Creating a Sea-Level-Enabled E3SM: A critical capability for predicting coastal impacts

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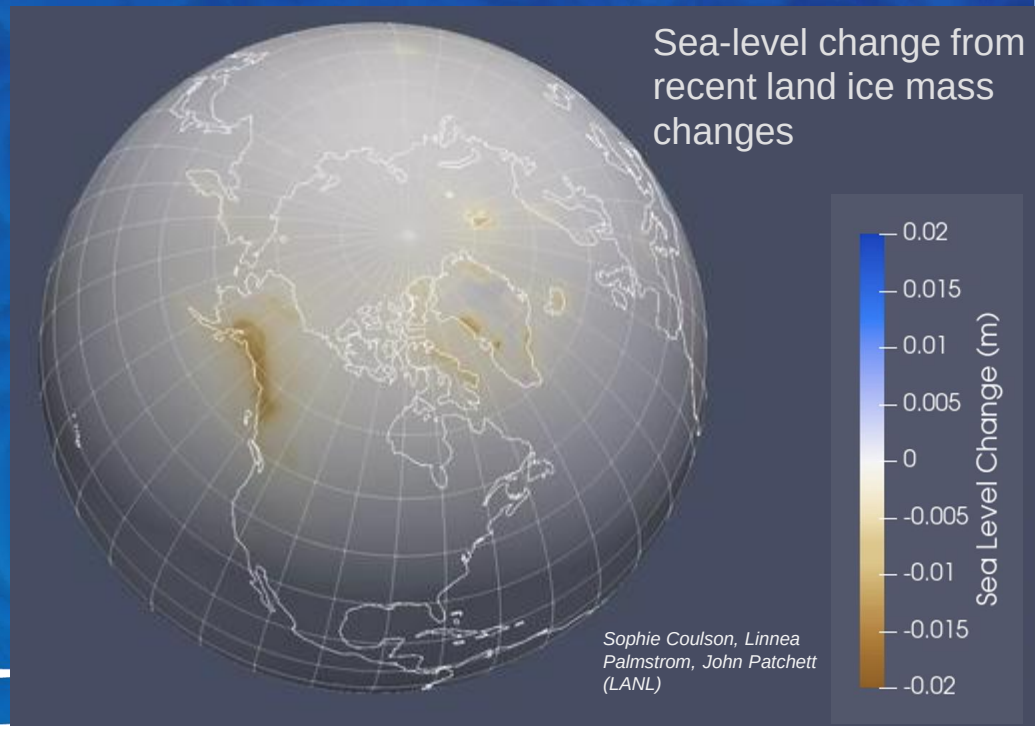

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Sophie Coulson (PD)
Trevor Hillebrand (PD, now staff),
Sid Bishnu (PD), Yaris Eidenbenz (HS intern)

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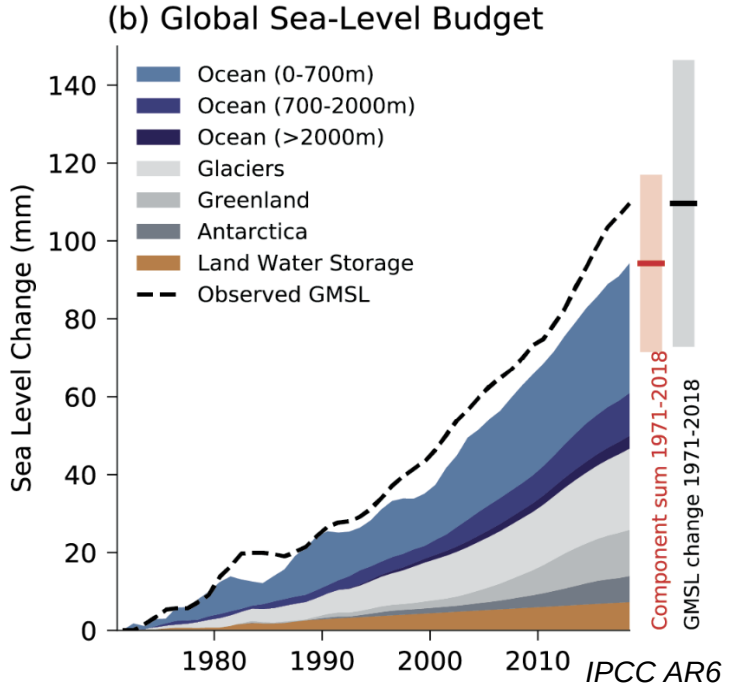
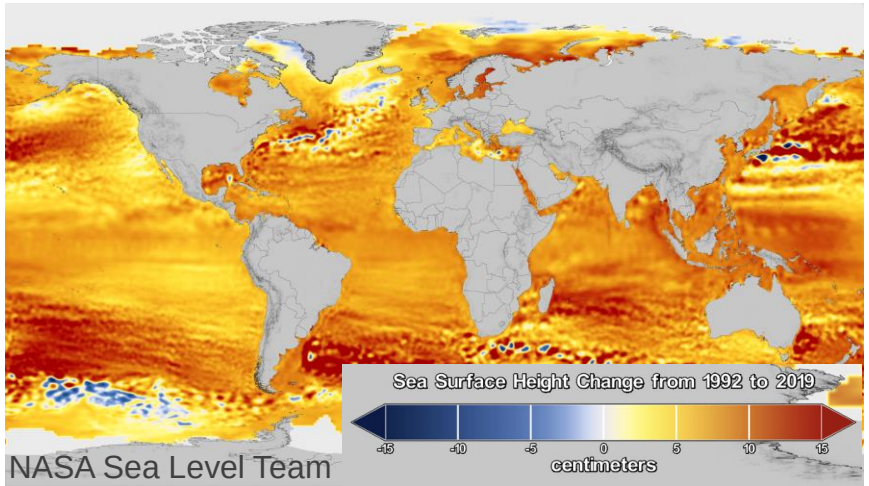
E3SM Energy Exascale Earth System Model

Challenges

- Sea-level change is major impact of climate change, but Earth system models only account for the ocean contribution

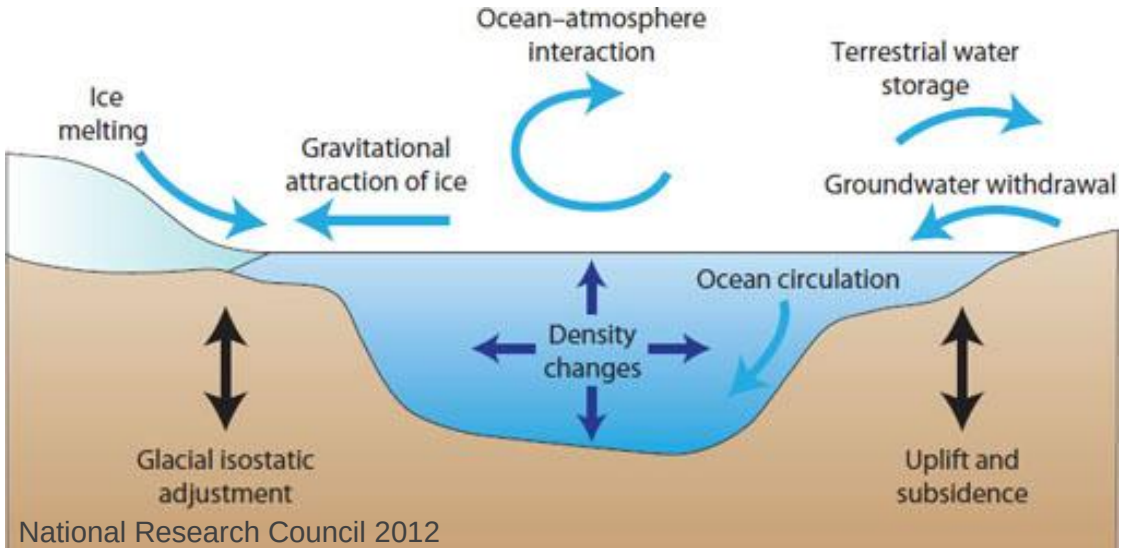


- Sea-level change varies regionally due to ocean and solid Earth processes



Project Objectives

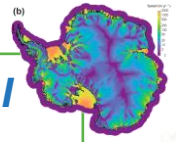
- Produce diagnostic evaluation of regional sea-level change in E3SM accounting for
  - land ice mass changes
  - terrestrial water storage changes
  - solid Earth deformation and gravitation changes
  - ocean density changes
  - ocean dynamics changes
- Add regional sea level representation to ocean & ice-sheet models
- Quantify sea-level/Earth-system feedbacks
  - Sea-level/ice-sheet interactions
  - Sea-level/ocean interactions

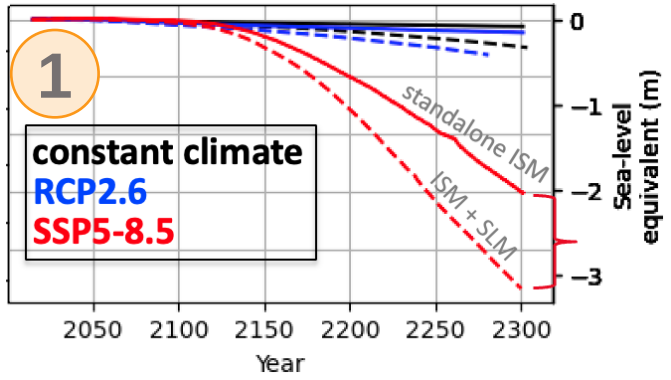


National Research Council 2012

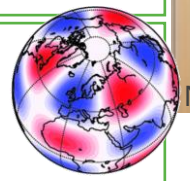
Contributions to Regional Sea Level

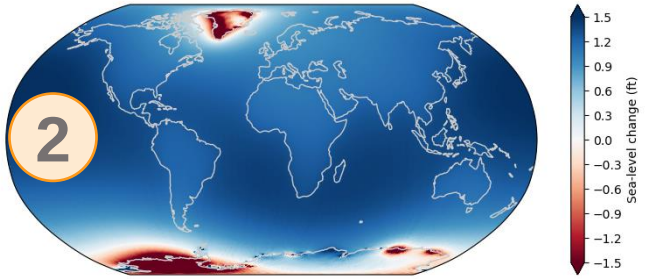
Ice-sheet mass change: *MALI*

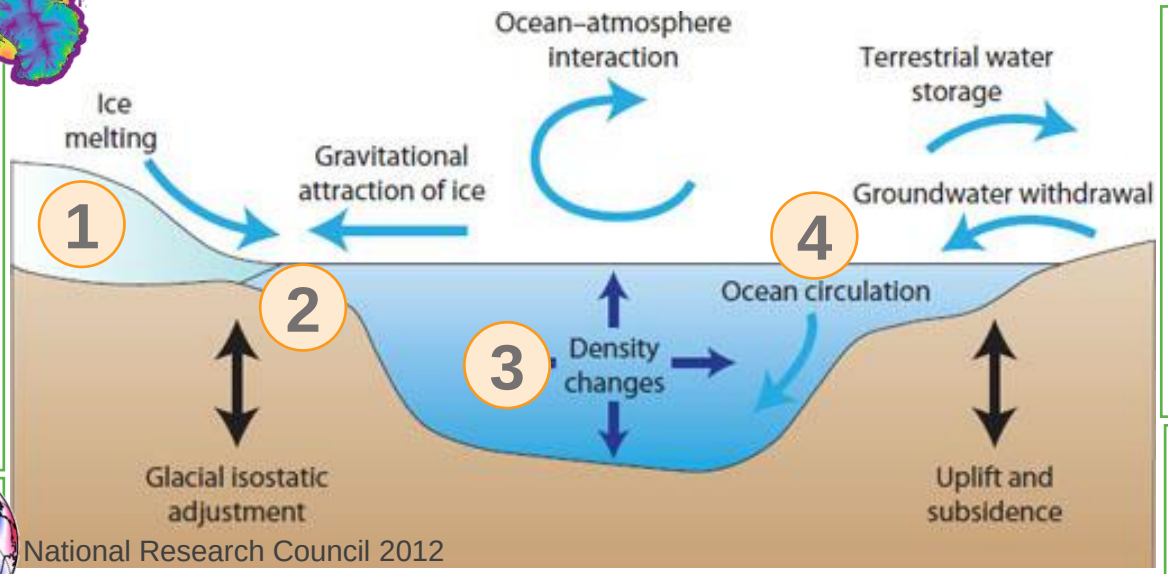




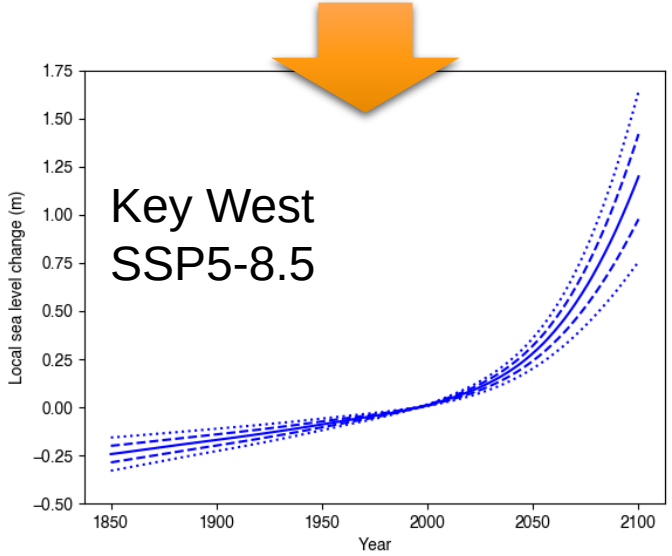
Gravitational, Rotational, Deformation effects: *Sea-Level Model*

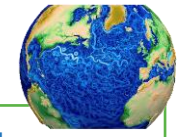




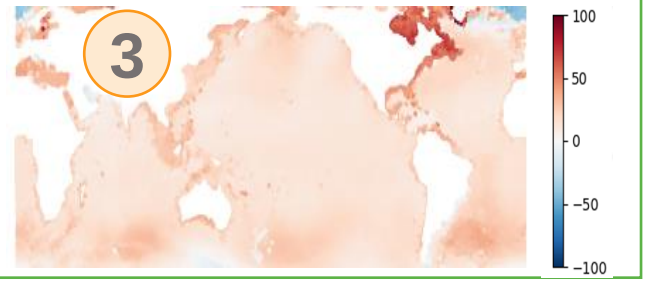


National Research Council 2012

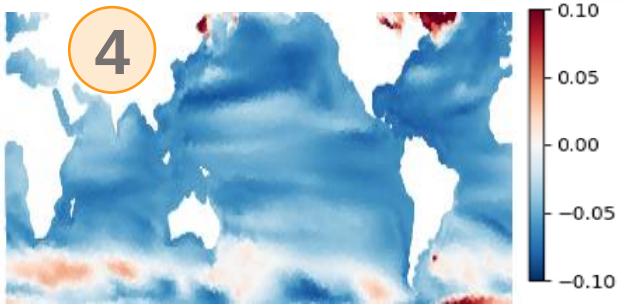




Ocean steric sea-level change: *MPAS-Ocean*



Dynamic sea-level change: *MPAS-Ocean*



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Sea-Level/Ice-Sheet Feedbacks

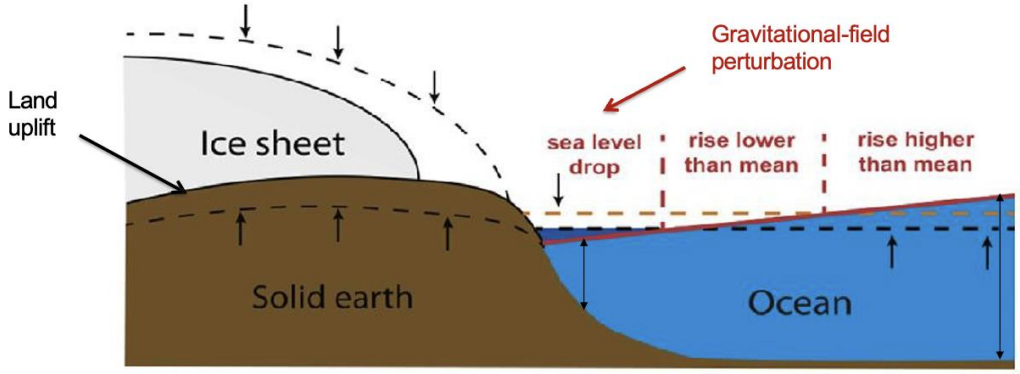
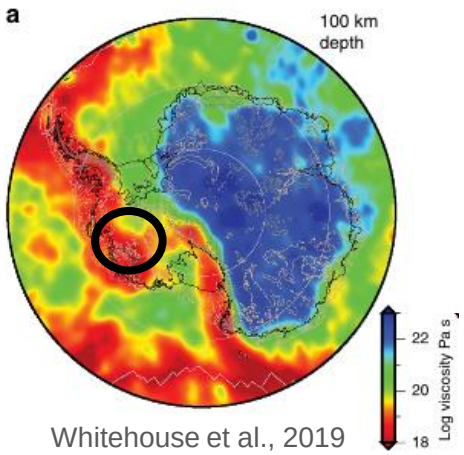
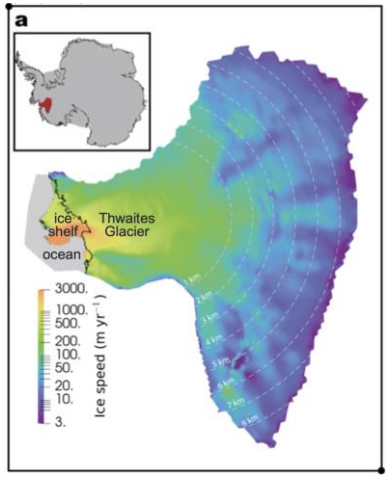
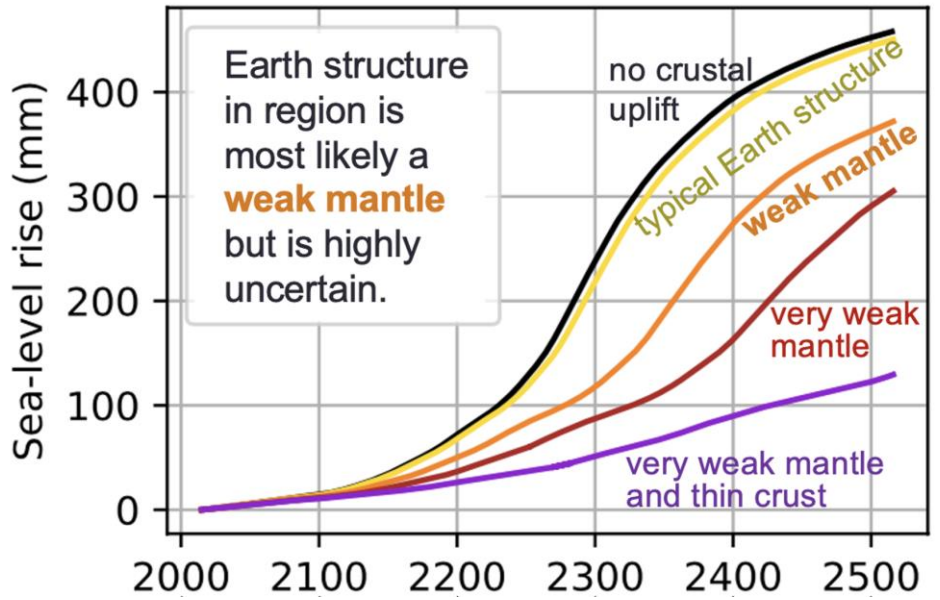


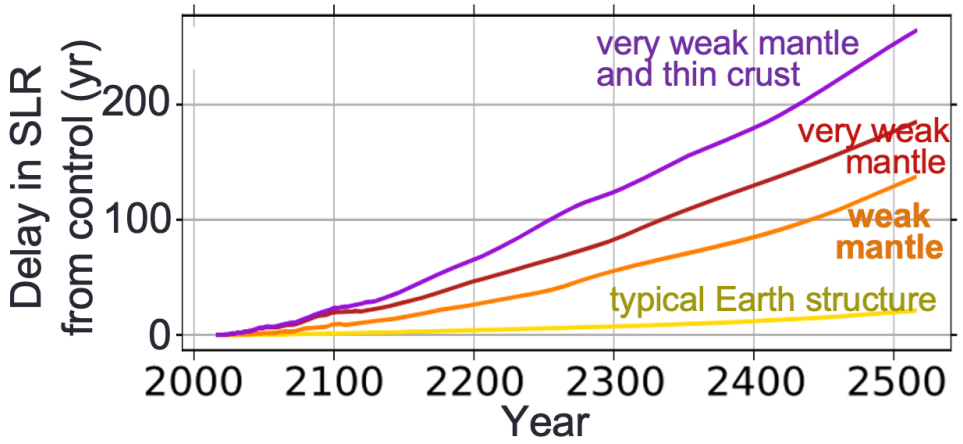
Figure 1. Schematic showing effects of ice-sheet melting on sea level (adopted from Fyke et al., 2017)



Whitehouse et al., 2019





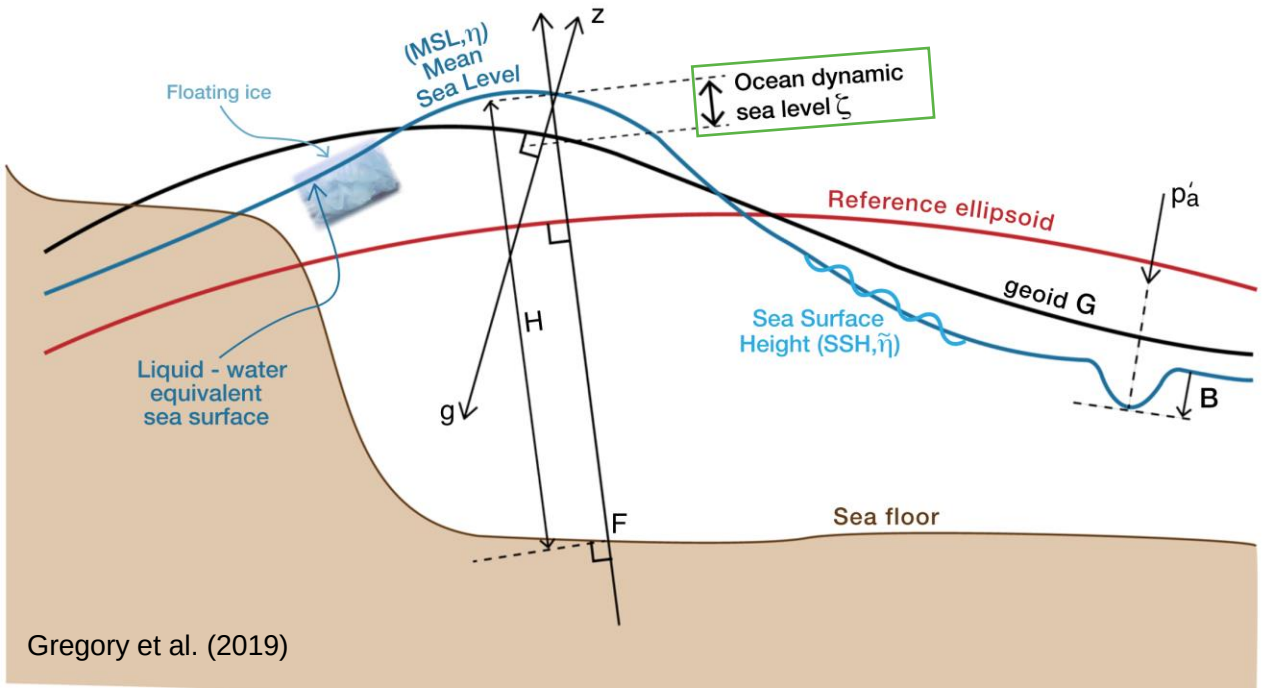


Book et al. EPSL (2020)

Solid Earth response to dynamic sea-level

- **Dynamic sea level** = deviation of sea surface height from geoid
- Predicted using global ocean models

- Mass redistribution from DSL is a load change to the solid earth.



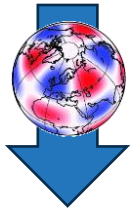
Gregory et al. (2019)

Research Question:
How much does solid Earth deformation modify DSL?

Solid Earth response to dynamic sea-level

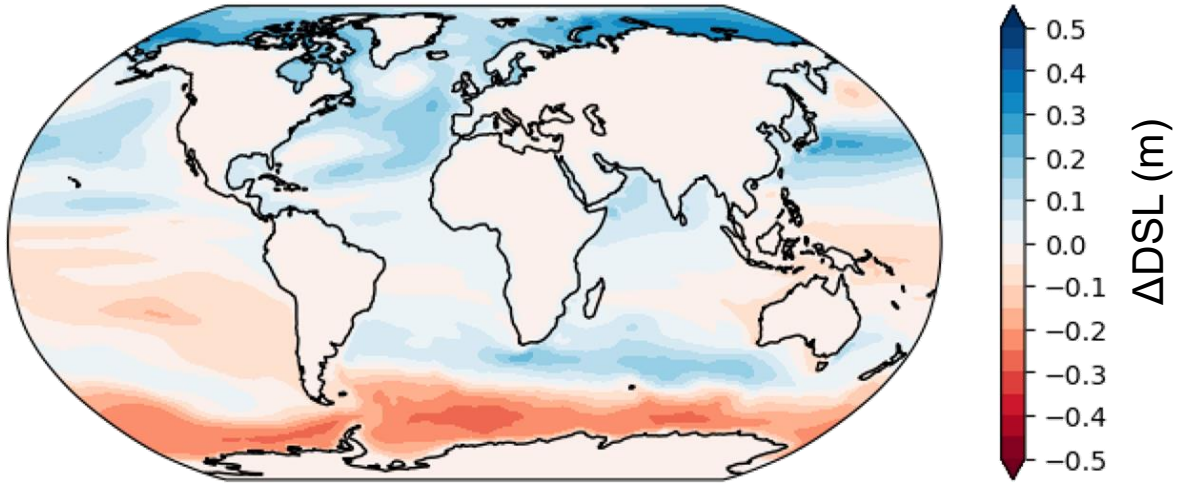
Dynamic sea level projections

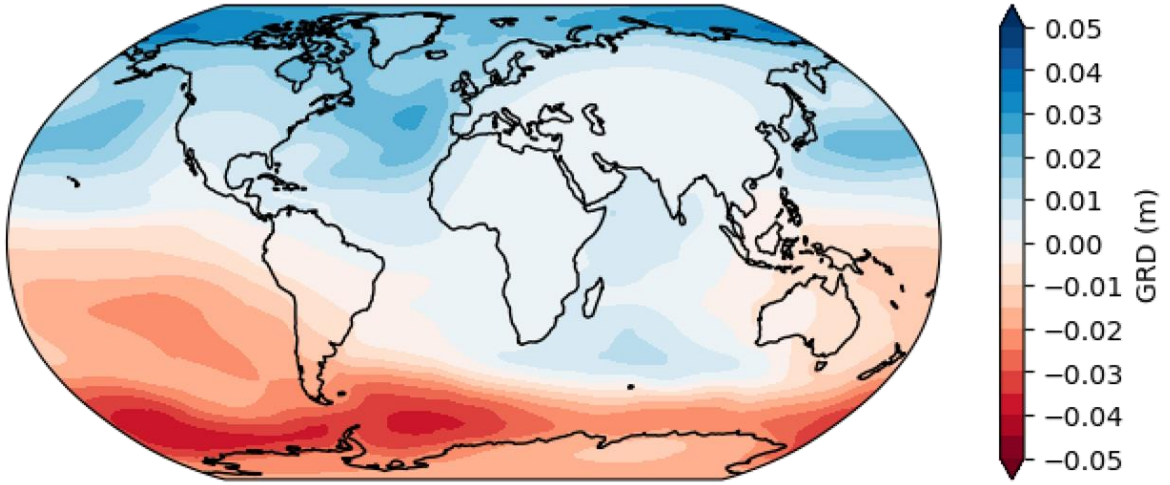
- Height variation of ocean surface due to ocean dynamics
- E3SM v1, 2015-2100



Additional sea-level change due to deformation & gravitation

- 1-D Sea-Level Model (Han et al. 2020)
- Apply ΔDSL as surface load change

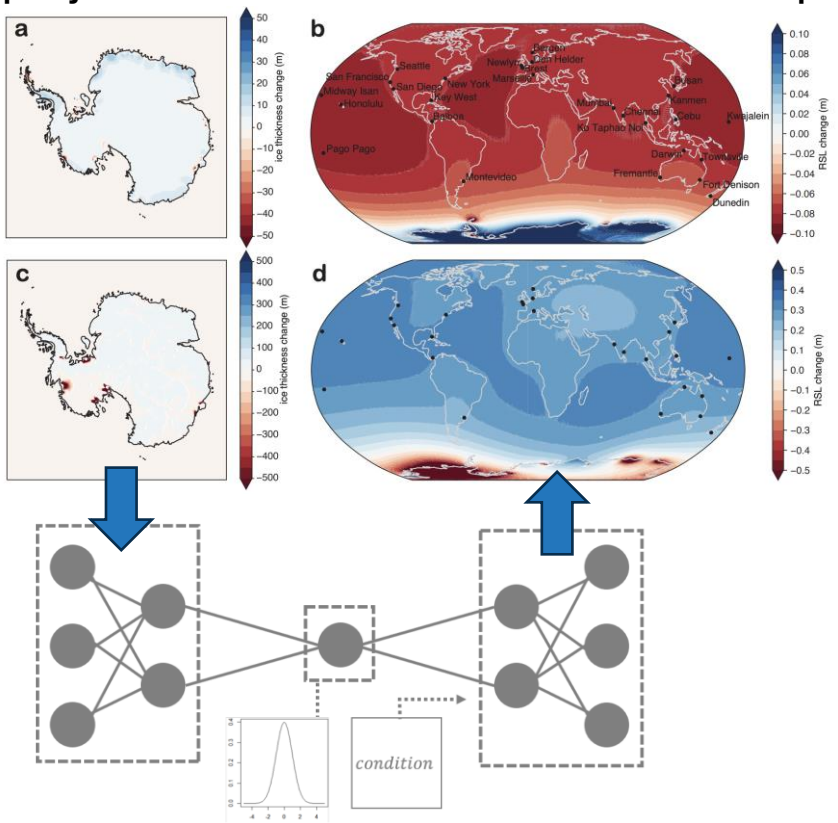


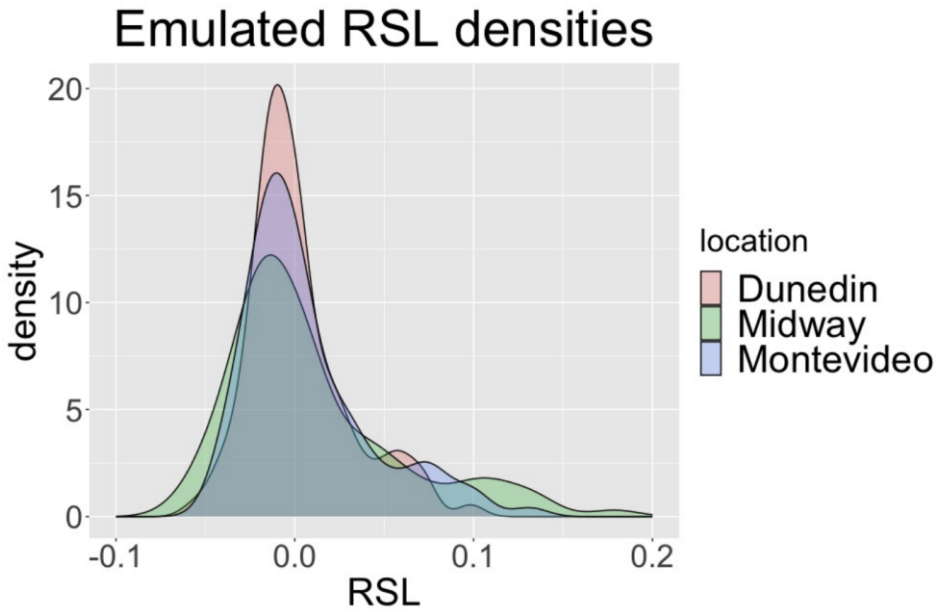


Machine learning emulation of regional sea-level model

Ice-sheet model projections

Corresponding sea-level model output





ML Emulator: 100x faster

(Conditional variational autoencoder)

Yoo et al. JGR-MLC (submitted) https://arxiv.org/pdf/2406.17729

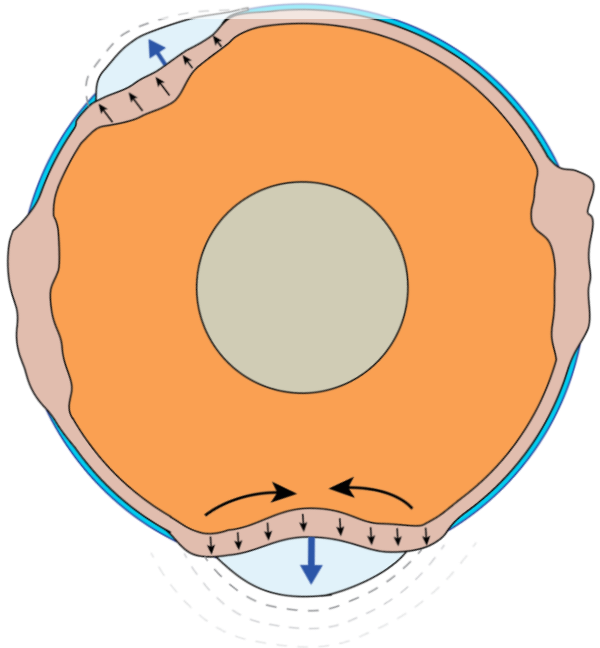
Outcomes

Career Growth with ECR

- Build reputation & collaborators in new discipline
  - Sophie Coulson – University of New Hampshire
  - Holly Han – NASA Jet Propulsion Laboratory
- ECR experience springboard to PI SciDAC project (FAnSSIE)
- Sea-Level Focus Group Co-Lead for Ice Sheet Model Intercomparison Project (ISMIP7)

Lessons Learned

- identify critical gaps
- interproject coordination critical
- working at intersection of disciplines requires finding common language, which takes time
- people make the project
- best software practices are best for a reason



Acknowledgements

- Early Career Research Program
- Earth and Environmental Systems Modeling program