Towed sensors and hydrodynamic model evidence the need to include submarine in coastal lagoons water balance, the Mar Menor example (SE Spain).

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Abstract – Hydrodynamic models have proven to be powerful tools to provide a better understanding of hydrological and biological processes occurring in water masses. Sea level gauges, meteorological stations, current meters and surface water stream gauging stations, between others, permit their calibration and validation.

Still, in the modeling of coastal lagoons, one parameter of the hydric balance is hardly monitored, and therefore generally unconsidered in such models: submarine groundwater discharges (SGD) from surrounding aquifers. In this paper, a hydrodynamic model developed for the Mar Menor lagoon, a highly anthropized Mediterranean, was combined with towed sensors of potential indicators of SGD: radon, radium and nitrate. Results revealed that SGD must be taken into account in hydrodynamic models of the Mar Menor lagoon, while combining both modeling and geochemical approaches provided precious insight on the localization of SGD in the lagoon.

This investigation therefore evidences the need of including submarine groundwater discharge fluxes in hydrodynamic models and demonstrates how hydrodynamic models can enhance geochemical approaches.

Keywords-: *Hydrodynamic models, ROMS, Submarine water discharge, Radionuclide tracers, Mar Menor.*

INTRODUCTION

Oceanographic numerical models have been applied worldwide to a wide range of spatial and temporal scales, from global partners currents circulation to trapped waves in coastal systems. In coastal lagoons they have been a very useful tool to understand the mechanism controlling the hydrodynamic of the lagoon and the water balance of the system.

In the Mar Menor coastal lagoon, data for model calibration was obtained from several studies on the different water fluxes, focusing mainly on the evaporation, water discharge by surface streams ([1], [2]) and water exchange through the communication channels. But, a fresh water income hadn´t been studies properly, the submarine groundwater discharge (SGD).

SGD can be determined using radionuclide mass balances as radon or radium, and has been applied successfully worldwide ([3], [4], [5], [6]). Usually, the presence of radionuclides in the surface water is limited, but when rivers drain aquifers or are fed by additional source of radionuclides, like in the Mar Menor lagoon, they may provide important quantities of radionuclides to coastal systems ([7]). In order to quantify and localize SGD and assess whether they should be included in the hydrodynamic model, a combined methodology of towed sensor and hydrodynamic model enabling to quantify the surface water discharges and establish to what extend the influence area of the Rambla was developed.

FIELD DATA

A ship was equipped with three kinds of sensors: a radon detector (Durridge RAD7) connected to a pump system, a nitrate sensor (Suna Satlantic) and a YSI Multiparameter sensor (Conductivity, Temperature, Ph and Oxygen). This system provided continuous measurement at 1.5 meters depth allowing detecting small changes in the radionuclide and nitrate values. Several campaigns were performed on 2010, 2011 and 2012 in order to reflect the potential effects of seasonality on water fluxes.

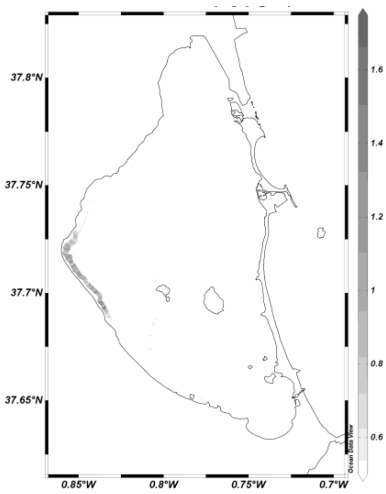

Fig. 1. NO3 measured on 2011. The influence of La Rambla del Albujon can be observed with higher nitrate value (darker color) at the southern Mar Menor coast

NUMERICAL MODEL

The hydrodynamic simulations of the lagoon were performed using ROMS-AGRIF [8], the ROMS version developed by the Institut de Recherche pour le Développement (IRD) using the AGRIF grid refinement procedure developed at the LJK-IMAG (Laboratoire Jean Kuntzmann, Grenoble, France). The Mediterranean Sea grid (150 m resolution) was nested to the Mar Menor grid (40 m) and to the inlets grids (of 5 to 20 m). All nesting grids were two-ways. The Mediterranean Sea model was forced with sea level fluctuations recorded by a sea level gauge in the Mediterranean Sea (northern part of the study area). The lagoon model was forced with hourly winds recorded at the meteorological station on the northwest coast of the lagoon in the San Javier Airport (run by the Spanish Meteorological Agency – AEMET). Modelling results were validated against Acoustic Doppler Current Profilers (ADCP) (Aquadopp, Nortek) with data recorded at the NW lagoon coast, 500 m to the meteorological station at a 4 m depth. The validation parameters for a 15 days period simulation were: Root Mean Square error (RMS) and correlation coefficient.

Regarding the hydrodynamic validation of the model, sea level data showed the best correlation ($r = 0.85$, RMS = 1.2 cm). The speed currents recorded by the ADCPs (Fig. 2) in the lagoon in the days of the surveys were very low (<0.1 m/s) giving a correlation coefficient (R) of 0.70 for current at 2 m above the bottom and 0.72 at 0.5 m above the bottom layer with RMS of 1.1 and 0.1 cm/s respectively. However, higher speed currents showed higher correlation coefficient reproducing correctly the main hydrodynamic patterns.

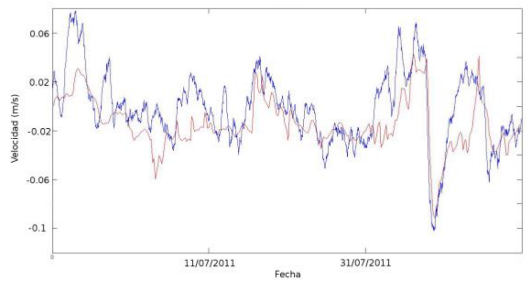

Fig. 2 North-South component of the current measured (blue color) between 6/07/2011 y 25/07/2011 at 3.7 m from the surface and obtained from the model (red line).

The model ran for 6 days with all the hydrodynamics forcing in order to let it spin up before the Rambla input was inserted into the model. Then, the hydrodynamic dispersion of the input of ^{222}Rn and ^{224}Ra (Fig. 2) generated by the Rambla into the lagoon (thereafter called "plume") was modeled.

The model considered mean values for discharge, ^{222}Rn, ^{224}Ra and ^{223}Ra activities of the Rambla, as well as for lagoon activities and Mediterranean Sea activities. The data was provided by field surveys.

RESULTS AND DISCUSSION

The radionuclide mass-balance [9] demonstrated that SGD fluxes are significant (0.4 ± 0.3 to 19 ± 8 10^8 m^3/y) and comparable with surface water inputs. The combination of continuous field data and hydrodynamic model output was then used to identify areas of SGD and areas influenced by the presence of surface water discharge. Fig.3 shows the Radon output model simulation for 10/07/2011, where the number indicates points with high radionuclide values out from the area attained by the plume of the Rambla de El Albujon surface discharge. The introduction of the tracer in the model started 6 days before the days of sampling, i.e. approximately 1.5 half-life of decay for ^{222}Rn. As no more than 25% of the input level of ^{224}Ra and ^{222}Rn was expected to persist at the time of sampling in the oldest parts of the plume, it provided additional criterion for evidencing the non-Rambla origin of measured values in these areas.

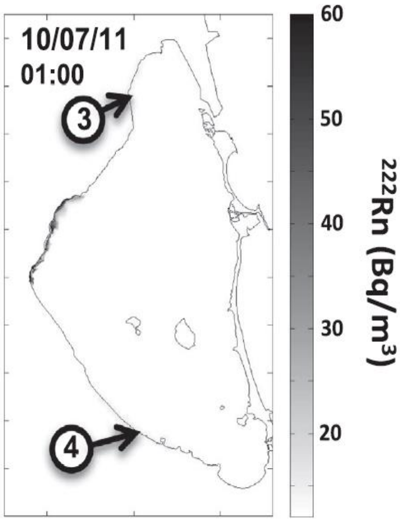

Fig.3 Radon simulation output for 10/07/11. The number indicates points where high Radon values where obtained non influenced by la Rambla del Albujon

CONCLUSION

This study evidenced the need to integrate submarine groundwater discharges (SGD) in the water balance of a coastal lagoon. It also illustrated how the combination of both hydrodynamic modeling and geochemical approaches can enhance the characterization of such fluxes. As hydrodynamic modelers do not usually take in account SGD inputs to their simulations, this study demonstrates the importance to add them, by activating or developing new modules to simulate the behavior of a fresh water input from the bottom.

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