A N E T U S

A coupled approach to Air-Sea Interactions in the *Atlantic North Eastern Tropical Upwelling System*

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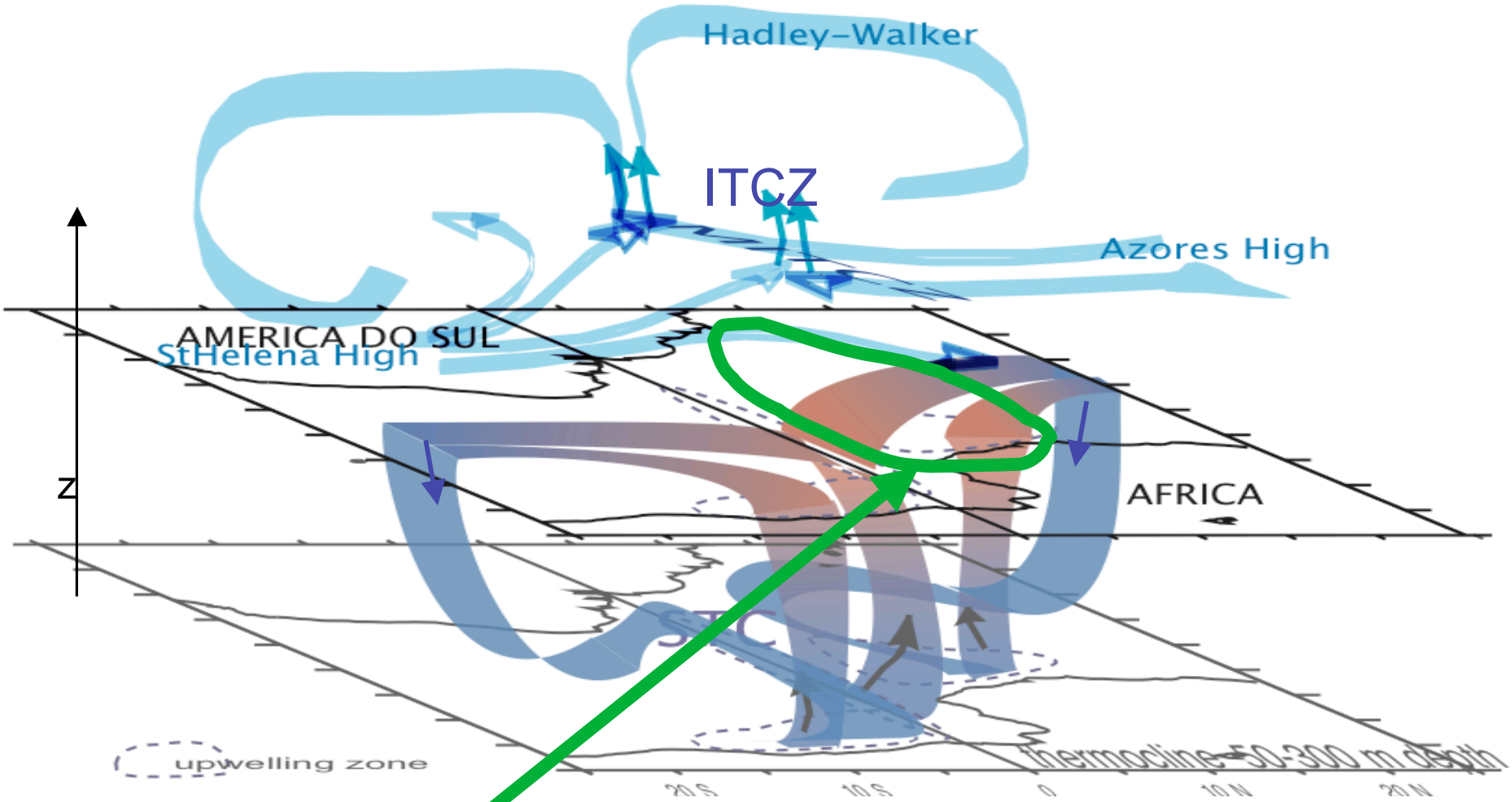
The aim of the ANETUS research project is to improve the understanding and modelling of ocean and coupled ocean-atmosphere variability in the upwelling system of the tropical north eastern Atlantic. In particular we want to know how differently upwelling regions function compared to the rest of the sub-basin.

***In situ*, satellite and model data will be used to study its structure, mechanisms, and relation to the African Monsoon and the Atlantic Inter-tropical Convergence Zone (ITCZ) complex. The Project is funded by CNES/NASA for three years (2004-2006).**

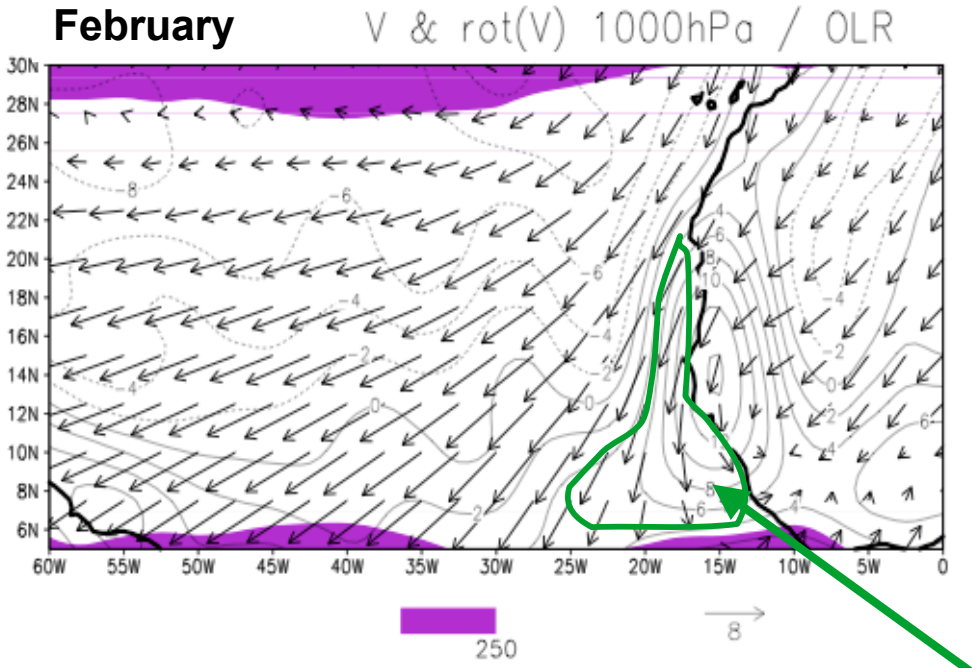
This poster presents results selected from the very first stage of the study, dedicated to THE MEAN SEASONAL CYCLE of the ANETUS.



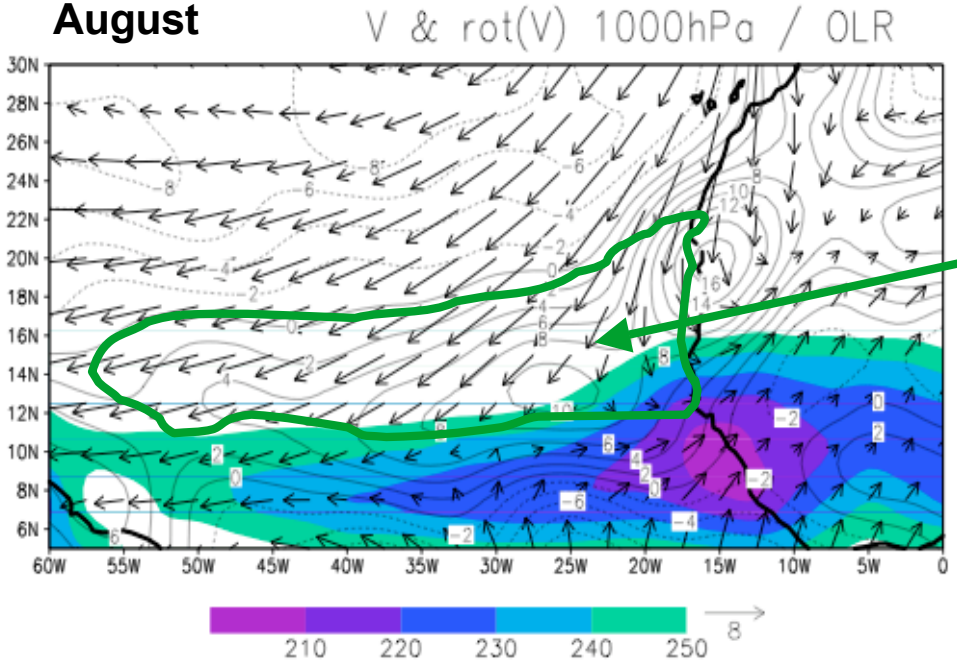
the Atlantic subtropical/tropical oceanic and atmospheric cells:
schematic view from the South-East of the basin

Within the context of the Atlantic climate variability, the ocean/atmosphere coupling can be schematized by Subtropical-Tropical interacting atmospheric and oceanic cells.
The ANETUS represents one of the surface terminations of the complex oceanic cells. It lies below the Inter Tropical Convergence Zone (ITCZ) and African Monsoon westerlies, where a coupling is thought to occur between Sea Surface Temperature (SST), winds, precipitation, and land surfaces.

February



August



The role of the atmosphere for the ANETUS (NCEP reanalysis)

Wind, Wind curl & OLR: Forcing or coupling ?

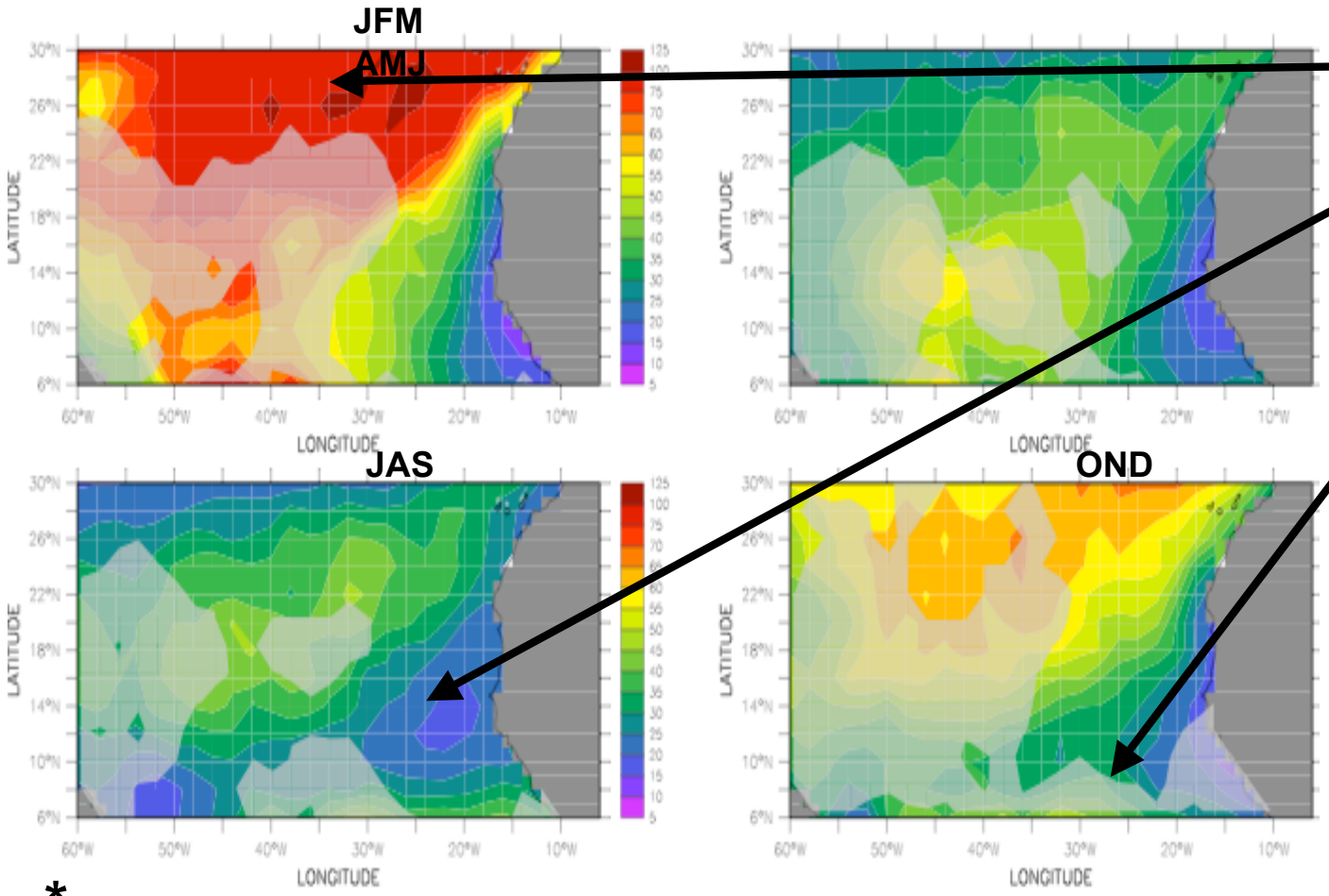
✓ **in winter (equatorial ITCZ):**
relatively homogenous forcing by the northern trades
⇒mimimum extension of ⊕ wind curl (near the coast)
⇒small upwelling area

✓ **in summer (northern ITCZ):**
⊕ wind curl on the ITCZ northern flank (Vintzileos&Delecluse,1998)
=>extended upwelling area.
Monsoon flow in the east involving air-sea continent interactions

Are the Marine ITCZ and the African Monsoon really sensitive to the SST ?

The ANETUS in oceanic *in situ* data

Mixed layer & Barrier Layer seasonal cycle from a new climatology based on individual profiles*



✓ Strong subtropical Entrainement/detrainement

✓ upwelling= Shallow ML

✓ ITCZ migration
=> Large mixed layer depth seasonal variations

✓ ITCZ precip in the east
=>fall/winter barrier Layers (in gray)

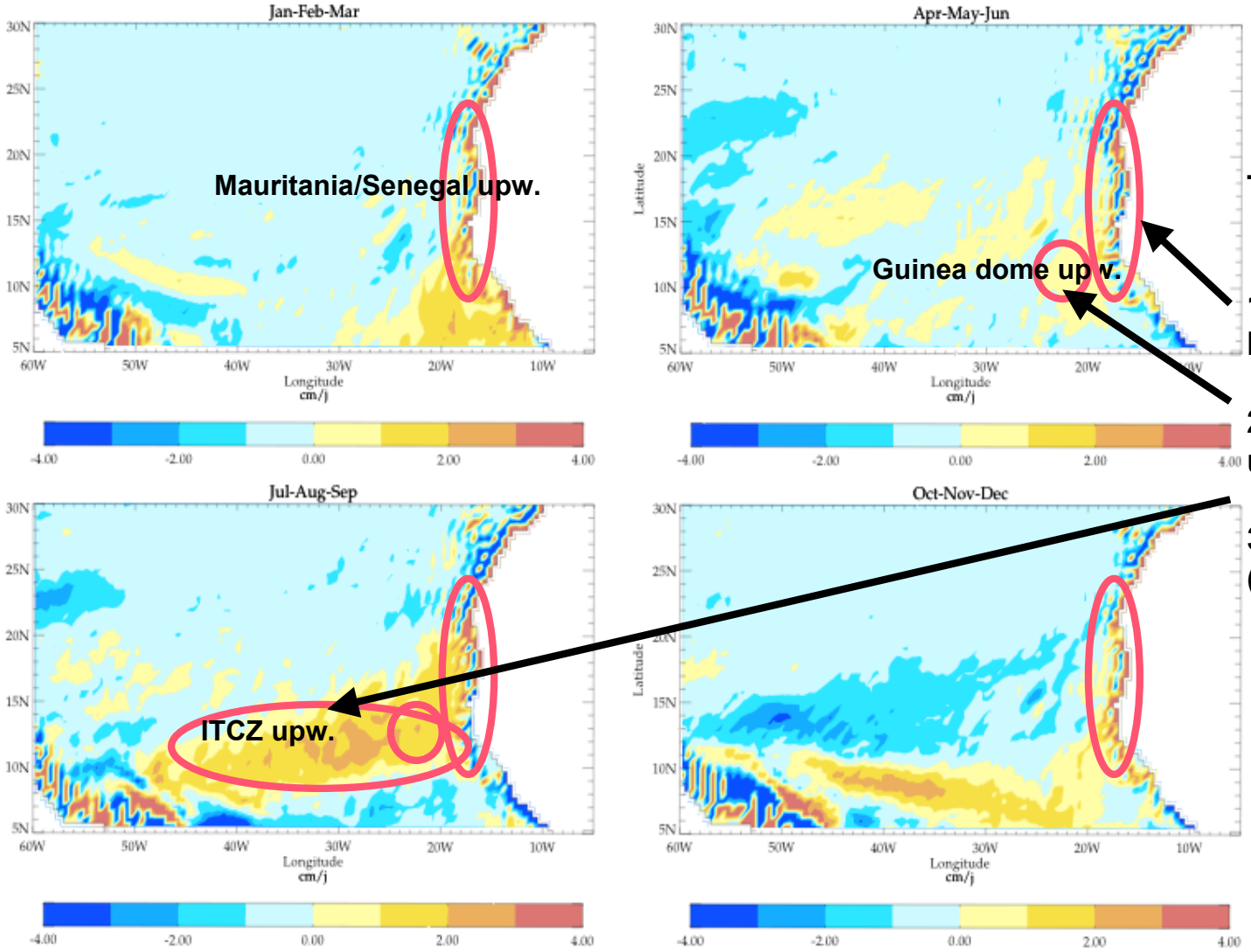
✓ Validation of the OGCM

In order to understand the mixed layer heat budget, satellite SSH and SST will be analysed; the role of planetary wave propagation will in particular be investigated

* DeBoyer Montegut, Madec, Fisher, Lazar, Iudicone, 2004; under revision for JGR

The ANETUS in the 1/2° global OGCM ORCA05 (IPSL)

Seasonal distribution of W_{10m}



Three main wind-driven upwellings:

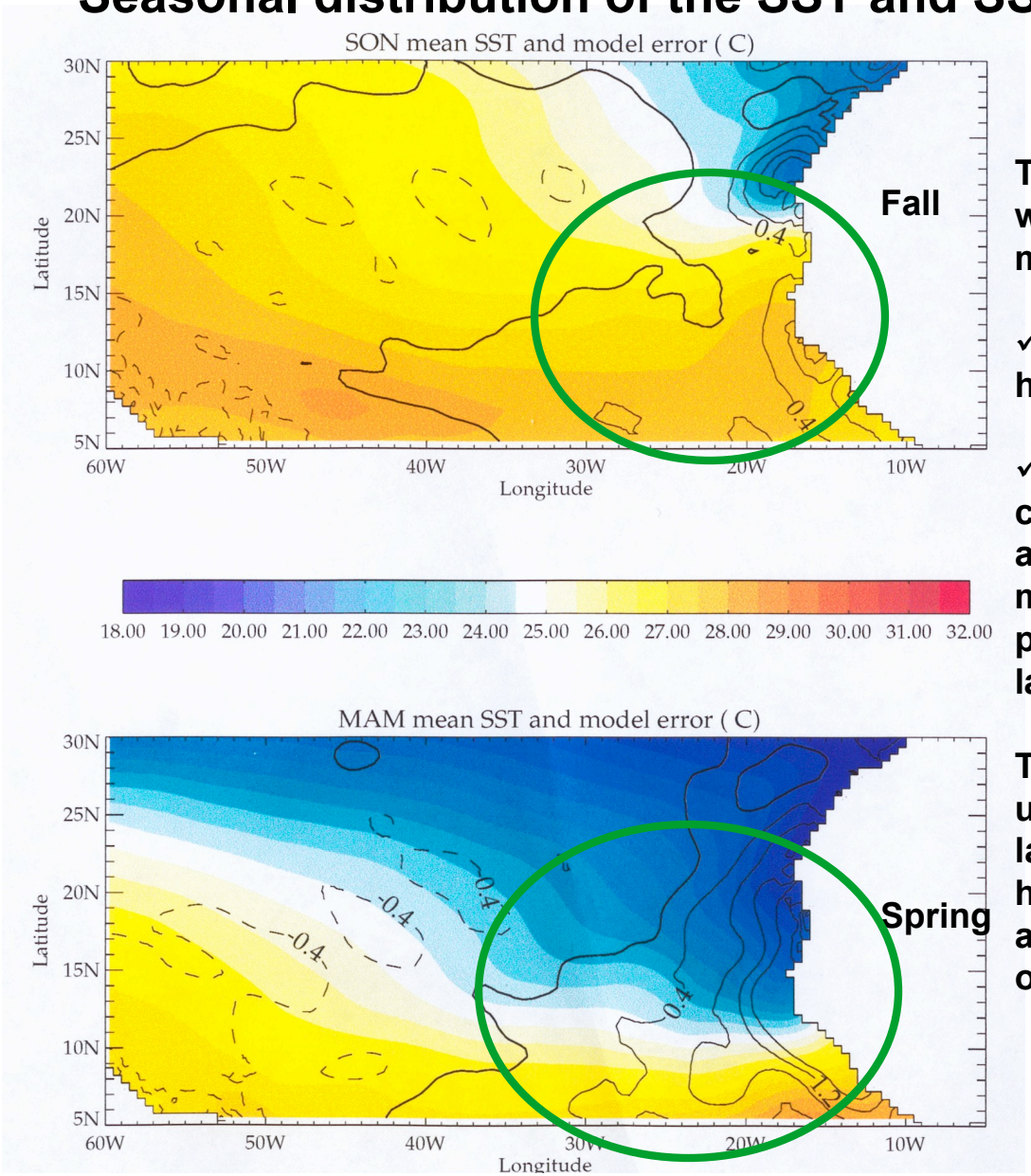
1/quasi-permanent Mauritania/Senegal upw.

2/ summer enhanced GD upw.

3/ ITCZ northern flank upw. (highly variable extension)

The ANETUS and its SST LARGE BIAS in CLIMATE MODELS

Seasonal distribution of the SST and SST errors in the OGCM



The ANETUS is caracterized by a large warm biases in state of the art Climate models:

✓The coastal signal is due to the lack of horizontal resolution in the OGCM

✓The open ocean signal has long been considered as a result of biases in atmospheric fluxes (scarce measurements and poor parameterization of atmospheric mixed layer and strato-cumulus cover)

The oceanic mixed layer processes in upwelling regime could alternatively lack of enough physics to simulate the heat budget correctly. It is one of the aim of the project to gain understanding on the problem.

MODEL MIXED LAYER PHYSICS

1. Climatological mixed layer heat budget

in order to focus on the M.L. physics, we look at the temperature trends for the entire mixed layer. We horizontally averaged the trends over the time-varying area of upwelling (upward W_{10m}, see figure above). In order to emphasize the upwelling physics, the average was weighted by W_{10m}

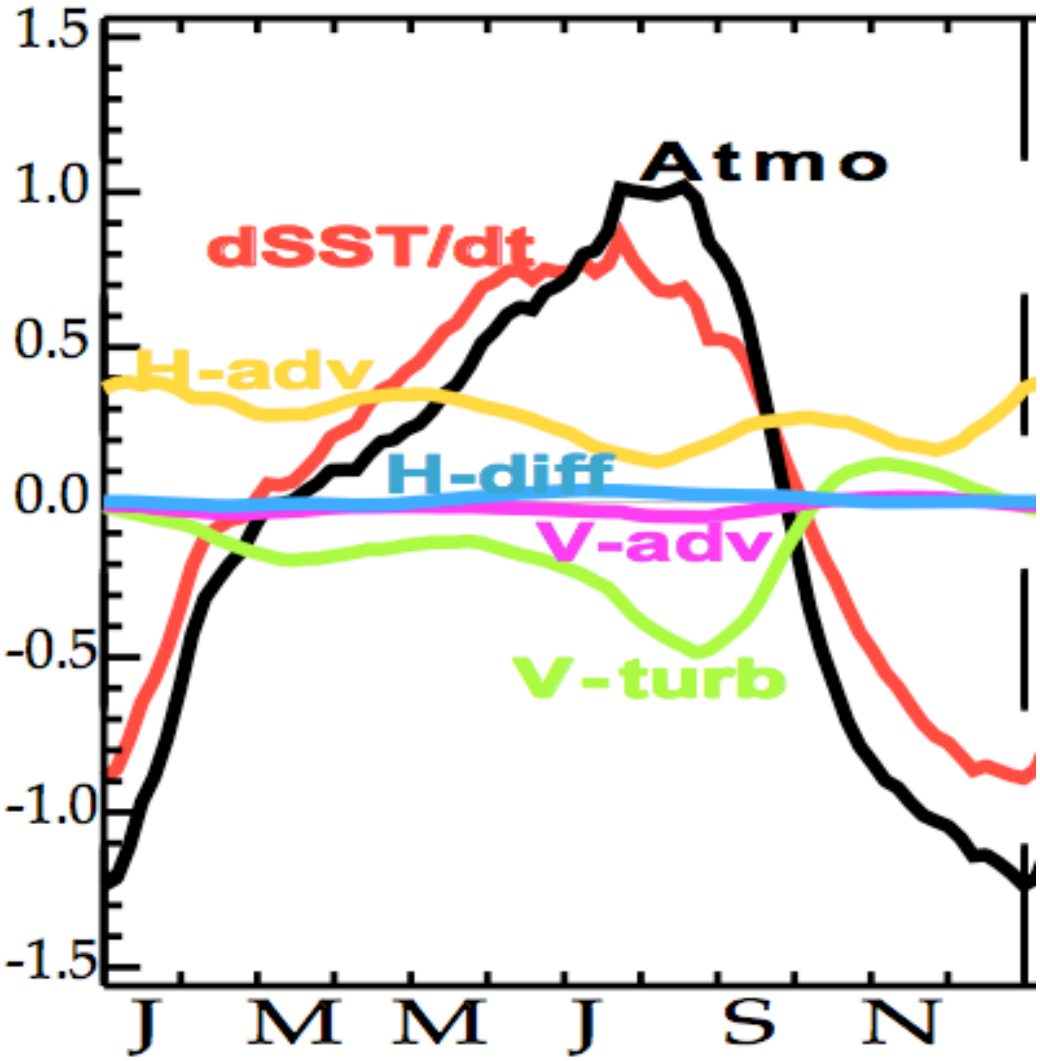
We checked that the result were representative of all the ANETUS, also locally:

✓SST is largely controlled by the atmospheric flux (mainly short wave+latent). In particular, the cooling period is controlled by atmospheric fluxes, not by vertical processes!

✓vertical diffusion cools the surface during the northward migration of the ITCZ. The presence of barrier layers within the upwelling region reverse the sign of the contribution in fall

✓Horizontal advection warms the layer

✓vertical advection has almost no direct contribution, its role is to generate a strong vertical gradient below the ML.



MODEL MIXED LAYER PHYSICS

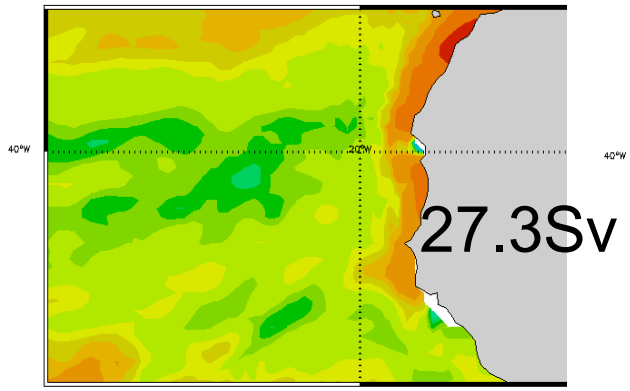
2. The actual contribution of the upwelling to water transfer into the mixed layer: Eulerian analysis

The annual mean transport from the thermocline to the ML was computed.

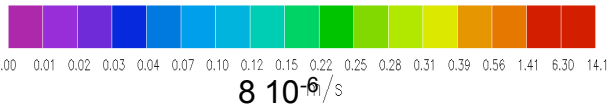
✓The total transport is about 27 Sv.
✓Half of the transport is due to entrainment, mainly in the sub-tropics.
✓The rest is equally divided into vertical and horizontal transfer, occurring mainly within the ANETUS region.
✓ The vertical transport is maximal on the northern coastal region while the horizontal transfer is more homogeneous.

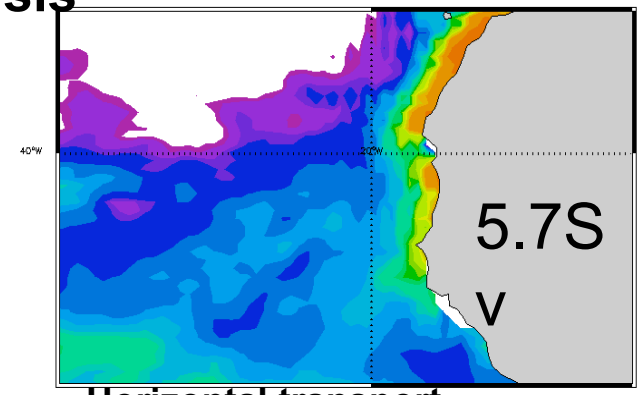
=> The vertical transfer *per se* represents only 25% of the transfer.

The analysis of the seasonal cycle is ongoing. Also, the role of Rossby waves will be quantified and discussed.

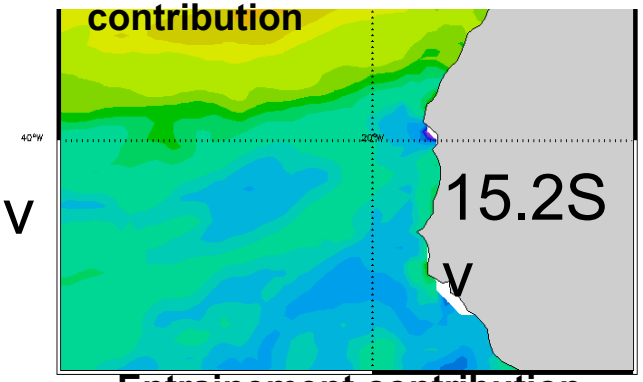


Total volume transport *into* the mixed layer

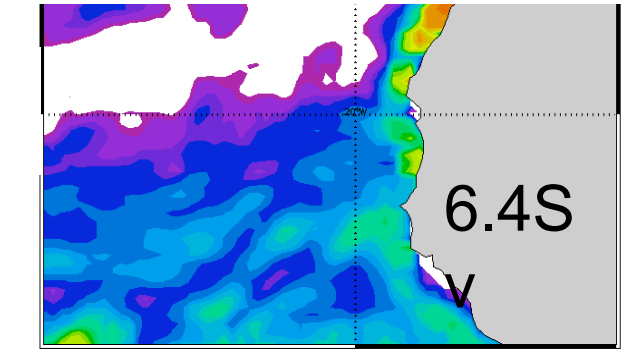




Horizontal transport contribution



Entrainement contribution



Vertical transport contribution

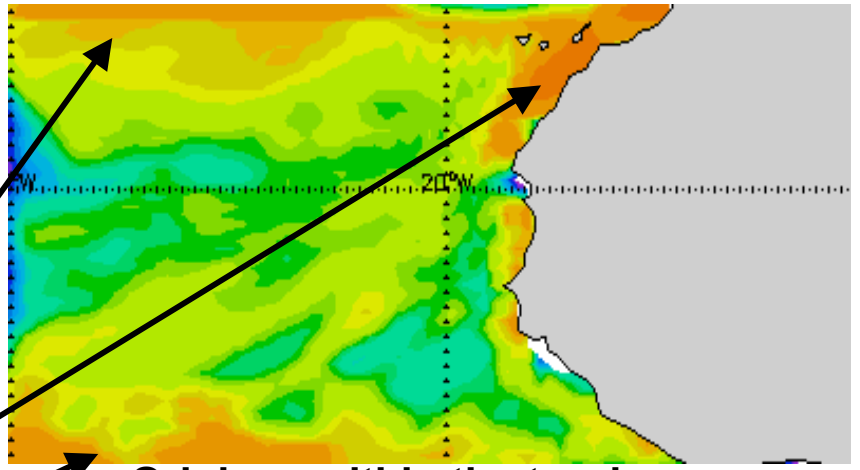
MODEL MIXED LAYER PHYSICS

2. The actual contribution of the upwelling to water transfer into the mixed layer: Lagrangian analysis

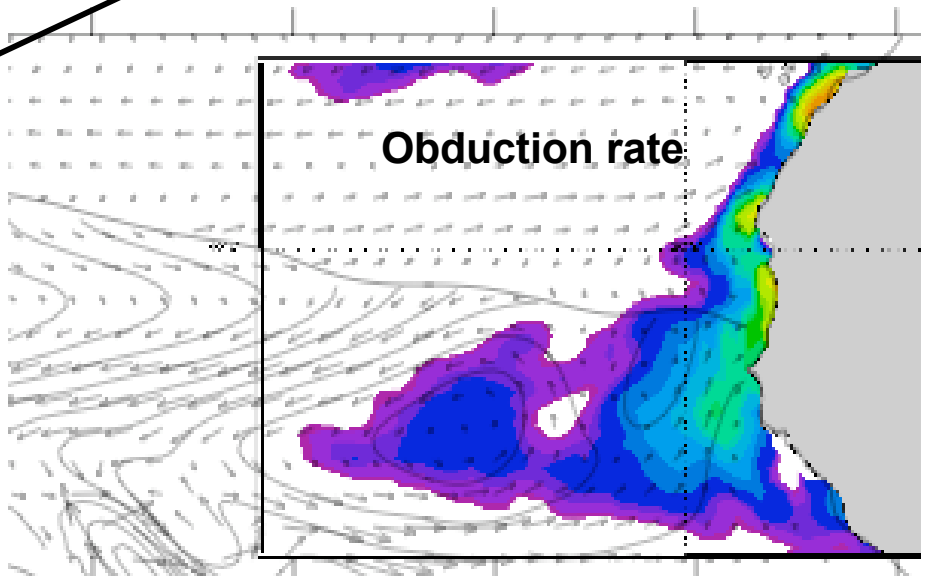
Lagrangian diagnostics provide insights on stucture of the upwelling associated with the 3-D circulation (see schematics, upper left panel) Using backward in time Lagrangian integration (ARIANE*), the full trajectories of the water parcels entering into the ML were computed.

✓The three main (mixed layer) sources of waters are:

- the salinity maximum water subduction region and NEC
- the Canary current
- the mixed layer within the NECC



Origines within the tropics

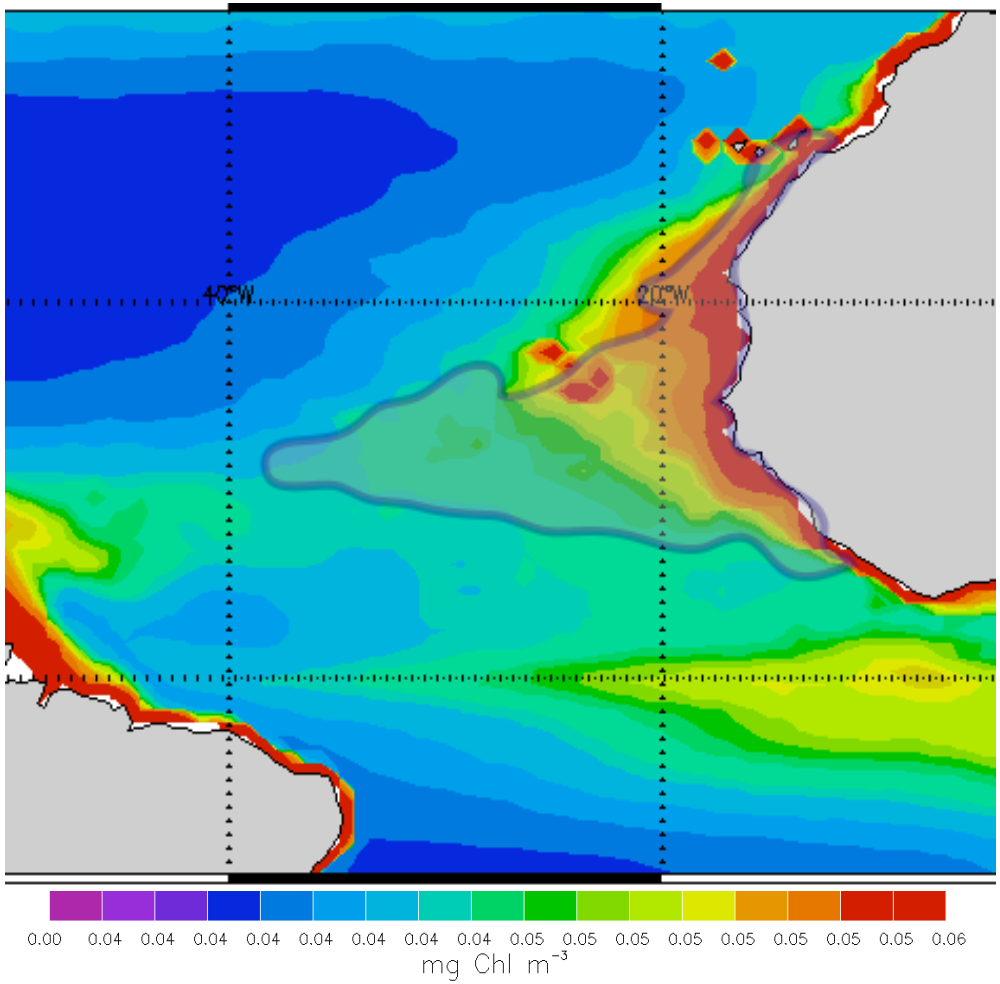


✓Only 1.7 Sv of the total tranport is found to spend at least 1 year in the interior (***obduction***), dominated by vertical transfer and entrainement.

- the southern hemisphere provides 2/3 of the transport (thermocline STC and South Atlantic Central Water $\sigma_0 \approx 26.7$).
- the remaining third comes from the salinity maximum water subduction site of the Northern STC

ANETUS and PRIMARY PRODUCTION

The link of the upwelling with the Chlorophyll distribution



surface Chl annual mean (SeaWiFS)

The ANETUS region is associated with very high primary production. The resulting chlorophyll displays a geographical distribution clearly similar to the extension of the upwelling system, even far away from the coastal region:

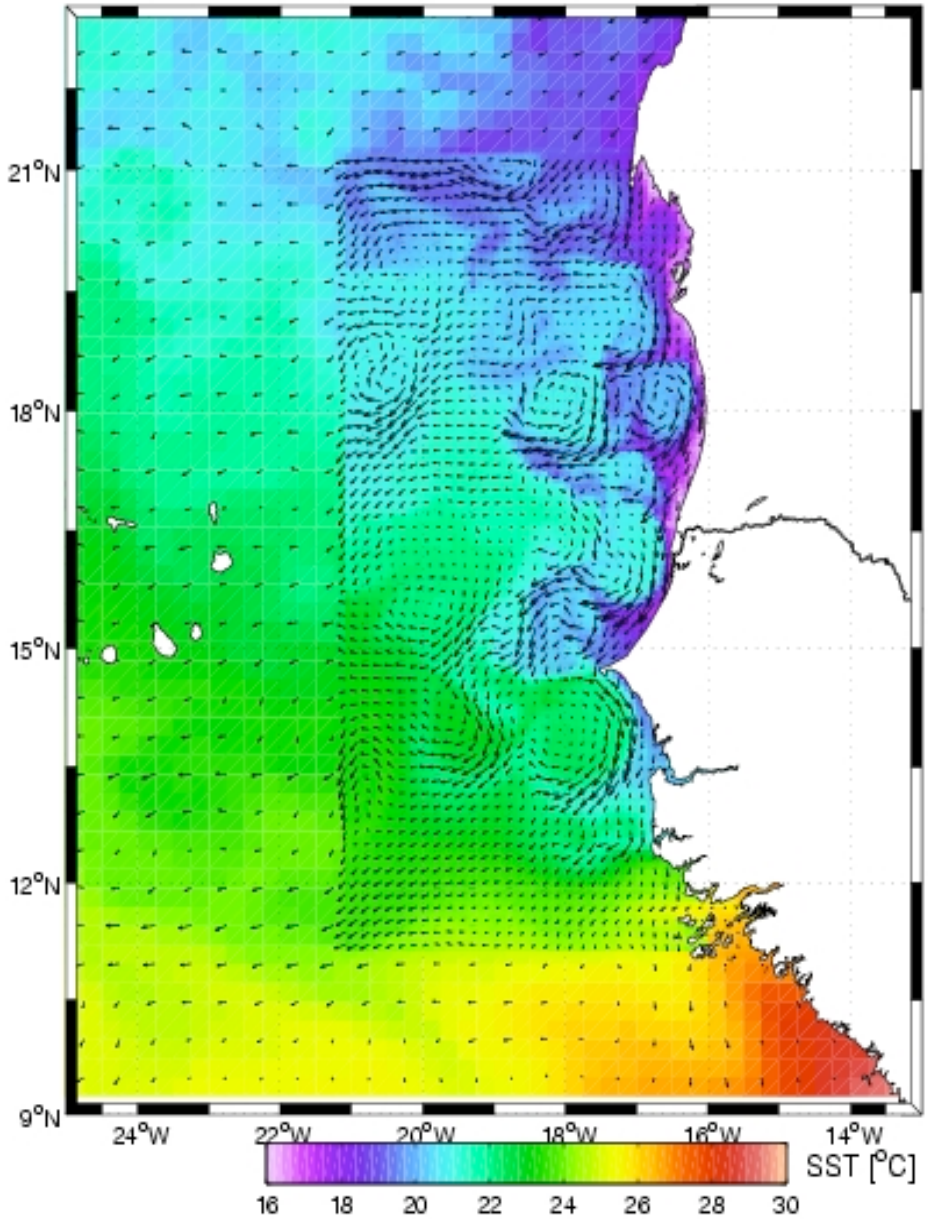
- high values around the Cap Verde Islands
- moderate values within the ITCZ upwelling

In order to estimate the role of the open ocean upwelling processes versus advection from the coast by surface currents, the Lagrangian diagnostics will be used in conjunction with observed subsurface nitrate distribution.

Here we simply overlay the limits of the obduction region on the Chlorophyll field. A good match is observed everywhere, also far away from the coast.
Only about (20°N, 25°W) either horizontal advection plays the major role, or the model obduction is erroneous.

Modelling the Coastal Upwelling

A High resolution model



As complement to data analysis and large-scale modeling, ANETUS includes a state-of-the-art high-resolution model of the oceanic circulation on the western African coast. P. Marchesiello has now started the application of The Regional Oceanic Modeling System (ROMS) to the region.

The configuration for the Canary Current System goes from 5N to 40N with a resolution of 25km. An embedded level at 6 km resolution is implemented in the southern region (Figure 4). At this resolution, the production of unstable flows associated to the upwelling process is already realistic. Filaments are vigorous and able to produce large exchanges of water and material properties between the coastal and offshore areas.

PERSPECTIVES

The ANETUS region is characterized by major climate-related features:

- **the seasonal and interannual SST variations are the largest of the tropical Atlantic**
- **it shelters the whole seasonal migration of the Atlantic Marine ITCZ (AMI) as well as part of the African Monsoon**
- **the lack of in–situ observation is among the highest of the basin**
- **forced ocean and atmosphere models have large systematic bias over the region.**

We presented a brief overview of some of the ongoing research activities focused on mixed layer physics. The two other main avenues being initiated are:

1. The planetary waves activity, and their local and remote effects on SST and SSH (satellite observations, theoretical development, and model studies)

2. The mechanisms of ocean/atmosphere/land coupling (data analysis as well as forced and coupled GCMs)

Selected references:

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