Modelling the Regional Coupled Earth system (MORCE): application to process and climate studies in vulnerable regions

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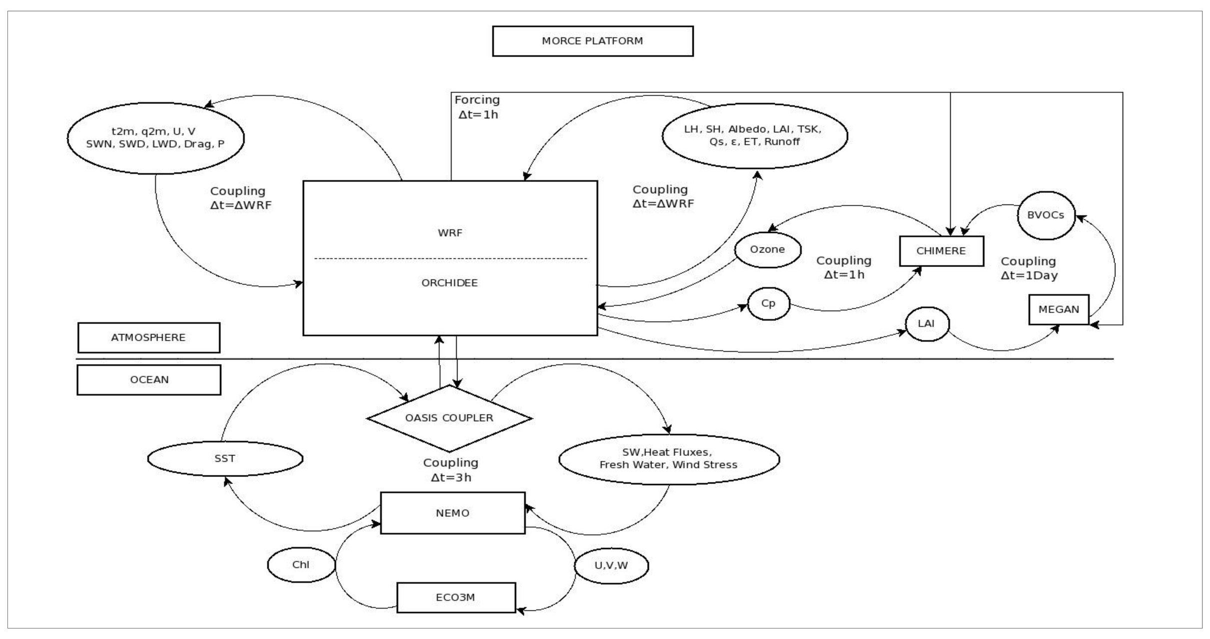
The Earth system is the physical, chemical, biological, and social components, processes, and interactions that together determine the state and dynamics of Earth, including its biota and human occupants. Developing regional Earth system models has two primary motivations: (i) with respect to climate science, to improve modelling capabilities and better understand coupled processes at regional scales and (ii) to support stakeholders who aim to use climate information for regionallyspecific impact assessment and adaptation planning.

The Institut Pierre Simon Laplace (IPSL) in collaboration with ENSTA and LOPB, developed the MORCE plateform for process and climate studies of the Regional Earth system. The original aspects of the MORCE plateform are:

1. the integration of a large number of coupled compartments (ocean, atmosphere and continent compartments) and processes (physical and atmospheric or ocean biochemical processes),
2. the transferability of the numerical plateform to dierent locations in the world,
3. the use of a non-hydrostatic model for the atmospheric module which allows numerical.



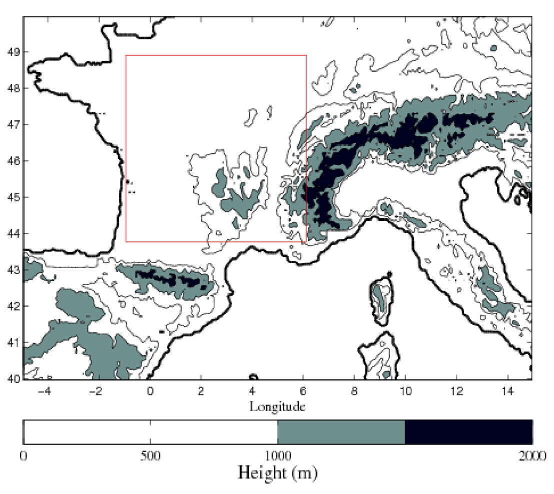
SOIL AND VEGETATION-ATMOSPHERE COUPLING

The atmospheric module is based on the dynamical core of numerical model WRF (Weather Research and Forecasting).

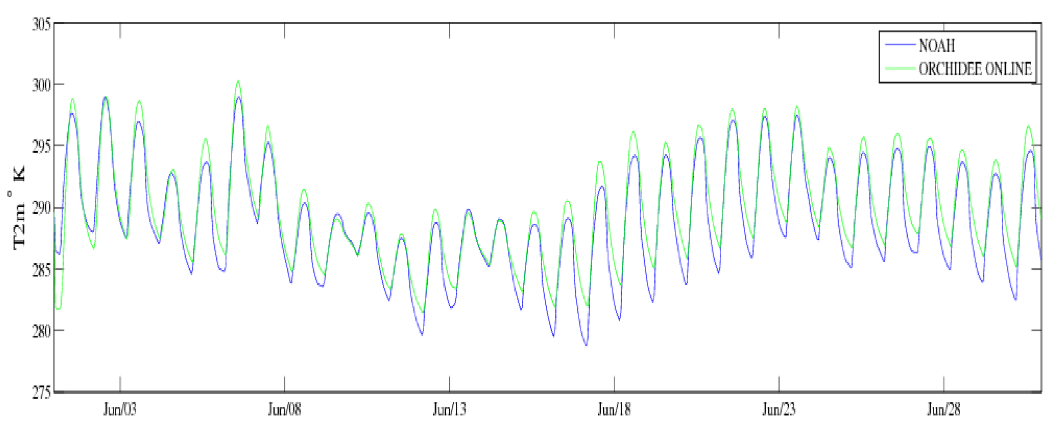
The land-surface model ORCHIDEE (ORganizing Carbon and Hydrology In Dynamic EcosystEms) is a SVAT model coupledto a biogeochemistry and a dynamic biogeography model.

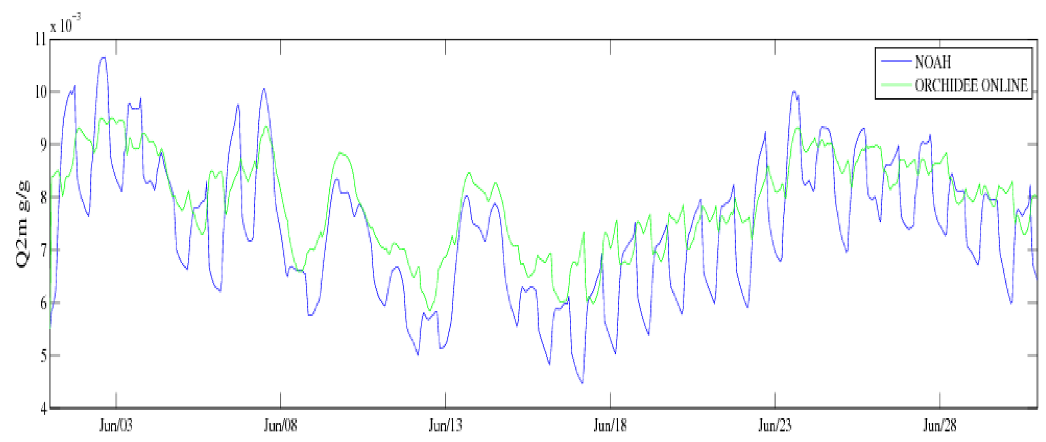
Specifically, ORCHIDEE simulates the fast feedback occurring between the vegetated land surface and the atmosphere, the terrestrial carbon cycle, and also changes in vegetation composition and distribution in response to climate change.

The first simulation a first simulation has been performed successfully on a domain covering 20× 20 grid points with a horizontal resolution of 30 km and centred at 41° N and 2.9°E (southern France), on a one month period (June 2000).



The next figure displays spatially averaged 2-m temperature and humidity as a functionof time. This graph shows a temporal variability in phase and similar amplitude between WRF/NOAH and WRF/ORCHIDEE. With the present coupling configuration, WRF/ORCHIDEE is warmer by about 1°- to 2°. We also note a slower evening cooling in WRF/ORCHIDEE than in WRF/NOAH. For 2-m humidity, the amplitude is much smaller in WRF/ORCHIDEE and at times, is out of phase with respect to WRF/NOAH time series. This is however expected since WRF/ORCHIDEE is initialized with constant soil moisture (0.3) whereas WRF/NOAH uses reanalysis data from ERA-interim. Aspin-up procedure must thus be applied in the future a better comparison with observations.



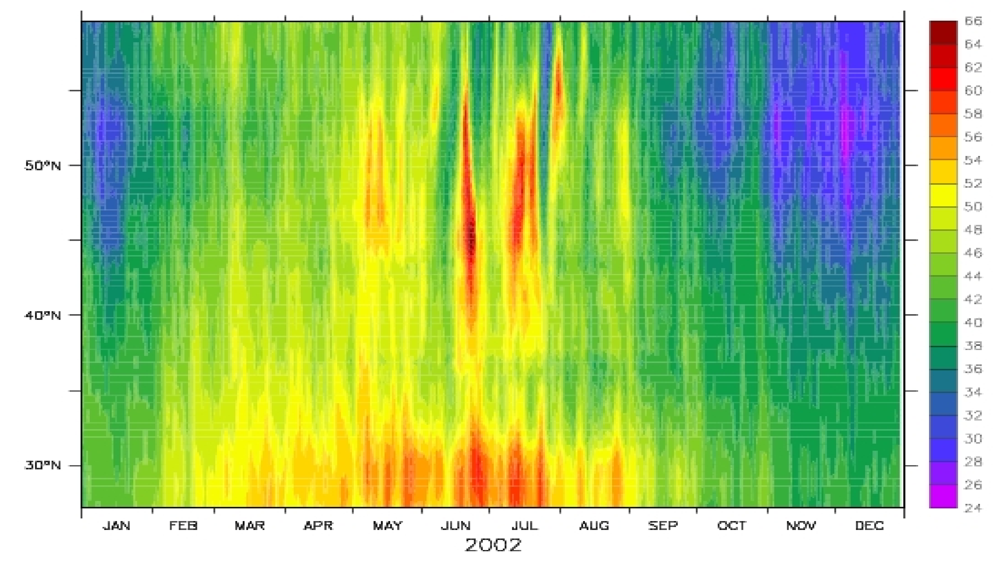


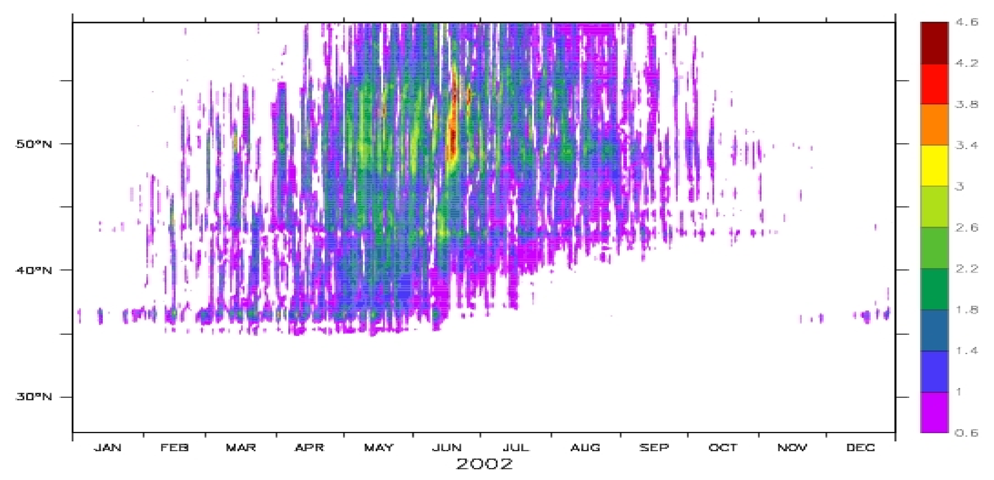
The following modelling experiments are planned for southern France area:
- An idealized simulation on 3 different years (a cold/humid year, a "standard" year, a hot/dry year – 2003) with a control run with ORCHIDEE hydrological module only, and with ORCHIDEE with hydrological and vegetation modules activated. The aim of the study is to analyse the role of carbon cycle on hydrological cycle for 3 contrasted years.
- A simulation over southern France will be performed following the CORDEX framework with WRF/ORCHIDEE (hydrological and vegetation modules activated) for present and future climates.

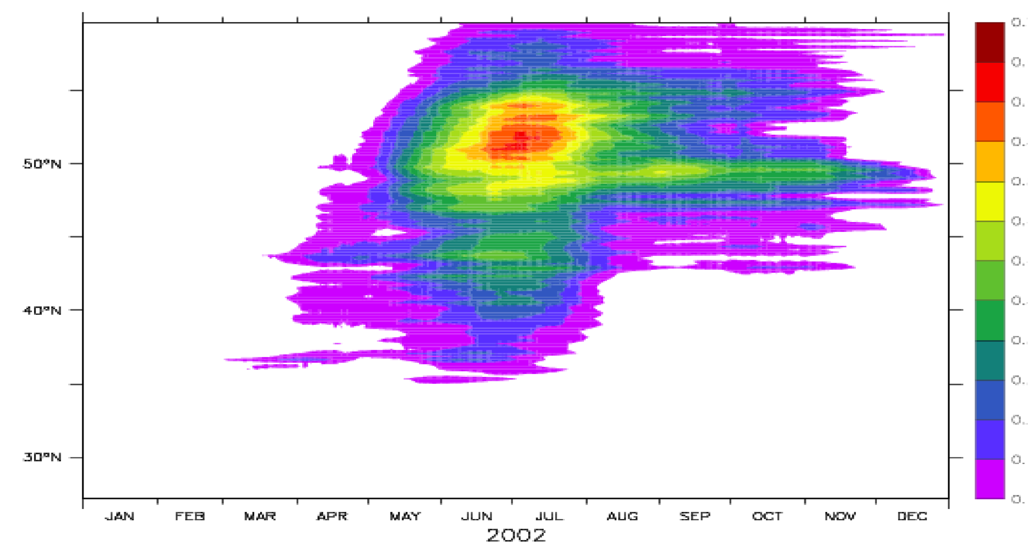
These simulations are also performed for the Humboldt GIS project (PI: P. Leadley).

ATMOSPHERIC CHEMISTRY-VEGETATION COUPLING

The atmospheric chemistry-vegetation coupled system is composed by CHIMERE and ORCHIDEE models. In this configuration, the models are coupled via the Leaf Area Index (LAI) and surface ozone. The ozone computed by CHIMERE is used into ORCHIDEE to account for the impact of ozone on photosynthesis; Generally, a severe ozone stress lead to a less amount of carbon allocated into the biomass, and therefore to a LAI Reduction.
The LAI computed by ORCHIDEE, indeed, is used into CHIMERE to Compute the biogenic emissions (BVOCs) by means the MEGAN model.
In following figures is shown the ORCHIDEE GPP reduction computed taking into account the impact of ozone on photosynthesis. The overall GPP reduction is About 22% of the yearly value (simulation year: 2002).







The episodes of increased ozone occur over most parts of central Europe during summer. During these episodes, many of which last for several consecutive days (a), the ozone concentrations rise to several times the boundary layer background over large areas of Europe.
The daily impact of ozone on GPP is shown in b as the zonal anomaly It is noteworthy that the maximum daily GPP reduction is about 4 gC m^{-2} and it takes place at the same latitude of the ozone peaks. Besides, the maximum GPP Reduction occurs in summer, during the same days of the ozone peaks.
During winter and autumn, generally the GPP reduction is weak.
Finally, the daily impact of ozone on LAI is shown in Figure 11c as the zonal difference It is noteworthy that after the high ozone stress occurring at the beginning of the summer there is a significant reduction in LAI, with a maximum of 0.7 m^{-2} m^{-2} located at the same latitudes of the maximum GPP reduction. A LAI reduction is expected since a decrease of photosynthesis lower the total amount of carbon that can goes to leaves. Moreover, there is a negative feedback between LAI and photosynthesis since a LAI decrease leads to a reduction of the total plant photosynthesis that, in turn, affects the LAI.
This feedback, as well as the simulated long term effect of ozone damage, explains the significant LAI decrease observed during the fall.

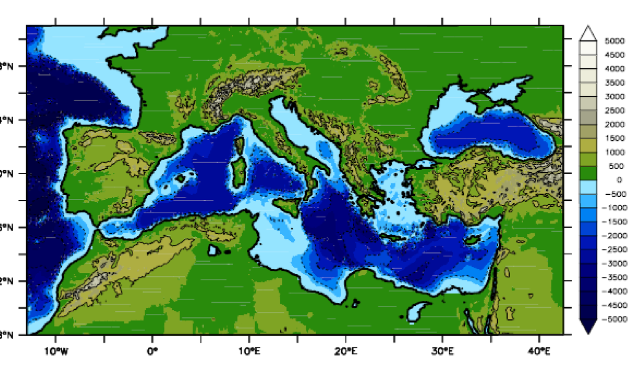
OCEAN-ATMOSPHERE COUPLING

The ocean-atmosphere coupled system is composed of the models WRF and NEMO. The coupling parameters (time-frequency and interpolation methods) are defined by the user via the OASIS coupler. The fields exchanged are the Sea Surface Temperature and the air-sea fluxes (solar heat, non-solar heat, wind stress module and components, and the freshwater flux).

Currently, two regional configurations of the NEMO-OASIS-WRF coupled system are used :

The Mediterranean region

The configuration of the OA coupled system over the Mediterranean region was build from previous numerical experiments done in the forced mode [Lebeaupin Brossier et al. 2010].

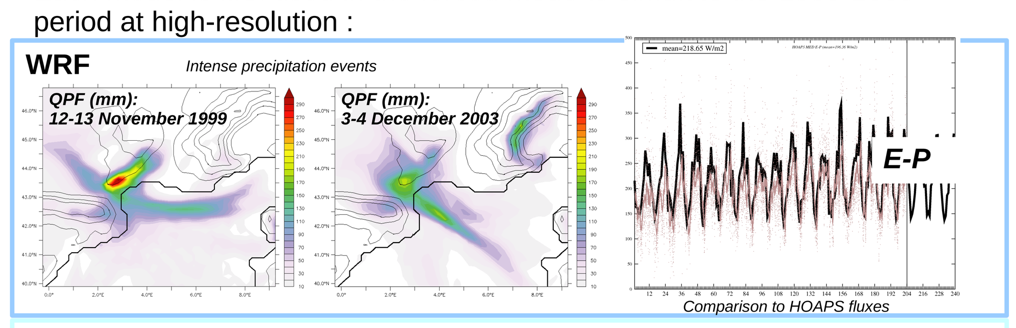


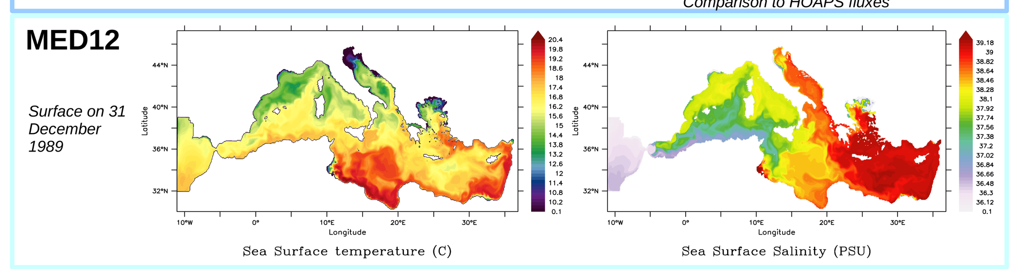
WRF:
Δx=20km
Δt=1 minutes
IC/BC=ERA-interim

NEMO:
Δx=1/12°
Δt=12 minutes
IC/BC=MODB4

OASIS
cpl freq=3h

Each model is first used in the forced mode to simulate the 1989-2008 period at high-resolution :

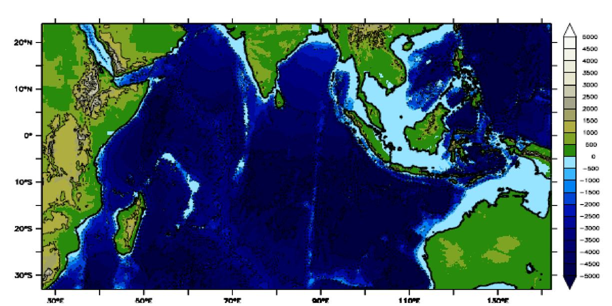




The ***air-sea coupled processes impact on the water budget*** of the Mediterranean region ***and their role on intense meteorological weather events*** will be examined in the coupled experiment run for the same period.

The Indian Ocean

The main objective is to provide a well-adapted tool to study the ***link between oceanic variability and cyclonic activity in this region***.



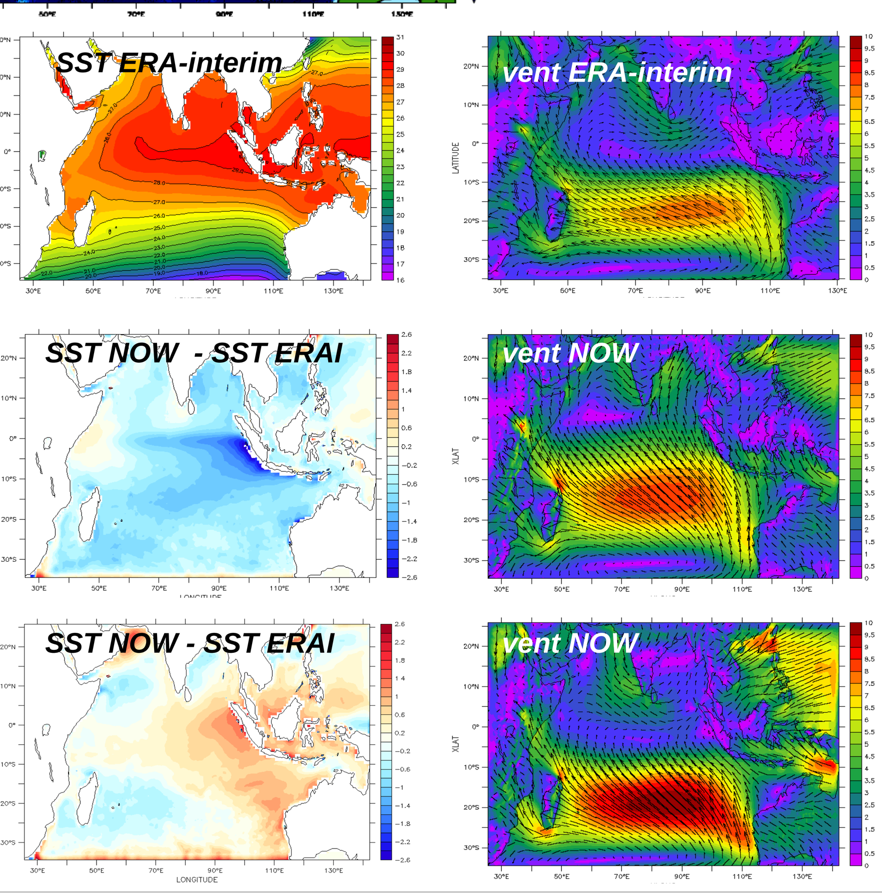
WRF:
Δx=1/4°Δt=2 minutes
IC/BC=ERA-interim

NEMO:
Δx=1/4°Δt=20 minutes
IC/BC=DRAKKAR ORCA0.25-G70

OASIS
cpl freq=1h

Simu 1: SW= Dudhia

Simu 2: SW= Goddard



Conclusions and perspectives

The perspectives are to couple:
1. the ATM and CHEM modules to include the interactions between atmospheric composition, radiative budget and nucleation processes
2. the CHEM module to the BIOCHEM module, to include the role of aerosols deposition on the sea surface as nutriments for marine ecosystems.

The MORCE plateform is used within the CORDEX program of WCRP regional downscaling experiment, with a special focus over the Mediterranean in the framework of MED-CORDEX and HyMeX actions. In this context, the coupling of ATM, OCE and SVAT modules are coupled over the Mediterranean basin. The simulations .... (ERA-interim, scenario). The MORCE plateform is also used to investigate air/sea exchanges in the Indian ocean, by coupling ATM/OCE modules.