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Report on scenarios for the Mediterranean Sea

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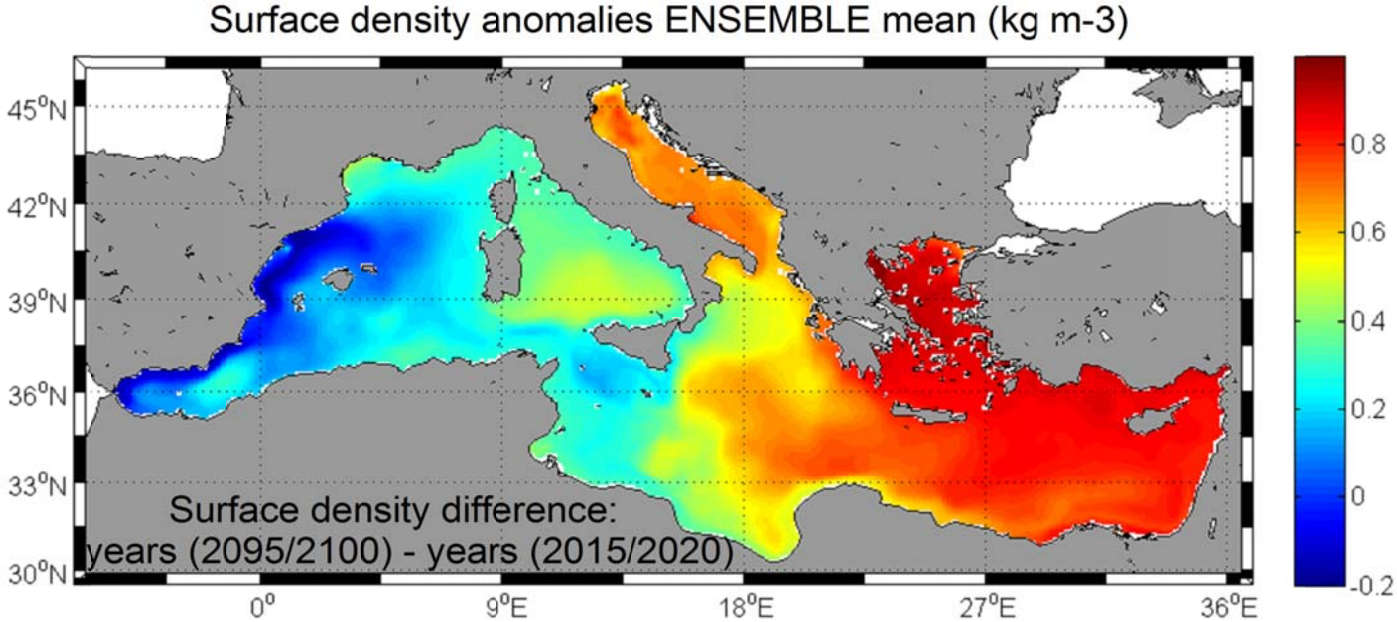

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Report on scenarios for the Mediterranean Sea

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Abstract

The SEACOAST project of the Water Resources Unit (H01) of the Institute of Environment and Sustainability (IES) has aimed during 2015 to monitor, model and assess the environmental status of the marine and coastal waters of European seas. The SEACOAST project assists in implementing the objectives of the Marine Strategy Framework Directive (MSFD) by the assessment of the marine environment through targeted modelling and monitoring activities.

Specifically, the main objective of the modelling activities within SEACOAST 2015 has been to assess the anthropogenic and climate driven changes on the marine environment by using adequate numerical modelling tools that include the main components of the Earth System; atmosphere, ocean, land and anthroposphere. In the scientific jargon, an integrated modelling system of this nature is typically referred as a Regional Earth System Model (RESM). In this context, the marine modelling group has been working to develop such modelling system for the Mediterranean Sea as a ‘benchmark’ case of EU regional seas.

Within Deliverable 6 of SEACOAST 2015 on scenarios of the Mediterranean Sea, we have used a regional climate model (RCM) developed within the EuroCORDEX initiative to obtain atmospheric conditions for the Mediterranean region for the 21st century. However, before using the RCM variables to force the ocean model an intense work was necessary to reduce the bias in surface properties induced by model deficiencies.

Once the present-day conditions in the basin could be satisfactorily simulated by using the RCM variables, this coupled atmosphere/ocean/hydrology system has been used to create a set of scenario simulations into the future under various emission scenarios (business as usual and worst case) and considering different options for freshwater management (associated with socio-economic scenarios).

The objective of this work during 2015 has been to create the model system and to test its capability to perform in scenario mode for the Mediterranean Sea. Now that the tool is created and tested, it could be used to explore consequences of different policy options for Europe in near future in combination with expected climatic changes in the context of the MSFD.

1. Introduction

The work carried out in the marine modeling group of SEACOAST during 2015 on the coupling of hydrodynamic and biogeochemical models to sustain multi-year simulations of future economic and climate scenarios for the Mediterranean Sea is summarized in Table 1. Sixteen scenario multi-annual simulations have been run using two emission scenarios with two available atmospheric projections each (until year 2100) as forcing of the Mediterranean Sea configuration, and in combination with several freshwater scenarios. Work on bias correction of the atmospheric fields and hindcast scenario runs has also been necessary as a previous step to the scenario runs of the 21st century to reduce as much as possible the sources and ranges of inaccuracy in the simulations. In the following sections a separated description of the performed work with the main results is included.

Emission scenario	GCM (RCM)	Freshwater scenarios	
		Flow modifications	Nutrients modifications (socioeconomic scenario)
rcp 4.5	MPI (CCLM- EuroCORDEX)	No change	No change
		Adjusted to EP changes	No change
			Best case (AM)
			Worst case (GO)
	Ec-Earth (CCLM- EuroCORDEX)	No change	No change
		Adjusted to EP changes	No change
			Best case (AM)
			Worst case (GO)
rcp 8.5	MPI (CCLM- EuroCORDEX))	No change	No change
		Adjusted to EP changes	No change
			Best case (AM)
			Worst case (GO)
	Ec-Earth (CCLM- EuroCORDEX)	No change	No change
		Adjusted to EP changes	No change
			Best case (AM)
			Worst case (GO)

Table 1: Scenarios for the Mediterranean Sea in 21st century.

2. Bias-correction of atmospheric forcing variables

A common problem to most atmospheric models is the presence of biases in some of the simulated atmospheric variables. If atmospheric conditions are not properly represented, the induced oceanic characteristics in the ocean model will be not correctly simulated.

A proper simulation of the present day surface characteristics of the oceanic system is crucial to analyze the biogeochemical conditions of the studied basin. Atmosphere-ocean interactions determine the level of vertical stratification and stability, the strength and position of currents and fronts and the mesoscale surface activity. All these physical characteristics determine the level and distribution of biological production in the ocean by controlling mixing and advection processes.

It follows, then, that before using climate models to carry out scenario runs on possible future conditions of oceanic ecosystems, it is necessary to perform validation work in order to obtain realistic results of the present surface conditions in the simulated ocean. We found that for the Mediterranean Sea basin, when using the atmospheric variables from regional climate models (RCMs) for the present period to force an ocean model, a clear underestimation of surface temperature is obtained (Fig. 1) that could be up to ~2°C for some atmospheric models. A too cold surface implies a weaker vertical stratification of the water column and a more intense mixing and fertilization of the surface layer, which have profound consequences of simulated values of biological productivity. Clearly, an effort to correct the atmospheric variables in order to obtain proper oceanic conditions was identified as necessary to be done before attempting to run any scenario simulation into the future.

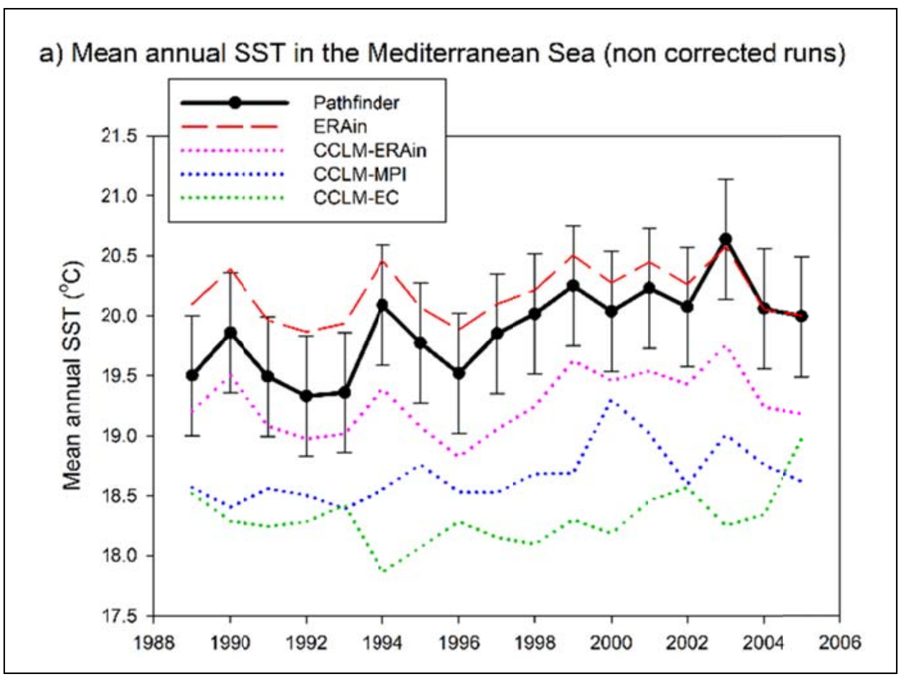

Figure 1. Mean annual sea surface temperature (SST) time series from satellite data (black line) and from the different non-corrected model runs.

2.1 Used models for the bias-correction exercise

We have used the General Estuarine Transport Model (GETM) to simulate the hydrodynamics of the Mediterranean Sea. We have coupled this Mediterranean configuration to a biogeochemical model via the Framework for Aquatic Biogeochemical models (FABM). When forced with atmospheric reanalysis fields from ECMWF ERA-Interim (Dee et al. 2011), this particular coupled model has shown to correctly simulate the surface characteristics (both physical and biological) of the Mediterranean basin during the past few decades (Macias et al. 2013; 2014a; 2014b). As a consequence even if reanalysis datasets may present considerable deviations from the '*true*' weather, in this study the ECMWF ERA-Interim (ERAin) reanalysis is considered as '*observations*' for the purposes of the bias-correction analysis presented below.

This same ocean model with the same exact configuration is also forced at the surface with the atmospheric variables provided by an RCM, namely the Cosmo Climate Limited-area Model (hereinafter CCLM) produced within the EuroCORDEX project (http://www.euro-cordex.net/). This RCM has been shown to provide quite accurate conditions for the European and Mediterranean region when using reanalysis data as boundary conditions and to improve water and heat fluxes over this basin with respect to the raw reanalysis. Three realizations of this RCM are considered here, both using the ERAin data as boundary conditions and using the simulations from two global circulation models (GCM) as lateral boundary conditions.

We have selected two GCMs from the CMIP5 climate projections, namely: the Max Plank Institute MPI-ESM-LR, and EC-Earth, i.e., the Earth System Model of the EC- Earth Consortium (http://ecearth.knmi.nl/). A time-slice (1989–2005) of the '*historical*' simulations (forced by observed natural and anthropogenic atmospheric composition) of both GCMs have been downscaled using CCLM and are named CCLM-MPI and CCLM-EC throughout the text and figures.

2.2 Bias-correction techniques

We have applied a bias correction technique based on a simplified version of the one proposed by Piani et al. (2010) and applied to climatic change simulations for Europe by Dosio and Paruolo (2011) and by Dosio et al. (2012). The basic principle is to find a transfer function (TF) that allows matching the cumulative distribution functions (CDFs) of modeled and observed data. With this methodology the CDFs of '*observed*' and '*corrected*' model variables are equivalent while the internal variability in the '*uncorrected*' model variable is retained. Contrary to previous works, we use spatially-averaged values of the '*observed*' and '*model*' variables over the entire Mediterranean Sea basin, so no spatially explicit correction is applied.

As shown by Fig. 1 above, the main problem with forcing the ocean model with the atmospheric variables provided by the different RCMs runs is an underestimation of SST. The three main atmospheric variables that determine SST are air temperature (t2), cloud cover (tcc) and wind intensity (u10 and v10). Henceforth, we have applied the transfer function approach explained above to all these three variables.

2.3 Results

As shown in Fig. 2 below, mean annual SST values simulated by the ocean model when using the bias-corrected atmospheric variables are much closer to the observed satellite values, with the mean bias substantially reduced (see Fig. 1).

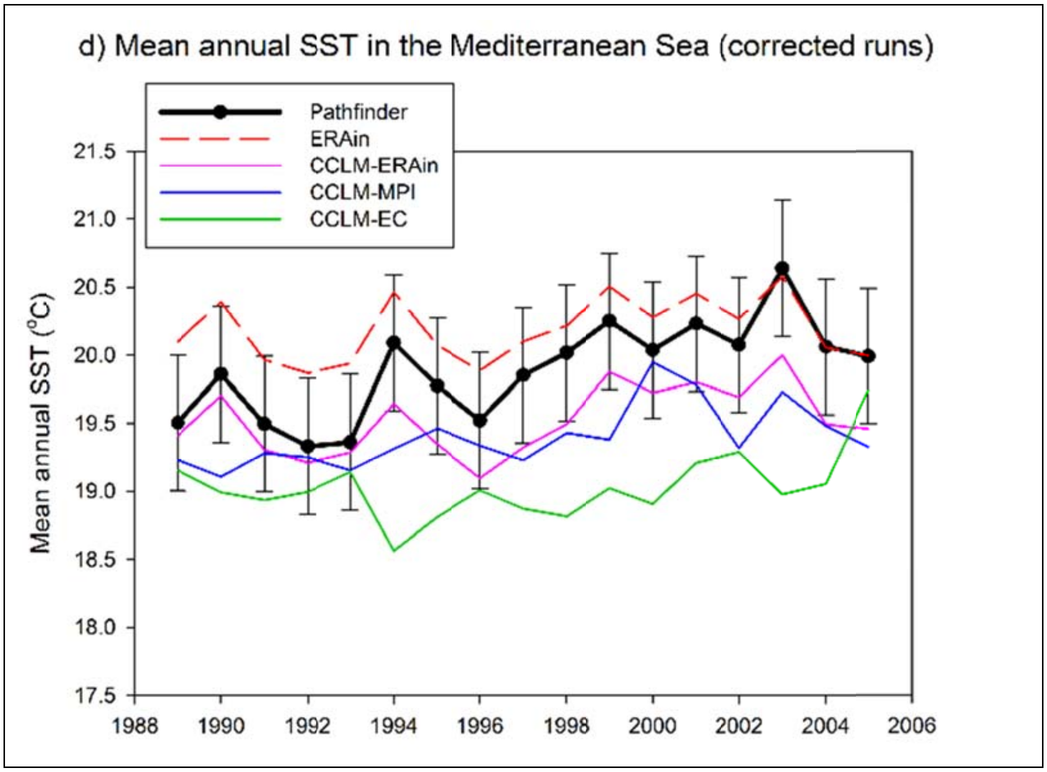

Figure 2. Mean annual sea surface temperature (SST) time series from satellite data (black line) and from the different corrected model runs.

To identify which of the atmospheric variables is more important to correct in order to obtain the right SST from the ocean model, several model runs have been performed by individually correcting the separate atmospheric variables. Results for the CCLM-ERAin case are shown in Fig. 3 below and clearly indicate that wind is the most important variable to correct. Only adjusting air temperature and cloud cover produces but little effect on simulated SST. The same pattern was found for the other two CCLM realizations (not shown) which consistently indicate that effort is needed to get a better representation of wind fields in RCMs if those are to be used to force Mediterranean ocean models in scenario mode.

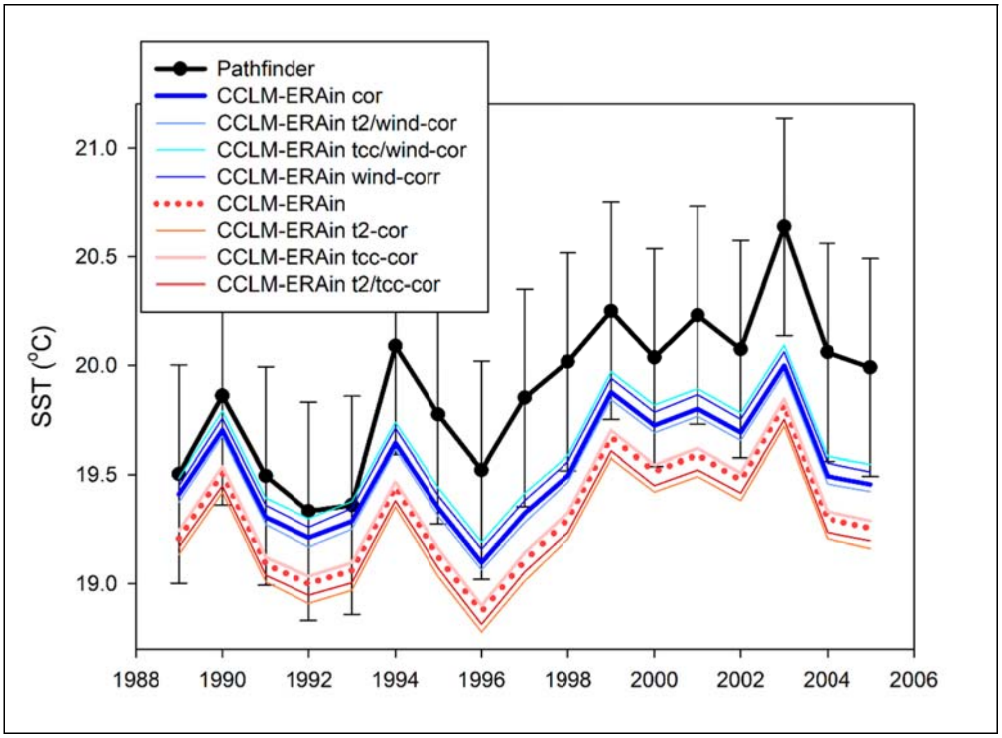

Figure 3. Mean annual SST time series from the different CCLM-ERAin individually corrected model runs. It includes the totally corrected run (dark blue line) and the uncorrected run (dotted red line). The individual corrections are indicated in the legend. The satellite annual mean SST is also included (black line) for comparison.

Finally, we have evaluated and confirmed numerically that the effect of bias-correcting atmospheric variables has a profound effect on the water column stability for the entire Mediterranean basin. In Fig. 4 the mean winter mixed layer depth (MLD) is shown for the uncorrected and corrected model runs. If the panels on the left column are compared with the top figure (the MLD obtained with ERAin forcing, our 'true' state) it is clear that all model runs severely overestimate the mean value and extension of the mixing in winter. As commented before, this will induce an over-fertilization of the surface layer and unrealistic production values. This is particularly true for the CCLM-MPI and CCLM-EC driven runs. After applying the bias-correction (right column in Fig. 4) the mean MLD, its spatial distribution is much more similar to the ERAin simulation, meaning that a great improvement of the vertical stratification structure is achieved in these later runs.

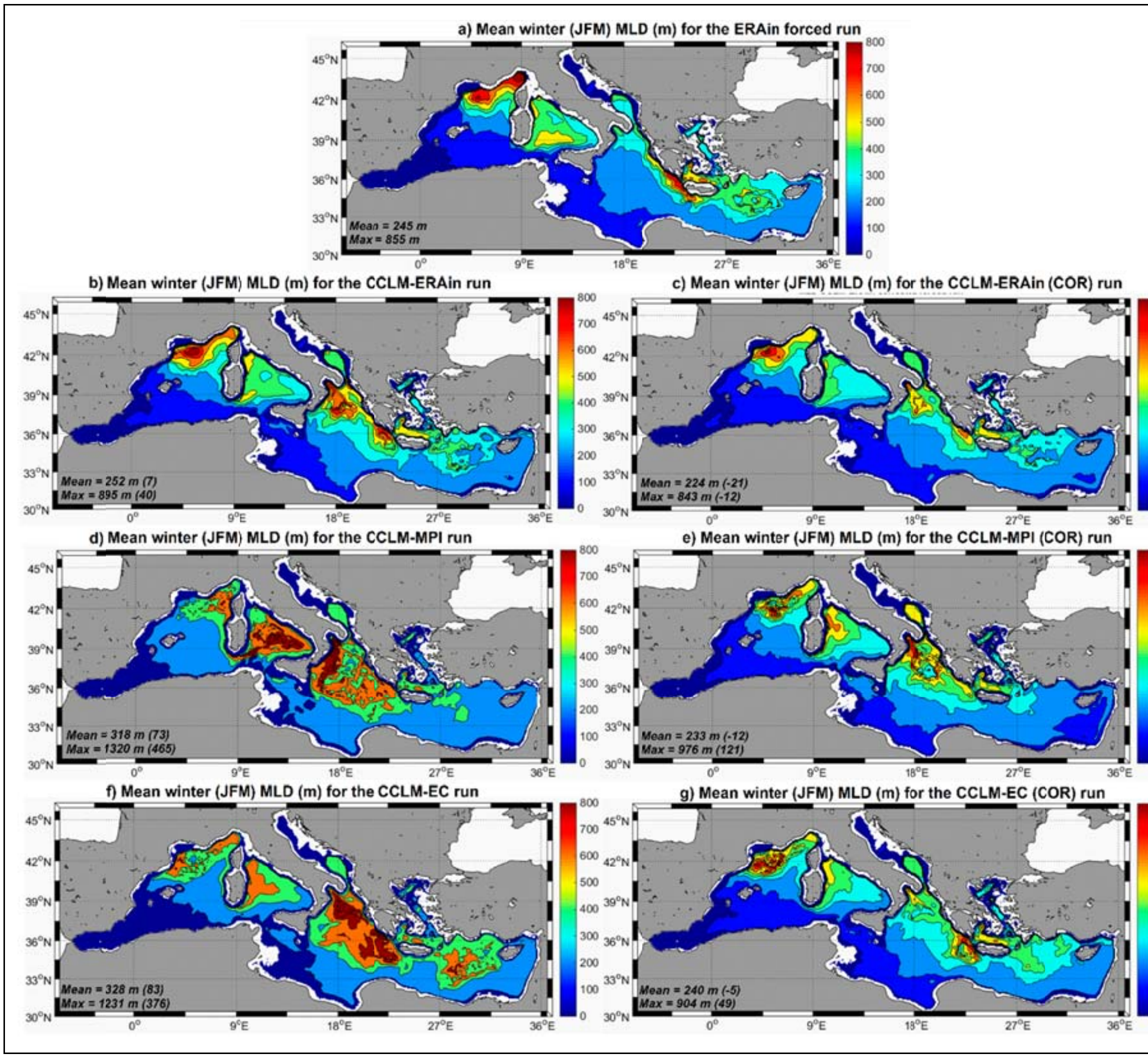

Figure 4. a) Mean annual winter (JFM) mixed layer depth (MLD in m) for the ERAin forced run. b) Mean annual winter (JFM) mixed layer depth (MLD in m) for the CCLM-ERAin forced run. c) Mean annual winter (JFM) mixed layer depth (MLD in m) for the CCLM-ERAin corrected forced run. d) Mean annual winter (JFM) mixed layer depth (MLD in m) for the CCLM-MPI forced run. e) Mean annual winter (JFM) mixed layer depth (MLD in m) for the CCLM-MPI corrected forced run. f) Mean annual winter (JFM) mixed layer depth (MLD in m) for the CCLM-EC forced run. g) Mean annual winter (JFM) mixed layer depth (MLD in m) for the CCLM-EC corrected forced run. Within each panel the mean and maximum MLD value for each run are indicated. Numbers in brackets are the difference with respect to the ERAin forced run (panel a).

2.4 Conclusions

From this exercise it is clear that atmospheric variables from RCMs could not be directly used to realistically force a Mediterranean Ocean model. A pre-processing step for reducing the bias in atmospheric variables is, then, necessary. This bias-correction not only improves the representation of the surface properties of the basin but also the vertical structure of the water column. A complete description of the work performed on this bias-correction issue can be found in the publication:

Macias, D., Garcia-Gorriz, E., Dossio, A., Stips, A., Keuler, K. (submitted) Obtaining the correct sea surface temperature: Bias correction of regional climate model data for the Mediterranean Sea. Climate Dynamics (PUBSY #: JRC97946).

Henceforth, the atmospheric variables produced by the RCMs under future scenarios (described below) need to be corrected before being used to force our Mediterranean basin model.

3. Baseline scenario simulations

As summarized in table 1, we have followed a step-by-step approach to the scenario runs in order to identify and quantify the individual effects of different forcings to assess the potential changes in Mediterranean Sea ecosystems.

The first set of simulations (which we call '*baseline*') aims to identify the isolated effect of changing atmospheric conditions. For this set of simulations, rivers conditions (flow and nutrient loads) are, henceforth, kept unchanged and equal to their present values for the entire simulation run (continuous simulation from 2013 to 2100). Even if this is a very unlikely scenario (at least rivers' flow will change according to evaporation/precipitation changes) it will allow to achieve our primary objective of isolating the direct effect of a changing climate on Mediterranean ecosystems.

3.1 Coupled atmospheric-oceanic model system

We force our Mediterranean basin-wide coupled hydrodynamic-biogeochemical model (*e.g.,* Macias et al., 2014a) with the atmospheric variables provided by the RCMs already used in the previous section (CCLM-MPI and CCLM-EC) under two different emissions scenarios RCPs (Representative Concentration Pathways), rcp4.5 and rcp8.5 (Meinhausen et al., 2011). Hence a total of four member ensemble runs are analyzed in this work.

Of course, atmospheric variables from the different RCM realizations have been bias-corrected following the techniques described in the previous section.

3.2 Results

Basin-wide averaged annual sea surface temperature (SST) and primary production rate integrated in the upper 50m (PPR) are shown in Fig. 5 for the hindcast run (1960 – 2012) and for the different scenarios runs (2014 – 2100). As expected, SST continuously increase in the different scenario runs with the two rcp4.5 runs (light colored lines in Fig. 5) showing a mean warming of ~1°C by 2100 (*i.e.,* a warming rate of ~0.12°C/decade for MPI and ~0.14°C/decade for EcEarth) and the two rcp8.5 runs (dark colored lines in Fig. 2a) indicating a warming of ~2.7°C by 2100 (~0.32°C/decade for both MPI and EcEarth). MPI-driven simulations (red lines in Fig. 5) are typically warmer than the EcEarth runs (blue lines in Fig. 5) for the two different scenarios considered.

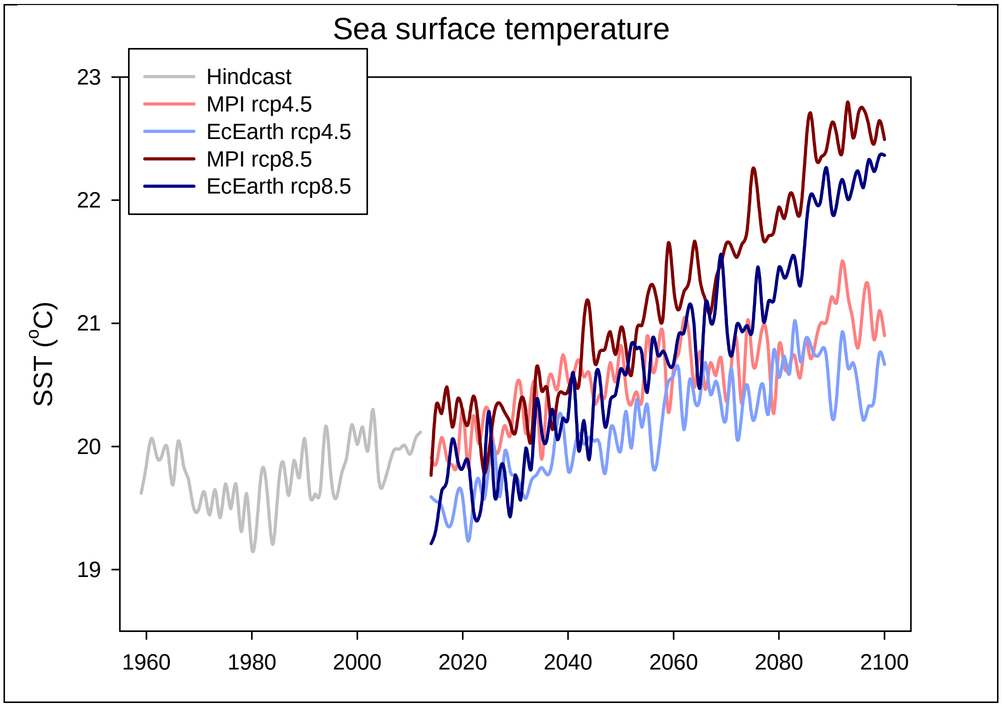

Figure 5. Time series of mean (basin averaged) sea surface temperature (SST) for the hindcast (gray line) and the different simulation scenarios (color lines).

PPR time series are quite constant during the different scenario runs (colored lines in Fig. 6) showing no significant trend but quite a strong interannual variability. On the contrary, the hindcast simulation (gray line in Fig. 6) shows the transition from low to high PPR described and commented by Macias et al. (2014b) linked with the rivers' flow and nutrients loads changes. Henceforth, and given that rivers conditions are not allowed to change in this ensemble of simulations, the lack of a clear trend in PPR levels is the expected result.

Mean SST and PPR agree relatively well at the end of the hindcast (2005, which is created using ERAin forcing) and during the initial years of the scenario runs (colored lines in Figs. 5 and 6), even if in SST in some runs (especially those forced by EcEarth) present some small cold bias (~0.4°C). This is a clear indication that the bias-correction applied is working correctly and provides a good description of the initial (present-day) conditions in the basin.

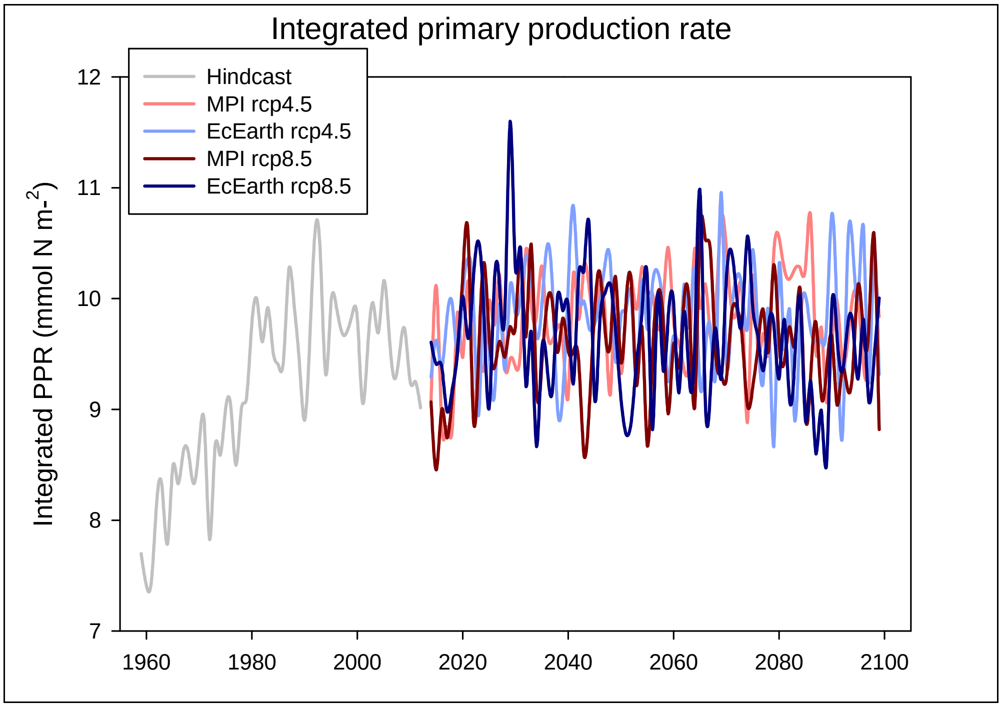

Figure 6. Time series of mean (basin averaged) sea primary production rate (PPR) for the hindcast (gray line) and the different simulation scenarios (color lines).

However, and in spite of the absence of a clear change in mean PPR values through the different simulations (Fig. 6), there is a quite consistent pattern of PPR anomalies distribution (Fig. 7). In this map it could be seen that the western basin tends to show negative PPR anomalies values (*i.e.,* more oligotrophy) while the eastern basin consistently show positive PPR anomalies (*i.e.,* more eutrophic).

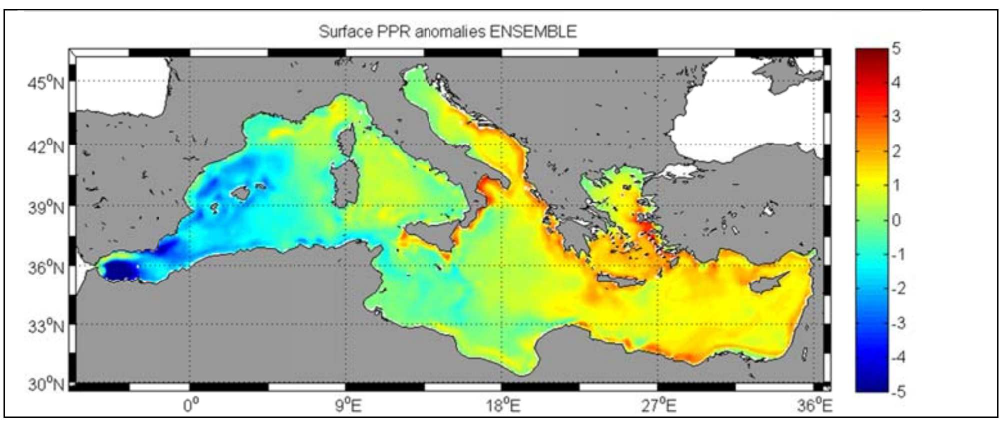

Figure 7. Mean PPR anomalies (2095-2099 minus 2015-2019) for all the simulations run under the different scenarios/models (ENSEMBLE mean)

When examining surface properties changes in these future scenarios, no coherent pattern is found for SST (not shown) but a familiar anomalies distribution is obtained for surface density (Fig. 8). For density, a decrease is simulated in the western basin (associated to surface warming) while in the eastern basin the different model runs predict an increase (linked to surface salinity increase).

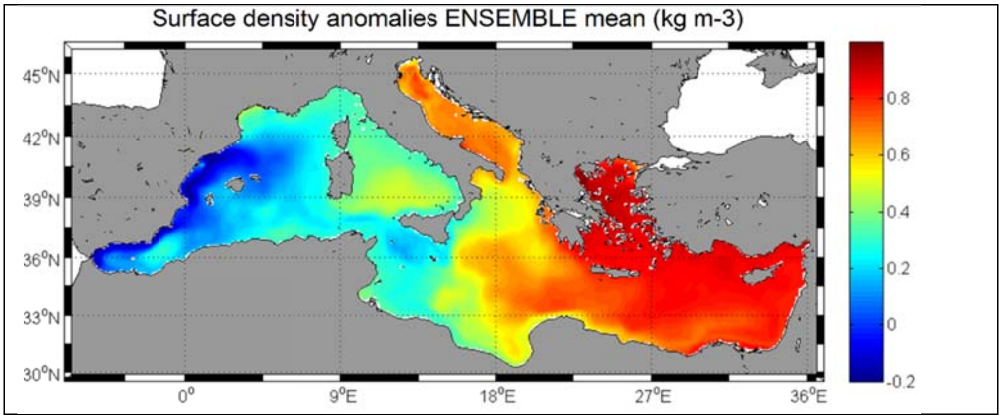

Figure 8. Mean surface density anomalies (2095-2099 minus 2015-2019) for all the simulations run under the different scenarios/models (ENSEMBLE mean)

Indeed, the scatter plot of surface density anomalies versus PPR anomalies (Fig. 9) shows a significant positive relationship. This means that in regions where surface density increases, vertical mixing is favored and so is biological production. In regions where surface density decrease, stratification increases dampening vertical mixing and reducing fertilization and biological production in the surface layer.

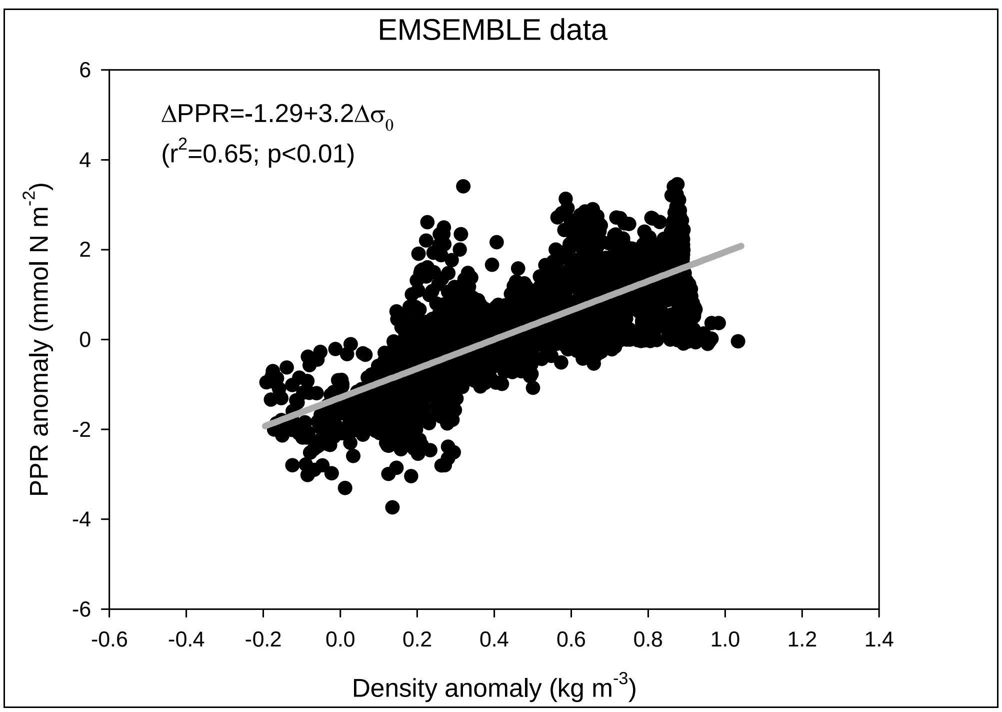

Figure 9. Scatter plot of surface density anomaly versus primary production rate anomalies for the ENSEMBLE model run

3.3 Conclusions

The four scenarios' ENSEMBLE analyzed in this exercise points out to a very consistent future modification of biological production levels in the Mediterranean basin driven by a changing climate. In all cases, and in spite of a substantial warming of the basin, there are no significant changes on the mean biological production rate in the basin. This is consistent with the no-changing river scenario adopted and serves as further support to the importance of river water quality for Mediterranean Sea ecosystems (*e.g.,* Macias et al., 2014b).

However, also a very coherent pattern found in all scenario runs is a spatially different PPR anomalies, with the western basin predicted to become more oligotrophic while the eastern basin tends to increase its biological productivity. Such productivity changes seems to be linked to an alteration of the vertical stability induced by surface density changes. Here we must consider that in a warming future the Mediterranean not only will become hotter but also saltier. These two changes alter in opposite way water density and together will determine the future state of the basin.

It is also quite clear that the inflow of 'fresher' waters from the North Atlantic Ocean through the Strait of Gibraltar plays a fundamental role in determining the extension of the positive/negative density anomaly areas. Those regions closer to the Strait will not suffer a strong surface salinity increase as the Atlantic inflow will help to stabilize its salinity levels. Henceforth, here the warming effect will be the most important one, driving the simulated decrease of surface density. In those regions farther away from the Strait, salinity increases due to excess evaporation will be the most relevant process and, therefore, explaining the density increase simulated by the ocean model.

Also, some differences could be observed within the different scenarios regarding the extension of positive/negative density anomalies areas. For rcp4.5 ~ 33% of the basin is simulated to present negative density anomalies (34% for MPI and 31% for EcEarth) while for rcp8.5 this percentage reduces to ~ 1.4% (1.3 % for MPI and 1.5% for EcEarth). This numbers indicate that the effect of warming is relatively (compared to salinization) more important in rcp4.5 than in rcp8.5 where the increase of salinity is much acute and generalized.

A complete description of this baseline scenario runs and associated consequences for the Mediterranean biological status can be obtained from the following publication:

Macias, D., Garcia-Gorriz, E., Stips, A. (2015) Productivity changes in the Mediterranean Sea for the twenty-first century in response to changes in the regional atmospheric forcing. Frontiers in Marine Science, 2, 79. doi: 10.3389/fmars.2015.00079 (PUBSY # JRC96947)

4. Complex scenario simulations

In spite of the usefulness of the *baseline* simulation described above to assess the direct effect of a changing climate on Mediterranean Sea ecosystems, it is a highly unlikely future as river flows will be altered by changes in the evaporation/precipitation rates on their catchment areas and also freshwater quality will change according to different management options (*e.g.,* depending on socio-economic/politic scenarios).

In order to test the ability of our model system to account for such changes and quantify the effect of these different forcings on biological status, we are working in creating a set of new scenarios by changing:

a) River flows. Adjusting present-day flow values by the relative change in evaporation and precipitation in the different rivers catchment areas.

b) Nutrient loads. Considering a set of socio-economic scenarios for 2050 and projecting them into the 2090-2100 decade.

This is still an ongoing work so no conclusive results could be presented right now. However a brief description of the procedure adopted to define the different conditions of the rivers is included below.

4.1 River flow modifications

As commented above, a proxy to estimate potential changes in freshwater flow in the different climate scenarios will be done by evaluating the relative change on precipitation over each river basin for the end of the century. Henceforth, first of all we must define the regions containing river catchments. These have been defined following the definition of the WISE river basin districts (http://www.eea.europa.eu/data-and-maps/data/wise-river-basin-districts-rbds-1) but grouping together set of rivers sharing a common basin area. This way, 8 different 'provinces' have been defined for the 39 rivers included in our model domain.

The spatial map of the different regions is as follows:

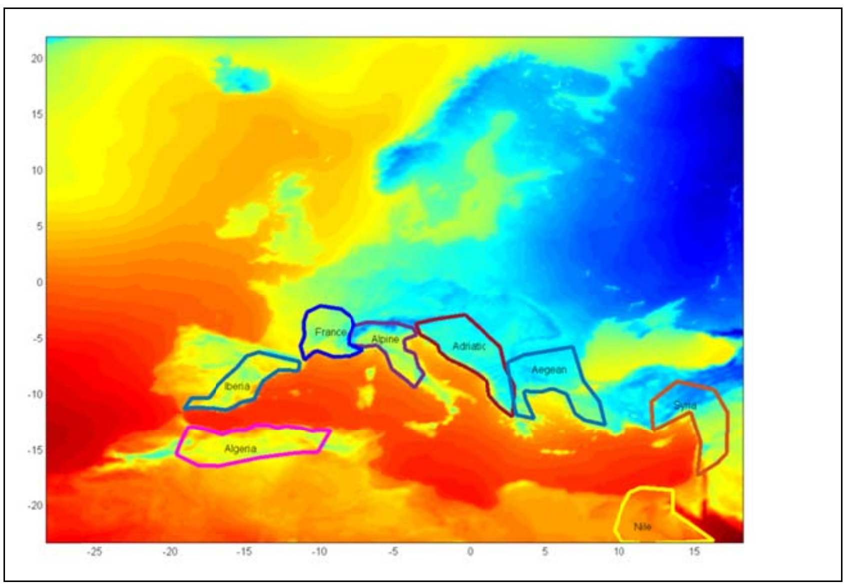

Figure 10. Polygons defining the different regions considered for rivers' basins.

Unfortunately, for the Nile the EURO-Cordex domain did not cover its catchment basin which is located further south in the Africa interior. Henceforth, for this river no scenario on water flow changes could be derived from the used data.

However, for the rest of the basins/rivers it is possible to compute relative changes (% of change) between the beginning of the forecasting period (2014 – 2019) and the end of the simulations (2094 – 2099). To consider also the seasonality of the potential changes, the climatological precipitation cycles for the first 5 years are compared to the climatological precipitation cycles during the last 5 years. This computation must be done for each RCM run (for the different GCMs and the different rcp scenarios, making a total of 4 scenarios).

4.2 Predicted changes in nutrient loads (concentrations)

Changes in nutrient loads for Mediterranean rivers are much more difficult to assess as they are heavily dependent on socio-economic changes. For our ocean model we are mainly concerned on macronutrients and, more specifically, on nitrate and phosphate. Although information of potential changes is very scarce there is a very relevant publication that could be used to our purposes, the paper by Ludwig et al. (2010). In there, potential changes on nitrogen and phosphate loads for different Mediterranean and Black Sea rivers are defined for years 2030 and 2050 under four different socio-economic scenarios using in the Millennium Ecosystem Assessment exercise (Carpenter et al., 2006):

Scenario name	Description
TG: *Technogarden*	TG depicts a globally connected world relying strongly on technology and on highly managed and often engineered ecosystems to deliver needed goods and services. Overall, eco-efficiency improves, but it is shadowed by the risks inherent in large-scale human-made solutions.
OS: *Order from Strength*	OS represents a regionalized and fragmented world concerned with security and protection, emphasizing primarily regional markets and paying little attention to common goods, and with an individualistic attitude toward ecosystem management.
AM: *Adaptive Mosaic*	AM depicts a fragmented world resulting from discredited global institutions. It sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared toward improving knowledge about ecosystem functioning and management
GO: *Global Orchestration*	GO depicts a worldwide connected society in which global markets are well developed. Supranational institutions are well placed to deal with global environmental problems. However, their reactive approach to ecosystem management makes them vulnerable to surprises arising from delayed action or unexpected regional changes.

Table 2. Socio-economic scenarios considered in the Millennium Ecosystem Assessment

Ludwig et al. (2010) provide changes on total nutrient loads (kt y^{-1}) for different rivers for each scenario shown above and for years 2030 and 2050. Henceforth those changes (provided in table 4 of their paper) incorporate both changes due to concentration alteration and because of total water flow changes. To calculate the nutrients concentration changes alone we need to correct the provided data with respect to the changes in water flows (provided in table 2 of their paper).

The relative changes for each catchment under each specific scenario are compiled in table 3 below:

Catchment	TG		AM		GO		OS	
Nutrient	N	P	N	P	N	P	N	P
Iberia	-46.2%	+80%	-59.96%	-71.4%	+65.5%	+113.3%	+27.5%	+103.3%
France	-46.2%	-49.4%	-56.66%	-42.71%	+45.8%	+18.83%	+18.83%	-26%
Alpine	-53.9%	+6.22%	-98%*	-37.62%	-23.8%	-2.57%	-2.57%	+12.4%
Adriatic	-21.58%	+23.6%	-56.29%	+12.1%	+42.2%	+19.48%	+19.48%	+30.7%
Aegean	-14.02%	+8.3%	-98%*	-49.93%	+1.84%	-26.93%	-26.93%	-20.9%
Syria	+62.8%	+25%	-98%*	+25%	+90.94%	+219.23%	+219.23%	+112.5%
Nile	+192%	+841%	-95.23%	+483%	+83.4%	+657.3%	+65%	+541.3%
Algeria	+16.48%	+112.9%	-98%*	+162.9%	+83.34%	+64.03%	+64.01%	+112.9%

*Table 3. Relative change of nutrient concentration in freshwater for the different catchments and under the different scenarios. Values with * are adjusted to a maximum threshold for reduction established at -98%*

As it would be very time-consuming in computer-time and difficult to run and analyze all four socioeconomic scenarios under the four climate models realizations (4x4=16 runs + 4 runs with constant nutrients + 4 runs with constant water and nutrients = 24 runs), we will select the best (largest nutrient load reduction) and worst (largest nutrient load increase) socioeconomic scenarios. From our computation the best case scenario correspond to the AM (green boxes in table 3) and the worst case scenario to GO (red boxes in table 3).

4.3 Effects on the Mediterranean Sea ecosystems

We are still in the process of running the 16 simulations (4 modifying the flow and 8 modifying the nutrients loads) for the period 2090-2100. Initial results seems to indicate that the modifications of the amount of freshwater has far reaching consequences in terms of SST anomalies and PPR modifications. On the contrary the change in nutrients load has much restricted consequences in the ecosystems.

However, it is still very early to draw any definitive conclusion from these scenario runs. At the present time, our modelling system is able to simulate changes associated to the change of lateral forcing. This is fundamental for the planned work for the following years (see section below).

5. Future work

Once the marine modelling framework has been tested and validated during 2015 on scenario mode, we plan to start using this system in two different but interlinked ways:

5.1 Testing potential consequences of policy implementations on freshwater management

We have started a productive collaboration with our colleague hydrologists in H01 in order to use their predictions of hydrological models for the near future (H2030), regarding freshwater quantity and quality, in our Mediterranean Sea configuration. The integration between the GREEN model and our system is on its way and, hopefully, we will start using the data provided by them as inputs to our ocean model during 2016.

5.2 Exploring consequences of marine management plans on Mediterranean ecosystems

In parallel to the future work mentioned in section 5.1, we would like to start using the modeling system to explore potential consequences of different policy options on marine management. We are in conversations with the policy DGs (mainly DG ENV) in order to define a set of policy scenarios (*e.g.,* marine aquaculture) that should be interesting to be tested in the context of the MSFD.

This planned future work demands, however, a substantial change of the ocean model setup. On the one hand the temporal horizon changes, as for policy testing a much more reasonable horizon is ~15 years (hence H2030), so no more centennial projections are foreseen. On the other hand, and to explore consequences on the coastal area, it is necessary to increase model resolution in order to be able to resolve local processes. This will require a higher computation demand, a considerable burden of technical work to prepare the system and, very probably, a new set of problems to be solved during the first few months of next year.

6. Conclusion

The work performed by the SEACOAST marine modelling team during 2015 has allowed to develop, build up and test a model framework for the Mediterranean Sea Earth System, including atmosphere, marine hydrodynamics and biogeochemistry, and hydrology. This modelling system is ready to be used on scenario mode, in order to assess the consequences of anthropogenic and climate-driven changes on the marine ecosystems in the context of the implementation of the Marine Strategy Framework Directive.

At this stage of development, collaborative work, constructive discussions and sharing information with other scientists (*i.e.*, the hydrology group within JRC IES-H01, and the fisheries group in JRC IPSC-G03) and policymakers (DG ENV) will allow to further develop policy-relevant simulations to identify and evaluate potential consequences of EU policy implementations.

Outside JRC and the Commission, this work is being also appreciated by different scientific communities, especially by those involved in regional climate modelling. Our impact-oriented approach and applications are considered as an example by many EU scientists.

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List of abbreviations and definitions

AM: Adaptative Mosaic socioeconomic scenario

CCLM: Cosmos Limited-area Model

GCM: Global Circulation Model

GETM: General Estuarine Transport Model

GO: Global Orchestration socioeconomic scenario

GREEN: hydrological model

MLD: winter Mixed Layer Depth

OS: Order from Strength socioeconomic scenario

PPR: Primary Production Rate

RCM: Regional Climate Model

RCP: Representative Concentration Pathways

RESM: Regional Earth System Model

rcp4.5 & rcp8.5: greenhouse gases emission scenarios

SST: Sea Surface Temperature

tcc: total cloud cover

TG: Technogarden socioeconomic scenario

t2: air temperature

u10: zonal wind velocity

v10: meridional wind velocity

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