Sea Level Modeling, Research, & Prediction Bipartisan Infrastructure Law Activities

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With contributions from: Jacob Steinberg, Sharon Gu, Liping Zhang, Liwei Jia, Brandon Reichl, Lucas Harris, He Wang, Robert Hallberg, Stephen Griffies, Olga Sergienko, Alistair Adcroft, Rebecca Beadling, Henri Drake, Katherine Turner, Jan-Erik Tesdal

Collaborations with Matt Newman (OAR/PSL), Xiaoyu Long (OAR/PSL), Laura McGee (OAR/PSL), and William Sweet (NOS/COOPS)

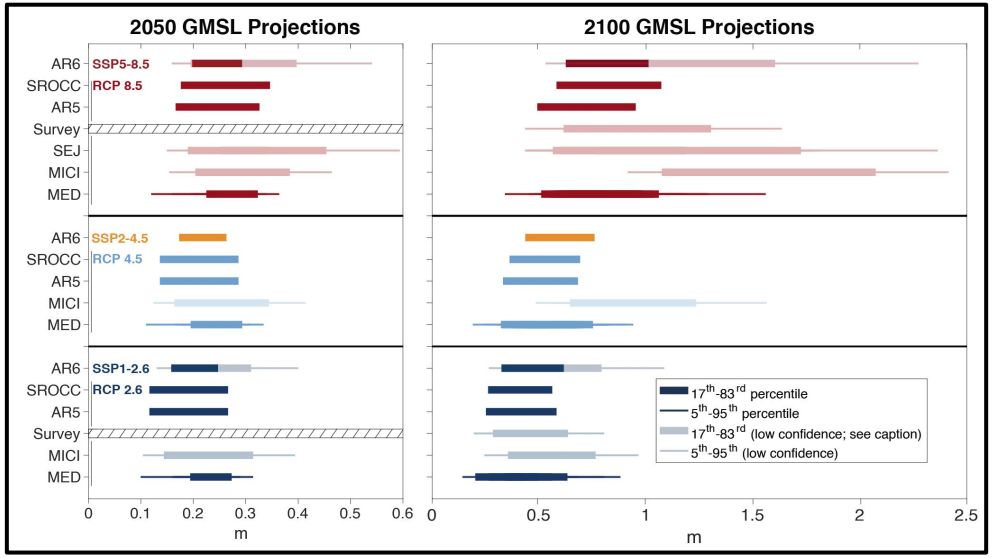
Q3: How can GFDL research and modeling be further utilized to meet NOAA stakeholder needs and enhance research partnerships to ensure GFDL's success?

NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY

Driving forces behind sea level research

Near-term projections of sea level:

- Extreme inundation events are increasingly costly and disruptive to coastal communities
- Opportunity: Provide information on sea level changes ***between now and 2050*** to aid planning.



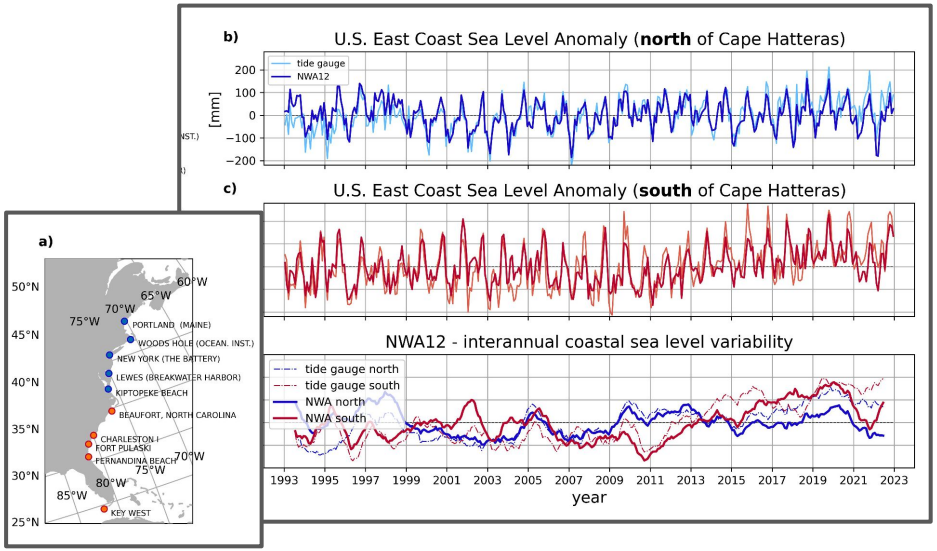
Catastrophic sea level rise beyond 2100:

- Incomplete modeling, theoretical, and observational understanding cryosphere-ocean interactions.
- ***Uncertainty remains high, given the potential consequences.***

GFDL is equipped with advanced models and knowledge to study sea level from weekly to centennial timescales

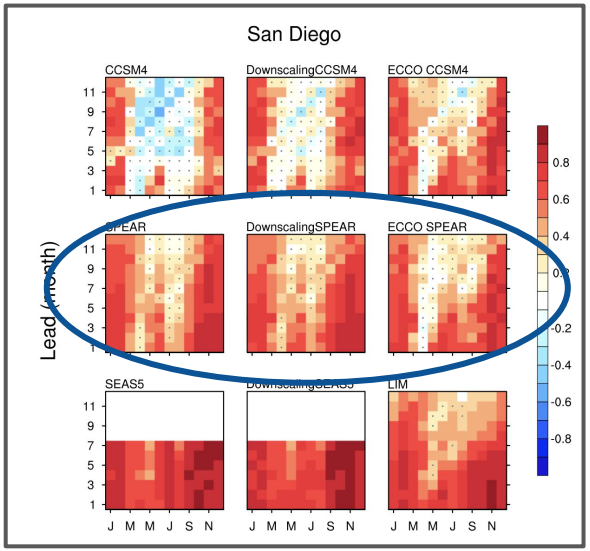
Advancing Seasonal Sea Level Forecasting

Steinberg et al. 2024, JGR Oceans



Identified predictable mechanisms of coastal sea level variability and connections with offshore warming using regional MOM6 configurations.

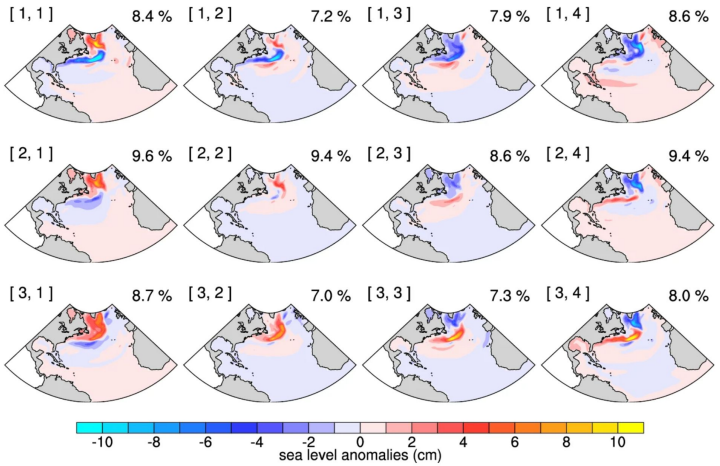
Long et al. 2024, J. Climate (w/ PSL)



SPEAR's wintertime ACC forecast skill at San Diego is comparable to SEAS5, which assimilates satellite altimetry.

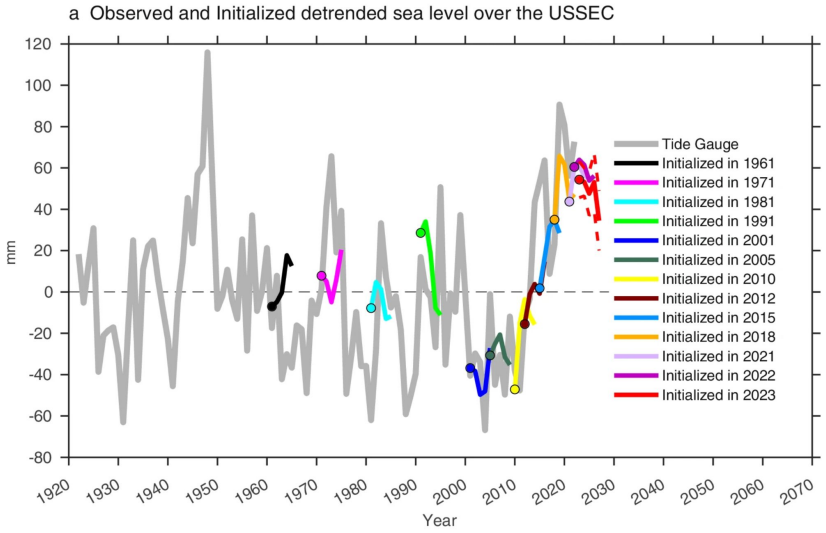
Identifying Sources of Seasonal to Decadal Prediction

Gu et al., 2024 Nat. Clim. Atm. Sci.



Based on analysis using machine learning (Self-Organizing Maps), the progression of sea level anomalies in the N. Atlantic is linked to AMOC.

Zhang et al., 2024 Nat. Clim. Atm. Sci.



Decadal hindcasts with SPEAR capture recent sea level rise along the US Southeast Coast.

BIL-Funded Plans for Improving Sea Level Prediction

Develop tools and knowledge to advance sea level and coastal inundation prediction

Ocean and coupled model development

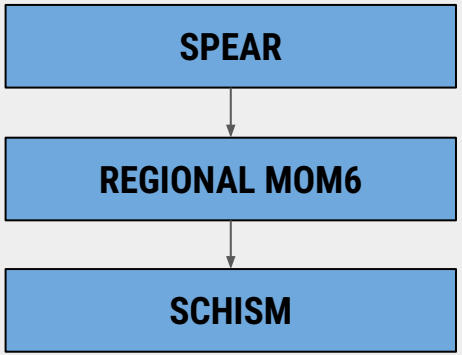
- Improve SL predictions through dynamical downscaling (SPEAR + regional MOM6)
- Develop Core ocean modeling capabilities (MOM6, regional coupled configs.)
- Improve coupling infrastructure and workflows for regional models
- Drive towards operations through CEFI- and BIL-funded efforts

Assessing Model Skill and Bias (with OAR/PSL and NOS)

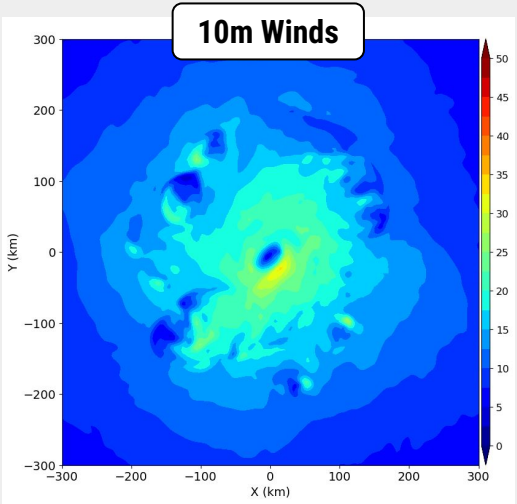
- Identify systemic model errors that span time scales
- Explore changes in variability between now and 2050
- Leverage observations (Argo, tide gauge, altimetry) to evaluate ocean models

New Regional Modeling Capabilities for Sea Level

Developing a Next-Generation system in coordination with the National Ocean Service and OAR partners



Proposed "two step" dynamical downscaling system for coastal inundation prediction relies on GFDL modeling capabilities.



Idealized coupled cyclone simulation (4km SHiELD + MOM6) illustrates upwelling of colder ocean water and feedbacks on wind intensity.

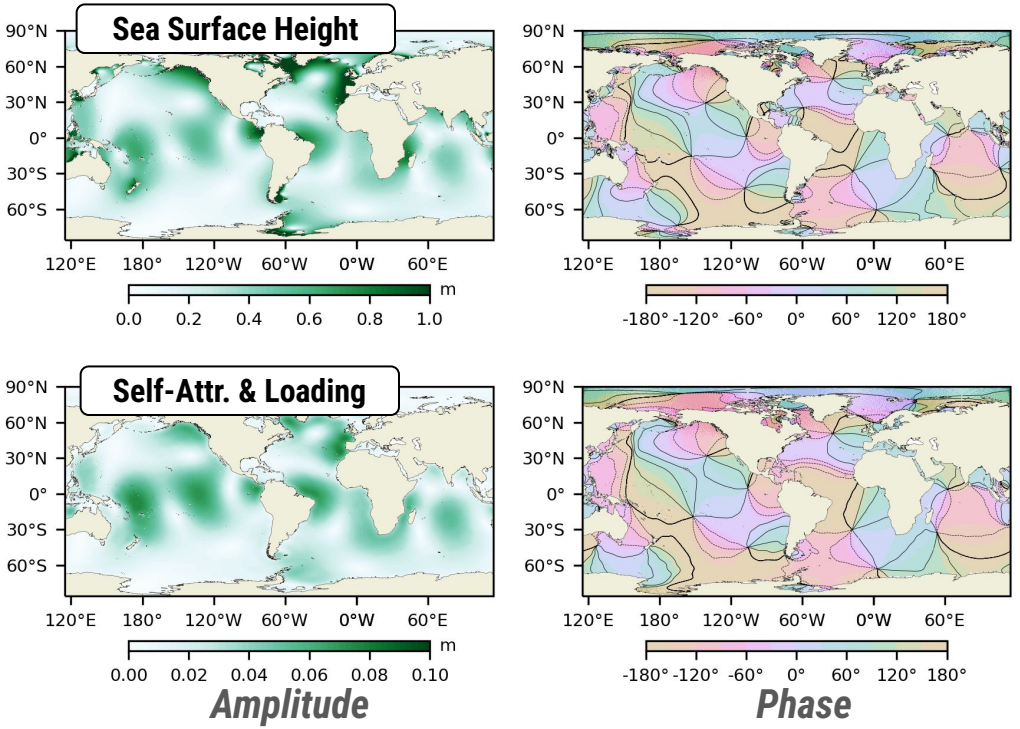
Efforts led by Lucas Harris and Brandon Reichl

Developing Ocean Models that Excel at Simulating Sea Level

MOM6 Global Simulations with Online M2 Tides

MOM6 Development Targets for Sea Level Applications

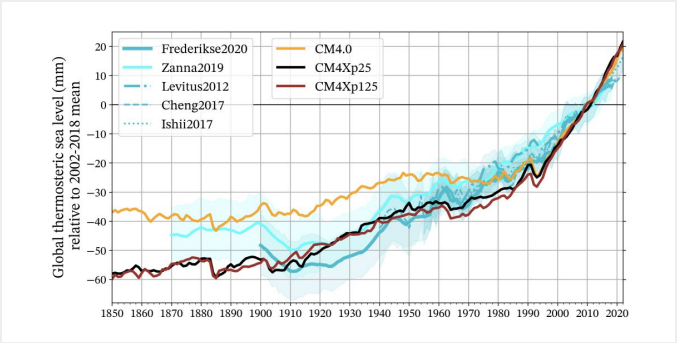
- Coupled Interactive Antarctic & Greenland ice sheets
- Improved sea ice-ocean coupling
- Non-Boussinesq implementation
- Improved vertical coordinate and interpolation schemes
- Representation of explicit tides
- Mixing associated with non-local internal tide breaking
- Additional updates and improvements to physics



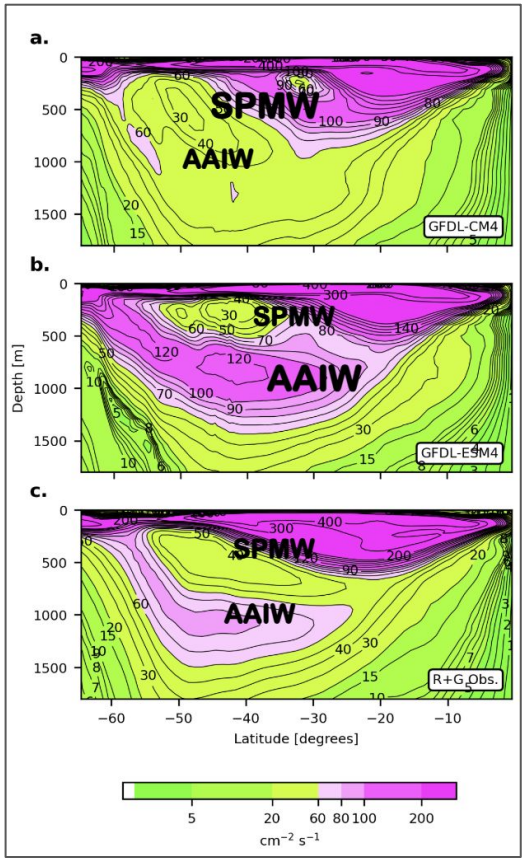
Higher Resolution Models for Sea Level Projections

Higher resolution ocean and climate models improve the simulation of oceanic heat uptake and sea level rise

Krasting et al. 2024 (right): GFDL-CM4 and ESM4 have different regional steric sea level biases that stem from their resolution and representation of broad-scale ocean dynamics and ventilation. ***Mesoscale eddy restratification and mixing play an important role in this bias.***



Griffies et al. in review: Improved physics and resolution CM4X lead to ***better estimates of historical thermal expansion***



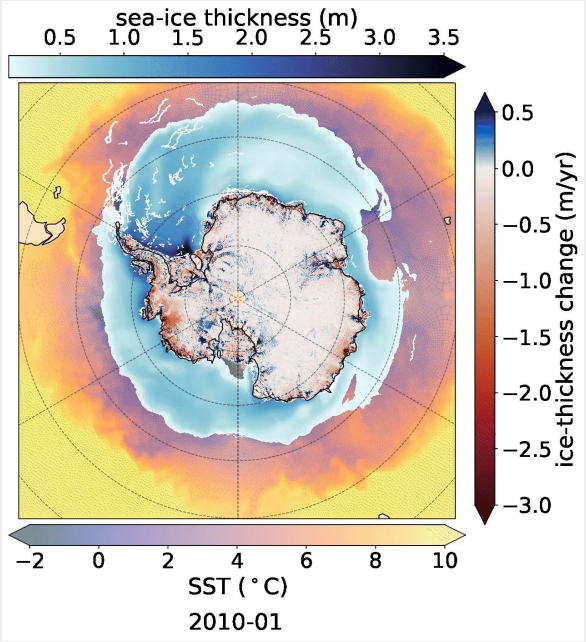
Simulating the Fate of the Antarctic and Greenland Ice Sheets

Coupling of dynamical ice sheet models

- Fox-Kemper et al. 2019: coupling ocean and climate models with ice sheet models will be a major focus of the coming decade

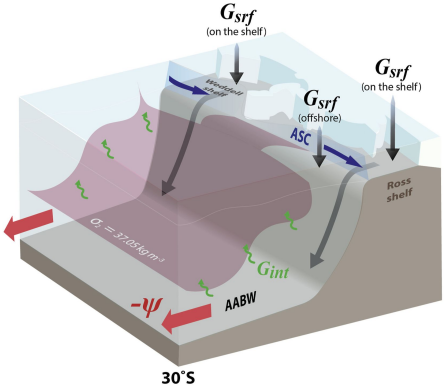
GFDL is exploring the responses in more idealized frameworks in the meantime

- Freshwater release experiments
- SOFIA (formerly FAFMIP)



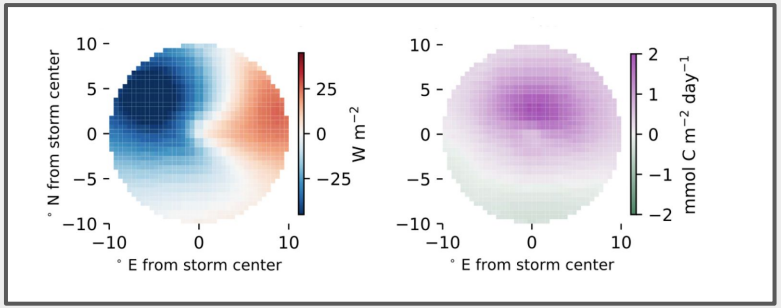
CM5 will be GFDL and NOAA's first coupled GCM with interactive ice shelves, capable of simulating meltwater contributions from Greenland and Antarctica for sea level rise.

Improved Understanding and Simulations of the Southern Ocean



Higher horizontal resolution is necessary to simulate Antarctic meltwater contributions to ocean circulation, and the fate of Antarctic Bottom Water (AABW).

Beadling et al. 2022, Tesdal et al. 2022, Drake et al. in review, Participation in SOFIA



SOCCOM2 - Storms in the Southern Ocean contribute up to a third of the total variance in heat and carbon fluxes in CM4 and ESM4 (Turner et al., in review)

Plans for SOCCOM3:

- *How do the winds and storm events influence heat and carbon uptake by the Southern Ocean?*
- *What processes drive Southern Ocean ventilation in climate models and how can we improve them?*
- *How do large scale modes of climate variability manifest through teleconnections over the Southern Ocean?*
- *What are the implications of a changing Southern Ocean for sea level and ice shelf interactions?*

Partnerships, Collaborations

Within NOAA:

- OAR/PSL and NOS-COOPS on BIL-funded sea level prediction
- Climate Program Office and OAR/PSL on improved estimates of sea level trends through 2050
- GFDL is a critical piece of NOAA's proposed Coastal Inundation at Climate Timescales Initiative

National and International Involvement:

- US Interagency Sea Level Task Force
- NASA / USGCRP Sea Level Change Team
- IPCC/SROCC Oceans and Cryosphere Report
- Modeling activities: OMIP, CMIP, SOFIA

Academic Collaborations

- Rutgers, NYU, UC Davis, Temple University, Woods Hole