

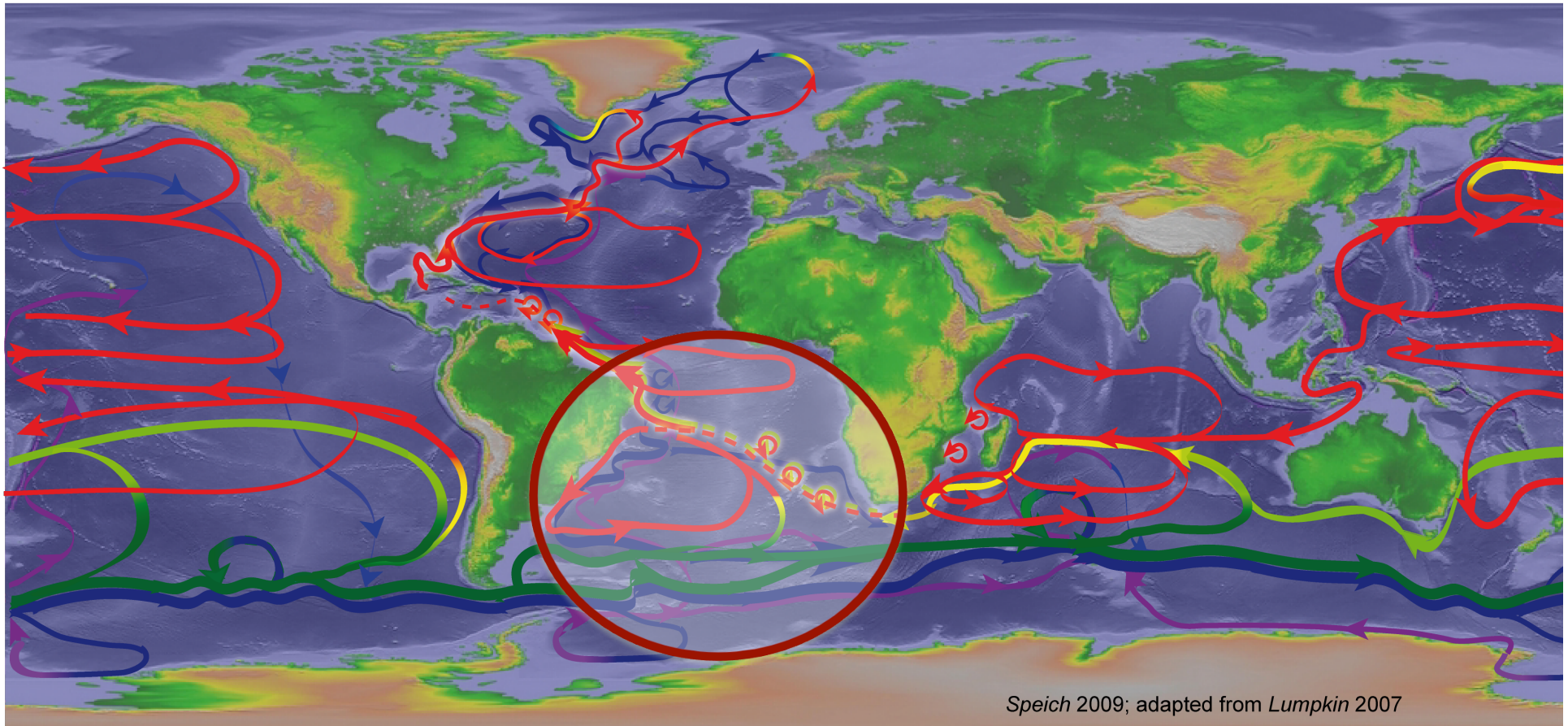
A highly turbulent interocean exchange South of Africa



S. Speich, M. Arhan, B. Blanke, T. Terre, M. Ollitrault, E. Rusciano, J. Rimaud,
T. Capuano, R. Laxenaire, J. Lepasquer, C. Messenger

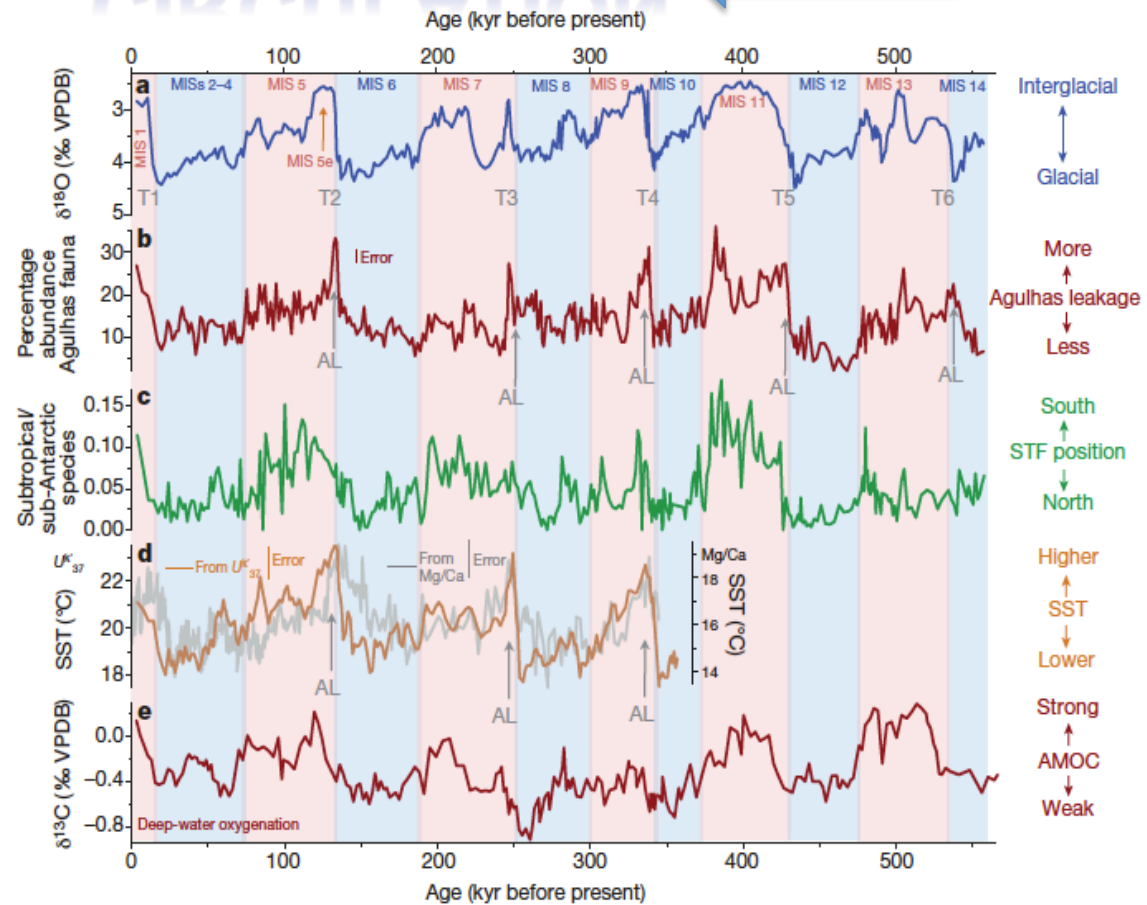
Sabrina.Speich@ens.fr

THE SOUTH ATLANTIC: AN ACTIVE BASIN WITH REGARDS TO THE MOC



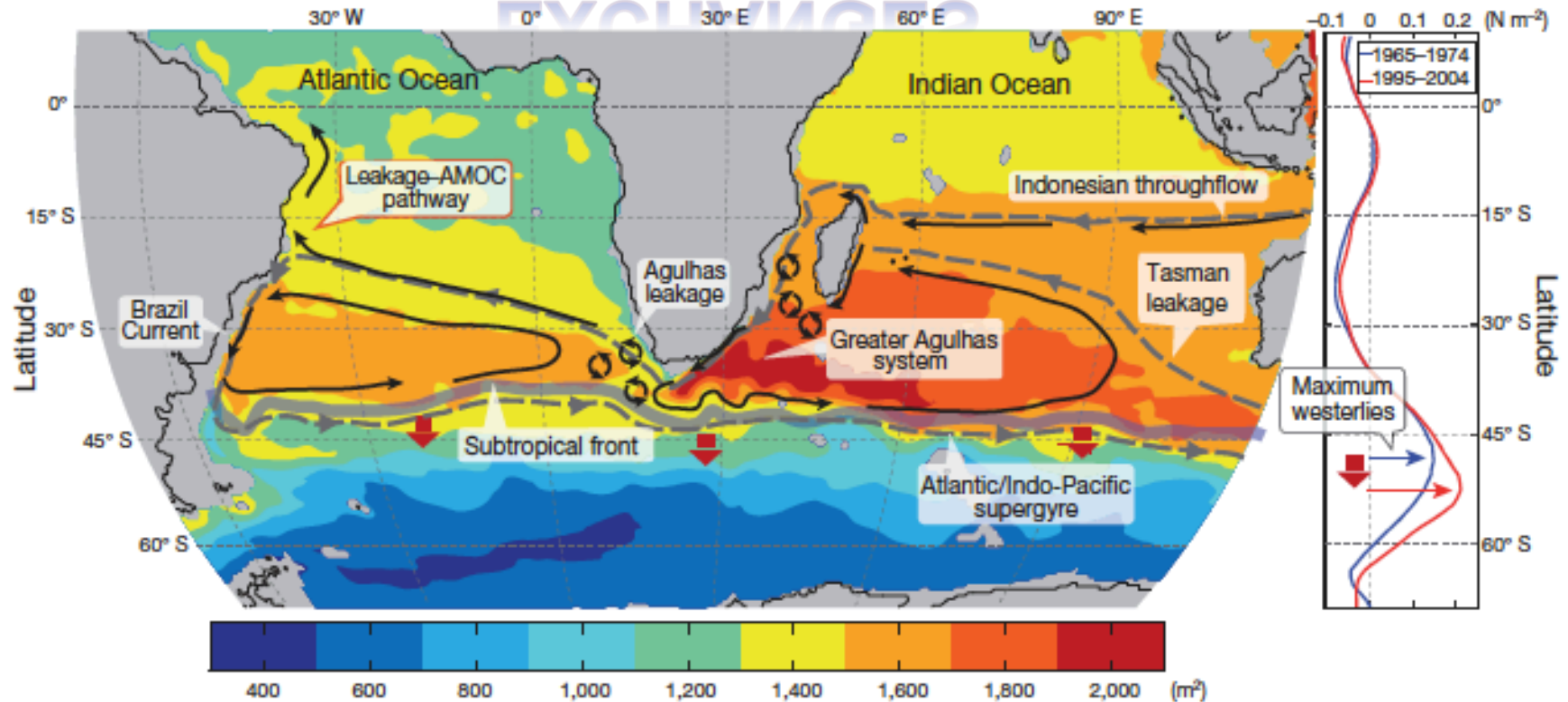
THE INDO-ATLANTIC EXCHANGE AT THE HEART OF THE GLOBAL OCEAN CIRCULATION

Atlantic MOC strength seems to increase at each glacial termination, leading to the hypothesis that Agulhas leakage may stimulate the AMOC.



From Beal et al 2011 review

CHANGES IN THE SUBTROPICAL GYRE. WHAT ABOUT INDO-ATLANTIC EXCHANGES



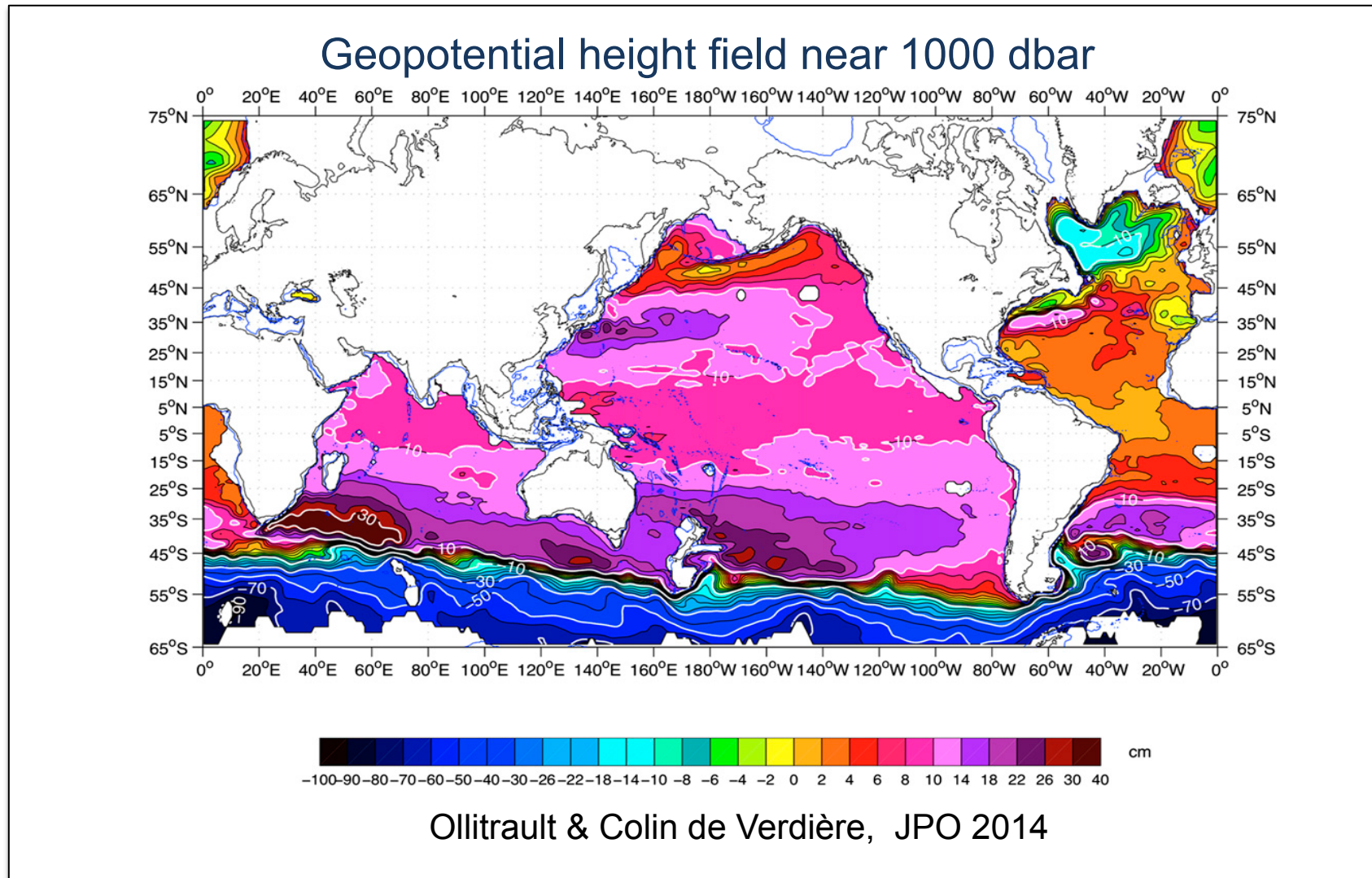
From Beal et al 2011 review

OUTLINE

- What exactly is the Indo-Atlantic exchange : Mean current, Eddies, or submesoscale dynamics?
- Eddies from *in situ* observations
- Eddies from satellite altimetry
- Evaluating associated fluxes by combining satellite altimetry and Argo profiles

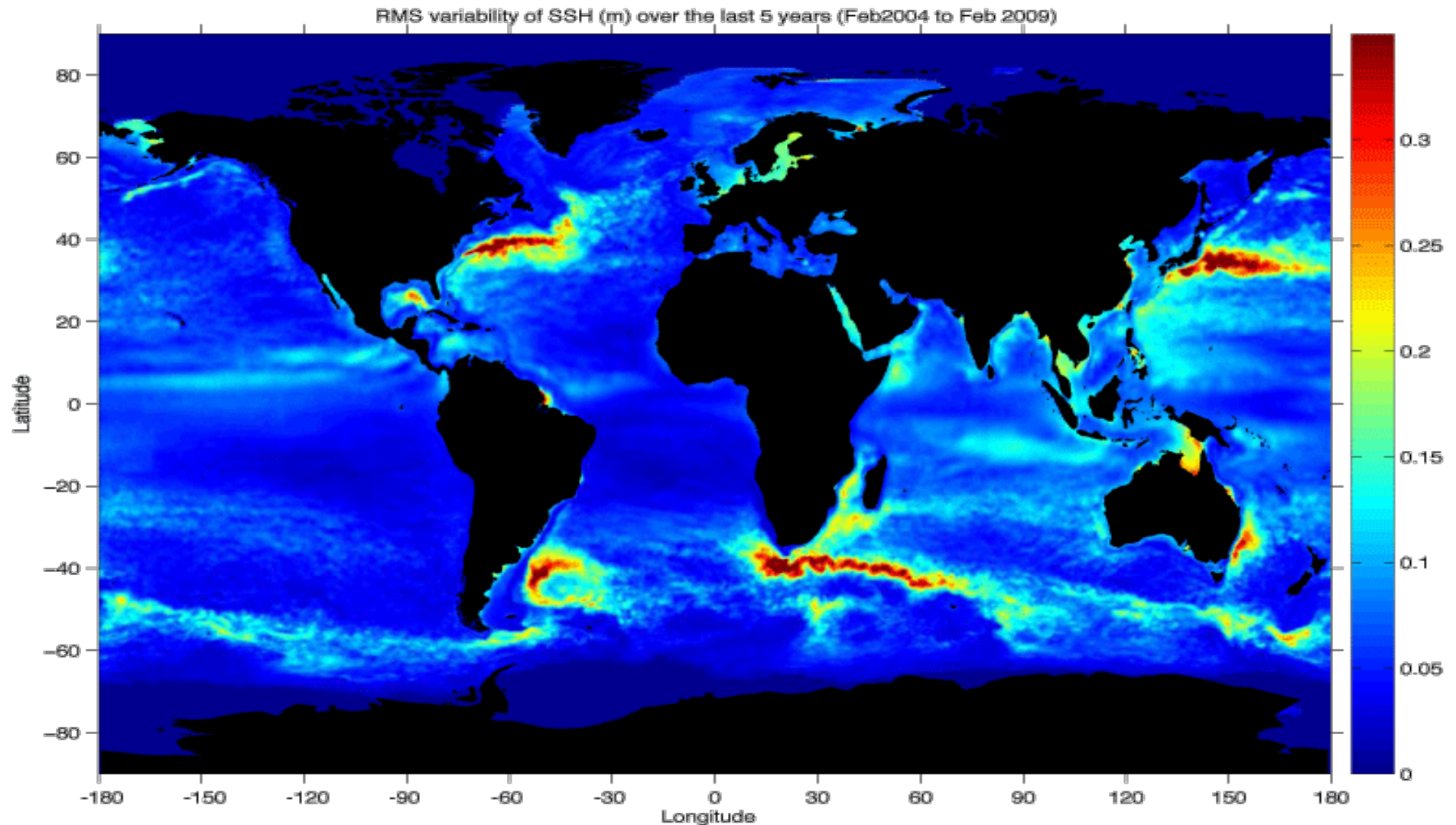
What exactly is the indo-Atlantic exchange ?

The Intermediate depth global ocean circulation

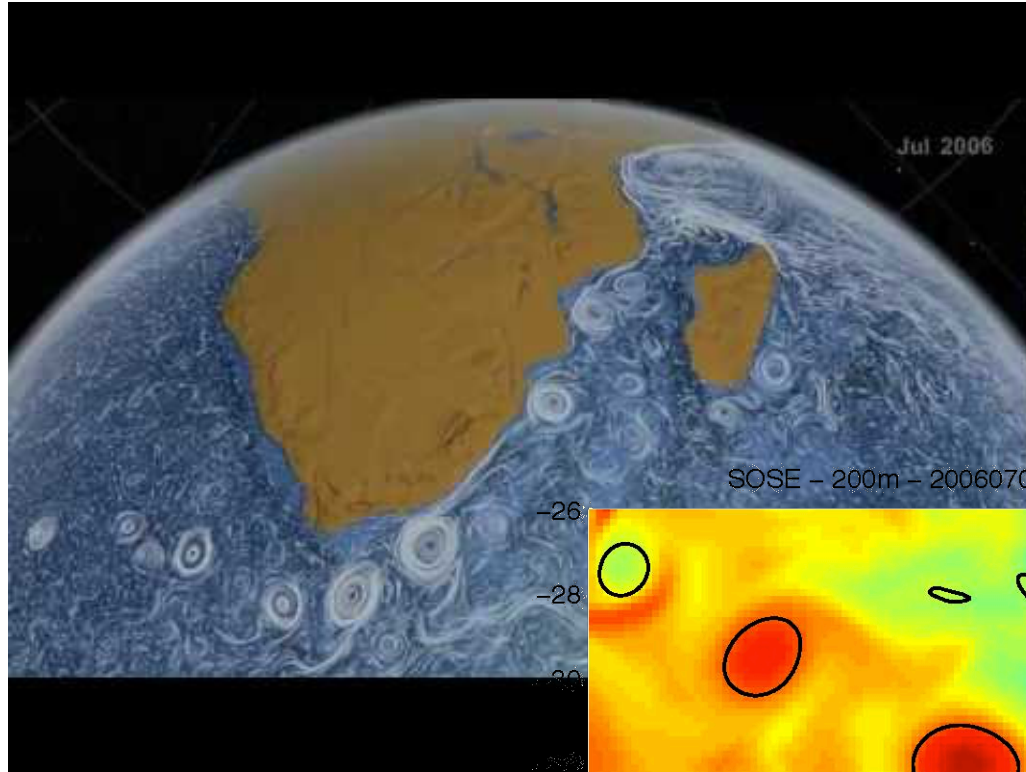


What exactly is the indo-Atlantic exchange ?

Agulhas & Cape Basin: a turbulent hotspot

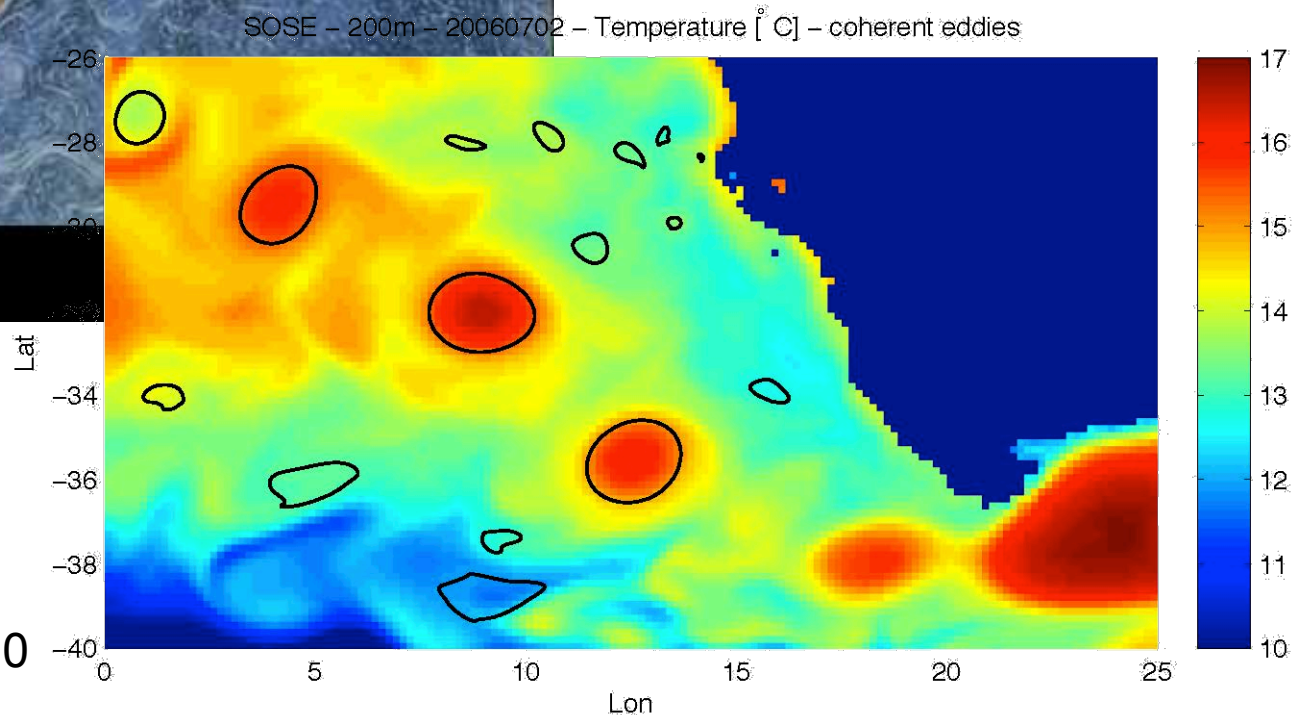


What exactly is the indo-Atlantic exchange ?



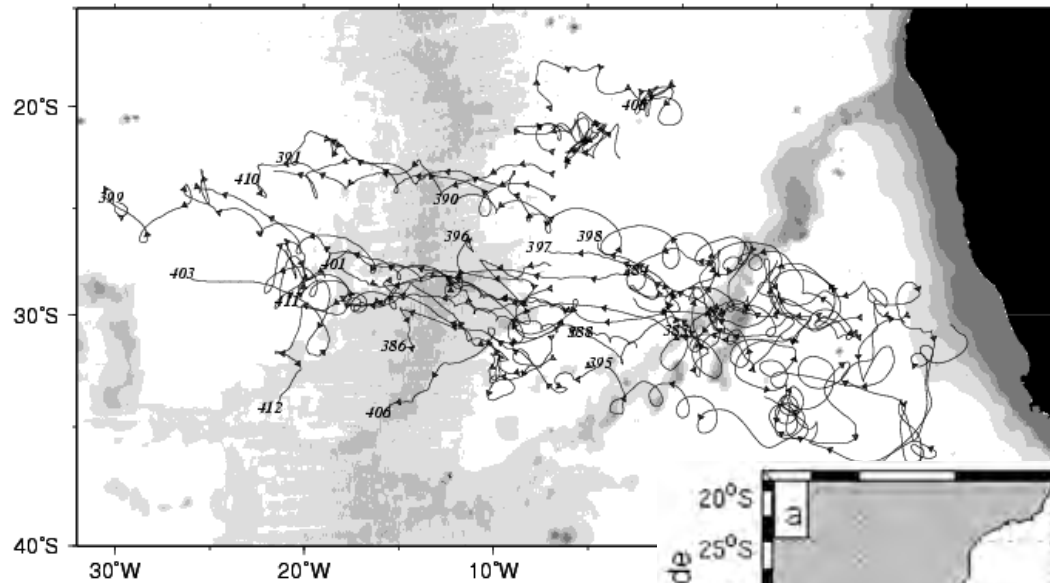
Agulhas “Big” Rings
from ocean models

ECCO2, Stammer et al. 2001



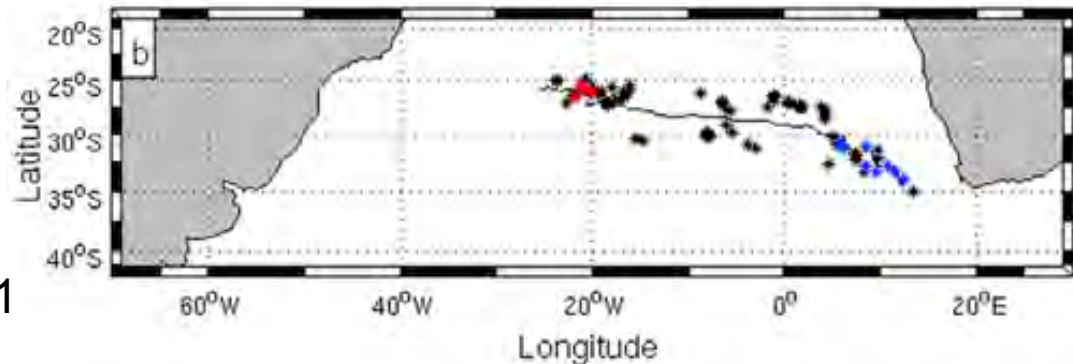
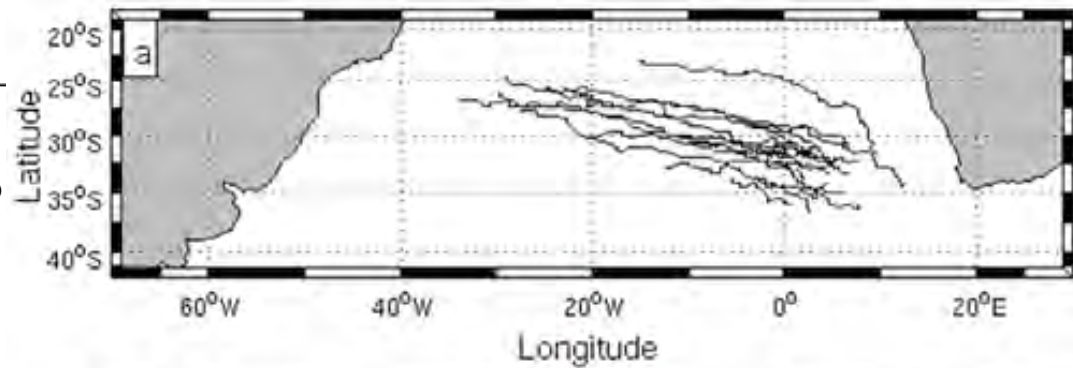
SOSE, Matzloff et al. 2010

What exactly is the indo-Atlantic exchange ?



Kapex ; Boebel et al. 2003

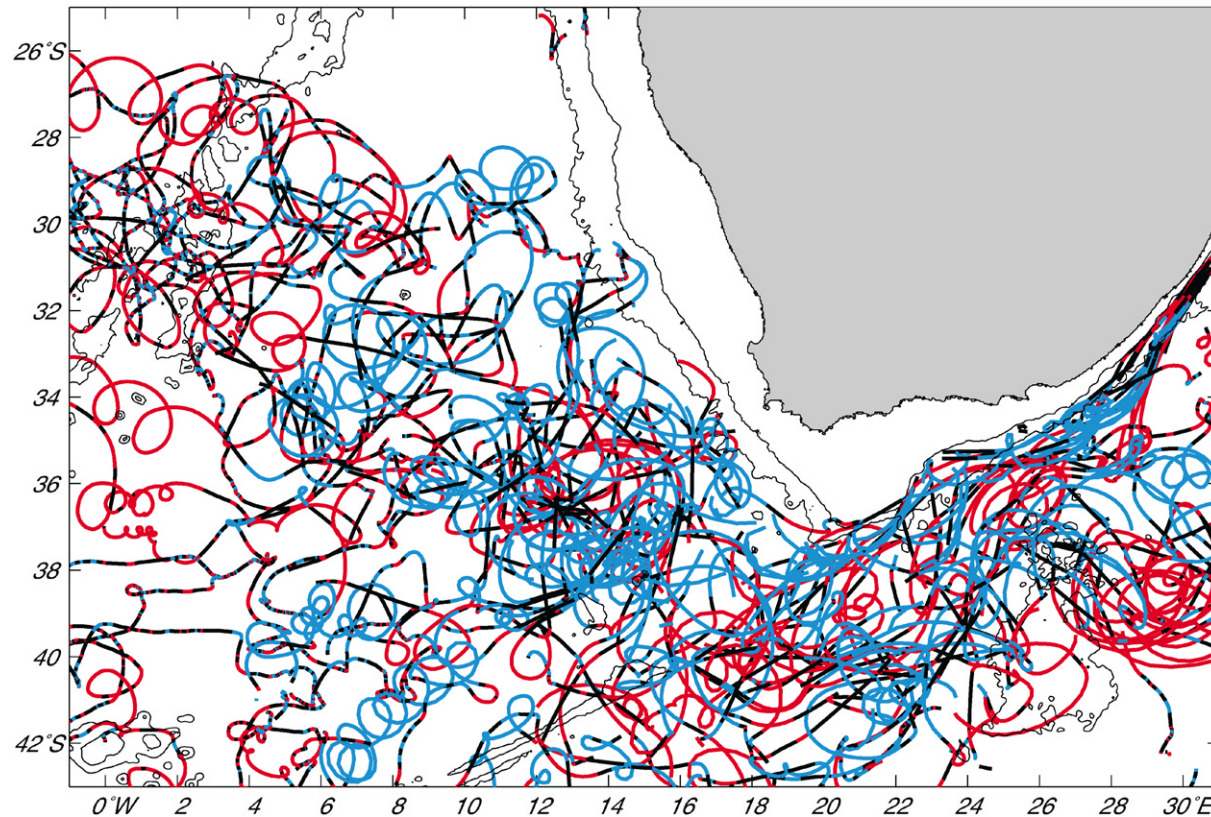
Agulhas rings
detection from floats
and remote sensing



Souza et al. 2011

What exactly is the indo-Atlantic exchange ?

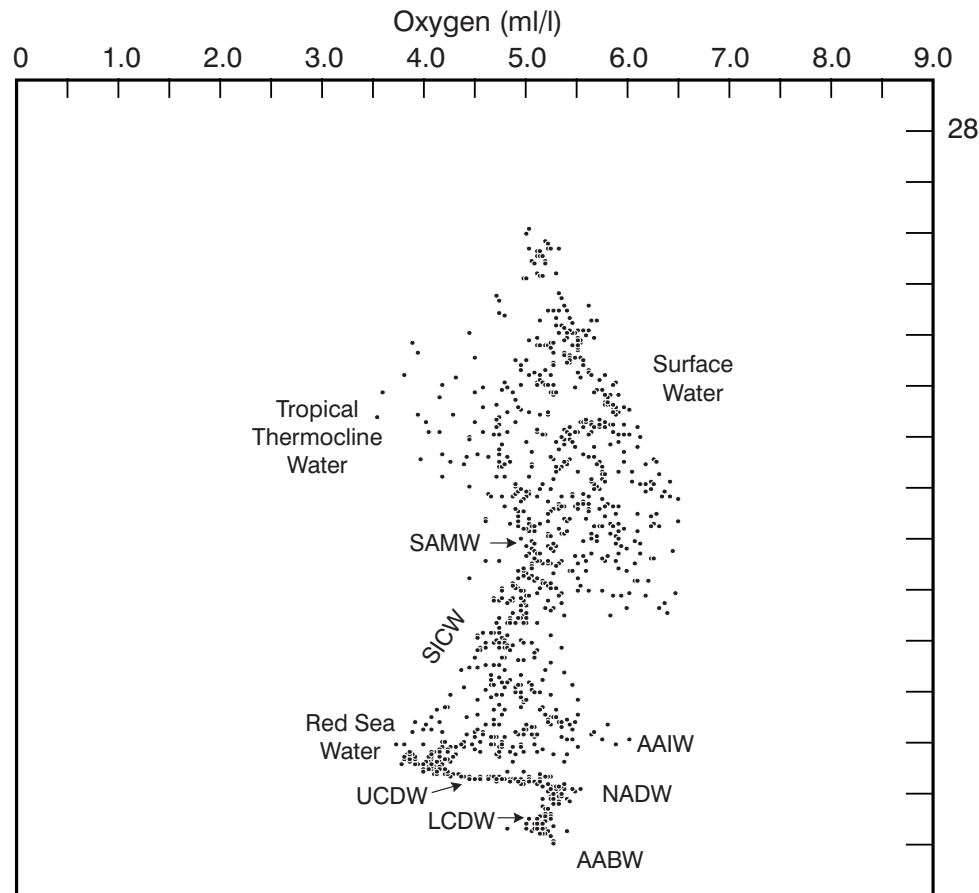
The Cape Cauldron (from subsurface floats)



Boebel et al. 2003

What exactly is the indo-Atlantic exchange ?

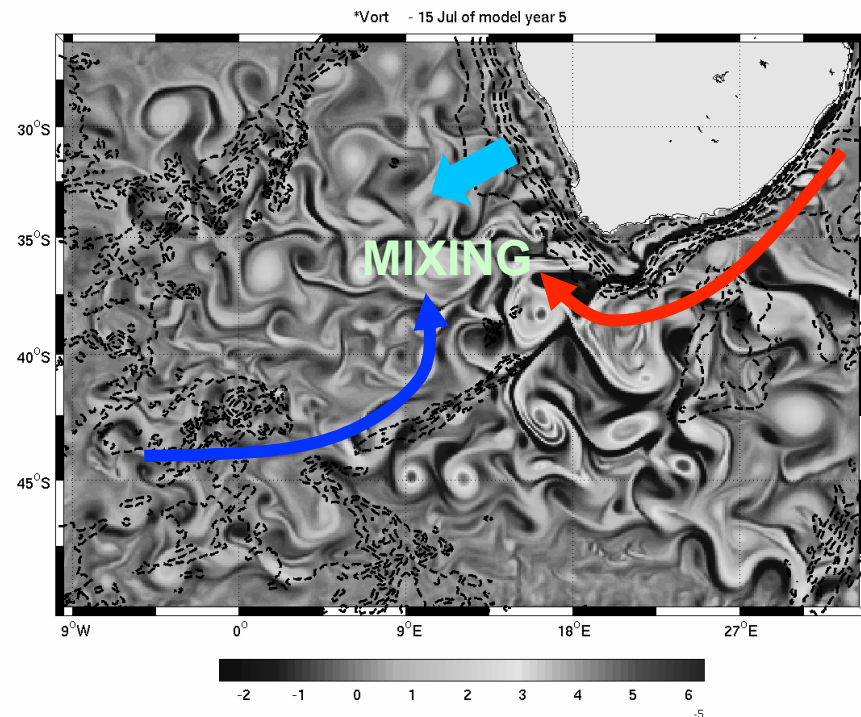
Agulhas Retroflection & the Cape Basin: a Cauldron merger of waters of different origins



Lutjeharms et al. 2003

SYNBIOS, 6-8 July 2015

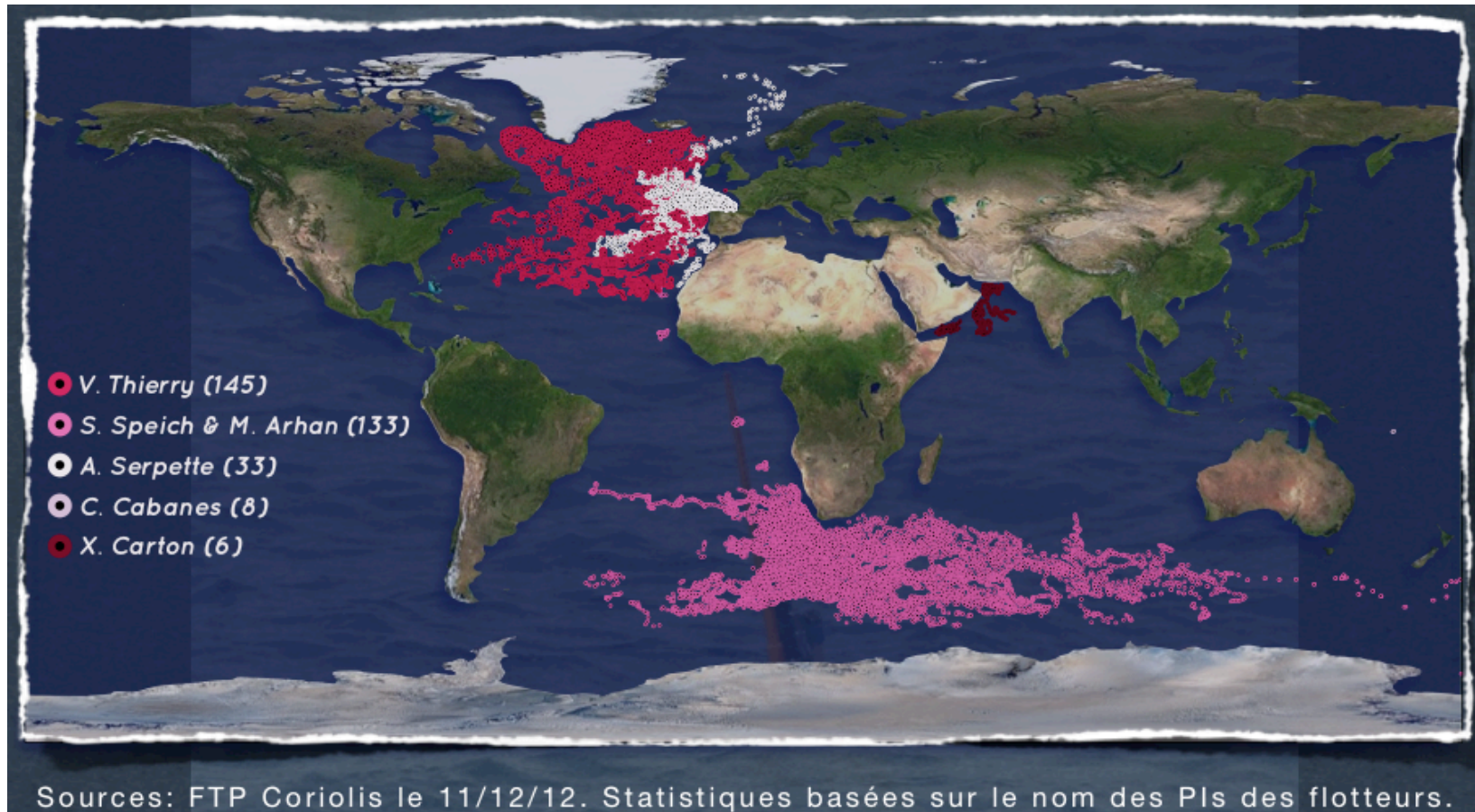
Roms simulation 1/12°



SAMOC CLIVAR Project—Sabrina.Speich@ens.fr.

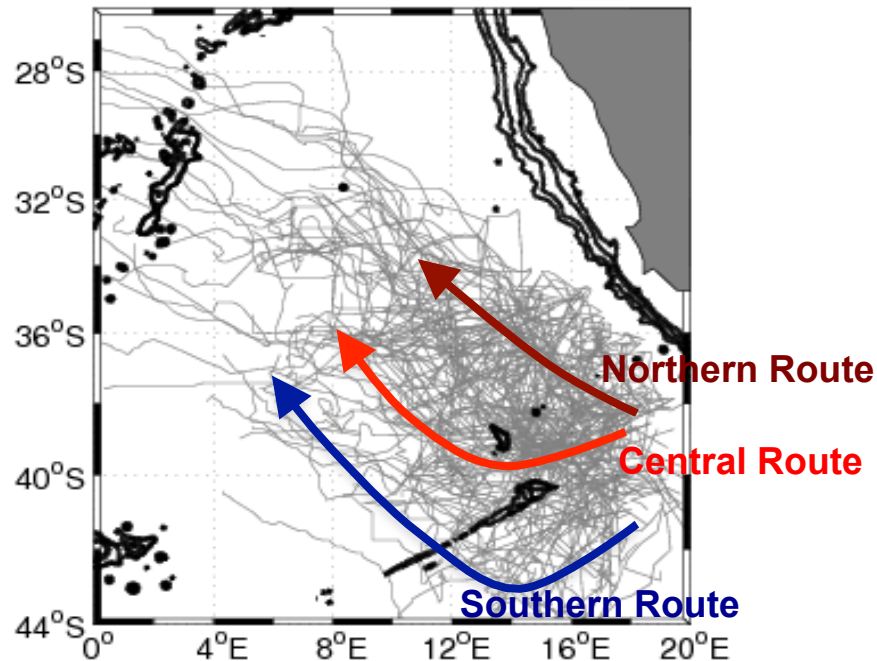
Eddies from *in situ* observations

Deployment of French Argo Floats up to end 2012



Eddies from *in situ* observations

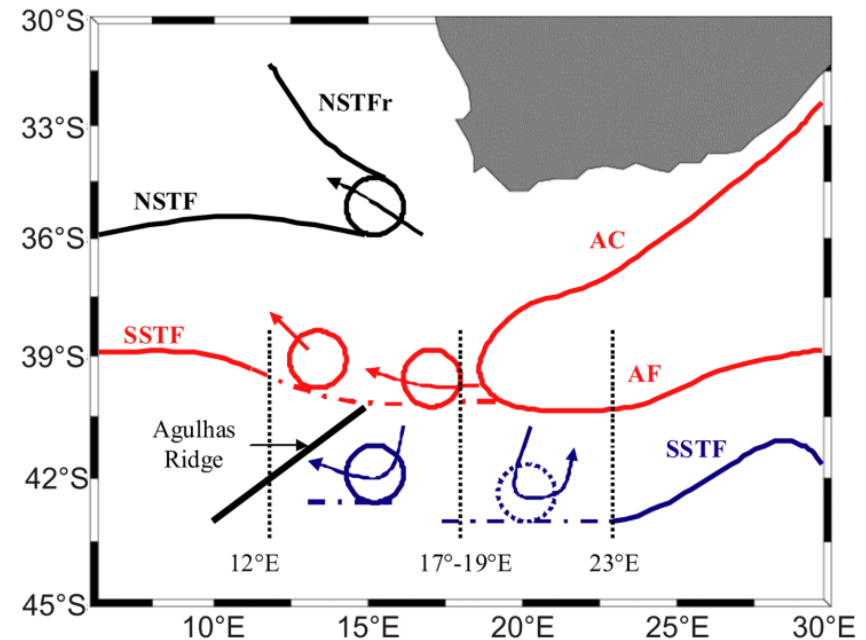
Trajectories of Agulhas Rings from AVISO MADT



3 principal routes

Dencausse, et al., 2010a, b & 2011

Mesoscale dynamics and front structure

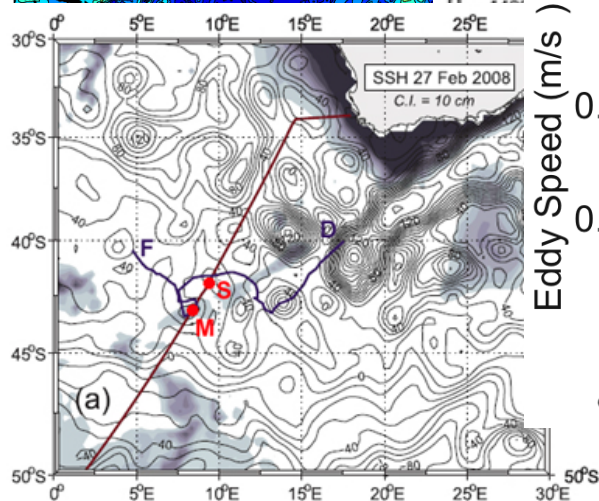
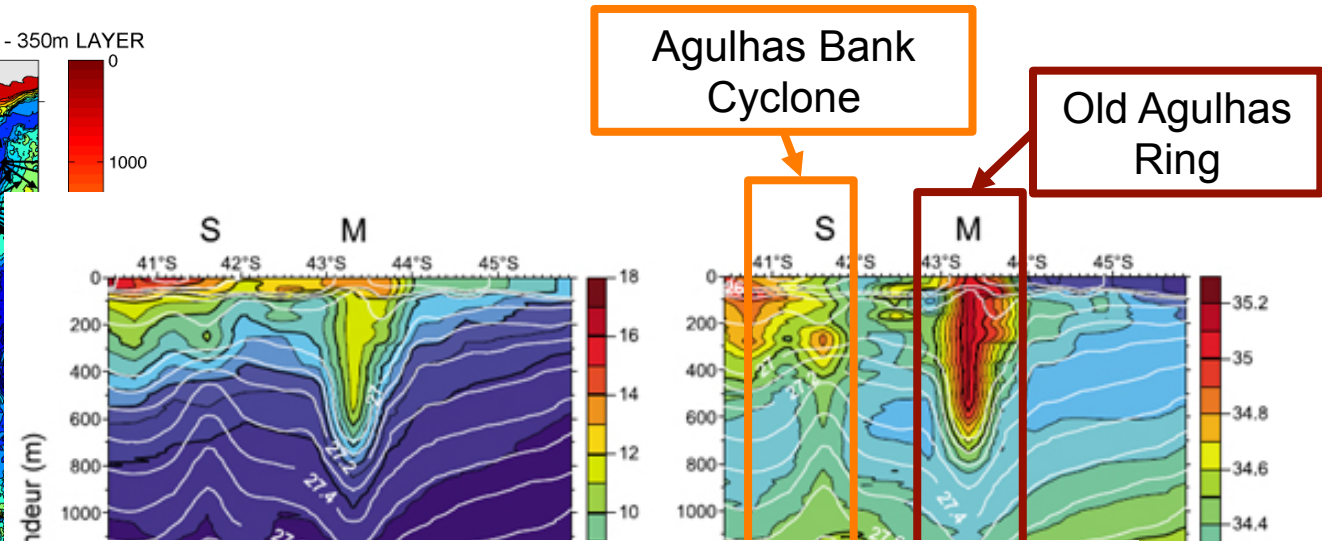
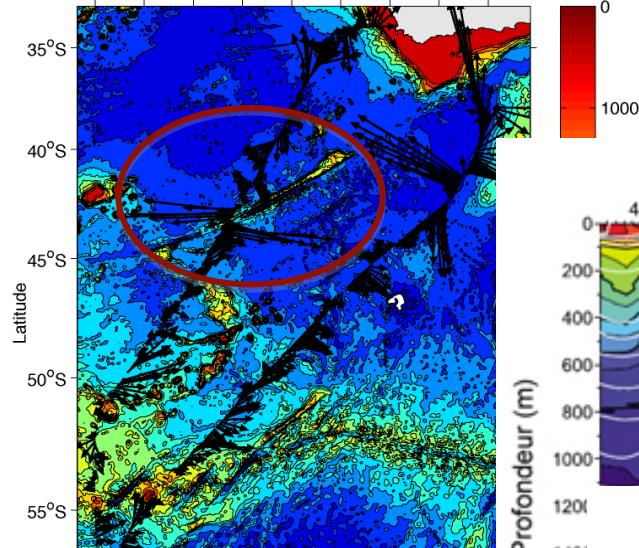


The S-STF south of Africa is not continuous but made of interacting eddies

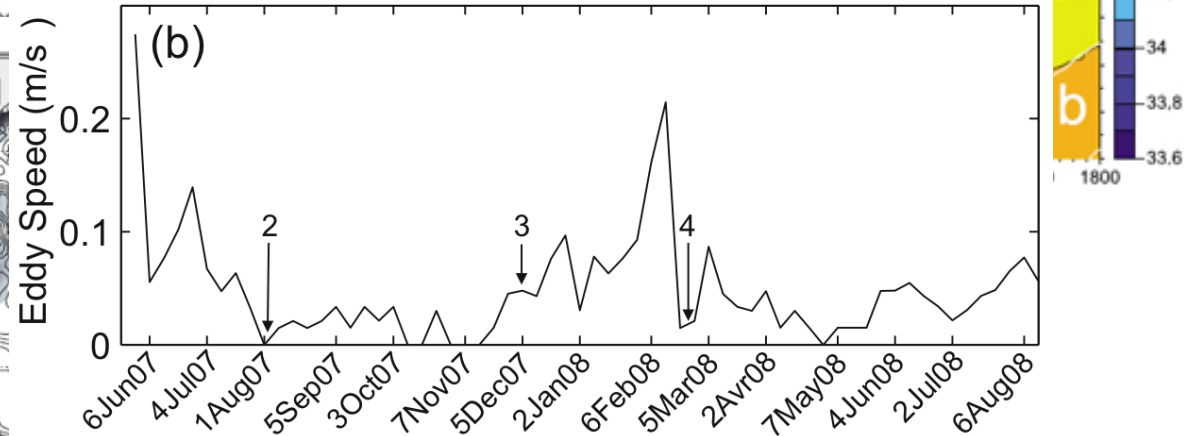
Eddies from *in situ* observations

BONUS-GoodHope IPY Cruise on the RV Marion Dufresne II

VM-ADCP AVERAGED VELOCITY VECTORS FOR 50 - 350m LAYER



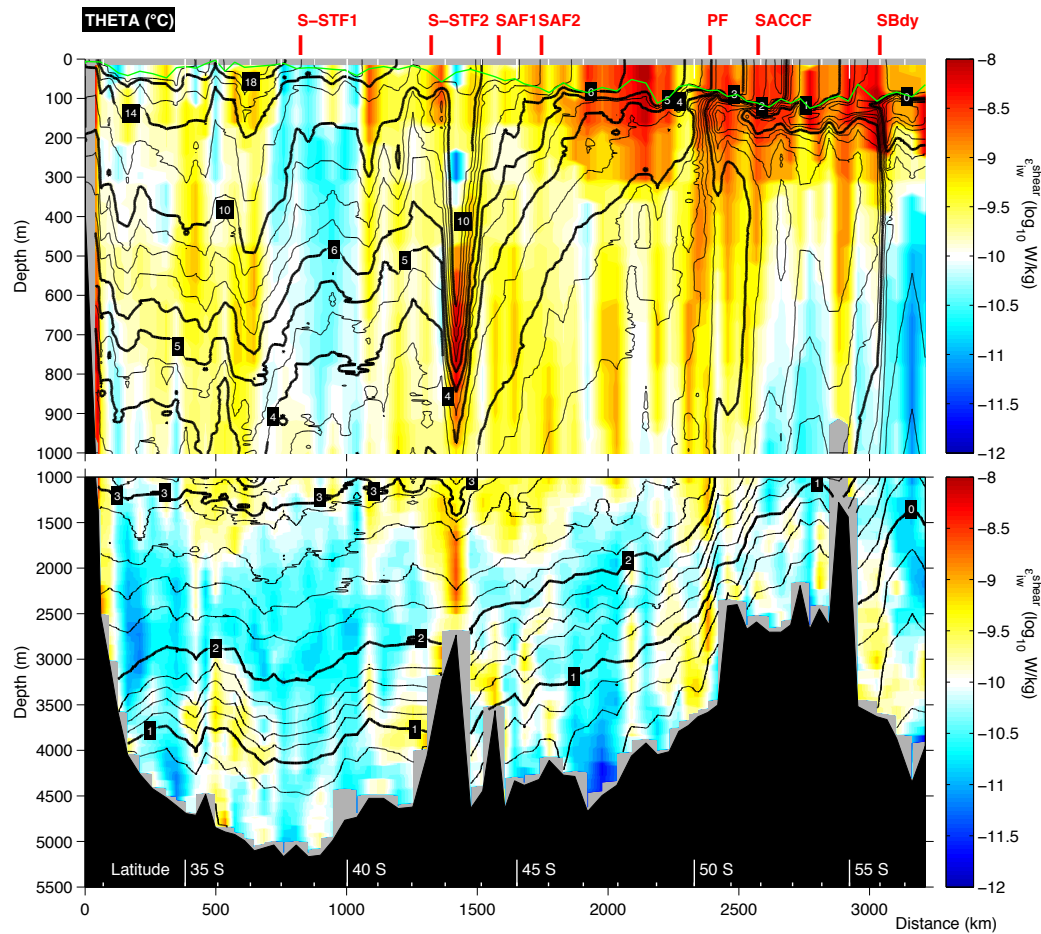
Agulhas Ring M velocity of translation



Arhan et al., 2011

Eddies from *in situ* observations

VERTICAL MIXING

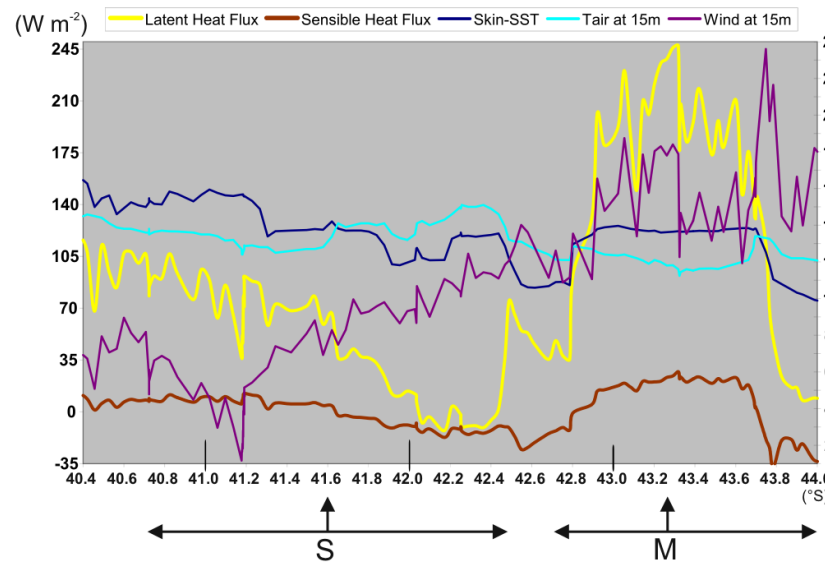


Energy dissipation
computed for the IPY
BONUS-GoodHope cruise
(Feb-March 2008)

Eddies from *in situ* observations

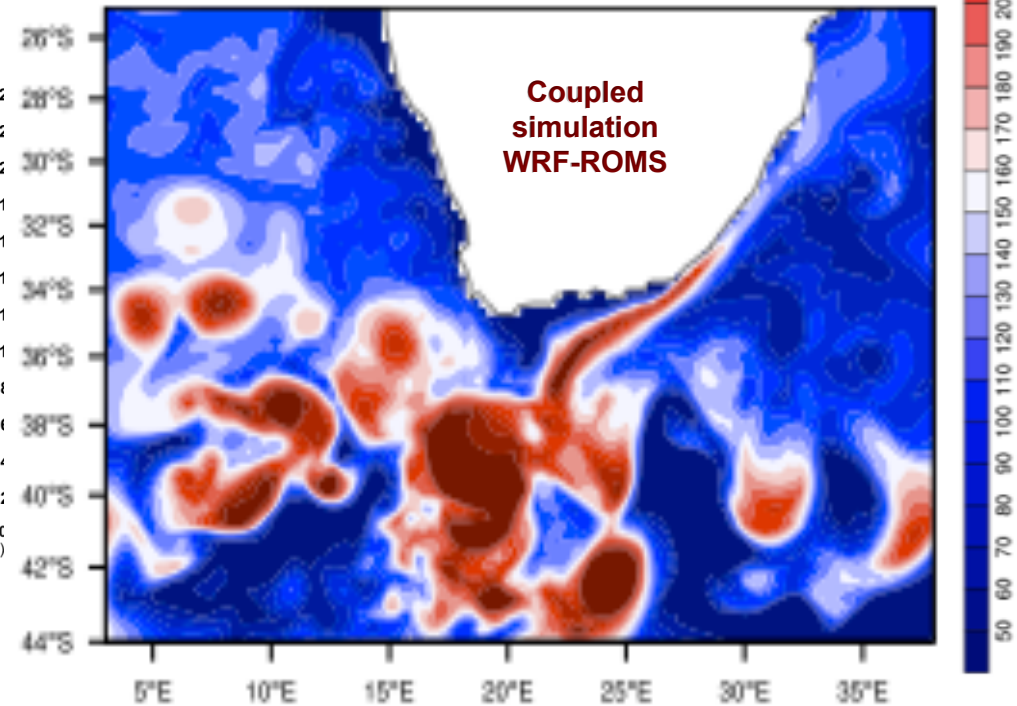
Air-Sea Interactions over Agulhas Rings

Observations during BONUS-GoodHope



Arhan et al., 2011

ROMS 1/12° - WRF 1/4° Latent Heat Flux

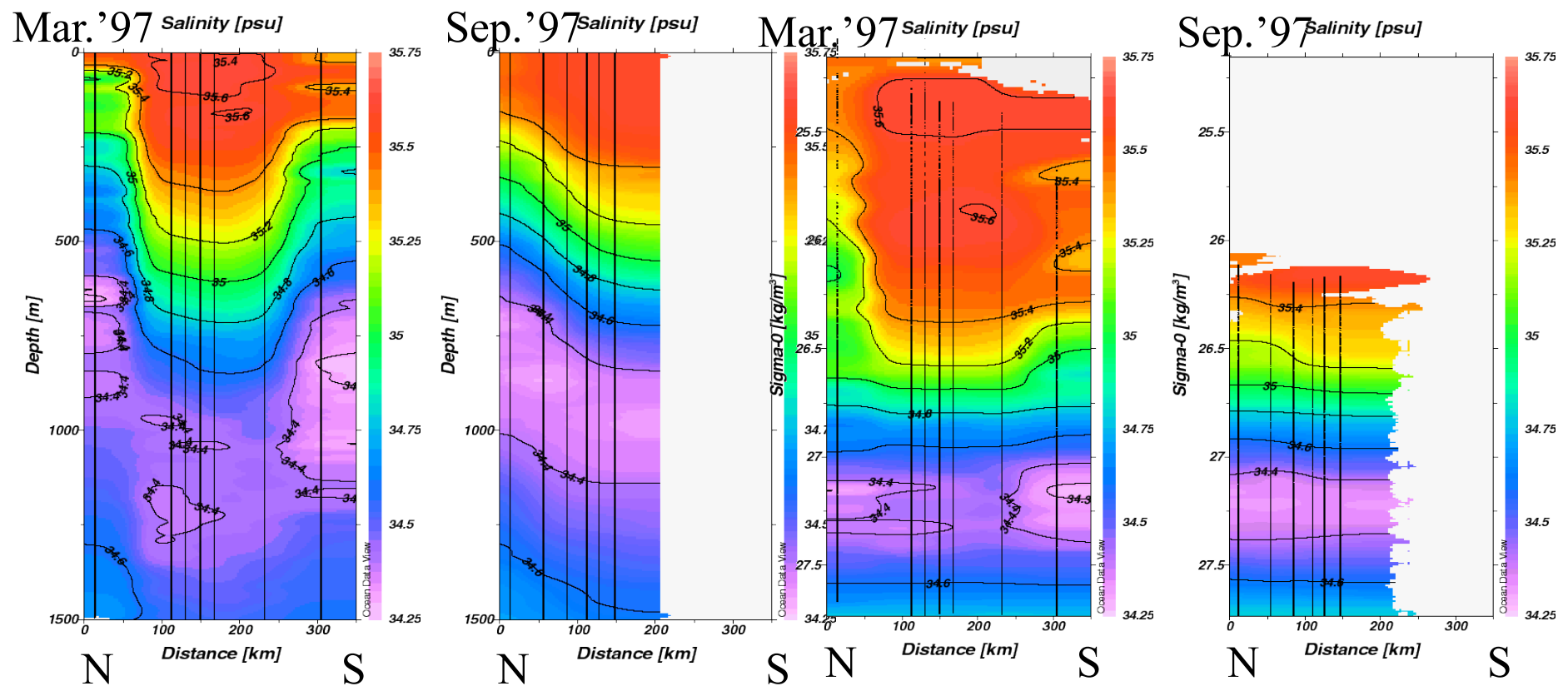


Le Bars, 2007; Rimaud PhD

Eddies from *in situ* observations

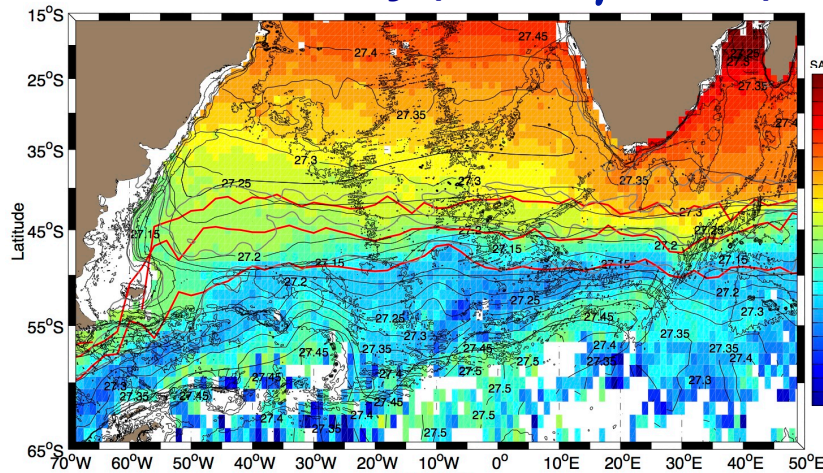
DATA

Anticyclones variations in Salinity from KAPEX
(Schmid et al. 2003)

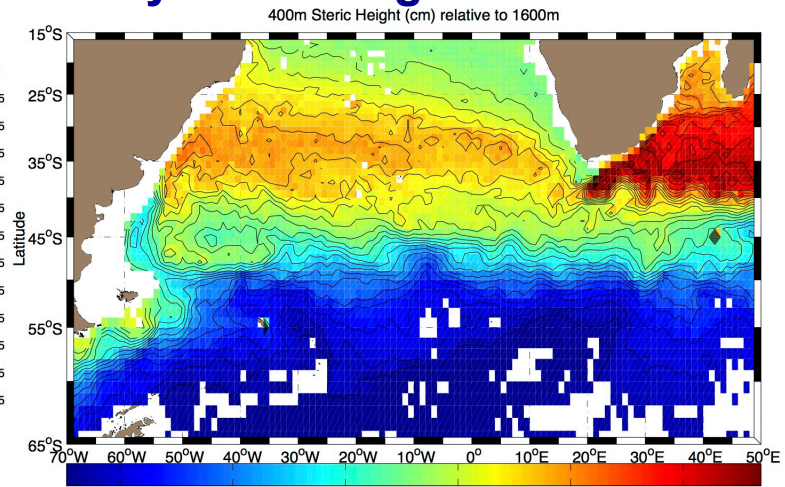


AAIW IN THE SOUTH ATLANTIC

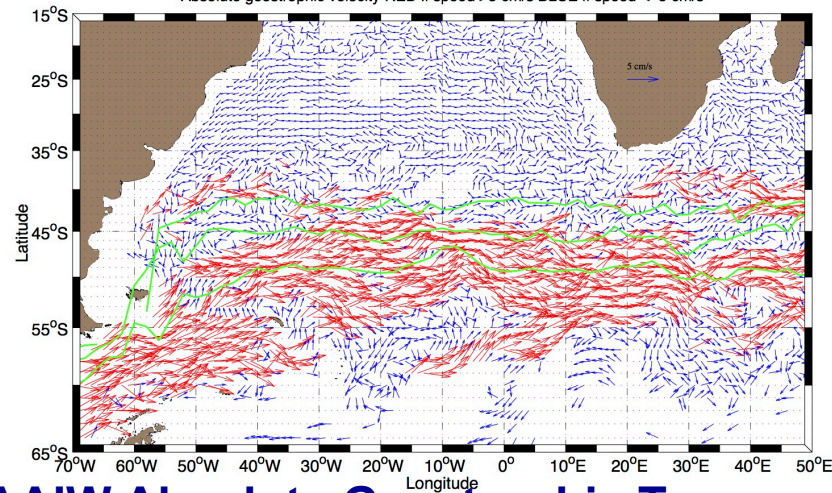
AAIW Salinity ($27.1 \leq \gamma \leq 27.6$)



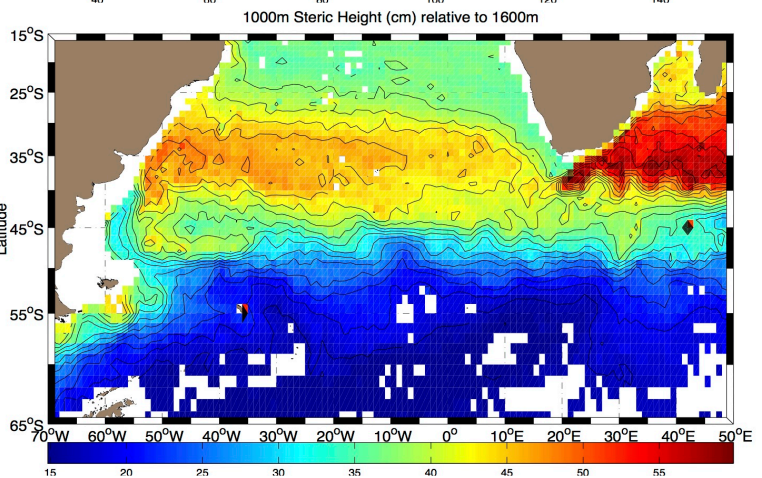
400 db Dynamic height ref. to 1500 db



Absolute geostrophic velocity RED if speed >5 cm/s BLUE if speed <=5 cm/s



AAIW Absolute Geostrophic Transport



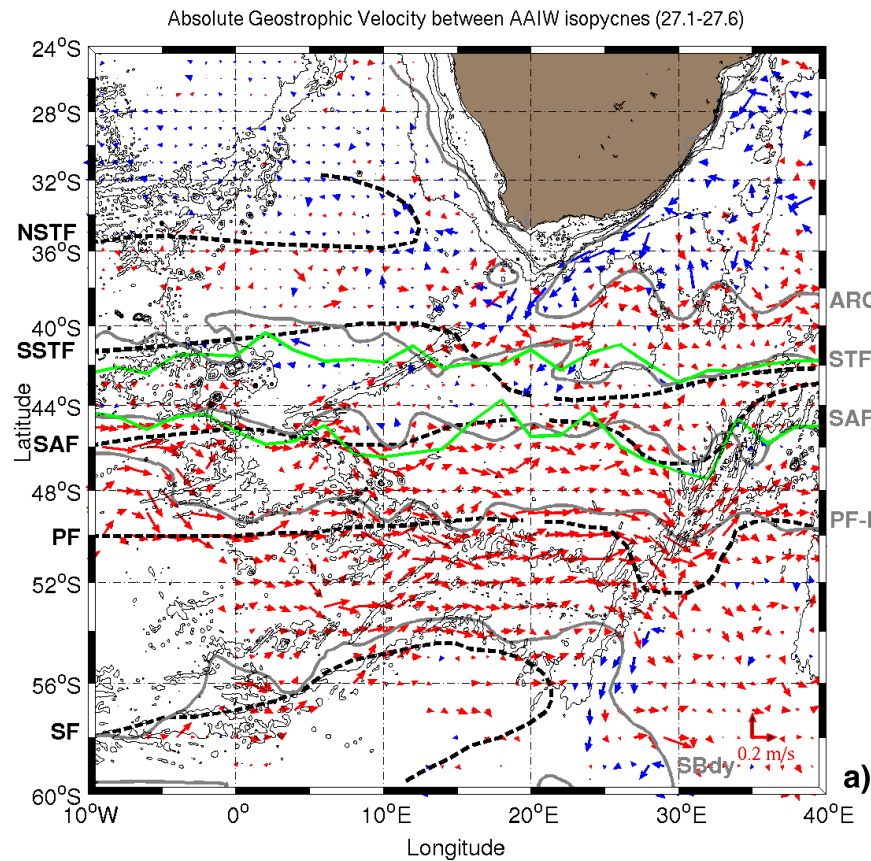
1000 db Dynamic height ref. to 1500 db

Eddies from *in situ* observations

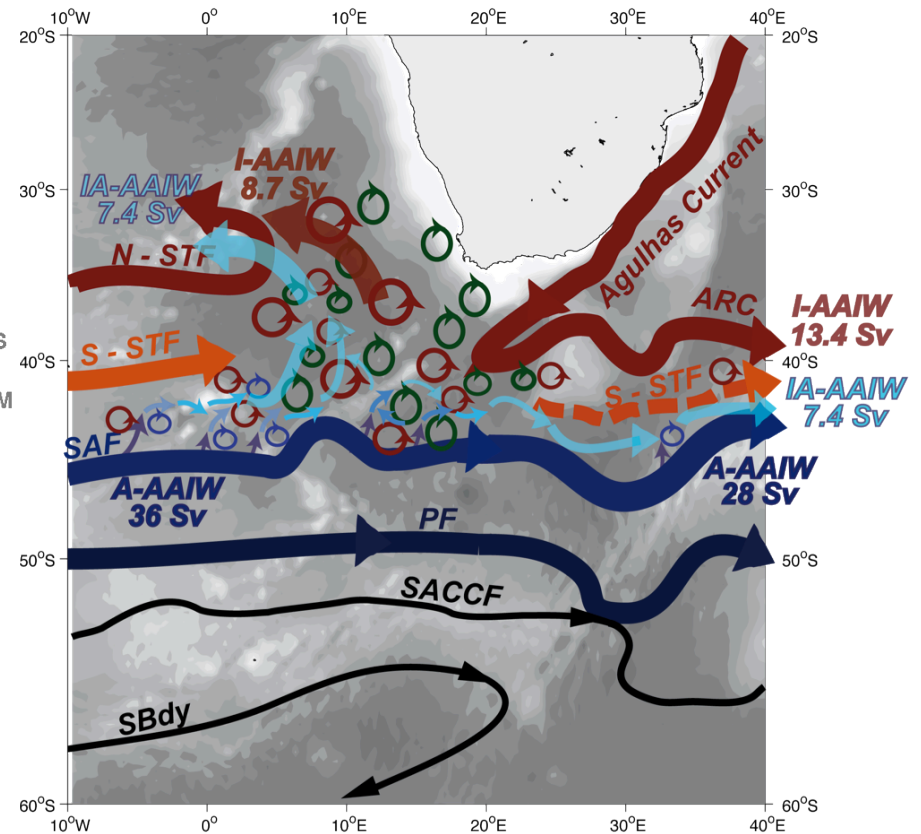
REGIONAL AAIW DYNAMICS from Argo

Using ANDRO velocity Atlas

ARGO ABSOLUTE
GEOSTROPHIC VELOCITY



SCHEME OF AAIW EXCHANGES



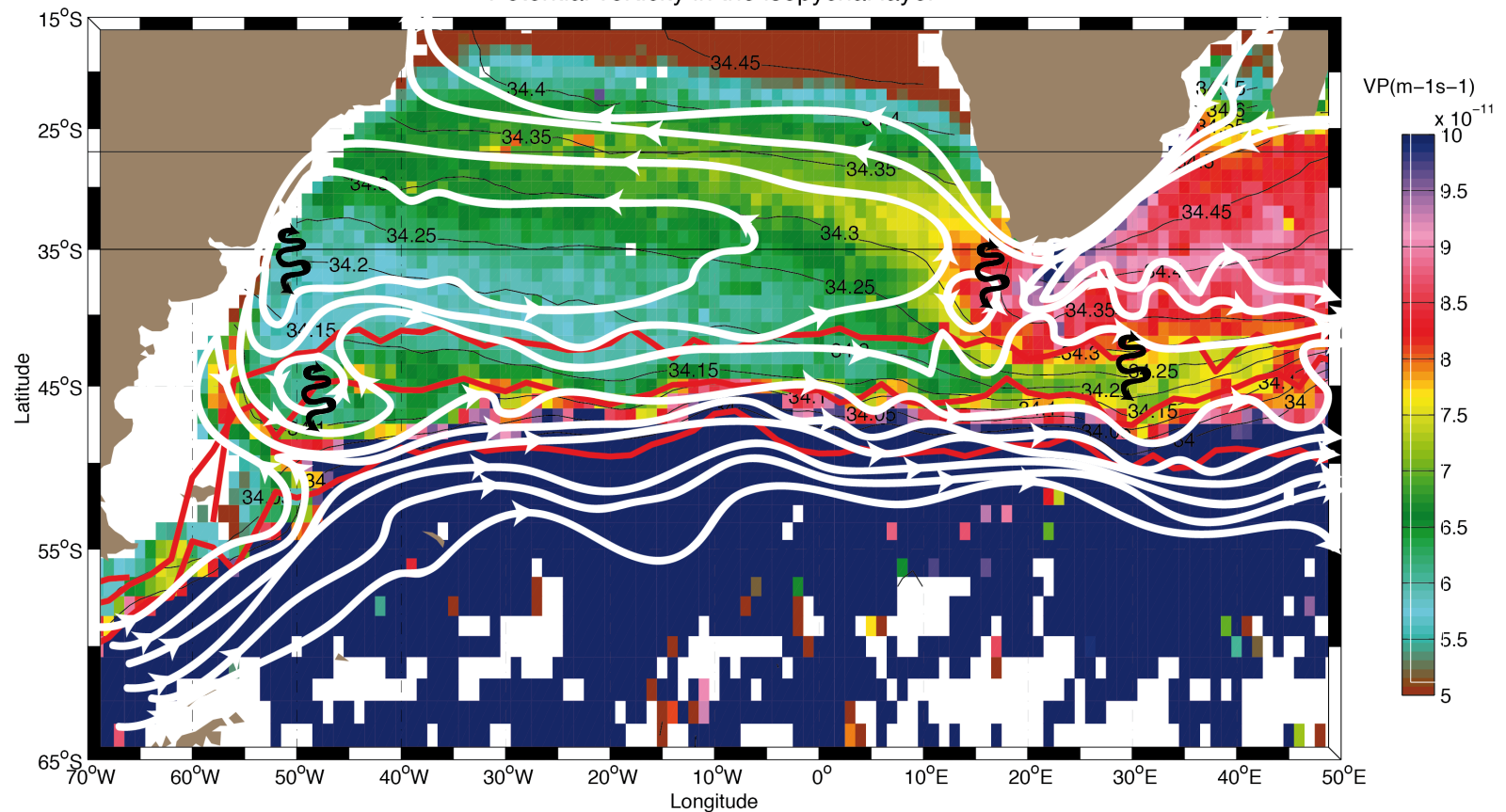
- Atlantic AAIW
- Indian AAIW
- Indo-Atlantic AAIW
- ⊙ Agulhas Rings (Anticyclones)
- ⊙ African slope cyclones
- ⊙ SAF cyclones

E. Rusciano, et al. 2012

AAIW IN THE SOUTH ATLANTIC

AAIW Potential Vorticity

Potential vorticity in the isopycnal layer

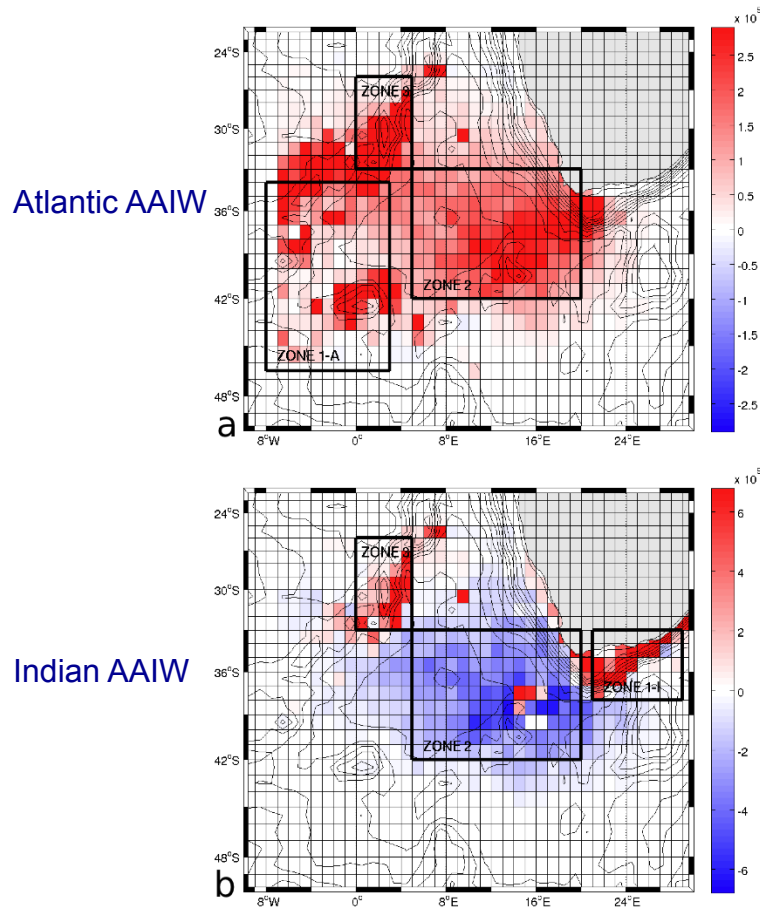


More to come with Lagrangian analyses applied on Argo floats data: Blanke et al. , *Lagrangian water mass tracing from pseudo-Argo, model-derived salinity, tracer and velocity* (2014)

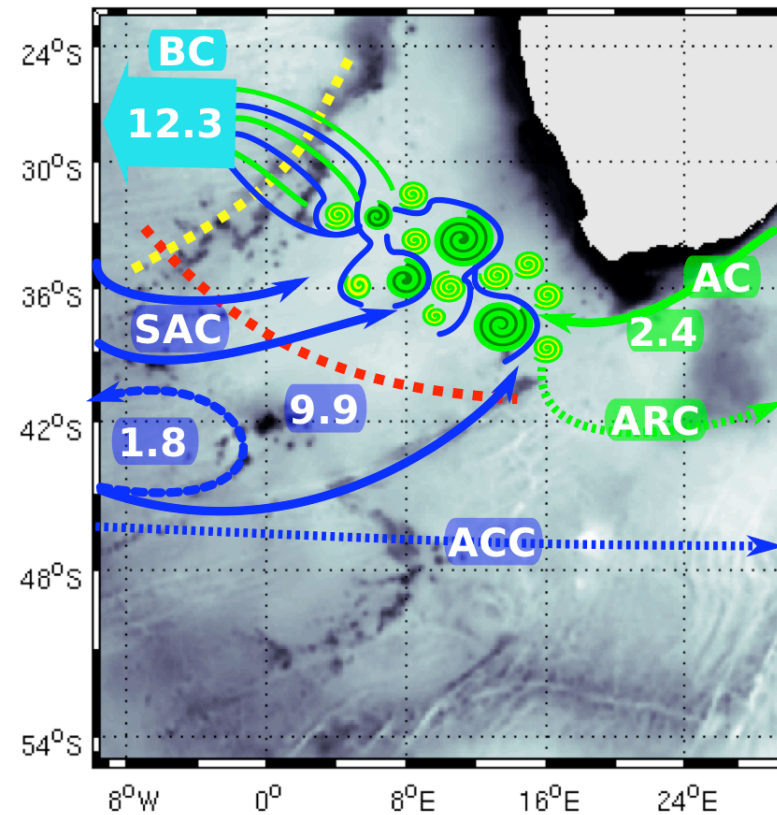
AAIW IN THE SOUTH ATLANTIC

Using ROMS & ARIANE Lagrangian diagnostic

Regions of Salinity Changes



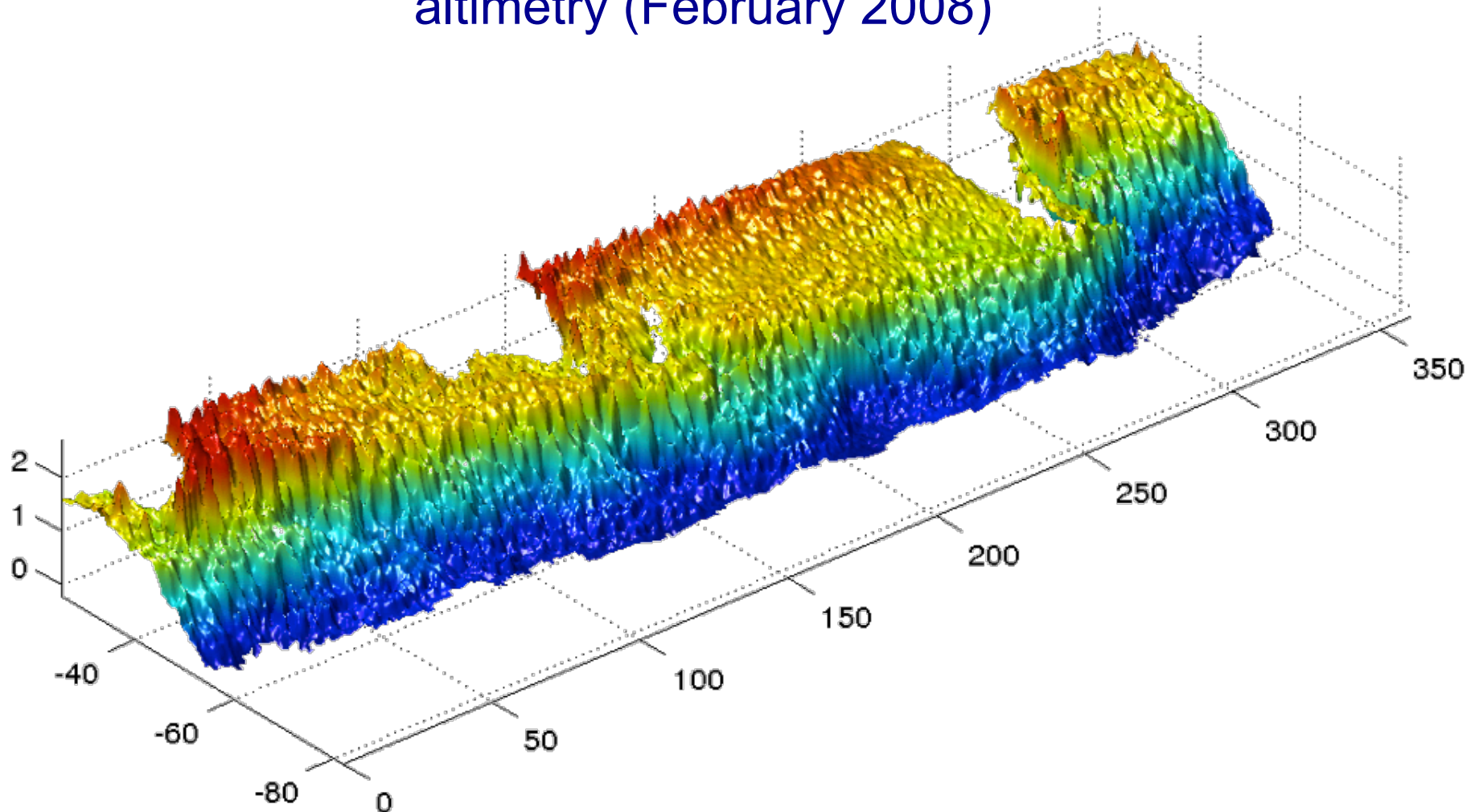
SCHEME OF AAIW EXCHANGES



Rimaud J., S. Speich, B. Blanke & N. Grima, 2012, JGR.

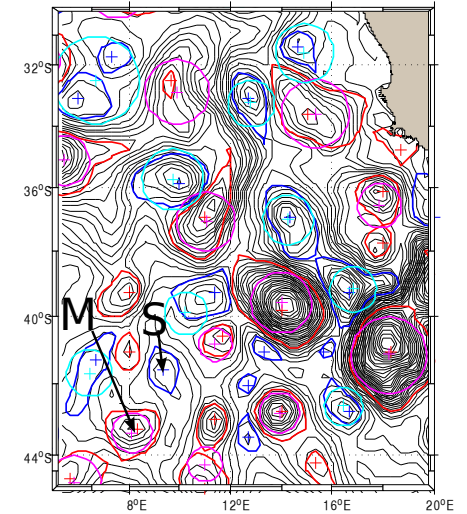
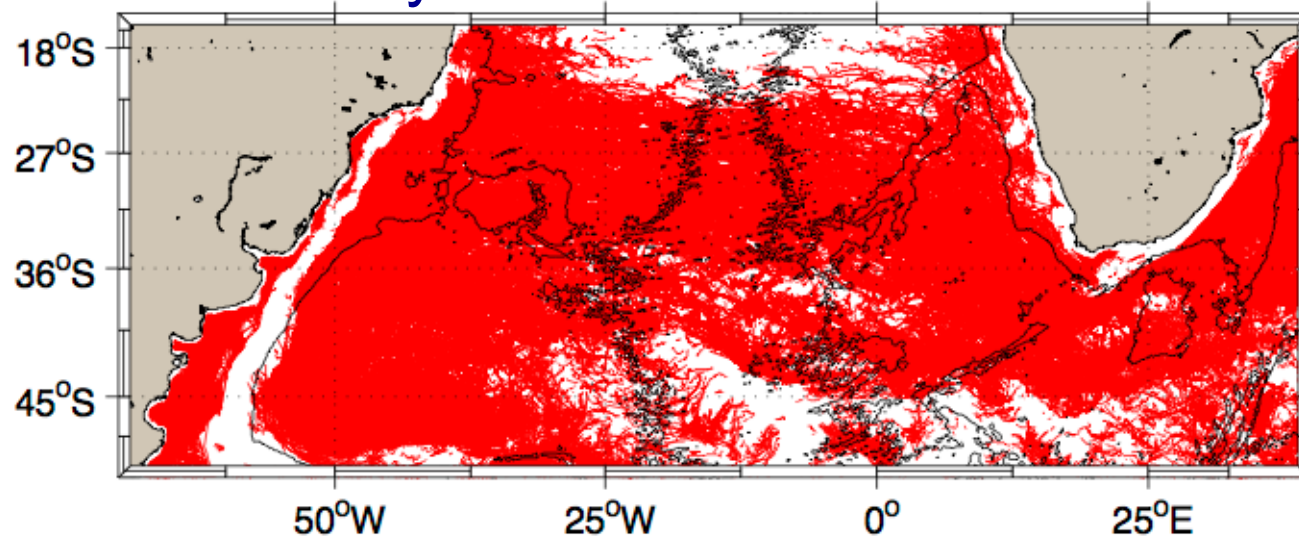
Eddies from satellite altimetry

A southern hemisphere snapshot from satellite altimetry (February 2008)

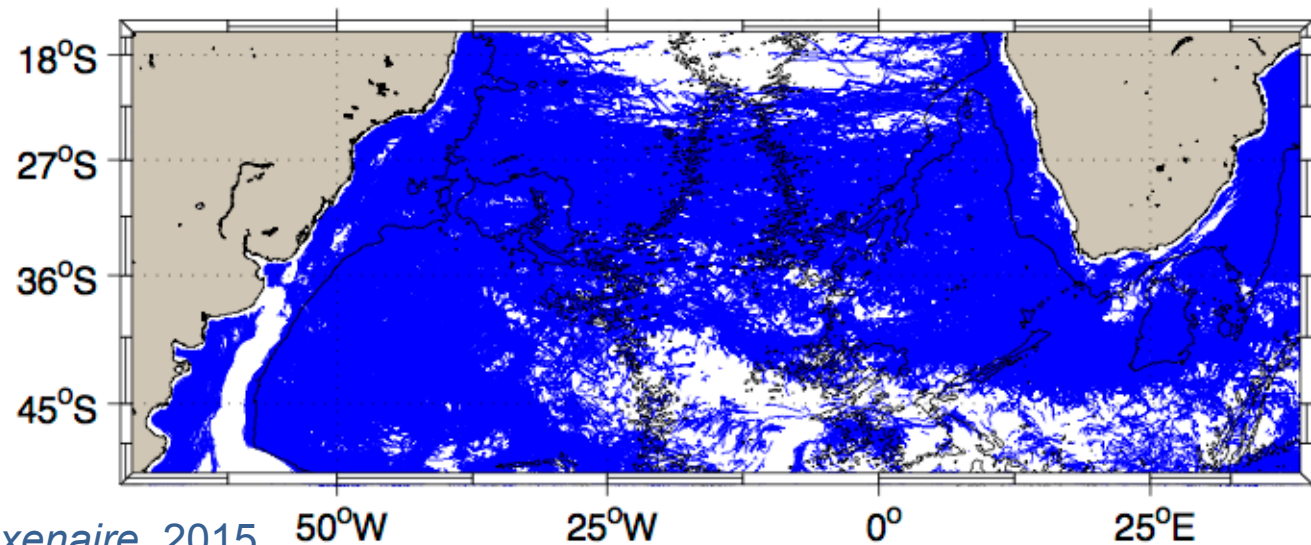


Eddies from satellite altimetry

Anticyclones

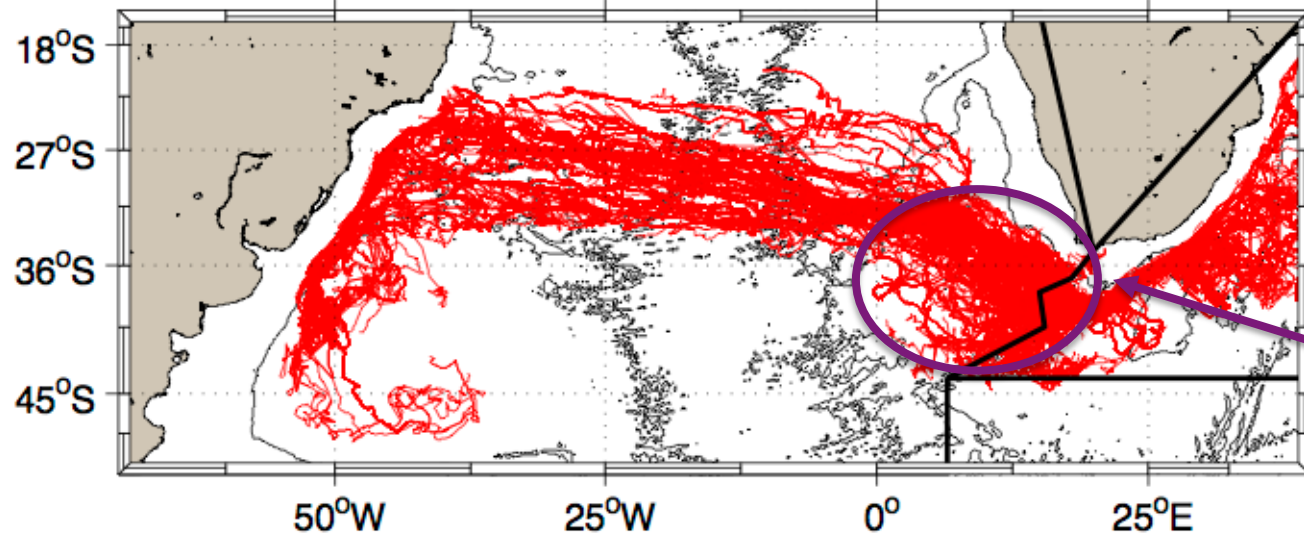


Cyclones



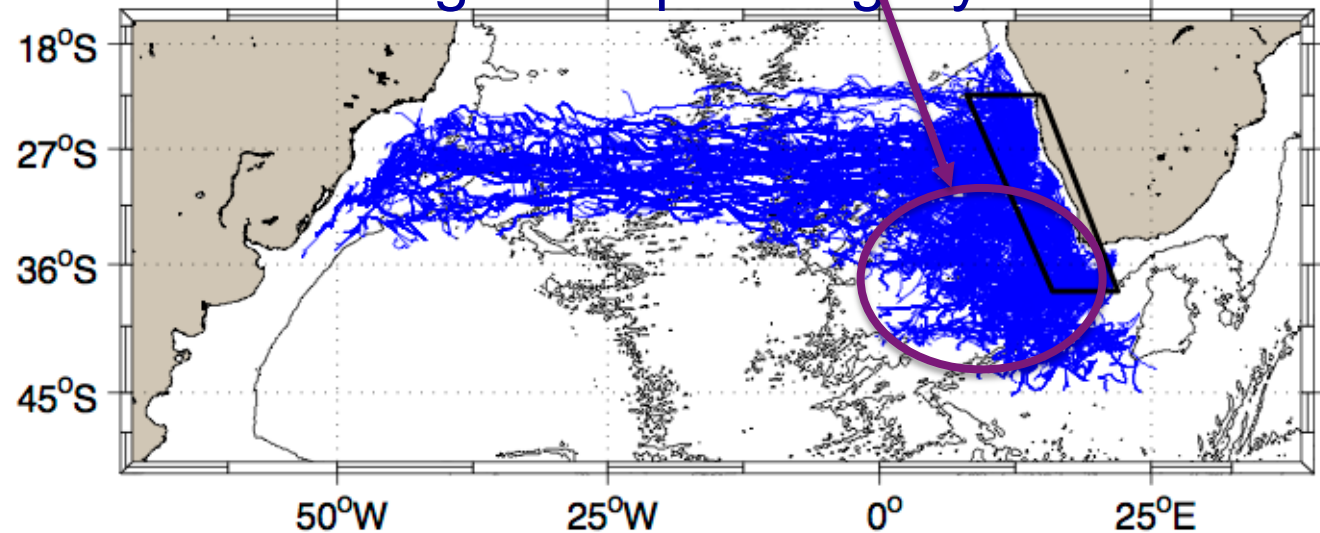
Eddies from satellite altimetry

Agulhas Rings (Anticyclones)



Most eddies disappear in the Cape Basin : very likely subduction and not dissipation

Benguela Upwelling Cyclones

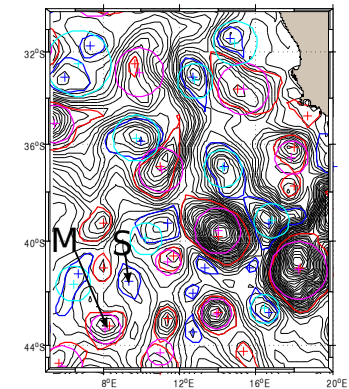
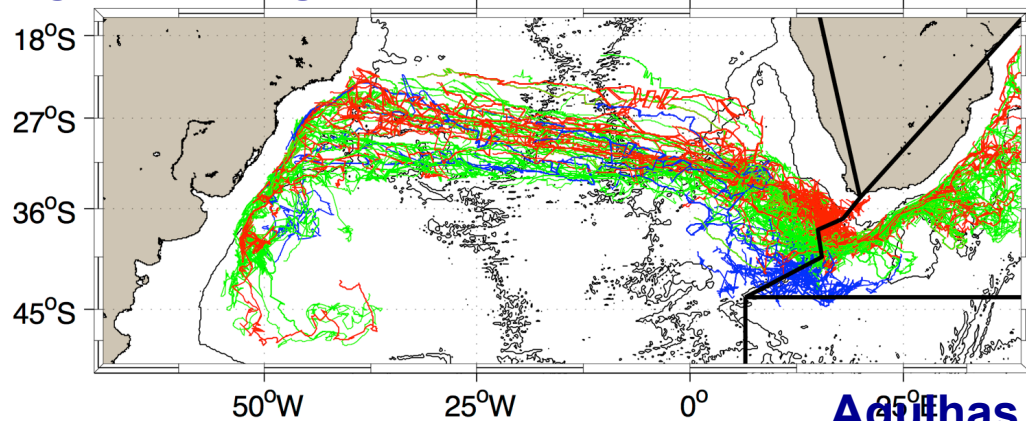


Eddies from satellite altimetry

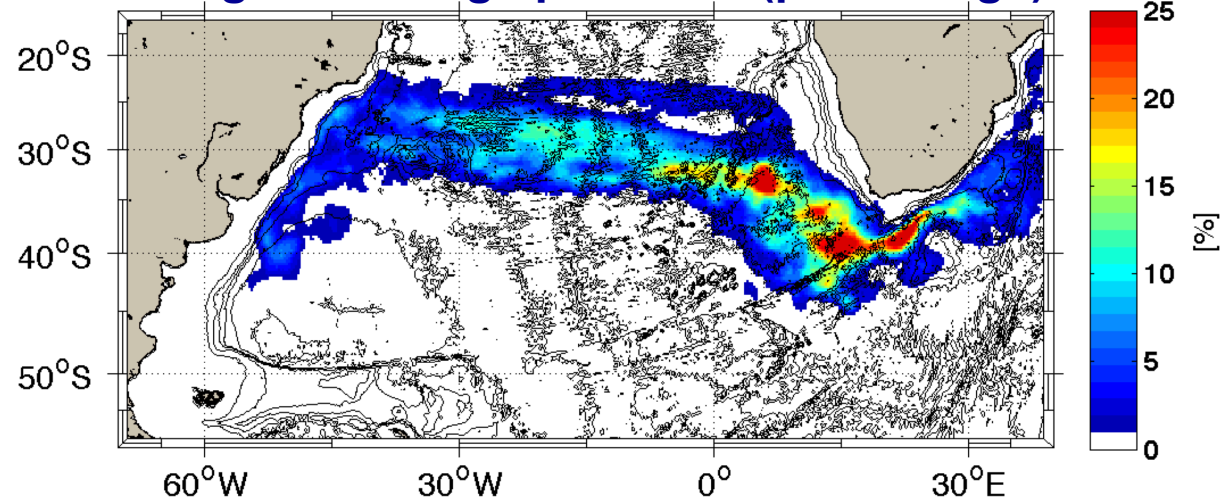
ESTIMATING EDDIES ROLE IN INTEROCEAN EXCHANGE

Agulhas Rings trajectories from altimetry 2004-2014

Agulhas Rings routes (as for Dencausse et al. 2011)



Agulhas Rings presence (percentage)



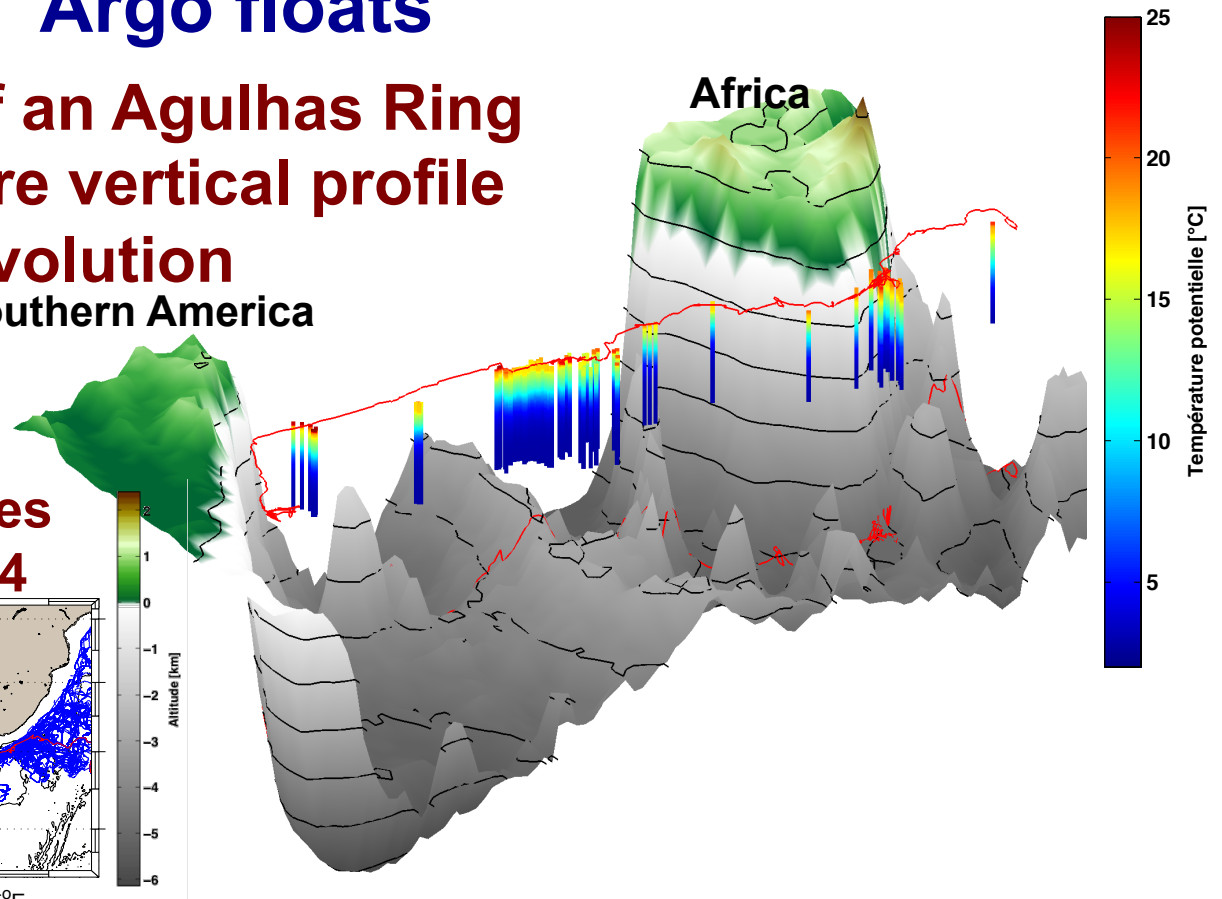
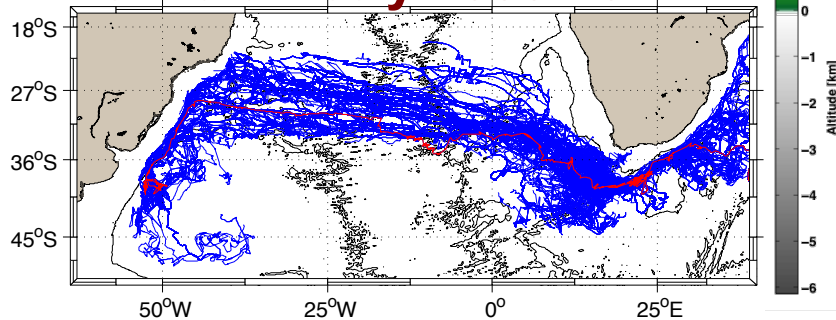
Master2 Thesis of Rémi Laxenaire

Estimating eddies role in interocean exchange

By collocating eddy tracking from altimetry and Argo floats

**Example of an Agulhas Ring
temperature vertical profile
evolution
Southern America**

**Agulhas Rings trajectories
from altimetry 2000-2014**



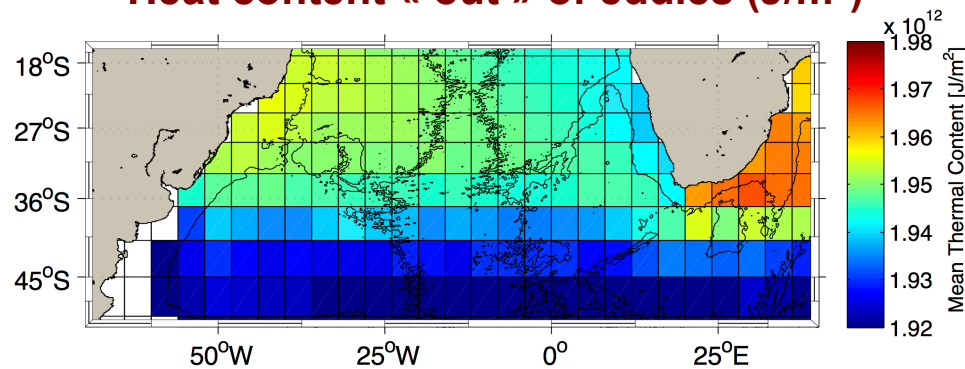
Master2 Thesis of Rémi Laxenaire, 2015

Estimating eddies role in interocean exchange

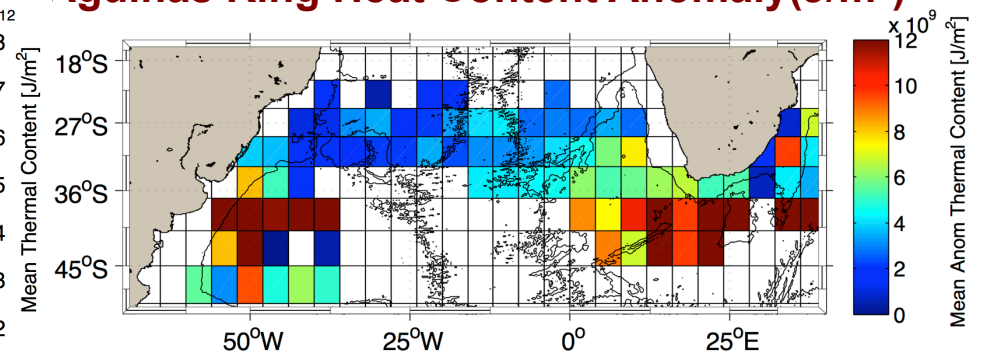
By collocating eddy tracking from altimetry and Argo floats

Agulhas Rings inflow of heat and salt from Argo floats (2004-2014)

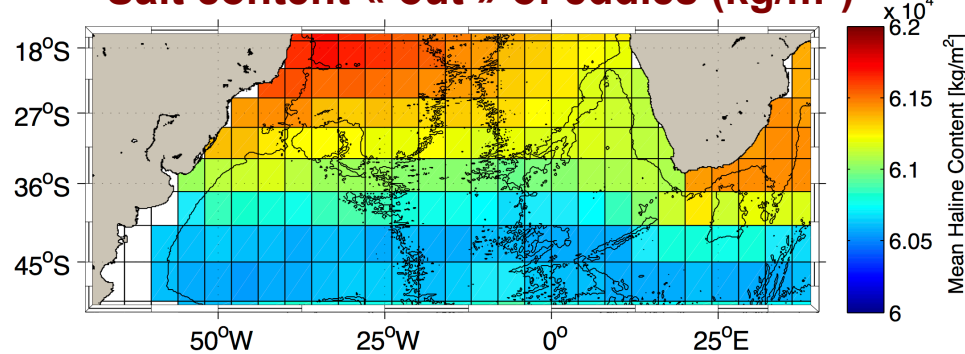
Heat content « out » of eddies (J/m^2)



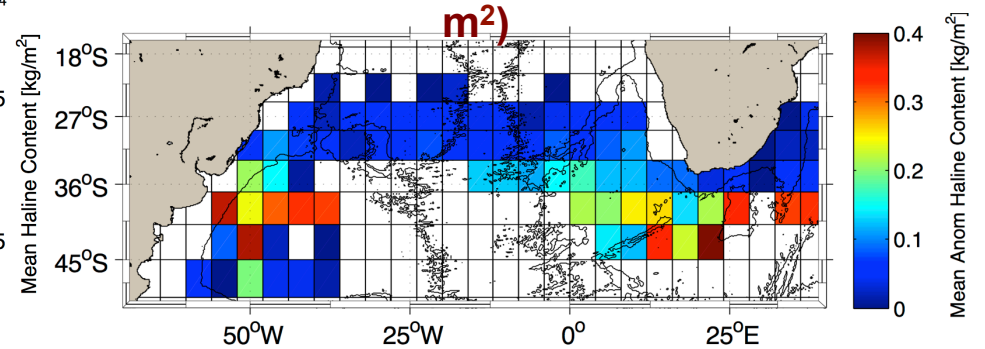
Agulhas Ring Heat Content Anomaly (J/m^2)



Salt content « out » of eddies (kg/m^2)



Agulhas Ring Salt content Anomaly (kg/m^2)

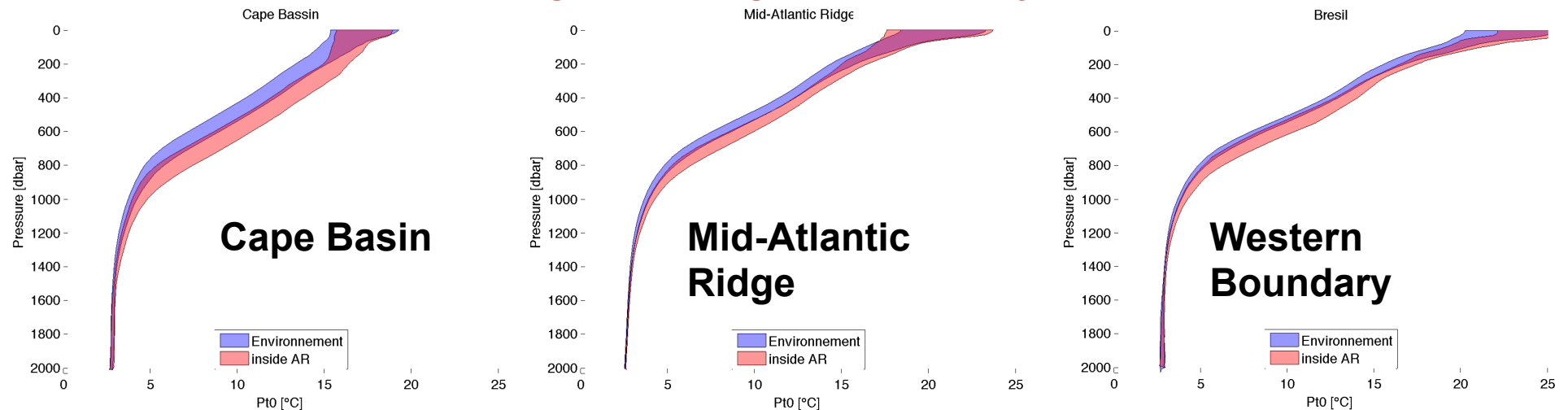


Master2 Thesis of Rémi Laxenaire, 2015

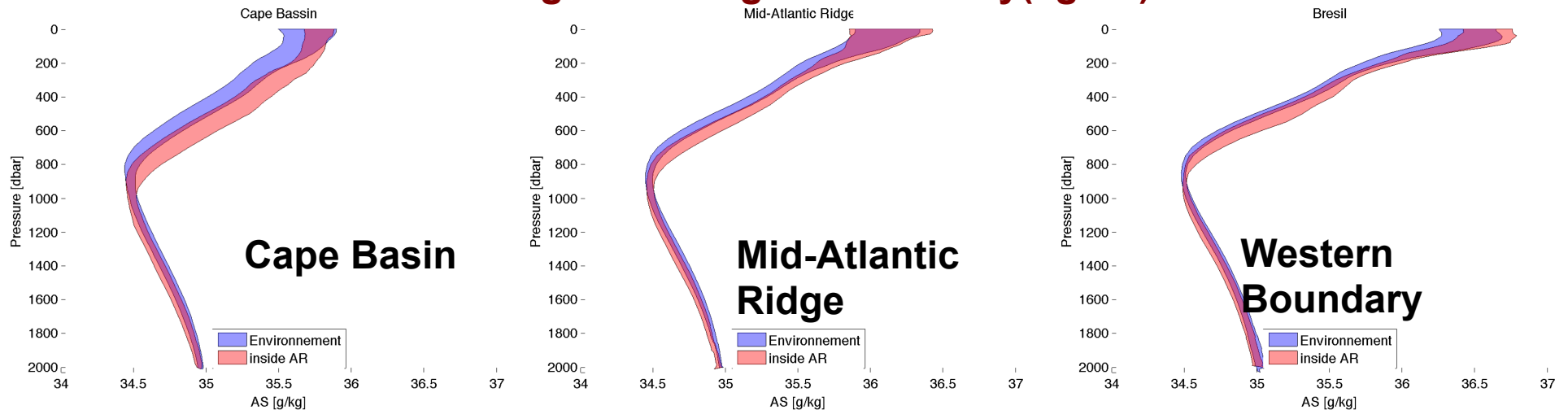
Evaluating associated fluxes by combining satellite & Argo

Agulhas Rings inflow of heat and salt from Argo floats

Agulhas Ring Heat Anomaly(J/m²)

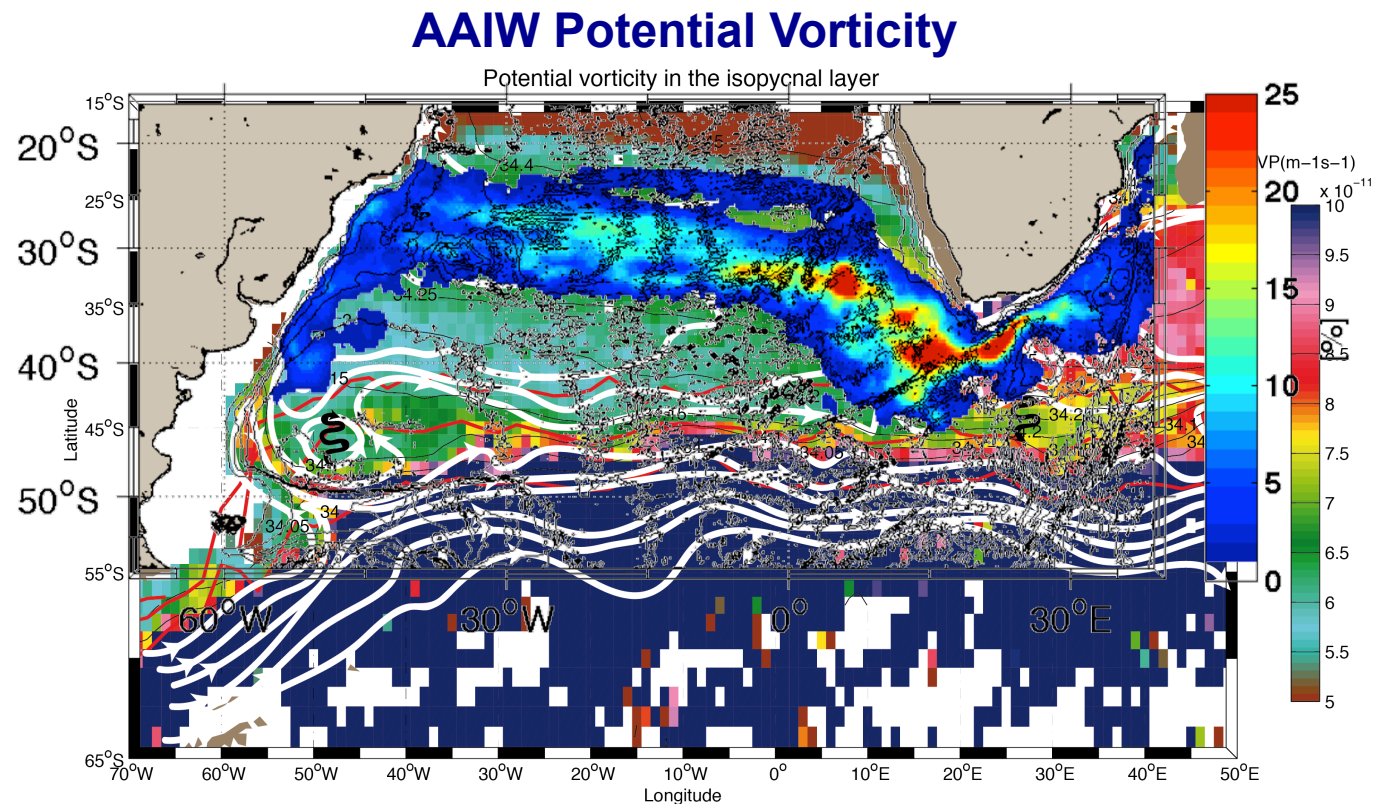


Agulhas Ring Salt Anomaly(kg/m²)



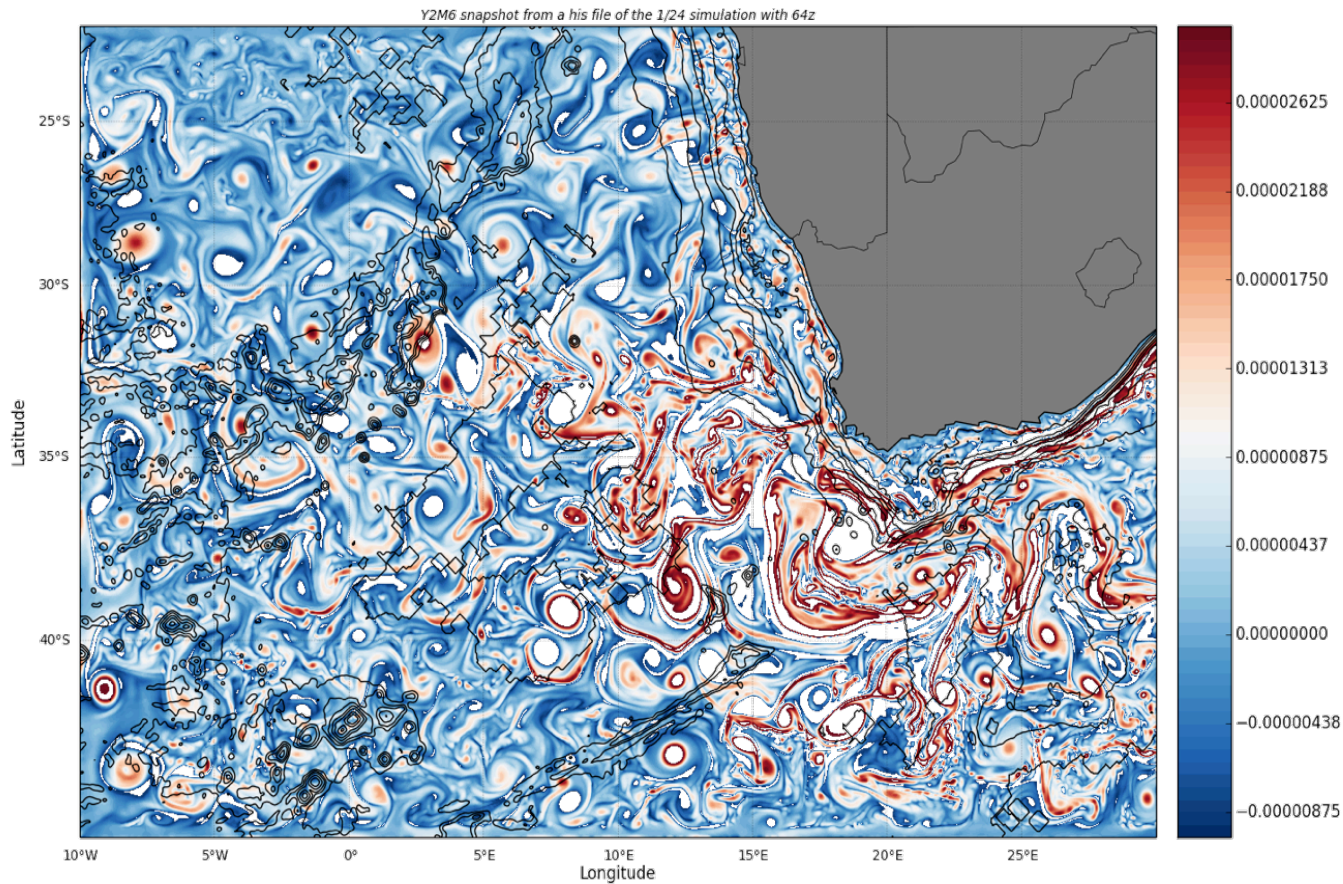
Evaluating associated fluxes by combining satellite & Argo

Eddies, ocean circulation, interocean exchanges



Perspectives on the modelling side

ROMS 1/24° Relative Vorticity at 10 m



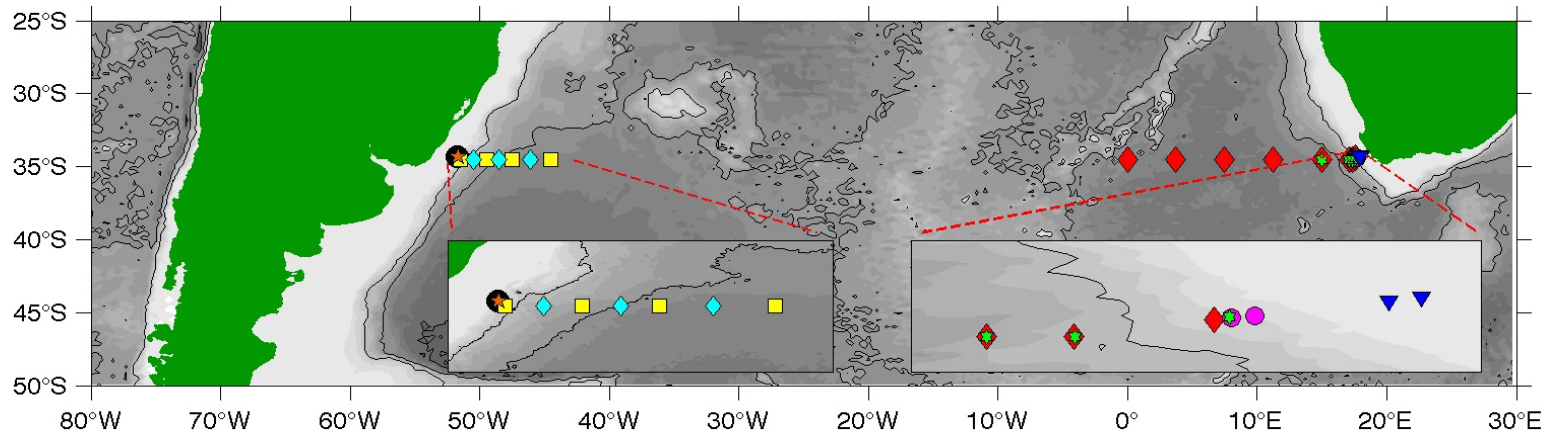
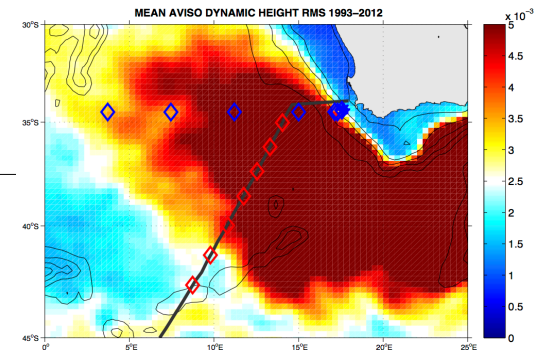
Perspectives on the observational side

THE SAMOC INTERNATIONAL INITIATIVE

- Since 2007 : establishment of A MOC observing system in the south atlantic, endorsed by CLIVAR
- Cooperation between Argentina, Brazil, France, South Africa and the USA with collaborators from Germany, Russia, Spain, and the UK.

- 7 PIES were deployed in Dec 2014 along oblique Goodhope transect (JASON-2 ground track) out to Agulhas Ridge
- Gray line: CLIVAR Goodhope line sampled twice/year

- PIES - NOAA - In place since March 2009
- ◆ CPIES - Brazil - In place since December 2012
- Bottom pressure - Brazil - In place since December 2013
- ★ Bottom ADCP - Brazil - In place since December 2013
- ◆ CPIES - France - In place since September 2013
- Bottom ADCP - France - In place since September 2013
- ▼ Shelf mooring - South Africa - In place since June 2014
- ★ Tall mooring - South Africa - In place since September 2014



Conclusions

- Indo-Atlantic Exchange is very important in terms of transport and it participates actively into heat and salt transfer into the South Atlantic;
- Eddies are a major actor in such a transfer as well as in mixing water masses
- Agulhas Rings transfer huge amounts of heat to the atmosphere
- Indo-Atlantic exchange through Agulhas Rings is not so quick, but slow and very turbulent: The Cape Basin is really a giant Cauldron
- Cyclones are very important too in transferring water mass properties into the ocean interior
- More data to better understand and quantify; regional modelling studies to investigate mixing processes (with submesoscale permitting/resolving models) & air-sea exchanges

Thanks!

