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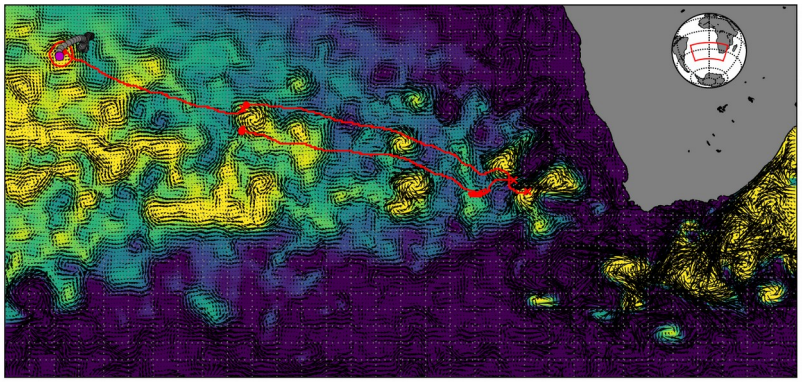
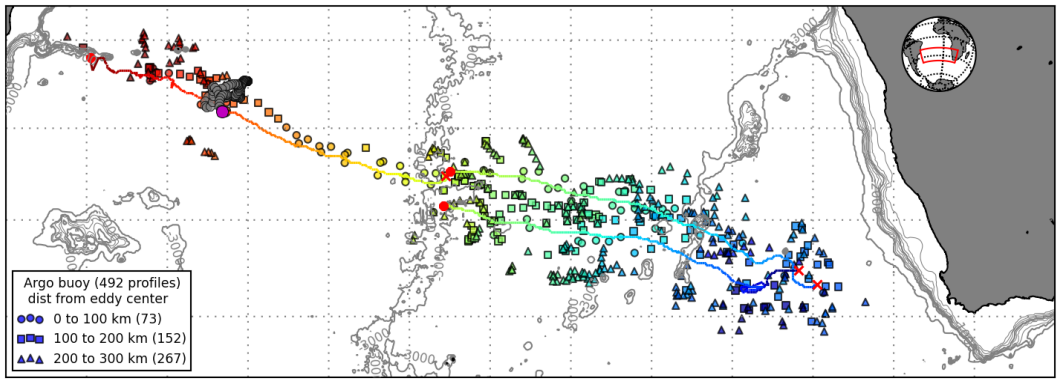
Transport efficiency of an Agulhas ring from combined satellite altimetry and Argo profiles

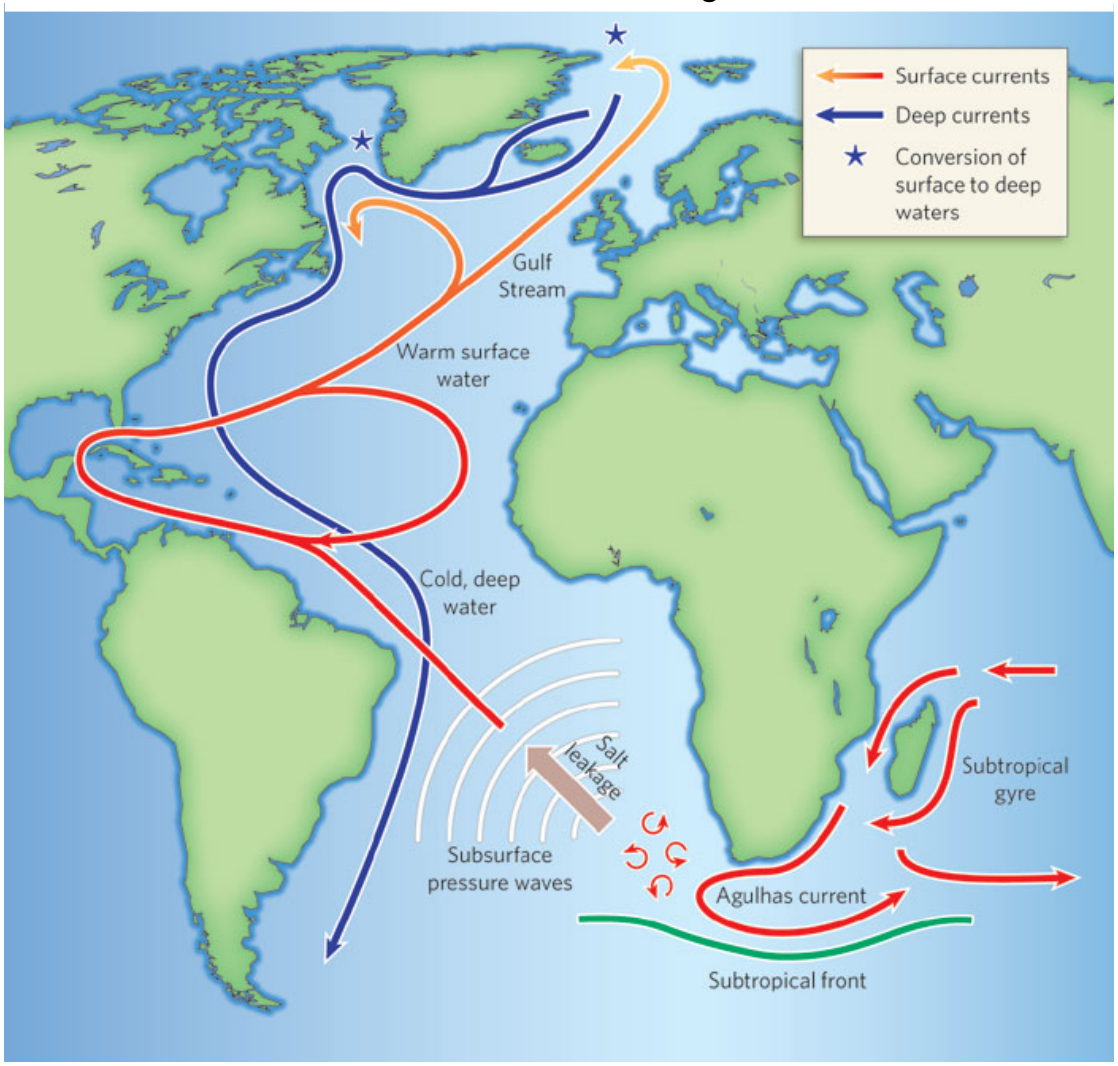
Francesco Nencioli, Giorgio Dall'Olmo





Motivation: AMOC and transport of Agulhas leakage

Atlantic Meridional Overturning Circulation



(from Zahn et al., Nature, 2009)

- **Agulhas region key component of the global ocean circulation**
- **Agulhas leakage** feeds surface branch of **AMOC**
- Connection between Indian and Atlantic basin
- Transported by Agulhas eddies across South Atlantic Ocean
- Efficiency of eddy-driven cross-basin transport still under debate
- Studies mainly based on model or altimetry data

Main Aim: Understand Agulhas ring transport efficiency

➔ Can we **quantify the effective contribution** of Agulhas rings to the Atlantic meridional overturning circulation (**AMOC**) from **in-situ observations**?

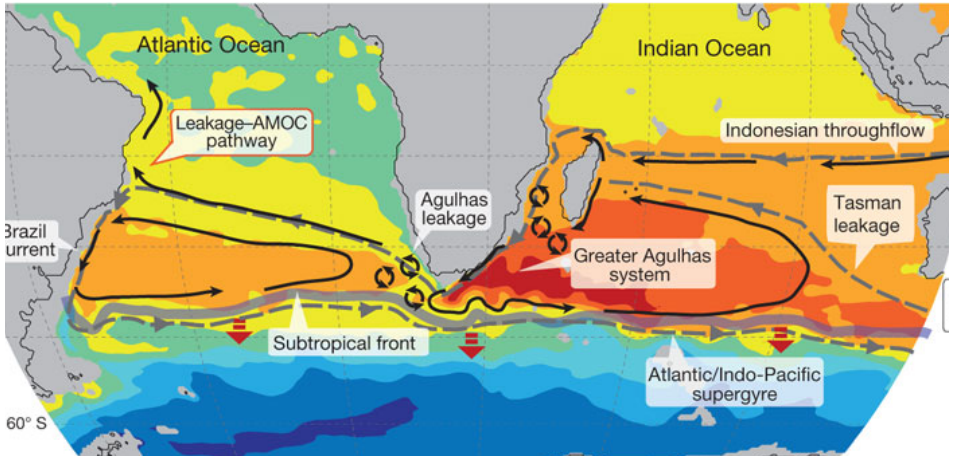
Objective 1: Quantify Agulhas ring transport and exchanges

➔ **How much** and **how far** Agulhas water is transported by the eddy?

➔ **Where** do exchanges occur?

Objective 2: Identify pathways of exchanged waters

➔ **Where** do the exchanged waters go?



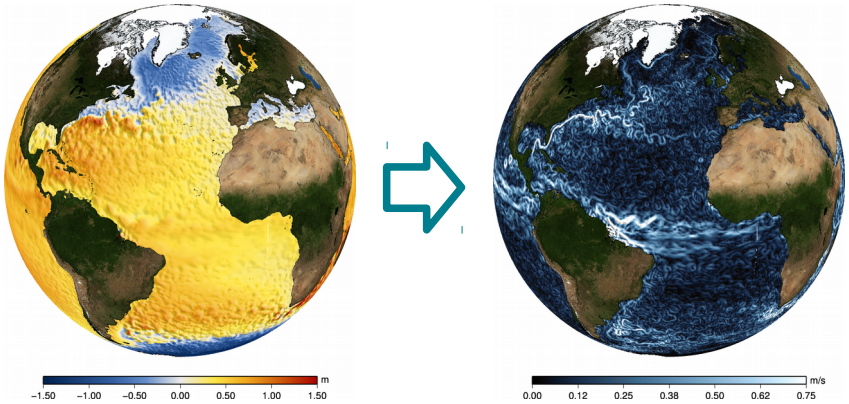
(from Beal et al., 2011)

Novel approach: Combine satellite and in-situ observations to investigate a specific mesoscale feature

1. Remote sensing: altimetry from AVISO

- **Global**, **cloud-free** measurements of sea-level anomaly
- **Daily** maps at **1/4 degree** resolution by combining multiple altimeter observations

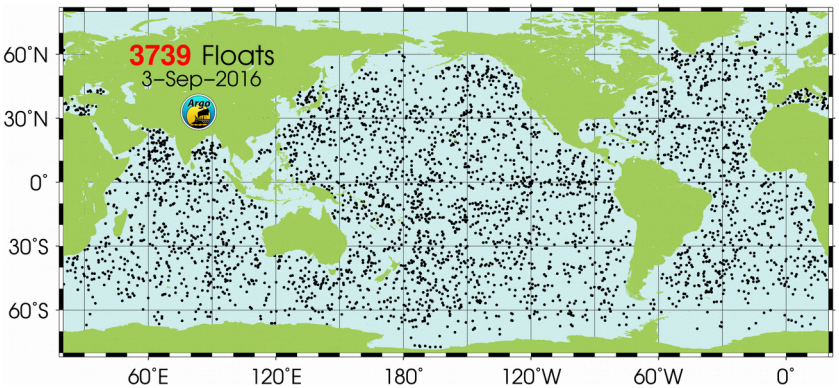
Absolute Dynamic Topography | **Surface Geostrophic Currents**

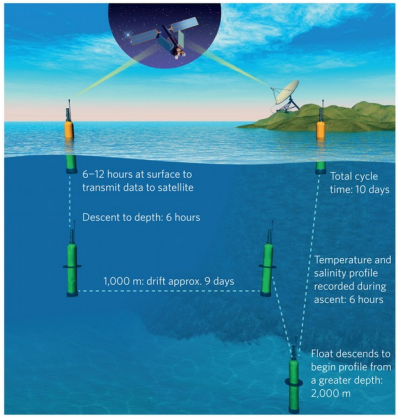


(all images from http://http://aviso.altimetry.fr)

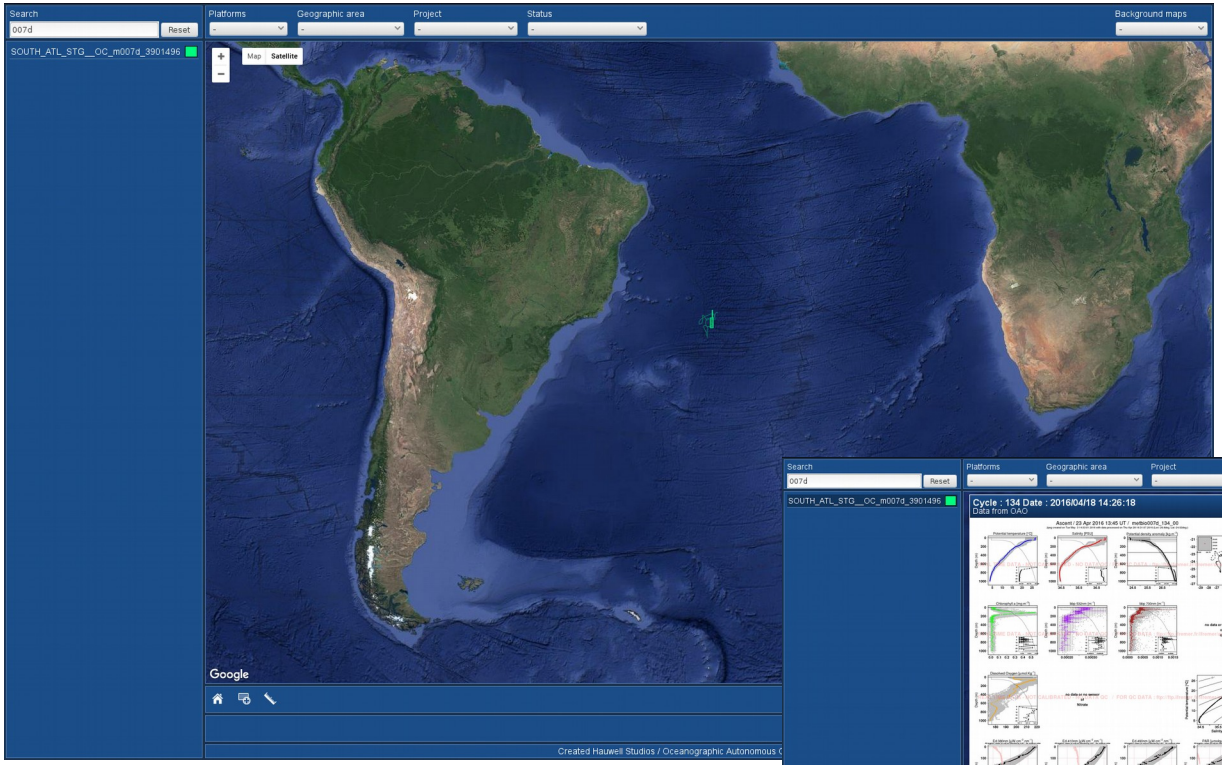
2. In-situ: observations from Argo

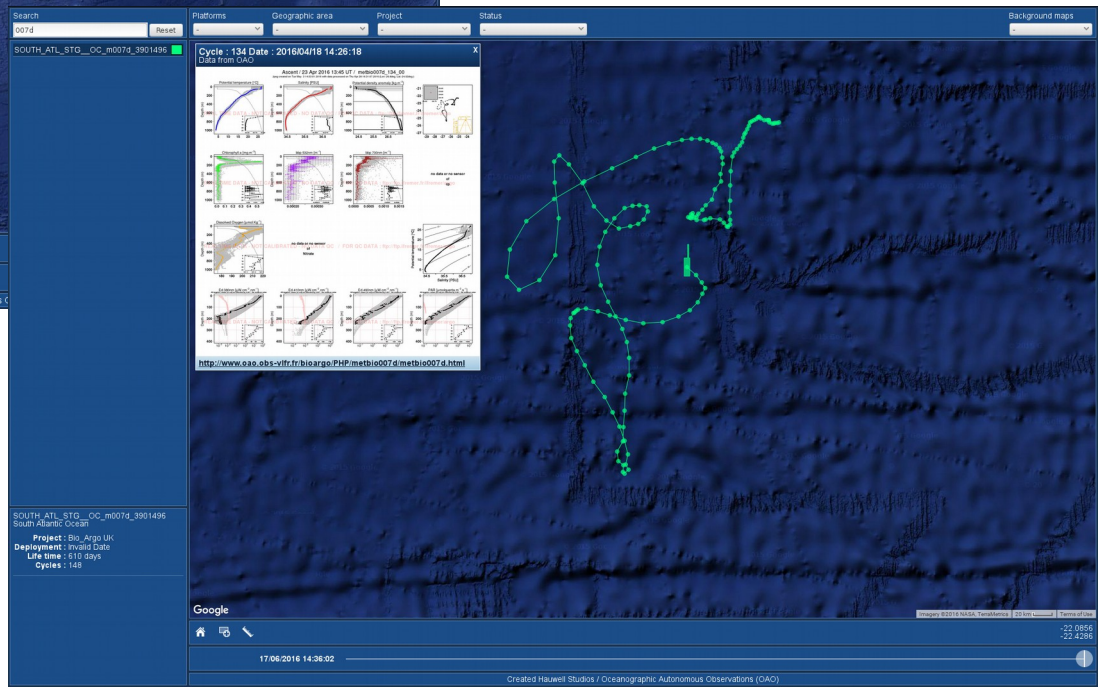
- **Global network** of **>3700** free-drifting profiling floats
- From each float **profiles of T and S** from **2000m depth** every **10 days**





Starting point: BioArgo float metbio007d





➔ Deployed in Oct 2014 during Atlantic Meridional Transect (AMT) 24

(from http://www.oao.obs-vlfr.fr/maps/en/)

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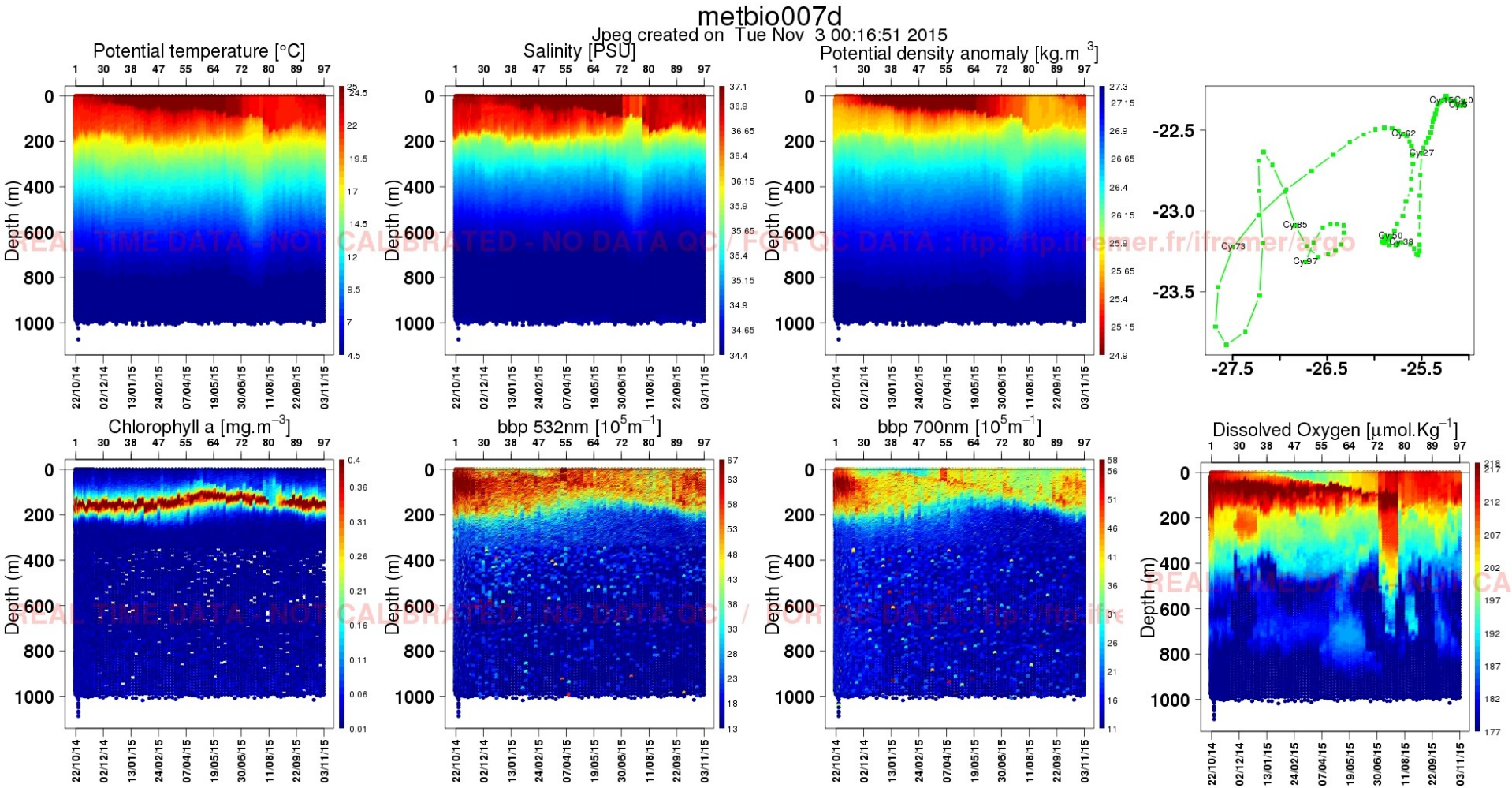
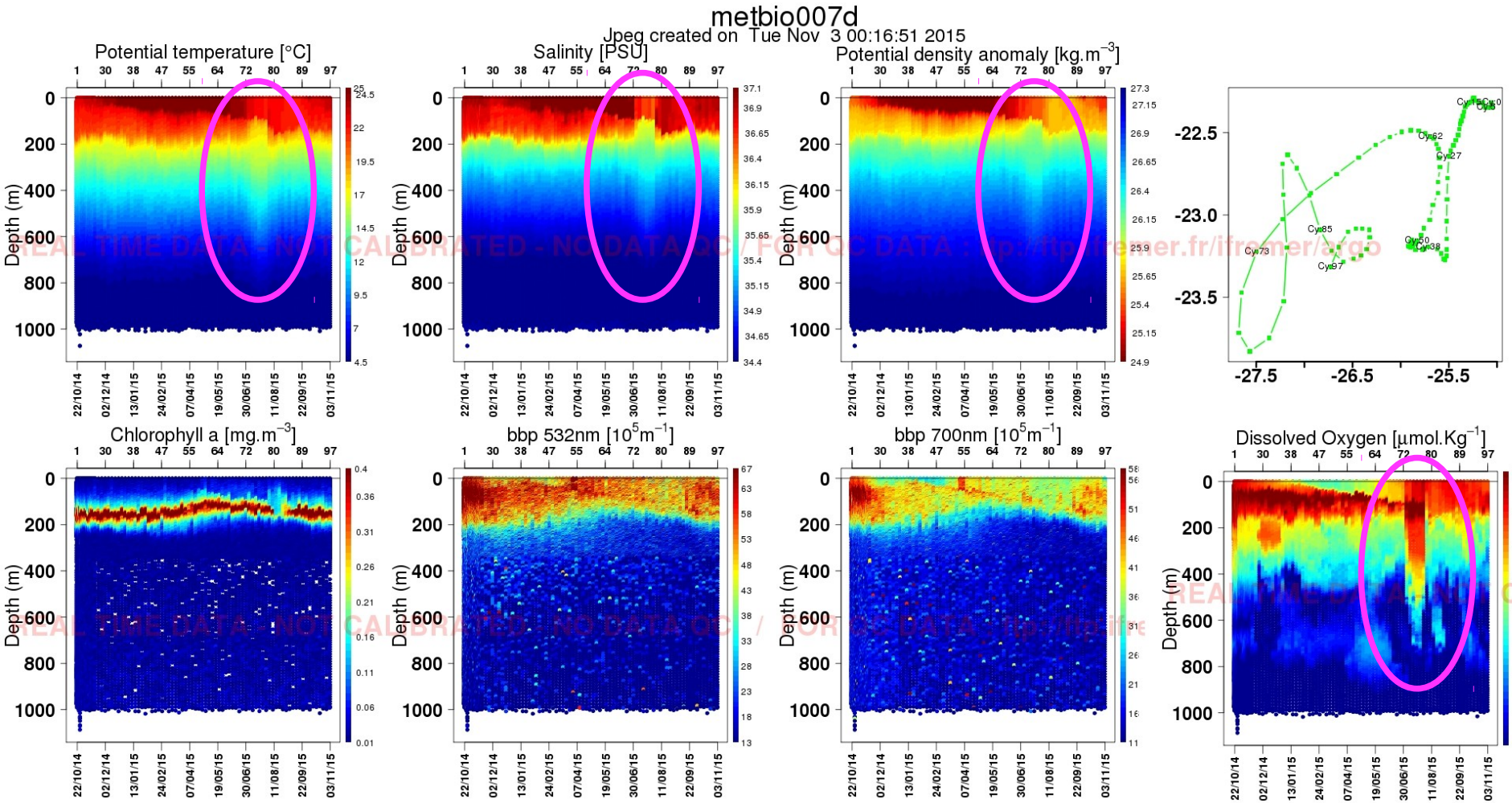


(from http://www.oao.obs-vlfr.fr/bioargo/PHP/metbio007d/metbio007d.html)

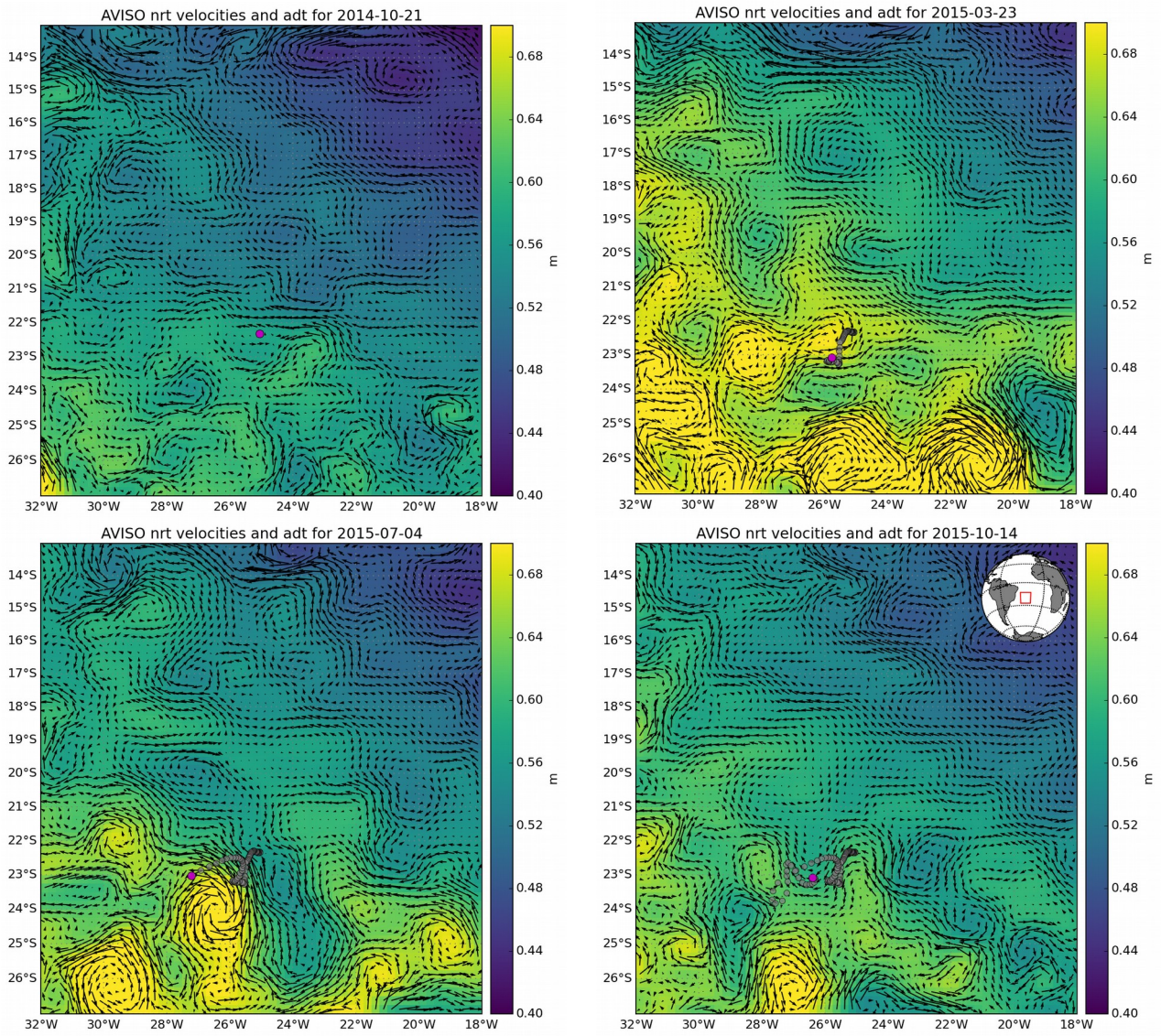
Starting point: BioArgo float metbio007d

➔ Strong **anomaly of physical and biogeochemical variables** in Jul-Aug 2015



(from http://www.oao.obs-vlfr.fr/bioargo/PHP/metbio007d/metbio007d.html)

Zoom Out 1: Origin of the anomaly?



- BioArgo float position over altimetry-based surface velocities (AVISO product)

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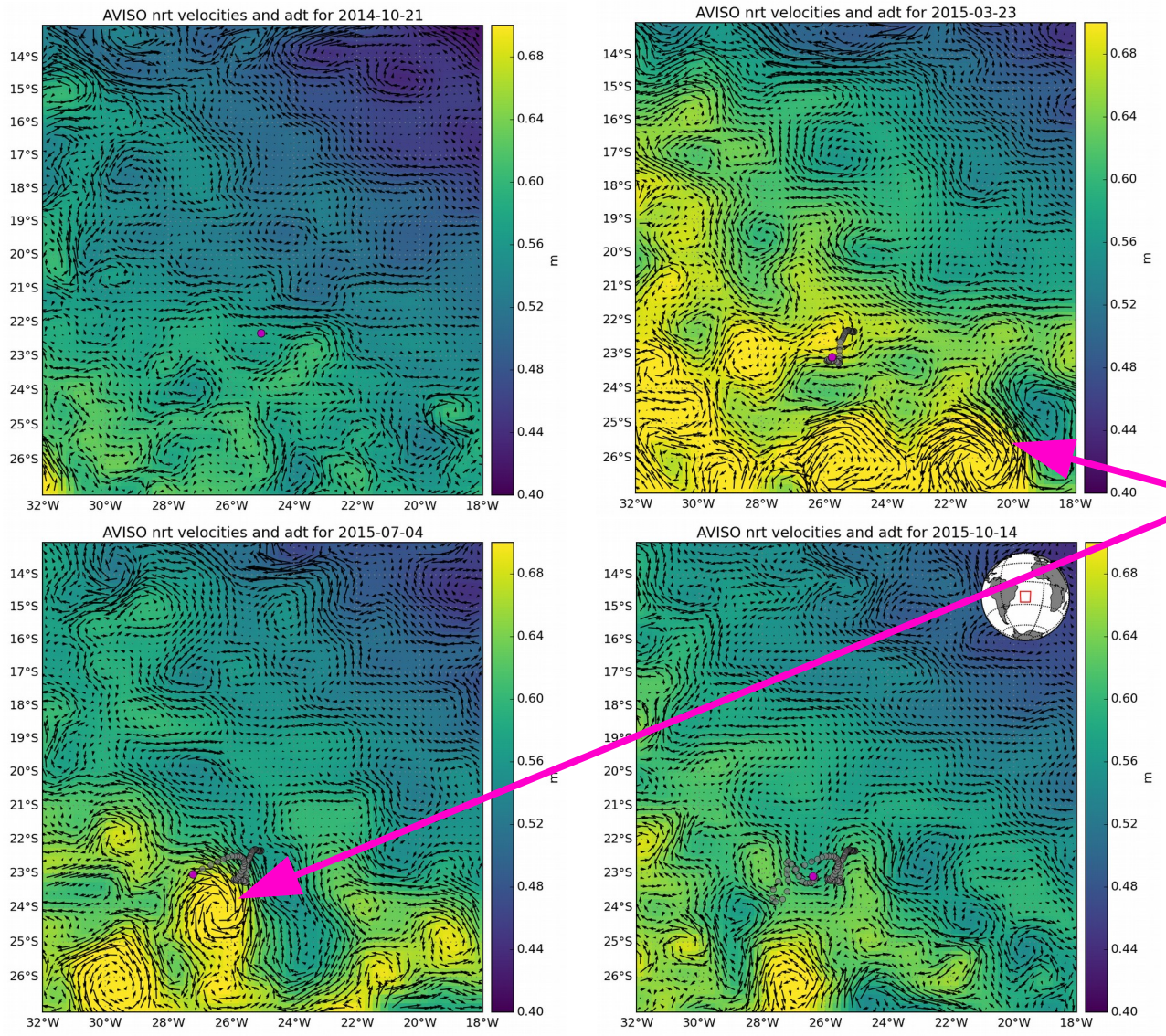
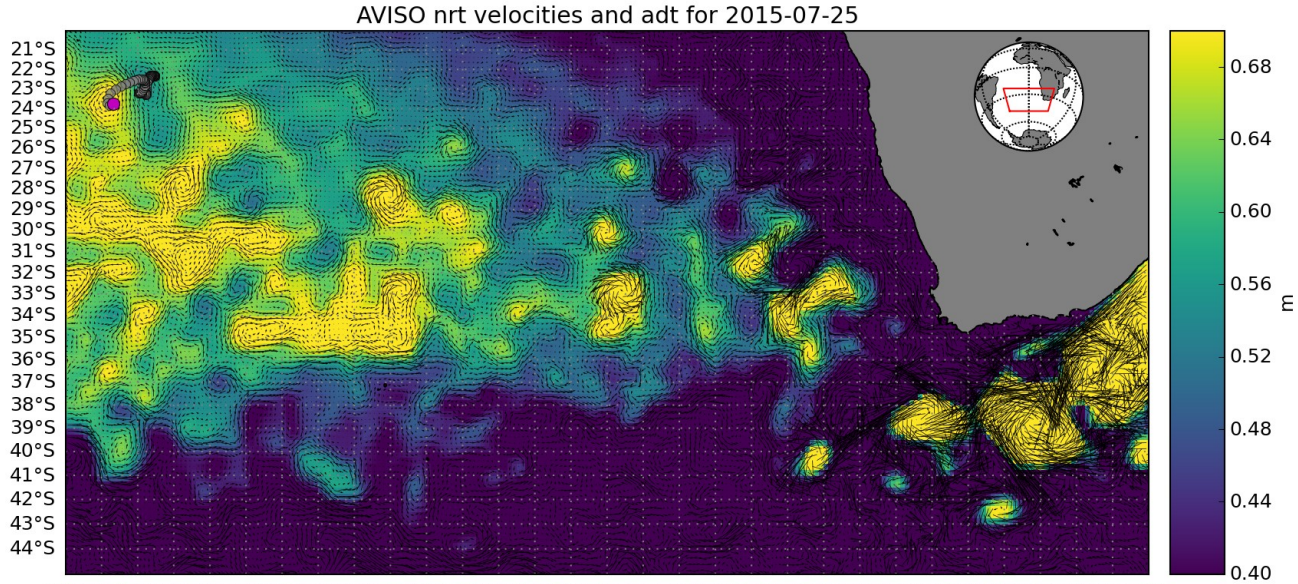
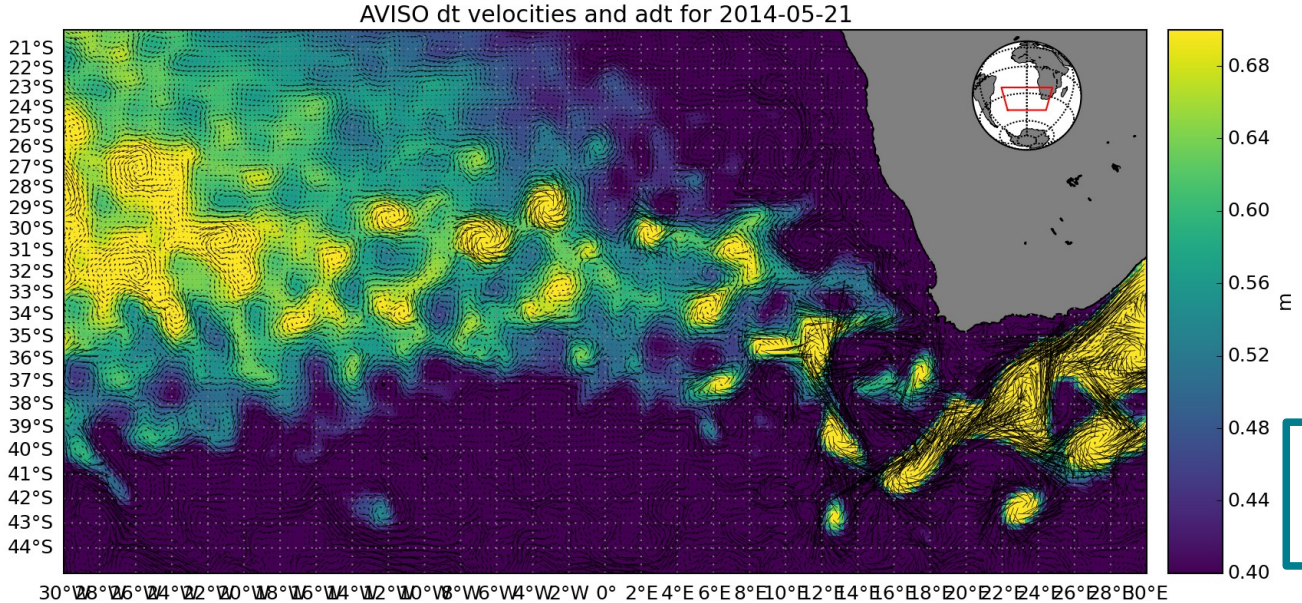


- BioArgo float position over altimetry-based surface velocities (AVISO product)
- Observed anomaly in O2, T and S is associated with **passage of a mesoscale eddy**

Zoom out 2: Origin of the eddy?



- Where did it come form?
- How old was it?
- Which waters were transported?



- Lots of eddy activity + long time-series

Automated detection

(from Nencioli et al. 2010)

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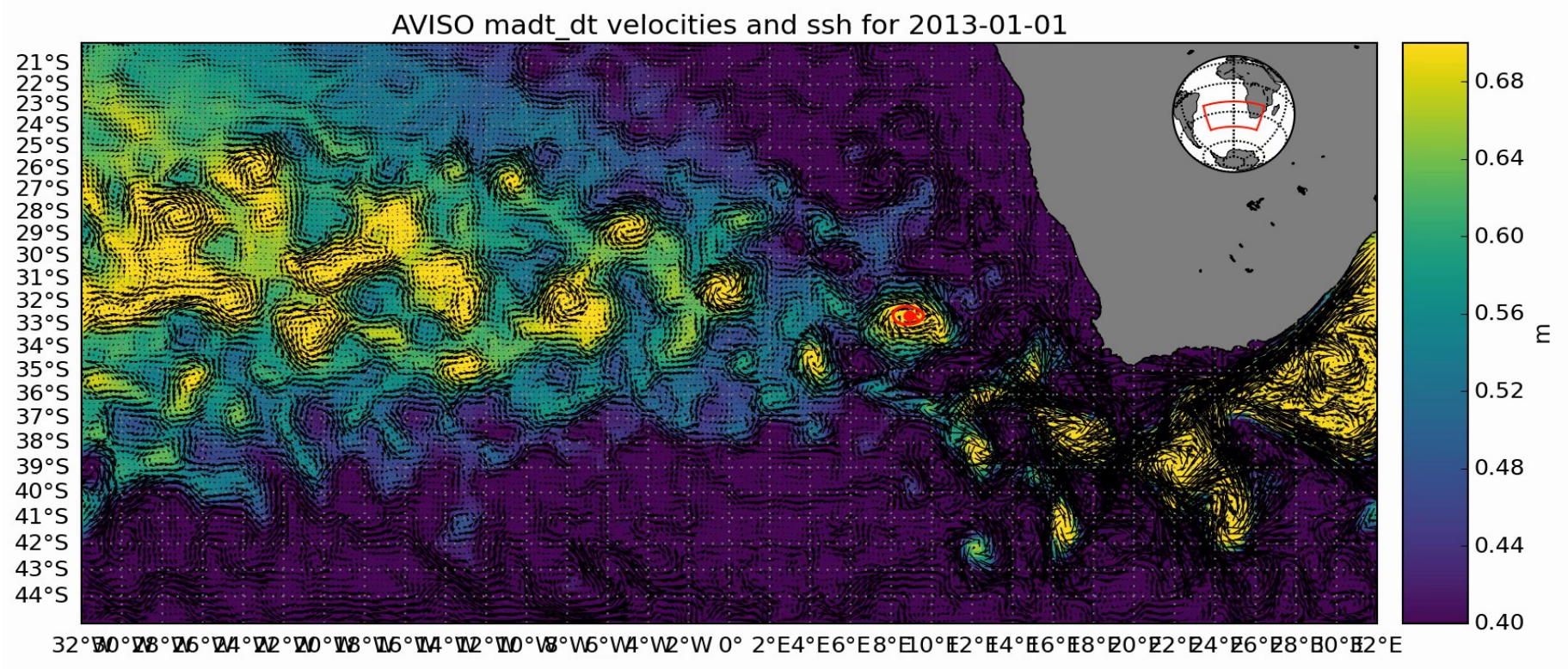

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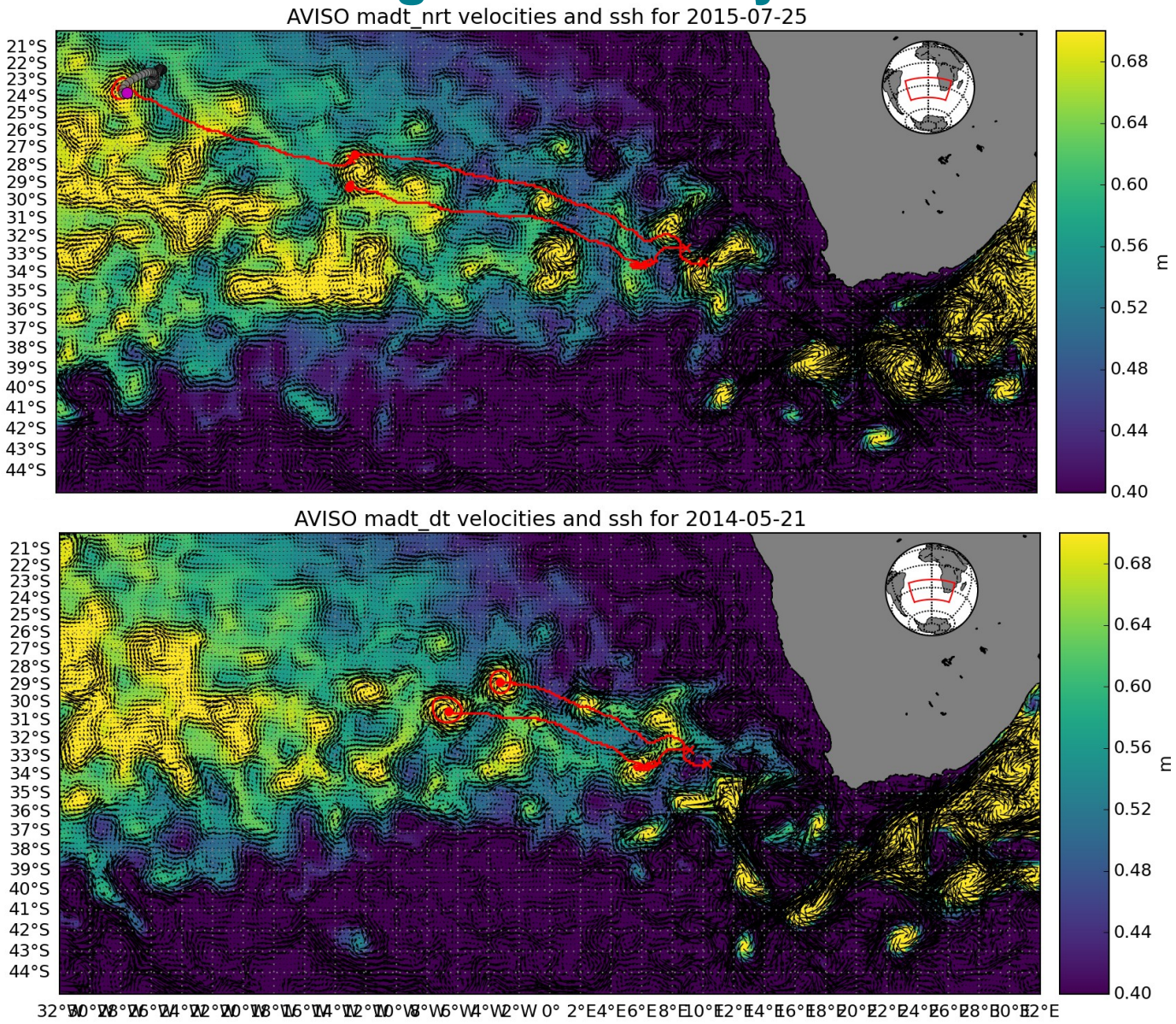
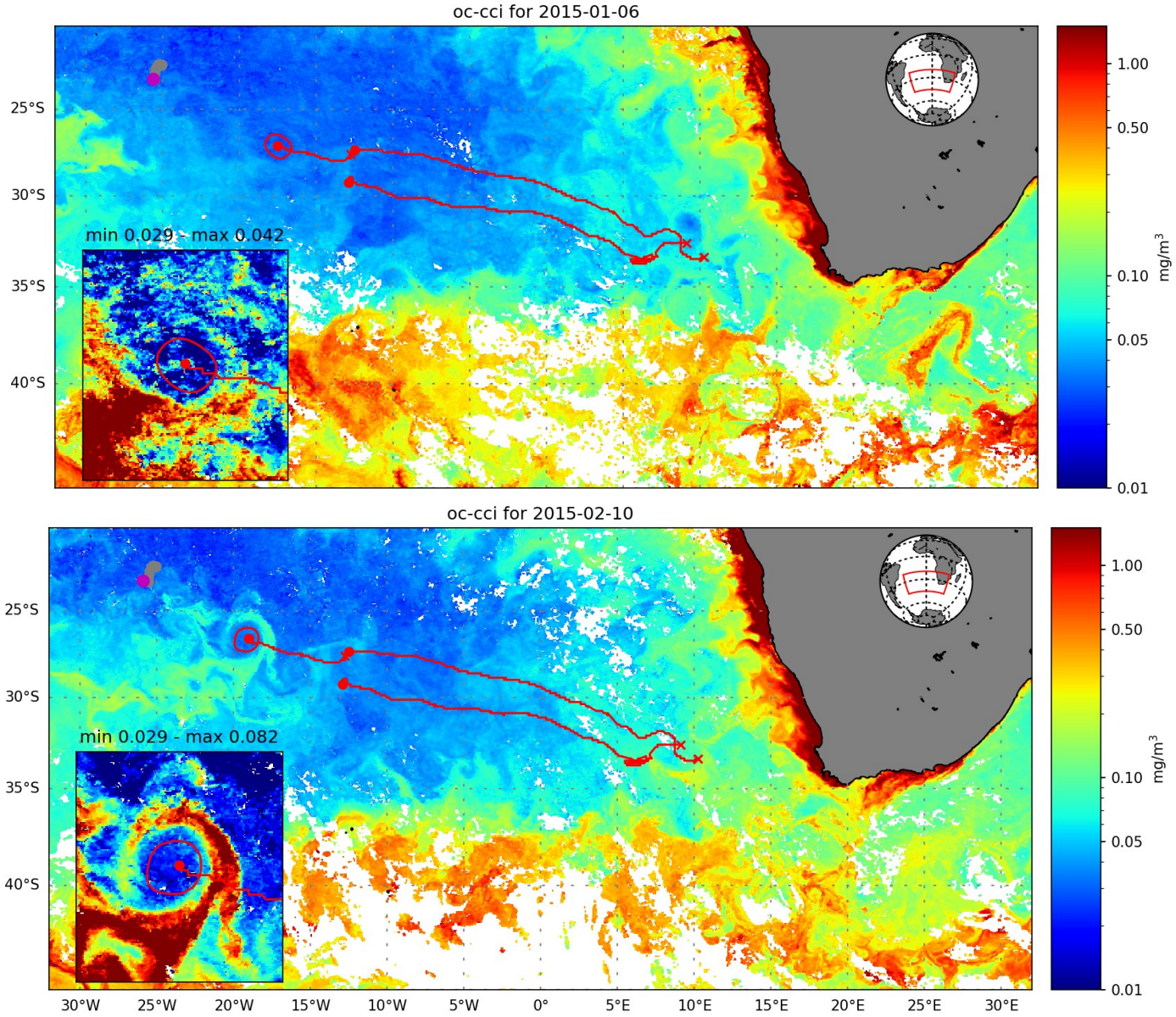


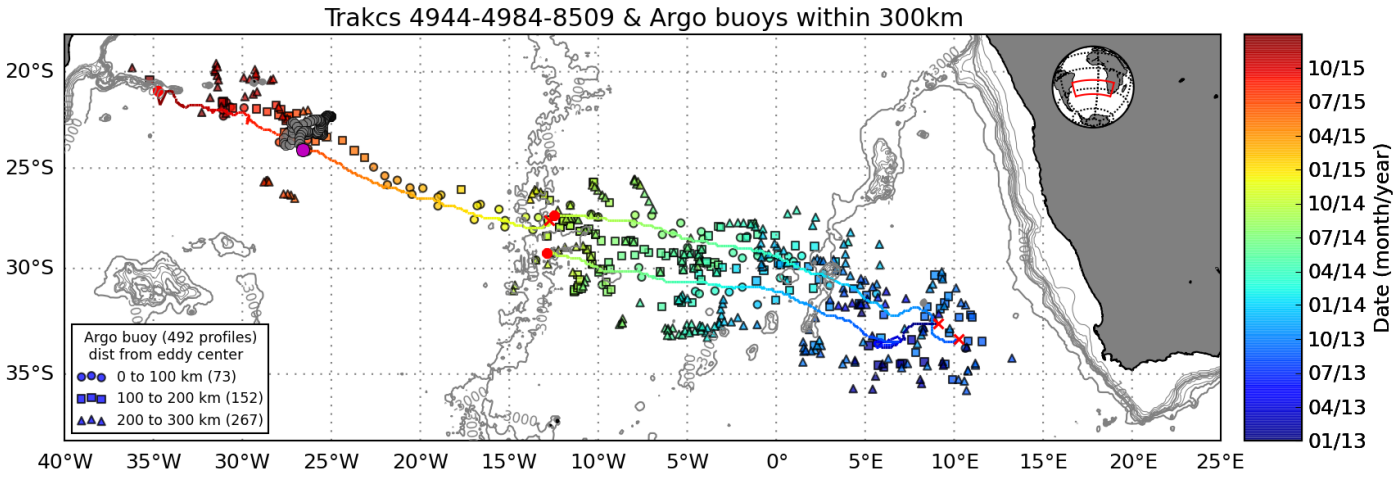
- Eddy sampled by BioArgo in Western South Atlantic on **Jul 2015**
- Originated by merging of two eddies from Agulhas region on **Oct 2014**
- Agulhas rings formed in Eastern South Atlantic on **Jan 2013**

Ocean colour CCI (8-day composites)



- Confirm **coherence of Agulhas ring**
- Core with lower chl-a concentrations
- Advection of higher chl-a filament around its core

In-situ: Argo observations within the eddy



➔ Retrieved Argo profiles within 400 km to the eddy centre along each eddy track

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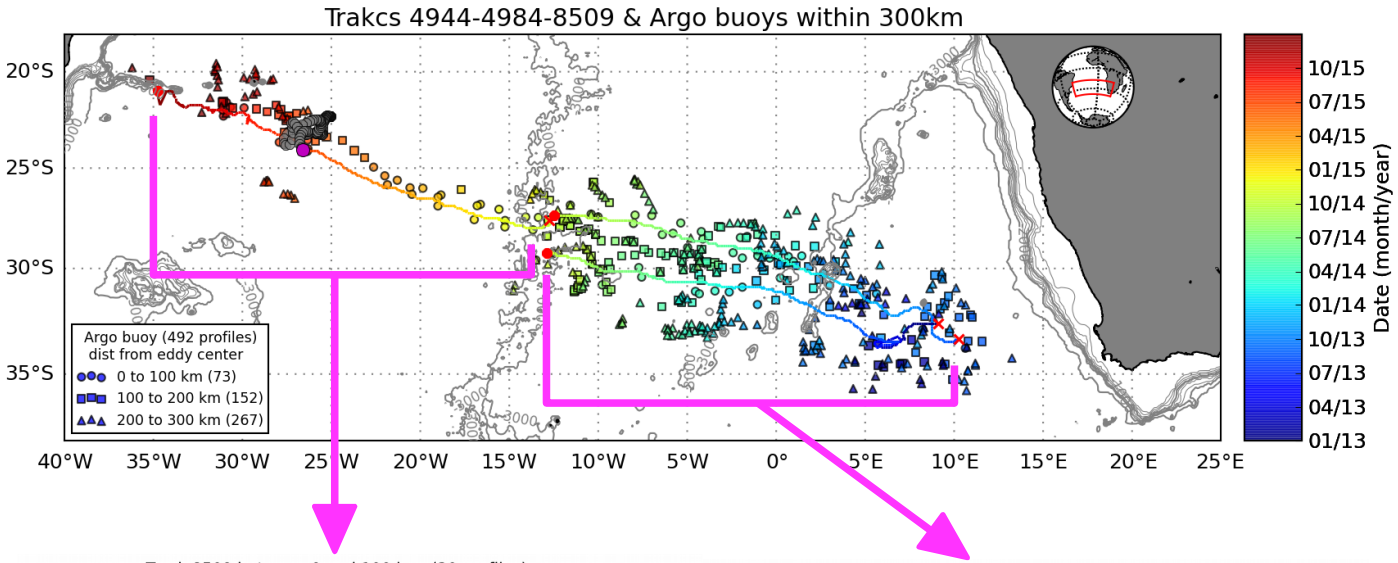

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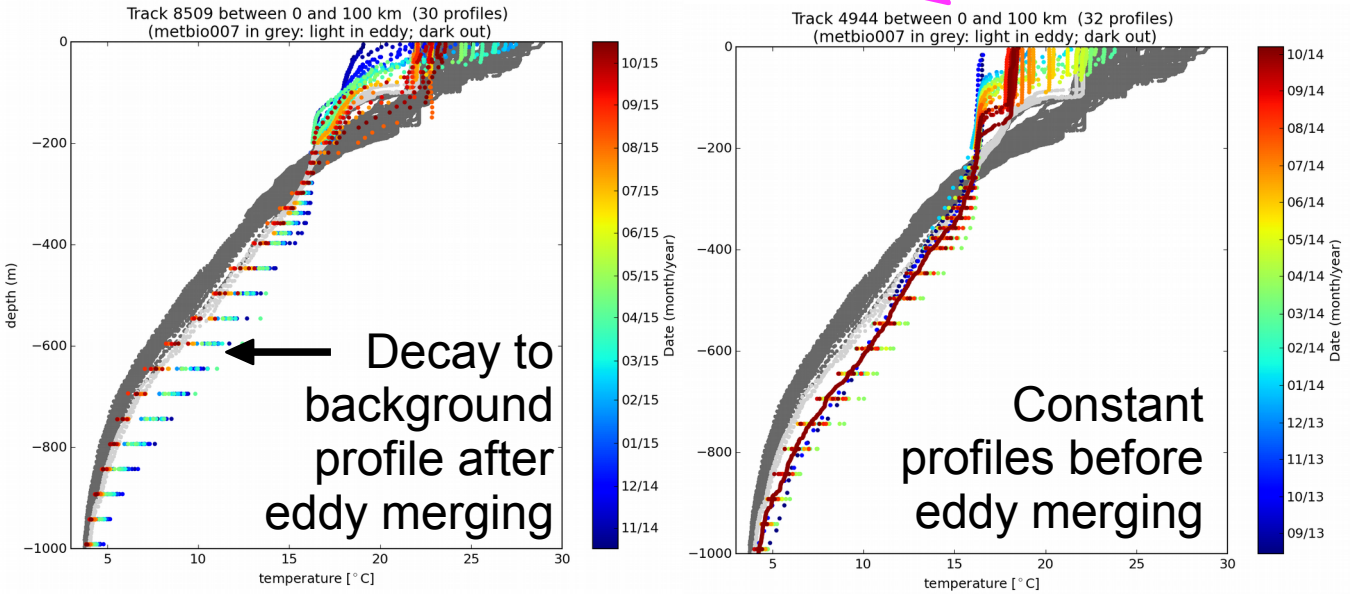


Temporal evolution of temperature profiles at eddy center (0 to 100 km)

Objective 1: Agulhas ring transport and exchanges

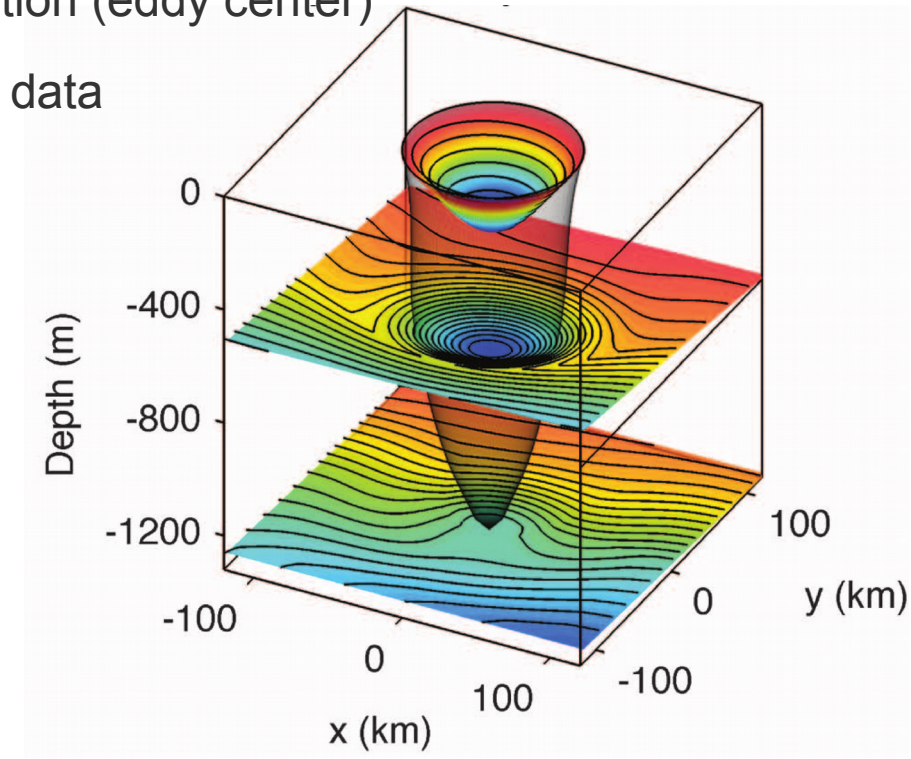
- **How much** and **how far** Agulhas water is transported by the eddy?
- **Where** do exchanges occur?

Reconstruct **volume** trapped within the Agulhas ring:

- Satellite provides only surface information (eddy center)
- 3D structure reconstructed using Argo data

Eddy associated with a pressure anomaly

It can be approximated by a depth-varying Gaussian shape



(from Zhang et al., 2014)

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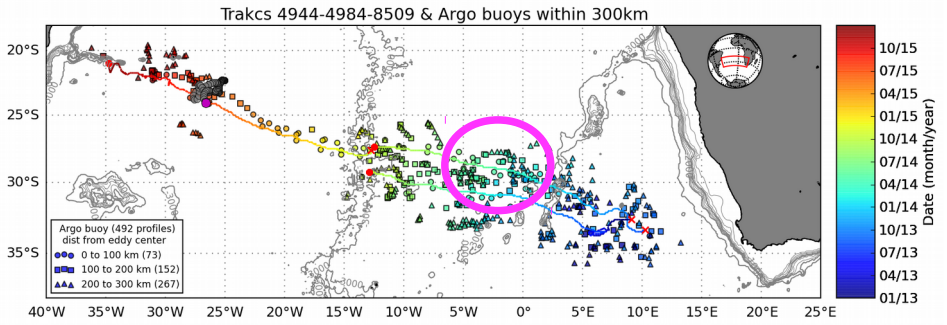
1. Use Argo profiles from a 3-mo. window within the time-series to **reconstruct sections across the eddy**



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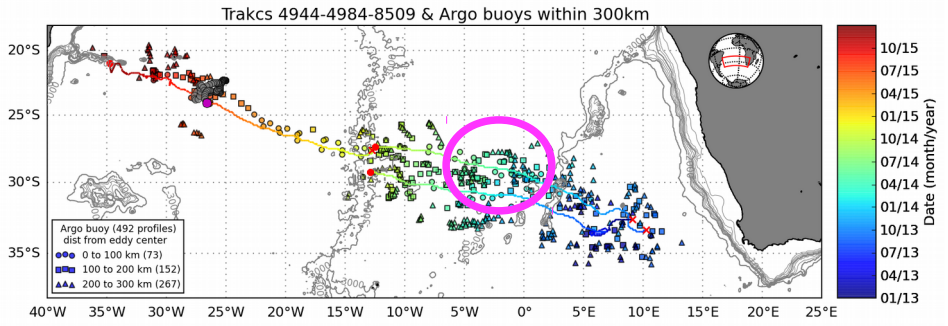

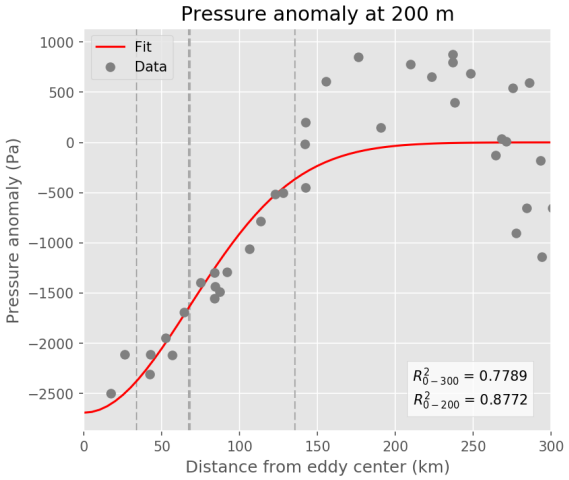

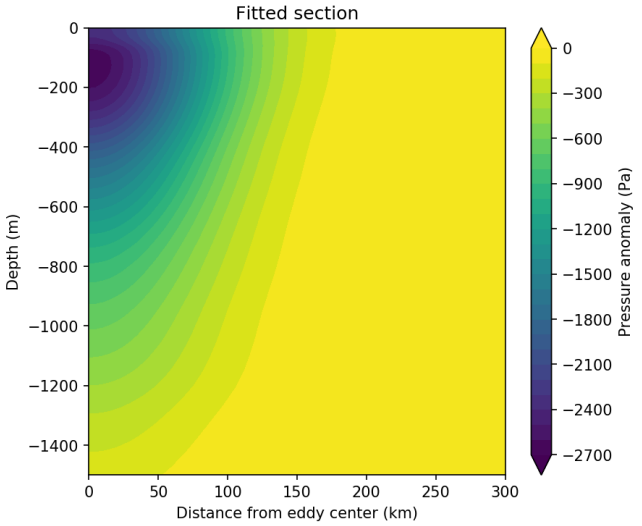

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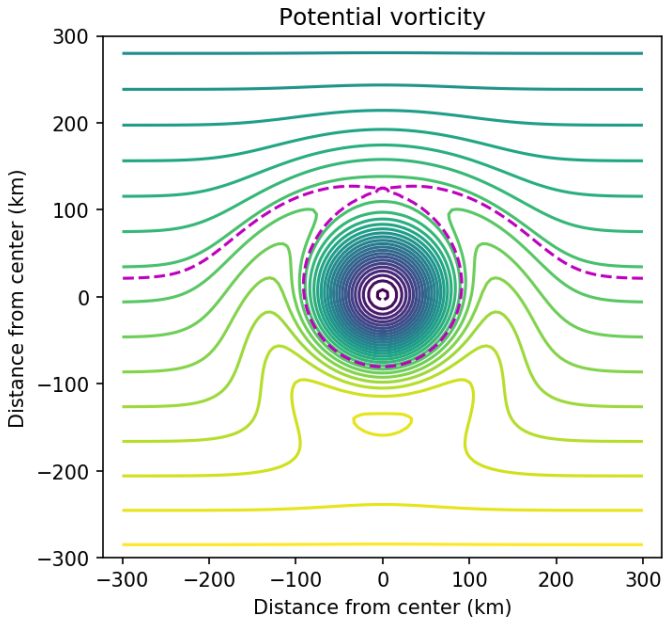
4. Define **eddy boundaries** with depth based on **potential vorticity**



$$v_\theta = \frac{1}{\rho f}\frac{\partial P}{\partial r} \Rightarrow \zeta = \frac{v_\theta}{r} + \frac{\partial v_\theta}{\partial r} \Rightarrow q = \frac{\partial \rho}{\partial z}(f + \zeta)$$

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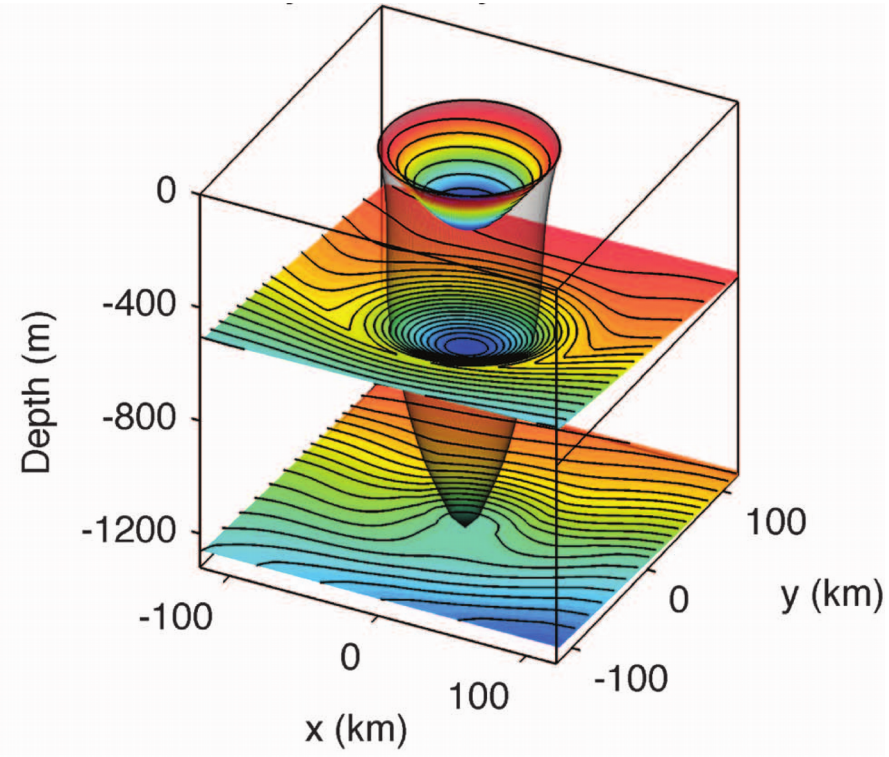
5. Compute the **total eddy volume** by integrating the resulting volumes at each depth

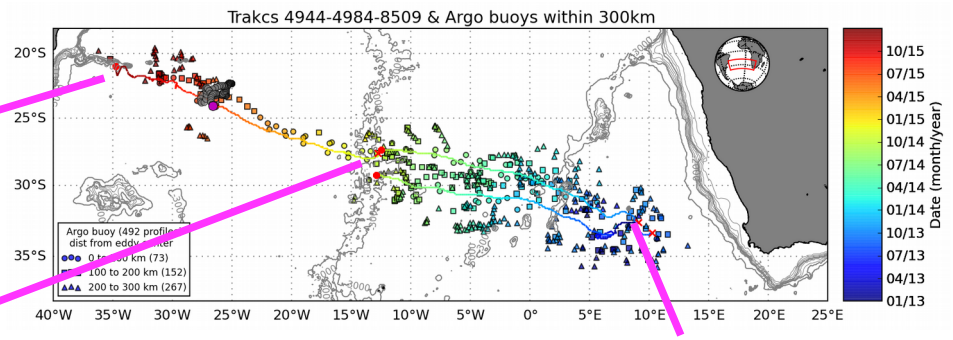


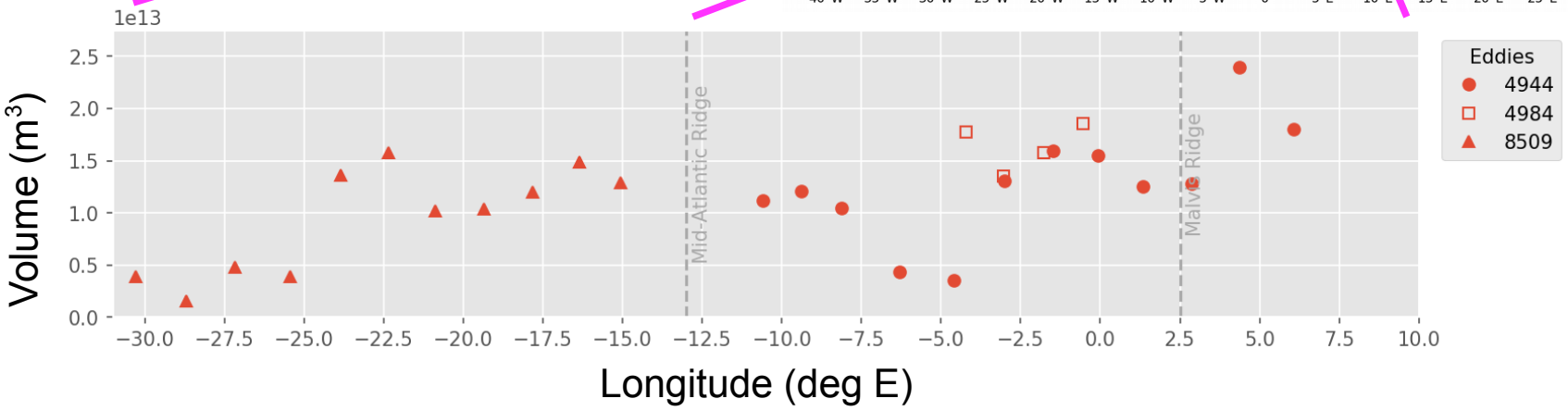
(from Zhang et al., 2014)

Results 1: Agulhas ring transport and exchanges

Time series of eddy volume

(Gaussian fit at various succesive months completely automated and unsupervised)





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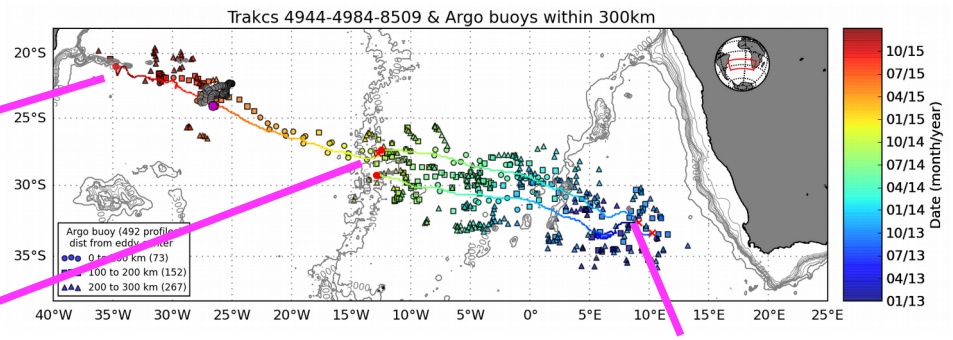

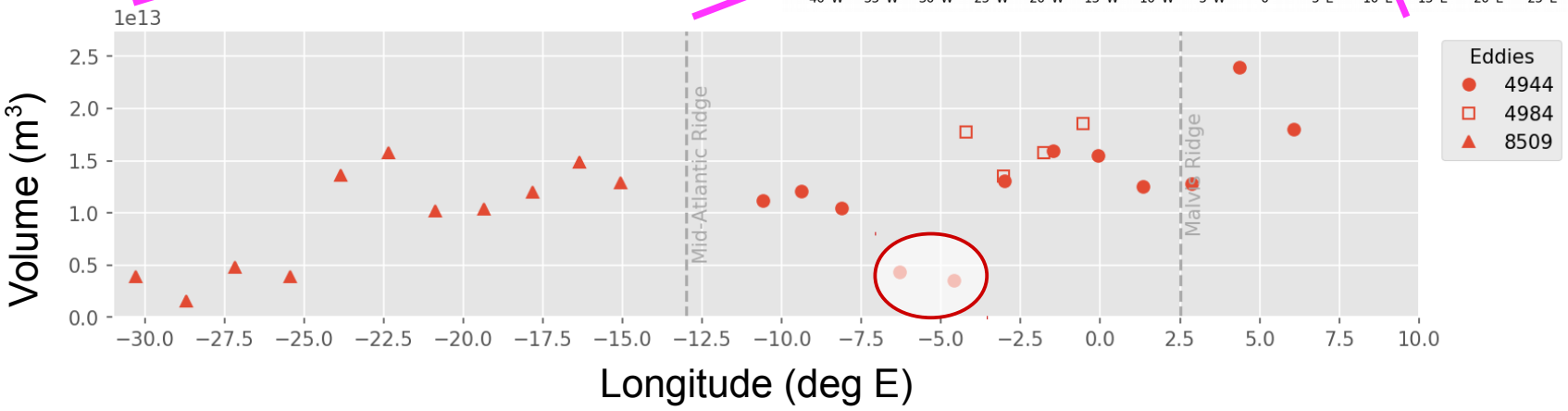

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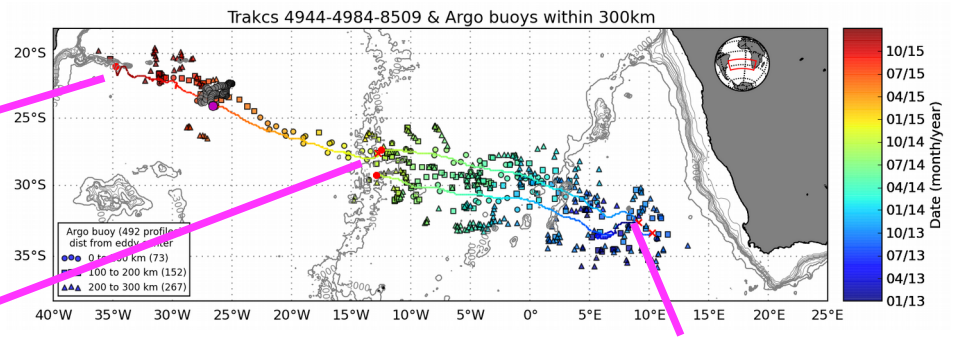

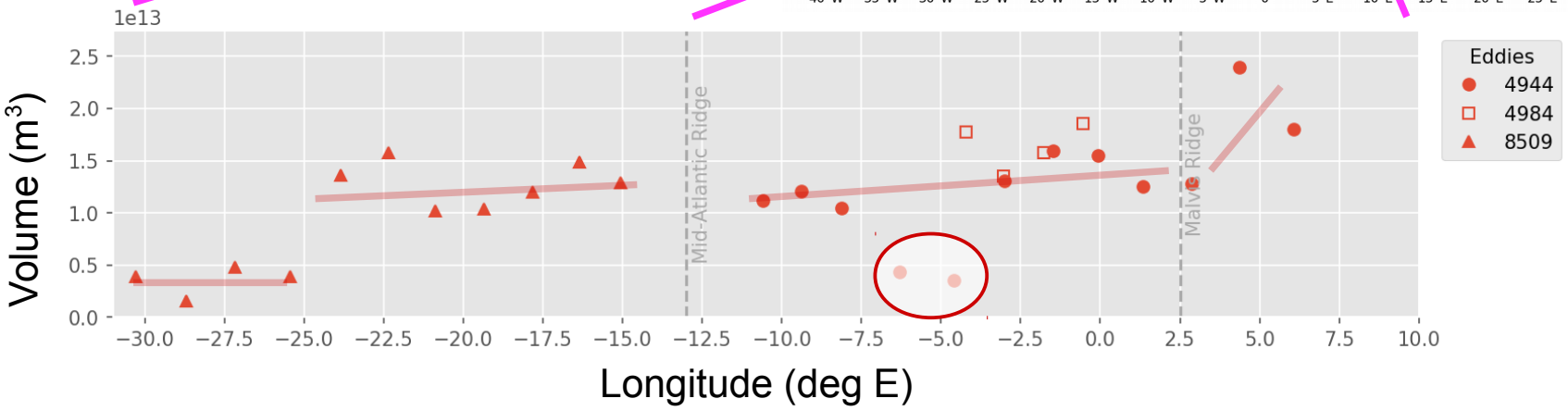

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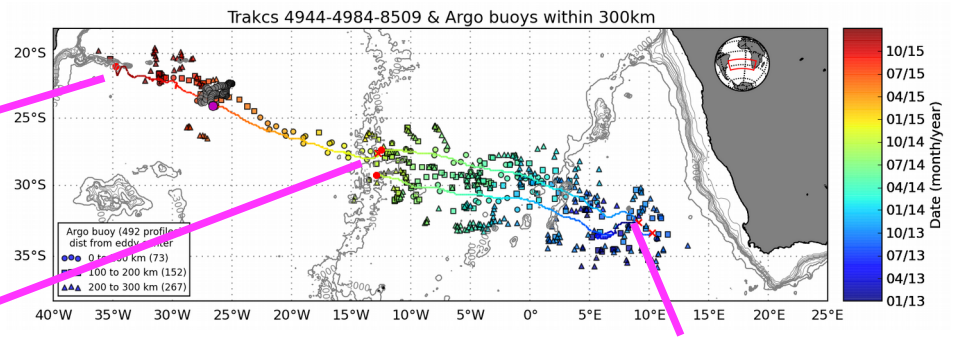

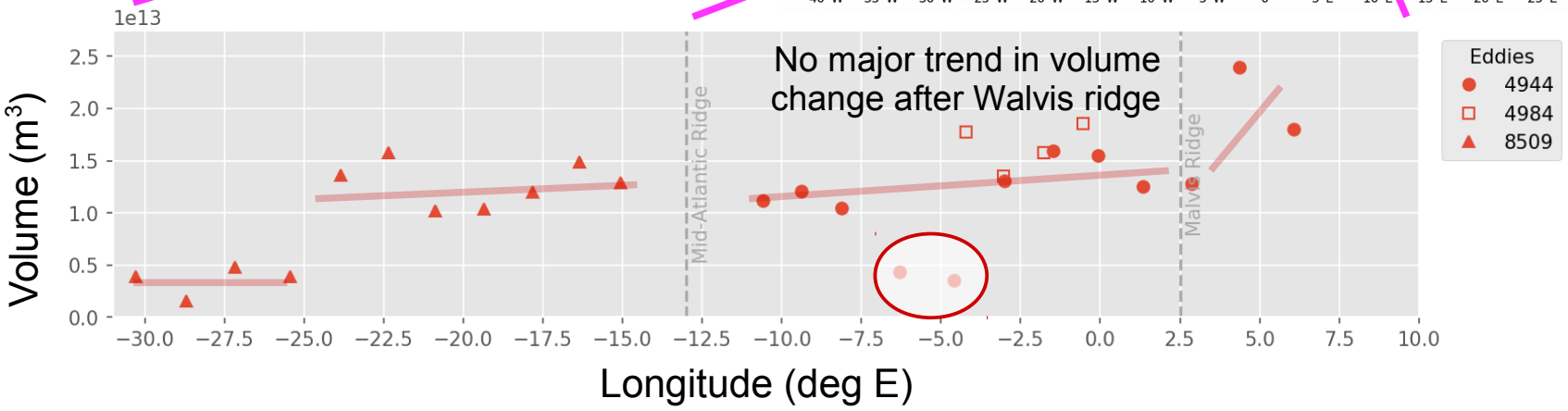

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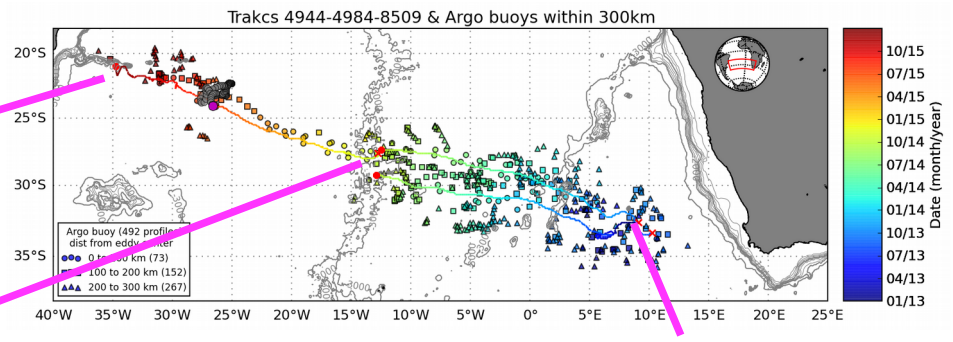

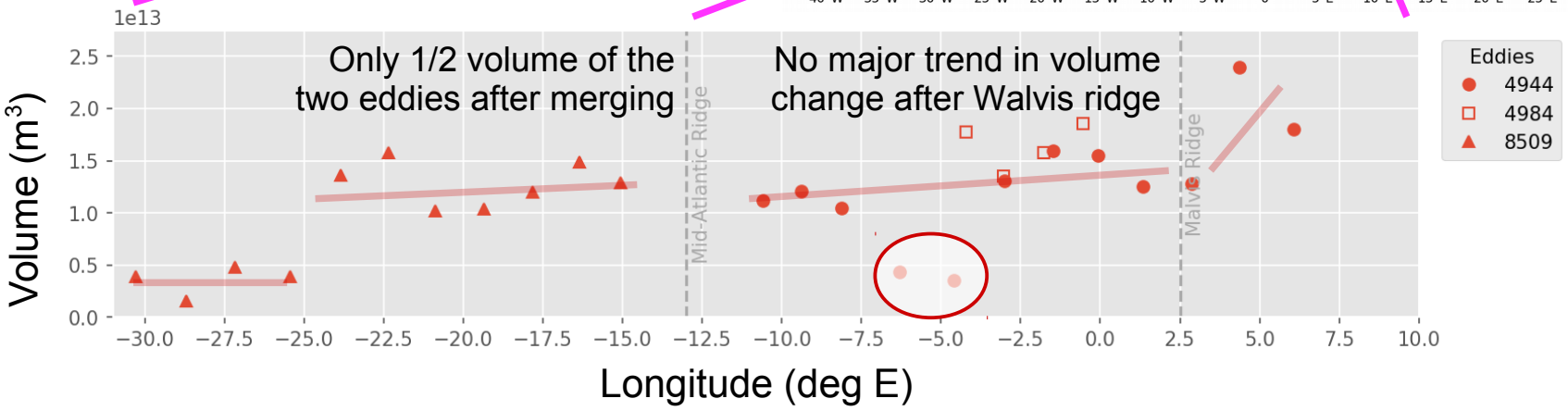

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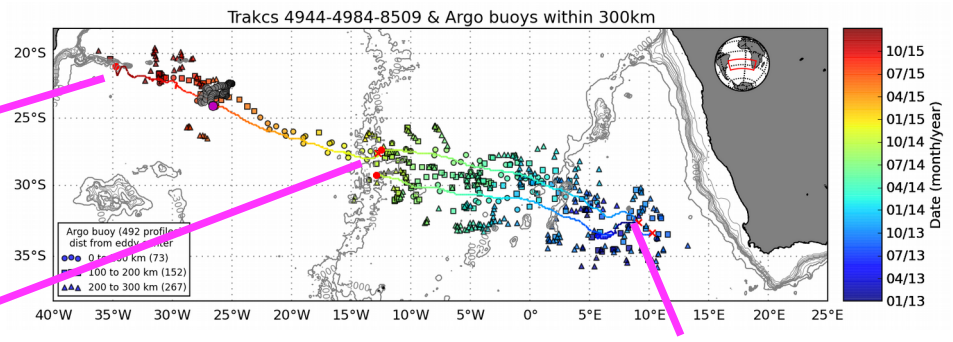

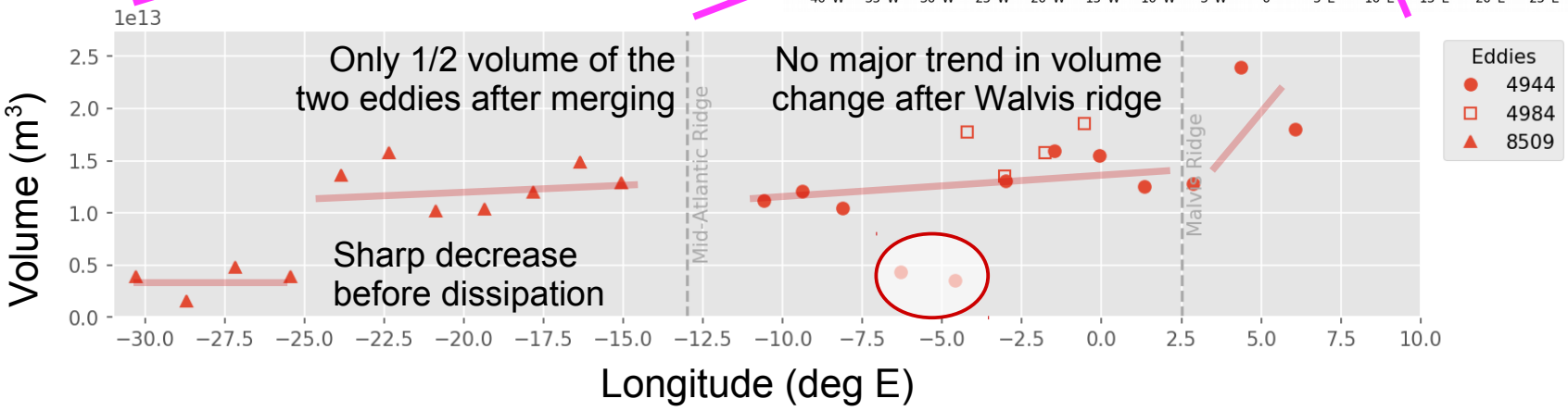

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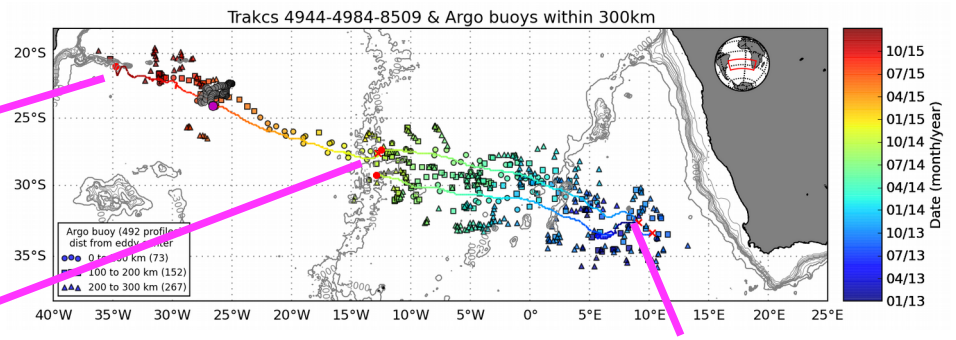

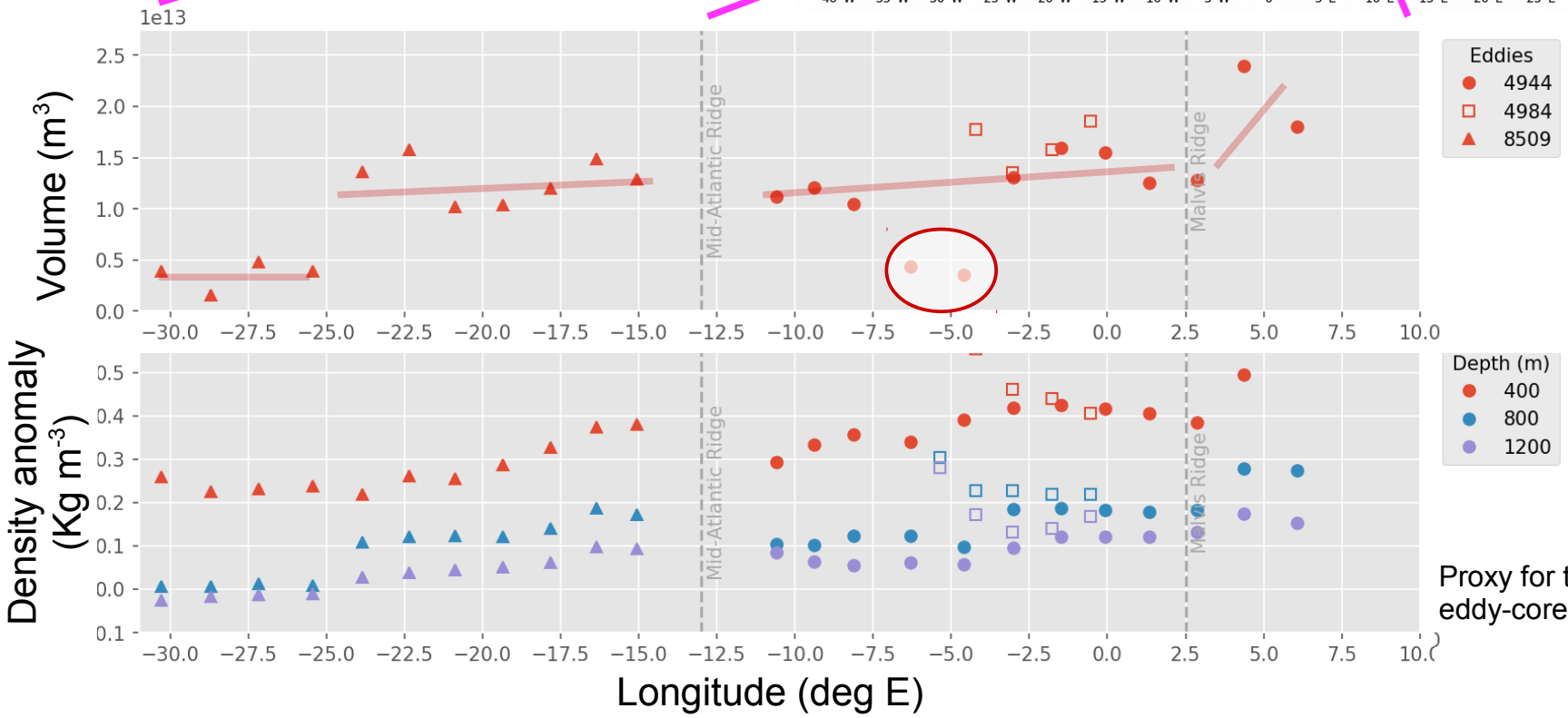

Proxy for type of eddy-core water

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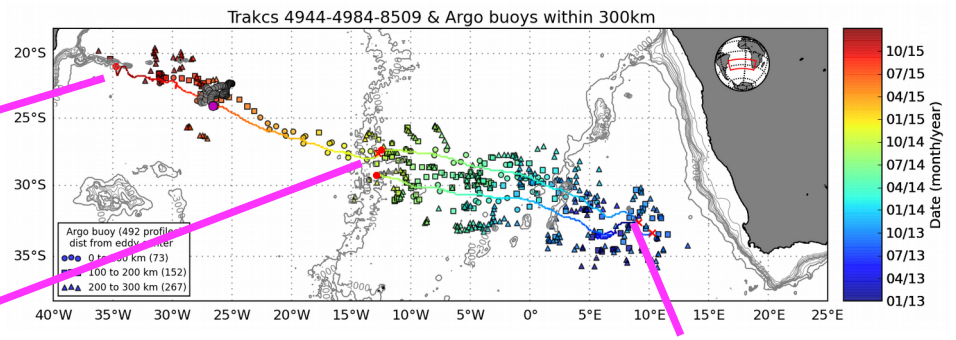

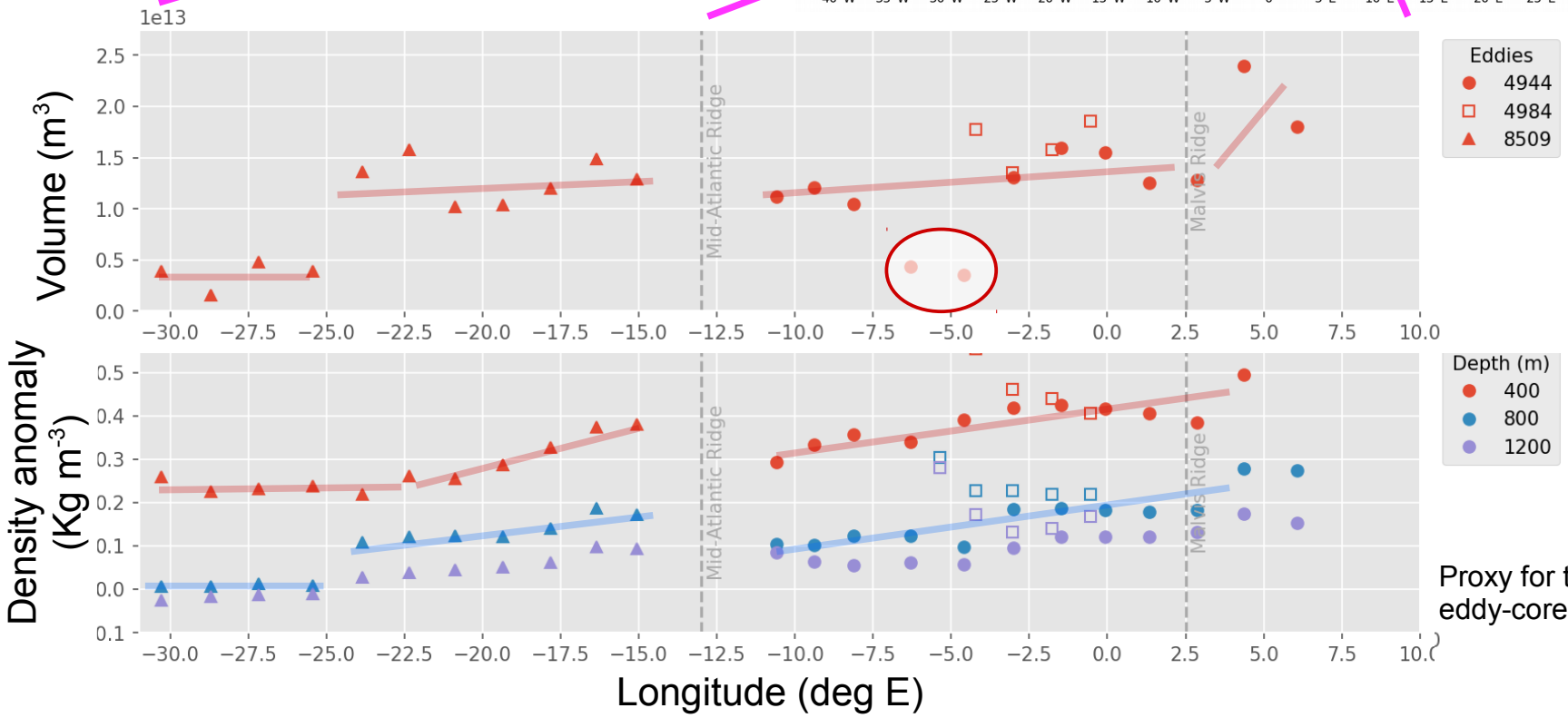

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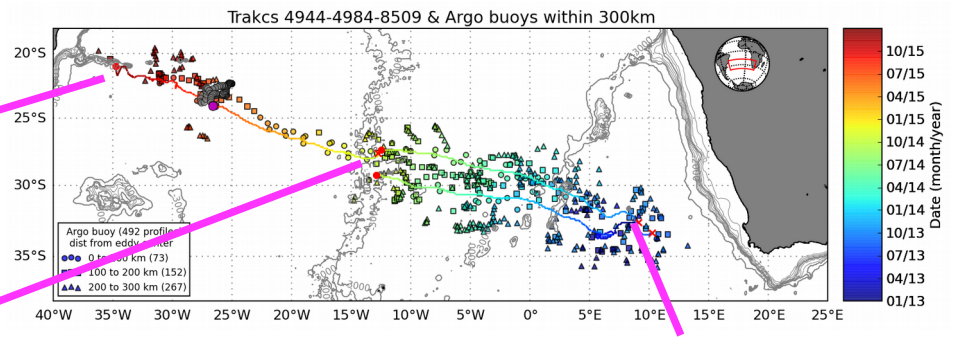

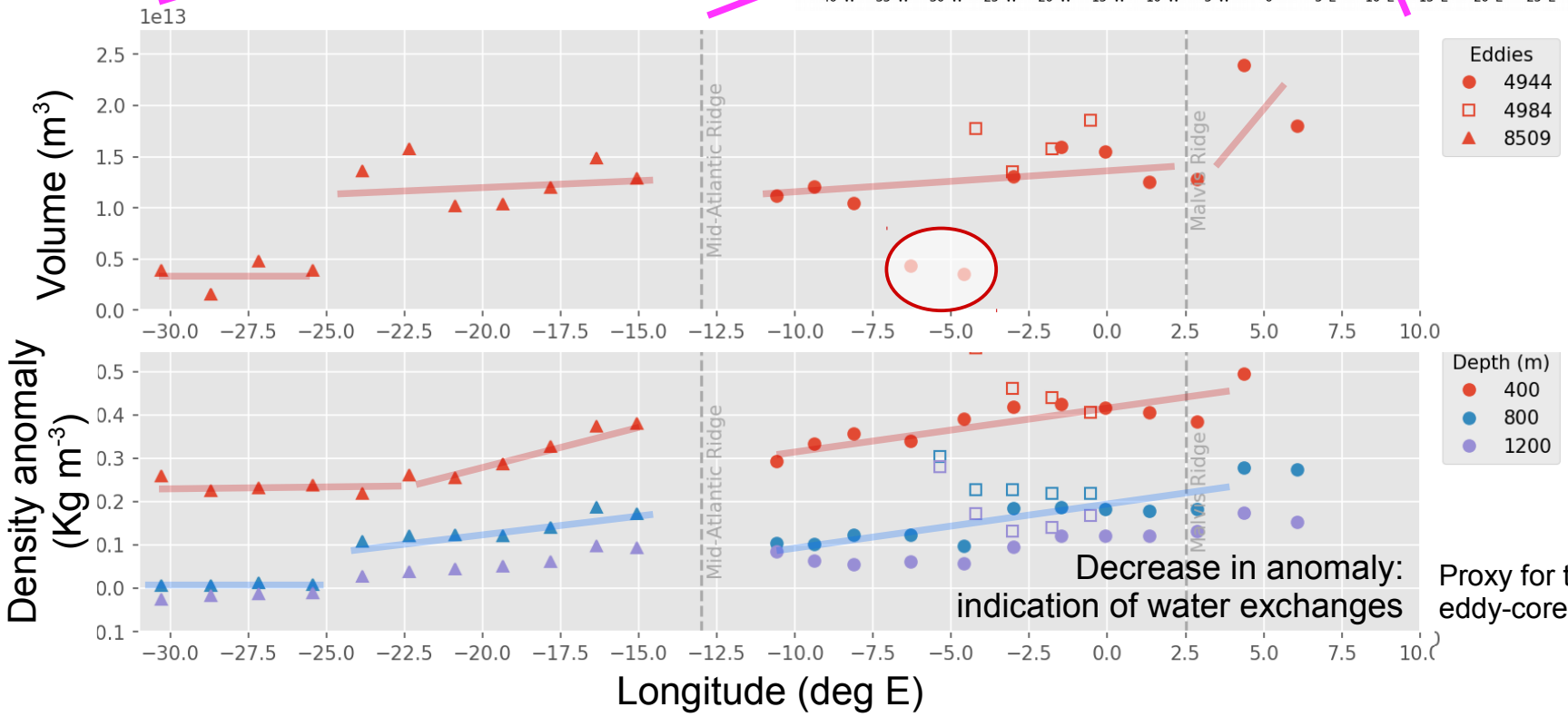

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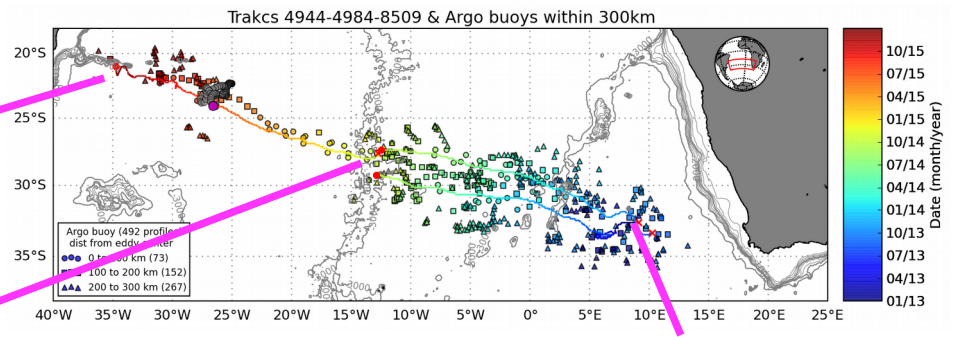
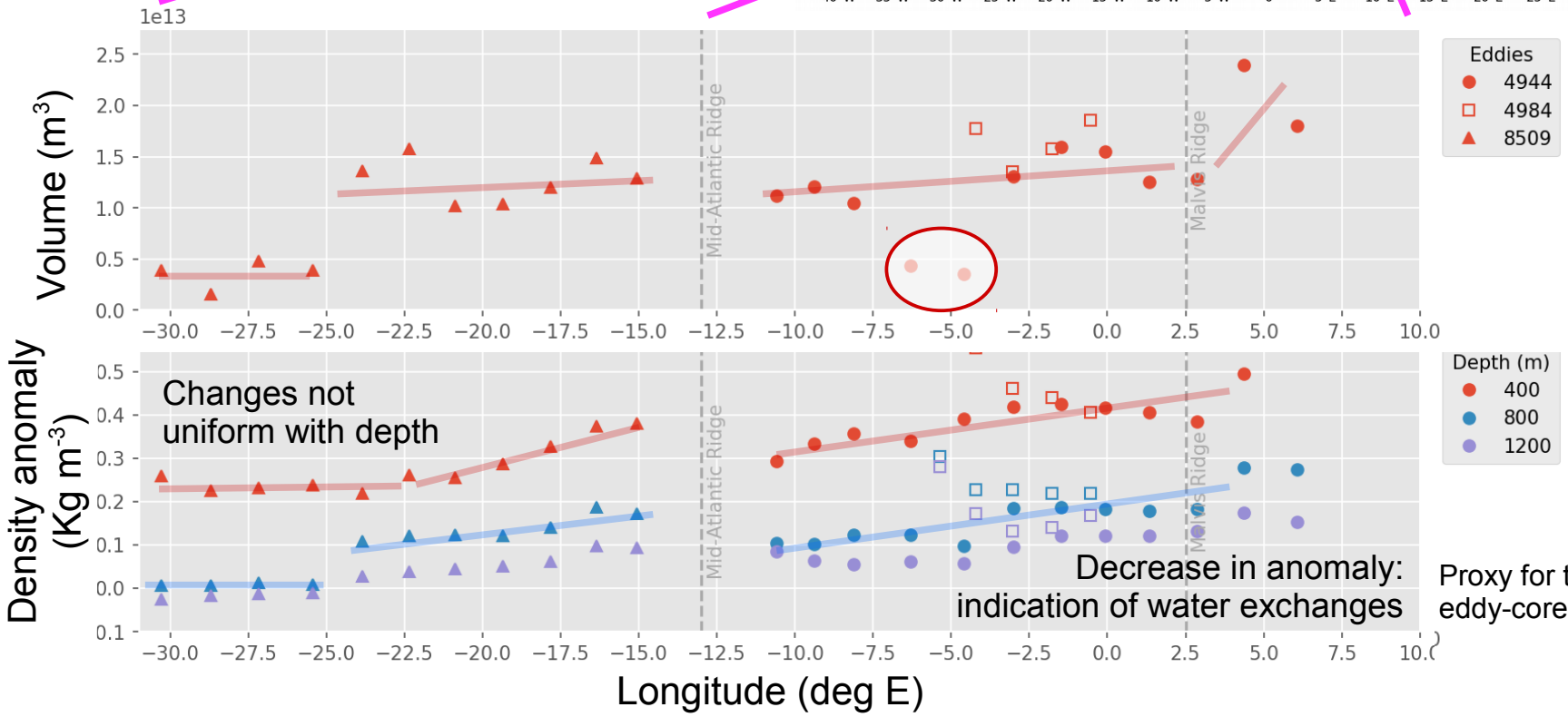
Time series of eddy volume

(Gaussian fit at various succesive months completely automated and unsupervised)



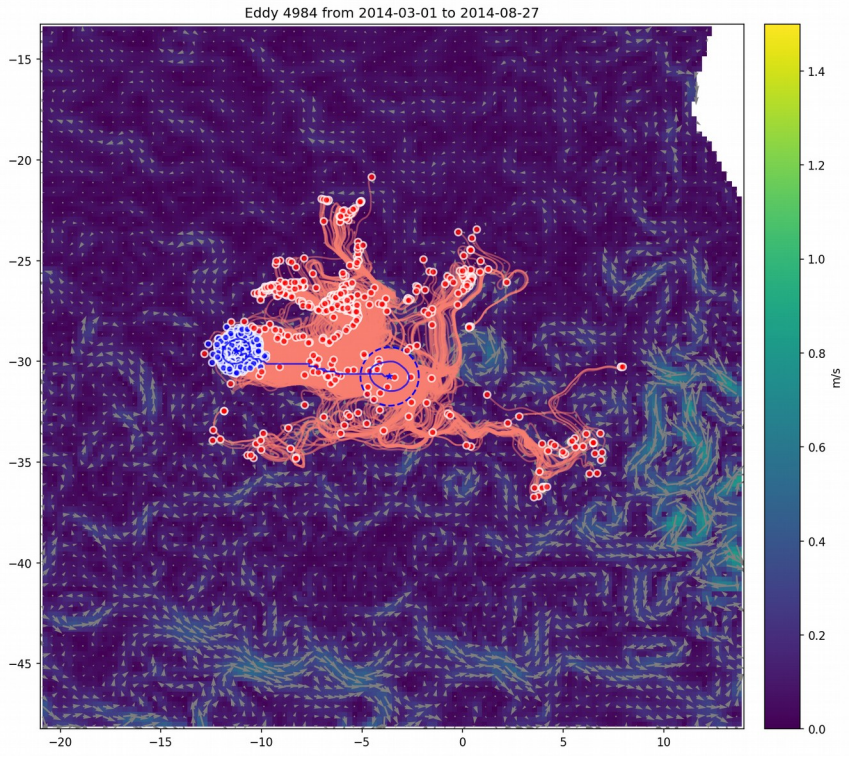


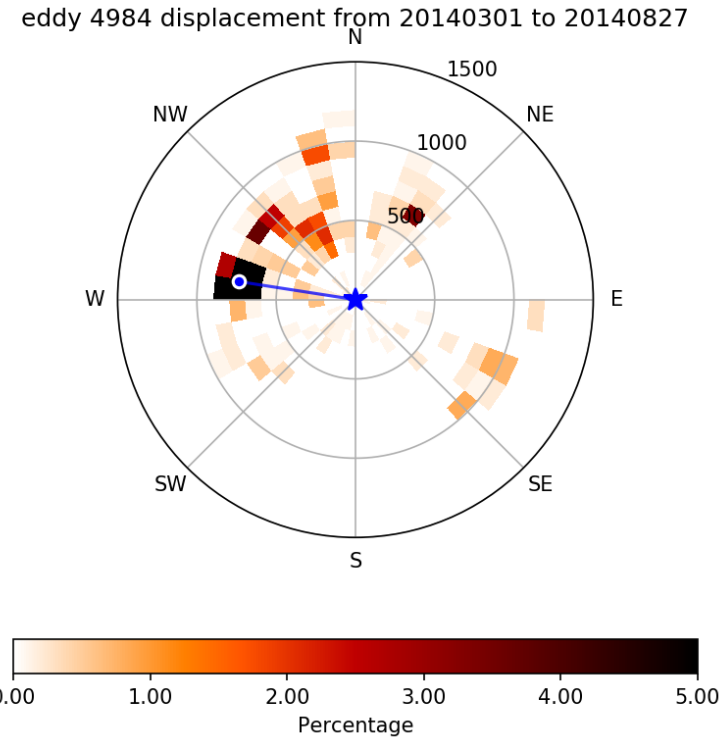
Objective 2: Fate of exchanged waters

➔ **Where** do the exchanged waters go?

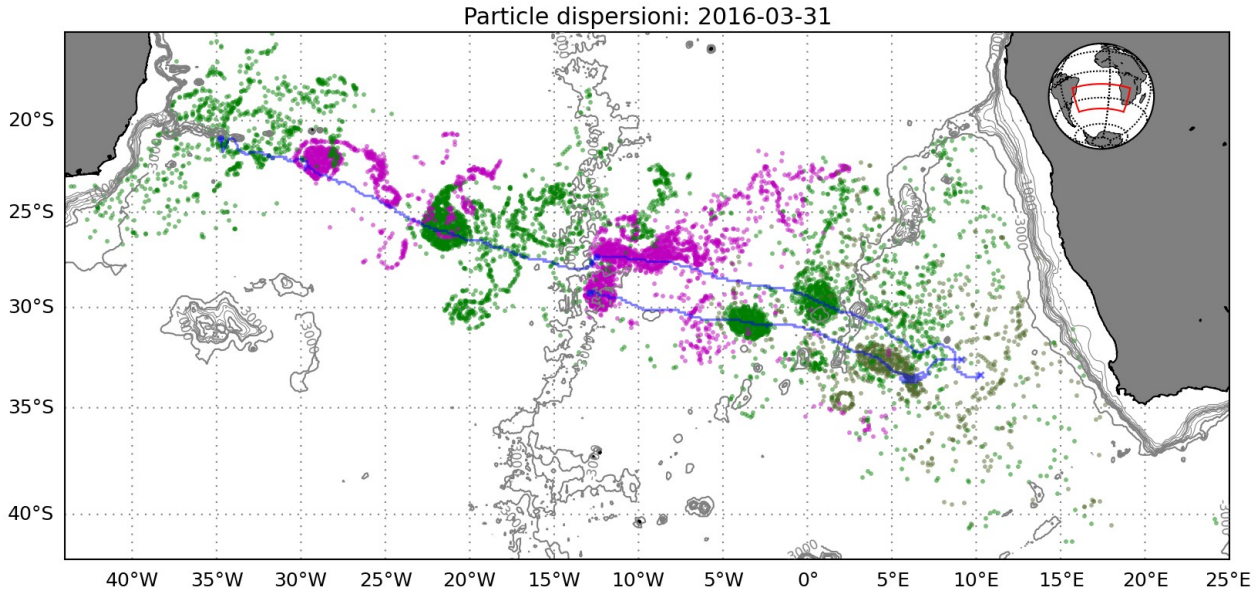
Lagrangian analysis

- Each month **particles deployed within 150 km** from eddy center
- **Advected for 6 months**: AVISO velocity field + RK4 advection scheme
- Investigate **final dispersion patterns**

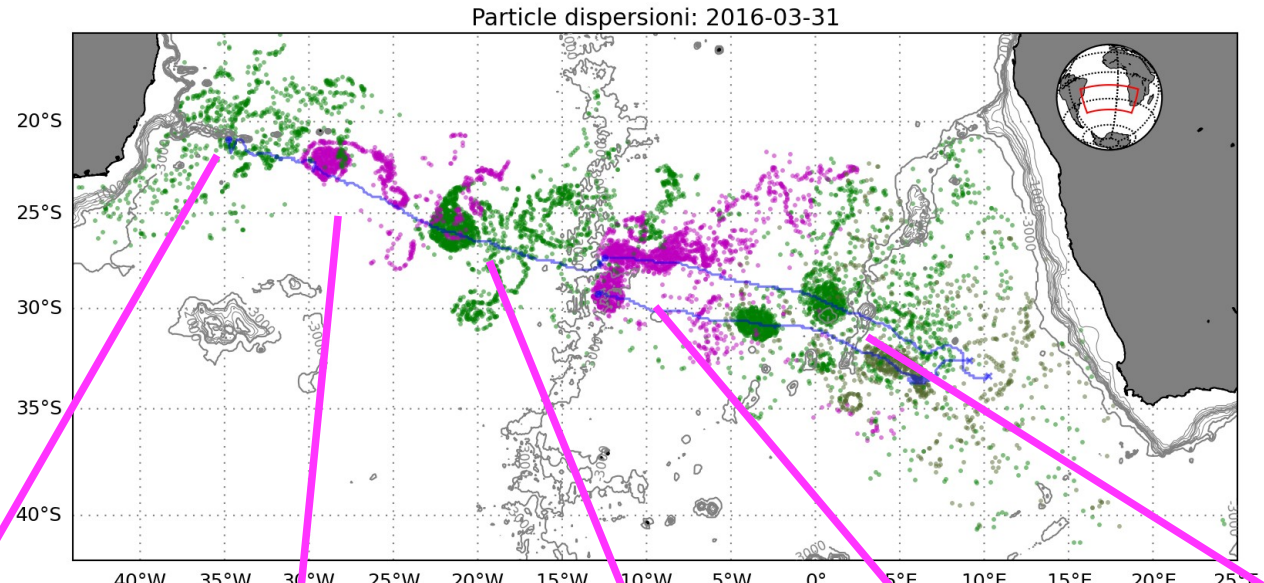


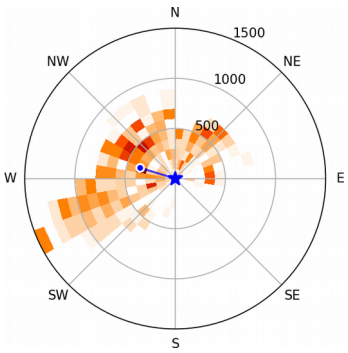


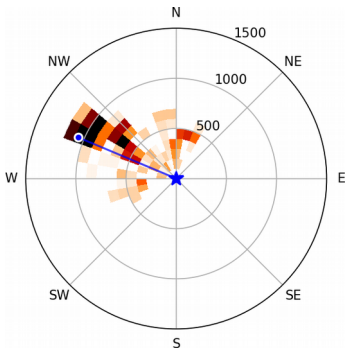
Results 2: Fate of exchanged waters

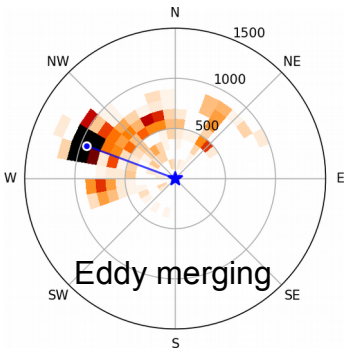


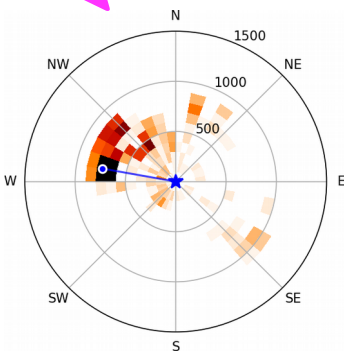
Results 2: Fate of exchanged waters

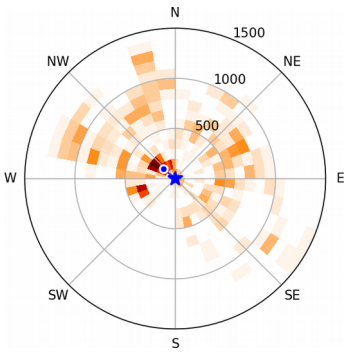










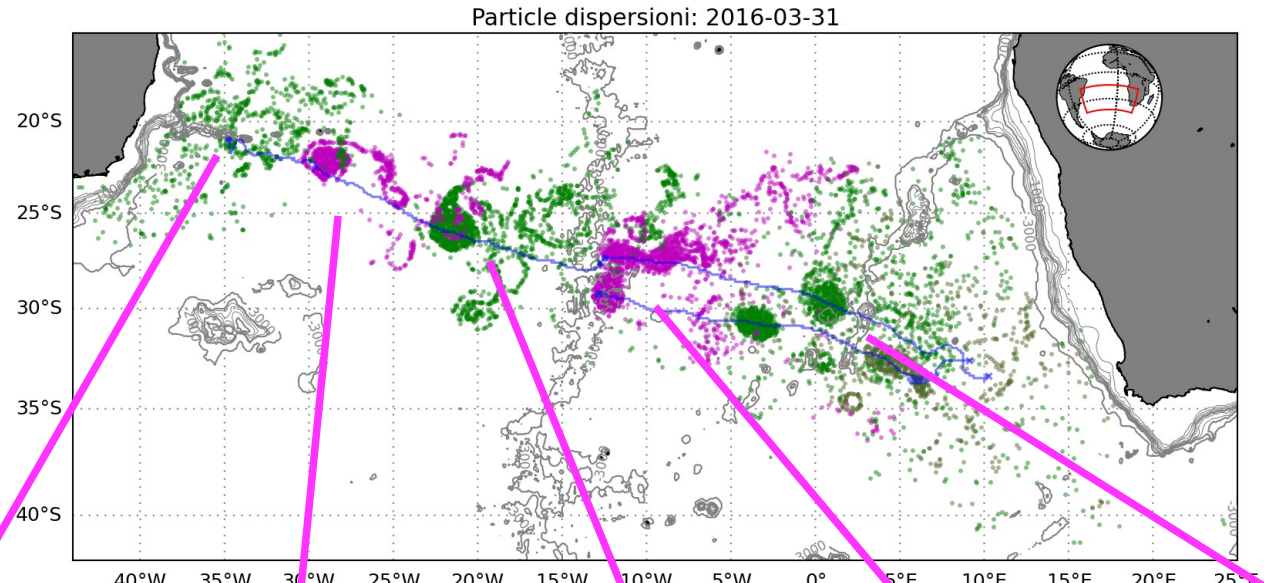


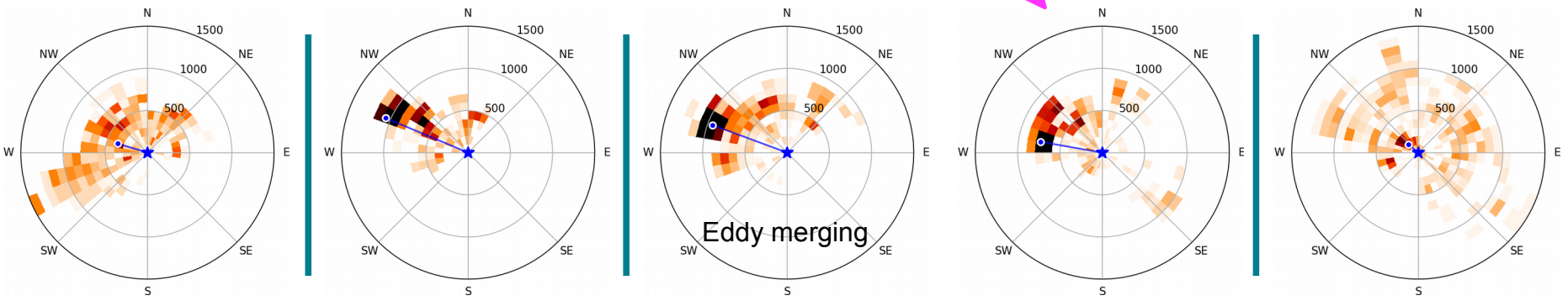
Dissipation region

Stable region

Unstable region

Results 2: Fate of exchanged waters





Dissipation region

Stable region

Unstable region

Conclusions

Agulhas ring transport efficiency

- Eddy most efficient mechanism for westward transport (~0.3 Sv year^{-1} eddy^{-1})
- Major volume losses due to bottom interaction (Walvis and Mid-Atlantic ridges)
- Volume almost entirely conserved within ridges
- However, constant exchanges with eddy core (diffusive-like processes)
- Water exchanges not uniform with depth
- After mid-atlantic ridge (eddy merging) exchanged water keeps contributing to AMOC

New questions

- What is the fate of the exchanged water at depth?
- How to quantify the diffusive-like exchanges?
- How representative is this particular eddy?

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