Physical Processes Impacting Regional Sea Level (PISeaL)

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Scientific questions:

- What physical processes influence sea level changes in different regions?
- What are their relative importance?

Motivations and Approach

Motivation:

- Global sea level has been rising at ~4.5 mm/year in the 21st century, twice as fast as that in the 20th century *(Hamlington et al. 2024)*
- The rise is not spatially uniform → different regions dominated by different processes

Formulations:

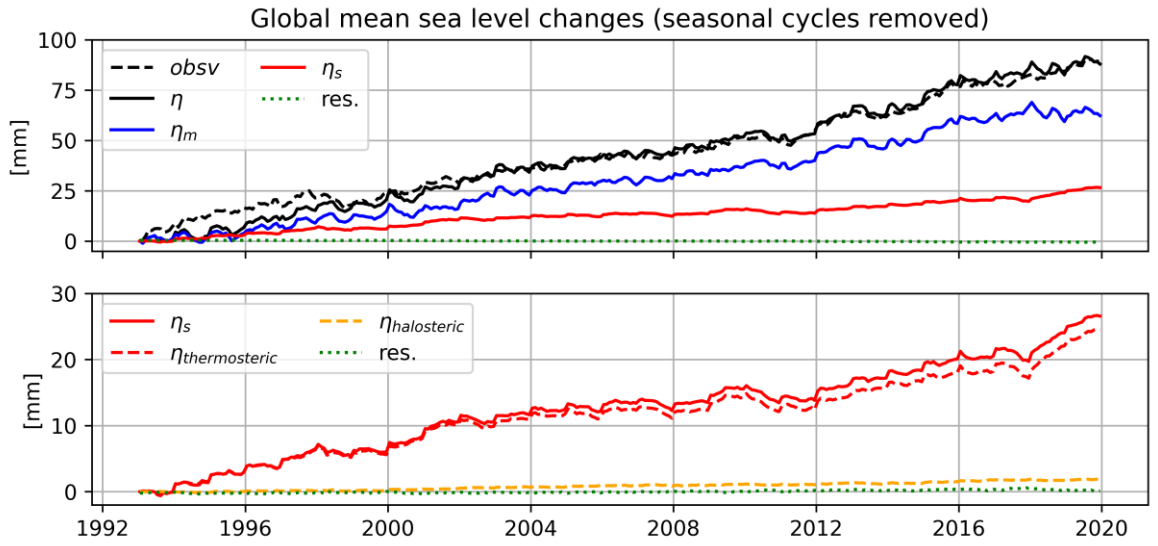
- Sea Level = manometric & steric components *(Piecuch et al. 2019)*:

$$\eta = \eta_m + \eta_s = \frac{p_b}{\rho_0 g} - \frac{1}{\rho_0}\frac{H+\eta}{H}\int_{-H}^{0}(\rho - \rho_0)\, dz^*$$

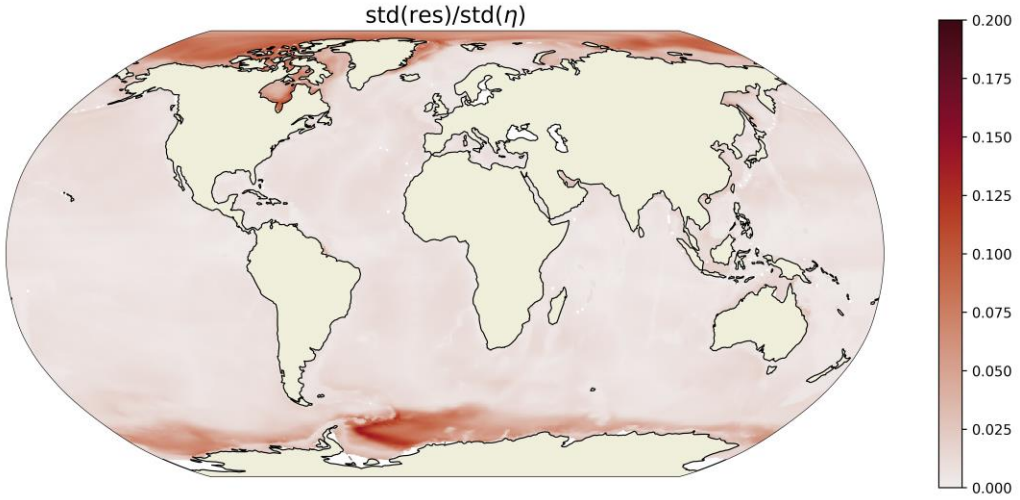
- Steric = thermosteric & halosteric components:

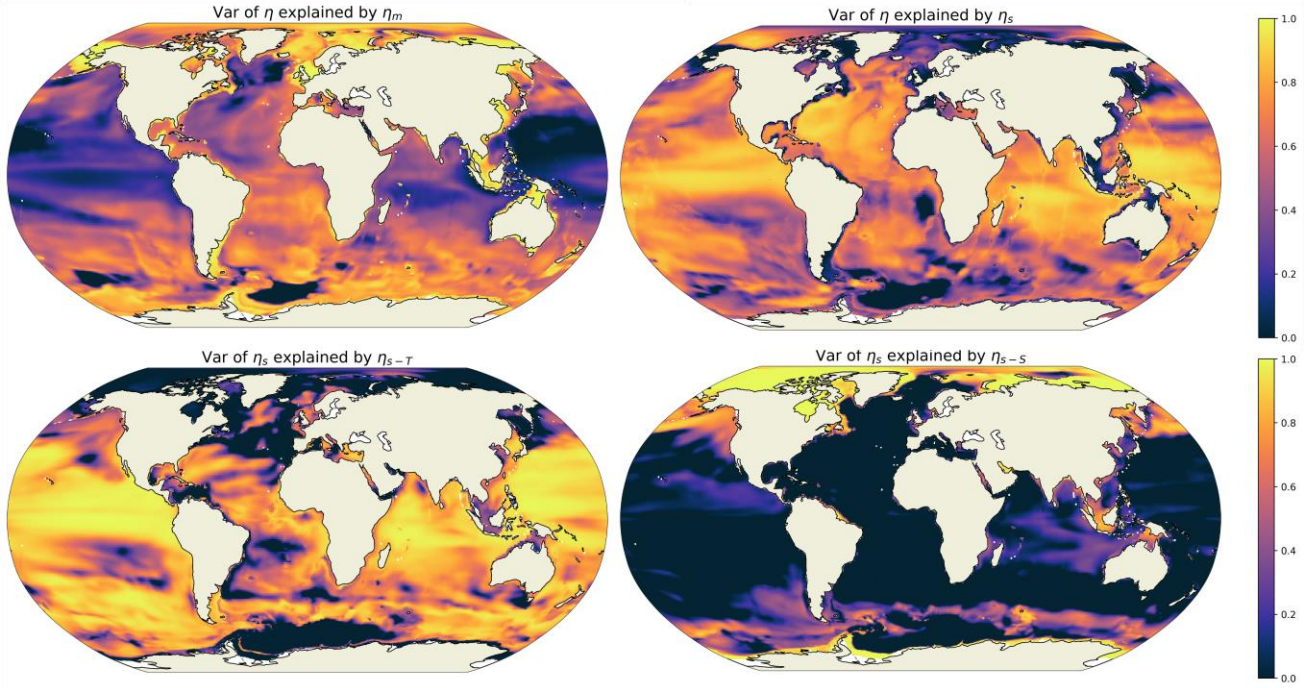
$$\eta_s = \begin{cases} \eta_{s-T} = -\frac{1}{\rho_0}\frac{H+\eta}{H}\int_{-H}^{0}[\rho(S_r, T, p) - \rho(S_r, T_r, p)]\, dz^* \\ \eta_{s-S} = -\frac{1}{\rho_0}\frac{H+\eta}{H}\int_{-H}^{0}[\rho(S, T_r, p) - \rho(S_r, T_r, p)]\, dz^* \end{cases}$$

Global Sea Level Decomposition



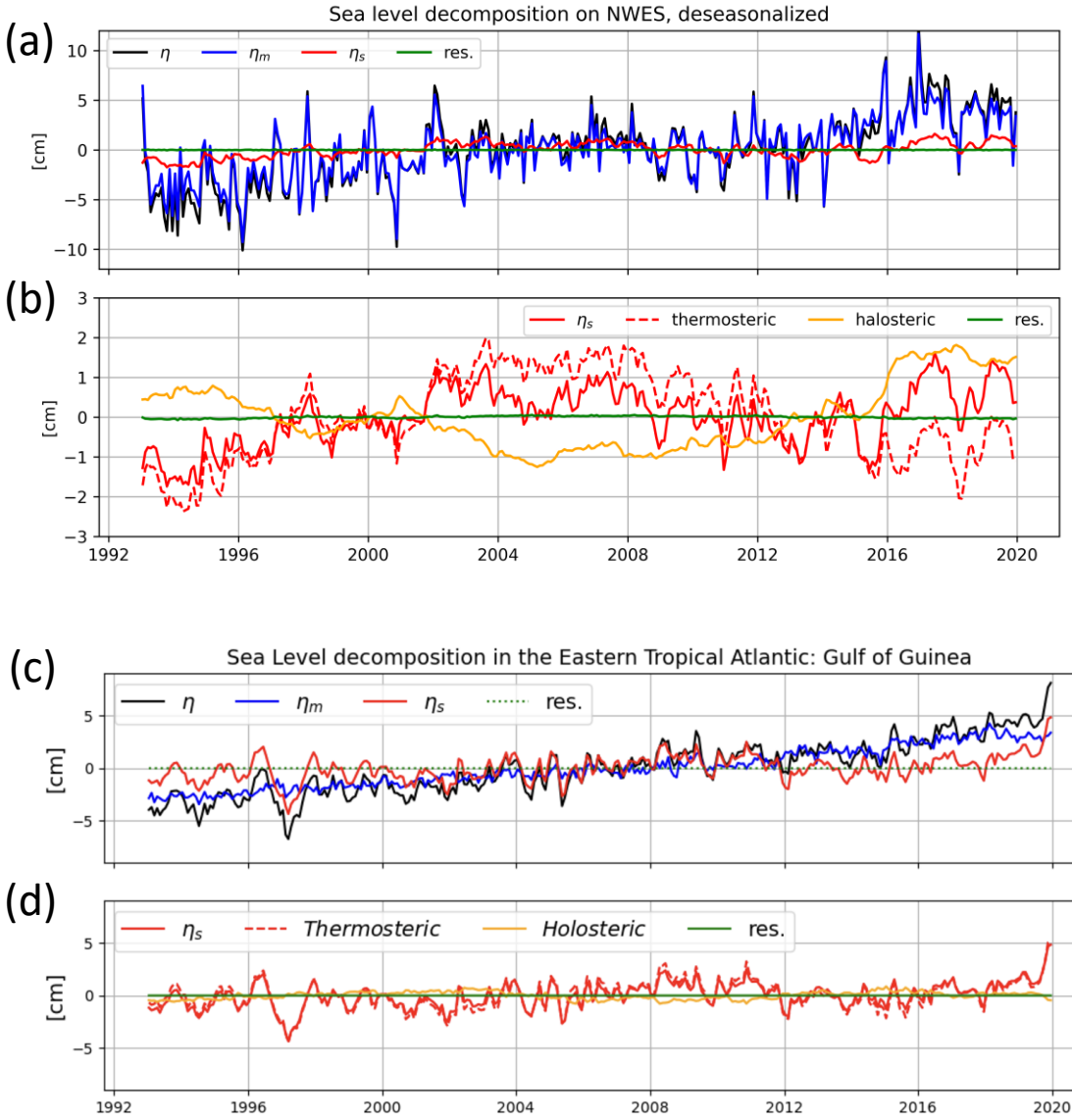
$$\text{res} = \eta - \eta_m - \eta_s$$

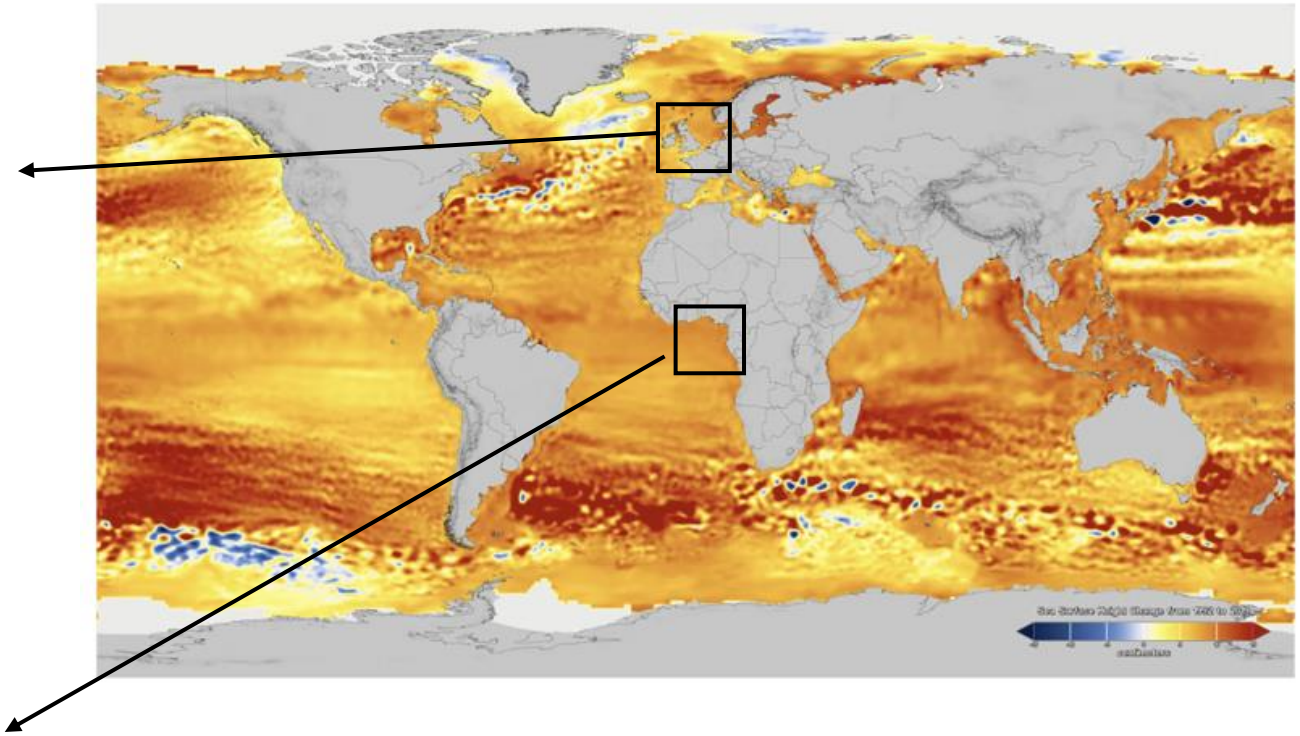




- In continental shelf and polar oceans, η variability is mainly explained by η_m
- In open oceans, η variability is mainly explained by η_s
- Overall thermosteric part dominates η_s, while halosteric part is more important in Artic Ocean
- Residual in the decomposition: impact of sea ice (TBC.)

Regional Sea Level Changes





Sea level change from 1992– 2019 measured by satellite [sealevel.nasa.gov]

- On European shelf, η_m dominates total sea level variability; in Eastern Tropical Atlantic, η_s dominates
- Thermosteric part dominates η_s variability in both regions

Conclusions

- ECCO's dynamical sea surface height can be decomposed into the manometric (mass) and steric (density) components, in most of the oceans.
- Mass change is more important in the shelf region, while the density change dominates in the open ocean
- Thermosteric effect is generally more important than the halosteric one except the Arctic Ocean
- Regional differences:
  - European shelf: η_m plays a dominant role in the total sea level variability
  - Eastern tropical Atlantic (Gulf of Guinea): η_s dominates the total variability, while η_m contributes to long-term trends

Reflections

Challenges:

- Our sea level decomposition is not closed in polar regions: effect of sea ice is mistreated in our calculation

What did we learn:

- How the sea level is computed in the model
- Volume conserving model (e.g., MITgcm) needs correction for global steric sea level changes due to density changes

New skills:

- Calculate the volume and heat budget
- Get familiar with the ECCO tile configuration — no longer scared of it!

Further work:

- Continue to look for origin of the residual and find out how to reduce it

Acknowledgement:

- Appreciations to Ian, Ou, Chris, Ichiro, and all the ECCO team/speakers