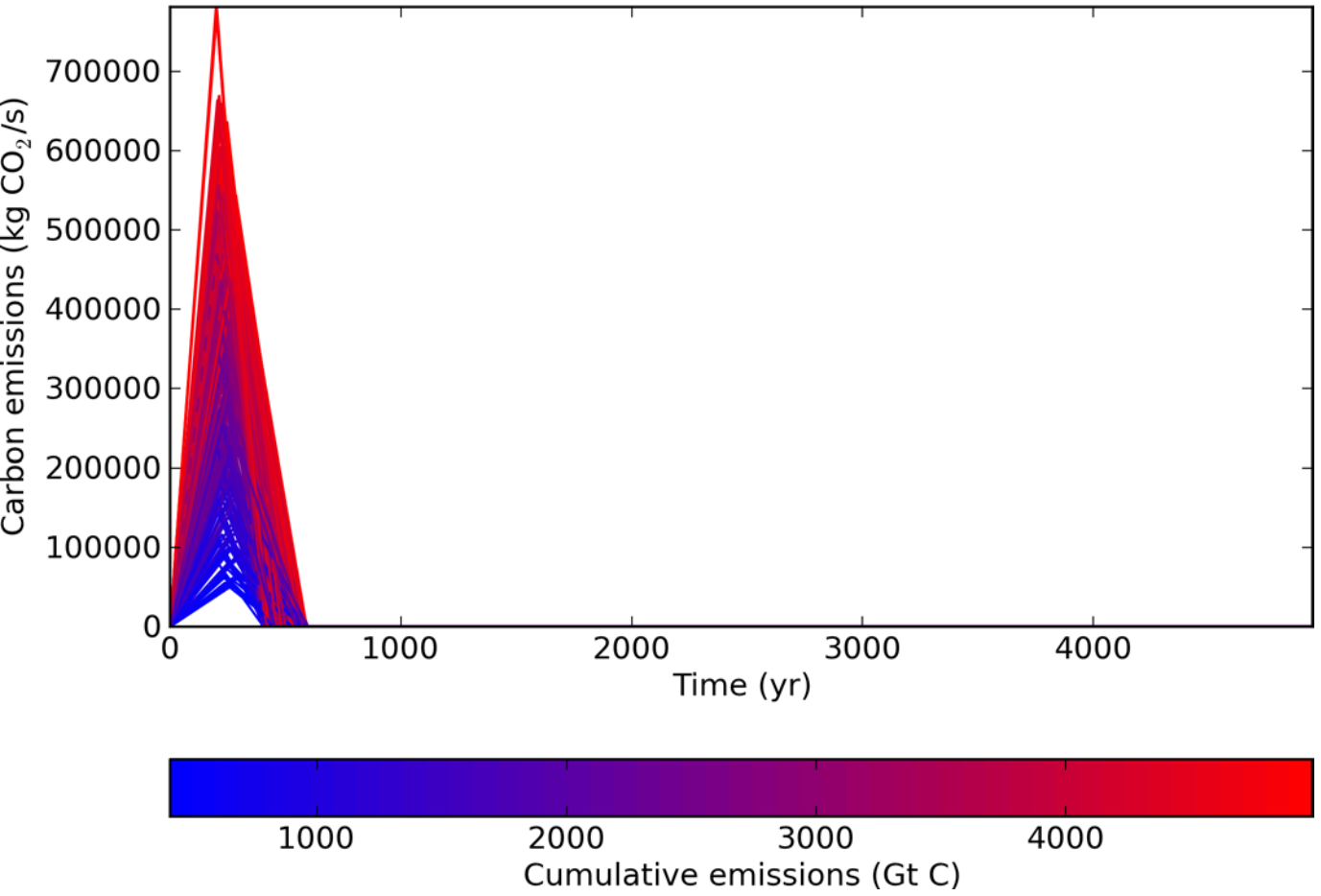
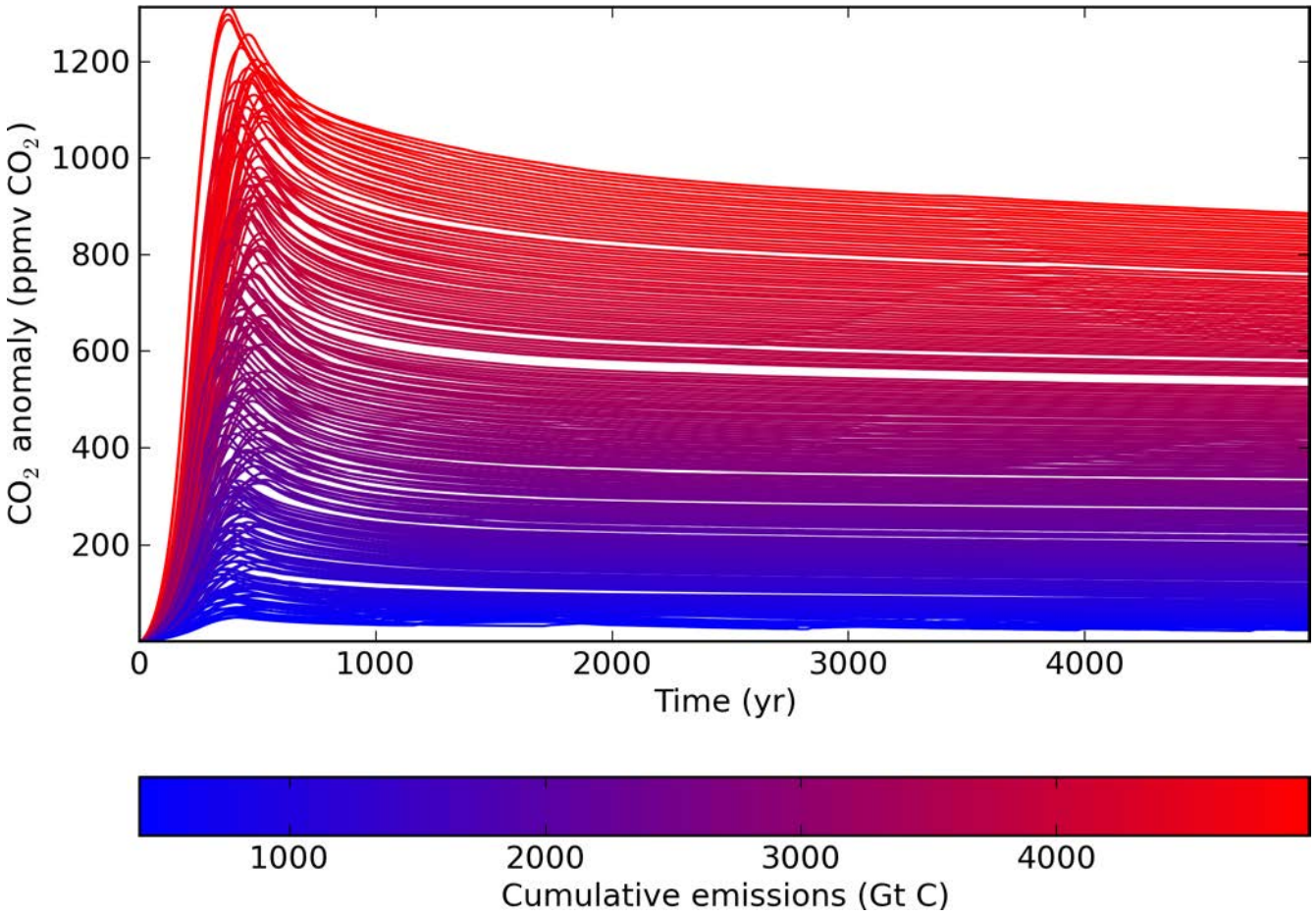



- **UVic ESCM: fully coupled ice-sheet/climate/carbon EMIC**
- **ICs**: transiently-spun up fully-coupled year 1850 state
- 200 symmetric emission profiles generated via2D Latin Hypercube Sampling of peak emissions and total emission period length (400-600 years) **-> 400-5000 Gt cumulative carbon emissions**

# GrIS cumulative carbon threshold




- $[CO_2]$ response due to oceanic/terrestrial/sediment C uptake

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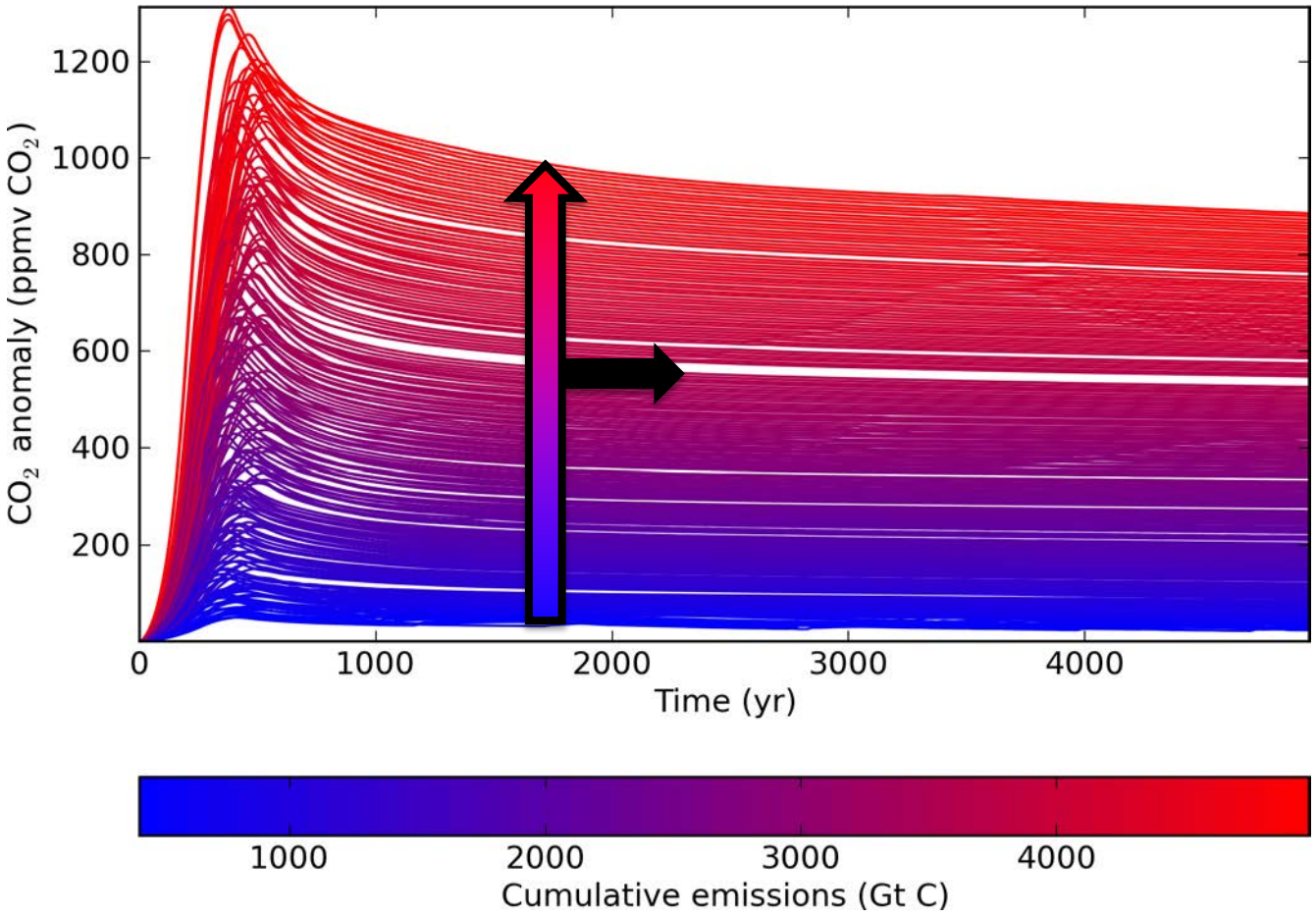


- $[CO_2]$ response due to oceanic/terrestrial/sediment C uptake
- Monotonic long-term $[CO_2]$/cumulative emissions relation: long-term $[CO_2]$ emissions pathway-independent (Eby et al. (2009), Matthews et al. (2009))

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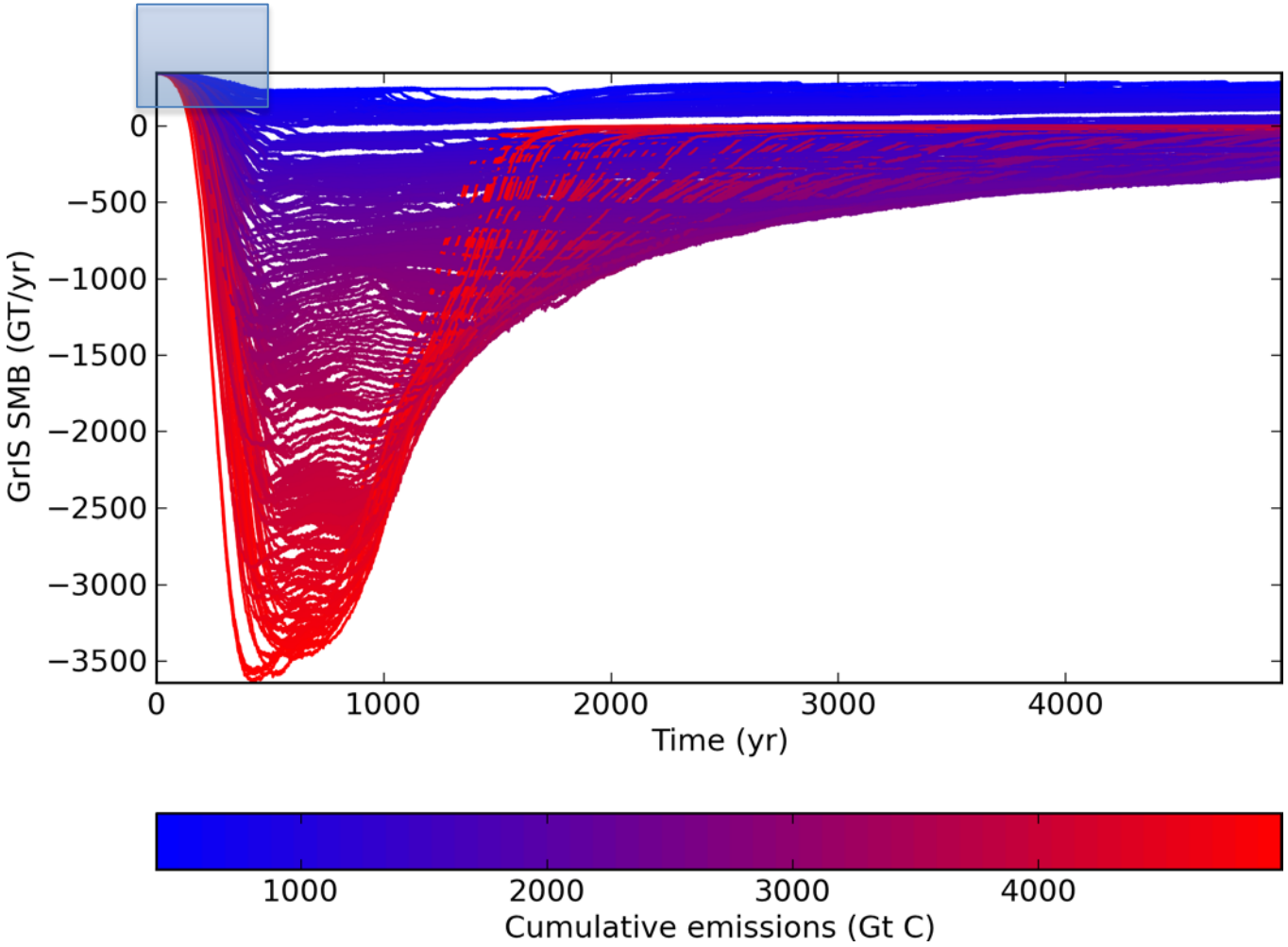


- Initial SMB within range of regional model recent historical estimates (e.g. RACMO2, Van Angelen et al. (2013))

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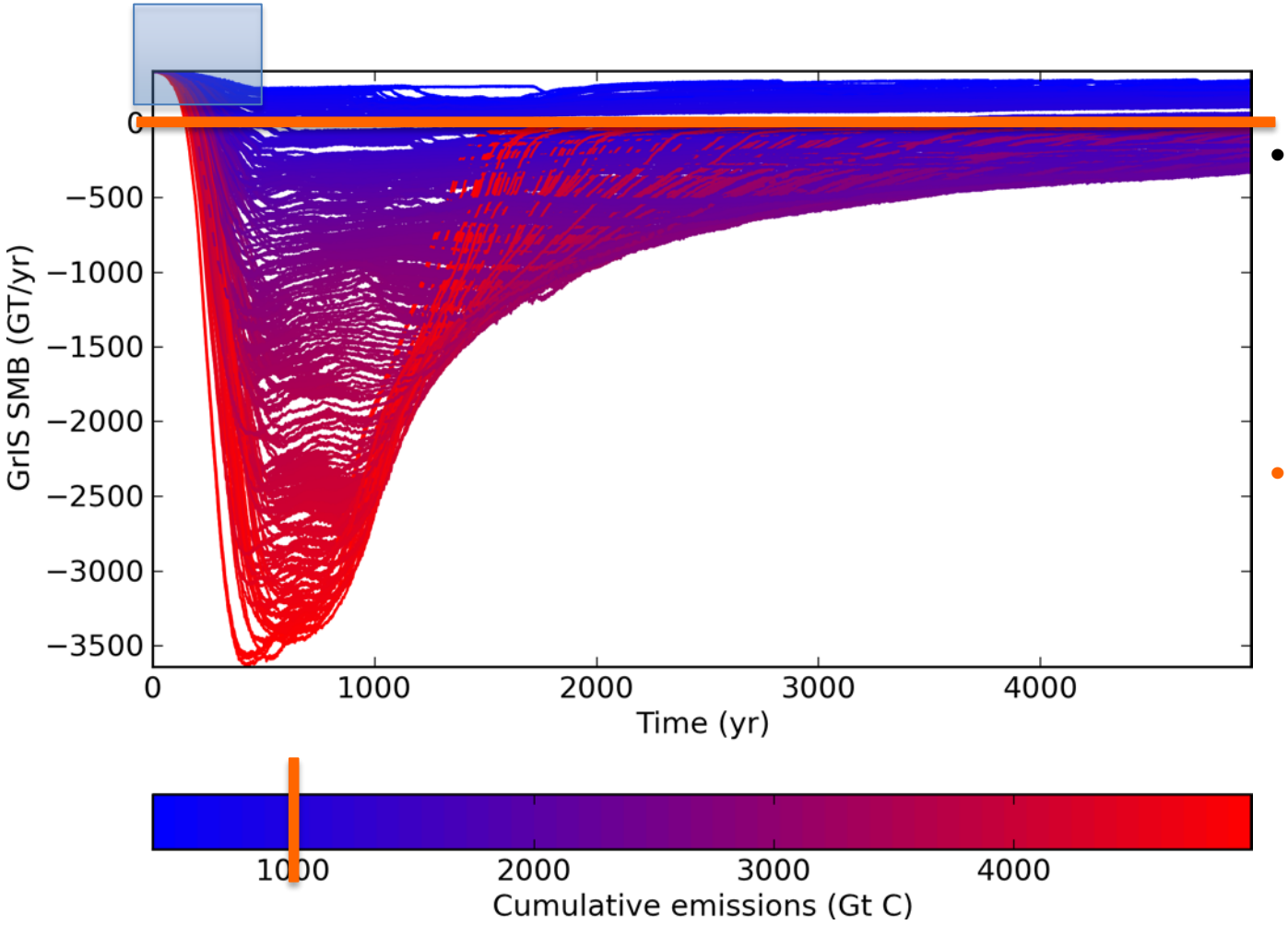


- Initial SMB within range of regional model recent historical estimates (e.g. RACMO2, Van Angelen et al. (2013)
- Negative climatological SMB occurs at least once above 1030 Gt C

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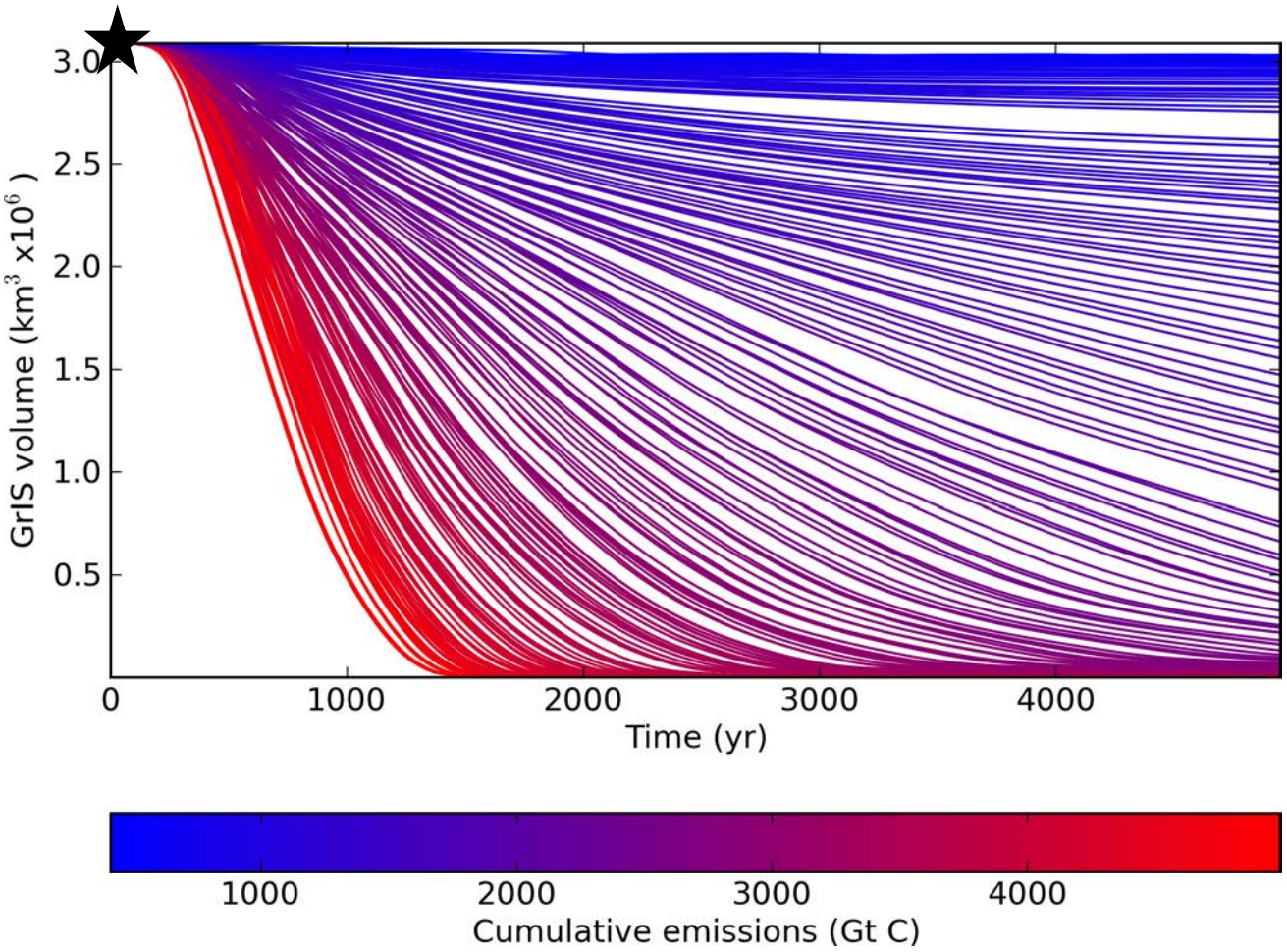


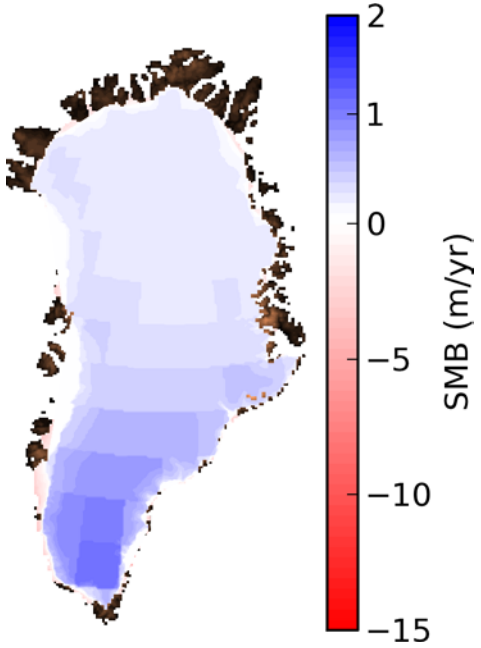

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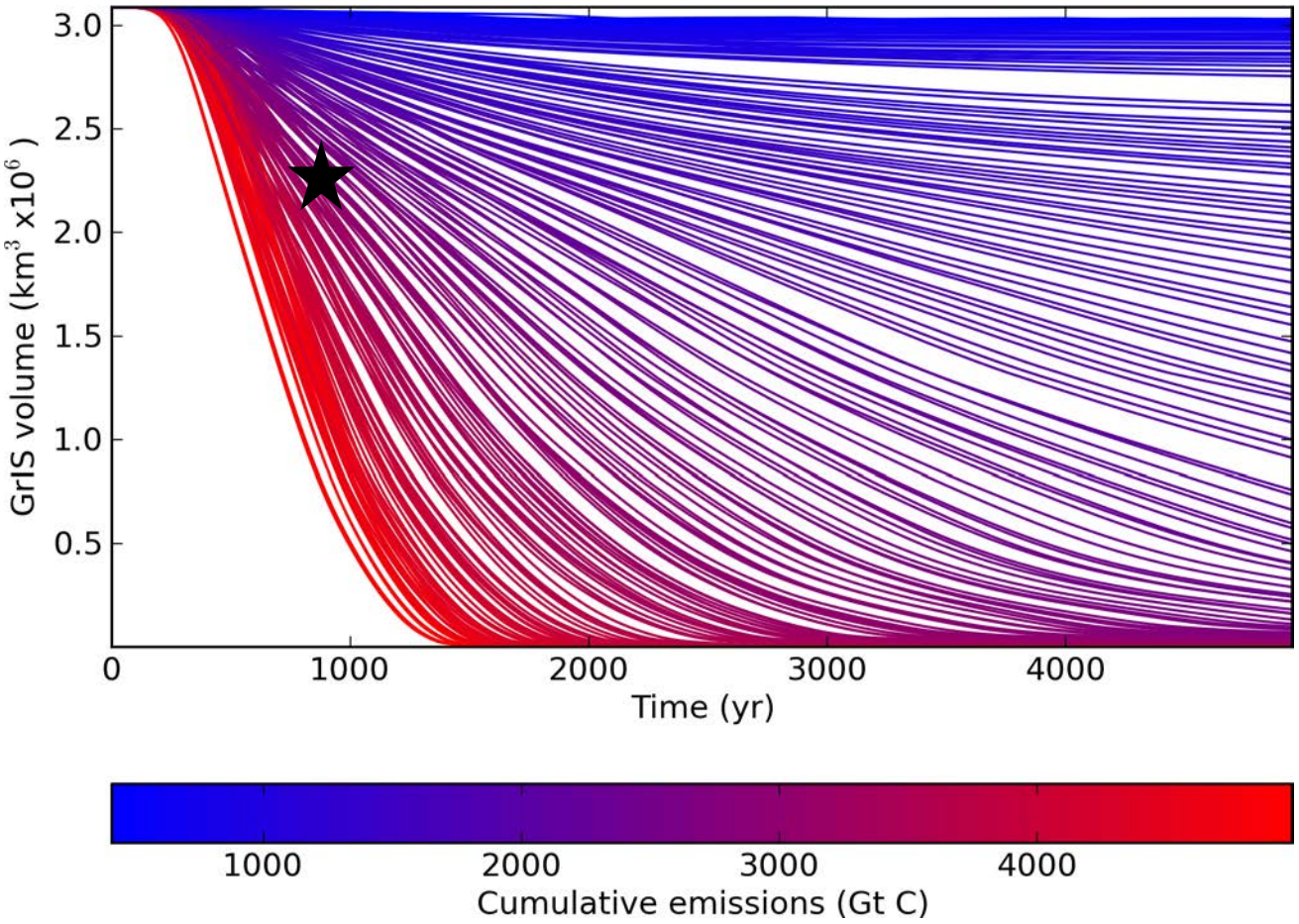


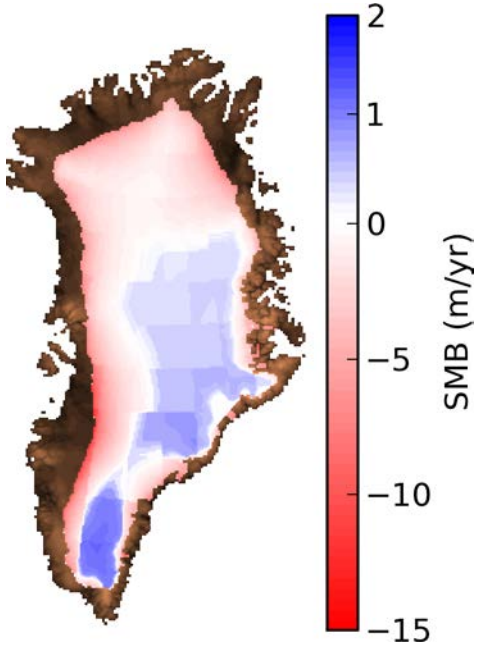

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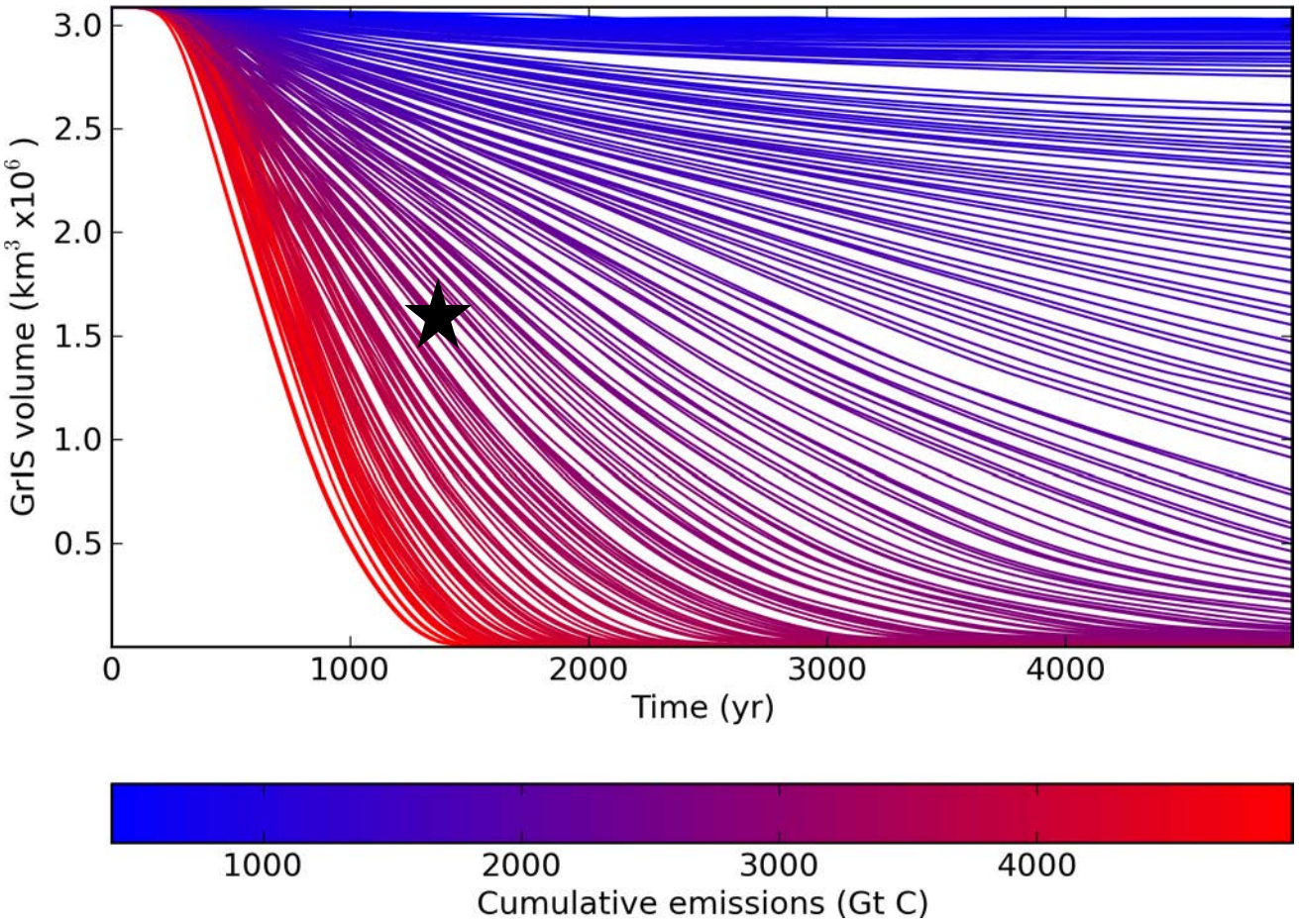


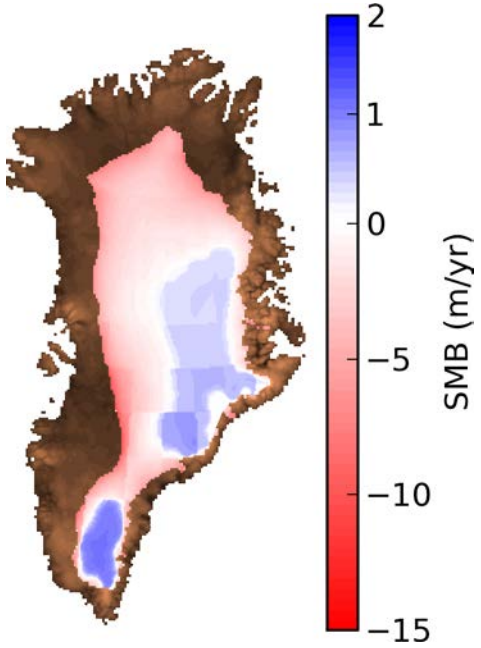

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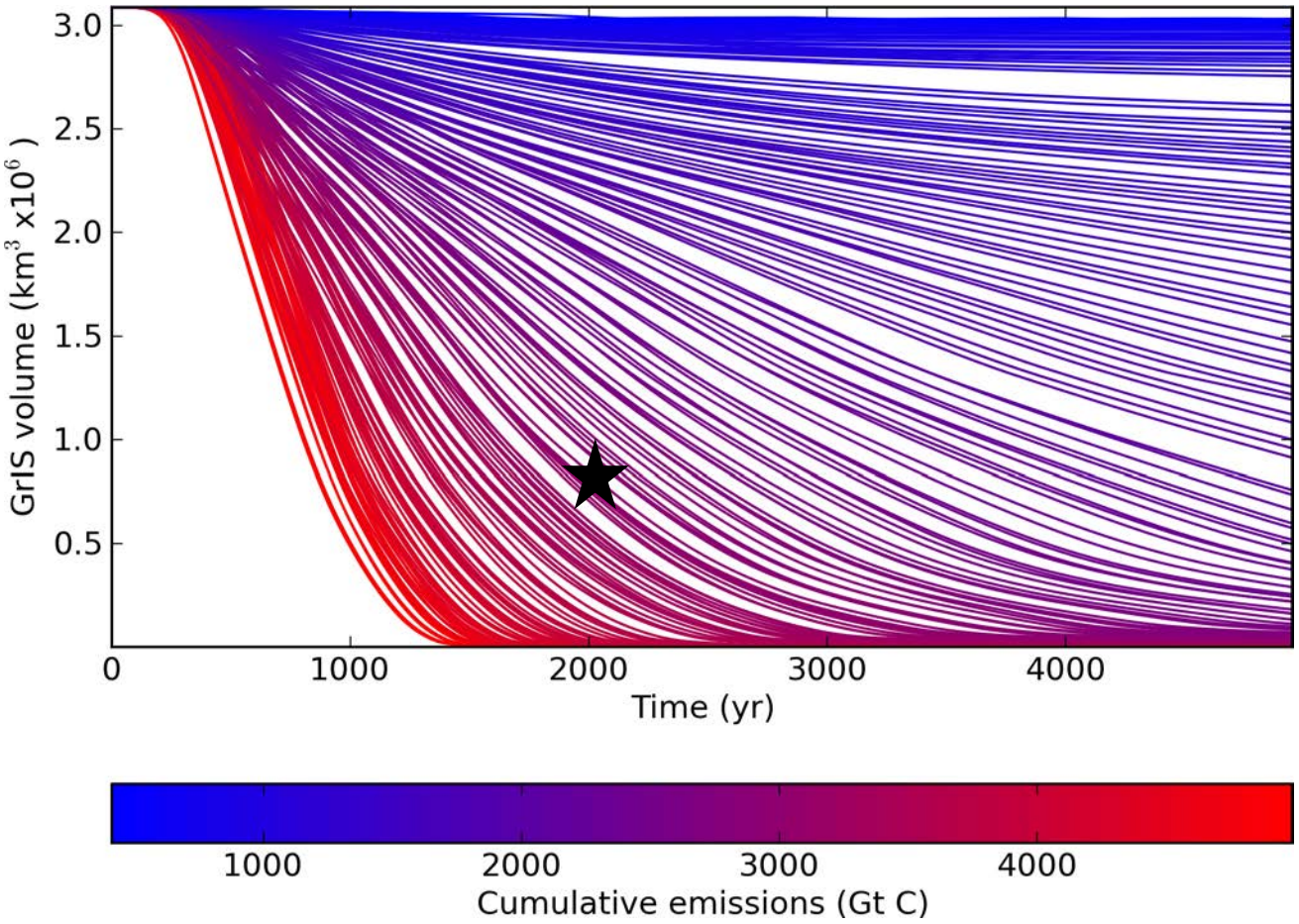


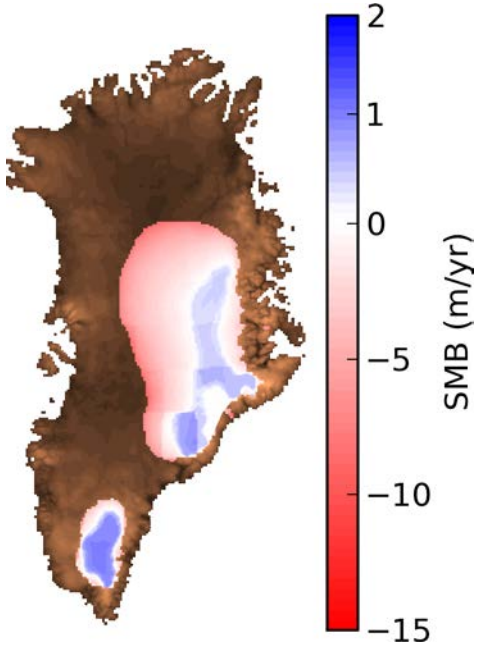

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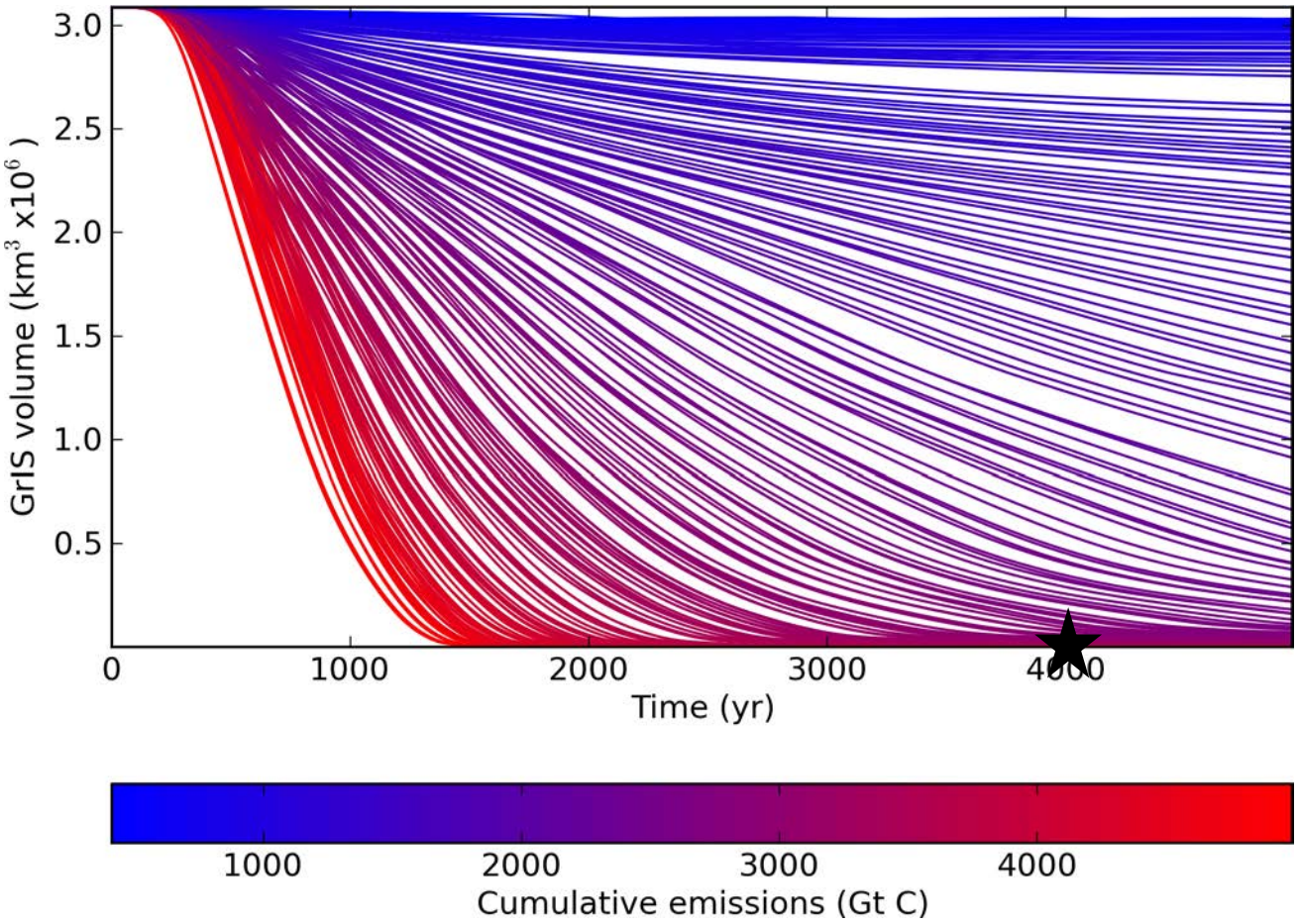


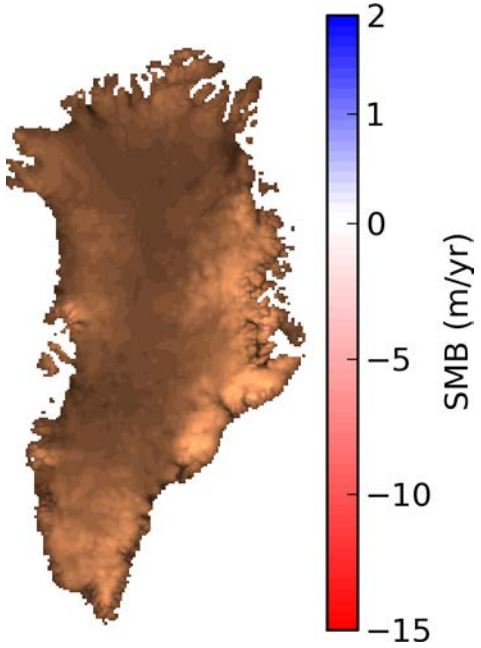

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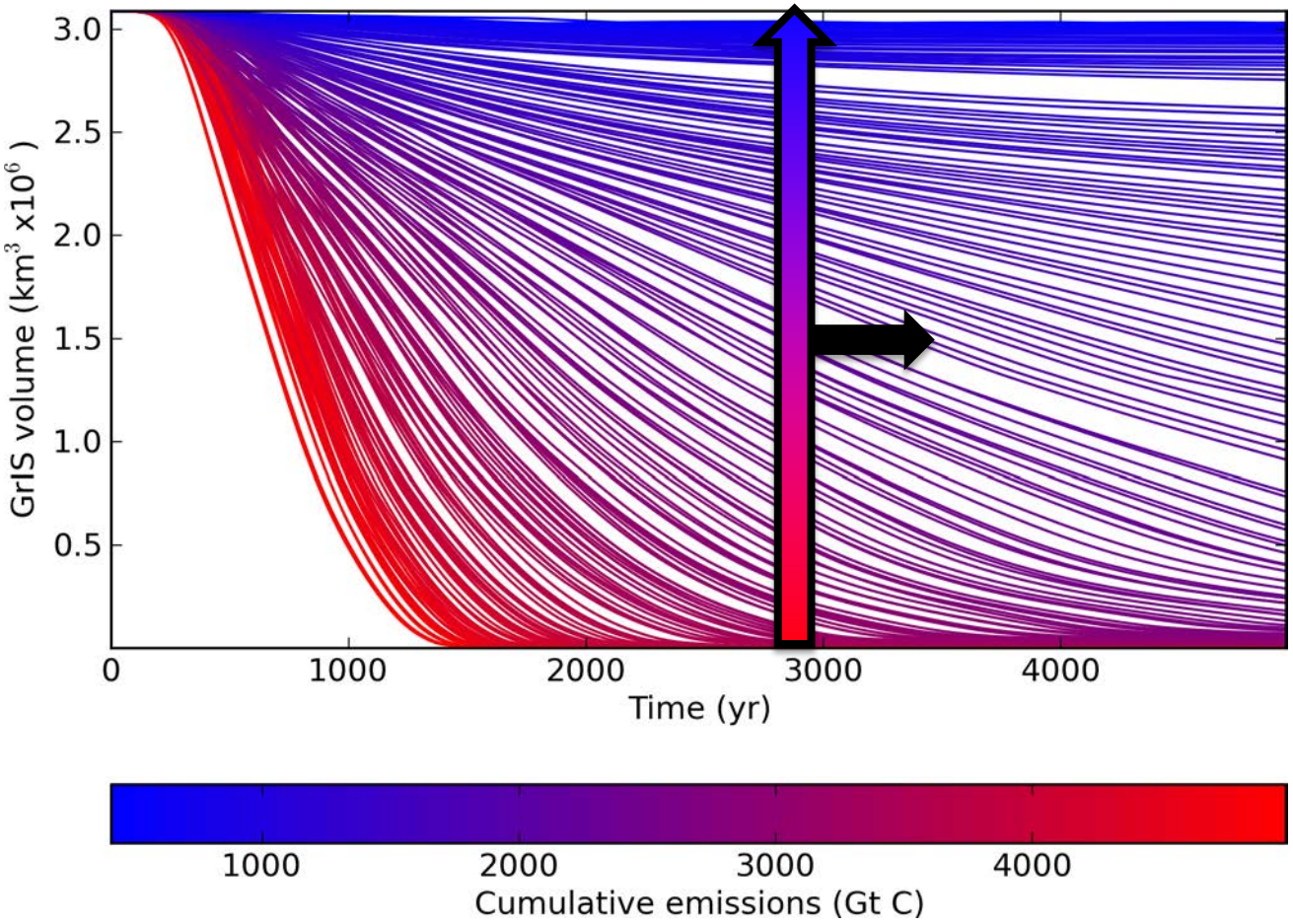
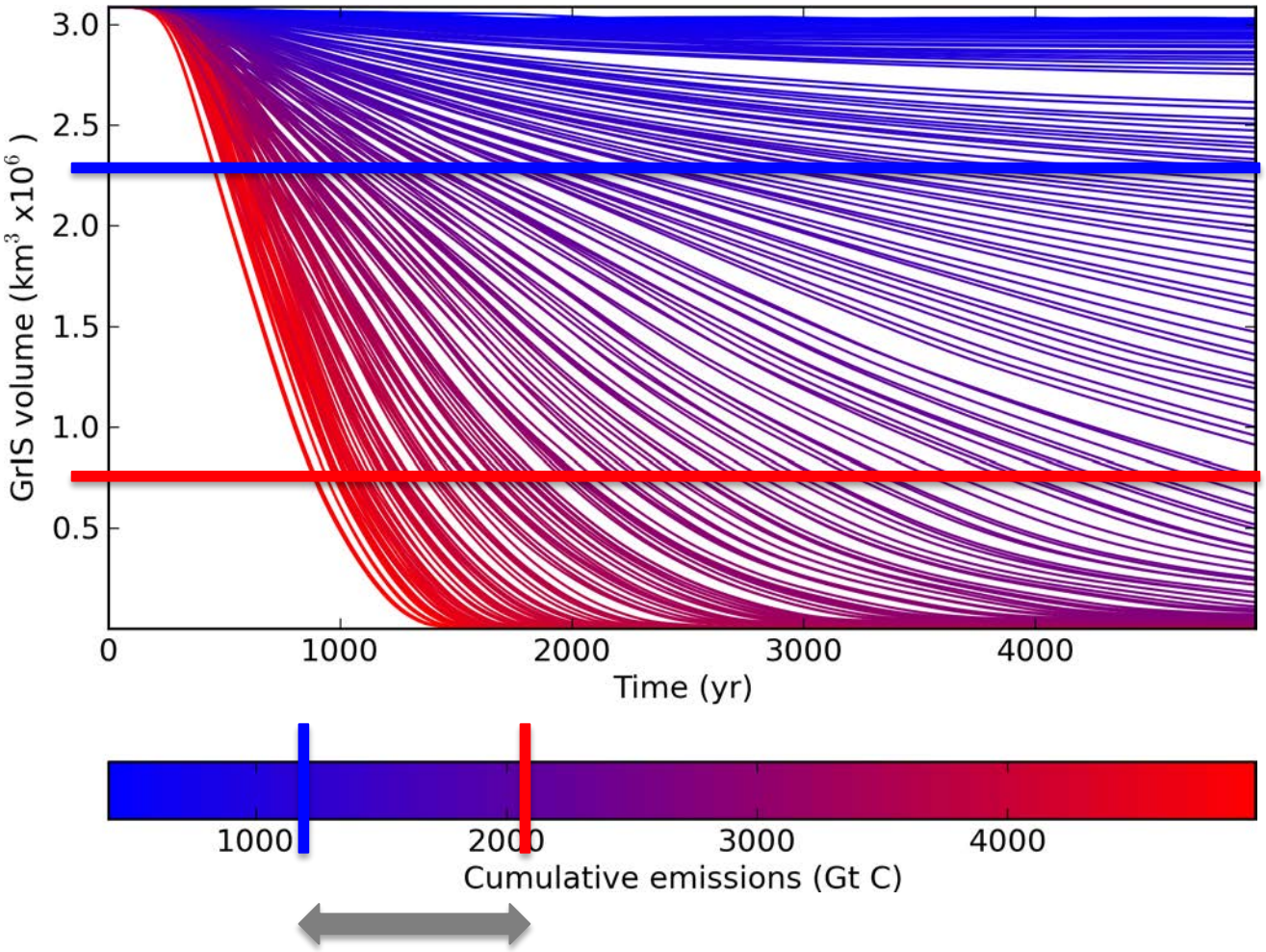


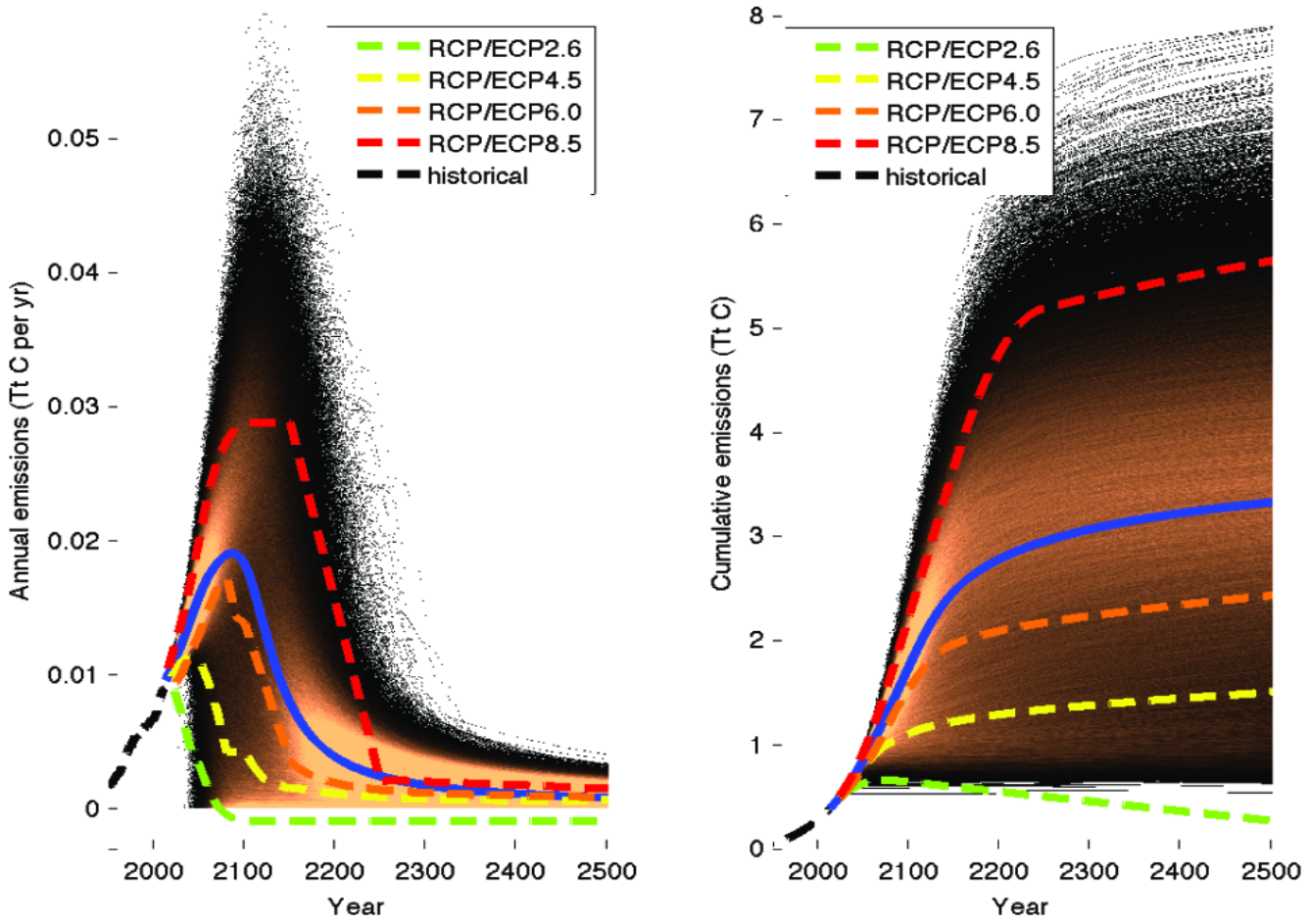

- Monotonic volume/cumulative emissions relation: GrIS long-term response largely independent of emission pathway

# GrIS cumulative carbon threshold




- Increasing segregation into ‘full-ice/no-ice’ states
- Below 1330 Gt C: <25% GrIS loss after 5000 years
- Above 2113 Gt C: >75% GrIS loss after 5000 years
- Intermediate range subject to long-term decay on deep-ocean sediment/orbital timescales

# Relation to climate policy




- $10^5$-member latin hypercube CEPM ensemble (range of social, economic, technological and policy assumptions)

Fyke and Matthews (2015, ERL)

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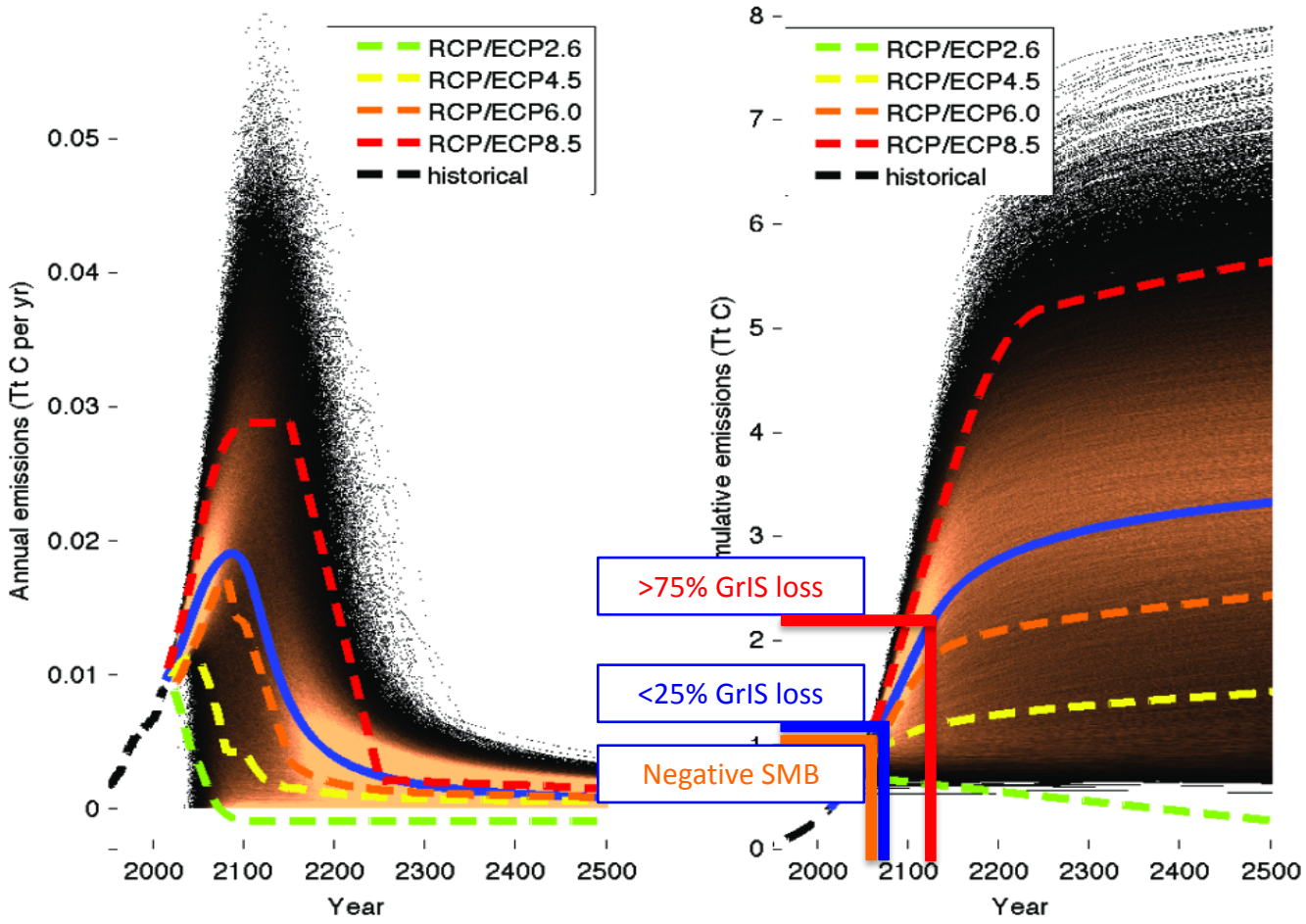
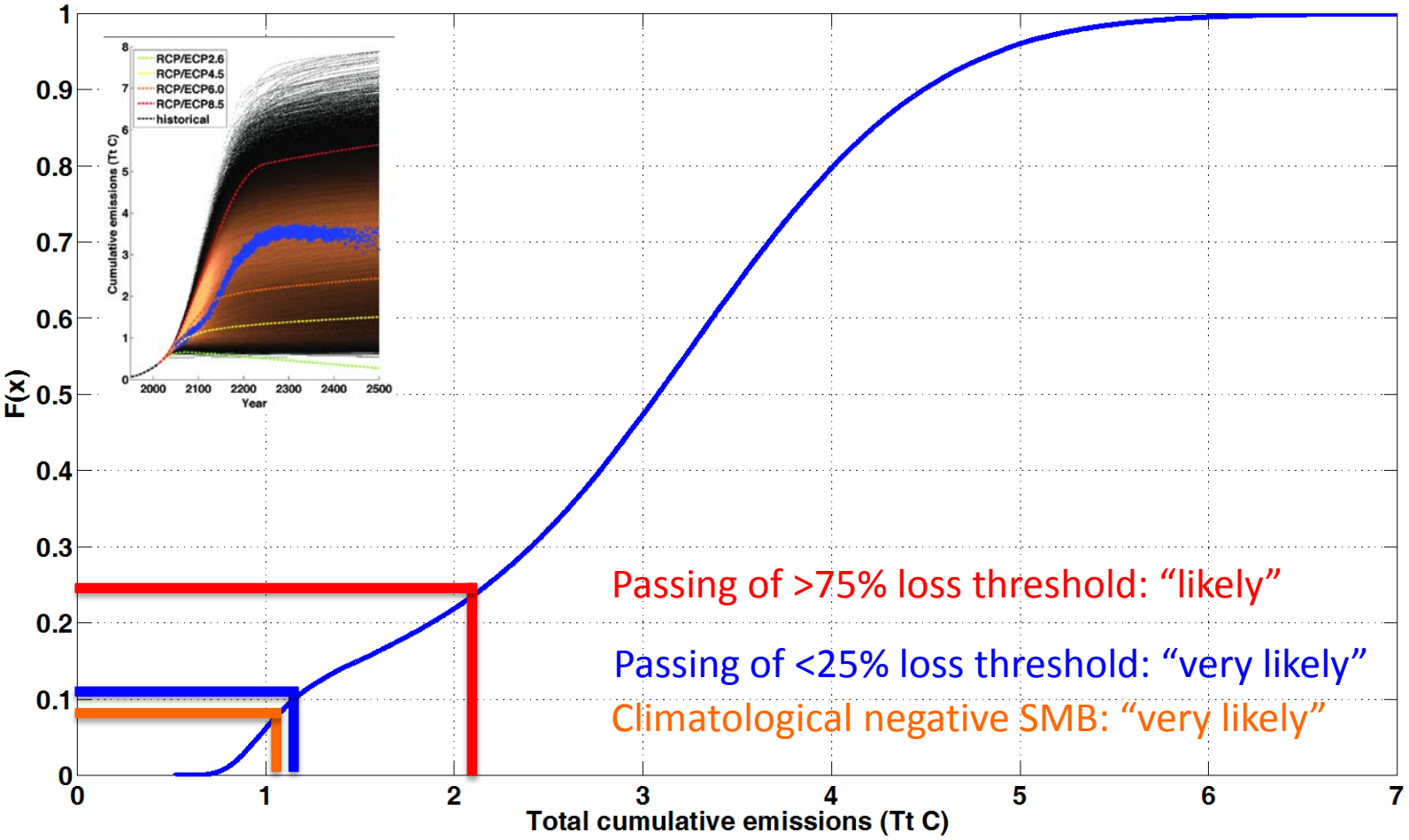



- Threshold remapping to IAM time-domain results -> ‘time-of-threshold-crossing’ estimates

# Relation to climate policy




- Threshold remapping to cumulative emissions CDF allows for IPCC-style likelihood statements

# Conclusions

- Coupled ice-sheet/climate/carbon model developed to relate GrIS response to cumulative anthropogenic emissions
- Cumulative carbon-based stability threshold ranges from 1331 Gt C (<25% GrIS loss) to 2113 Gt C (>75% GrIS loss)
- Probabalistic cumulative emissions modeling: >75% GrIS loss “more likely than not”

Thanks!

# Questions for LIWG

- Is there any other feasible way of determining ice sheet stability in a policy-relevant framework?
- Can we tackle this problem with CESM?
  - CESM has (new):
    - Ice sheet coupling
    - Coupled carbon cycle
    - No EMIC-style 'short-cuts' elsewhere in climate system
  - But:
    - Very expensive!
      - Carbon cycle and ice sheet among slowest of Earth System components to spin up
      - Assessment of stability requires multi-millennial future simulations
    - Many cats in a coupled ice-sheet/carbon/climate simulation
  - One answer: increasing support for 2 degree CESM version
    - Generation of necessary infrastructure
    - Validation of (e.g.) climate, SMB, ice dynamic response