Collaborative Project

CLIM-RUN

Climate Local Information in the Mediterranean region Responding to User Needs

WP 2 – WP New climate modeling and analysis tools
Task 2.2: Development of new tools

Development of new regional modeling tools

Project No. 265192– CLIM-RUN

Start date of project: 1st March 2011 Duration: 36 months

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1. Introduction.

Within the CLIM-RUN project three modelling partners are developing new modelling tools for application to specific targeted simulations in support of the CLIM-RUN case studies. The three partners are: CNRM (Centre National de Recherche Météorologiques, Météo-France, France), ENEA (Italian National Agency for New Technologies, Energy and the Environment, Italy) and ICTP (International Centre for Theoretical Physics, Italy). Some of the model developments derived directly from the needs expressed by the stakeholders involved in the case studies and emerged after the first round of stakeholder workshops. All these new modelling tools are based on the use of pre-existing and enhanced regional Climate Models (RCMs) capable of reaching relatively high horizontal resolution over the Mediterranean area. In the previous deliverable 2.1 an exhaustive list of possible model improvements was provided and discussed, and it is summarized in the following Table:

Institute	**Interactive fully coupled modelRCSMs**	**New components**	**Resolution (space/time)**	**Improving/test**
ENEA	Atmosphere: RegCM up to 25km Ocean: MITgcm-1/8° Land+ Hydrology:BATS River: IRIS	Sea level (pressure effect) Wave model Tides effect	Up to 1/16° (for stand-alone oceanic simulations)	SST skin layer Diurnal cycle
ICTP	RegCM4 (coupled with interactive aerosols, Lake; Sub-grid land surface, tiling)	Interactive chemistry and vegetation Urban land use Ocean (ROMS)	10-15 km tiling - 1km	RegCM4 New and modified physics options (convection, clouds, Planetary Bound Layer (PBL), land surface)
CNRM	Atmosphere: ALADIN-50km Ocean: NEMOMED-1/8° Land + Hydrology: ISBA-50km River: TRIP-50km	Urban Lake Aerosols Wave Sea level	Atmosphere: 10 km Diurnal cycle: every 3h Surface tiling (SURFEX) snow cover (off-line)	Cloud Snow cover Shortwave radiation Air-sea fluxes Extremes Convection Boundary layer Aerosols spectral nudging

Table 1: List of the possible improvements which can be carried out by the different CLIM-RUN climate modelling partners.

In this deliverable we now detail for each modelling partner what improvements were actually implemented and what new targeted simulations are planned within the CLIM-RUN framework.

3. Models

3.1 The CNRM model.

3.1.1 Main new developments

The stakeholder meetings performed by WP5 (Tourism), 6 (Forest fire) and 7 (Energy), 8 (Integrated case study) and synthetized with WP4 during the first year of CLIM-RUN allowed WP2 to precise the list of the required new developments of climate modelling tools. Among the stakeholder needs, we decided to focus on the following issues:

- Improvement of the regional sea surface temperature (SST) representation (Tourism case study and integrated case study): we developed fully-coupled Regional Climate System Models (RCSM) with free interaction between the ocean and atmosphere components leading to an improved SST variability and change
- Improvement of the sea level representation (Tourism case study and integrated case study): we developed fully-coupled Regional Climate System Models (RCSM) and improved the representation of the regional sea level in the ocean component of the model.
- Improvement of the extreme weather events (all case study): we developed higher resolution RCM (12 km) and we focused on the evaluation and improvement of the heavy precipitation Mediterranean events and the strong winds (over the sea)
- Improvement of downward solar radiation simulated by the models at the surface (energy case study): we tested new parameterization for the cloud cover (without success up to now) and we improved the representation of the aerosol fields used in the model
- Improvement of the wind field (energy case study): we tested new parameterizations of the air-sea exchanges and we focused on their evaluation with respect to the representation of the winds in the RCSM
- Delivery of higher resolution regional climate model outputs (all case study): we developed higher resolution RCM (12 km) and we focused on the evaluation of their added-value. We also the surface tiling technique for the land-surface model using the SURFEX land surface scheme instead of ISBA.
- Delivery of information on the lake summer temperature (Tourism case study): we started to investigate the possibility to add lake modelling within the CNRM RCSM.

For each of those new developments, we gave some details below.

3.1.2: Model configurations and simulations:

The main models used at CNRM are ALADIN-Climate for the atmosphere (50 and 12 km resolution), the NEMOMED8 model (10 km) for the ocean, the IBSA or SURFEX land surface (50 km) and the CNRM Regional Climate System Models for the fully coupled version. These models have been described in details in Deliverable D2.1. With these 3 kind of models, we performed hindcast simulations (also called poor-man regional reanalysis) to study the past climate variability and scenarios simulations to study the regional climate change.

Hindcast simulations:

- ALADIN 50 km, 1979-2011, CORDEX framework
- ALADIN 12 km, 1979-2011, CORDEX framework
- NEMOMED8 10 km, 1961-2011, Med-CORDEX framework
- CNRM RCSM, 1979-2011, Med-CORDEX framework

Scenario simulations:

- ALADIN 50 km, 1950-2100, RCP4.5, RCP8.5, CORDEX framework
- ALADIN 12 km, 1950-2100, RCP4.5, RCP8.5, CORDEX framework

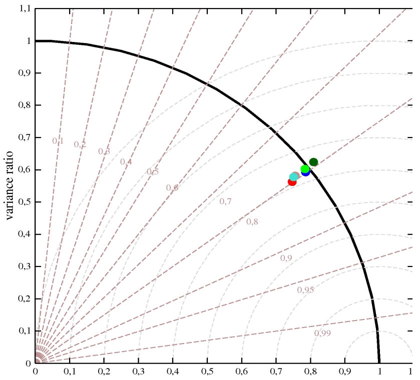
Other improvements concerning the cloud physics, air-sea interaction physics, aerosols, tiling have been tested on shorter simulations (10 years hindcast) and are ready for use. Note that some developments are not ready yet (lake modelling) and that some other developments proposed in D2.1 have been abandoned as not required by any case study (urban modelling) or because of priority choices (wave modelling; skin layer SST).

3.1.3 Evaluation of the SST and wind over the sea for CNRM RCSM

Here is an example of evaluation of the CNRM RCSM: uncoupled and fully coupled simulations have been compared to the two Météo-France weather buoys (LION and AZUR) dataset for the last decade (1999-2010). Thus, the effects of the horizontal resolution,

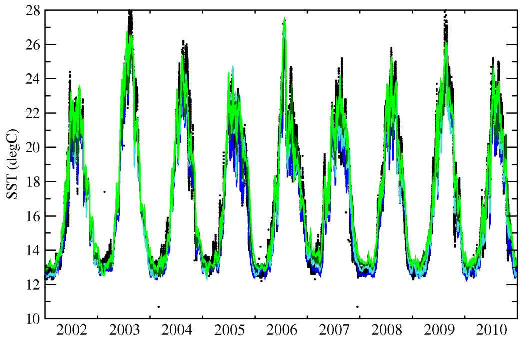
coupling, spectral nudging and sea surface fluxes parameterization on the very local meteorology over the Mediterranean Sea have been highlighted (Fig. 1 and 2). This comparison evidences in particular:

- A better representation of the wind speed and structures with the fine resolution (12 km instead of 50 km);
- A significant increase in the wind speed in simulations with spectral nudging;
- A decrease in evaporation when using the ECUME parameterization instead of Louis. This induces in the coupled runs an increase of the SST locally compared to the buoys data and at the basin scale in better agreement with the Marullo and EN3 dataset.
- With ECUME reduction of the wind stress is also evidenced, associated with an increase in the low-level wind speed.



uncpl/50km/Louis/NoSN bias:-0.33m/s
uncpl/12.5km/Louis/NoSN bias:-0.25m/s
cpl/50km/Louis/SN bias:-0.17m/s
cpl/50km/Louis/NoSN bias:-0.42m/s
cpl/50km/Ecume/SN bias:0.48m/s
cpl/50km/Ecume/NoSN bias:0.24m/s

Fig. 1: Taylor diagram for the daily 10m-wind speed (m/s) compared to the LION buoy dataset.



* observations
cpl/50km/Louis/SN bias:-0.56℃
cpl/50km/Louis/NoSN bias:-0.14℃
cpl/50km/Ecume/SN bias:0.09℃
cpl/50km/Ecume/NoSN bias:0.36℃

Fig. 2: SST daily time-series in coupled simulations comparison to the LION buoy dataset.

3.1.4: Improvement of the surface radiative flux using a more realistic aerosol field

We developed and implemented in ALADIN a realistic aerosol climatology over the Mediterranean basin. The final goal is to improve the mean value and the variability at different temporal scales of the downward surface solar radiation in the model. We evaluated the new results for the year 2006 for which good observations (satellite and stations) are available. Figure 3 compares two simulations (without aerosol and with the new climatology) with respect to the SRB-QC satellite products and the Carpentras BSRN surface station. The figure shows the improvement obtained with the simulation with the new aerosol climatology for all seasons and compared with both reference dataset.

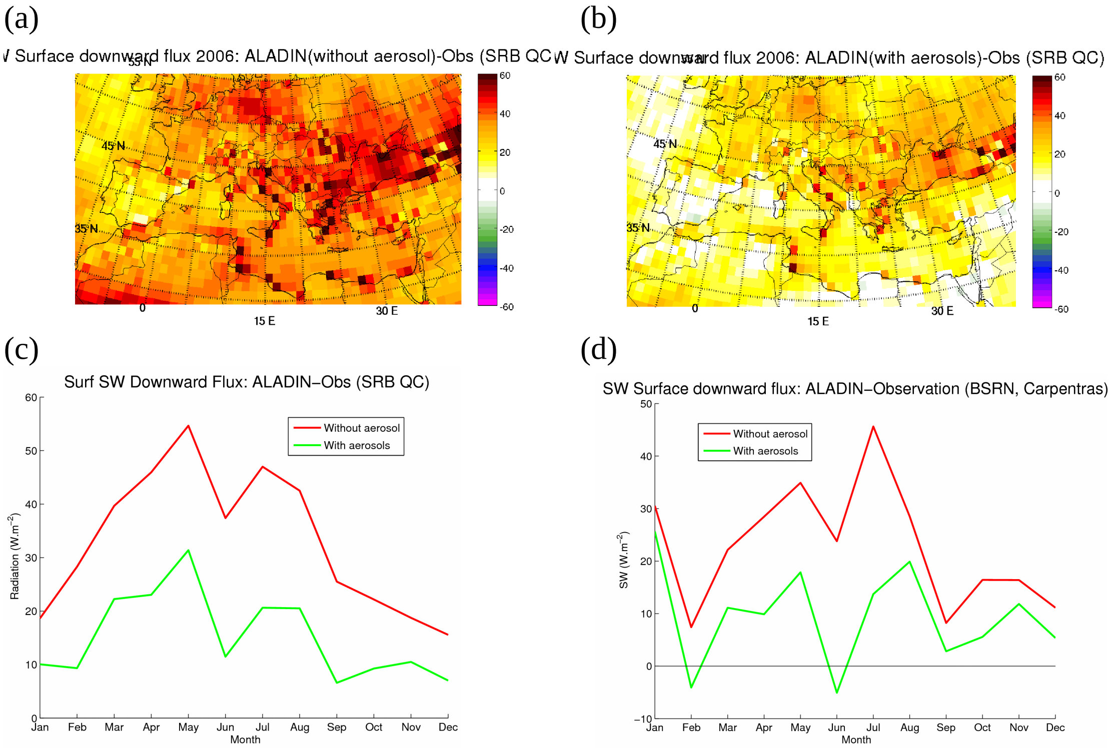


Figure 3: Biais map of the downward surface shortwave flux (W/m^2) for ALADIN compared with the SRB-QC reference for the year 2006 for (a) the simulation without aerosol and (b) with the new climatology. Seasonal cycle of the same bias (c) averaged over the Mediterranean Sea and (d) over the Carpentras city (France) but compared to the BRSN local station.

3.1.5 Higher horizontal resolution RCMs for the Mediterranean area (12 km atmosphere)

CNRM developed a configuration of ALADIN with a 12 km horizontal resolution over the Mediterranean area. This configuration based on the so-called Med-CORDEX domain covers all the geographical case study of the CLIM-RUN project (see Figure 4).

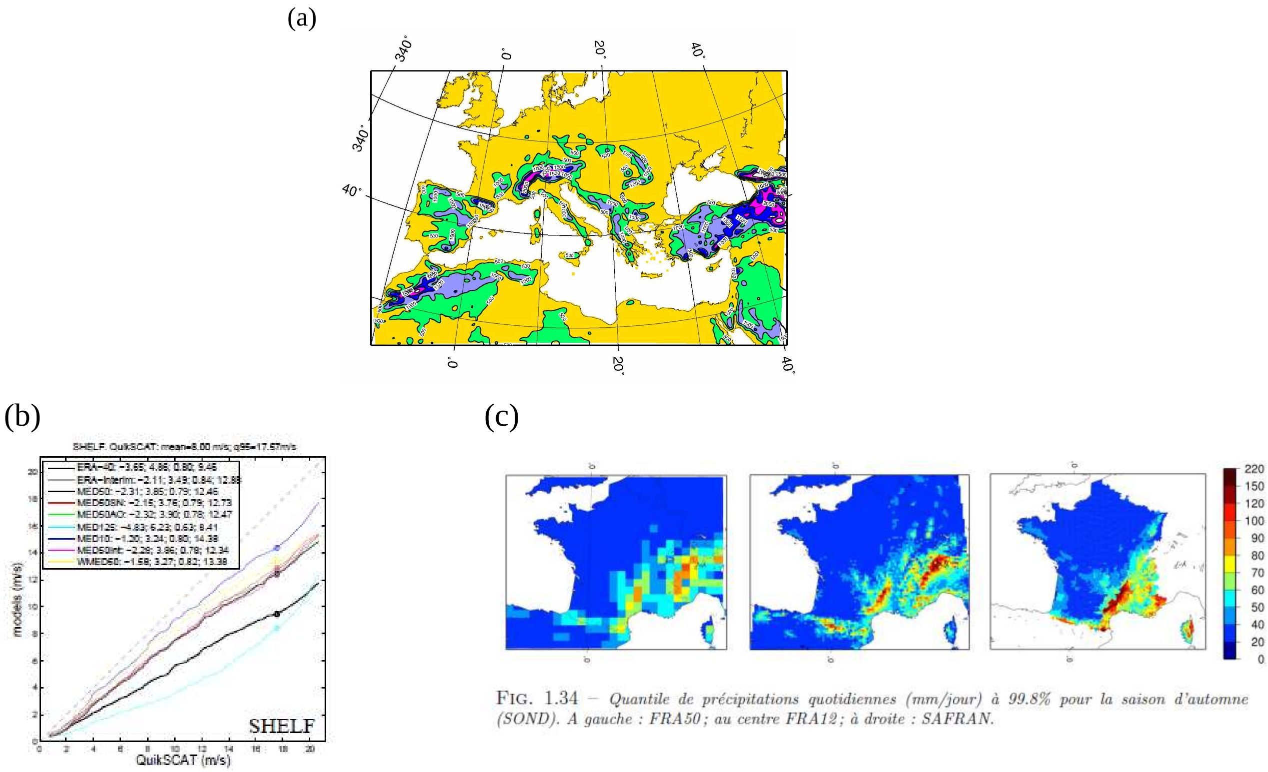


Figure 4: (a) Orography and land-sea mask of the new 12km resolution configuration of ALADIN developed for CLIM-RUN. (b) Added-value of the 12 km run with respect to the simulation of the wind over the sea for the year 2000 (quantile-quantile plot of the daily wind speed for a coastal point 3.7°E-42.6°N), extracted from Herrmann et al. (2011) (c) Added-value of the 12 km run with respect to the simulation of extreme precipitation (99.8% quantile for the season SOND) in the SE of France (50km-RCM left, 12km-RCM centre, SAFRAN observation analysis right), extracted from Colin (2011).

3.1.6 Improvement of the representation of extreme weather events

The impact community is very much interested by the climate change impact on weather extreme events such as strong wind, heavy precipitation, drought and heat wave. Within CLIM-RUN, one demand arising from the stakeholder meetings was the need to a better representation of the extreme events specially heavy rainfall for the North Adriatic case study and the Savoie case study and strong wind over the sea for the energy case study. Using the 12 km resolution RCM ALADIN, we demonstrated the added-value of such a resolution with respect to more classic 50 km resolution for the representation of heavy rainfall (South-East of France was used for the study as high-quality gridded observations are available and the Cevennes is known for its very heavy rainfall events) and of strong sea wind (year 2000 was used as high-quality Quikscat dataset is available). Figure 4b and 4c show illustration of the main results summarized in Colin (2011) and Herrmann et al. (2011).

To go one step further in the improvement of the extreme events in climate models, CNRM has submitted in May 2012 a project to the French national research agency (ANR) targeting the improvement of extreme events (droughts, heavy precipitation, extreme sea level events). The project has been accepted recently and will start in 2013. For extreme precipitation, the project will work on the links between the convection parameterization and the precipitation distribution function in the Mediterranean area focusing on the Cevennes area (France).

3.1.7 Improved representation of the Mediterranean Sea level

The Mediterranean Sea is an evaporation basin, the evaporation volume being compensated by the Atlantic inflow through the Gibraltar Strait. In a regional ocean model like NEMOMED8 (CNRM regional ocean model), a special treatment must be added to be sure that the volume is conserved and thus the sea level (or Sea Surface Height) can be used as an output of the model. One method is to put the evaporated volume of the Mediterranean part in the Atlantic part of the model grid, as an input of precipitation. The consequence of this method is that the seasonal cycle of the ssh of the Atlantic part is the opposite of the seasonal cycle of the Mediterranean water budget, and the seasonal cycle of the ssh of the Mediterranean part is almost flat what is non realistic. The second method, described in Beuvier et al., 2012, in the NEMOMED12 model, and now available in NEMOMED8, is to apply an ssh relaxation in the Atlantic part, towards an observed ssh. In the CLIMRUN simulations, the NEMOVAR-COMBINE reanalysis is used for the ssh relaxation in the Atlantic part, as well as for the relaxation in temperature and salinity on the Western side of this Atlantic part, ensuring a coherence between these boundary conditions. The figure 20 shows the improvement of the ssh representation as a consequence of the ssh relaxation in a 2003-2008 experiment performed with the ERA-Interim driven CNRM-RCSM.

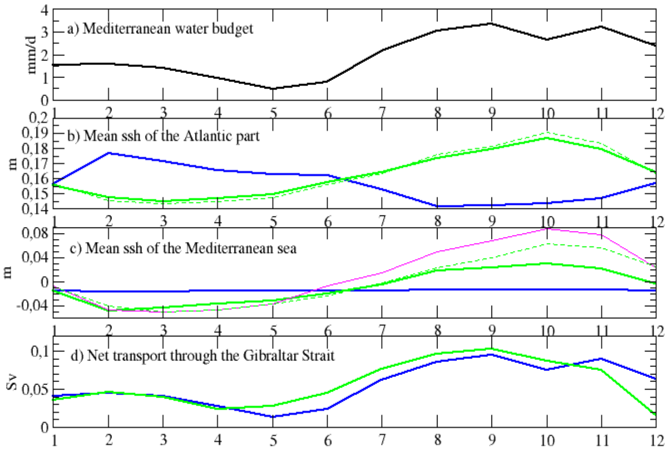


Figure 5: 2003-2008 seasonal cycle of the Mediterranean water budget, Atlantic and Mediterranean mean ssh, and Gibraltar Strait net water transport, for the old method in blue and the improved method in green. The water budget is the same for both experiment. Reference dataset AVISO (produced by Ssalto/Duacs) in pink and the reanalyze NEMOVAR (COMBINE project) in dashed green have been added to measure the added-value for the ssh representation

3.1.8 :References

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Colin J. (2011) Etude de la variabilité climatique des événements précipitant intenses en Méditerranée : approche par la modélisation climatique régionale. *PhD thesis.* Université Paul Sabatier, Toulouse III., 284 pp. PhD supervisor : M. Déqué, S. Somot

3.2. The ENEA contribution:

In the Deliverable 2.1 the list of possible modelling tools that can be developed by ENEA group comprised:

- PROTHEUS regional coupled simulations for different time periods with new improved configuration for the Euro-Mediterranean region;
- Stand alone time-slices atmospheric simulations performed by RegCM3 with a SST skin layer module and with hourly surface fields outputs to better describe the diurnal temperature cycle.
- Stand-alone oceanic simulations performed by a new improved version of MEdMITgcm with a spatial resolution up to 1/16°, with modules for considering the tidal forcing and the explicit representation of the atmospheric surface pressure on the oceanic surface elevation.
- Wave model (WAM model) up to 1/16°x1/16° resolution forced by operational analysis and by regional simulations.

Starting from the users needs came out in the first round workshop for the different case studies, and as better finalised in the CLIMRUN General Assembly of Barcelona 2012, ENEA group has performed the following activities:

1) New regional coupled PROTHEUS simulations for Euro-Mediterranean region, as requested by:

i) Tourism case studies in Tunisia, in Savoie and Croatia ;

ii)Energy case studies;

iii)North Adriatic integrated case studies.

2) Wave model (WAM model) up to 1/16°x1/16° resolution forced by operational analysis, as requested by Tourism case studies in Tunisia .

<u>1): PROTHEUS Simulations</u>

As already reported in Del2.1, the PROTHEUS coupled system is composed of the RegCM3 atmospheric regional model and the MITgcm ocean model. For a complete description of the coupled system the reader is referred to Artale et al. (2010). The coupling of RegCM3 and MITgcm is done with OASIS3 coupler (Valcke and Redler, 2006) that performs both the

synchronization of the two models and the interpolation of coupling fields from the source to the target grid. Every 6 hours, the ocean model receives the wind stress components and the total heat and freshwater water fluxes from the atmosphere. At the same frequency, the atmospheric model updates the sea surface temperature patterns with those produced by the ocean model. No relaxation to climatology is applied. The model configuration adopted for the present purposes has a uniform horizontal grid spacing of 30 km on a Lambert conformal projection and 18 σ-levels. The simulation is performed over the entire Mediterranean Sea. The domain and the topography are shown in Figure1.

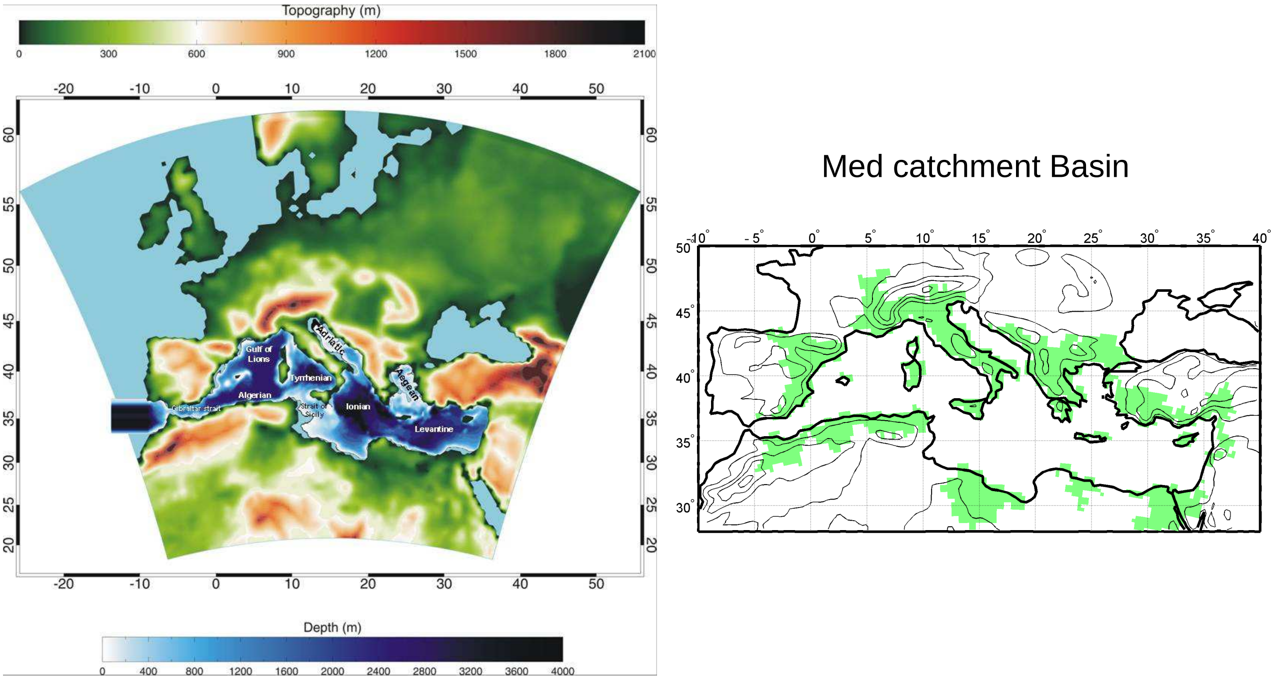

Figure 1: a)Domain for the PROTHEUS simulation with corresponding topography and bathymetry. Units are m. b) Mediterranean catchment basin (TRIP dataset).

The fresh water flux passed to the oceanic model at the river mouths is obtained consistently with the simulated atmospheric branch of the hydrological cycle by computing runtime monthly river discharges from the RegCM3 total runoff. River discharge is calculated by spatially integrating the simulated monthly mean total runoff field over each catchment basin. Such integration is based on the Total Runoff Integrated Pathway (TRIP) dataset, which maps information on land water flow directions onto a 0.5°x0.5° regular global grid (Oki and Sud 1998). By following the TRIP classification, we identify 148 river mouths discharging into the Mediterranean Sea (Fig.1b), and 50 river mouths discharging into the Black Sea. Starting from the river mouths, the catchment basins are reconstructed using TRIP

information and mapped onto a 0.25°x0.25° intermediate grid. The total runoff is interpolated onto the intermediate grid by using an inverse distance interpolation procedure. To derive a realistic estimate of the freshwater flux that reaches the Mediterranean Sea from the Black Sea through the Dardanelli Strait, the value for the total discharge in the Black Sea is rescaled (runtime) using coefficients computed from a previous RegCM3 standalone simulation forced by reanalysis to match the Stanev climatology (Stanev et al , 2000). The rescaled water flux is then treated as a single river mouth for the Aegean Sea. The effect of the rescaling is to reduce the total discharge in the interior of the Black Sea, with larger impact during winter.

Here we report some results from the validation PROTHEUS run driven by ERA40 global Reanalysis dataset (hereafter P_ERA40). In particular, we address here the capability of PROTHEUS to describe the high spatio-temporal variability of the Mediterranean system. To this aim, we compare simulated and observed daily data for the year 2000, when a large amount of observational data is available. We use the daily OISST data computed by Marullo et al. (2007).

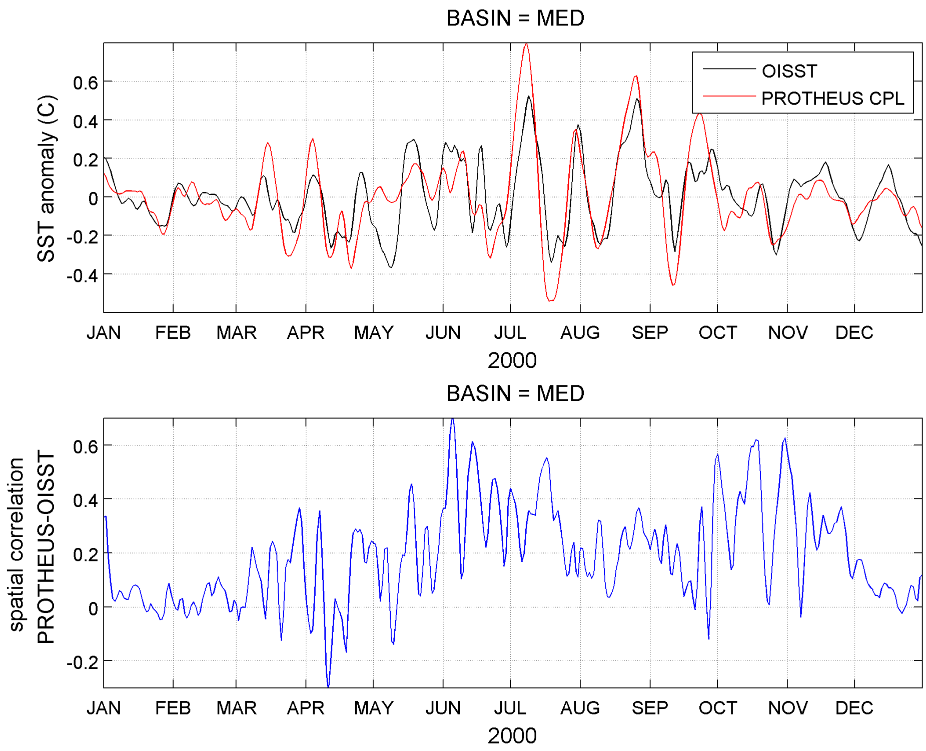

Figure 2a). Time series of SST anomalies (see text for details) for P_ERA40 simulation (red line) and OISST (black line). Values are averaged over the whole Mediterranean basin. b) Time series of spatial correlation between the daily P_ERA40 SST and OISST for the year 2000 computed over the whole Mediterranean basin .

In terms of representation of surface ocean temperature intraseasonal variability , Figure 2a shows the evolution of the daily SST anomalies for year 2000 computed by removing a 30-day running mean. Even if the SST in P_ERA40 shows a detectable bias compared to observations the daily SST anomalies are well reproduced, both in terms of amplitude and timing (temporal correlation of 0.83 obtained after filtering). This is confirmed also in Fig. 2b, where we report the time series of the spatial correlation PROTHEUS –OISST for the whole Mediterranean basin. During the first months of 2000 the spatial correlation reaches low values with small variability: in this period the SST patterns are characterized by feature at too small scales to be captured by the model. After the end of March, the correlation reaches higher values in correspondence of the formation of larger scale patterns of SST anomalies.

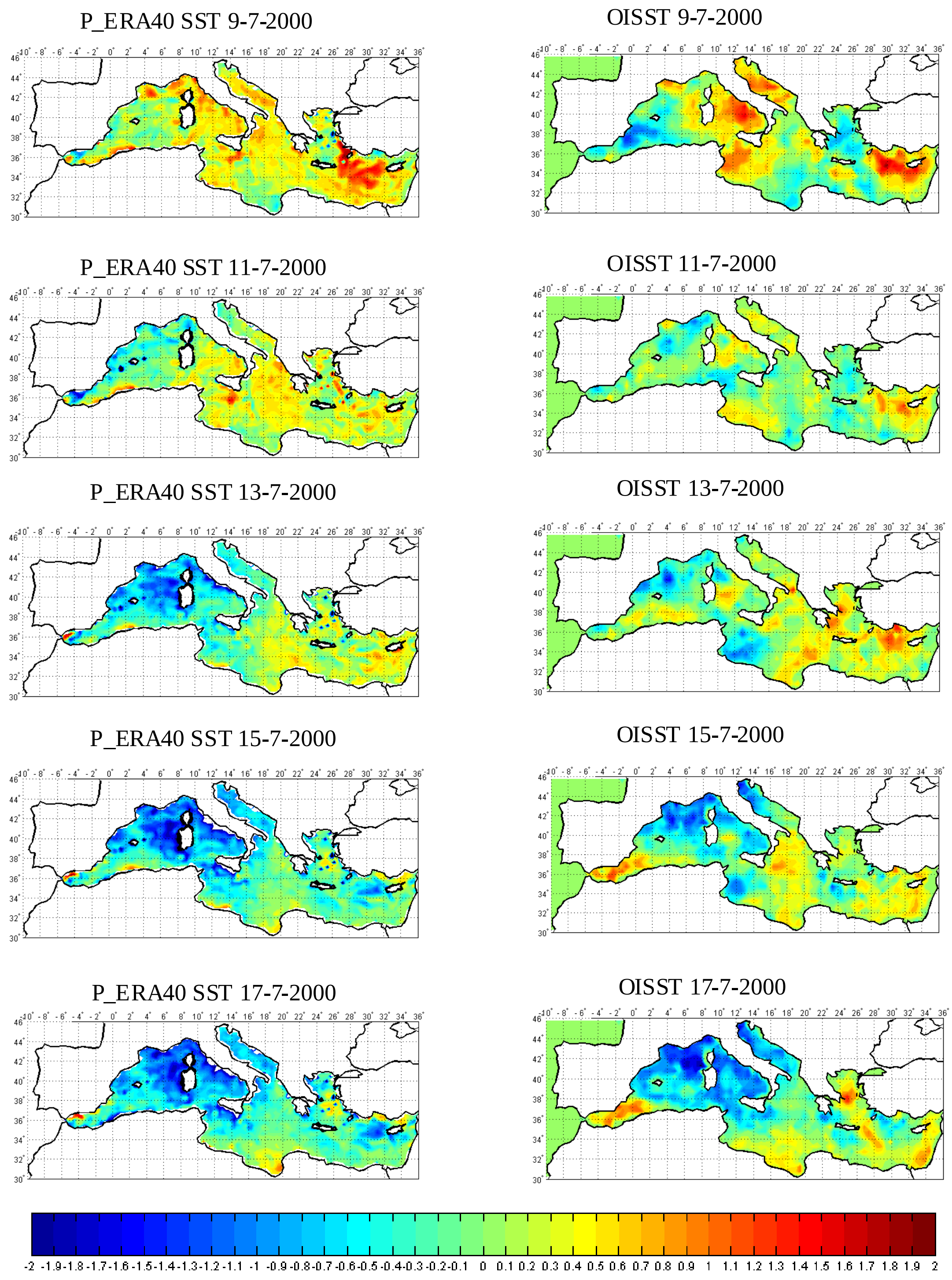

Fig 3. SST anomalies (degrees C) between 09/07/2000 and 17/07/2000 in P_ERA40 and in fine scale observations (see text).

A closer inspection of the cold windy and rainy event of July 9th -17th further demonstrates the capability of PROTHEUS to describe SST features. Observations show a .7°C decrease of basin SST during this period (Fig. 2a). P_ERA40 represents correctly an SST decrease, actually stronger than observed (-1.2°C in P_ERA40). The maps of SST anomaly during this episode (Fig.3) show that P_ERA40 correctly reproduces the daily evolution of the spatial pattern of this event associated to a strong cooling in the northwestern area. In particular, P_ERA40 describes well the increasing negative anomaly over the Gulf of Lions that in some days extends up to the Tyrrhenian sea and most of the western basin, eventually affecting also the Adriatic region. We then note that also some concomitant features in the eastern basin (over Aegean sea and around Cyprus) are well reproduced. In those days the spatial correlation P_ERA40 -OISST over the whole basin reaches a relative maximum of .57 (Fig. 2b)

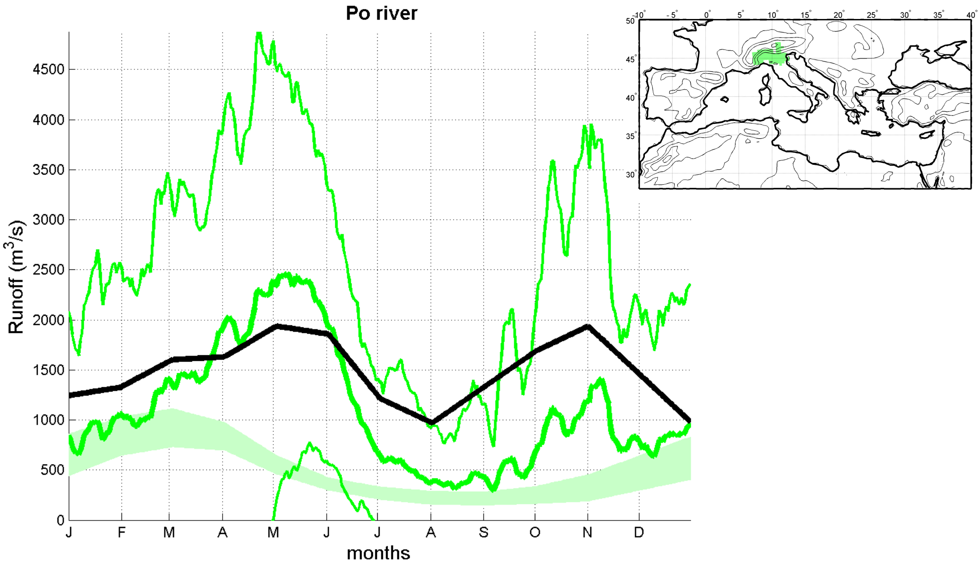

Fig.4 Seasonal cycle of total runoff (surface + drainage) mrro integrated over the Po catchment basin. We also report the map of the associated catchment basin (TRIP dataset). The green line represents the P_ERA40 while ERA40 is also reported as light corresponding shaded regions The thick line is the average seasonal cycle and the thin lines mark +/- 1 std above or below the mean. The black line panel is the average seasonal cycle of the observed Po discharge in Pontelagoscuro.

Just as example of possible information can be extracts by the PROTHEUS model output, we report here estimated river discharge, which is the final outcome of a whole range of processes described by climate models, from air-soil interaction to condensation and atmospheric convection, with a relevant role played by the description of steep orography and snow melting. We choose here to focus our analysis on the case of the Po river whose water sources are mainly in the Alps. The Po river is an optimal case to test the improvements for

impact studies coming from the downscaling of global climate models. Moreover, the Po discharge plays a key role in affecting the oceanic circulation of North Adriatic (Artegiani et al 1997). The correct reproduction (as well as a reliable projection in the future climate) can be a useful information, among others, for integrated case study people (CLIMRUN WP8).
In Figure 4, the average seasonal cycle of river runoff is compared to observed climatological values of the Po river discharge observed at the station of Pontelagoscuro (close to the Po delta) from RivDIS dataset (Vörösmarty et al 1998). In P_ERA40 the mean level of total runoff is consistent with an observed average river discharge of about 1500 m3/s whereas in the global reanalysis the aggregated total runoff of Po river is consistently lower (light shaded curve). The seasonal cycle of the Po discharge shows also significant differences in the comparison between the global Reanalysis and the regional downscaling . In the case of P_ERA40 the minimum is reached in August-September. A relative maximum is also present during fall, while during November-December, we obtain a decreasing Po discharge, related with the snow precipitation on Alps, occurs. These features are in quite good agreement with the observations.

Finally, we have verified the ability of the coupled system in reproducing the sea level variability comparing the P_ERA40 output against with satellite altimeter data over the Mediterranean sub-basins. As reported in Fig. 5, an overall agreement turns out, with the highest correlation with total sea level data obtained in them, eastern Mediterranean, where also the highest range of values is present.

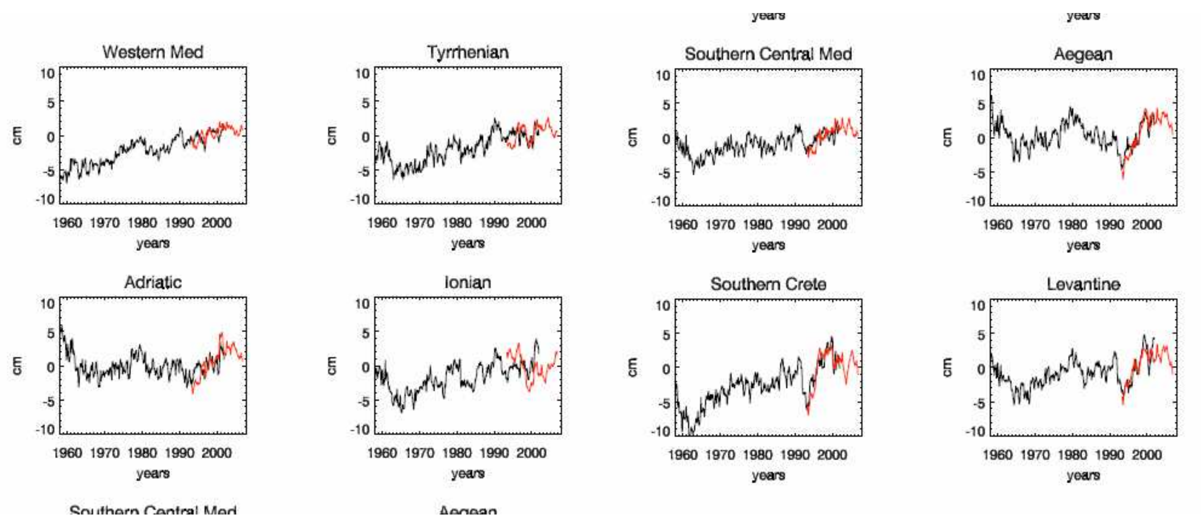

Fig 5. Sea level anomalies for the Mediterranean sub-basins. Values computed from P_ERA40 (black line), & altimeter data (red line).

As already specified in Del2.1 the model can be used to reconstruct past or produce reliable projection fo future climate.

- For past and present climate, the period covered is over:
  - o ERA40 period (1957-2001)
  - o the ERA Interim period (1982-2011)

- For the scenario, the period covered is between 1860-2100.
  - The period 1860-2005 is forced by observed greenhouse gases concentrations,
  - for the period 2005-2100 is forced by a greenhouse gases concentrations following the emission scenario RCP4.5.

2) Wave model (WAM model)

WAve prediction Model (WAM; WAMDI group 1988), has been implemented on the Mediterranean area at a resolution of 1/16°x1/16°. The model has been forced with wind fields coming from ECMWF analysis to perform a first validation analysis. A climatological simulation has been performed for the period 2001-2010 using the WAM Cycle 4.5.3 model. The domain covers the entire Mediterranean Sea and has been discretized with a regular grid in spherical coordinates at a uniform resolution of 1/16°x1/16°. The model has been forced with six-hourly wind fields obtained from ECMWF operational analysis at ¼° spatial resolution.

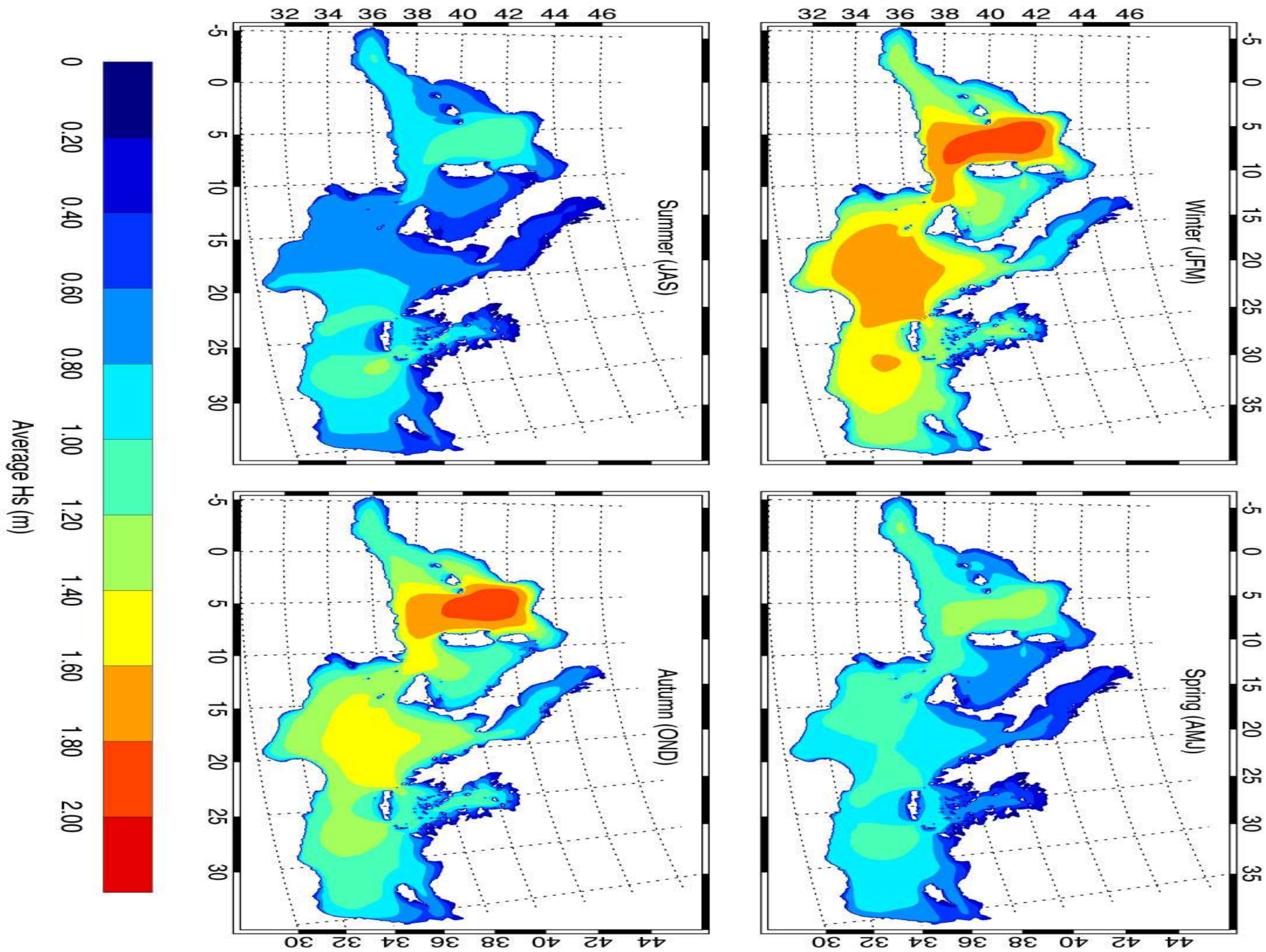

Figure 6: Climatological maps of the Significant wave height for the period 2001-2010

In Figure 6 seasonal climatological maps of the Significant wave height computed over the entire simulation are shown.

3.2.4: References

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3.3. The ICTP model:

Here we summarize the basic configuration of the ICTP model along with the improvement implemented particularly after the needs expressed during the stake-holder meetings.

3.3.1: Model configuration:

3.3.1.a: The ICTP-RegCM4 basic configuration and its improvements:

As described in D2.1, the basic modelling tool utilized by the ICTP for CLIM-RUN is the latest version of the RegCM modelling system, RegCM4 (Giorgi et al. 2012). This is a compressible, hydrostatic model which has been developed for the last 2 decades and used by a large community for a wide variety of applications over virtually all land regions of the World. The model was used from short seasonal runs applied to process studies to centennial long climate change projections. Since it is a hydrostatic model, RegCM4 has a grid spacing of ~10 km as limit of application.

RegCM4 can use a number of different physics options detailed in Giorgi et al. (2012), and can run with lateral boundary conditions either from reanalysis of observations (ERA-Interim, ERA-40, NCEP) or from different GCMs (e.g. Among such GCMs currently are HadGEM, GFDL, MPI, EC-Earth). Upgrades to the code of RegCM4 were recently implemented which make it a fully parallel code which scales well up to several hundred processors. This enhancement is especially important when the model will be used for the high horizontal resolutions envisioned in CLIM-RUN.

A particular feature of RegCM4 for the CLIM-RUN project is the capability of using a sub-grid tiling scheme (Giorgi et al. 2003), in which the model grid box (e.g.10 km size) is divided into a regular grid of land surface sub-grid tiles (e.g. 10x10 1 km boxes) accounting for sub-grid scale variations in land surface type and topography. This feature can be used to obtain a first order evaluation of local land surface effects and processes, and to produce high resolution scale climate information. The sub-grid tiling has been tested for a number of regions, including the Mediterranean, and has shown its capability of improving the

simulation of land surface processes, in particular concerning the snow cover cycle, thus providing improved information for winter tourism assessment studies.

A number of potential improvements were mentioned in D2.1 for possible use in CLIM-RUN:

- Inclusion and testing of an urban land type (Kueppers 2008)
- Inclusion and testing of the Tiedtke (1989) convection scheme
- Inclusion and testing of the University of Washington PBL scheme (O-Brien et al. 2011)
- Improvement of cloud microphysics
- Inclusion of aerosol indirect effects
- Coupling with a full gas phase chemistry model (Shalaby et al. 2011)
- Coupling with the ROMS ocean model (Shchepetkin and McWilliams 2005)
- Activation and testing of the interactive biosphere component of CLM

Of these, the first three (urban type, UWPBL scheme and Tiedtke convection scheme) have been achieved and are fully operational. The coupled gas-phase chemistry module has also been successfully implemented, however it is very computationally demanding and therefore it is unlikely that it will be used within the CLIM-RUN context. Some optimization and simplification of the scheme is currently under way to make better suitable for climate-long simulations. The other improvements in the list are still currently under development or testing.

Below we detail two other features of the model that emerged as needs from the stake-holder meetings.

3.3.1.b: The coupled aerosol scheme:

RegCM4 includes a simplified aerosol module which is coupled both dynamically and radiatively to the climate component of the model (Solmon et al. 2006; Zakey et al. 2006; 2008). The aerosol scheme includes sulphate, organic carbon (OC) and black carbon (BC) particles, desert dust, and sea spray. It has been applied to a variety of studies over different

regions, such as Africa (e.g. Konare' et al. 2005; Solmon et al. 2008), East Asia (Giorgi et al. 2002; Zhang et al. 2009), South Asia (Nair et al. 2011), and Europe (Solmon, work in progress). Figure 3.1 shows examples of aerosol optical depth and aerosol radiative forcing over the Mediterranean region calculated in a RegCM4 simulation driven by ERA-Interim boundary conditions for the period 2000-2009.

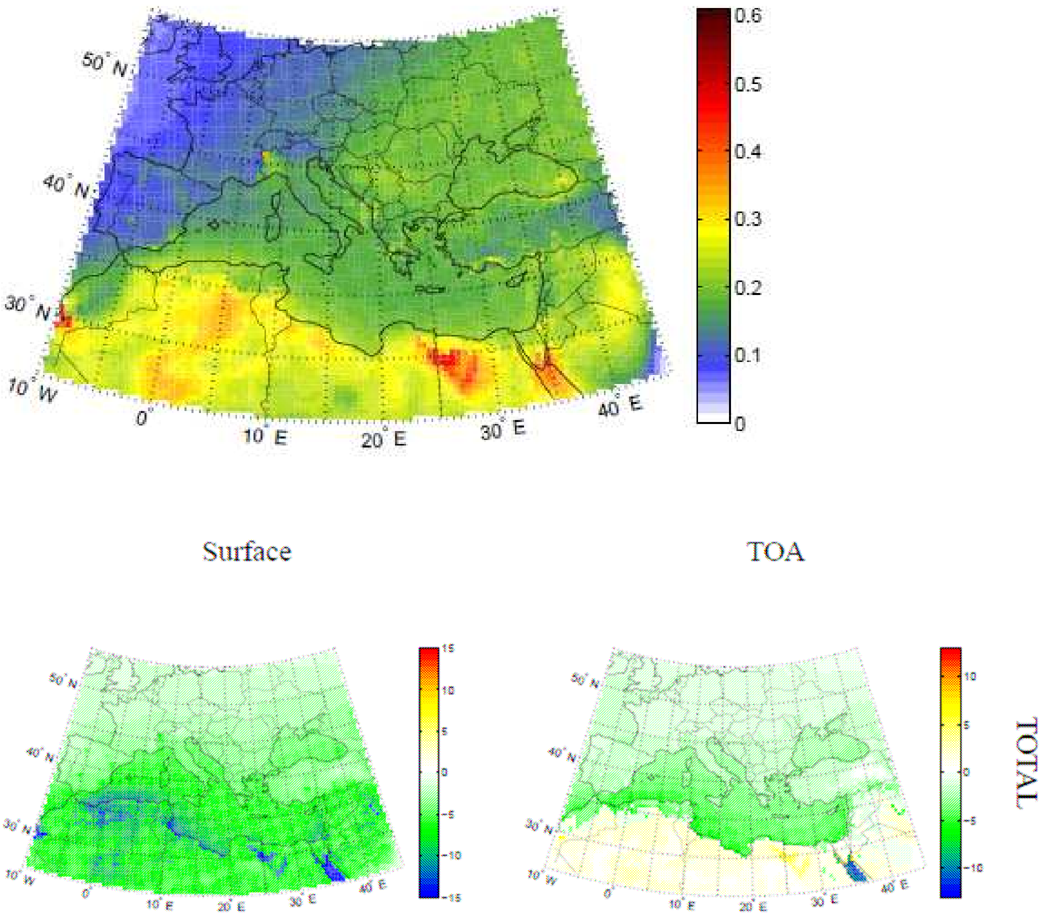

Figure 3.1. Upper panel: Aerosol optical depth calculated over the Mediterranean with RegCM4 for the period 200-2009. Lower panels: Surface (left) and top of the atmosphere radiative (right) radiative forcing for the same simulation.

This aerosol scheme can be used in the calculation of depletion of solar radiation by aerosols for application to solar energy estimations in the solar energy case study.

3.3.1.c: The coupled lake model:

RegCM4 includes as an option a coupled one-dimensional lake model (Hostetler et al. 1993) including vertical turbulent and convective mixing as well as heating by solar radiation. This coupled lake model can be used in the case study on summer tourism in the Savoy region. An example of application for the Caspian Sea is shown in Figure 3.2, which compares observed and RegCM-simulated lake sea surface temperatures for the period 1995-2008.

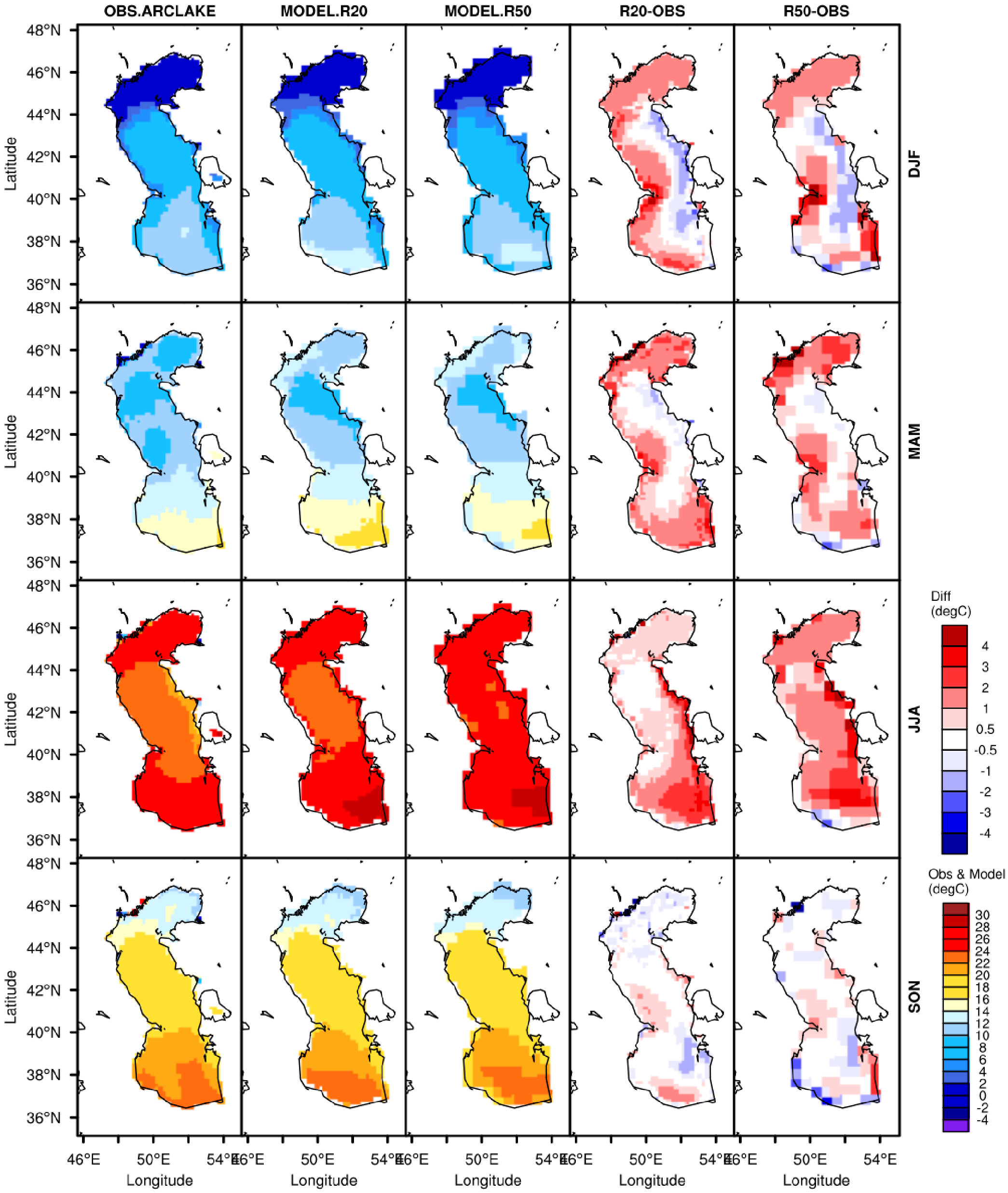

Figure 1: Seasonal averages of lake surface temperature (C°) for the period 1995-2008 in ARCLAKE[1] observations, R20 (20 km grid spacing) and R50 (50 km grid spacing) simulations along with their difference

[1] http://www.geos.ed.ac.uk/arclake/

3.3.2: Simulation strategy:

The simulation strategy was better defined compared to D2.1, particularly in response to the needs emerged in the stake-holder meetings. Two sets of simulations will be carried out, both for the entire Mediterranean region so as to potentially provide data for all case studies. In both cases the priority scenario will be the high end RCP8.5, which will allow us to examine a greater range of radiative forcing and climate response. Candidate driving global models are MPI and HadGEM.

In the first, the model will be run at a relatively coarse horizontal resolution of 50 km. In this case the simulation is relatively inexpensive and thus will allow the completion of a relatively large set of experiments for different driving global models and RegCM4 configurations. This will provide information necessary to characterize uncertainties in the climate scenarios.

In the second approach, the model will be run at high resolution (grid spacing of 12 km + land sub-grid at 2-3 km). In this case, due to the large computational resources needed to run the model, only relevant multidecadal time slices for one or two scenarios and global models will be performed. These simulations will allow us to provide fine scale information for the case studies, particularly regarding land surface conditions, and a better representation of extreme events. All the data will be made available to the case study groups.

3.3.3: References:

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4. Conclusions:

This deliverable details the new climate modelling tools which have been developed in order to provide improved information for the CLIM-RUN case studies. Some of the developments were specifically implemented and tested to meet the needs expressed in the stake-holder meetings. As a result of this process, beyond state-of-the-art modelling tools are available for CLIMRUN, in particular allowing us to represent coupled ocean-atmosphere and sea level processes in the Mediterranean, very high atmospheric (dx=12 km) and land surface (dx=1-3 km) resolution which allows a better representation of surface hydrology and extreme events, interactively coupled lake models and coupled aerosol models. These modelling tools will be used to produce a new generation of targeted simulations to support the CLIMRUN impact case studies.