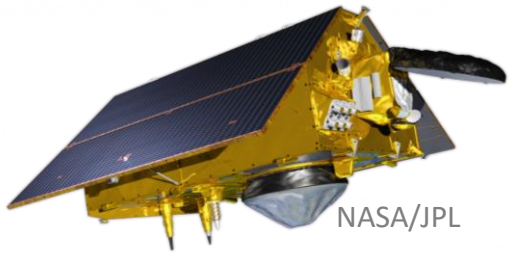
Assessing the Closure of the Sea Level Budget in the Southwest Pacific Basin Using Deep Argo



NASA/JPL

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

[1]Cooperative Institute for Satellite Earth System Studies (CISESS), University of Maryland

[2]NOAA's Laboratory for Satellite Altimetry (LSA)

[3]NOAA's Pacific Marine Environmental Laboratory (PMEL)

MRV Systems

Science I - OSTST 2022

plavin@umd.edu

Breaking Down a Sea Level Budget

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

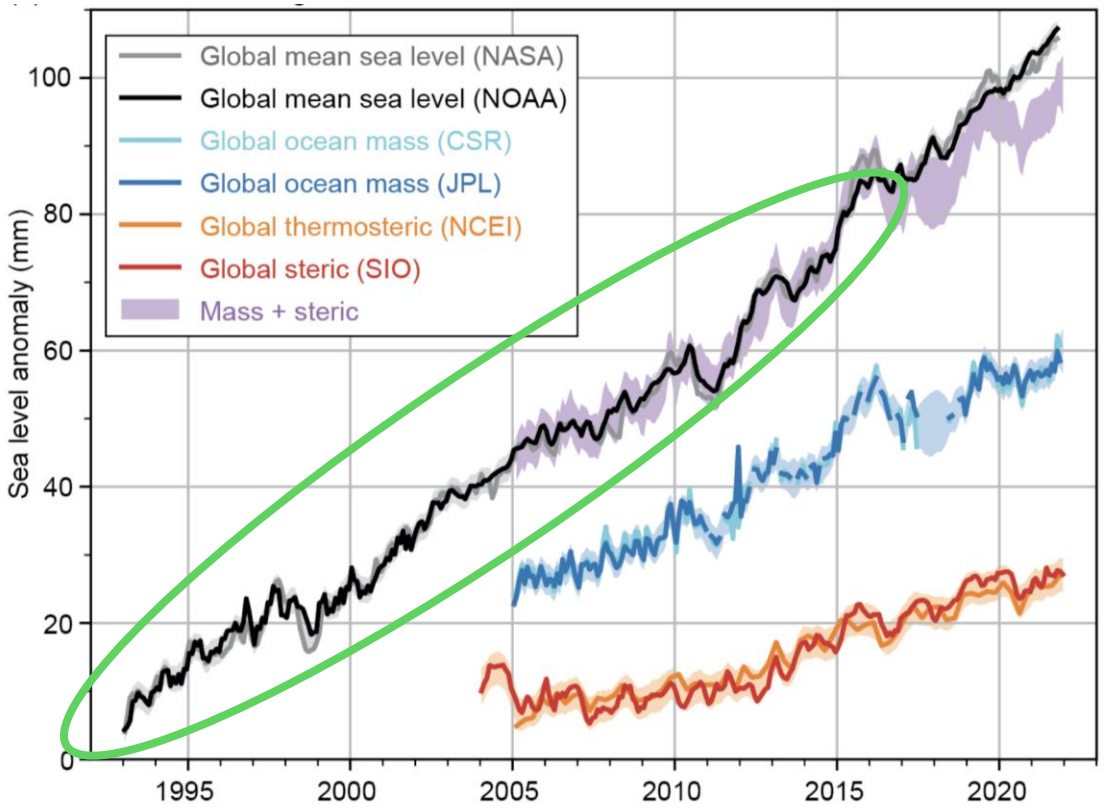
Sea level anomaly (SLA) from altimeters
Source: NOAA/EUMETSAT Radar Altimeter Database System (RADS)

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?

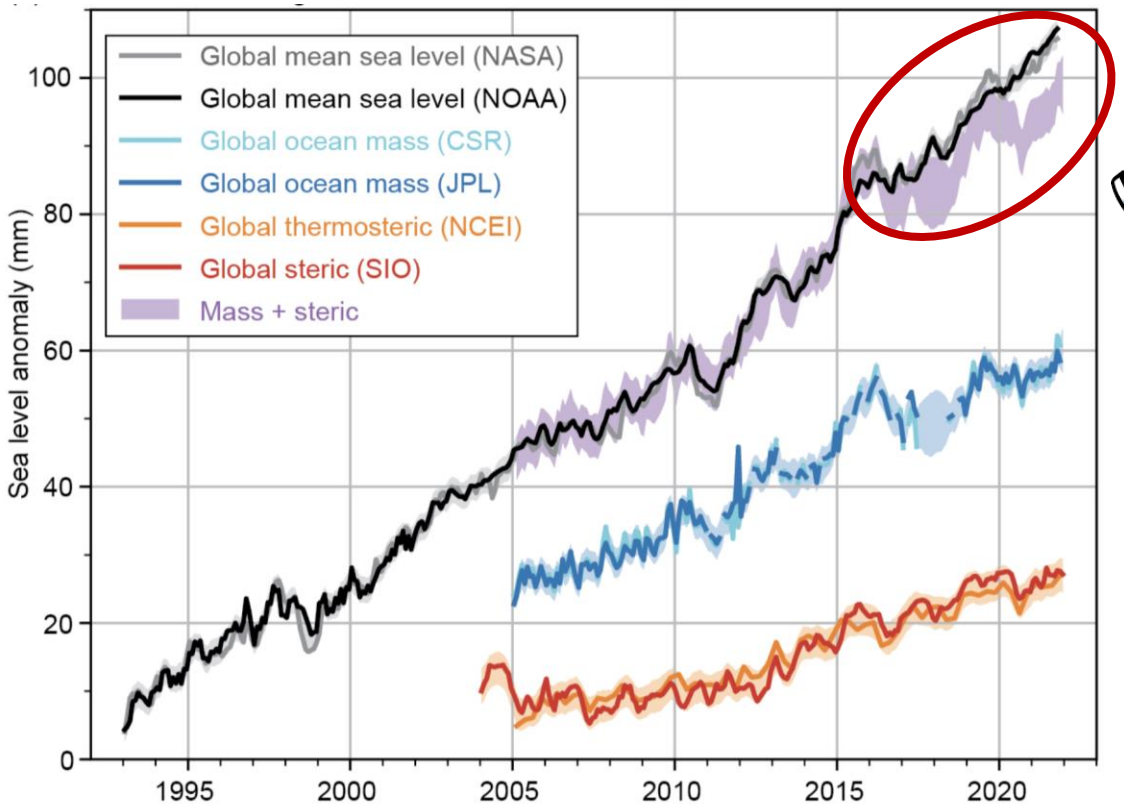


Thompson et al., 2022: State of the Climate in 2021. 10.1175/BAMS-D-22-0072.1

✓ **Yes (from 2005–2015)**

plavin@umd.edu

Global Sea Level Budget – Does it close?



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

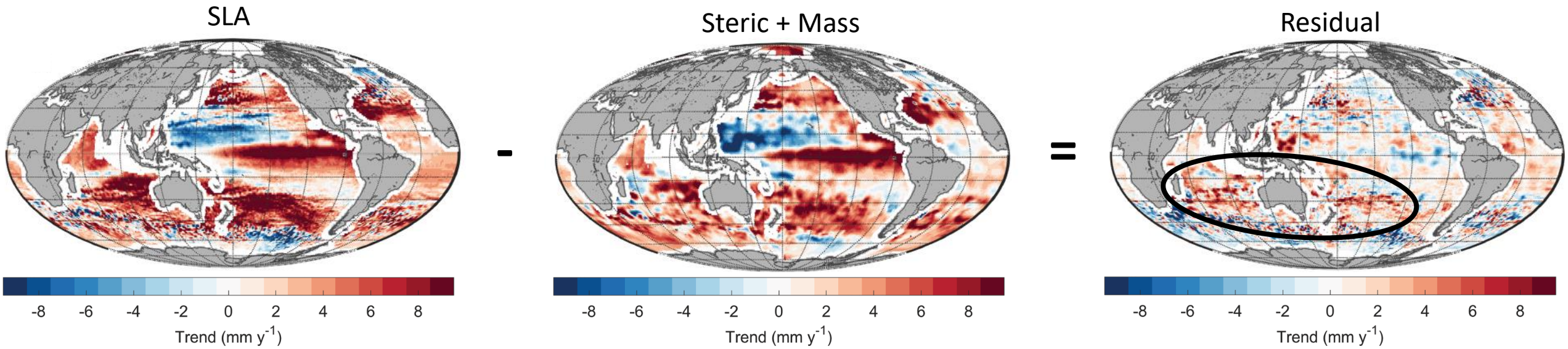
Yes (from 2005–2015)

Potential sources of mismatch from 2016 onward:

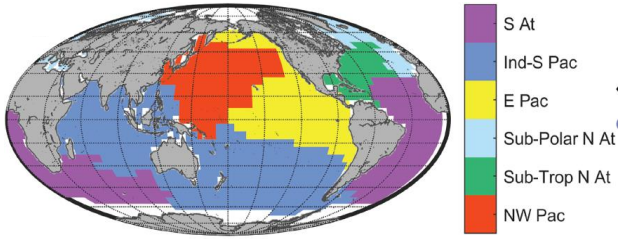
- SLA: Wet tropospheric correction for altimeters
- Mass: GIA model and accelerometer changes for GRACE/GRACE-FO
- Steric: Salty drift in Argo float salinities

plavin@umd.edu

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

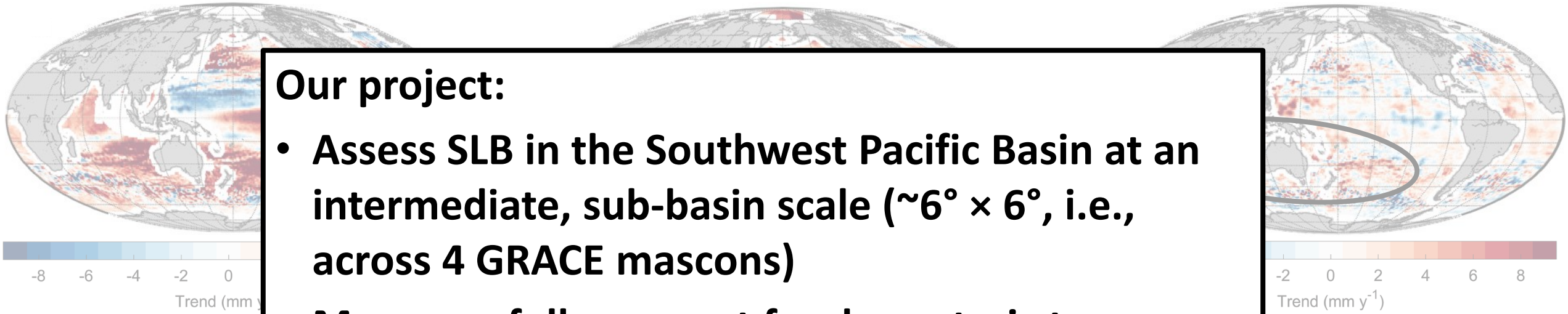
plavin@umd.edu

Regional Sea Level Budget – Does it close?

SLA

Steric + Mass

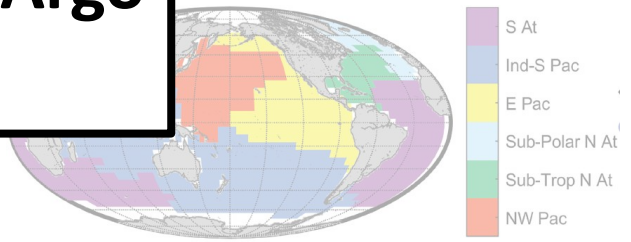
Residual



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**

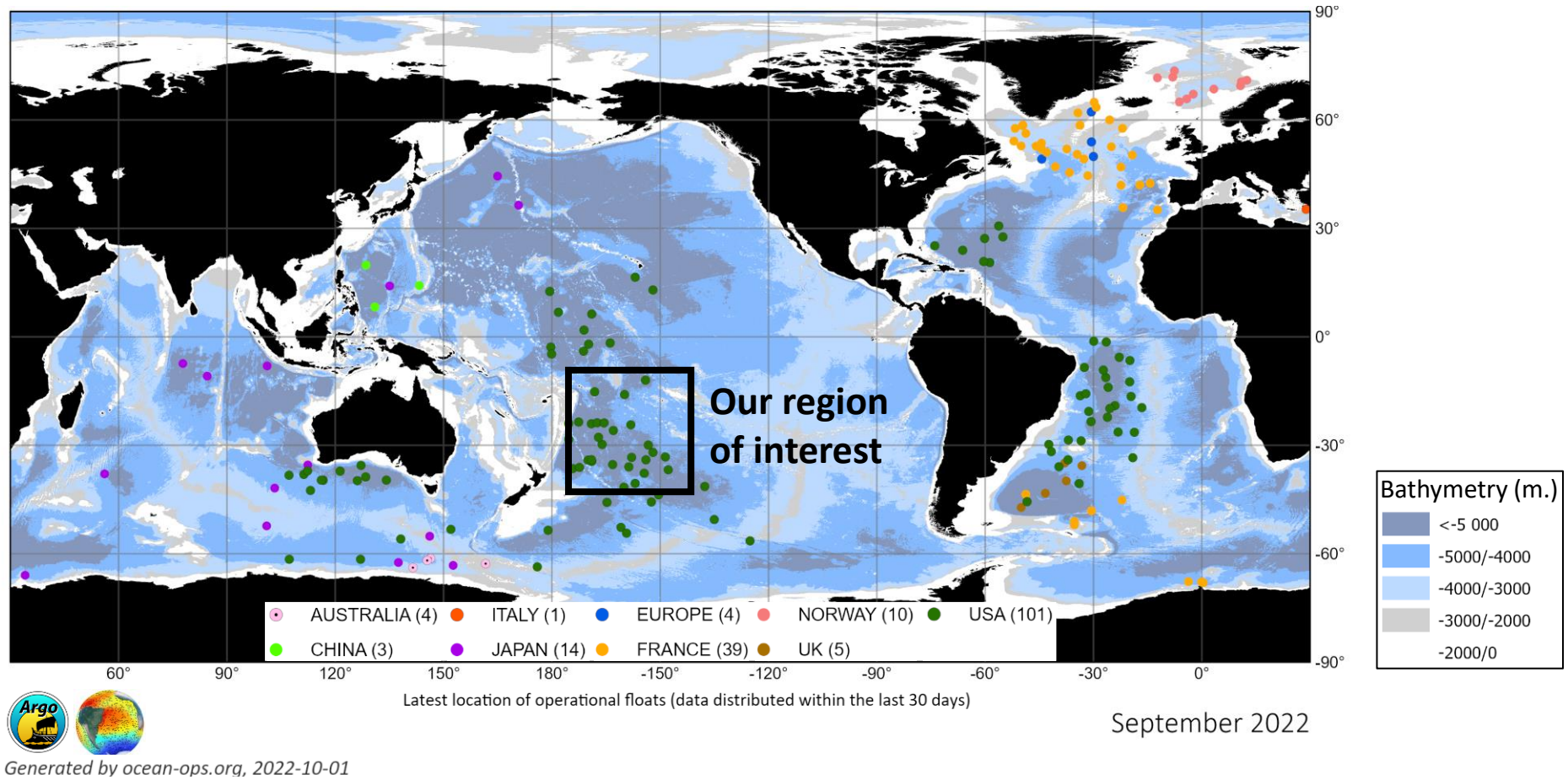
- Spatial pat… …ot fully match those of SL…
  - ⇨ SLB clo…
  - ⇨ Steric …
  - ⇨ Observation processing differences at the hemisphere scale (e.g., GRACE GIA correction and altimetry orbital altitude) also contribute to mismatch



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

Royston et al., 2020

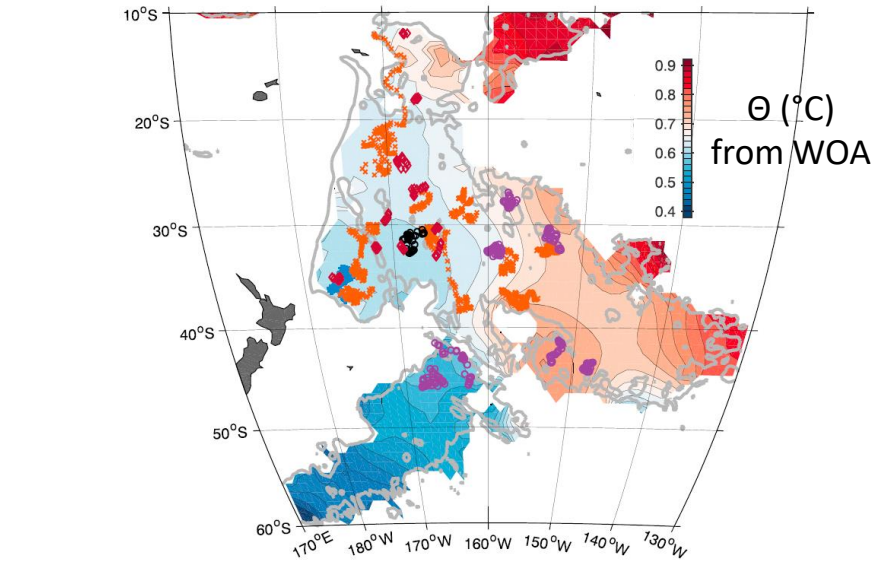
Deep Argo array is growing!

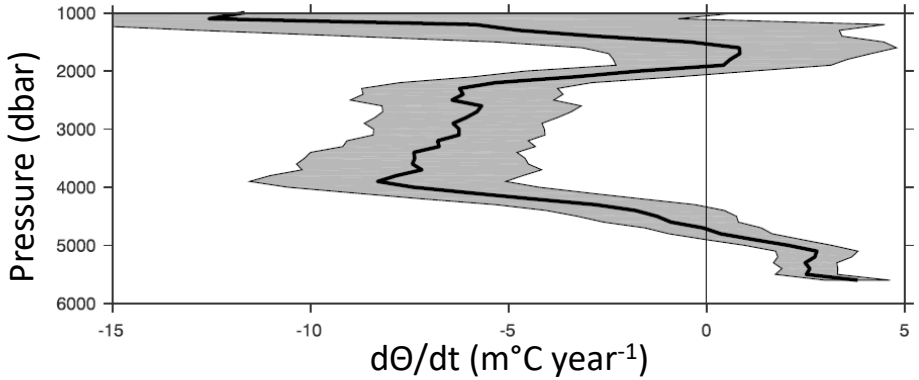


- Currently 181 active floats across several regional arrays
  - Measure down to 4000 or 6000 dbar

Deep Argo is already measuring significant changes in bottom water properties

- Profiles from June 2014 to Nov 2018 (~4.4 years)
- Warming observed at an average rate of 3 (±1) m°C/year from 5,000 to 5,600 dbar (near-homogeneous layer of cold, dense bottom water of Antarctic origin)
  - ⇨Suggests an acceleration of previously reported long-term abyssal warming trends in this region
- **Demonstrates the ability of Deep Argo to quantify changes in the deep ocean in near real-time over short periods with high accuracy**



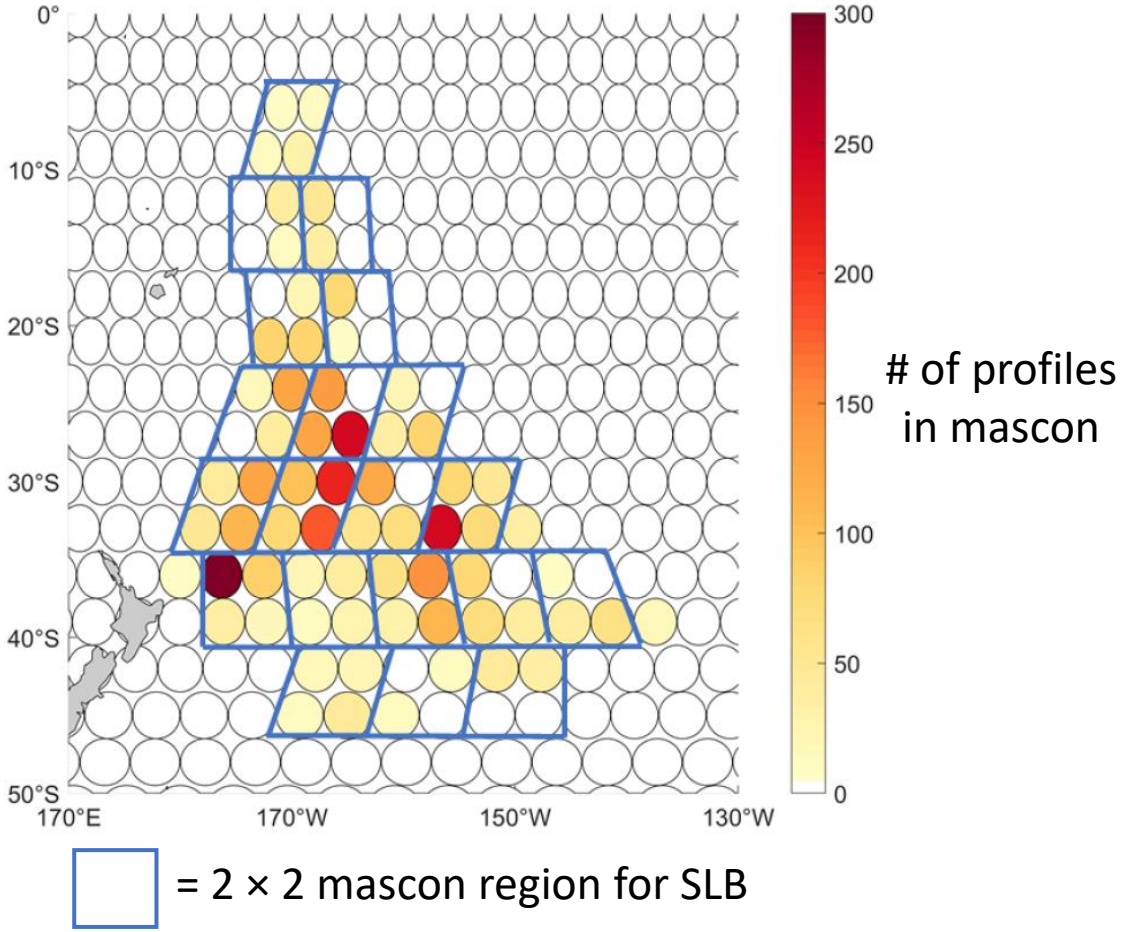


Johnson et al., 2019

plavin@umd.edu

Robustly Quantifying the Steric Term Using Deep Argo

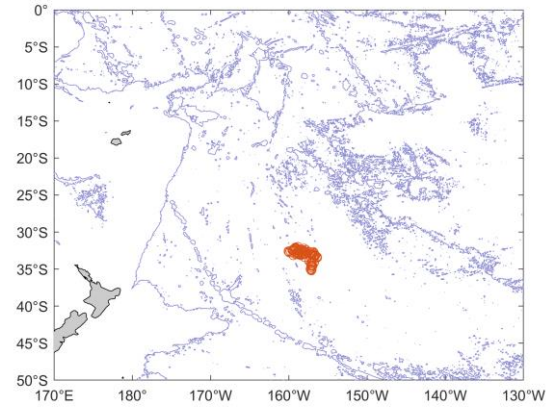
- ~4200 Deep Argo profiles from June 2014 to February 2022
- 55% D-mode, 45% A-mode
- Applied QC flags 1 & 2
- Manually applied correction for compressibility of conductivity cell to A-mode profiles float-by-float

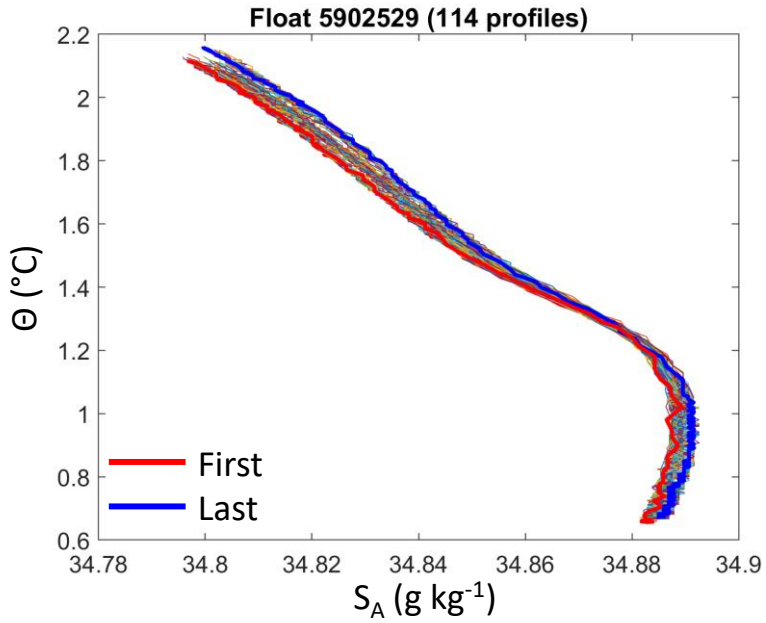


plavin@umd.edu

Robustly Quantifying the Steric Term Using Deep Argo

- ~4200 Deep Argo profiles from June 2014 to February 2022
- 55% D-mode, 45% A-mode
- Applied QC flags 1 & 2
- Manually applied correction for compressibility of conductivity cell to A-mode profiles float-by-float
- Visual QC and drift correction (ongoing)

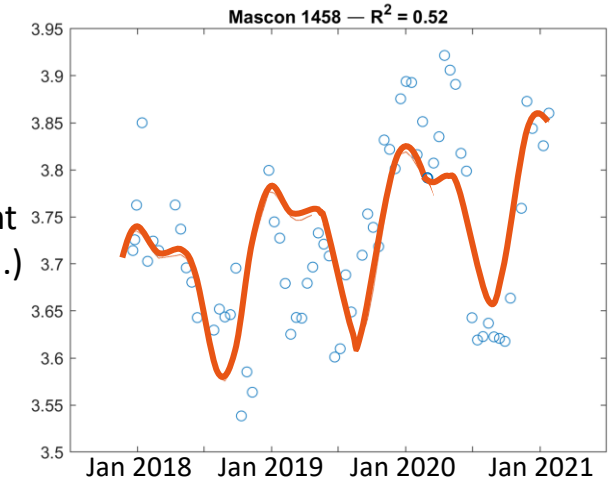




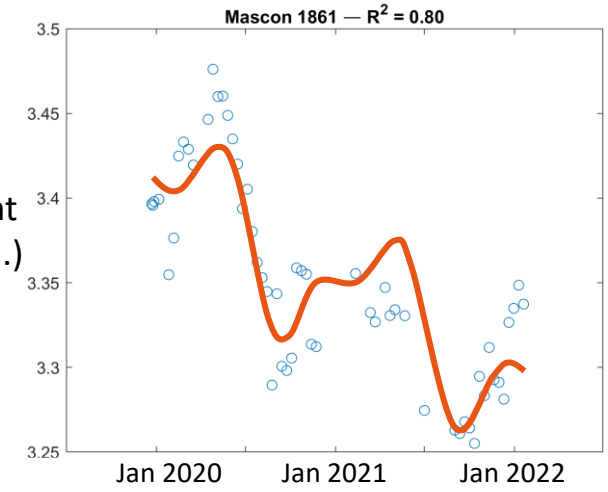
plavin@umd.edu

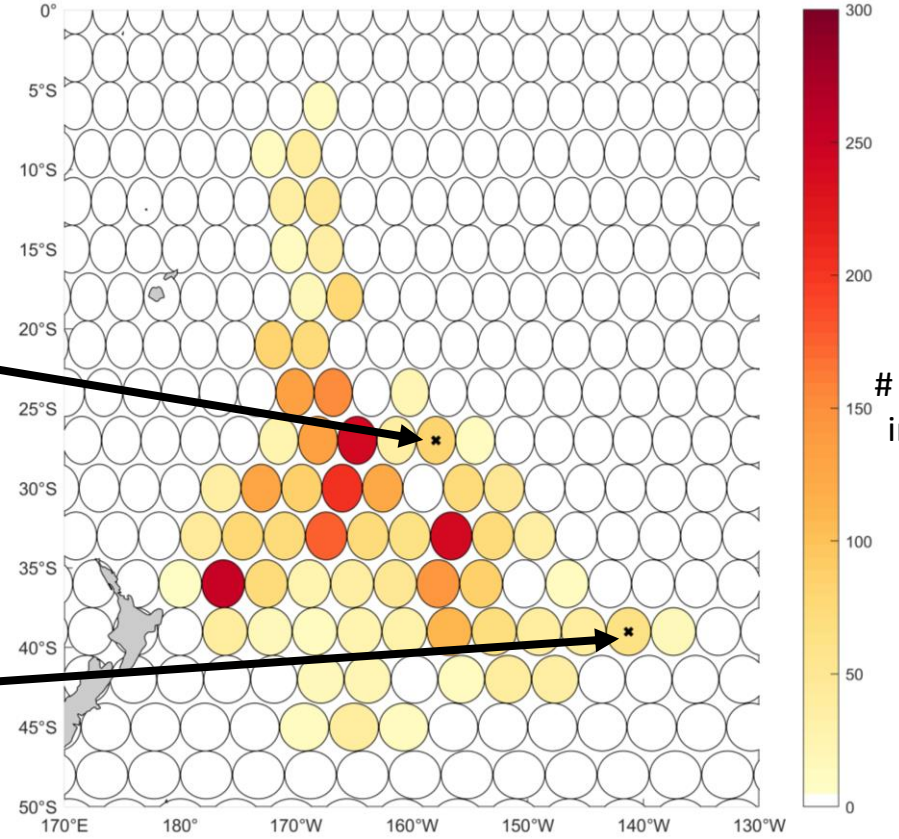
Robustly Quantifying the Steric Term Using Deep Argo

Steric Height Anomaly (m.)



Steric Height Anomaly (m.)

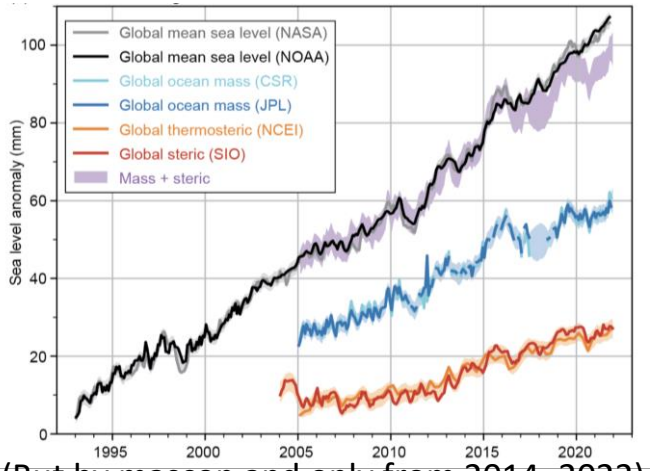




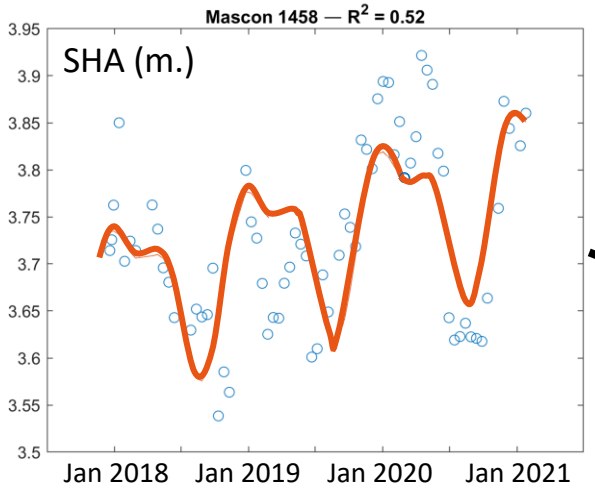
# of profiles in mascon

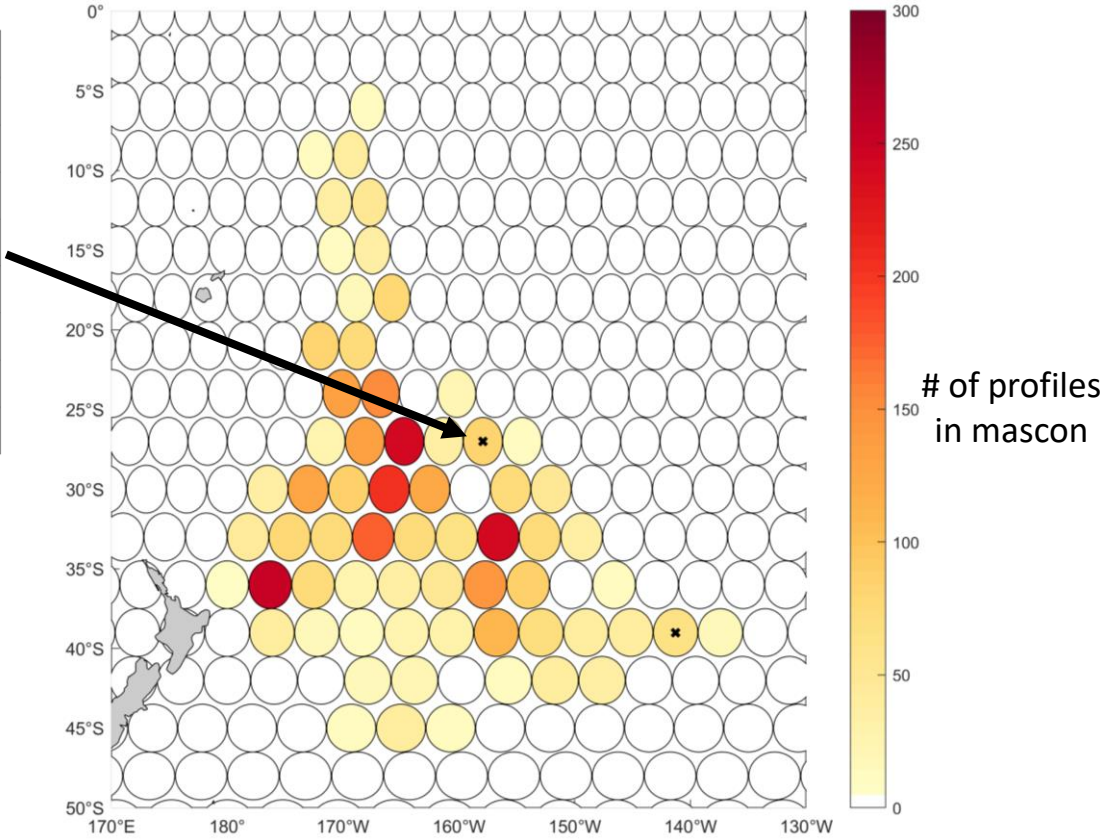
plavin@umd.edu

What's next? (Goals by next OSTST)



(But by mascon and only from 2014–2022)





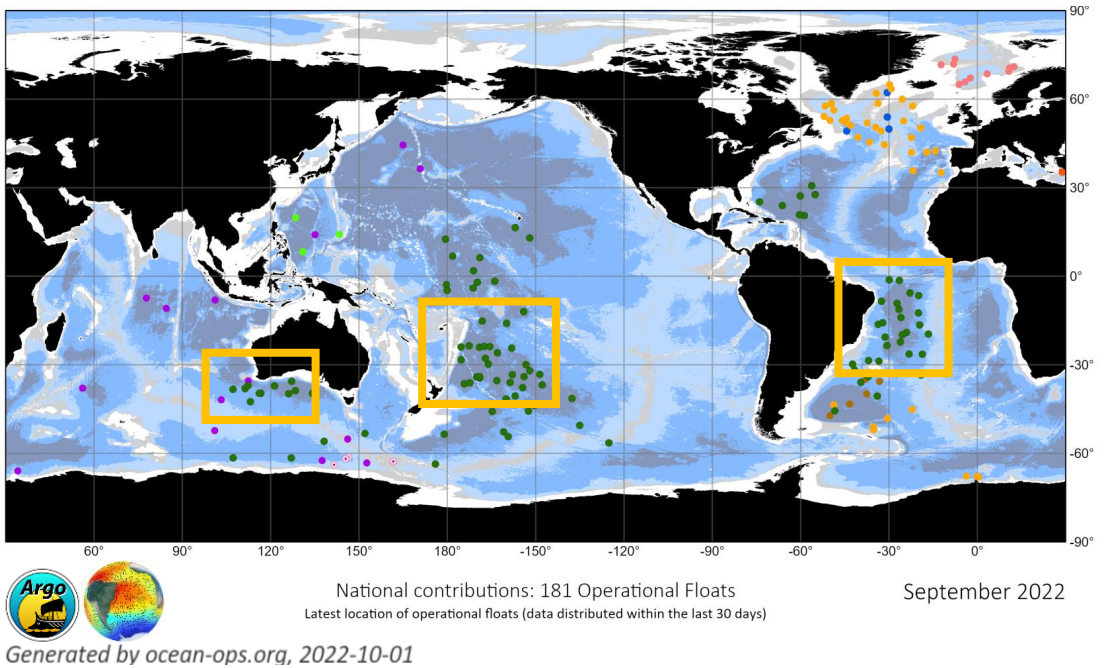
- Separate Deep Argo steric term into upper (<1900 dbar) and deep (>1900 dbar) ocean components
- Use Core Argo data to better resolve upper ocean steric term
- Evaluate closure of budget *at sub-basin scales* using RADS SLA & the mass term from GRACE (for multiple mascon solutions)
- Compare to American Samoa tide gauge

plavin@umd.edu

Plans for Rest of Award Period (through 2025)

- Quantify the impact of Deep Argo data on the closure of regional SLB trends in three deep basins (2016–present)
- Assess the seasonal variability of the observed SLBs at these regional scales

- These analyses will also provide critical validation of the S6 regional sea level drift objective (5 mm yr^{-1}) in these deep basins.
- ***Looking forward*: Continued expansion of Deep Argo will be key for evaluating if we are meeting this objective in other basins.**



plavin@umd.edu