Synergies between Argo, GRACE and Altimetry

Summary

Deep-ocean steric sea level variations in the Northwest Atlantic Ocean revealed using Deep Argo data and BATS profiles

Nathalie Zilberman, William Llovel, Jacob Steinberg, and Antoine Hochet (Oral presentation):

Results from Deep Argo temperature and salinity measurements collected between 2017-2022 in the Northwest Atlantic Ocean reveal Deep Argo's ability to resolve changes in deep steric sea level. Deep Argo data show interannual variations of deep-ocean steric sea level stronger along the path of the deep western boundary current (DWBC, floats 6027 and 6029) than over the abyssal plain (floats 6021, 6025, and 6026 and at the Bermuda Atlantic Time-series Study (BATS) station). The deep ocean contributes 30% of the full-depth steric sea level in the DWBC, compared to about 10% over the abyssal plain. Interannual variations of deep-ocean steric sea level from Deep Argo are consistent with the geodetic approach and ocean reanalysis (GLORYS, CGLOR, ORAS, and FOAM) products over the abyssal plain, but strongest variations seen in the DWBC are not well resolved in the geodetic approach and ocean reanalysis.

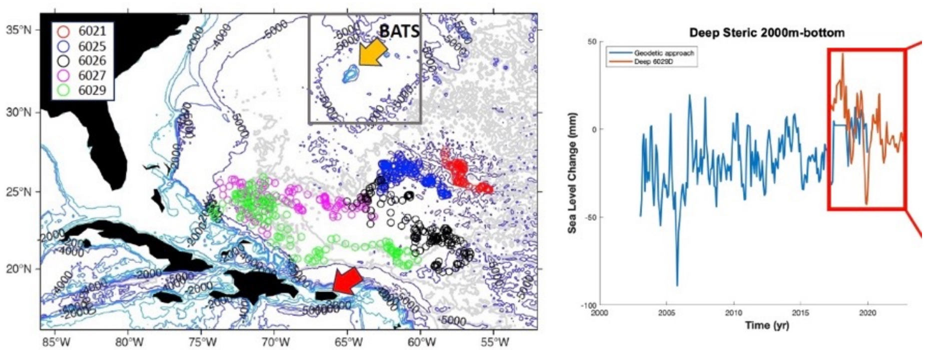


Figure: (a) Locations of full-depth profiles collected from Deep Argo floats and at the BATS station (Zilberman et al., In Prep). (b) Comparison of deep steric sea level estimates in the DWBC from Deep Argo float 6029 and the geodetic approach using DUACS altimetry, GRACE/GRACE-FO and Roemmich and Gilson's climatology.

Can Deep Argo close the sea level budget in the Southwest Pacific Basin?

Paige Lavin and Gregory Johnson (Oral presentation):

Deep Argo profiles collected between 0-6000m in the regional pilot array of the Southwest Pacific Basin show 10-30% deep steric contribution to sea level change at interannual time scale. Results show that some of the non-closure of trends in the sea level budget (SLB) seen in parts of the Southwest Pacific Basin is due to the deep ocean and can be resolved using Deep Argo floats, though there is substantial variability in this term throughout the basin. Future work will consist of assessing the SLB over groups of 2 × 2 mascons (using Core Argo data for shallow steric sea level) both with respect to the trend and seasonal variability of the SLB components.

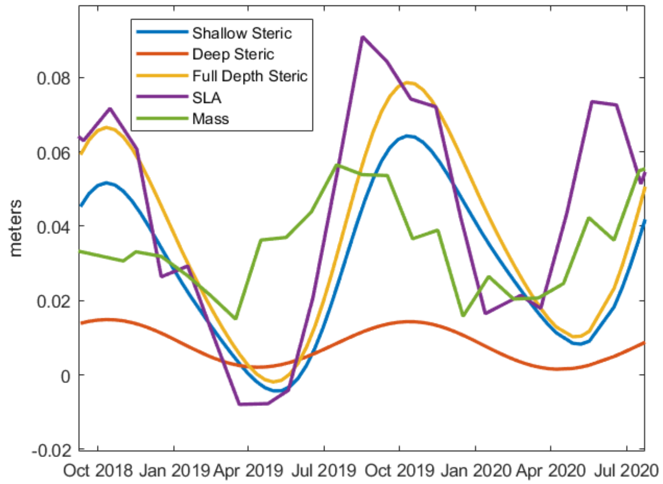


Figure: Sea level budget in a mascon of the Southwest Pacific Basin (Lavin and Johnson, In Prep). The difference between sea level anomaly and the sum of steric and mass components is small (~2.3 mm/year).

Investigating Steric Sea Level anomalies: Combining satellite altimetry, GRACE/GRACE-FO, and Argo

Sara Reinelt and Don Chambers (Oral presentation):

Comparisons of the difference between total sea level from altimetry, mass addition from GRACE/GRACE-FO and steric sea level from Core Argo floats (measuring only temperature and salinity in the upper 2000m) with Roemmich and Gilson’s climatology suggest occurrence of drift in salinity measurements from six Core Argo floats after 2017. The authors will work with Argo delayed-mode operators to investigate further the adjusted fields of Core Argo salinity and study comparisons with raw Argo data.

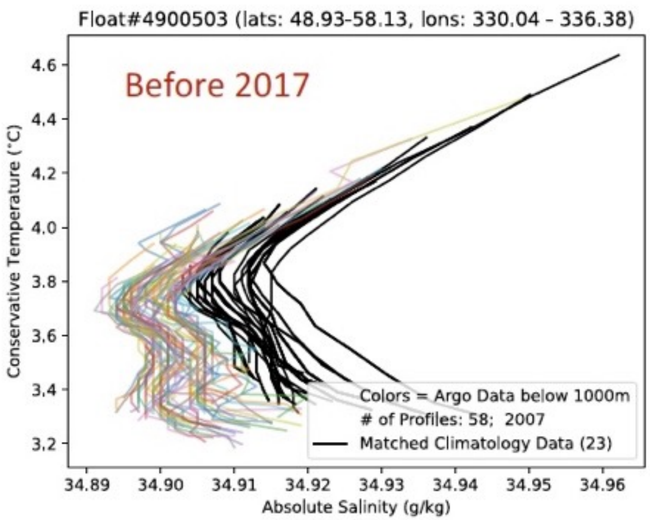


Figure: OHC trends in the Atlantic Ocean inferred using the geodetic approach between 2002-2020

Monitoring the regional Ocean Heat Content change over the Atlantic Ocean with the space geodetic approach

Victor Rousseau, Robin Fraudeau, Matthew Hammond, Odilon Joël Houndegnonto, Benoît Meyssignac, Michaël Ablain, et al. (Poster presentation):

Thermosteric sea level (SL) time series are generated for the case of the Atlantic Ocean between 2002-2020 as the difference between total SL from satellite altimetry and the sum of barystatic SL change from satellite gravity and halosteric SL variations from in situ data. Ocean Heat content (OHC) is then calculated from thermosteric SL using the integrated expansion efficiency of heat (IEEH) coefficient. Results show 0.17 W/m^2 OHC trend in the Atlantic ocean with strongest warming in the southern and northwest Atlantic, and cooling in the northeast Atlantic. Uncertainties in OHC trends stem from manometric uncertainties ranging from 70% to 90% from east to west. OHC trends from the geodetic approach show good agreement with independent datasets from the RAPID and OVIDE sections.

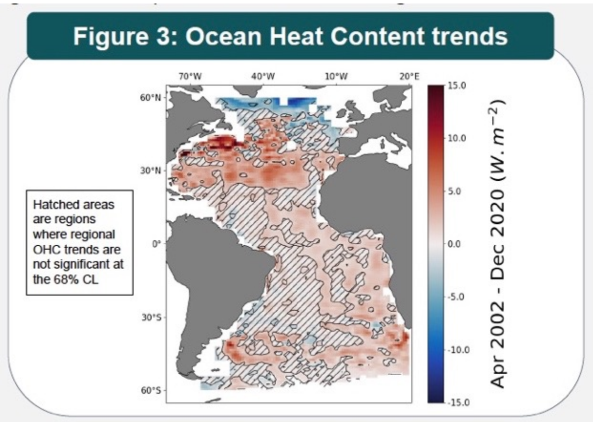
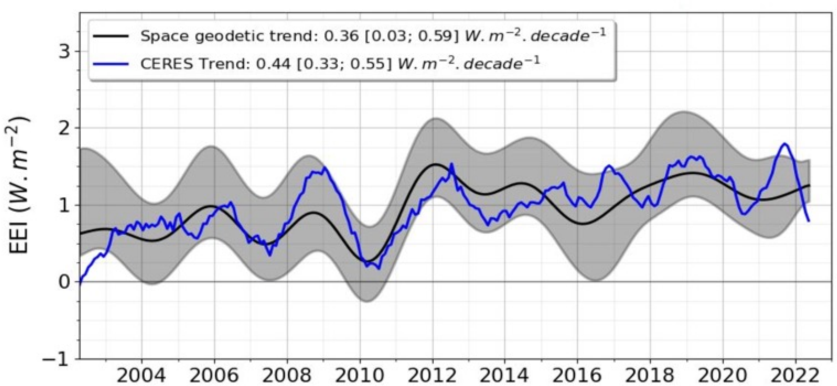


Figure: (a) Locations of full-depth profiles collected from Deep Argo floats and at the BATS station (Zilberman et al., In Prep). (b) Comparison of deep steric sea level estimates in the DWBC from Deep Argo float 6029 and the geodetic approach using DUACS altimetry, GRACE/GRACE-FO and Roemmich and Gilson's climatology.

Monitoring the global ocean heat content from space geodetic observations

Michael Ablain, Marti Florence, Rousseau Victor, Fraudeau Robin, Benoit Meyssignac, Alejandro Blazquez:

The ocean absorbs much of the excess energy stored by the Earth system that results from the greenhouse gas emission by human activities in the form of heat (~91%). As the ocean acts as a huge heat reservoir, global ocean heat content (GOHC) is therefore a key component in the Earth's energy budget. An accurate knowledge of the GOHC change allows us to assess the Earth energy imbalance (EEI), which refers to the difference between the amount of energy the Earth receives from the sun and the amount of energy it radiates back into space. Various methodologies exist to estimate EEI from the GOHC, including the use of temperature and salinity profiles, the measurement of the ocean thermal expansion from space geodesy, ocean reanalysis and net flux measurements. Among these approaches, the space geodetic approach, detailed in Marti et al. (2022), leverages the maturity of satellite altimetry and gravimetry measurements, enabling precise, extensive spatial and temporal coverage, and full-depth estimates of ocean thermal expansion.

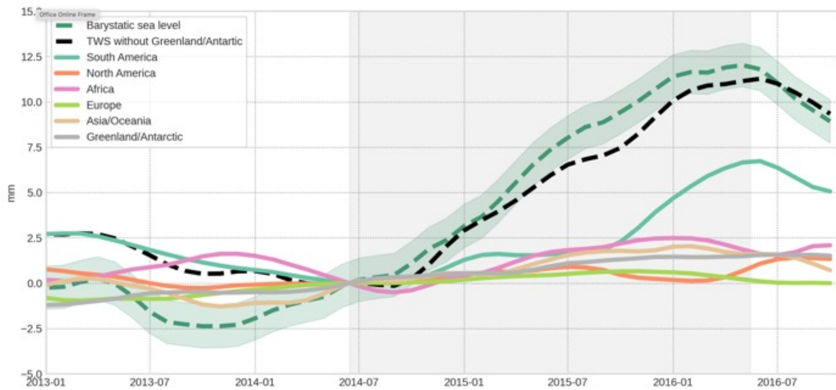


As the EEI magnitude is small (0.5-1.0 W/m2) compared to the amount of energy entering and leaving the climate system (~340 W/m2), a high level of precision and accuracy are required to estimate the EEI mean (< 0.3 W/m2) and its time variations at decadal scale (< 0.1 W/m2). In this regard, the space geodetic approach emerges as a promising candidate capable of meeting the stringent EEI precision and accuracy requirements.

Cause of substantial global mean sea level rise over 2014-2016

William Llovel, Kevin Balem, Soumaia Tajouri, Antoine Hochet:

Global mean sea level rise is one of the direct consequences of the actual global warming. This rise has been monitored for years by satellite altimetry missions which provide high quality data at nearly global coverage. This global rise is caused by global ocean warming (known as thermosteric sea level) and the continental freshwater discharge from land ice melting (i.e., Greenland and Antarctica ice sheets and mountain glaciers; known as barystatic sea level). On top of the background sea level trend, large interannual variability can occur which can be attributed to natural climate mode of variability (such as ENSO, PDO, etc). Since 2005 and at global scale, ocean warming and barystatic sea level can be assessed by complementary observing systems such as Argo profiles and GRACE/GRACE-FO data, respectively. In this study, we investigate the extreme El Nino events occurring in 2014-2016 and their imprints on the global mean sea level change by assessing all the different components of the sea level budget.



Over 2014-2016, we find that the global mean sea level experiences a rise of 1.5 cm over 24 months. 20% of this rise can be attributed to global ocean warming and 80% to barystatic sea level rise. Half of the barystatic sea level rise can be attributed to terrestrial water changes in South America with a significant contribution from the Amazon basin (5mm)

Impacts of GIA Modeling Uncertainties on the Closure of the GMSL Budget

Ashley Bellas, Robert Steven Nerem:

The closure of the global mean sea level (GMSL) budget can be impacted significantly by errors in modeling Glacial Isostatic Adjustment (GIA). GIA affects both the altimeter estimates of global mean sea level as well as the ocean mass estimates from GRACE/GRACE-FO. We examine the sensitivity of the GMSL closure to choices made in modeling GIA. As an example, relatively small changes in the Earth model used in the GIA modeling can have significant impacts on the GMSL closure between GMSL (altimetry), ocean mass (GRACE), and thermosteric sea level change (Argo). We will summarize these differences and suggest avenues for future research.