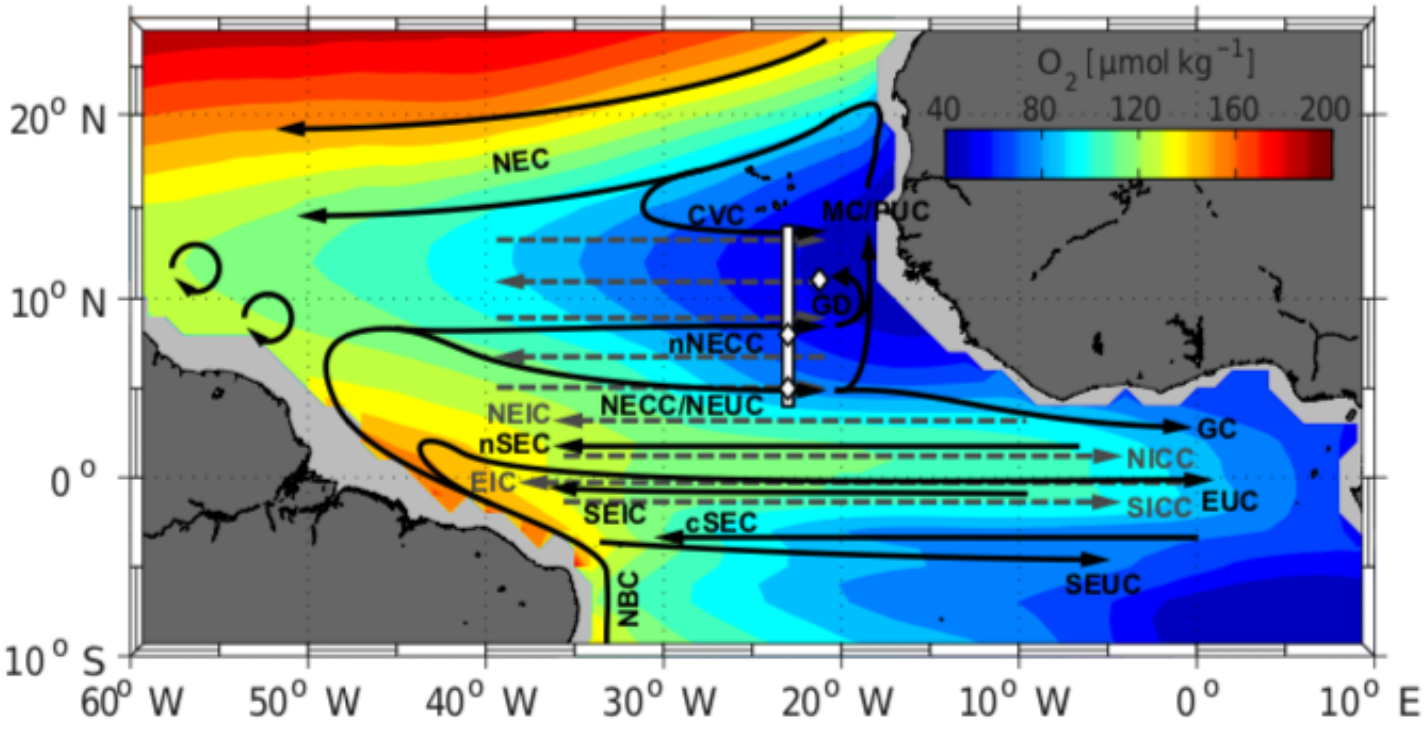
Dynamical processes of the West African oxygen minimum zone: results from the SENOX project

Vincent Echevin, Soeren Thomsen, Xavier Capet, A.W. Tall,
Eric Machu,Olivier Aumont, J. Jouanno, S.Ndoye



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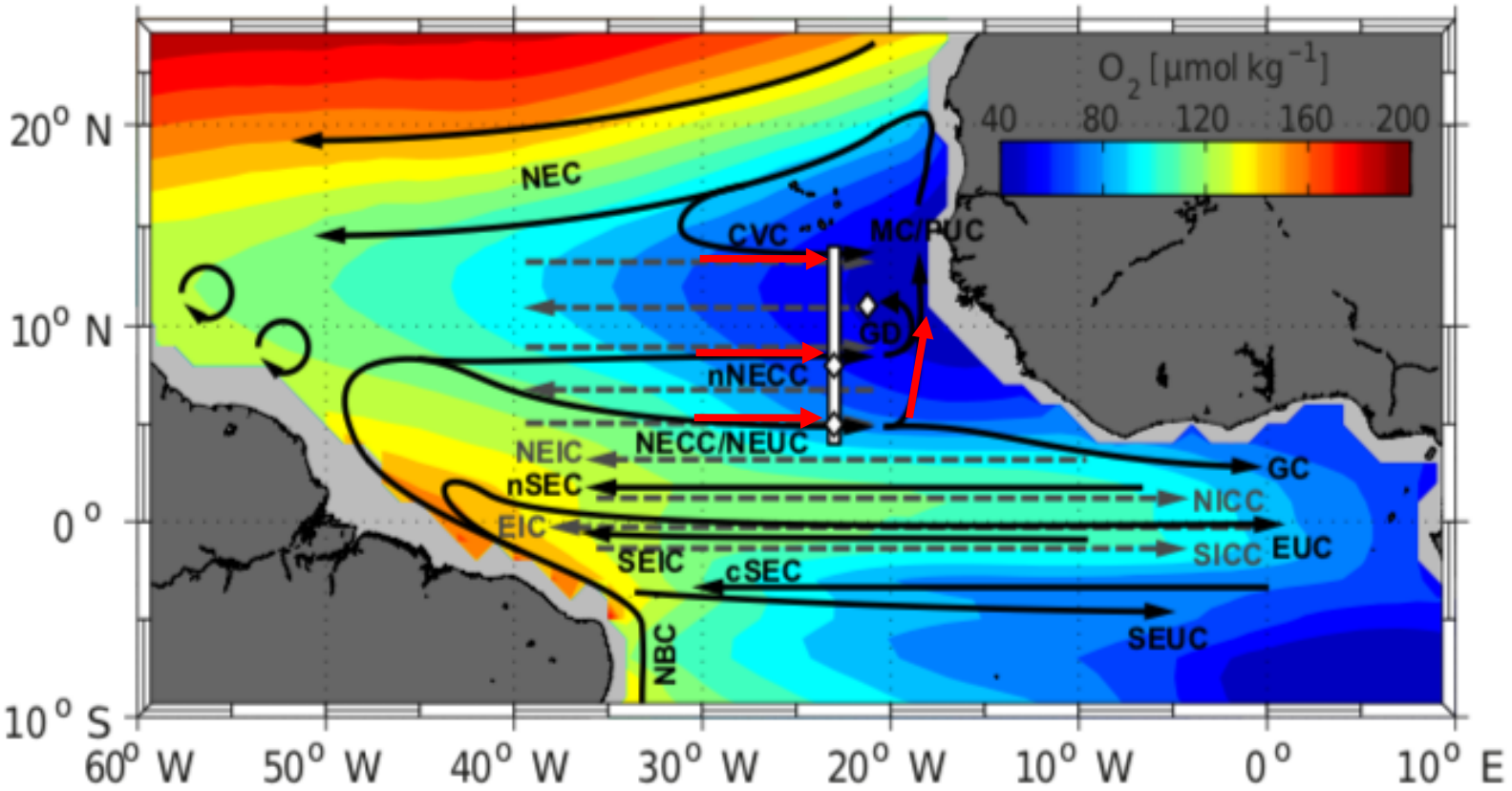
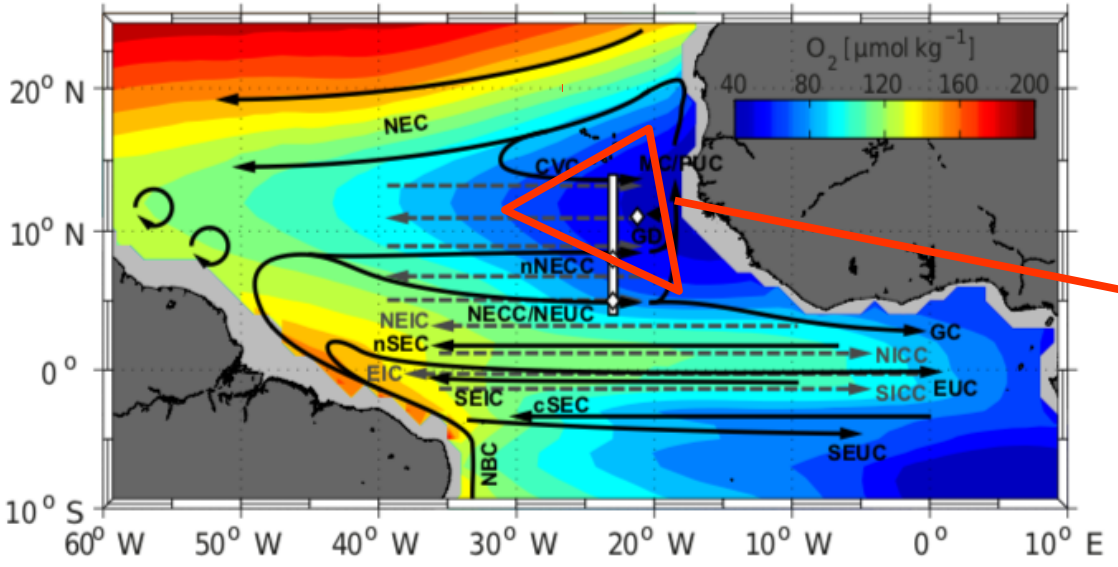
Shallow and deep OMZ off West Africa



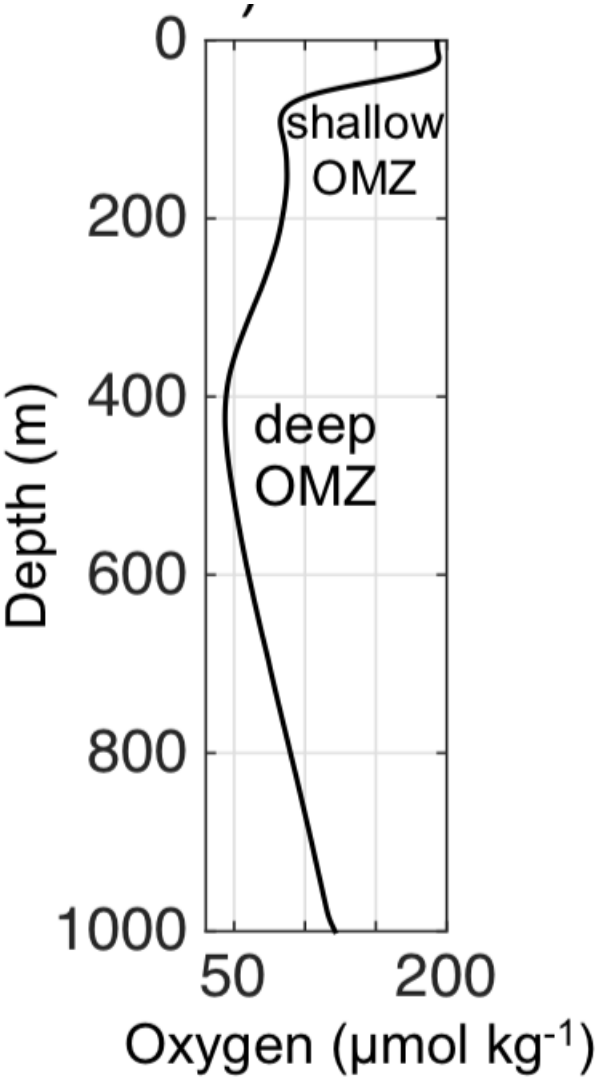
Hahn et al. 2017

Isopycne
=27.1 kg/m3
Depth ~500 m

Shallow and deep OMZ off West Africa

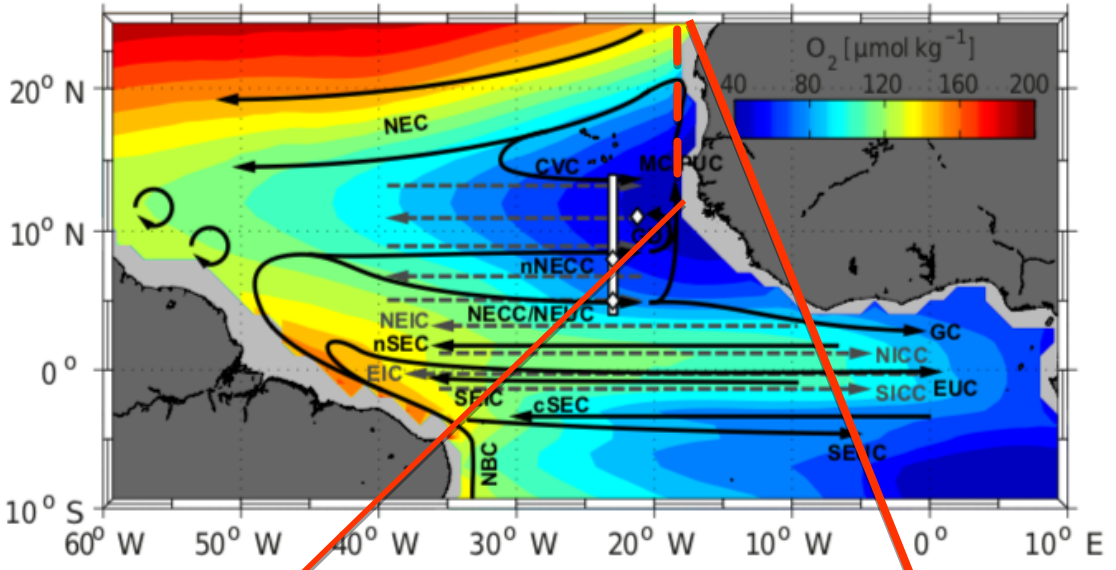


Hahn et al. 2017

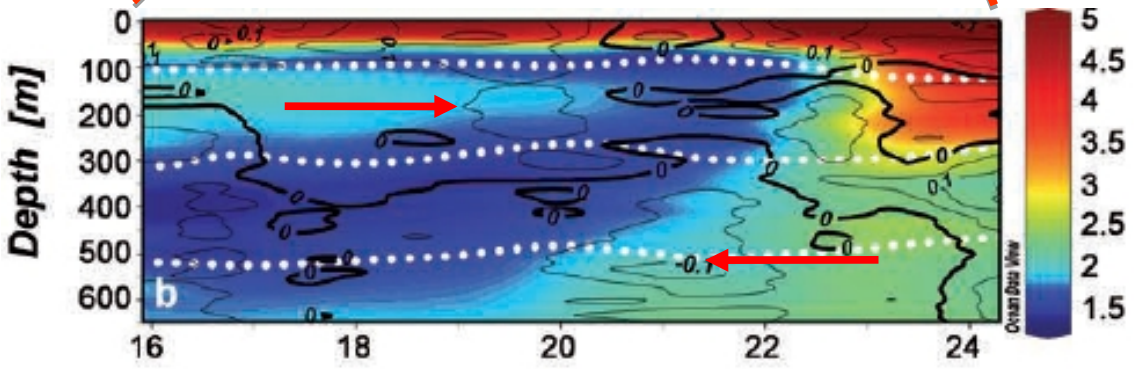


Schütte et al. 2016

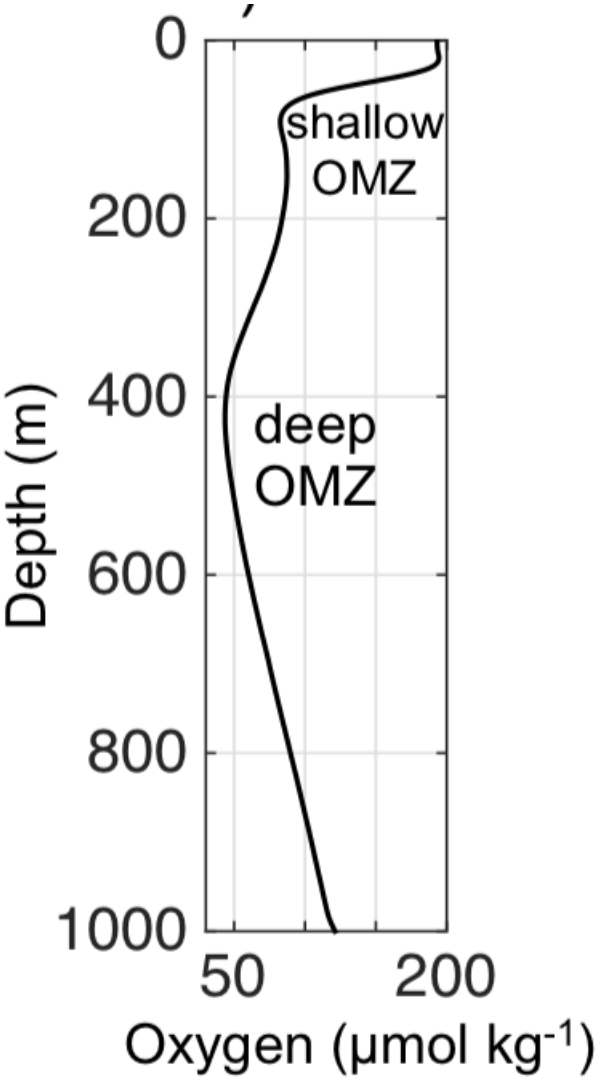
Shallow and deep OMZ off West Africa



Hahn et al. 2017

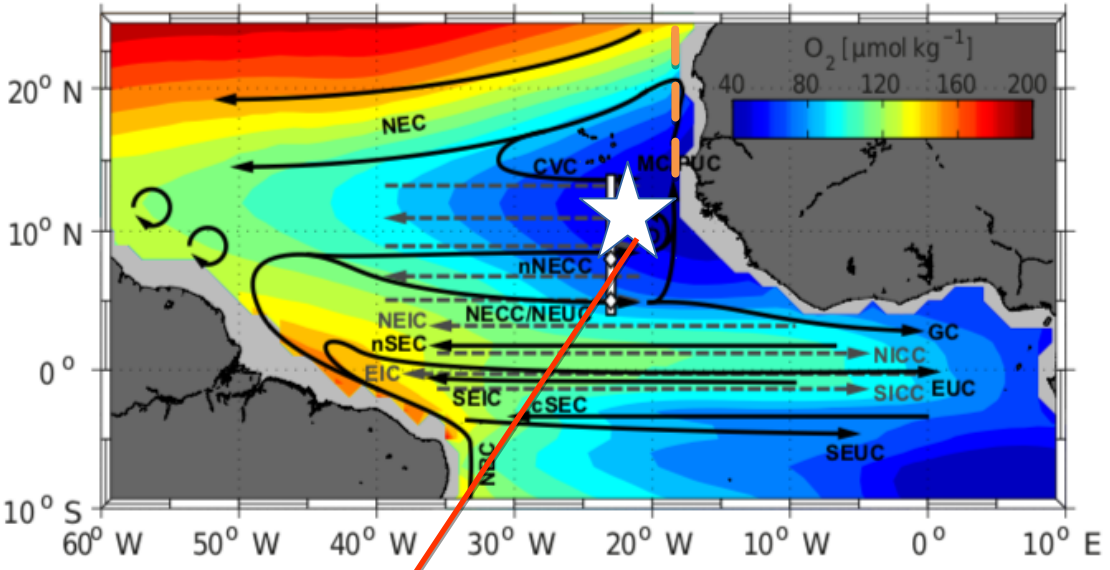


Peña-Izquierdo. 2012

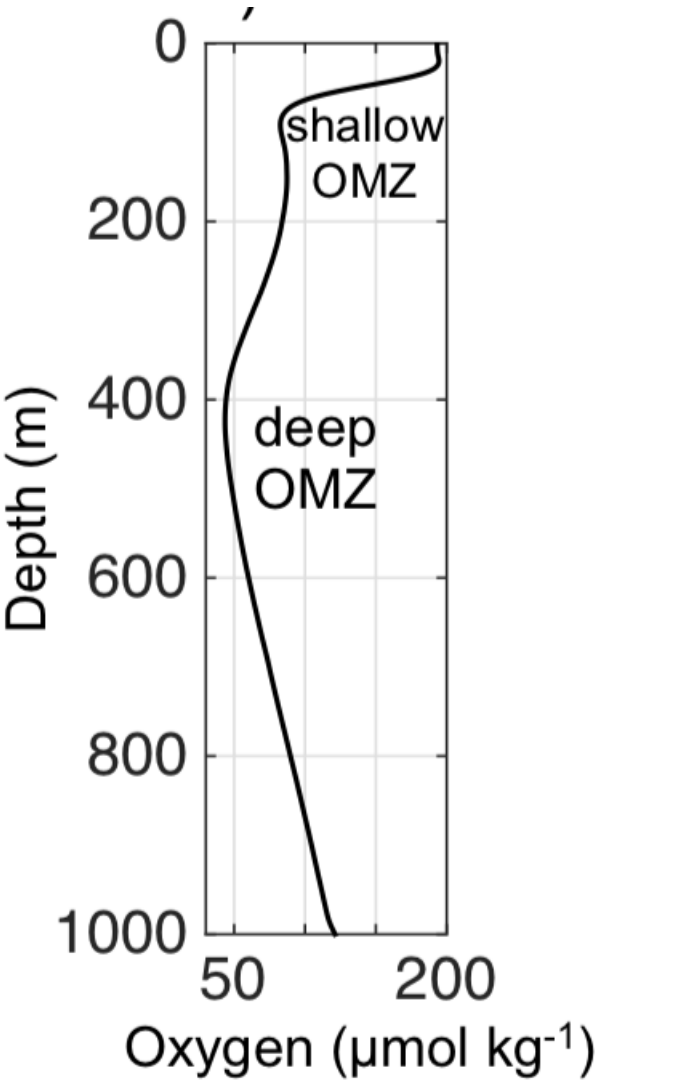


Schütte et al. 2016

Shallow and deep OMZ off West Africa

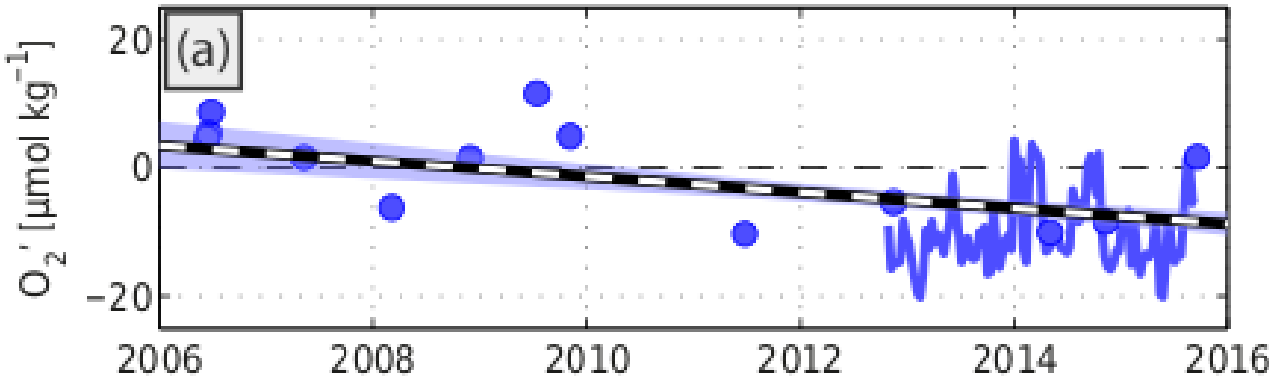


Hahn et al. 2017



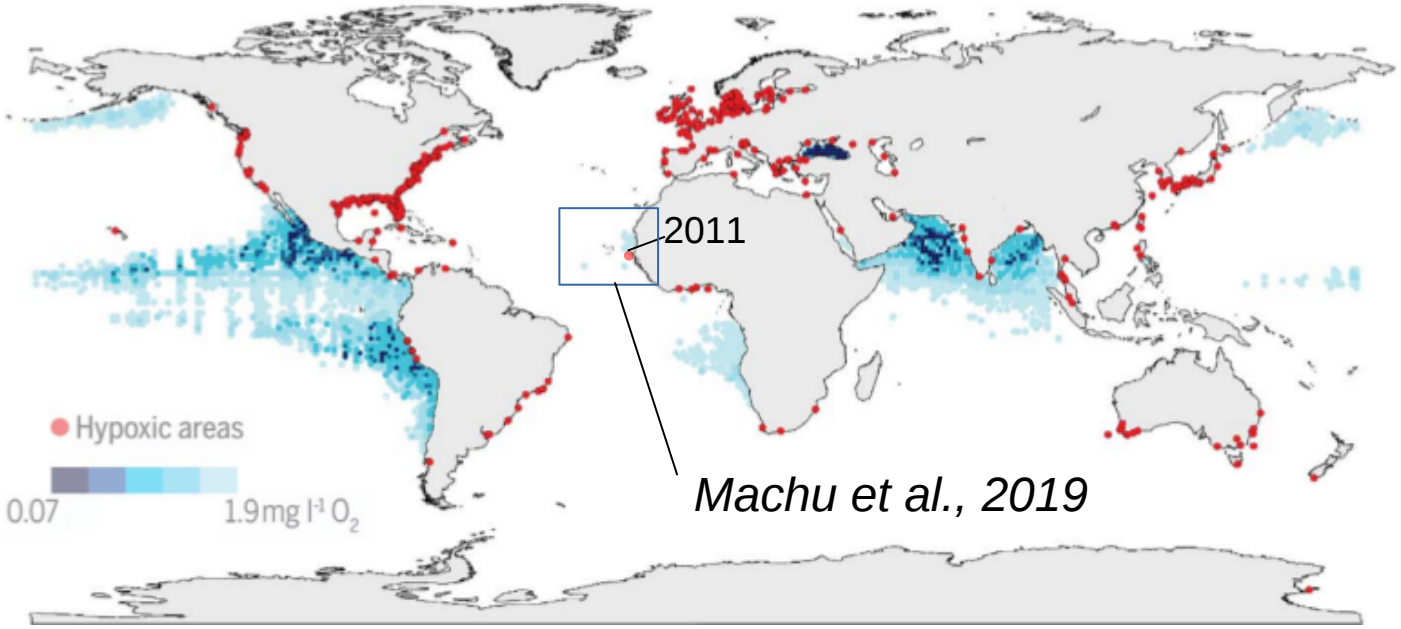
Schütte et al. 2016

O2 trend (11N, 21W), 200-400 m average



Hahn et al. 2017

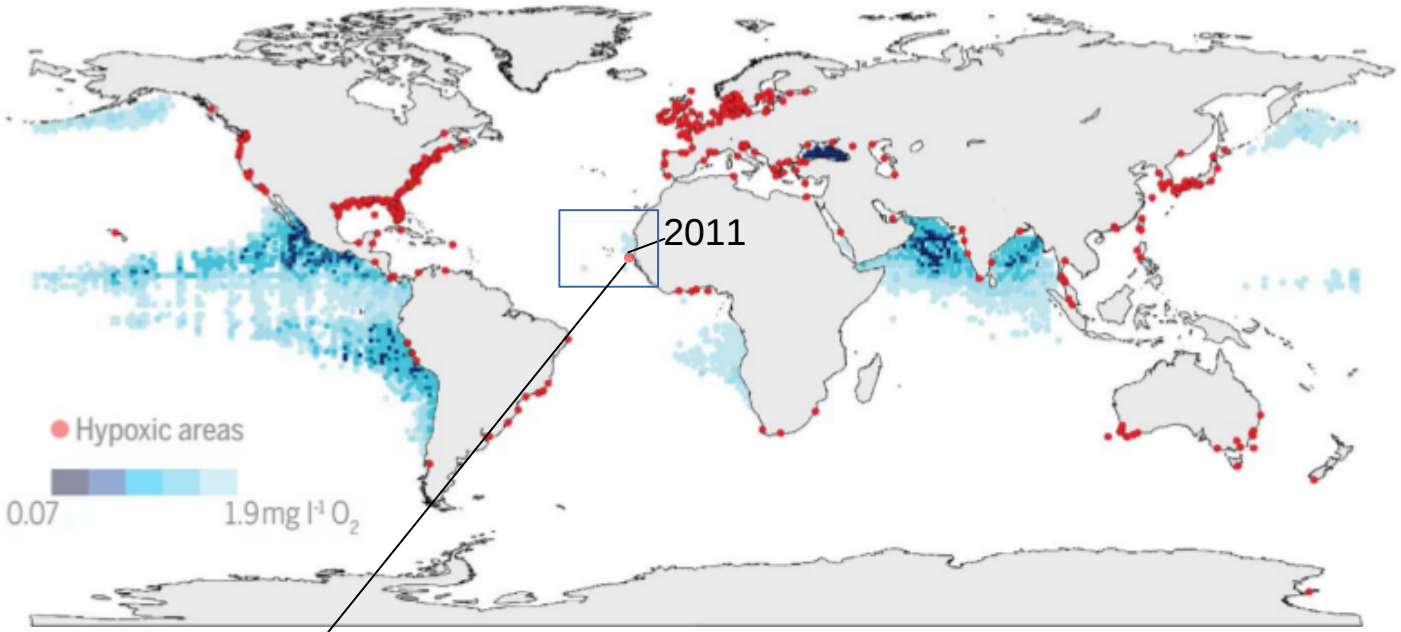
Deoxygenation off West Africa



Hypoxic coastal areas O_2<60 µmol.L^{-1}

Breitburg et al. 2018

Deoxygenation off West Africa



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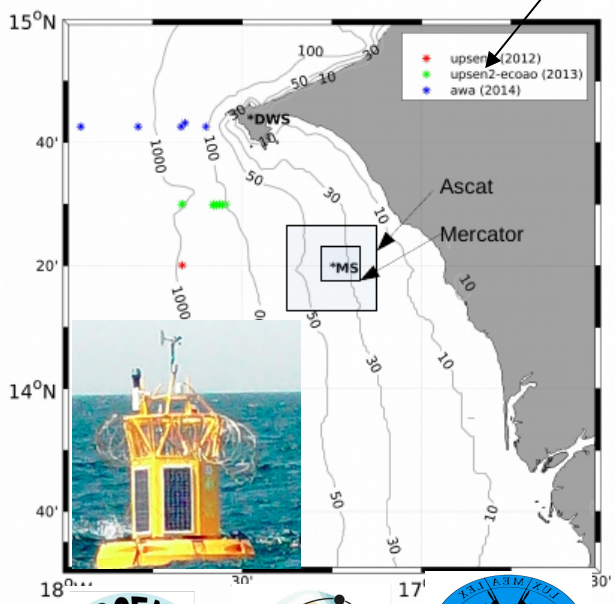
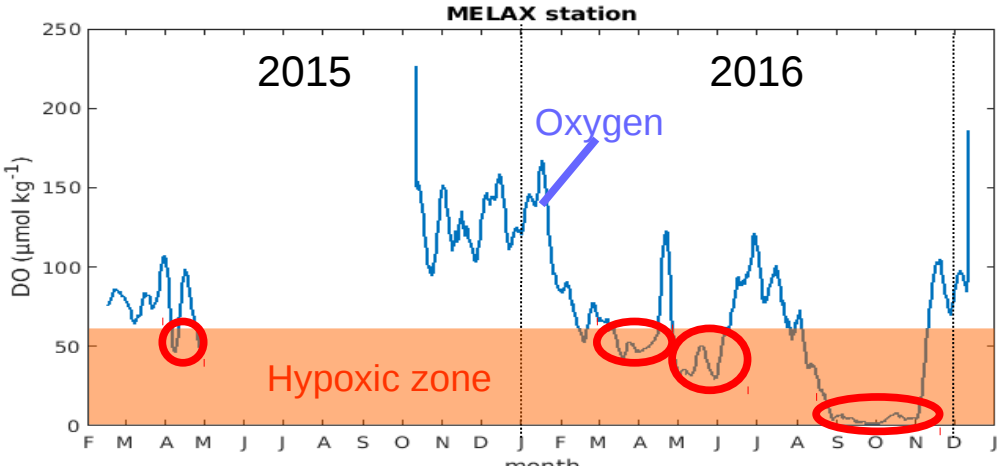




Tall et al. in prep.

Scientific questions

- How do MOI GCMs (and others) reproduce the deep and shallow OMZ ?

- How does a regional model (croco-pisces) reproduce the oxygen variability?

- What are the physical /biogeochemical processes responsible for the model biases?

Approach:

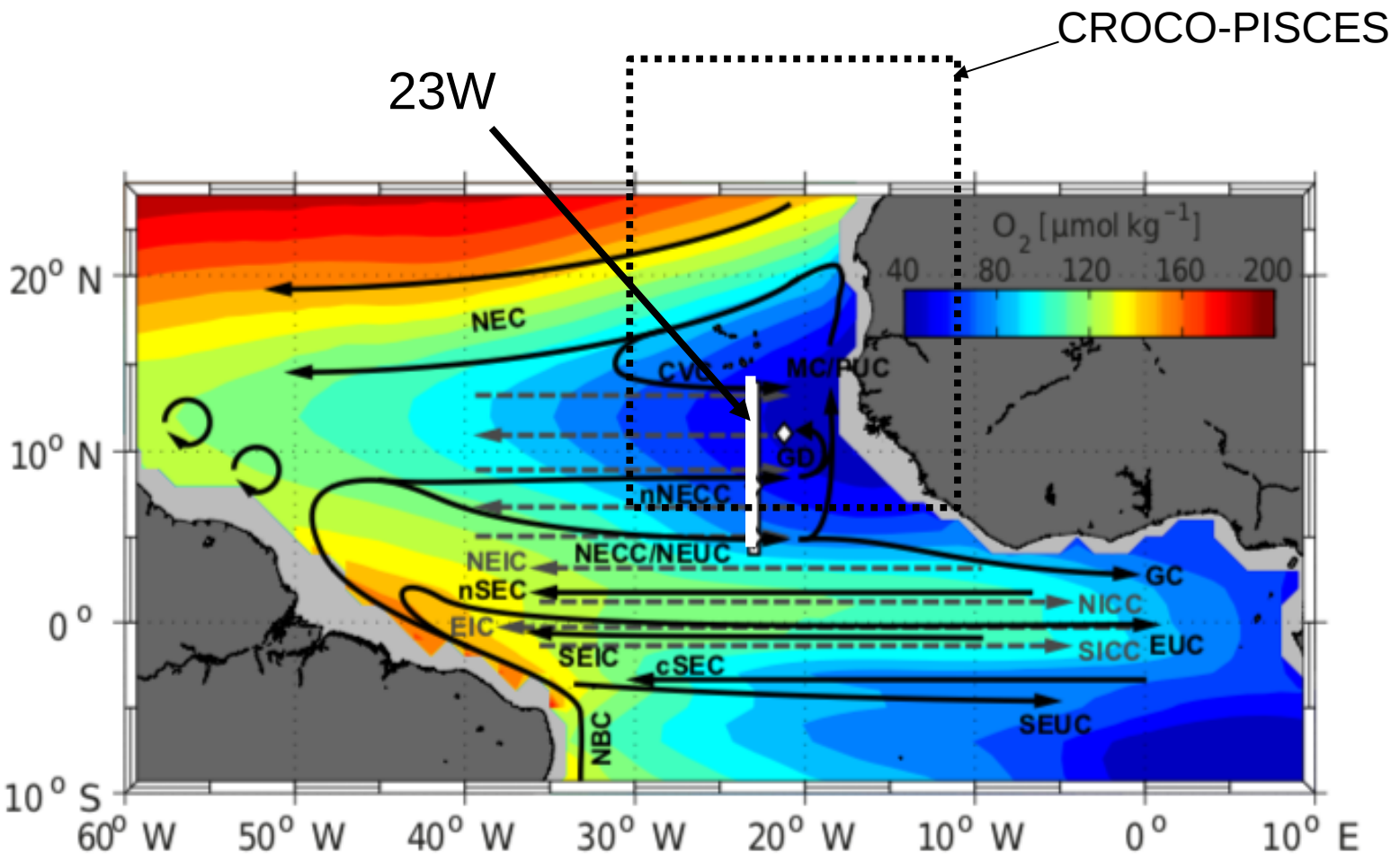
- Analysis of several GCMS:

  - BIOMER (bio offline,with data assimilation, PISCESv2)
  - BIOMERFREE (bio online, no data assimilation, PISCESv2, param1)
  - TATL025 (online, 30N-30S, PISCESv2, param2,J.Jouanno, LEGOS)

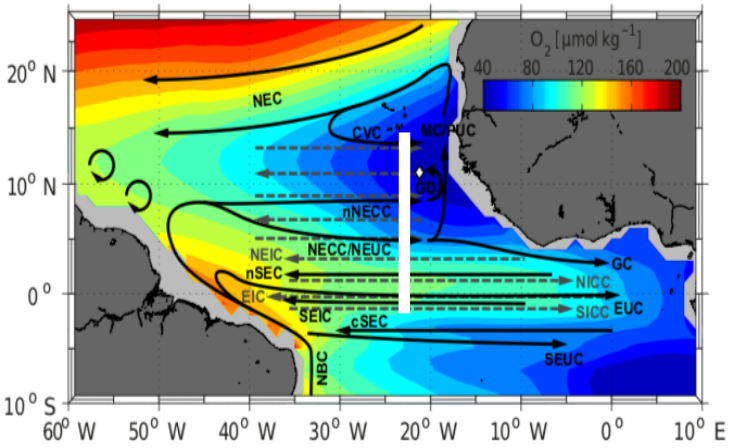
- Analysis of a regional model: CROCO-PISCESv1 at 10 km (6N-35N, 30W-10W)

  - climatological (20 years, SODA clim boundary conditions +WOA bio)
  - interannual (2013-2018, PSY4V3 (1/12°) boundary conditions+ WOA bio)

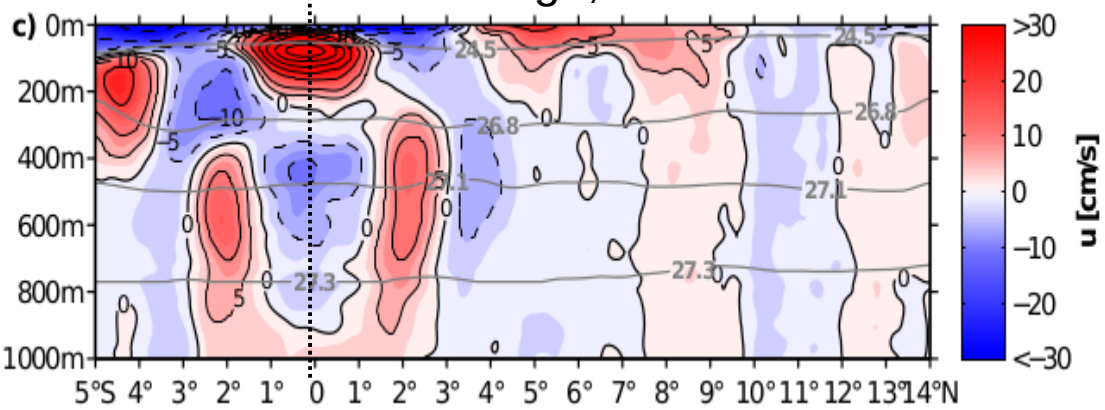
Oxygen and current section at 23°W



Zonal current at 23°W : observations vs models

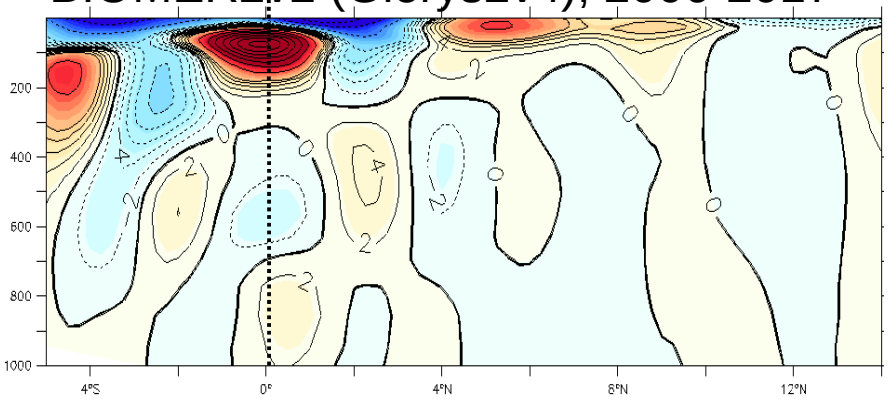


1999-2012 average, Brandt et al. 2015

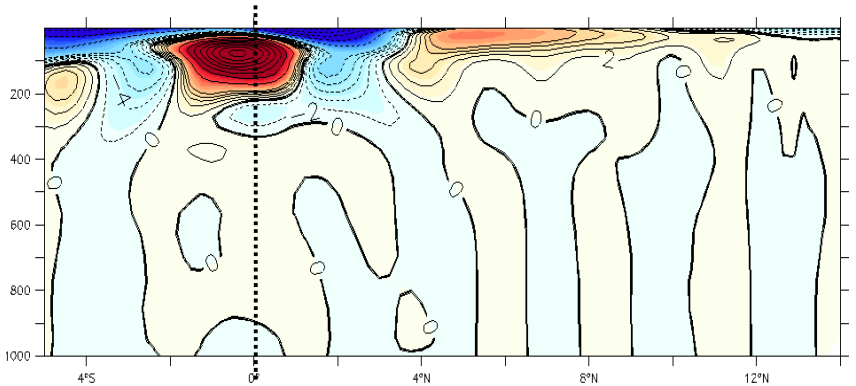


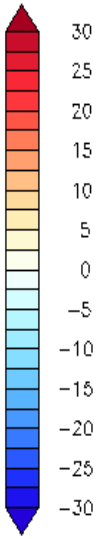
BIOMERFREE2v4 (2006-2017)

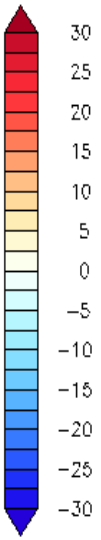
BIOMER2v2 (Glorys2v4), 2006-2017



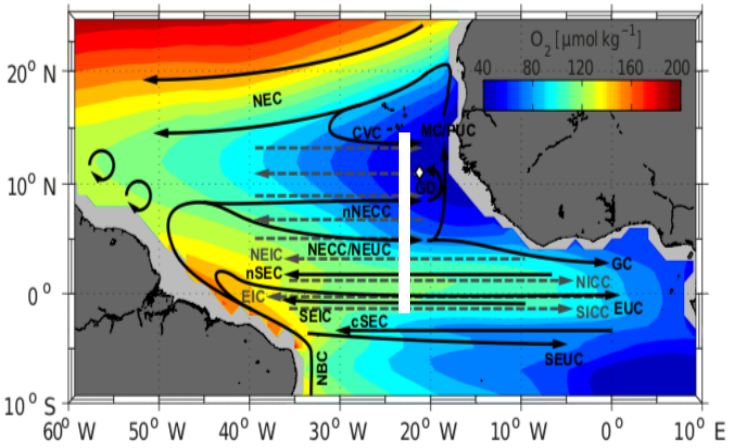
TATL025-PISCES (2006-2017)



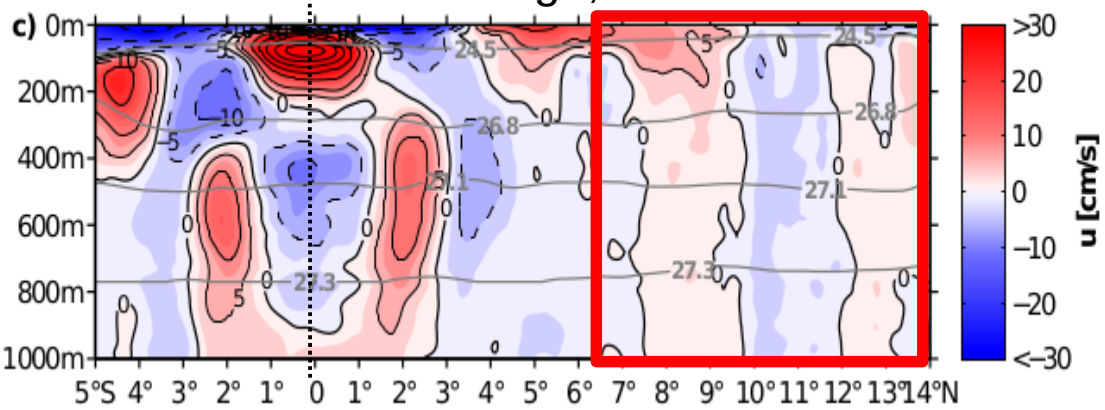




Zonal current at 23°W : observations vs models

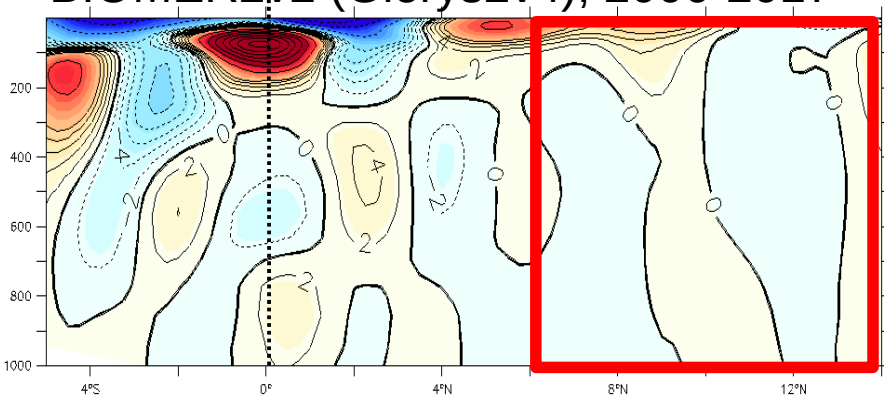


1999-2012 average, Brandt et al. 2015



BIOMERFREE2v4 (2006-2017)

BIOMER2v2 (Glorys2v4), 2006-2017



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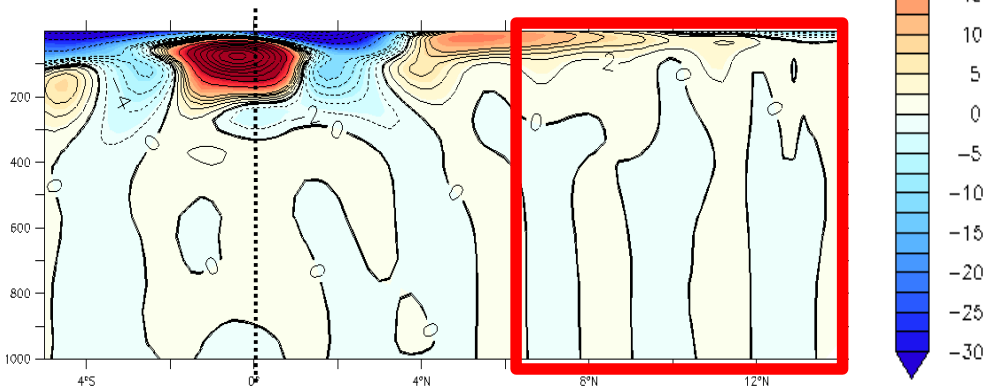
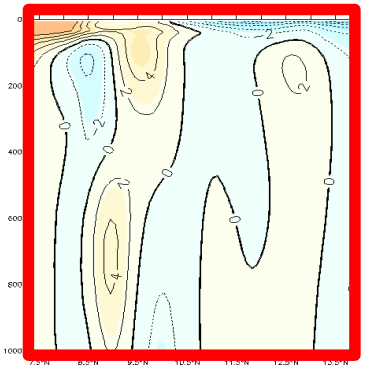
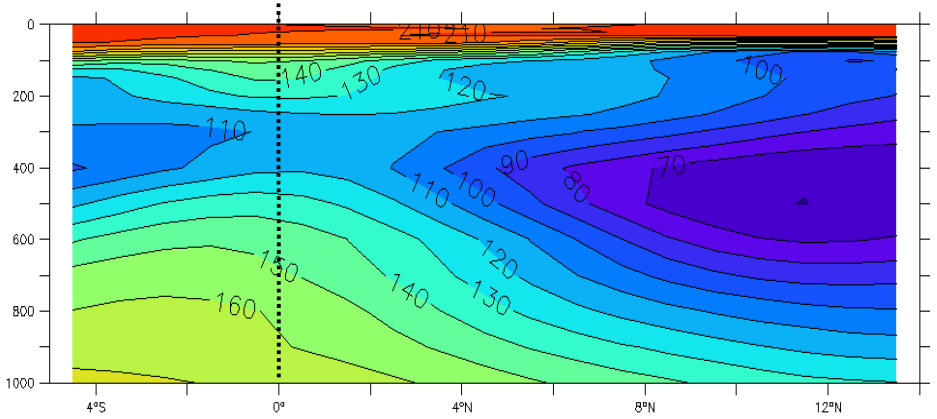


CROCO-PISCES

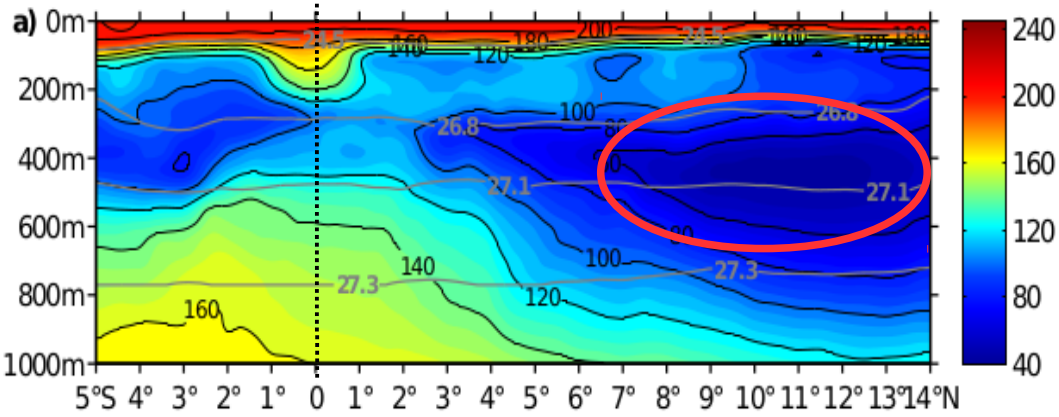


Oxygen section at 23°W : observations vs models

WOA



1999-2012 average, Brandt et al. 2015



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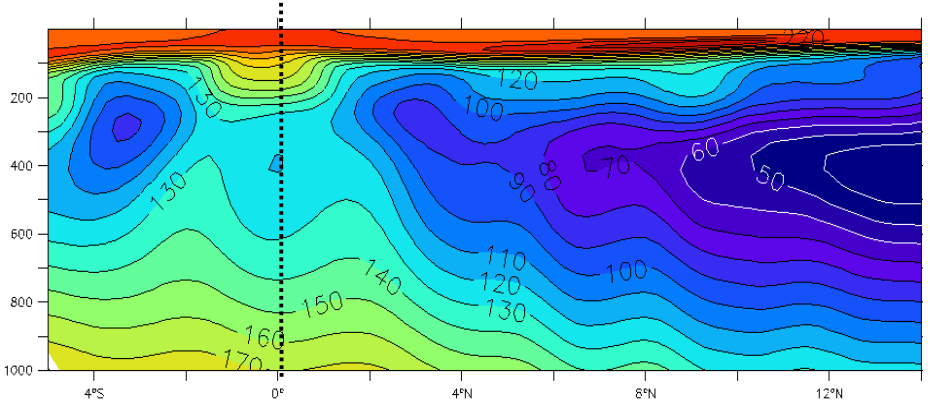

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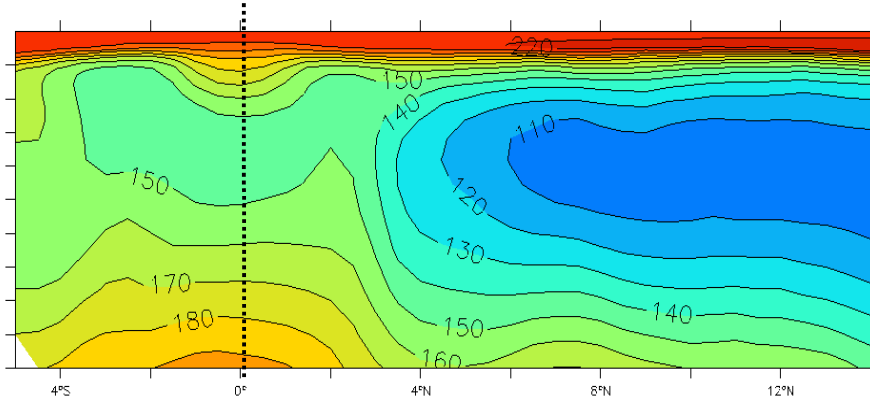

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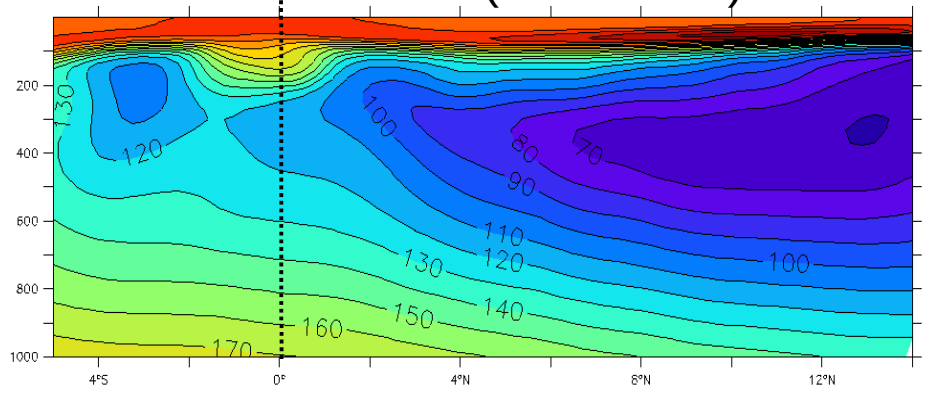

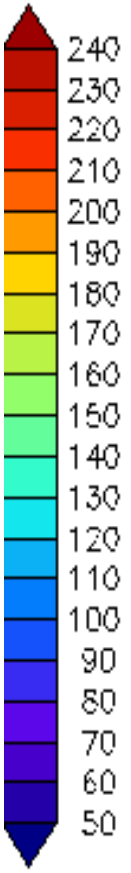

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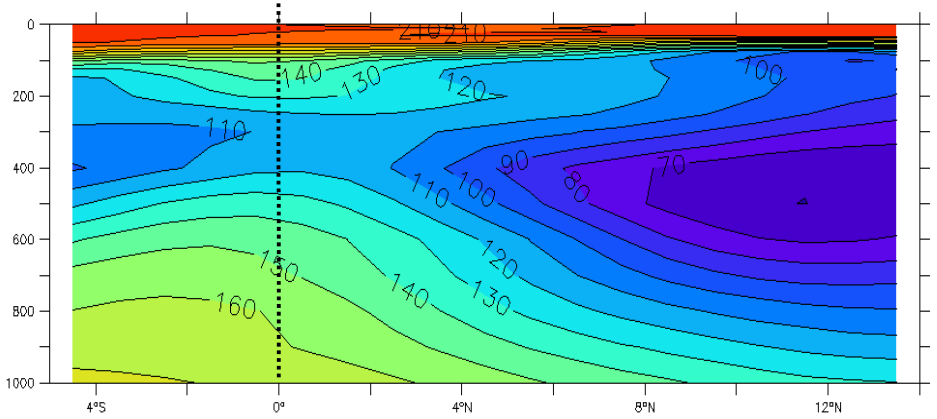
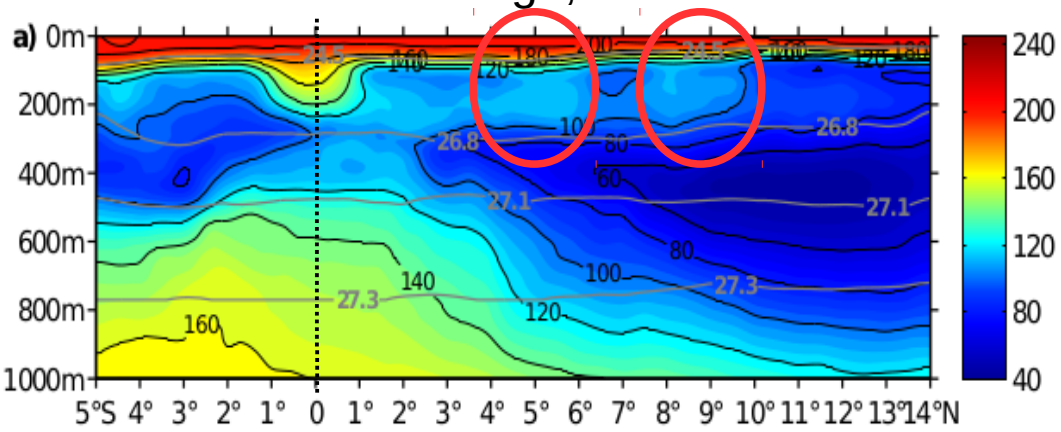


1999-2012 average, Brandt et al. 2015



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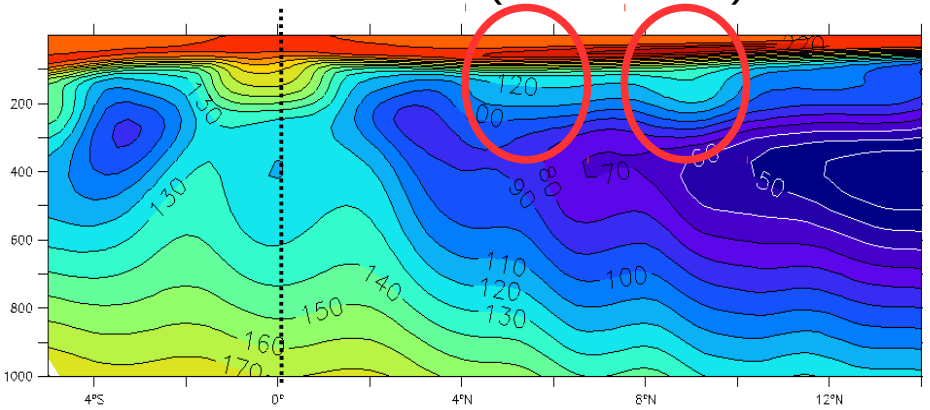

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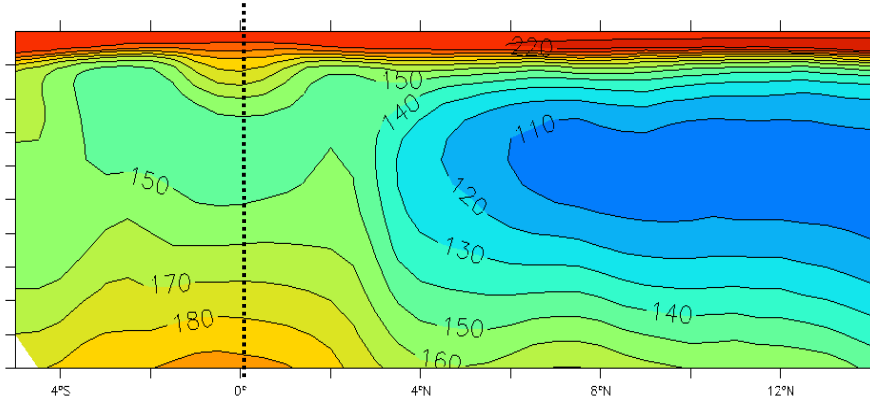

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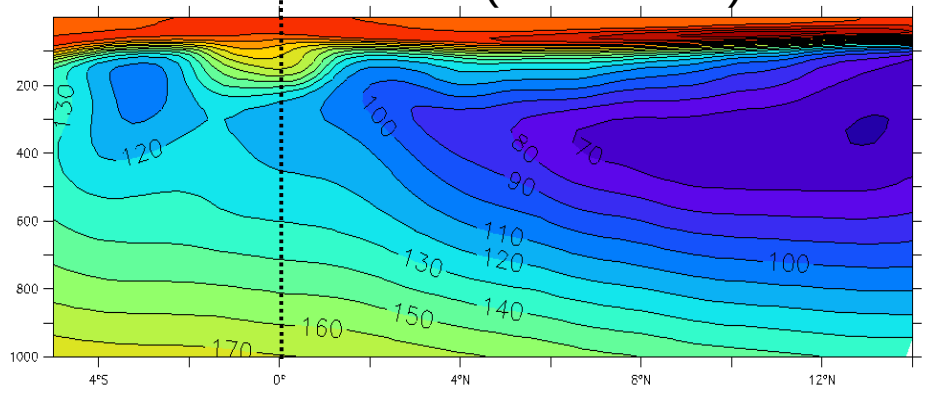
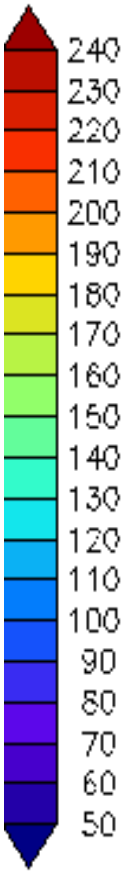
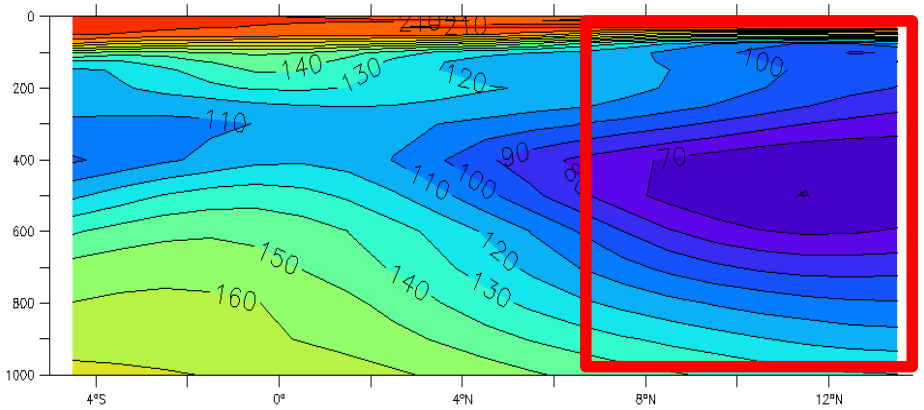


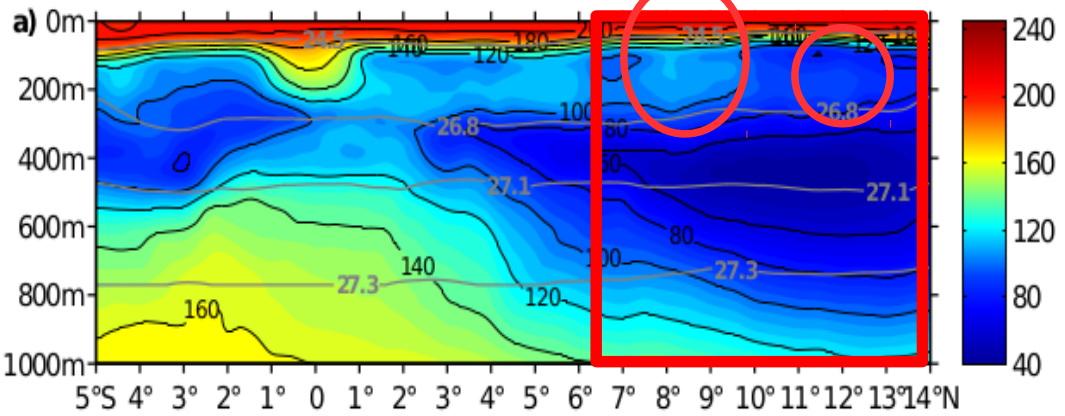


Oxygen section at 23°W : observations vs models

WOA



1999-2012 average, Brandt et al. 2015



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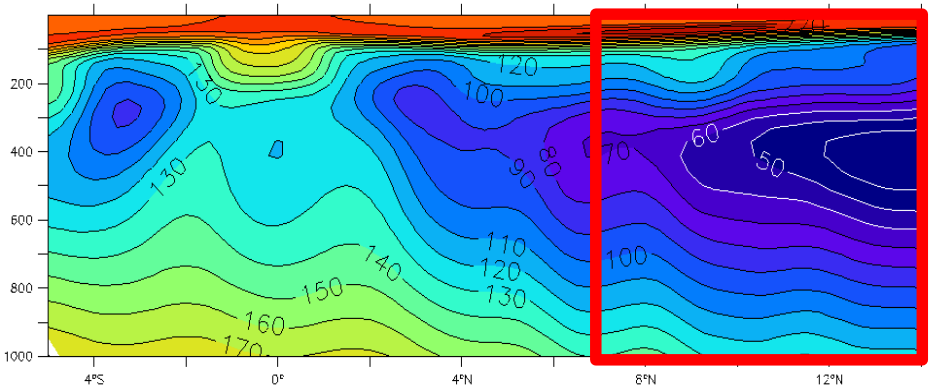

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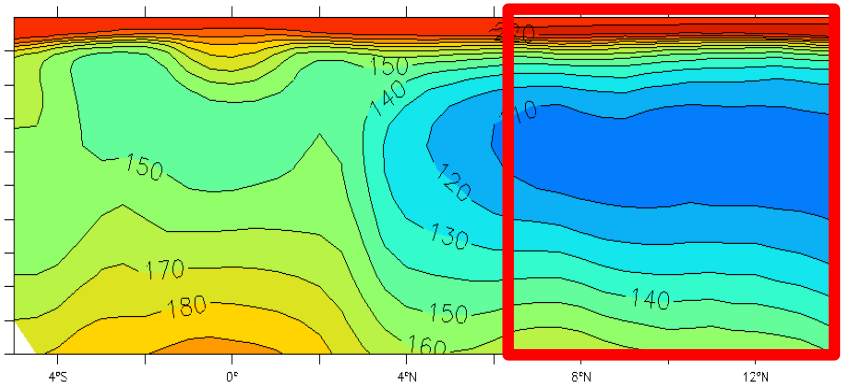

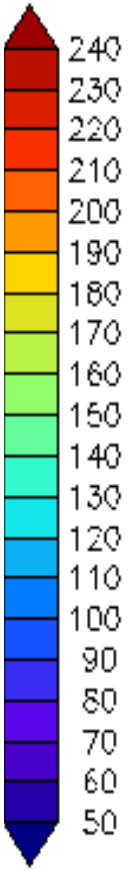

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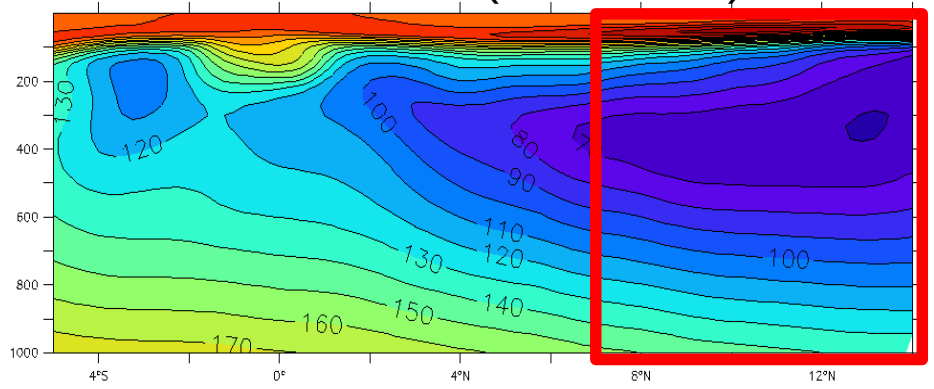
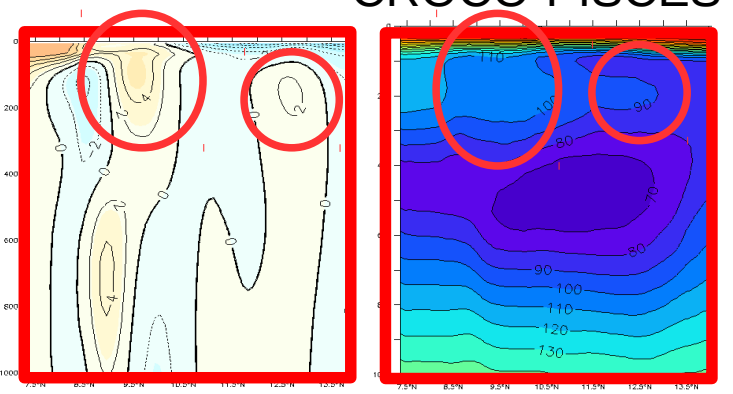
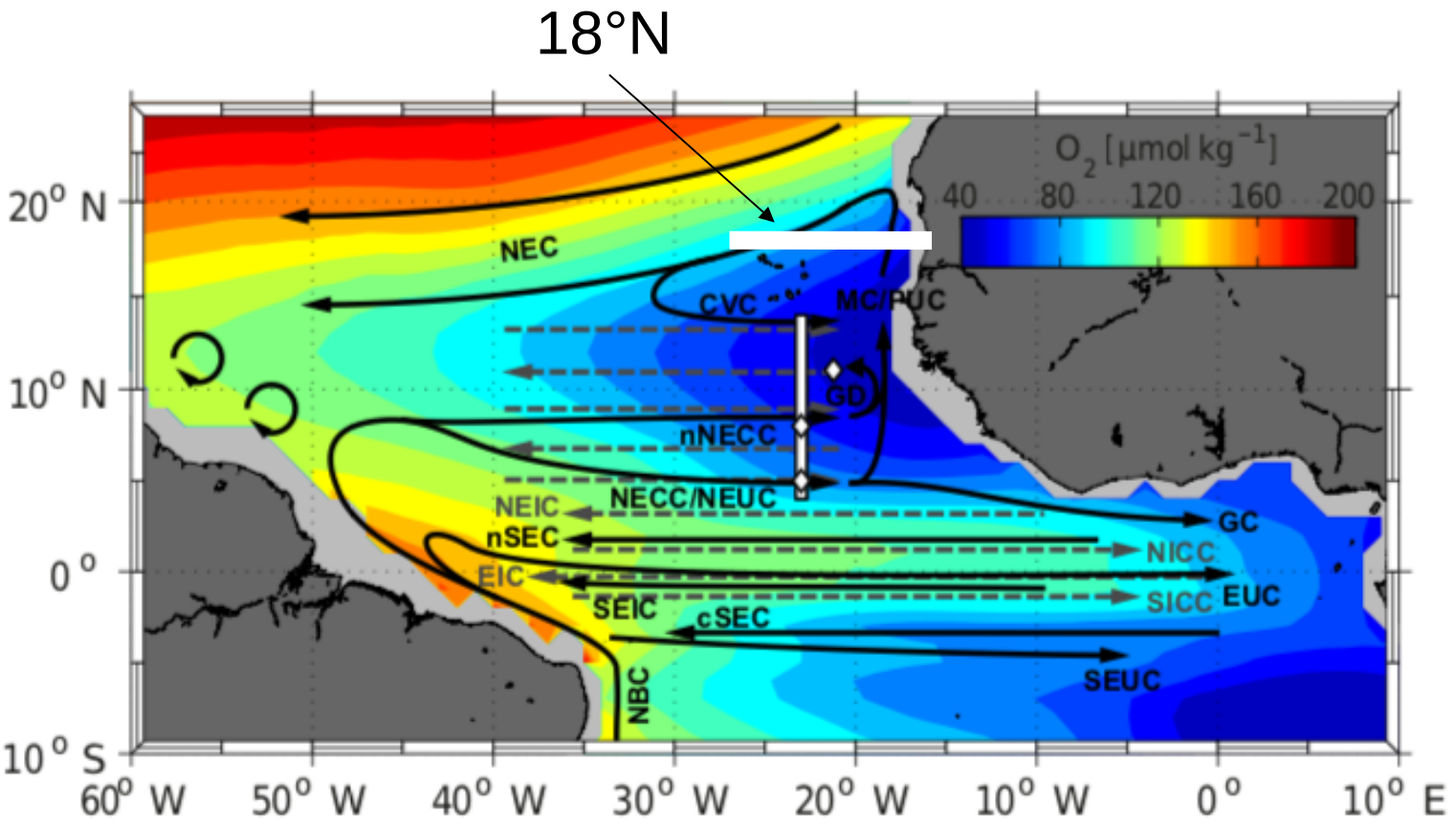


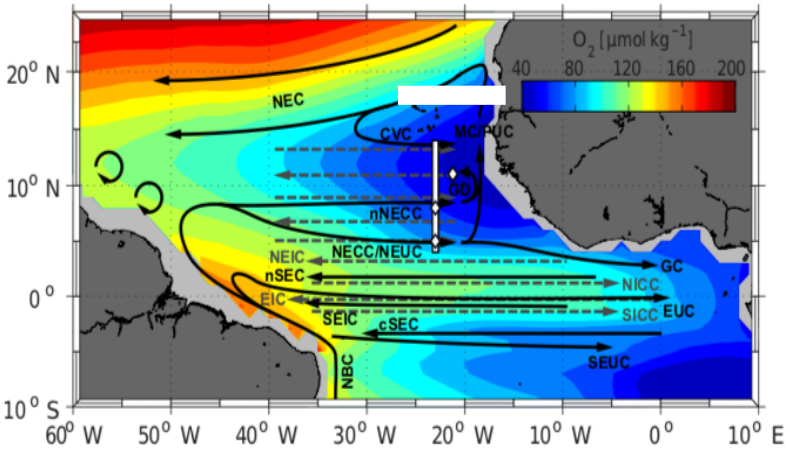
CROCO-PISCES (clim)



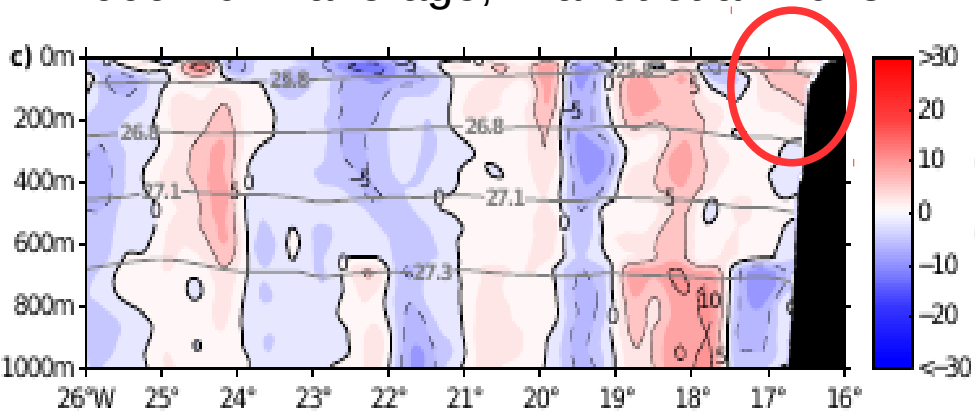
Oxygen and current section at 18°N



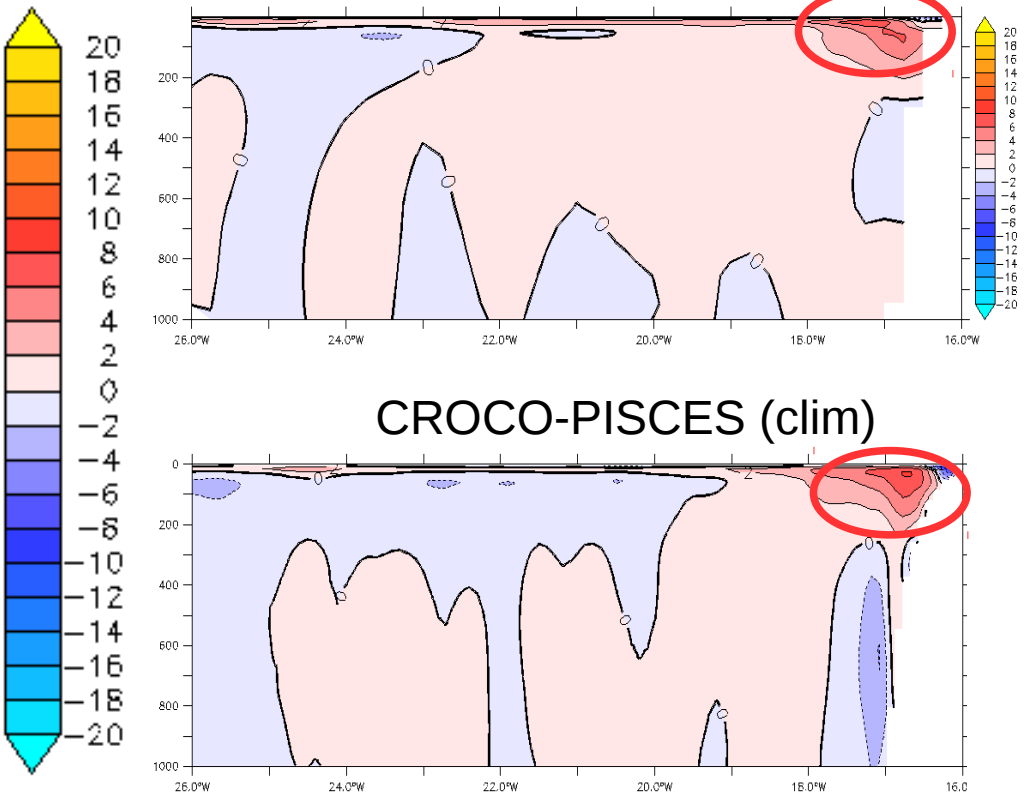
Current section at 18°N : observations vs models



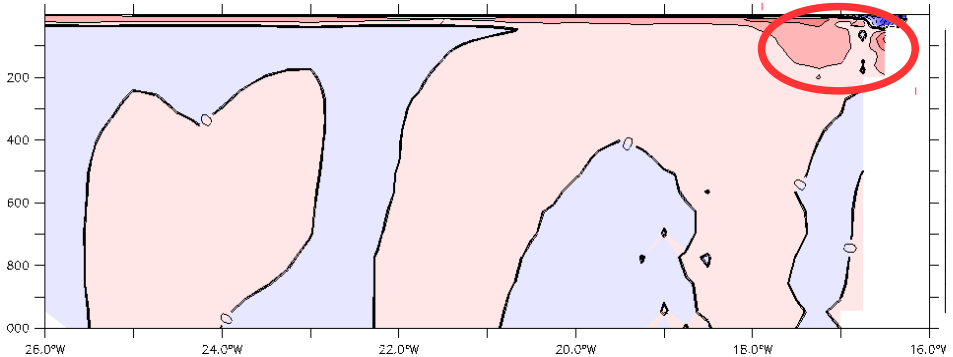
1999-2012 average, Brandt et al. 2015



BIOMER2v2 (Glorys2v4), 2006-2017

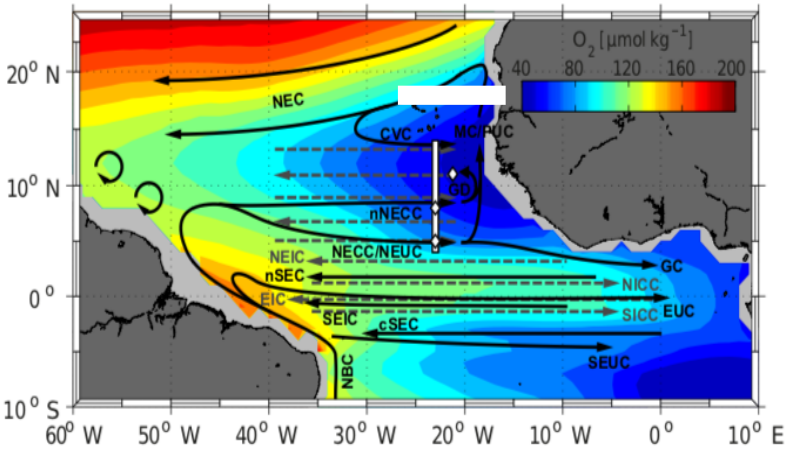


TATL025, 2006-2017

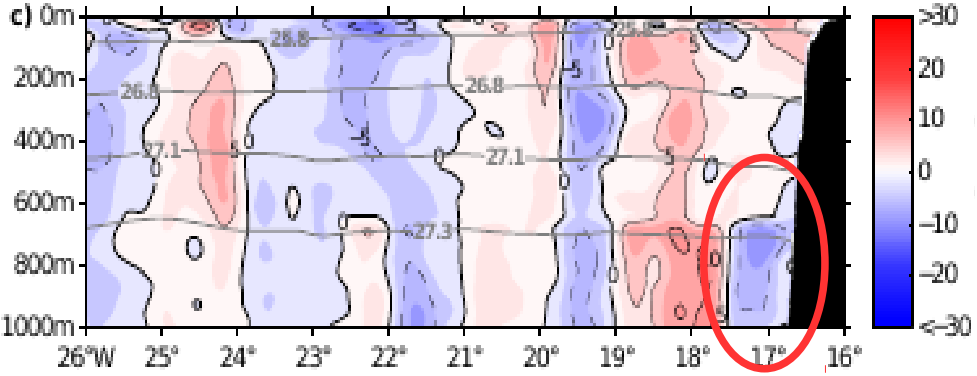


CROCO-PISCES (clim)

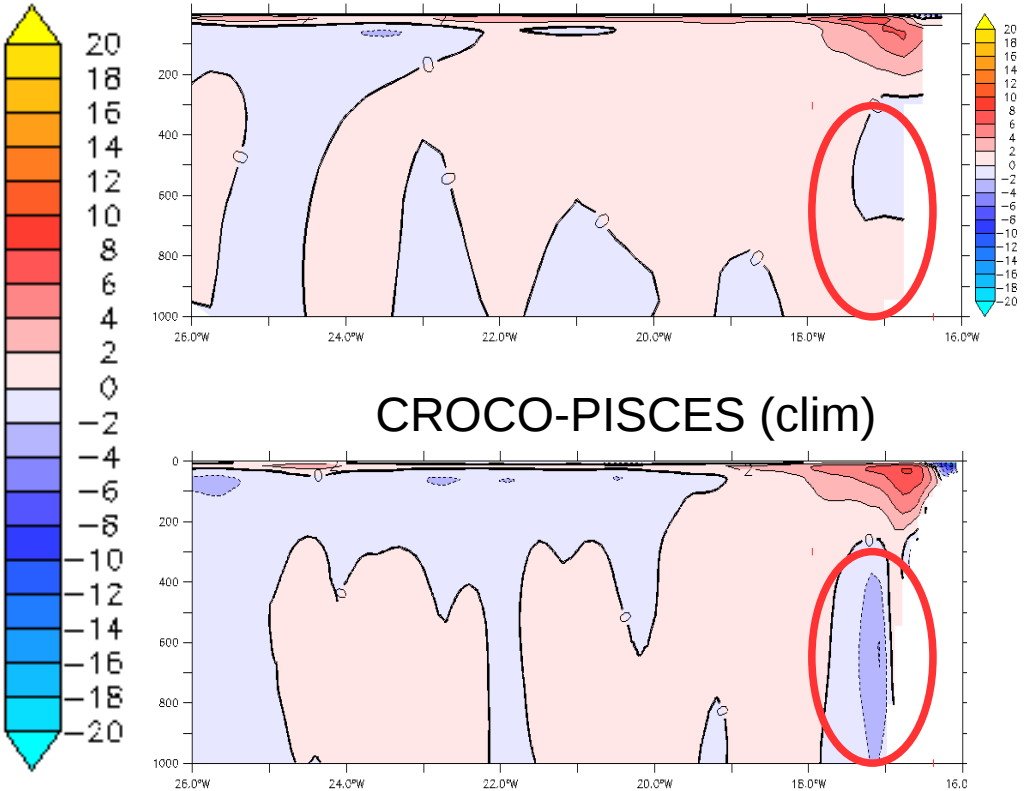
Current section at 18°N : observations vs models



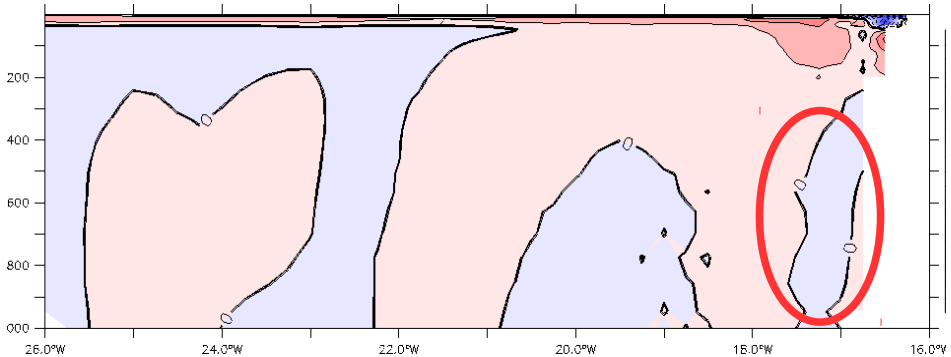
1999-2012 average, Brandt et al. 2015



BIOMER2v2 (Glorys2v4), 2006-2017



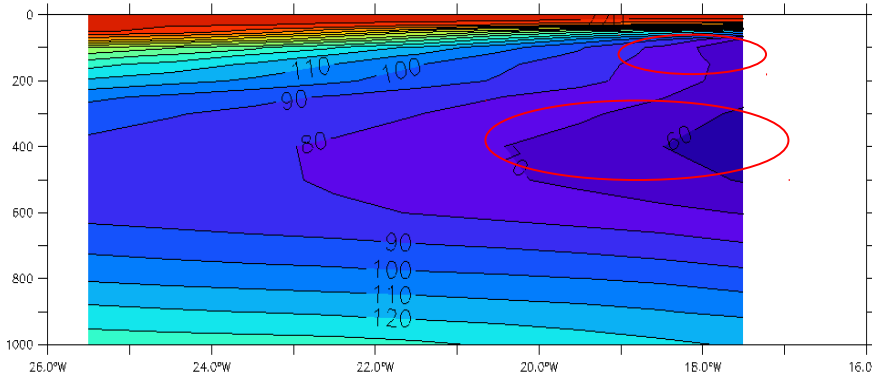
TATL025, 2006-2017



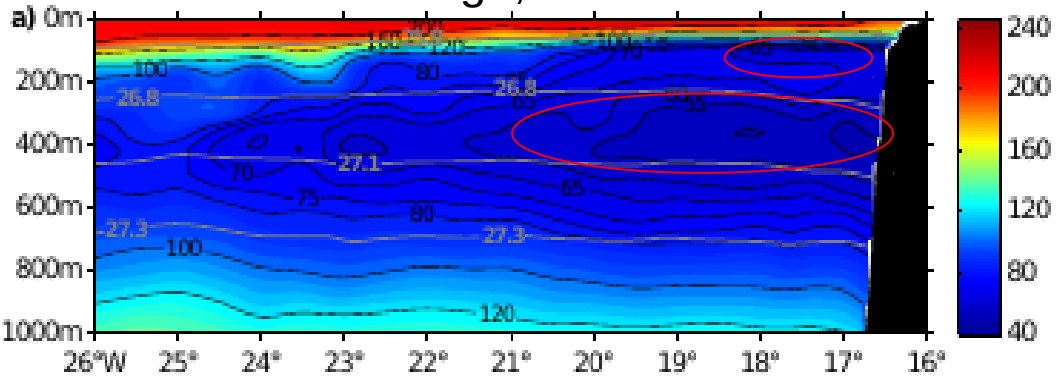
CROCO-PISCES (clim)

Oxygen section at 18°N : observations vs models

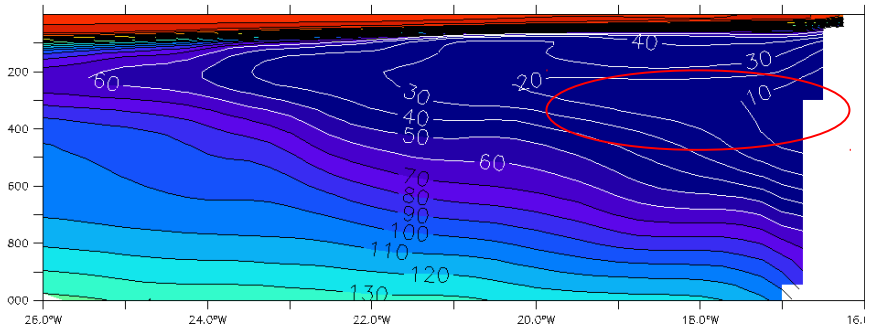
WOA2009 (=WOA2013)



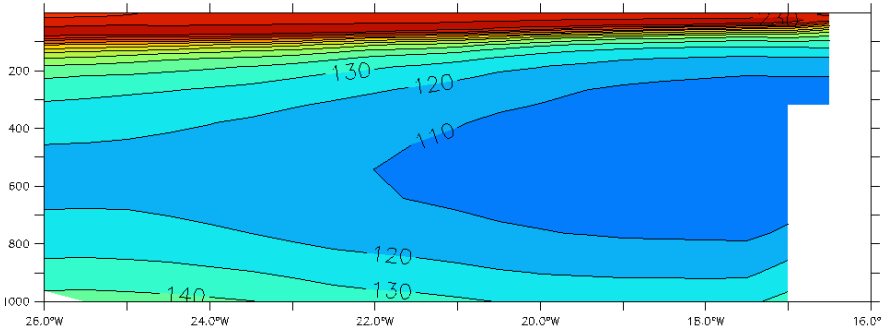
1999-2012 average, Brandt et al. 2015

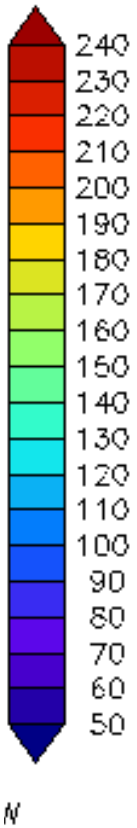


BIOMERFREE2v4 (2006-2017)

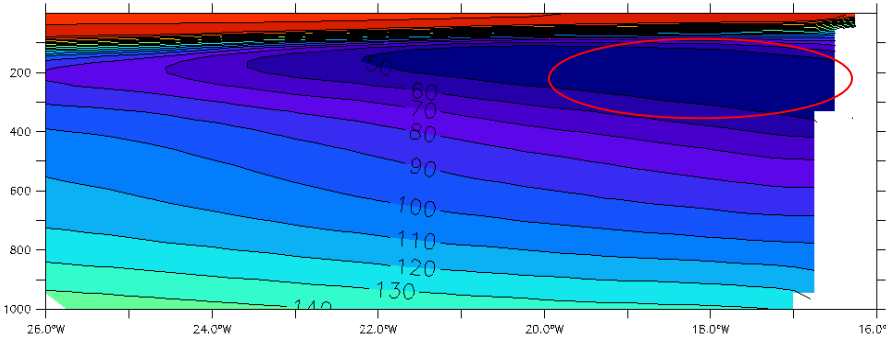


BIOMER2v2 (2006-2017)





TATL025-PISCES (2006-2017)



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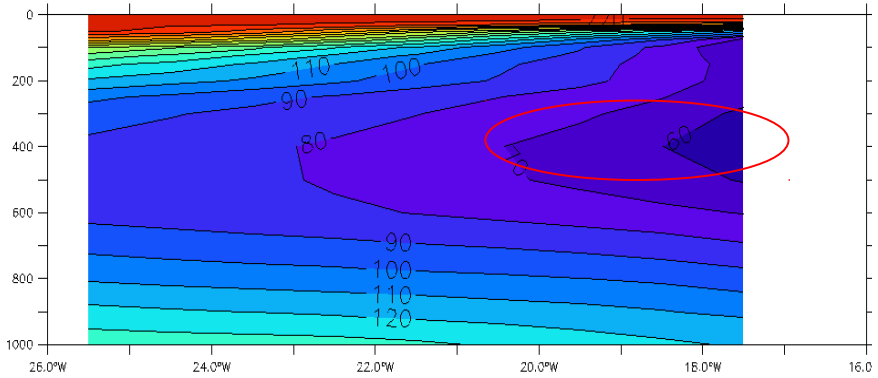

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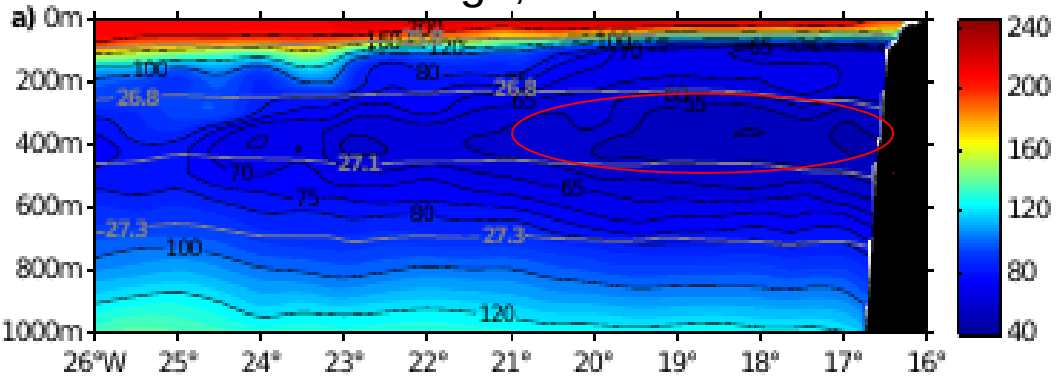
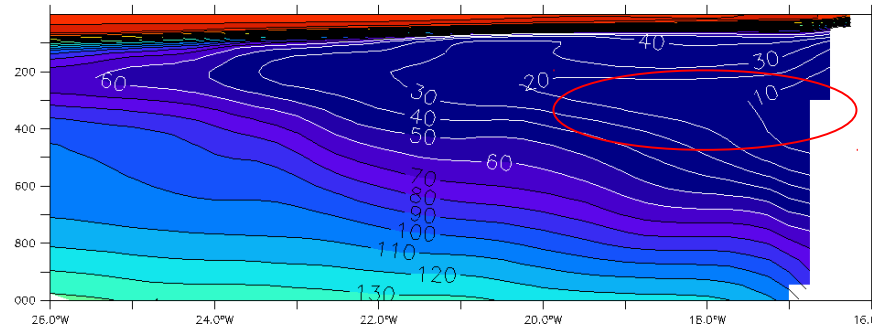
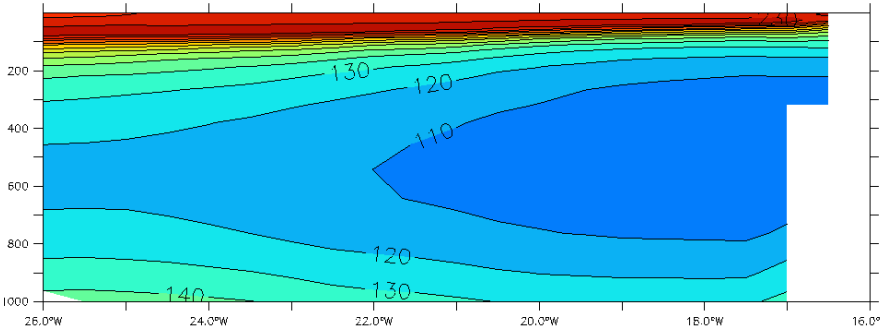
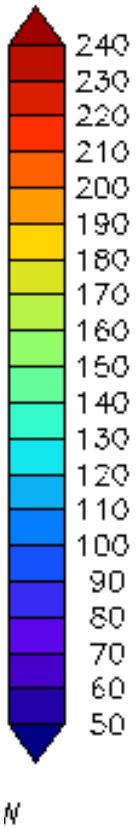


BIOMERFREE2v4 (2006-2017)

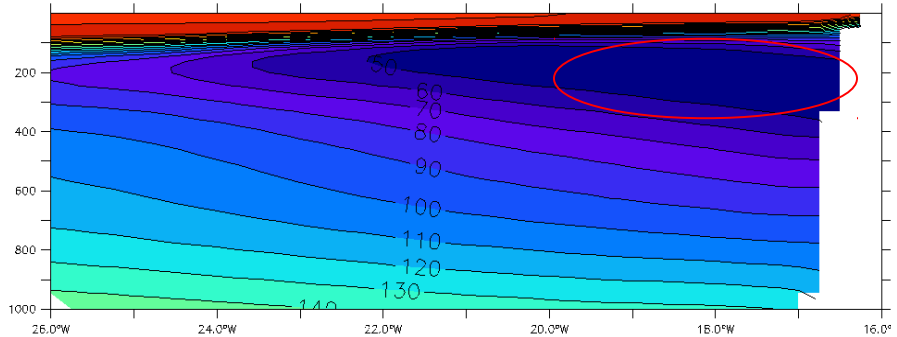


BIOMER2v2 (2006-2017)

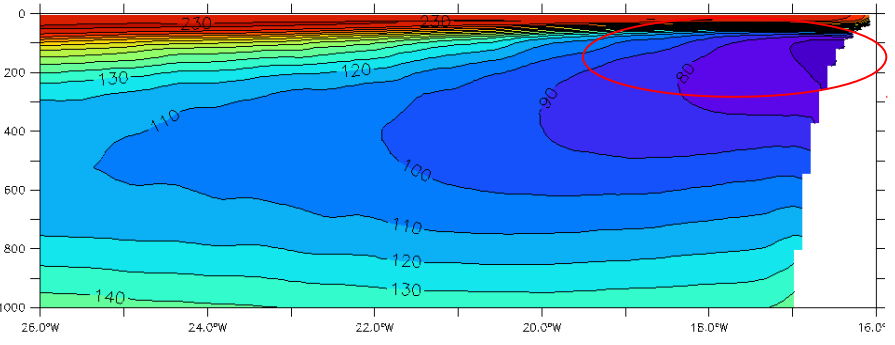




TATL025-PISCES (2006-2017)

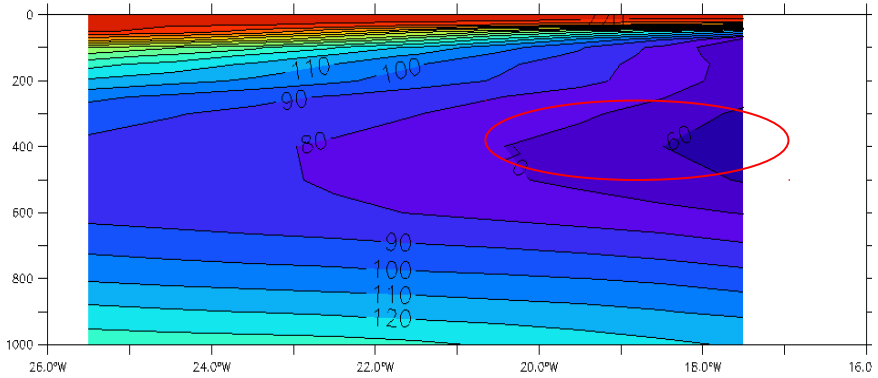


CROCO-PISCES (clim)

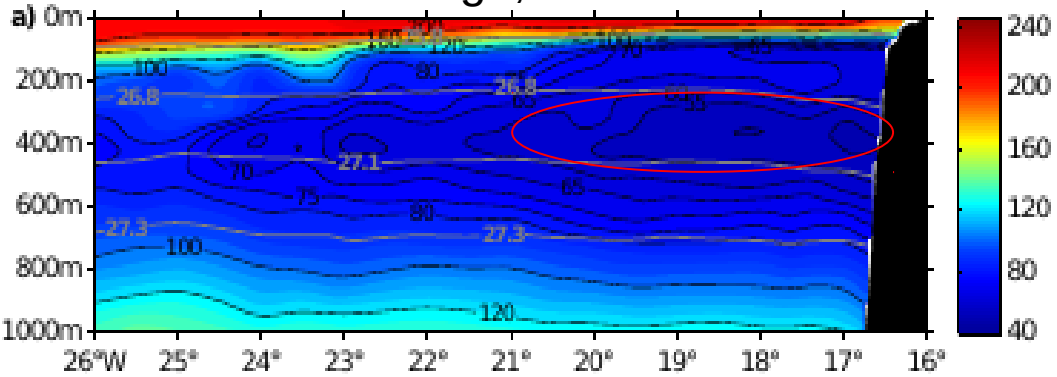


Oxygen section at 18°N : observations vs models

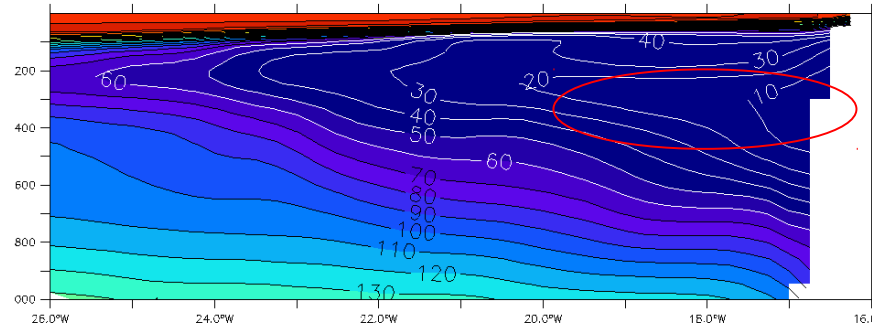
WOA2009 (=WOA2013)



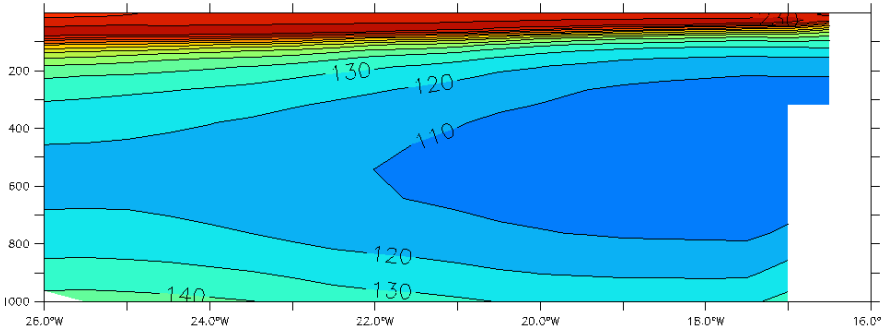
1999-2012 average, Brandt et al. 2015

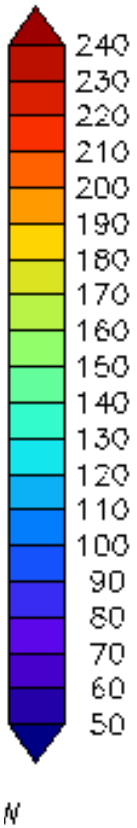


BIOMERFREE2v4 (2006-2017)

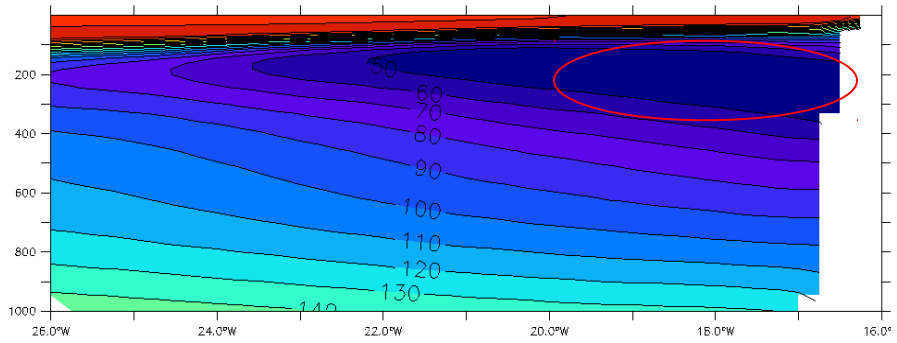


BIOMER2v2 (2006-2017)

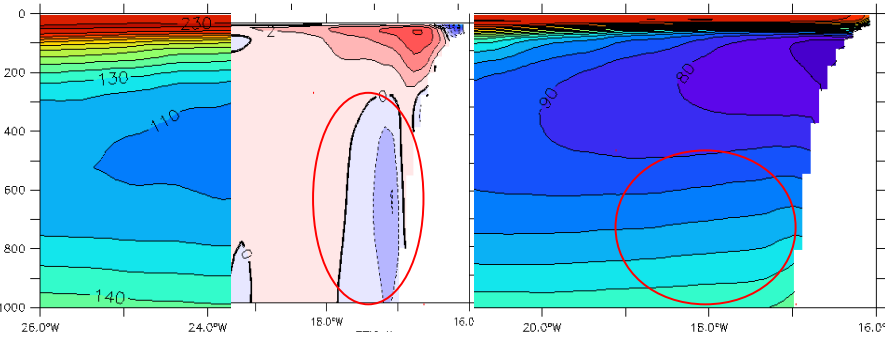




TATL025-PISCES (2006-2017)

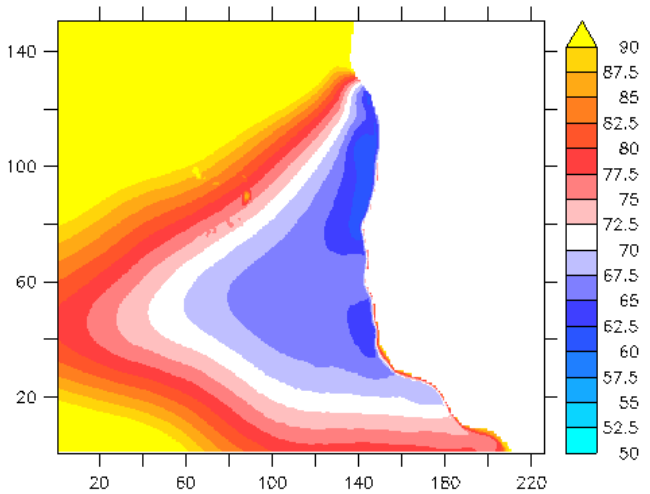


CROCO-PISCES (clim)

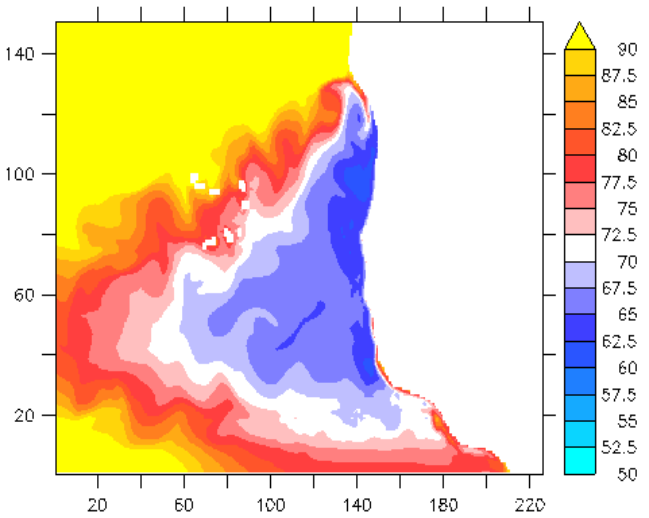


Evolution of the deep OMZ (200-600 m layer) during 5 years (CROCO-PISCES)

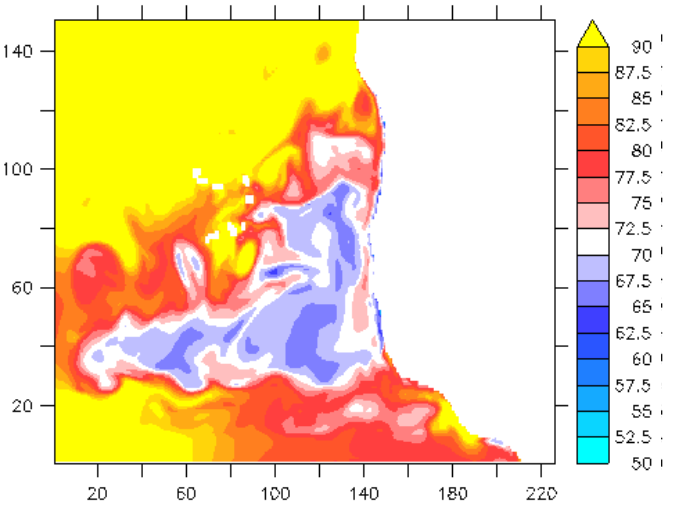
t0(Initial state)= WOA



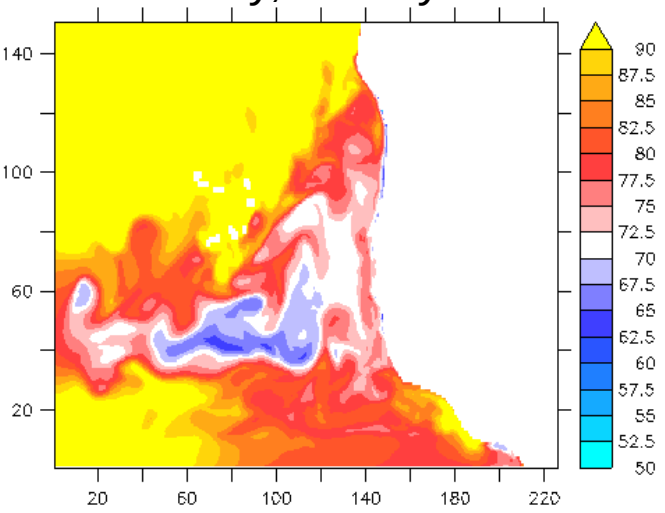
January, t0+ 1 year



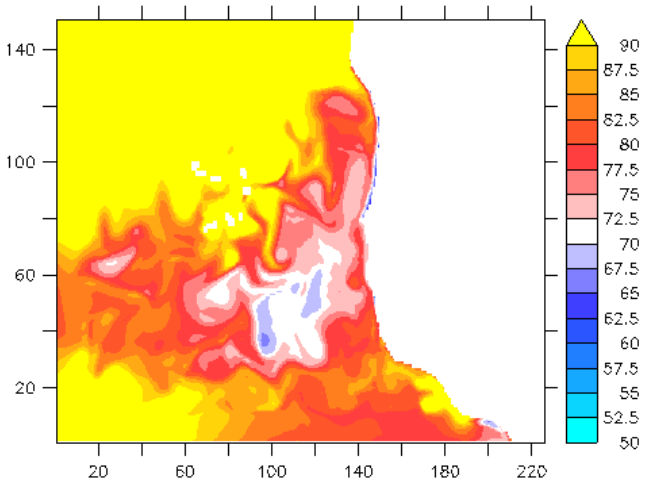
January, t0+ 2 years



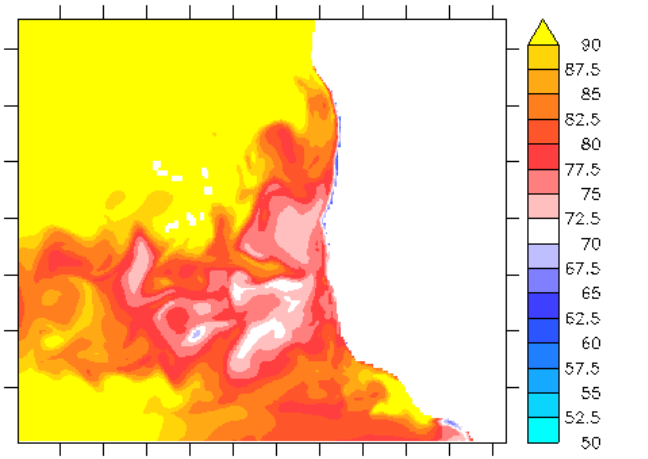
January, t0+ 3 years



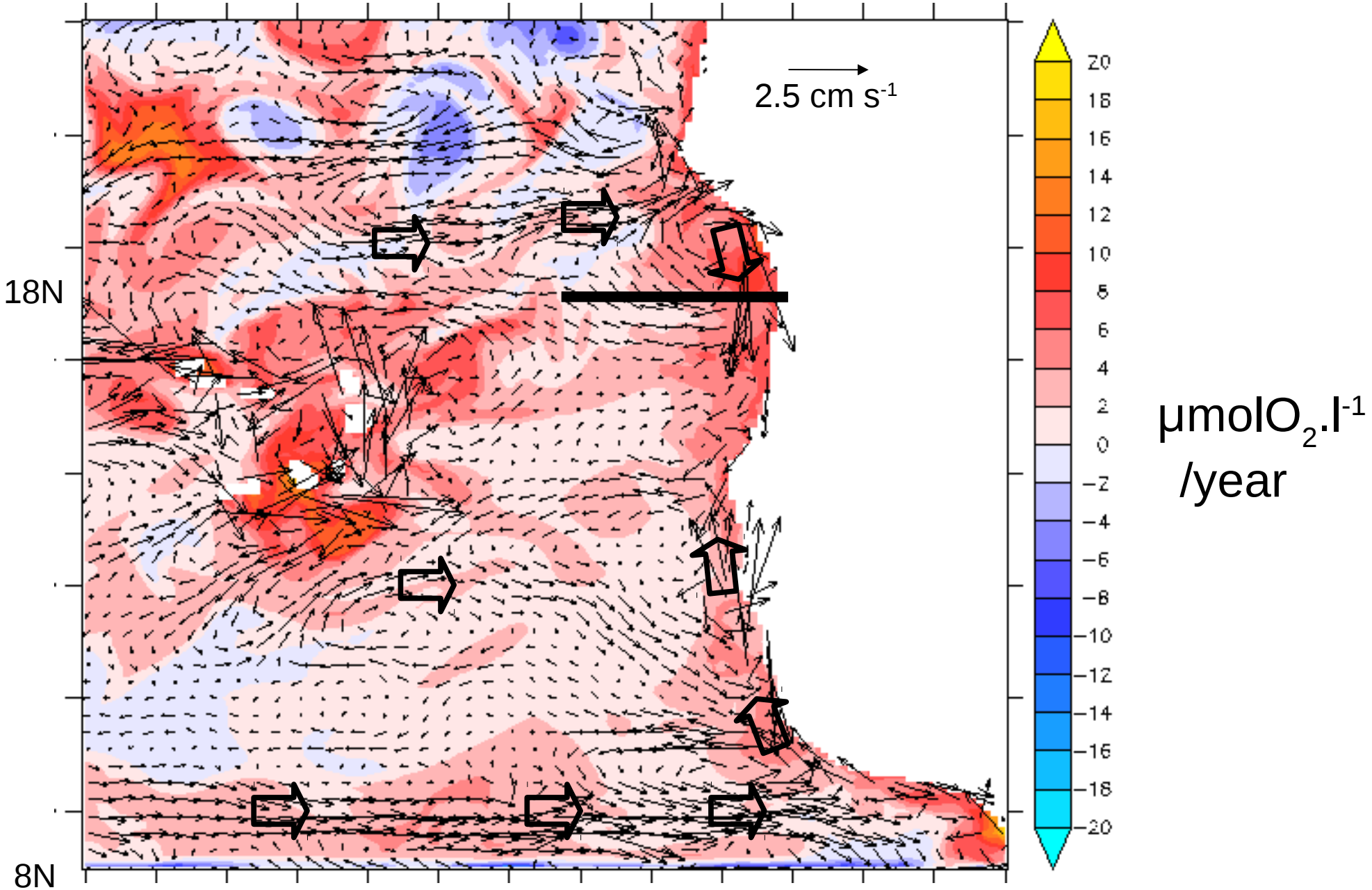
January, t0+ 4 years



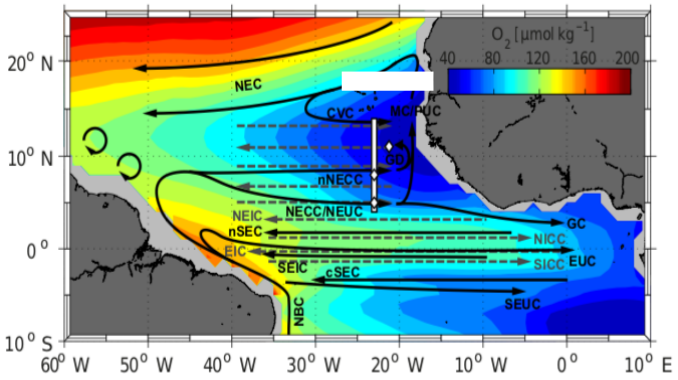
January, t0+ 5 years



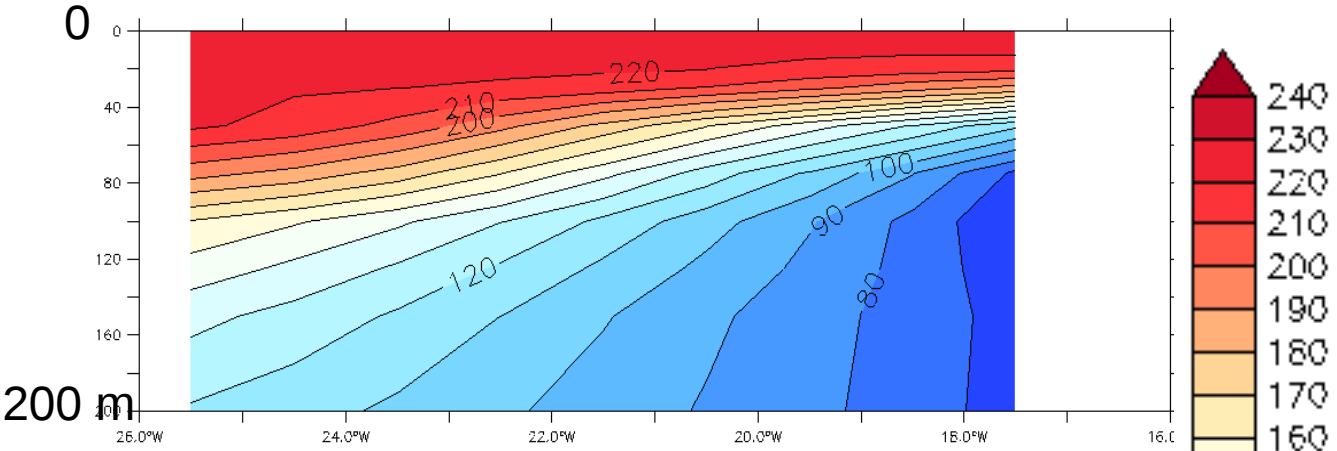
Advection of oxygen (400-600m depth) during spin-up phase & 10-year average circulation



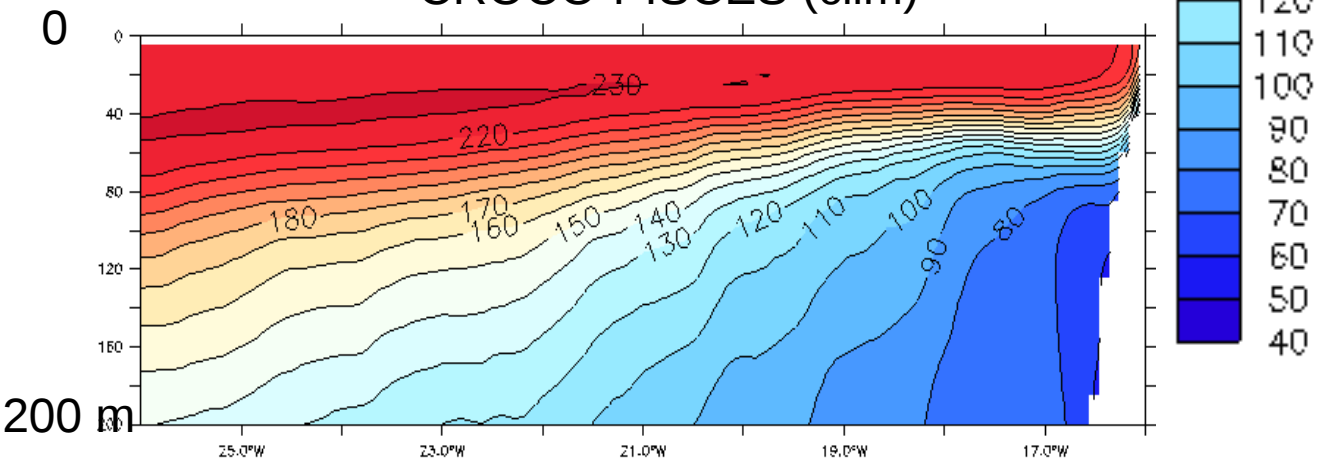
Oxygen section at 18°N (0-200m): observations vs models

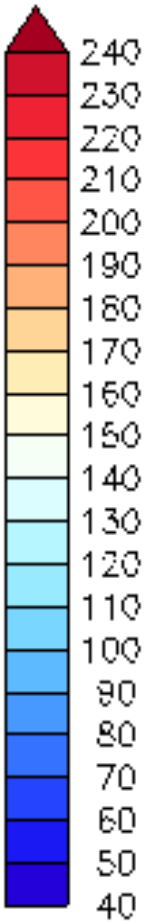


WOA



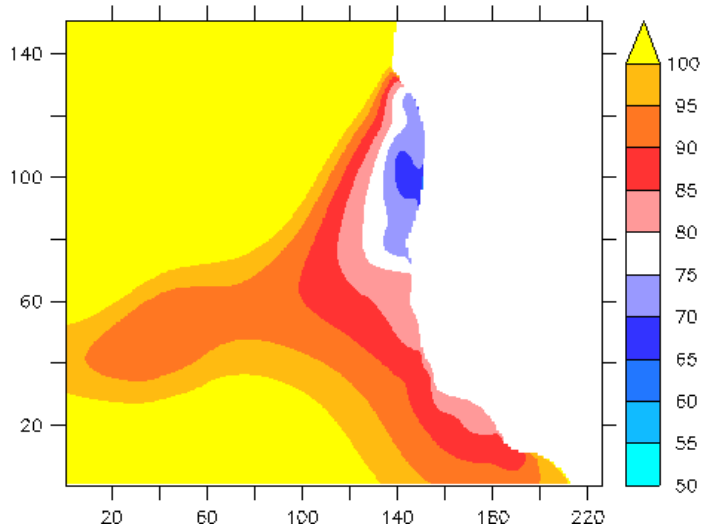
CROCO-PISCES (clim)



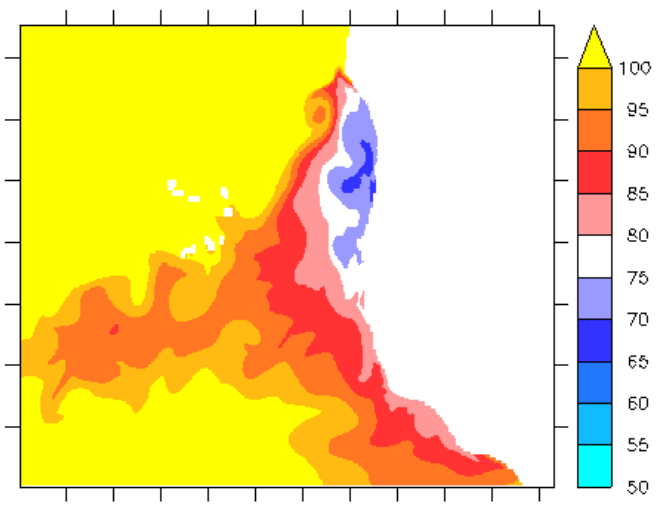


Evolution of the shallow OMZ (100-200 m layer) during 5 years (CROCO-PISCES)

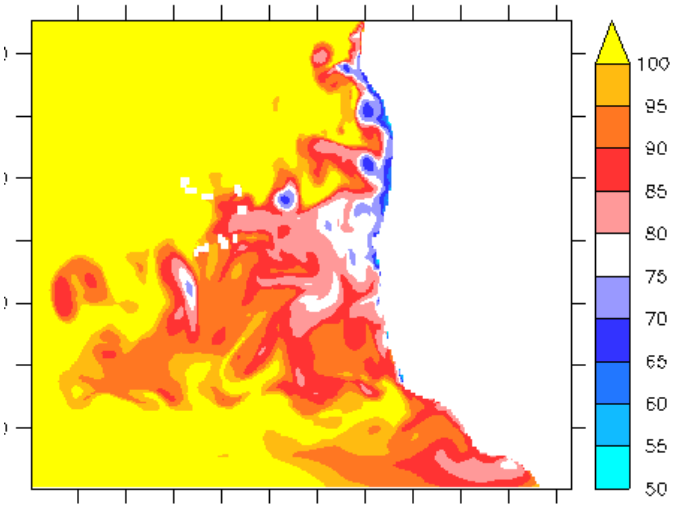
Etat initial= WOA



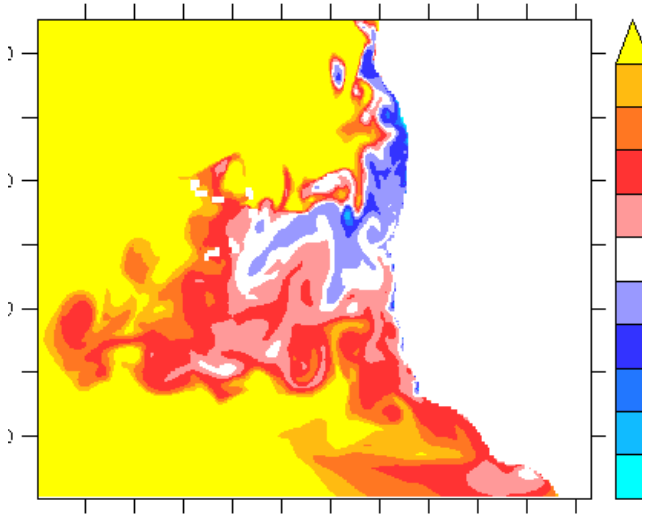
Jan, year 1



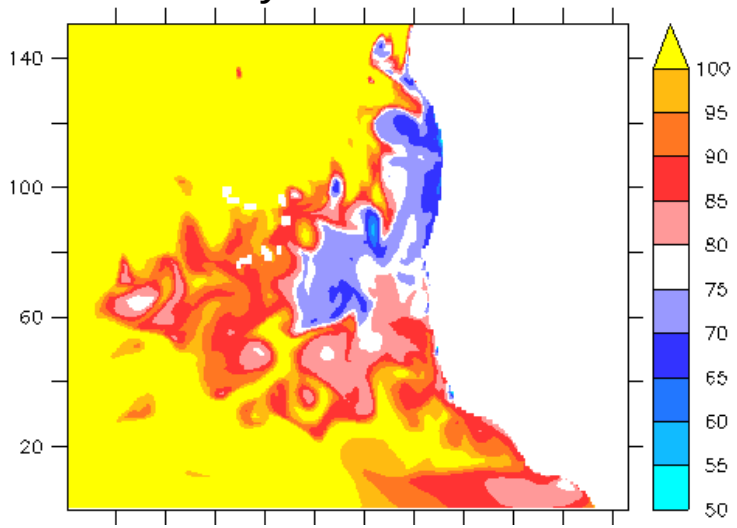
jan,year 2



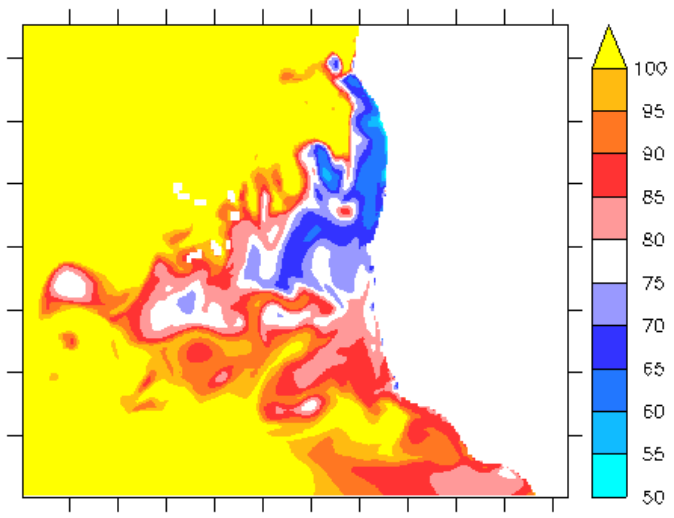
Jan, year 3



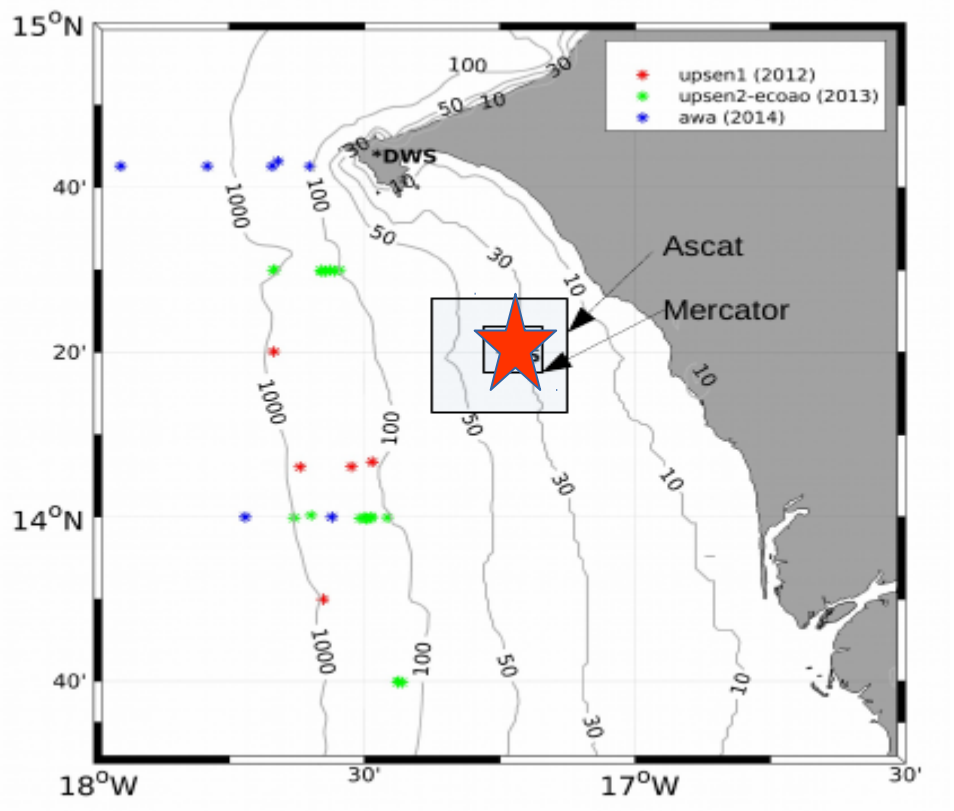
Jan, year 4



jan, year 5



Observations at MELAX mooring off Senegal shelf



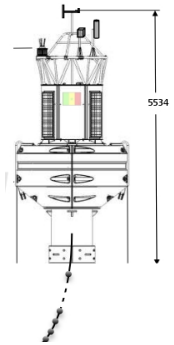
Temperature,Salinity, Oxygen at 30 m depth
=> good agreement with Mercator model
1/12° (PSY4V3R1)

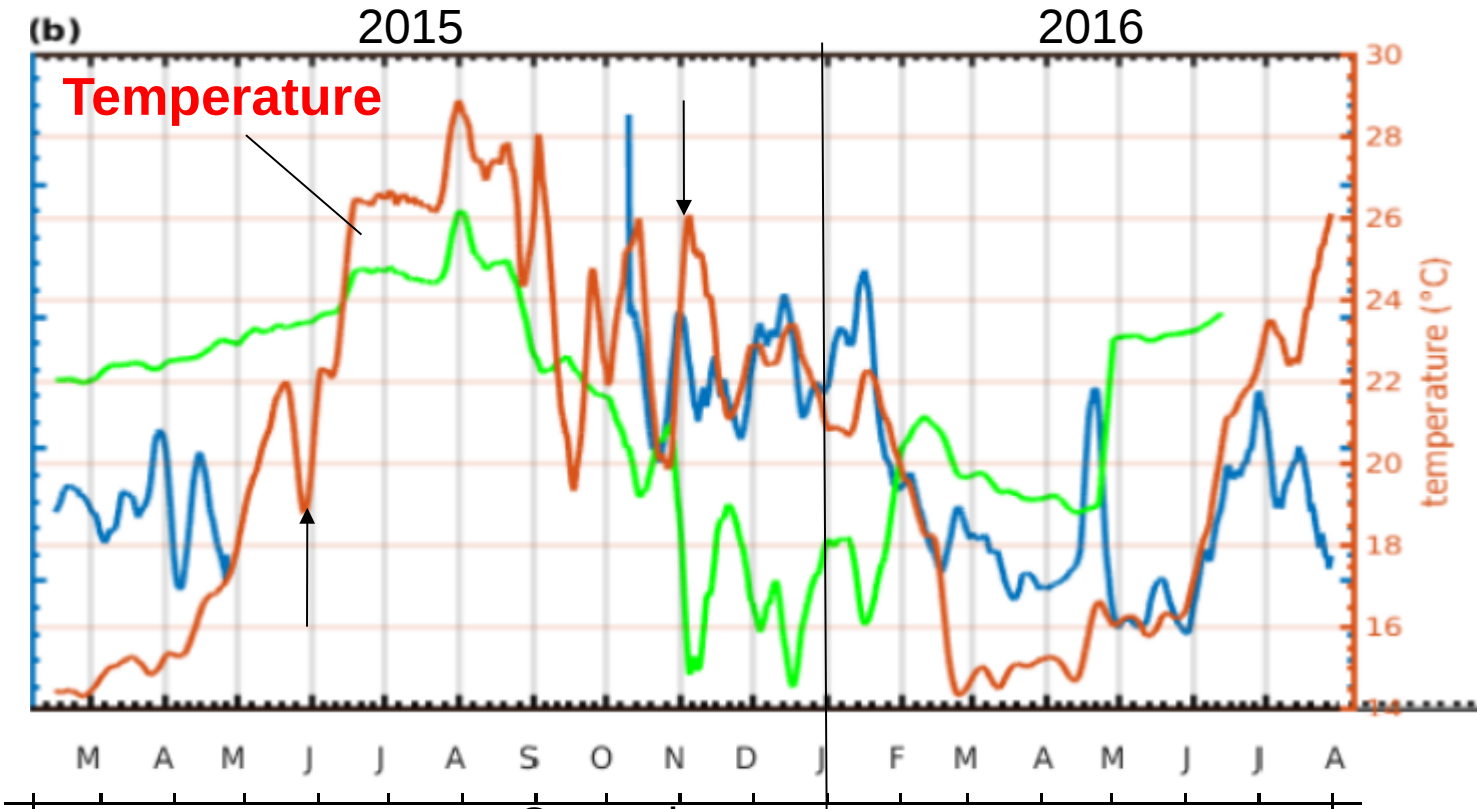
2015-2019 (several months without data)

Analysis of oxygen variability : PhD of A.W. Tall (LPAOSF)

Obs

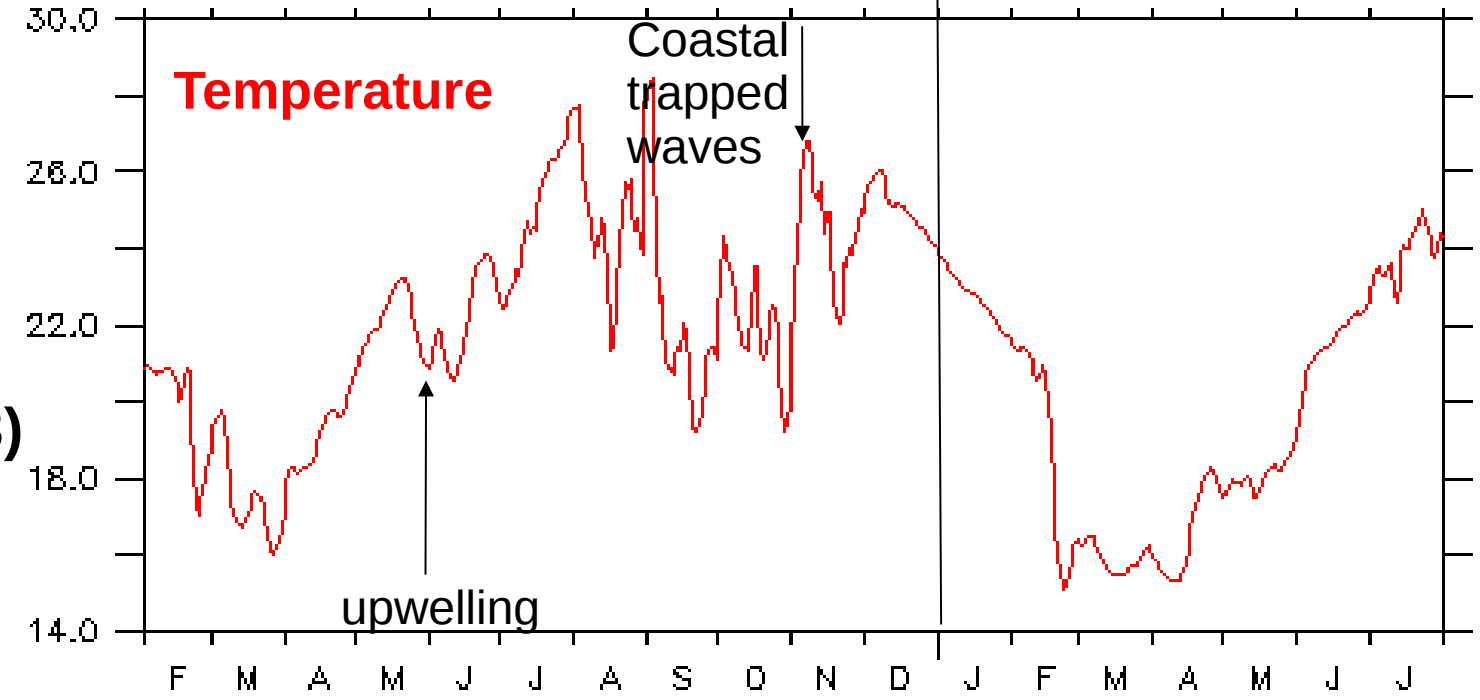
30m





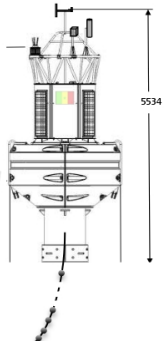
CROCO-PISCES (forced by PSY4V3)

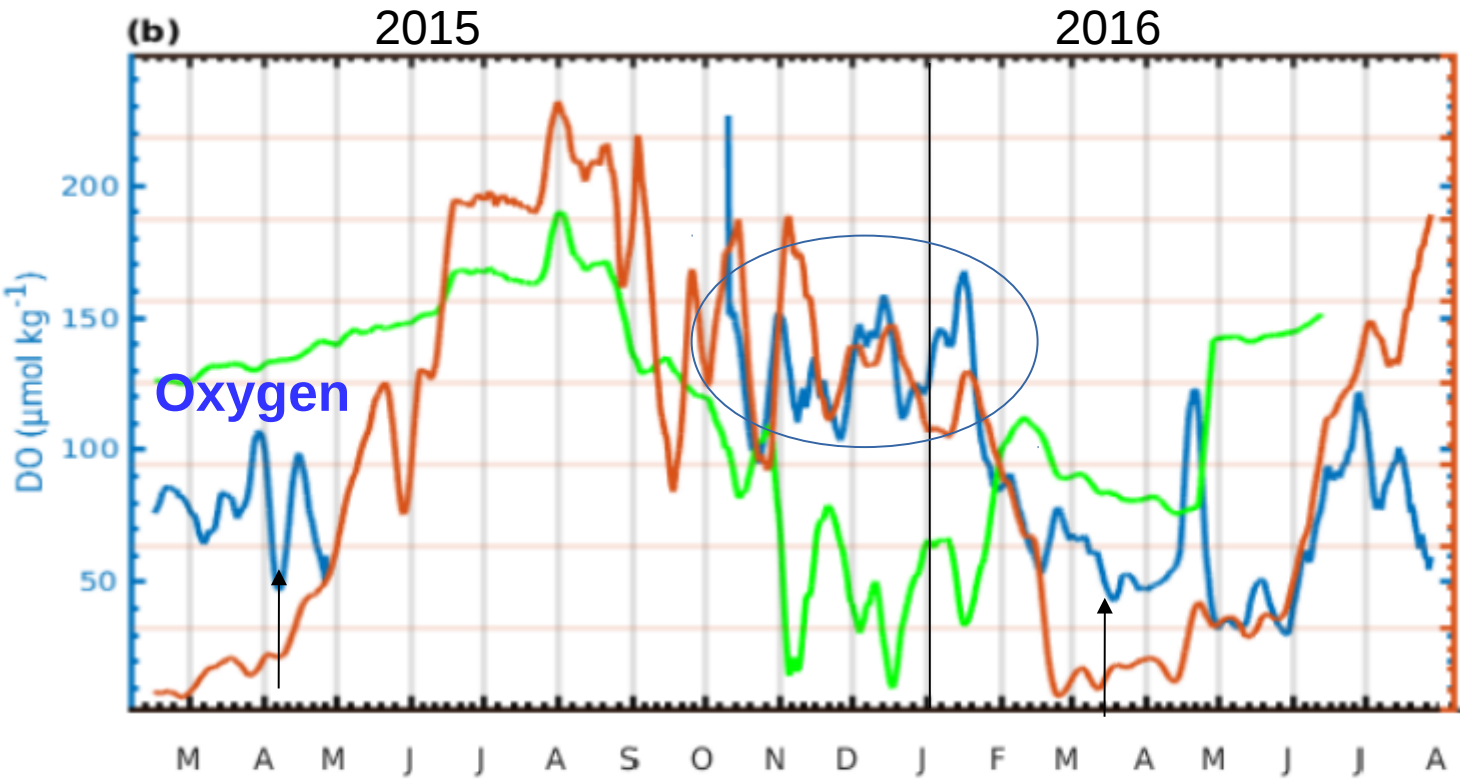
30m



Obs

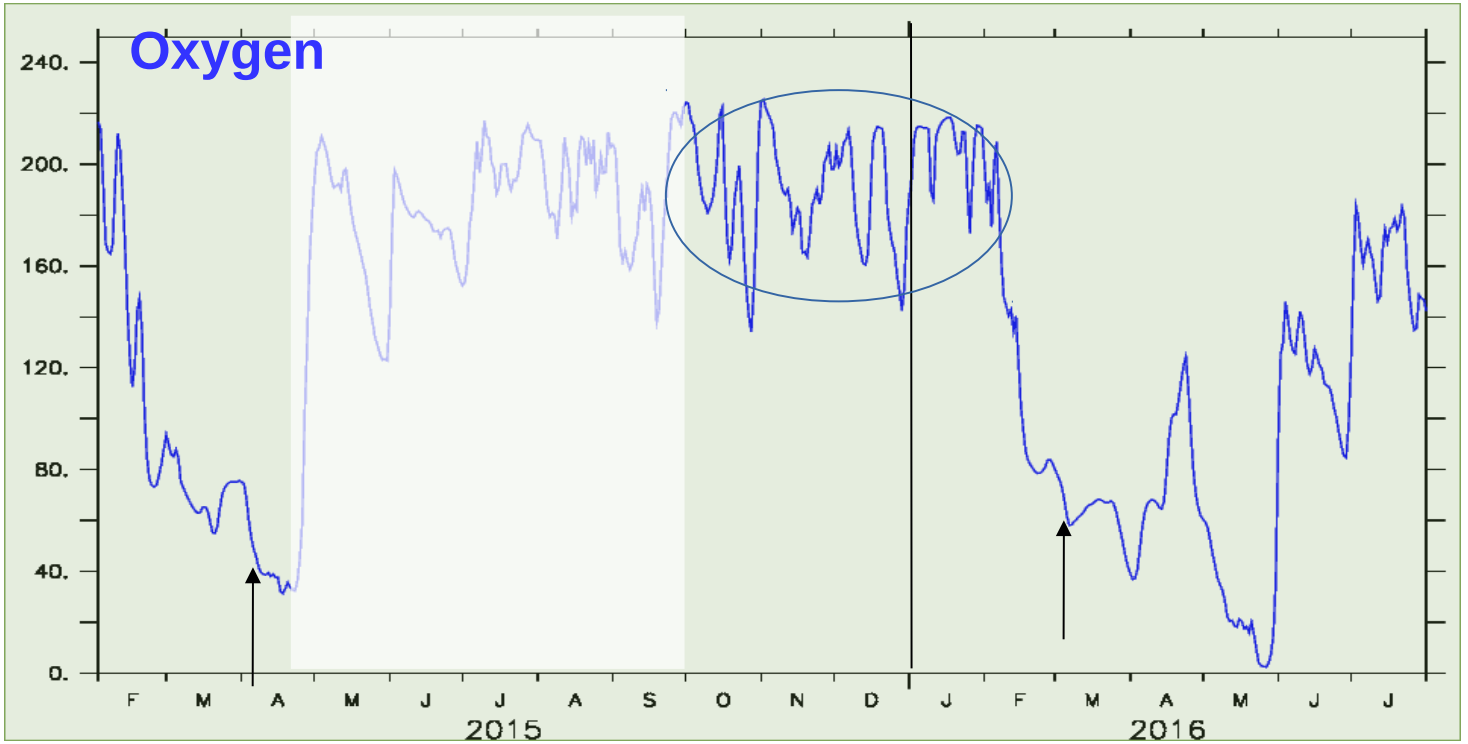
30m





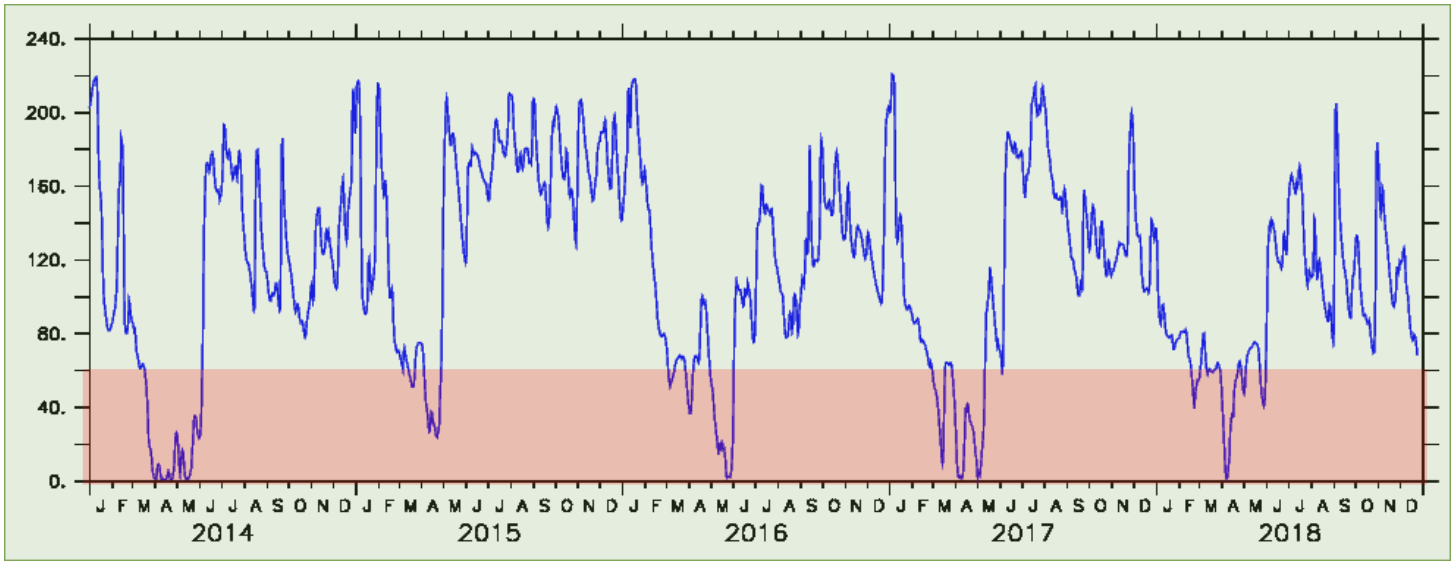
CROCO-PISCES (forced by PSY4V3)

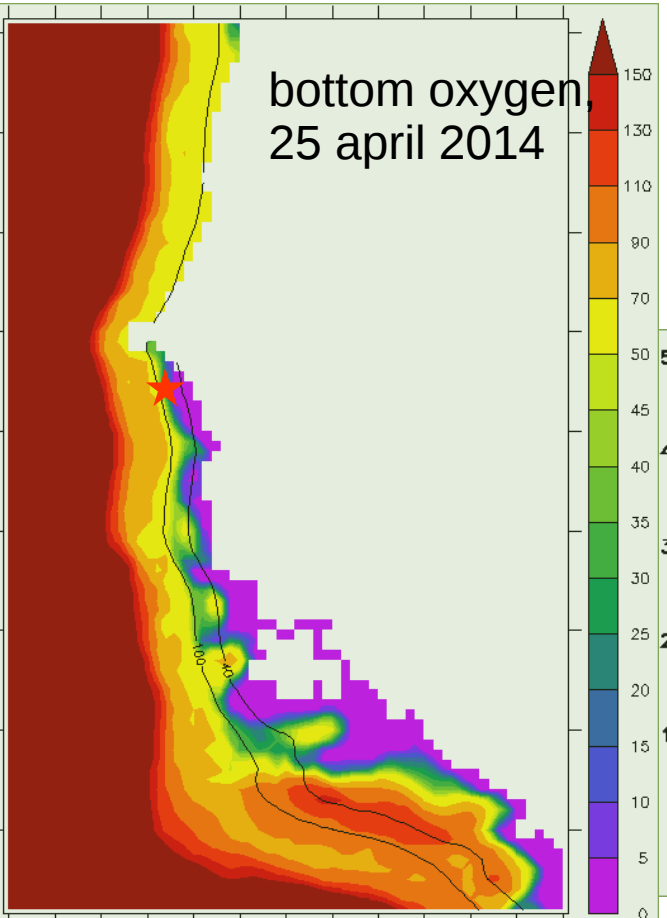
30m



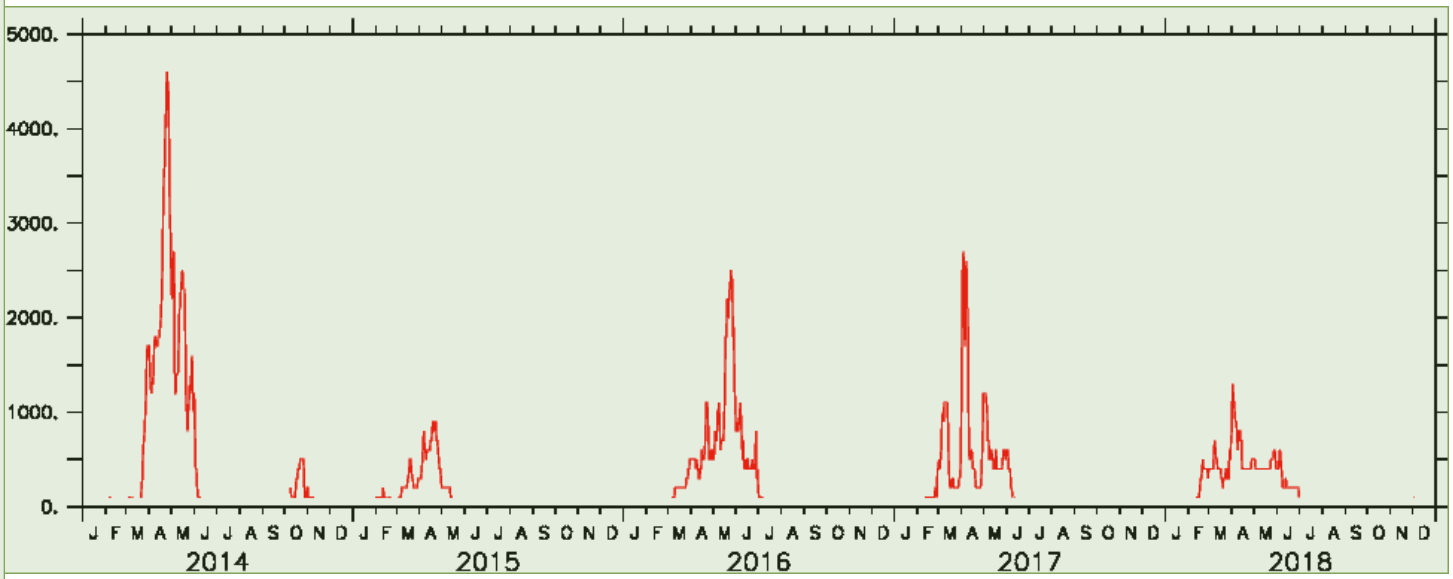
Modelled interannual variability at MELAX

Hypoxic threshold (60 µmol/kg)





Extent of anoxia (<5 µmol/kg, in km^2) on Senegal shelf



Conclusions & future work

- Deep OMZ: not well represented in all models

  OMZ impacted by deep jets (equatorial and coastal) of unknown intensity

- Shallow OMZ and bottom oxygen on shelf relatively well reproduced using Mercator

  1/12° model (PSY4v3)

Conclusions & future work

- Deep OMZ: not well represented in all models

  OMZ impacted by deep jets (equatorial and coastal) of unknown intensity

- Shallow OMZ and bottom oxygen on shelf relatively well reproduced using Mercator 1/12° model (PSY4v3)

Future work:

- deep OMZ: better understand differences between BIOMERFREE and TATL (circulation, param)

  Lagrangian experiments to trace origin of OMZ waters in CROCO

  test PISCESv2 in CROCO

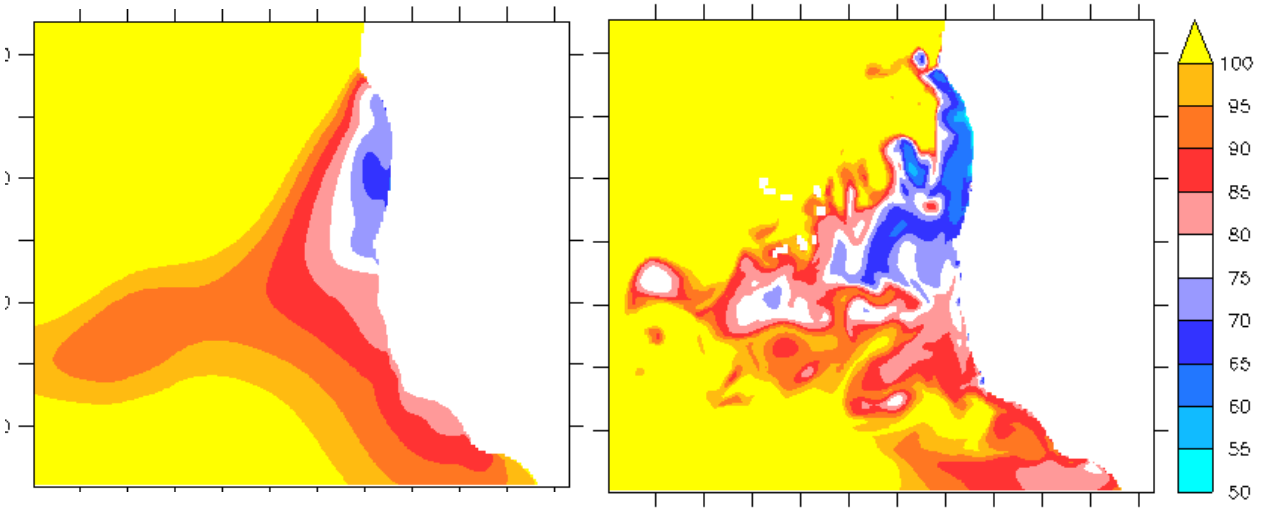
- Shallow OMZ: higher resolution (2 km) and improved physics (tides, wet & dry, more realistic topography)

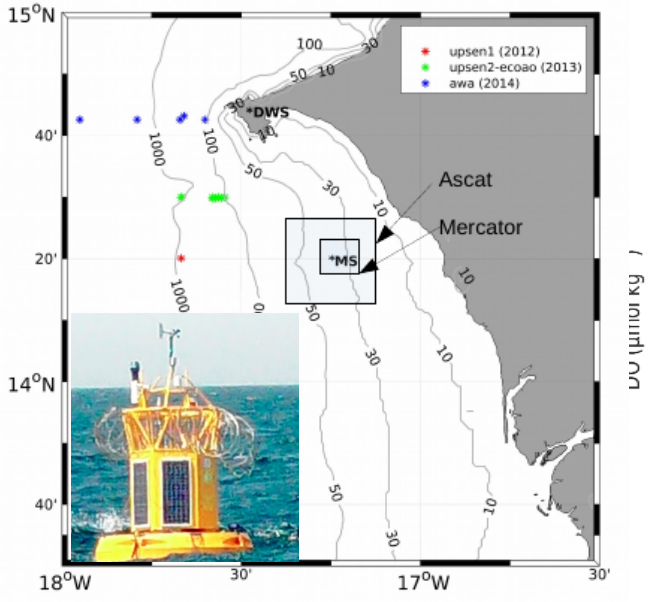
- Intraseasonal and interannual variability in the period 2014-2019 (A.W. Tall PhD)

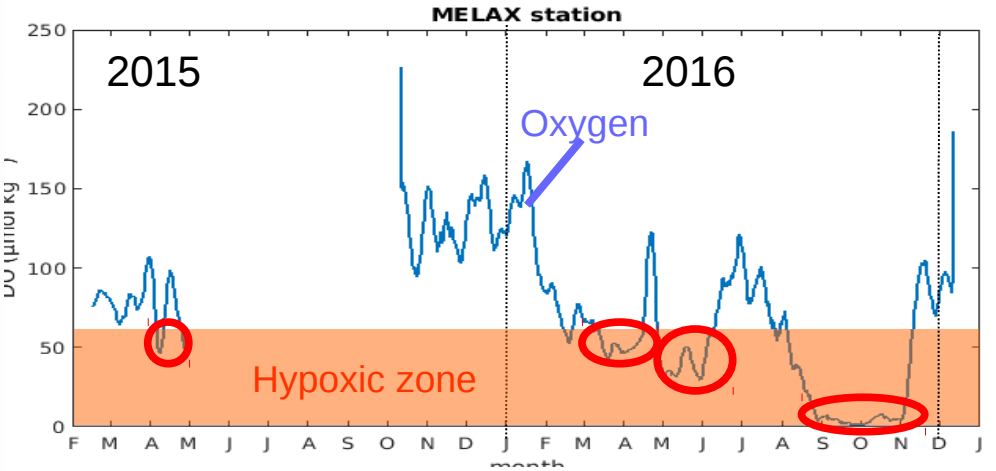
- Impact of a better representation of plankton dynamics on primary production and oxygen cycle using PISCES-quota

  (PhD thesis at LOCEAN, 2019→.., ANR SOLAB)

Merci !


100
95
90
85
80
75
70
65
60
55
50


15°N
40'
20'
14°N
40'
18°W
30'
17°W
30'
upsen1 (2012)
upsen2-ecoao (2013)
awa (2014)
*DWS
*MS
Ascat
Mercator


MELAX station
2015
2016
Oxygen
Hypoxic zone
250
200
150
100
50
0
F M A M J J A S O N D J F M A M J J A S O N D J

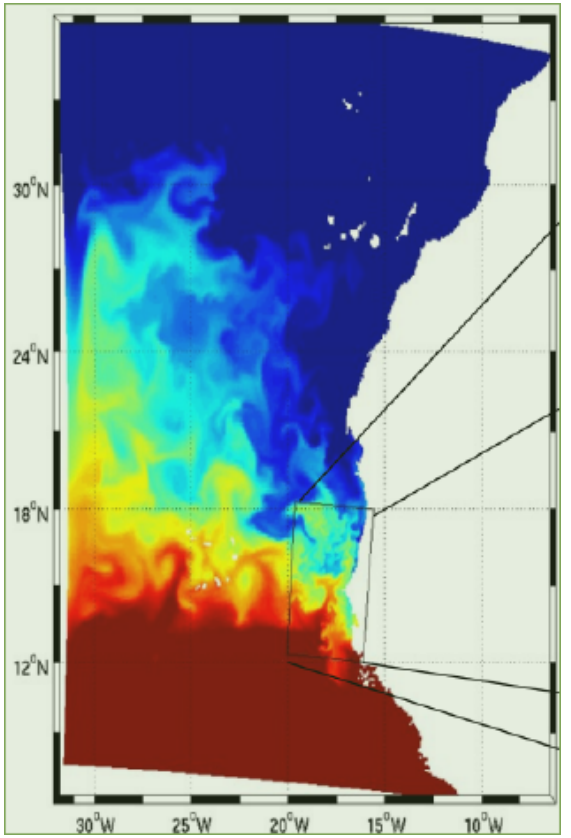
Regional modelling setup

croco-pisces model (‘old’ PISCES version « 2008 »)

- can11 configuration 10 km

- **can11bio1** : **climatological simulation** (10 years)
  OBC phys=sodaclim ; OBC bio=World Ocean Atlas (WOA)
  forcing : SCOW climatological wind stress
  Relaxation to clim « homemade » SST (Ndoye, 2016)
  Tropflux climatological heat fluxes

- **can11bioi3** : interannual simulation (2013-2018)
  OBC phys=orca12 2013-2018 ; OBC bio=WOA
  forcing : ASCAT daily wind stress
  Relaxation to clim « homemade »
  Tropflux climatological heat fluxes

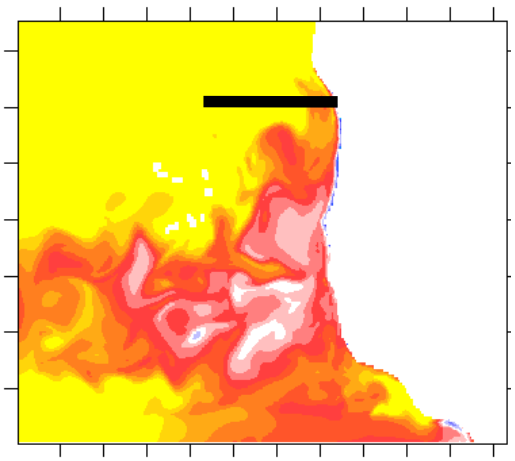


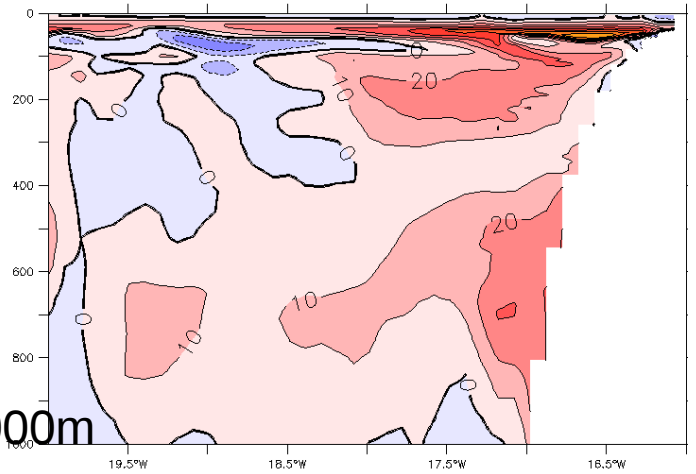
Oxygen budget : trends at 18°N (6th year)

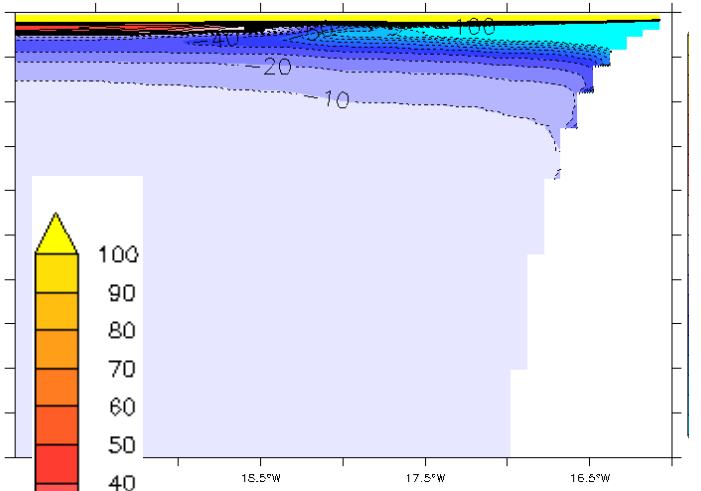
$$\partial O2/\partial t = adv + diff + Bio$$

dO2/dt

Biological sources & sinks

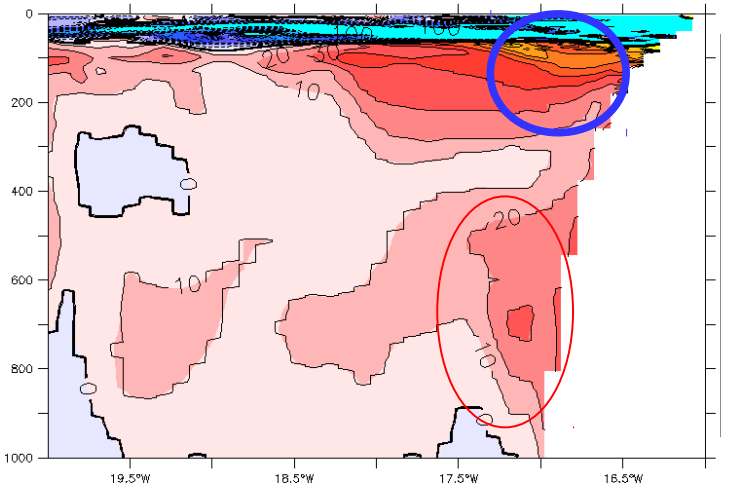


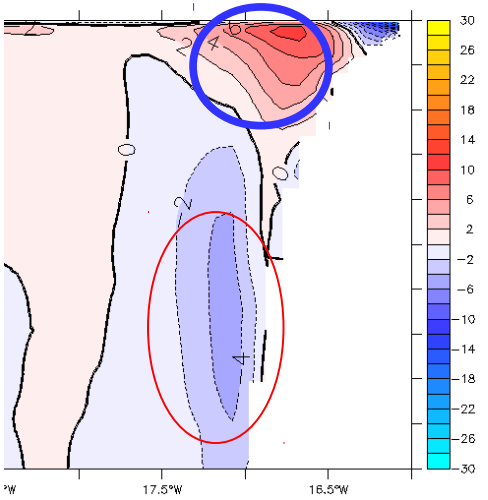




Oxygen advection

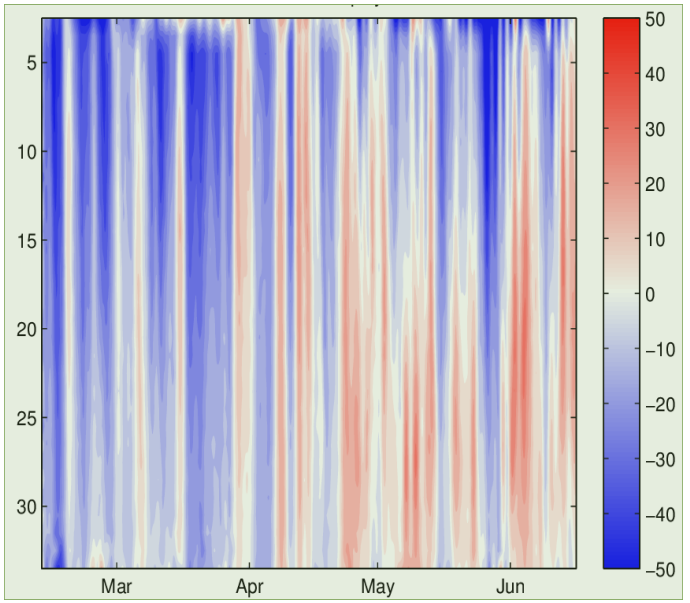
V



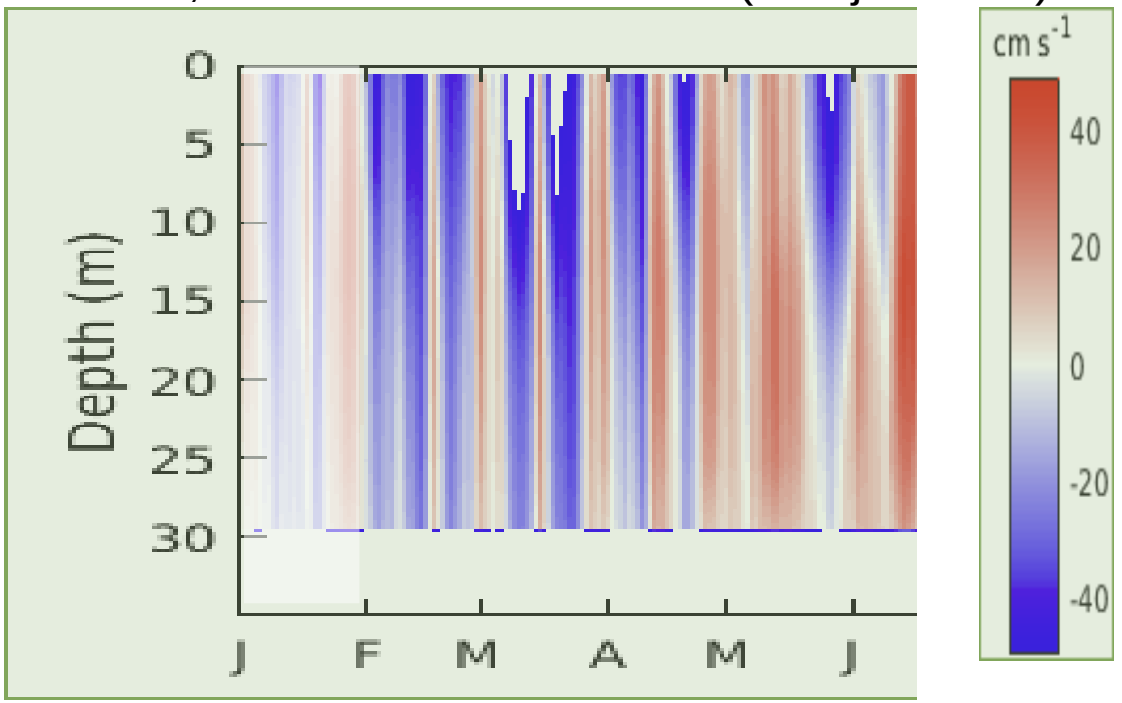


Comparing Mercator 1/12° model and MELAX data

V , adcp melax (Feb-jun 2015)

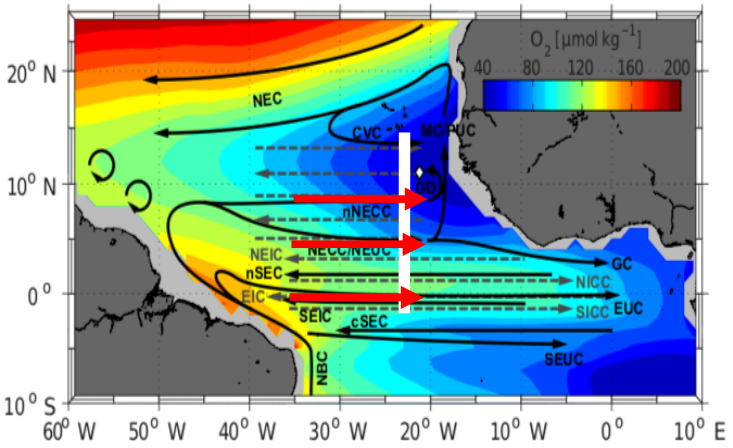


V , mercator 1/12° at melax (Feb-jun 2015)

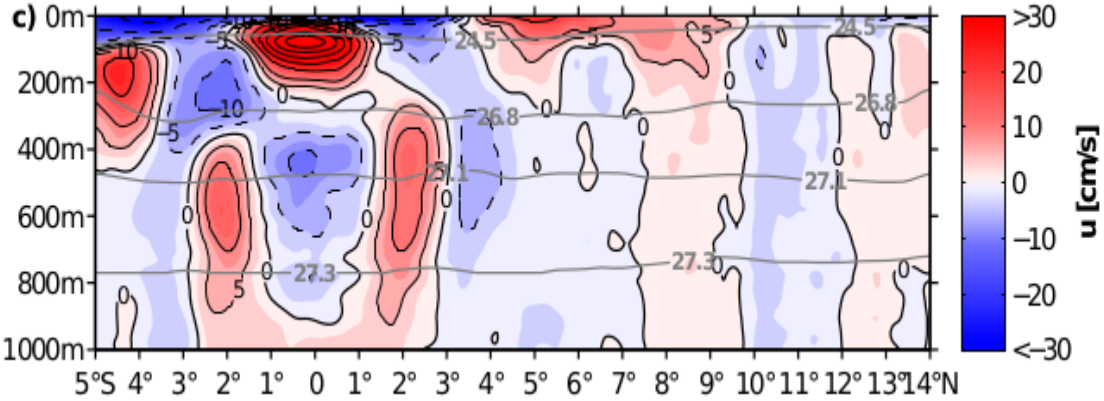


		a	b	R^2	r
Velocity	$u_{Melax/Mercator}$	0.5348	-0.0012	0.8141	0.9023
	$v_{Melax/Mercator}$	0.9606	0.0350	0.8068	0.8982

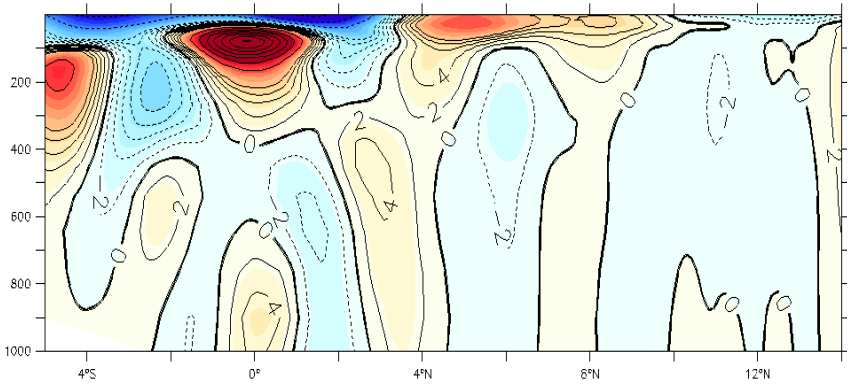
Zonal current at 23°W : observations vs models

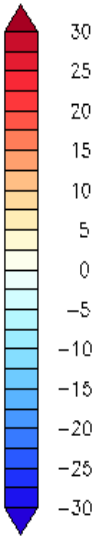


1999-2012 average, Brandt et al. 2015

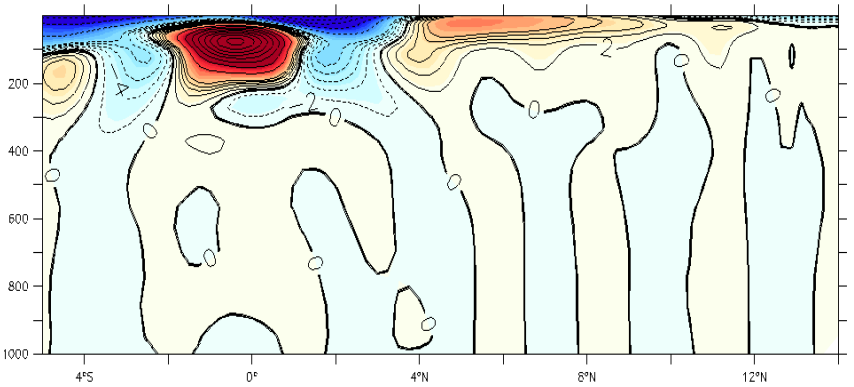


Glorys12v1, 2006-2017

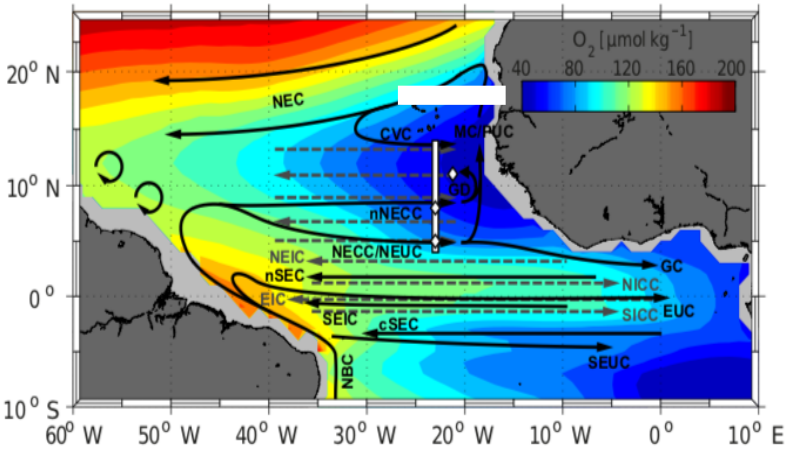




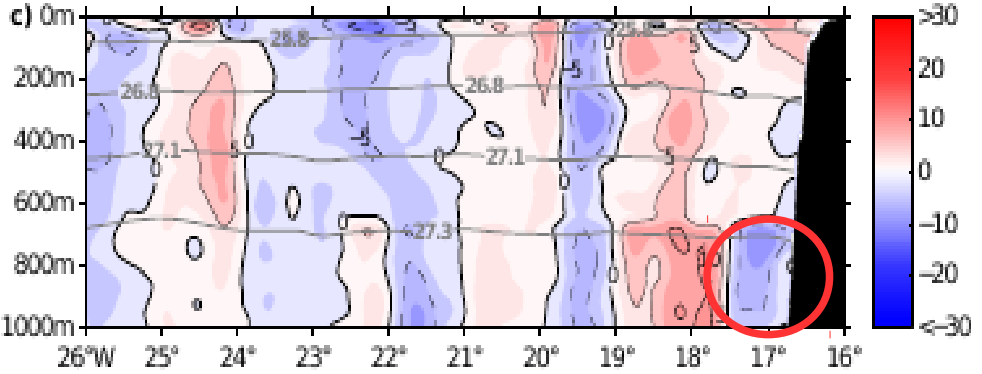
TATL025-PISCES (2006-2017)



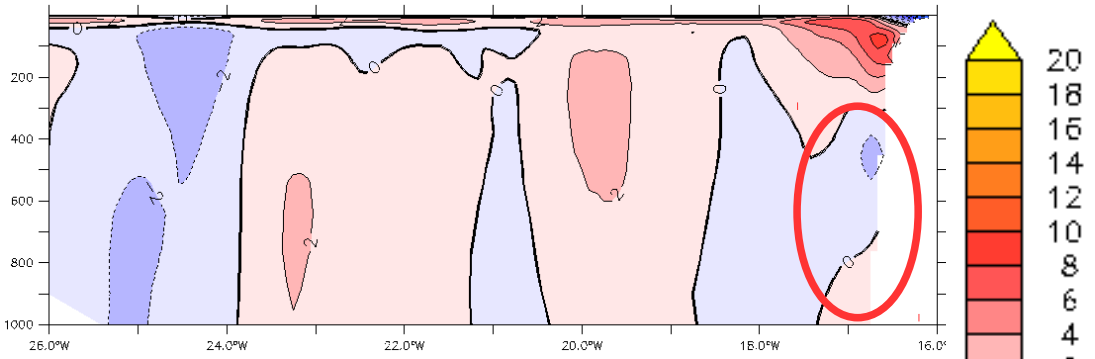
Current section at 18°N : observations vs models

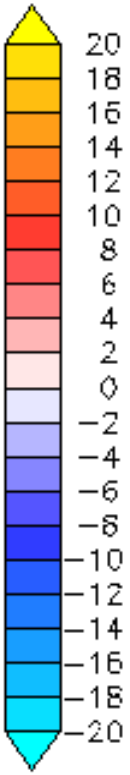


1999-2012 average, Brandt et al. 2015

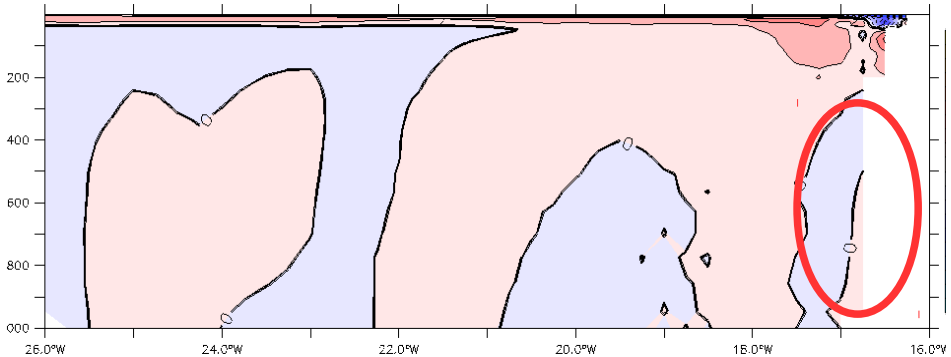


Glorys12v1, 2006-2017

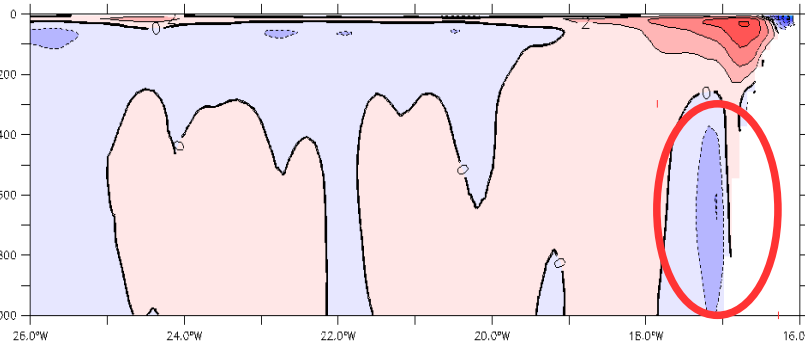




TATL025, 2006-2017

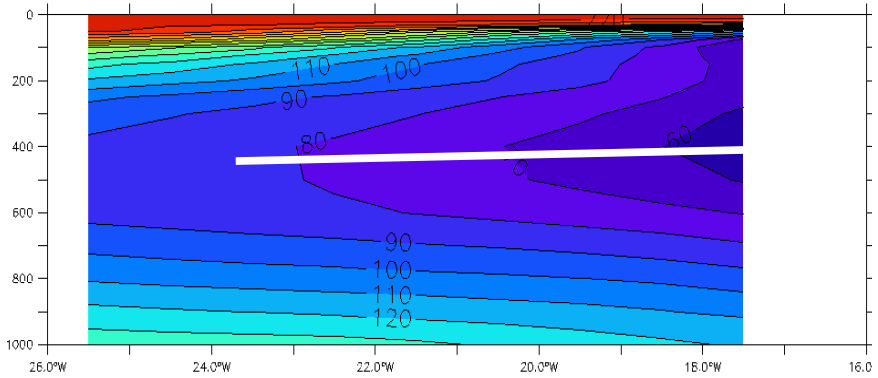


CROCO-PISCES (clim)

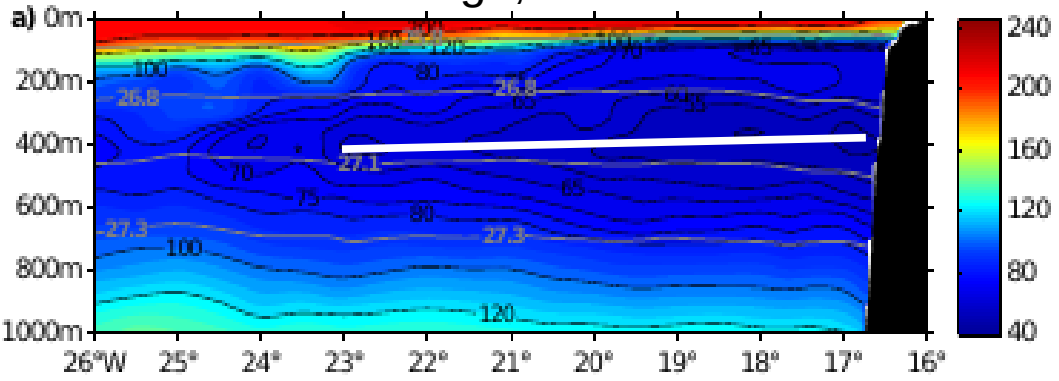


Oxygen section at 18°N : observations vs models

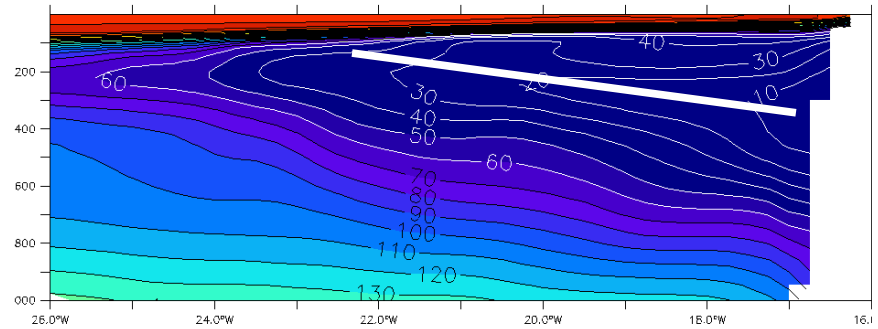
WOA2009 (=WOA2013)



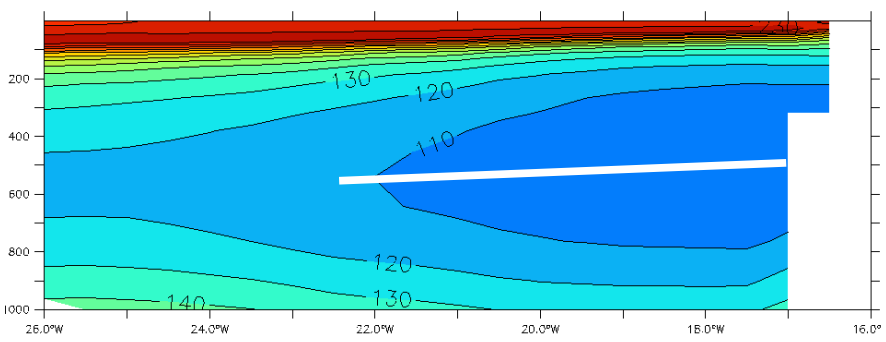
1999-2012 average, Brandt et al. 2015

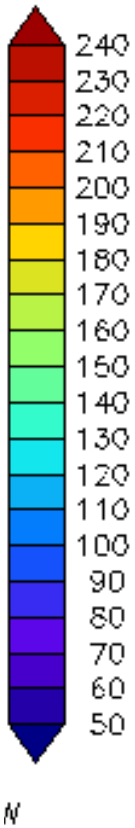


BIOMERFREE2v4 (2006-2017)

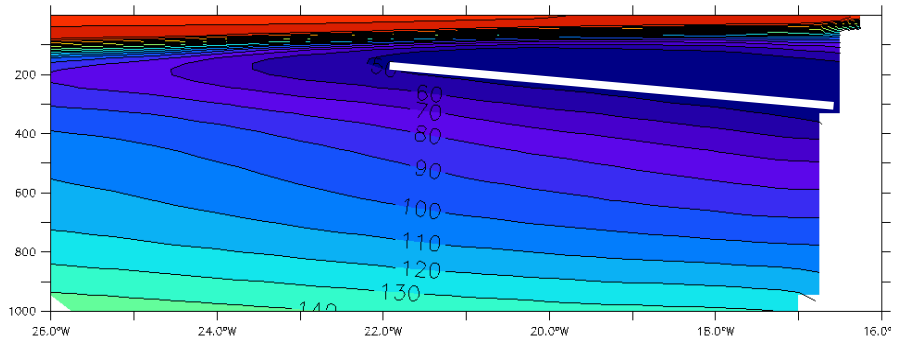


BIOMER2v2 (2006-2017)

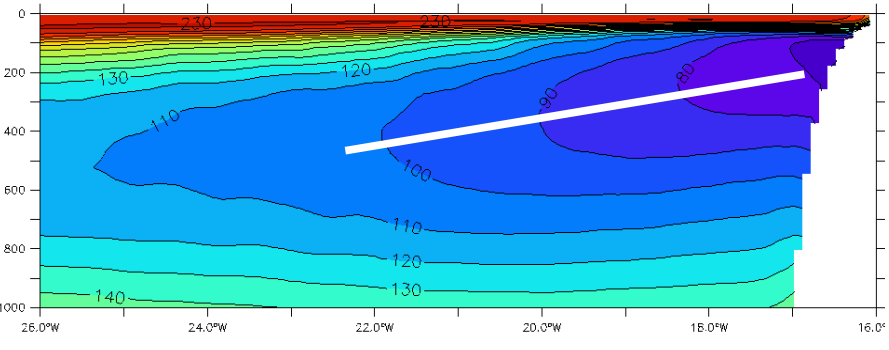




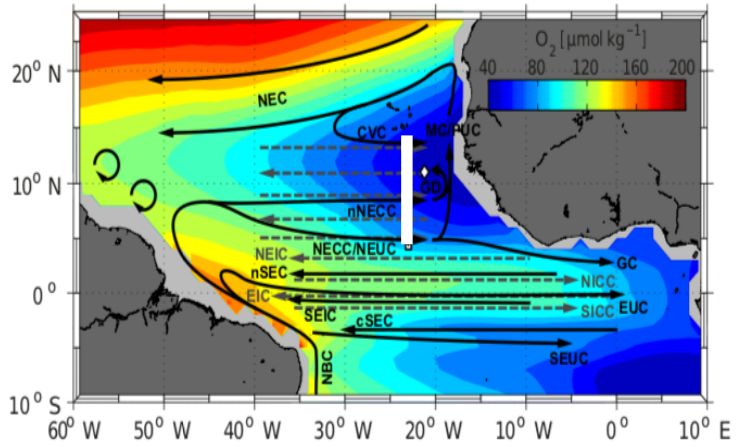
TATL025-PISCES (2006-2017)



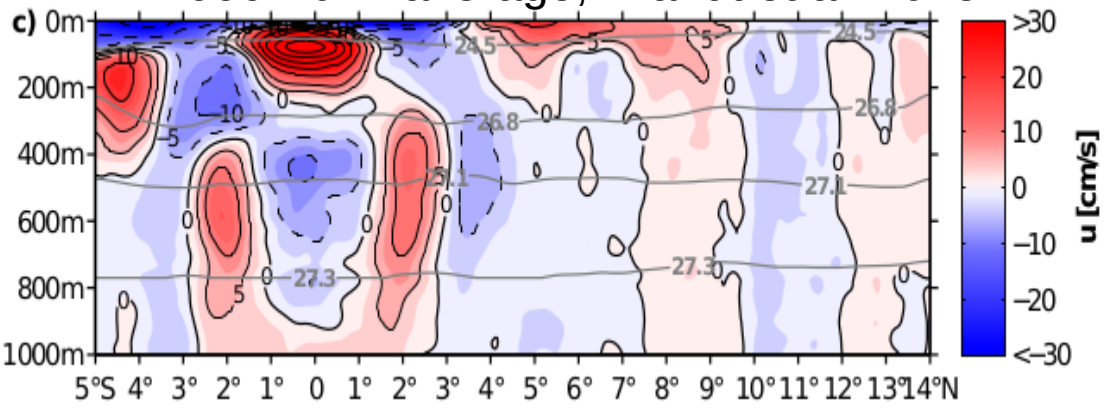
CROCO-PISCES (clim)



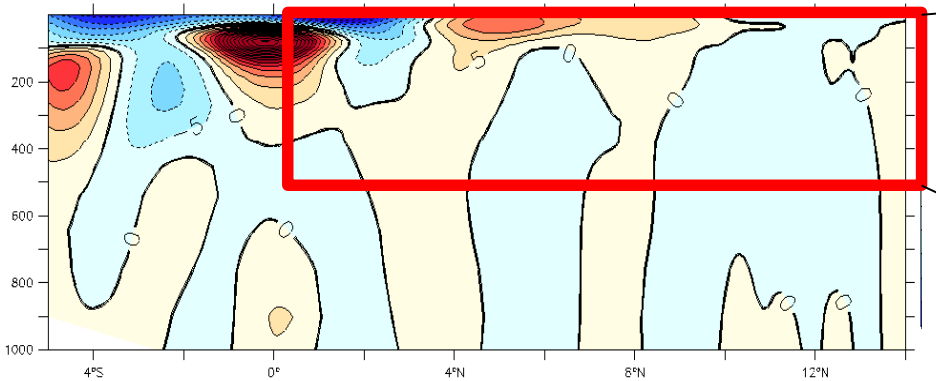
Zonal current at 23°W : observations vs models



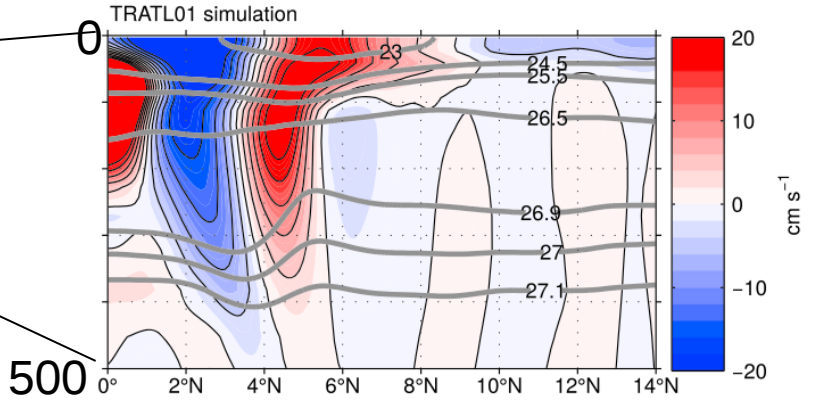
1999-2012 average, Brandt et al. 2015



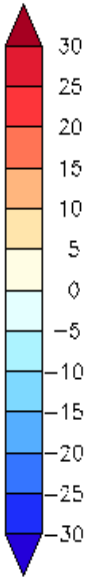
Glorys12v1, 2006-2017



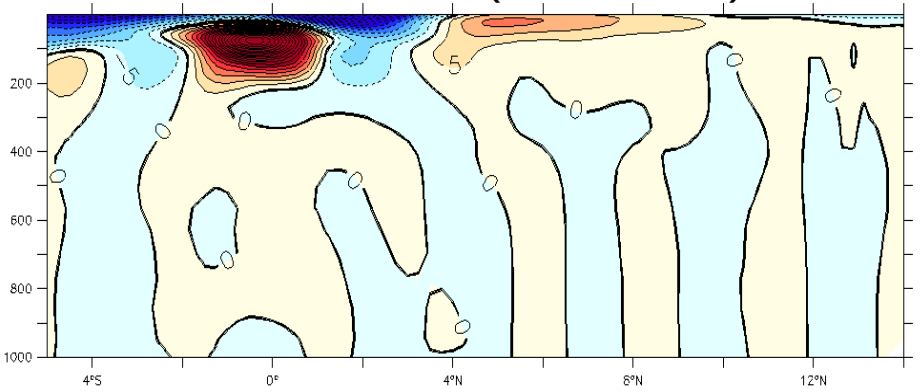
1/10° NEMO model



Burmeister et al., 2019

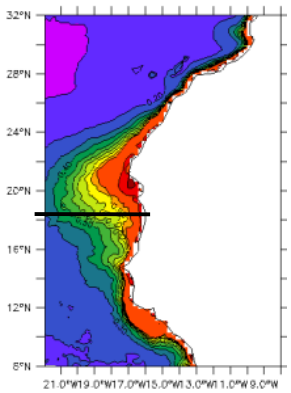


TATL025-PISCES (2006-2017)

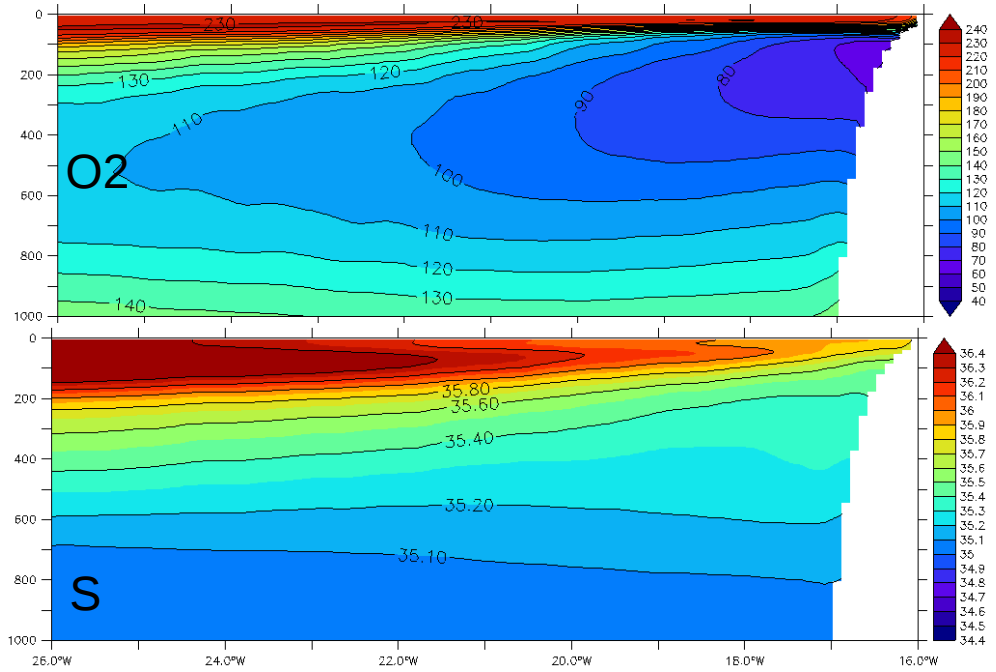


Section 18°N

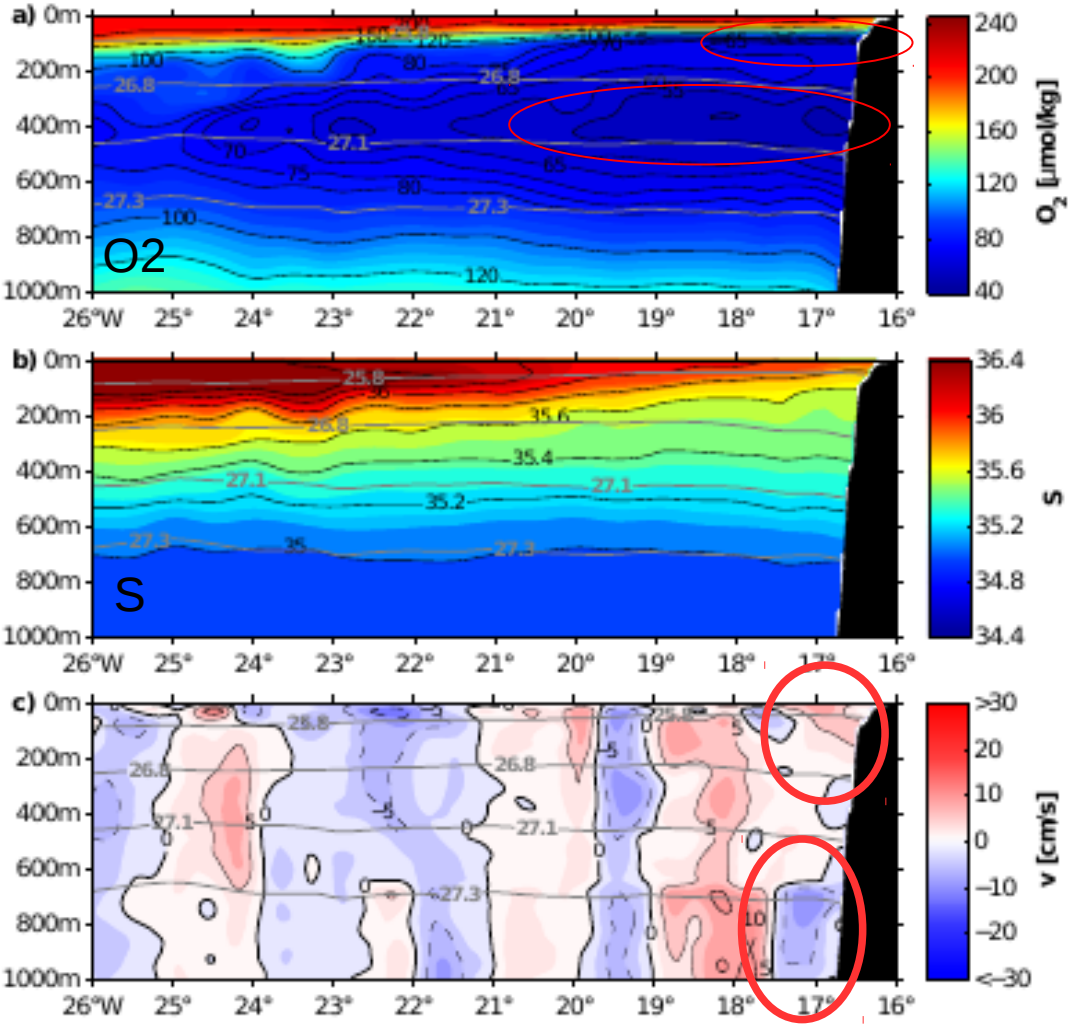
observations (Brandt et al. 2015)



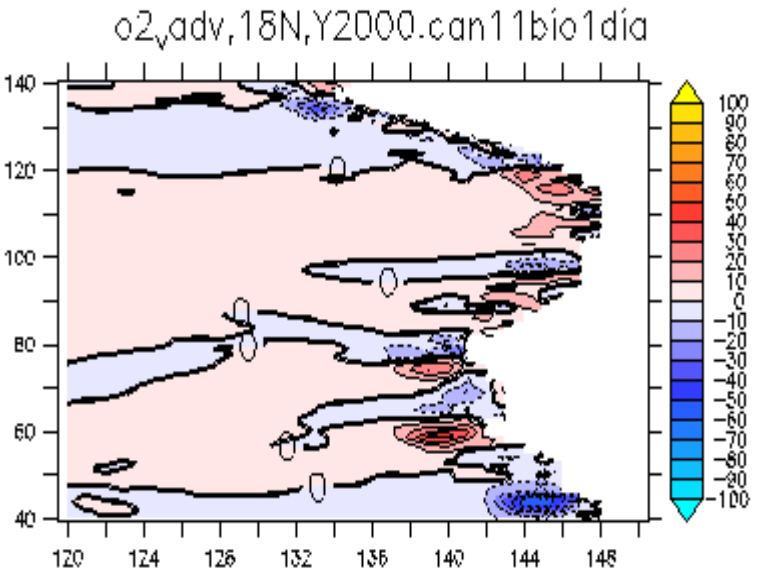
CROCO-pisces (obc soda climato)

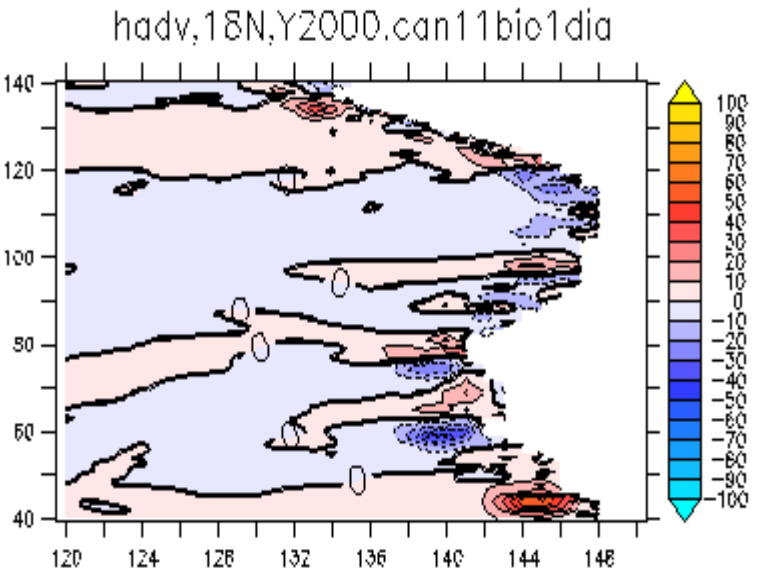


Brandt et al's observations

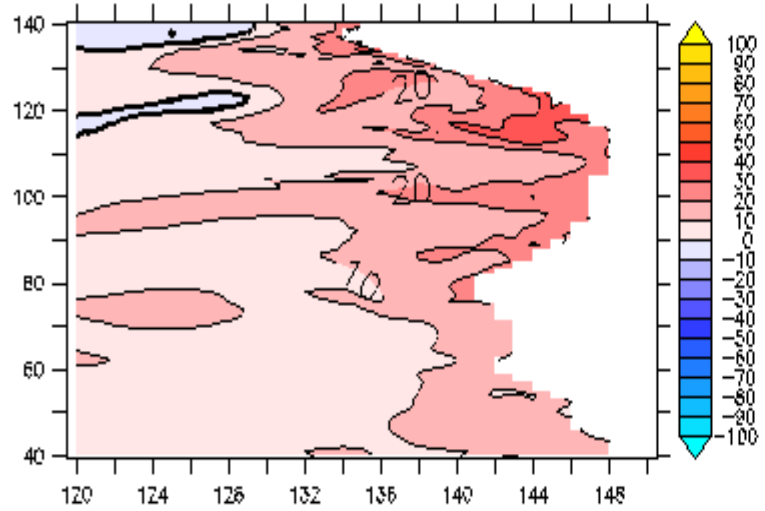


Oxygen budget : trends during the first year (400-600 m averaged)

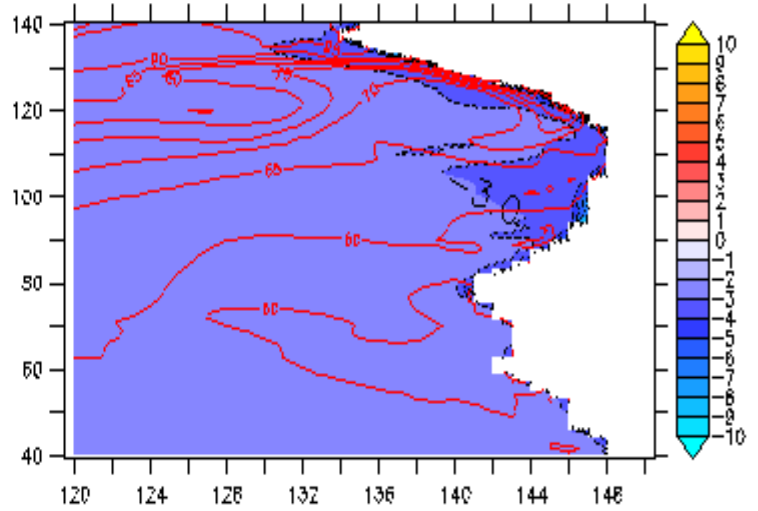




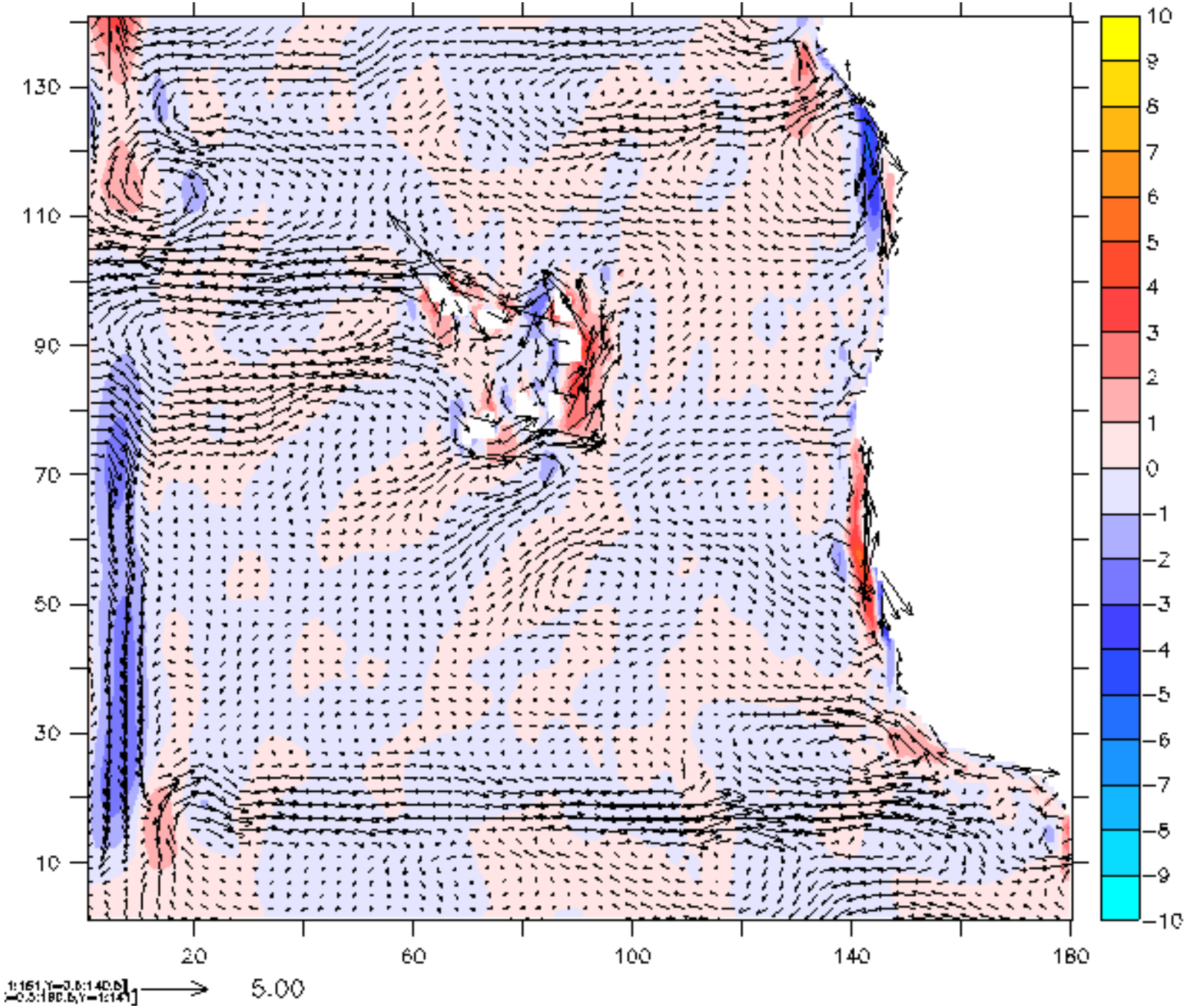
Total advection



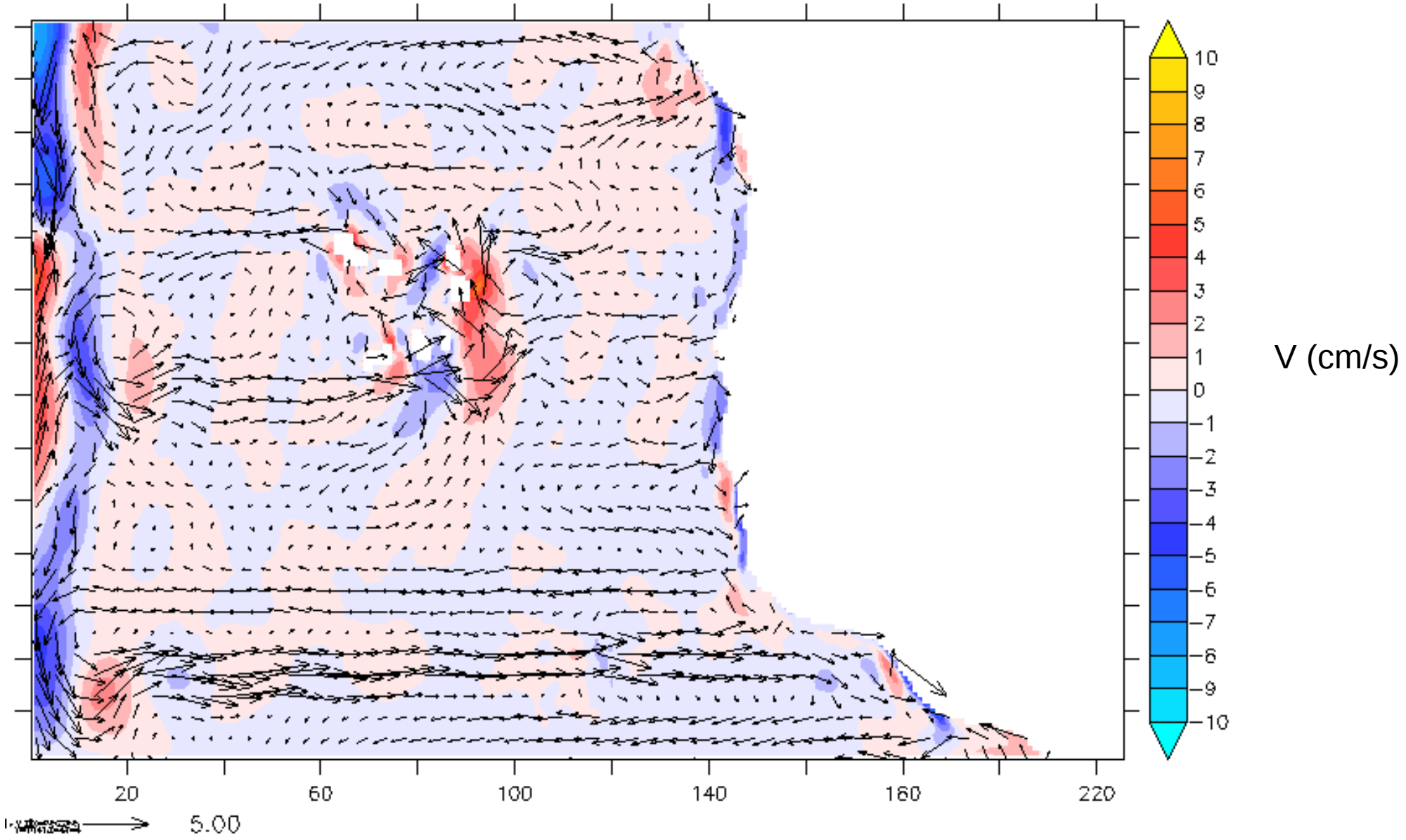
Bio + scale



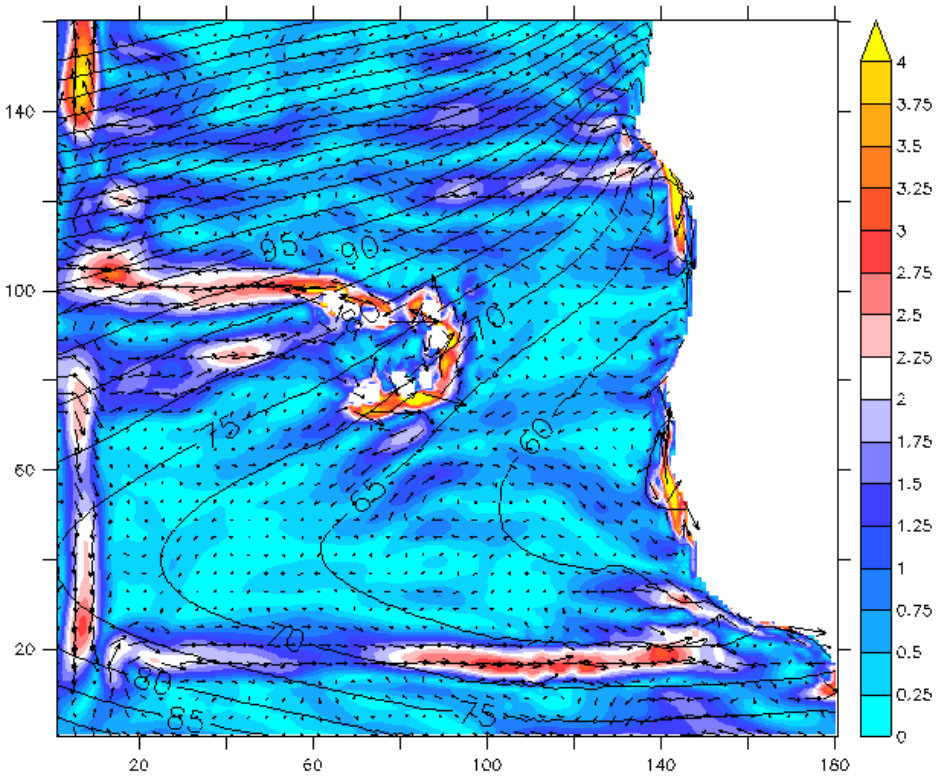
U, V (400-600 m average), 11 year average, can11bio (obc soda).

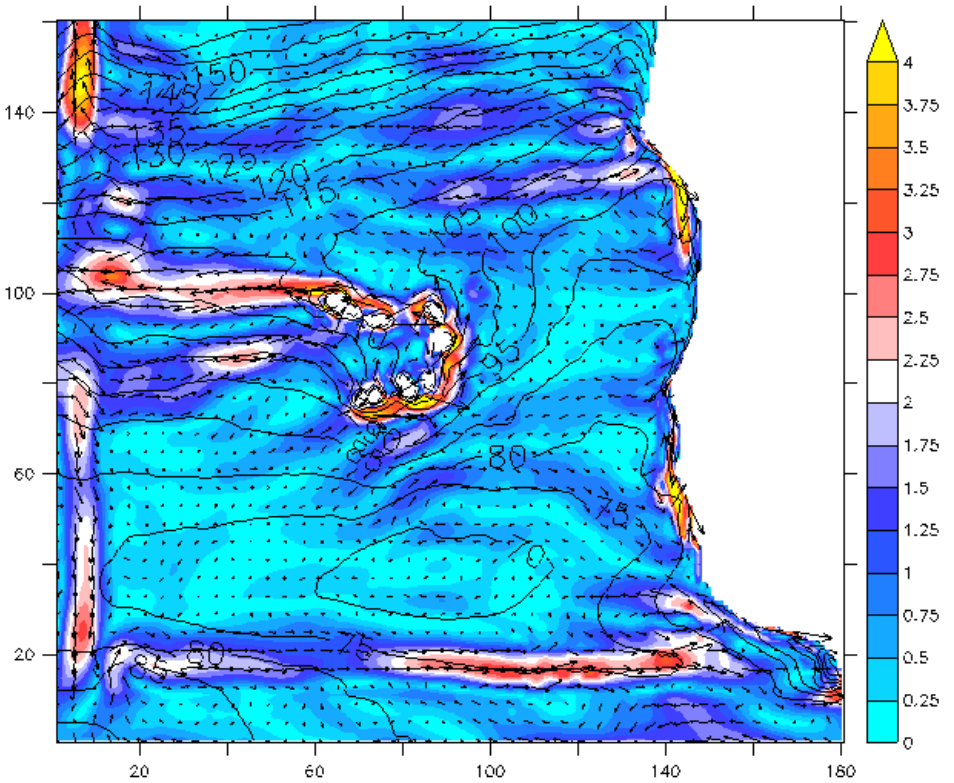


U, V (400-600 m average), 10 year average, can11bio (obc GLORYSclim).



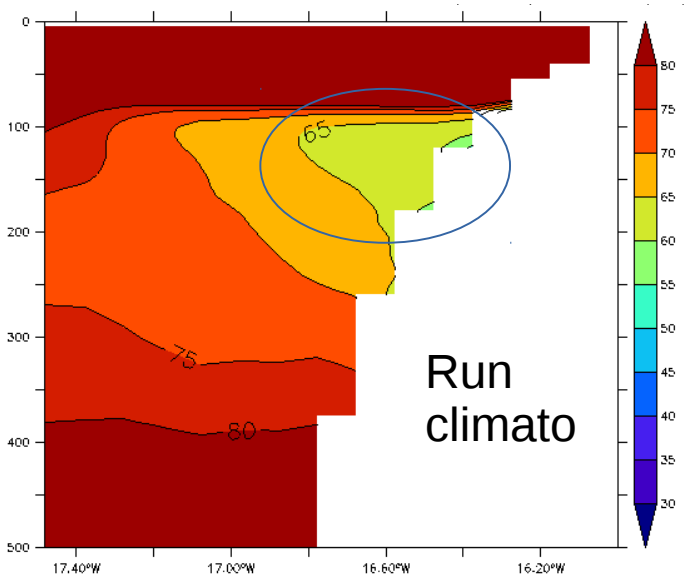
U, V (300-600 m average),
11 year average, O2 WOA (ini)

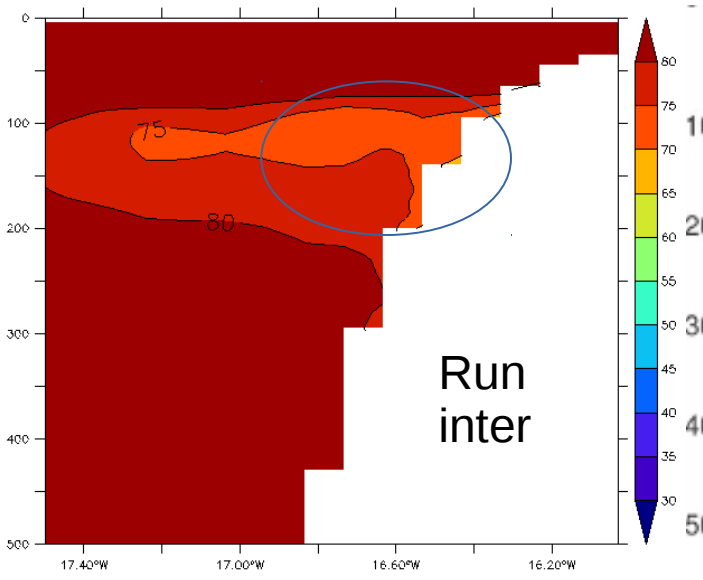


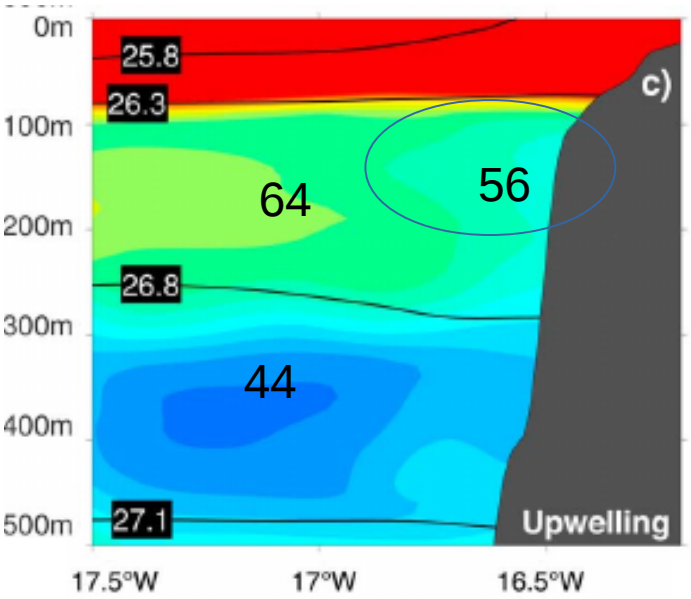


O2, 18N, comparaison modèle/obs, cycle saisonnier

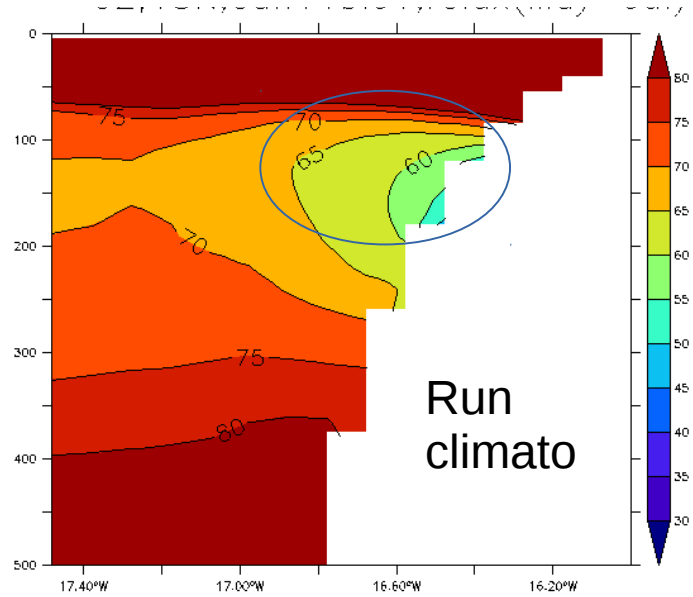
Période d'upwelling (jan-avril)

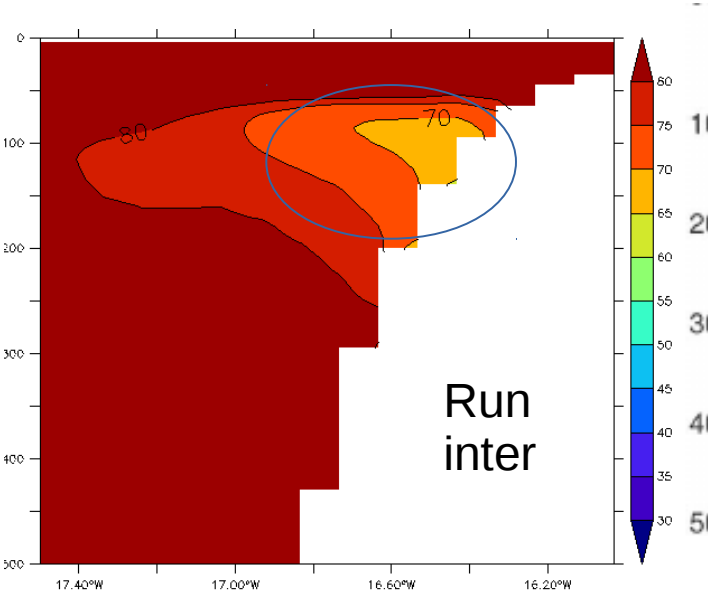


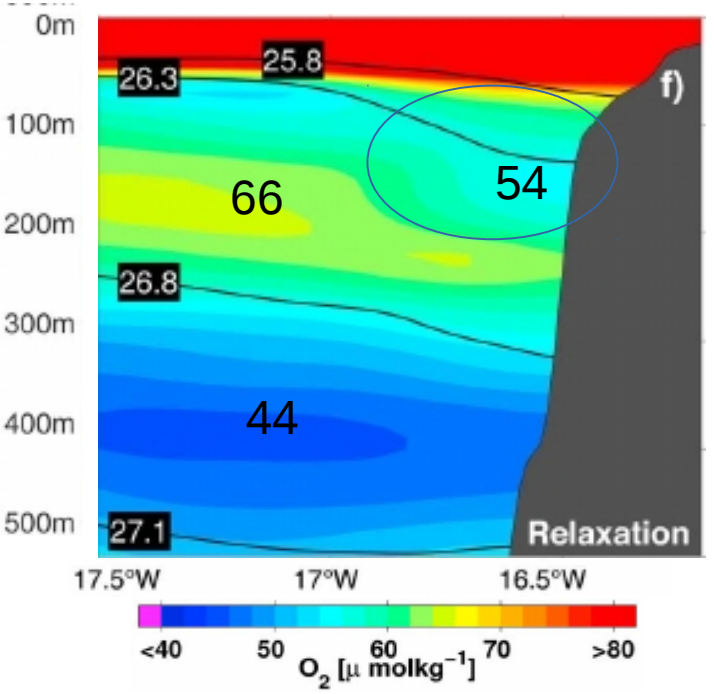




Période de relaxation (Mai-jul)

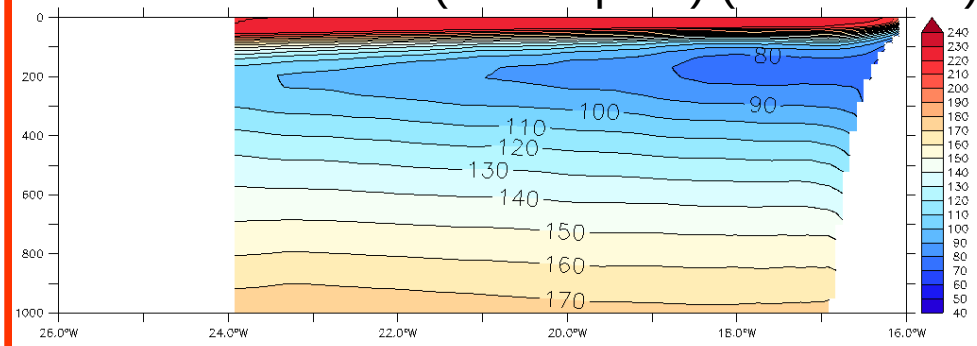




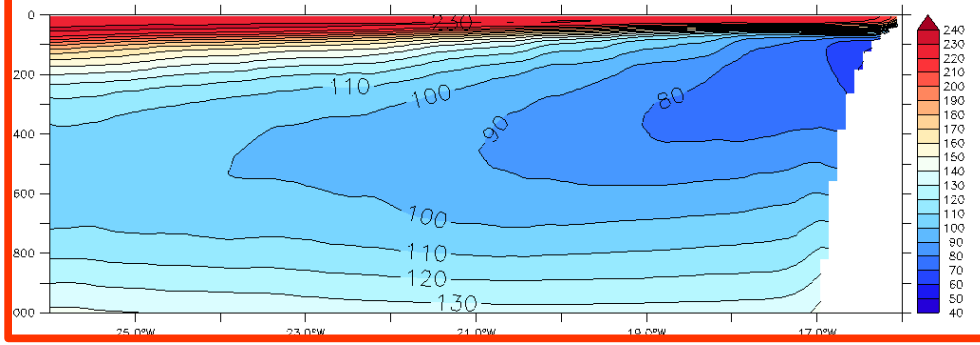


Section 18°N, O2, comparaison modèles /obs

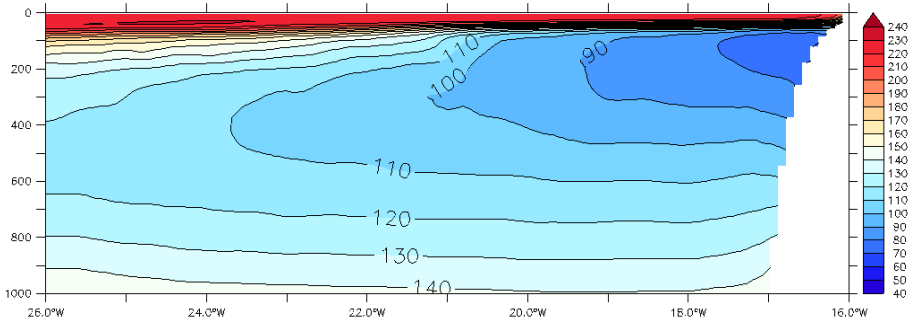
Roms-PISCES (ANR Epure) (1998-2009)



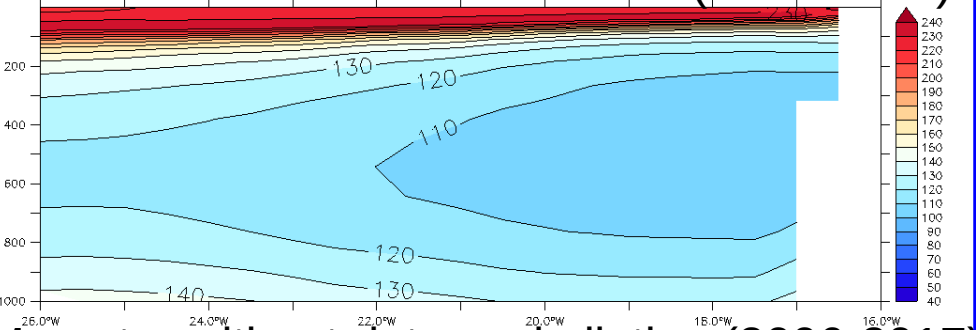
CROCO-PISCES can11 run clim (y1-5)



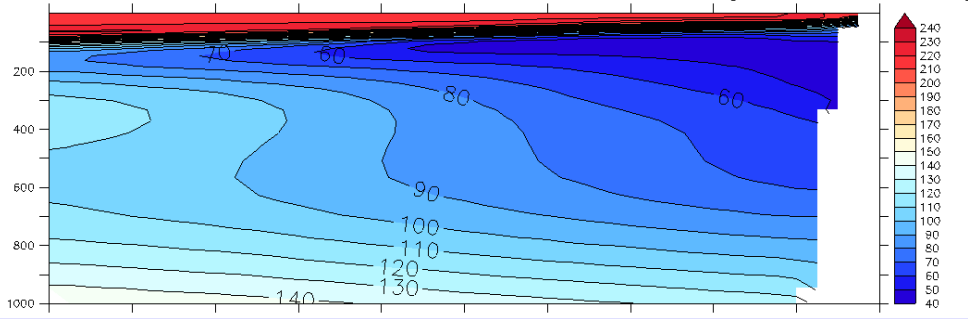
CROCO-PISCES can11 run inter (2014-2017)



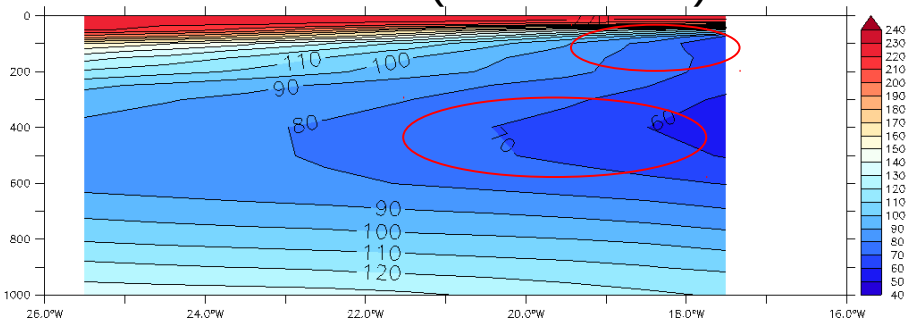
Mercator with data assimilation (2006-2017)



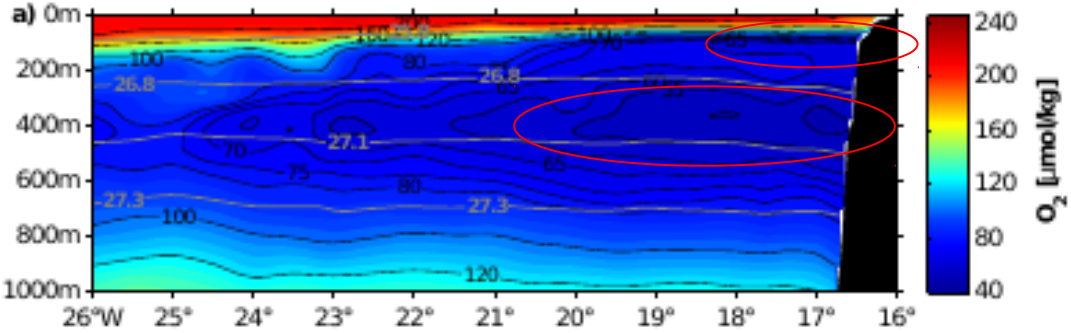
Mercator without data assimilation (2006-2017)



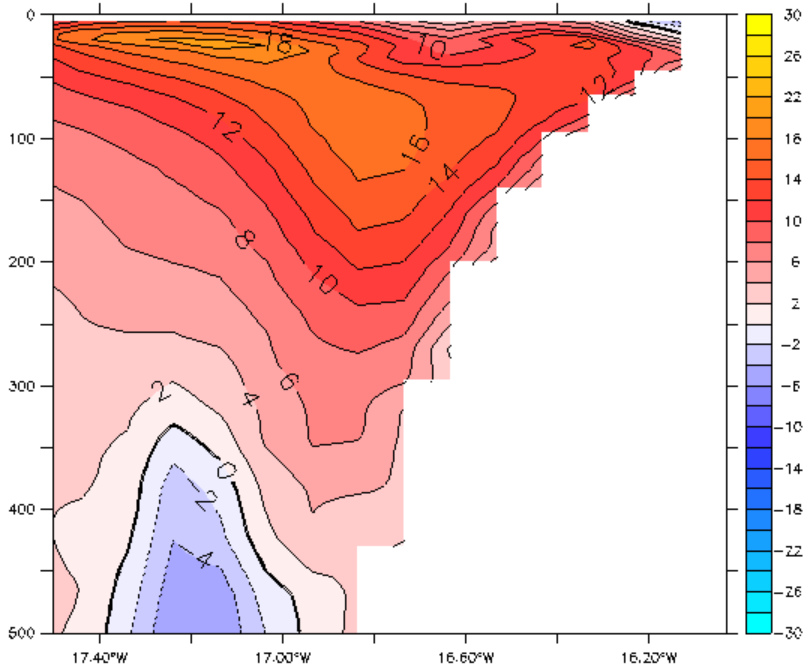
WOA2009 (=WOA2013)



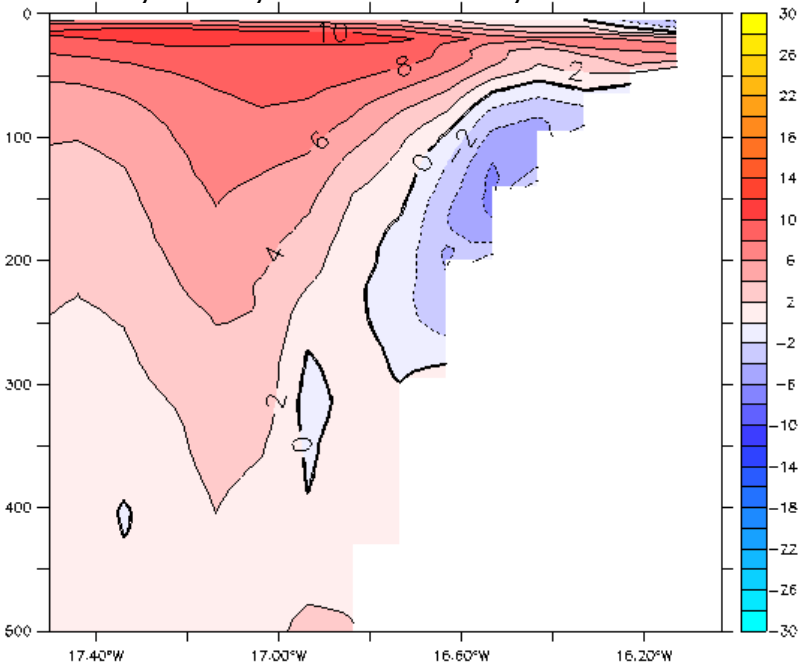
Section Brandt et al. 2015



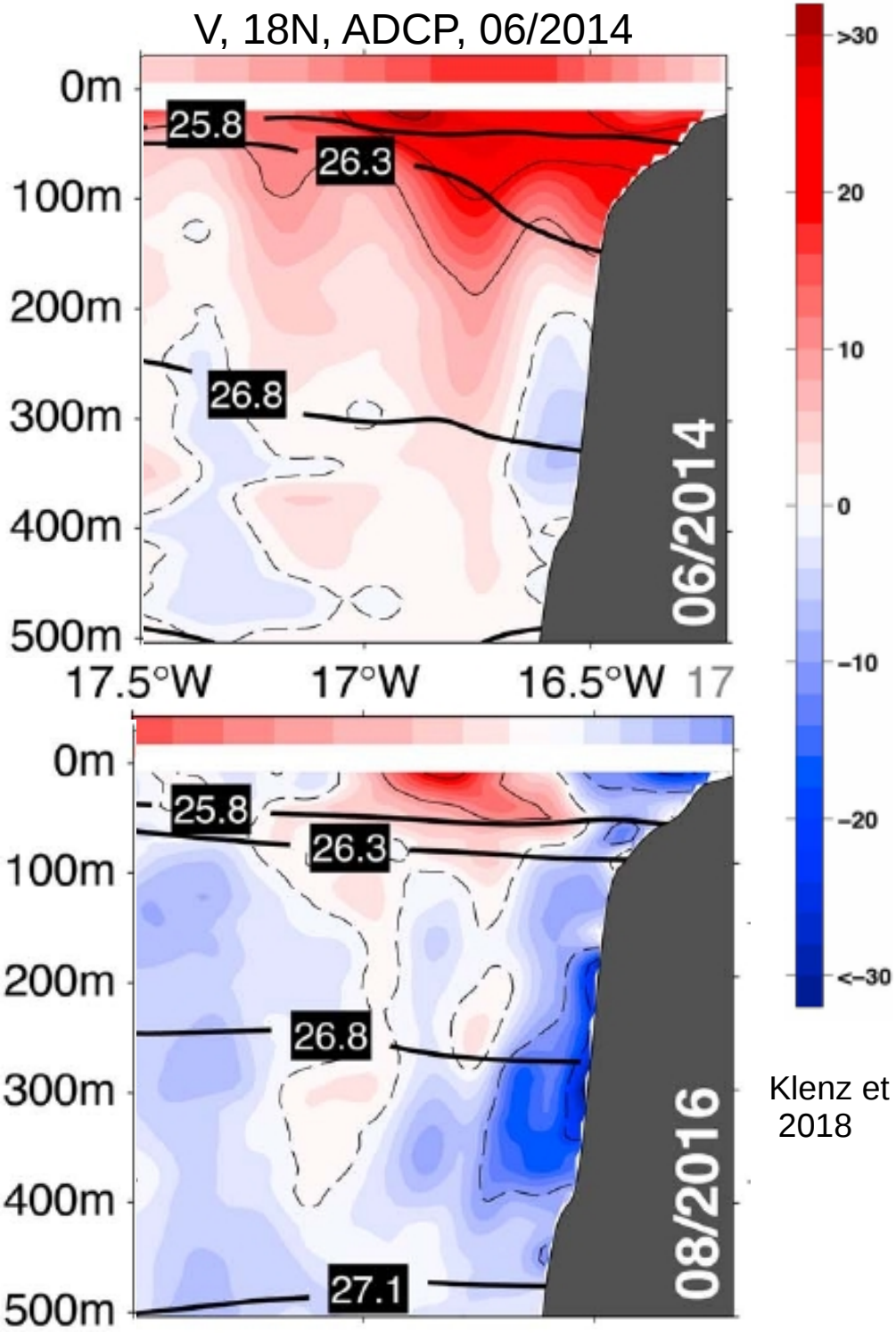
V, 18N, can11bioi2, 06/2014



V, 18N, can11bioi2, 08/2016



V, 18N, ADCP, 06/2014



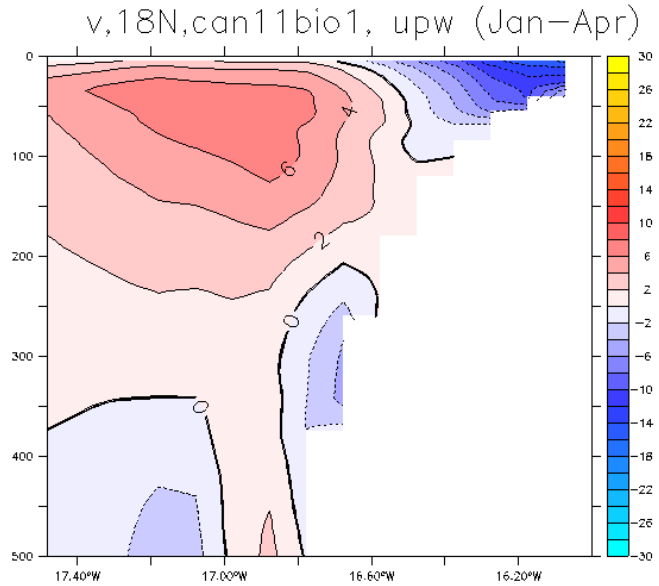
Klenz et al., 2018

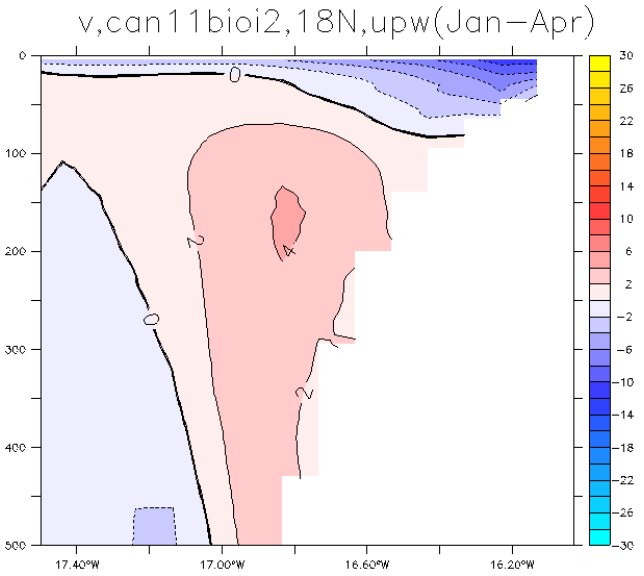
V, 18N, comparaison model/obs

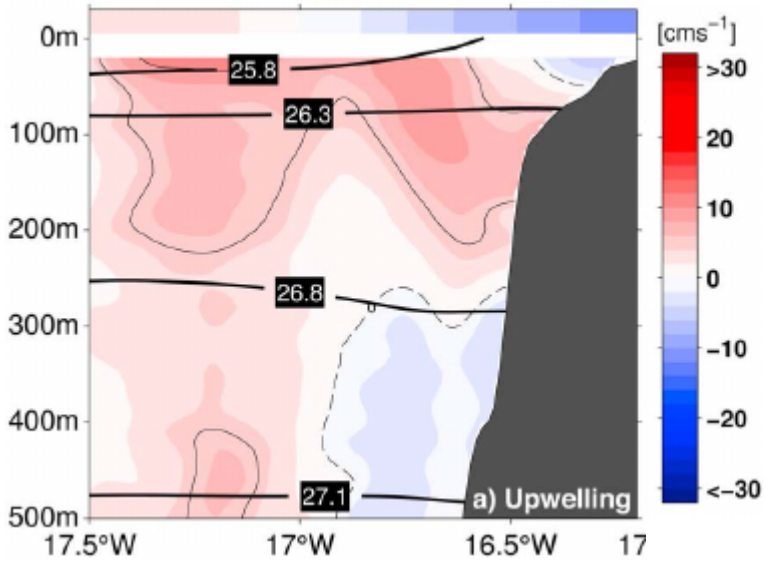
Run can11bio1,
obc sodaclim (y1-5)

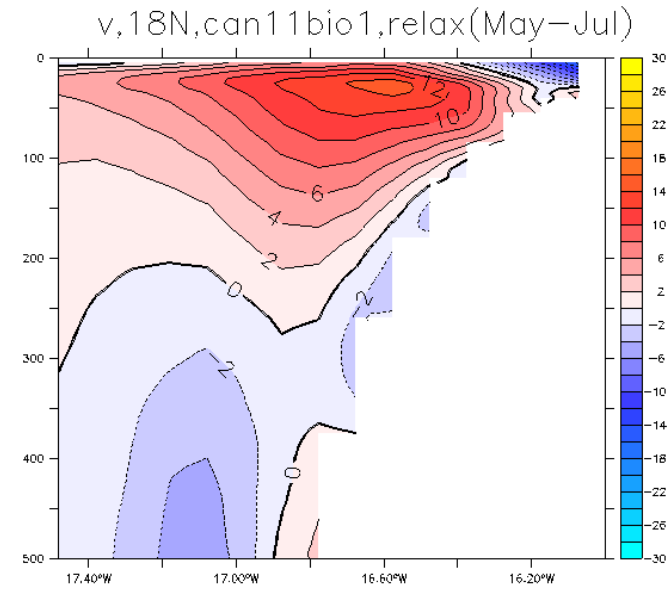
Run can11bioi2,
obc orca12 (2014-2017)

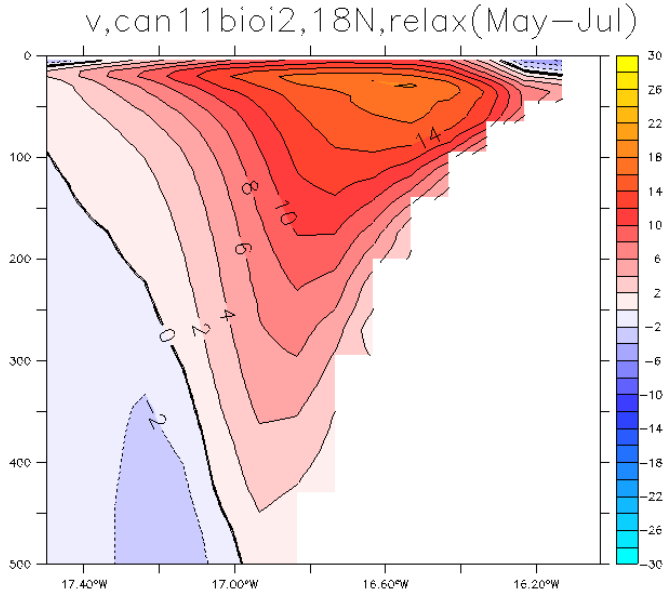
ADCP, 2005-2016 (qq sections)

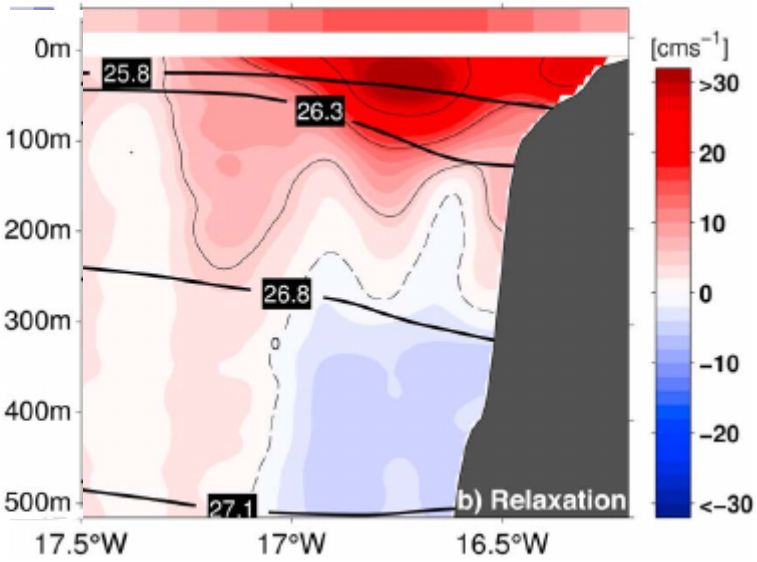




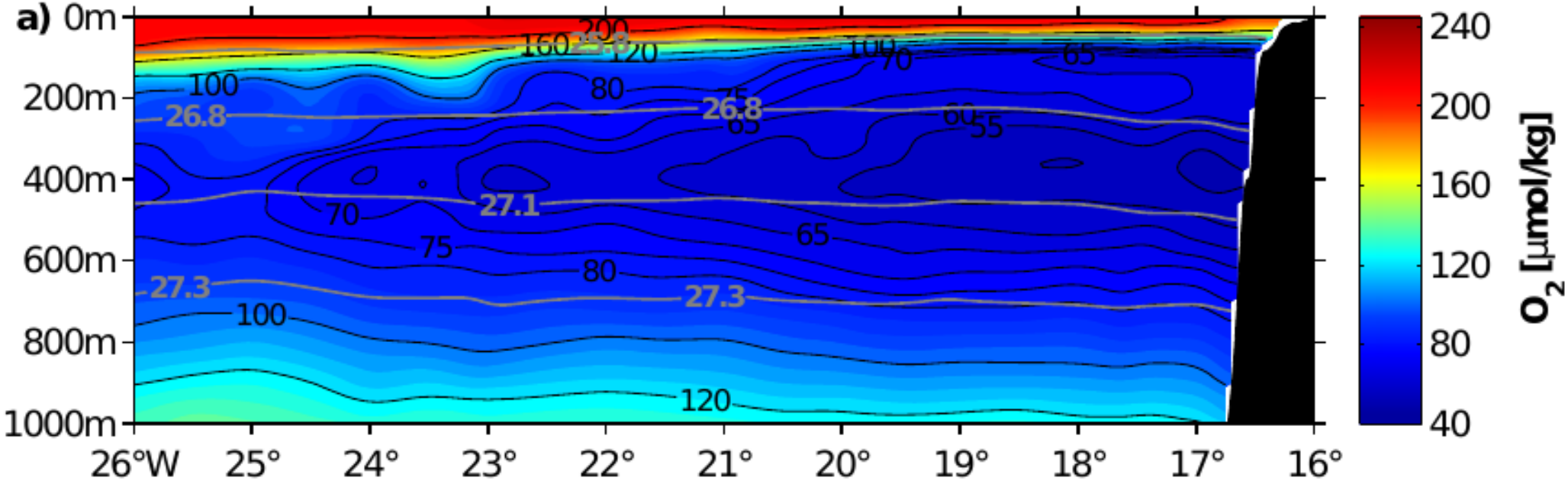




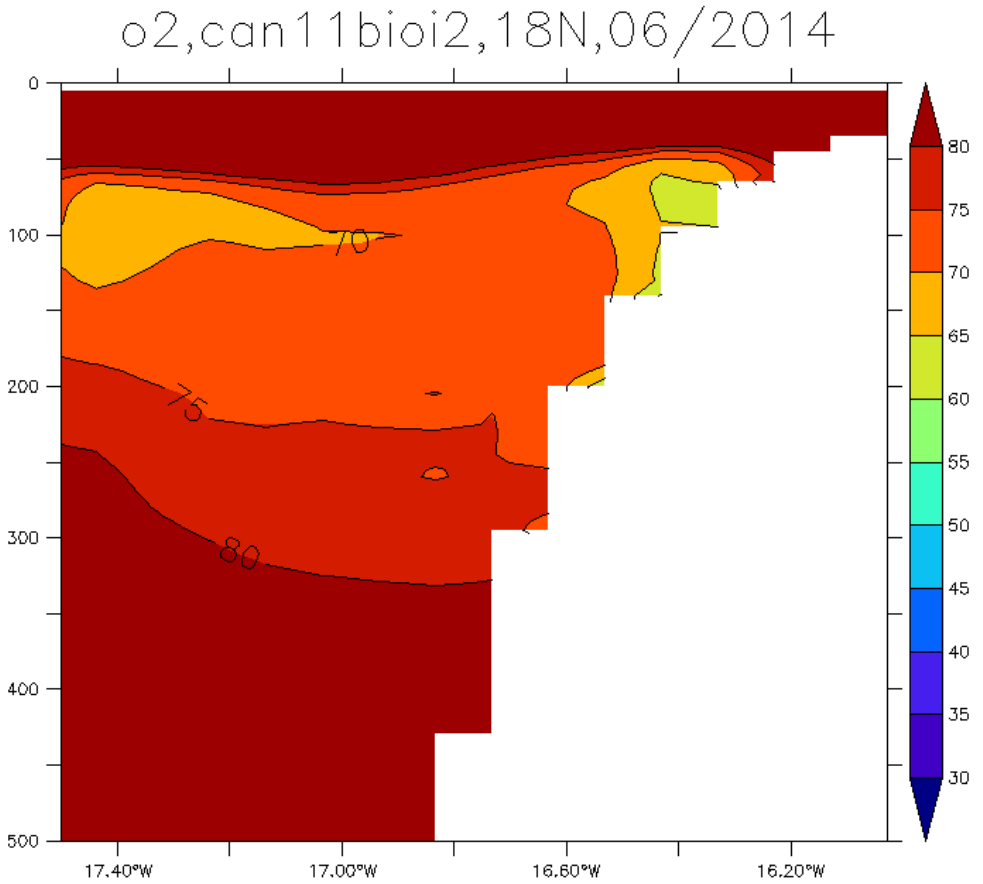




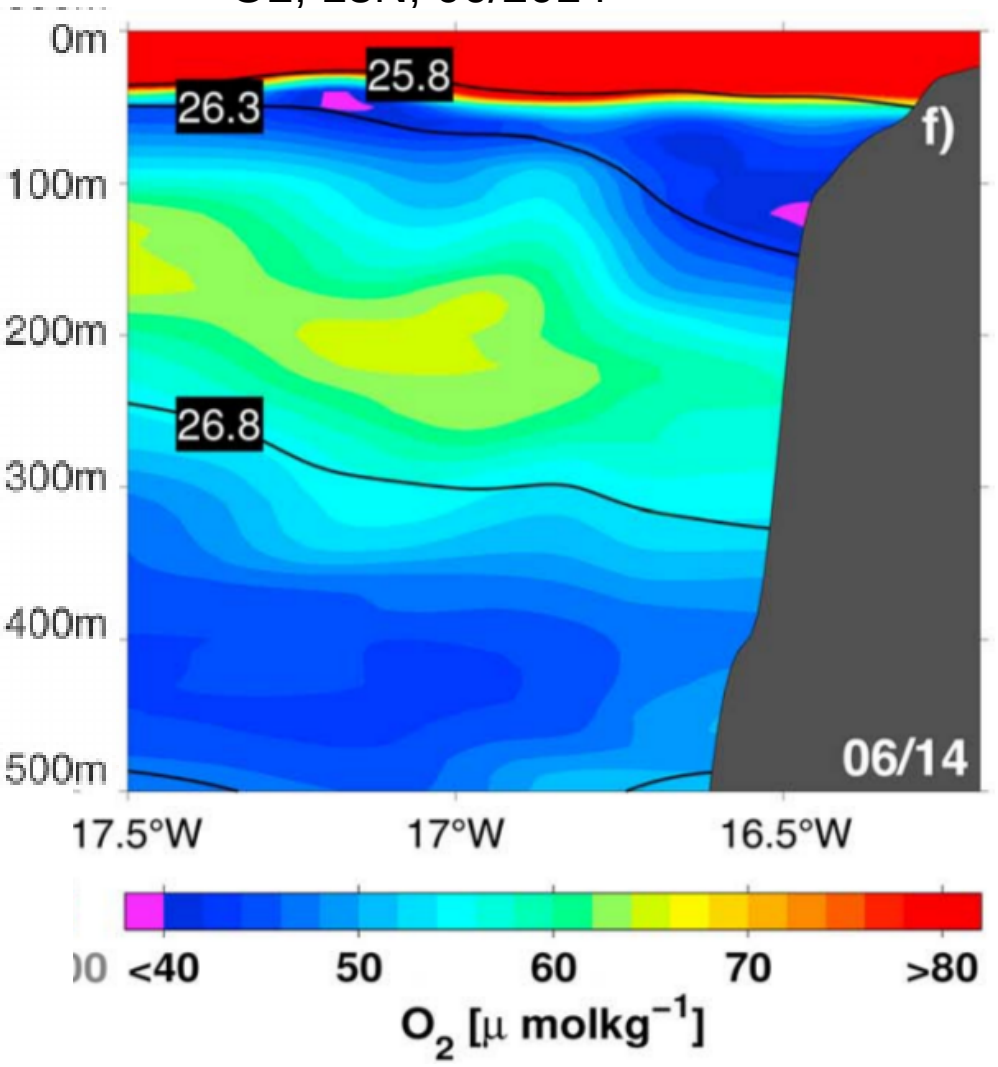
Klenz et al.,2018


a) 0m
200m
400m
600m
800m
1000m
26°W
25°
24°
23°
22°
21°
20°
19°
18°
17°
16°
26.8
27.1
27.3
240
200
160
120
80
40
O2 [µmol/kg]

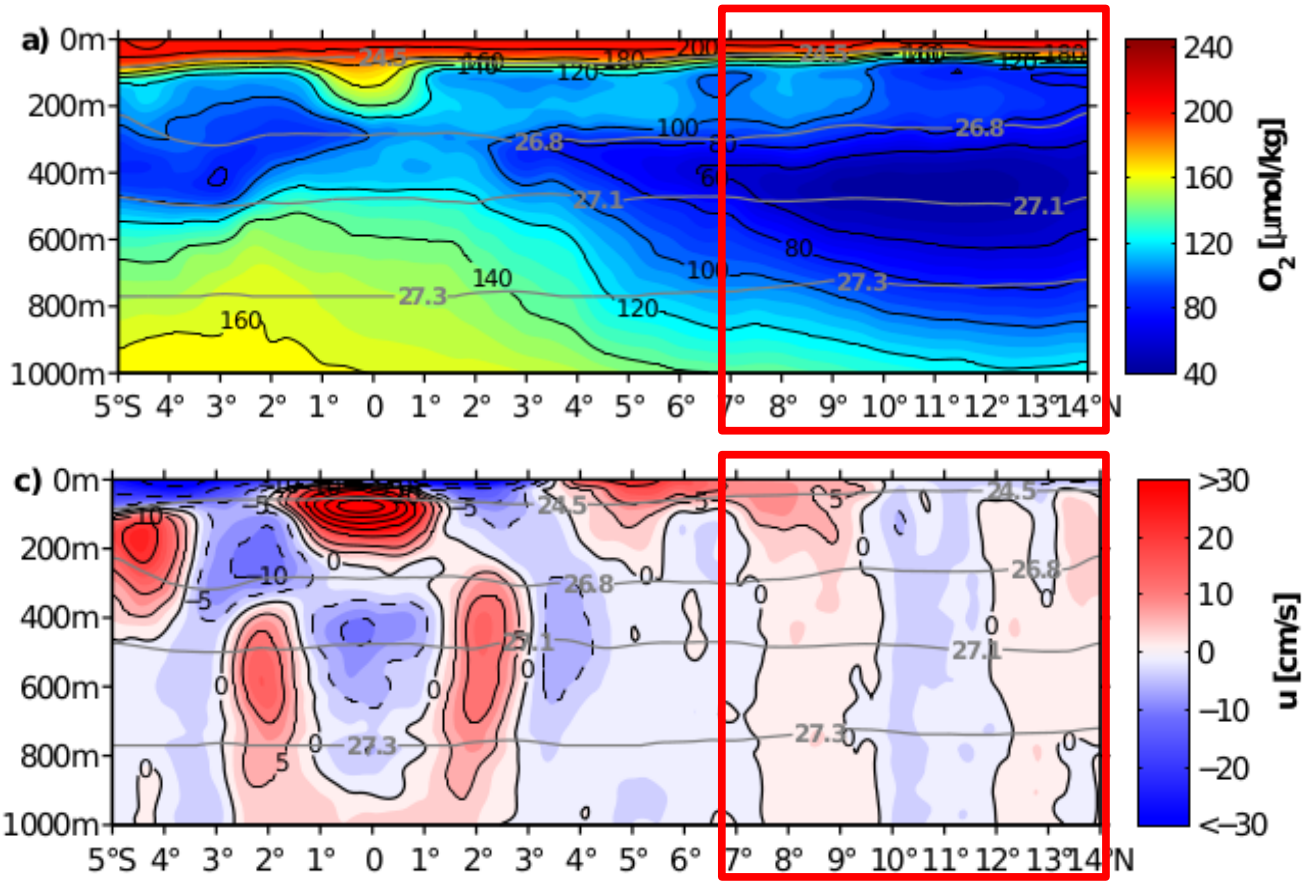
O2, 18N, comparaison model/obs

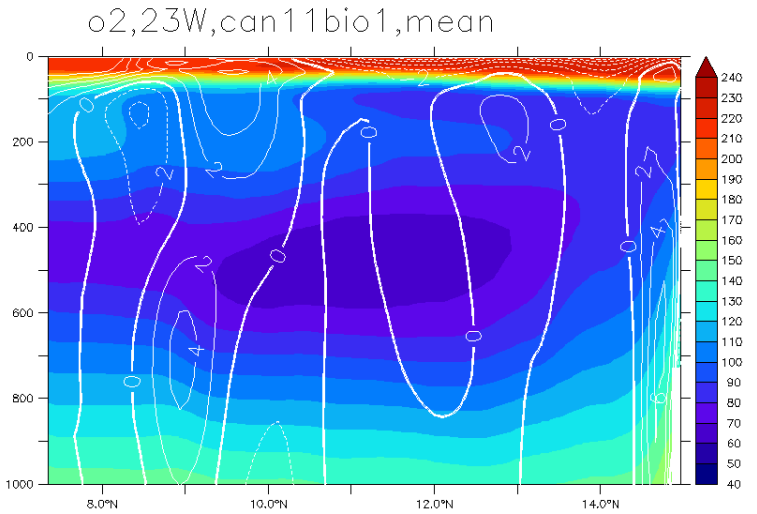


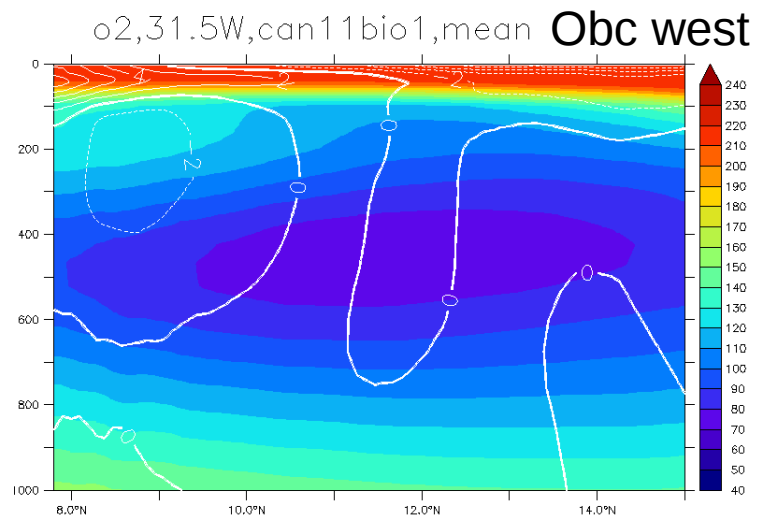
O2, 18N, 06/2014



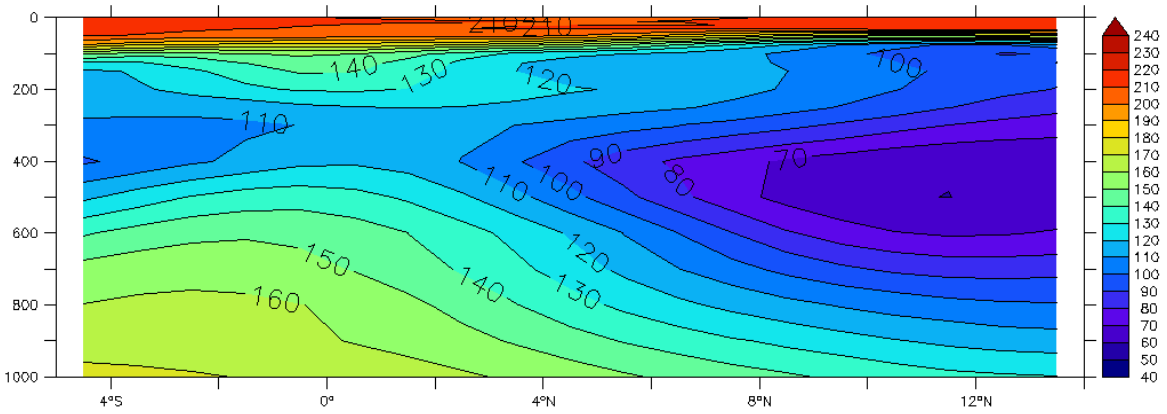
Oxygen section, 23W, 1999-2012, Brandt et al. 2015



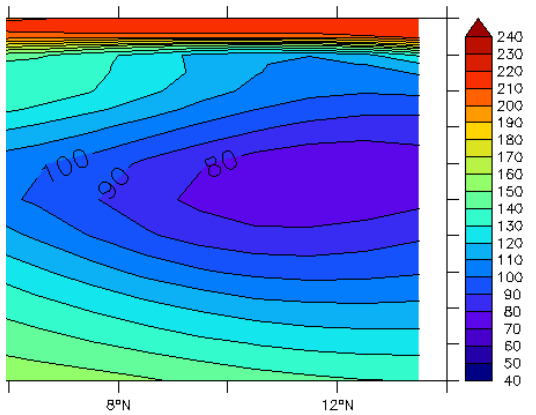




Oxygen section, 23W, WOA2013 (= woa2009)

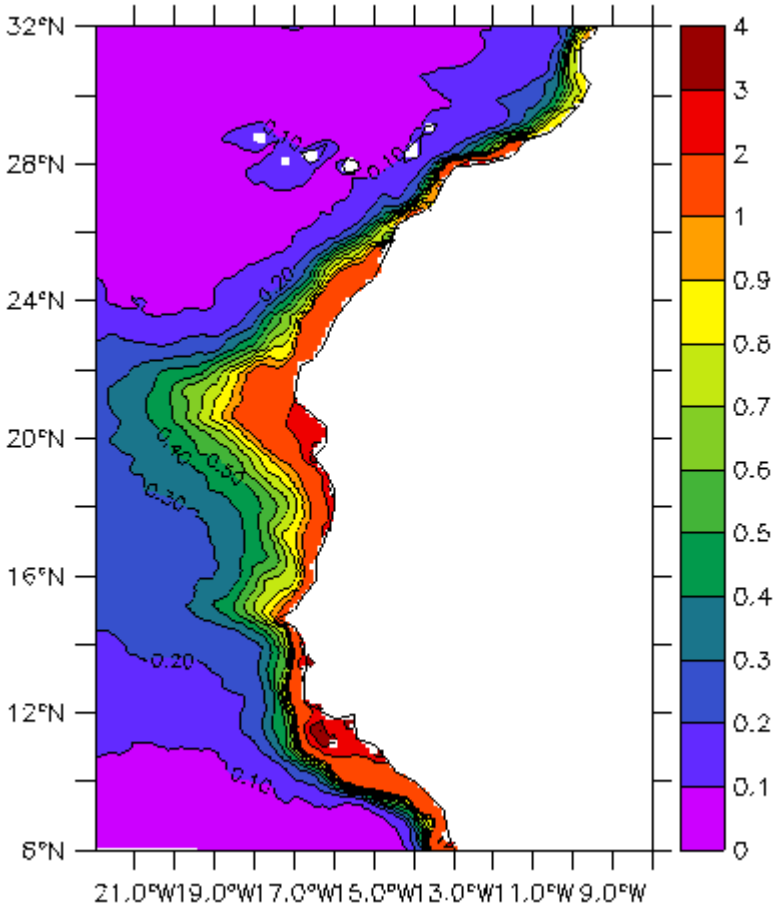


WOA, 31.5W, Obc west

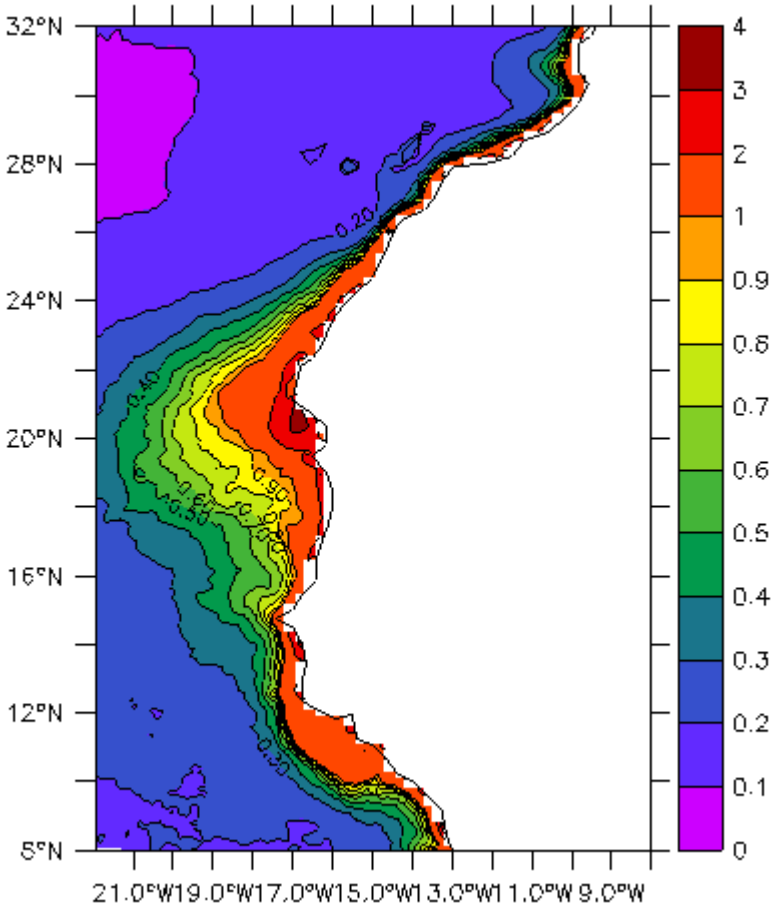


chlorophylle de surface

Chl surf model can11bio1 (y1-4)



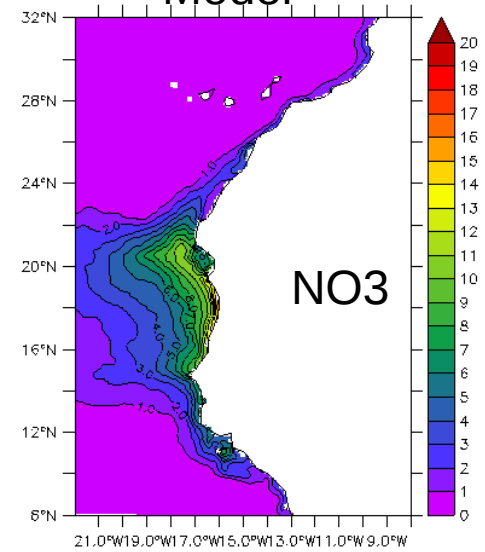
Chl surf sat 1996-2016(multi-sat)



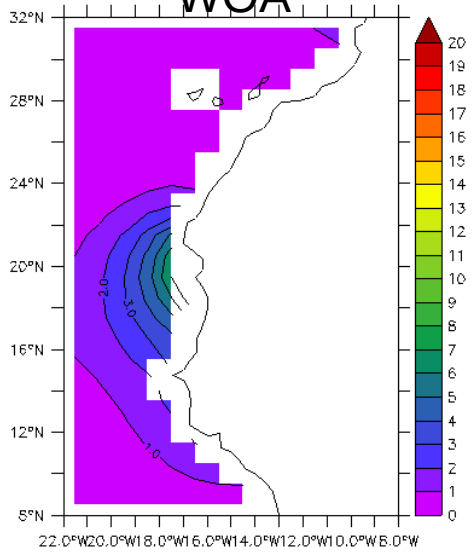
=> OK dans la zone côtière, +faible au large

Surface nutrients & O2 : model (y1-4)/obs (WOA)

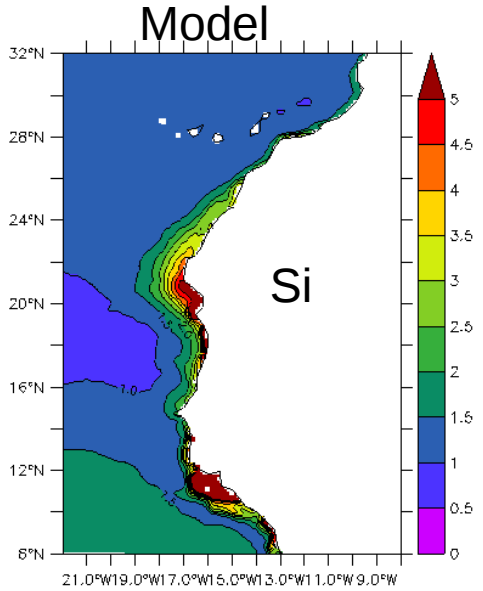
Model



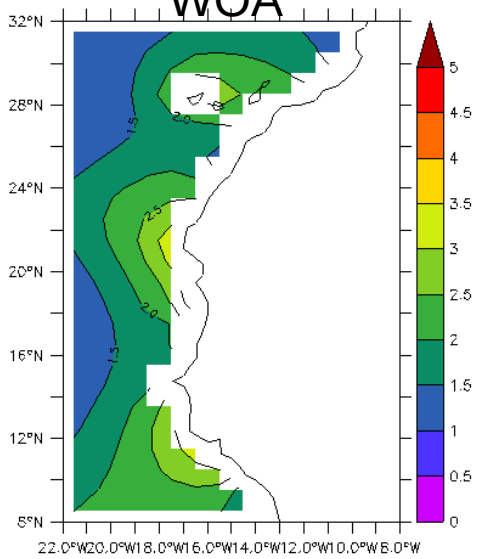
WOA



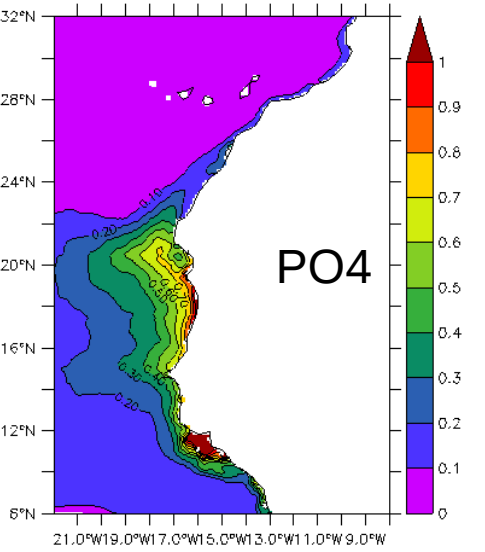
Model



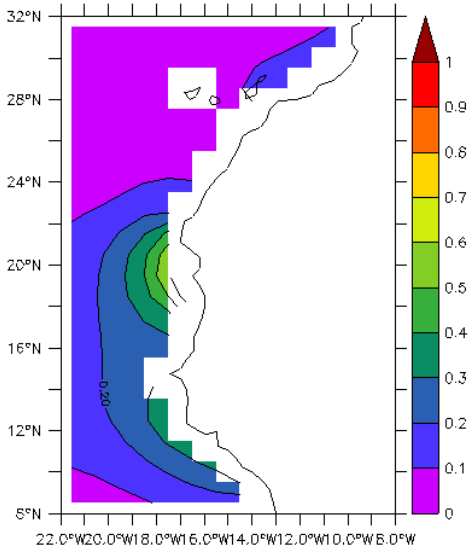
WOA



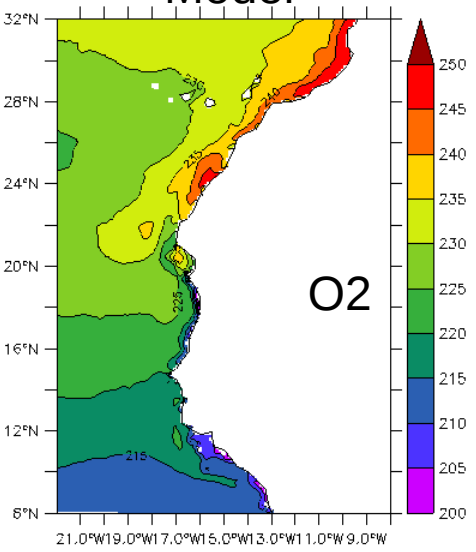
Model



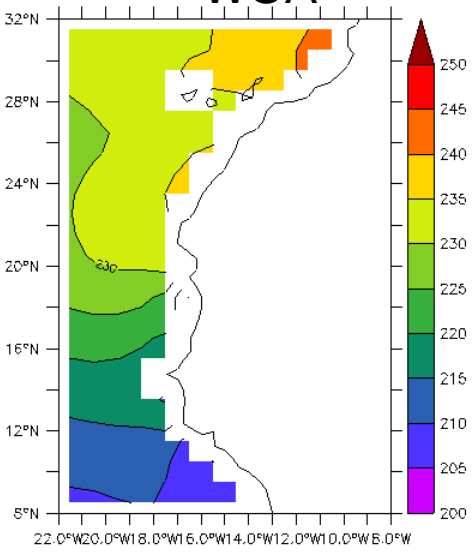
WOA



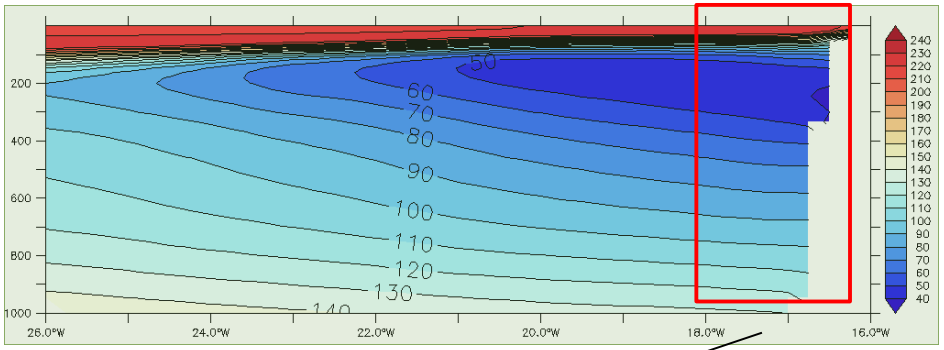
Model



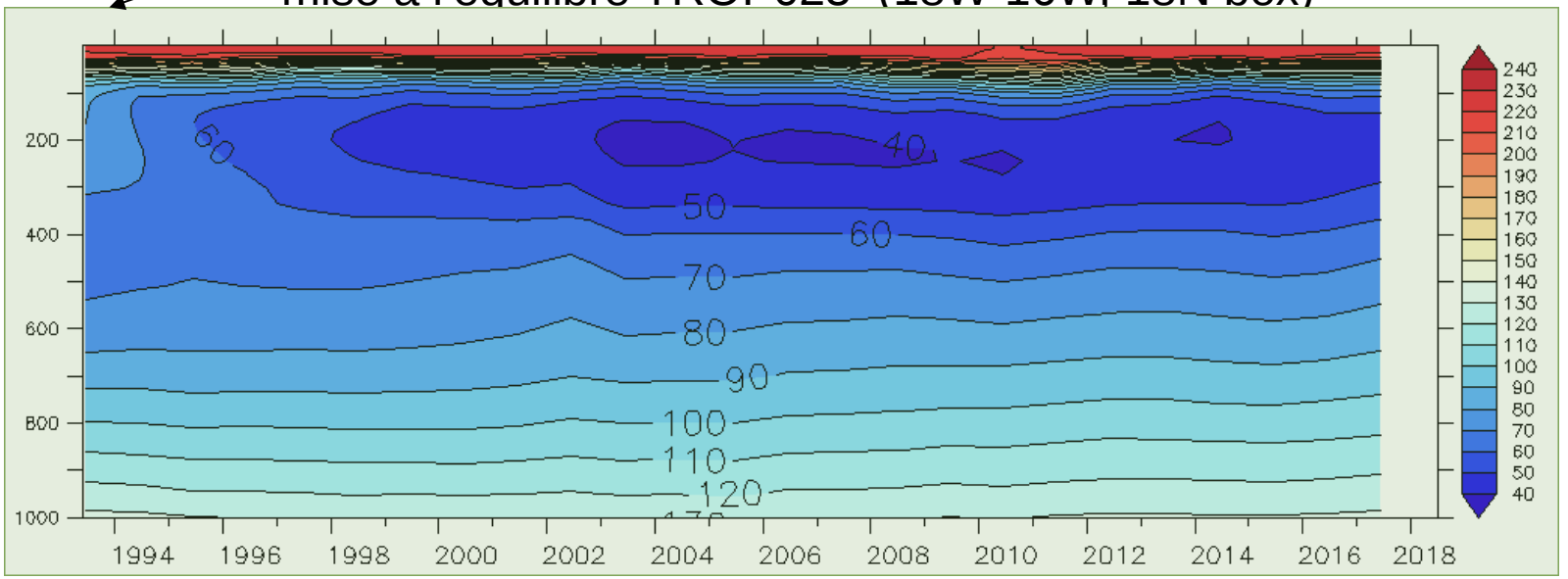
WOA



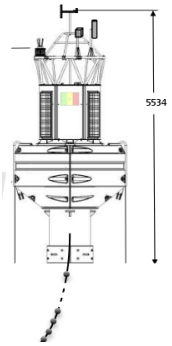
Section 18°N, TROP025(2006-2017)



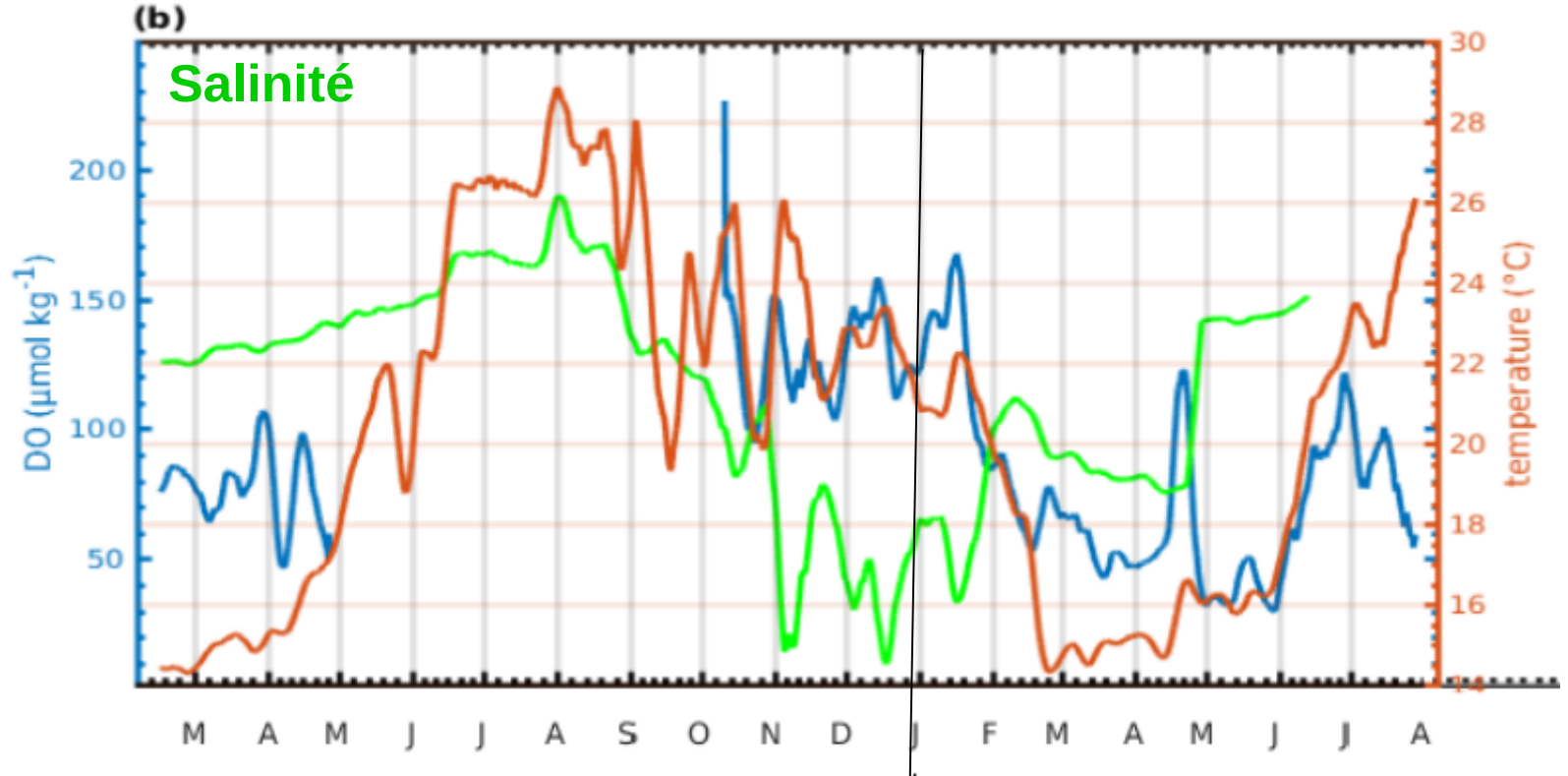
mise à l'équilibre TROP025 (18W-16W, 18N box)



=> biais se met en place en ~ 2 ans



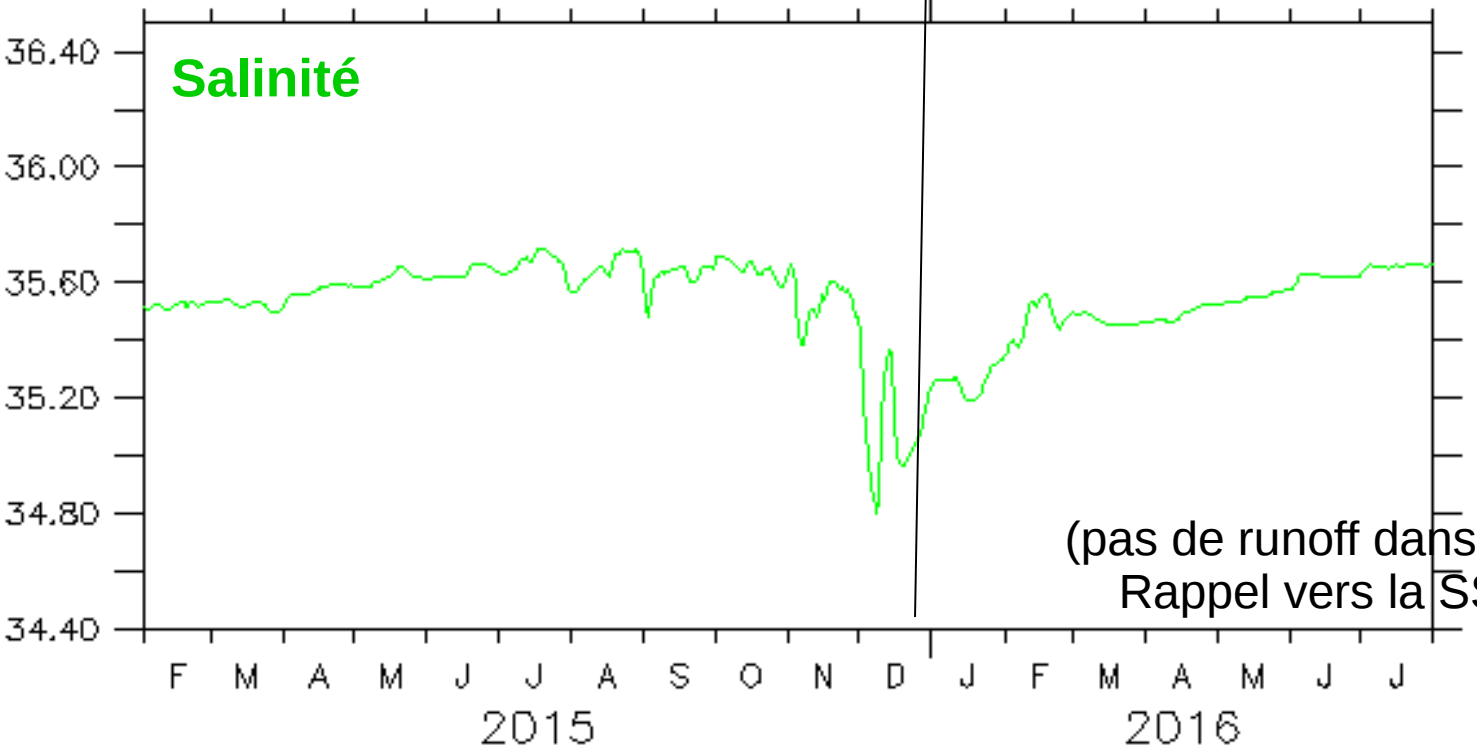
Obs
30m



36.5

34.4

Modèle
30m



(pas de runoff dans le modèle
Rappel vers la SSS clim)