Towards Assessing the Adriatic Sea Coastal Vulnerability to Regional Climate Change Scenarios: Preliminary Results

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Abstract

Preliminary results from numerical climate simulations of the Adriatic sea at high resolution (1/25°), performed during two time-slice integrations, are presented for the period 1960-90 and the 21st century (2070-2100), according to the "A1b" scenario defined by IPCC.
This aims at addressing the feasibility of downscaling procedure in a regional basin, resolving features that are generally still not included when using global models and gaining useful indications on climate-change induced impacts on the wave climate and ocean circulation.
For this purpose, a fully coupled version of the ROMS-SWAN model has been implemented, using interpolated meteorological forcings from the SINTA Project (SImulations of climate chaNge in the mediTerranean Area, a joint scientific cooperation of CMCC-INGV-Univ. of Belgrade).
Within the Impacts on Soil and Water Division (ISC) of the CMCC, the numerical downscaling approach is integrated in a GIS-based Decision Support System (DSS) aimed at the integrated analysis of climate change impacts and risks on coastal zones at the regional, aimed at guiding decision-makers in the definition of adaptation strategies.
Despite further experiments are needed to reach definitive results, the outcomes indicate the feasibility of the numerical downscaling approach; nevertheless, they also highlight uncertainties intrinsic to this approach that may be leading, at least at the present state of the art, to results of difficult interpretation.

1 Introduction

Within the framework of activities of the FISR funded Project "VECTOR", namely the WP1 tasks "CLICOST, Coastal climatology and circulation in the Adriatic Sea", several numerical studies have been performed to assess the climate-change related effects and modifications on the wave climate and circulation in the Adriatic region. Here we present preliminary results from numerical climate simulations of the Adriatic sea at high resolution (1/25°), performed during two time-slice integrations: the periods covering years between 1960-

90 and 2070-2100, the later reflecting "A1b" scenario as defined by IPCC. The aim of the activity was that of addressing the feasibility of a numerical downscaling procedure from global models to regional scale, resolving features that are generally not included in the former and gaining therefore useful indications on climate-change induced impacts on the wave climate and ocean circulation at a regional scale.

For this purpose, a fully coupled version of the ROMS-SWAN model has been implemented, forced by interpolated meteorological fields as resulting from the SINTA Project (SImulations of climate chaNge in the mediTerranean Area, a joint scientific cooperation of CMCC-INGV-University of Belgrade). SINTA is a dynamic downscaling experiment of the global climate model SINTEX-G (maintained by CMCC-INGV Italy, this global model is constituted by ECHAM4 model in the atmosphere and OPA model in the ocean, and provides output at 1° resolution every 6 hours). The SINTA project adopted a Regional Coupled Model (RCM) named EBU-POM, maintained by the Univ. of Belgrade, Serbia, and constituted by the Eta Belgrade University for the atmosphere and the POM for the ocean. This RCM runs at 1/5° with 6 hour resolution, using initial and boundary conditions from the global model. EBU-POM downscaling experiments were initialized with database MODB in 1960 and using SINTEX-G fields in 2071.

Additional information about SINTA can be found in Gualdi et al. [1].

The fields resulting from SINTA were then adequately interpolated on the new high resolution grid and used to force the full Adriatic sea basin for the years 1960-90 and 2070-2100. Analysis of the results focused on ocean currents, temperature, salinity, density fields, as well as significant wave height, wave periods, directions and energy, and on the combined wave-currents bottom stress.

Within the Euro-Mediterranean Centre for Climate Change (CMCC, www.cmcc.it) the numerical simulations performed to study climate change impacts on wave climate and ocean circulation in the Northern Adriatic Sea region are included in a risk-based Decision Support System (DSS) aimed at the integrated assessment of climate change impacts on coastal zones at the regional scale. The DSS will guide decision-makers in the identification of relevant climate change hazards on coastal systems (e.g. erosion, inundation, extreme storm surges and water quality variations) and in the assessment of the related impacts and risks, in order to guide the definition of adaptation strategies. As discussed in the following paragraph, the use of high resolution hydrodynamic models forced by Global Climate Models (GCMs) and Regional Climate Models (RCMs) gives the opportunity to construct climate change hazard scenarios and provide science advancements for the delivery of climate change information to stakeholder and decision-makers.

2 Discussion

A careful assessment on how climate-change induced variations in the winds and heat fluxes may impact the wave climate and the ocean circulation at regional scale in the Adriatic region is still missing in the international literature.

To our knowledge, a tentative has been produced by Pasaric and Orlic [2], limited though to the anlaysis of available meteo-

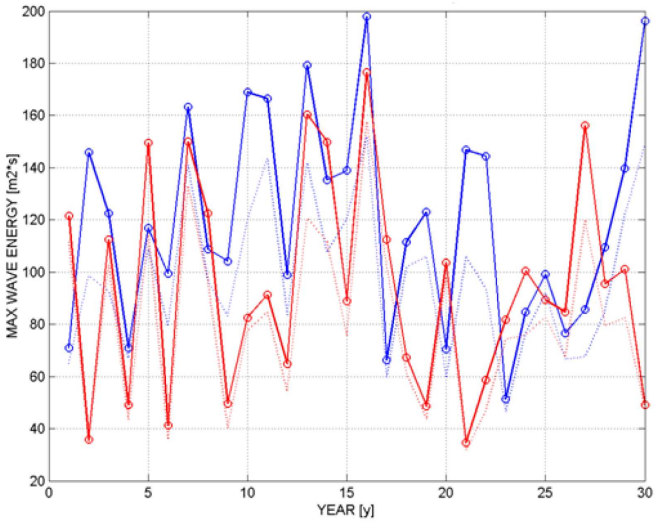

Figure 1: Yearly maximum wave energy comparison between 21st century case (red line) and the 20th century one (blue line).

rological fields at a coarse resolution.
In the novelty approach presented in this paper, though, SINTA bora winds feeding the high-resolution implementation in the Adriatic sea seem to be underestimated, a fact that may play a crucial role in driving the overall circulation and dense water formation in the basin.
The significant wave height fields resulting in the Adriatic basin show a decreasing trend in the 21st century w.r.t. those of the 20th century, a tendency confirmed for the wave energy incident to the coast and for the bottom stress due to currents-waves interactions. In Figure 1 the yearly maximum wave energy comparison between 21st century case (red line) and the 20th century one (blue line) is shown for a region including the Venice littoral. In this region, the expected extreme wave with a return period of 100 years is indeed moving back from about 5.5 m to 5.1 m.
Nevertheless, the seasonal and spatial variation of wave energy can show different features; for instance, Figure 2, presenting the percentage variation of averaged wave energy between 21st and 20th century, highlight a relative increase in wave energy impacting the coast in the Trieste gulf. These results, as far as the data until 1999, are well integrated by those presented by Martucci et al. [3]. First 3D current analysis of the difference in the surface mean circulation between the two centuries evidences the formation of a recirculation area in the northern Adriatic gyre, as well as a decrease in the intensity along the western coast (the WAC, Western Adriatic Current), at least until the Gargano promontory. Associated to this, there is evidence of a generalized increase in the surface temperature in the whole basin, while

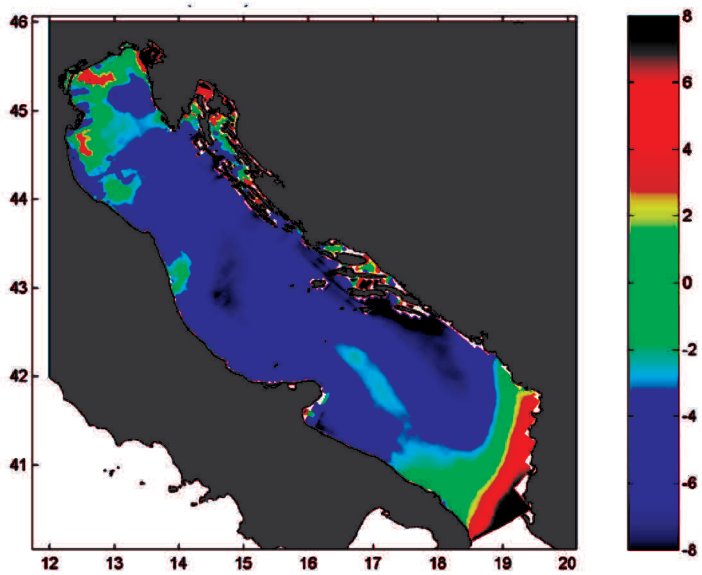

Figure 2: Percentage variation of averaged wave energy between 21st and 20th century.

in the bottom regions this seems to be valid only for the northern Adriatic sub-basin.

Focusing on the northern Adriatic basin (northern than 44.0 ° N), the heat fluxes seem to increase in the 21st century, becoming slightly positive, even though different type of boundary conditions (e.g. river flows) should be tested for this hypothesis. This may play a crucial role in triggering the formation of dense water masses that, originated in this region of the Adriatic basin, are subsequently deepening and sinking flowing southward. Within the northern Adriatic sub-basin the mean temperature increases of about 1.5-2.0 °C in the 21st century w.r.t. the 20th century; interestingly, the sea surface temperature seems to increase of about 1-1.5°C, therefore suggesting that the heat adjustment within the water column is probably once again entering and regulating the highly non linear interplay between these water masses and the different ones intruding from south, the real engine of the Adriatic circulation.

Last, Figure 3 presents the difference of averaged bottom stresses (due to the combined effect of currents and waves) between the 21st and 20th century in the Northern Adriatic basin log10 (N $m^{-2)}$. From the figure it is visible that there is a tendency showing a decrease in the stress along the western coast of the basin, thus suggesting that the intensity of the WAC related current may be weakening during the next century w.r.t the current status.

Within the risk-based DSS developed to study climate change impacts on coastal zones at the regional scale, numerical results and maps obtained for the North Adriatic Sea basin (including the analysis of ocean currents, temperature, salinity, wave

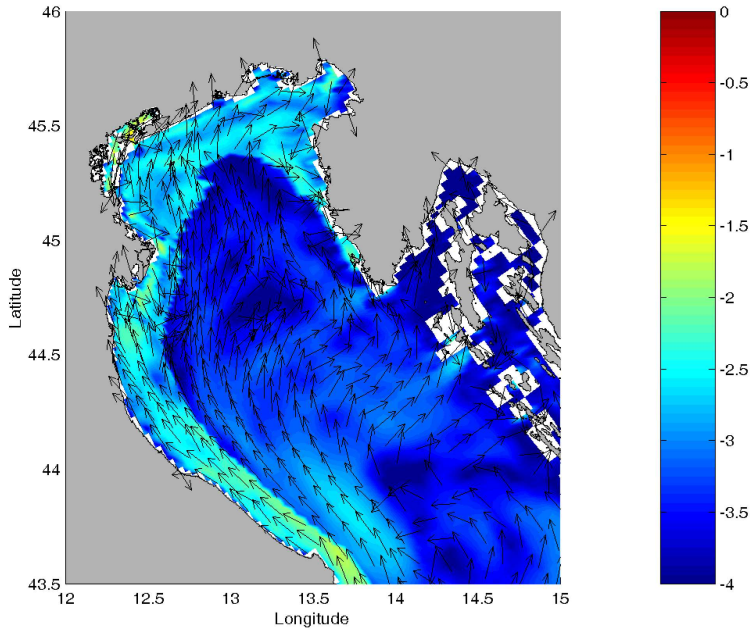

Figure 3: Difference between the average 21st and 20th century bottom stresses (N m^{-2}) due to current and waves. Units are shown in $\log_{10}$.

periods, heights, directions, energy and bottom stress) are used to construct climate change hazard maps representing the exposure to climatic changes against which a system operates.

The conceptual framework of the DSS is composed of 3 main phases: the Scenarios Construction phase which is aimed at the definition of future climate scenarios for the examined case study area at the regional scale, the Integrated impact and risk assessment phase which is aimed at the prioritization of impacts, targets and affected areas at the regional scale, and finally the Risk and impact management phase which is devoted to support adaptation strategies for the reduction of the risks and impacts in the coastal zone, according to Integrated Coastal Zone Management (ICZM) principles. Within the aforementioned framework, the main output of the second phase is the development of GIS-based risk maps obtained through the integration of hazard maps (i.e. maps resulting from the analysis of outputs provided by high resolution numerical models) and vulnerability maps (i.e. maps representing the spatial distribution of environmental and socio-economic vulnerability factors).

3 Conclusions

The numerical downscaling seems to be a feasible approach from global climate models to regional ones, even tough intrinsic uncertainties may be leading to results of difficult interpretation.
Despite further experiments are needed to reach definitive results, the outcomes indicate the feasibility of the numerical downscaling approach from global climate models to RCM ones. At the same time, they also highlight uncertainties intrinsic to this approach that may be leading, at least at the present state of the art, to results of difficult interpretation and that should be drawn with precaution.
For instance, since bottom sediments mobilization is linked mostly to episodic highly energetic events, their dynamics would surely benefit from higher resolution forcings w.r.t. the currently available ones.
The numerical downscaling approach developed to study climate change impacts on coastal dynamics at the regional scale is also an innovative way to bridge the gap between the coarse information of climate scenarios provided by GCMs and RCMs and the detailed information necessary to investigate climate change impacts and risks at the regional/local level. However, precaution is still needed to identify and evaluate the main sources of uncertainty and to transfer information to stakeholders and decision-makers, improving adaptation and ICZM processes.

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