FACING GLOBAL WARMING IN TRANSITIONAL AREAS: CHARACTERIZATION OF VARIABILITY IN SIX MEDITERRANEAN LAGOONS BY MEANS OF NUMERICAL MODELING

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Abstract
The Global Warming strongly affects coastal areas and can deeply change the status of transitional areas like lagoons. Numerical modeling is presented as a tool to characterize lagoons and to quantify their rate of change. The SHYFEM model has been applied to six Mediterranean lagoons and a comparison study between the lagoons has been carried out. The lagoons are the Venice lagoon and the Marano-Grado lagoons in the Adriatic Sea, the Taranto basin in the Ionean Sea, The Cabras lagoon in Sardinia, the Mar Menor in Spain and the Nador lagoon in Morocco, giving a representative picture of the lagoons situated around the Mediterranean basin. The numerical study of each lagoon is the baseline from where the different responses to climate changes, in terms of temperature and salinity variation, are studied.
Keywords: Lagoons, Models, Coastal Systems, Global Change

Introduction
Lagoons are fragile systems in an unstable equilibrium due to their characteristics, in transition between land and sea. Abrupt changes in terms of increasing temperature and major water supply due to global warming and sea level rise, can strongly modify these environments, particularly for those around the Mediterranean Sea. Monitoring permits to study the variation of the lagoon characteristics from measurements. Numerical Modeling allows the investigation also of future scenarios. The application of a model in a number of lagoons around the Mediterranean Sea and the inter-comparison of the responses of the lagoons to different forcings, in terms of temperature and salinity variation, can help both for the general characterization of lagoons and for the future scenarios of global warming on the areas of transition.

Description of Sites
The lagoons we chose are located all around the Mediterranean, and are part of very different environments, interacting both with shallow coastal areas, like the Venice [1] and the Marano-Grado [2] lagoons in the North Adriatic, or deep seas, like Mar Menor [3] and the Nador lagoon [4]. The lagoons range from a leaky type of lagoons (Venice) to a choked type (as for the case of the Cabras lagoon [5]). The number of inlets ranges from just one in the Nador lagoon [4] to 6 in the case of the Marano-Grado lagoons. Lagoons normally communicate directly with the sea, but, in the case of Taranto, a semi-enclosed basin between the sea and the lagoon is present [6]. Tidal range is from micro-tidal to meso-tidal. The depth ranges from an average depth of 1 m to up to 6 meters.

Fig. 1. Location of the six Mediterranean lagoons studied.

All lagoons show strong impact of wind forcing. In most lagoons fresh water input is small, but it is relatively strong in the Marano-Grado case [2]. Wind and tidal stirring normally prevent the lagoons from developing stratification but less dynamic lagoons could show different vertical configurations. The exchange rate depends mainly on the inlet configuration, but also on the wind regimes in the case of multi-inlet lagoons. The exchange rate is also an important factor that can determine the residence time distribution inside the lagoons.

Methods
The model (SHYFEM) is a finite element model, especially suited to shallow water basins with complicated geometric and morphologic variations [1]. It solves the well known hydrodynamic equations with the semi-implicit algorithm on a flexible grid made of triangular elements. It has been applied in its 3D version in order to study the dynamics of lagoons introducing vertical variability and to properly describe the precipitation, evaporation and the river runoff effects in these areas. The model can compute the basic hydrodynamics, dispersion of tracers, temperature and salinity evolution, sediment transport and ecological parameters.

Results and Discussion
Temperature and salinity mean values and variability have been computed for the six lagoons, serving as the reference simulations. The A1B global change scenario has been applied to the lagoons, in terms of air temperature and evaporation increase, precipitation decrease, sea level rise and river runoff variation. In all lagoons higher residence times are registered, compared to the reference simulation, also caused by the major lagoon water volume, due to sea level rise. Lagoons become more saline partially due to the negative value of precipitation-evaporation. The 6 Mediterranean Lagoons have been classified using the division in choked, restricted and leaky. Leaky lagoons, as Marano-Grado Lagoons, are mainly governed by the exchange with the open sea and response to climate change is comparable with the open sea. On the other hand, chocked lagoons (Mar Menor) show more severe variations and experience the highest changes in temperature and salinity fields. Restricted lagoons show intermediate behaviour.These results are important also for other disciplines, like biology and ecology, to handle the global warming effects in transition areas.

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