Testing the stepping method to derive western ocean bottom pressure gradient and the western boundary contribution to overturning transport at the 26.5°N RAPID-MOCHA-WBTS array

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1. Theory

The stepping method consists in deriving pressure gradients down continental slopes and meridional transports using near-bottom boundary density and velocity measurements.

$$\rho v_g = \frac{1}{f}\frac{\partial p}{\partial x} \xrightarrow{\int \cdot\, dx} M(y,z) \equiv \int_{x_W}^{x_E} \rho v_g \, dx = \frac{1}{f}\left[p_E(y,z) - p_W(y,z)\right]$$

$$\xrightarrow{\partial/\partial z} \frac{\partial M(y,z)}{\partial z} = \frac{1}{f}\frac{\partial}{\partial z}\left[p_E(y,z) - p_W(y,z)\right] \xrightarrow{\iint \cdot\, dz}$$

eastern and **western** layer overturning transports

boundary pressure gradient from generalized hydrostatic equation:

$$\boldsymbol{\nabla} p = -\boldsymbol{k} \times (\rho f \boldsymbol{u}_g) - \boldsymbol{k}\rho g \xrightarrow{\int_1^2 \cdot\, ds} \frac{\partial p_b}{\partial z} = -\frac{\rho f V_L}{H_s} - \rho g$$

Ocean Bottom Pressure gradient along a slope

References: Hughes et al. (2013), Elipot et al. (2013), (2014), (2017), Xing et al. (2026)

2. Data

We use data from the RAPID-MOCHA-WBTS array at 26.5°N: near-bottom density, velocity, and direct pressure records since 2023. The pressure gradient is reconstructed in discrete steps down the slope of the Bahamas escarpment. Overturning layer transports relative to a given reference depth are compared to layer transports derived from the full RAPID array but holding the eastern array constant (McCarthy et al. 2015).

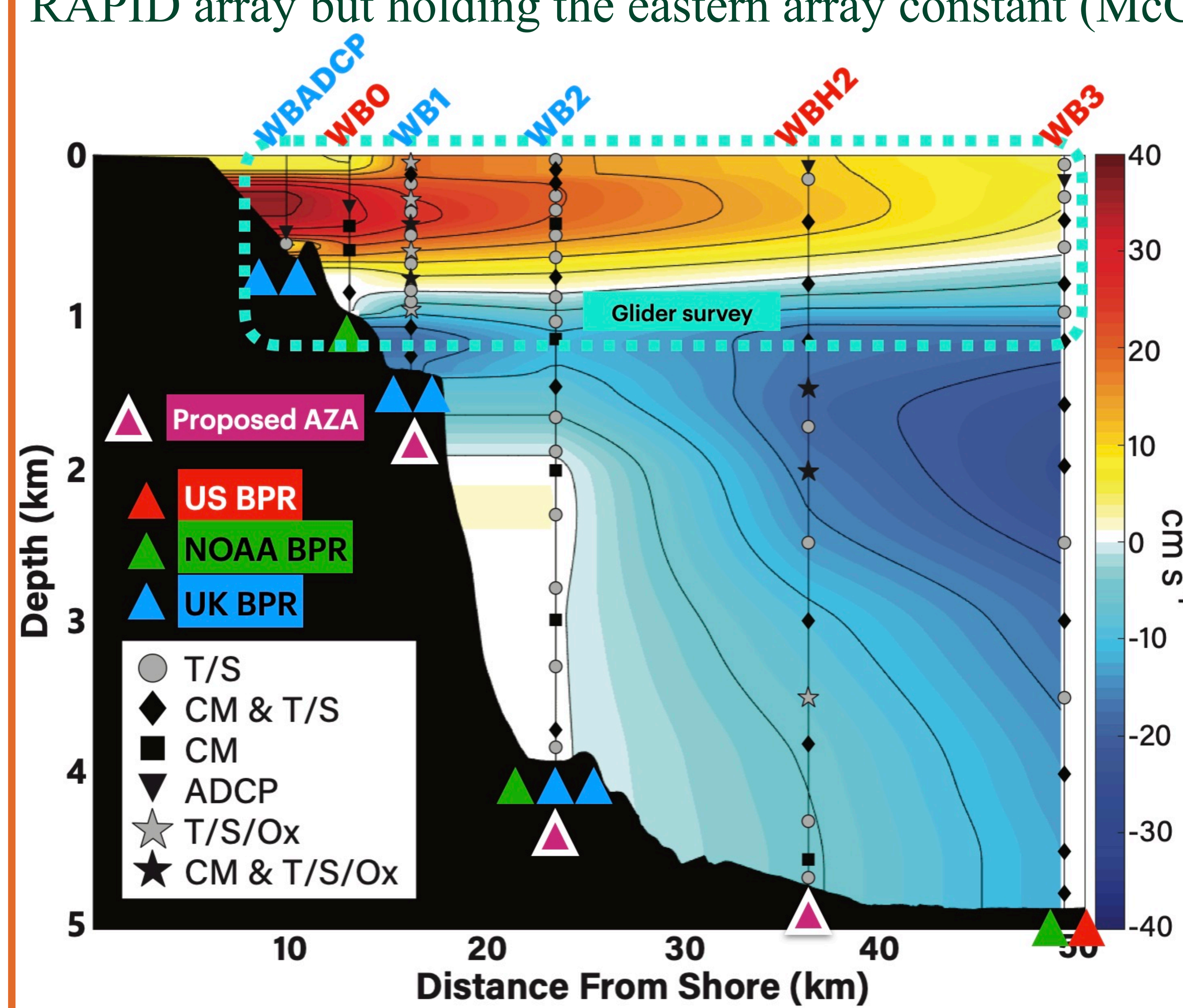

Fig 2.1: The RAPID western boundary array off Abaco. This mooring array captures volume, temperature, and freshwater transports from current meters (CM), Acoustic Doppler Current Profilers (ADCP), and temperature and conductivity sensors (T/S). Ocean Bottom Pressure is measured using Bottom Pressure Recorders (BPR) and Pressure-sensor equipped Inverted Echo Sounder (PIES)

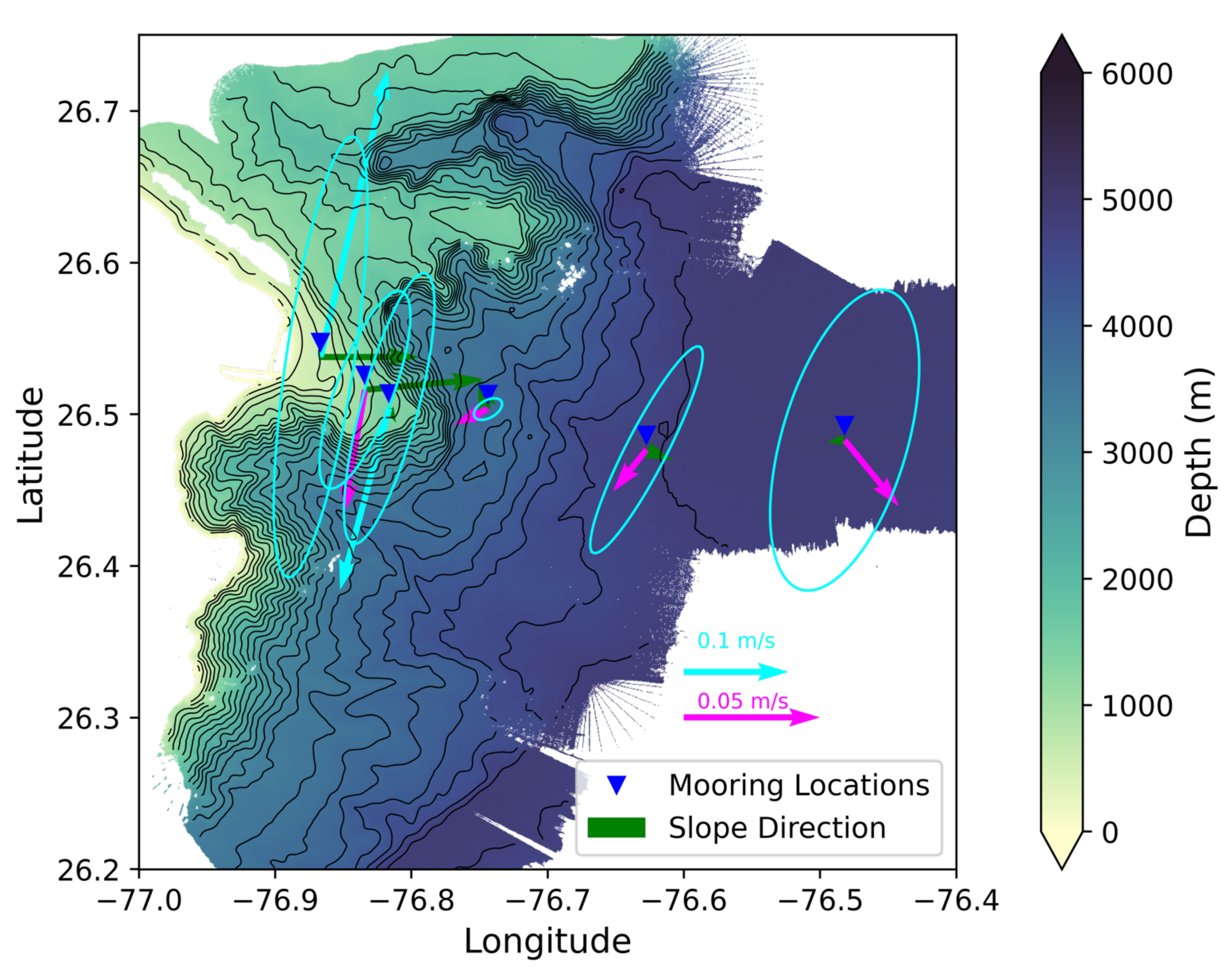

Fig 2.2: Bathymetry and Bottom Currents for 2023-2024. The near-bottom currents are strongly steered by bathymetry. We consider that the velocity components along the major axes of the standard deviation ellipses set the down-slope pressure gradient.

3. Results

We present overturning meridional transport comparisons over three steps from WBADCP to WB0 (488 m), WB0 to WB1 (283 m), and WB1 to WB2 (2502 m) (See Fig 2.1).

Fig 3.1: Comparisons of layer transport estimates from the RAPID array, BPRs records, and near-bottom density and velocity records.

These results are encouraging and indicate strong coherence between transports estimated from the full RAPID array and those derived using the stepping method across the WBADCP–WB0 and WB1–WB2 steps. Yet, the BPR-derived transport shows higher coherence over the WB0–WB1 step. Overall, pressure-derived transports systematically underestimate the full-array transport (gain < 1). Further work is therefore required to refine and optimize the transport derivations.

4. Next steps

We will attempt to use drift-correcting bottom pressure records to improve the direct pressure gradient reconstruction and to use the stepping method with continuous density and velocity profiles from gliders to derive the pressure gradient in the top 1000 m at the western boundary.

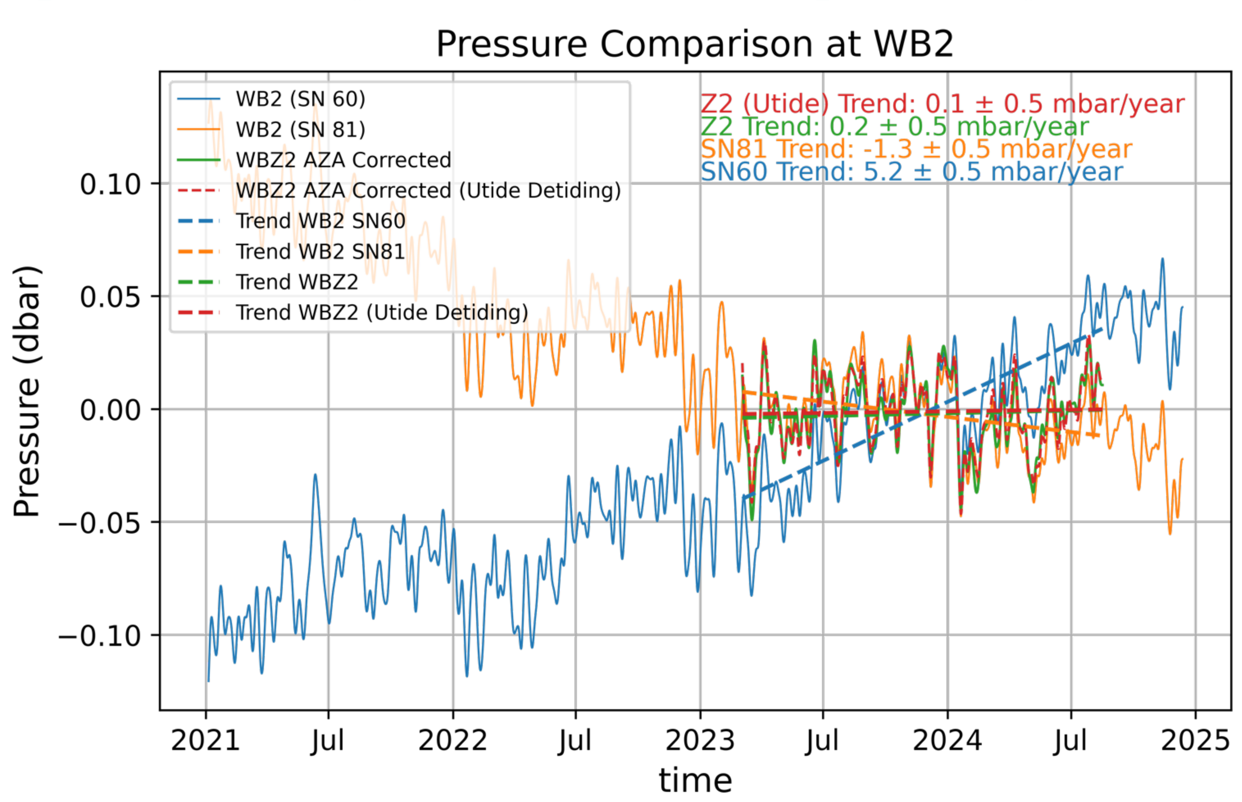

Fig. 4.1: Comparison of ocean bottom pressure from standard BPRs and a "drift-correcting" BPR (AZA).

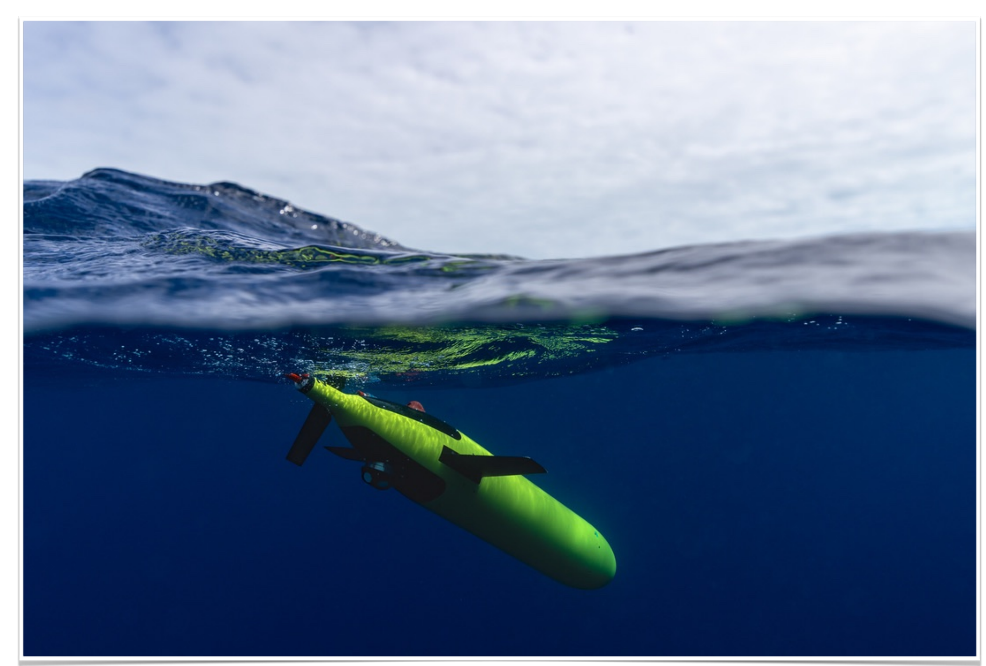

Fig. 4.2: Photo Credit: Claudia Campi, Cape Eleuthera Institute. Seaglider SGX Ken off the coast of Eleuthera, Bahamas.

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