Changing the vertical layer distribution in HYCOM and understanding the impact on the Agulhas (retroflection)

Björn Backeberg, Julie Deshayes, Marion Bezaud, Johnny Johannessen & Chris Reason

Layered Ocean Model Workshop, Copenhagen, 2-4 June 2015

Project funding from the Nansen-Tutu Centre, NERSC, the South African National Research Foundation through Grants 87698 and 91426 and the NOTUR project number nn2993k.

Financial support to attend LOM from ONR.

NANSEN-TUTU CENTRE
MARINE ENVIRONMENTAL RESEARCH

Ma-Re
Marine Research Institute

NERSC

NRF National Research Foundation

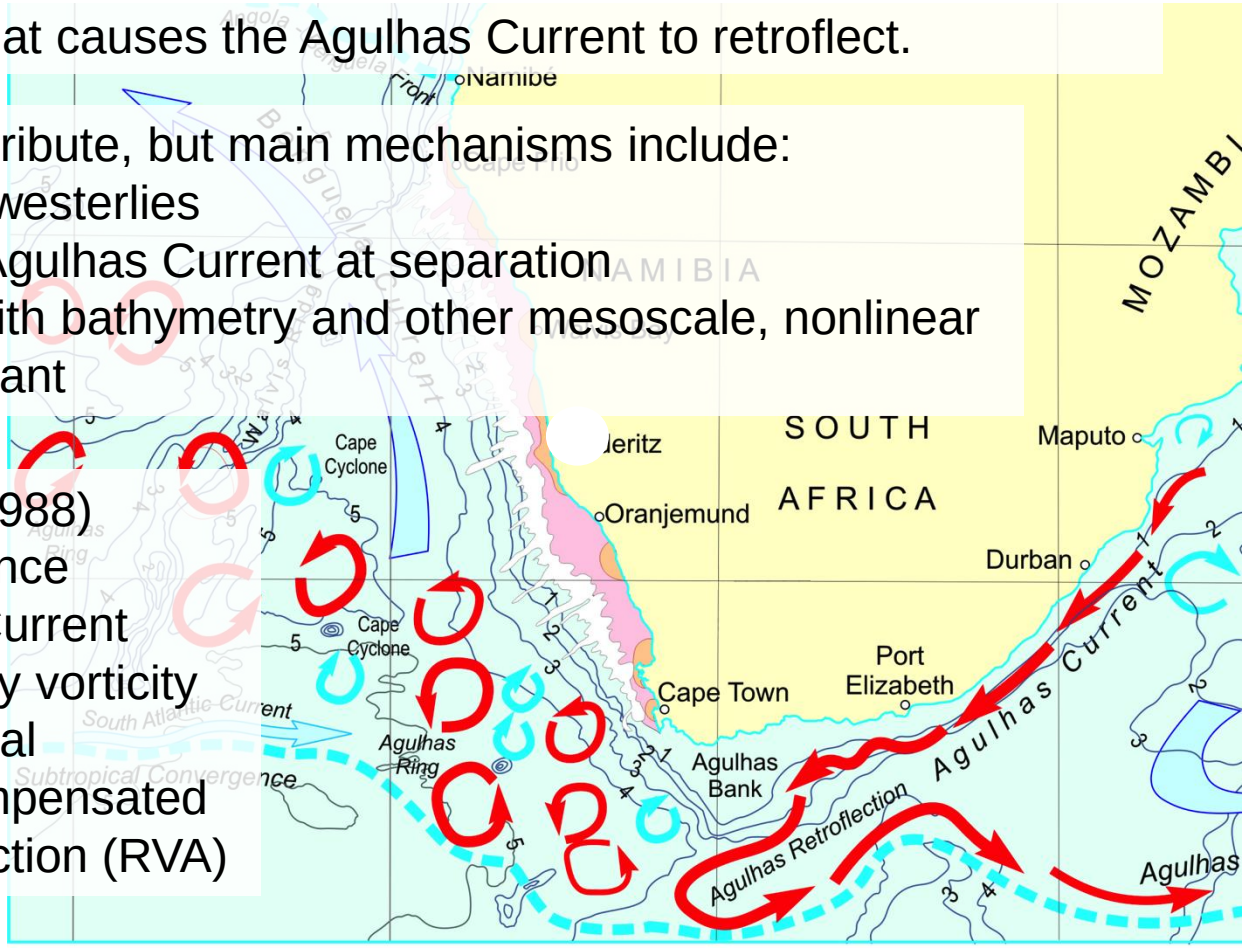
Agulhas Current retroflection

There is still debate over what causes the Agulhas Current to retroflect.

A number of processes contribute, but main mechanisms include:

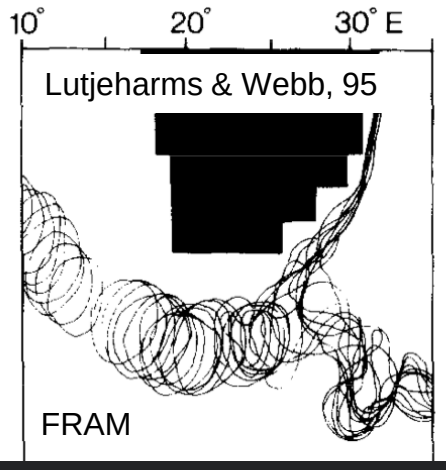
- latitude of the maximum westerlies
- southward inertia of the Agulhas Current at separation
- instabilities, interaction with bathymetry and other mesoscale, nonlinear dynamics are also important

Boudra and Chassignet's (1988) analysis of the vorticity balance suggests that the Agulhas Current retroflects because planetary vorticity advection (BETA) and vertical stretching (STRCH) are compensated for by relative vorticity advection (RVA)



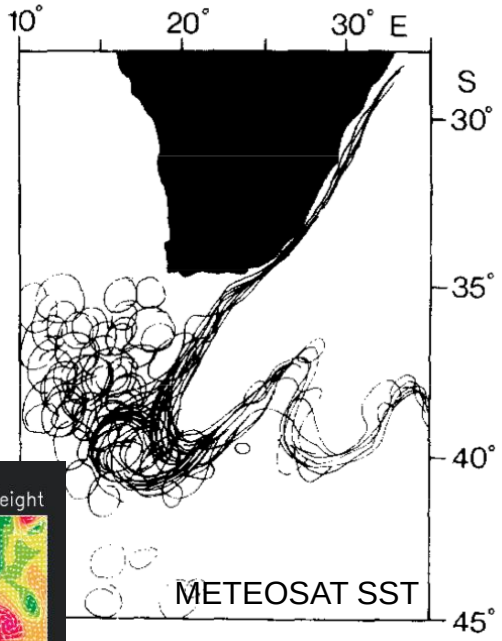
The importance of deep currents and the Agulhas Undercurrent have not been studied in the context Agulhas Current separation and retroflection.

Modelling the Agulhas retroflection

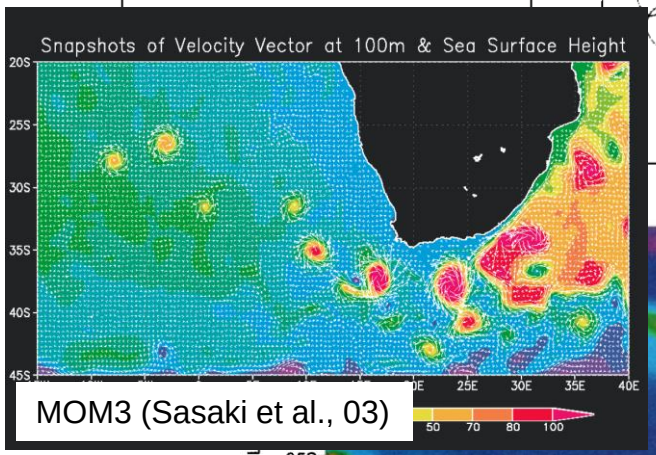


Lutjeharms & Webb, 95

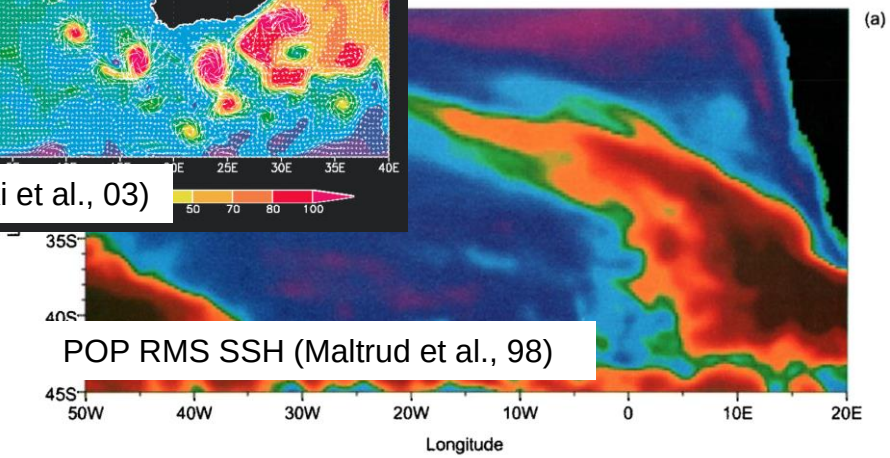
FRAM



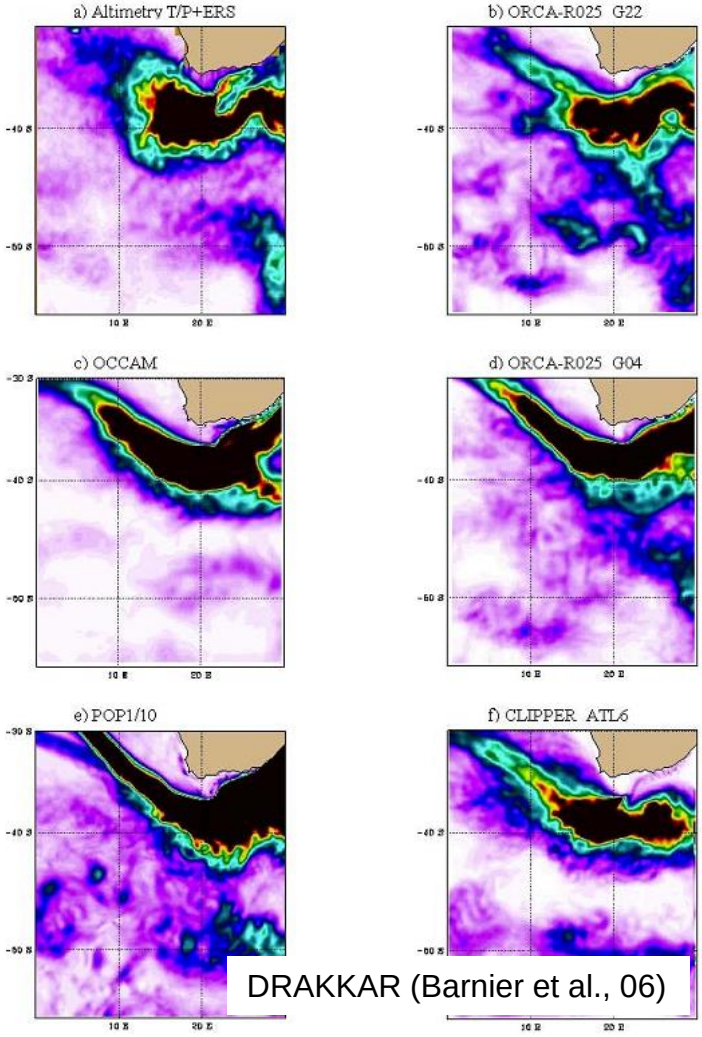
METEOSAT SST



MOM3 (Sasaki et al., 03)

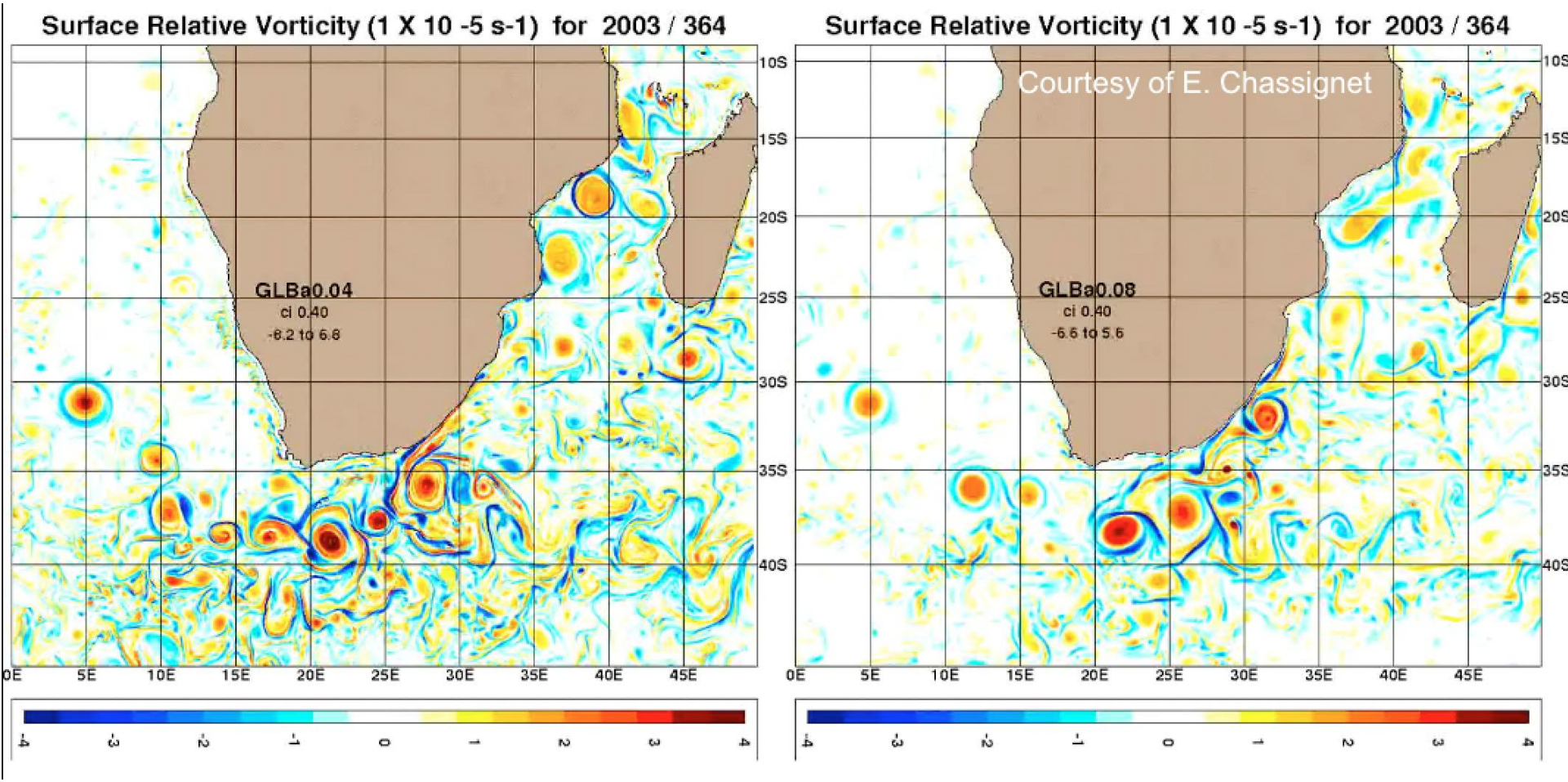


POP RMS SSH (Maltrud et al., 98)



DRAKKAR (Barnier et al., 06)

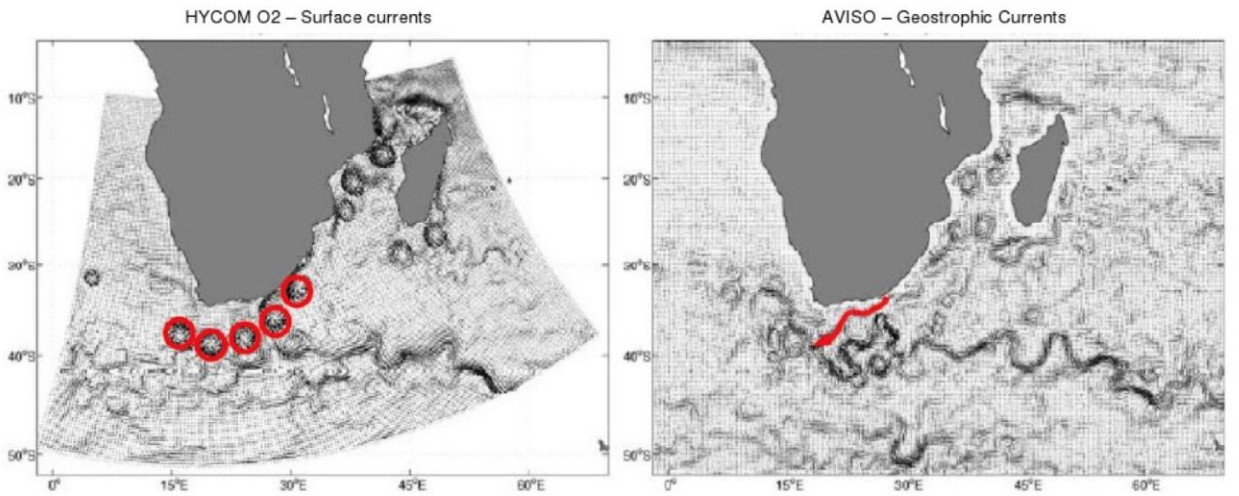
Increasing the model resolution

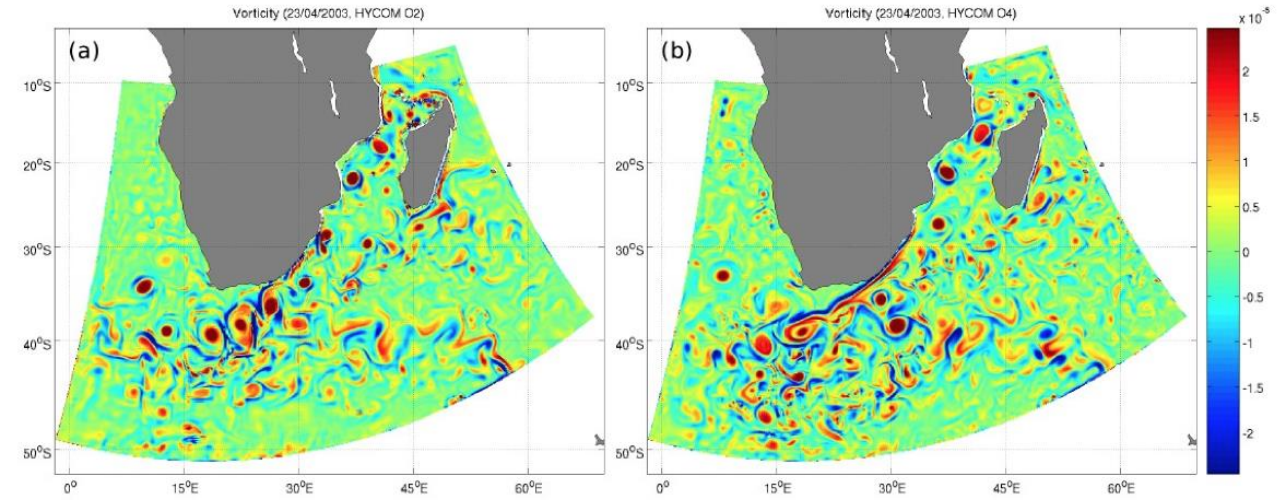


Increasing the model resolution from 1/12º to 1/25º of a degree does not improve the Agulhas retroflection and ring shedding bias.

Experiments in a regional HYCOM

2nd order momentum advection scheme in HYCOM also produces train of successive eddies propagating into the South Atlantic Ocean from an early retroflection.





Vorticity

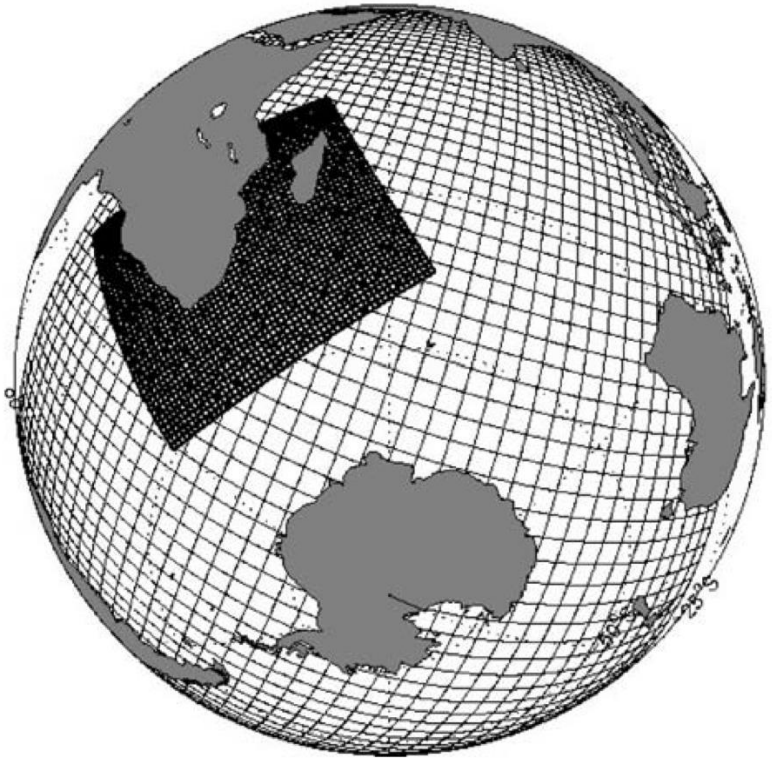
4th order momentum advection scheme in HYCOM changes the nature of the southern Agulhas Current and retroflection dynamics.

In this study…

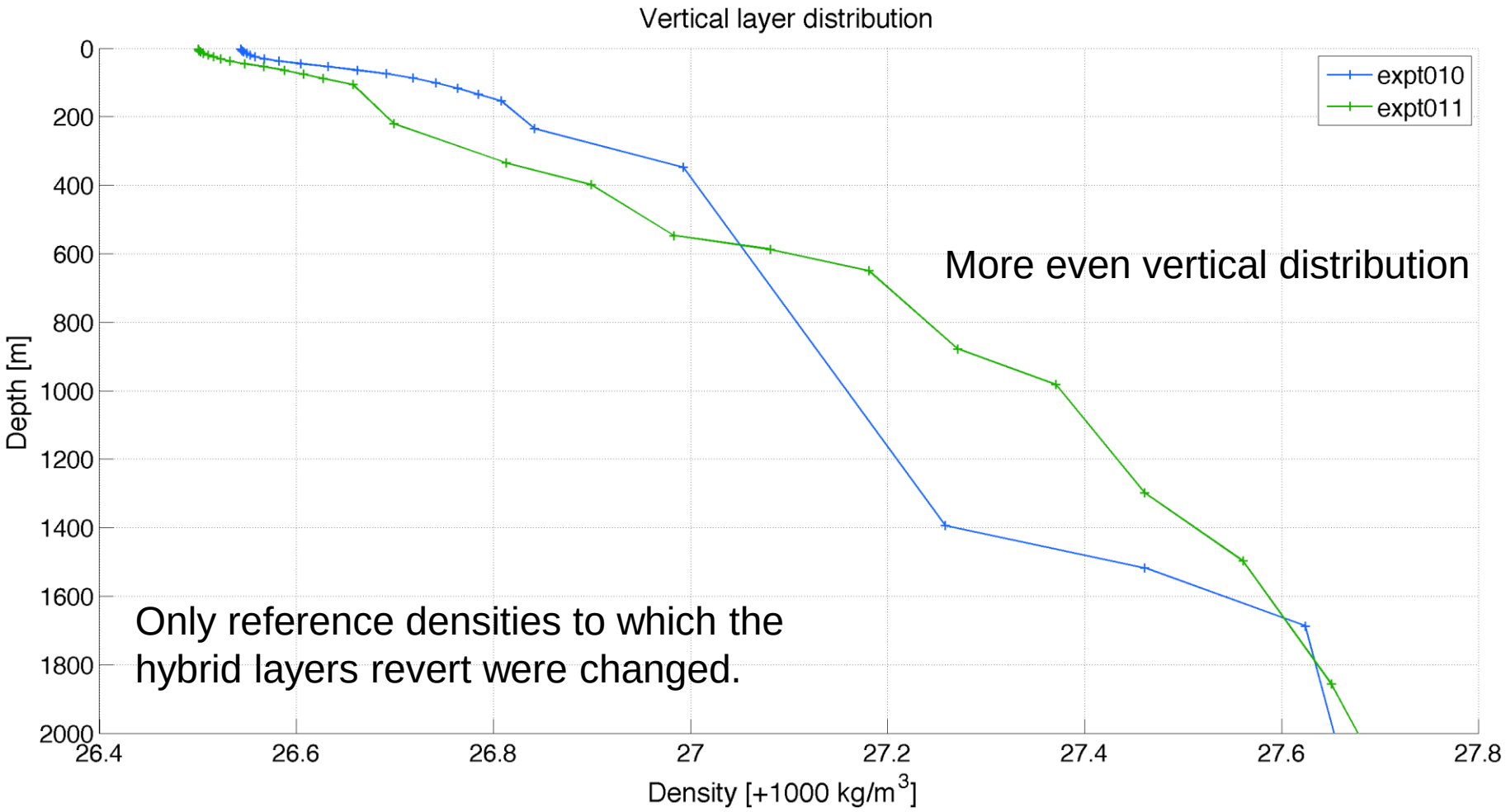
… we compare two simulation experiments in a regional 1/10º HYCOM. Only the reference densities to which the hybrid layers revert to were changed.

Objective

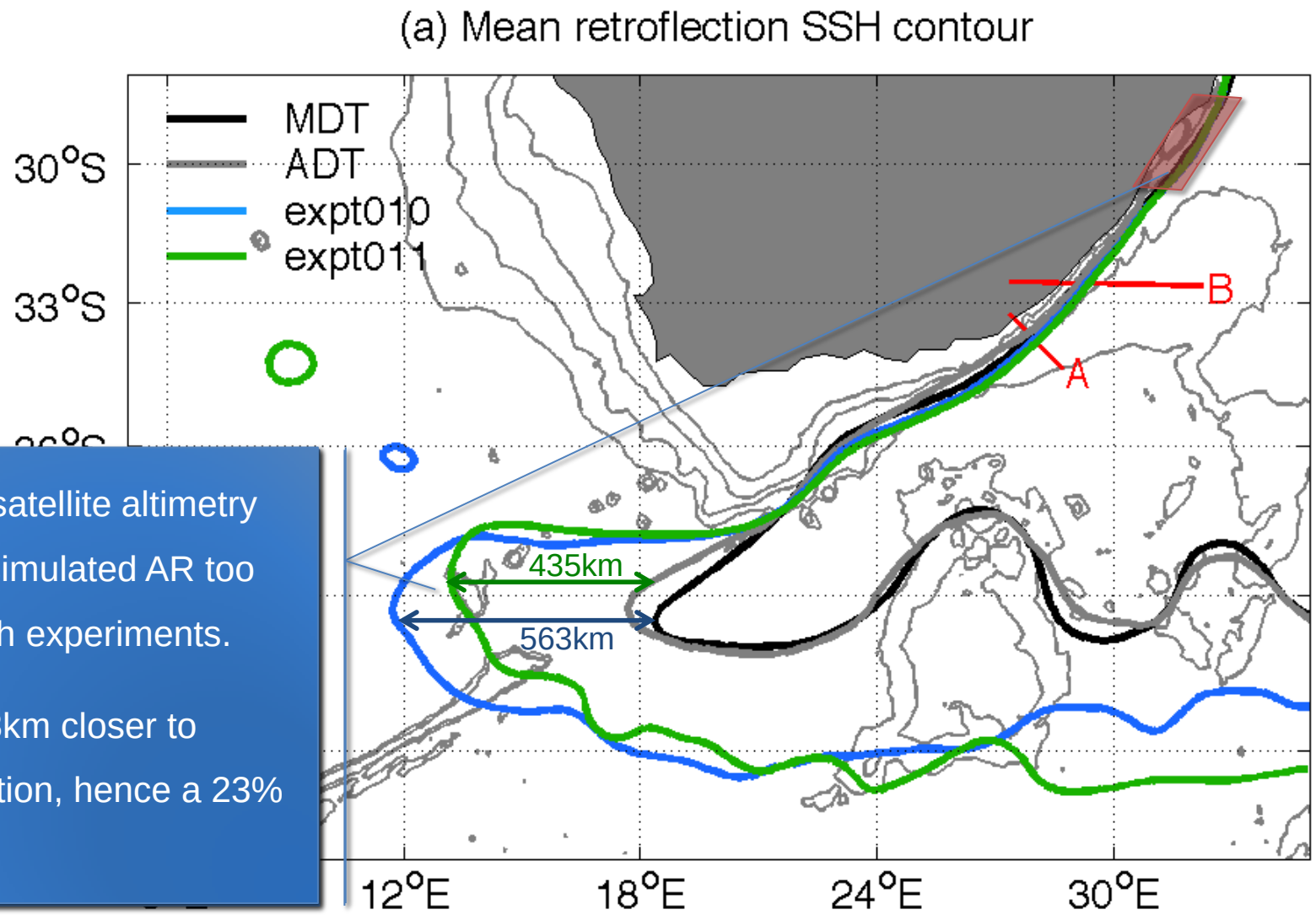
Illustrate how changing vertical stratification in HYCOM impacts the simulated dynamics (and the Agulhas retroflection).



Simulation experiments



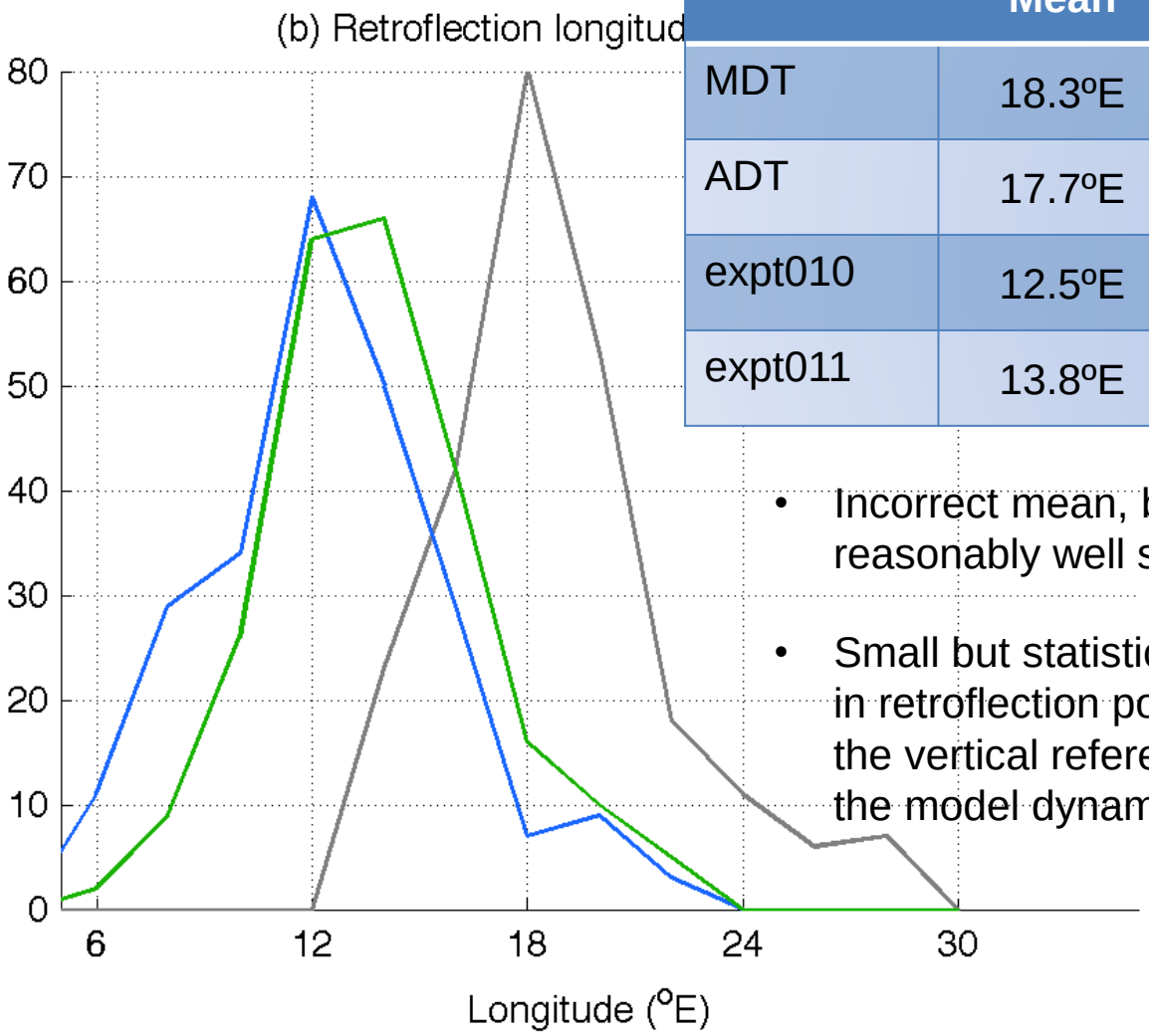
Tracking the Agulhas retroflection



Compared to satellite altimetry derived SSH simulated AR too far west in both experiments.

expt011 is 128km closer to observed position, hence a 23% improvement.

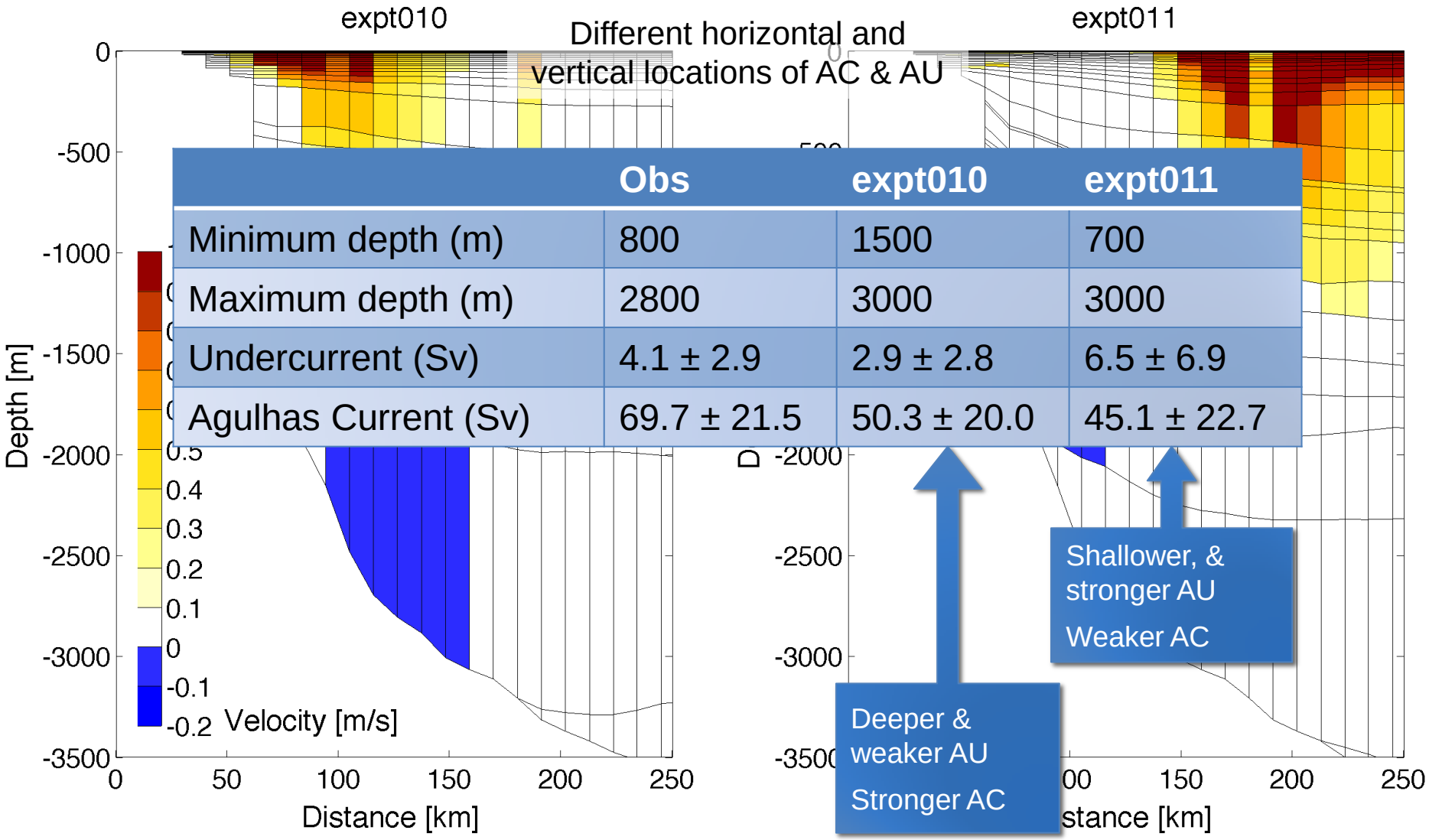
Tracking the Agulhas retroflection



	Mean	Std	% west of 5ºE
MDT	18.3ºE	N/A	N/A
ADT	17.7ºE	3.1º	0%
expt010	12.5ºE	3.3º	5%
expt011	13.8ºE	3.0º	0%

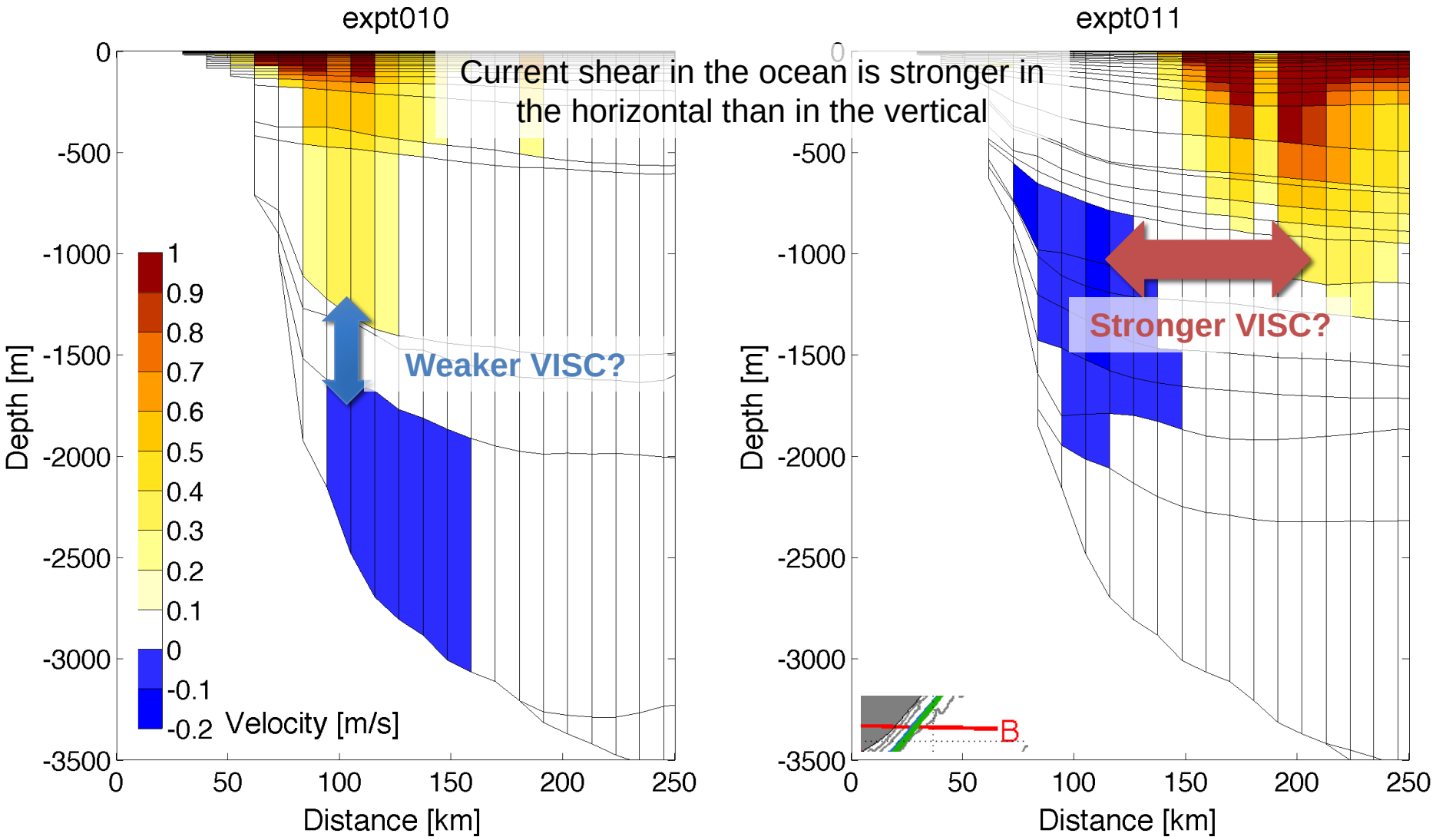
- Incorrect mean, but similar distribution suggest reasonably well simulated dynamics.
- Small but statistically significant positive change in retroflection position suggests that changing the vertical reference densities have affected the model dynamics.

Link with Agulhas Undercurrent?



	Obs	expt010	expt011
Minimum depth (m)	800	1500	700
Maximum depth (m)	2800	3000	3000
Undercurrent (Sv)	4.1 ± 2.9	2.9 ± 2.8	6.5 ± 6.9
Agulhas Current (Sv)	69.7 ± 21.5	50.3 ± 20.0	45.1 ± 22.7

Does the vertical and horizontal change in the currents introduce enhanced shear that impacts horizontal viscosity dissipation?



Estimate of VISC

from time average velocity field

Layer 23

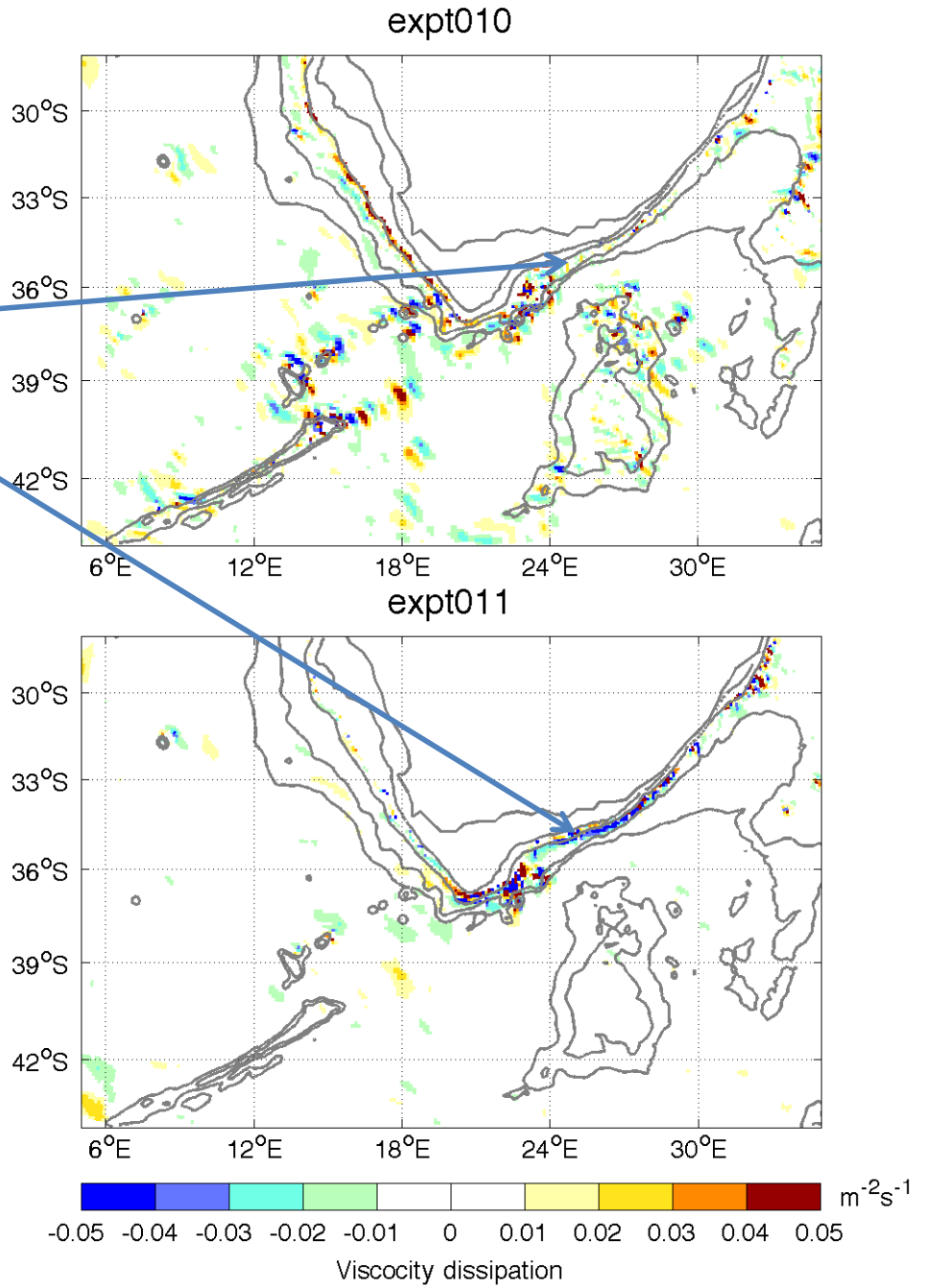
$VISC_{expt010}$ weak & slightly positive

$VISC_{expt011}$ negative, i.e. **enhanced**

Suggests that

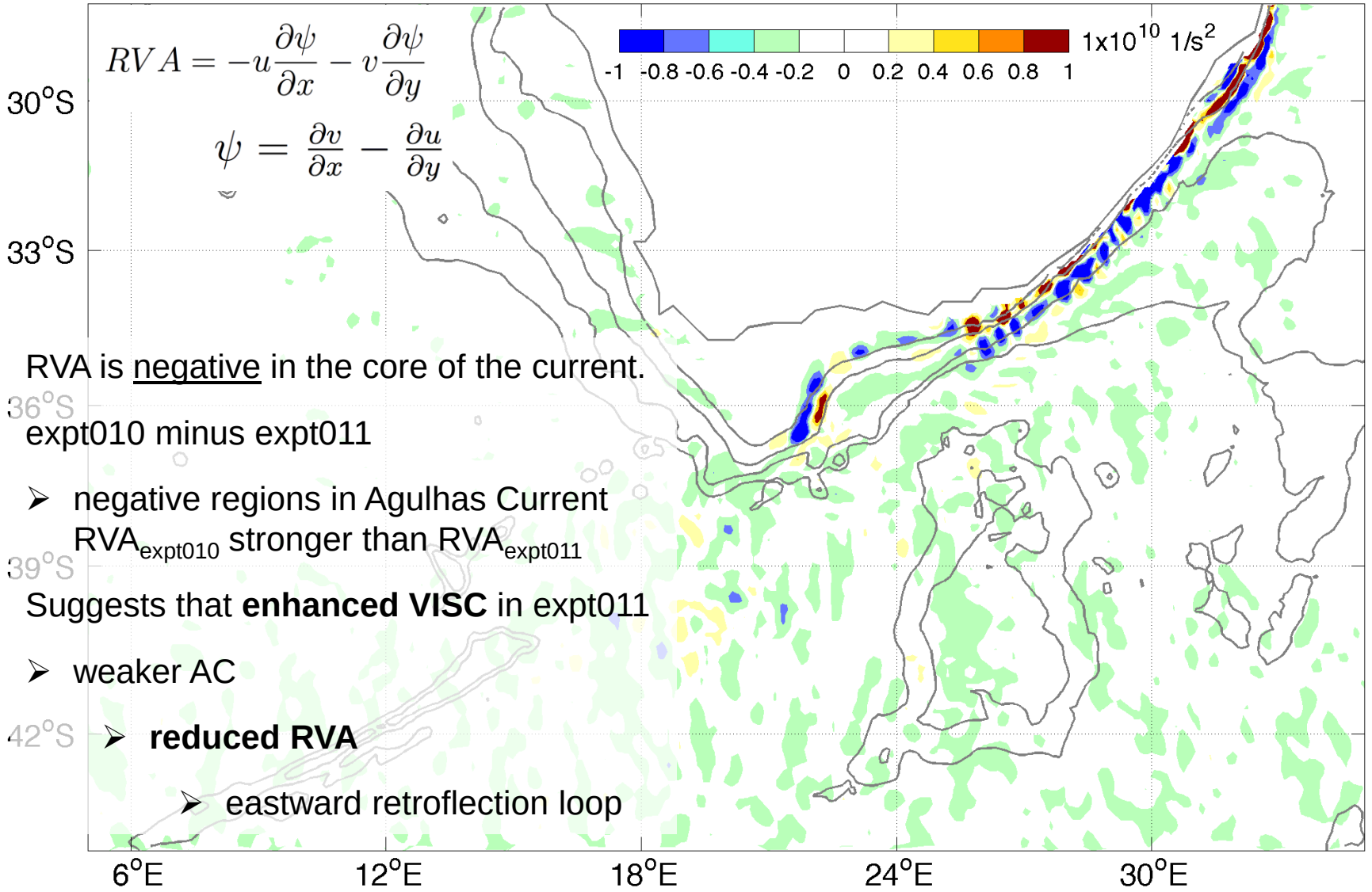
- Shallower and stronger AU facilitates enhanced interaction with AC.
- Causes a higher velocity shear and weaker AC.

How are relative (RVA) and planetary (BETA) vorticity advection affected?



Estimate of relative vorticity advection (RVA)

using time averaged velocities



RVA is <u>negative</u> in the core of the current.

expt010 minus expt011

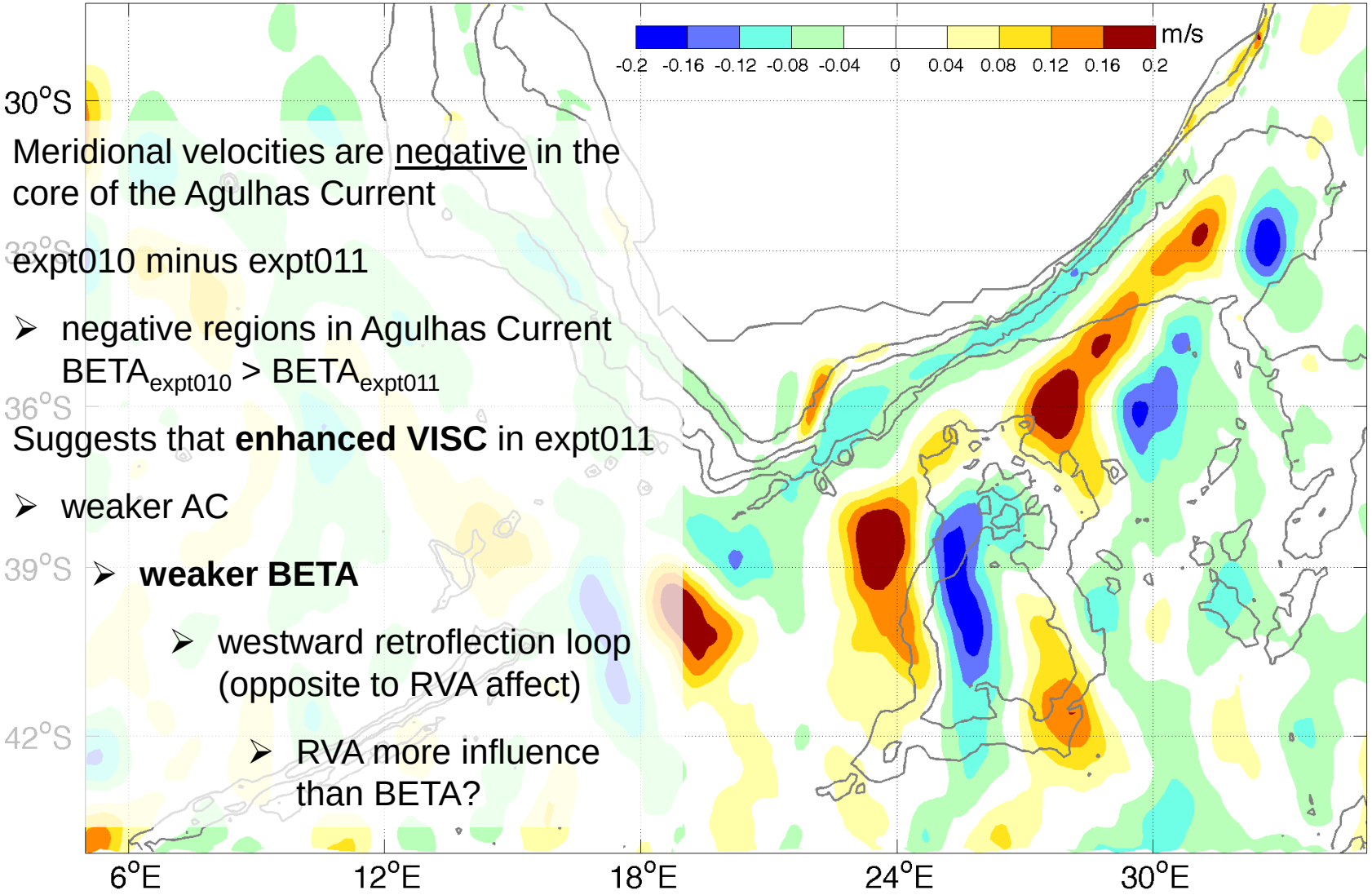
- negative regions in Agulhas Current
  $RVA_{expt010}$ stronger than $RVA_{expt011}$

Suggests that **enhanced VISC** in expt011

- weaker AC
  - **reduced RVA**
    - eastward retroflection loop

Proxy for planetary vorticity advection (BETA):

time averaged meridional velocities



Meridional velocities are negative in the core of the Agulhas Current

expt010 minus expt011

- negative regions in Agulhas Current $BETA_{expt010} > BETA_{expt011}$

Suggests that **enhanced VISC** in expt011

- weaker AC
- **weaker BETA**
- westward retroflection loop (opposite to RVA affect)
- RVA more influence than BETA?

In summary

Analysis would benefit from an improved approach to calculate PVA, e.g. Androulidakis et al. (2009) and Le Hénaff et al. (2012).

Results so far suggest that:

Shallower and stronger Agulhas Undercurrent ➔ stronger VISC through enhanced interaction between AU and AC ➔ weaker AC due to stronger horizontal shear ➔ reduces RVA ➔ more eastward retroflection.

Is BETA opposing the RVA and VISC effect? Is this the reason why there is only a relatively small change in retroflection position?

Does RVA play a larger role than BETA in determining the retroflection position?

Very difficult to say anything conclusive about the vertical stretching.