Ocean transport estimates from altimetry, GRACE and dynamic height

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Introduction

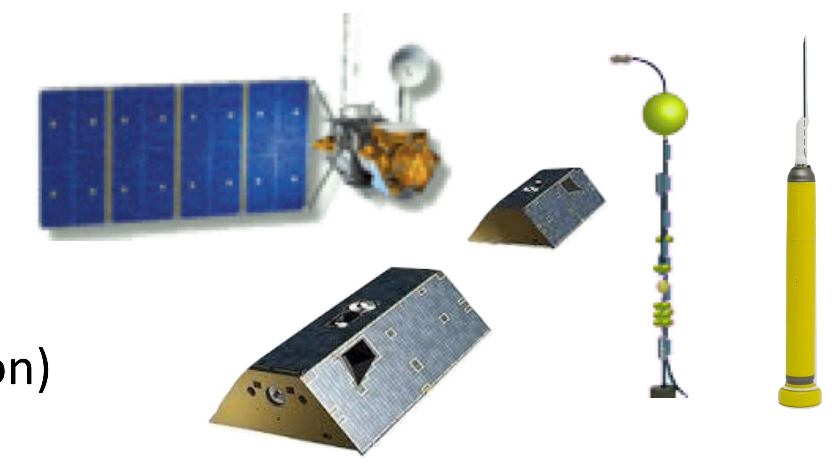
The AMOC is a large-scale, climate relevant circulation comprising net northward flow in the upper 1000m of the Atlantic, and net southward flow below. Mooring arrays have measured the AMOC at individual latitudes since 2001 (MOVE), 2004 (Rapid) and 2014 (OSNAP). To synthesize observations from different latitudes, we propose to use satellite altimetry and gravimetry with in situ Argo to diagnose at the basinwide ocean circulation.

We'd like to know:

- Full-depth transport variability at a range of latitudes
- The zonal distribution of large-scale transports
- On timescales of seasonal to decadal.

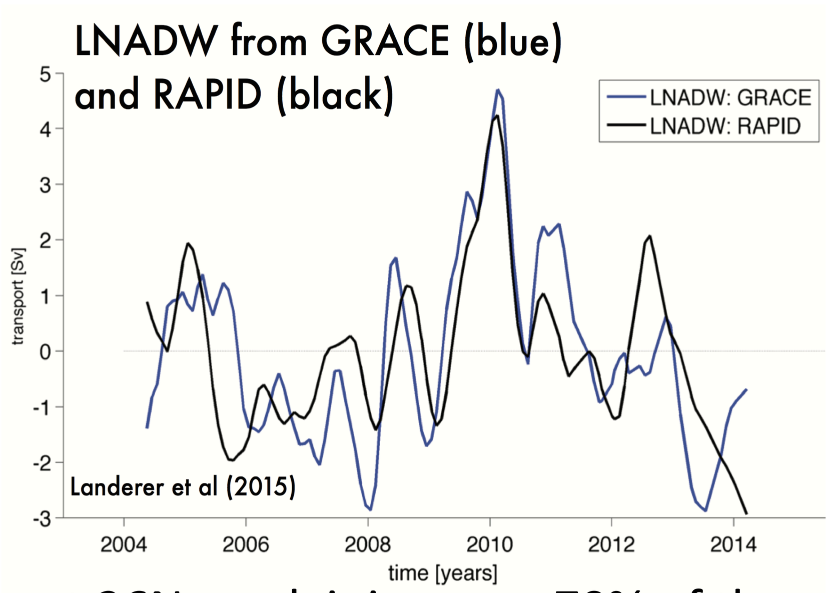
Data

- GRACE ocean bottom pressure
- Satellite altimetry
- Argo float profiles
- Moored observations (for validation)

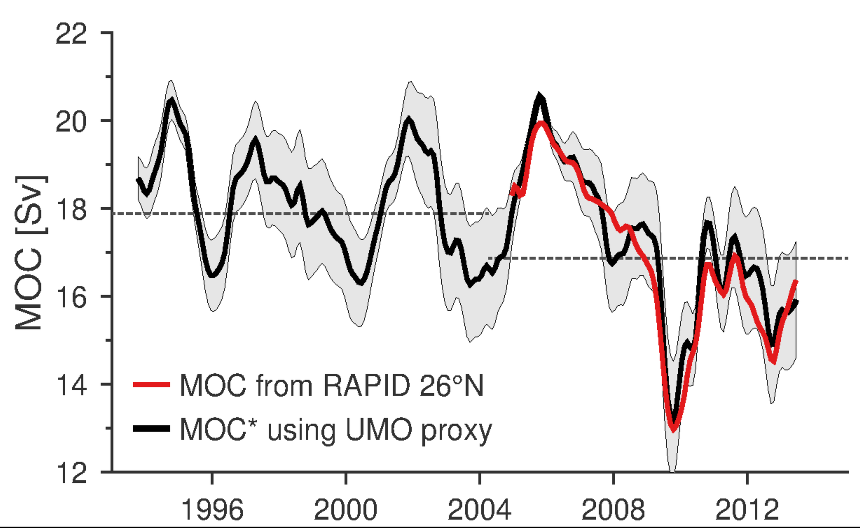


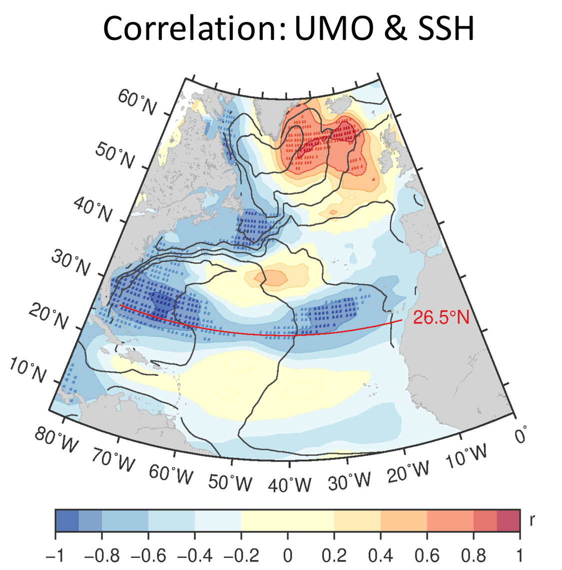
Past results

Gradients in GRACE ocean bottom pressure give a good estimate of deep transport variability from RAPID after detrending (Landerer et al., 2015)



SSH anomalies, spatially smoothed & deseasonalised, provide an empirical proxy of top 1100m transport variability at 26N, explaining over 70% of the interannual variability (Frajka-Williams, 2015)





Approach

The proposed approach:

1. Apply geostrophic balance to derive mid-ocean circulation.
2. Combine with Ekman transport from reanalysis winds
3. At 26N, use additional transport information from the Florida Cable

Bottom velocities can be derived from ocean bottom pressure gradients:

$$f v_b = \frac{1}{\rho}\frac{\partial p}{\partial x}$$

Shear (dv/dz) can be derived from density profiles through thermal wind:

$$f\frac{\partial v}{\partial z} = -\frac{g}{\rho}\frac{\partial \rho}{\partial x}$$

Surface velocities can be derived from sea surface height gradients:

$$f v_{surf} = g\frac{\partial \eta}{\partial x}$$

Ambition

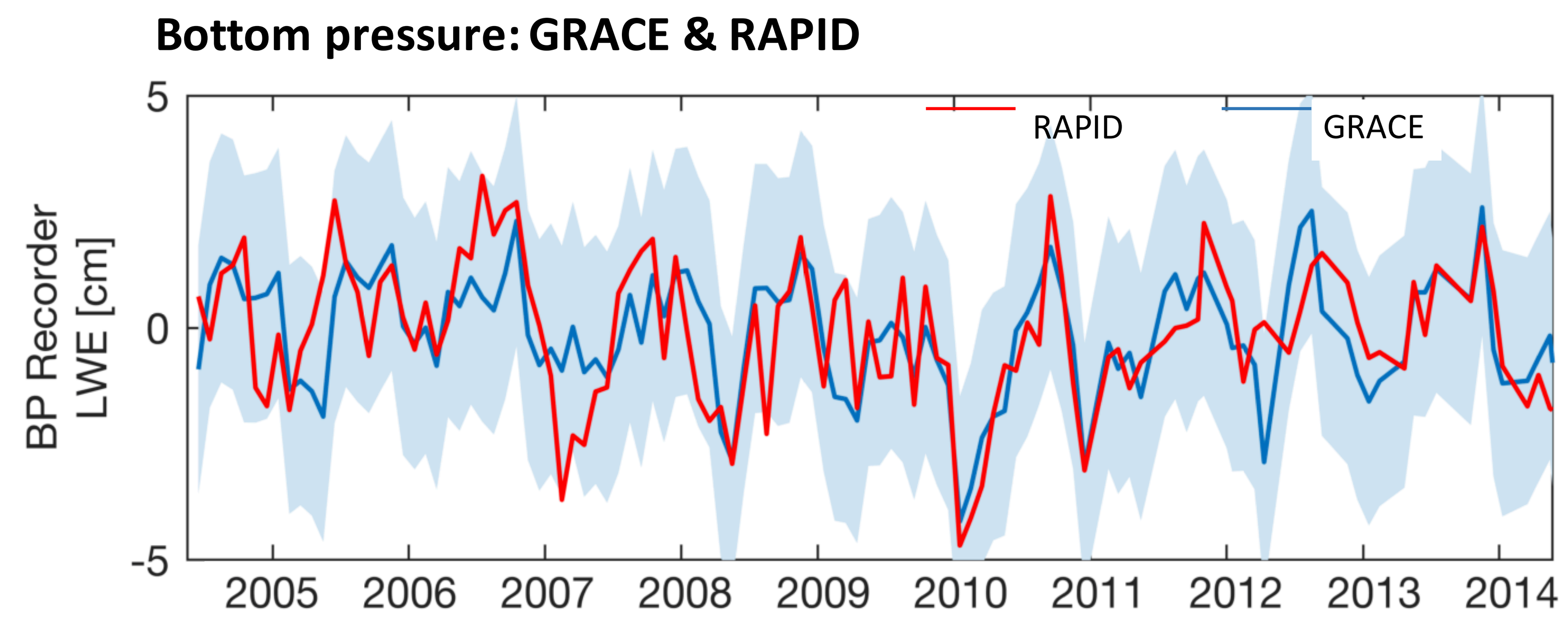
Determine the ocean circulation using altimetry, gravimetry and density.

Aim: Full-depth, zonally-resolved 2-layer circulation at 26N.
Approach: Combine **SSH** and **OBP** to estimate transports by assuming a 2-layer circulation (top X m varies with SSH, bottom Y m varies with OBP)
Limitation: Assumption that the ocean behaves as a 2-layer circulation

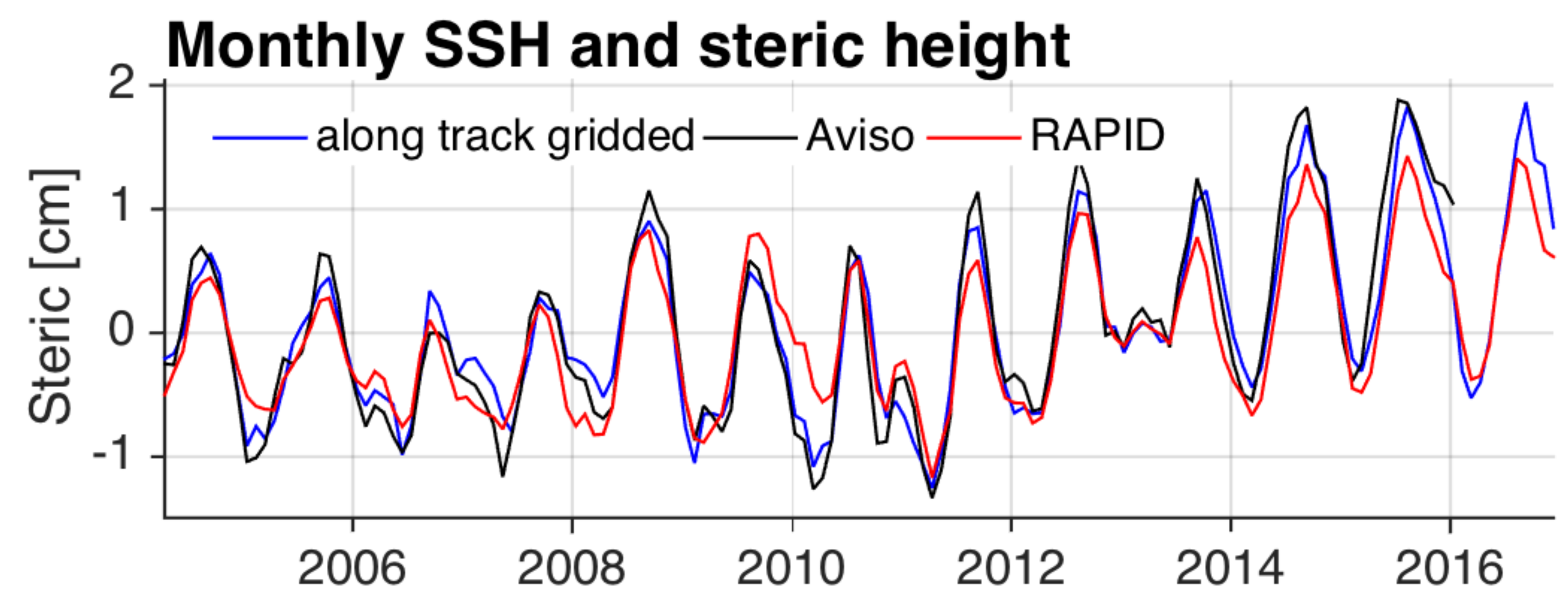
Aim: Full-depth, zonally-resolved circulation at 26N.
Approach: Combine **SSH**, **OBP** and dynamic height from **Argo** to estimate a top 2000m circulation (Argo and SSH, referenced to SSH) and transport variability below 2000m from OBP. Apply a time-mean compensation correction to ensure zero net mass transport. Choices for combining Argo and altimetry include Willis & Fu (2008) or gridded Argo (Roemmich & Gilson, 2013; Schmidtko et al, 2013) with Aviso SSH.
Limitation*:* Long time (13 year) variability of the bottom velocities cannot presently be determined from GRACE OBP (Landerer et al., 2015).
SSH is expected to be degraded near coasts. Argo resolution is expected to be limited near coasts. The consequence is that the derived circulation may be more variable than the true transbasin circulation as measurements away from boundaries are more strongly influenced by mesoscale eddies (Hughes et al., 2018)

Early results

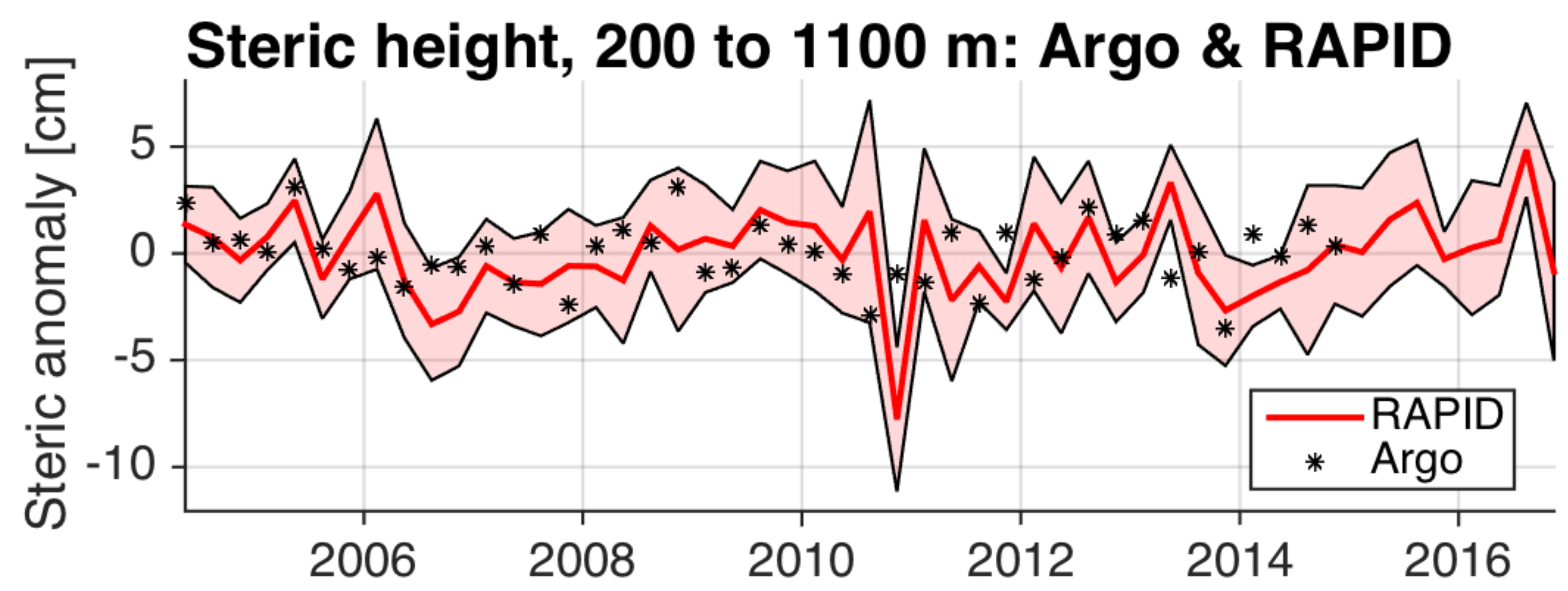
GRACE to RAPID bottom pressure records at west (Worthington et al. submitted)



Altimetry and RAPID dynamic height near boundaries (Lobelle, report)



Argo (Roemmich&Gilson) and RAPID dynamic height at west, 3-monthly



Outlook

The greatest limitation may be the availability of Argo profiles at boundaries.

- The method of Schmidtko et al to grid Argo near bathymetry may provide the needed additional resolution at the western boundary of the Atlantic.
- The method of Willis & Fu may enable further reduction of aliasing of the mesoscale field into the desired interannual and longer timescale variability of ocean circulation.
- Considering variations on longer timescales may reduce error due to sampling

References: Frajka-Williams (2015). Estimating the AMOC from altimetry and cable measurements. *GRL*.
Hughes et al. (2018). A window on the deep ocean: The special value of ocean bottom pressure for monitoring the large-scale deep-ocean circulation. *Progress in Oceanography.*
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Williams et al. (2015). Detecting trends in bottom pressure measured using a tall mooring and altimetry. *JGR-Oceans*
Willis & Fu (2011). Combining altimetry and subsurface float data to estimate the time-averaged circulation in the upper ocean. *JGR: Oceans*.

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