

Modeling Deep Ocean Currents: *persistent challenges, recent insights and potential implications*

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Climate
Modelling
Center

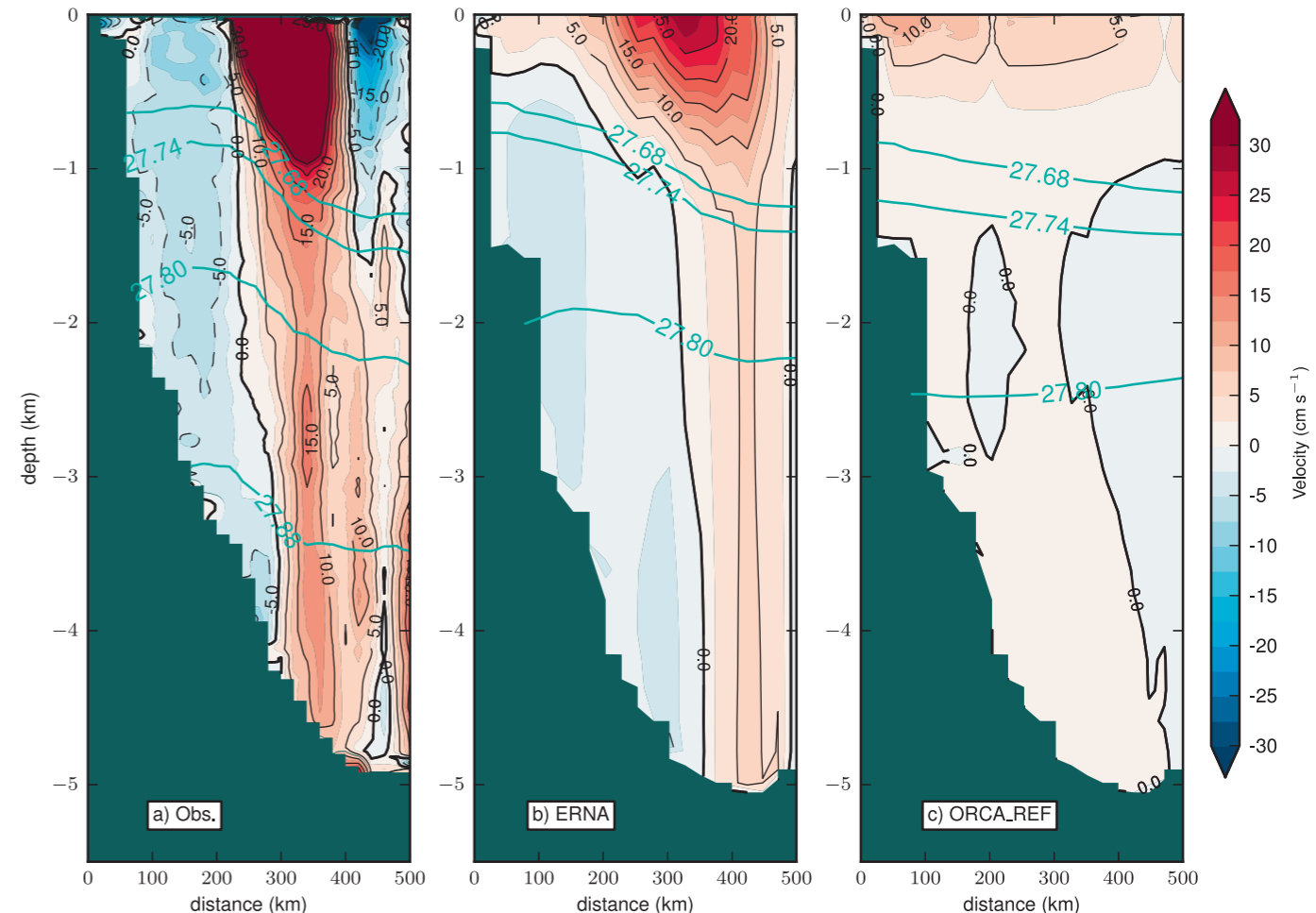
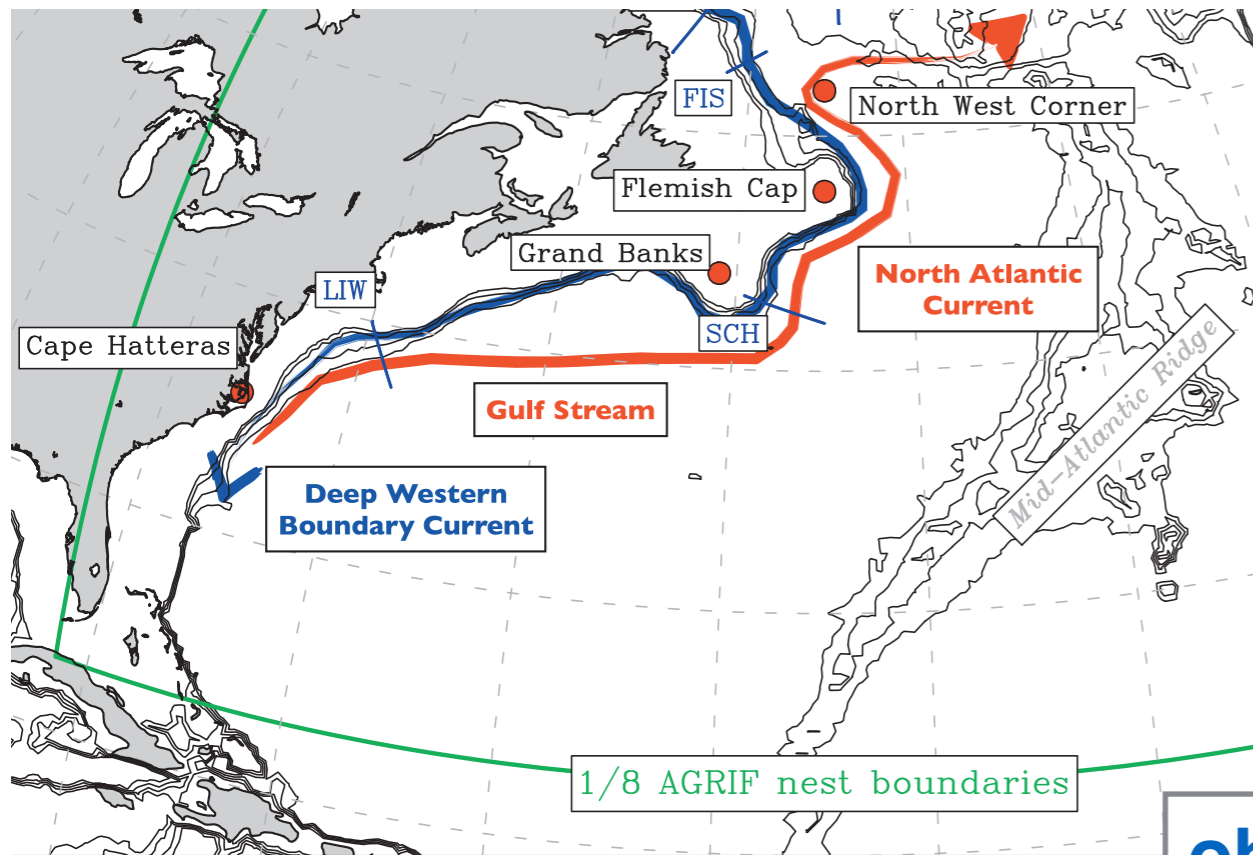
the next-generation climate model of my dreams

- ▶ producing 20 yr / day \gg 1000 yr simulations to check adjustment and mean state + run multiple experiments to quantify uncertainties
- ▶ tracking, if not controlling, energy routes, sources and sinks

why is it important to
represent *properly* Deep Ocean
Currents in climate models ?

MOC, DWBC and NADW formation (I/2)

Talandier et al. (2014, Ocean Modelling) :
 increasing spatial resolution improves
 circulation at the surface and at depth,
 as illustrated here along Line W



observations

ERNA 1/8°

ORCA 1/2°

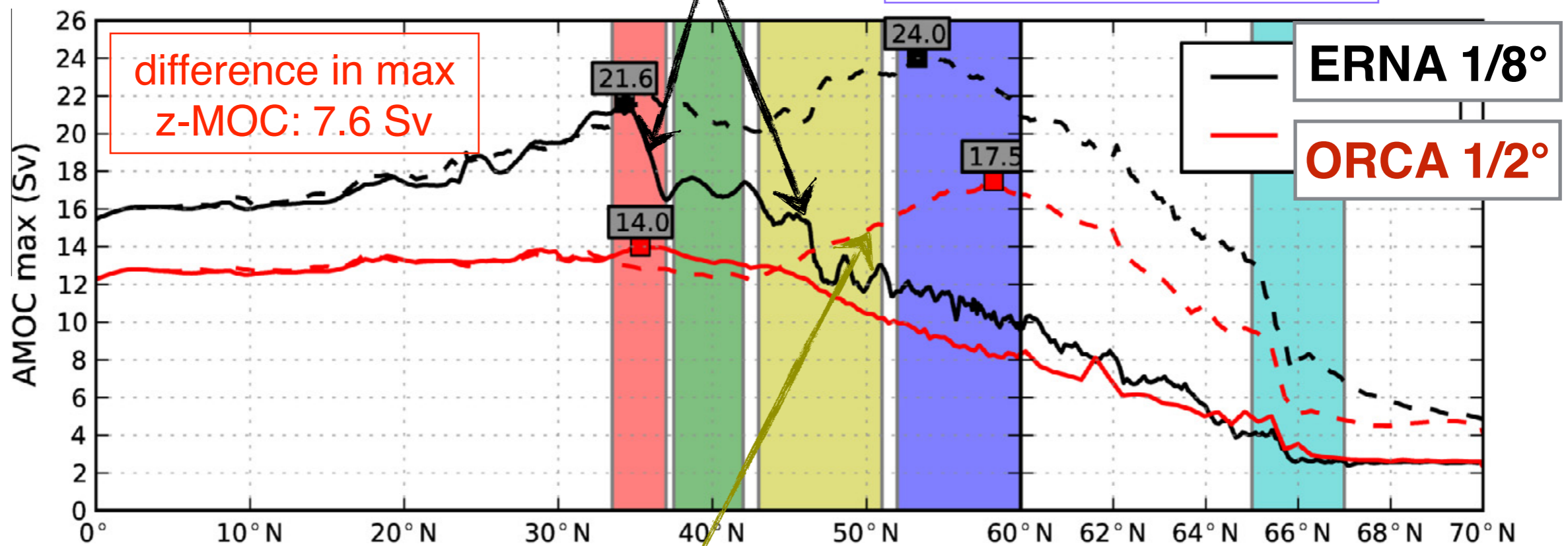
ERNA = ORCA05 + 1/8 AGRIF 2-way zoom over North Atlantic

MOC, DWBC and NADW formation (2/2)

Talandier et al. (2014, Ocean Modelling)

in ERNA: sharp change in MOCz as DWBC crosses underneath NAC and GS

difference in max density-MOC (ie dense water formation): 6.5 Sv



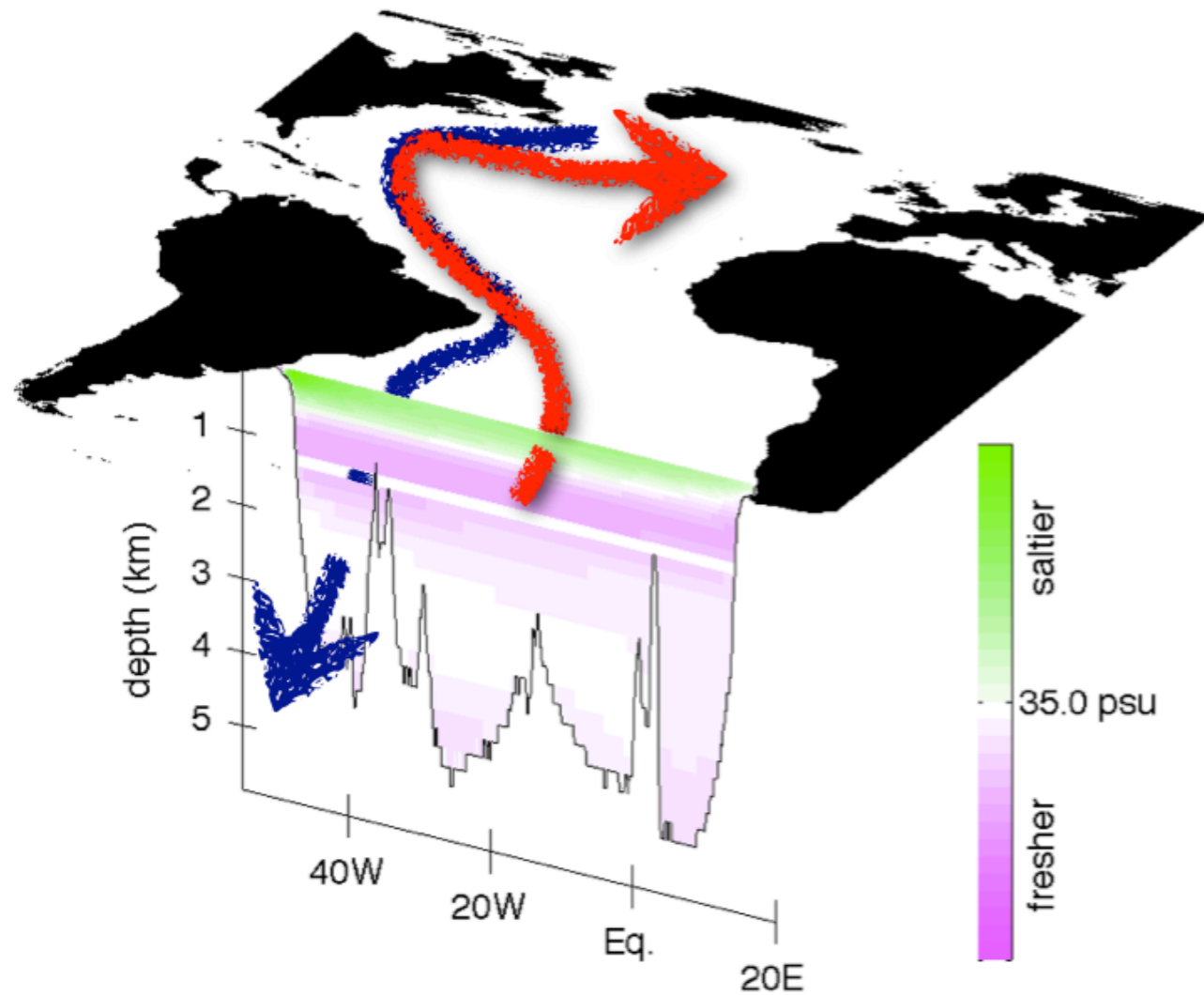
in ORCA: destruction of NADW due to diapycnal mixing as DWBC flows eastward to MAR

subpolar gyre exit

overflows

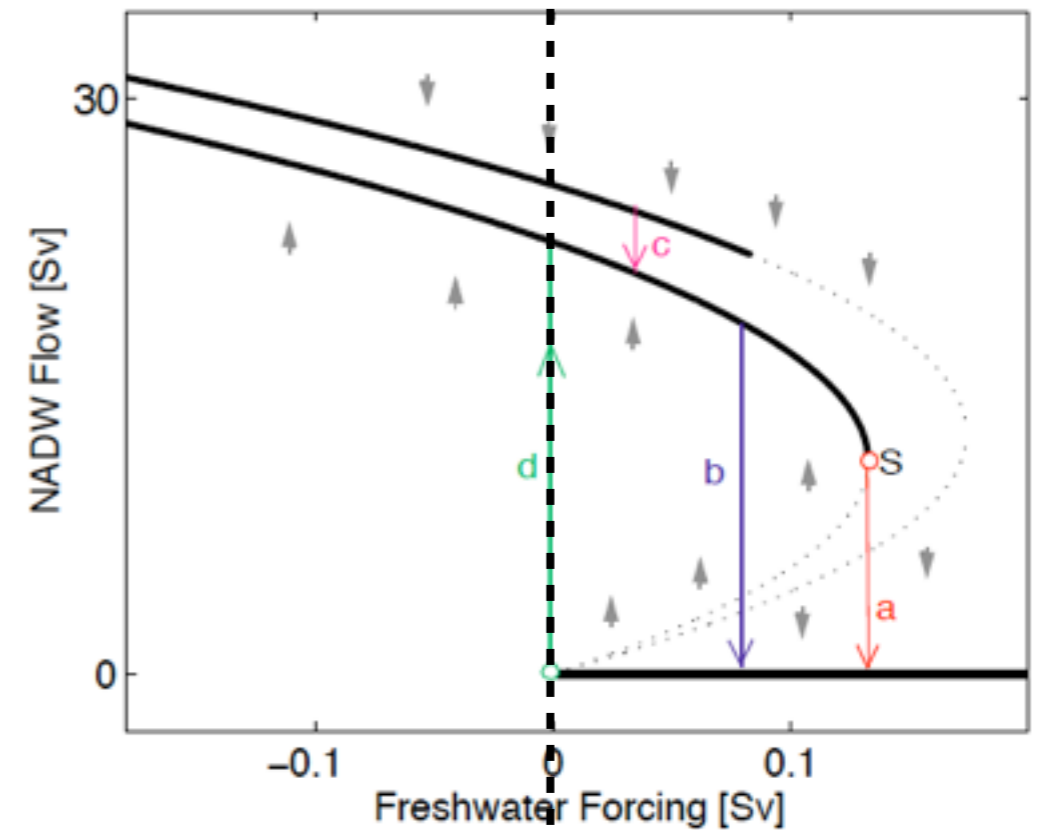
entrainment, formation of dense water

Salt advection feedback of AMOC (1/2)



Deshayes et al. (2013, GRL)

Rahmstorf (1996) THC stability diagram



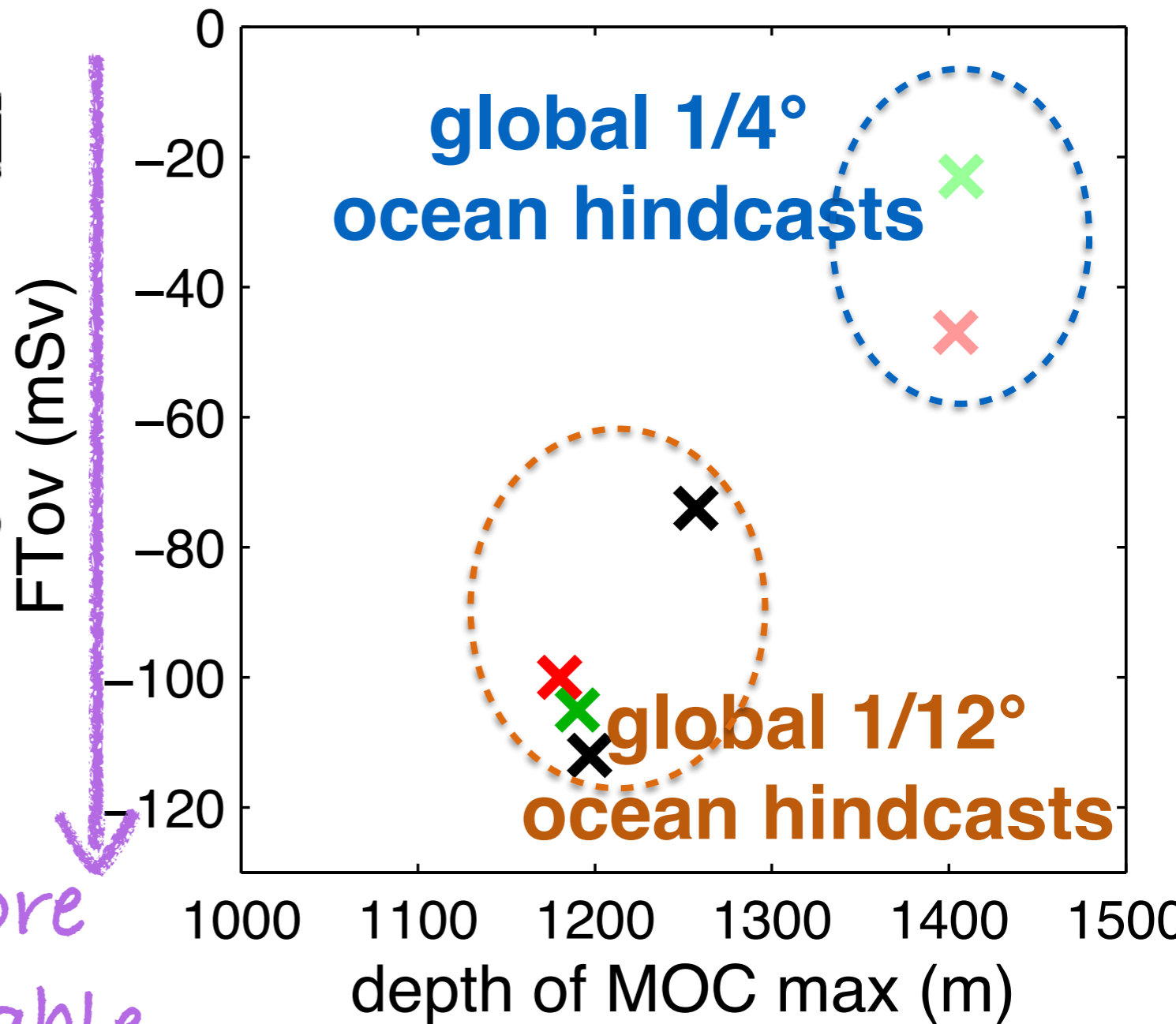
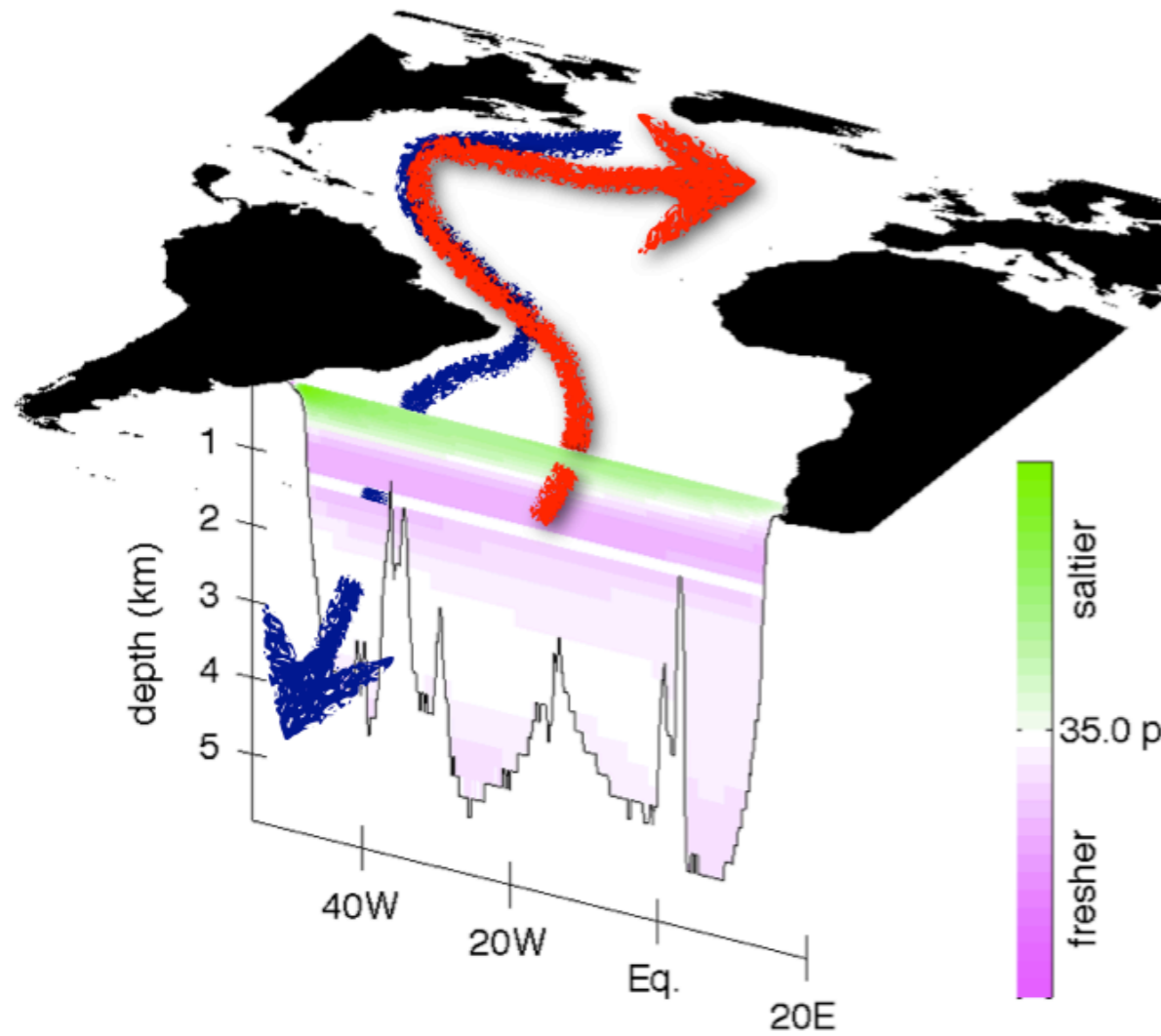
$FT_{ov} > 0$

ie AMOC transports
freshwater northward
>> salt advection negative
feedback

$FT_{ov} < 0$

ie AMOC transports salt
northward
>> salt advection positive
feedback

Salt advection feedback of AMOC (2/2)



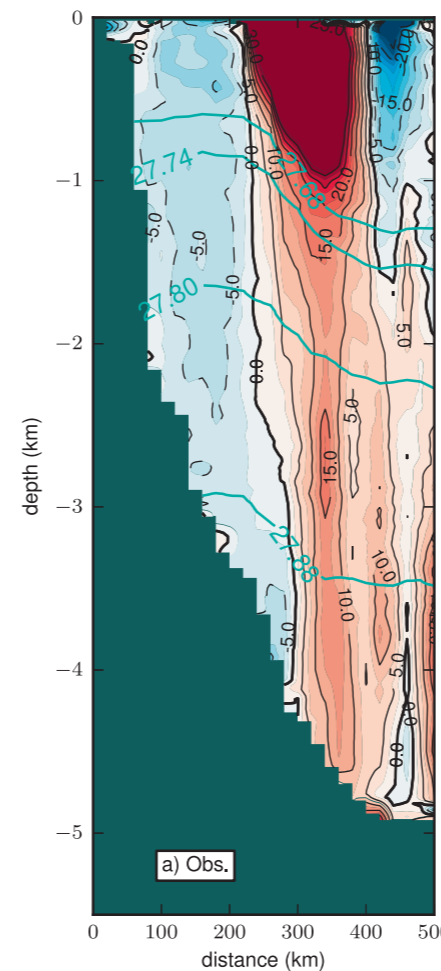
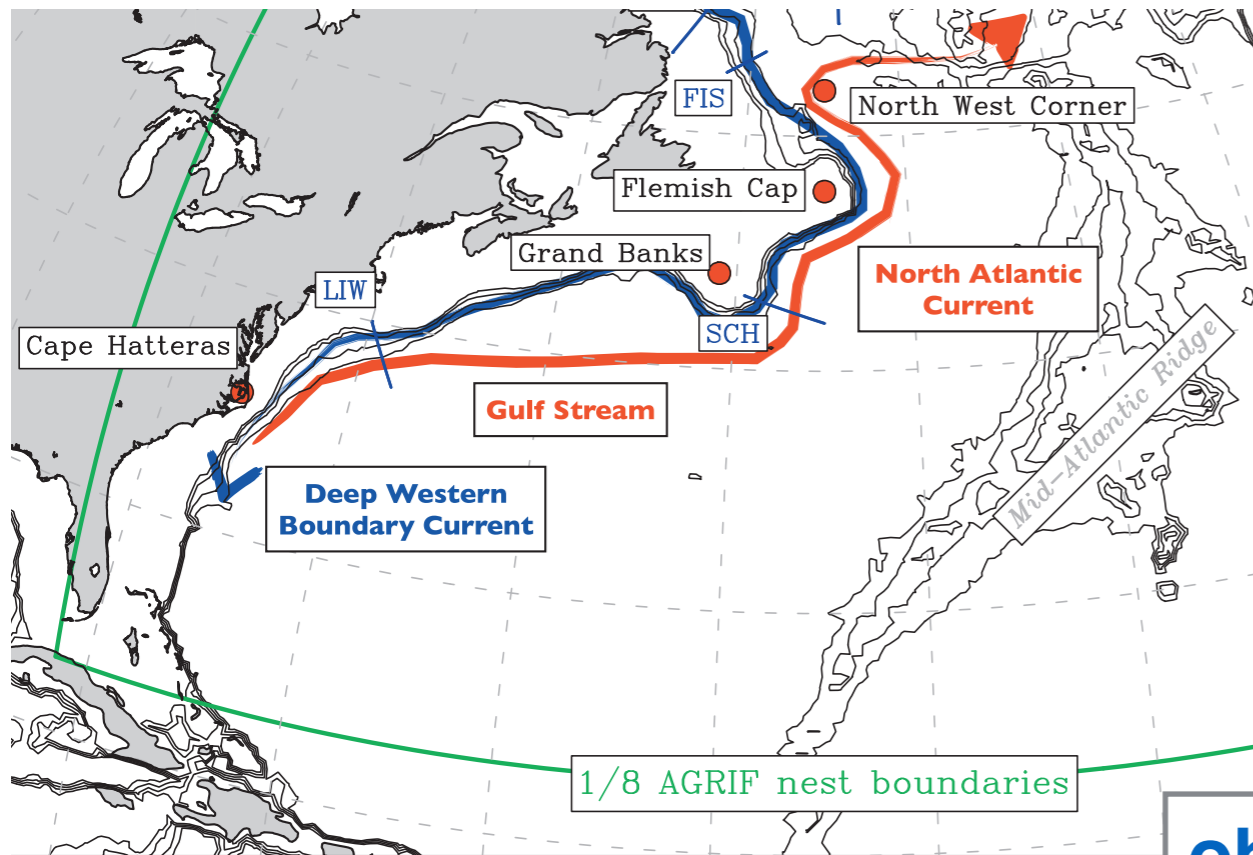
Deshayes et al. (2013, GRL)

more
bistable
AMOC

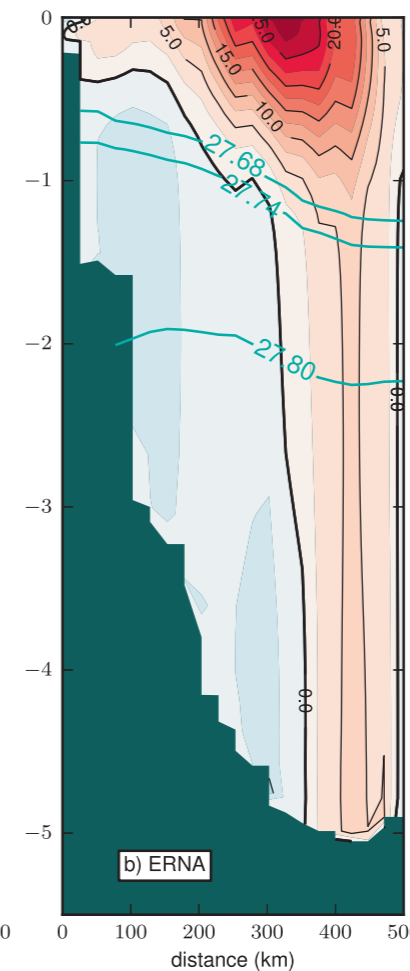
how can we improve
representation of Deep
Ocean Currents ?

increasing spatial resolution may help...

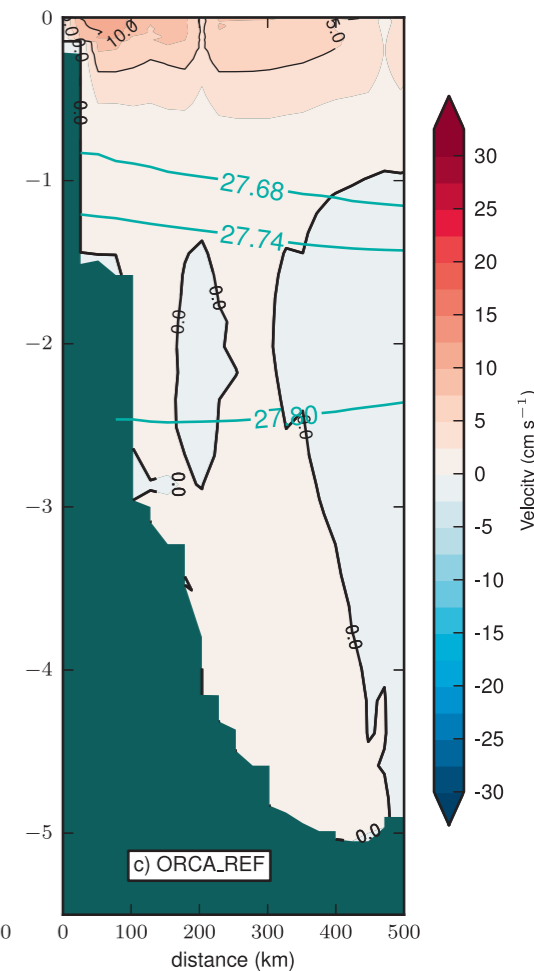
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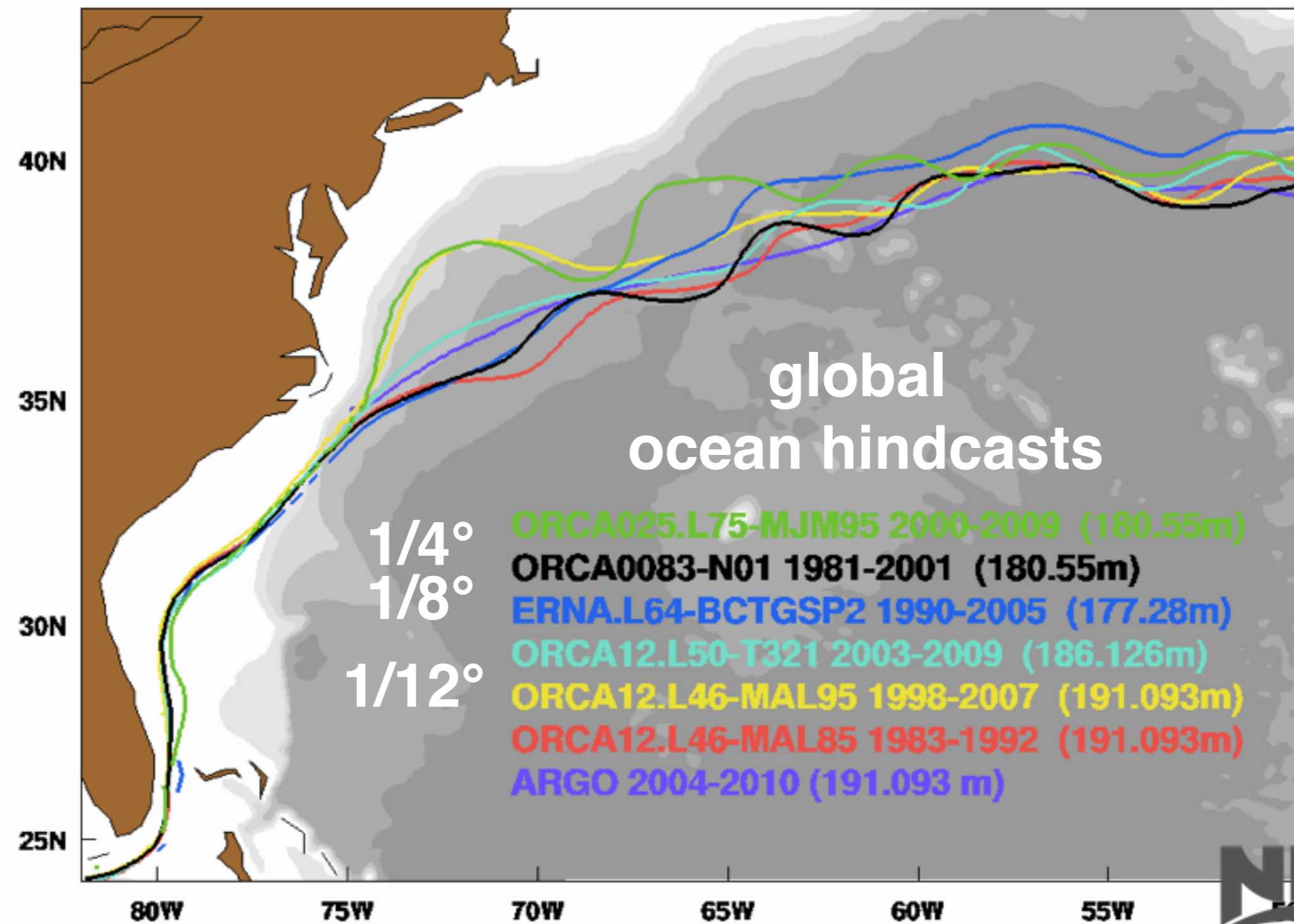
ERNA 1/8°



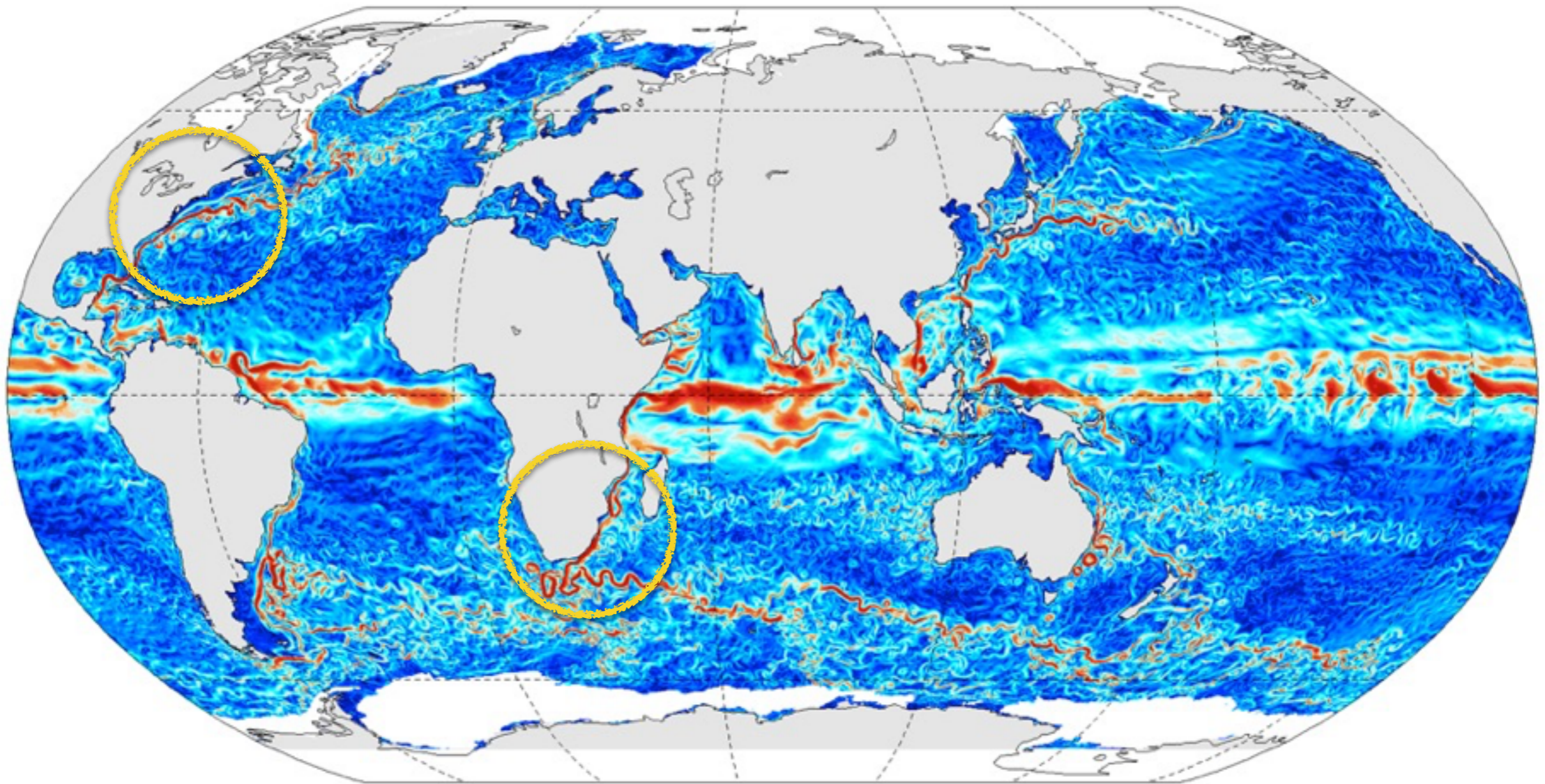
ORCA 1/2°

ERNA = ORCA05 + 1/8 AGRIF 2-way zoom over North Atlantic

but as for upper WBC, increasing spatial resolution is not sufficient !



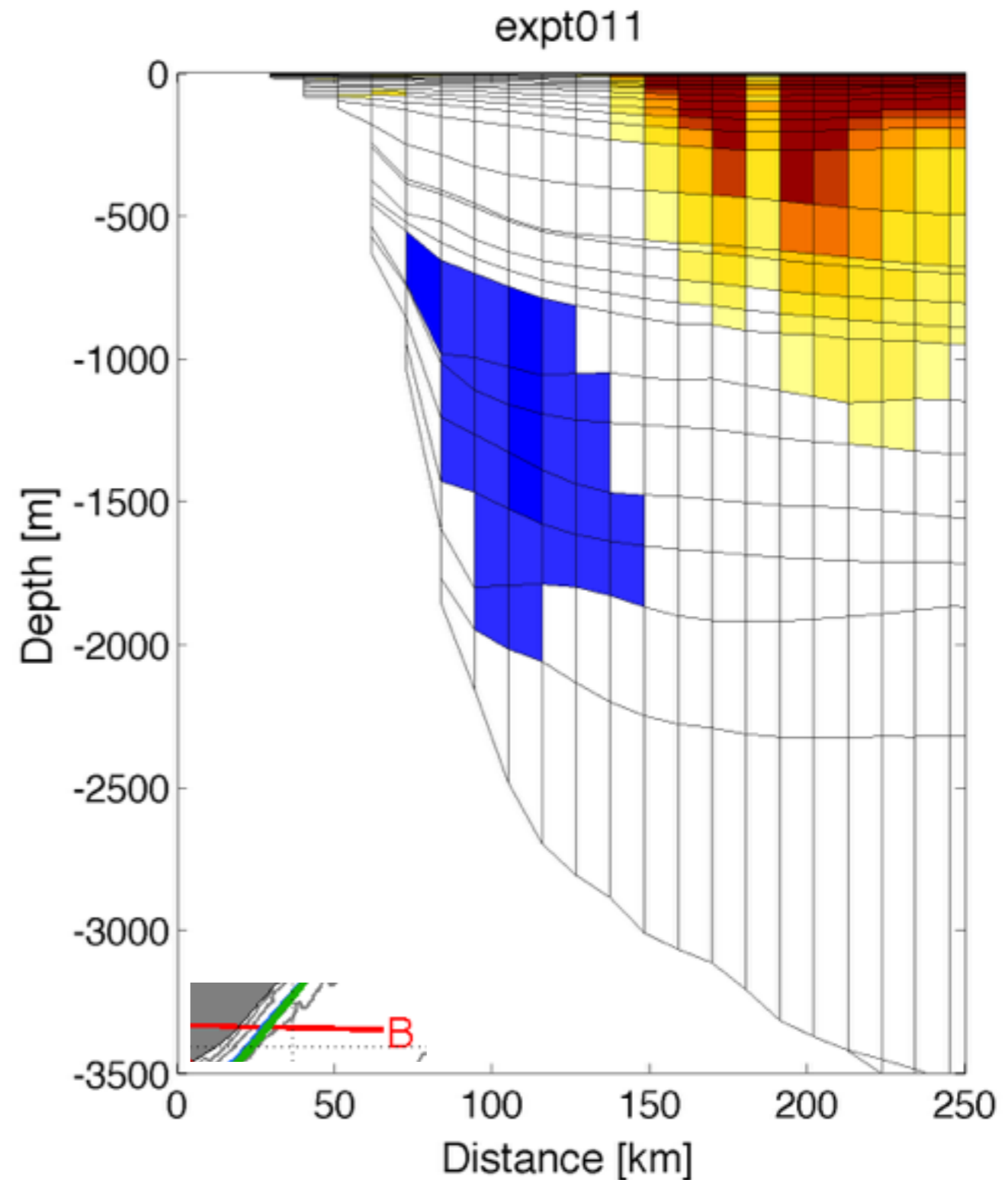
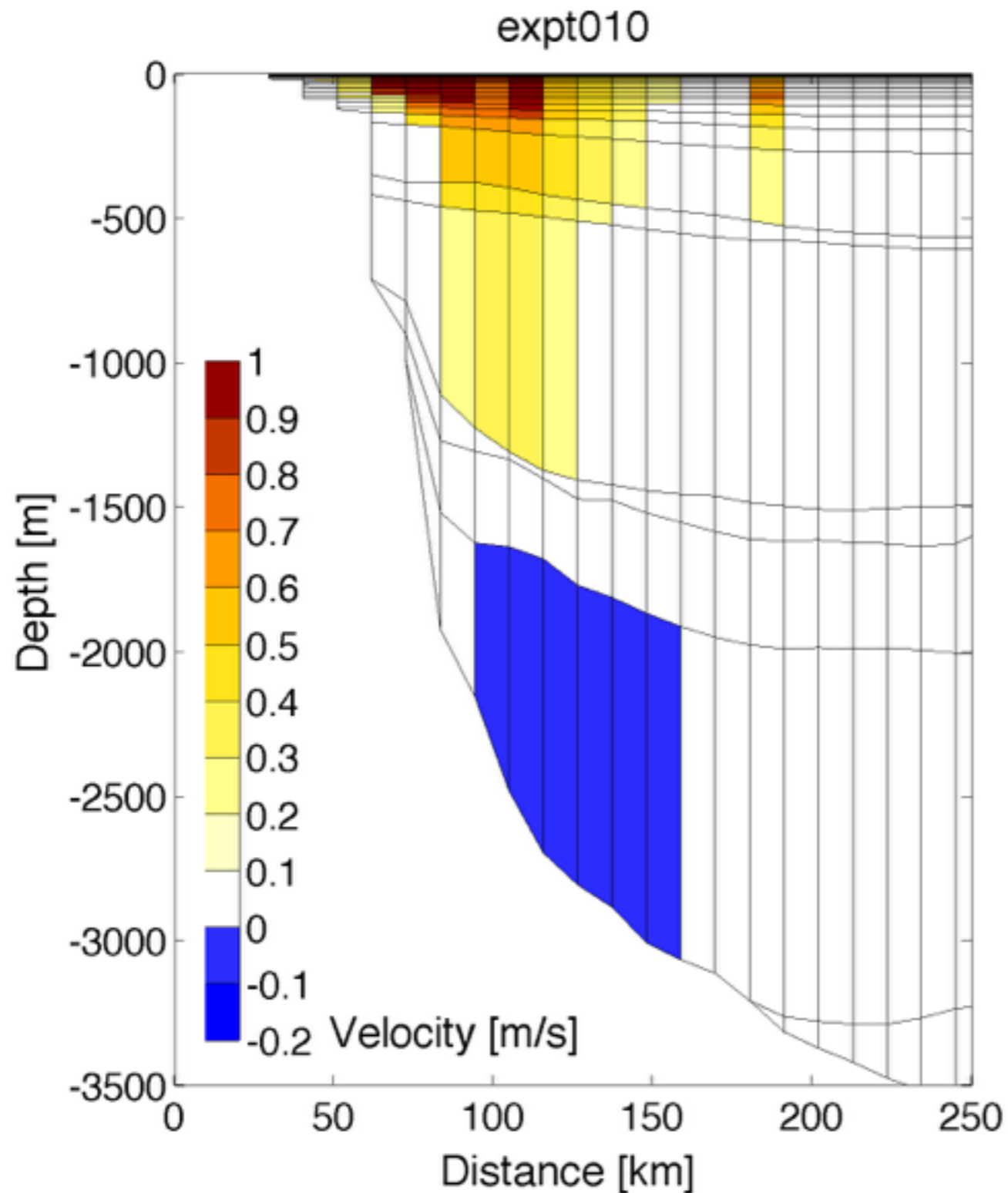
switching from Gulf Stream to Agulhas Current System (and back)



Snapshot of velocity at the surface in the ORCA12 ocean model
A. Lecointre and J.M. Molines, LGGE, France

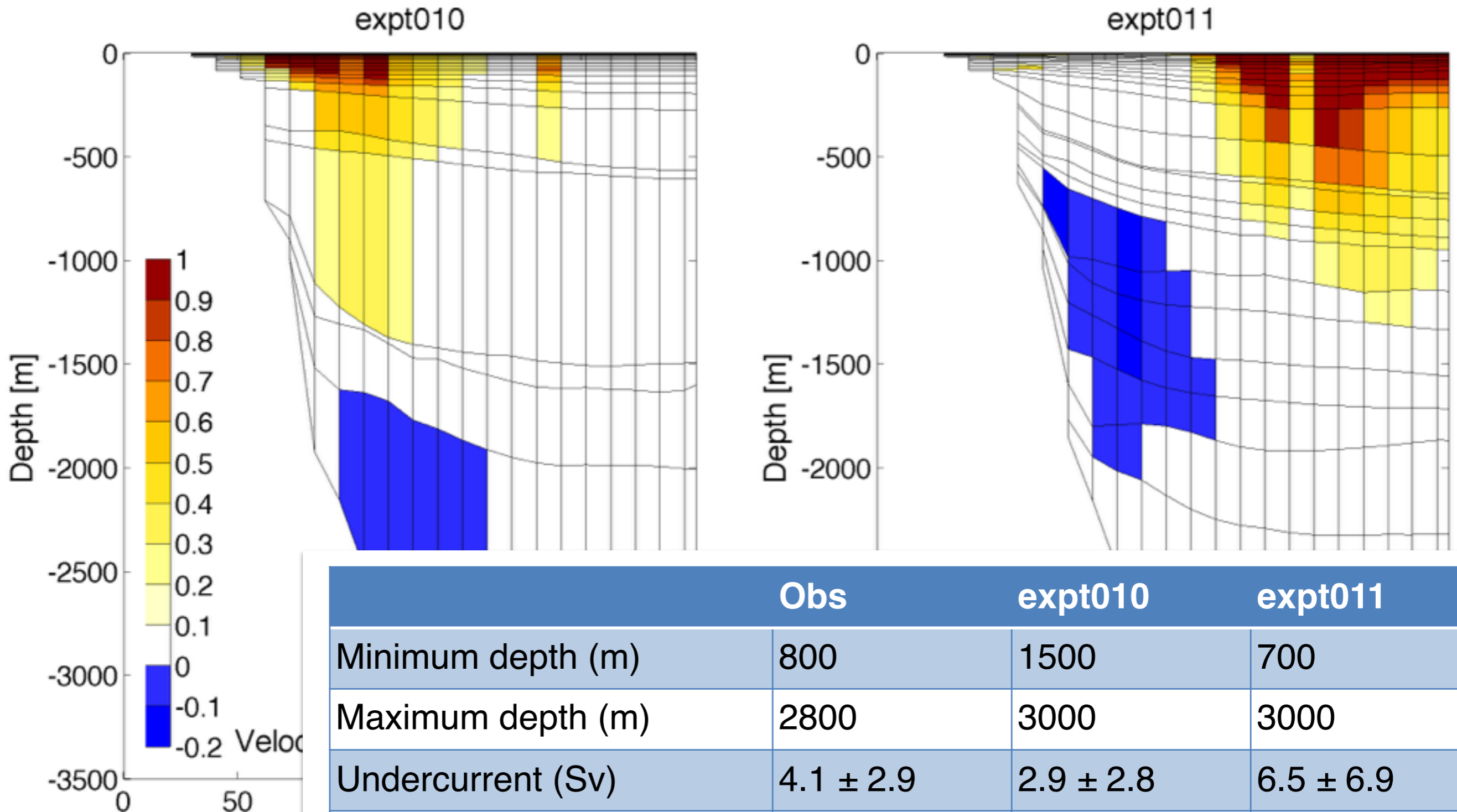
adjusting layers density may help...

B. Backeberg's HYCOM simulations of the Agulhas Current System (1/10°)



adjusting layers density may help...

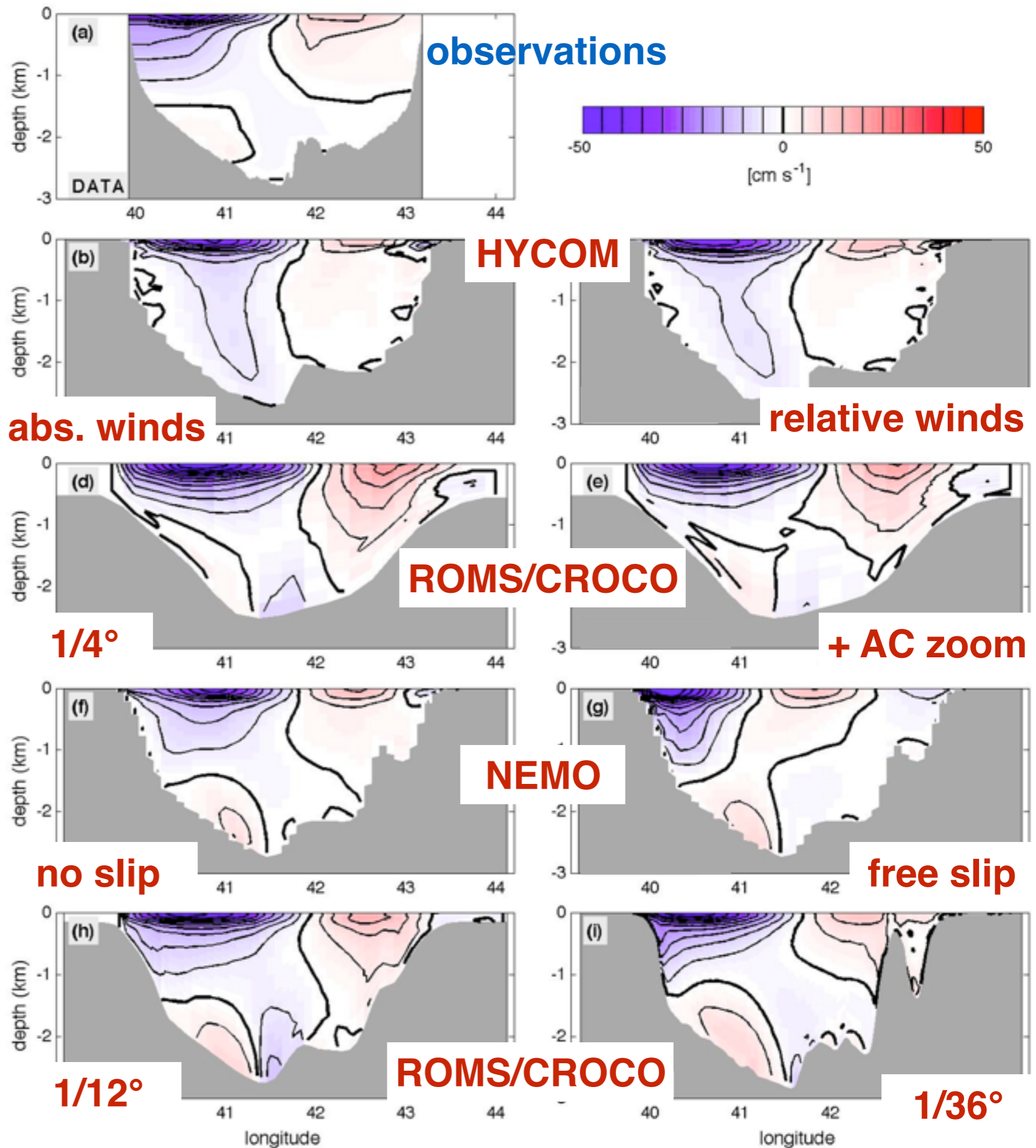
B. Backeberg's HYCOM simulations of the Agulhas Current System (1/10°)



	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

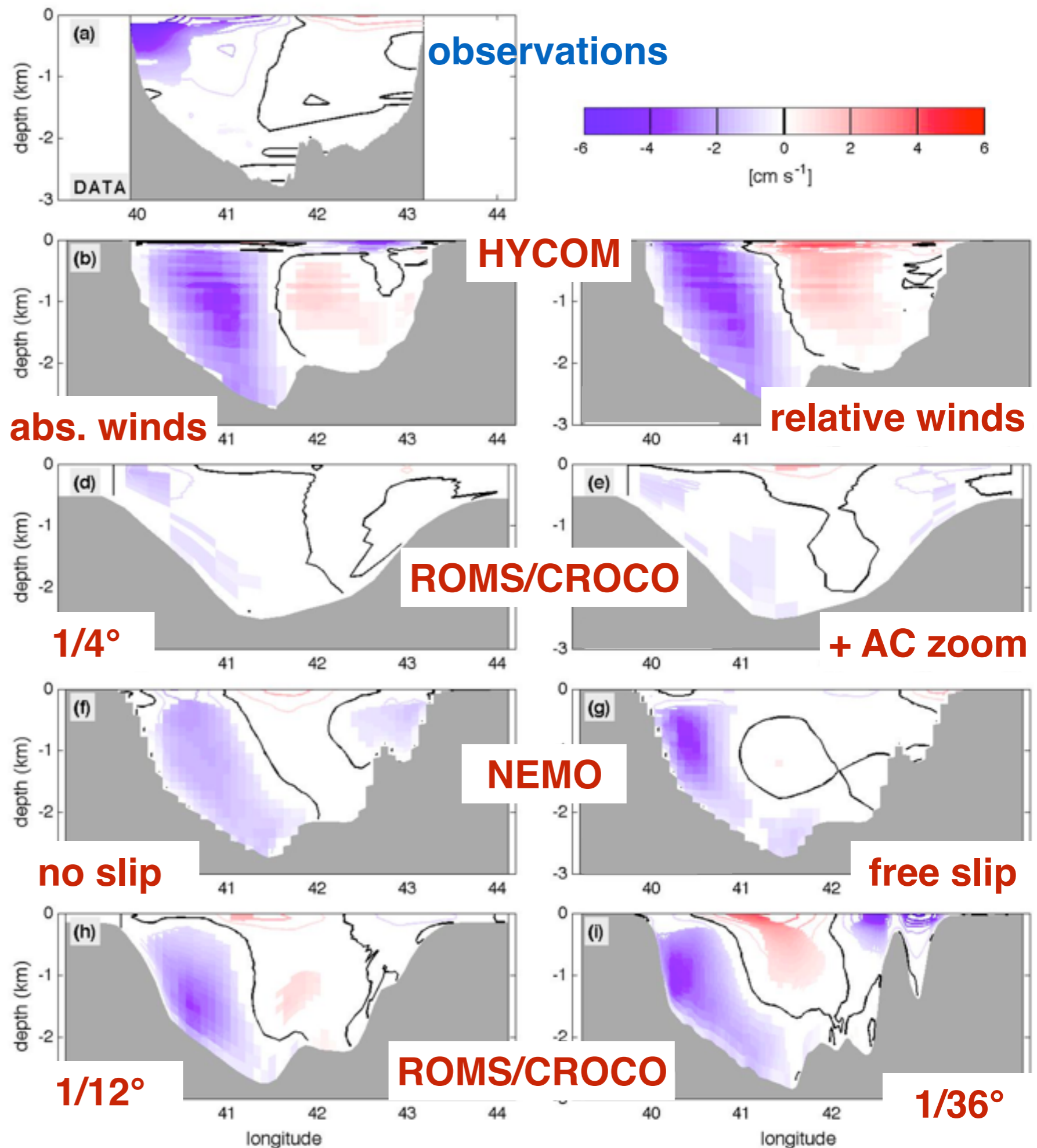
but representing deep circulation in the Mozambique Channel remains a challenge...

Pous et al. (2018)
mean circulation



but representing deep circulation in the Mozambique Channel remains a challenge...

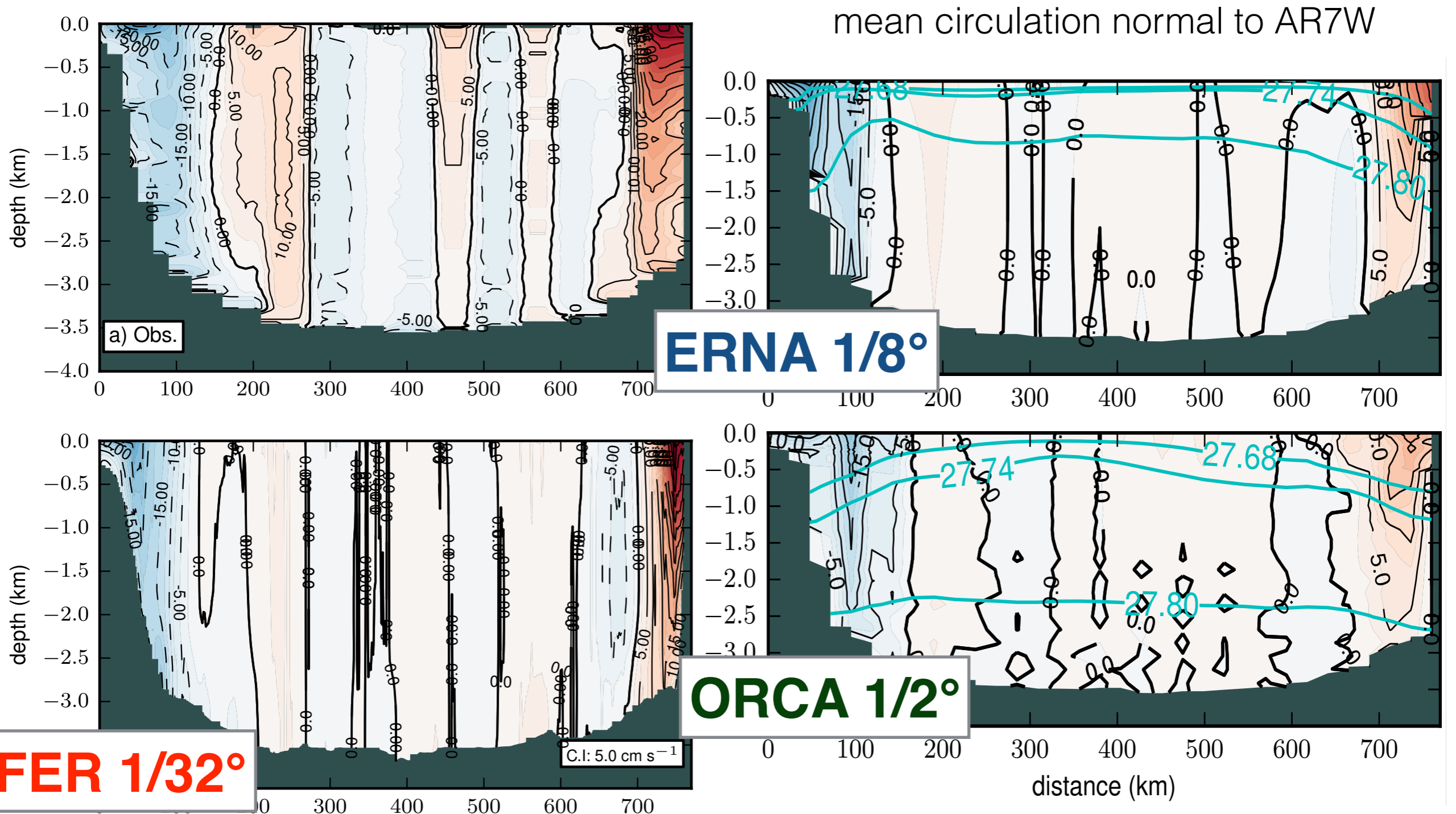
Pous et al. (2018)
 projection of total transport in Channel onto velocities normal to section at low frequency (period > 544 days)



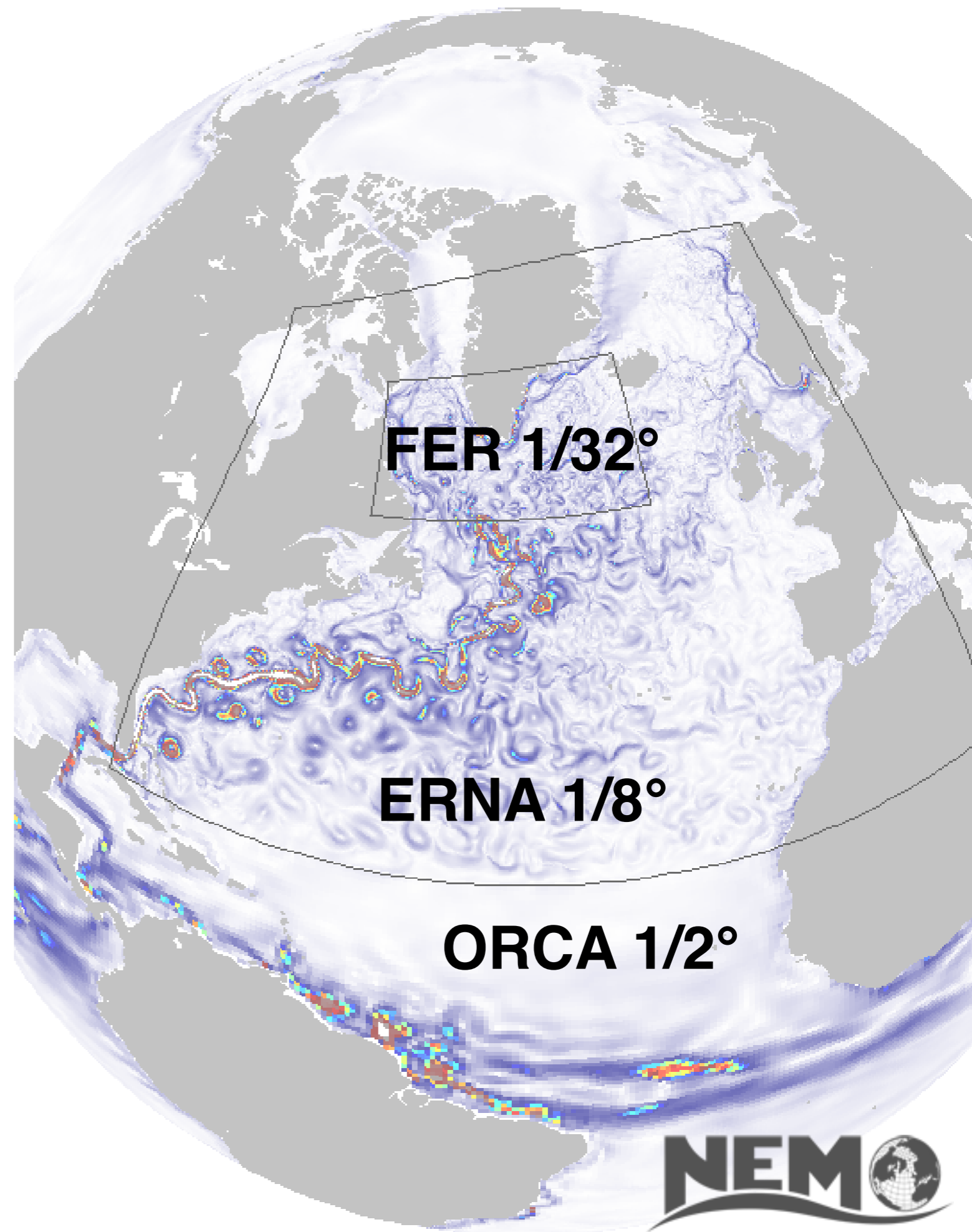
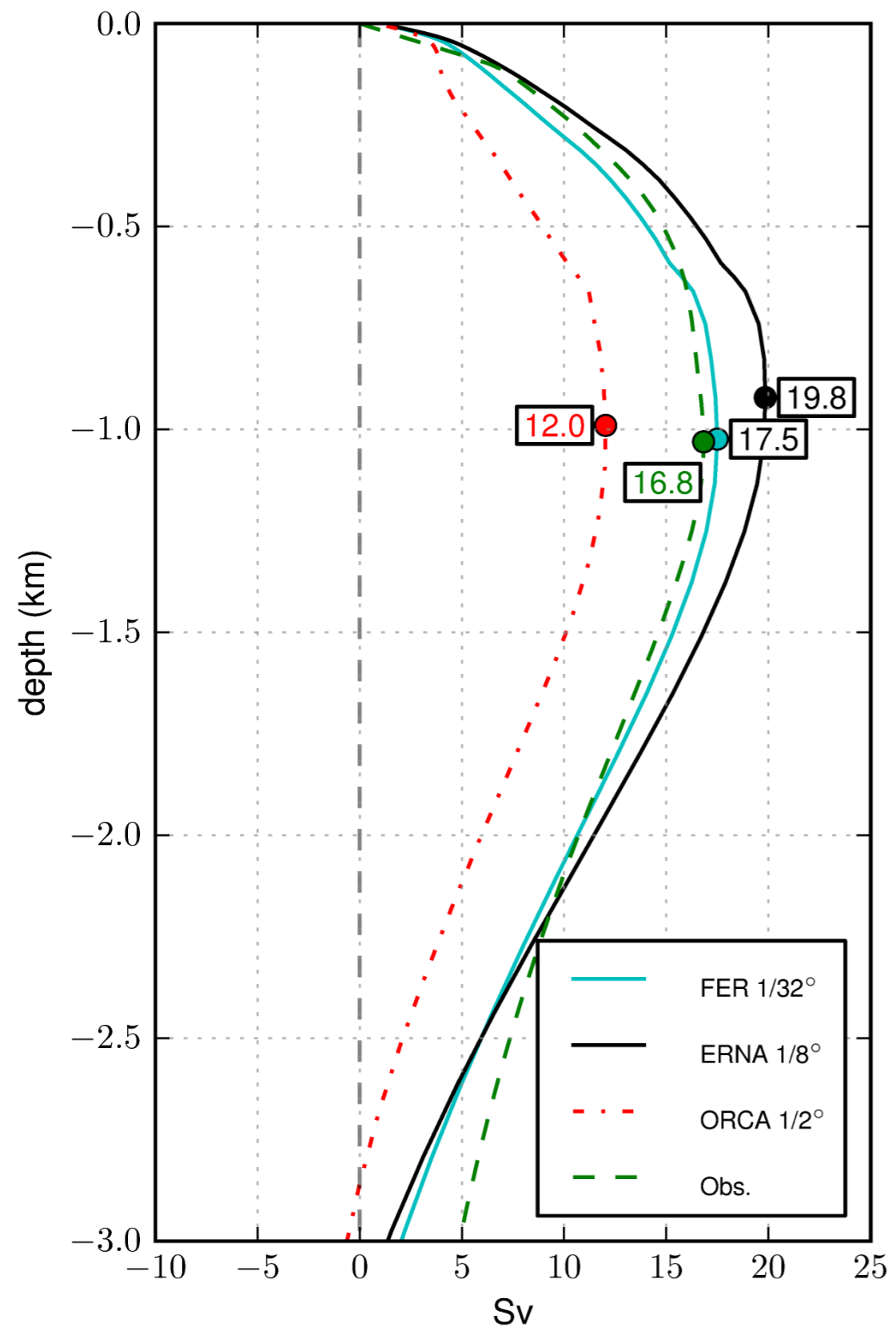
how to integrate this information in climate models ?

- ▶ improving upper WBCs could benefit deep WBCs, and vice versa !
- ▶ understanding hence representing better energy dissipation of WBCs
- ▶ increasing spatial resolution **in key regions...**

increasing horizontal spatial resolution helps representing the vertical structure of NA subpolar gyre



AMOC at 26N : most realistic in FER



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should spatial resolution be increased?

only in exploratory mode, to produce benchmarks for the development / improvement of parameterizations,

NO ! in production mode, it is crucial to ensure long integrations and multiple realizations to quantify uncertainties.