# Changes in the Peruvian upwelling system under future climate scenarios

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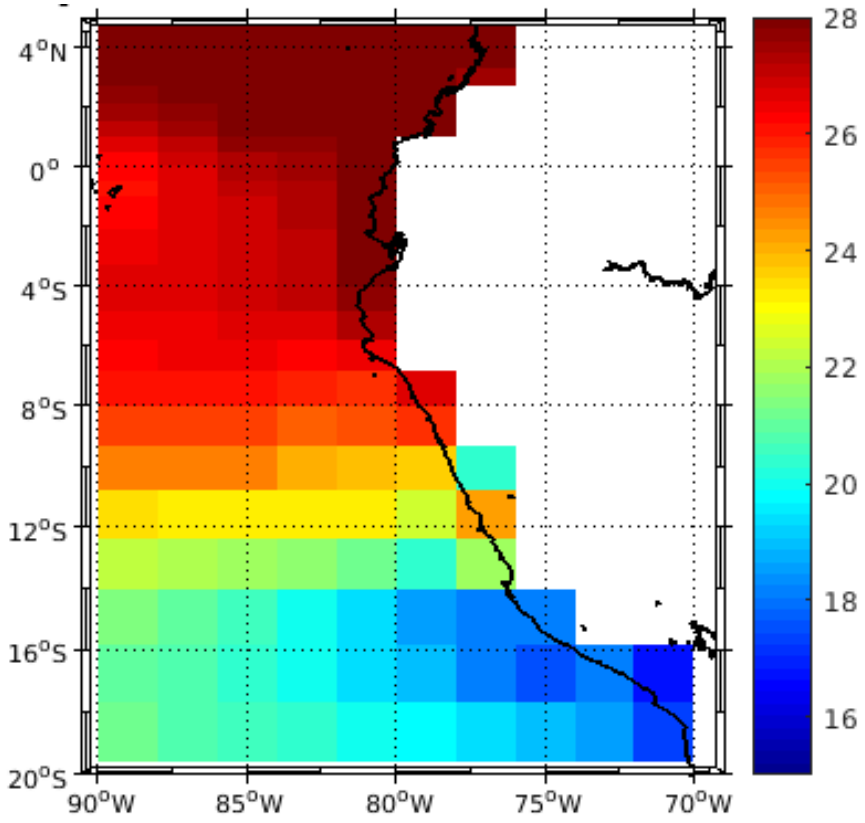
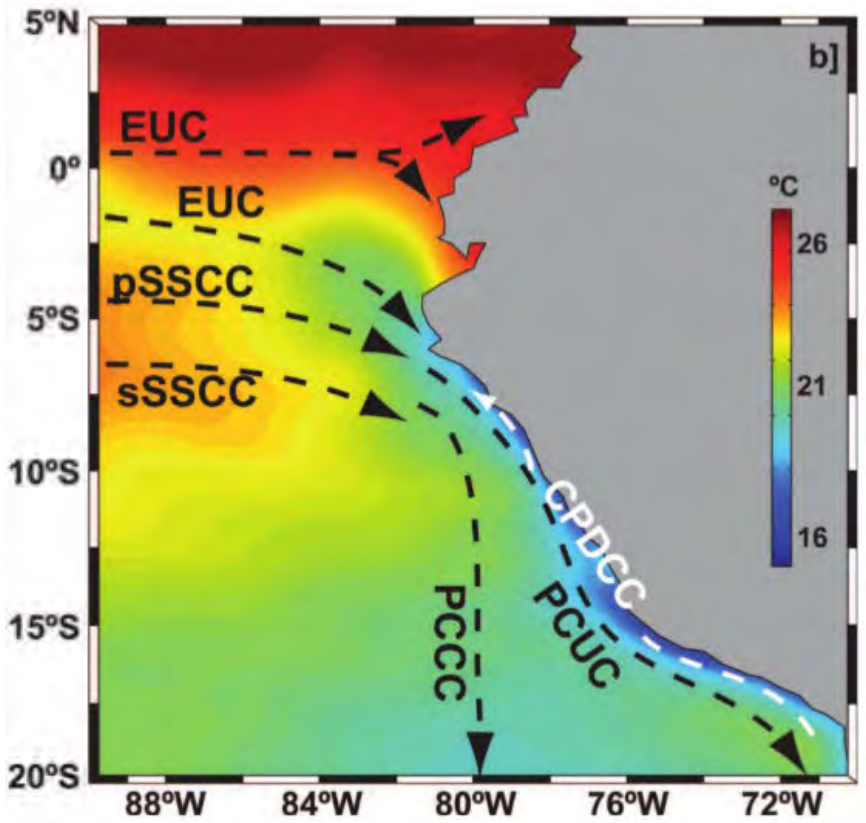
# Introduction : why do we need regionalization ?

Sea Surface Temperature (SST)




IPSL-CM5A-MR
(ocean at 2° of resolution)

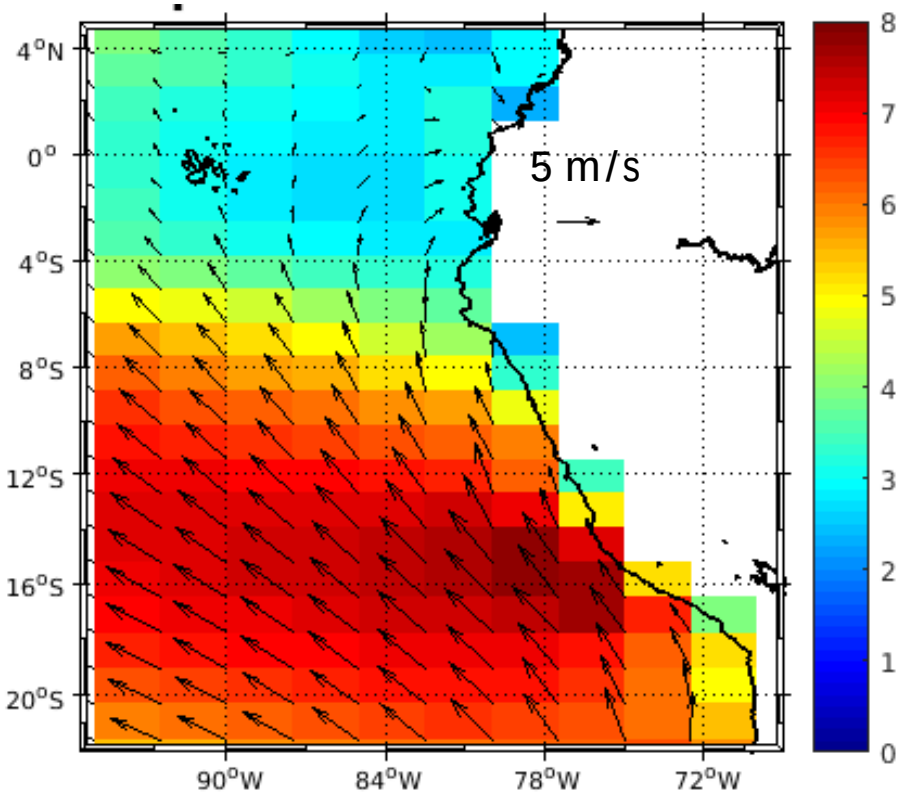



CARS
Figure from *Chaigneau et al, 2013*

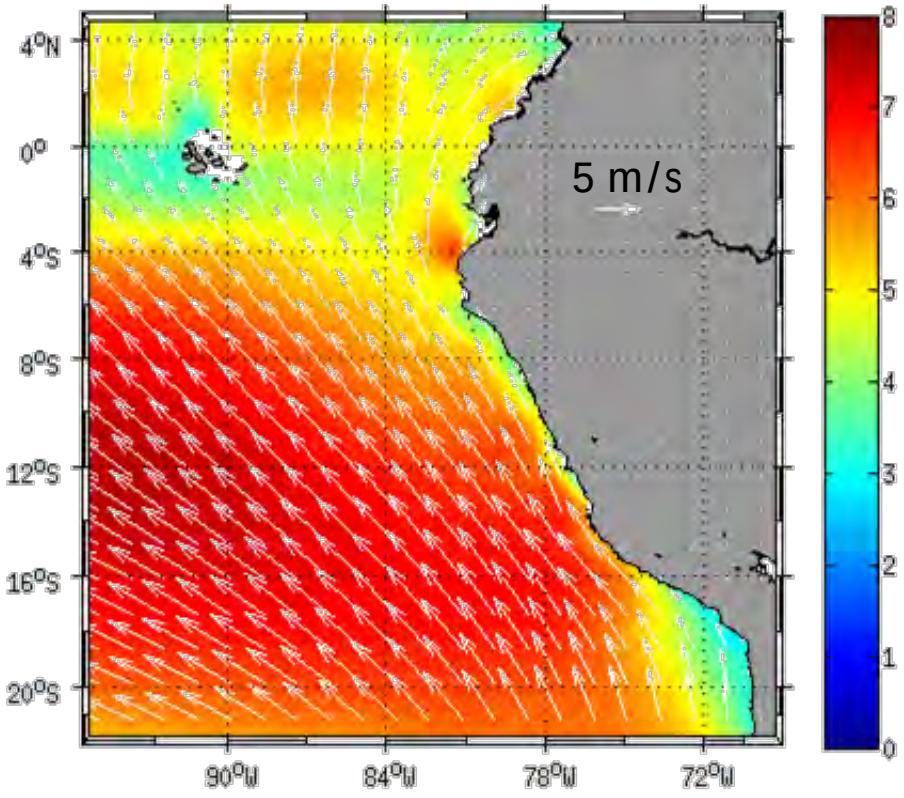
- **Global models : coarse spatial resolution ⟶ coastal upwelling not resolved**

# Introduction : why do we need regionalization ?

Wind speed




IPSL-CM5A-MR
(atmosphere at 2.5°x 1.25° of resolution)




QuikSCAT

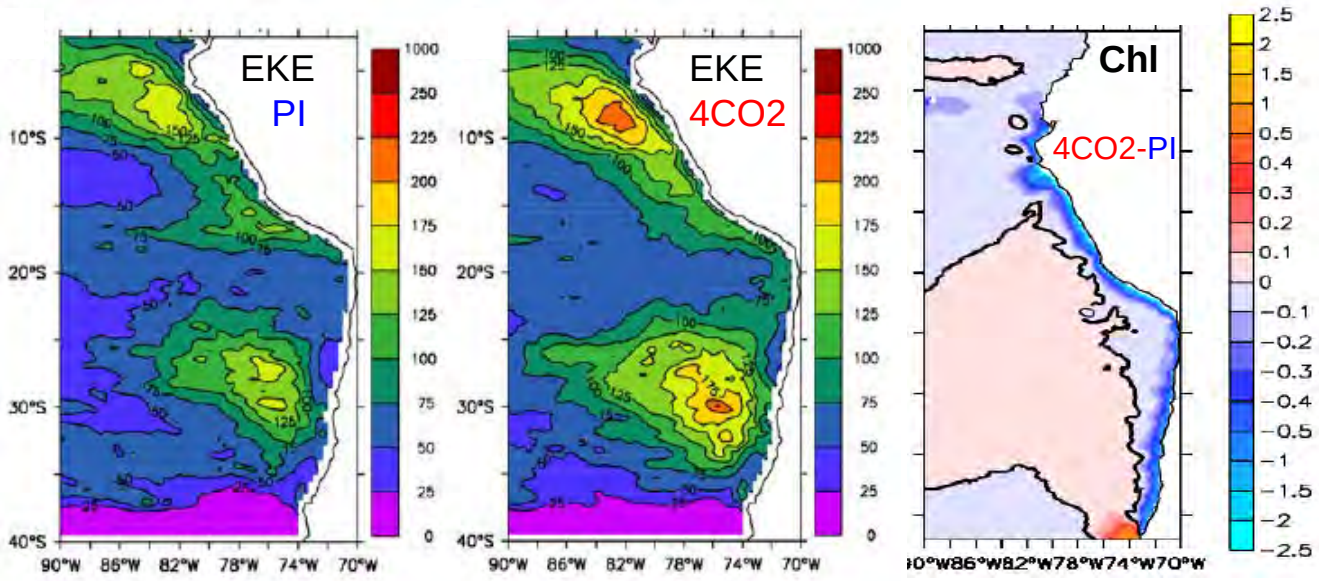
- **Global models : coarse spatial resolution ⟶ nearshore wind structure not resolved**

# Previous studies of climate change in the Humboldt system

Downscaling of IPSL-CM3 (Phy & BGC) : Idealized scenarios (Preindustrial, 2xCO2 and 4CO2)

- **Atmospheric response** :
  - Statistical and dynamical downscaling **show no wind increase off Peru**

*Goubanova et al., 2011 ; Belmadani et al., 2013*




- **Ocean dynamics using ROMS (1/6°):**
  - Nearshore SST & Eddy Kinetic Energy increase
  - Vertical flux (upwelling) decrease

*Echevin et al.,2012 ; Oerder et al., 2015*

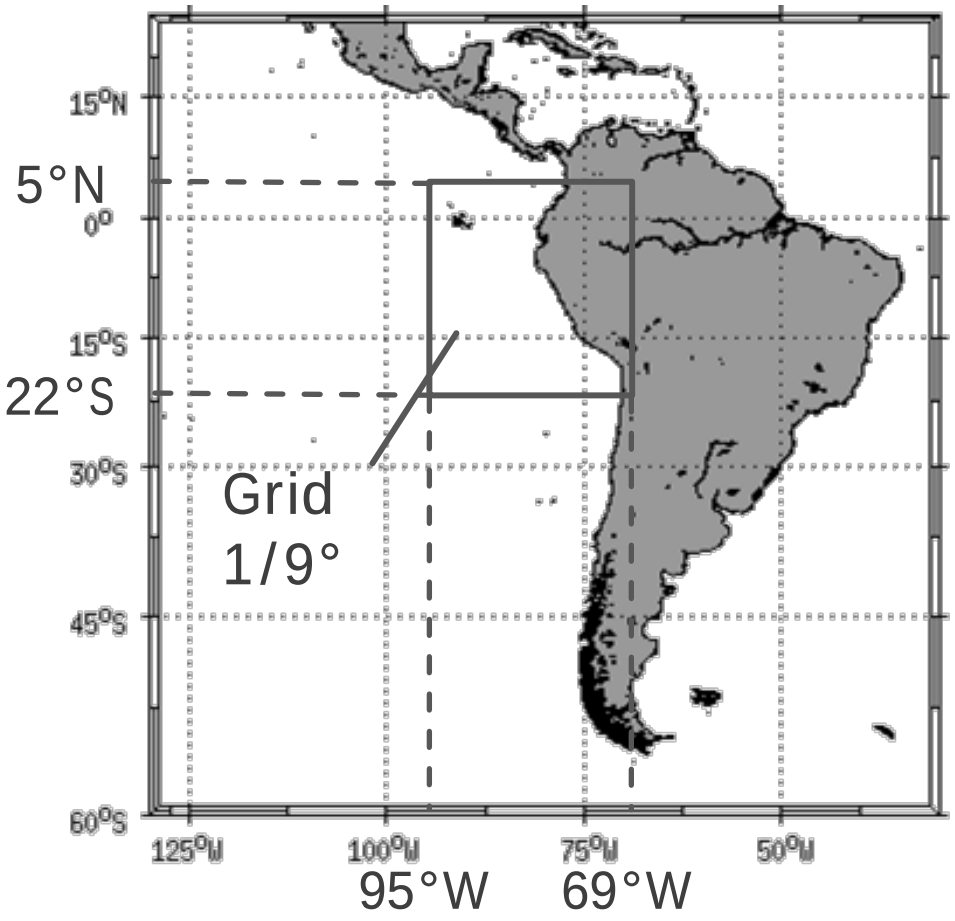
**Biogeochemistry using ROMS-PISCES:**

- Strong surface chlorophyll decrease due to decrease of nutrient content

*Brochier et al., 2013*

# Method and data

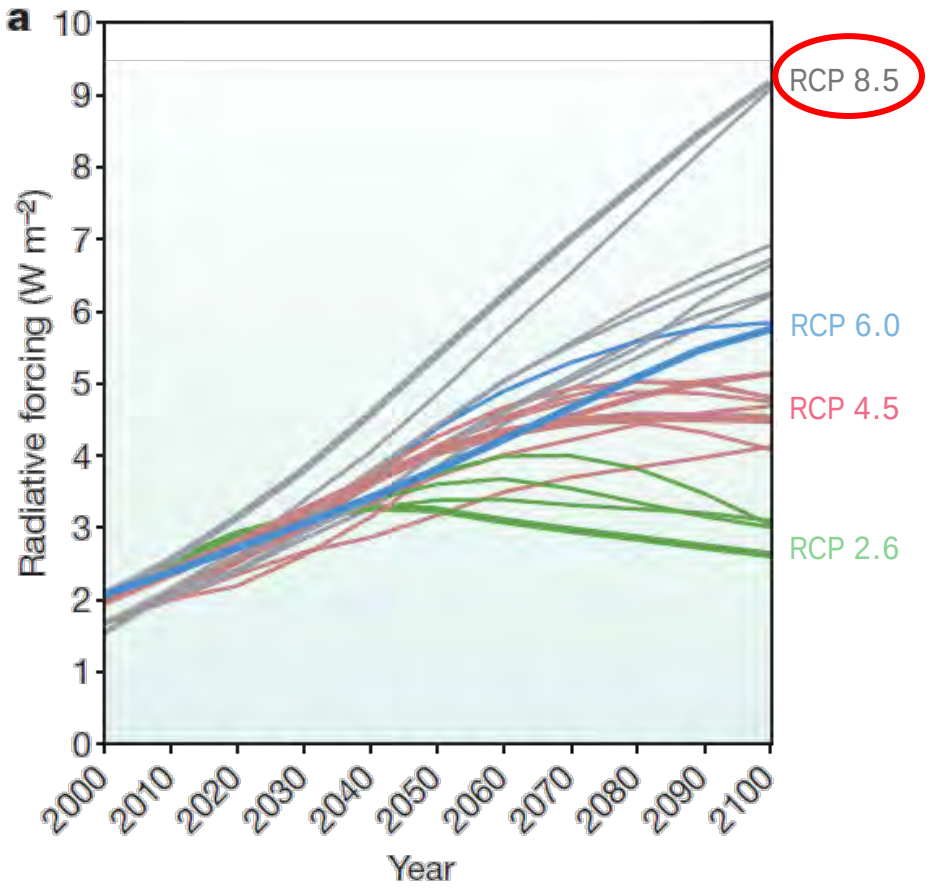
- Modeled area




- Downscaling of 3 IPCC models (Phy & BGC)

CNRM-CM5, GFDL-ESM2M, IPSL-CM5A-MR

- Model : ROMS – PISCES (dx = 1/9°)




most pessimistic

2 periods :

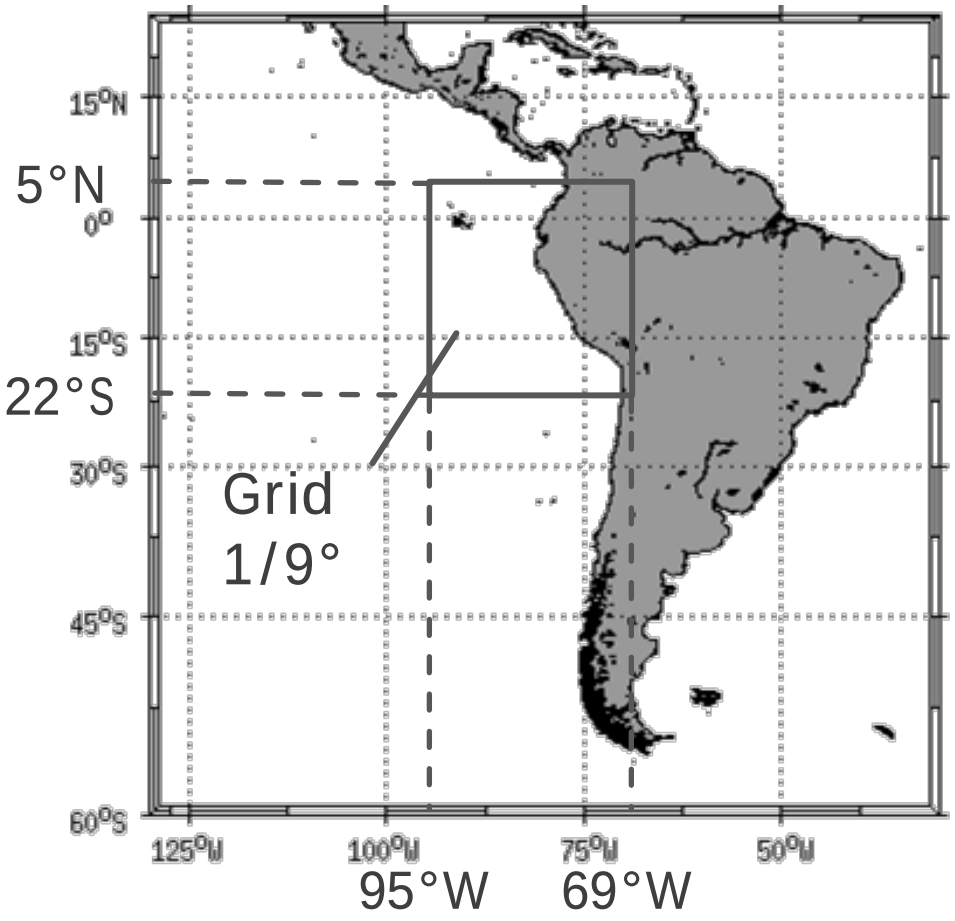
2006-2015 (Control)

2091-2100

Figure from *Moss et al., 2010*

# Method and data

- Modeled area




- Downscaling of 3 IPCC models (Phy & BGC)

CNRM-CM5, GFDL-ESM2M, IPSL-CM5A-MR

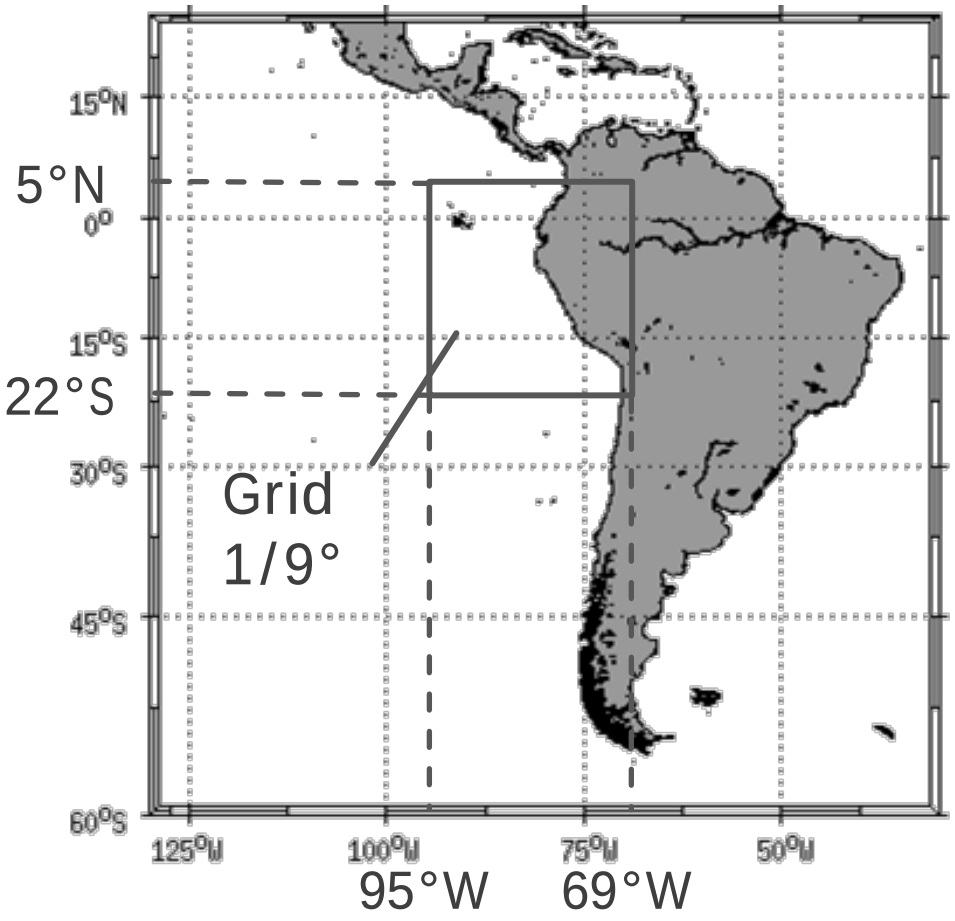
- Model : ROMS – PISCES (dx = 1/9°)

- **Atmospheric forcing** :
  - "poor guy downscaling" of IPCC models :

    bias correction using QuikSCAT and COADS
    - $X = X(obs) + (X_{rcp8.5}(GCM) - X_{hist}(GCM))$
  - Bulk formulae for wind stress and heat fluxes
  - Monthly means

# Method and data

- Modeled area




- Downscaling of 3 IPCC models (Phy & BGC)

CNRM-CM5, GFDL-ESM2M, IPSL-CM5A-MR

- Model : ROMS – PISCES (dx = 1/9°)

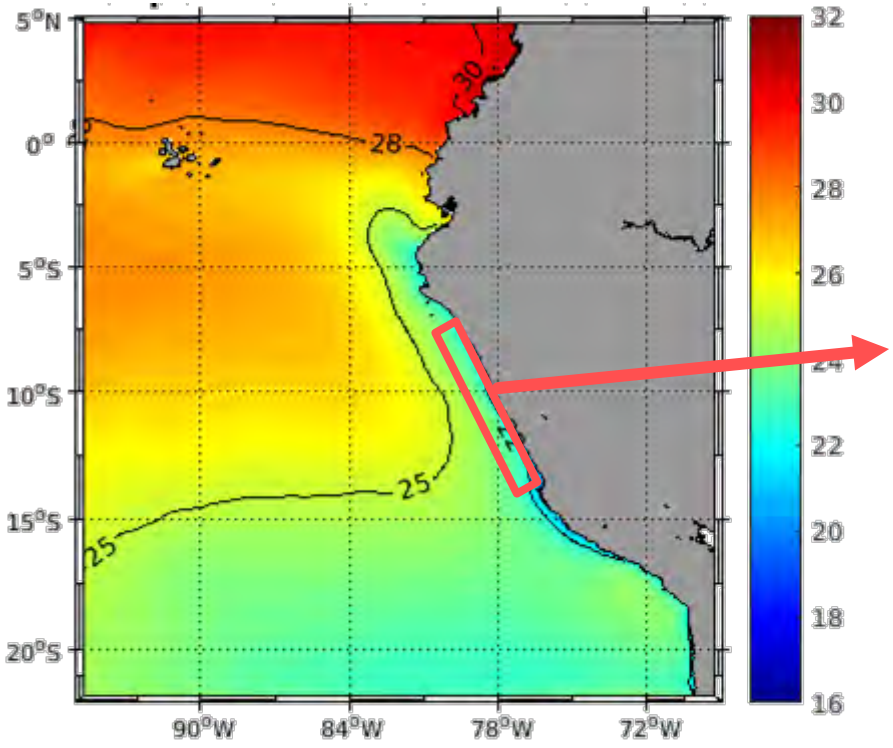
- **Oceanic boundaries :**
  - GFDL and CNRM : monthly means
  - IPSL : annual means
- **Biogeochemistry :**
  - "poor guy downscaling" of IPCC models : bias correction using WOA

ex : $NO3_{OBC}$ = NO3(WOA) + $NO3_{rcp8.5}$(GCM) – $NO3_{hist}$(GCM)

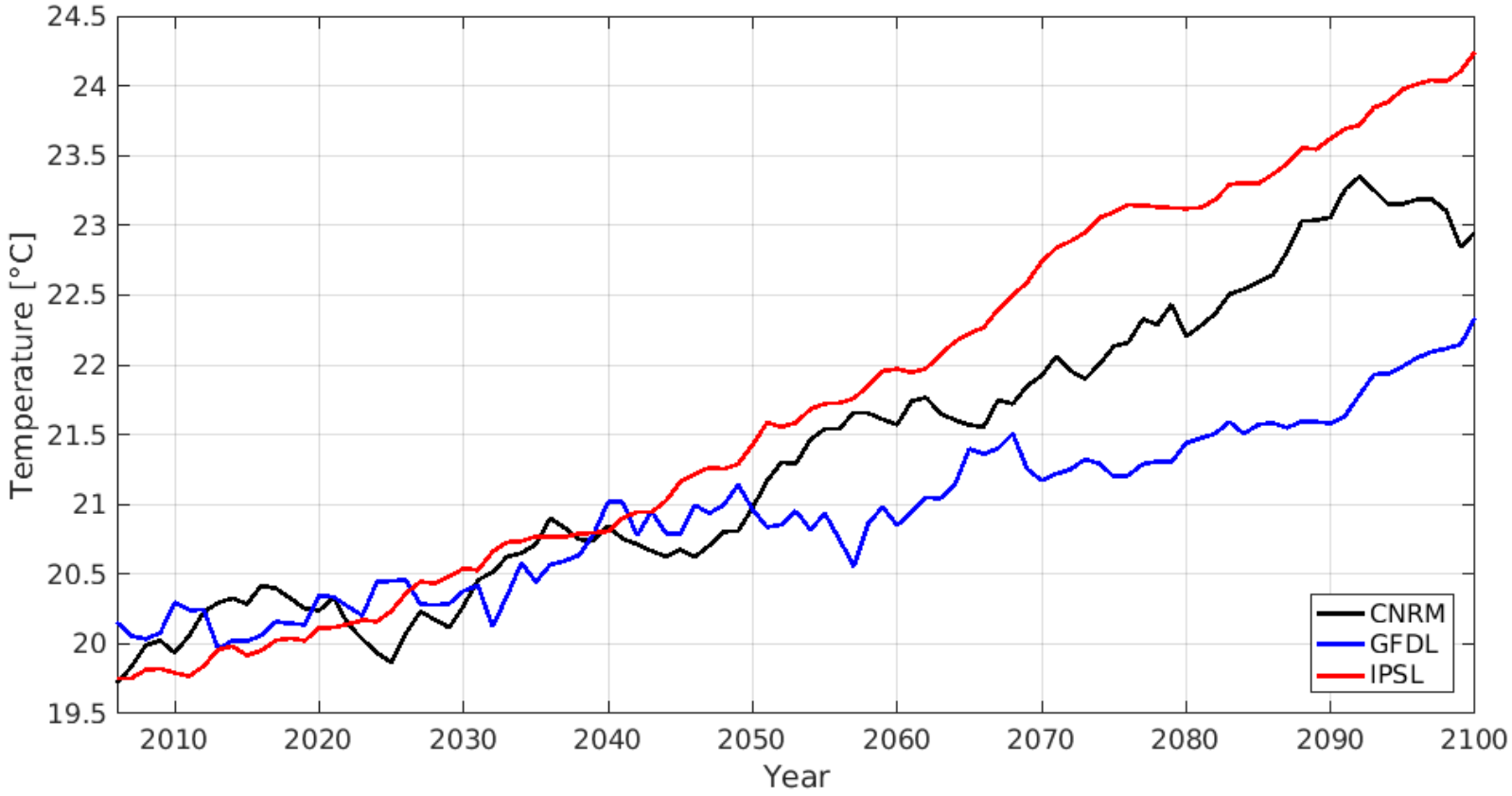
  - Annual means

# Sea Surface Temperature time series

CNRM - 2091-2100



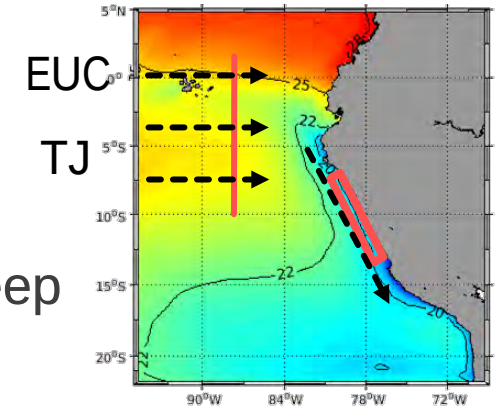

Mean in a coastal box – 10 years moving average
(7°S-13°S, 0-100 km)




- **Strong SST increase, amplitude depending on the downscaled model**

# Vertical temperature anomalies

Annual differences between 2091-2100 and Control

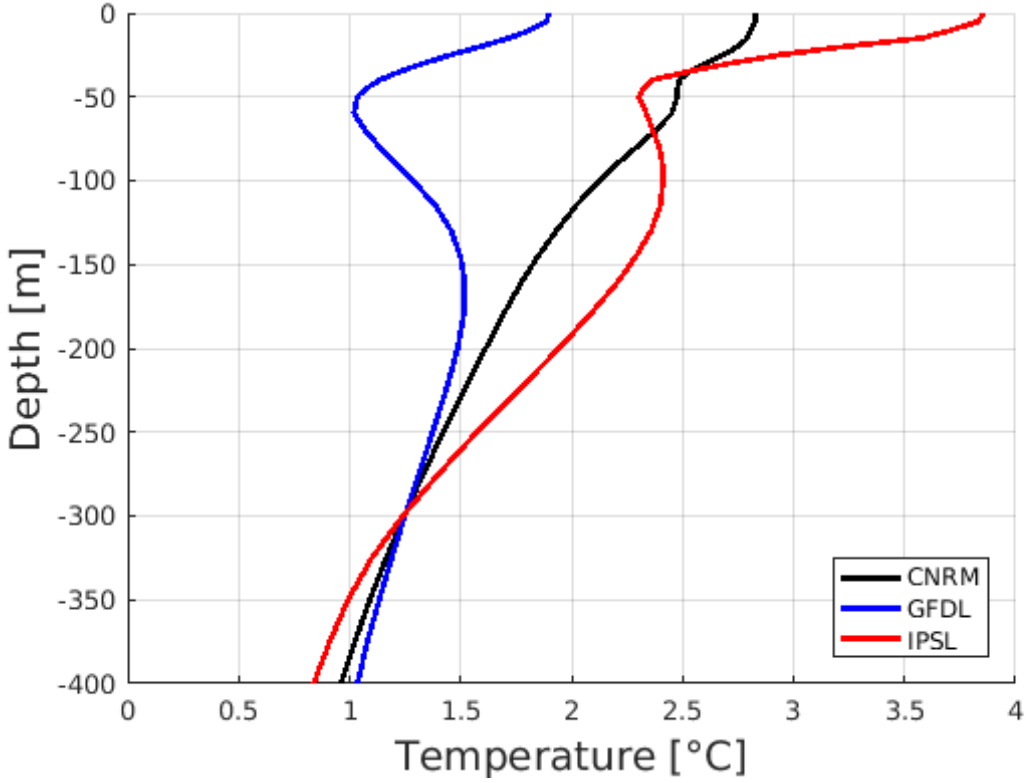


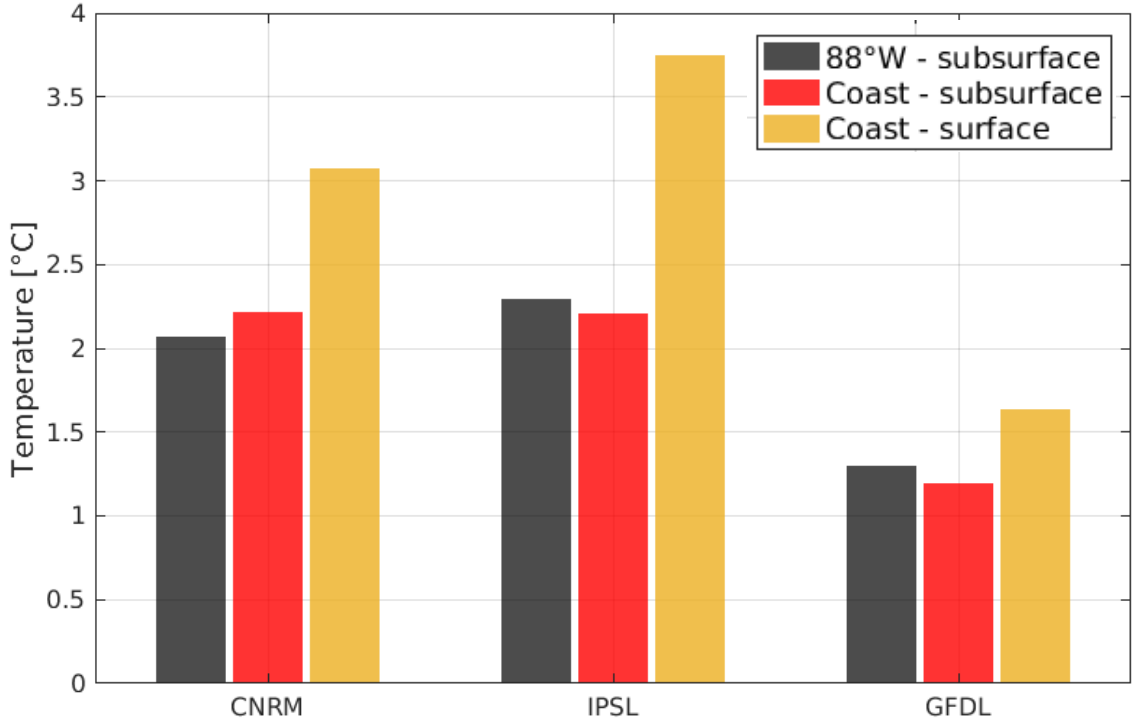

Offshore section

(88°W, 2°N-10°S)

Subsurface box : 50-200 m deep

Surface box : 0-20 m deep

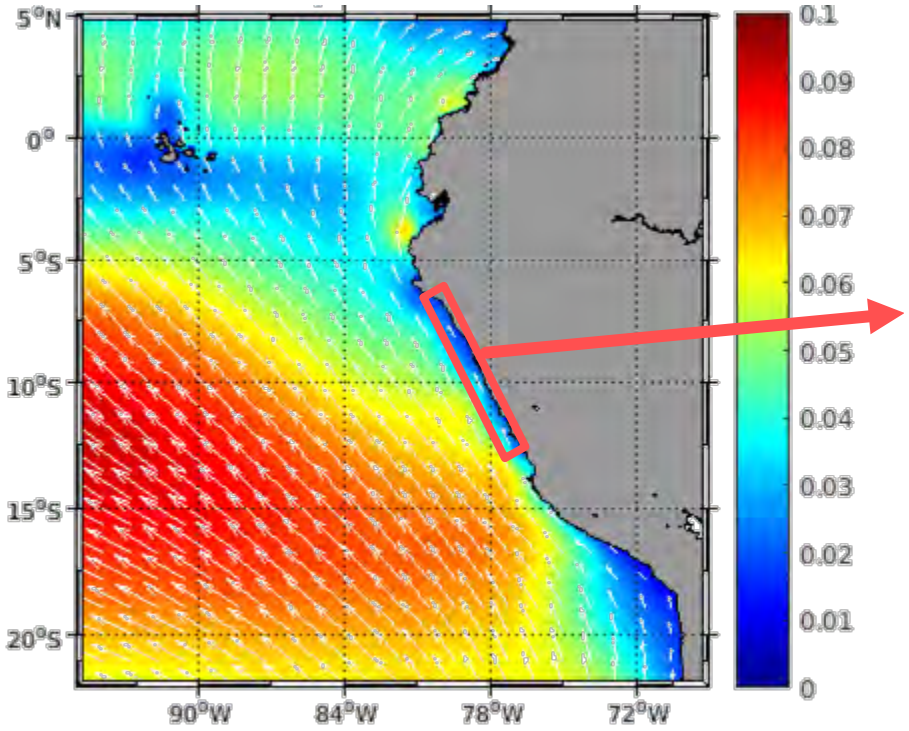


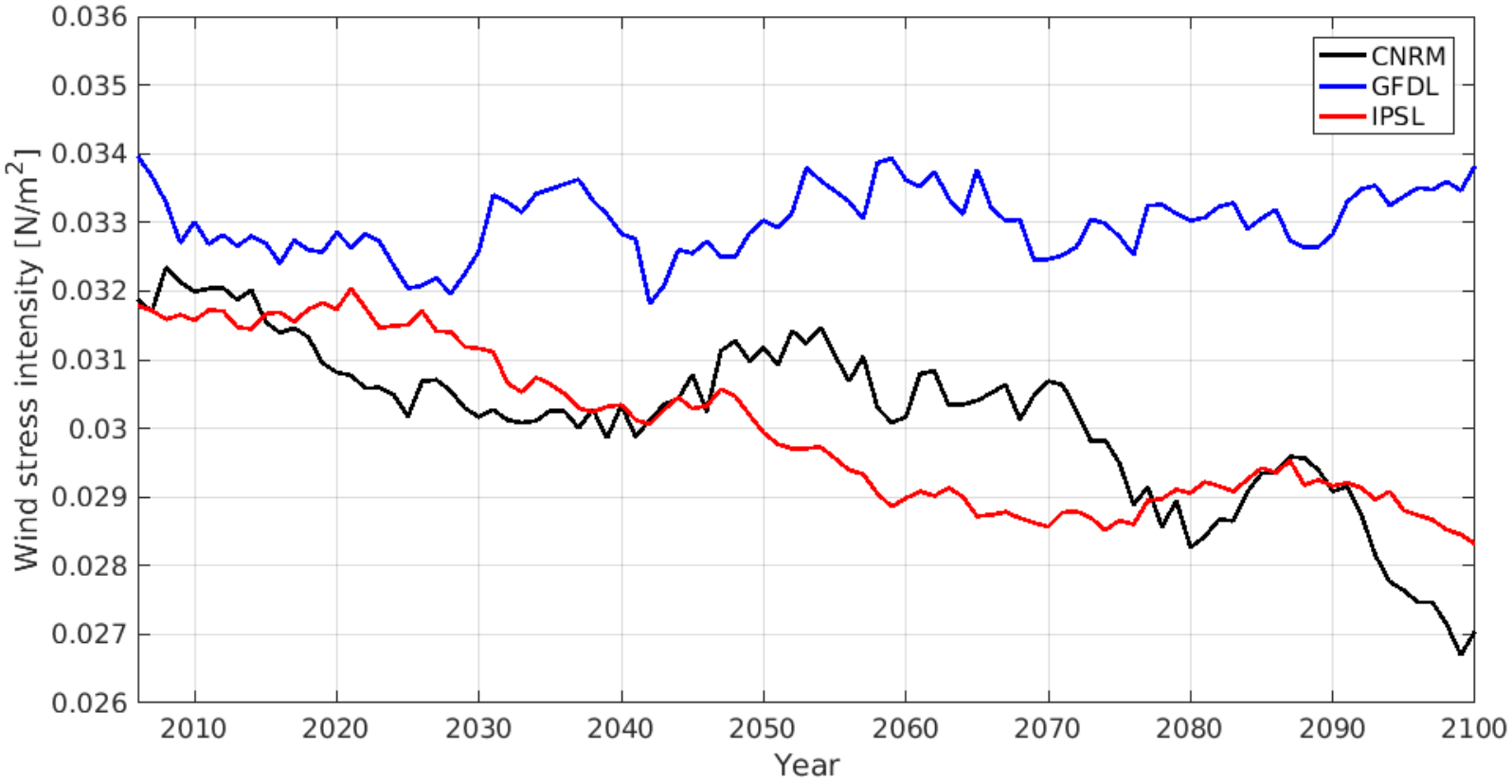

- **Same subsurface anomalies offshore and nearshore**
- **Different surface anomalies related to different surface forcings**

# Wind stress intensity time series

CNRM – Control (2006-2015)




Mean in a coastal box – 10 years moving average
(7°S-13°S, 0-100 km)



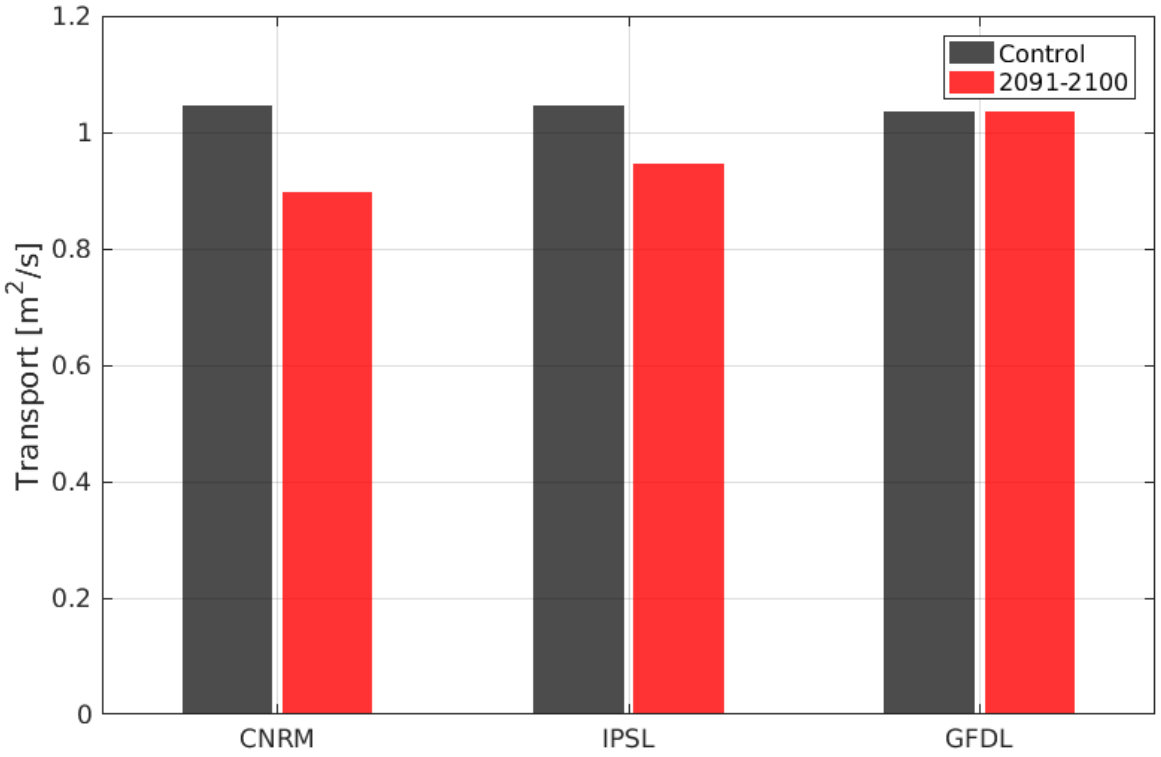

- **~10-15% decrease in IPSL and CNRM, no change in GFDL**

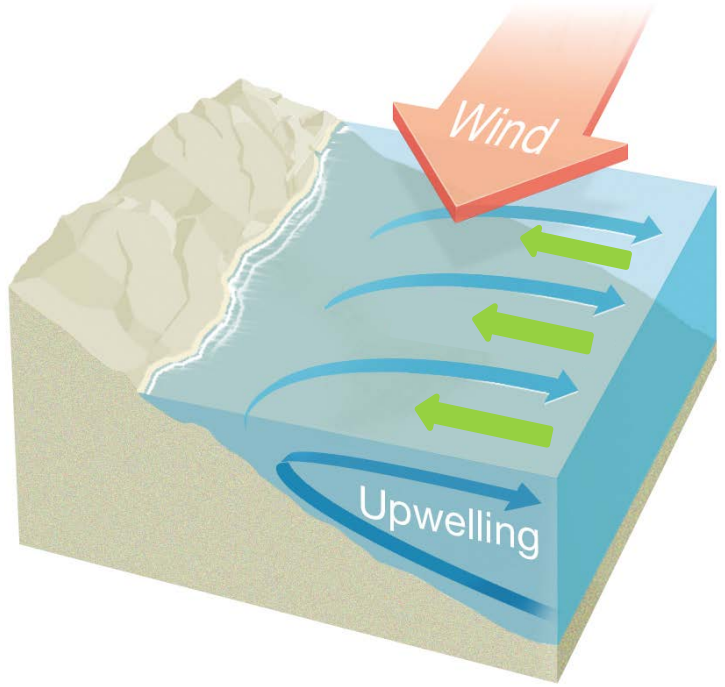
**poster of Chamorro et al. seen yesterday**

# Net offshore transport = measure of actual upwelling

Annual means at the coast for Control and 2091-2100

(7°S-13°S, 0-100 km)




Ekman transport

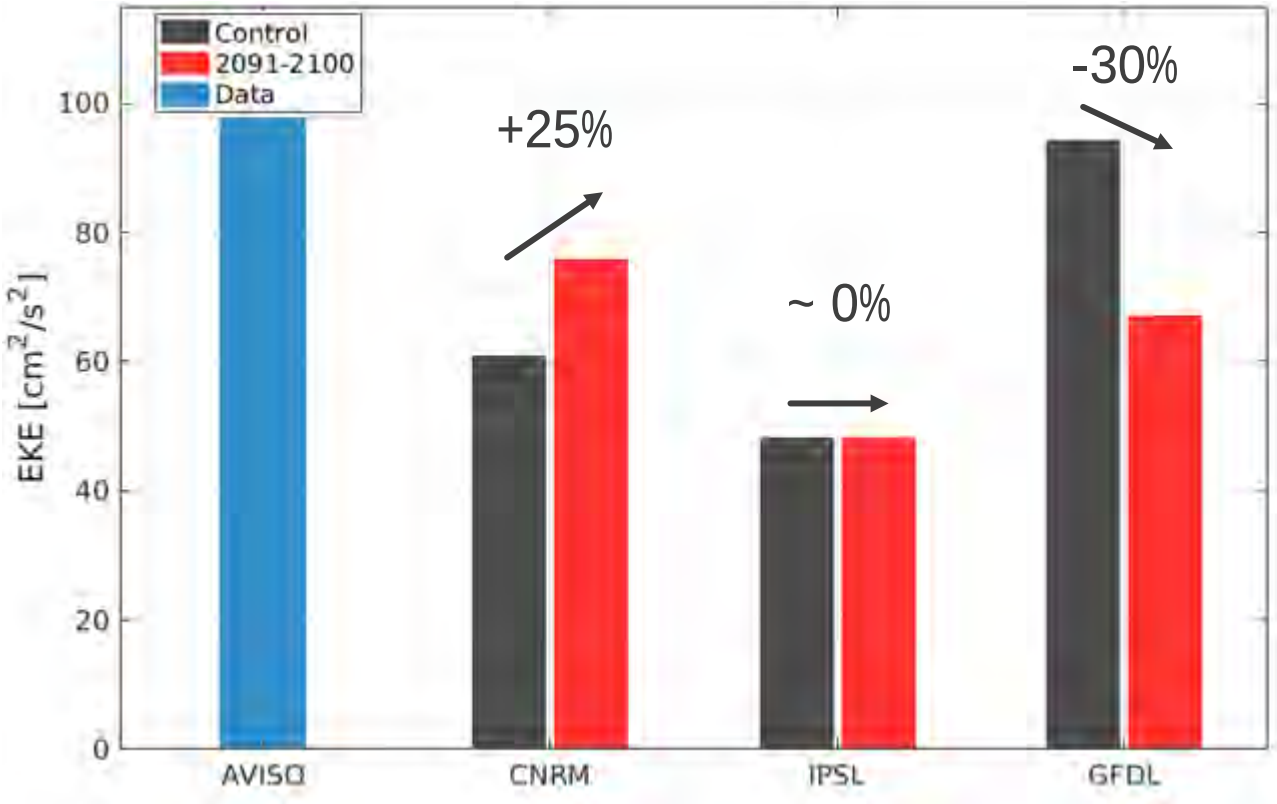
geostrophic flow

Upwelling = Ekman transport + cross-shore geostrophic flow

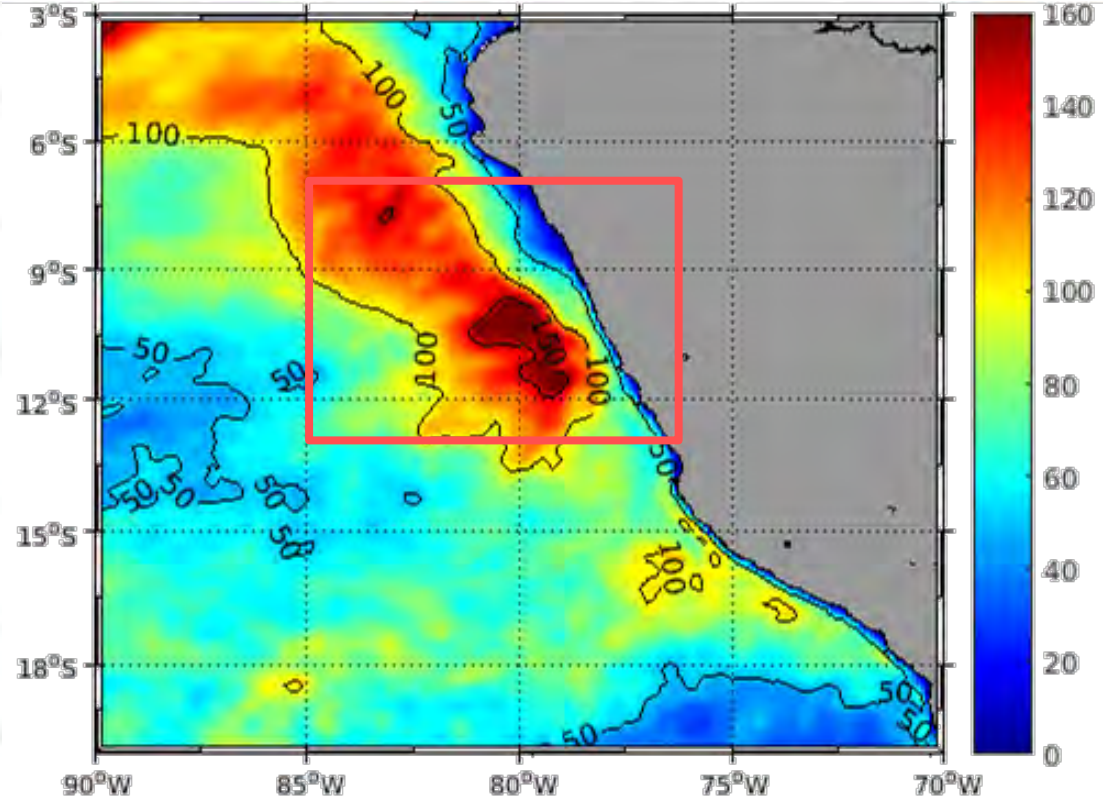
- **~10-15% decrease in IPSL and CNRM, no change in GFDL**

# Geostrophic Eddy Kinetic Energy (EKE)

Annual means nearshore for Control and 2091-2100
(85°W-76°W, 7°S-13°S)



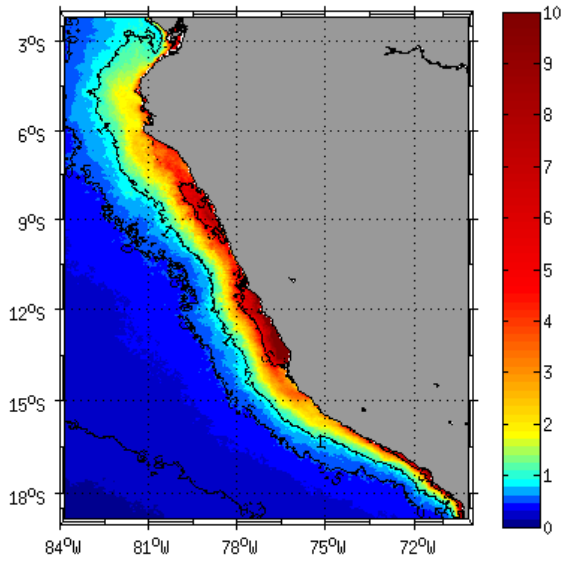

GFDL - Control (2006-2015)



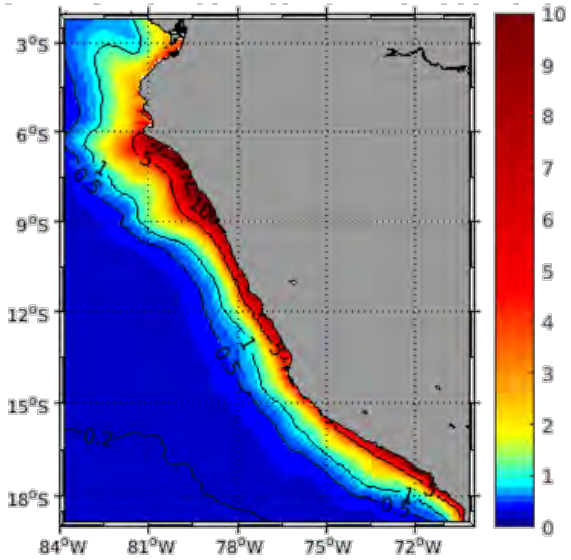

- **Very different tendencies from one model to the other**

# Chlorophyll

## Modis

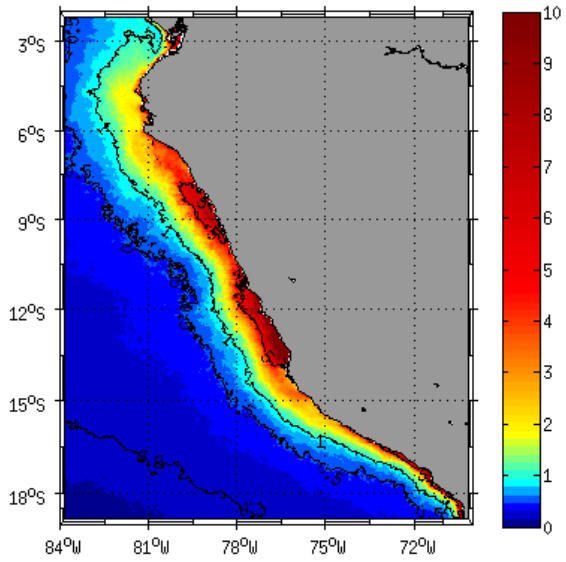



## CNRM - Control (2006-2015)



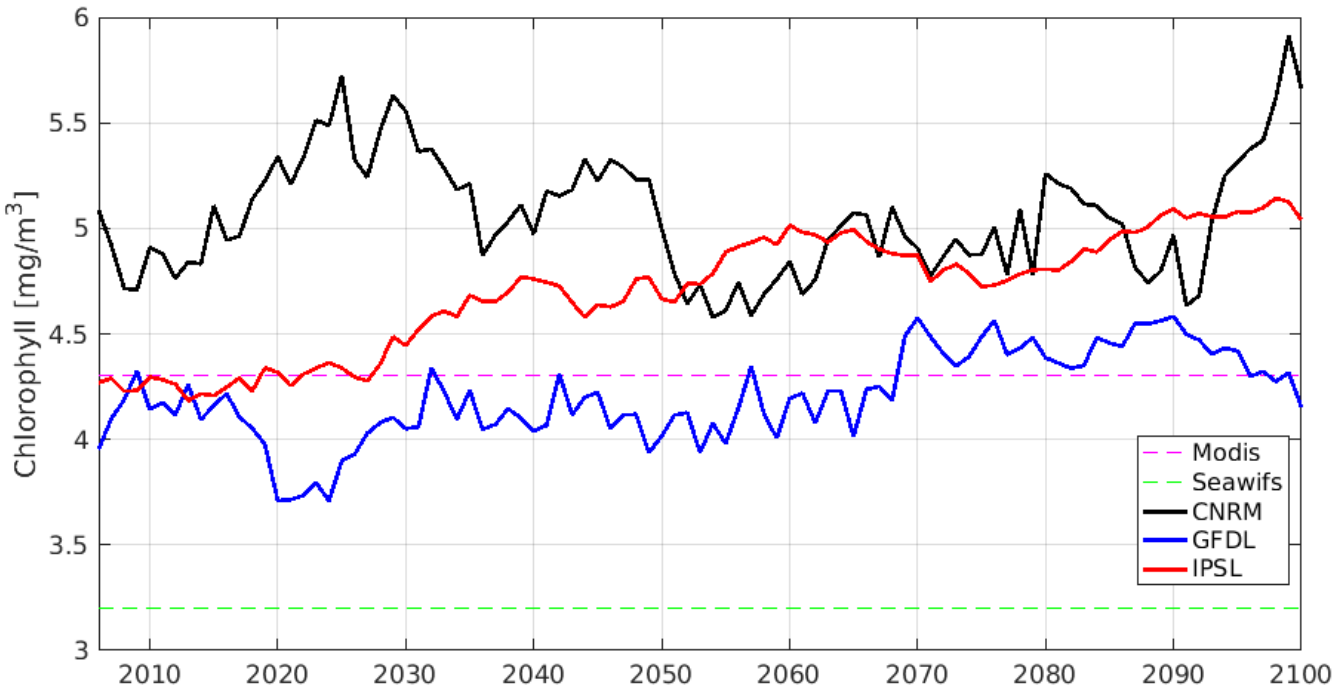
# Chlorophyll

Modis

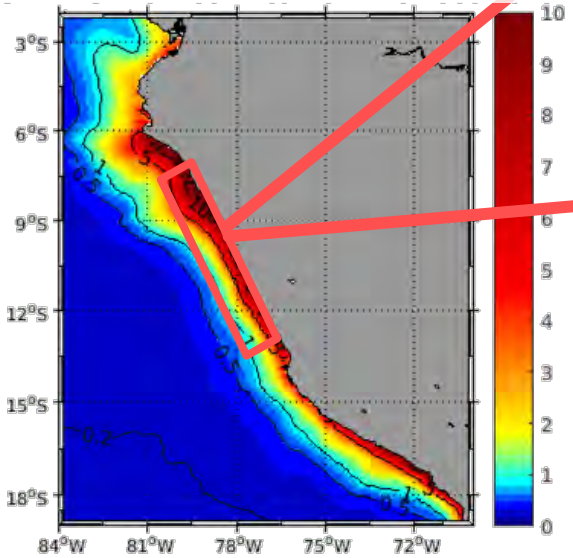



Mean in a coastal box (7°S-13°S, 0-100 km)

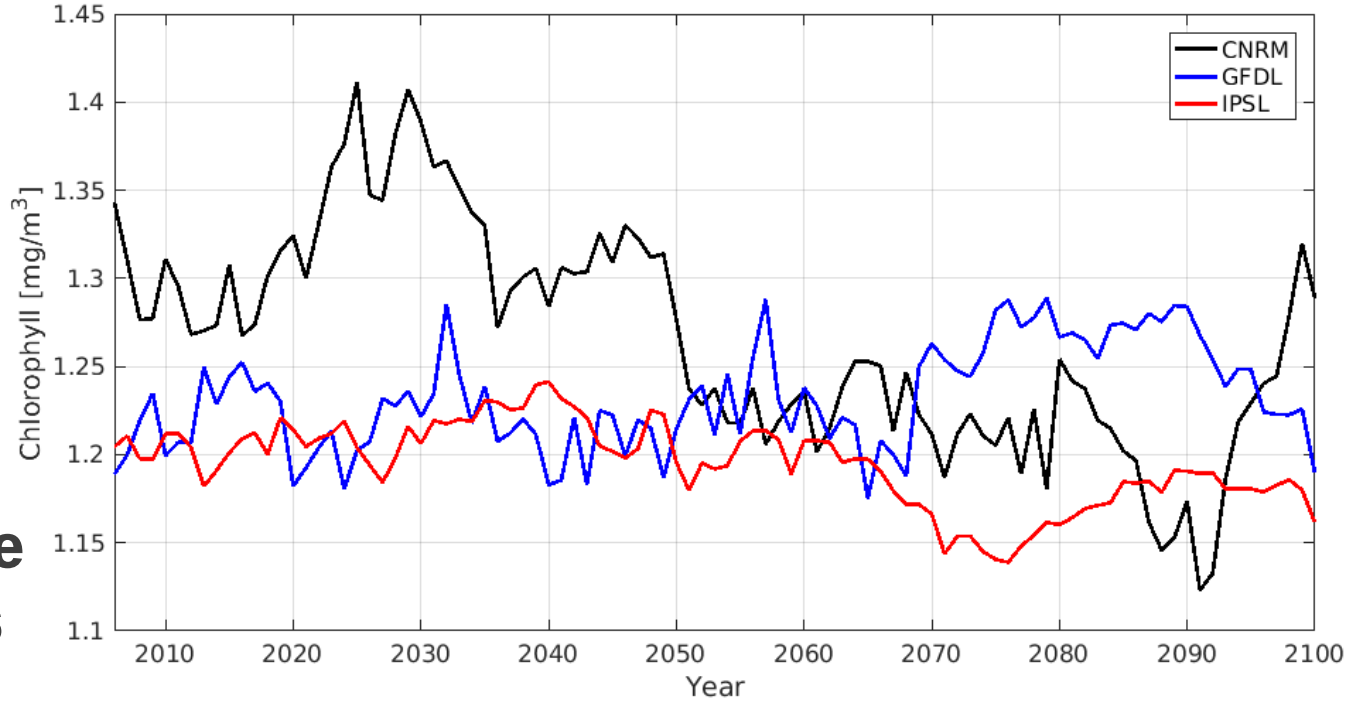
**0-5 m**




CNRM - Control (2006-2015)




**0-50 m**

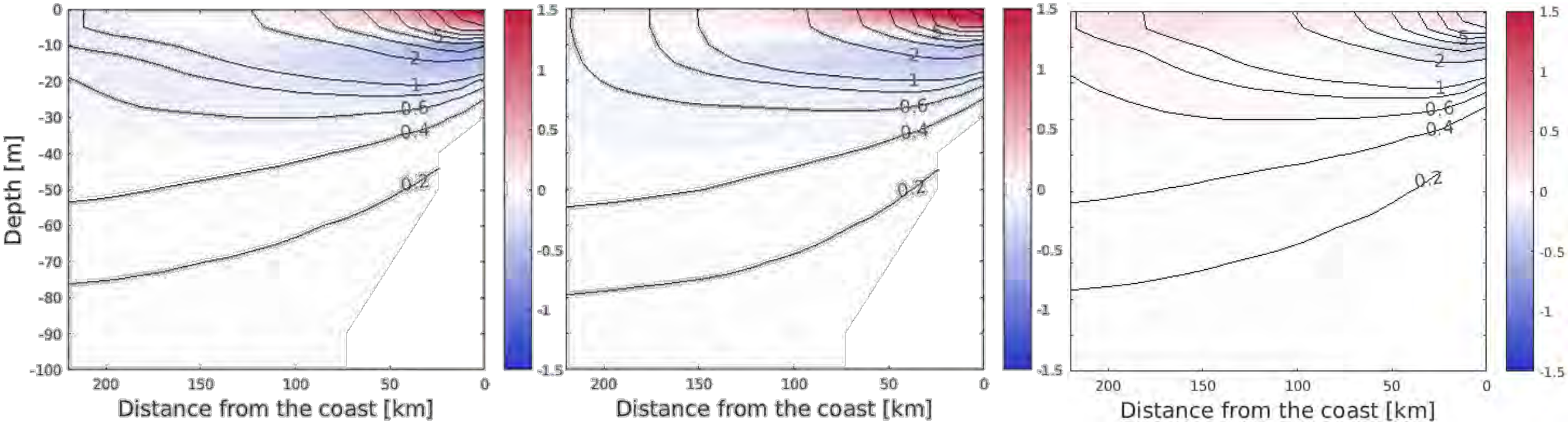



- **No decrease in surface chl unlike previous studies**

# Chlorophyll sections

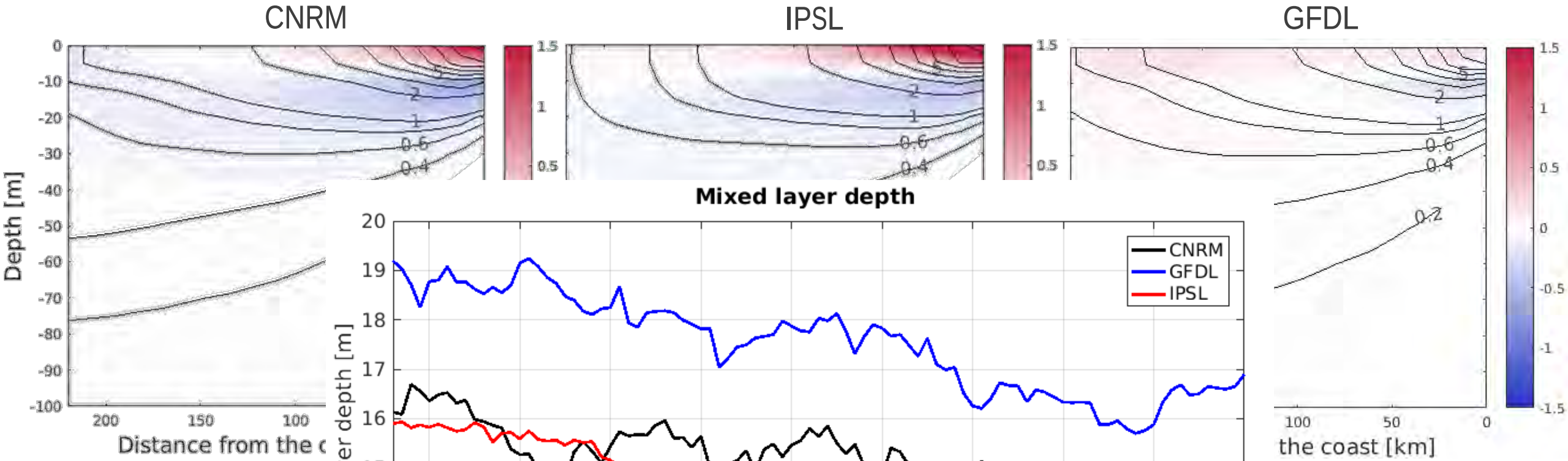
Color : differences between 2091-2100 and Control / Contours : Control

CNRM IPSL GFDL




- **Increase at the surface, decrease below**

# Chlorophyll sections

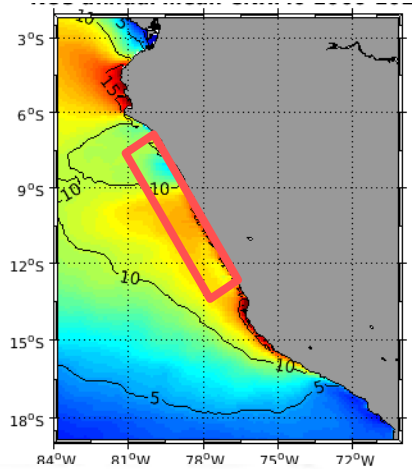






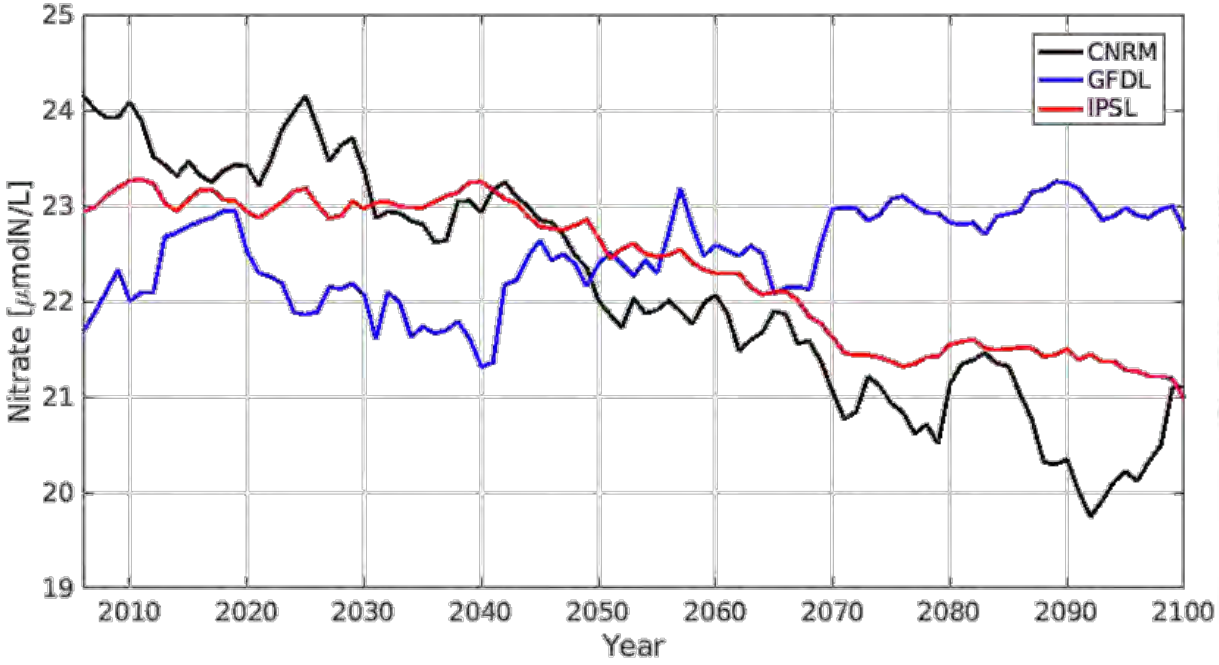
- **in relation with near-surface stratification increase**

# Nitrate and oxygen time series (work in progress)



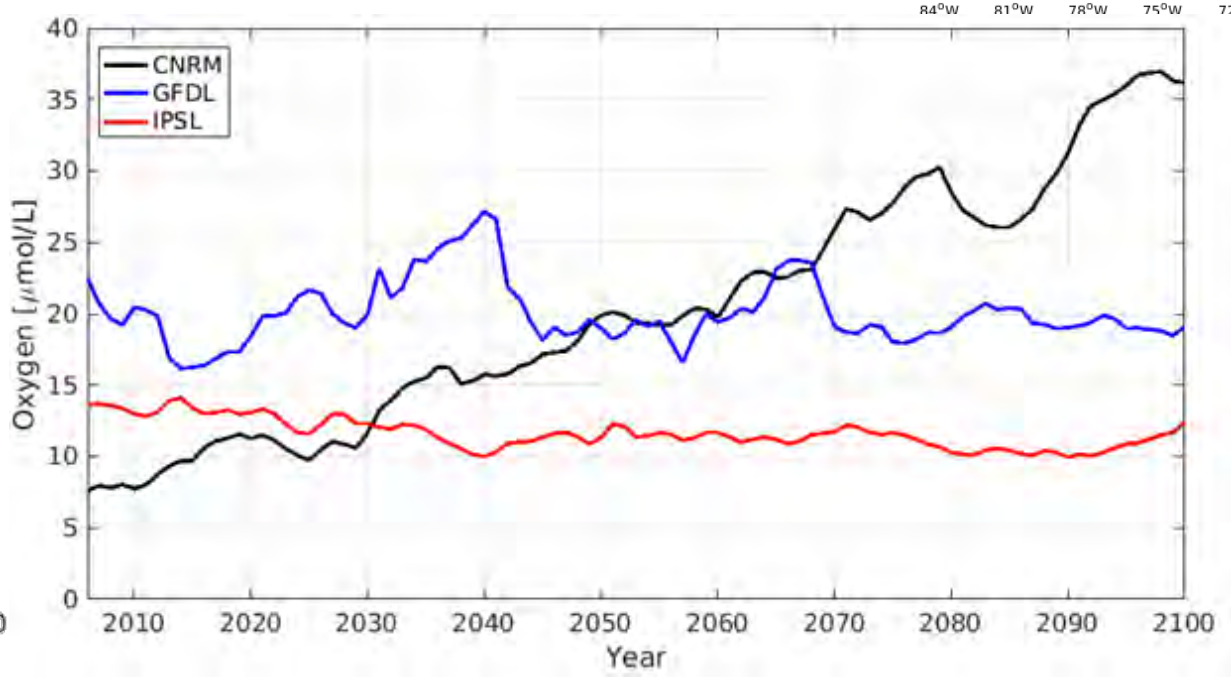

## Nitrate

Mean in a coastal box
(7°S-13°S, 0-100 km,
40-100 m deep)




## Oxygen

Mean in a coastal box
(7°S-13°S, 0-100 km,
100-200 m deep)




- **Nitrate variations at subsurface not related to surface chlorophyll variability : other nutrients (Si, PO4) may play a role ⟶ to be continued**

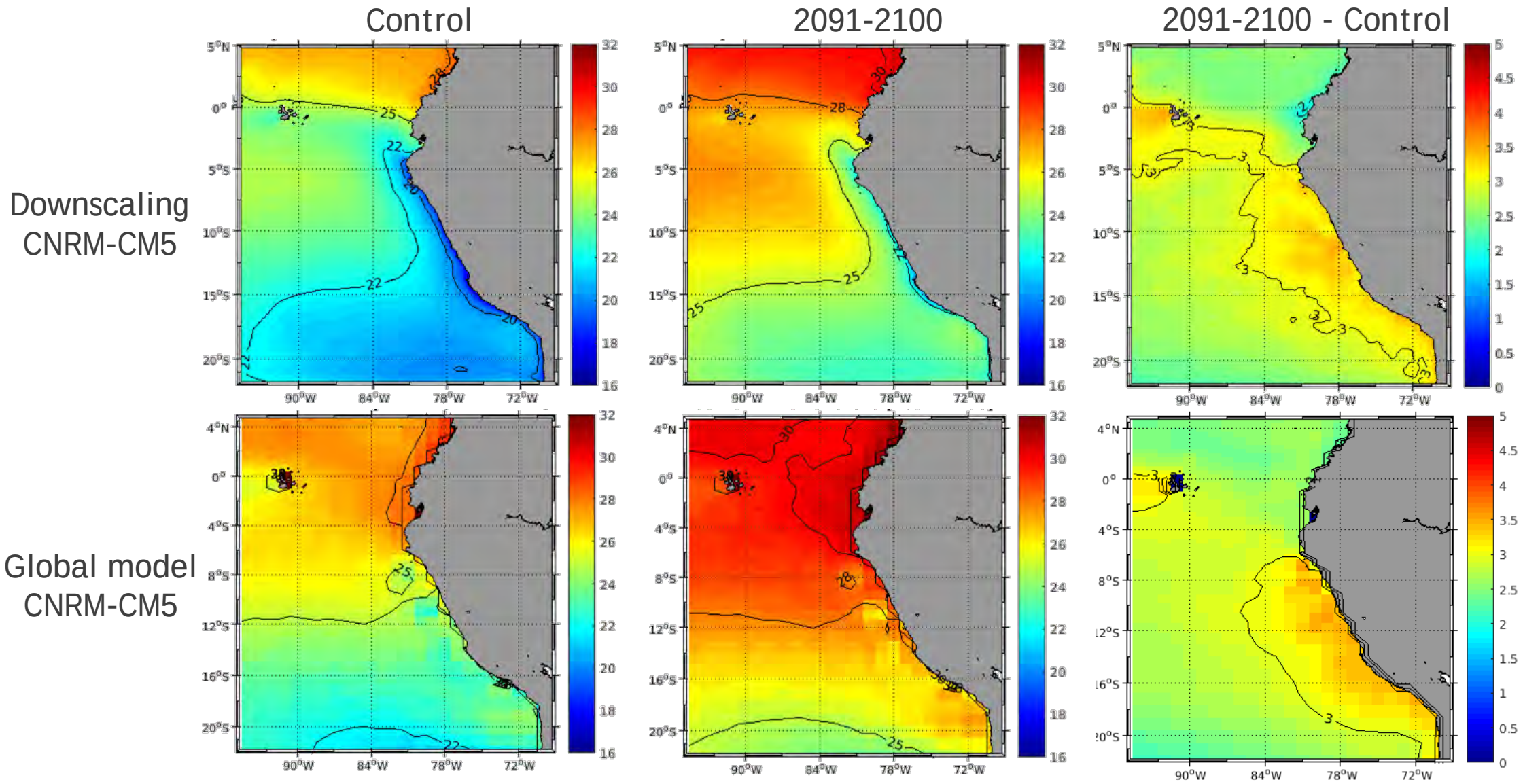
- **No OMZ intensification – but are GCMs $O_2$ trends reliable ?**

# Conclusions

- **Summary :**
  - Strong decadal variability
  - Increase in SST
  - Few changes in wind
  - No clear trend in EKE and chlorophyll
  - Stratification increase leads to shallower chlorophyll reach layer

- **Limitations of this study :**
  - 3 models is few to draw tendencies
  - Methodology made the assumption of correct GCM variability (only mean state bias corrected)

# SST - comparison global model vs downscaling




- **SST anomalies alike with and without dynamical downscaling**