COMBINING A RTM BIOGEOCHEMICAL MODEL AND HIGH-FREQUENCY IN SITU OBSERVATIONS FOR THE SHORT-TERM PREDICTION OF ALGAL BLOOMS

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Abstract
In the present study we propose a methodological approach for the early detection of macroalgae blooms in the lagoon of Venice. The approach basis on merging the pieces of information brought by a quasi real-time monitoring network and by a Reaction-Transport model of the lagoon. A case study is presented, where the relevant macroalgae standing crop observed in spring 2005 was satisfactorily estimated by constraining the model with continuous Dissolved Oxygen data collected at 7 lagoon sites. The results highlighted that the method is a valuable tool for the quasi real-time tracking of the primary productivity in the lagoon. That makes the approach a valuable tool for the early detection of threats to the ecosystem, such as the risk of anoxic crisis induced by macroalgae proliferation in coastal areas.

Keywords: Lagoons, Models, Monitoring, Blooms, Coastal Management

Introduction
Worldwide coastal areas are subjected to a composite ensemble of human pressures and evidences indicate that these ecosystems have increasingly become more stressed and dysfunctional [1,2]. In the last decades, monitoring, regulatory and management efforts have been carried out with the objective of improving the capability of these environments to recover their natural productivity and, thus, to contribute to the human welfare. The Lagoon of Venice is a valuable example of the complexity of the interaction between hydrodynamics, biogeochemical processes, and human actions aimed at counteracting the eutrophication processes [3,4]. Indeed, in the latest years, macroalgae standing crop have increased again in some lagoon areas were massive proliferations and critical anoxic conditions were observed in the eighties, despite anthropogenic loads of ammonia and reactive phosphorous have decreased. This sudden change in the decreasing trend of macroalgae population was promptly detected by the observing system set up by the Venice Water Authority [5]. The system integrates quasi real-time observations of hydrological parameters and periodical field surveys of trophic parameters. The aim of the present study is to propose a methodological approach useful for the early detection of macroalgae blooms in coastal areas. This approach integrates the continuous observations of parameter sensitive to primary production – in particular Dissolved Oxygen concentration (DO) - with a Reaction-Transport Model (RTM) of the ecosystem. A case study is presented, were the approach has been applied to the estimation of the relevant macroalgae standing crop observed in the some areas of the Venice lagoon in spring 2005.

Materials and methods
The RTM model of the Venice lagoon couples four modules: (i) a 2D transport module; (ii) a water temperature module, (iii) a pelagic biogeochemical module, and (iv) a benthic biogeochemical module, which describes the macroalgae dynamics. The Reaction-Transport equation is solved by means of an operator-splitting technique [6], i.e. the model solves the advective-diffusive processes at each time-step, while the reaction term is integrated using a larger time step. The model input data are current velocity fields, watershed loads of Nitrogen and Phosphorous, meteorological forcings, and the fluxes at the lagoon/sea boundary. The RTM model was applied to the estimation of macroalgae standing crop in spring 2005. To this aim, the model was firstly calibrated by exploiting monthly data collected in the lagoon in 2004 by the Venice Water Authority. The model was then applied to quantify the macroalgae standing crop in spring 2005 by using an "inverse" procedure. In this procedure, the model was iteratively run by varying the winter initial macroalgae biomass up to the value that lead a good fitting of the continuous DO observations in the spring months.

Results and Discussion
The model calibration for the year 2004, lead to a good representation of the observed fields of monthly nutrient and dissolved oxygen concentrations. The iterative model runs for spring 2005 lead finally to track satisfactorily the continuous dissolved oxygen data collected by the quasi real-time observing system, as one can see in Fig. 1. The figure shows that the maximum daily values of the dissolved oxygen observations rise to 180 % passing from April to May, providing an evidence of a rapid increase in the primary production. The model reproduced quite promptly the increase in the daily ranges of the dissolved oxygen observations. The estimated values of macroalgae biomass leading to such a DO dynamic were in agreement with the results of field surveys carried out in spring 2005.

Conclusion
The case study demonstrated the usefulness of integrating the information brought by observing systems and Reaction-Transport models. Quasi-real time data can provide preliminary signals of macroalgae blooms, while their standing crop and biomass can be estimated by using the RTM model, opportunely calibrated by using the field observations. This integrated approach allowed us to investigate short and medium-term changes in macroalgae population in the lagoon of Venice. That suggests that the approach can support the efforts of early detection of threats to the ecosystem, such as the risk of anoxic crisis induced by macroalgae proliferation in coastal areas.

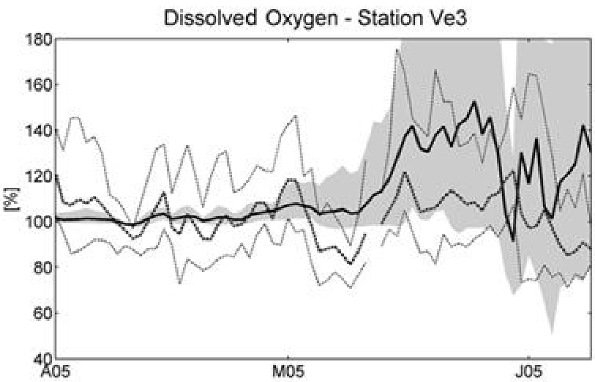

Fig. 1. Mean values and ranges of the i) field observations (dotted lines) and ii) model hindcast (continuous line and shaded area) of the Dissolved Oxygen concentrations in April-June 2005 at the Ve3 monitoring station.

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