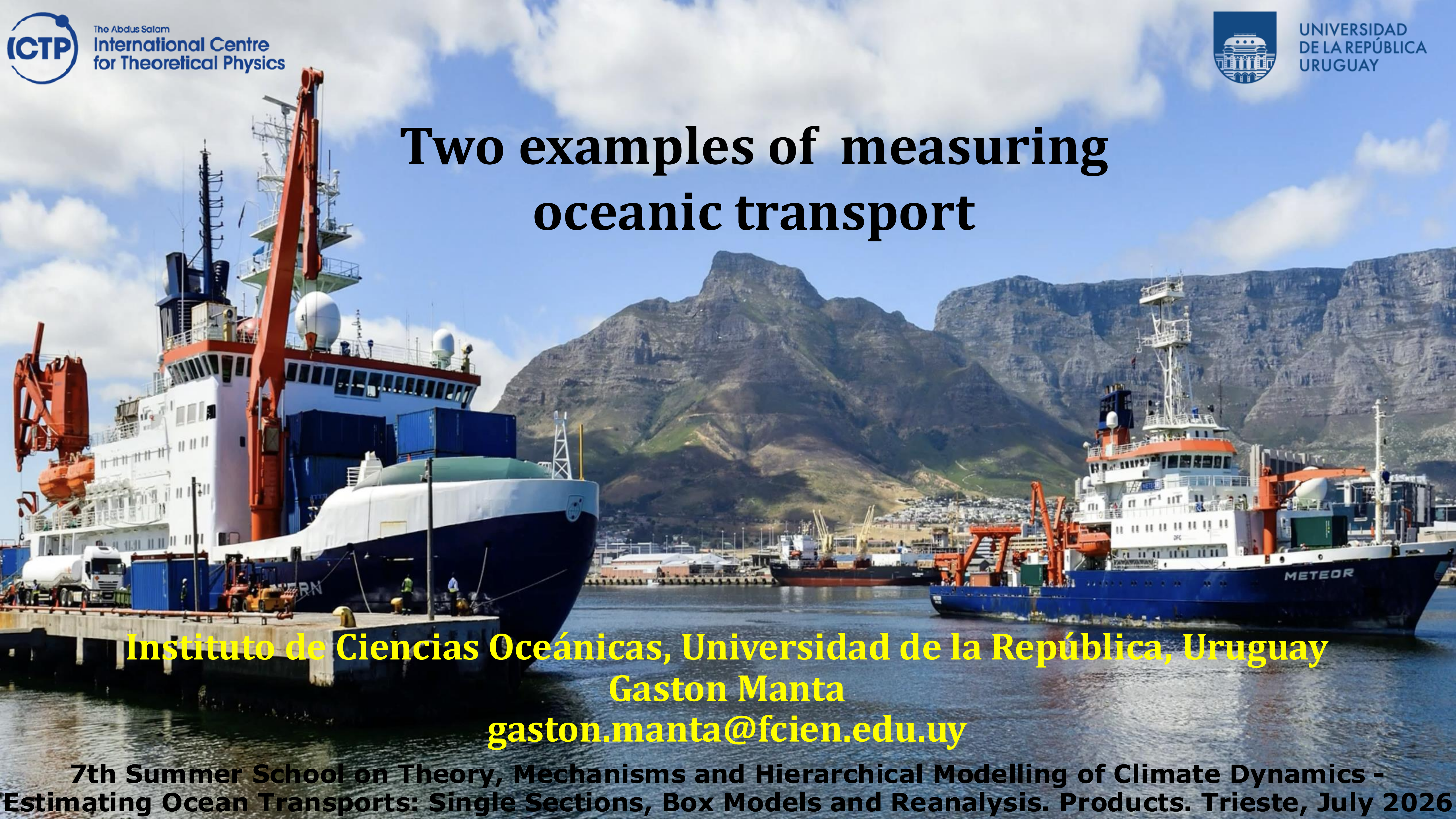

The Abdus Salam International Centre for Theoretical Physics (ICTP)

Universidad de la República Uruguay

Two examples of measuring oceanic transport

Instituto de Ciencias Oceánicas, Universidad de la República, Uruguay

Gaston Manta

gaston.manta@fcien.edu.uy

7th Summer School on Theory, Mechanisms and Hierarchical Modelling of Climate Dynamics - Estimating Ocean Transports: Single Sections, Box Models and Reanalysis. Products. Trieste, July 2026

Introducing myself and the talk in 1 minute

Marcelo Barreiro

UNIVERSIDAD DE LA REPÚBLICA URUGUAY

Crusie, then internship + summer school

Martin Visbeck

GEOMAR

Johannes Karstensen

"I try to combine in situ and satellite observations (and sometimes, models) to study the ocean circulation"

Alberto Piola

Phd

ENS

Sabrina Speich

Postdoc

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Uwe Send

Two Atlantic crossing at 34.5ºS separated by 2 weeks

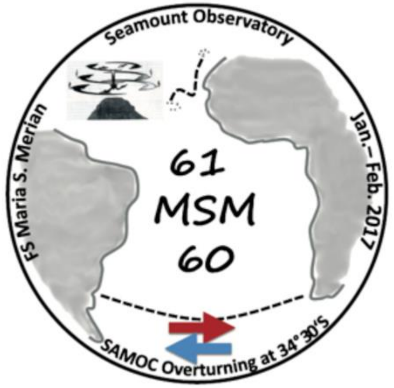
(A paper using both sections it's still to be done!)

Got me into PO

Met my PhD advisor
Ended up working with the section

Two Atlantic crossing at 34.5ºS separated by 2 weeks

(A paper using both sections it's still to be done!)



Got me into PO

Met my PhD advisor Ended up working with the section

Embrace opportunities, one takes to the next one!

Introducing myself and the talk in 1 min

GEOMAR

Phd

ENS

1st case: Ocean transport from a cruise section

Postdoc

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2nd case: Ocean transport from moorings

1st case: Ocean transport from a cruise section

ENS

The South Atlantic Meridional Overturning Circulation and Mesoscale Eddies in the First GO-SHIP Section at 34.5°S

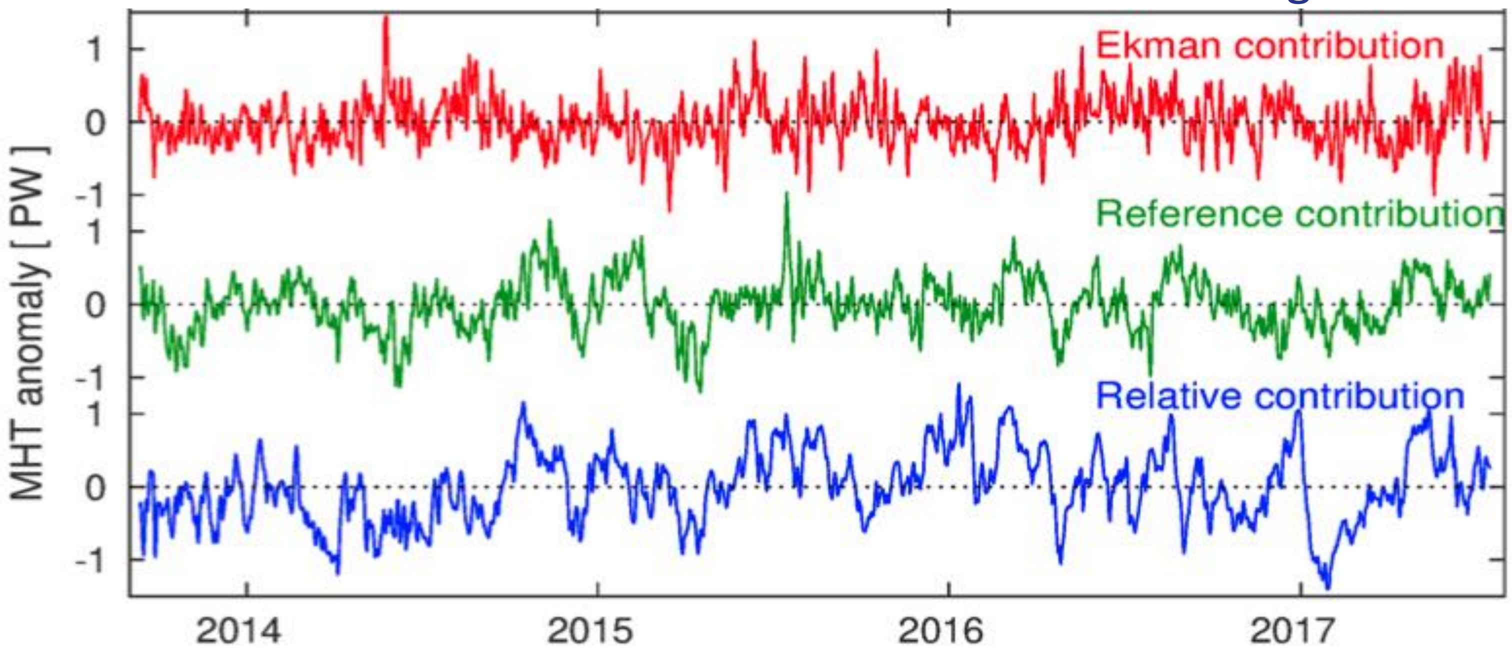
G. Manta[1,2], S. Speich[1], J. Karstensen[3], R. Hummels[3], M. Kersalé[4,5], R. Laxenaire[6], A. Piola[7,8,9,10], M. P. Chidichimo[7,9,10], O. T. Sato[11], L. Cotrim da Cunha[12], I. Ansorge[13], T. Lamont[13,14,15], M.A. van den Berg[14], U. Schuster[16], T. Tanhua[3], R. Kerr[17], R. Guerrero[18], E. Campos[11,19], and C. S. Meinen[5]

[1]Laboratoire de Météorologie Dynamique, LMD-IPSL, École Polytechnique, ENS, CNRS, Paris, France, [2]Departamento de Ciencias de la Atmósfera, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay, [3]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, [4]Cooperative Institute for Marine and Atmospheric Studies,

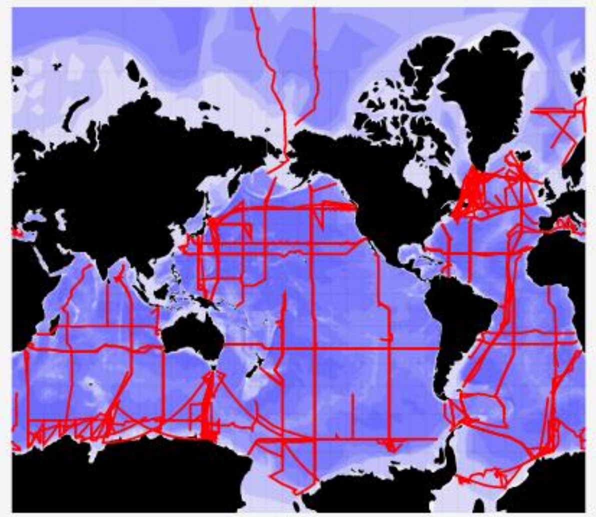
Motivation

- Since the 70s, GO-SHIP sections have been crucial to study the ocean
- Since 2004, moorings have been deployed to obtain timeseries of the MHT
- At 34.5ºS, moorings were deployed in 2009, but no GO-SHIP was done until 2017

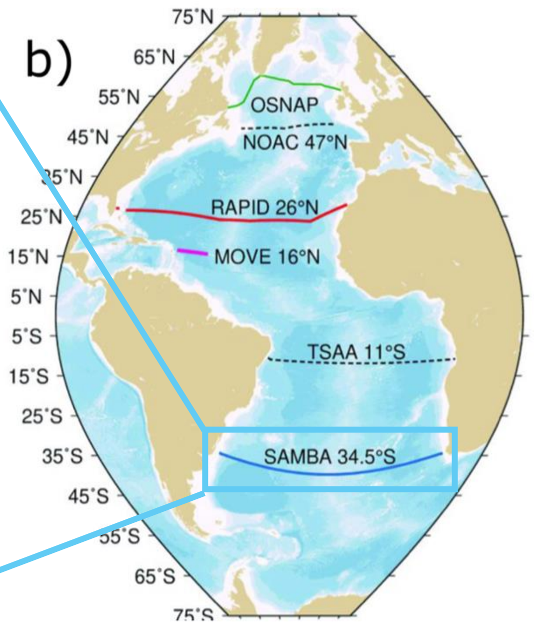
Timeseries at the SAMBA line at 34.5ºS from moorings



GO-SHIP sections

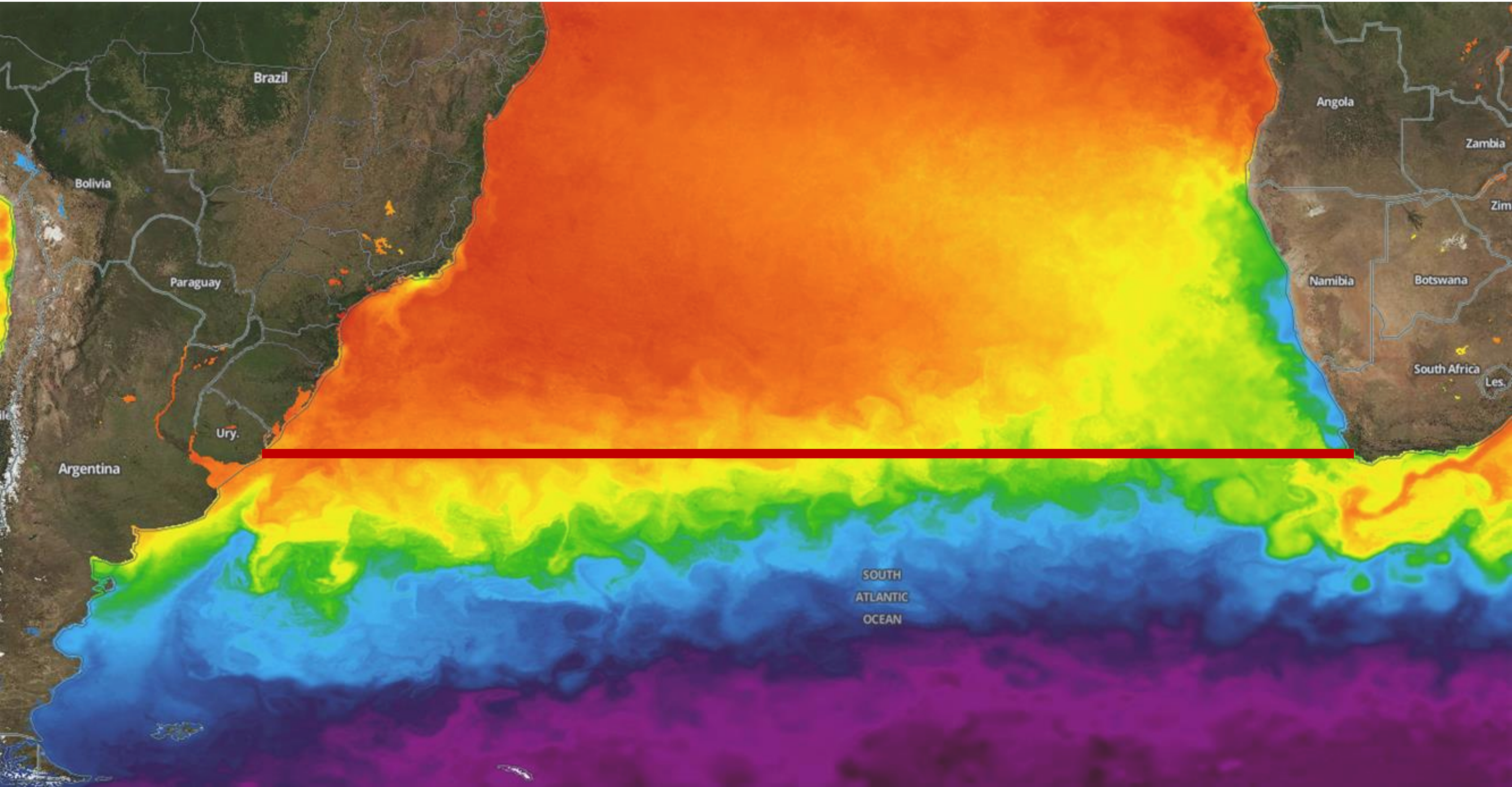


Mooring arrays



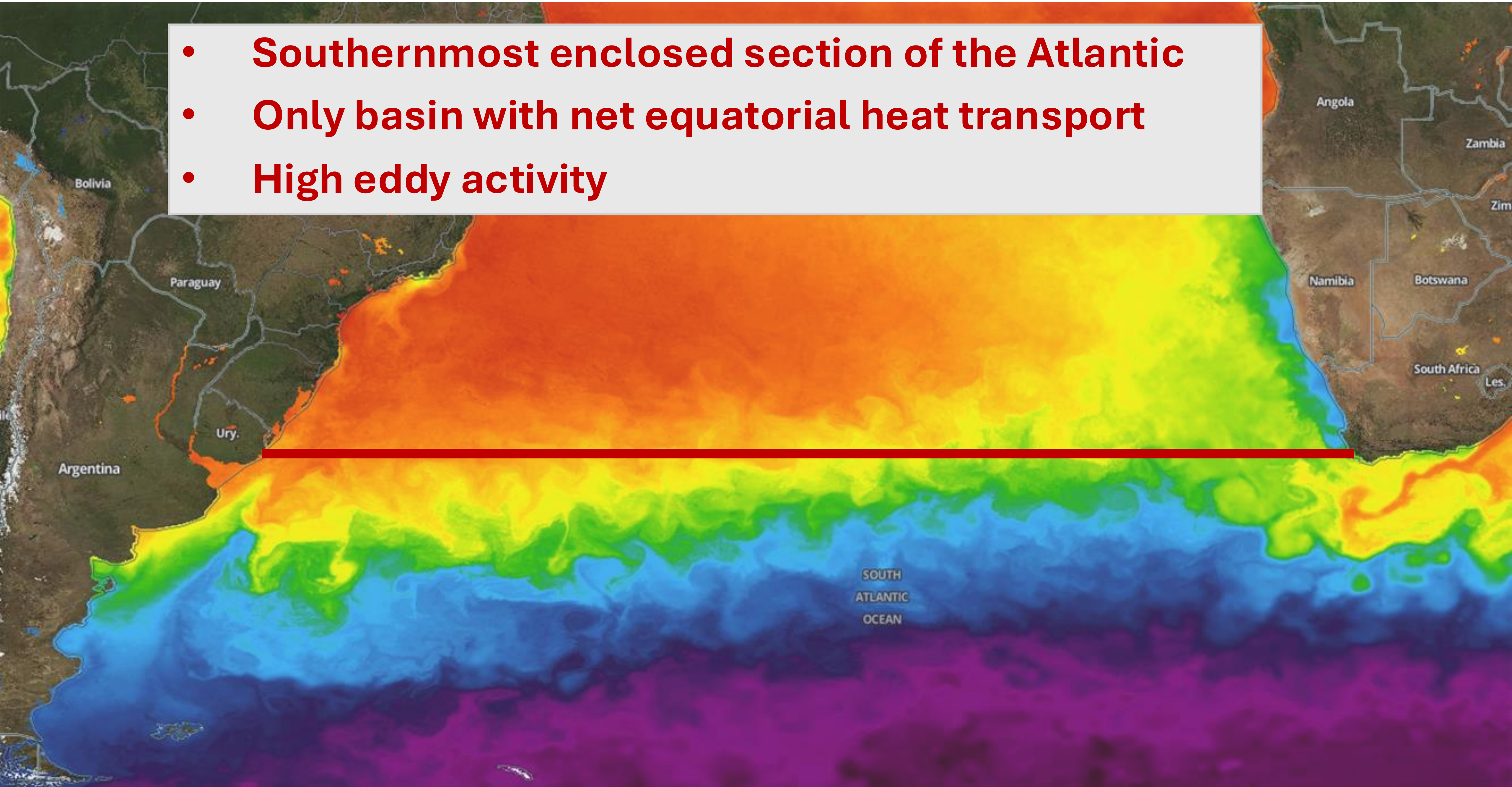
(Kersalé et al., 2021;2020; Talley 2003; https://www.go-ship.org/)

34.5ºS: Why is it interesting?



34.5ºS: Why is it interesting?

- Southernmost enclosed section of the Atlantic
- Only basin with net equatorial heat transport
- High eddy activity



34.5ºS: Why is it interesting?
Ends in Cabo Polonio

Data

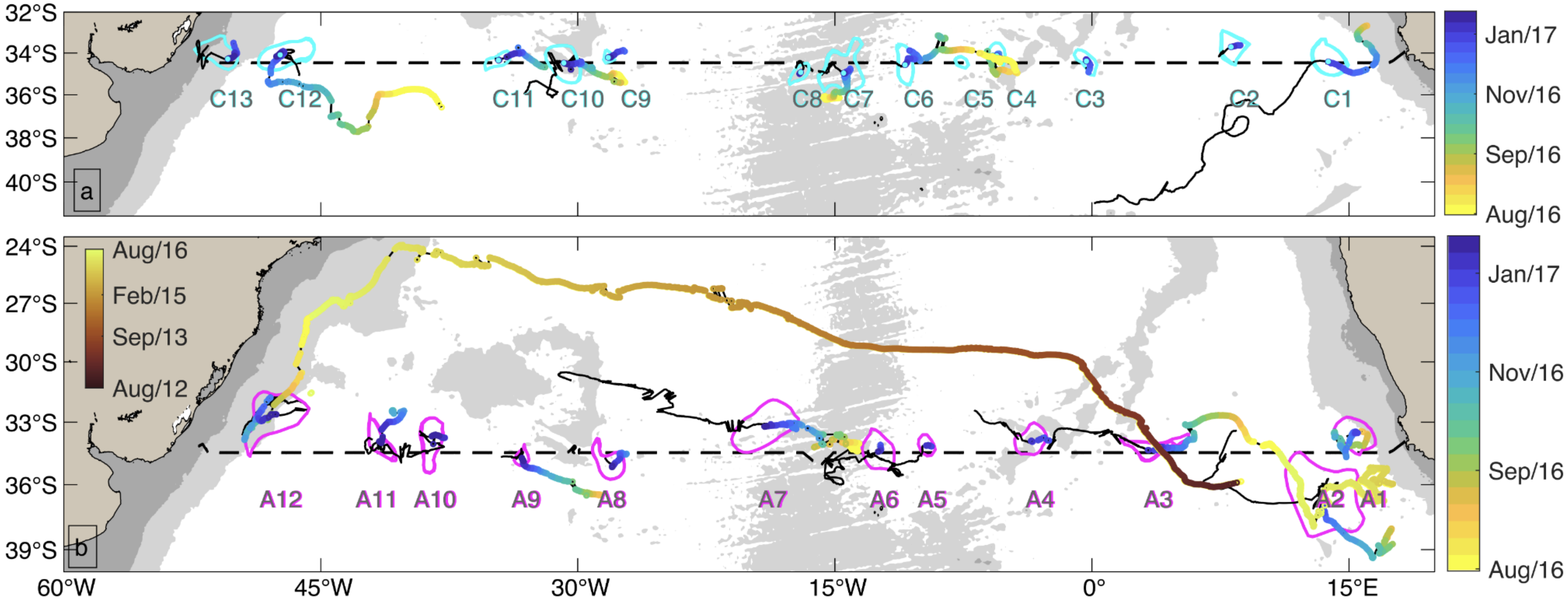
- Ship Observations

-128 full depth CTD profiles following GO-SHIP standards
+ underway measurements.

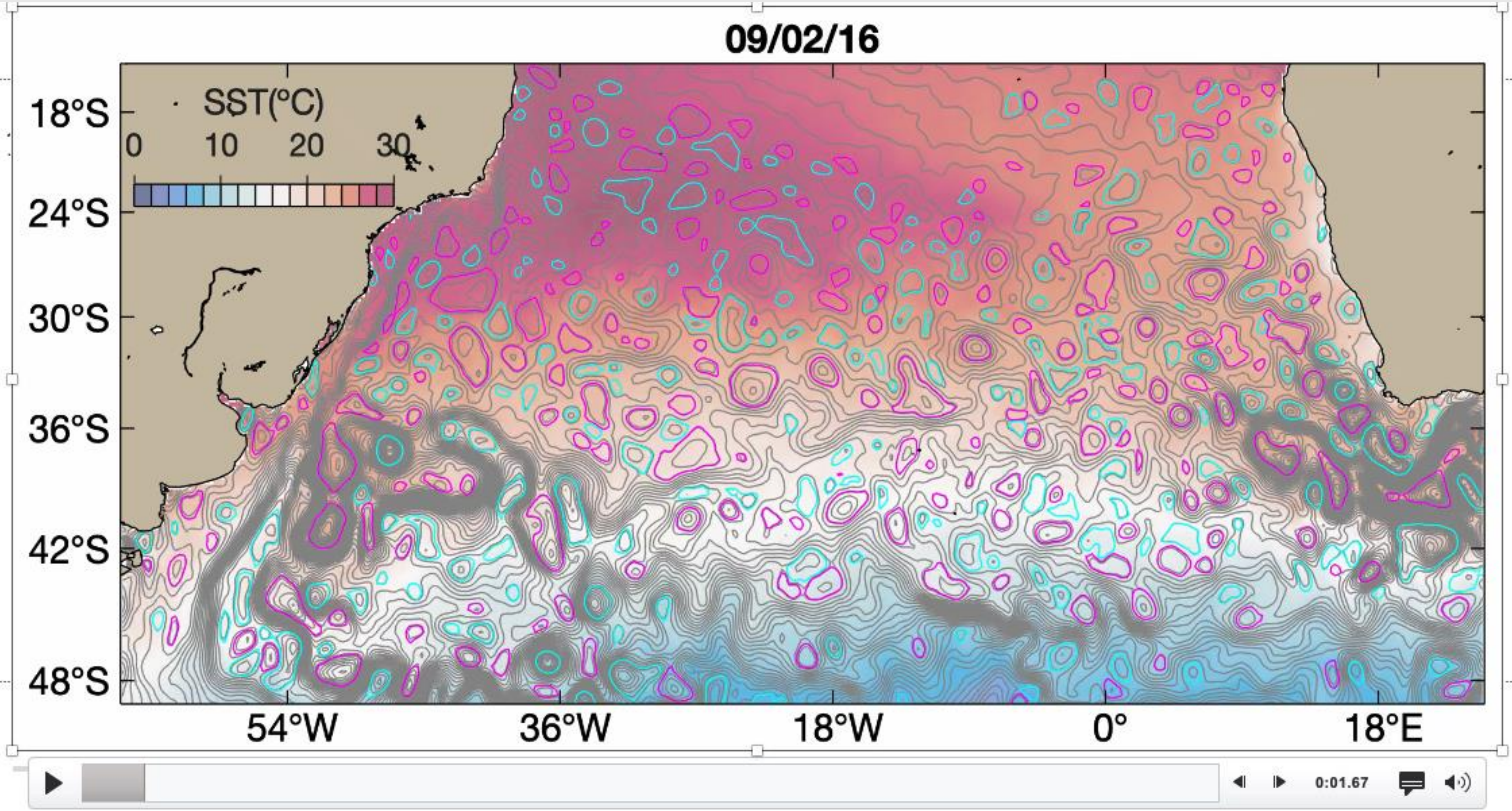
-GO-SHIP sections A09 at 24°S and A10 at 30°S

- Satellite Observations

-Winds, SST, altimetry, eddy detection algorithm TOEddies (Laxenaire et al., 2016)



1st problem: A lot of mesoscale activity occurs at this latitude in one month



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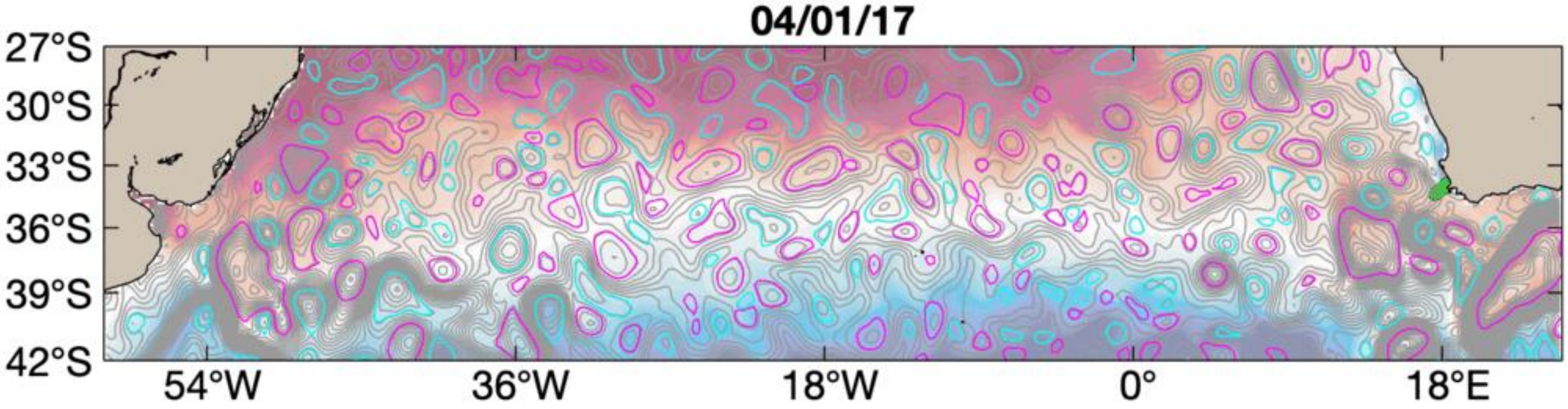
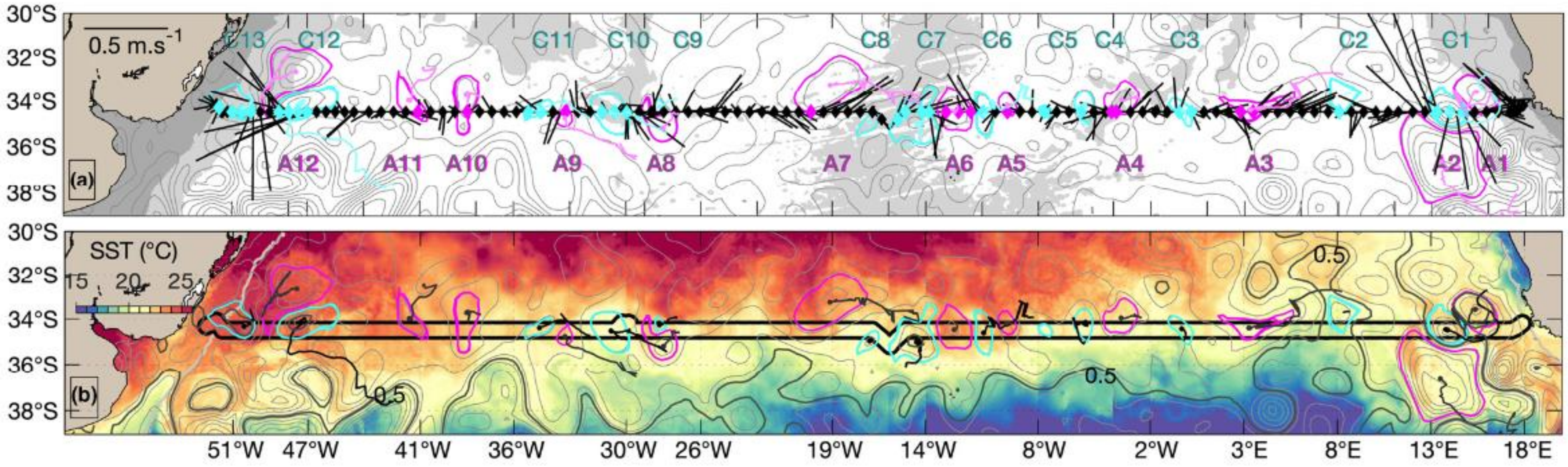
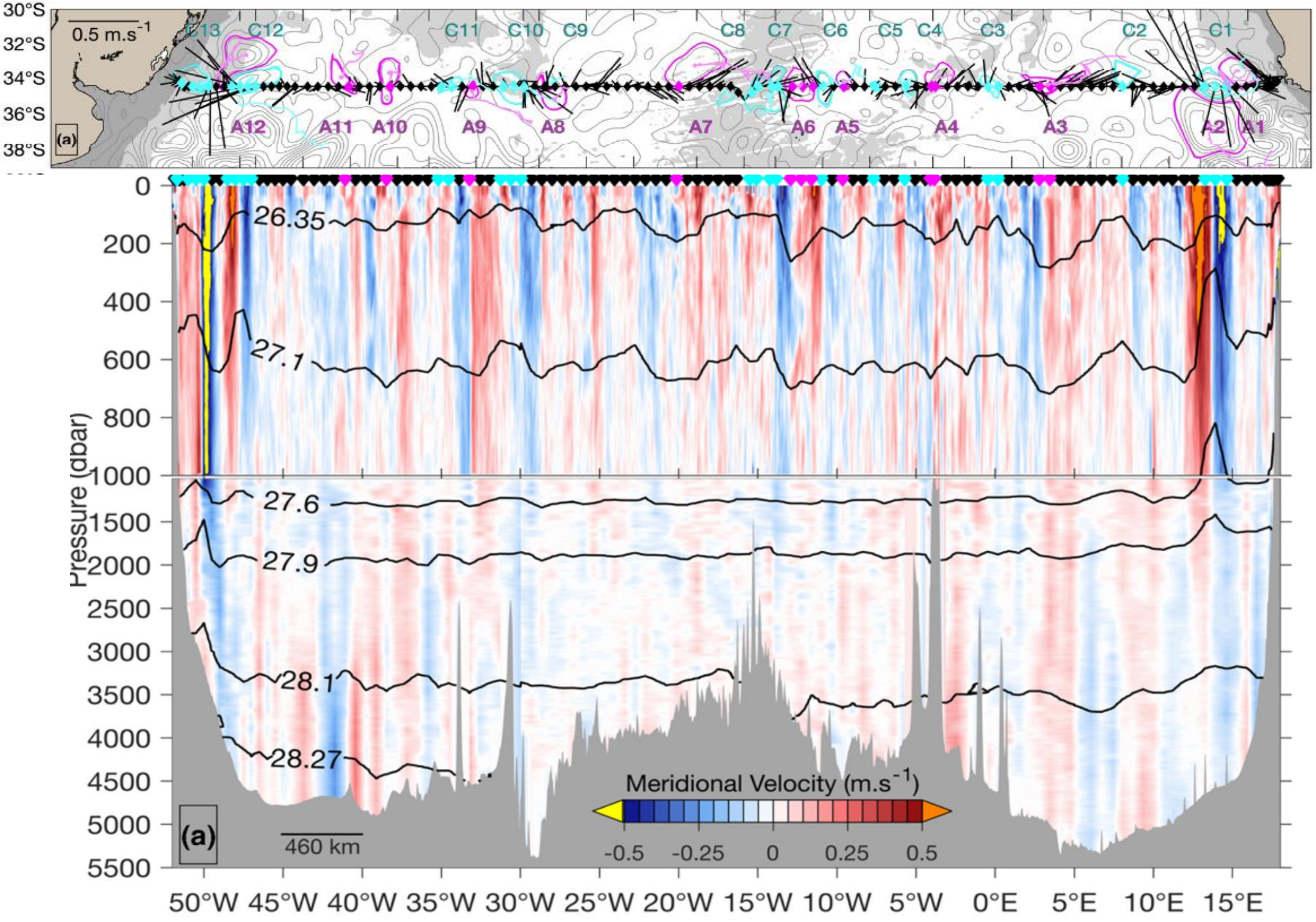


My favorite composite (each xtick is a different day)



- 25 mesoscale eddies crossed. 3 Agulhas rings, 1 in Brazil coast >4 years old
- 2 strong cyclonic eddies with from Benguela Upwelling System and Zapiola Gyre

Generating the section



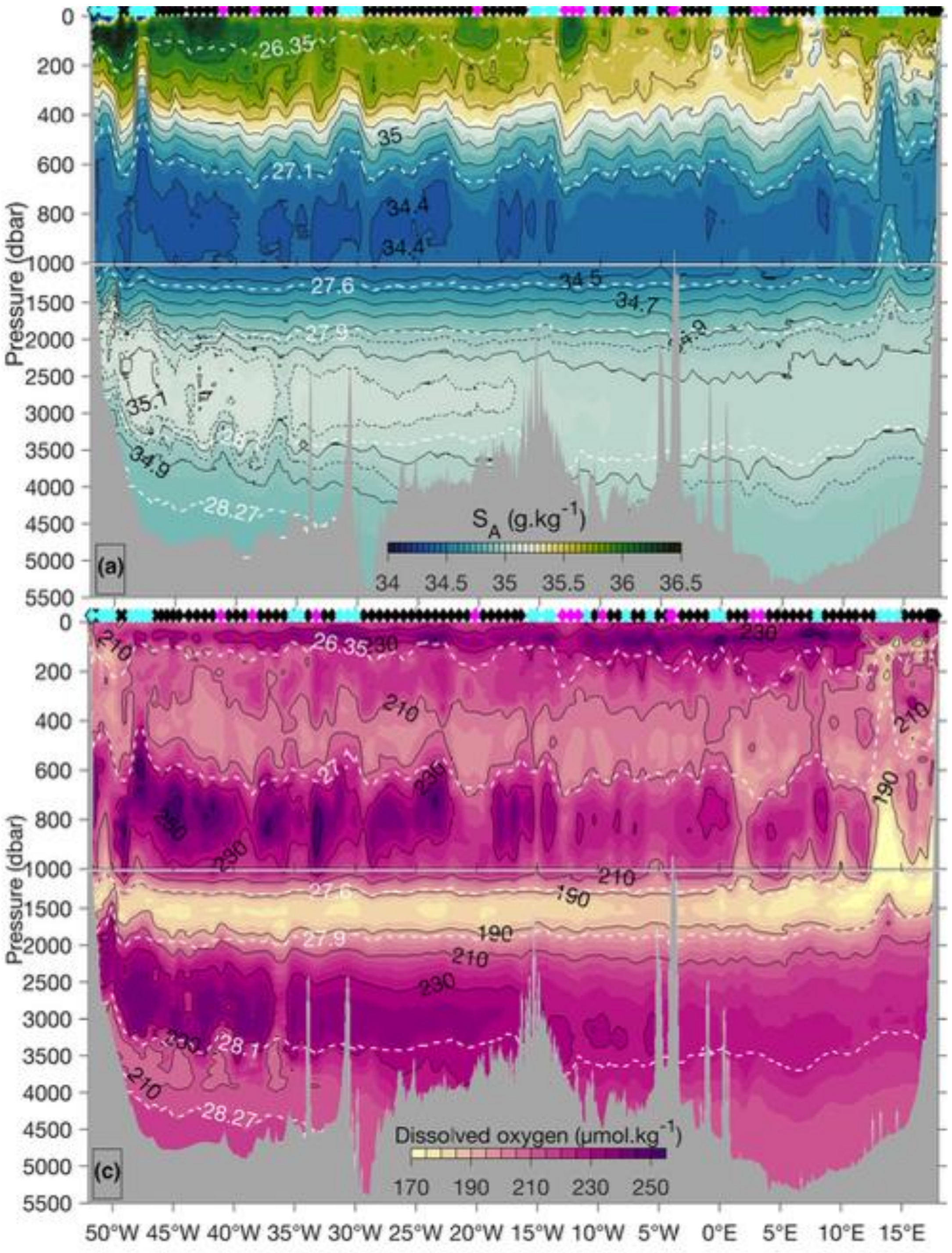
- Data gridding: Every 5 km, with underway ADCP and bathymetry measurements and the 128 LADCP/CTD profiles (''reduce ''bottom triangle problem'')
- Section built with SADCP in the upper 1000 every 5km and 128 LADCP profiles below
- Largest velocities were due to the Brazil Current and mesoscale eddies in the boundaries

Water masses characterized by neutral density ranges

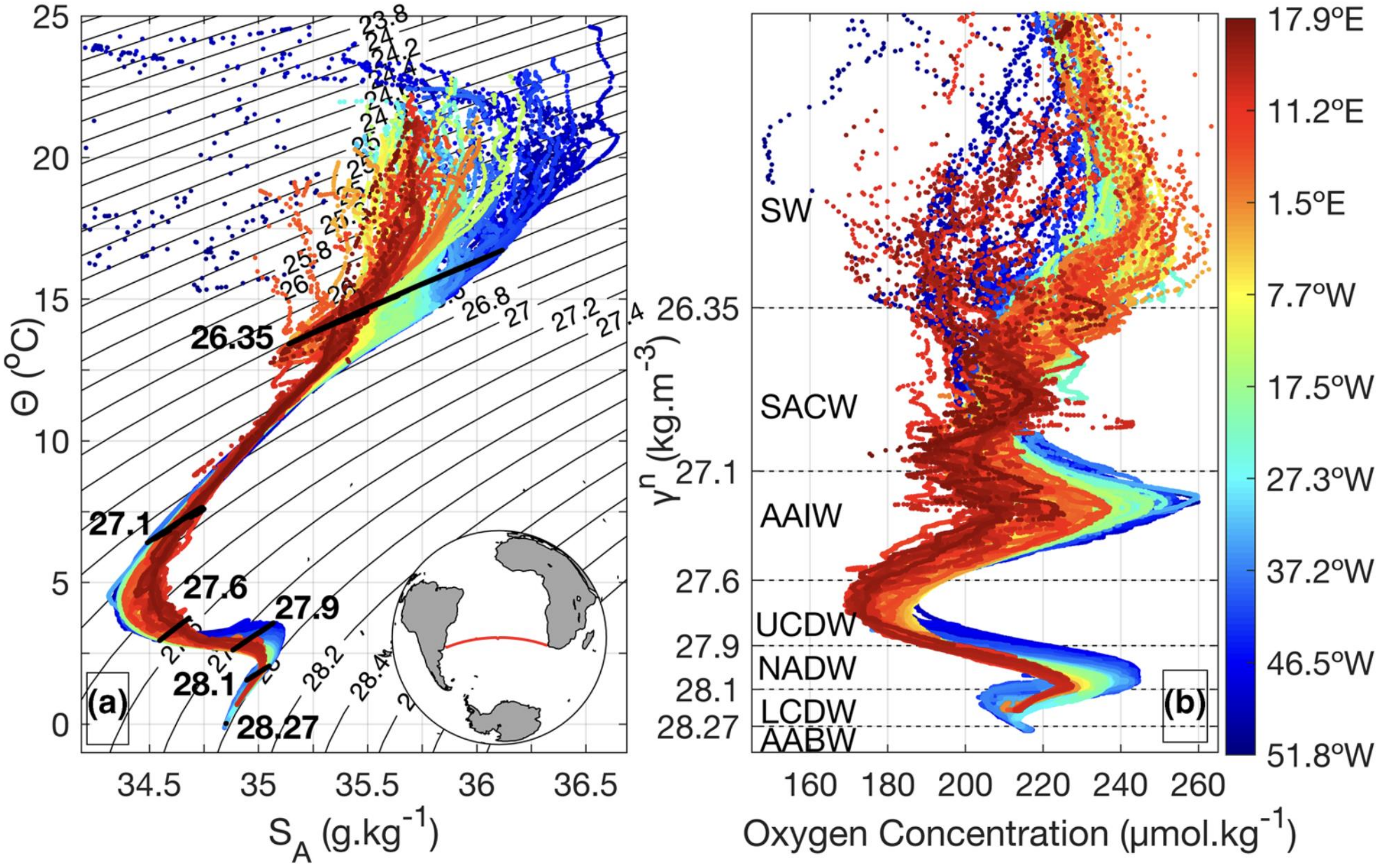
Neutral Density Ranges (γ^n) and Mean Pressure, Conservative Temperature (Θ), Absolute Salinity (S_A), Practical Salinity (S_P), and Oxygen Concentration (µmol kg^{-1}) per Water Mass Across 34.5°S in the Atlantic

Water Mass	γ^n (kg m^{-3})	Pres. (dbar)	Θ (ºC)	S_A (g kg^{-1})	S_P (psu)	O_2 (µmol kg^{-1})
SW	<26.35	79	17.85	35.74	35.57	228.13
SACW	26.35–27.10	377	11.63	35.22	35.05	211.34
AAIW	27.10–27.60	921	4.34	34.48	34.31	216.66
UCDW	27.60–27.90	1549	2.88	34.76	34.59	185.59
NADW	27.90–28.10	2,637	2.47	35.02	34.85	223.39
LCDW	28.10–28.27	4,432	1.07	34.92	34.77	216.09
AABW	>28.27	4,544	-0.07	34.85	34.67	215.87

Note. Acronyms correspond to Surface Water (SW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW), Upper Circumpolar Deep Water (UCDW), North Atlantic Deep Water (NADW), Lower Circumpolar Deep Water (LCDW) and Antarctic Bottom Water (AABW).

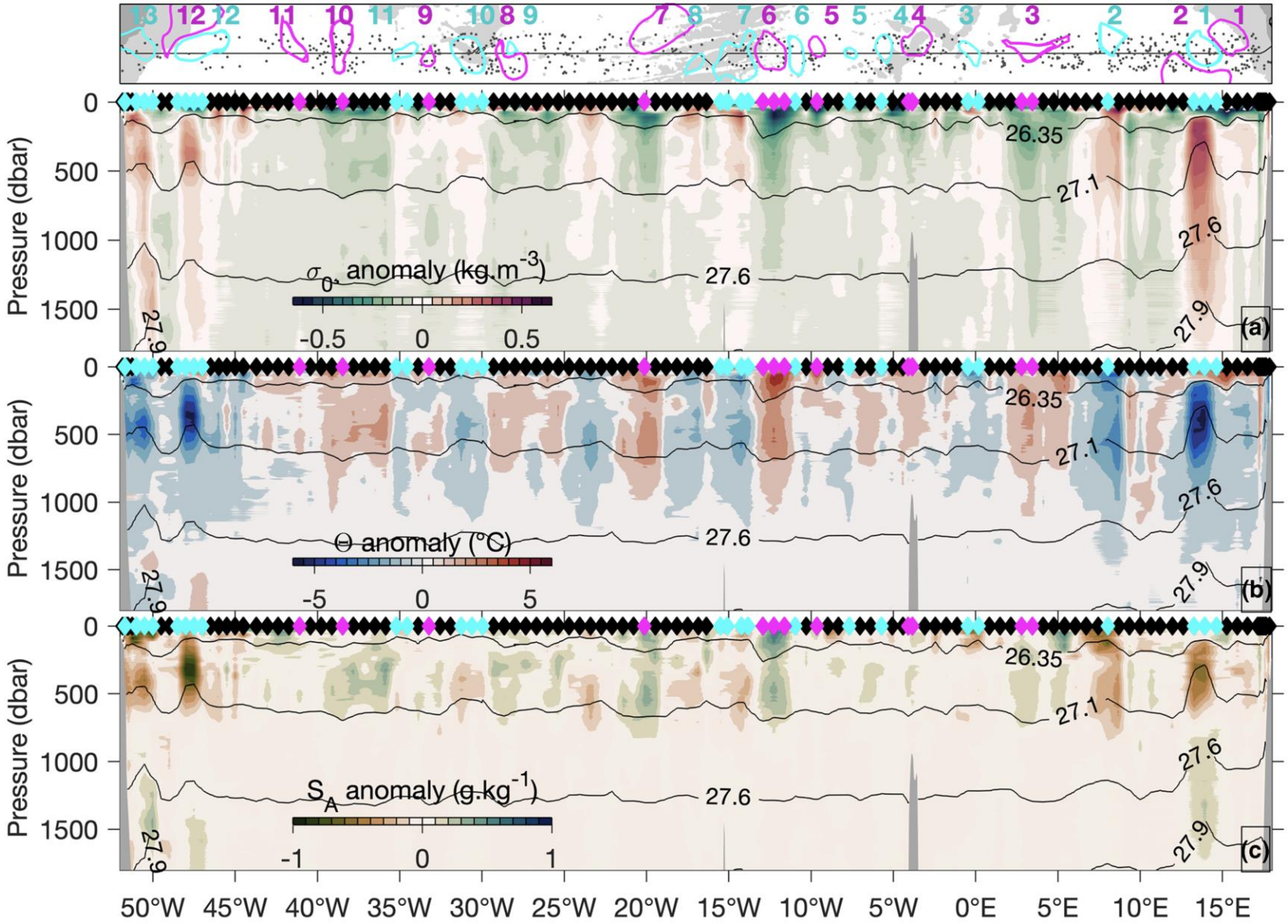


Water masses characterized by neutral density ranges



Older water masses in the East (less salinity and oxygen)

We constructed a section removing the eddies and replaced it with an Argo climatology with profiles outside eddies in the upper 1600 dbars

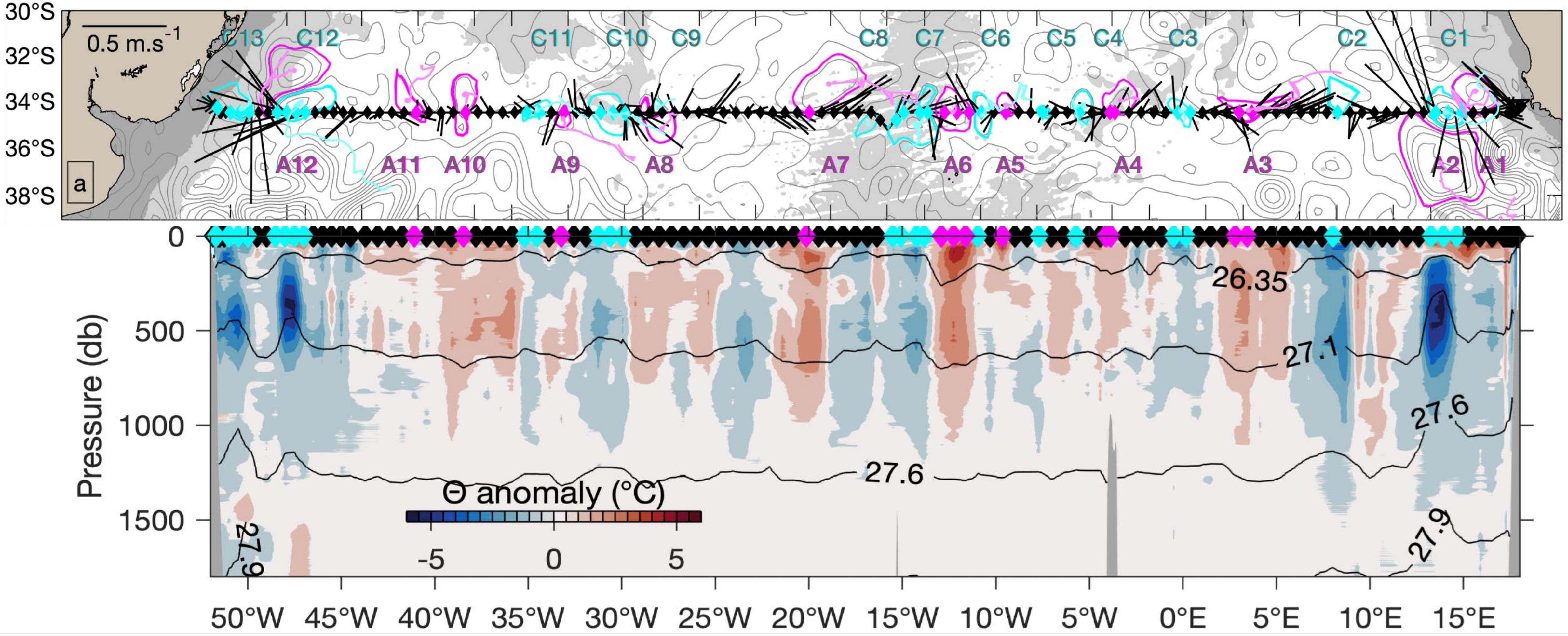


We constructed a section removing the eddies and replaced it with an Argo climatology with profiles outside eddies in the upper 1600 dbars

Huge fan of Argo!

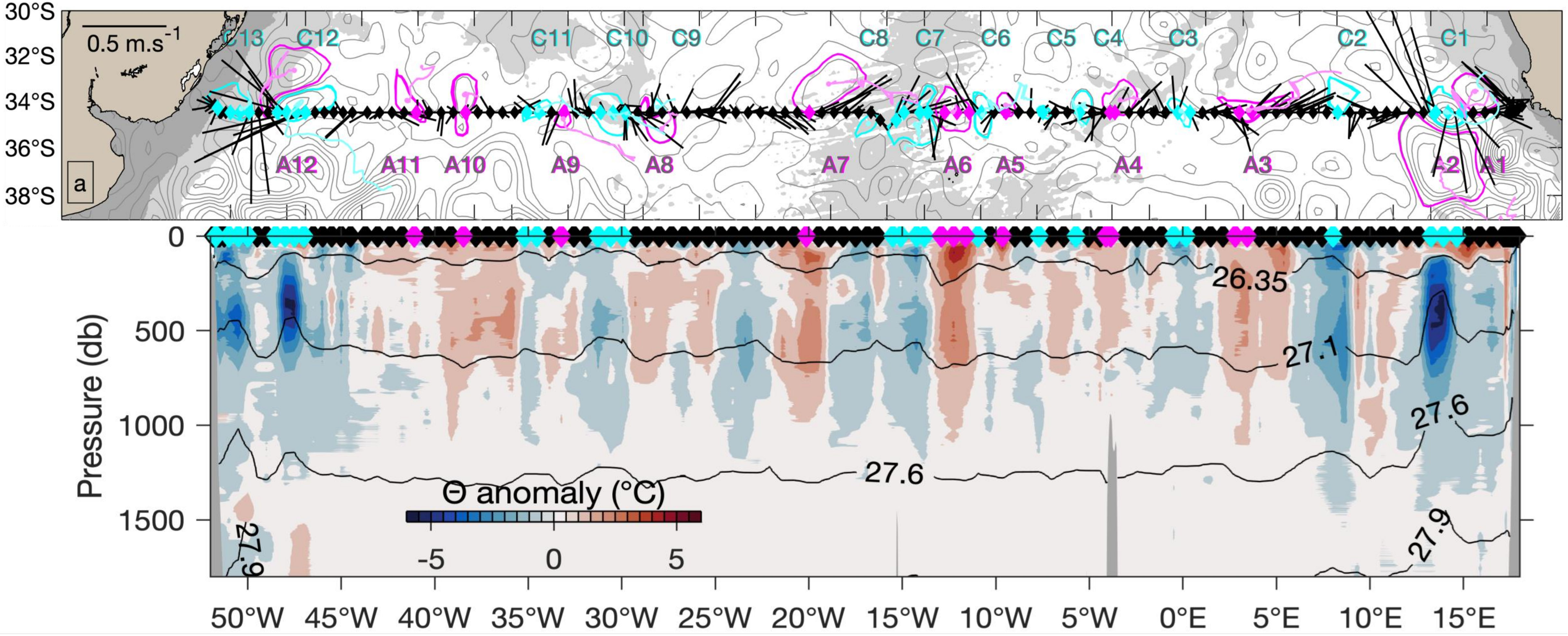
(majority of deep ocean CTD profiles in my country)

A closer look into eddies



- Anomalies up to 5.5ºC at 400 dbar
- More cyclonic eddies in the section, reduced about 30% the MHT (next slide)

A closer look into eddies



Eddies matter!

- Anomalies up to 5.5ºC at 400 dbar
- More cyclonic eddies in the section, reduced about 30% the MHT (next slide)

2 I Results: South Atlantic Overturning Circulation (SAMOC)

- 5 different methods in order to obtain an error estimation

Overturning Maximum (AMOC), Meridional Heat Transport (MHT) and Freshwater Transport (MFT) in the South Atlantic at 34.5°S Calculations Using Different Approximations

Method	1	2	3	4	5
Data set	ADCPs	CTDs	CTDs	CTDs	Argo/CTDs
Level of no-motion	-	$\gamma^n 28.1$	3,400 dbar	Bottom	$\gamma^n 28.1$
Barotropic adj.	-	Mass balance	Mass balance	LADCP bottom + Mass balance	Mass balance
AMOC (Sv)	11.14	15.18	14.55	17.21	15.20
MHT (PW)	0.26	0.23	0.19	0.38	0.35
MFT (Sv)	0.16	0.21	0.24	0.25	0.10

Note. CTD, conductivity-temperature-depth; LADCP, lowered acoustic doppler current profilers.

$$v = v_{ageos} + v_{geos} + v_{ref}$$

$$MHT = C_p \rho_0 \int_{xWest}^{xEast} \int_{pmax}^{pmin} v\Theta \, dx dp,$$

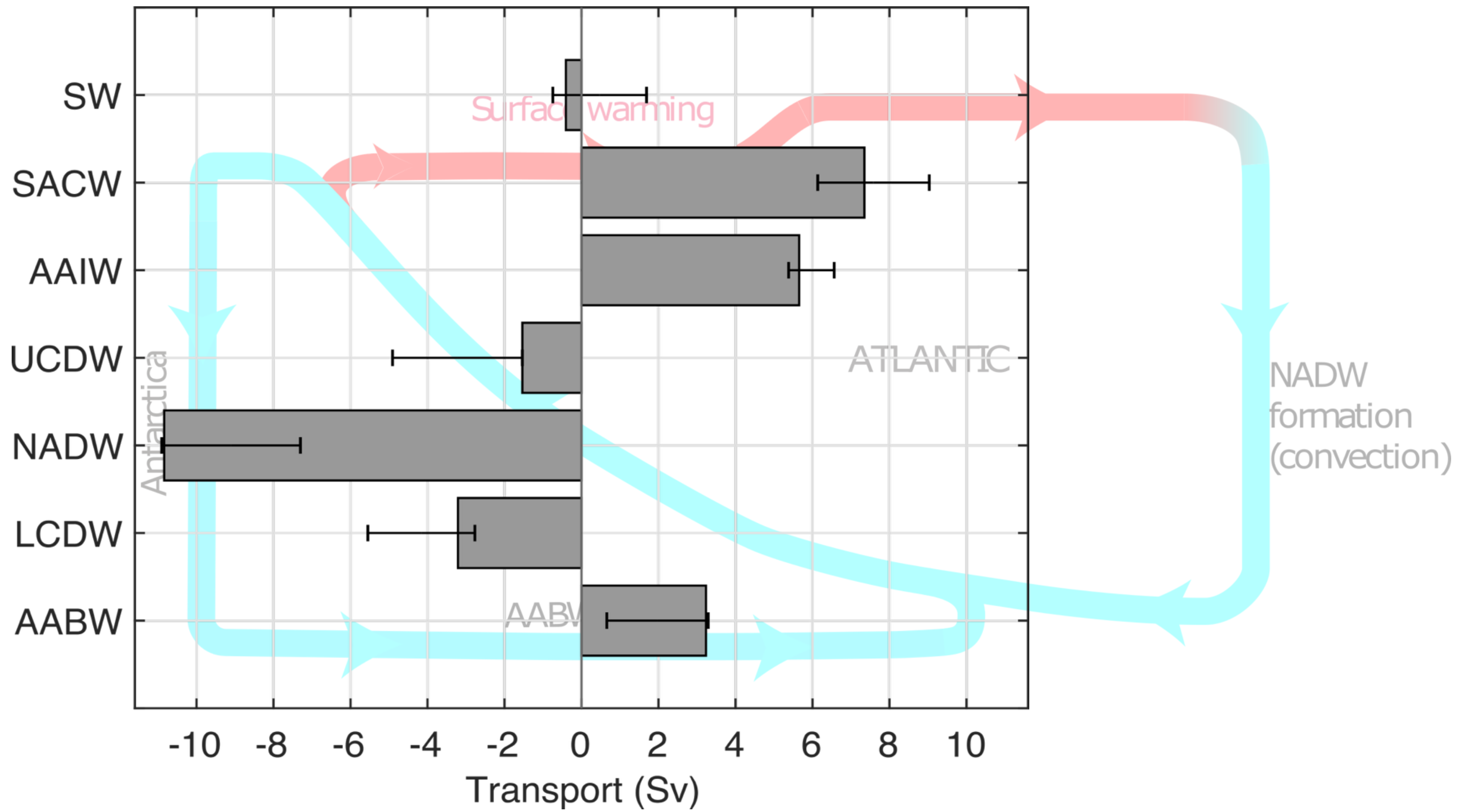
$$MFT = \int_{xWest}^{xEast} \int_{pmax}^{pmin} v \left(1 - \frac{S_A}{S_0}\right) dx dp,$$

$$\Psi(y,z) = \int_{xWest}^{xEast} \int_{pmax}^{pmin} v \, dx dp,$$

$$AMOC_{max} = \max \Psi(z)$$

Data gridding: Every 5 km, with underway ADCP and bathymetry measurements and the 128 LADCP/CTD profiles

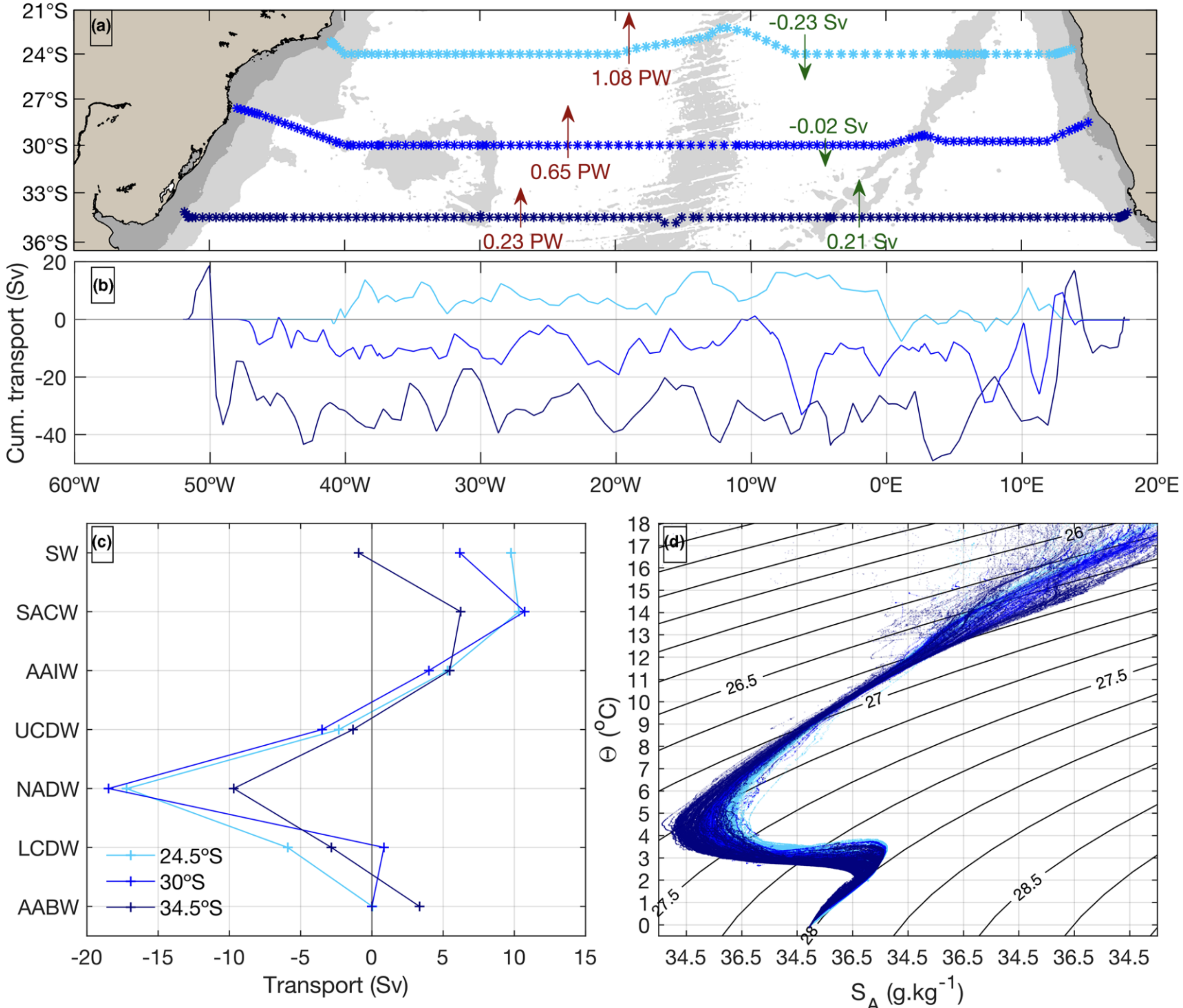
South Atlantic Overturning Circulation (SAMOC)



- Upper and abyssal overturning cell are observed
- $AMOC_{max}$ is 15.64 ± 1.39 Sv located at 1250 dbar
- Net Northward Meridional Heat Transport (MHT) 0.27 ± 0.10 PW

Surface Water (SW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW), Upper Circumpolar Deep Water (UCDW), North Atlantic Deep Water (NADW), Lower Circumpolar Deep Water (LCDW) and Antarctic Bottom Water (AABW)

Comparison with closest GO-SHIP sections



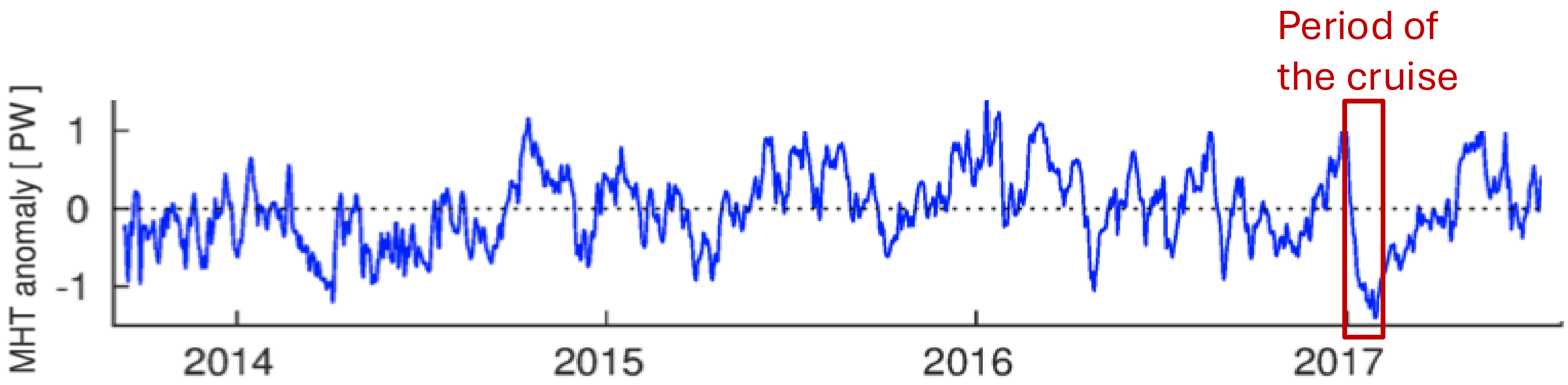
-From 24.5 ºS and 34.5ºS: decrease in northward heat transport transport because upper layers are colder and Brazil Current southward transport intensifies

-Consistent with results from Hernandez Guerra et al., (2019) at 30ºS and Bryden et al., (2011) at 24.5ºS, although absolute values are sensitive to the method

Summary

Using the first GO-SHIP section at 34.5ºS in the South Atlantic we:

- Assessed water masses characteristics and zonal differences
- Eddy tracking evidenced inter-oceanic exchanges and changes in MHT
- Computed the AMOC (15.6 Sv) and MHT (0.27 PW): consistent with nearby GO-SHIP sections and the low MHT period according to moorings at 34.5ºS



(Bryden et al., 2011; Hernandez-Guerra et al., 2019; Kersalé et al., 2021)

2nd case: Ocean transport from moorings

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Predicting the Loop Current dynamics combining altimetry and deep flow measurements through the Yucatan Channel

Gaston Manta[1*], Giovanni Durante[2], Julio Candela[2], Uwe Send[1], Julio Sheinbaum[2], Matthias Lankhorst[1] and Rémi Laxenaire[3,4,5]

[1]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, United States, [2]Departamento de Oceanografía Física, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Ensenada, Mexico, [3]Center for Ocean-Atmospheric Prediction Studies, Florida

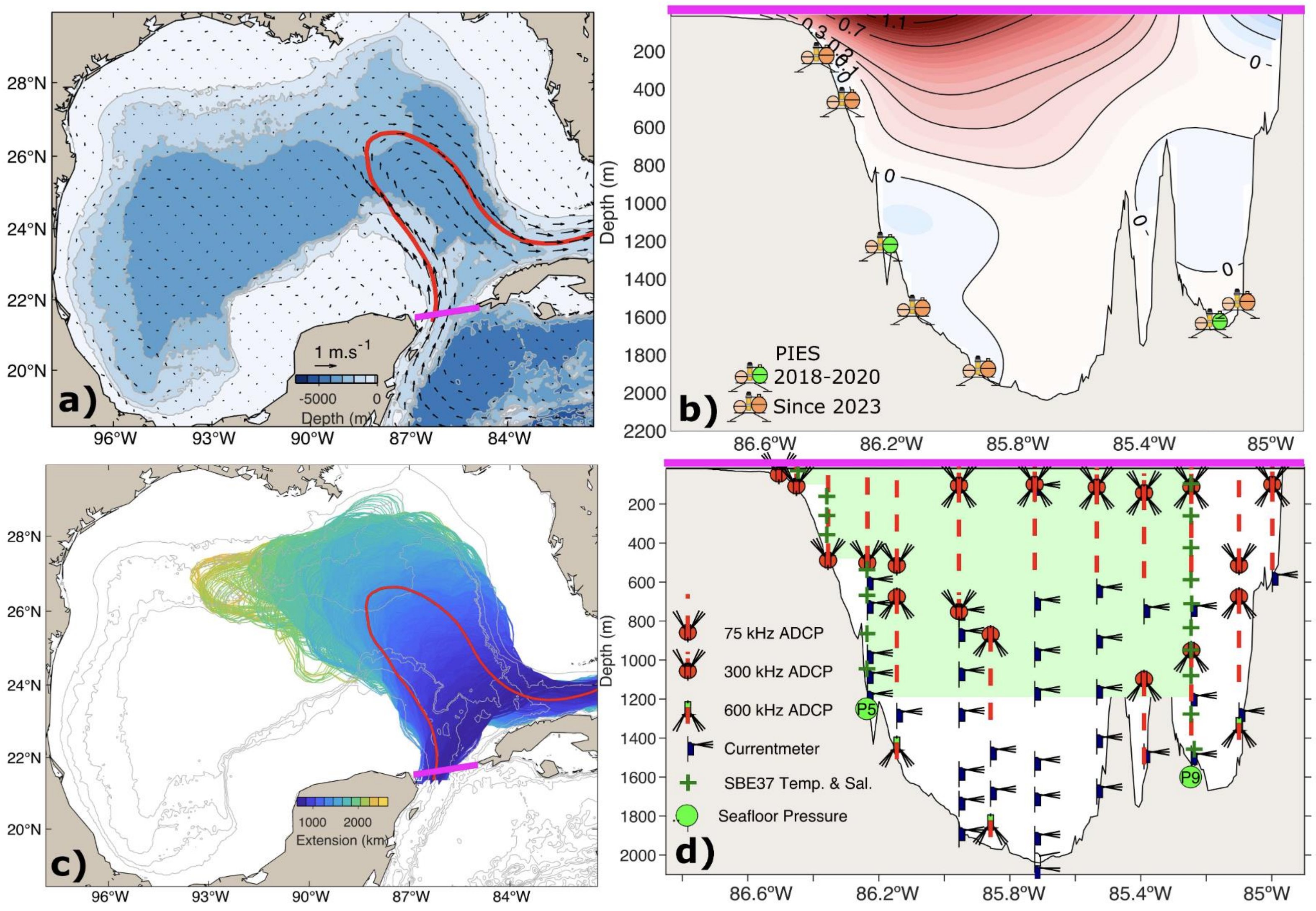
and

Potential for predicting the Loop Current extension from Pressure-Sensing Inverted Echo Sounders (PIES) in Yucatan Channel

Gaston Manta[1,2,3*], Uwe Send[1], Matthias Lankhorst[1], Yang Zhang[1], Giovanni Durante[4] and Julio Sheinbaum[4]

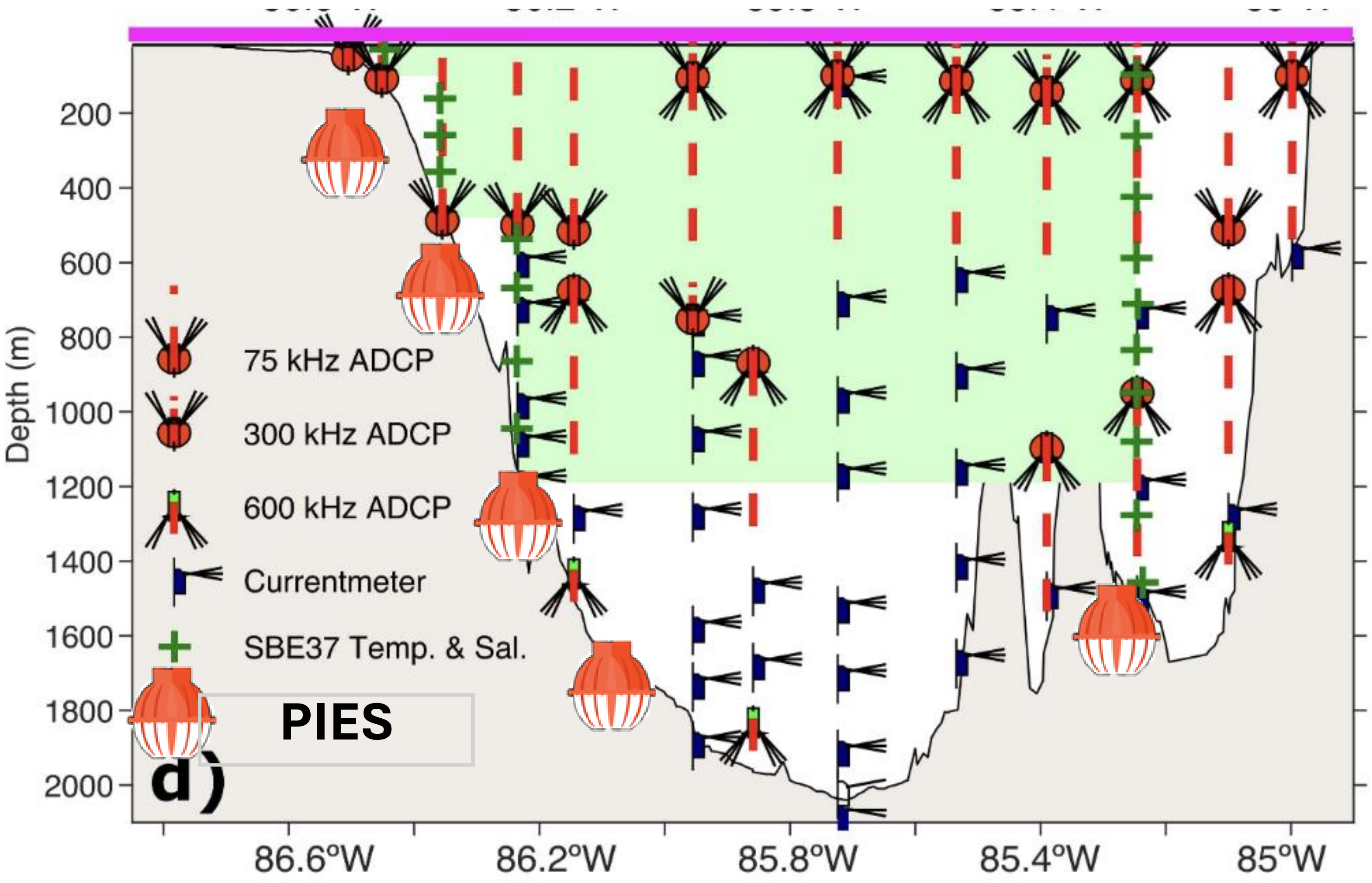
(under review)

Loop Current (LC) is the main mesoscale feature in the Gulf of Mexico



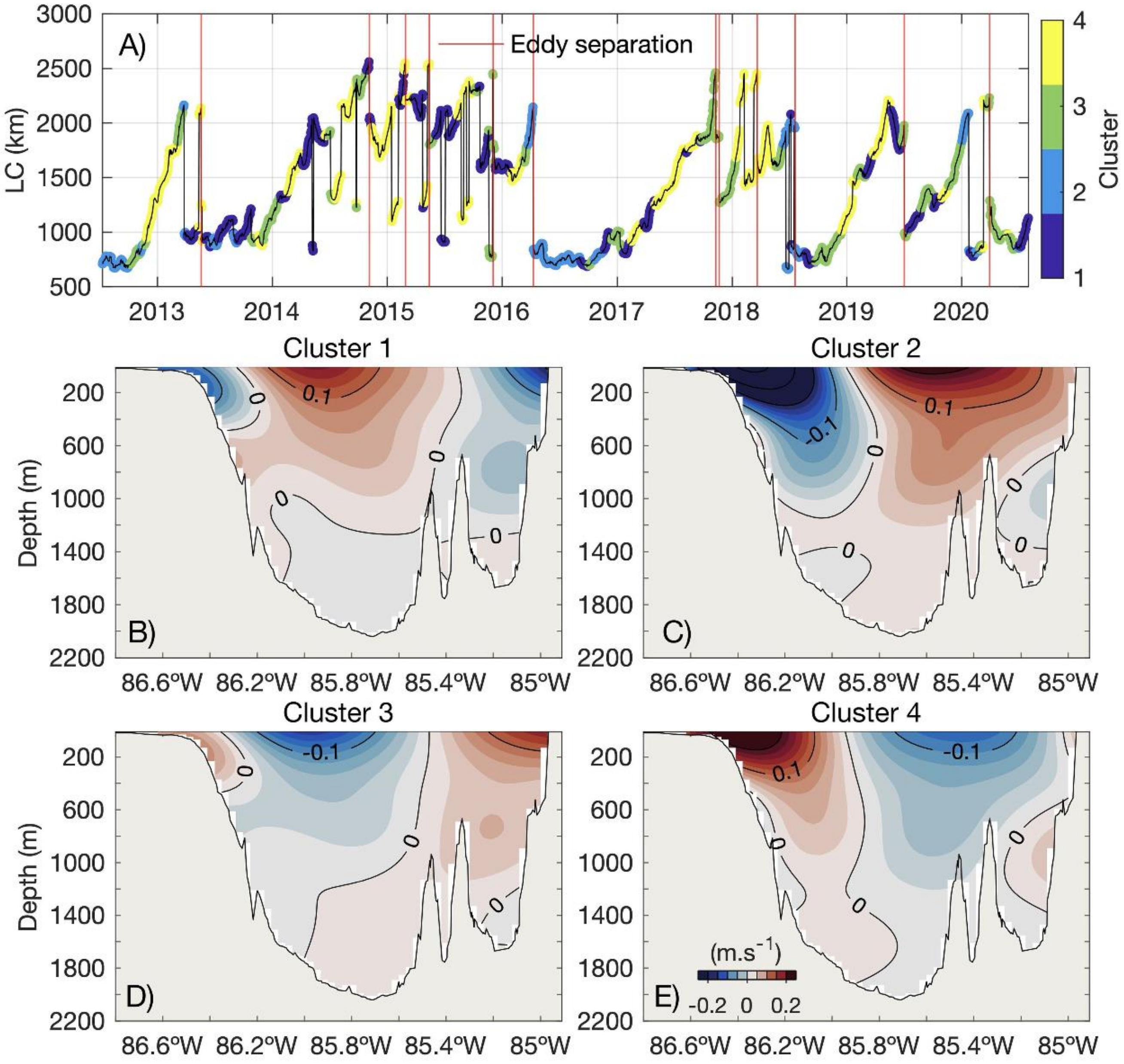
- LC extension is trackable with altimetry
- Yucatan Channel is the upstream boundary condition of the LC and therefore holds predictability
- Several moorings and PIES measure the flow through Yucatan Channel

A wide variety of instruments are deployed in the Yucatan Channel



Ideal for comparing methodologies

Predicting the Loop Current extension



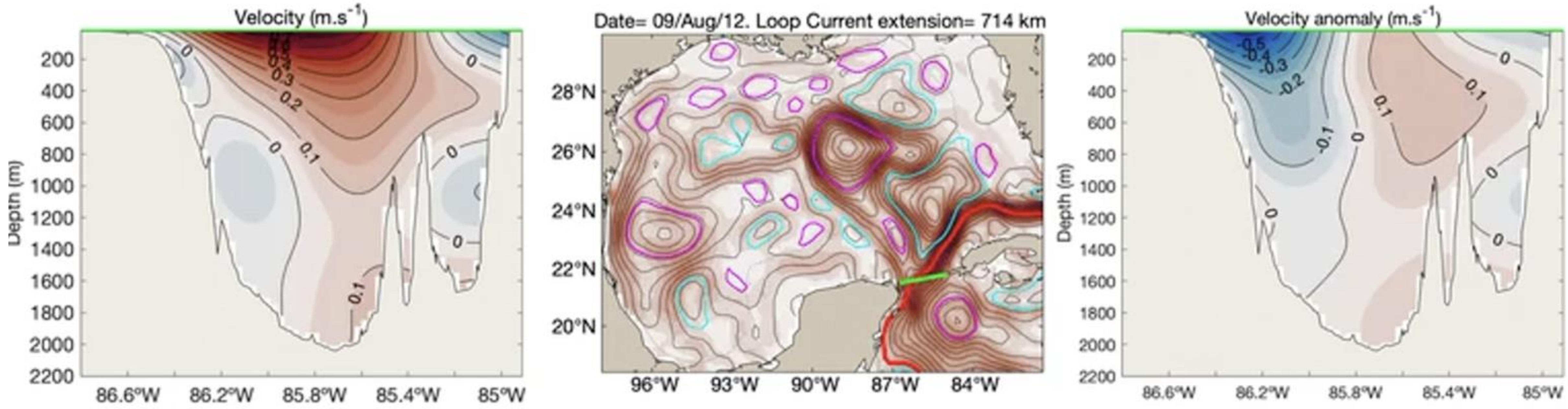
8 years of daily mapped velocity data from ADCPs in Yucatan Channel (Durante et al., 2023)

4 clusters of flow anomalies in Yucatan Channel associated to different phases of the Loop Current (LC)

Loop Current shifts Westward – LC grows

Loop Current shifts Eastward - LC decays

Predicting the Loop Current extension



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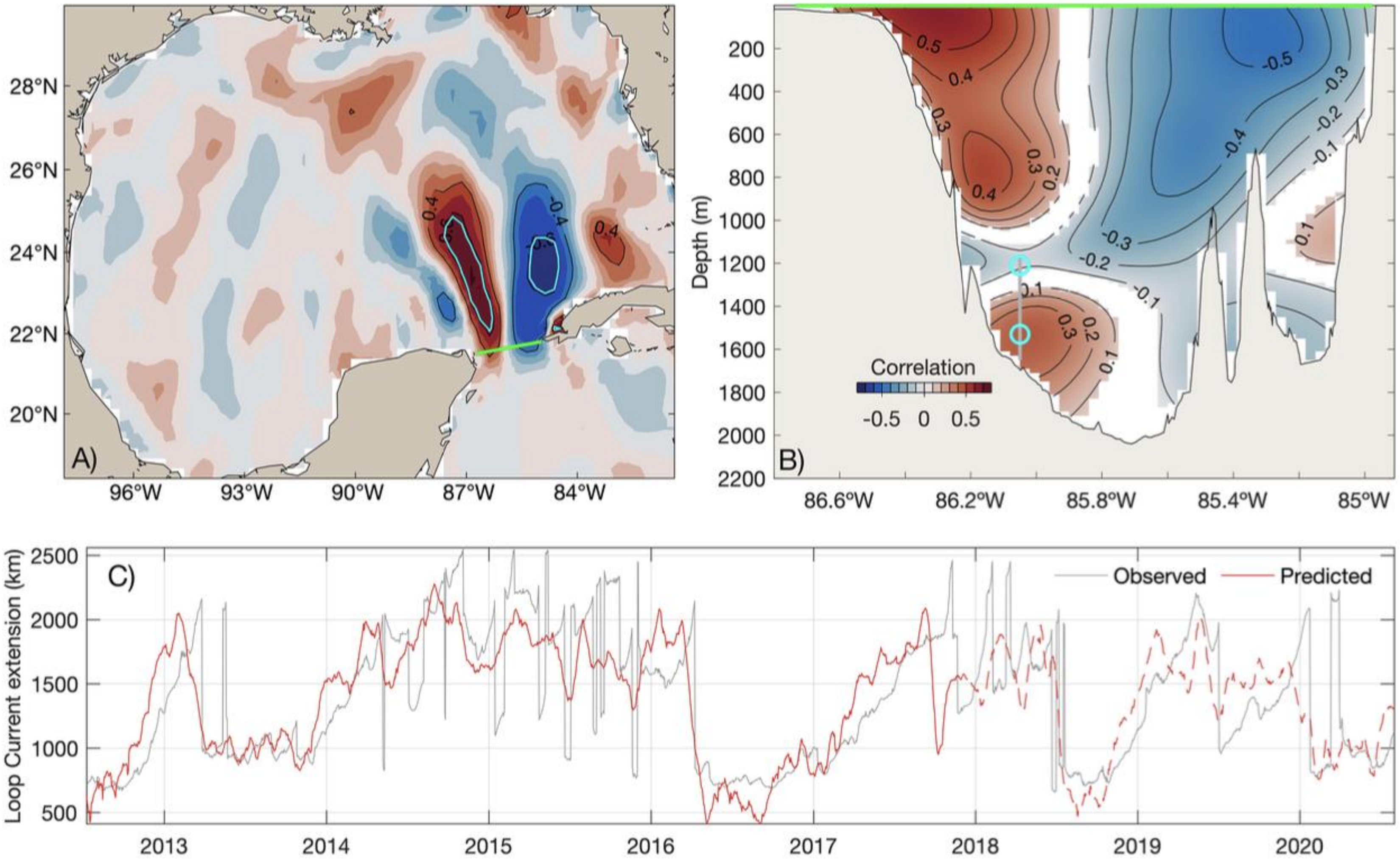
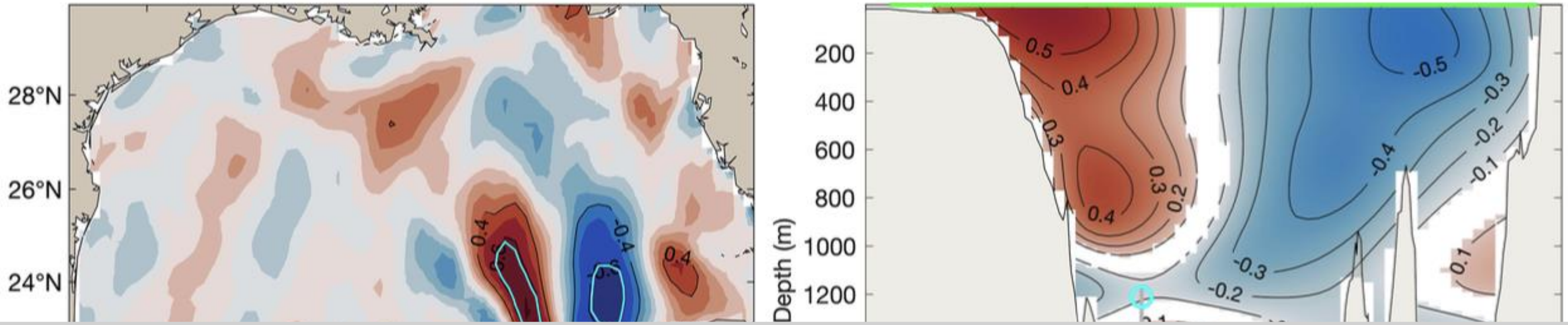
Predicting the Loop Current extension

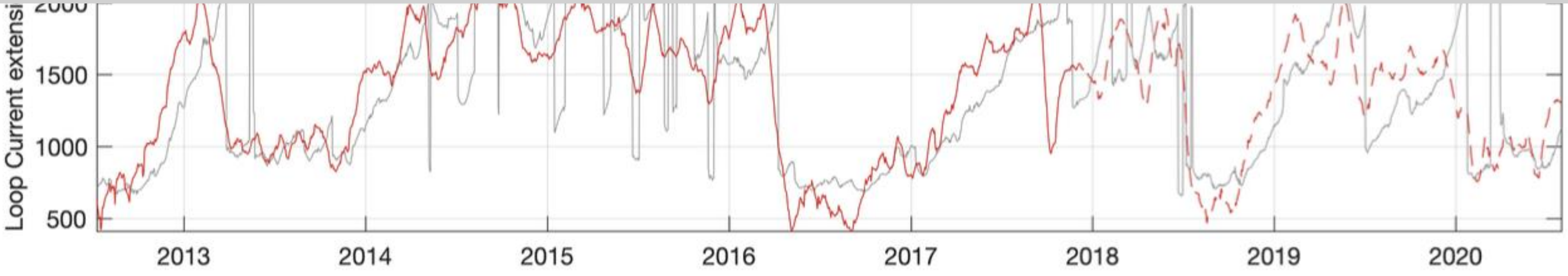


- A multiple linear regression using altimetry and data from moorings can predict the Loop Current extension with 1 month in advance with statistical significance (R2=0.74, $p<0.05$, RMSE= 338 km)

Predicting the Loop Current extension

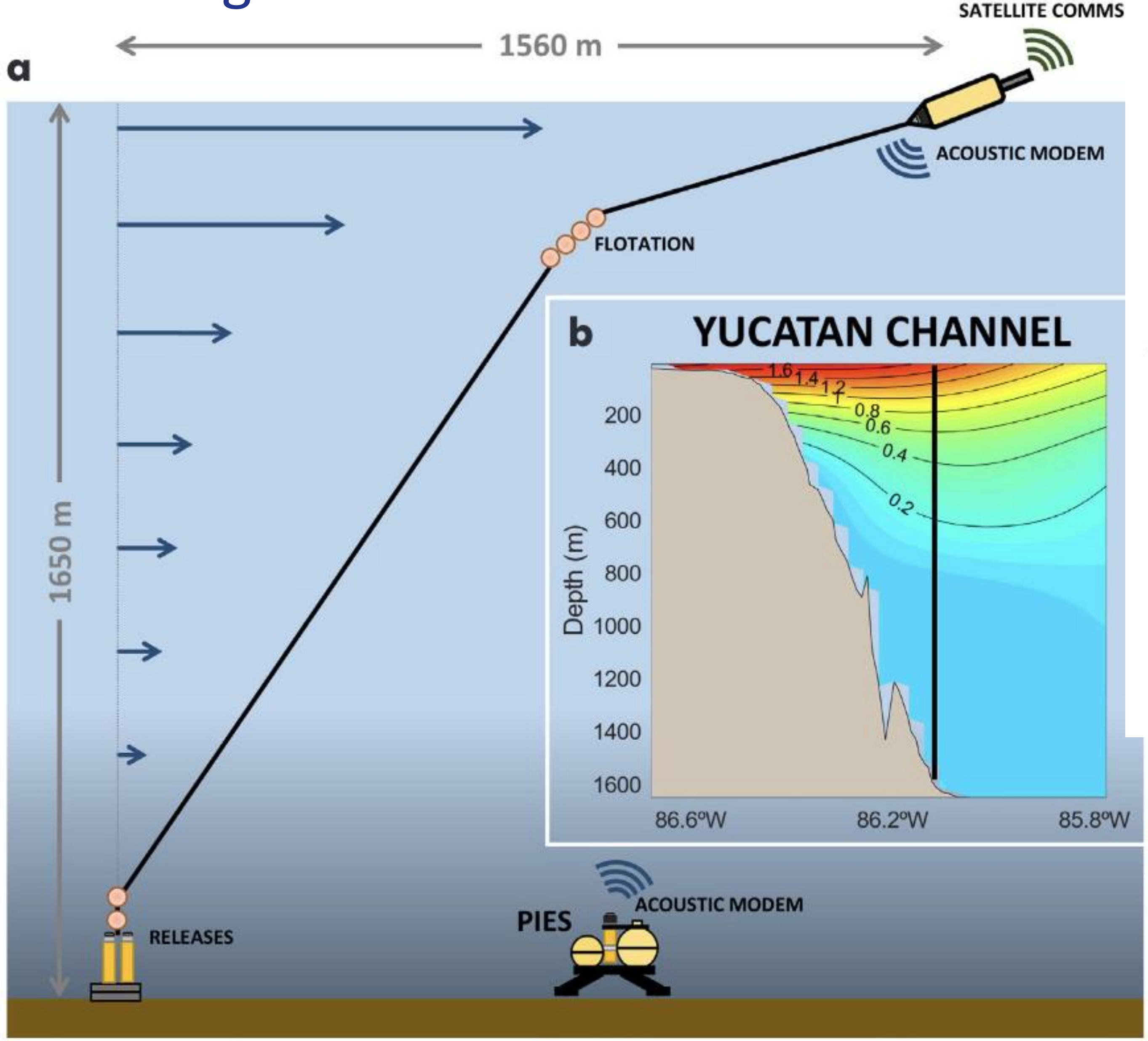


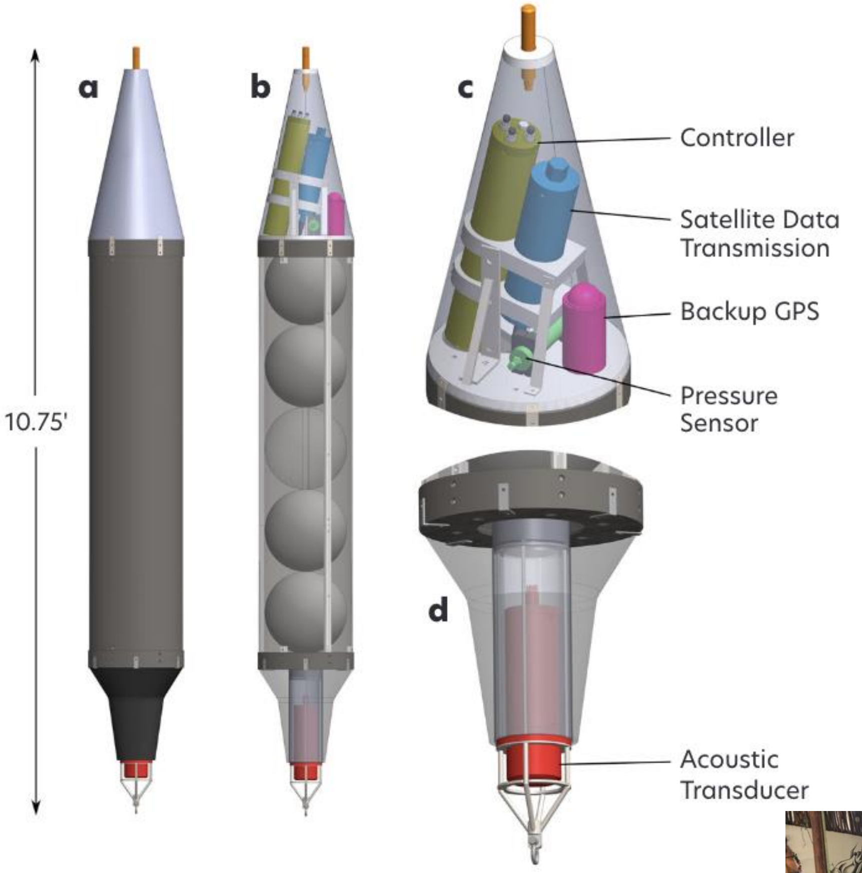
But transmiting in real time all the data from ADCPs is logistically very complex



- A multiple linear regression using altimetry and data from moorings can predict the Loop Current extension with 1 month in advance with statistical significance ($R2=0.74$, $p<0.05$, RMSE= 338 km)

"Let's build a buoy that sinks, collects PIES data, transmits in real time, and sheds Sargassum"

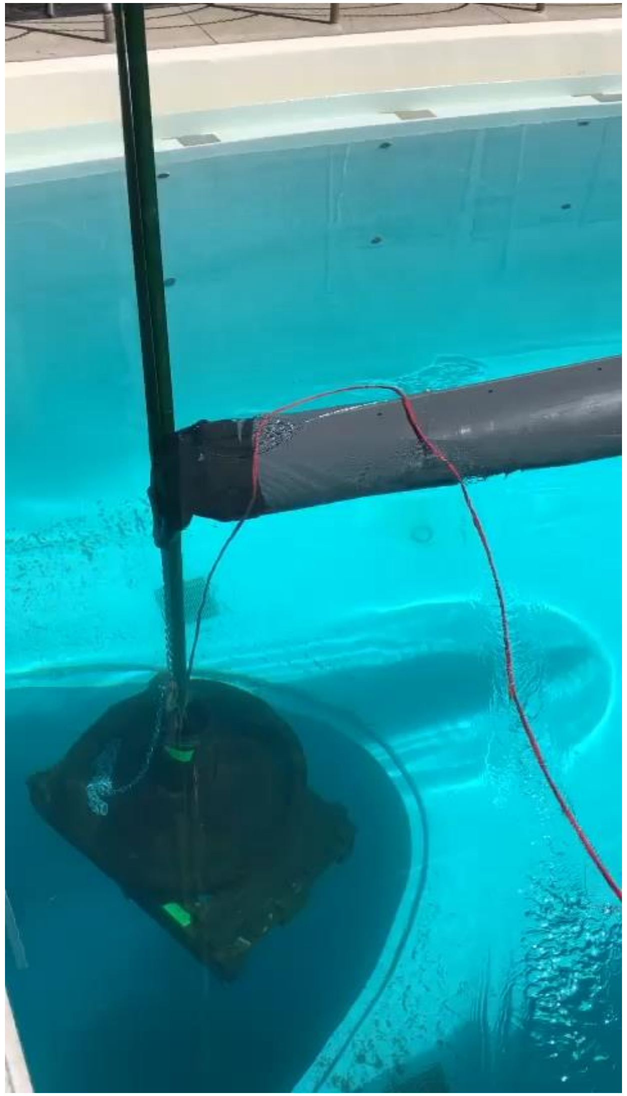




(Ewert et al., 2025)

https://www.jstor.org/stable/27374574

"Let's build a buoy that sinks, collects PIES data, transmits in real time, and sheds Sargassum"

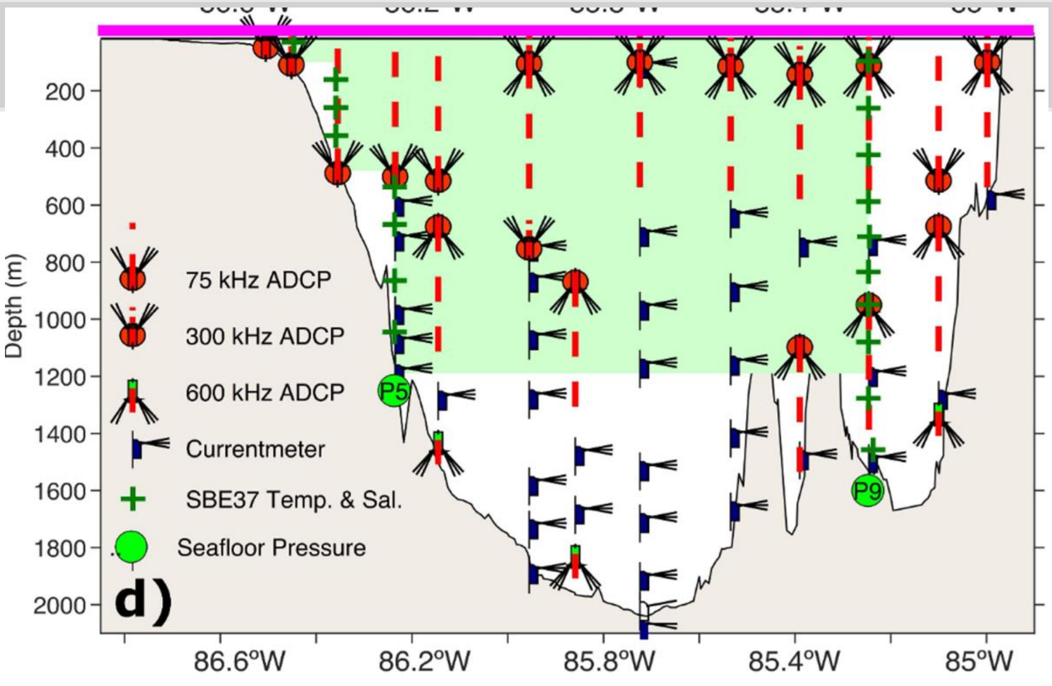


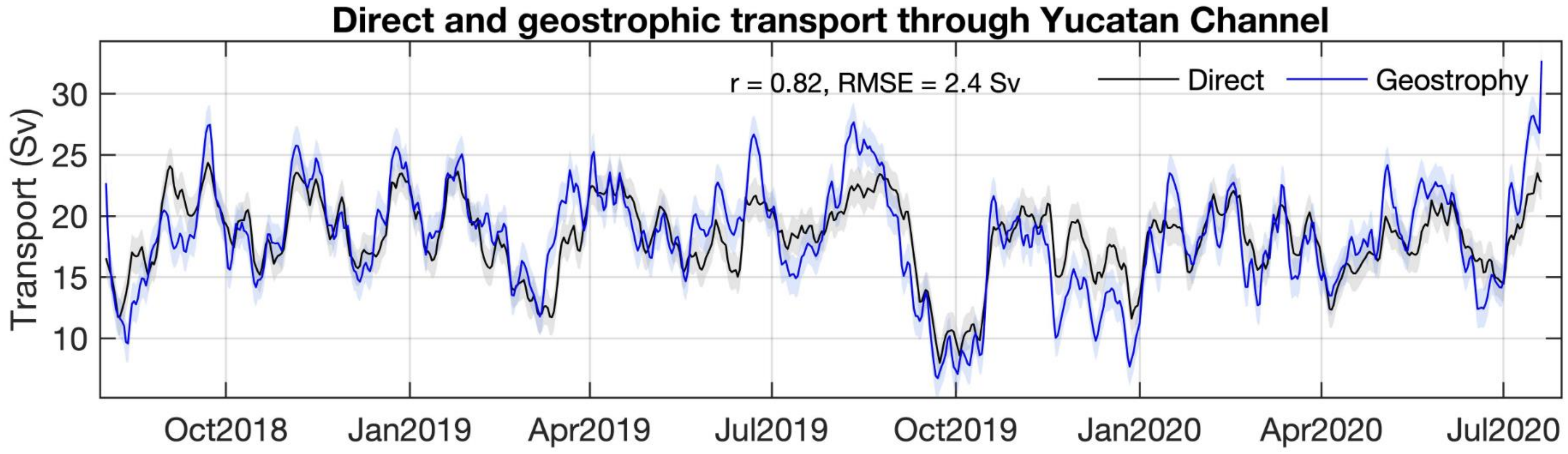
How it started

How it ended
(just the 1st attempt)

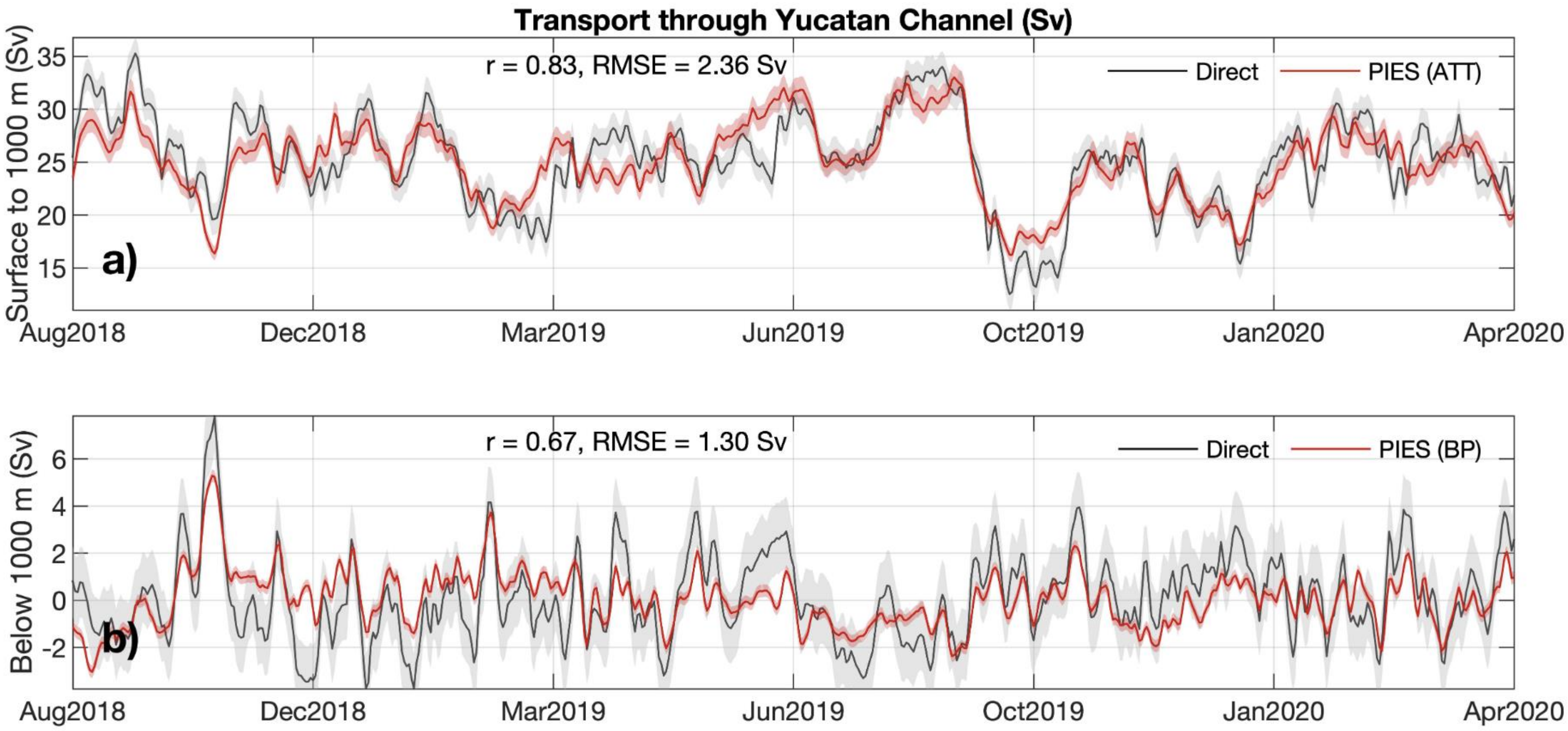
(Ewert et al., 2025) https://www.jstor.org/stable/27374574

The transport is mostly geostrophic



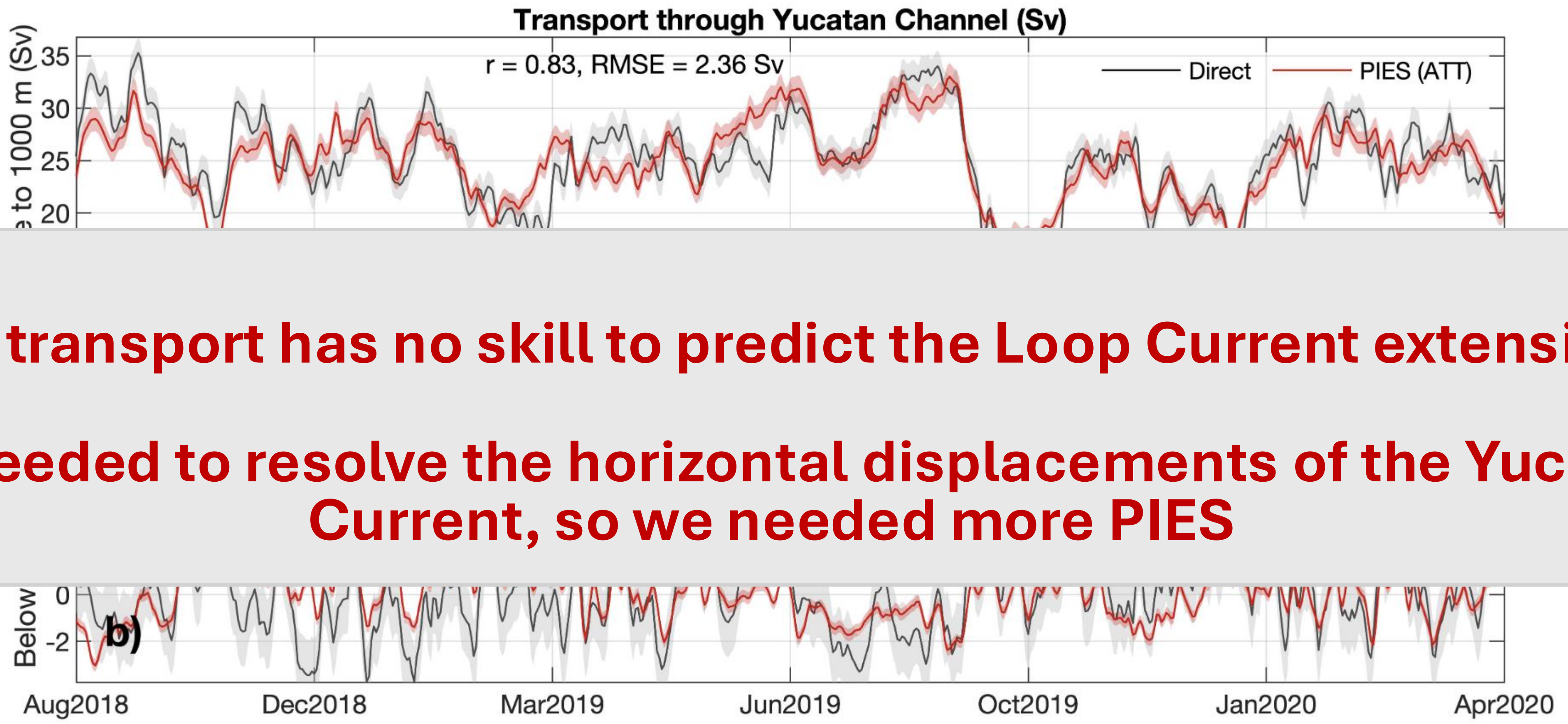


2 PIES capture the transport



- Δτ and ΔBP reproduces the upper and lower transport through the Yucatan Channel, respectively

2 PIES capture the transport very well



But transport has no skill to predict the Loop Current extension

We needed to resolve the horizontal displacements of the Yucatan Current, so we needed more PIES

- Δτ and ΔBP reproduces the upper and lower transport through the Yucatan Channel, respectively

Predict PIES data directly from flow distributions to design the best array

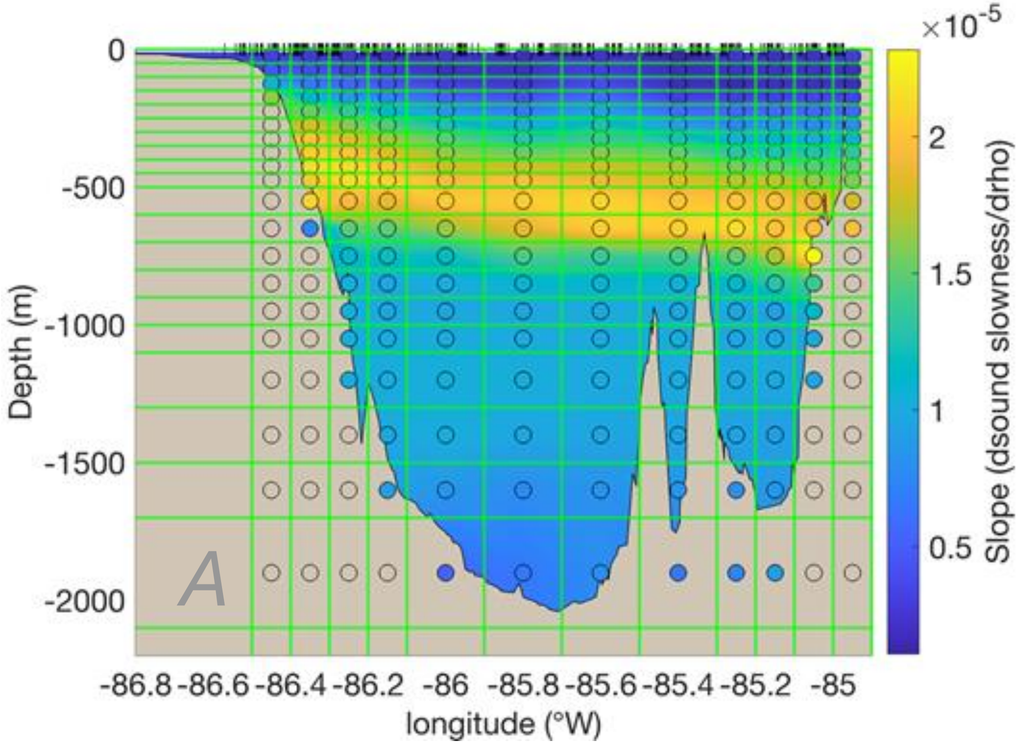
Assume YC flow is geostrophic:

Calculate horizontal Bottom Pressure (BP) differences from: $$fv = \frac{1}{\rho}\frac{\partial p}{\partial x}$$

Calculate horizontal Acoustic Travel Time (ATT) differences from:

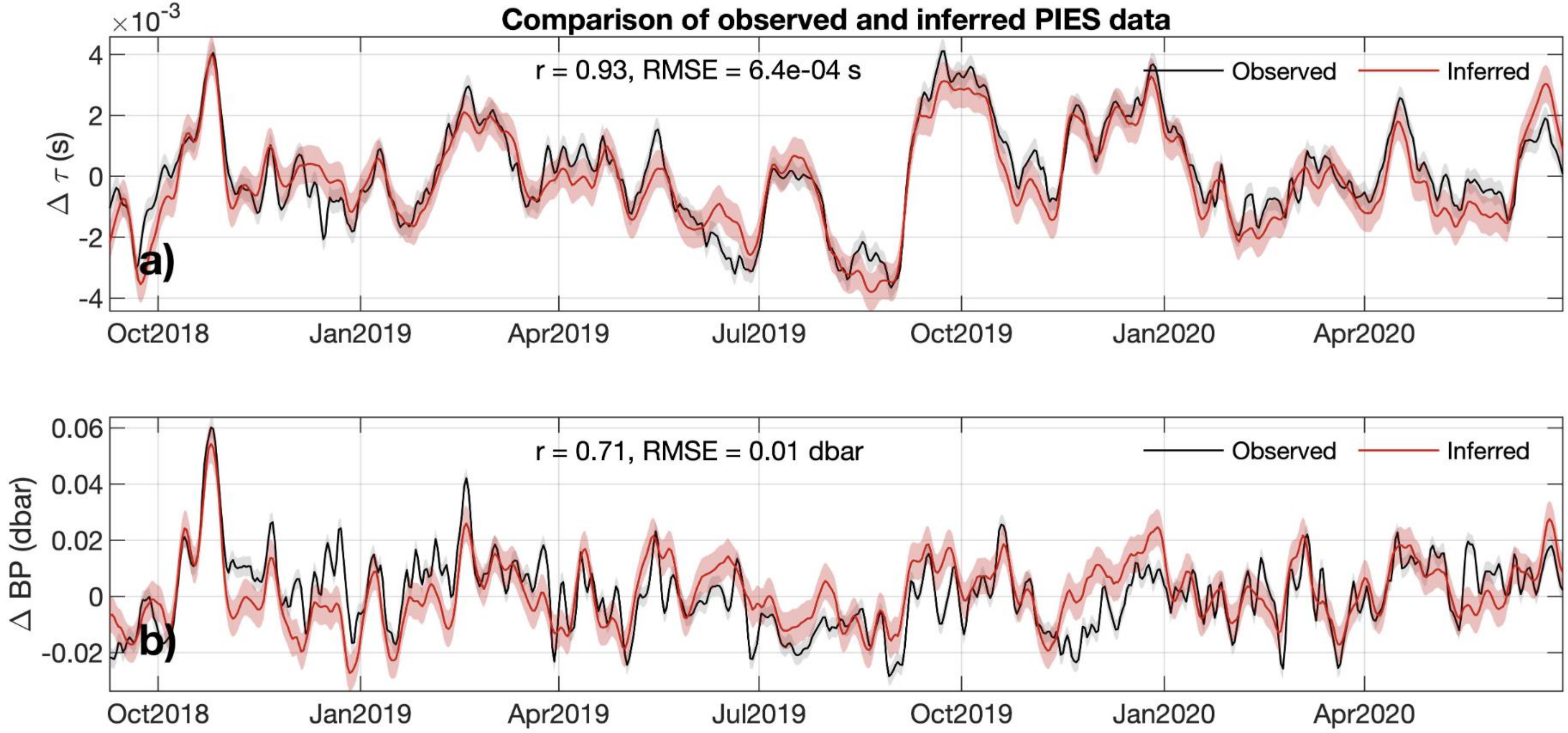
(1) $$\frac{\partial v}{\partial z}\frac{f\rho_0}{g} = -\frac{\partial \rho}{\partial x}$$

(2) $$\frac{\partial \tau}{\partial x} = 2\int \frac{\partial \rho}{\partial x} A\,dz$$



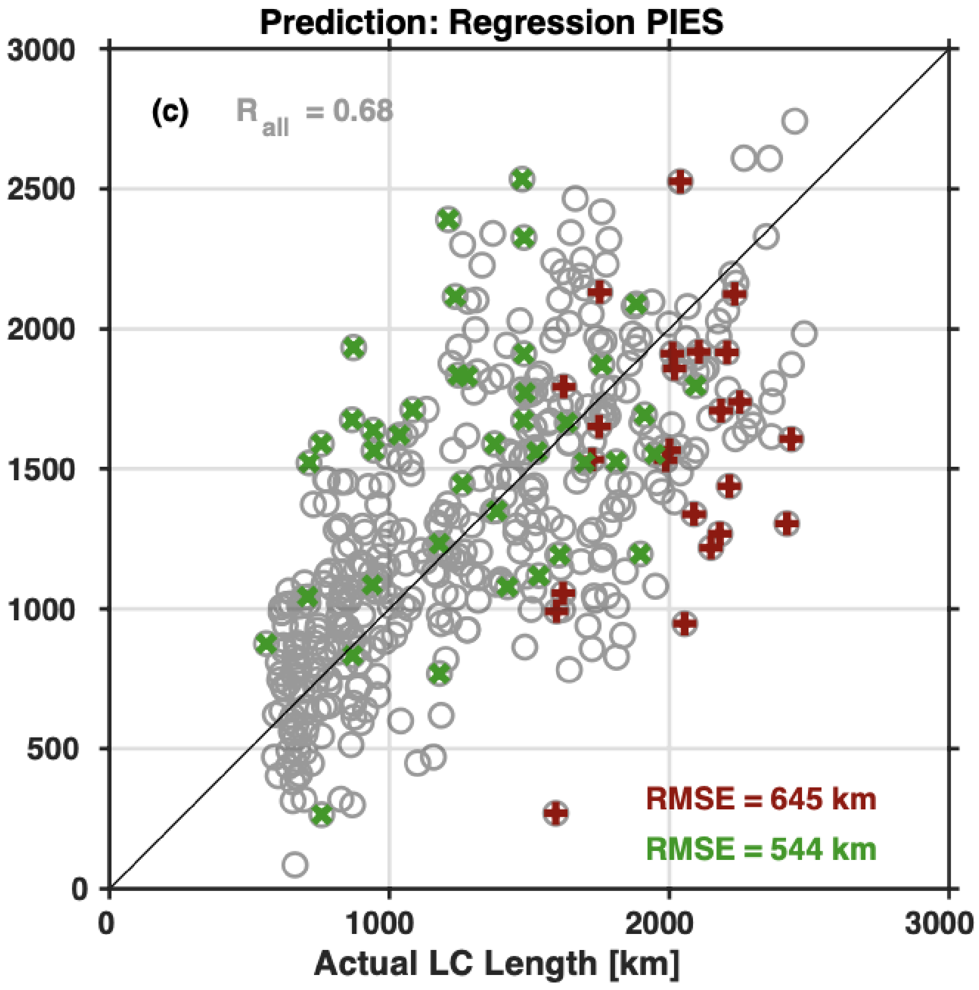
A(x,z) describes the horizontal change of inverse sound speed with density changes from 353 CTD stations

Comparison with inferred vs observed data

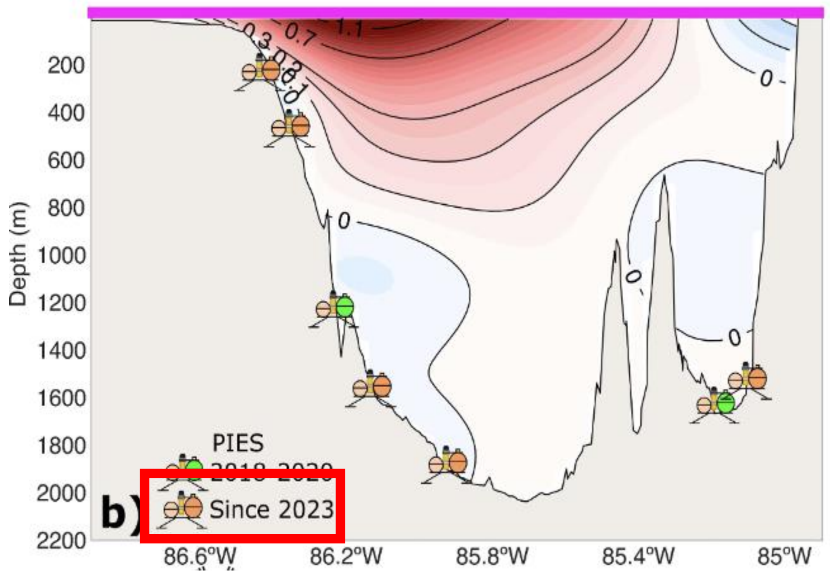


- With this method, we can test the results for any PIES array in Yucatan Channel

So we deployed 5 PIES



- A linear model using Δτ and ΔBP from the deployed 5 PIES alone shows a relatively good skill to predict the Loop Current extension



Summary

- Geostrophy explains most of the flow in the Yucatan Channel
- Total transport alone cannot predict the Loop Current extension, whereas horizontal displacement can
- PIES can capture these displacements
- Near-real-time transmission of PIES data for operational forecasting of the Loop Current appears feasible in the short term

Grazie mille