Ocean responses using atmospheric fields at different space-time resolutions

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0. Context

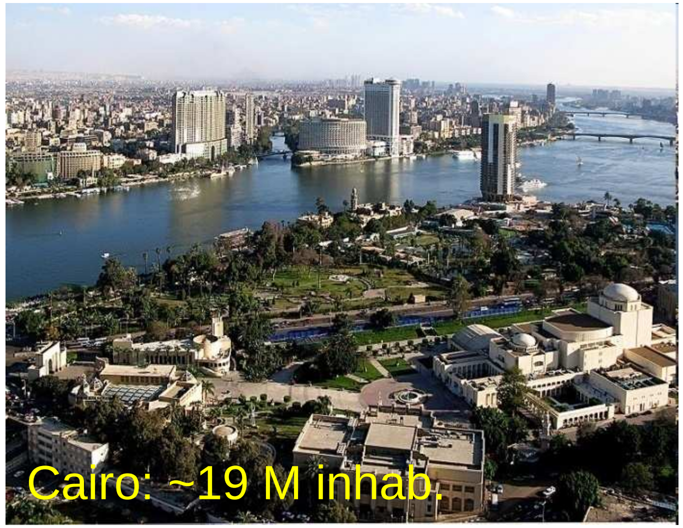
A nearly enclosed sea…

~2000 km

~4000 km

0. Context

… surrounded by very urbanized littorals …



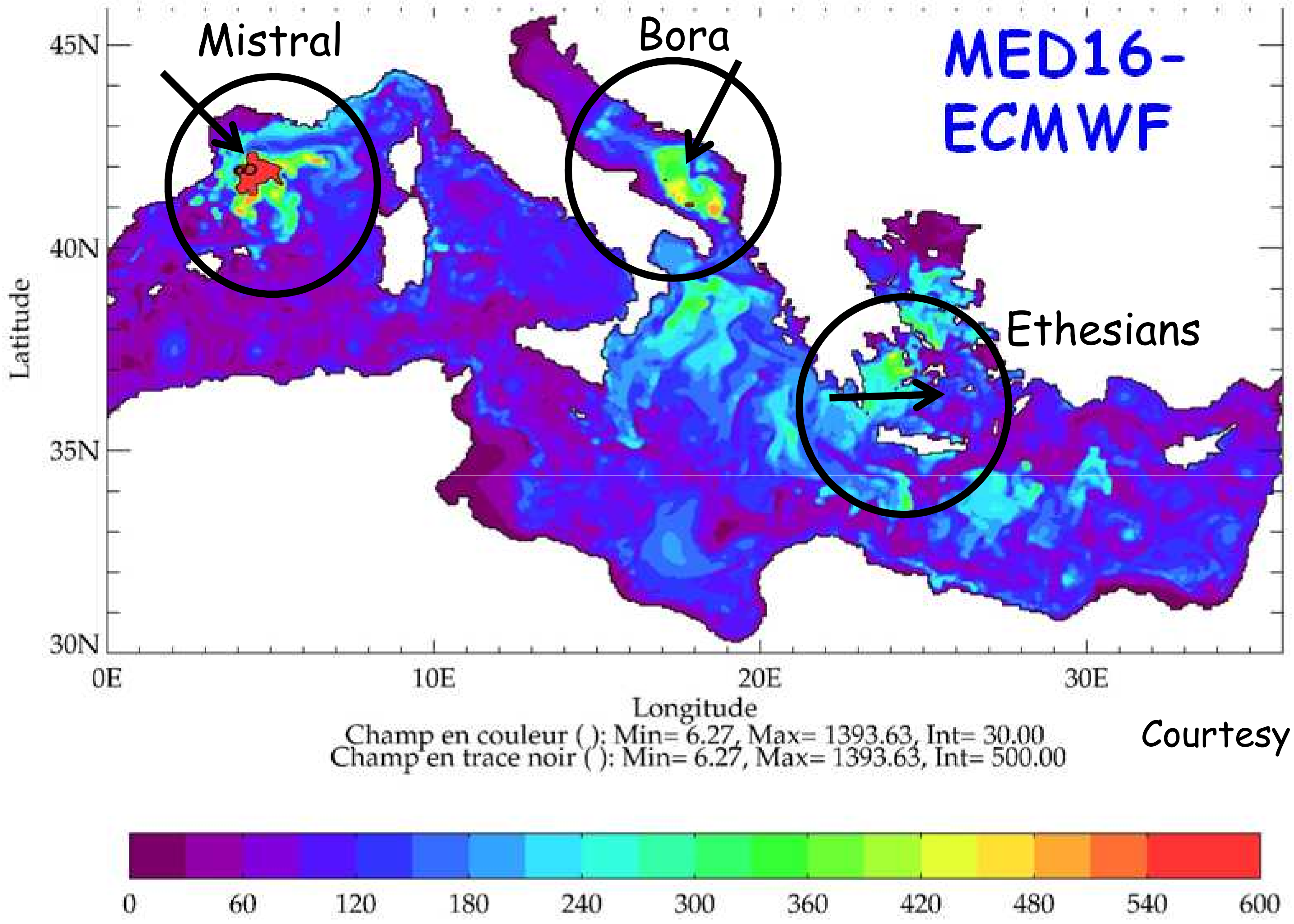
0. Context

… and mountains …

0. Context

… from which numerous rivers originate...

… which affect the Mediterranean thermohaline circulation, the quality of the waters and the marine life



Courtesy to K. Béranger

0. Context

In this context, there is a crucial need to:

- improve our understanding of the ***water cycle***, with emphases on the ***predictability and evolution*** of ***intense events*** by monitoring and modelling:
    1. the Mediterranean ***coupled system*** (atmosphere-land-ocean),
    2. its ***variability*** (from the event scale, to the seasonal and interannual scales) and characteristics over decades in the context of global change

- to evaluate the ***vulnerability*** of marine life in the context of global change.

HyMeX
Hydrological in the Mediterranean eXperiment

MERMeX
Marine Ecosystems Response in the Mediterranean Experiment

1. Experimental design

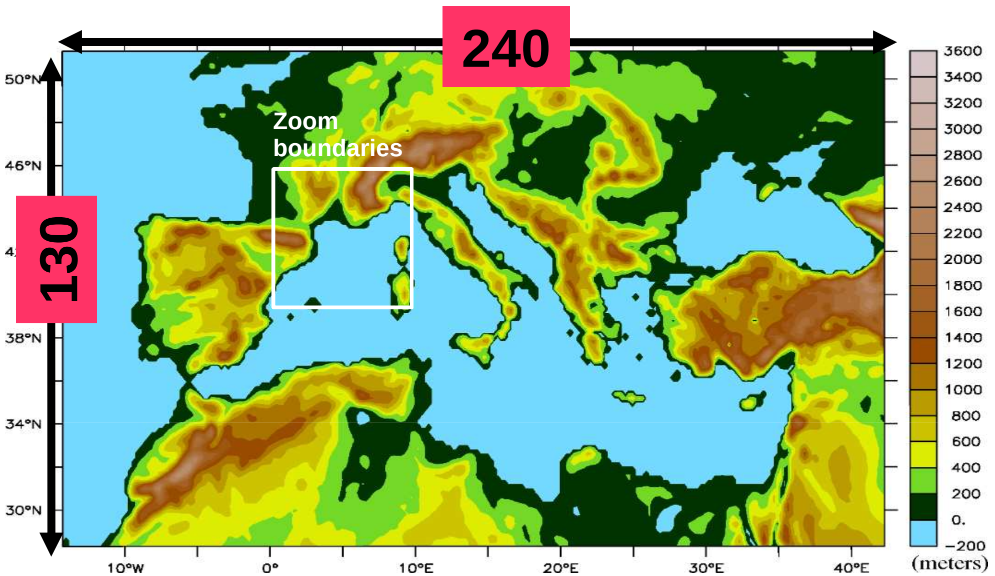
Regional atmospheric model

The *WRF* configuration:
code version 3.0 [Skamarock, 2008] non-hydrostatic
Regional domain: 240x130 grid-points – Δx=20km – Δt=60s
28 vertical levels
Initial and boundary conditions from *NCEP* reanalysis (2°x2°)

Zoom domain: 105x105 grid-points – Δx=6.7km – Δt=20s
28 vertical levels
Initial and boundary conditions from the regional domain simulation

SST field updated every 6hrs from reanalyses

microphysics: WSM3
convection: Kain-Fritsch
turbulence: YSU-PBL
IR radiation: RRTM [Mlawer et al., 1997]
solar radiation: Dudhia [1989]
turbulent fluxes: «MM5 similarity» [Monin and Obhukov, 1954]

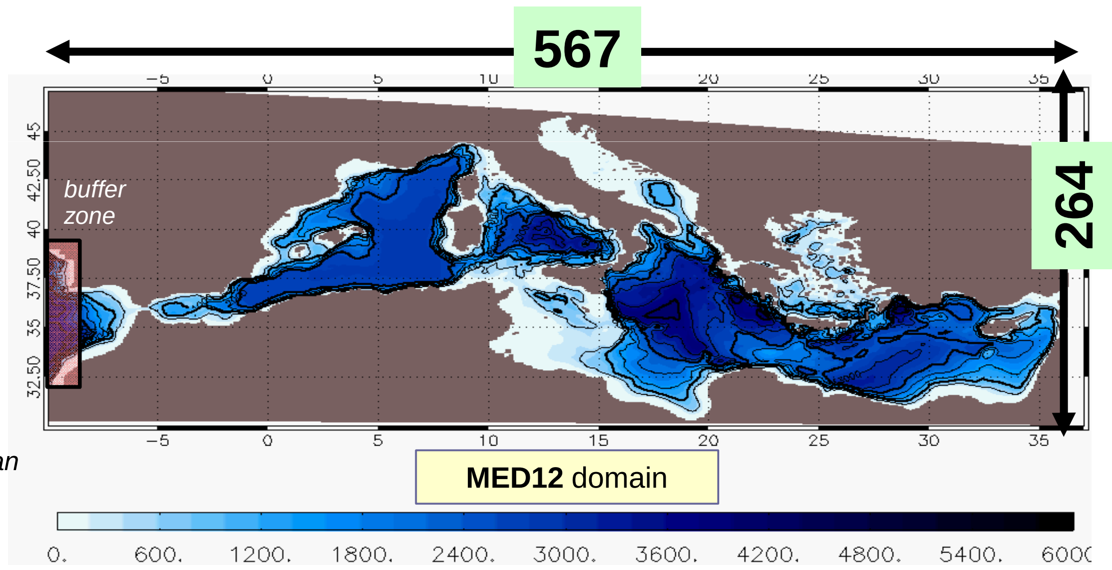


WRF regional domain

Ocean model

The *MED12* model configuration:
NEMO code v2_3 [Madec 2008]
ORCA12 grid, *i. e.* Δx≈6 to 8 km-resolution from North to South
50 vertical levels
Δt=12mn
Initial state (T,S): Levitus [2005]

Exchanges with the Atlantic Ocean via a bufferzone
Black Sea inputs modelled as a runoff.
A climatology for the main rivers catchments is taken for runoffs
Free surface parameterization: The evaporated volume in the Mediterranean zone is reported in the bufferzone as an Atlantic Water surface input.



MED12 domain

See also poster MWB10

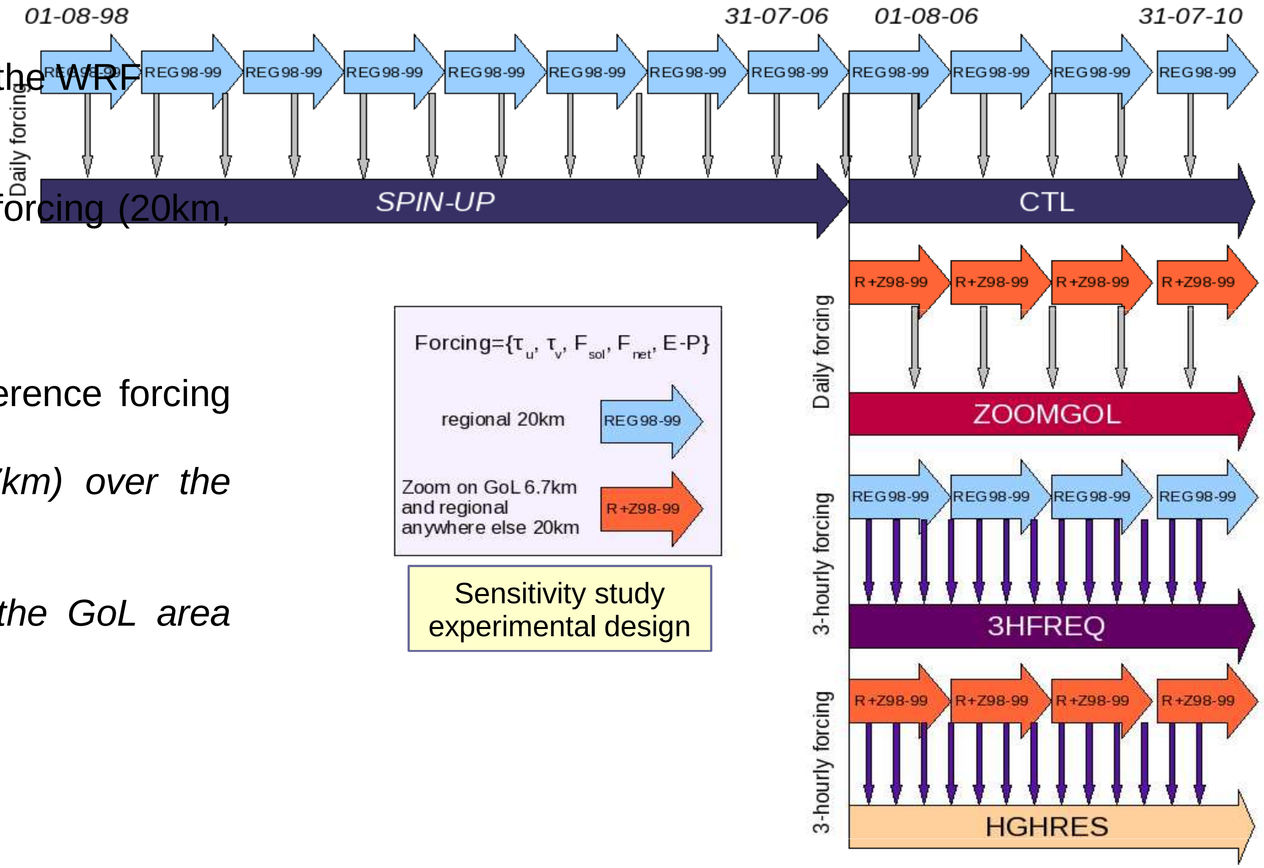
1. Experimental design

Air/Sea experiments in the forcing mode

MED12 simulations in perpetual mode using the WRF atmospheric forcing.

1. **Spin-up** run (8 years) with the reference forcing (20km, daily).

2. Sensitivity experiments (4 years):
The control experiment (**CTL**) used the reference forcing (20km, daily).
In **ZOOMGOL**: *high spatial resolution (6.7km) over the GoL area*
In **3HFREQ**: *high temporal resolution (3 hrs)*
In **HIGHRES**: *high spatial resolution over the GoL area (6.7km) and high temporal resolution (3hrs)*



QUESTIONS:

Considering the Mediterranean basin's particularities, what are the required spatial and temporal resolutions of the atmospheric model for coupled regional climate modelling ?

Quality of the sea surface fluxes from the non-hydrostatic high-resolution WRF model ? Impacts of a finer spatial resolution over the North-Western Mediterranean basin ? Benefit of a higher temporal resolution ?

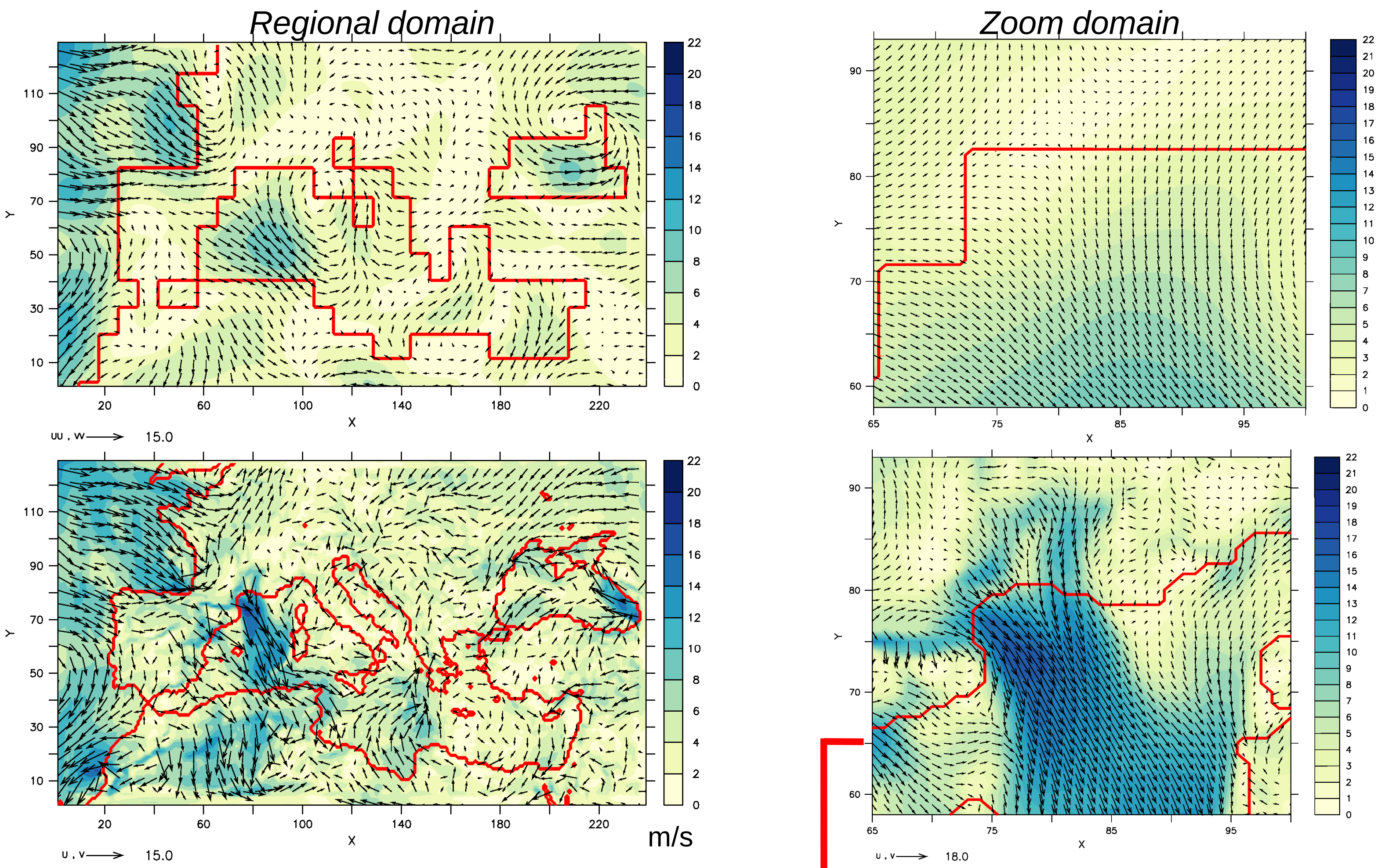
Sensitivity of the NEMO-MED12 ocean model to the space-time resolution of the forcing ? Effects on the thermohaline circulation ? Impacts on the ocean response at mesoscale under intense weather events ?

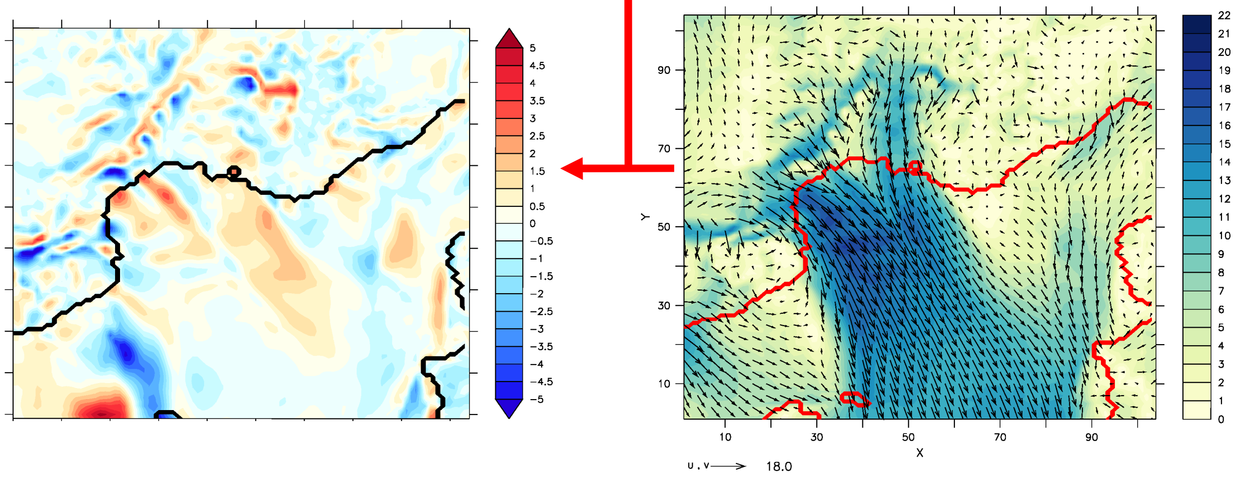
2. Validation

25 Nov 1998 06:00 – surface wind (m/s)

NCEP 2.5°

WRF 20km

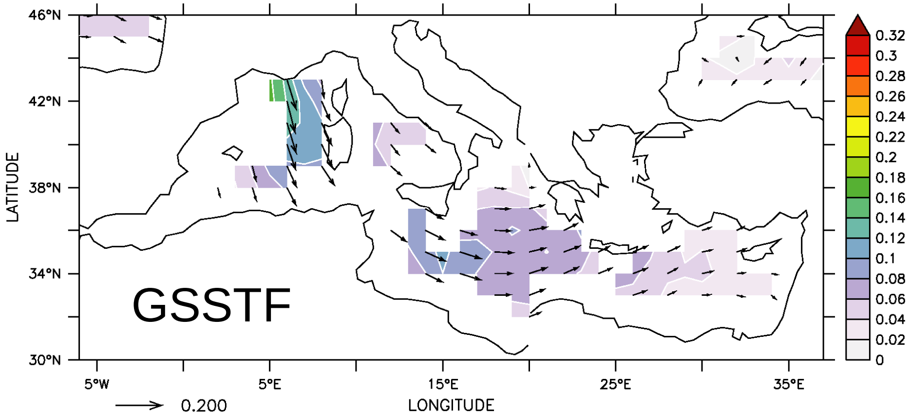




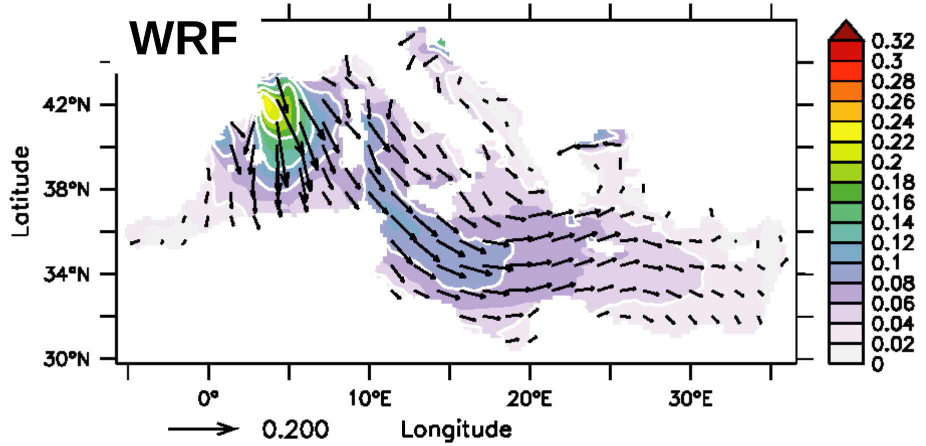
WRF 6.7km

- ***NCEP offshore moderate wind***
- ***WRF20km stronger and coastal winds***
- ***finer low-level jets in the zoom (WRF6.7km)***

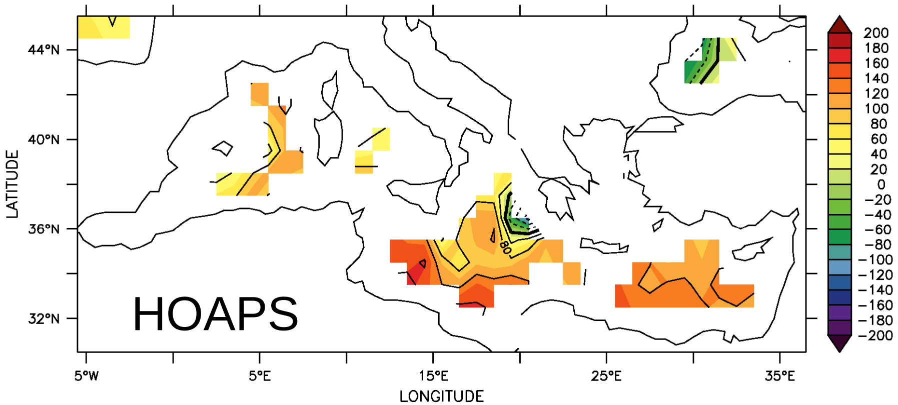
2. Validation



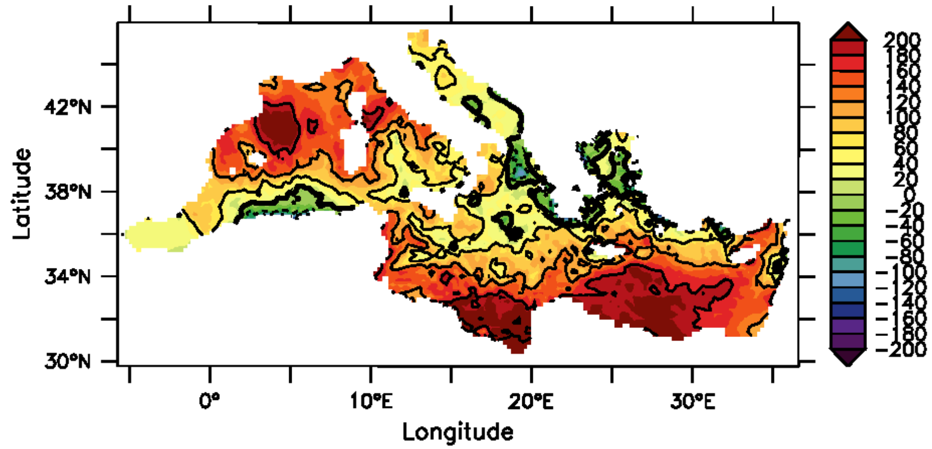
Wind Stress Module N/m2



Wind Stress Module N/m2 – November

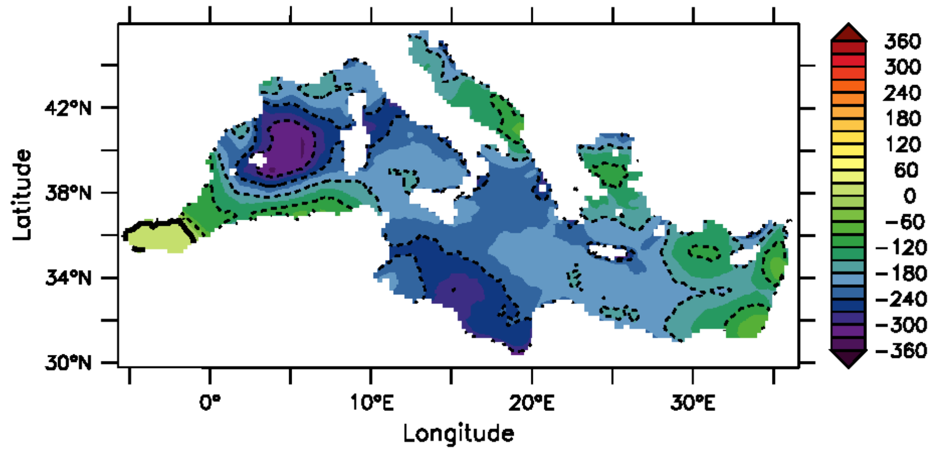


HOAPS E–P mm/month



Freshwater Flux mm/month – November

Forcing fields (wind stress [N/m2], freshwater flux [E-P mm/month], heat flux [SW-LW-H-LE W/m2]) in november 1998

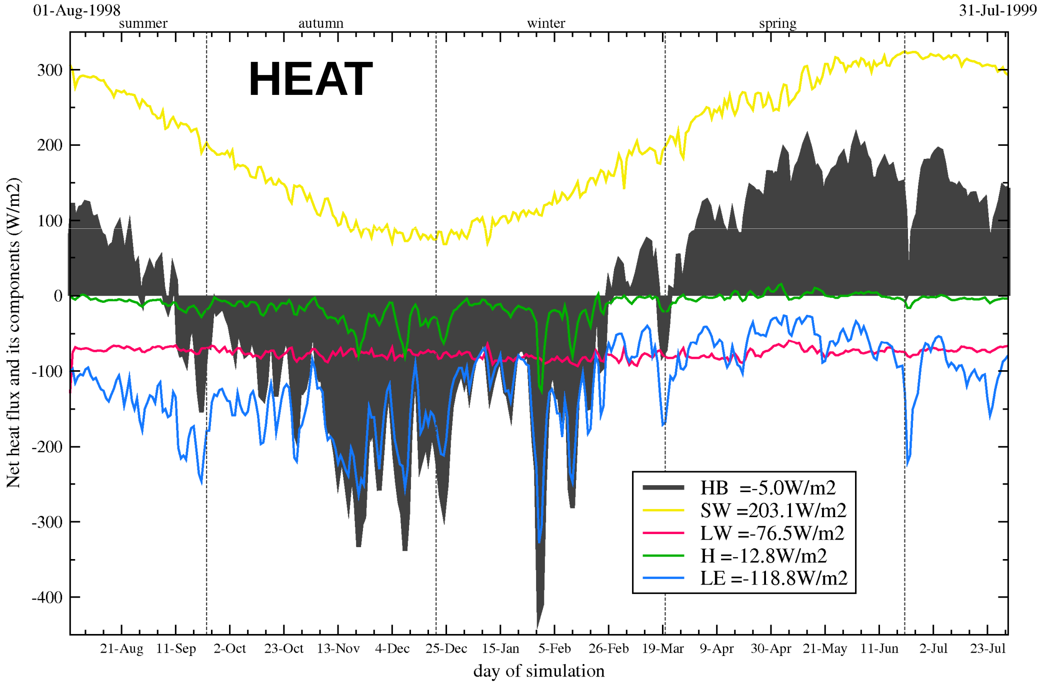


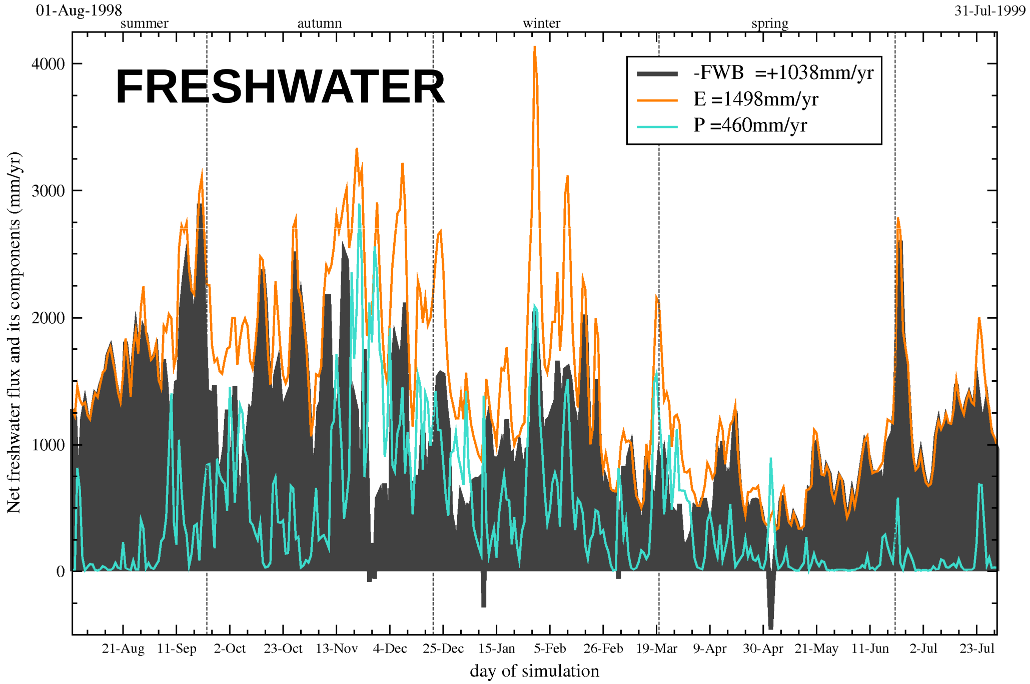
Net Heat Flux W/m2 – November

2. Validation

Evaluation of the reference forcing

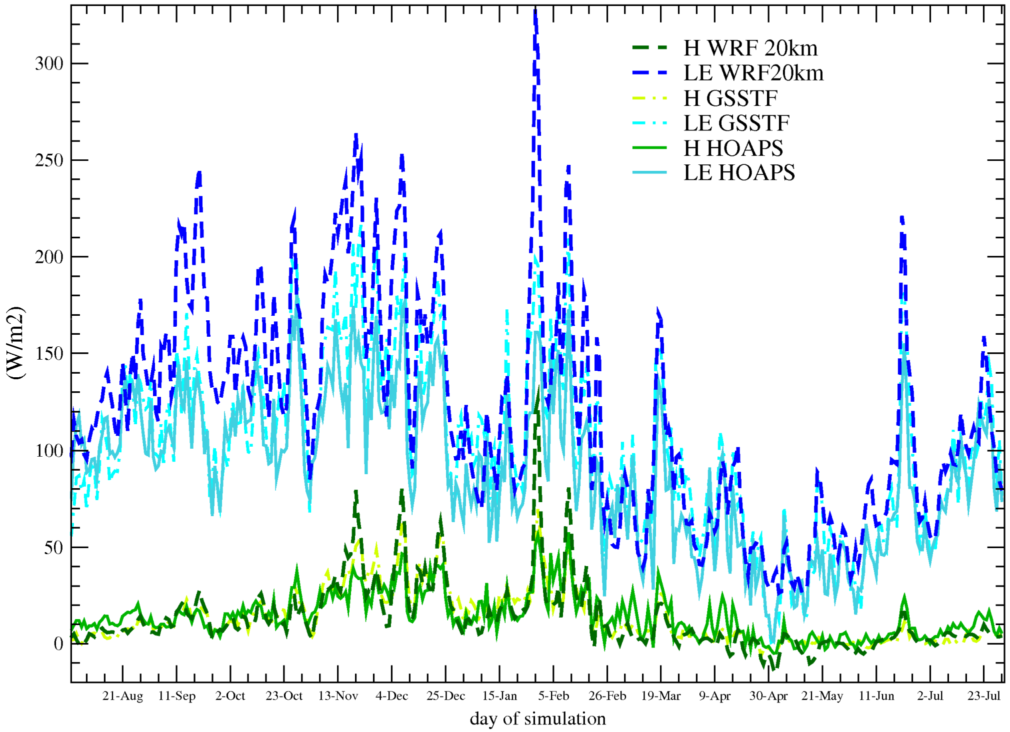
Heat and freshwater annual **budgets** in the reference atmospheric forcing (20km, daily)



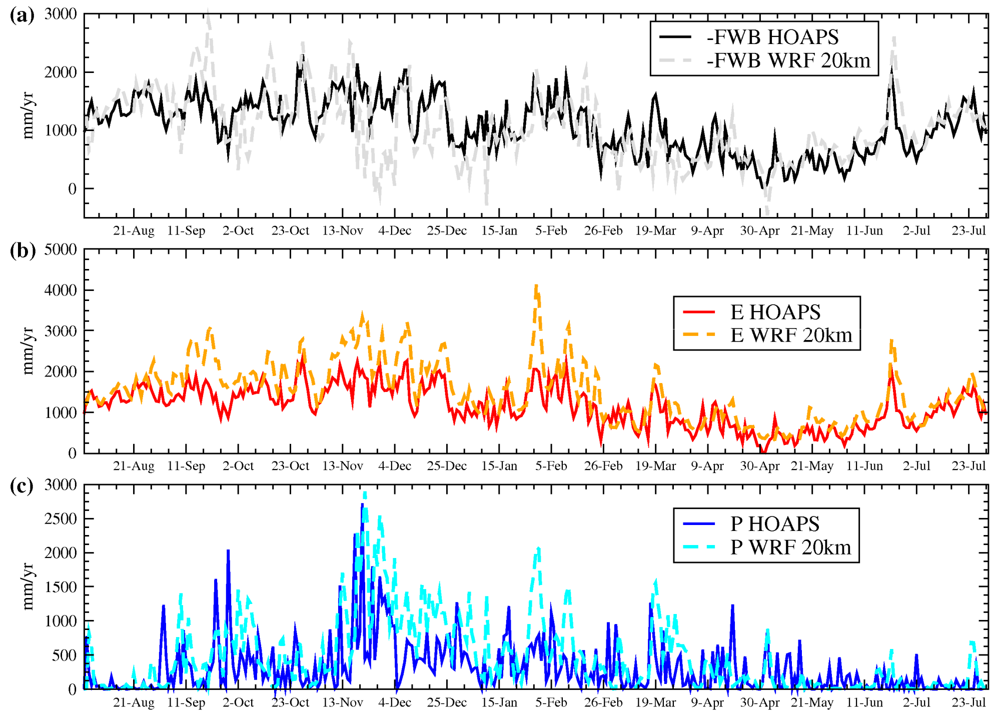


2. Validation

Evaluation of the reference forcing



Sensible (H) and latent (LE) heat fluxes



Evaporation (E) and Precipitation (P)

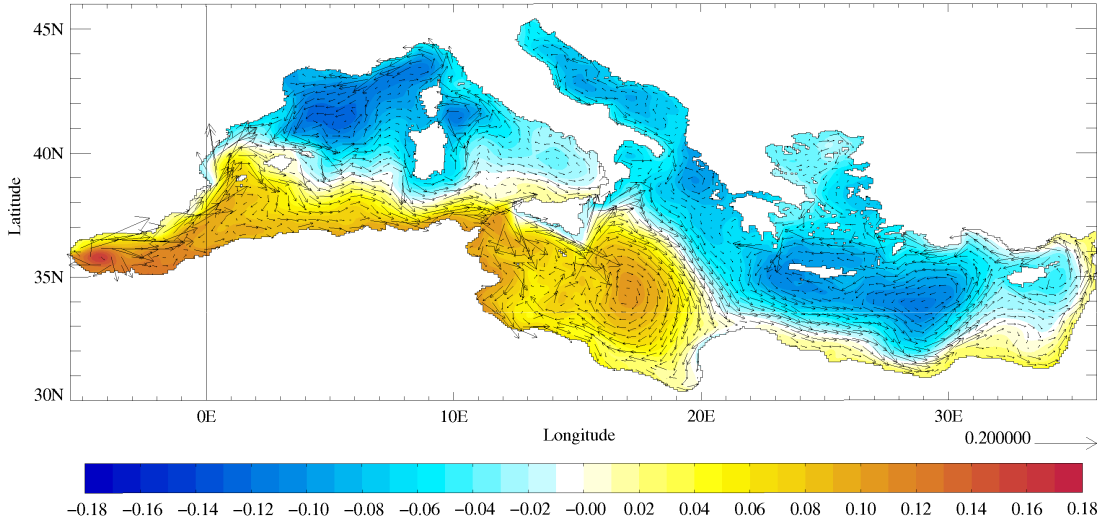
Scores against the GSSTF2 [Chou et al., 2003] and HOAPS3 [Andersson et al., 2007] air-sea fluxes products over the Mediterranean region.

		H (W/m^2)	LE (W/m^2)	E (mm/yr)	P (mm/yr)
HOAPS	correlation	**0.83**	**0.90**	**0.89**	**0.61**
	bias	-1.55	29.64	352	155
	rms	10.40	40.92	499	452
GSSTF	correlation	**0.92**	**0.90**	-	-
	bias	-0.57	17.25	-	-
	rms	7.34	30.59	-	-

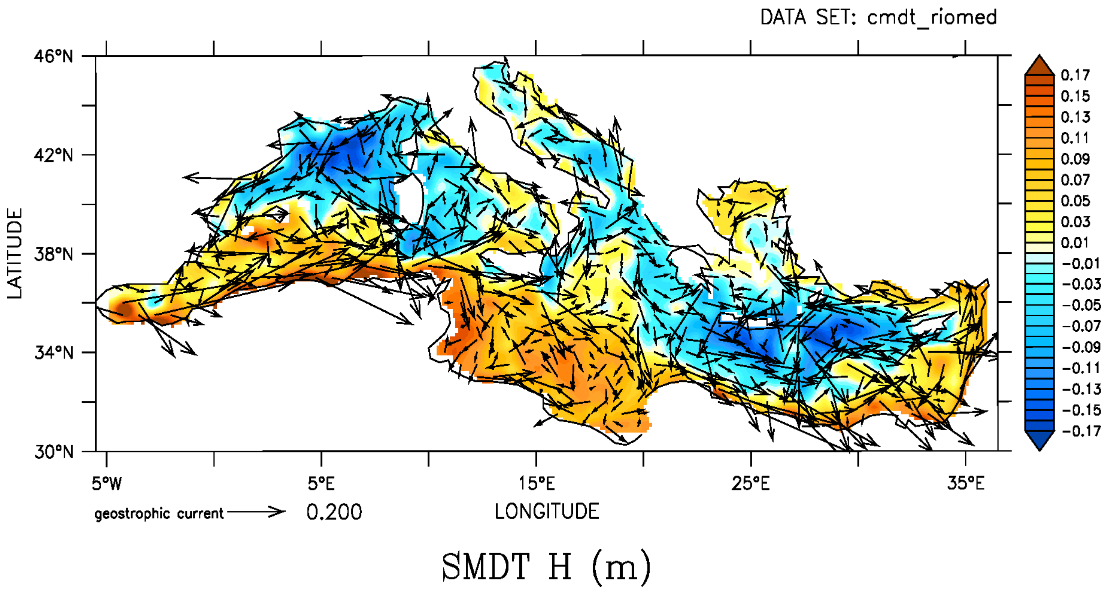
2. Validation

General circulation during the spin-up: SSH

Mean **SSH** (m) + mean **current** at 47m

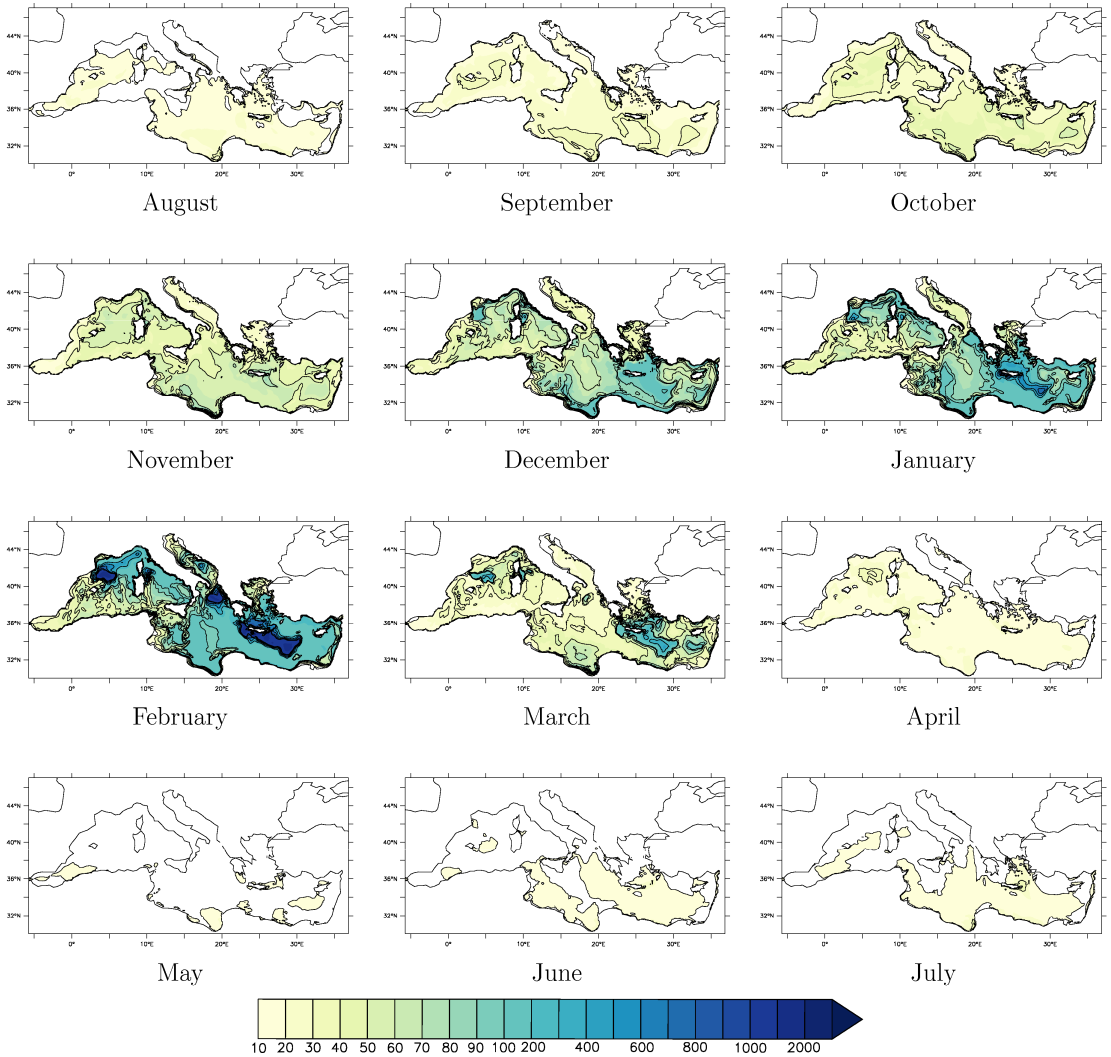


Mean Dynamic Topography from altimetry and in-situ measurements and derived **geostrophic currents** [Rio et al., 2007]



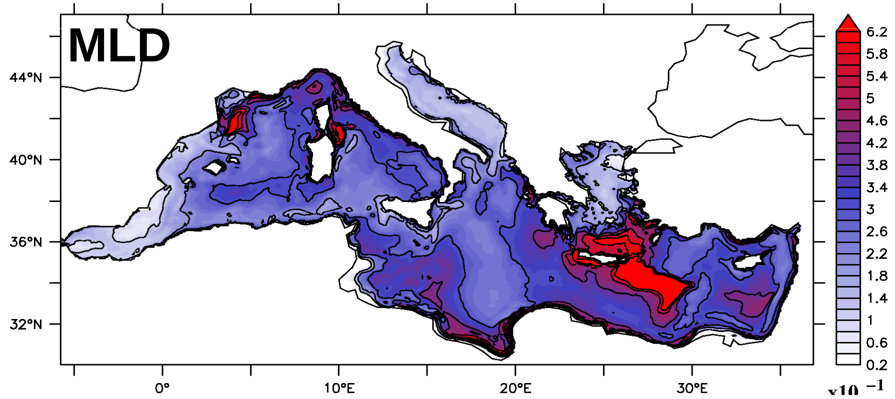
2. Validation

General circulation during the spin-up: MLD



Monthly mean Mixed Layer Depth (m) for the last year of the spinup

Good representation of the seasonal MLD compared to D'Ortenzio et al., 2005

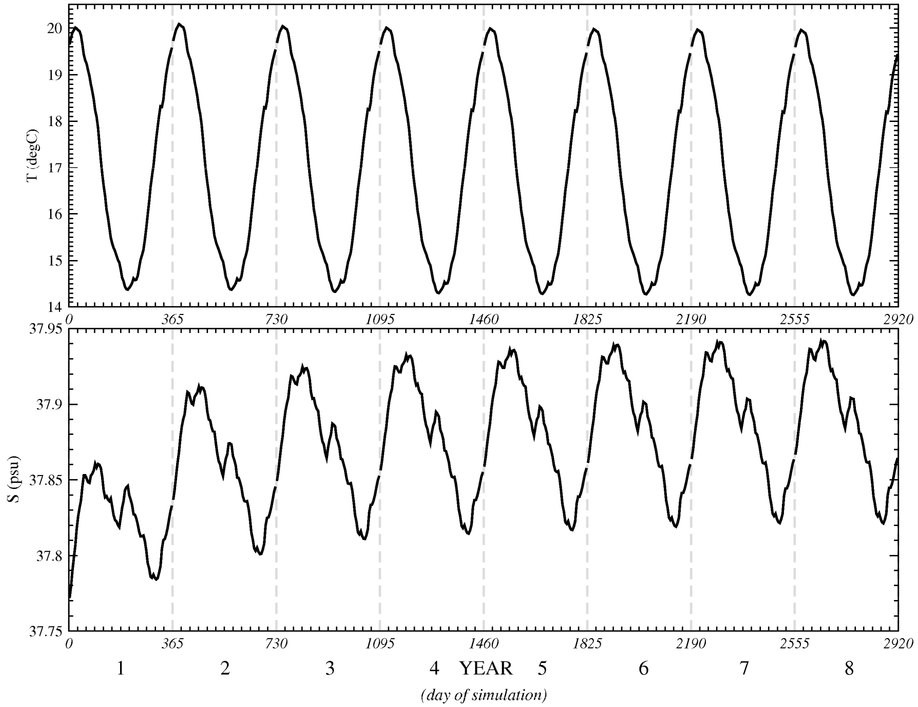


RMS calculated using differences between daily and monthly mean values
–> interannual and seasonal cycles filtered

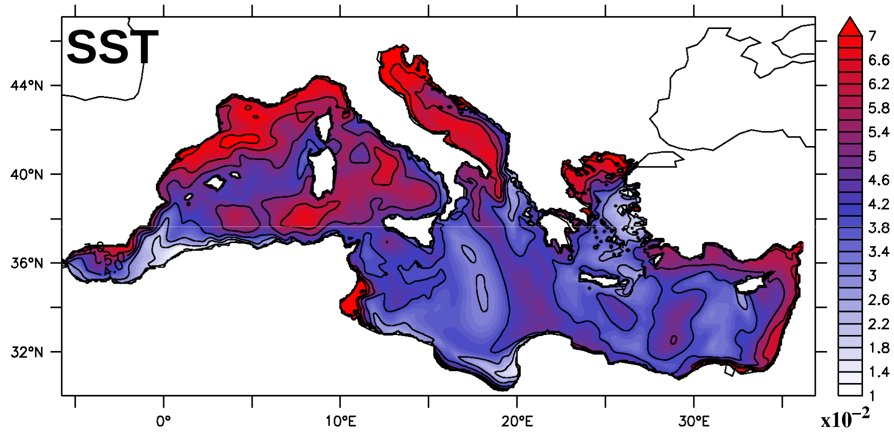
Short-range variations are located along boundary currents and in convective areas

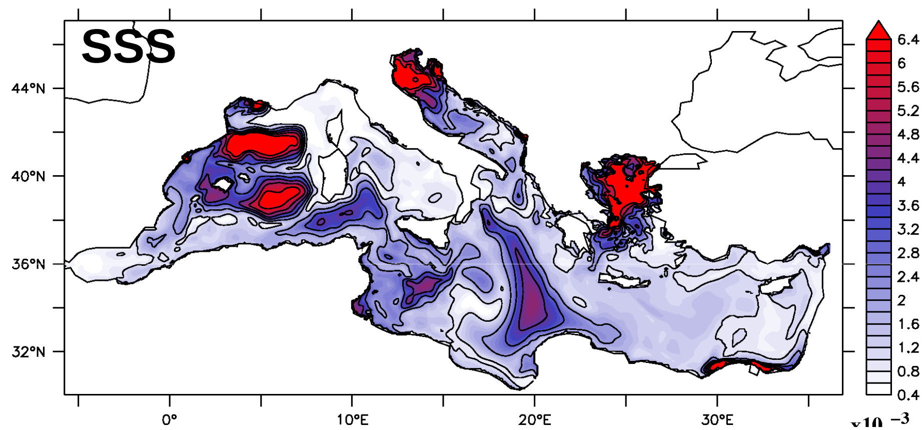
2. Validation

General circulation during the spin-up: SST, SSS



Thermal and salt contents in the first 300 meters during the spin-up





RMS calculated using differences between daily and monthly mean values
–> interannual and seasonal cycles filtered

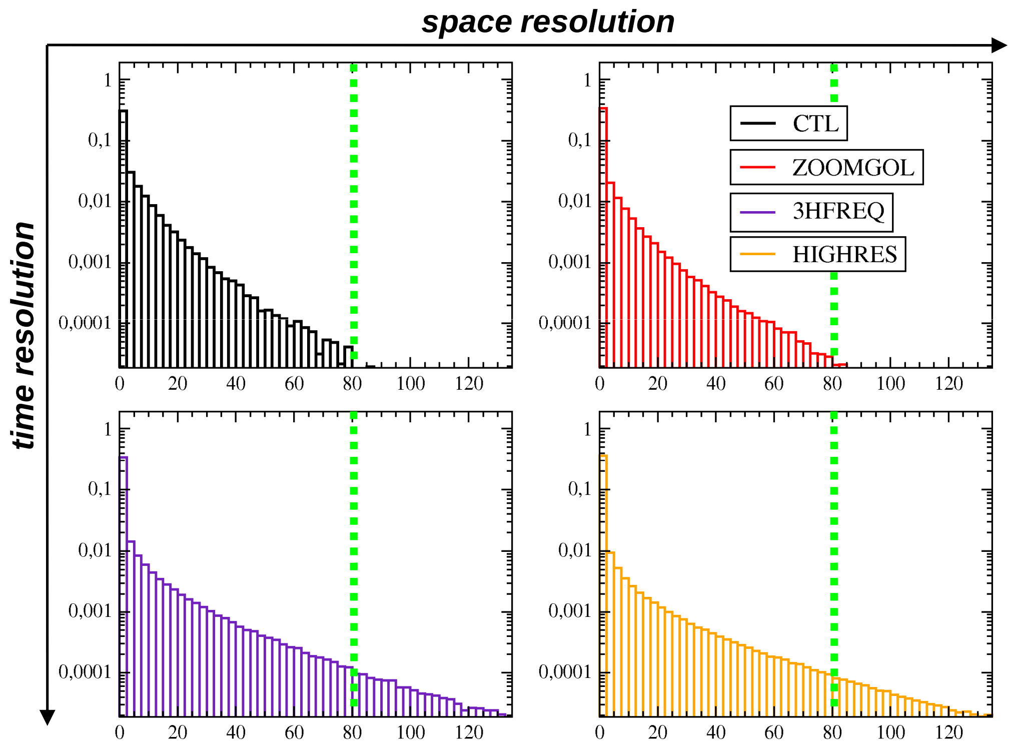
After 4 year, no drift in the first 300 meters in S and T

Short-range variations:
SST: along boundary current
SSS: mainly near rivers

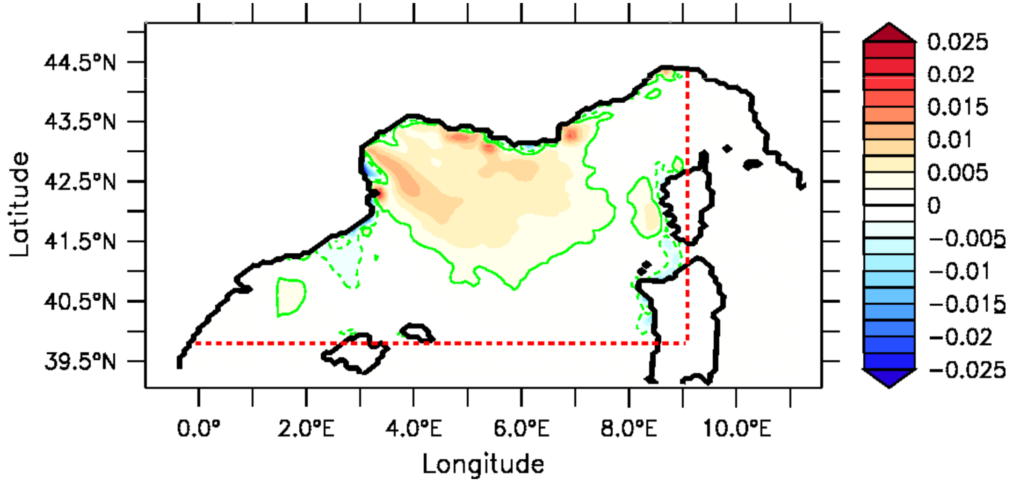
3. Impacts of the high resolutions

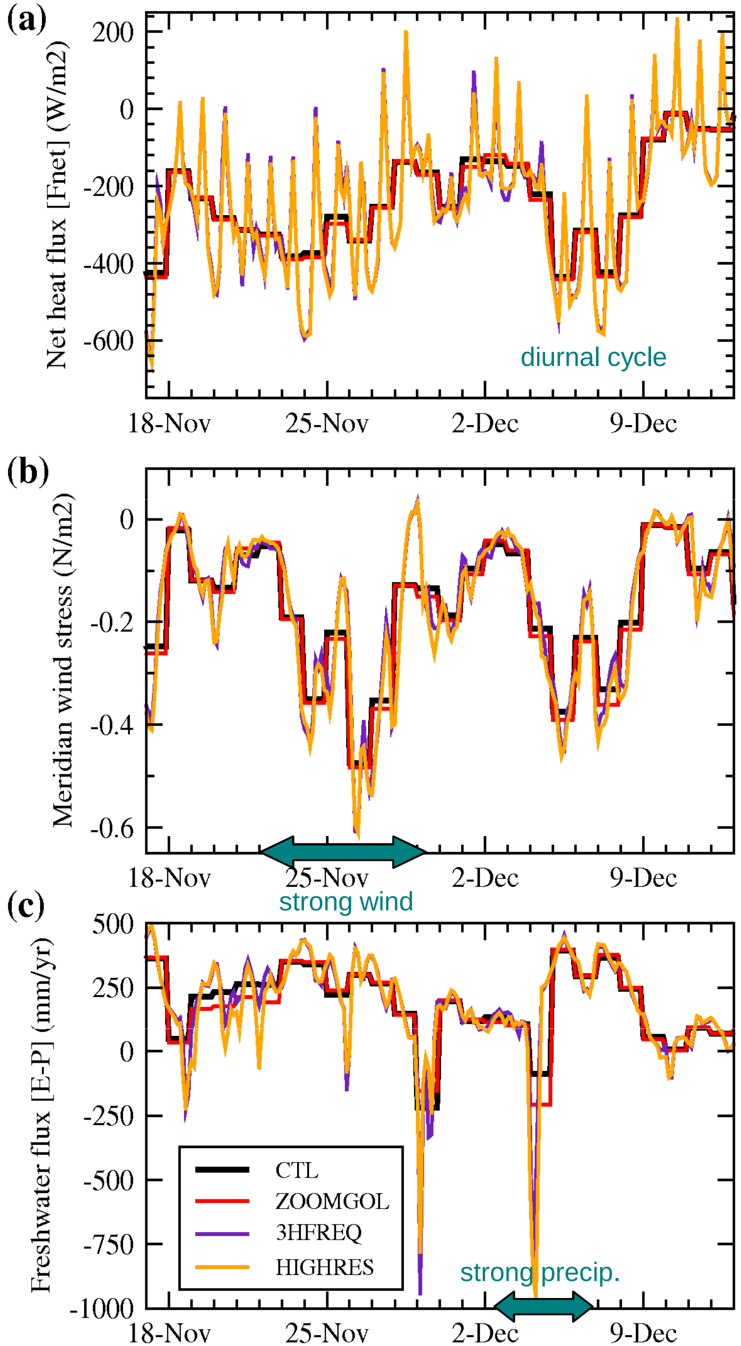
Comparison of the various atmospheric forcings

Probability density functions for the precipitation rate in the various forcings



Differences in the annual wind stress module between **ZOOMGOL** and **CTL**





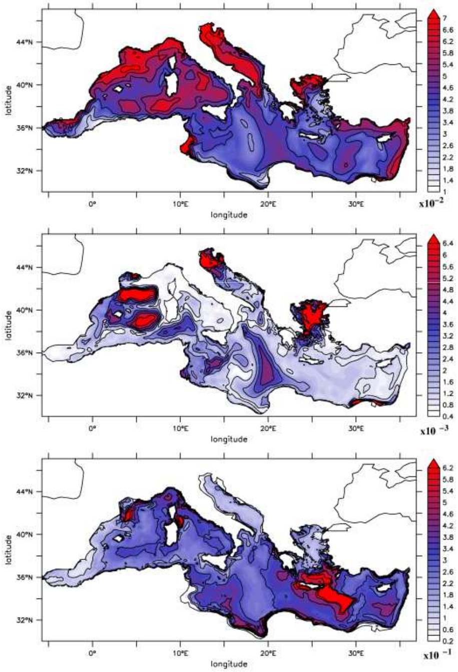
Example of the **different forcing** components between 12 November and 12 December 1998 at 4.9°E-42°N.

High resolution atmospheric forcing ►significant impacts on the intense forcing

3. Impacts of the high resolutions

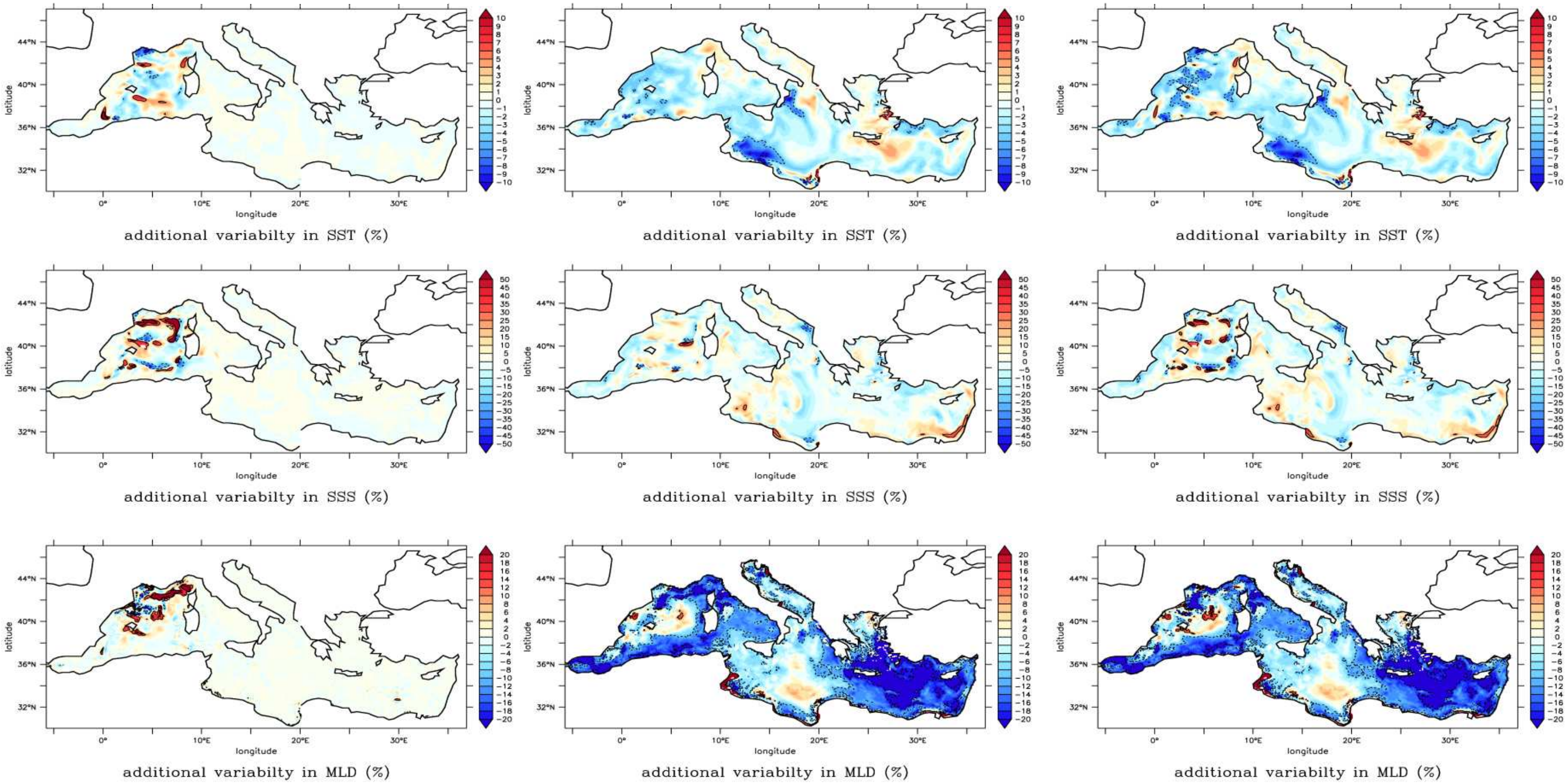
IMPACTS ON THE MED CIRCULATION OF DIFFERENT SPACE/TIME RESOLUTION FORCINGS

CTL



Additional variability in **ZOOMGOL**, **3HFREQ** and **HIGHRES**

ZOOMGOL-CTL ***3HFREQ-CTL*** ***HIGHRES-CTL***

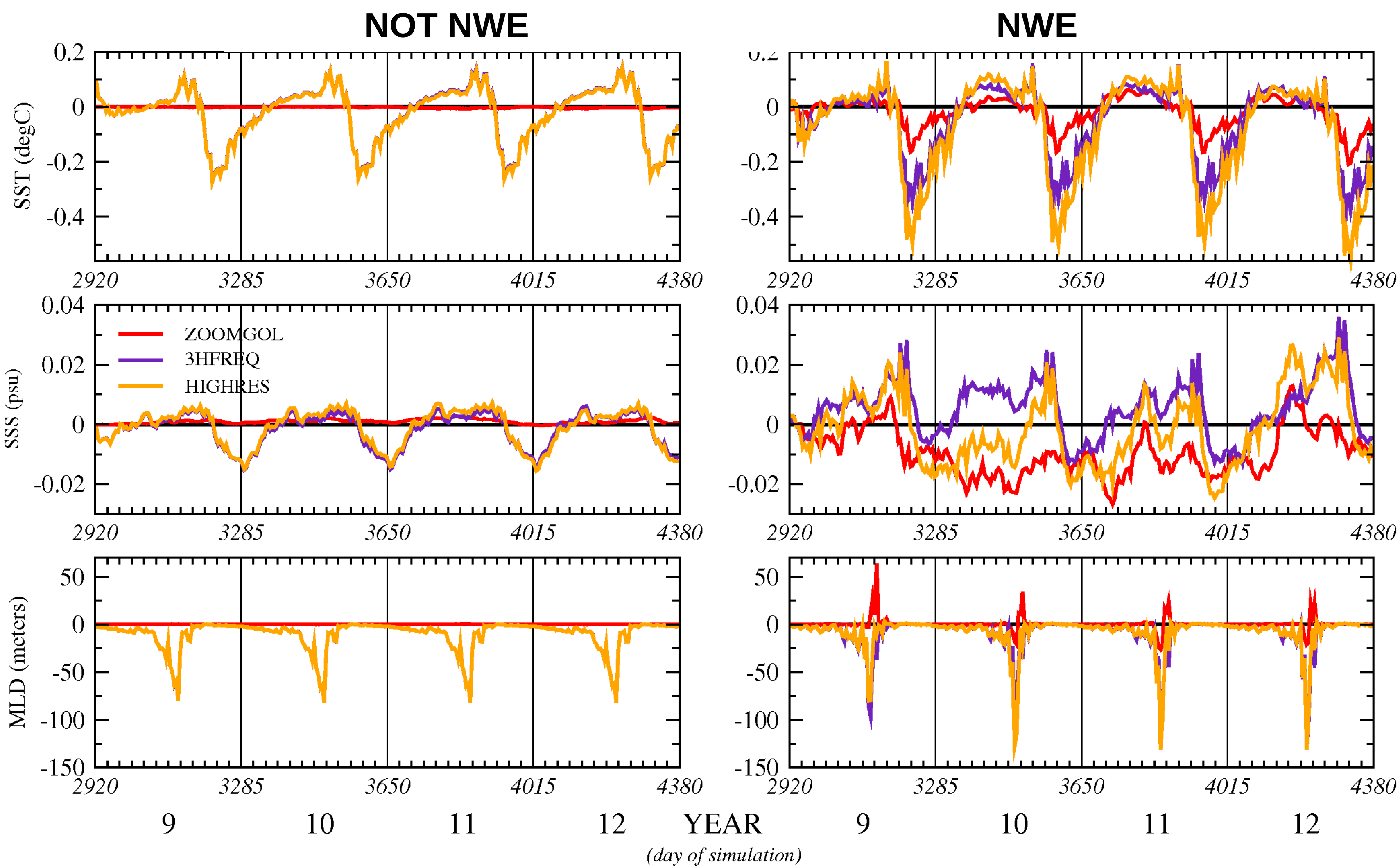


Modifications by 5 to 10% of the variability, until +50% locally

3. Impacts of the high resolutions

IMPACTS ON THE OML CHARACTERISTICS OF DIFFERENT SPACE/TIME RESOLUTION FORCINGS

Differences in SST (°C), SSS (psu) and in MLD (m) in **ZOOMGOL**, **3HFREQ** and **HIGHRES** against the **CTL** experiment (a) in the whole basin except the NWE and (b) in the NWE



three-hourly atmospheric forcing ►significant improvements and in particular a more realistic diurnal restratification of the upper layers

finer spatial resolution in NWE ►strong modifications of the ocean upper layer characteristics and of the circulation variability

3. Impacts of the high resolutions

EFFECTS ON THE DEEP CONVECTION

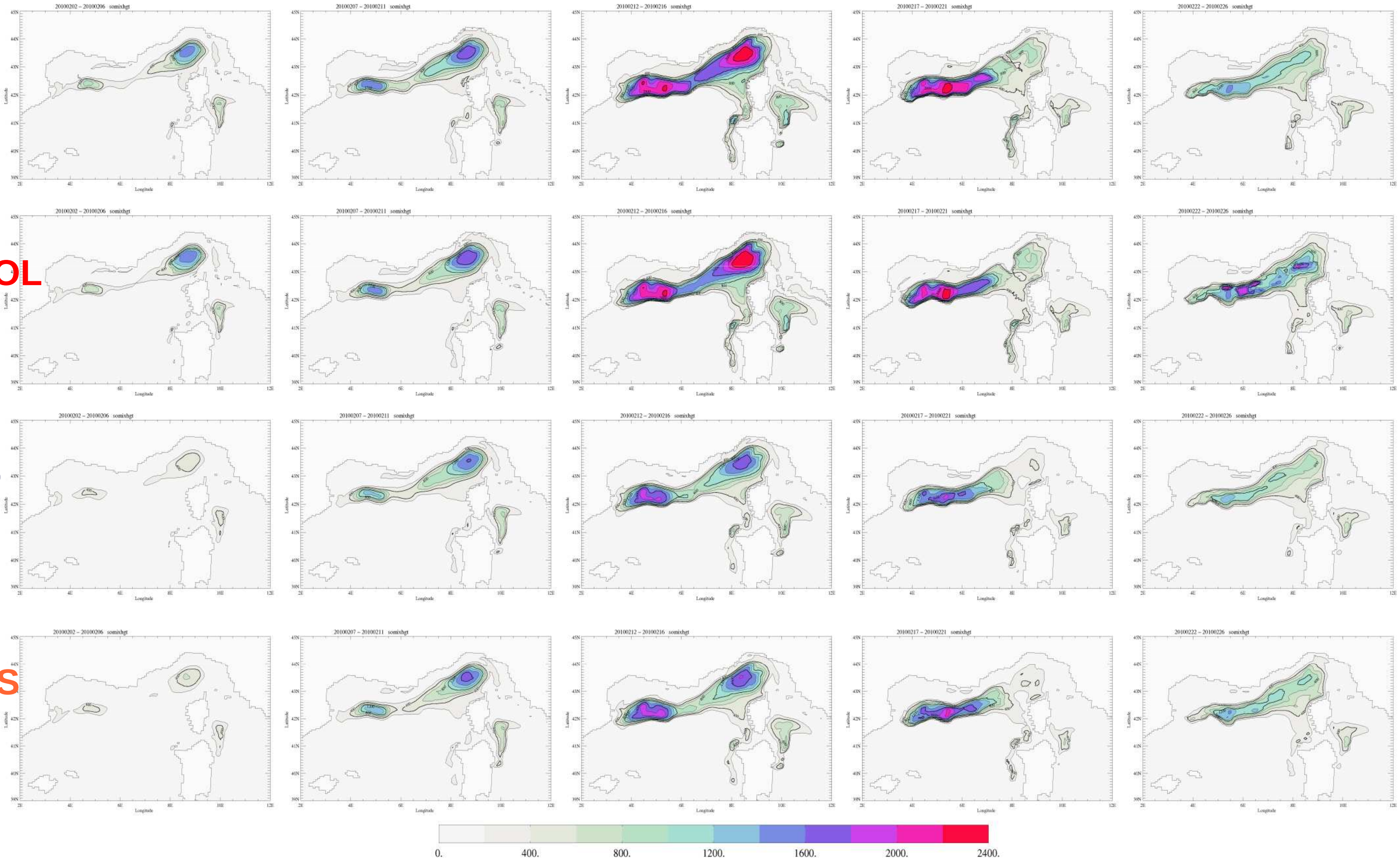
Year 12: *2 Feb* *7 Feb* *12 Feb* *17 Feb* *22 Feb*

CTL
(20km, daily)

ZOOMGOL
(6.7km, daily)

3HFREQ
(20km, 3hrs)

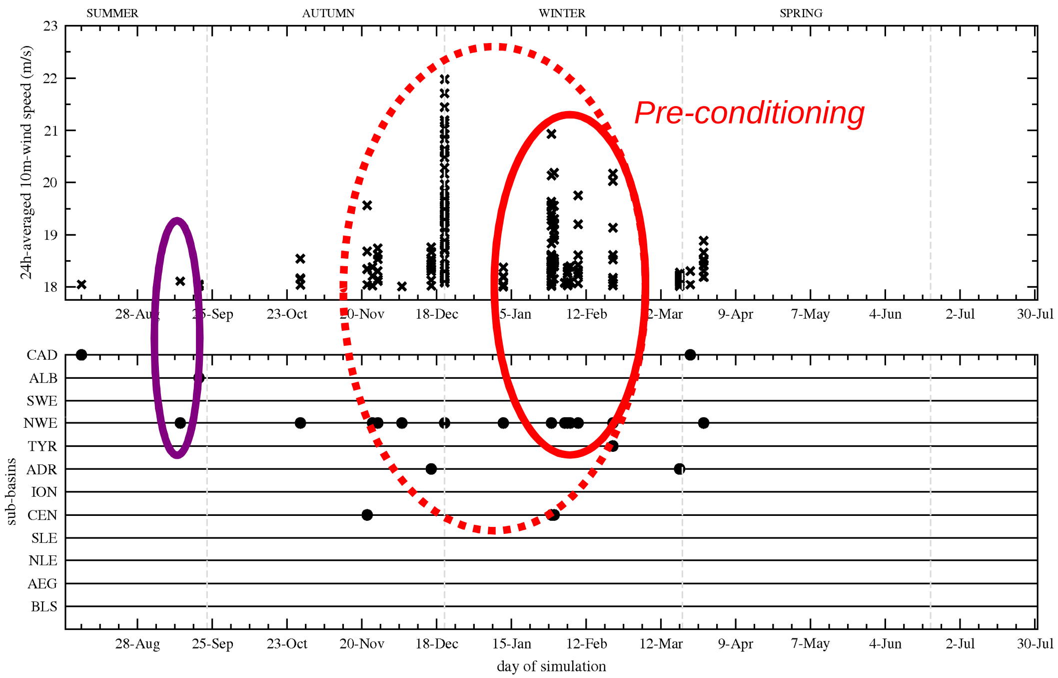
HIGHRES
(6.7km, 3hrs)

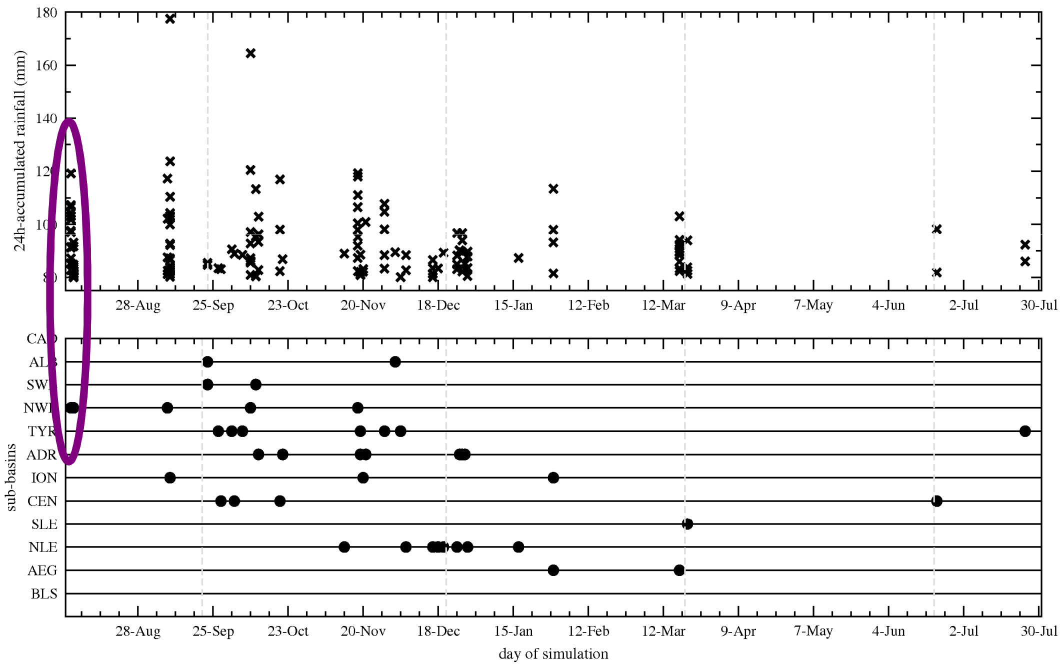


***Mixed Layer Depth** (m) in NWE*

The diurnal cycle in the 3-hourly forcing tends to limit the ocean deep convection
Some convective chimneys persist a few days later with the high space resolution forcing

4. Rapid upper ocean responses



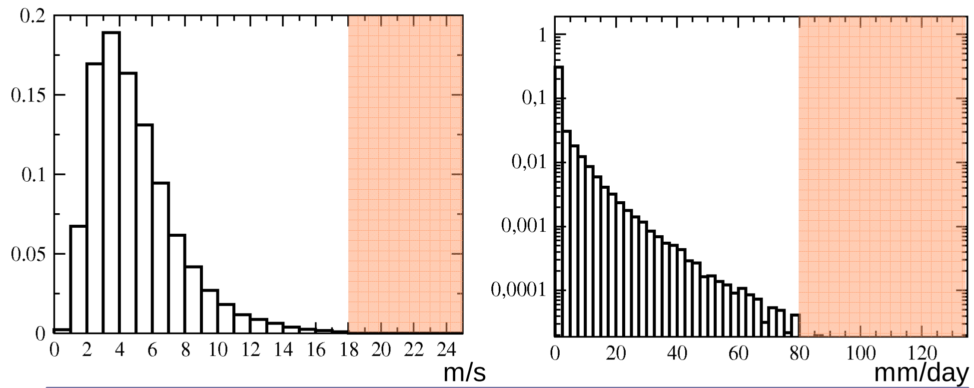


Extreme meteorological events detection with thresholds:

HWE: daily averaged 10m-wind >18m/s
HPE: daily accumulated precipitation >80mm

Heavy windy episodes mainly located in the North-Western part of the Mediterranean;

Heavy precipitation events more scattered over the basin and more frequent in summer and autumn

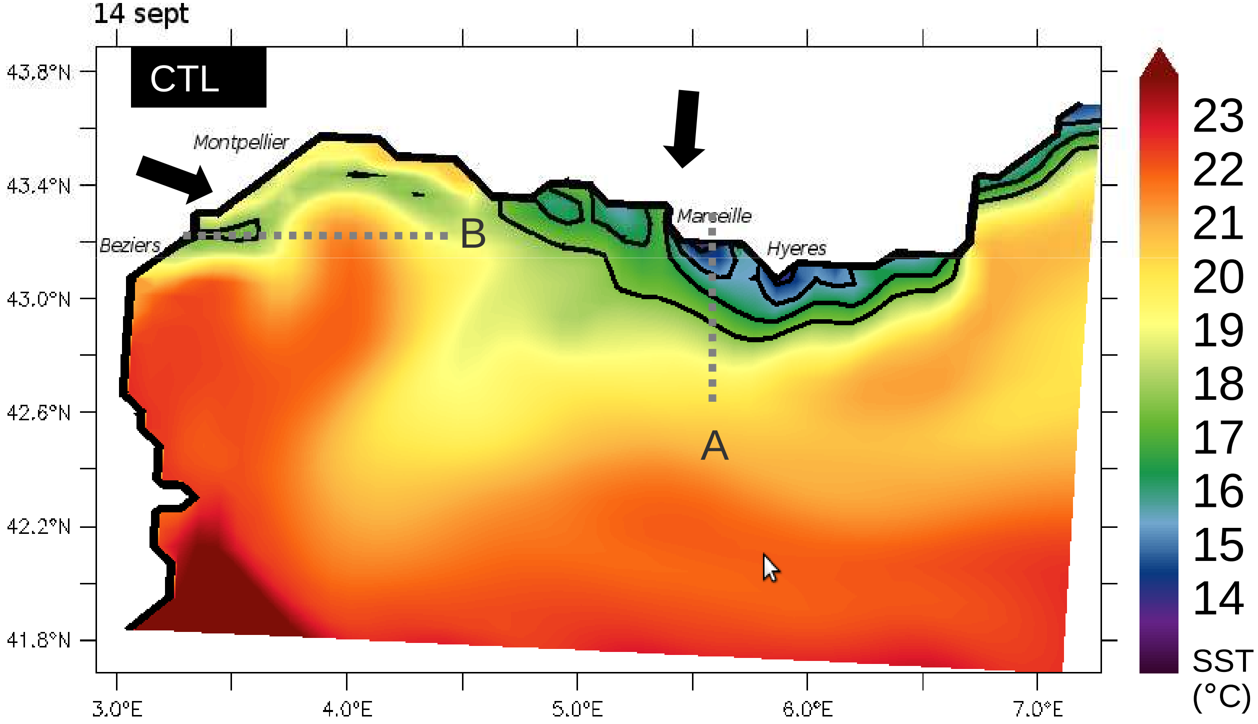


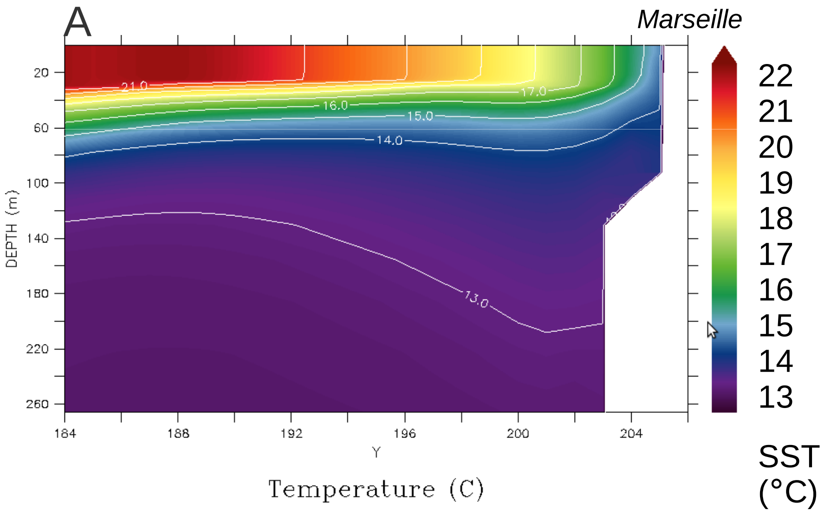
Probability density functions for the precipitation rate and the 10m-wind speed in the reference forcing.

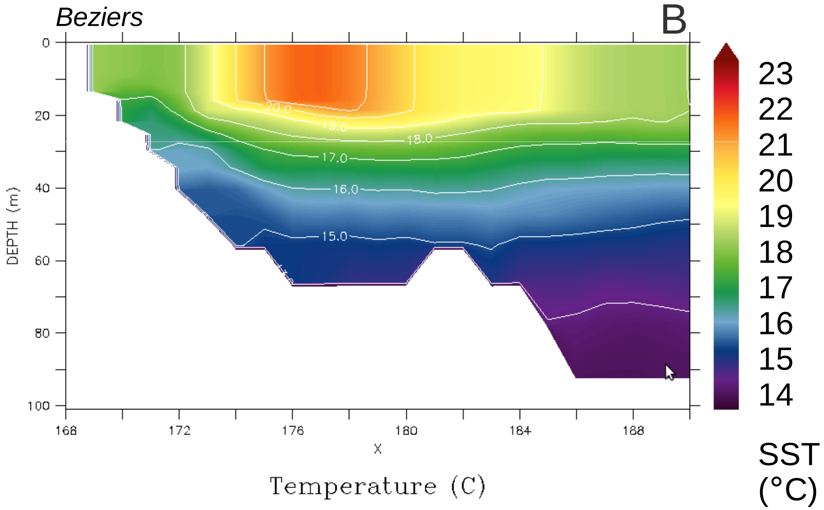
4. Rapid upper ocean responses

UPWELLING UNDER HIGH WIND

Daily **SST**(°C) [year12] in NWE







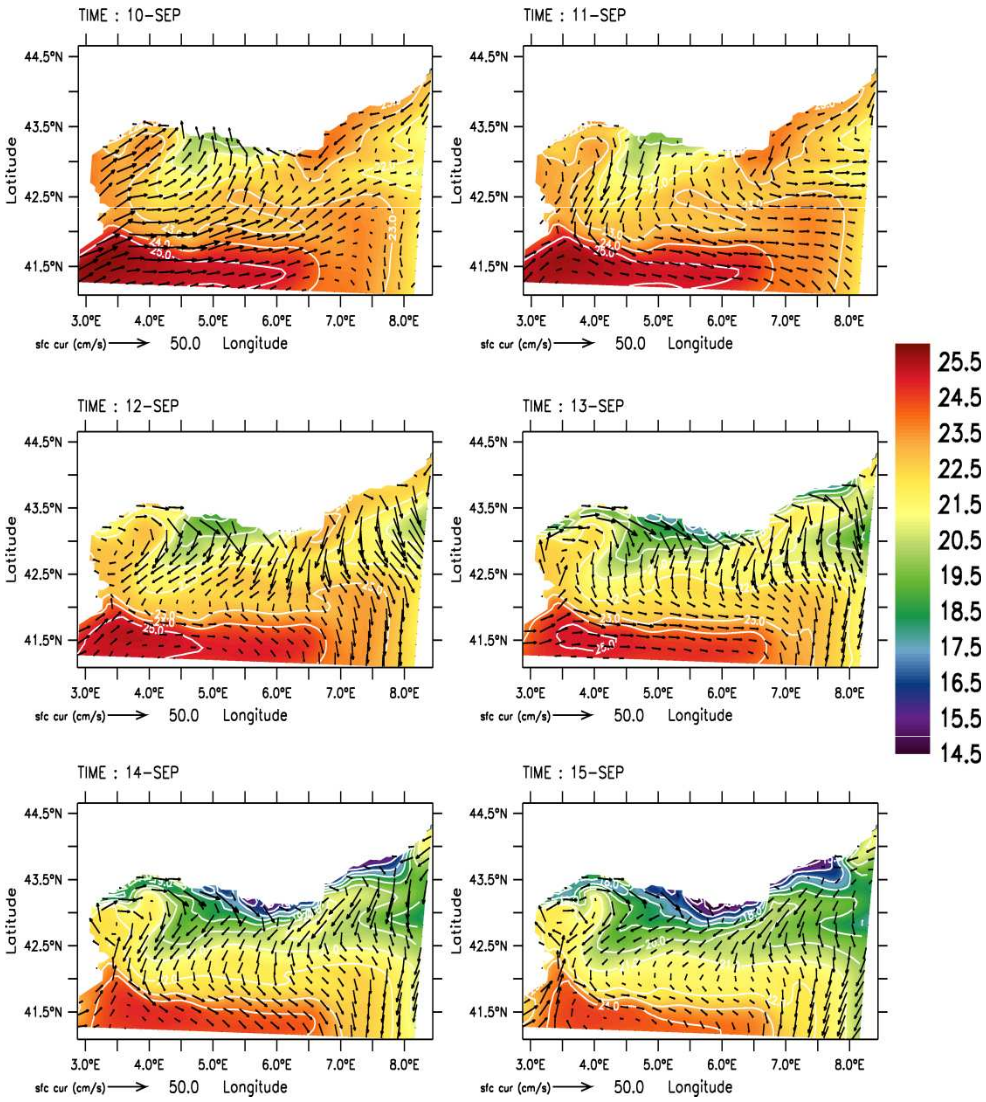
Good correspondence with the upwelling zones reported in Millot, 1979

4. Rapid upper ocean responses

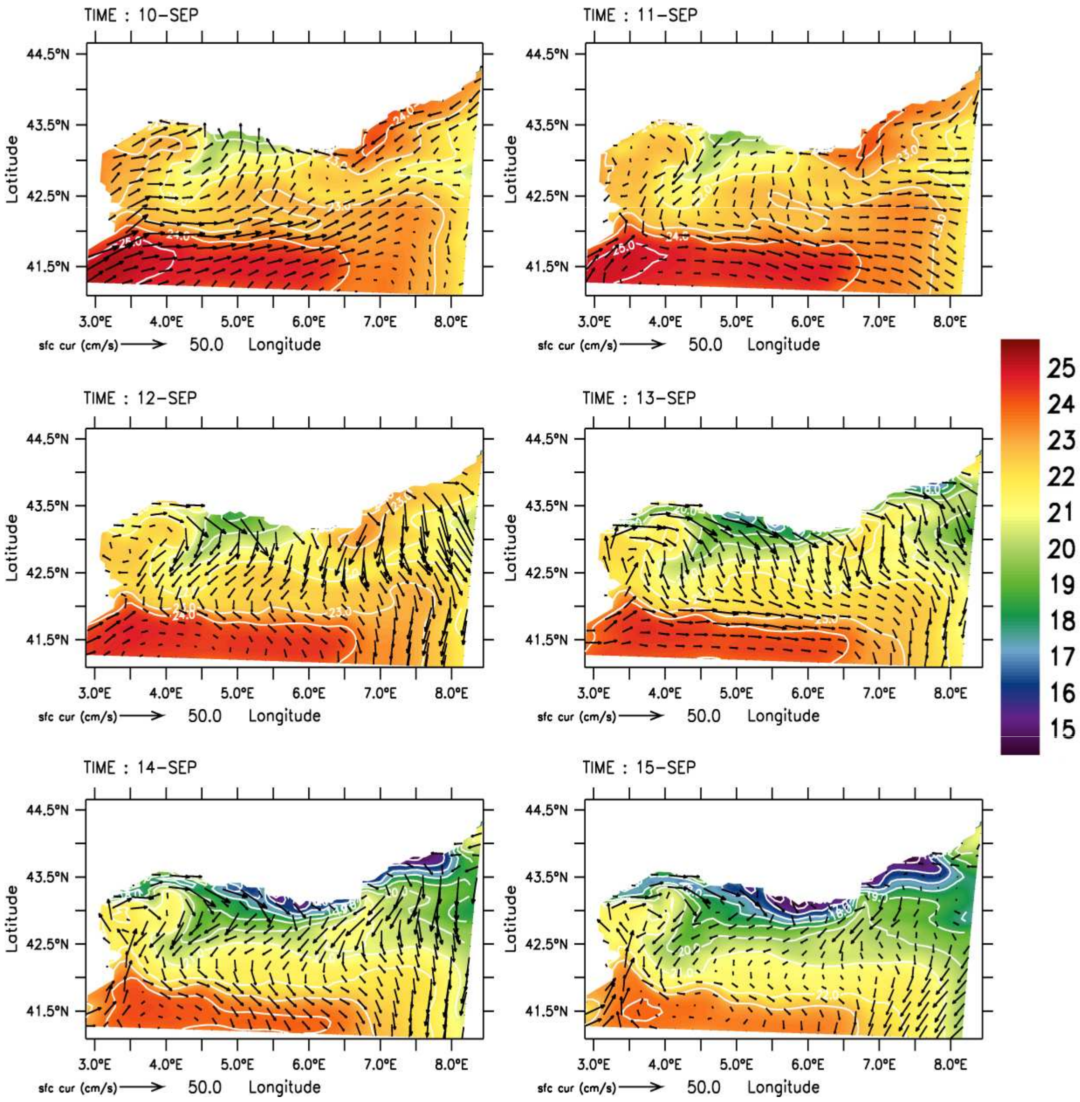
UPWELLING UNDER HIGH WIND

Daily **SST**(°C) + surface **currents** (cm/s) [year12] in NWE

CTL



HIGHRES

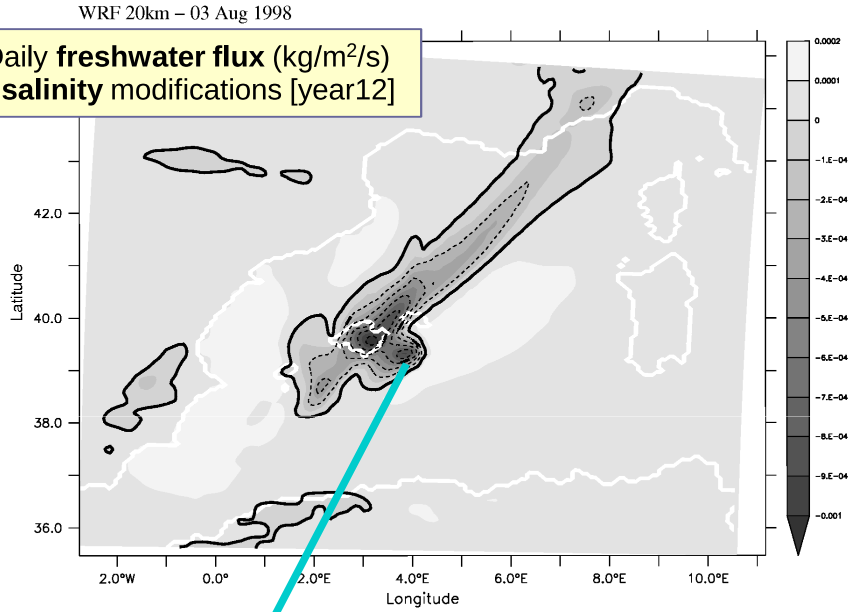


Strong variations in the surface current, finer Rhône river plume with the high space-time resolution

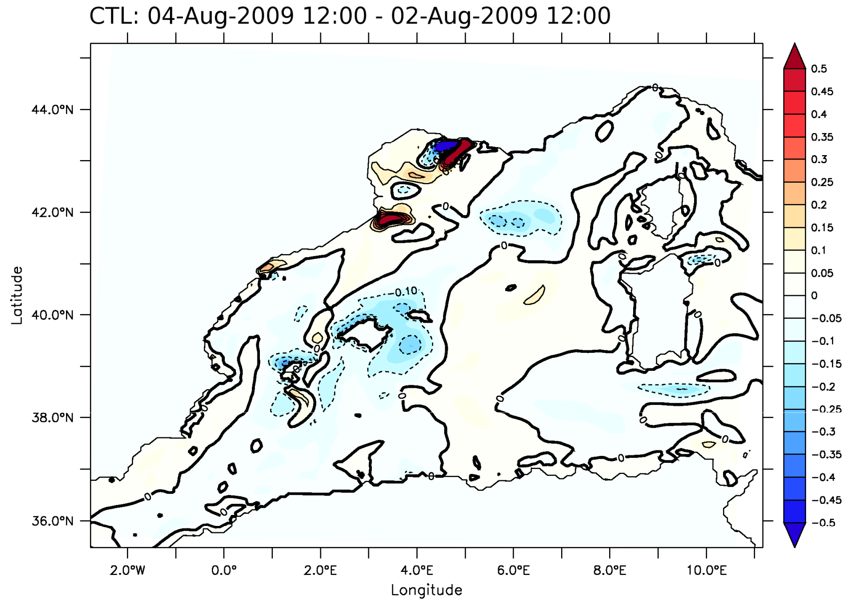
4. Rapid upper ocean responses

FRESHENING UNDER STRONG RAIN

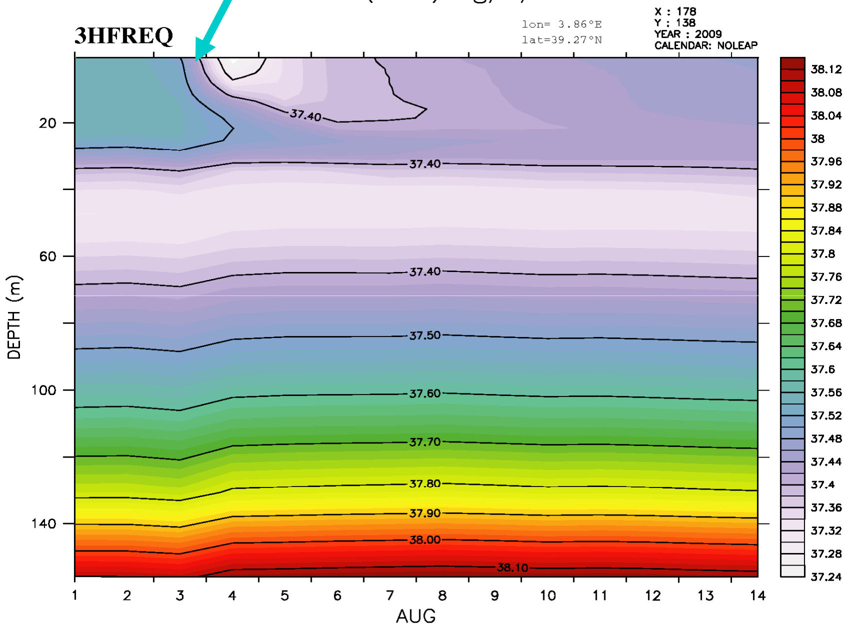
Daily **freshwater flux** (kg/m²/s)
+ **salinity** modifications [year12]



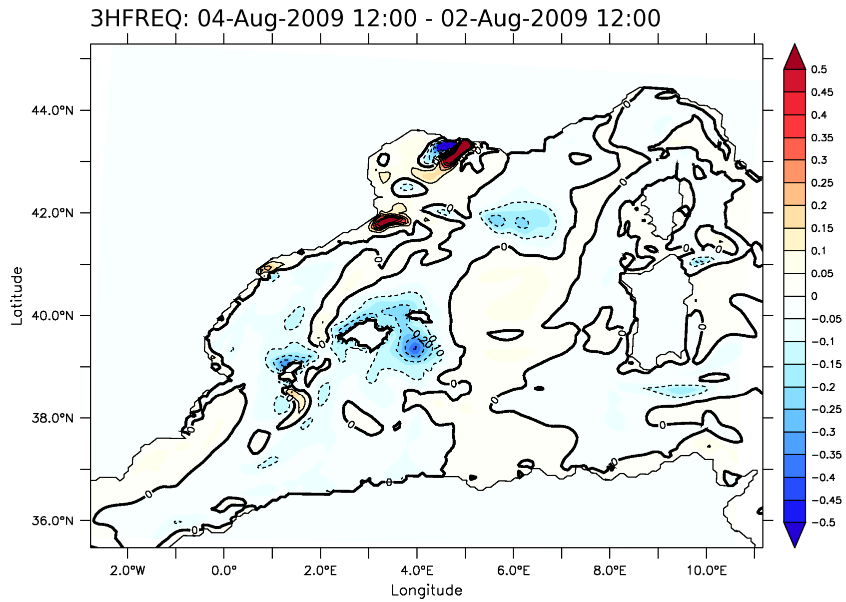
Water flux (E−P) kg/s/m2



SSS differences



Salinity (PSU)



SSS differences

*Same amount of water exchanged between **CTL** and **3HFREQ** but short range and intense precipitation peaks leads to a more significant freshening*

5. Conclusions and perspectives

The sensitivity experiments show that:

(I) the WRF model is able to produce ***accurate sea surface fluxes***

- good estimation of the heat and water annual budgets
- representation of extreme meteorological events.

(II) the MED12 model ***well represents the Mediterranean circulation patterns***

- cyclonic main circulation and main mesoscale gyres and coastal currents
- accurate seasonal cycle of the ocean mixed layer depth

(III) the Mediterranean thermohaline and surface circulations are ***significantly sensitive to the space-time resolutions*** of the atmospheric forcing

- strong modifications of the ocean variability at mesoscale

(IV) ***High space-time resolutions are crucial*** to well represent ***the local ocean response under intense meteorological events***

- 3-hourly forcing crucial to represent the diurnal cycle and the intense forcing peaks
- High space resolution allows a finer representation of the wind jets and of the mesoscale precipitating systems

Based on Lebeaupin-Brossier et al. (2010a,b)

5. Conclusions and perspectives

Next steps:

Coupling WRF-(oasis)-MED12

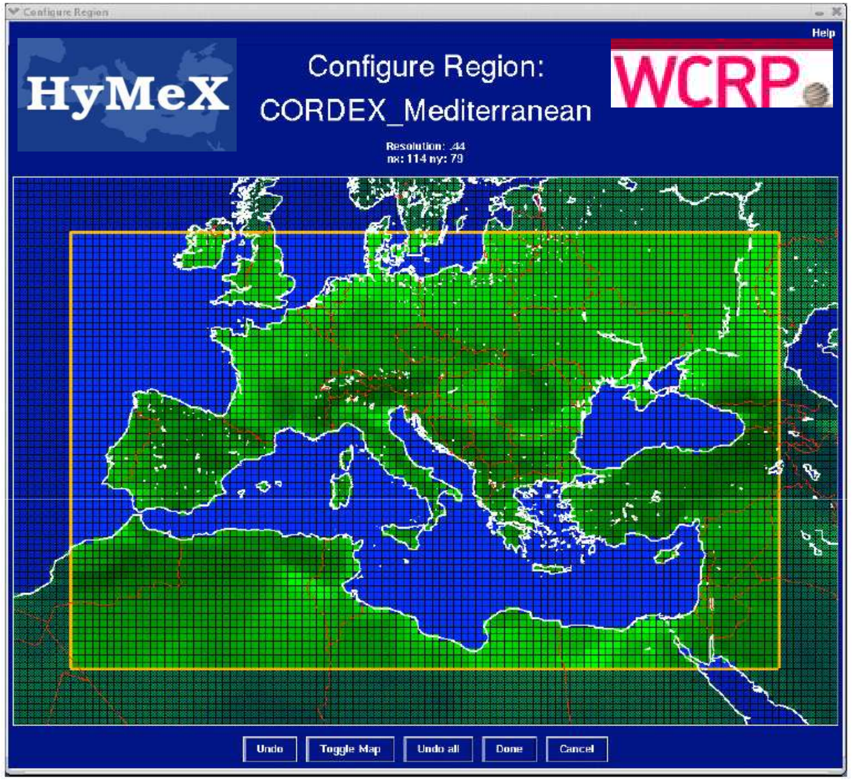
Perform 20-year runs (ERA-Interim period) in the forced and coupled modes:

MED-CORDEX program: joint intiative between CORDEX (COordinated Regional climate Downscaling Experiment of WCRP) and HyMeX

The main goals of CORDEX are to:

- provide a *quality-controlled regionally downscaled data* set of information for the *recent historical past and 21st century projections*, covering the majority of *populated land regions* on the globe based on the GCM climate scenarios and predictions of CMIP5
- *provide support and information to climate impact assessment and adaptation groups* interested in utilizing CORDEX material in their research.

Region 12: Mediterranean (HYMEX/MED-Cordex)



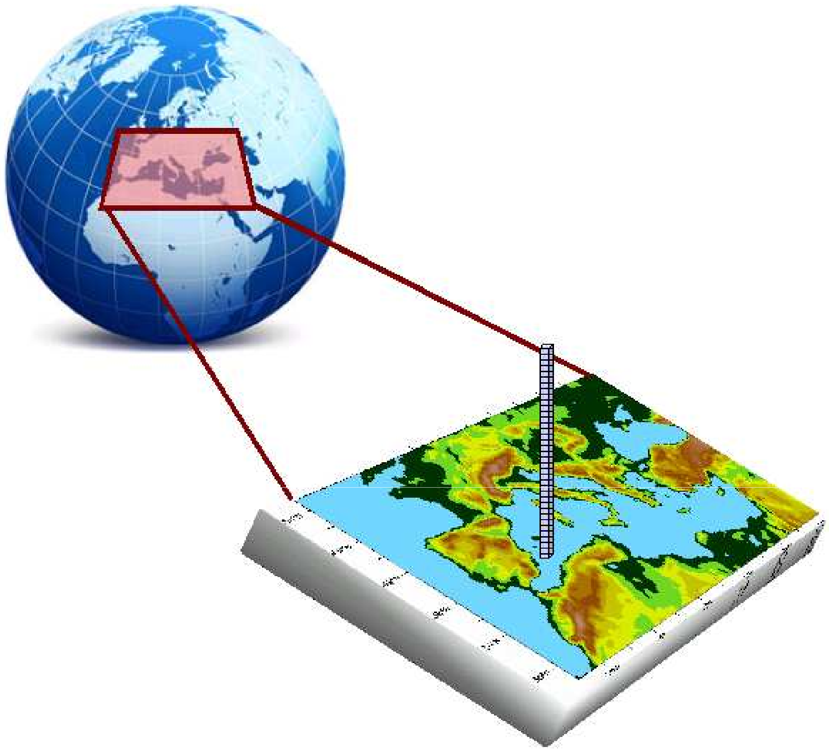
Coupling MED12-ECO3M (+PISCES)

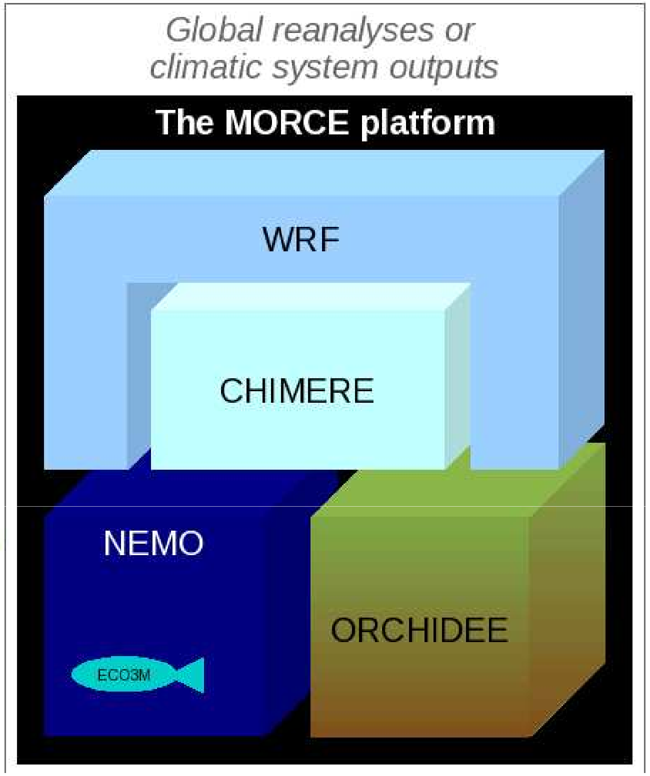
Perform coupled physics and biogeochemistry run at mesoscale for periods of interest (impacts on marine ecosystems of strong/low, winter convection, heat wave...)

5. Conclusions and perspectives

These coupled systems are part of the ***MORCE-Med*** regional earth system:

- *Examine the present Mediterranean climate and the processes and interactions between the compartiments*
- *Evaluate the modifications over the Mediterranean in the context of climate change*





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MORCE MED

CLIMAT ENVIRONNEMENT SOCIÉTÉ Groupement d'Intérêt Scientifique