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

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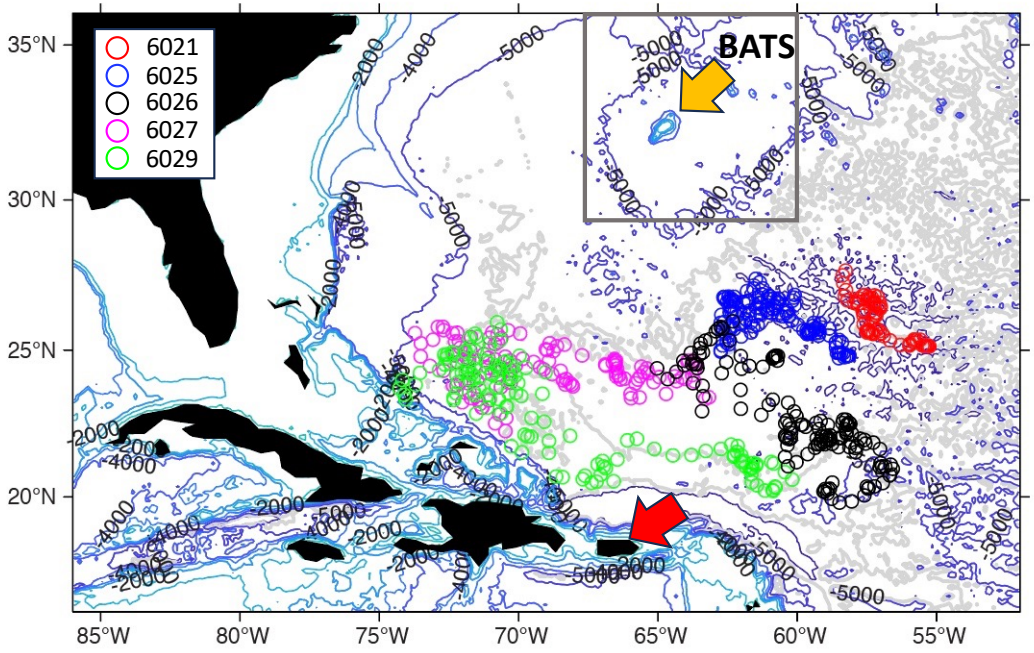
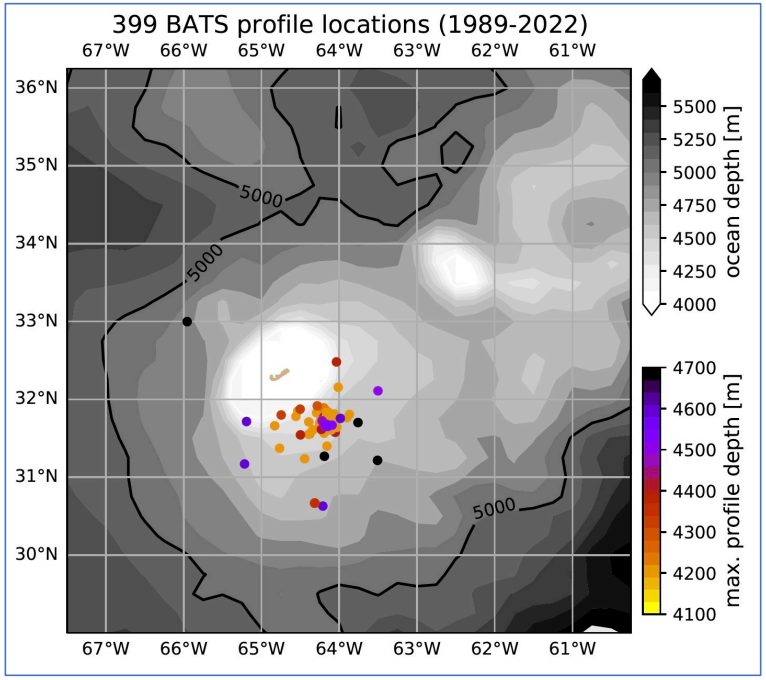
Independent observations of the deep ocean collected from Deep Argo floats and at the BATS station

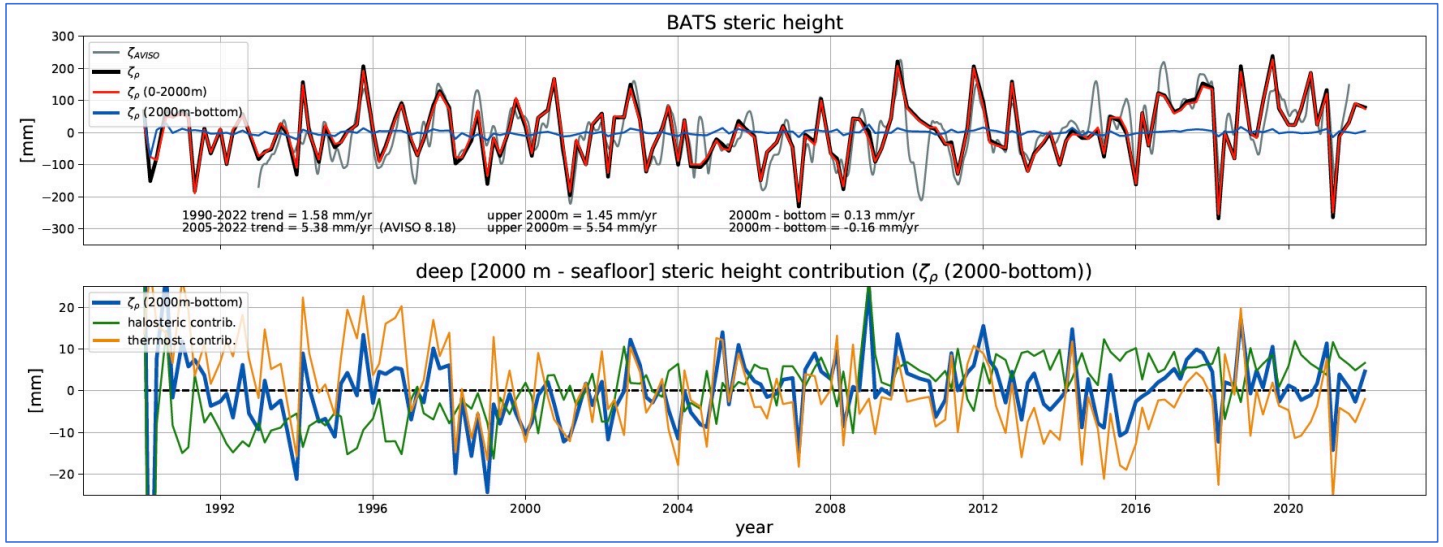


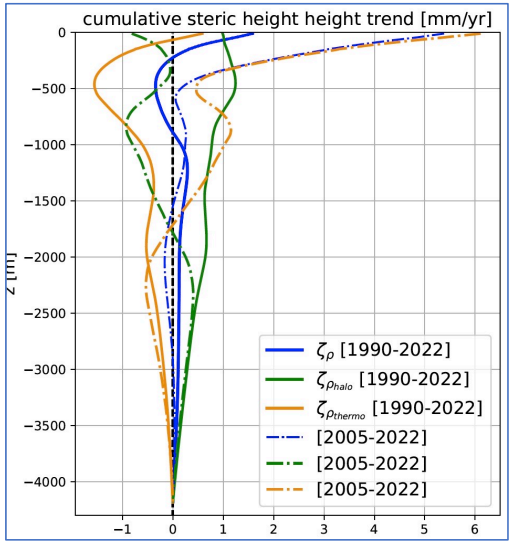
- **700** Deep Argo temperature and salinity profiles (15-day sampling) collected over 5-6 years (since 2017) from 5 Deep SOLO floats between 0-6000m in the regional pilot array of the Northwest Atlantic Ocean



- **400** temperature and salinity profiles (1 CTD cast per month) collected over 30 years (since 1989) between 0-4300m at the BATS station

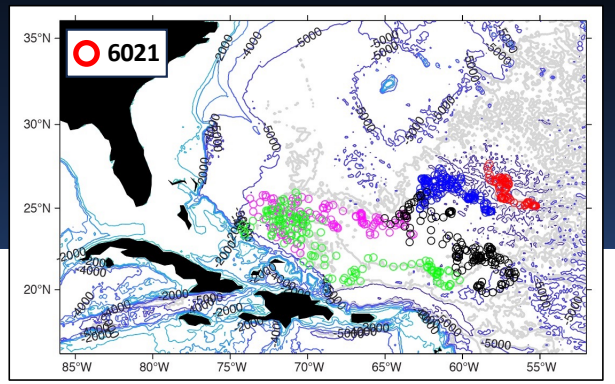
Measurements of deep-ocean steric Sea Level at the BATS station



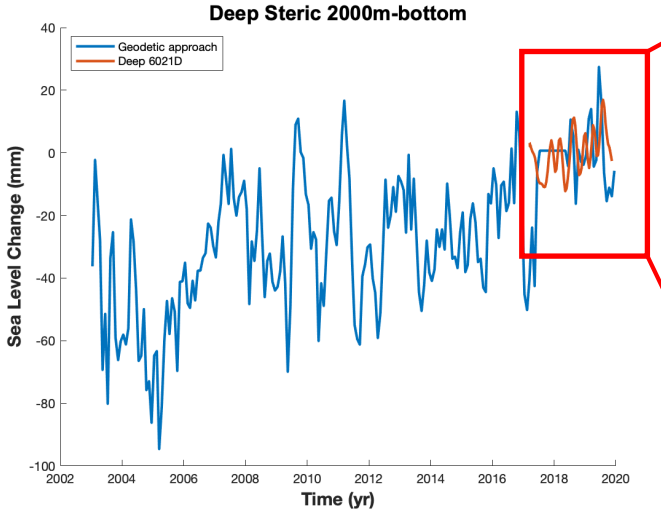


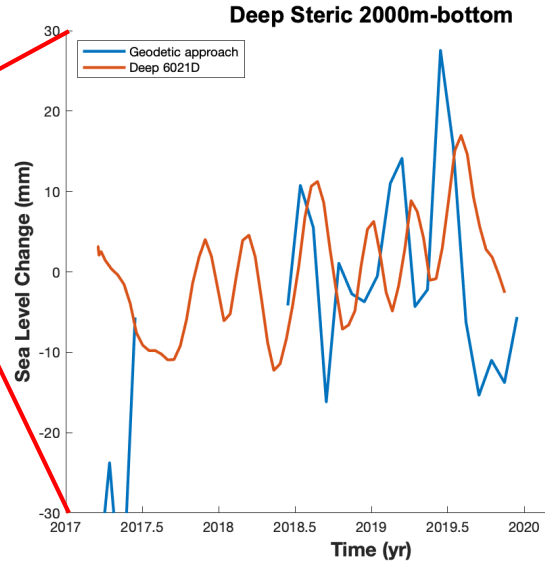
- Upper-2000m steric sea level trend has increased in 2005-2022 (5.54 mm/yr) compared to 1990-2022 (1.45 mm/yr)
- Deep (>2000m) steric sea level trend has decreased in 2005-2022 (-0.16 mm/yr) compared to 1990-2022 (0.13 mm/yr) due to temperature decrease and salinity increase
- Deep ocean steric sea level shows ± 6.5 mm interannual variations, ~5% of the full-depth signal between 2017-2022
- Interannual variations of deep steric sea level show contribution from temperature and salinity

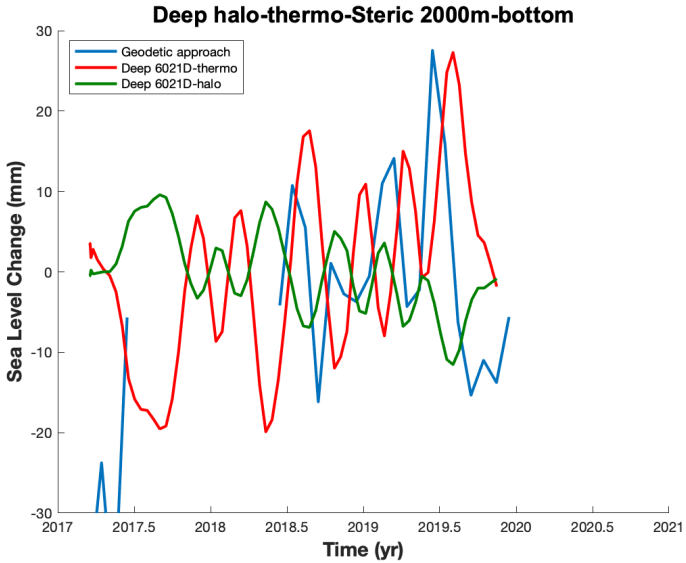
Comparisons of deep Steric Sea Level from Deep SOLO float 6021 and geodetic approach in the abyssal plain



Geodetic product = Altimetry – GRACE/GRACE-FO – Argo-based (0-2000m) steric

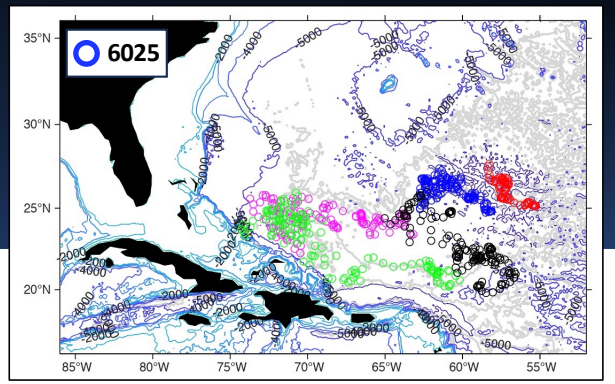




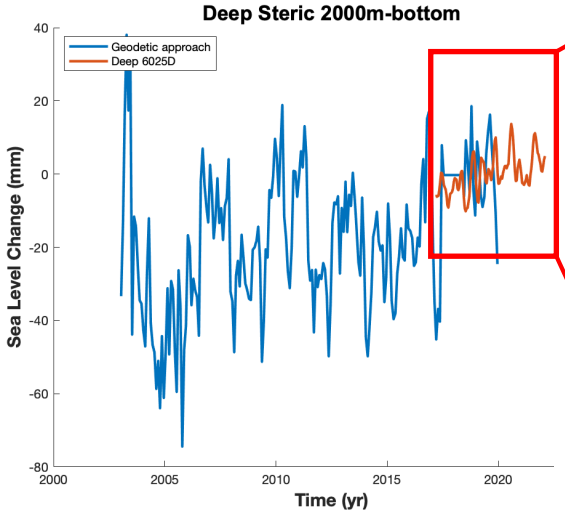


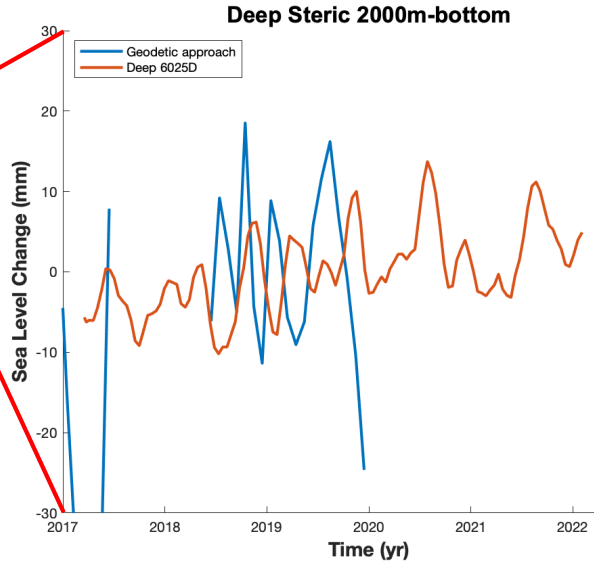
- Magnitude of deep steric sea level from Deep Argo float 6021 over the abyssal plain (±7 mm, 12% of the full depth signal) are consistent with the geodetic approach and measured at the BATS station
- Apparent 1-2 month lag between the Deep Argo and geodetic approach estimates of deep steric sea level

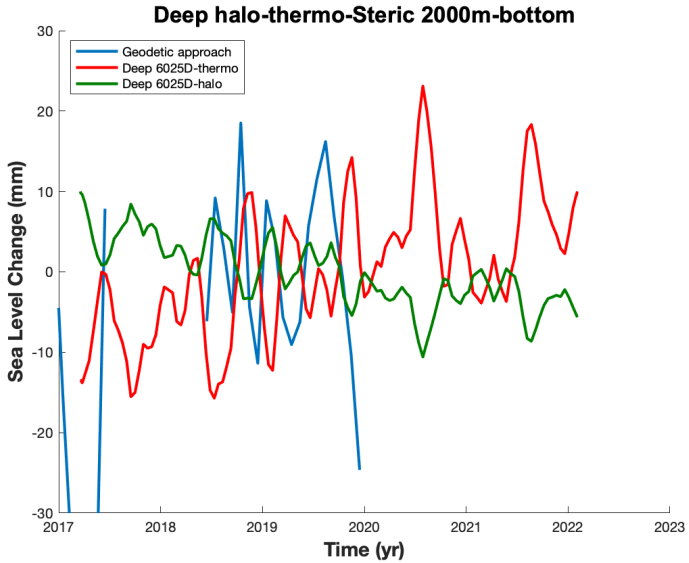
Comparisons of deep Steric Sea Level from Deep SOLO float 6025 and geodetic approach in the abyssal plain



Geodetic product = Altimetry – GRACE/GRACE-FO – Argo-based (0-2000m) steric

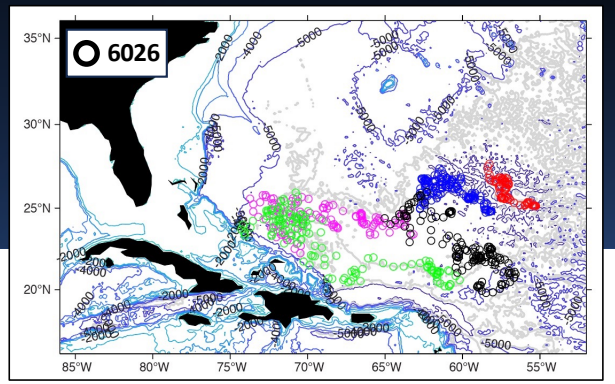




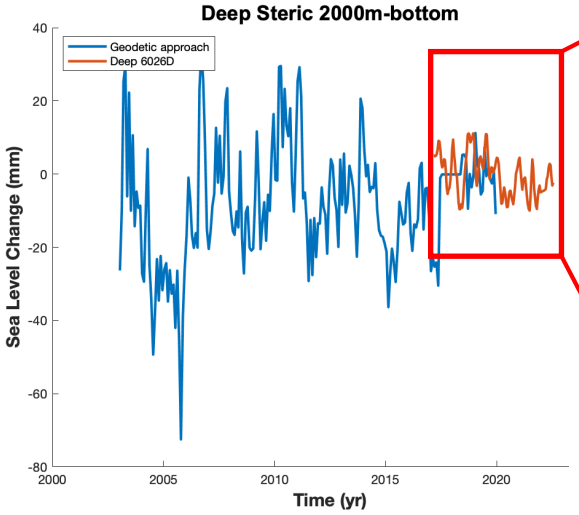


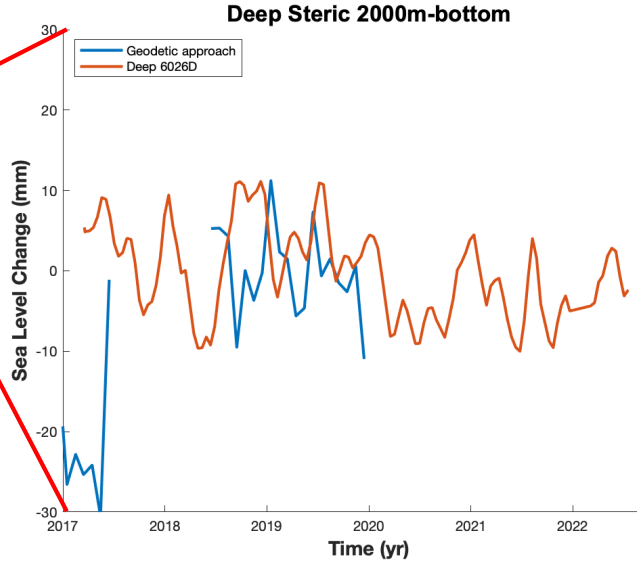
- Magnitude of deep steric sea level from Deep Argo float 6025 in the abyssal plain (±5 mm, 11% of the full depth signal) are consistent with the geodetic approach and measured at the BATS station
- Apparent ~5-6-month lag between the Deep Argo and geodetic approach estimates of deep steric sea level
- Apparent increasing trend in deep steric sea level (+2.5 mm/yr) observed between 2017-2022

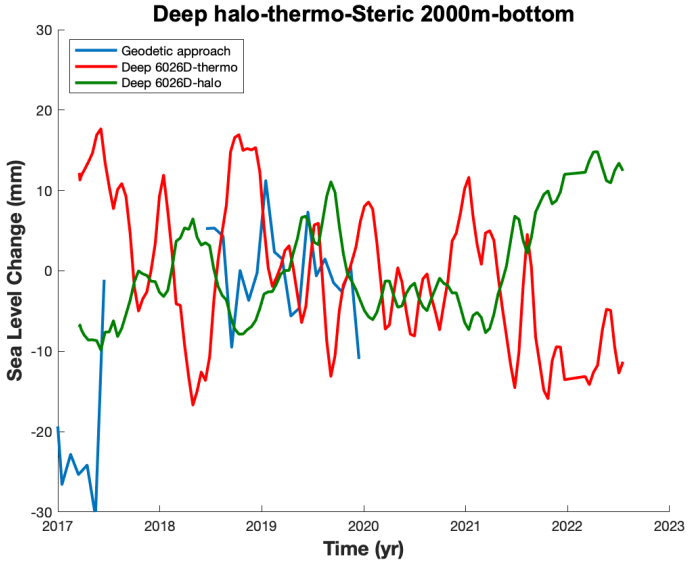
Comparisons of deep Steric Sea Level from Deep SOLO float 6026 and geodetic approach in the abyssal plain



Geodetic product = Altimetry – GRACE/GRACE-FO – Argo-based (0-2000m) steric

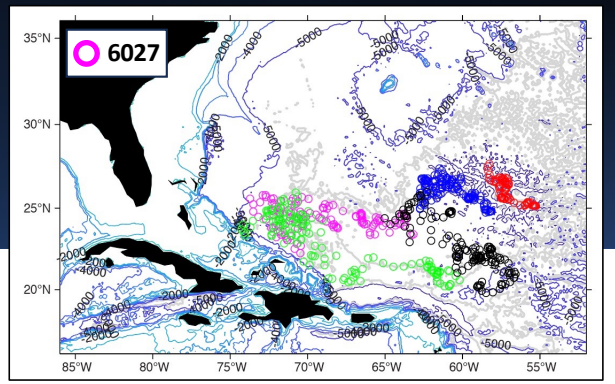




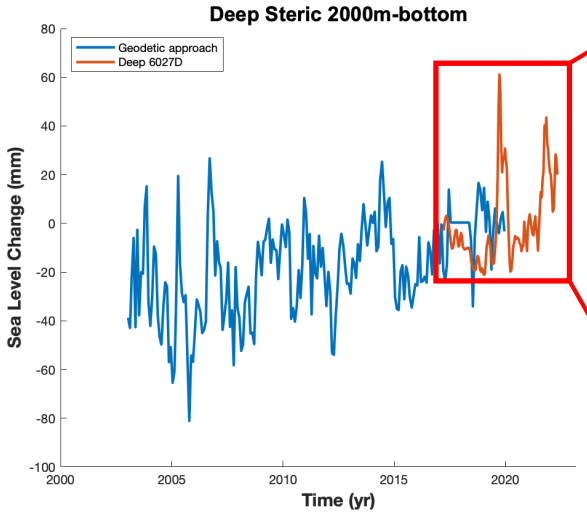


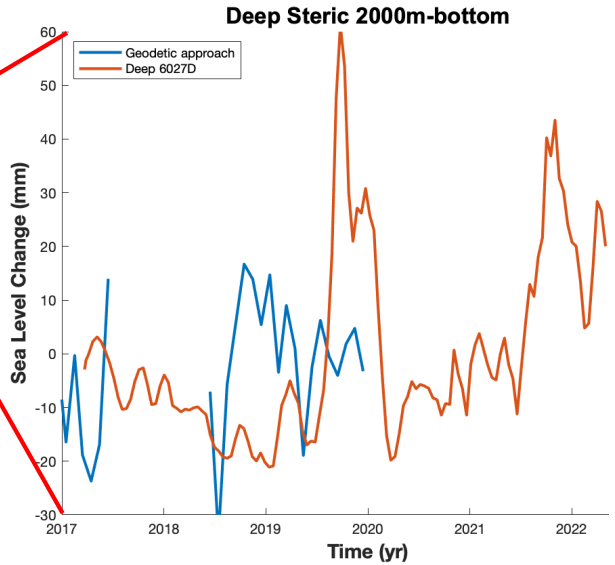
- Magnitude of deep steric sea level from Deep Argo float 6026 in the abyssal plain (±6 mm, 11% of the full depth signal) is consistent with the geodetic approach and estimates at the BATS station
- Apparent decreasing trend in deep steric sea level (-2.2 mm/yr) observed between 2017-2022

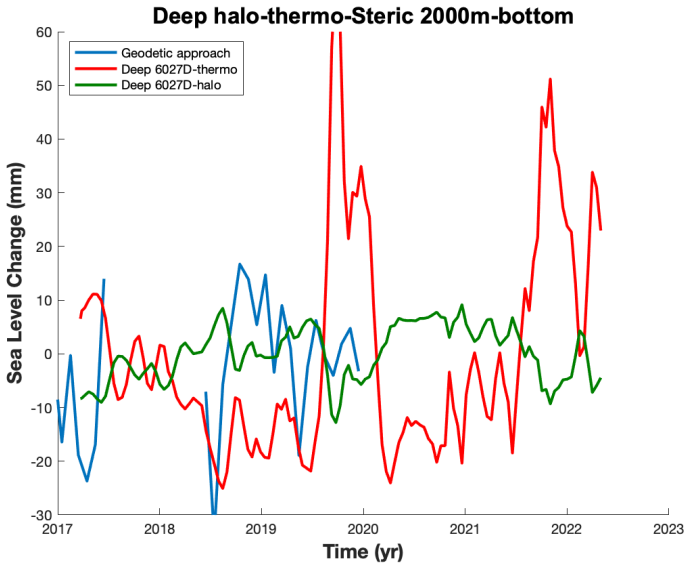
Comparisons of deep Steric Sea Level from Deep SOLO float 6027 and geodetic approach in the deep western boundary current (DWBC)



Geodetic product = Altimetry – GRACE/GRACE-FO – Argo-based (0-2000m) steric

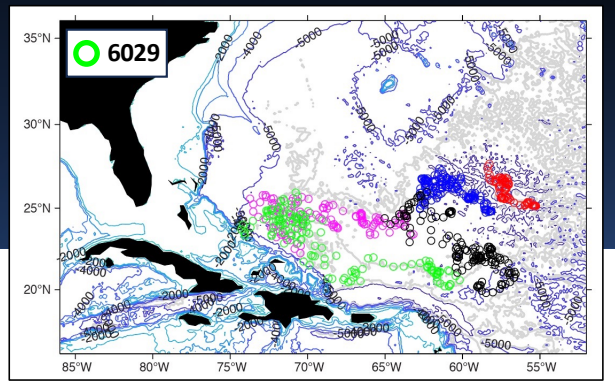




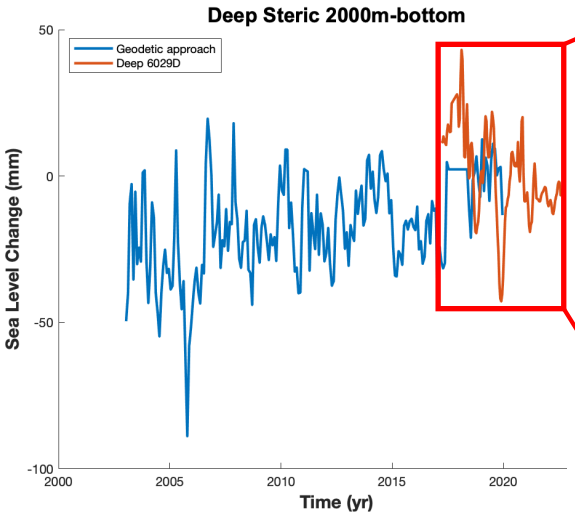


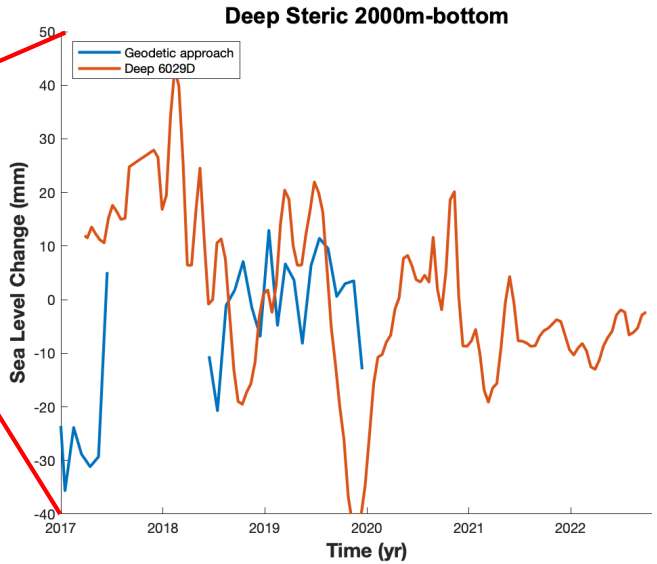
- Interannual deep steric sea level variations from Deep Argo float 6027 in the DWBC (±17 mm, 28% of the full depth signal) are higher than using the geodetic approach and measured at the BATS station and from 6021, 6025, and 6026 over the abyssal plain
- No evident trend in deep steric sea level is observed between 2017 and 2022

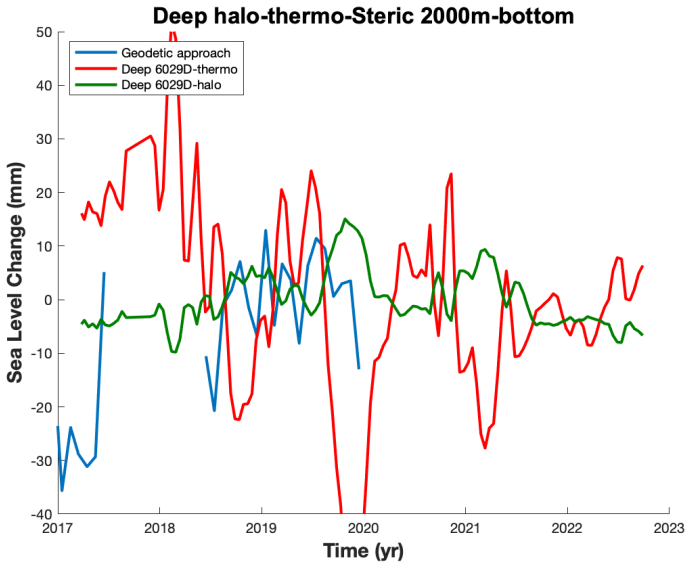
Comparisons of deep Steric Sea Level from Deep SOLO float 6029 and geodetic approach in the deep western boundary current (DWBC)



Geodetic product = Altimetry – GRACE/GRACE-FO – Argo-based (0-2000m) steric

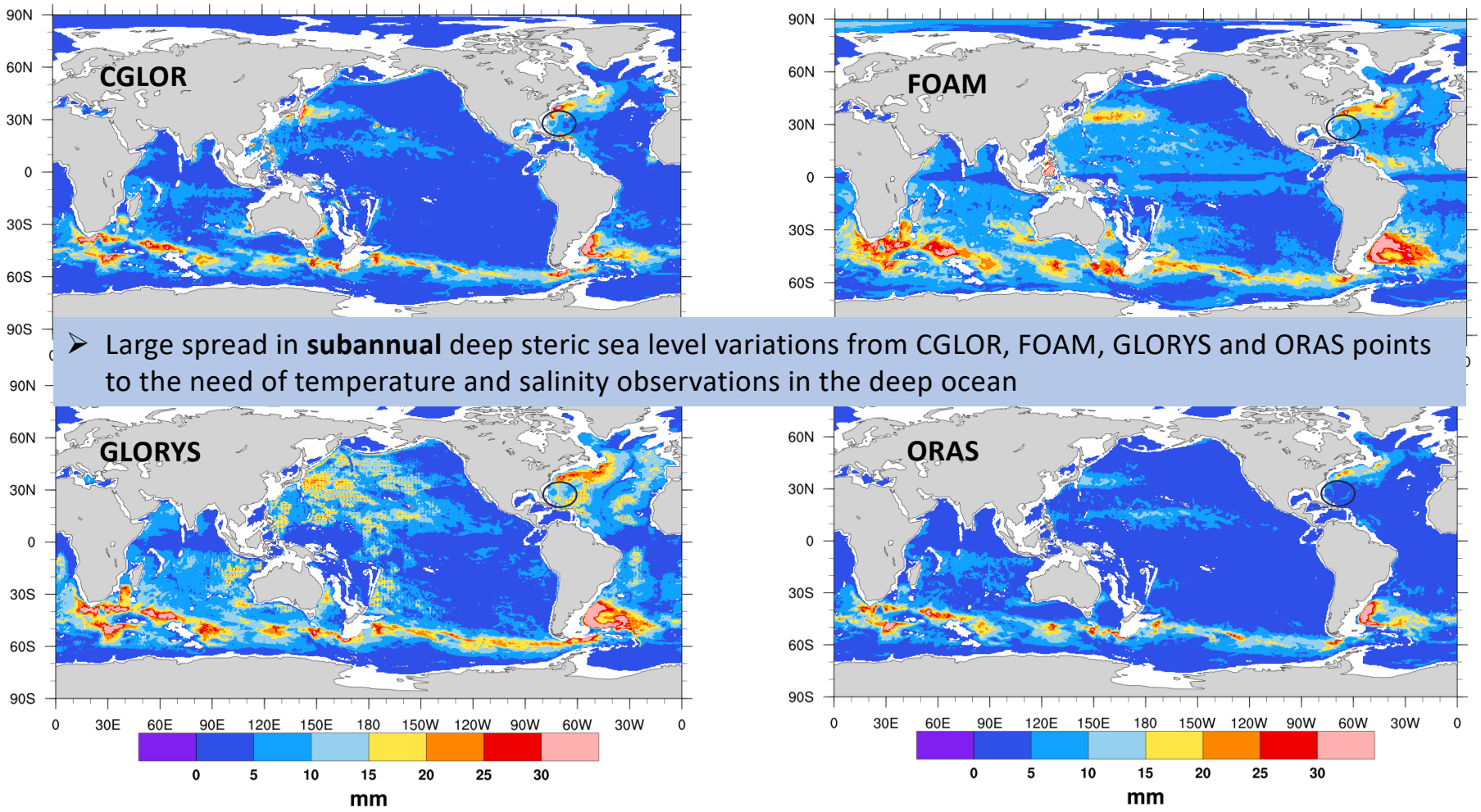






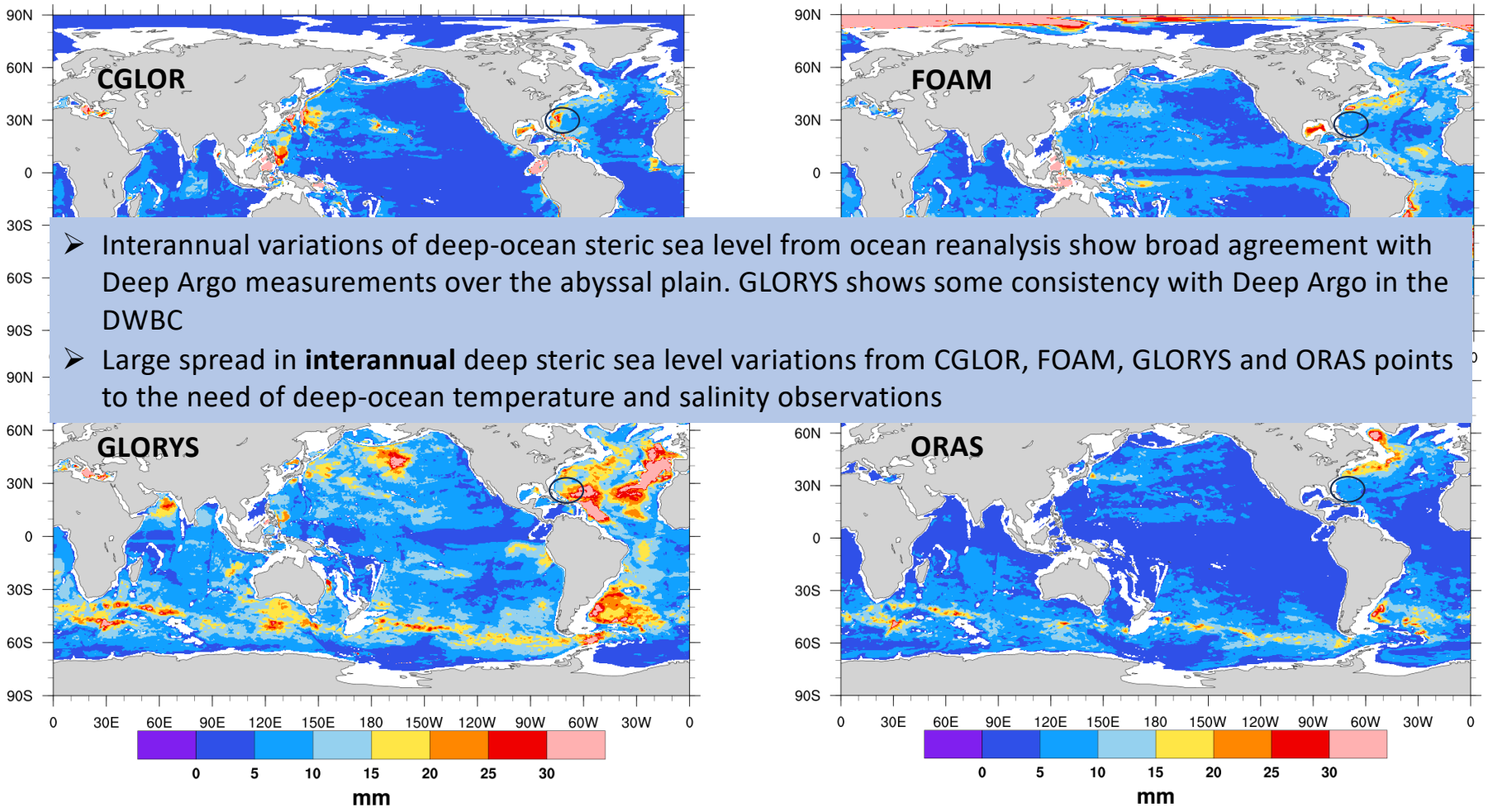
- Interannual deep steric sea level variations from Deep Argo float 6027 in the DWBC (±15 mm, 30% of the full depth signal) are higher than using the geodetic approach and measured at the BATS station and from 6021, 6025, and 6026 over the abyssal plain
- Apparent decreasing trend in deep steric sea level (-4.8 mm/yr) observed between 2017-2022

Subannual Variability of deep-ocean steric sea level over 1993-2020 simulated from ¼° Ocean Reanalysis

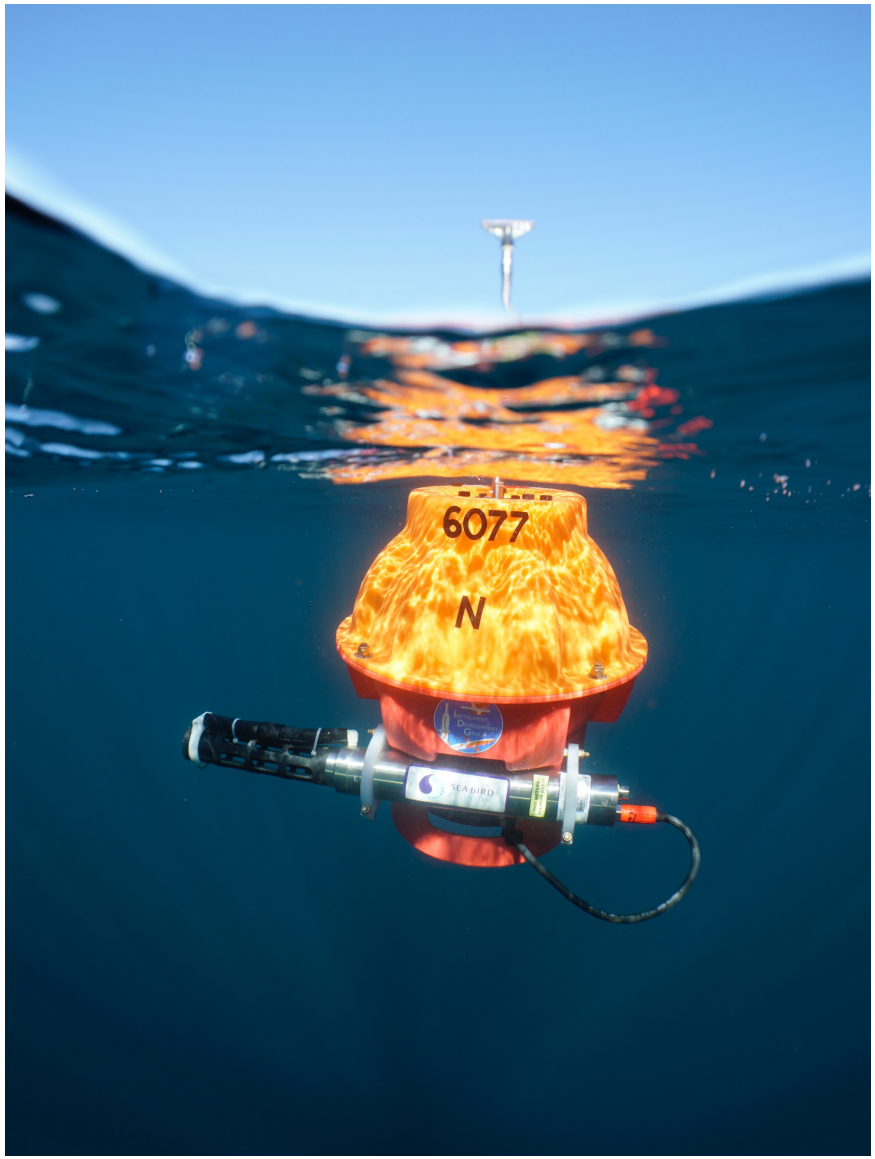


- Large spread in **subannual** deep steric sea level variations from CGLOR, FOAM, GLORYS and ORAS points to the need of temperature and salinity observations in the deep ocean

Interannual Variability deep-ocean steric sea level over 1993-2020 simulated from ¼° Ocean Reanalysis



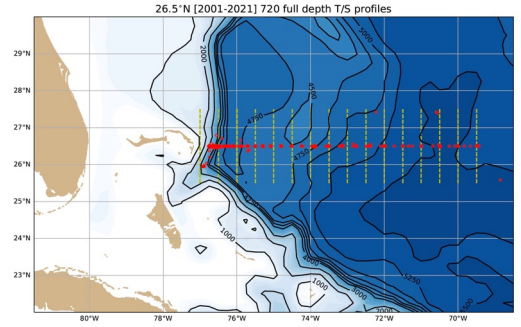
- Interannual variations of deep-ocean steric sea level from ocean reanalysis show broad agreement with Deep Argo measurements over the abyssal plain. GLORYS shows some consistency with Deep Argo in the DWBC
- Large spread in **interannual** deep steric sea level variations from CGLOR, FOAM, GLORYS and ORAS points to the need of deep-ocean temperature and salinity observations



Conclusions

- Deep Argo's ability to resolve deep and abyssal steric sea level has been demonstrated for the case of the Northwest Atlantic Ocean
- Interannual variations in deep-ocean steric sea level are higher along the path of the DWBC compared to BATS station and the abyssal plain, and contribute to ~30% of the full-depth signal
- Ocean reanalysis show large spread in simulated deep-ocean steric sea level at subannual to interannual time scale
- 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) over abyssal plains, but strongest variations in the DWBC are not well resolved in the geodetic approach and ocean reanalysis

Future Work



- Study sources of discrepancies between deep-ocean steric sea level variations measured from Deep Argo floats and the geodetic approach in the Northwest Atlantic Ocean
- Improve our understanding of spatial variations in deep steric sea level using measurements from Deep Argo floats and collected at the BATS station and RAPID array, and make comparisons with ocean reanalysis simulations
- Investigate the physical processes driving observed subannual to interannual fluctuations in deep-ocean steric sea level and deep western boundary current structure in the Northwest Atlantic Ocean