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Multistability and Transient Response of the Greenland Ice Sheet to Anthropogenic CO_2 Emissions

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Melting of the Greenland Ice Sheet

- Melting of Greenland ice sheet (GIS) drives sea level rise: potential for 7m
- But response to temperature rise is nonlinear and slow (kyr timescale)

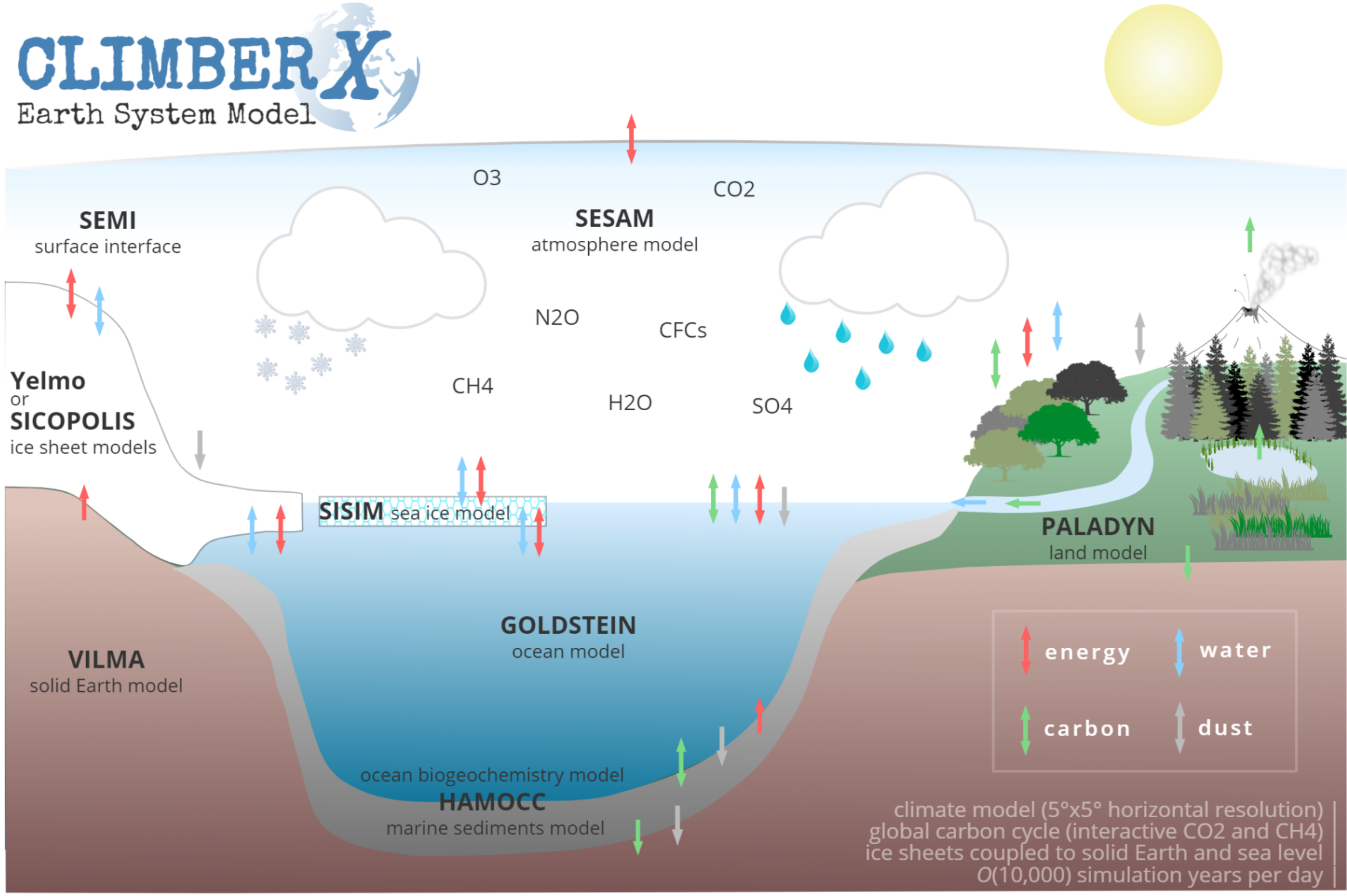
- Stable states and tipping points?
- Critical cumulative CO_2 emission?

Apusiaajik Glacier, Greenland © NASA/JPL

Methods: Earth System Model CLIMBER-X

- Fully coupled Earth system model of intermediate complexity
- 3D ice sheet model SICOPOLIS applied to GIS

1. Explore equilibrium states of GIS
2. Transient simulations with different cumulative CO_2 emissions, explore crossing of critical thresholds



Willeit et al. 2022, 2023

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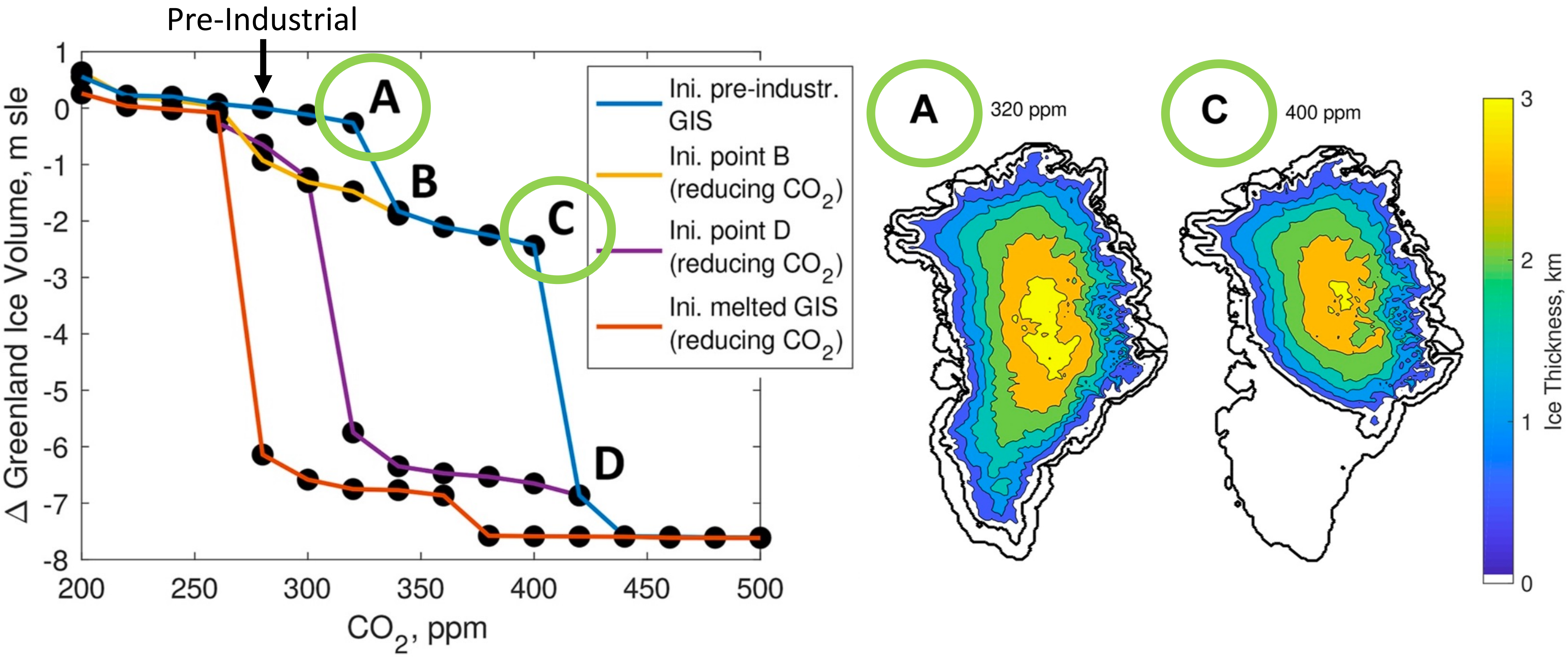
Constant CO_2 Simulations: Equilibrium States of the Ice Volume



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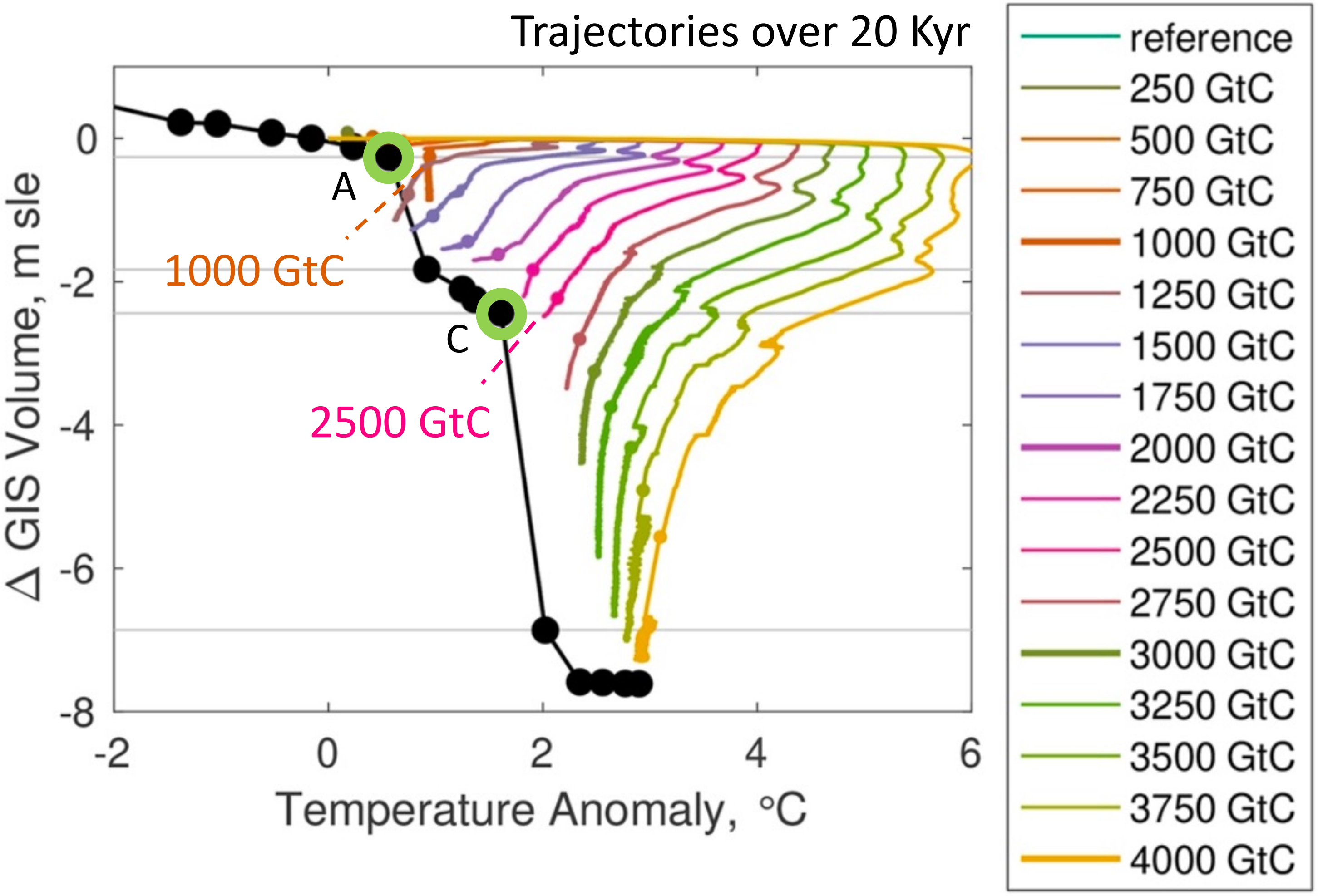
Link Emission Pulse Scenarios to Equilibrium States

- First tipping point crossed for >1000 GtC → 1.8 m sea level rise
- Second tipping point crossed for >2500 GtC → ~7m sea level rise

Humanity emitted 500 GtC so far



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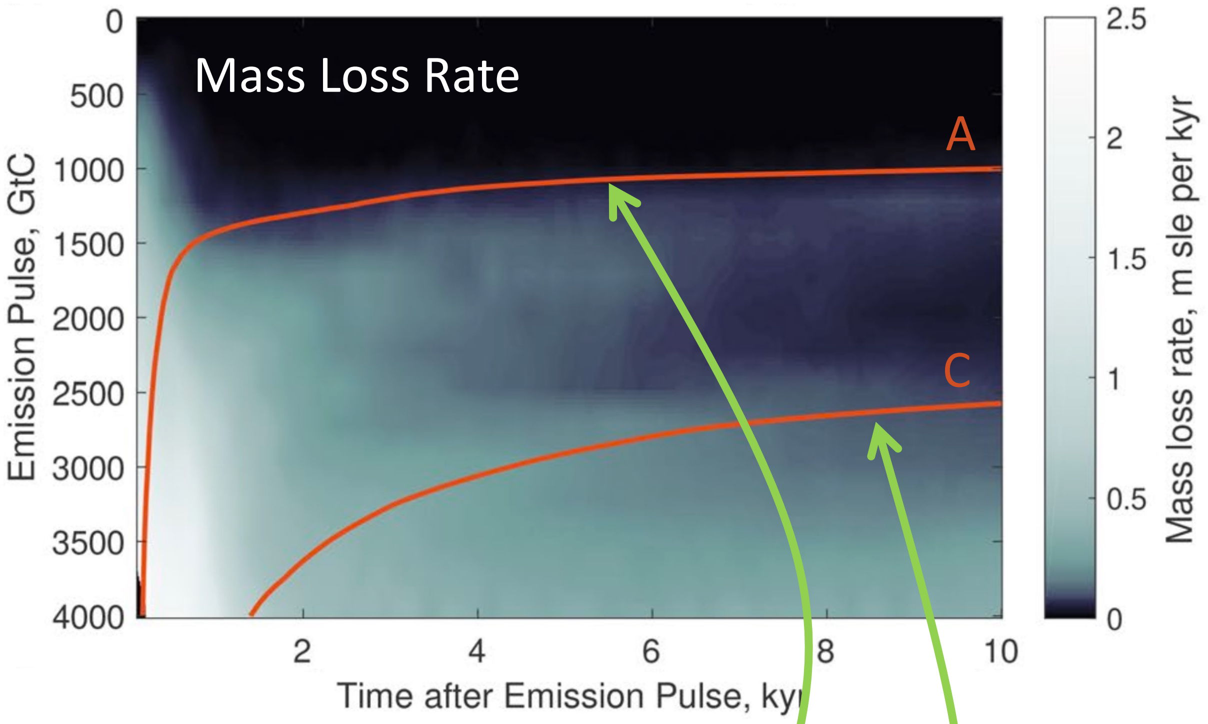
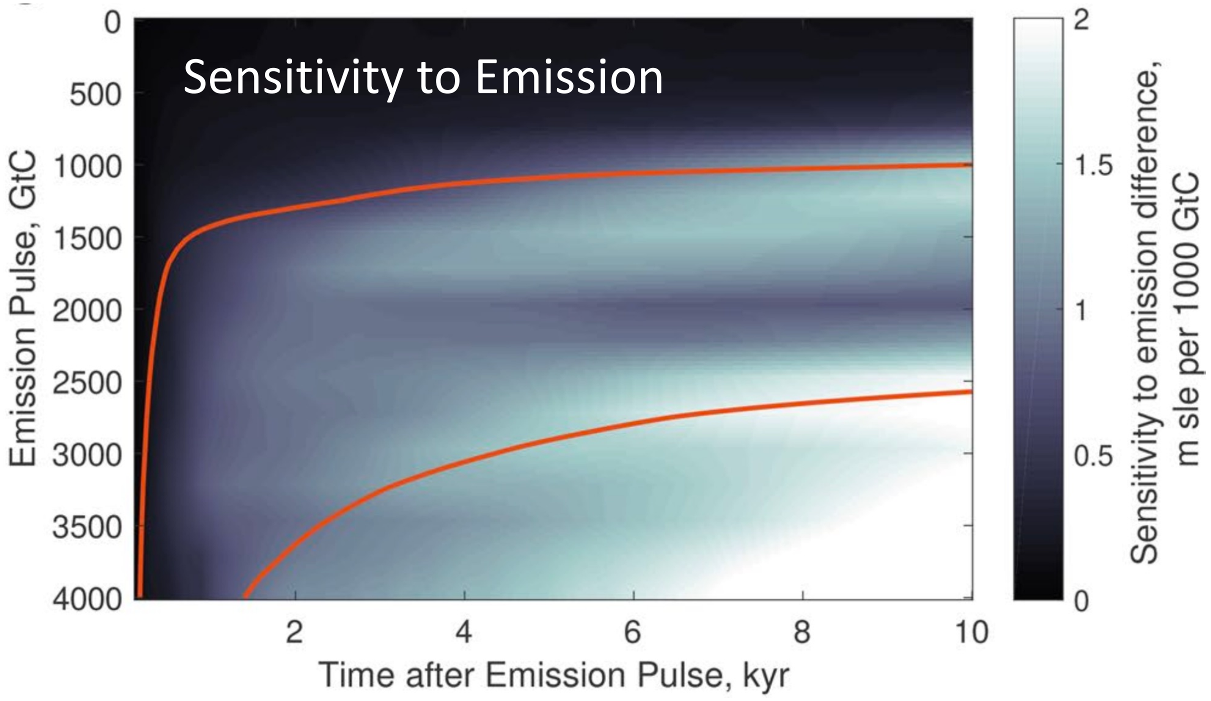
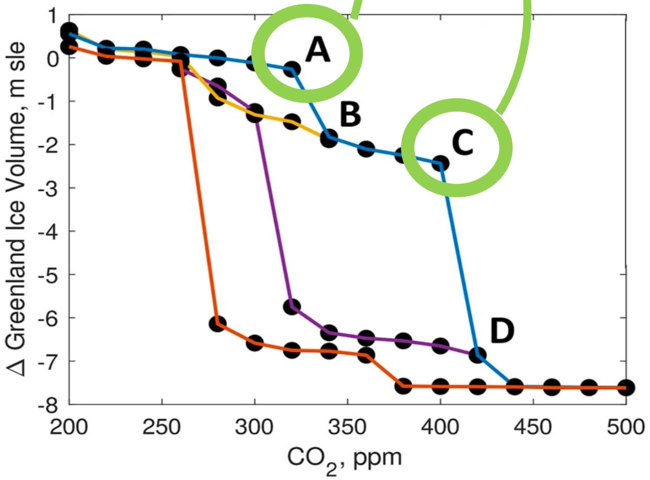
Mass Loss Rate and Sensitivity to Cumulative Emission







→ High mass loss rate and high sensitivity to cumulative emission near the tipping points

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Conclusions

- Tipping points of Greenland ice sheet crossed for anthropogenic emissions >1000 and >2500 GtC

→ Committed sea level rise by 1.8 and 7m

- Crossing implies peak melting rates and peak sensitivity to cumulative emission
- Melting of the GIS will take millennia – but its path will be decided this century

NASA/JPL

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