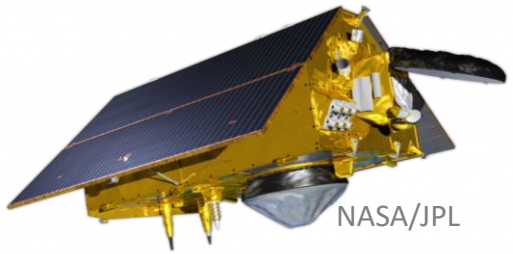
# Can Deep Argo Close the Sea Level Budget in the Southwest Pacific Basin?



NASA/JPL


**Paige D. Lavin[1,2]**, Gregory Johnson[3]

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MRV Systems


Synergies between Argo, GRACE, and Altimetry - OSTST 2023





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# Breaking Down a Sea Level Budget

$$\Delta\eta = \Delta h_m + \Delta h_\rho$$

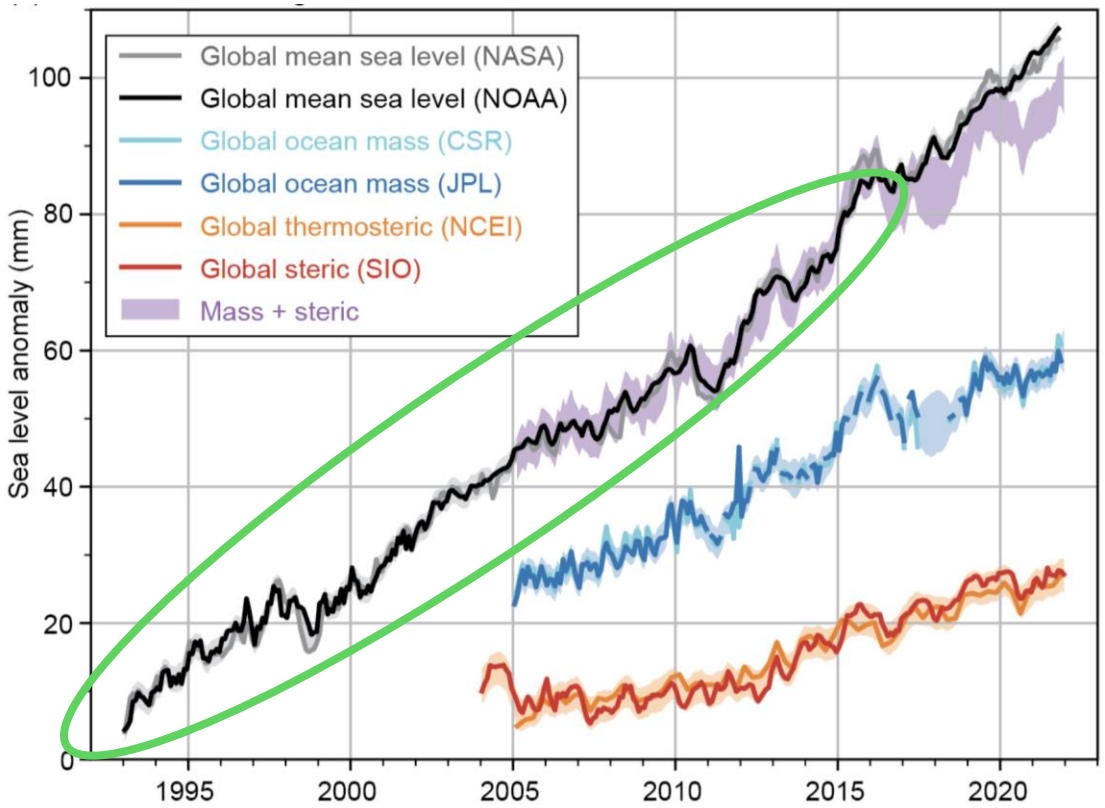
Sea level anomaly (SLA) from altimeters
**Source: NOAA/EUMETSAT Radar Altimeter Database System (RADS)**


Gravimetry measurements *or* observations of the land-ocean exchange of freshwater mass
**Source: GRACE/GRACE-FO**


$$h_\rho = \int_{z_{seafloor}}^{2000\ m} \frac{\Delta\rho(T,S,p)}{\rho_0(p)}\,dz + \int_{2000\ m}^{\eta} \frac{\Delta\rho(T,S,p)}{\rho_0(p)}\,dz$$

*In situ* T, S, and P (hence ρ) measurements
**Source: Core and Deep Argo floats**

# Global Sea Level Budget – Does it close?




Thompson et al., 2022: State of the Climate in 2021. 10.1175/BAMS-D-22-0072.1

✓ **Yes (from 2005–2015)**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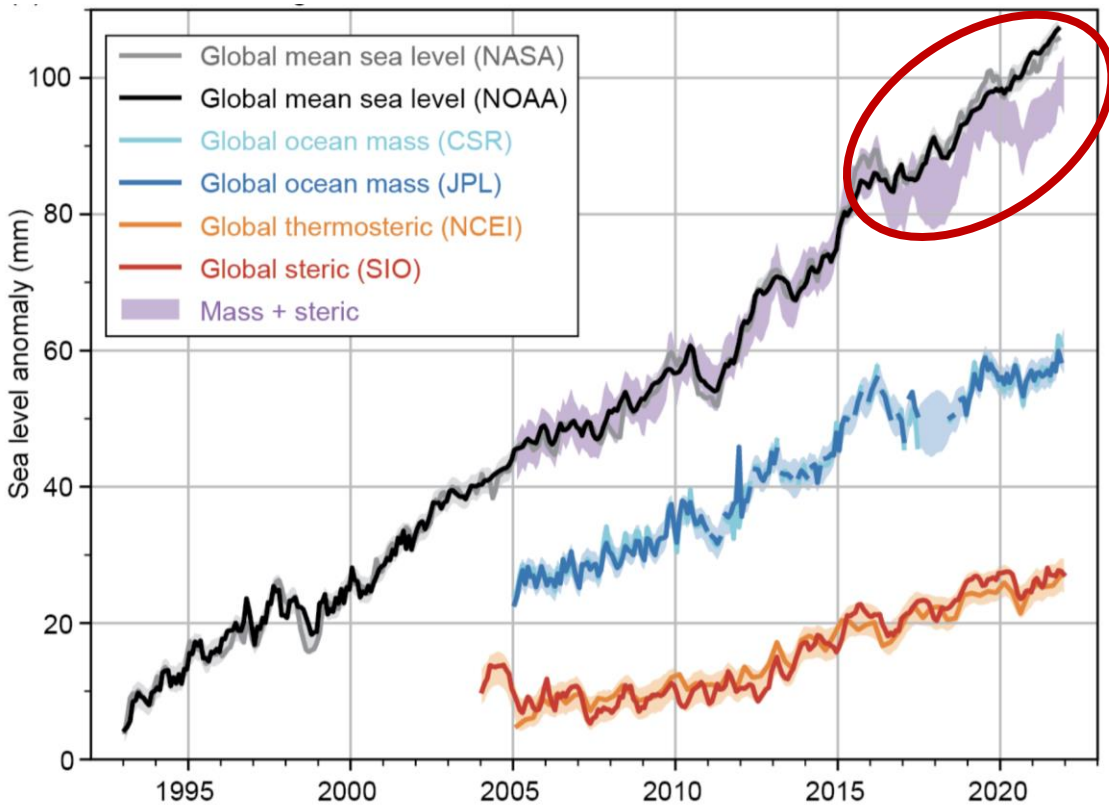


Thompson et al., 2022: State of the Climate in 2021. 10.1175/BAMS-D-22-0072.1

**Yes (from 2005–2015)**

**Potential sources of mismatch from 2016 onward:**

- SLA: Wet tropospheric correction for altimeters
- Mass: GIA model and accelerometer changes for GRACE/GRACE-FO
- Steric: Salty drift in Argo float salinities


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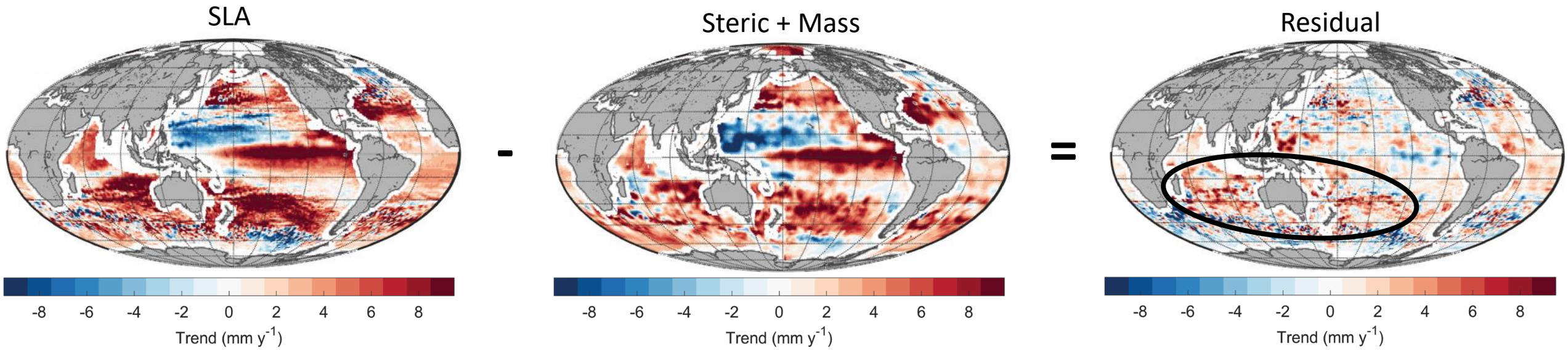
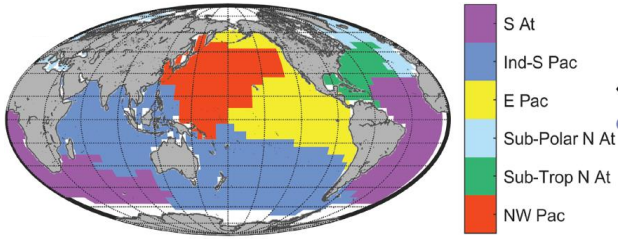
# Regional Sea Level Budget – Does it close?




- Spatial patterns of trend in combined steric & ocean mass sea level contributions **do not fully match** those of SLA from satellite altimetry at 1° grid resolution (2005–2015)
  - ⇨ SLB closure on the global scale likely due to a cancelation of errors
  - ⇨ Steric + ocean mass fields lack small-scale features seen in the satellite altimetry
  - ⇨ Observation processing differences at the hemisphere scale (e.g., GRACE GIA correction and altimetry orbital altitude) also contribute to mismatch




- **SLB closes when aggregated to ocean-basin scale, except in Indian-South Pacific region**

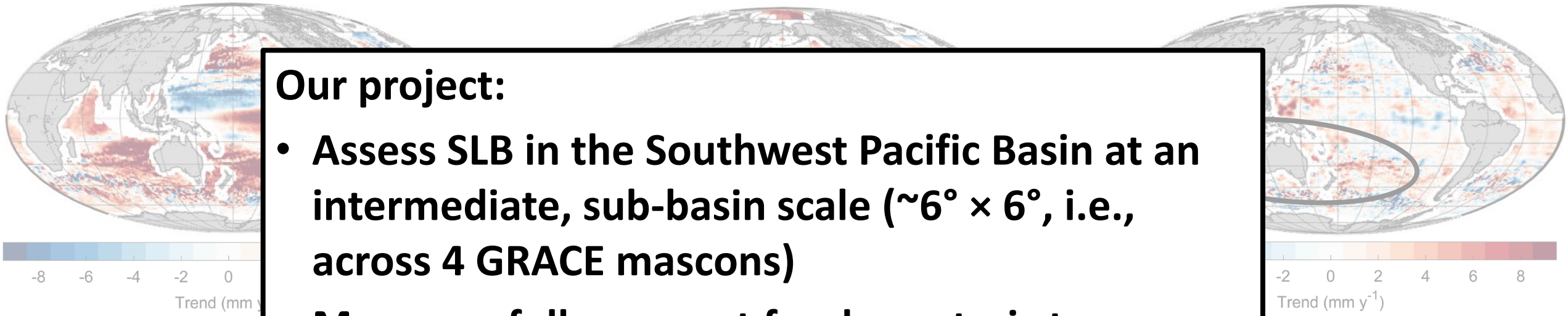
Royston et al., 2020

# Regional Sea Level Budget – Does it close?

SLA

Steric + Mass

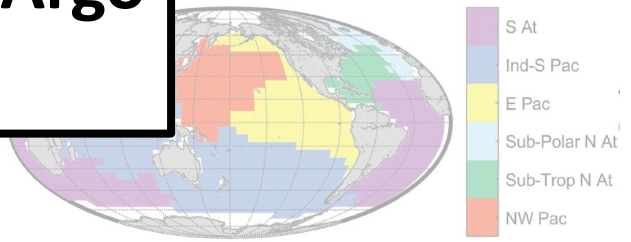
Residual




**Our project:**

- **Assess SLB in the Southwest Pacific Basin at an intermediate, sub-basin scale (~6° × 6°, i.e., across 4 GRACE mascons)**
- **More carefully account for deep steric term spatial & temporal variability by using Deep Argo**

- Spatial pat… …ot fully match those of SL…
  - ⇨ SLB clo…
  - ⇨ Steric …
  - ⇨ Observation processing differences at the hemisphere scale (e.g., GRACE GIA correction and altimetry orbital altitude) also contribute to mismatch

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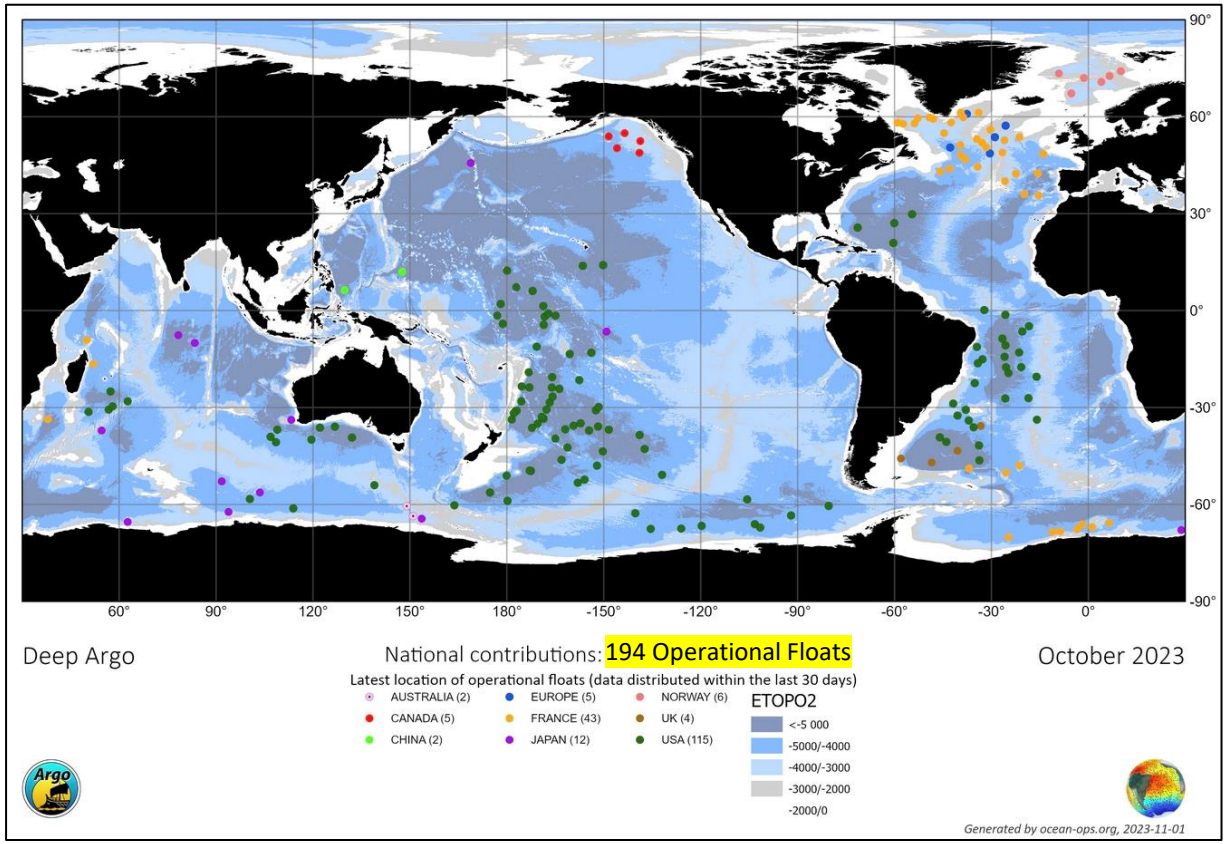
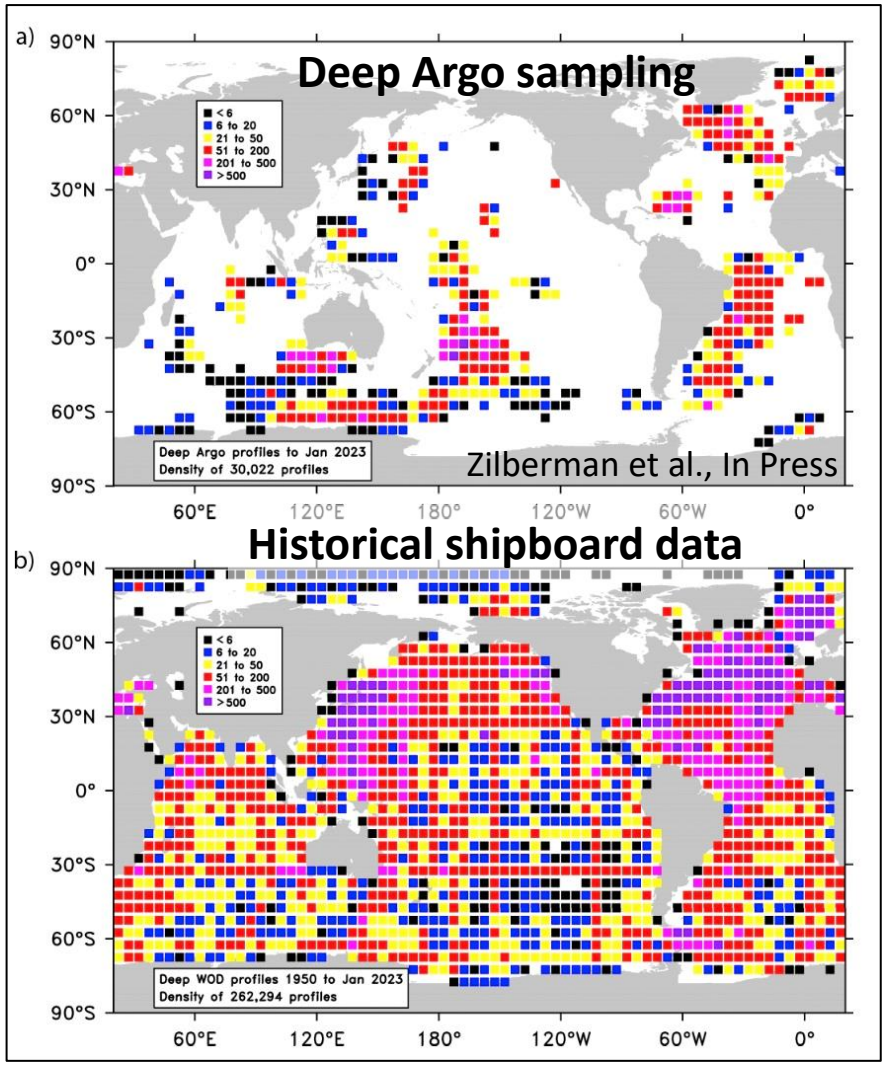
# Deep Argo is rapidly increasing our sampling of the deep ocean




- In <7 years, Deep Argo has accumulated in regional pilot arrays about as many full-depth profiles as ships over the past 70 years (Zilberman et al., In Press)
- Floats measure down to 4000 or 6000 dbar

Slide courtesy of Nathalie Zilberman

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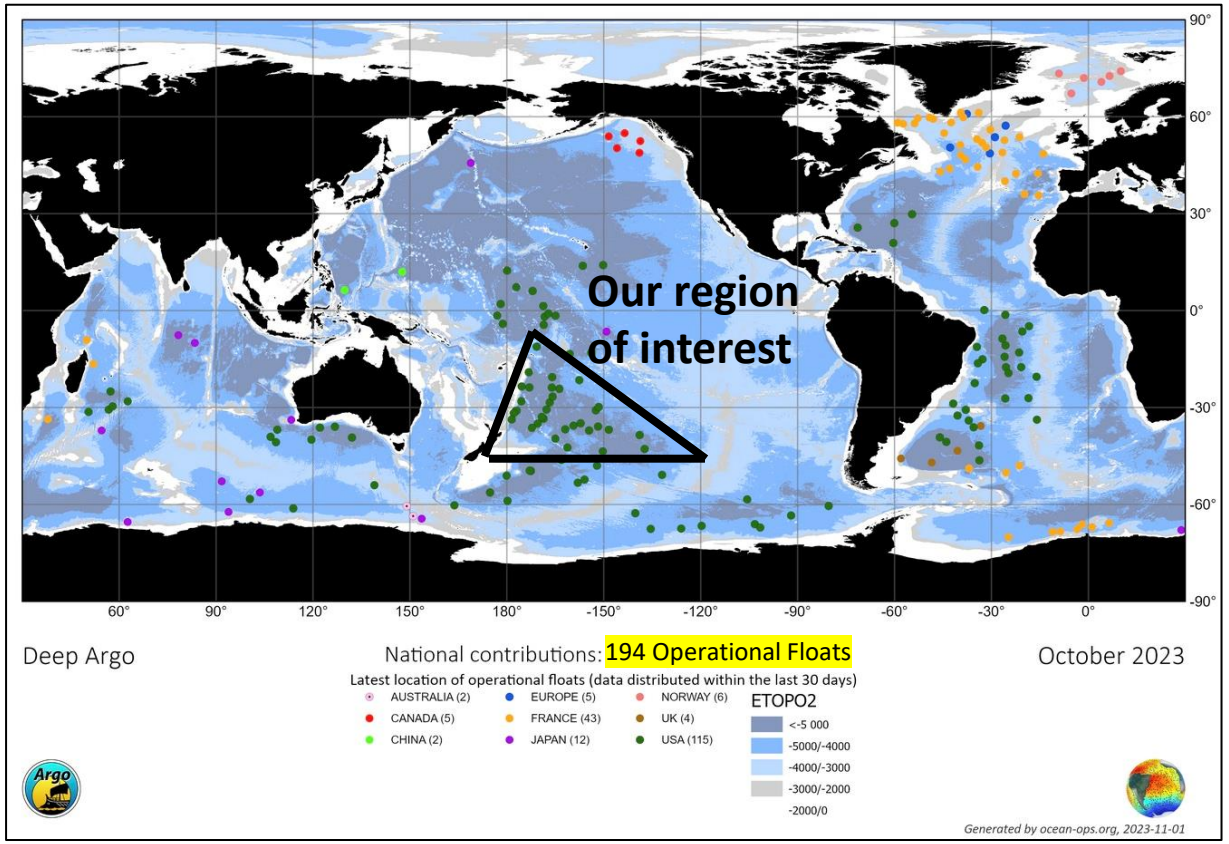


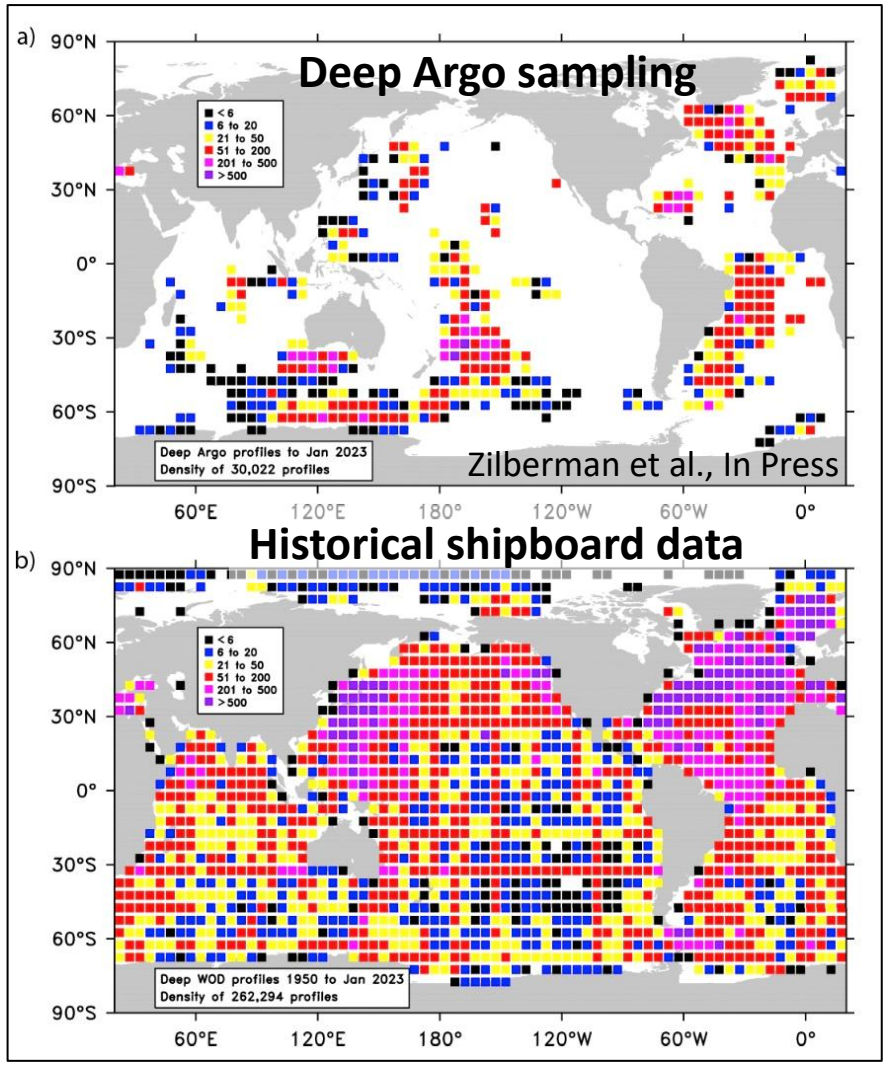


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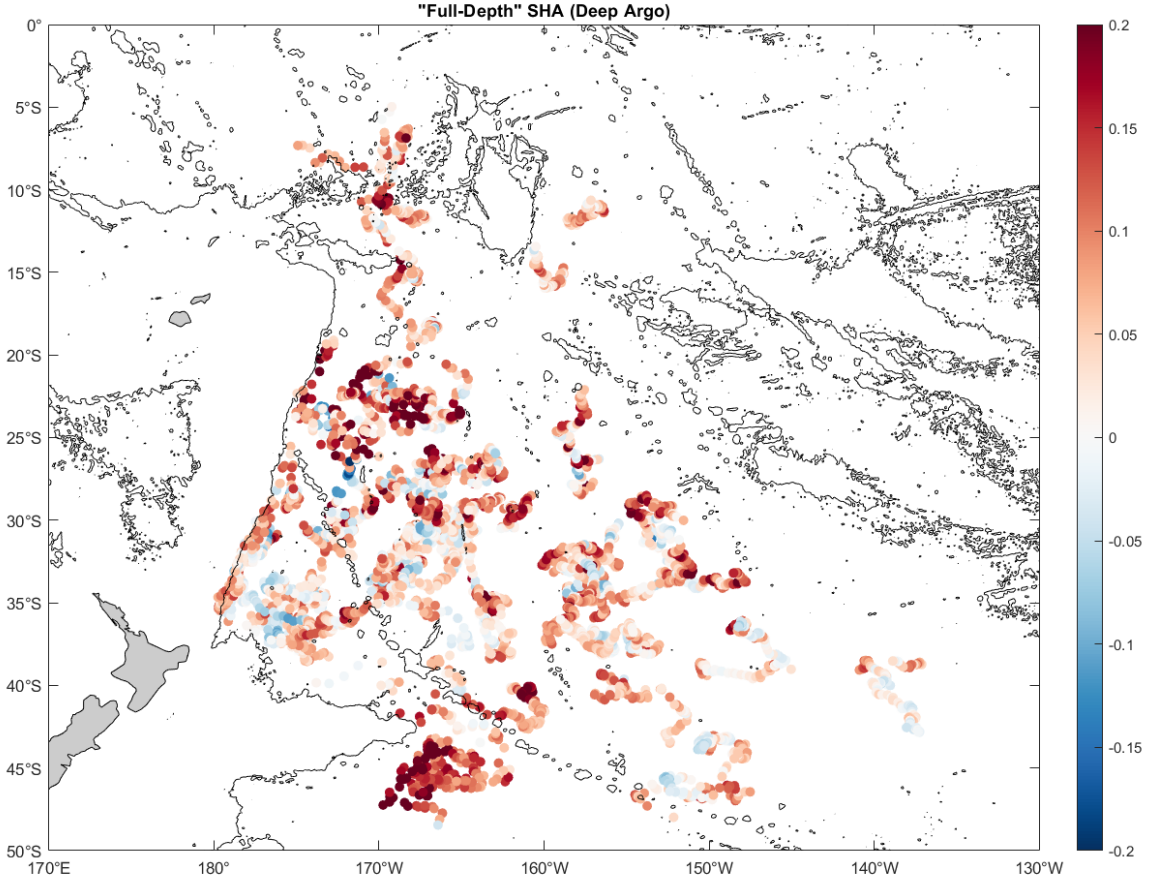
# Deep Argo allows us to look at the temporal variability of full-depth steric height anomaly




**m.**

**Note: This includes data from ALL YEARS**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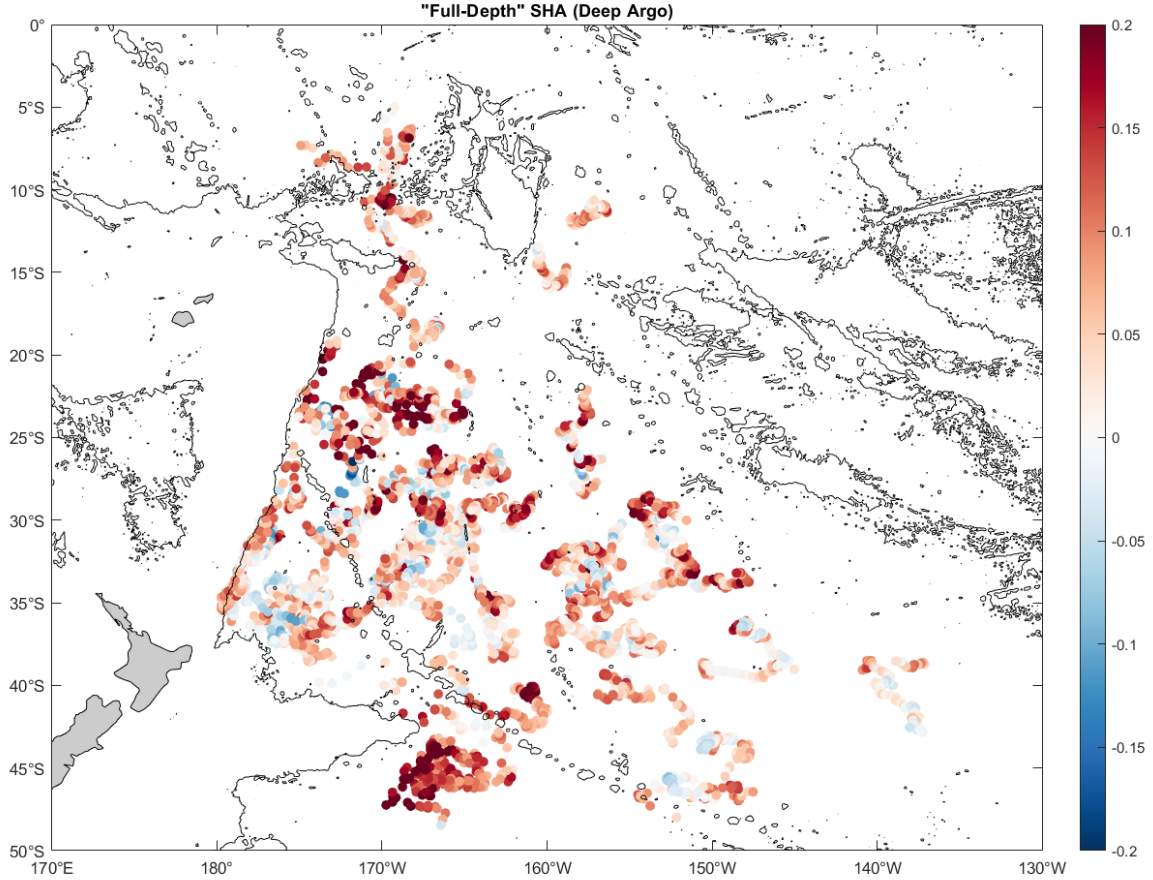
# Deep Argo allows us to look at the temporal variability of full-depth* steric height anomaly**




**m.**

**Note: This includes data from ALL YEARS**

**Reference pressure for steric height calculation was set by balancing using the deepest level possible with using the greatest number of profiles possible (~5000 dbar on average)*

***SHA values are relative to World Ocean Atlas steric height values for this region (calculated within each GRACE/GFO mascon)*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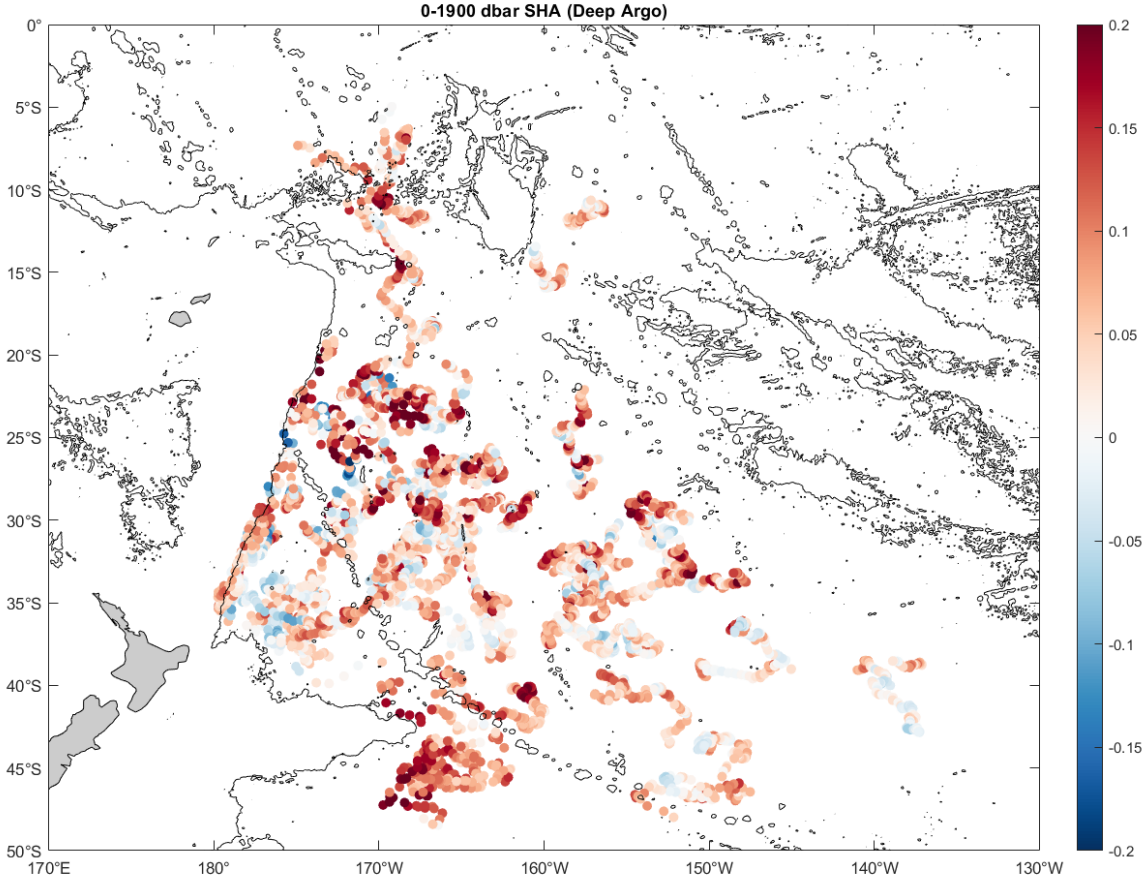
# As expected, upper ocean (< 1900 dbar) SHA dominates the full-depth SHA signal…




**m.**

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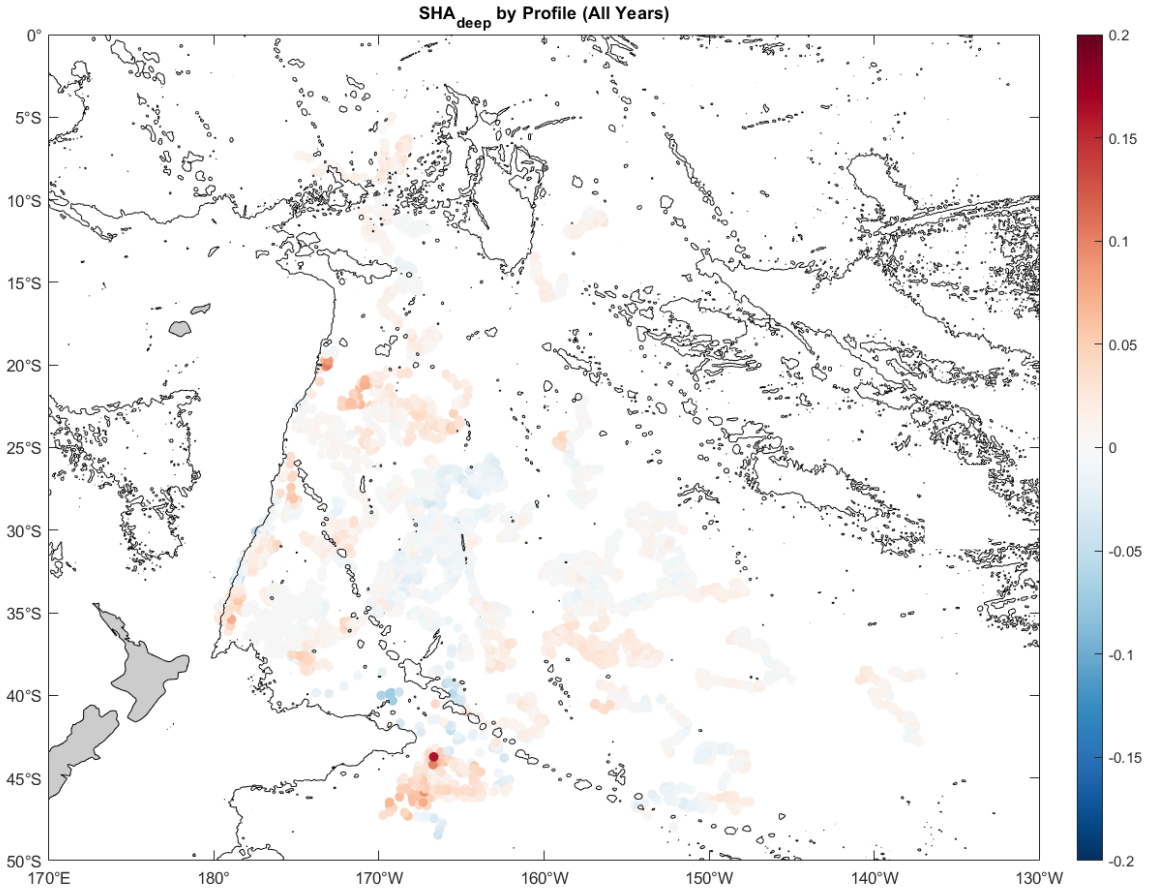
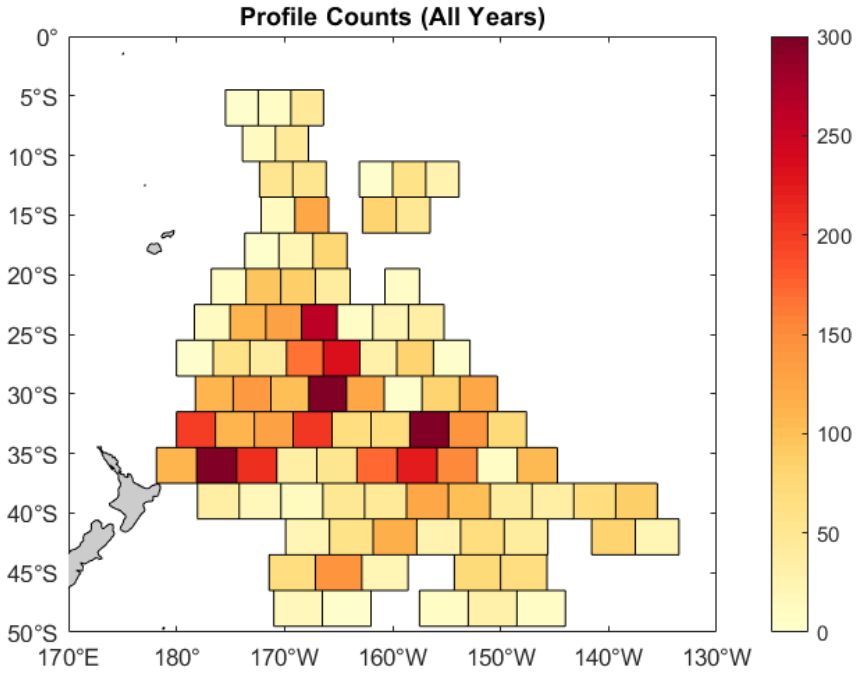
# …while deep SHAs are small but still highly variable spatially (and temporally)

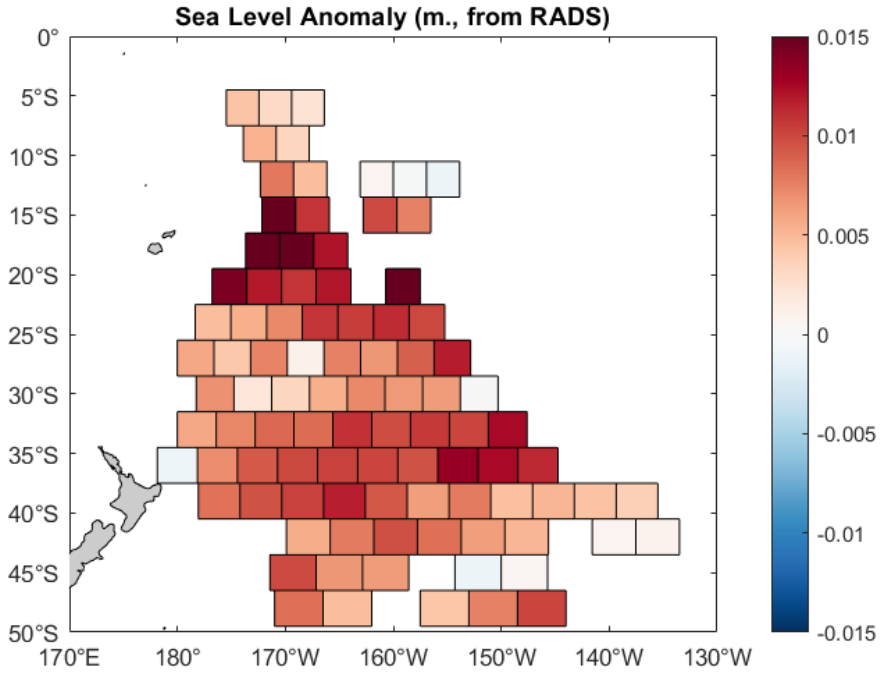



**Typically 0–30% the size of the full-depth steric term**

# Availability of Deep Argo Data Constrains Scale and Location of SLB Analysis




- After quality control, ~7300 Deep Argo profiles remain from June 2016 to October 2023




- 1st attempt: Can we assess the SLB at the resolution of the 3° × 3° GRACE/GFO mascons?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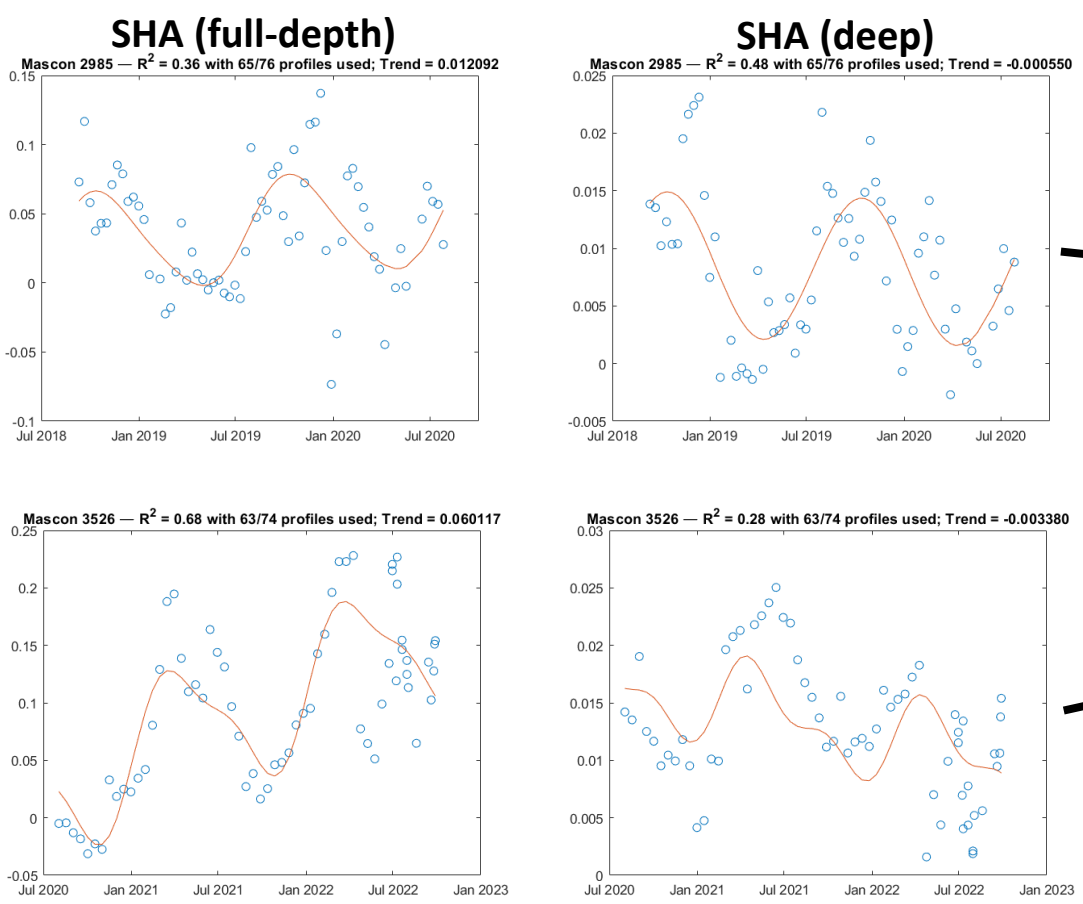
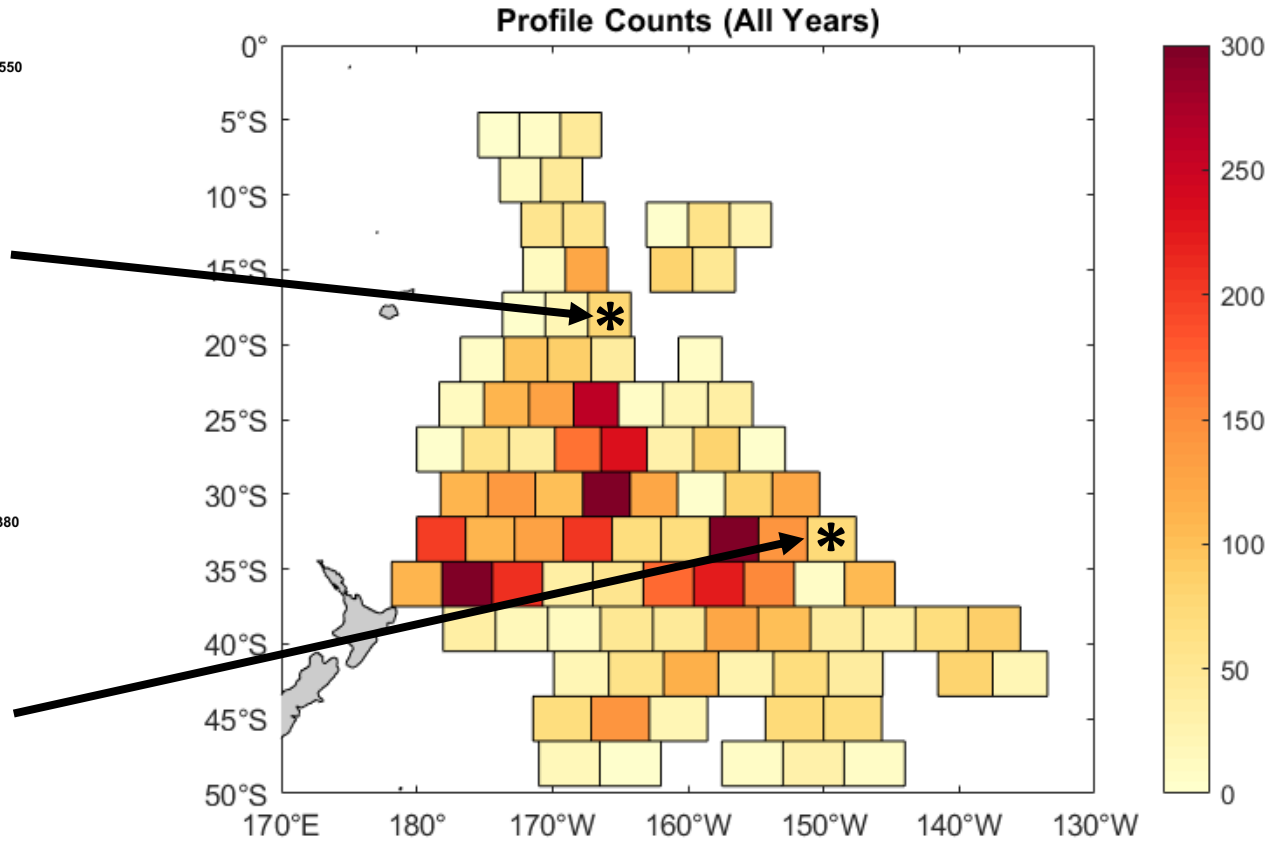
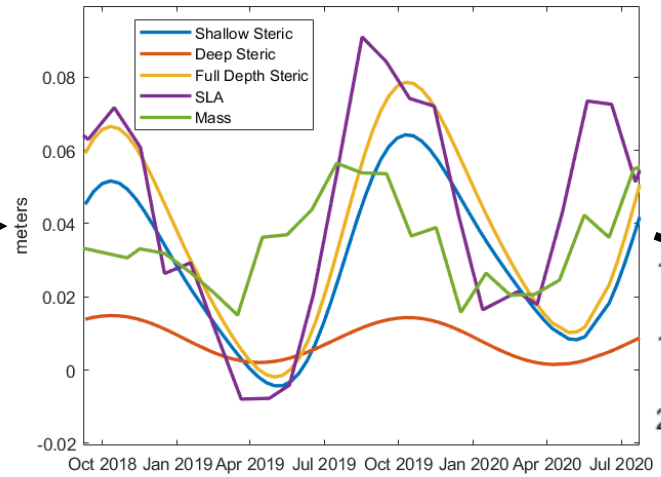
# Ex: Two Well-Sampled Mascons Show Temporal Variability in Full-Depth and > 2000 dbar SHA

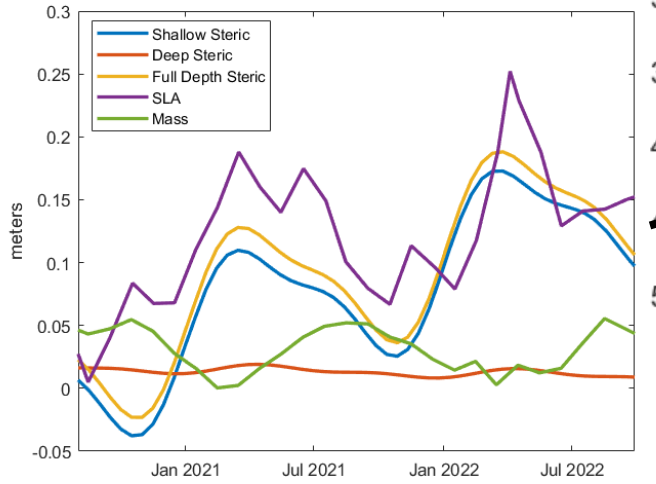


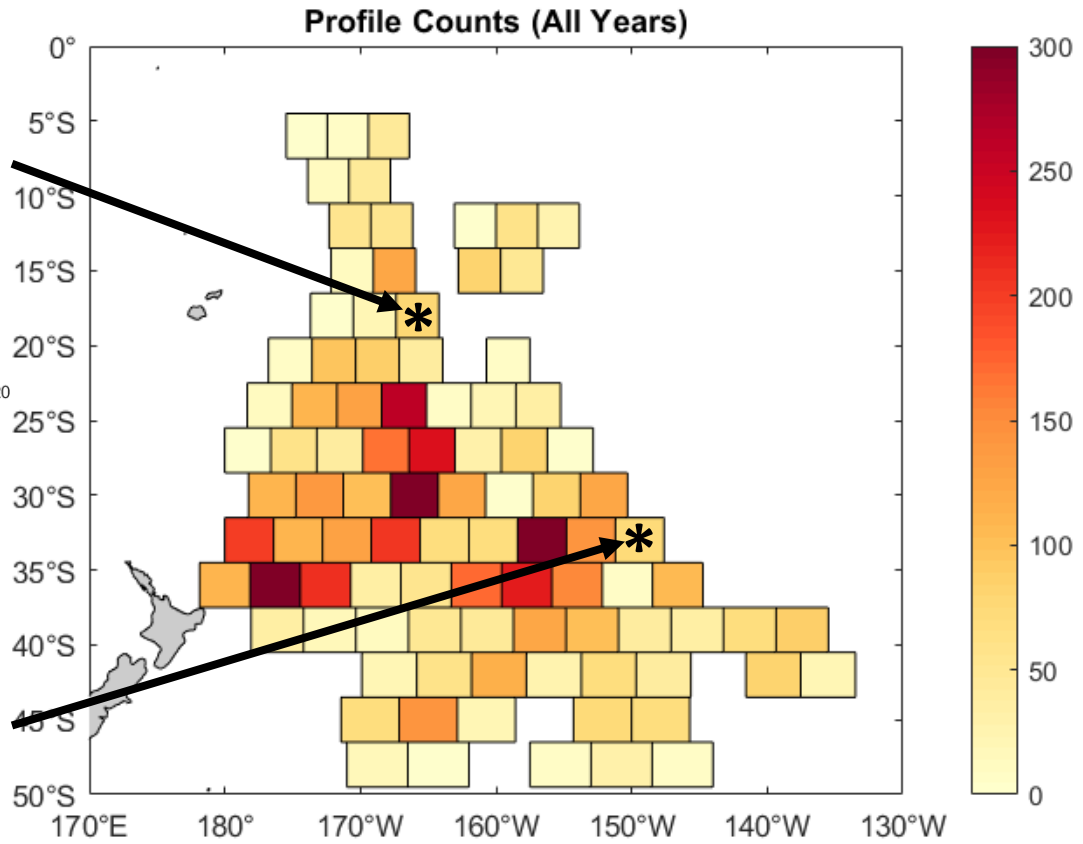



# For each mascon: Full depth steric + Mass = SLA?

| Trend in Each Term in Mascon 2985 | |
|---|---|
| Shallow steric | 12.643 mm/yr |
| Deep steric | -0.550 mm/yr |
| Full depth steric | 12.092 mm/yr |
| Mass | 2.329 mm/yr |
| Steric + Mass | 14.4 mm/yr |
| Sea Level Anomaly | 12.1 mm/yr |
| **SLA – (Steric + Mass)** | **2.3 mm/yr** |




- There is sufficient data (and low noise) in several, but not all, of the mascons of interest to do SLB analysis
- In some mascons, the difference between SLA and Steric + Mass is very small! (E.g., 2.3 mm/yr in mascon 2985)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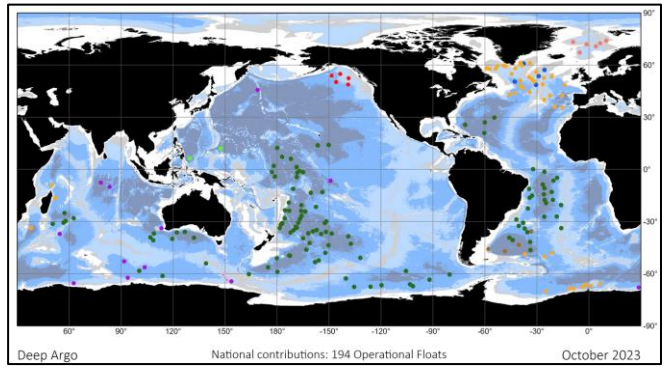
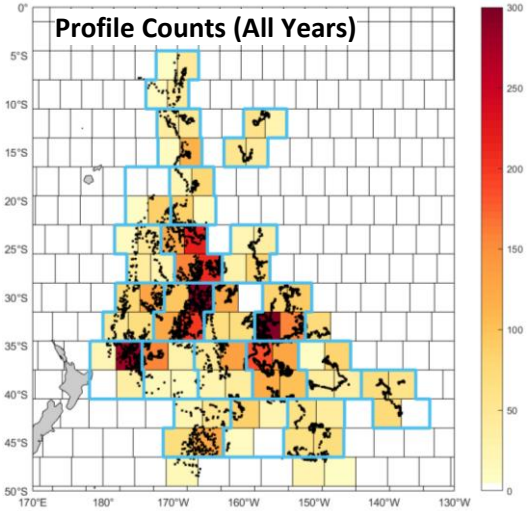
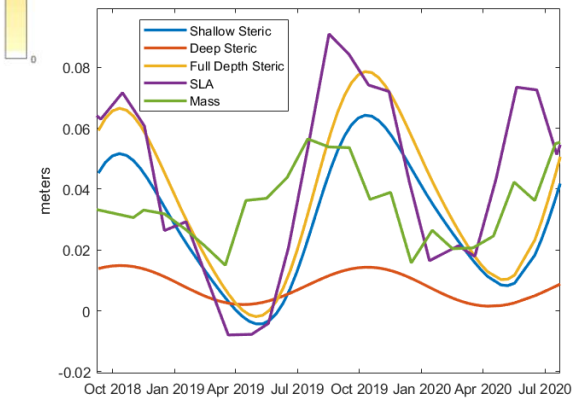
# Takeaways

- Deep Argo data can be used to calculate the deep steric sea level component in the SWPB
- More work is needed to determine if these deep SHA data will enable us to close the SLB in throughout this basin of interest vs. only in a few mascons
- **Ongoing work**: Assess the SLB over groups of 2 × 2 mascons (with Core Argo data for shallow steric sea level) both with respect to the trend and seasonal variability of the SLB components
- **Aiming to provide critical validation of the S6 regional sea level drift objective (5 mm yr$^{-1}$) in these deep basins** → Continued expansion of Deep Argo will be key for evaluating if we are meeting this objective in other basins





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