Toward a method to estimate geostrophic transport from along-track coastal altimetry on shelf and shelf-break regions

Matthieu Le Hénaff[1,2]

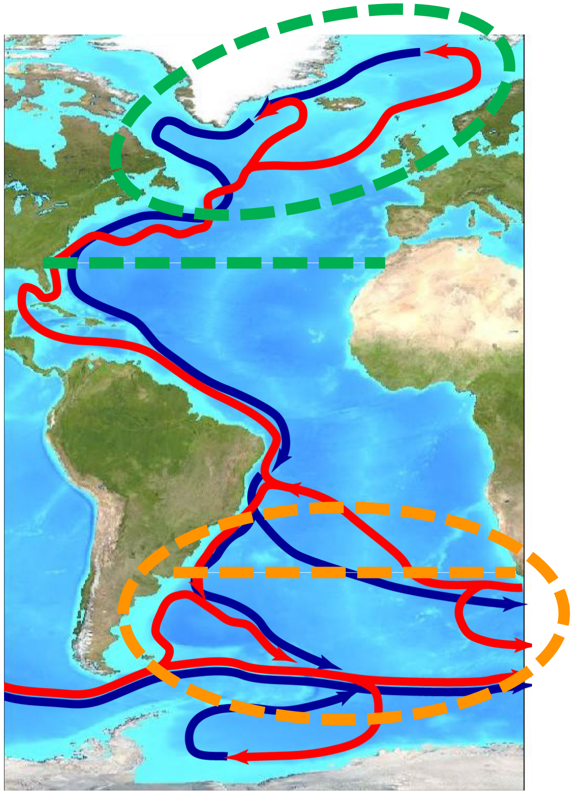
Marion Kersale[1,2], Christopher S. Meinen[2]
Renellys C. Perez[2]

(1) UM-CIMAS, Miami, FL
(2) NOAA-AOML, Miami, FL

Collaborators: Daniel Valla (Univ. Buenos Aires, UMI/IFAECI, CONICET, Argentina) and Edmo Campos (Univ. São Paulo, Brazil)

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

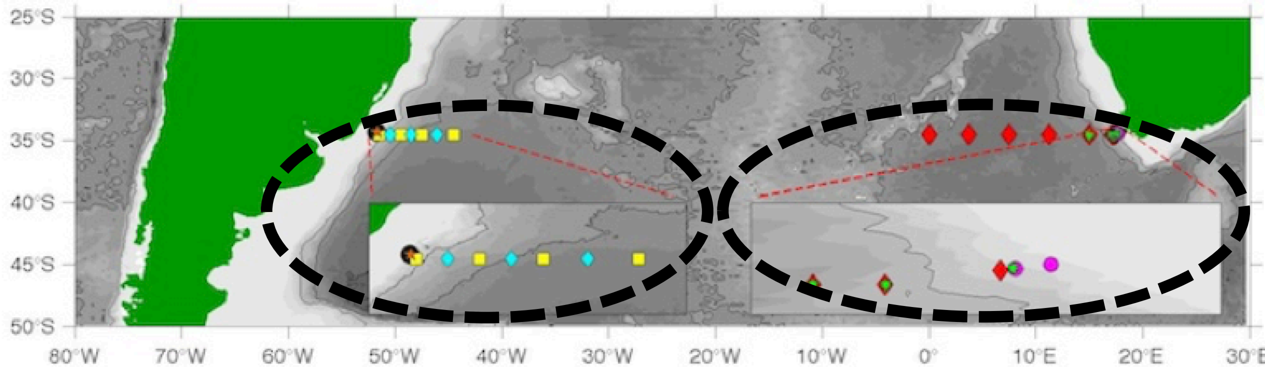
Motivation



Schematic of the main MOC in the Atlantic (Perez et al., 2015). Blue arrows: cold, dense water in the lower limb of the MOC cell. Red arrows: warm, light waters in the upper limb of the cell.

- The Atlantic **Meridional Overturning Circulation** (MOC) is a crucial component of the **climate system**
- **North Atlantic:** region of **deep water** formation
- **South Atlantic: nexus** for **water masses formed remotely**: Indian and Pacific Oceans, Antarctic bottom waters, North Atlantic Deepwater
- The **South Atlantic** is the only basin where **heat is transported equatorward** (and not poleward)
- **North Atlantic** (26.5 deg.N): RAPID-MOCHA array since **2004**
- **South Atlantic** MOC Basin-wide Array (SAMBA, 34.5 deg.S) since **2009**

Motivation



Location of moorings of the 34.5 deg.S SAMBA array, with U.S., Brazilian, French, and South African moorings.

- SAMBA array mostly composed of Pressure-equipped Inverted Echo Sounders **PIES** moored instruments: acoustic measurements (travel time) + look up tables from *in situ* data: => **vertical thermohaline structure**

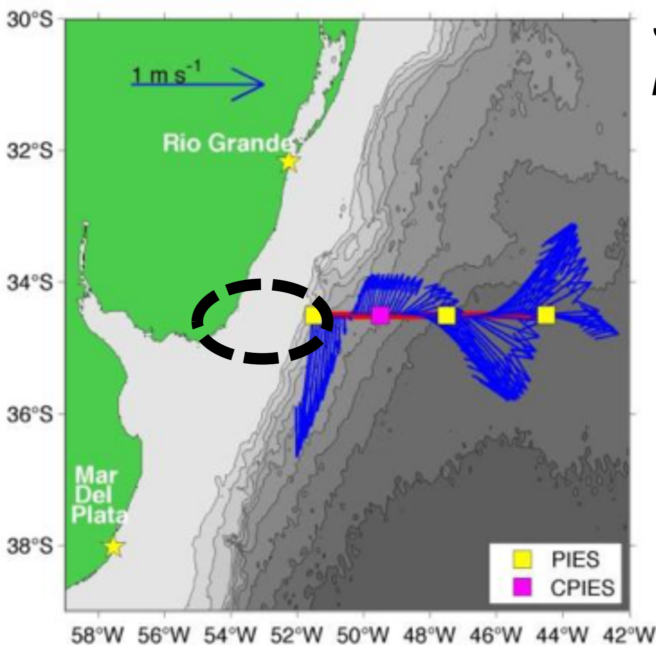
- Between 2 moorings: integrated **geostrophic current** anomaly

- Dense array at both **western** and **eastern boundaries**

- **Total MOC transport**: **17.3±5 Sv** (Kersalé et al., 2020)

Ref: Kersale, M., Meinen, C.S., Perez, R.C., Le Henaff, M., Valla, D., Lamont, T., Sato, O.T., Dong, S., Terre, T., van Caspel, M. and Chidichimo, M.P. (2020). Highly variable upper and abyssal overturning cells in the South Atlantic. Science advances, 6(32), p.eaba7573.

Motivation



Surface velocities (blue arrows) from shipboard-ADCP in 2009. Locations of the PIES/CPIES instruments (yellow + magenta)

- **Limitations** of the SAMBA array:
  - Most inshore moorings at ~1300 m depth
  - No continuous measurements inshore

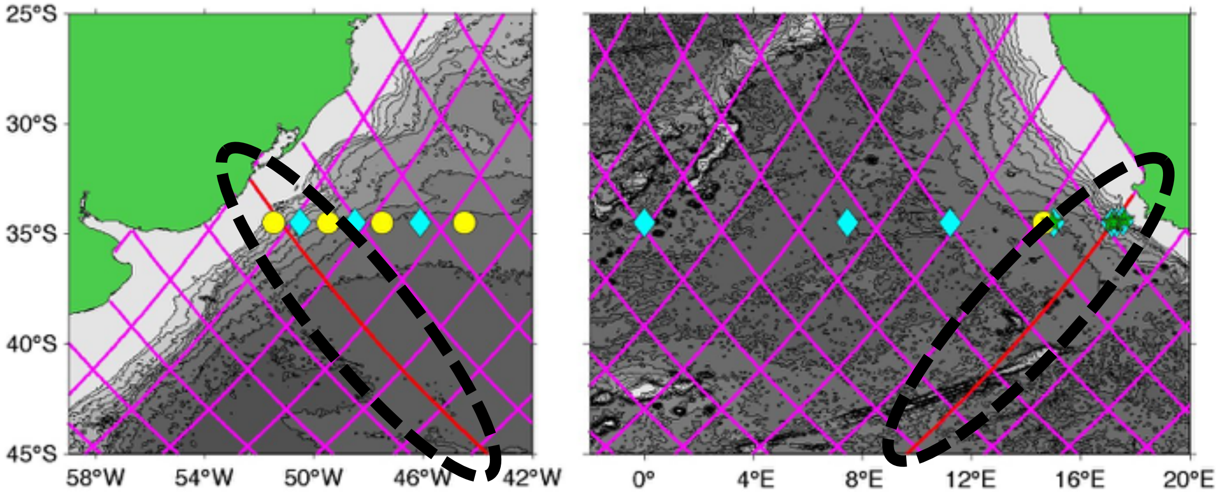
- Currently, **transport inshore** of the moorings estimated using **model simulations**

- Inshore transport: **~3 to 4 Sv**, i.e. **~20%** of the total MOC estimated **without direct observations**

- We proposed to use **coastal altimetry** to **fill the gap** between the most inshore moorings and the coasts:

Project “**Combining coastal altimetry and in situ observations to improve Meridional Overturning Circulation estimates in the South Atlantic**”, supported by **NASA Physical Oceanography Program**

Methodology and data



Jason tracks (magenta), with, in red, tracks used in our project. In yellow and cyan: PIES and CPIES, in green: tall moorings

- We are using the **reference TOPEX/Poseidon-Jason** series **tracks**:
    - Track #254 in the West along South America
    - Track #209 in the East along South Africa
- Focus on **Jason-2** data first (2008-2016, longest overlap with SAMBA array), to be extended to T/P, Jason-1 and Jason-3
- Along-track **Sea Level Anomaly**, then **Geostrophic Current Anomaly**
- Project the Geostrophic Current Anomaly on the vertical => **Geostrophic Transport Anomaly**

Methodology and data

- **How can we estimate the geostrophic transport from altimetry?**
  - Needs to **estimate the vertical structure** of the flow (**barotropic** and **baroclinic** components)
  - Use **available *in situ* data** to estimate these components
  - Data available:

Western side of the 34.5°S array	**Eastern side**
10 PIES (SAMBA)	8 PIES (SAMBA)
1 bottom pressure recorder	4 tall-moorings
1 bottom mounted ADCP	2 bottom mounted ADCP on the shelf
Lowered ADCP sections	Ship-board ADCP sections
CTD sections	CTD sections

- Focus on western (South American) side of the SAMBA array

Analysis

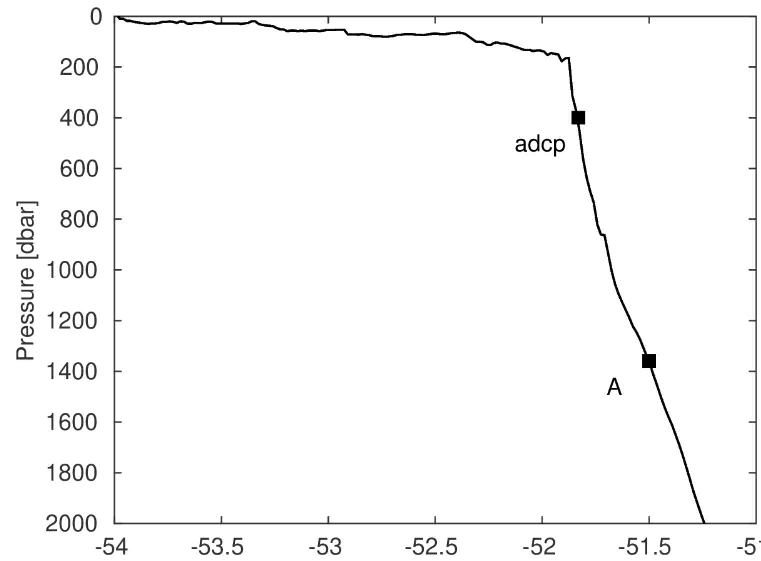
- 2 **PIES moorings** closest to shore: **bottom pressure** and **density profile**
  - $\eta'_{bt} = \frac{p'}{\rho_b g}$: **barotropic component** of the sea level (ρ_b: bottom dens.)
  - $\eta'_{bc} = \frac{\Phi}{g}$: **baroclinic component** (Φ: geopotential height anomaly)
  - $\eta'_{pies} = \eta'_{bt} + \eta'_{bc}$
- **Variance** statistics (2009-2018):

Mooring	η'_{bc} variance (cm^2)	η'_{bt} variance (cm^2)	Total (cm^2)
A (~1300 m)	62 (**89%**)	8 (11%)	70 (100%)
B (~3600 m)	235 (**96%**)	10 (4%)	252 (100%)

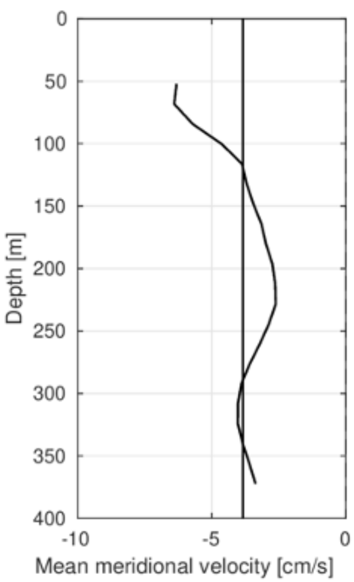
- **Sea level dominated by baroclinic variability**
- On the lower part of the shelf break, we will need a **vertical regression to project surface altimetry data** from the surface downward

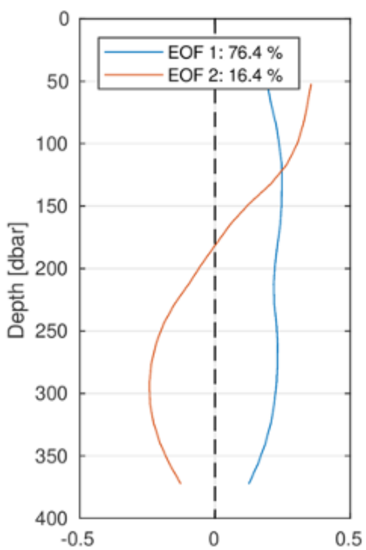
Analysis

- **Upper on shelf break** (~400 m): bottom-mounted Acoustic Doppler Current Profiler (**ADCP**), during Dec. 2013 – Nov. 2015
$\Rightarrow$ **Currents**



- Same approach as Lago et al. (2019):
    - **Barotropic**: vertical average
    - **Baroclinic**: Total minus Barotropic
    - **EOF analysis** of velocity



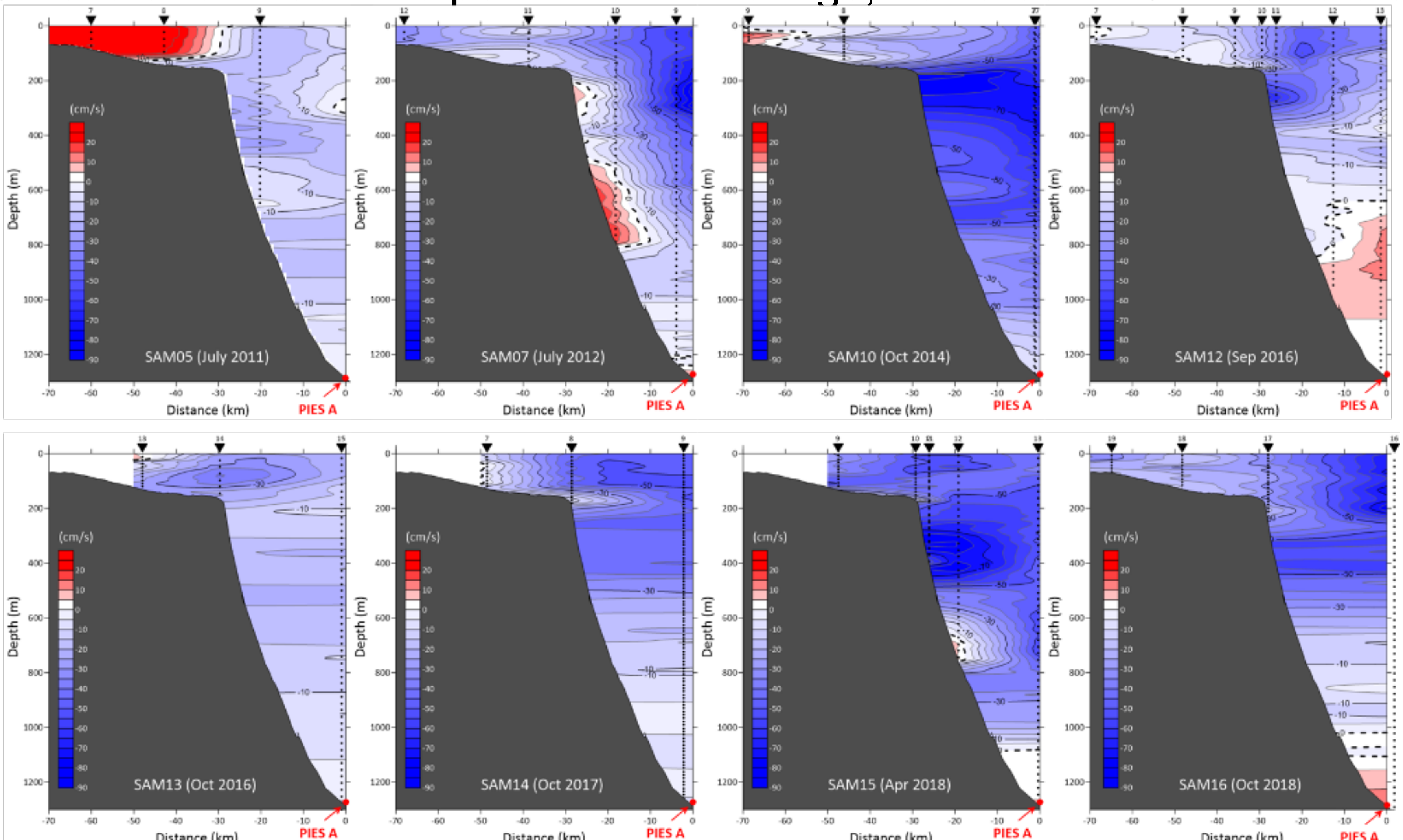


- Current **dominated** by **barotropic component**
- Baroclinic component not negligible
- Need to estimate if assuming the current as purely barotropic is valid, or if a regression is necessary

Ref: Lago, Saraceno, Martos, Guerrero, Piola, Paniagua, Ferrari, Artana, Provost (2019). On the wind contribution to the variability of ocean currents over wide continental shelves: a case study on the northern Argentine continental shelf. *J. Geophys. Res.*, 124(11), pp.7457-7472.

Analysis

- **On the shelf itself**: no permanent moorings; Lowered ADCP from cruises



Vertical section of current perpendicular to ship track, between the coast and 1st mooring of SAMBA array, between July 2011 and Oct. 2018 (SAM project, courtesy of D. Valla).

- Large variability, but current on shelf appear generally barotropic (consistent with Lago et al., 2019, further south)

Conclusion – future work

- Work in progress
- **Lower shelf break** (inshore SAMBA moorings):
  - **Baroclinic** variability **dominates**
  - We will use linear regression of altimetry data to estimate transport on the vertical
- **Upper shelf break** (~400 m) and **on the shelf**:
  - **Barotropic** current **dominates**
  - We will integrate altimetry-derived surface geostrophic current on the vertical to estimate transport
- We will use in situ data to **validate** the approach