Dynamical downscaling of the atmospheric and oceanic circulation In the Peru upwelling system for IPSL-CM4 climate scenarios

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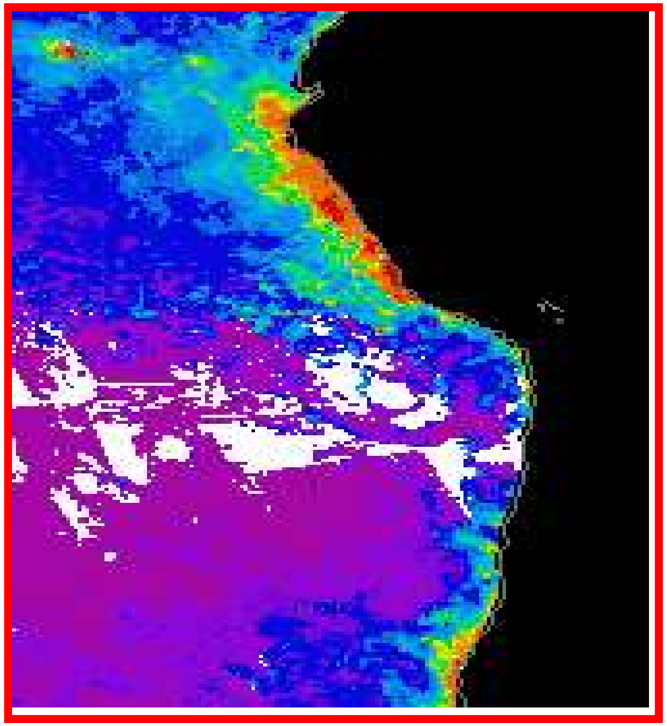
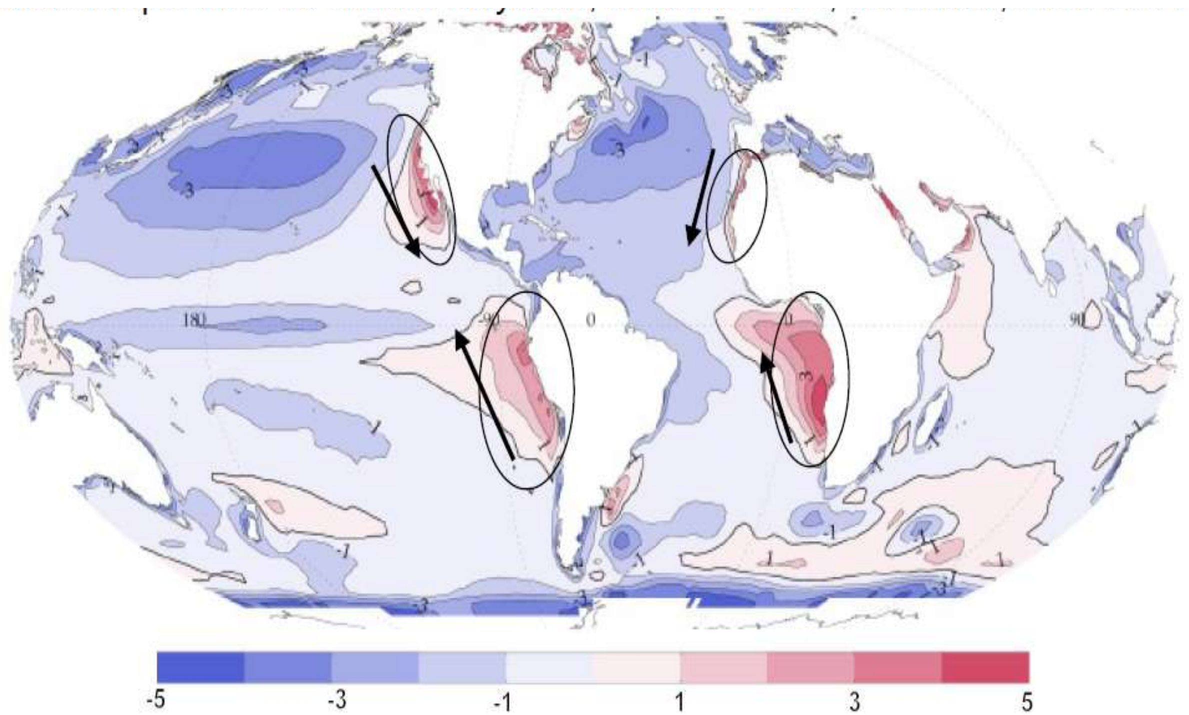
Francis Codron (LMD)

Why downscale climate change in upwelling systems?

Intense biological activity
... and in the future?



Chlorophyl map (phytoplankton)

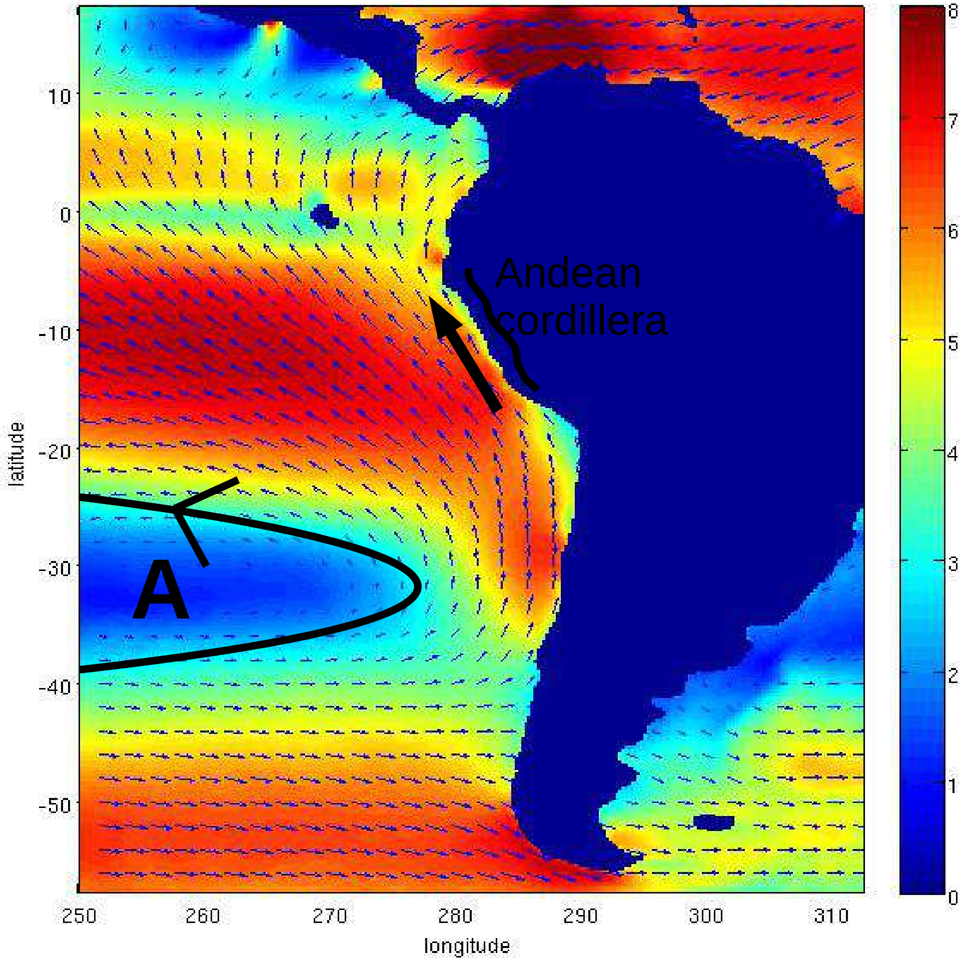


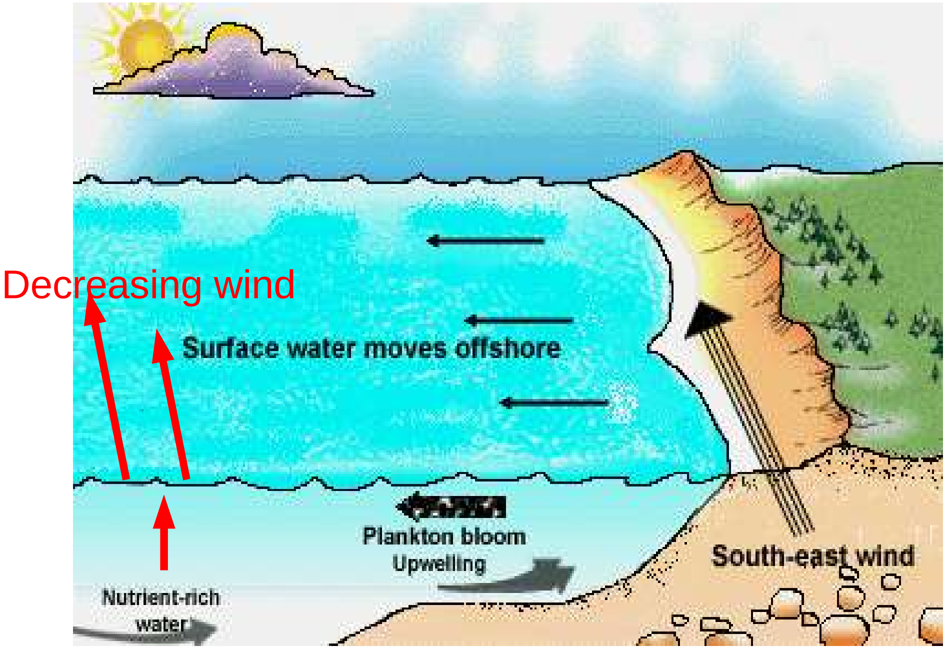
Mean SST bias for the IPCC models (AR4 models)

Eastern boundary upwelling system
=
strong bias in global models

A wind induced upwelling near Peru

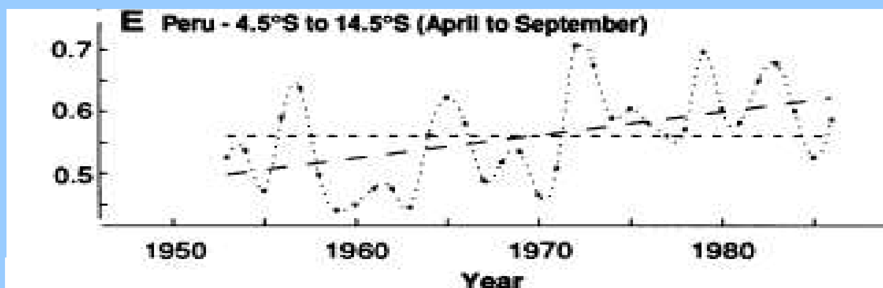
Quicksat surface wind





Evolution with climate change ?

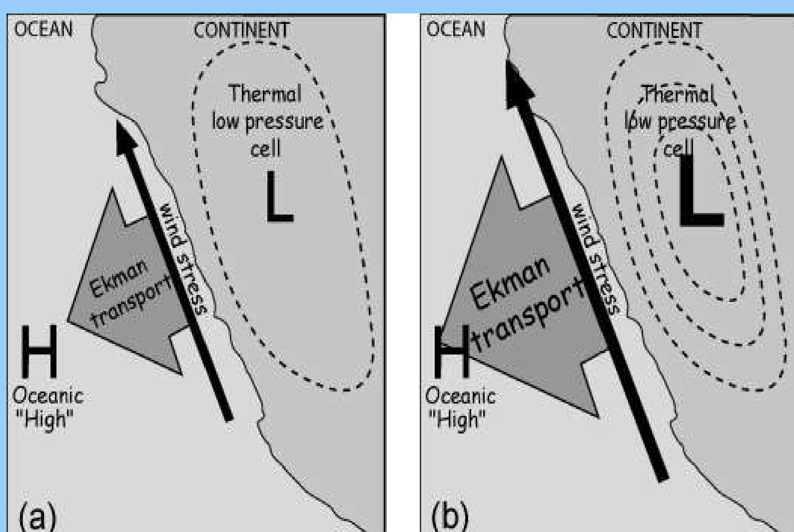
Bakun's hypothesis (Bakun, 1990) :



Alongshore wind stress observations

Now

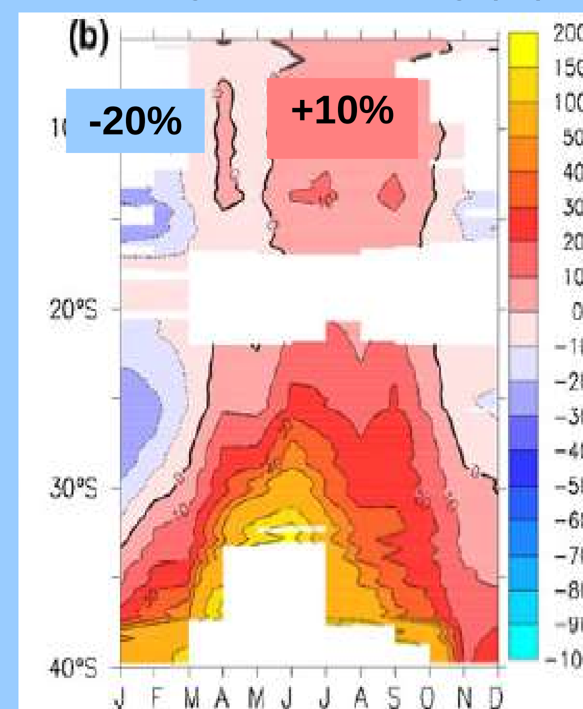
Future



Atmospheric downscaling :

- Garreaud and Falvey (2009) :
regional model PRECIS :
alongshore wind intensification near Chili
- Goubanova et al. (2011) :
statistical downscaling

Alongshore wind intensity modifications with global warming (%)

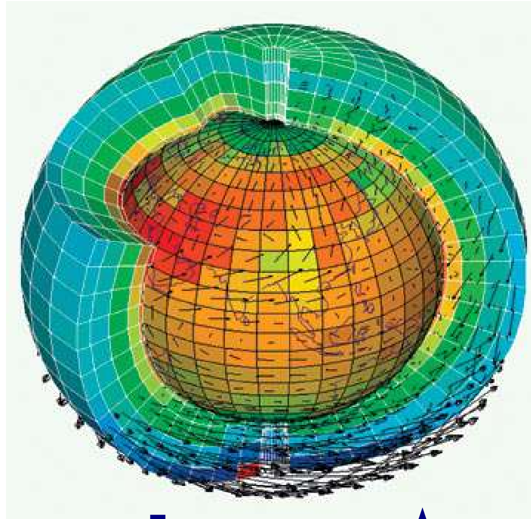


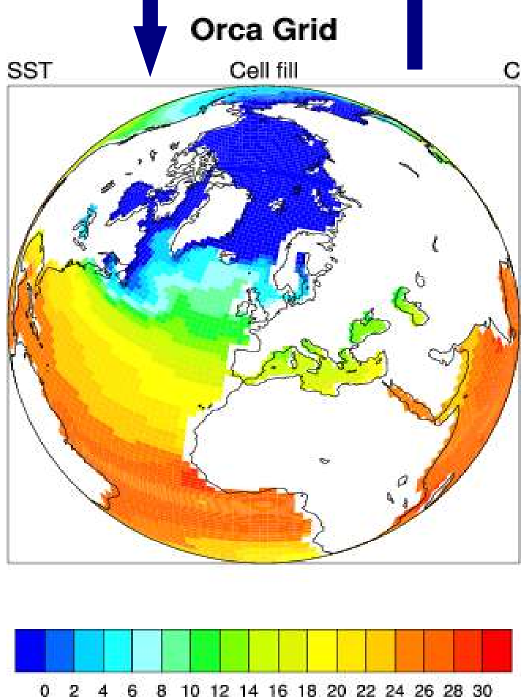
An atmospheric dynamical downscaling

IPSL-CM4 global model

<u>LMDZ :</u>

Atmospheric component
19 vertical level
2° horizontal resolution

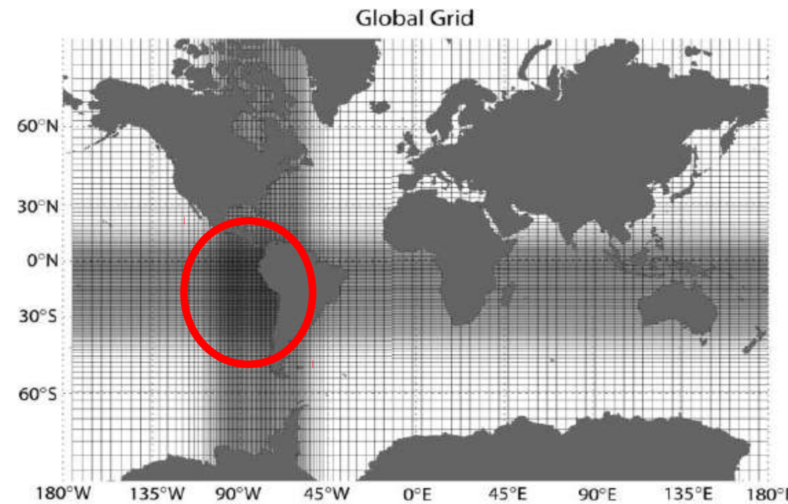




<u>ORCA2 :</u>

Oceanic component
2° horizontal resolution

<u>LMDZ with refined grid</u>



Resolution near Peru : 50km
Resolution otherwise : 2°

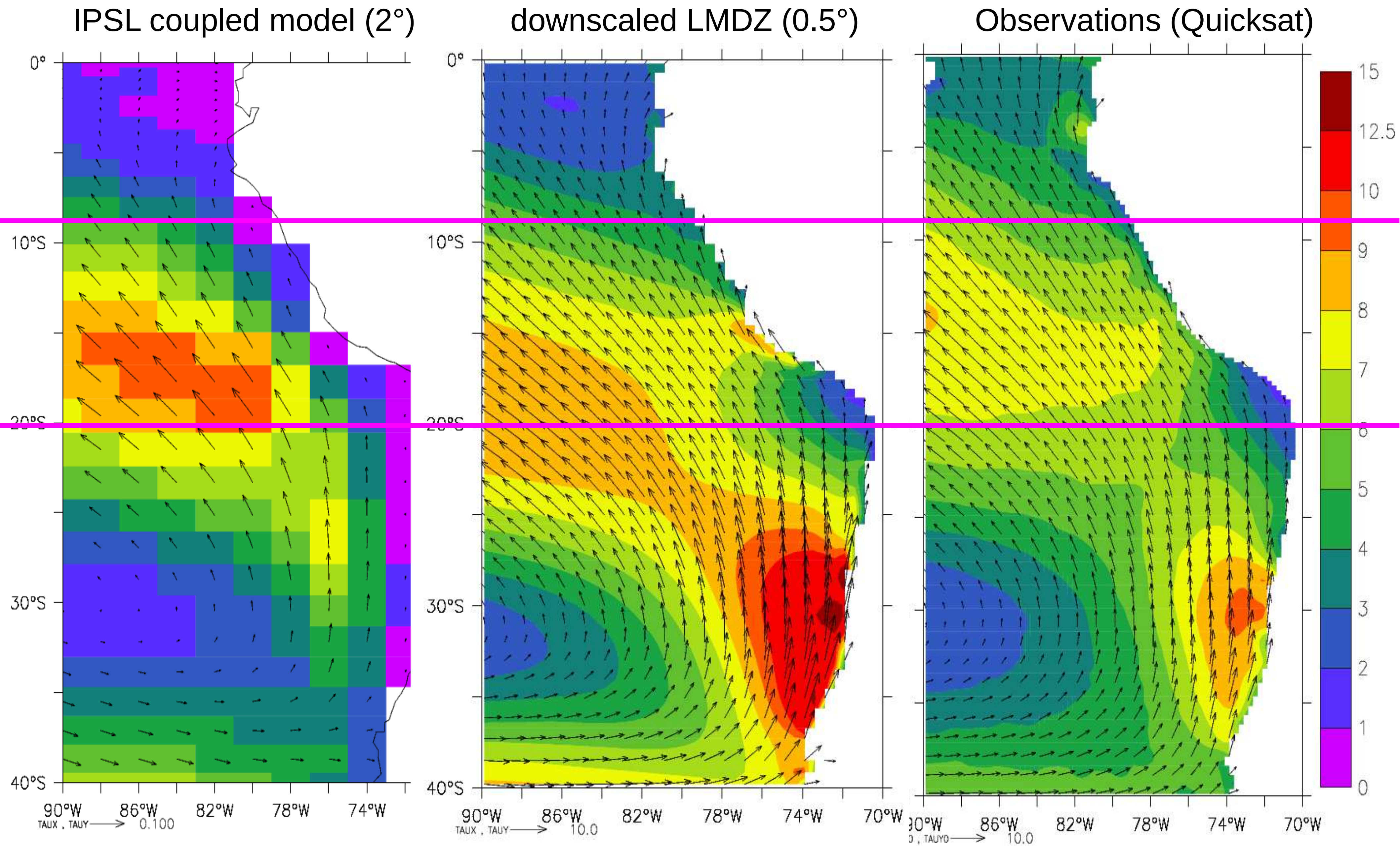
SST forcing :
$SST^{obs} + SST^{IPSL}_{scenario} - SST^{IPSL}_{Ctl}$

SST^{obs} : AMIP climatology (0.5°)

Radiative forcing : using CO_2 concentrations

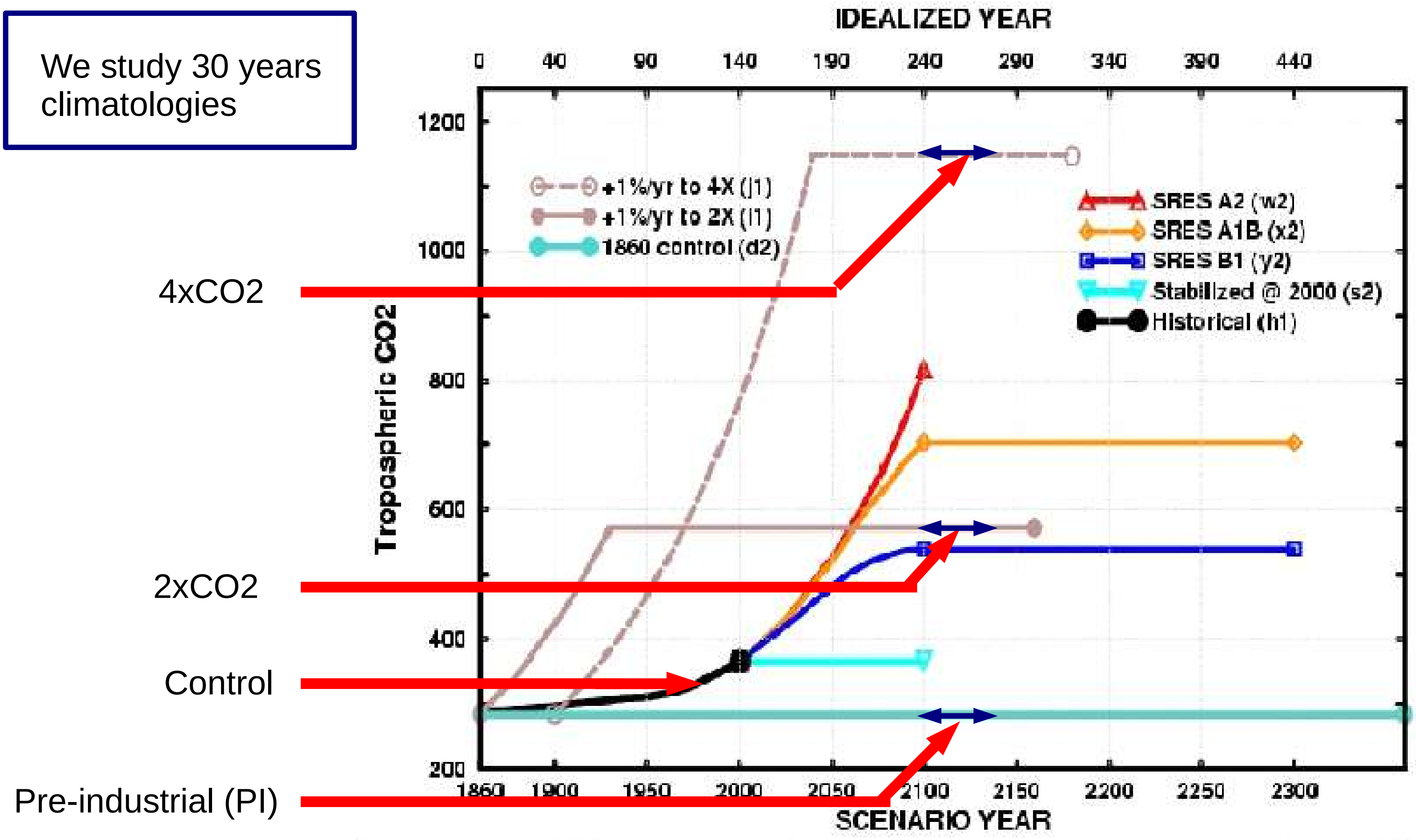
Validation of the simulations

Surface wind intensity



4 climate scenarios with different tropospheric CO_2 rates

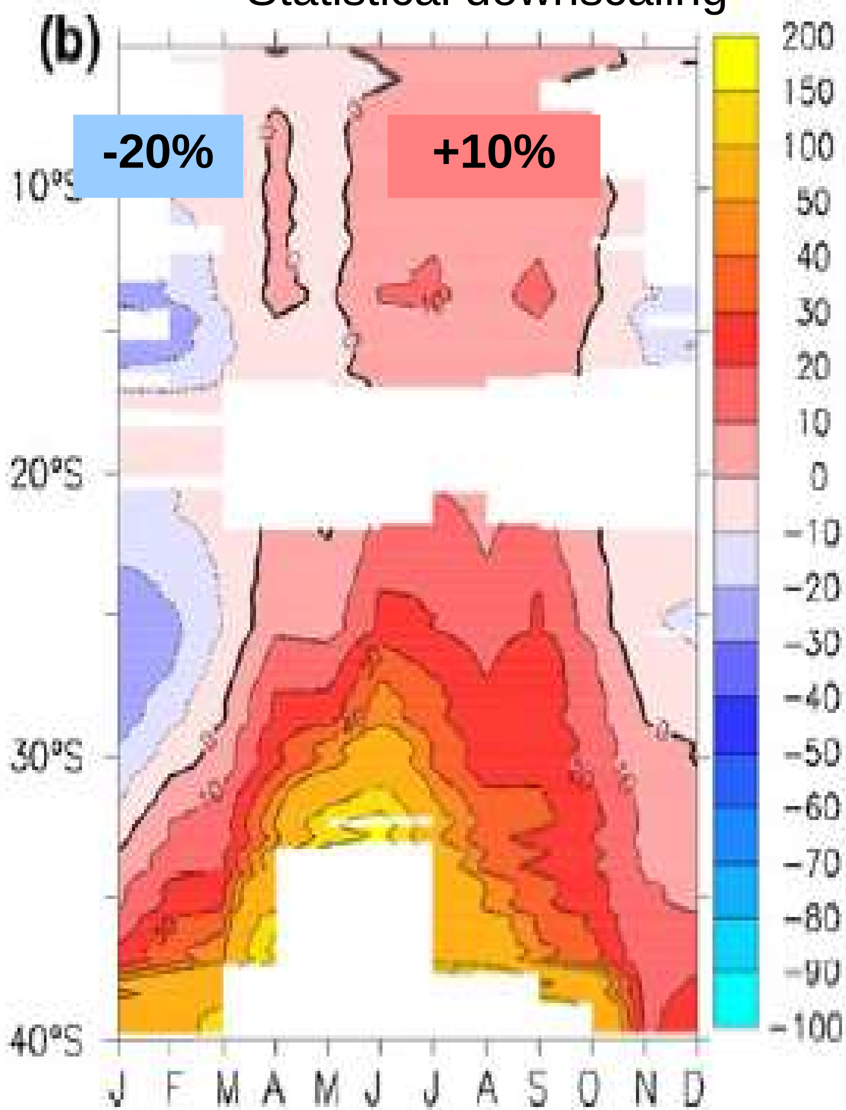
We study 30 years climatologies



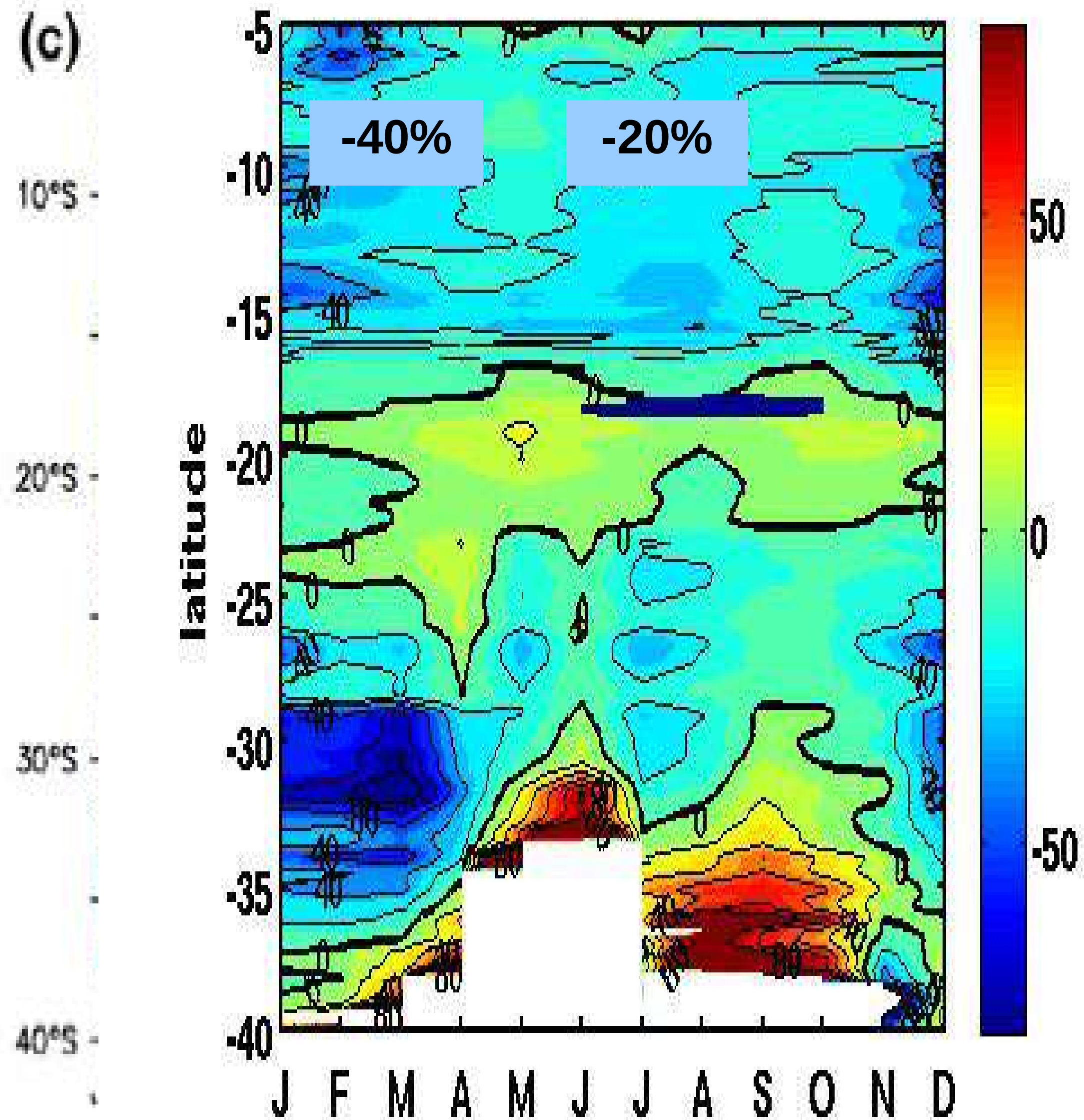
Main result : alongshore wind

Alongshore wind stress intensity difference between 4CO2 and PI (percent)

Goubanova et al. (2010) : Statistical downscaling



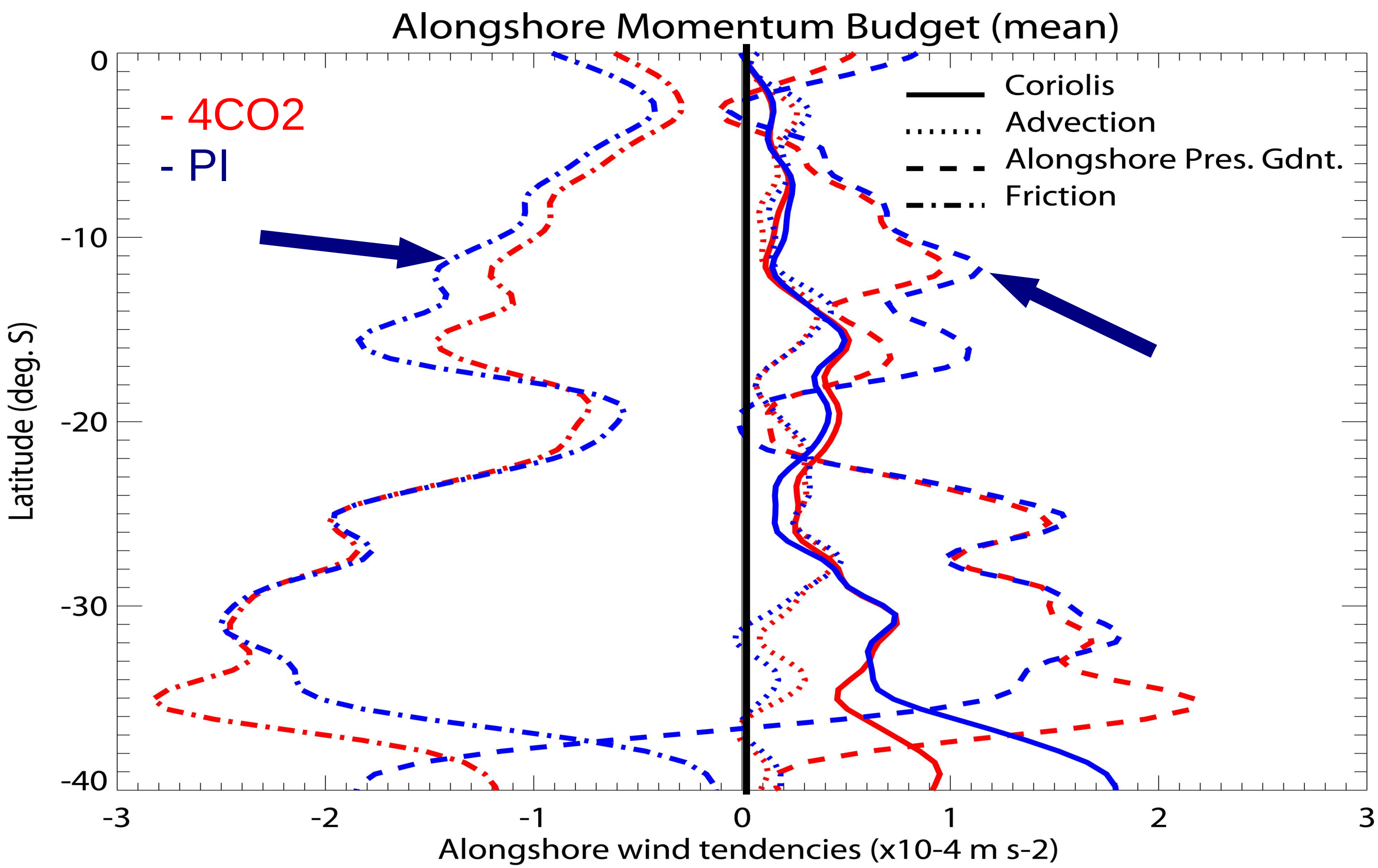
Dynamical downscaling

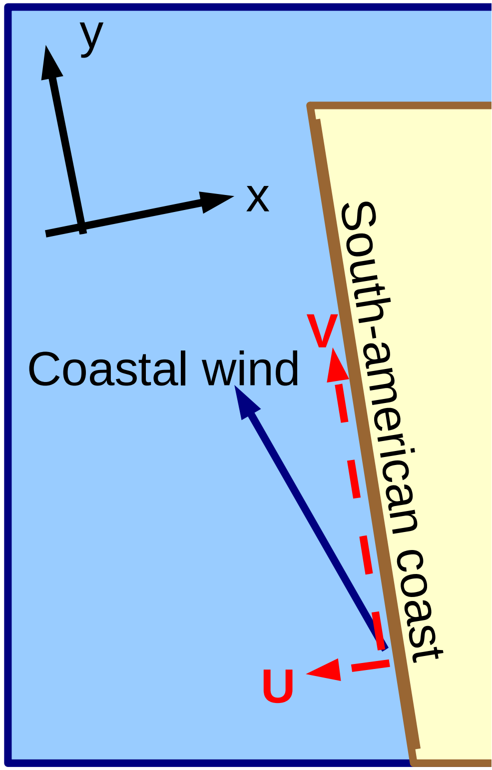


Alongshore momentum balance

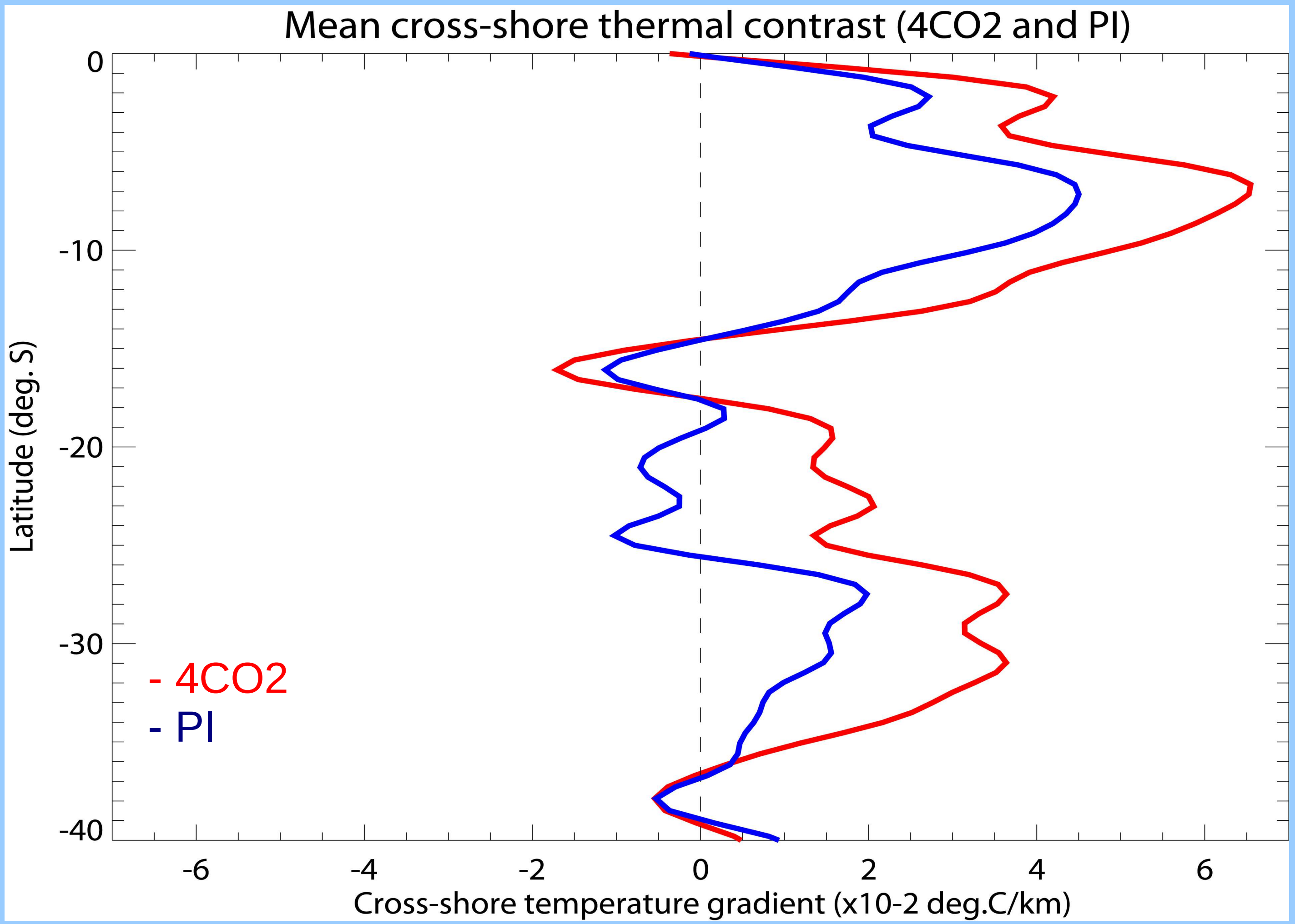
$$\frac{\partial V}{\partial t} = \underbrace{-U\frac{\partial V}{\partial x} - V\frac{\partial V}{\partial y} - W\frac{\partial V}{\partial z}}_{\text{Advection}} \underbrace{- \frac{1}{\rho}\frac{\partial P}{\partial y}}_{\text{Alongshore pressure gradient}} \underbrace{- fU}_{\text{Coriolis}} + \underbrace{V_m}_{\text{Friction}},$$

Advection — Alongshore pressure gradient — Coriolis — Friction





$$\frac{1}{\varrho}\frac{\partial P}{\partial y} = V_m = -cV \qquad (1)$$

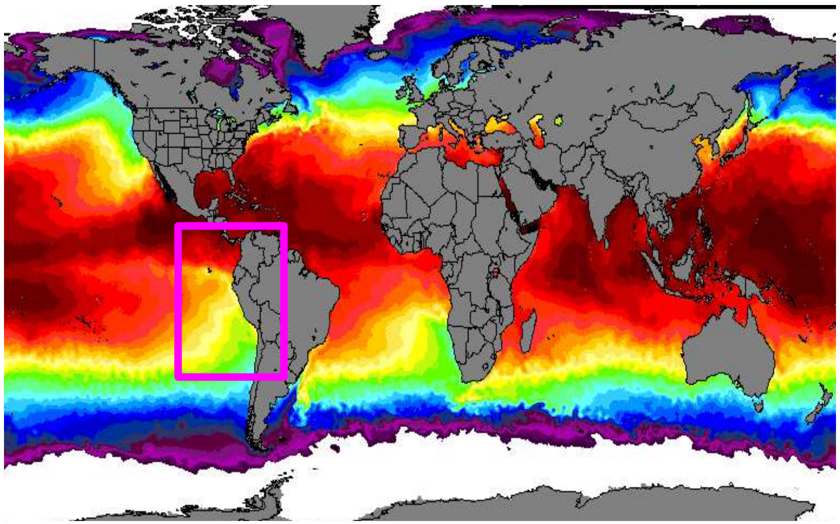


$$grad\,T = \frac{\partial T}{\partial x}$$

-Increase of cross-shore thermal gradient (cf Bakun)

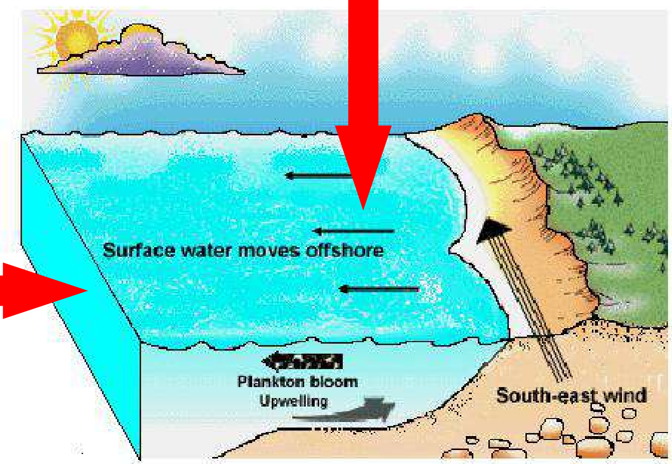
- But no compensation of the large scale effect : $\frac{\partial P}{\partial x}$ *decrease*

Oceanic response to climate change



Atmospheric forcing :
Dowscalled LMDZ

Boundary conditions :
Coupled simulation from IPSL-CM4



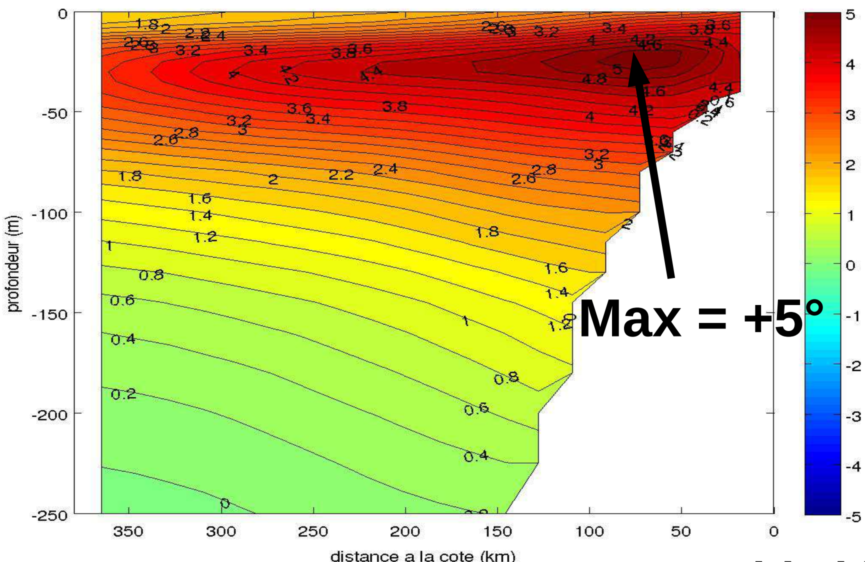
ROMS
Resolution 1/6° (18km)
32 vertical level
Configuration Echevin et al. (2012)

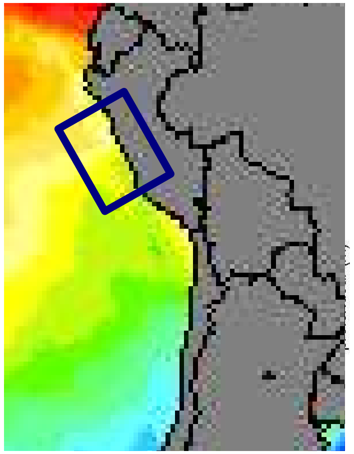
Run	Forcing
roms_ctrl_lmdz	LMDZ control simulation
roms_ctrl_quicksat	Observations (Quicksat + COADS)
roms_PI	LMDZ PI scenario
roms_2CO2	LMDZ 2CO2 scenario
roms_4CO2	LMDZ 4CO2 scenario

Oceanic impact of the “raw” downscaled forcing

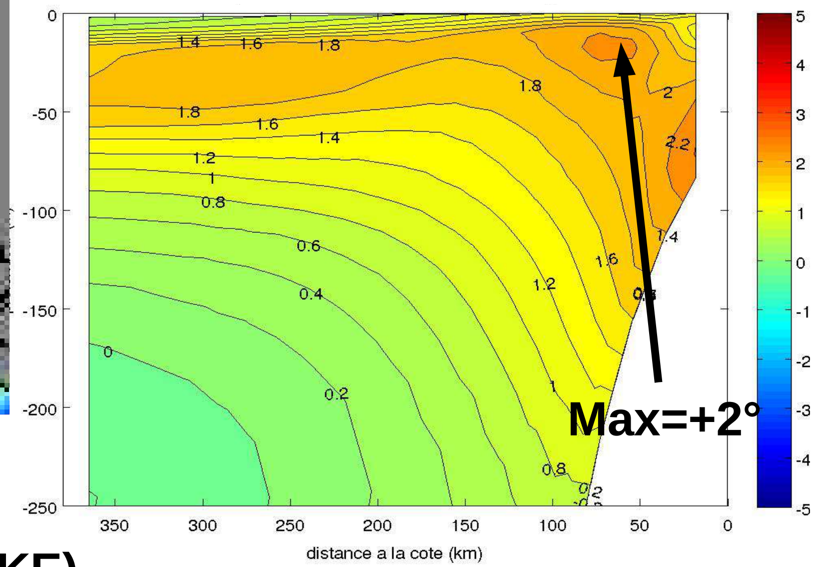
Zonal section off central peru coast : summer temperature anomalies with CARS (obs)

roms_ctrl_lmdz



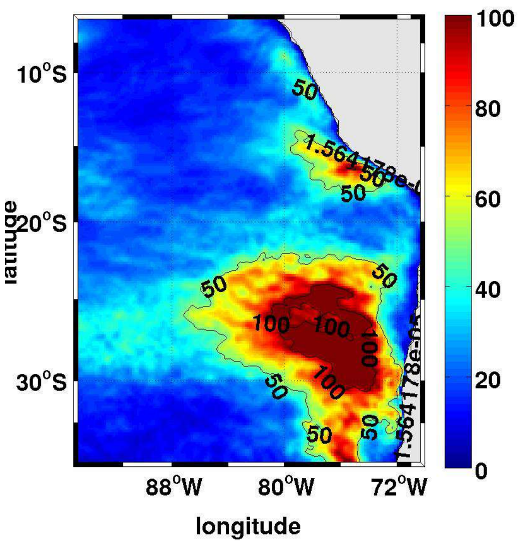


roms_ctrl_quicksat

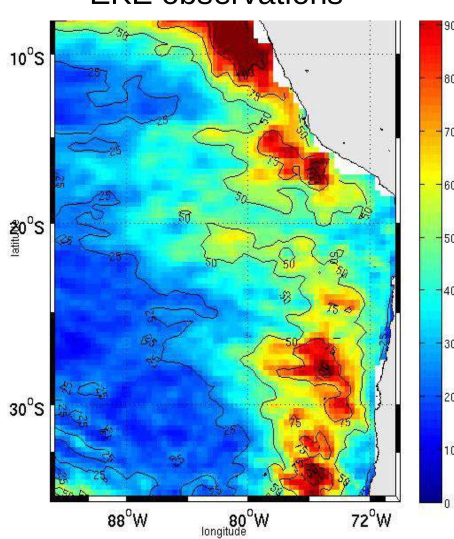


Eddy kinetic energy (EKE)

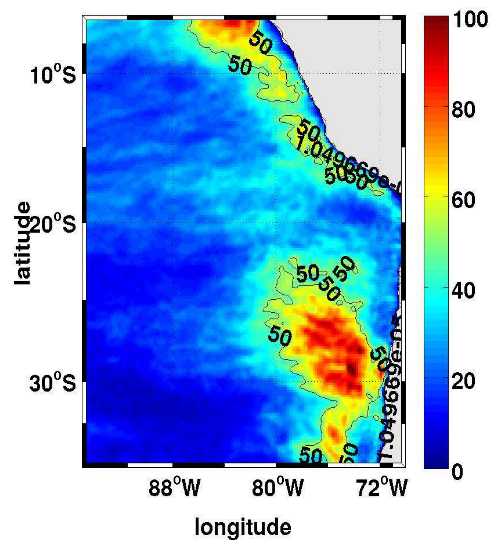
EKE (annual mean) in cm²/s² (roms ctl lmdz)



EKE observations



EKE (annual mean) in cm²/s² (roms ctl quicksat)



We used LMDZ global warming anomalies to force ROMS

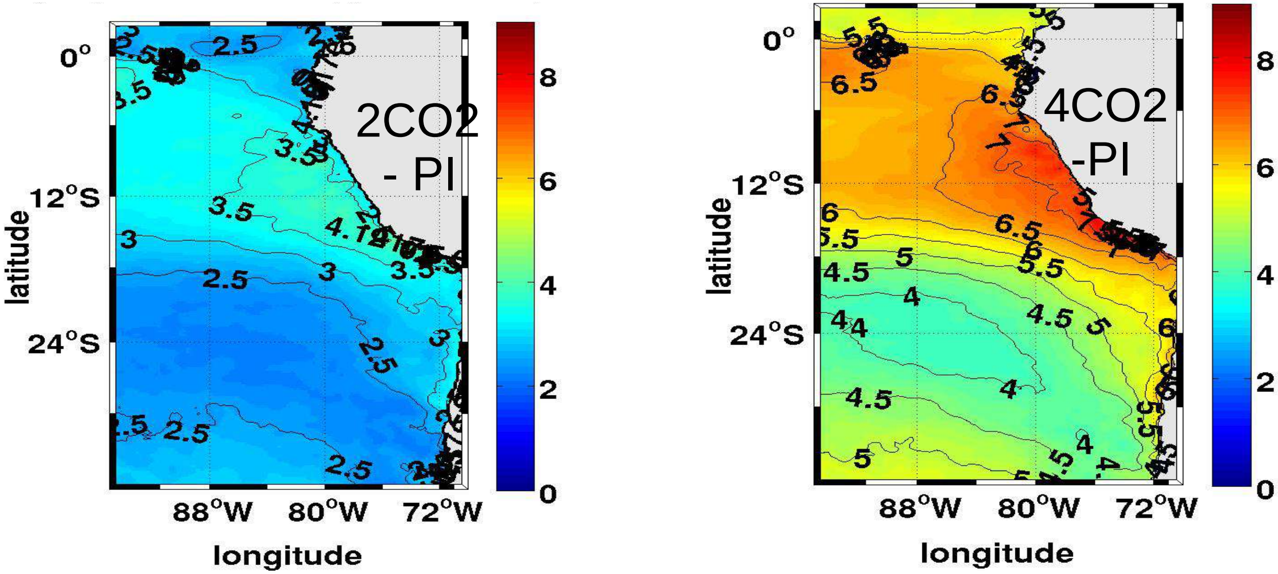
Observational climatology + LMDZ anomalies

EX : Scow wind + (LMDZ 4xCO_2 wind – LMDZ control wind)

Hypothesis : The bias introduced by LMDZ is not modified with climate change

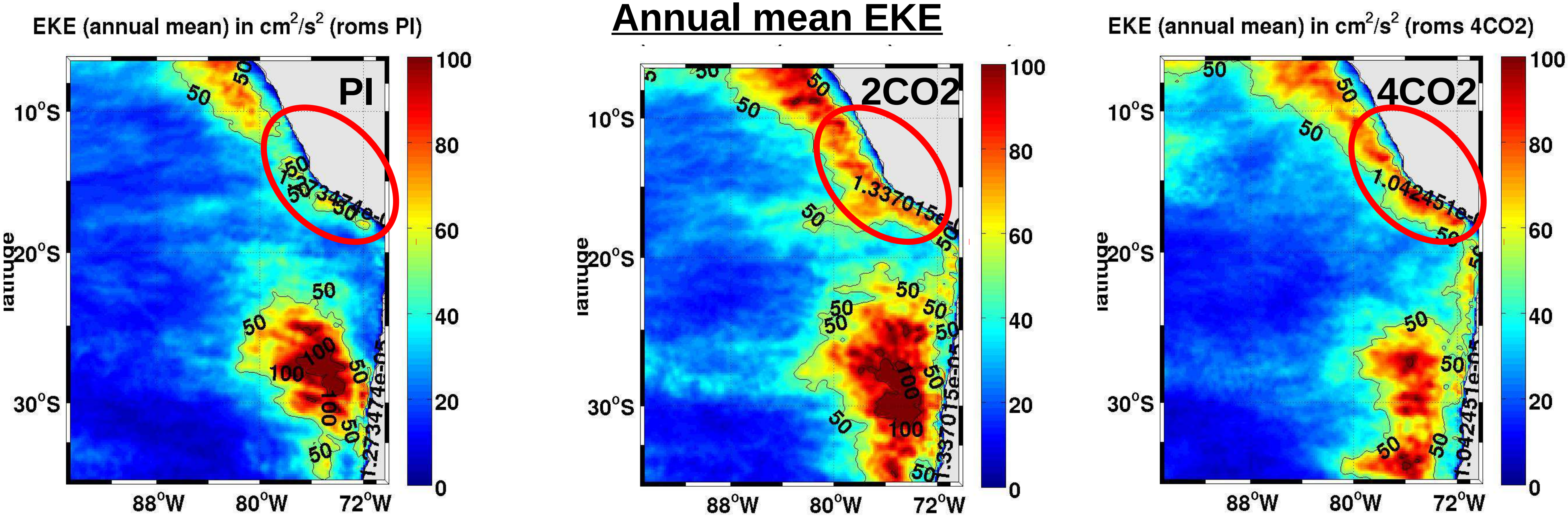
Main results

SST anomalies with PI



More intense global warming near peruvian coast

Annual mean EKE



Conclusion

An atmospheric downscaling :

LMDZ global model with a refined grid

Alongshore wind diminution near the peruvian coast due to diminution of pressure gradient

↓ Force

An oceanic downscaling :

Regional ROMS model

Relatively realistic atmospheric simulation => too much bias
-> use of anomalies

Peruvian upwelling diminution, even more than predicted by wind

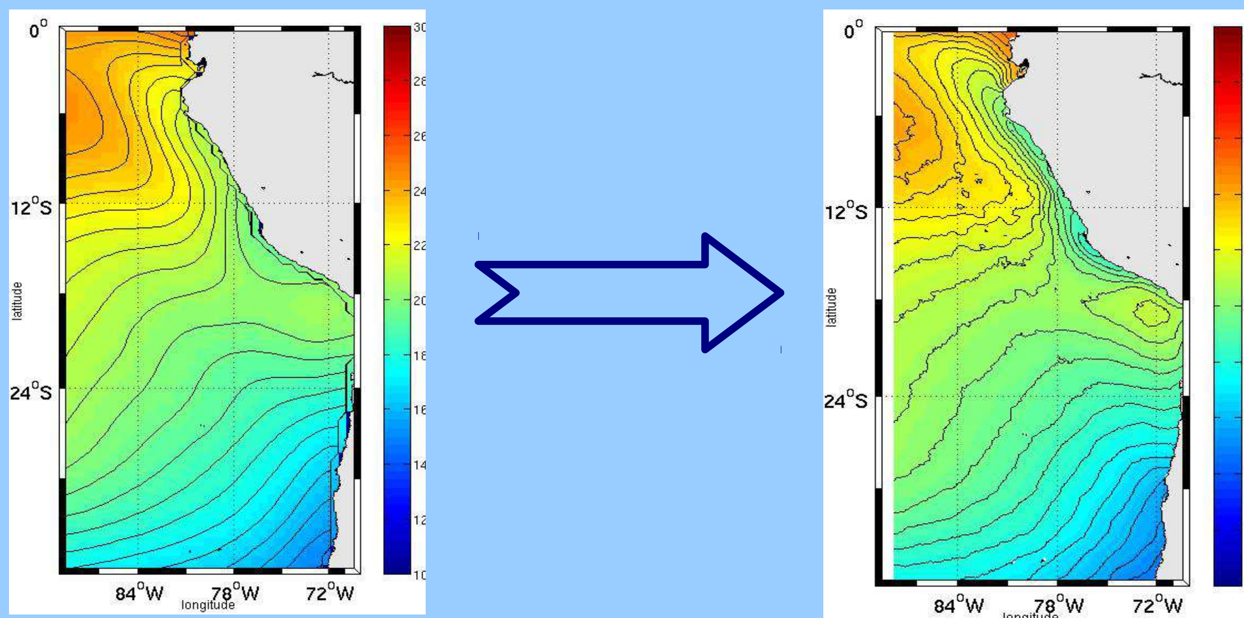
EKE intensification (near Peru)

Perspectives

Higher horizontal resolution to modelize better the coastal effects

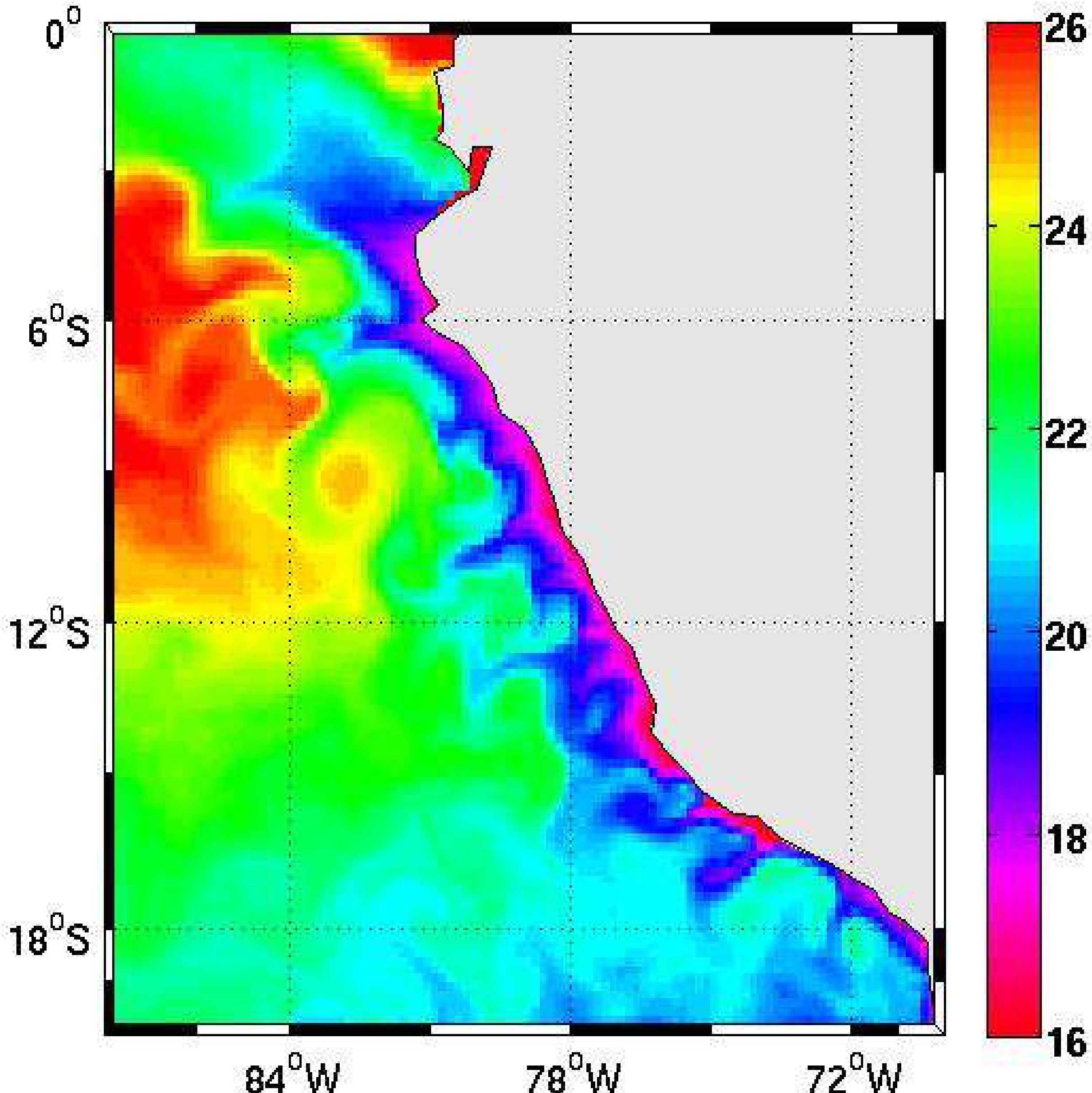
Higher LMDZ vertical resolution : to improve the cloud modelization (heat flux)

Higher SST resolution to force LMDZ dilated



Coupled regionals models : WRF + NEMO => My thesis!

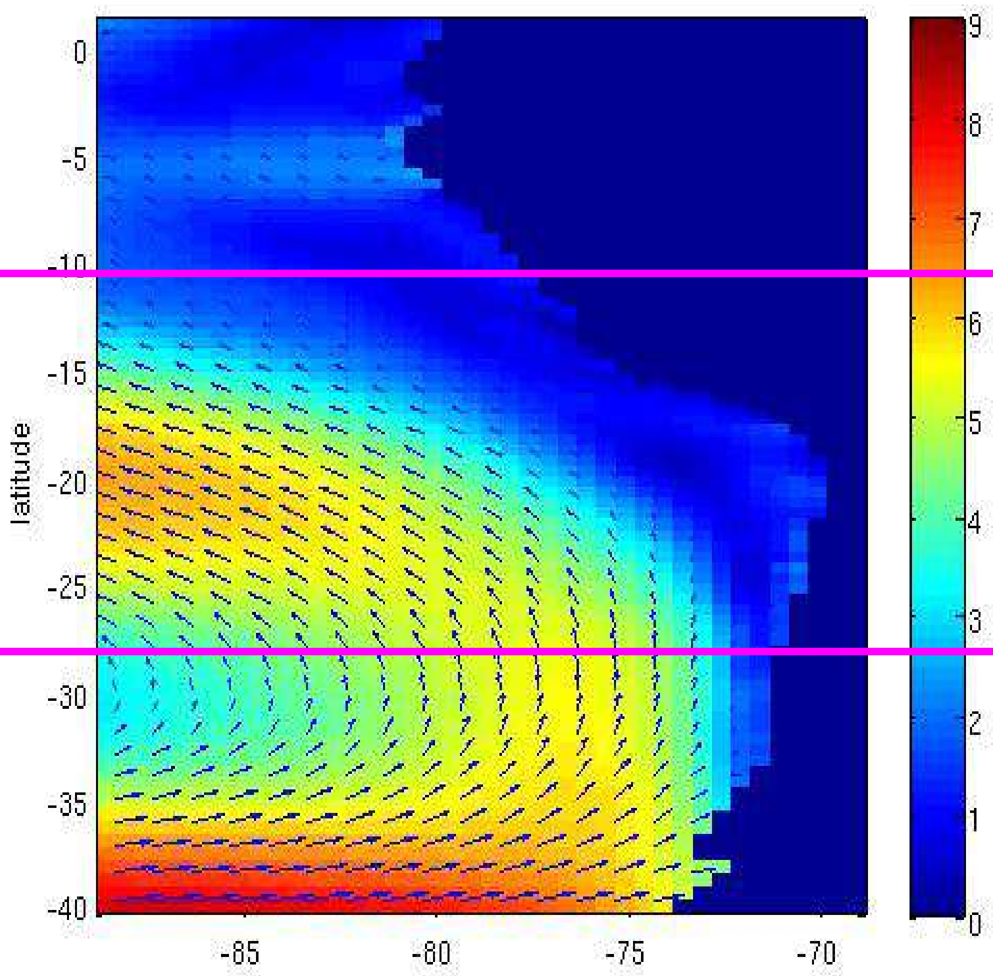
A strong mesoscale activity : influence on biology



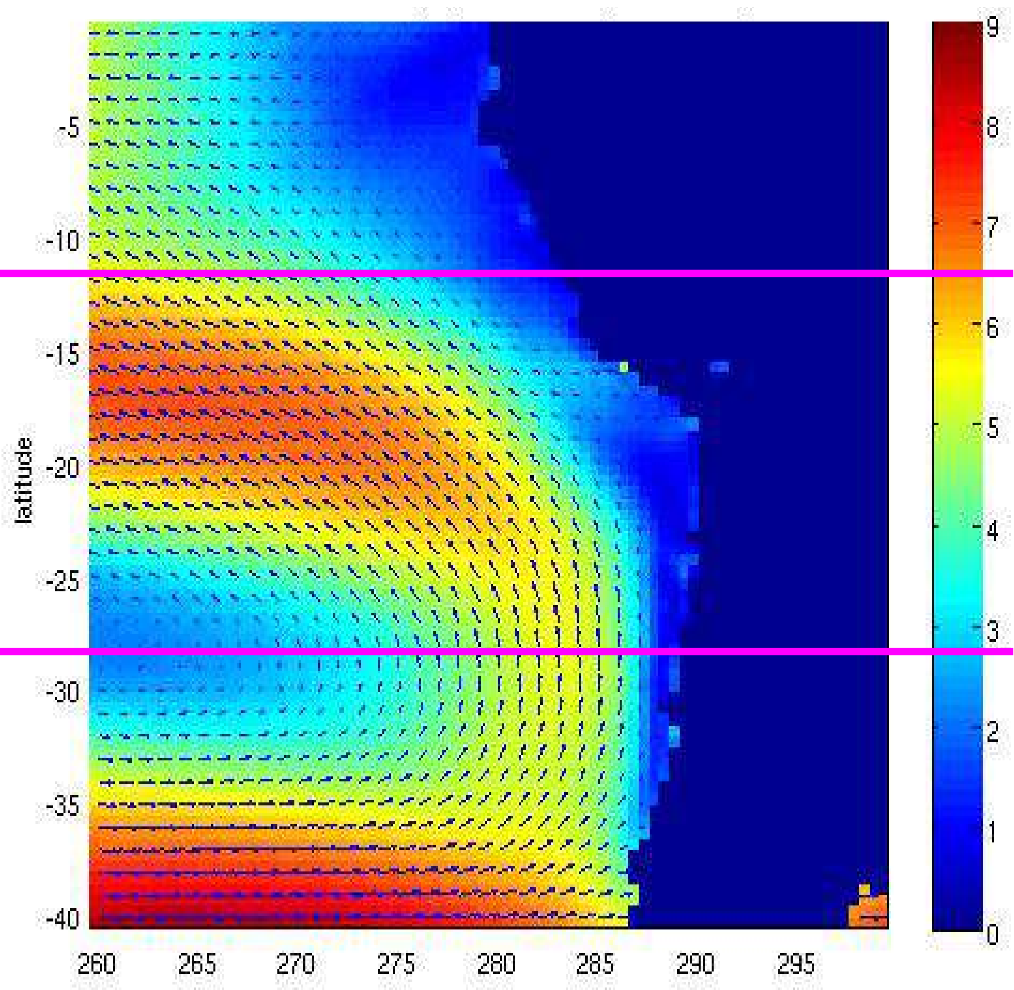
Validation of the simulations

Wind intensity at 850 HPa (annual mean)

Downscaled LMDZ

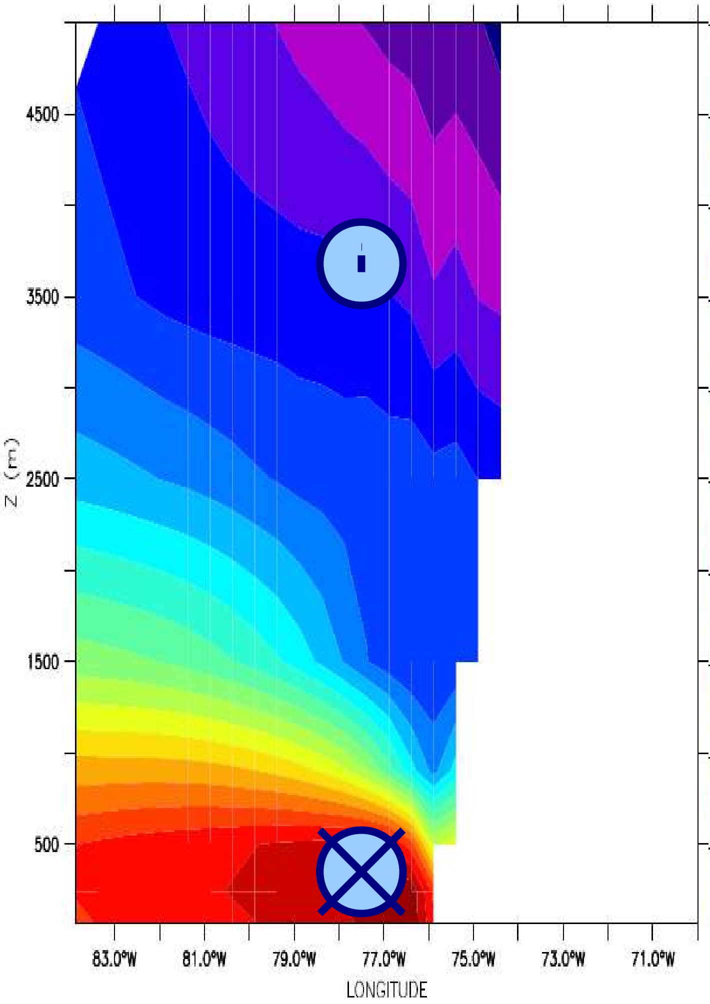


CSFR (reanalysis)

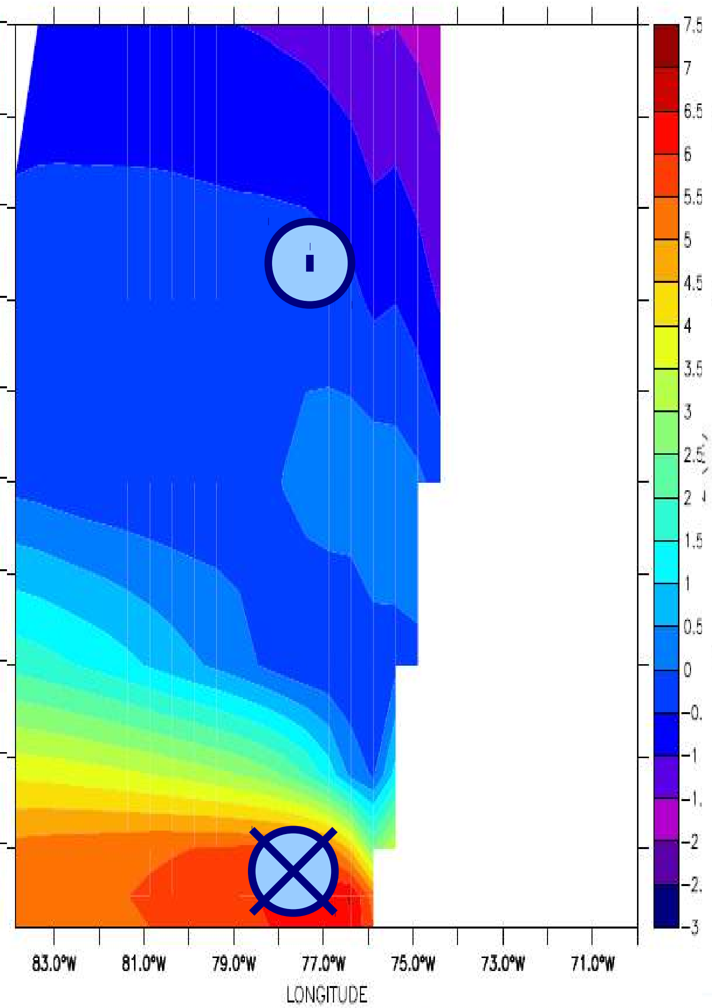


Global warming evolution

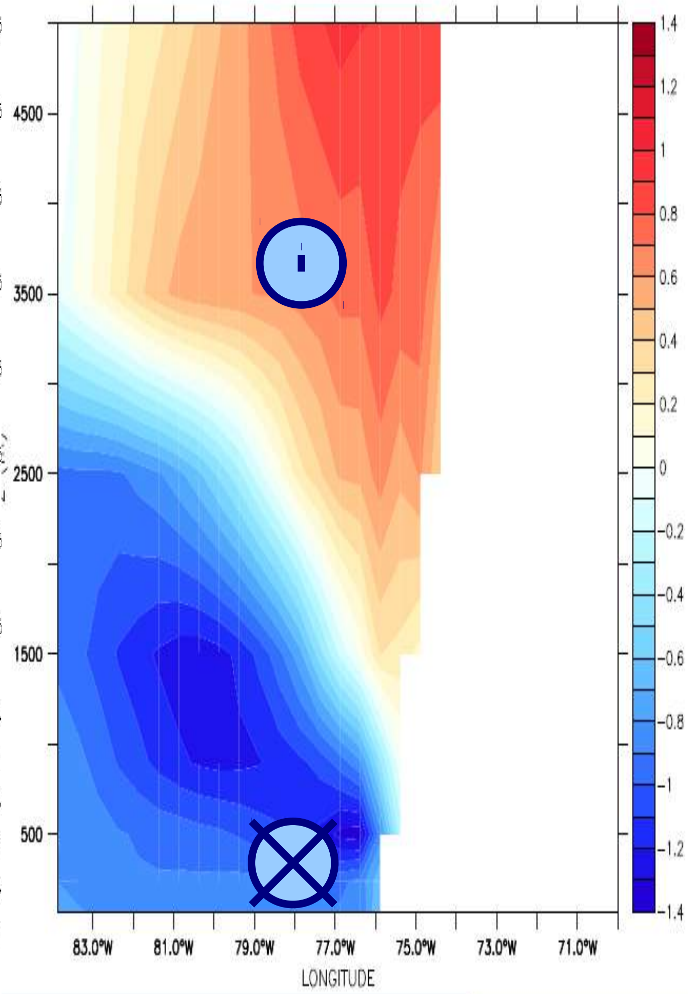
Zonal cut at 15°S : meridian wind (m/s) during winter



Pre-industrial

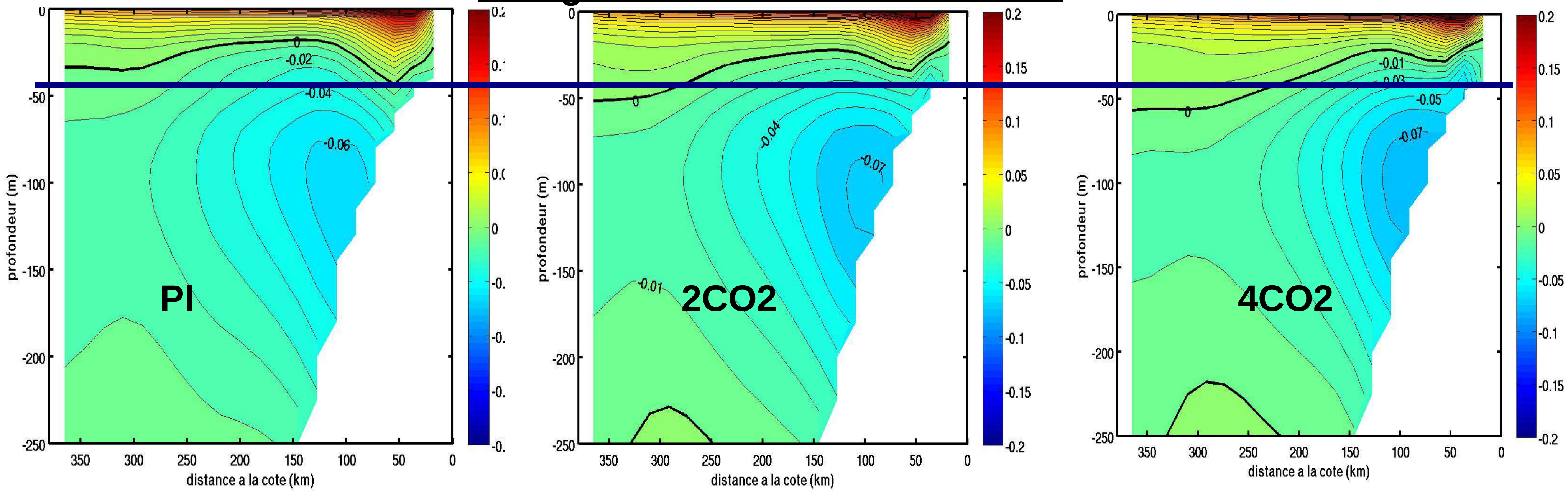


4CO2



Difference 4CO2-PI

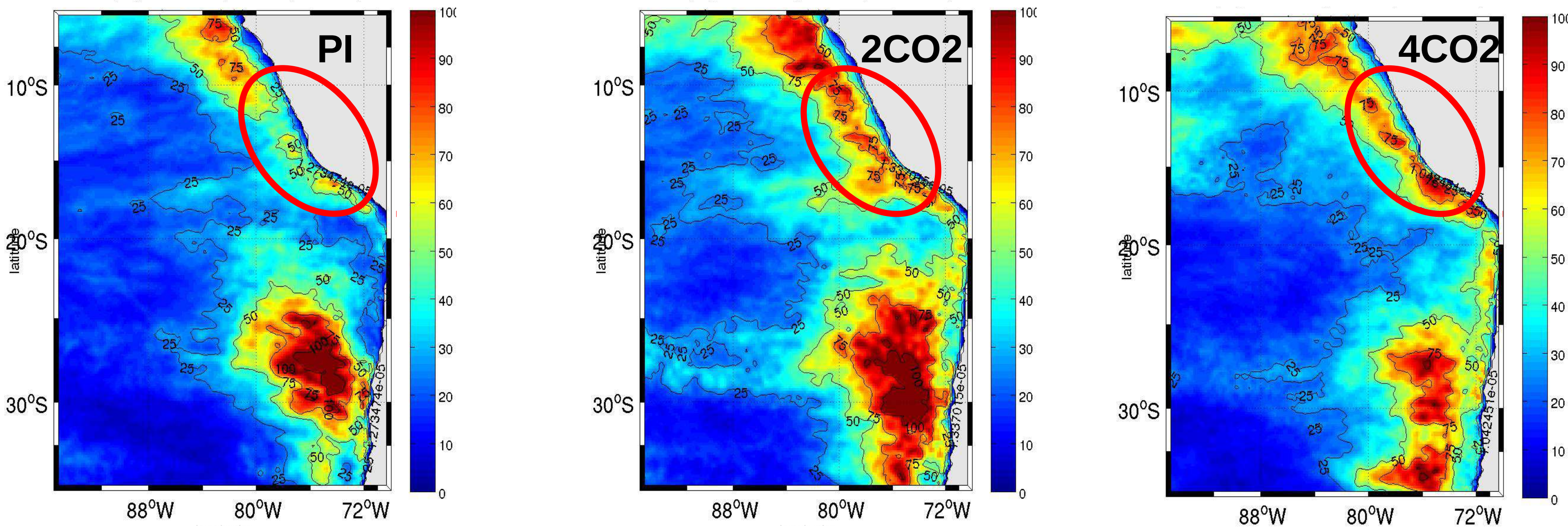
Alongshore current zonal section



Shallowing of the surface current
Counter current intensification

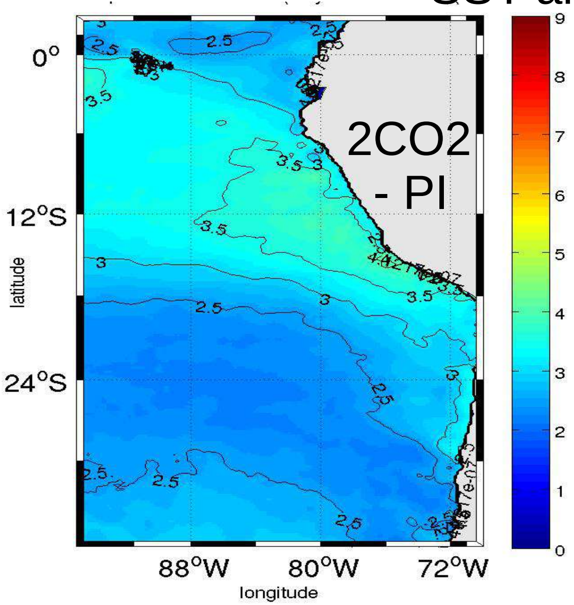
} vertical shear intensification => baroclinic instability intensification

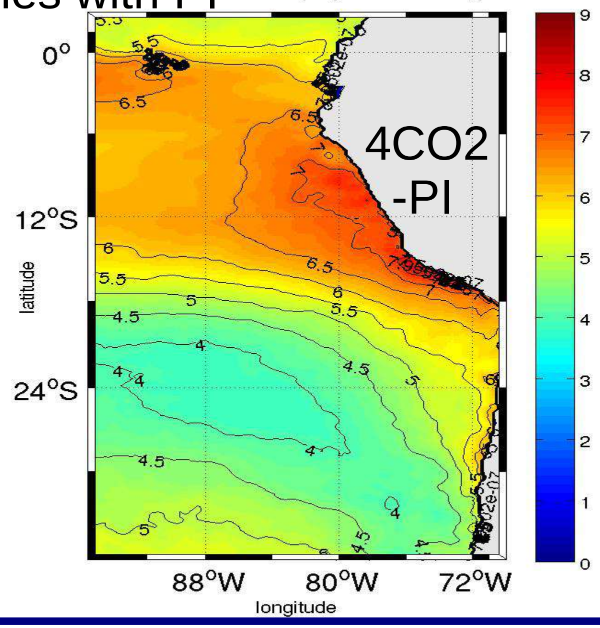
Annual mean EKE



Main results

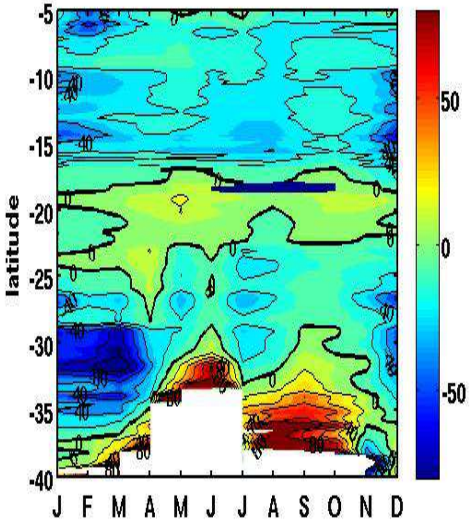
SST anomalies with PI

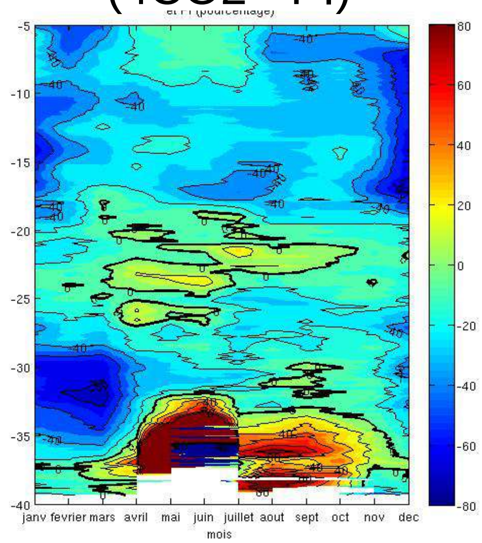




More intense global warming near peruvian coast

Upwelling rate change (%)
(4CO2 - PI)





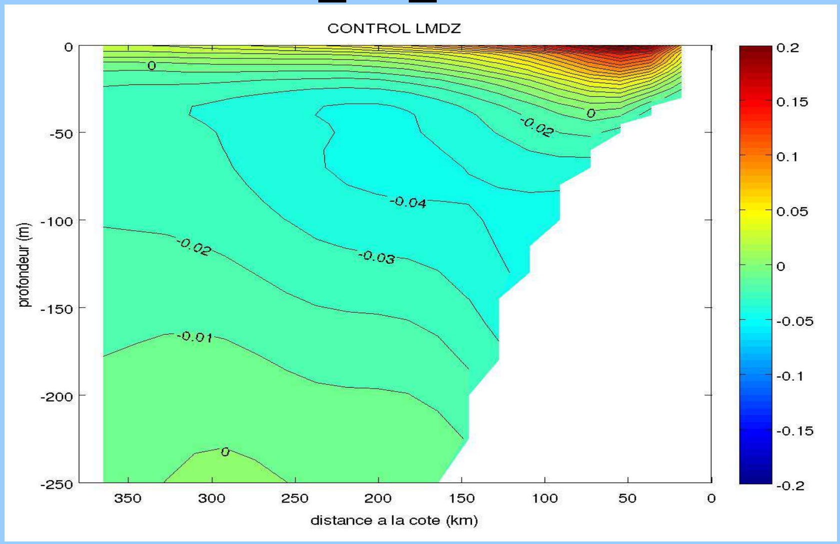
upwelling reduction during the whole year near peruvian coast

Ocean response is not linear with the alongshore diminution

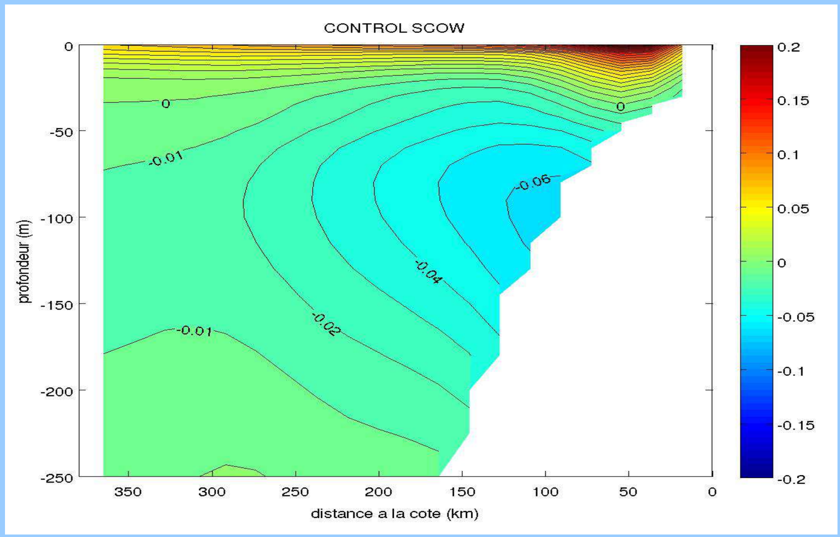
The use of the LMDZ => a strong bias

Zonal cut off central peru coast : Alongshore velocities

roms_ctrl_**lmdz**



roms_ctrl_**quicksat**



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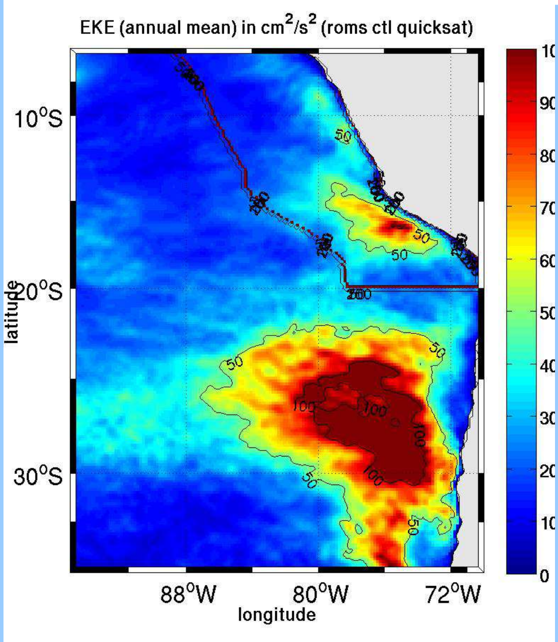
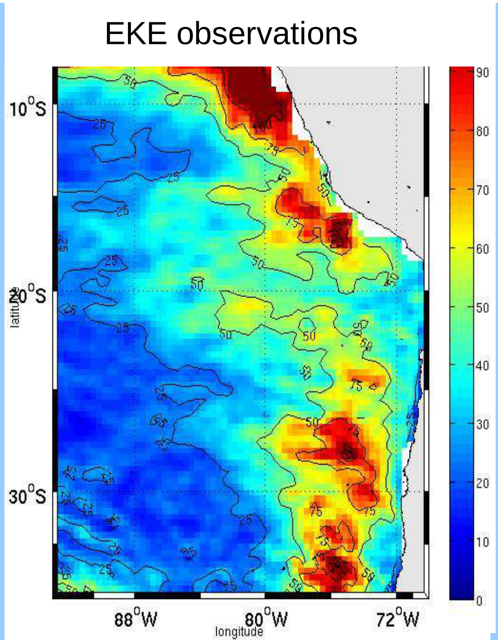
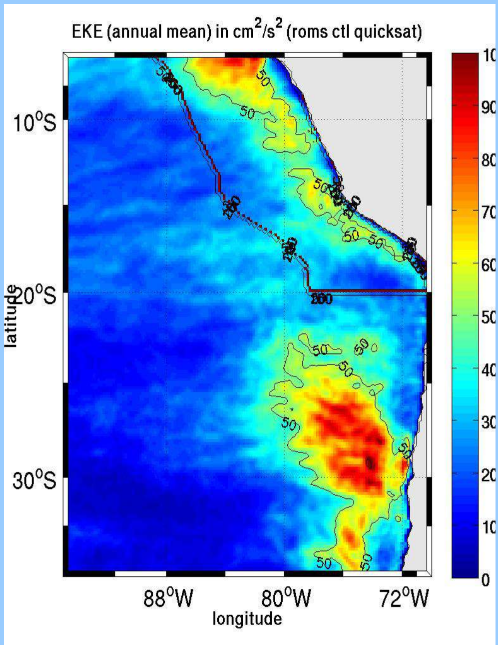


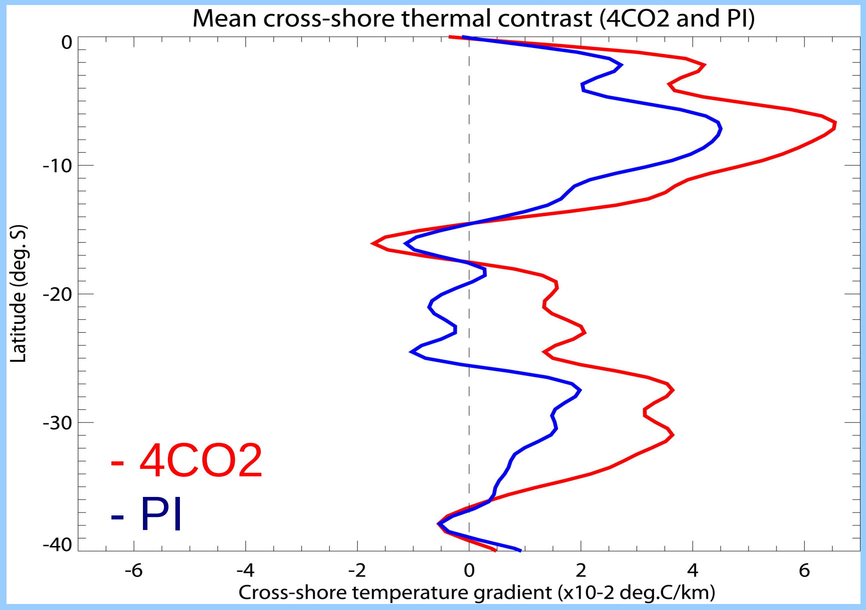




Cross-shore momentum balance

$$0 \approx -\frac{1}{\rho}\frac{\partial P}{\partial x} + fV. \quad \textbf{(2)}$$

$$(1)+(2) \rightarrow \frac{1}{c}\frac{\partial P}{\partial y} = \frac{-1}{f}\frac{\partial P}{\partial x}$$



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