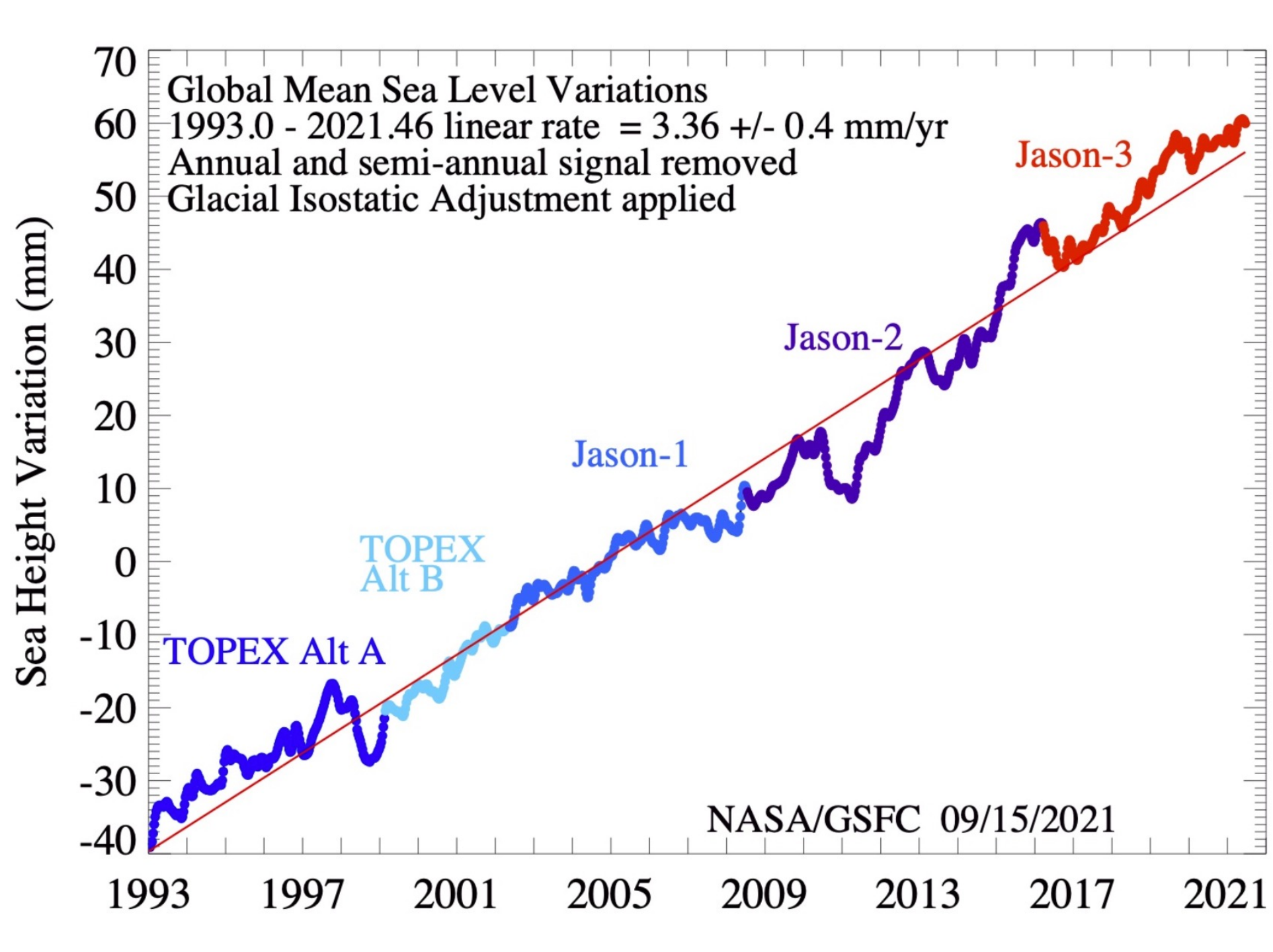


Topic 7:

Sea Level Rise from Mass Gain and Thermal Expansion

Ruth Moorman

(Caltech PhD Student)

NASA CCS Summer 2022

* Figure from **MEaSUREs** (Making Earth Science Data Records for Use in Research Environments) multi-mission **altimetry** product

What contributes to Global Mean Sea Level rise?

‘Eustatic’ Sea Level Rise

Expansion of the oceans due to increasing ***mass***.

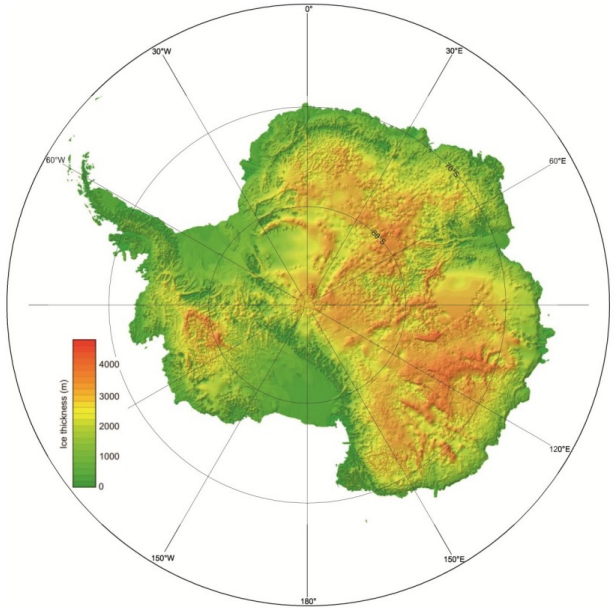
Broadly, this involves water moving from the land to the oceans.

Over long timescales this is mostly due to the **melting of grounded ice sheets.**

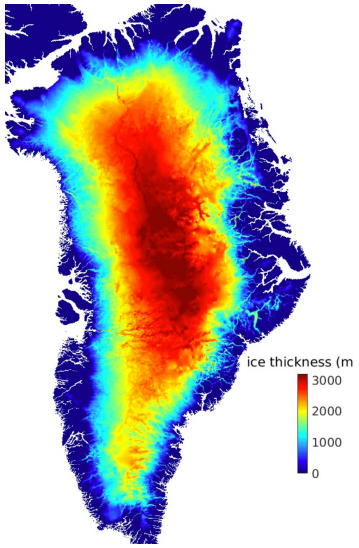
‘Steric’ Sea Level Rise

Expansion of the oceans due to increasing ***volume*** (or decreasing ***density***).

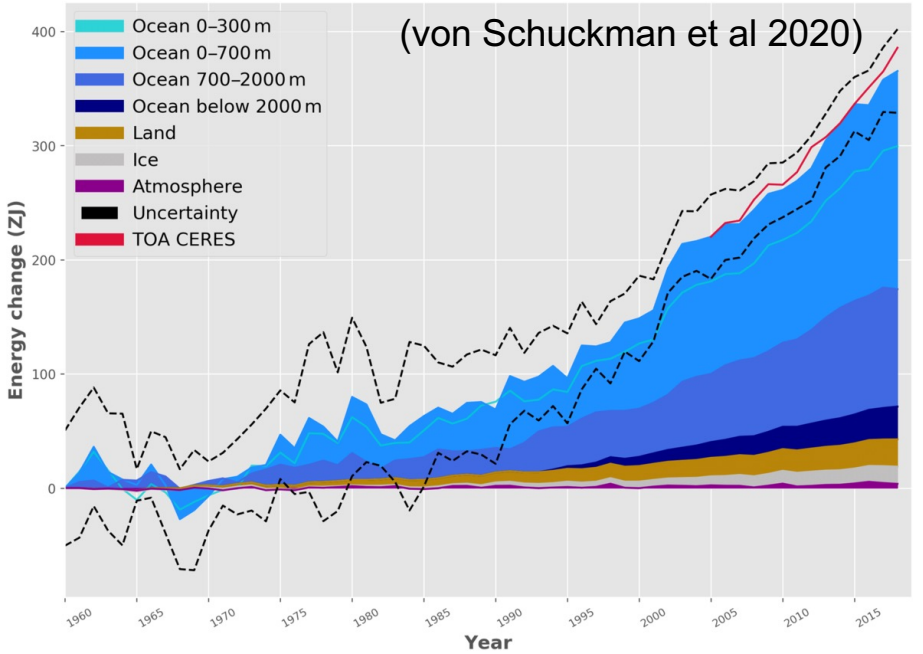
Steric sea level rise can involve both ocean **warming** and **freshening**, though warming is dominant.



Bedmap2 (Fretwell et al 2013)



Bedmachine3 (Morlighem et al 2017)



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Broadly, this involves water moving from the land to the oceans.

Over long timescales this is **melting of grounded**

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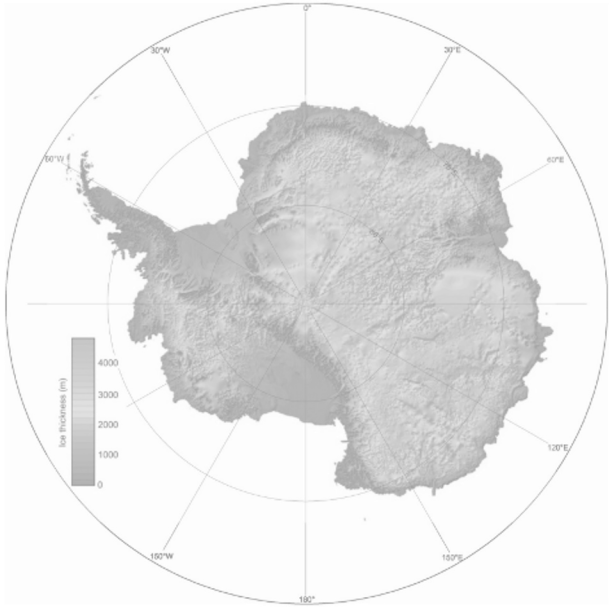
Expansion of the oceans due to increasing ***volume*** (or decreasing ***density***).

rise can involve both ocean **shening**, though warming is dominant.

Disentangling these contributions is very important!

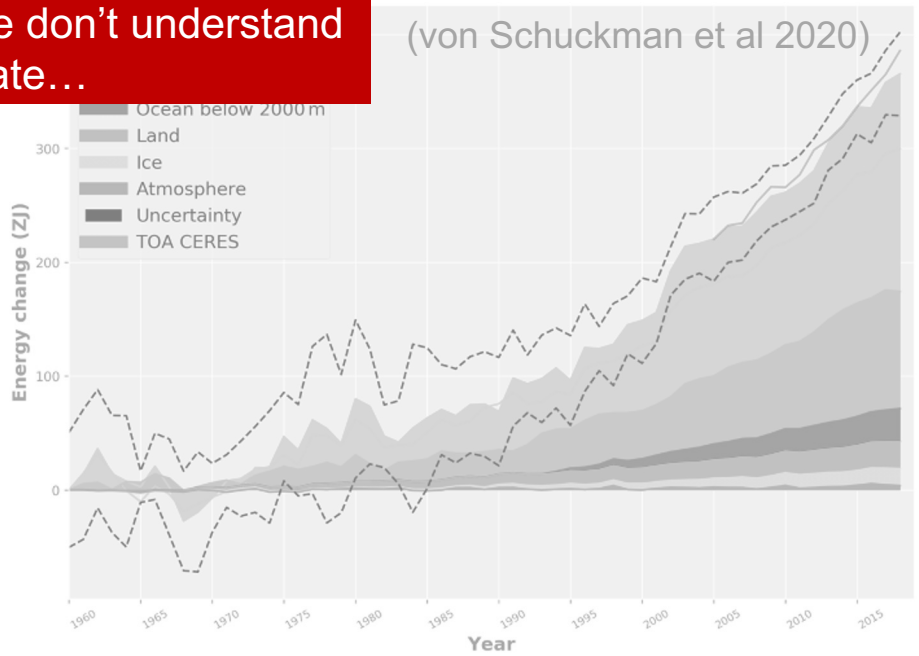
e.g. helps us understand ocean heat uptake, it’s difficult to project sea level rise if we don’t understand the current system state…



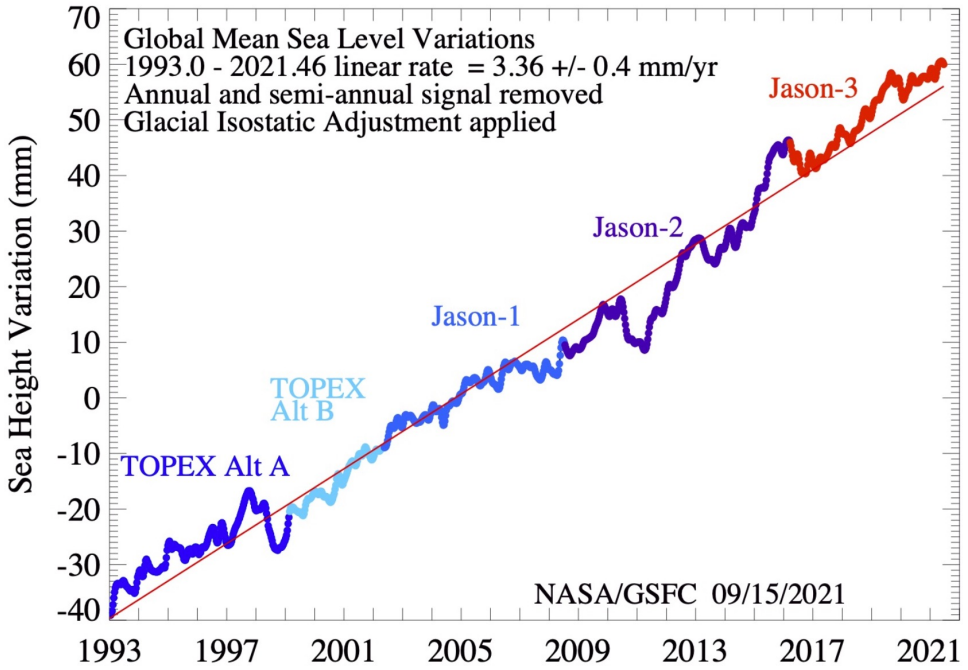
Bedmap2 (Fretwell et al 2013)

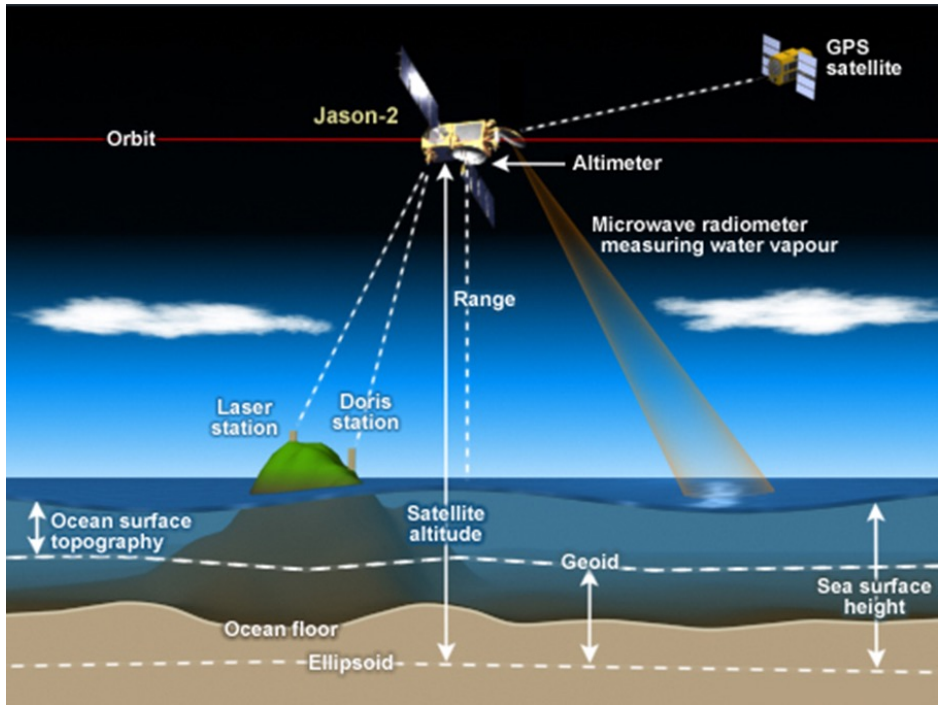
Bedmachine3 (Morlighem et al 2017)

(von Schuckman et al 2020)



Measuring (total) Sea-Level Rise: Altimetry



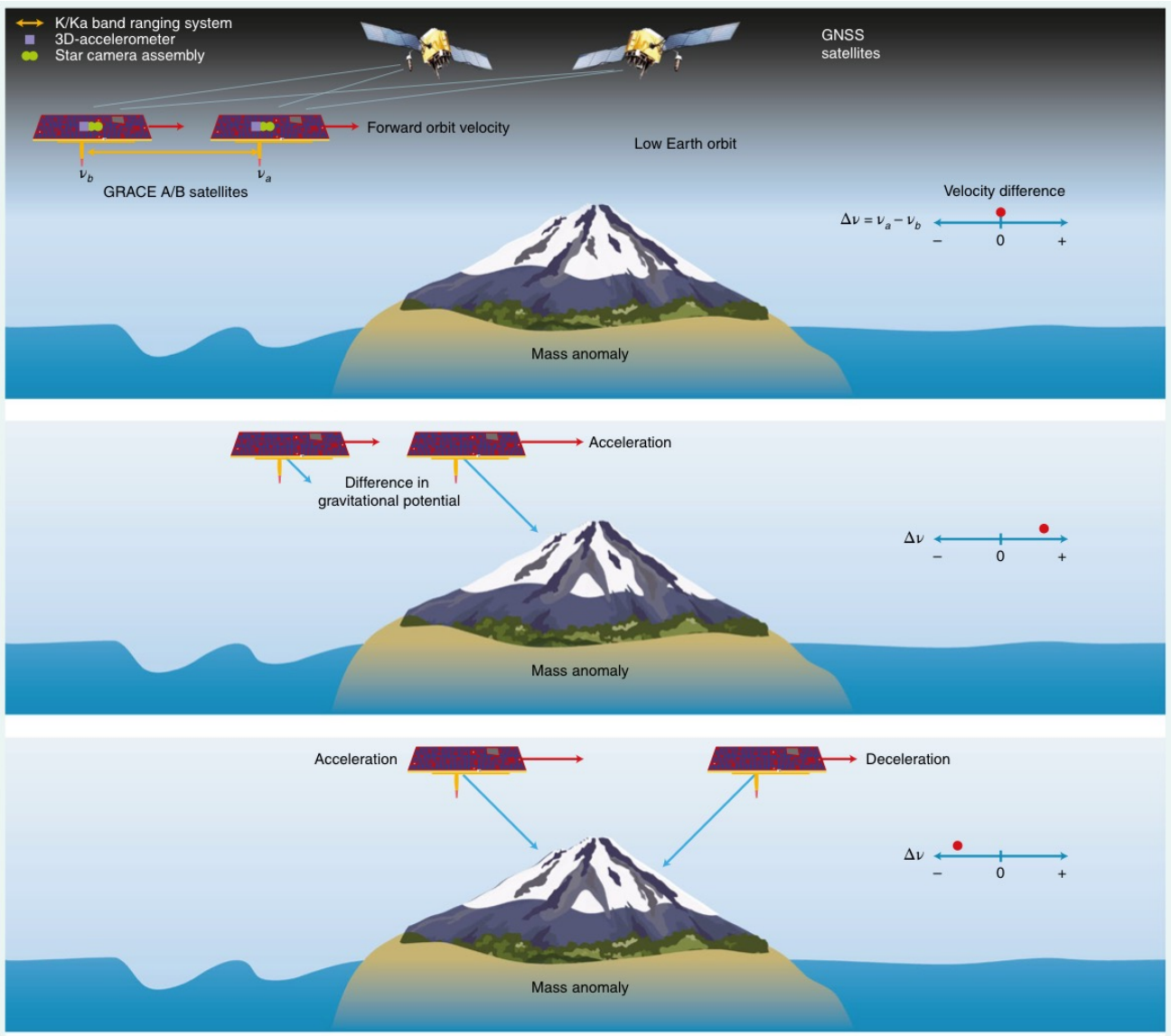


Satellite altimeters (TOPEX/Poseidon, Jason-1,2,3, IceSat-2, CryoSat-2, SWOT) measure sea surface elevation relative to the geoid, capturing the *total* (eustatic + steric) sea level change.

Key observations are position data and the time taken for EMR by the satellite to bounce off the surface (generally the ocean but sometimes snow or ice) and return to the satellite.

Note: **high temporal and spatial resolution**

Measuring (eustatic) Sea-Level Rise: GRACE

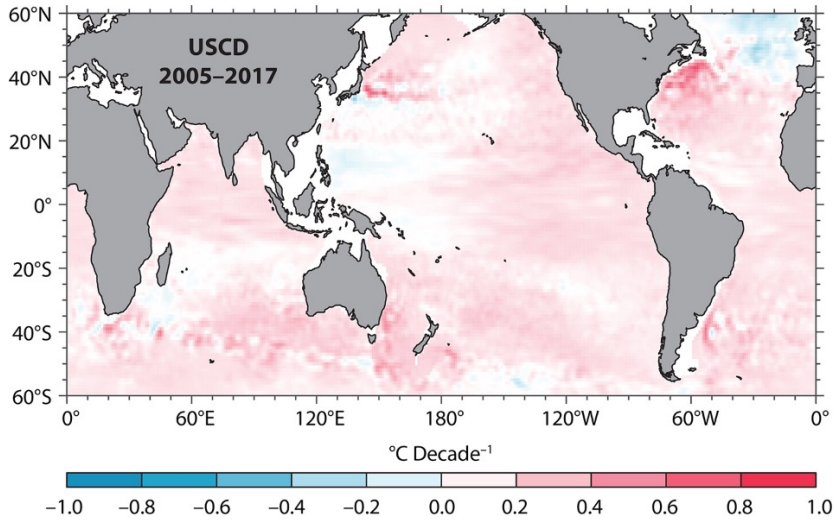


Satellite gravimeters (GRACE) measure the Earth's gravity field, which can be used to estimate changes in the water mass stored in the oceans and on land.

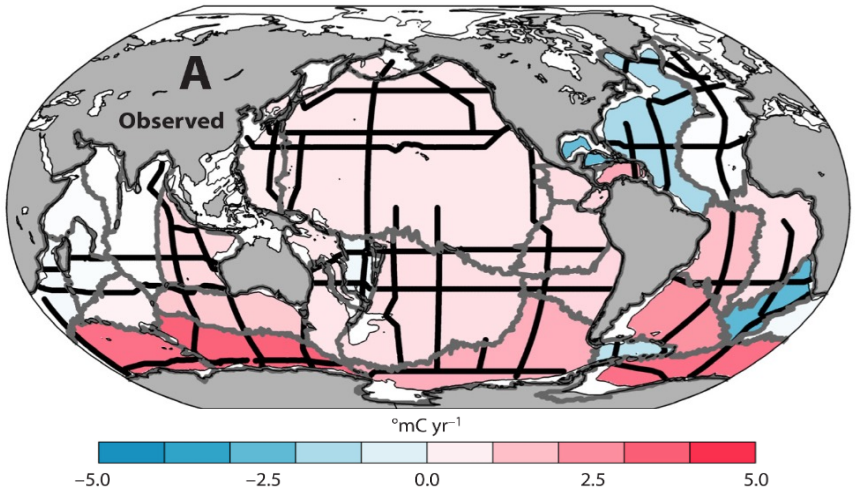
Key observations are position data and the intersatellite range, which varies as the two satellites feel the gravitational pull of masses they pass over at different times.

Note: **lower temporal and spatial resolution**

Measuring (steric) Sea-Level Rise: ARGO, XBT, etc



Upper 2000m depth averaged ocean warming (2005-2017) from ARGO.



Below 2000m average ocean warming (1990s-2018) from ships.

(Durack et al 2018, review)

*not directly measured from satellites

Conductivity Temperature Depth (CTD) profilers measure the temperature and salinity of ocean water, from which we can compute density.

The Argo mission (2000-) has greatly increased temperature and salinity observations in the upper ocean (<2000 m) with a large array of autonomous floats with attached CTDs. Deep ocean (>2000 m) heat content is undersampled.

Note: **lowest temporal and spatial resolution**

Topic #7: Sea Level Rise

- **Topic: Sea Level Rise from Mass Gain and Thermal Expansion**
- Datasets: MEaSUREs-SSH (multi mission altimetry: TOPEX/Poseidon, Jason-1,2,3), GRACE water storage (equivalent water height over land and ocean), NOAA World Ocean Atlas steric sea level products (based on ARGO, XBT etc).
- Geographic foci: Global
- Tools: CMDA tools and xarray tools

- Questions:
    - Use MEaSUREs-SSH multi mission altimetry to fit linear and quadratic (i.e. accelerating) trends to global mean sea level. If these trends are simply projected forward, how much would we anticipate sea level to rise between now and 2100? What issues are associated with such simple projections? What types of processes may be missed?
    - For the period where the records overlap, compare the contribution of mass change (from GRACE) and steric change (from NOAA WOA) to the total rise in GMSL. Why are the total, mass, and steric records available at such different temporal resolutions? Where do the records agree and differ? Do the steric and mass records add up to the total record? What are some possible reasons for the discrepancies between the NOAA derived steric sea level trend and that which can be obtained from the residual between altimetry and mass change?
    - The ocean is gaining mass from the land. Compare timeseries of grace_over_ocean and grace_over_land (discuss possible sources of difference). Map changes in land water storage. Where is most of the mass loss from the land occurring? Do you see anything surprising?
- **Contact: Ruth Moorman (rmoorman@caltech.edu)** [Caltech graduate student – currently on East Coast]