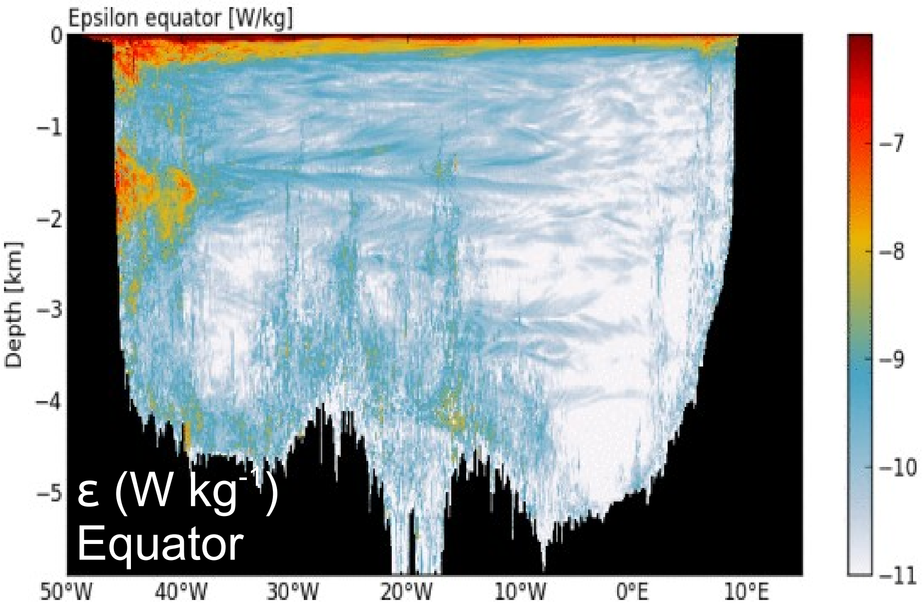
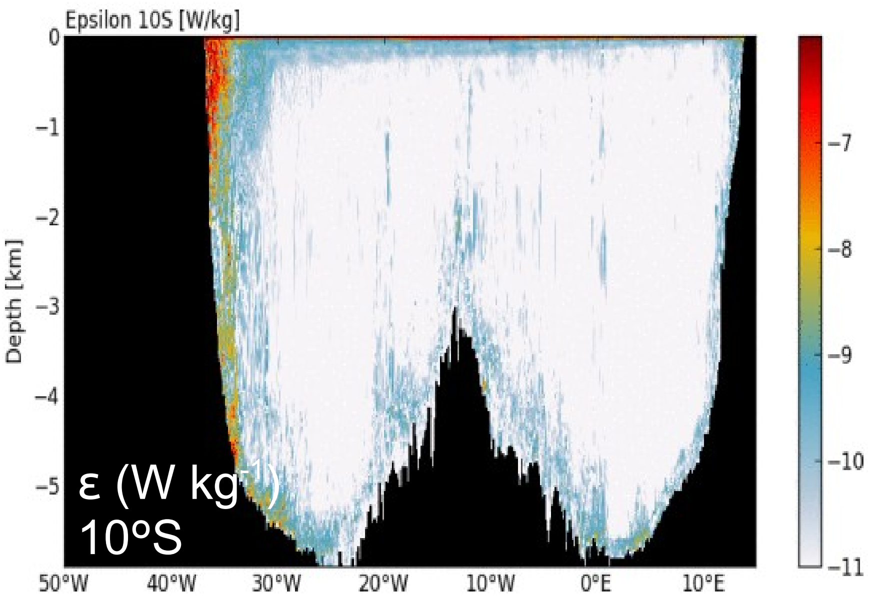
Mixing in the Tropical Atlantic: the contribution of tides, intra-seasonal winds and equatorial dynamics.



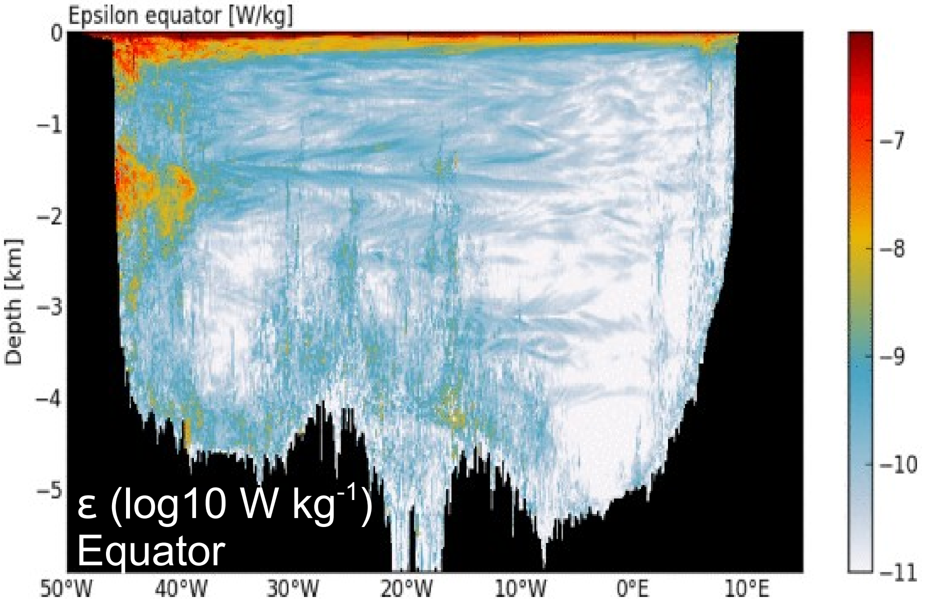


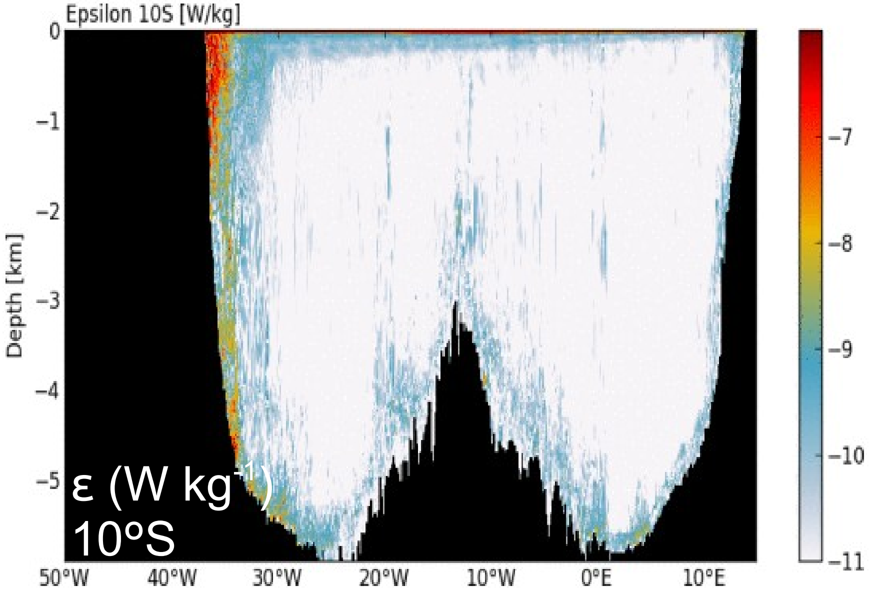
Julien Jouanno (IRD, LEGOS) and Xavier Capet (CNRS, LOCEAN)

EU Project PREFACE and ANR SMOC

PREFACE Meeting – Cap Town – August 2015

Mixing is patchy in space and time : exemple of KE dissipation rate ε in a 1/36 model





Important to get the rates and patterns right :

- Role in the dynamical balance of the equatorial current system (Crawford and Osborn 1981, Eden 2006)

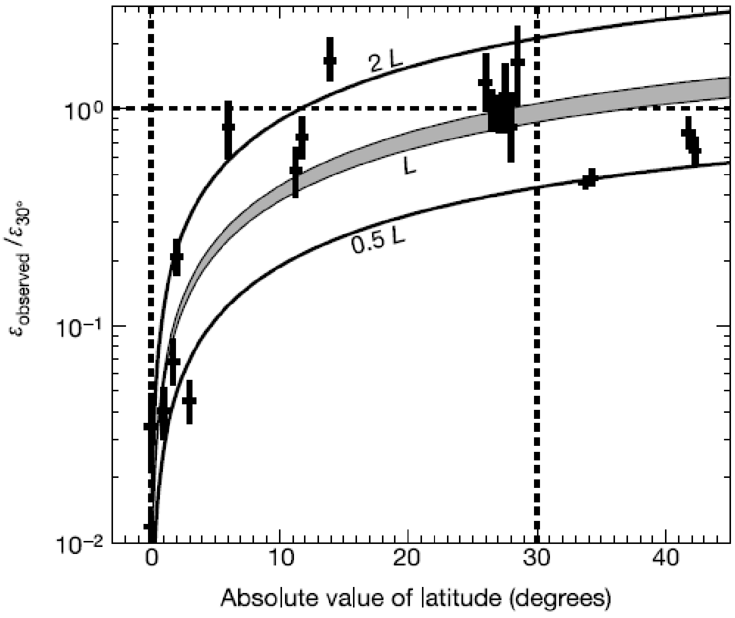
- Near surface and deep water mass transformation

Amounts of mixing near the equator : uncertainties remain

- Equatorial drop off of ε

Dissipation rates near the equator are less than 10 % of those at mid-latitudes for a similar background of internal waves [Gregg et al., Nature, 2003]

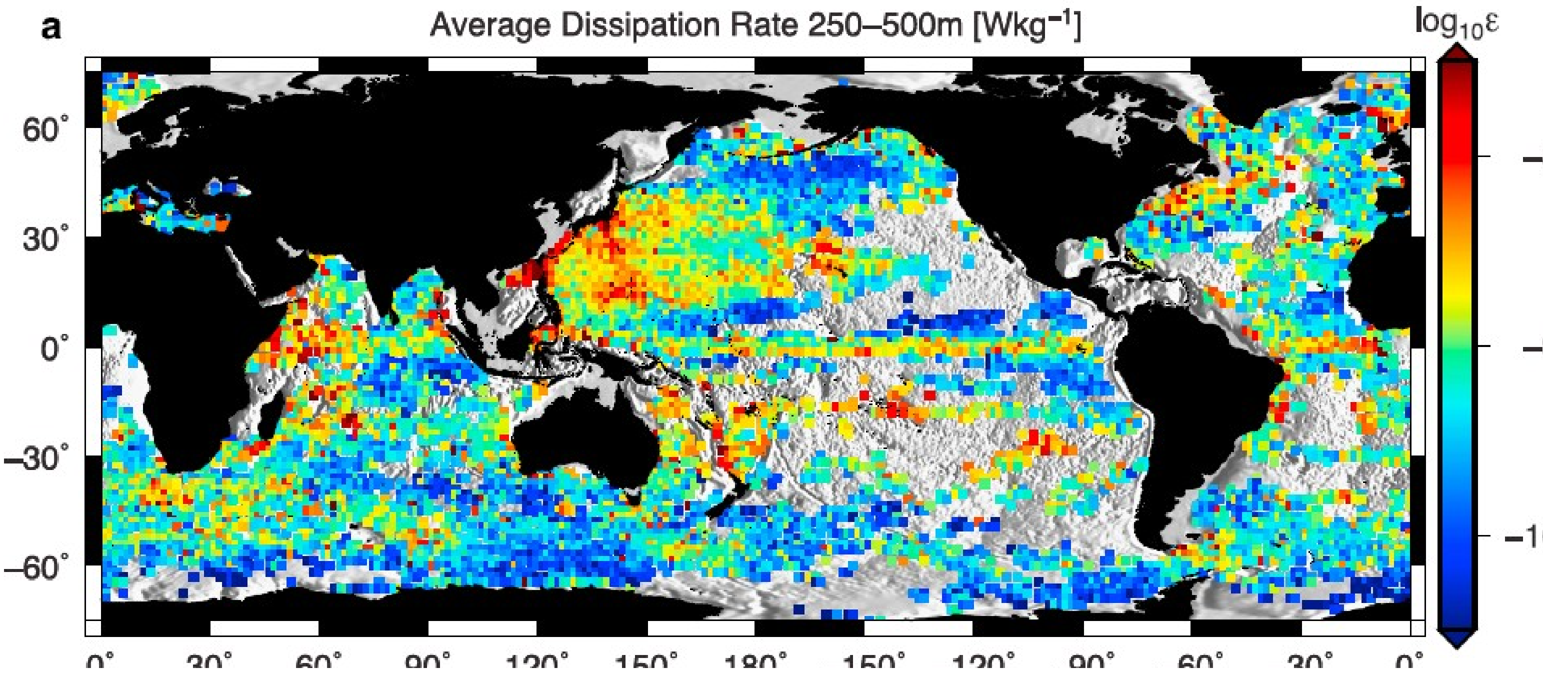
-> small time slices of the turbulence field + they skipped the strong mean shear region



- vs « increased ε near the equator…»

Indirect estimates from ARGO strain measurements [Whalen et al. 2012]

-> but not all strain close to the equator is generated by internal waves



Source of mixing in the Equatorial Atlantic

- <u>Tides</u> (breaking of internal tides)

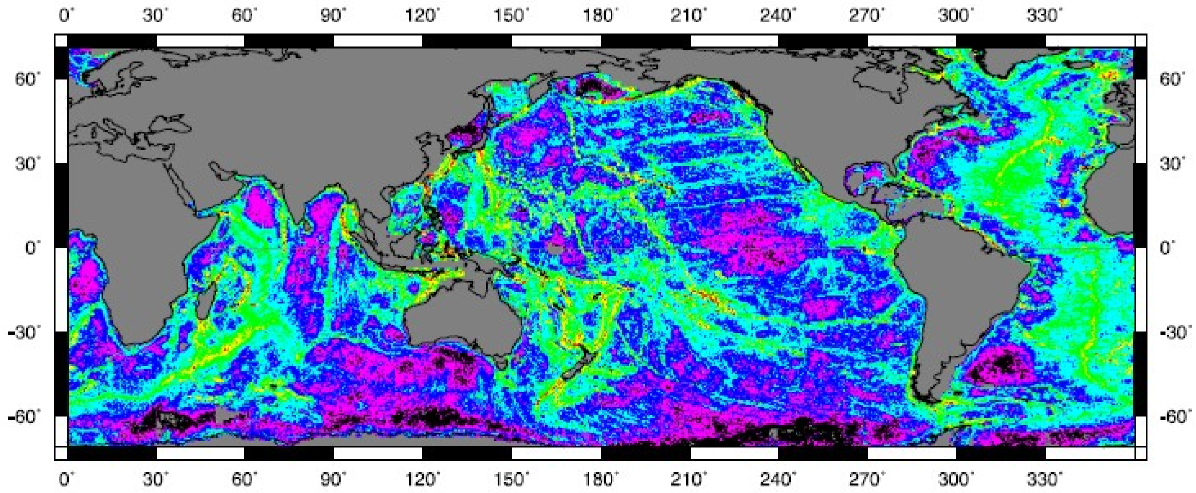
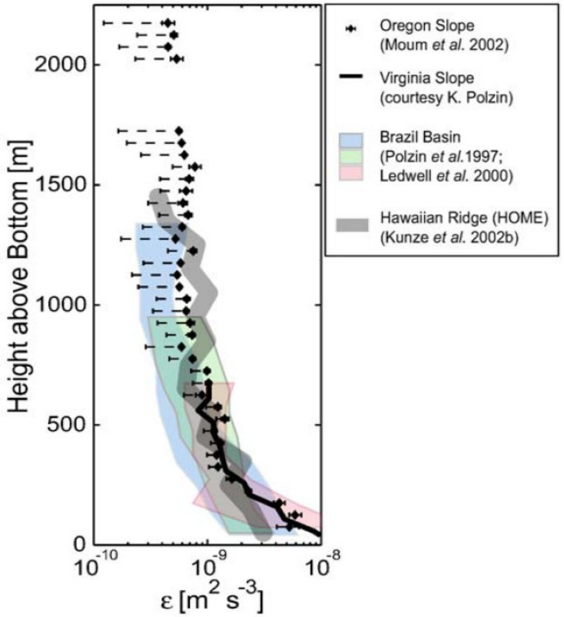
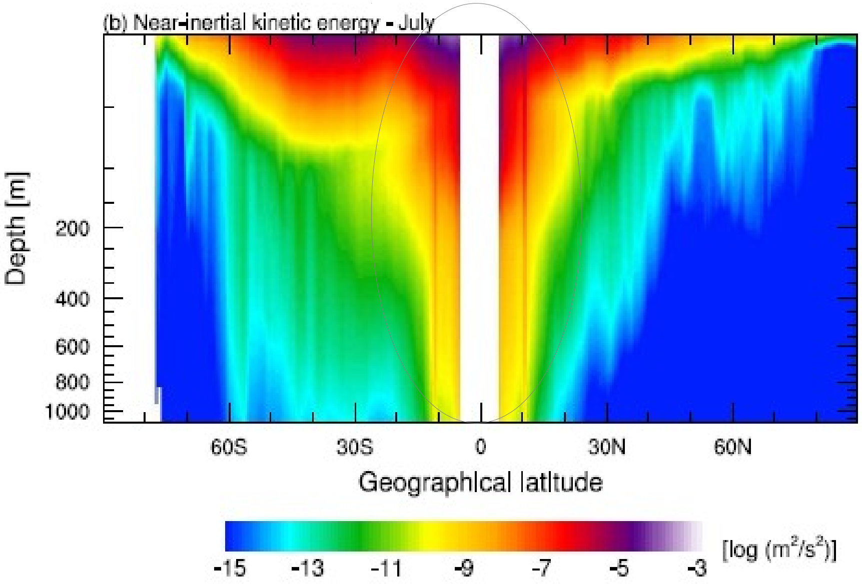


Figure : energy flux from M2 to internal tides (Nykander 2005)



- <u>Near-inertial waves</u>

Figure : NI-EKE from a global (1/12) model which illustrates Internal wave energy increase toward the equator [source : Rimac 2014]



Source of mixing in the Equatorial Atlantic

- Lee-waves (bottom KE enhanced at the equator)

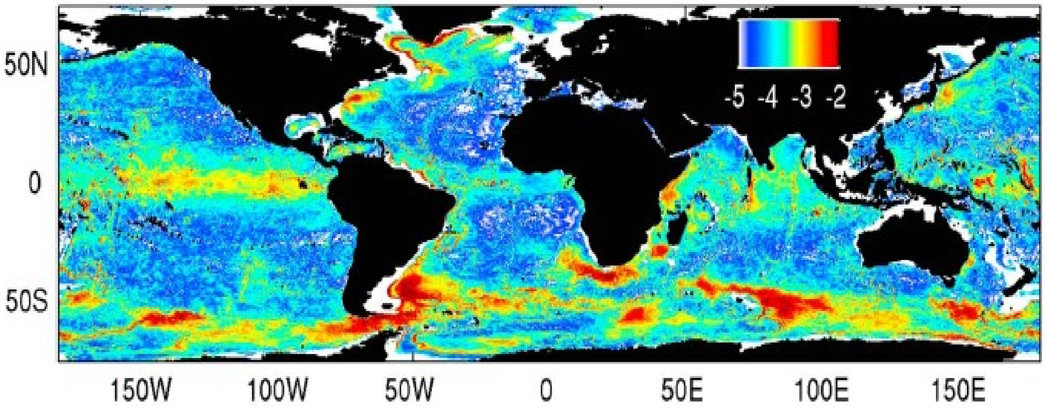


Figure : Bottom KE (Nikurashin & Ferrari 2008)

- Stacked-jets

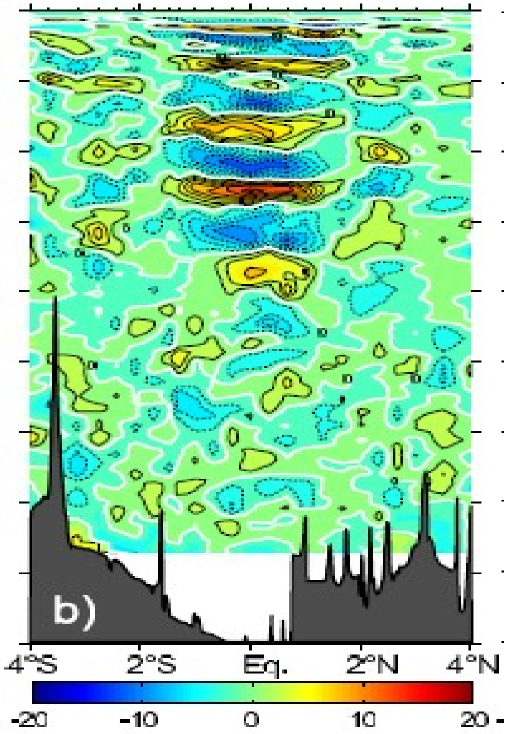


Figure : Snapshot of equatorial currents (Eden and Dengler 2006)

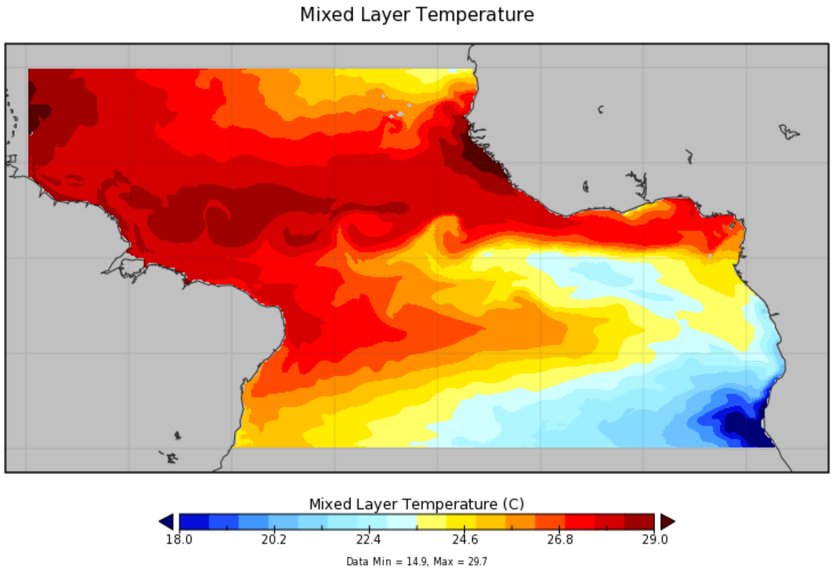
Objectives

- How mixing is distributed in a Tropical Atlantic model ?
- Which processes control mixing distribution in the region ?
- To what extent mixing distribution depends on model resolution ?

TROP04 & TROP36 regional simulations

General

Code: NEMO 3.6
Boundaries : Mercator Daily GLORYS2V3
Forcing : DFS5.2 (3h ERA-I)
Vertical mixing : GLS (default options)
Momentum : UBS (third order scheme)
Free surface : time-spliting (60 sub time steps)
Tracers : TVD + laplacian isoneutral
Initial conditions : T/S from GLORYS2V3 at 01-01-2004
Tidal forcing : FES2012
Bathy : Etopo1
Period : 2004-2005 **Spin-up :** only one year...



Configurations & Experiments

TROP04 : 1/4° & 75 vert levels & diff 300m2/s

TROP36 : 1/36° & 300 vert levels & diff 45 m2/s

REF : reference
NO-HF : low-passed windstress (30days cutoff)
TIDE : tidal forcing included

Energy diagnostics

$$\epsilon_v = \iiint \rho\, \boldsymbol{u_h} . \partial_z \left(\kappa_v \partial_z \boldsymbol{u_h} \right) dV$$

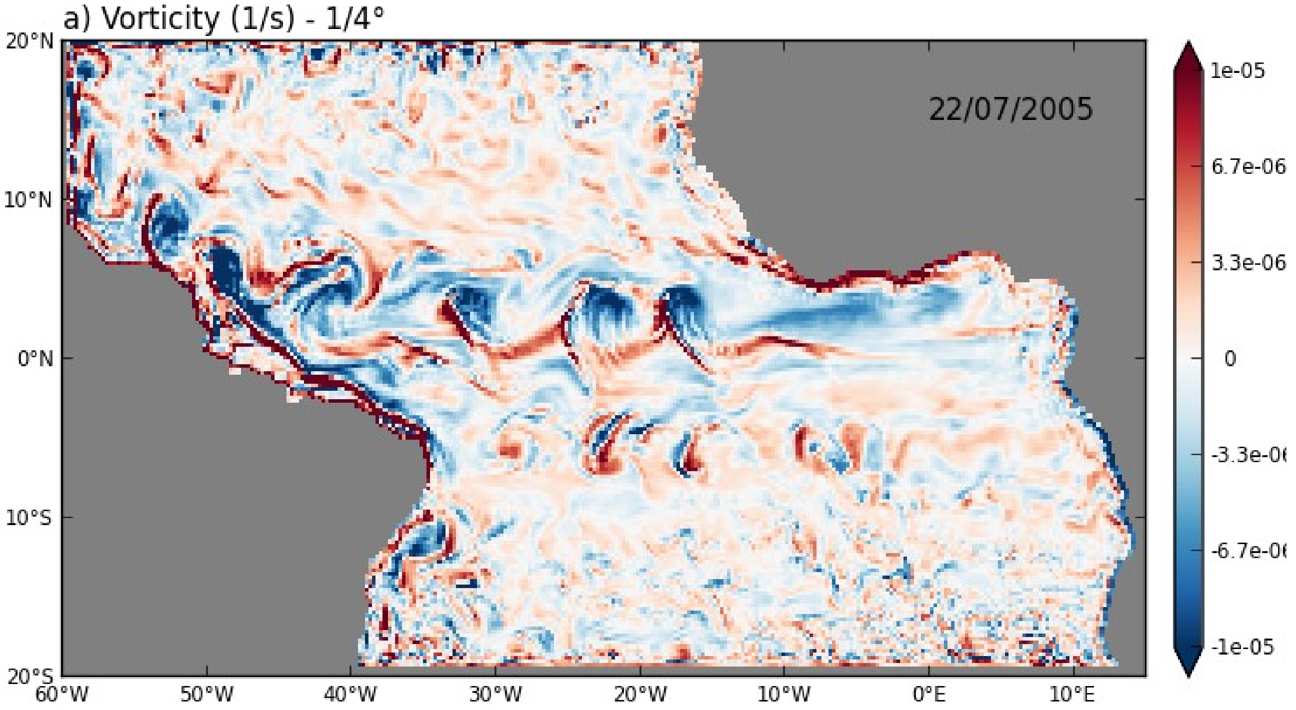
$$\epsilon_h = \iiint \rho\, \boldsymbol{u_h} . \boldsymbol{D_h}\, dV$$

←

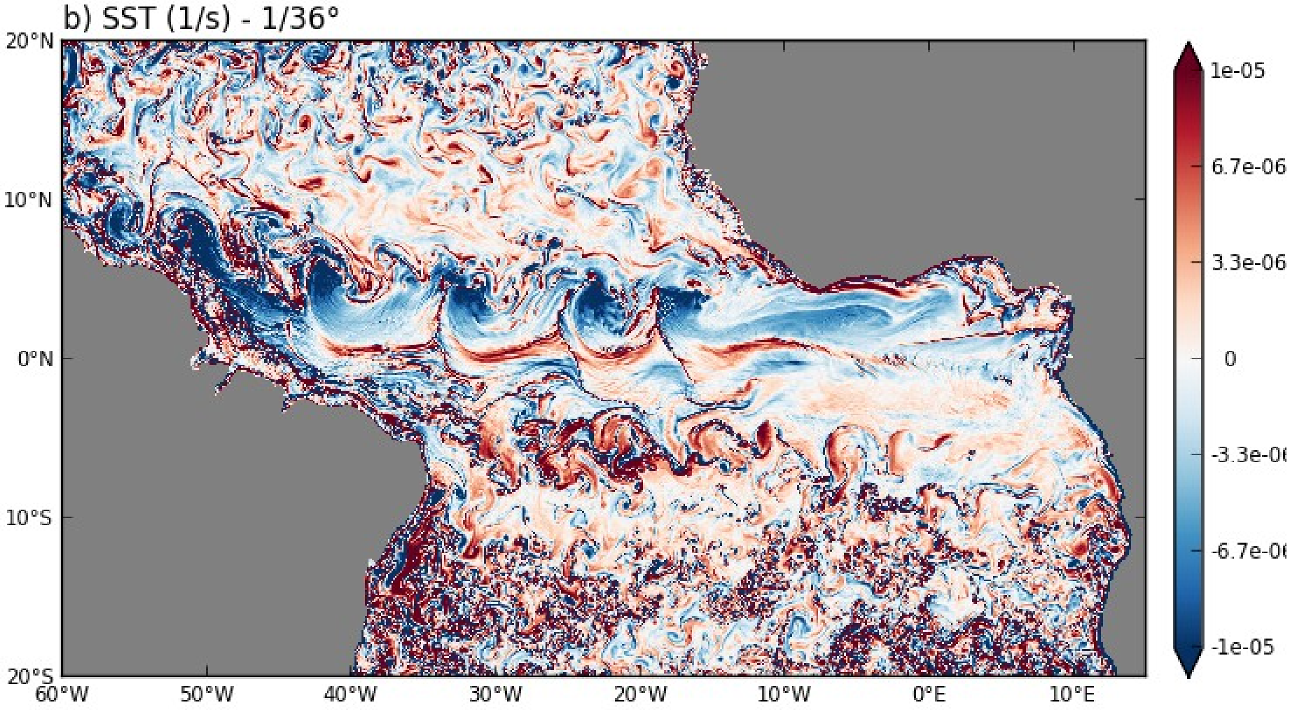
UBS intrinsic horizontal diffusivity estimated as the difference between UBS momentum trend and the trend given by a 4th order advective scheme.

Model intercomparison - 1/4 vs 1/36

Vorticity
1/4°

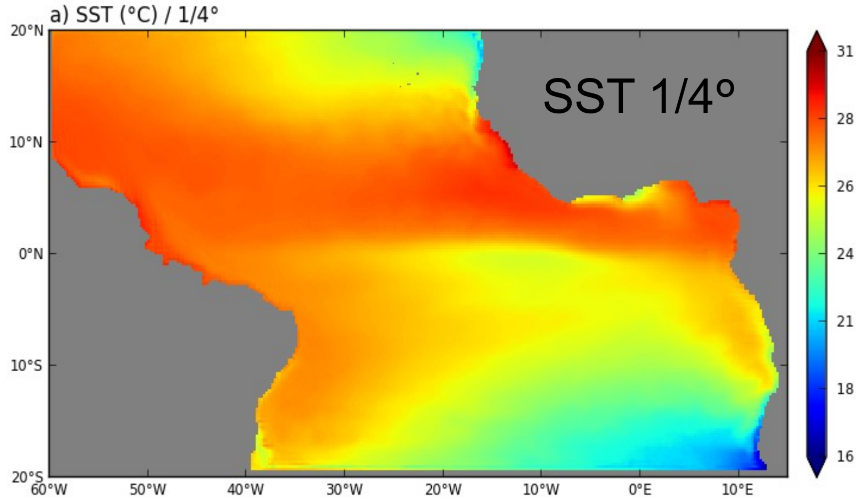

a) Vorticity (1/s) - 1/4°

Vorticity
1/36°

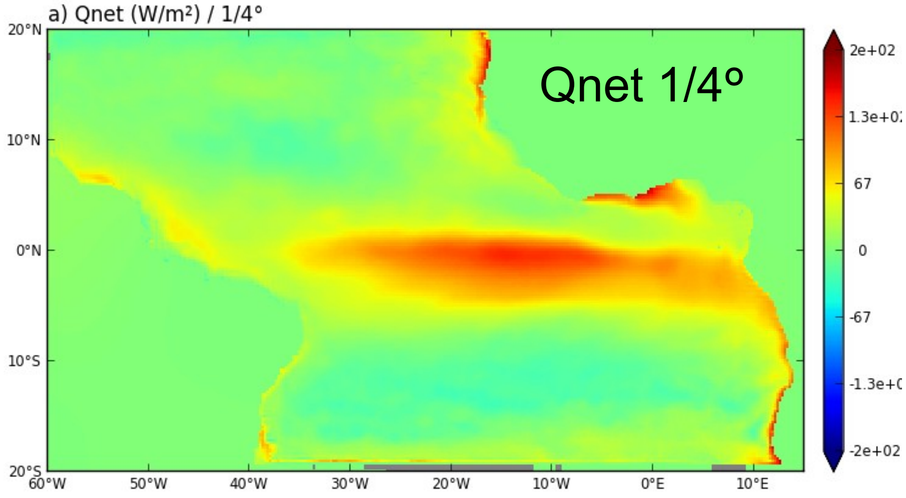

b) SST (1/s) - 1/36°

Model intercomparison : SST(°C) and Qnet (W m^{-2})

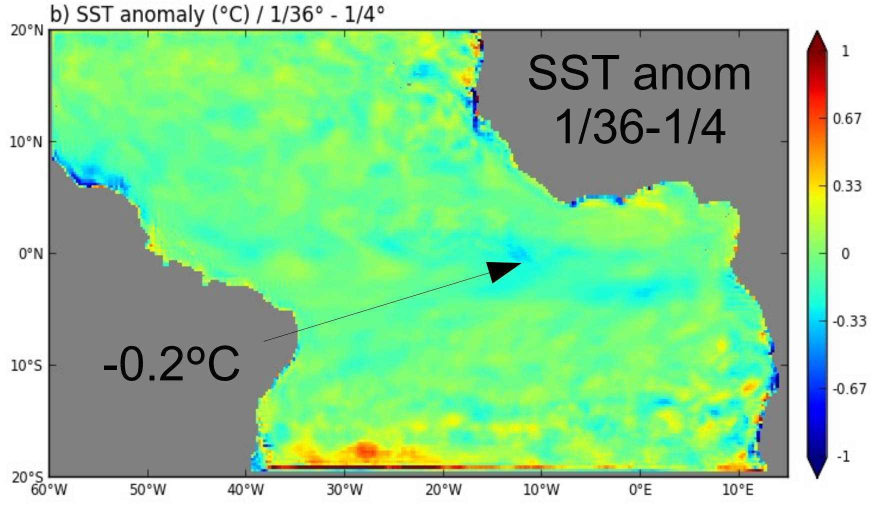
-> Weak impact of model resolution on SST and Qnet (1 year average)



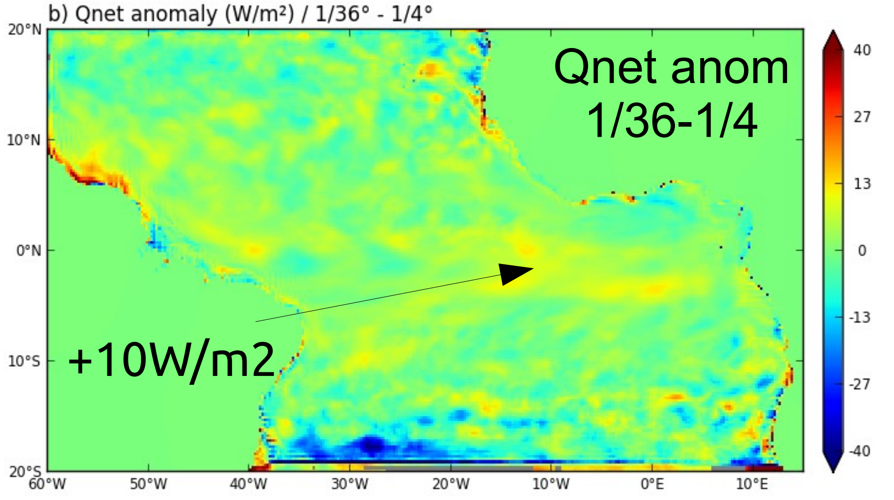
a) SST (°C) / 1/4°



a) Qnet (W/m²) / 1/4°

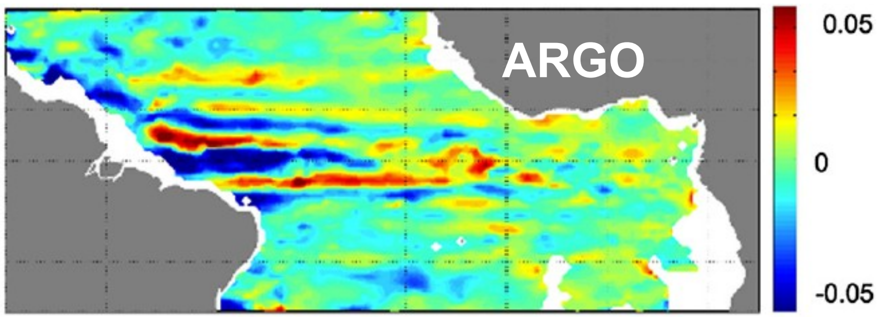


b) SST anomaly (°C) / 1/36° - 1/4°

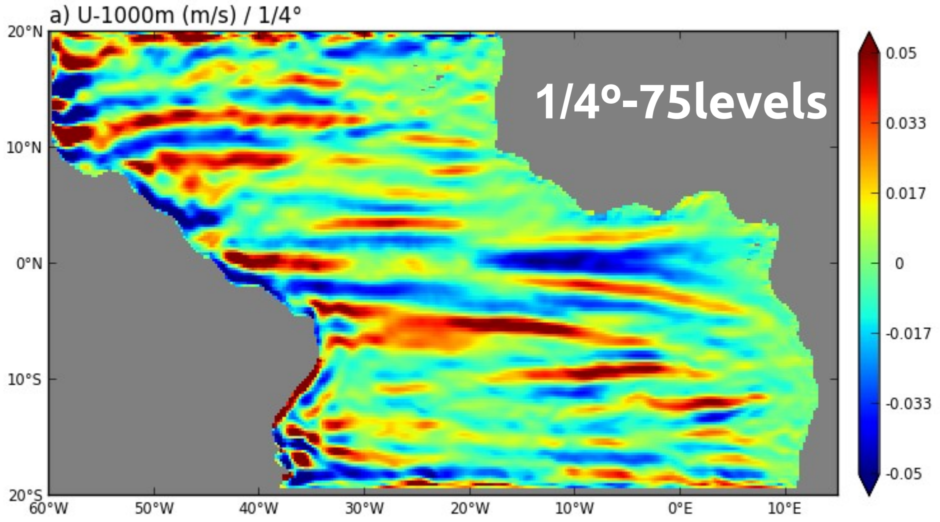


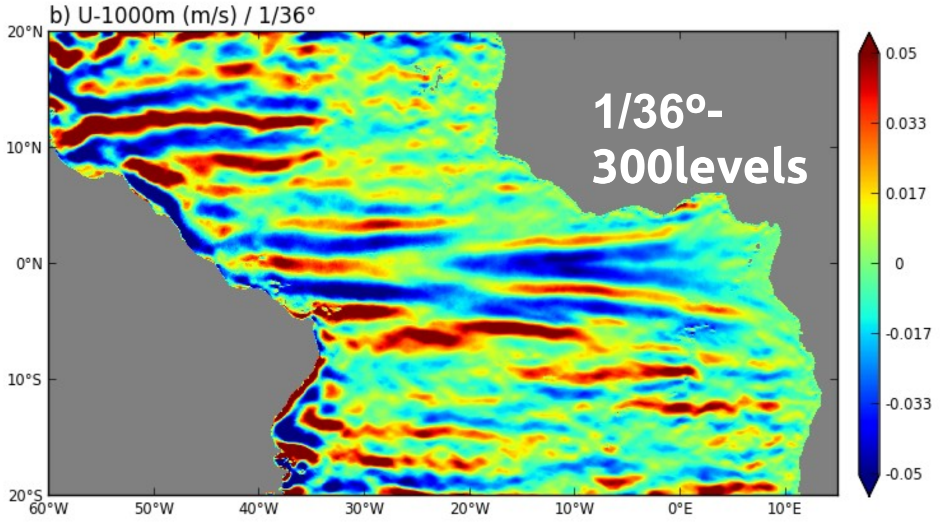
b) Qnet anomaly (W/m²) / 1/36° - 1/4°

Model intercomparison : 1000-m zonal jets



Rosell-Fieschi (2015)

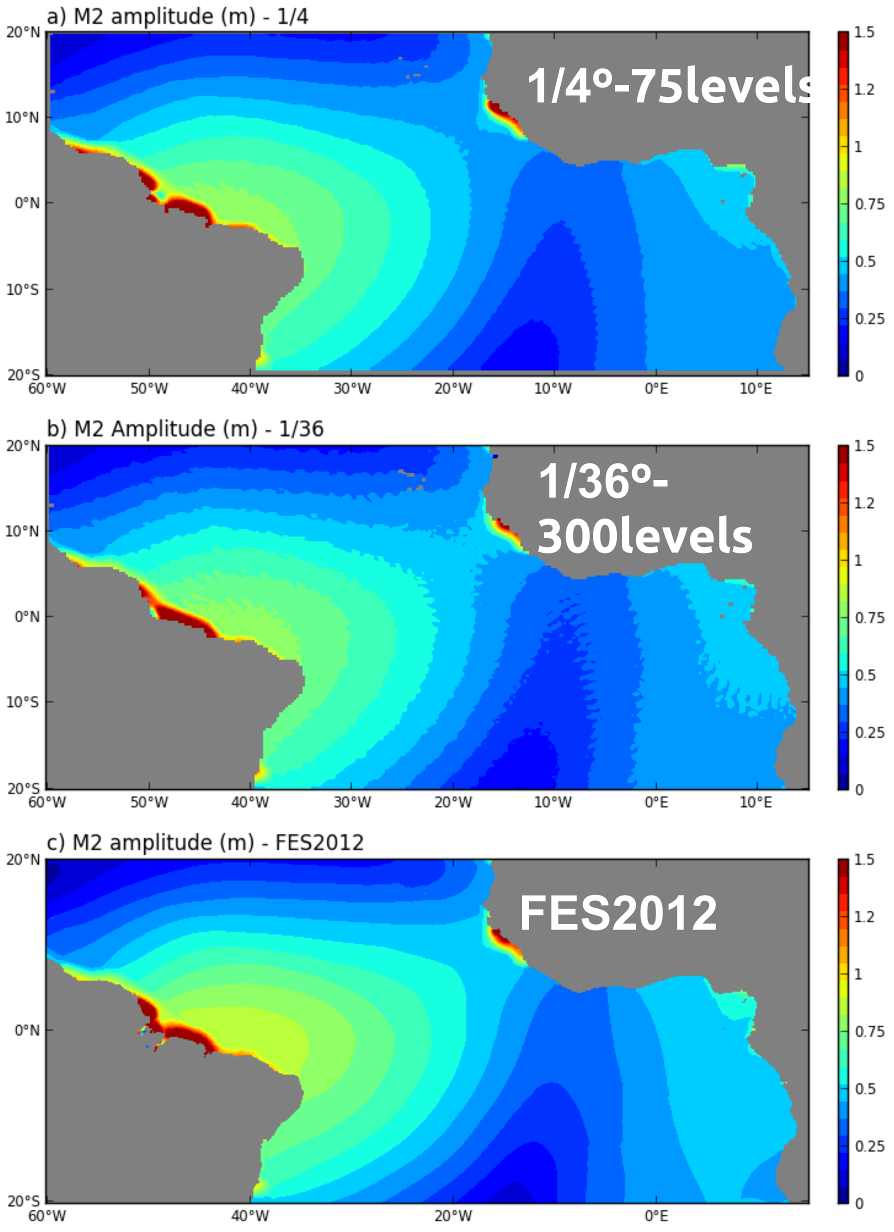




- Deep currents of O 5-10 cm/s as observed
- At first order, <u>no significant improvement at higher resolution</u>

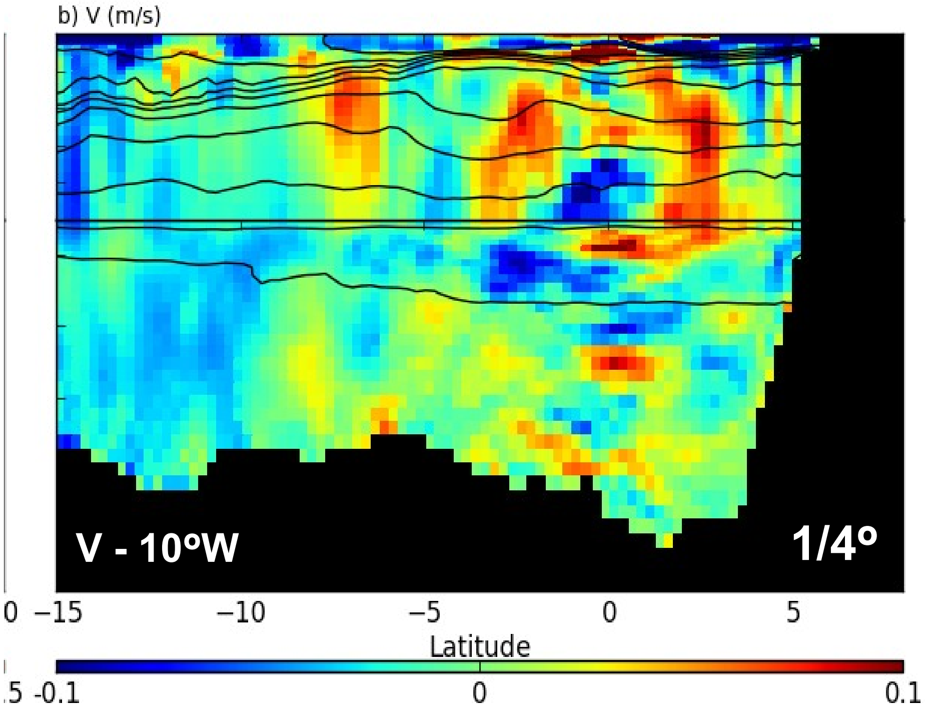
Model intercomparison : tides

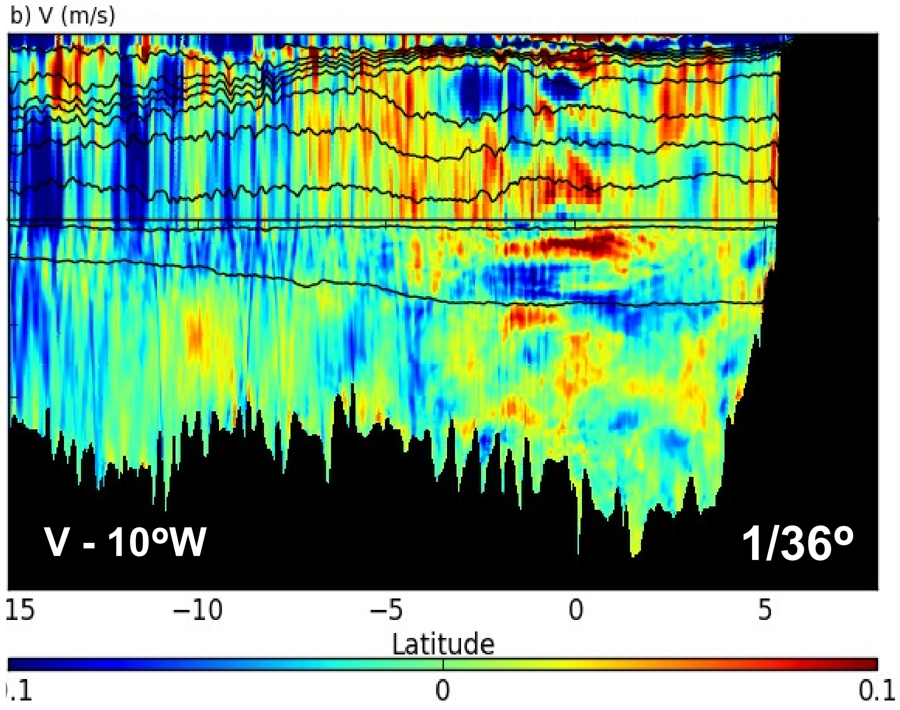
- Barotropic tides well represented
- No difference between experiments



Comparison of M2 amplitude

Model comparison - 1/36 vs 1/4 with tides





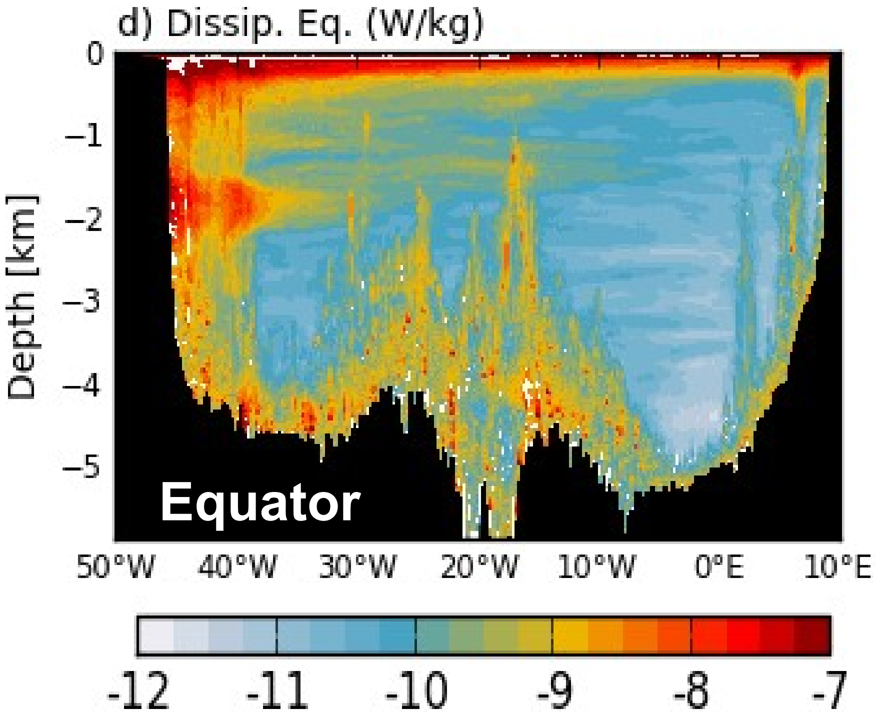
- Deep zonal jets not much more energetics at 1/36°

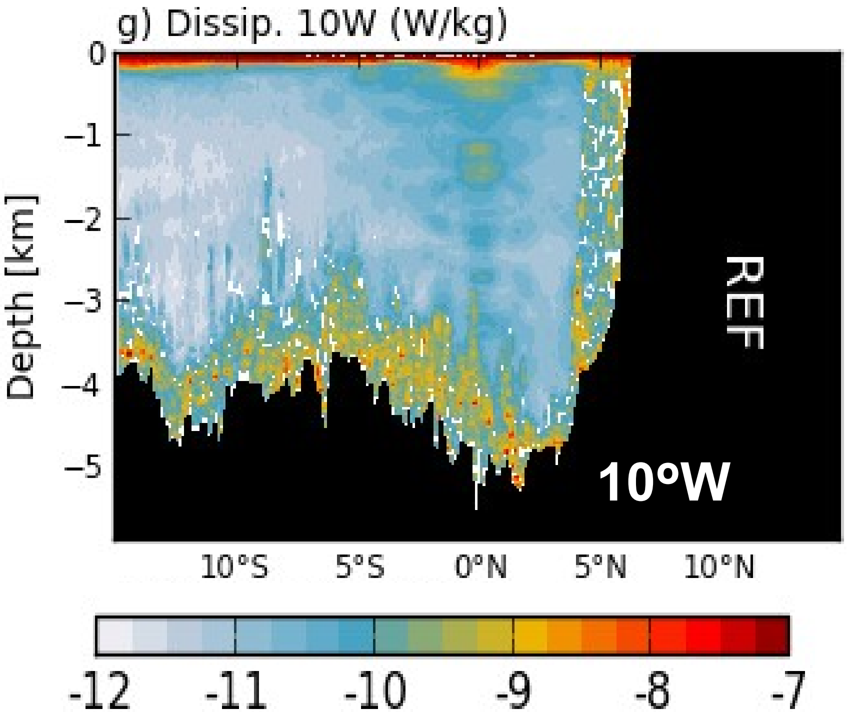
- Evidence of baroclinic tides at 1/36° with horizontal wavelength of order the scale of the bathymetry

Energy dissipation

KE dissipation

- Increased dissipation over rough topography / ridges and western boundary
- East to west increase of ε
- Increase of ε at the equator

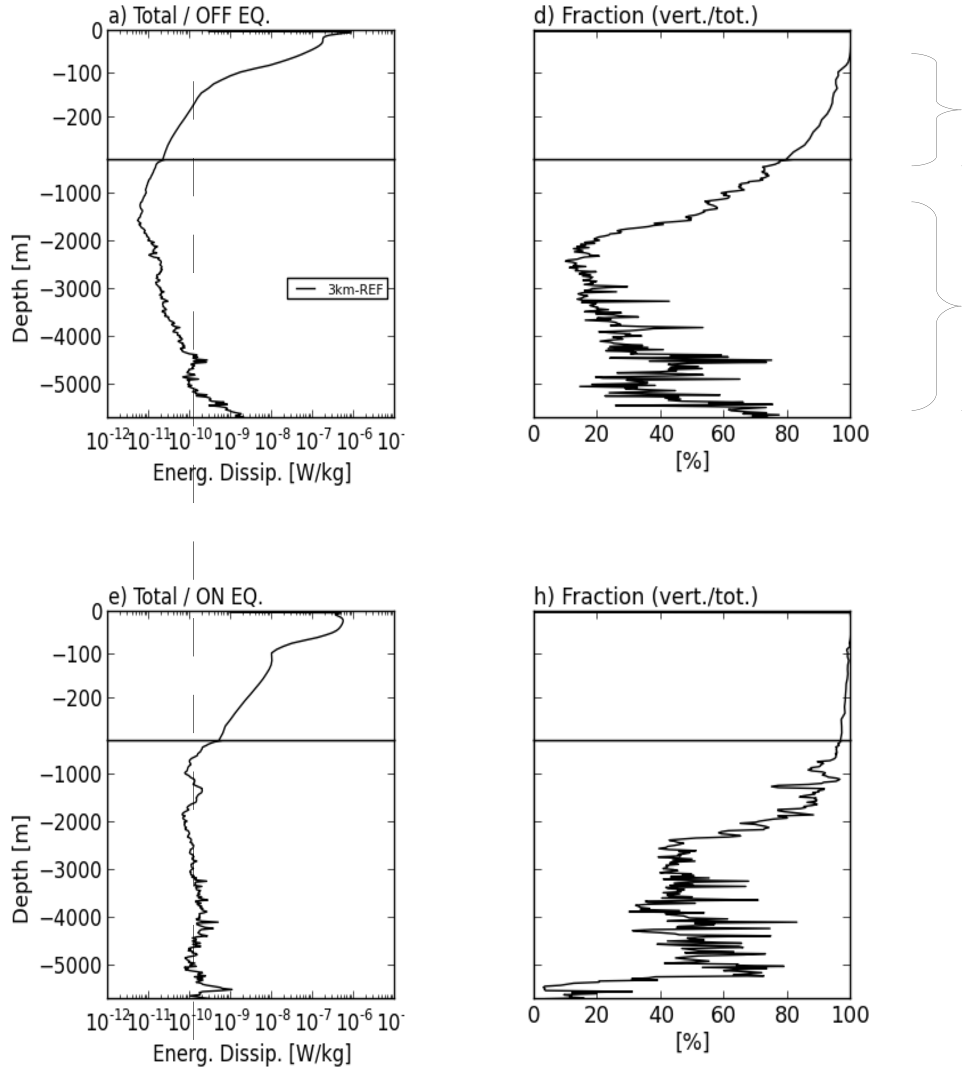




Horizontal vs vertical dissipation (30W-0E zonal average)

- Near the surface we get the observed rates (10-7-10-8 W/kg ; e.g. Hummels et al. 2014)
- Interior dissipation > at the equator
- Horizontal dissipation important (dominant) in the interior

OFF
EQUATOR
(5S-10S)



ε_v dominates

ε_h strongly contributes

AT-THE
EQUATOR
(1S-1N)

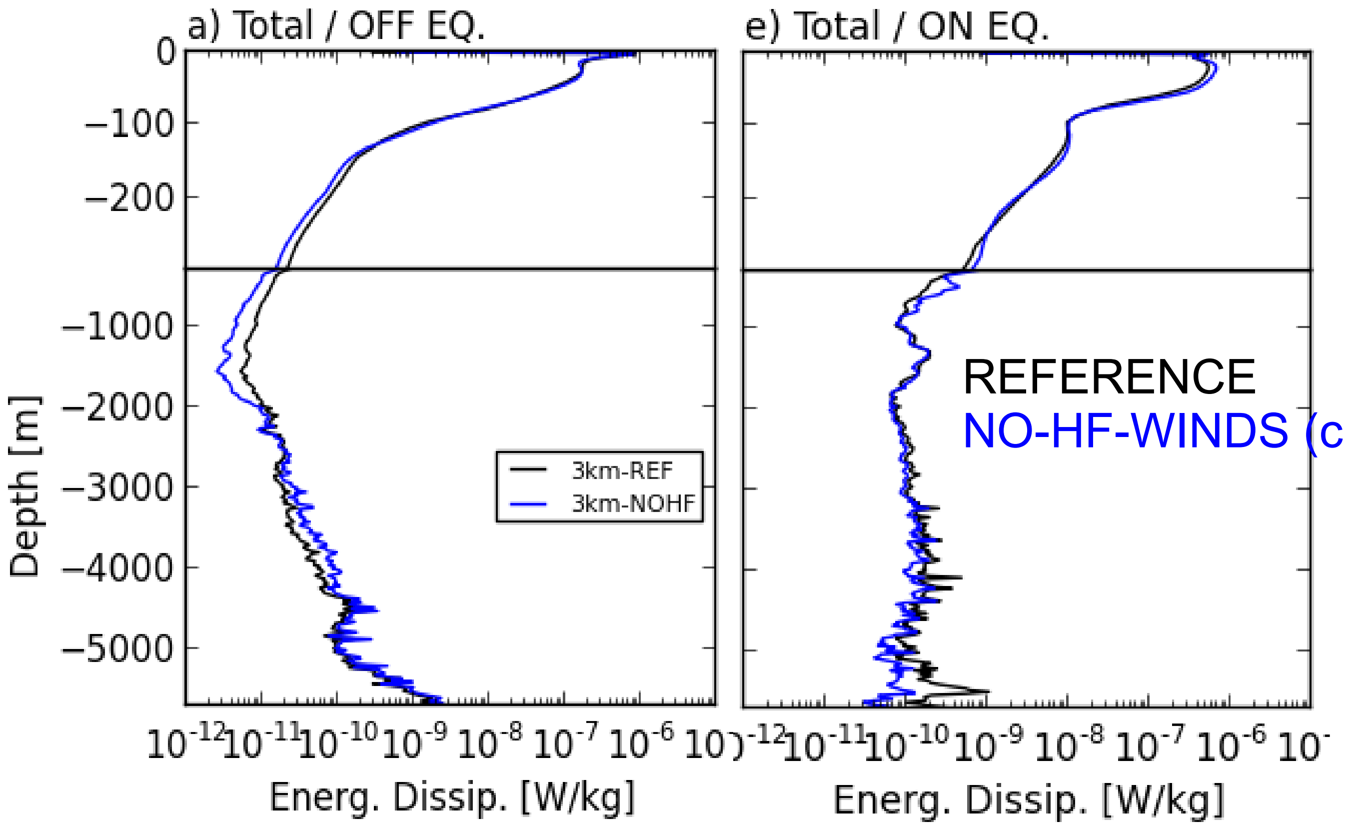
ε (W/kg)

ratio $\varepsilon_v/\varepsilon_h$ (%)

High-frequency winds inject energy into the ocean (NIWs + intraseasonal equatorial waves).

Simulations without HF winds :

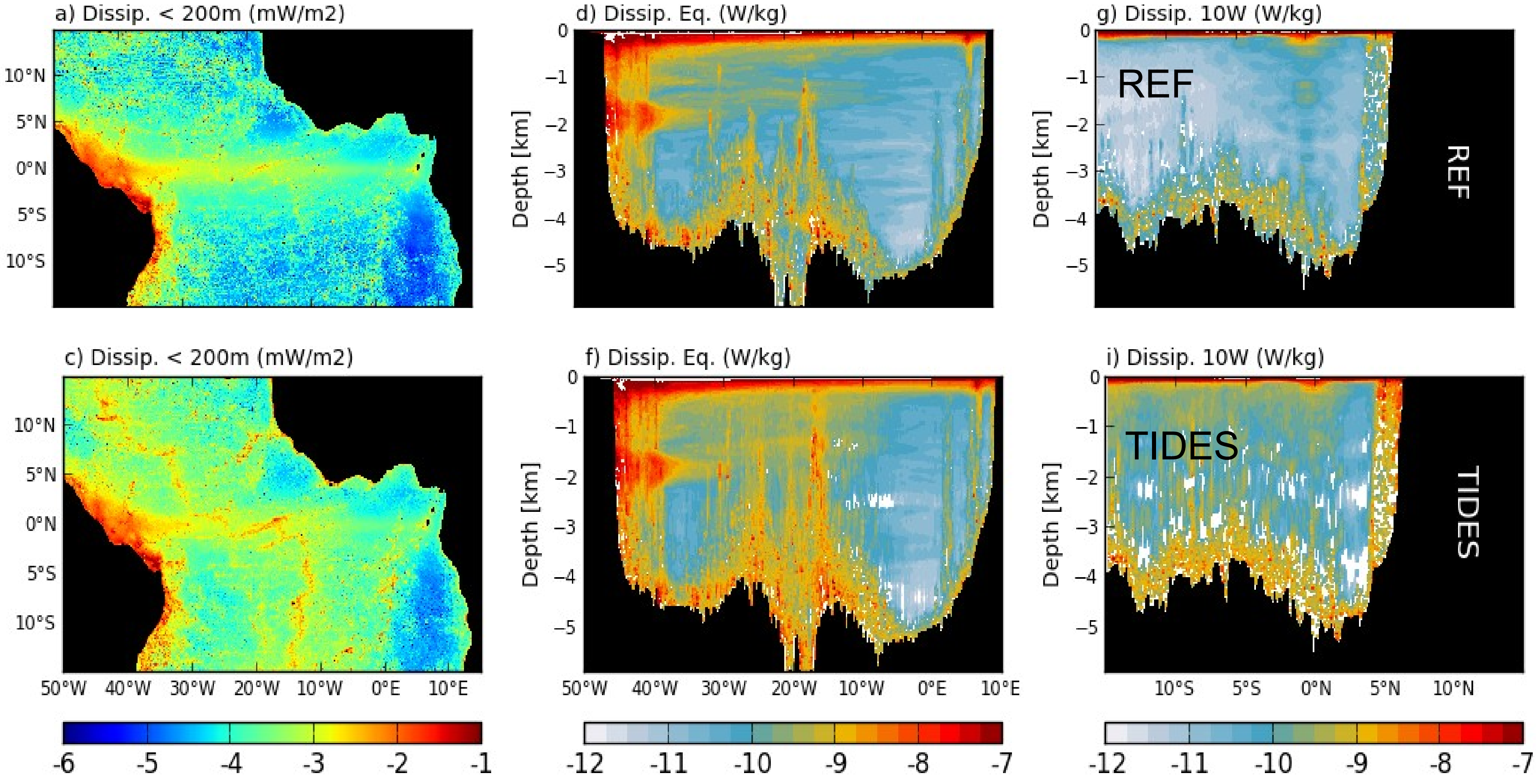
- Weak decrease of ε off-equator
- Almost no increase of ε at the equator



REFERENCE

NO-HF-WINDS (cutoff 30 days)

Impact of the tides on interior dissipation



- Weak increase of epsilon at the equator (the level of dissipation were already high)
- Stronger increase off-equator

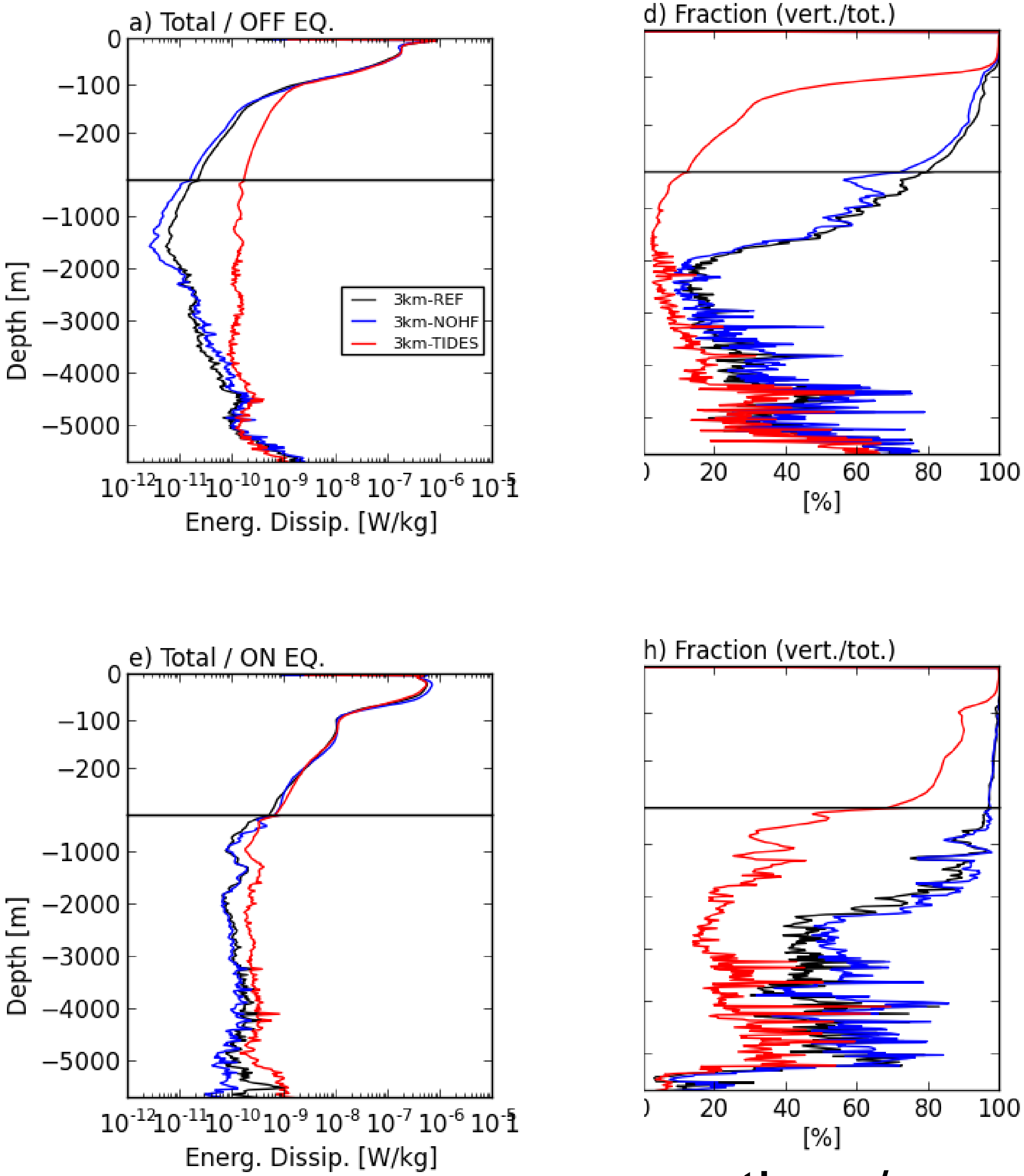
Most of the additional dissipation is :

- far to resemble theoretical predictions or parametrizations
- achieved by horizontal processes !

OFF
EQUATOR
(5S-10S)

AT-THE
EQUATOR
(1S-1N)

REF
NO-HF
TIDES



ε (W/kg)

ratio $\varepsilon_v/\varepsilon_h$ (%)

Summary

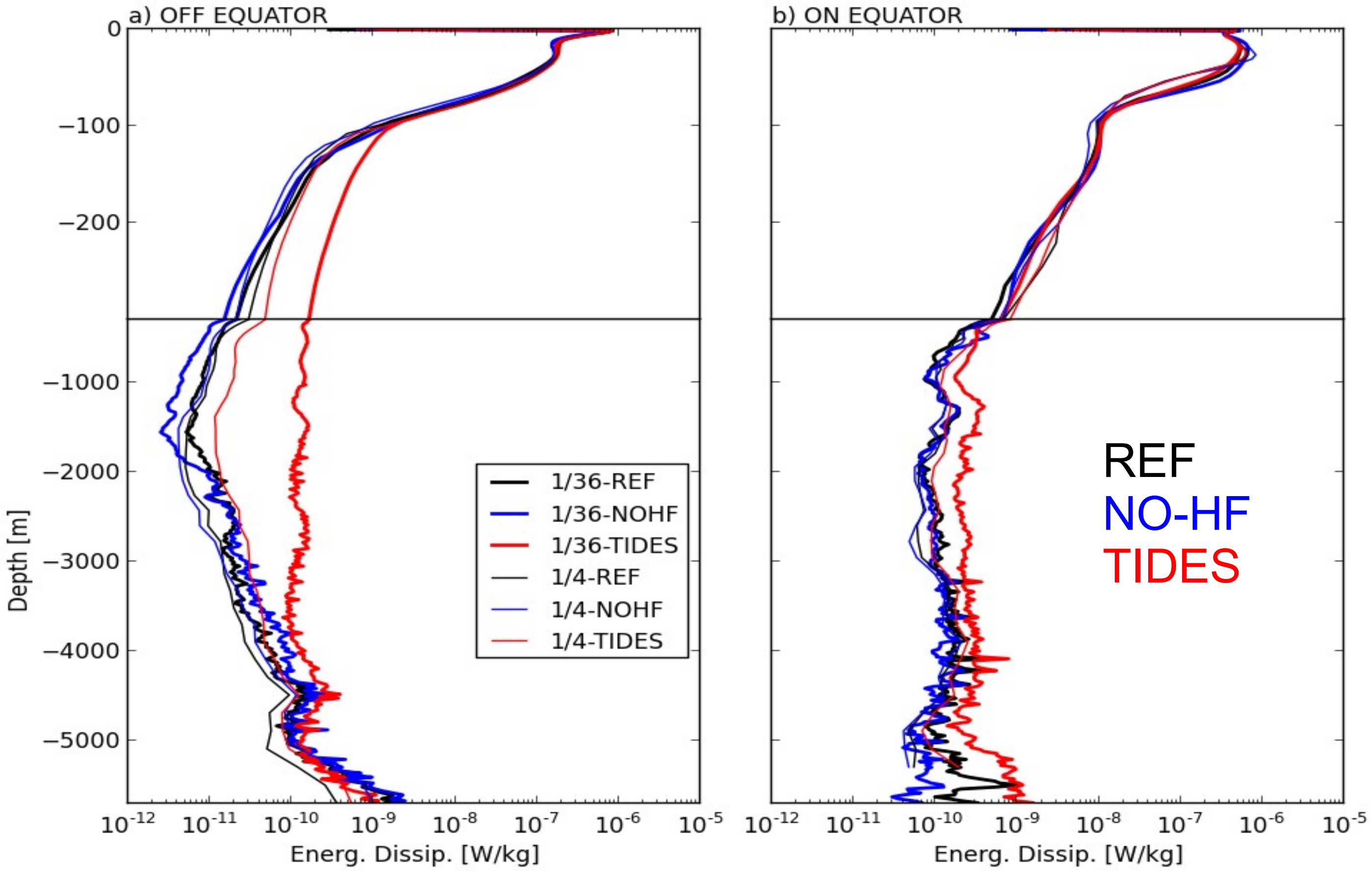
1. At the exception of the experiment with tides, the differences between simulation at ¼ (75 levels) and 1/36 (300 levels) are rather weak.

2. High-frequency winds have only a weak impact on interior mixing in the Tropical Atlantic

3. At 1/36°-300 levels interior ε (in the band 100-4000 meters) is dominated by tides.

Is this true ?

→ Convergence far to be achieved.



The amount of diapycnal mixing in the interior equatorial ocean remains open here... not sure up to which point the models will help...