Short Term Mobility call 2017

Activities Report

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Program Title

Development of a synergistic approach to CO2 fluxes in coastal environments by means of mathematical modelling

Hosting Institution

University of California San Diego - SCRIPPS INSTITUTION OF OCEANOGRAPHY (SIO) - Marine Ecosystem Sensing, Observation and Modelling Laboratory – MESOM

Visiting period

2018 - May, 14th to June, 1st

Objectives

The CO2 flux between the atmosphere and the oceans and their consequent acidification is an important scientific issue and the contribution of the coastal lagoons to CO2 fluxes is still not well understood.

The MESON Laboratory is focused on the observations, data collection and modeling of the ecological processes in the coastal marine waters. Part of this research, funded by the U.S. National Ocean and Atmospheric Administration (NOAA) via the National Centers for Coastal Ocean Science (NCCOS) program at SIO, consists of a series of measurements at the Agua Hedionda Lagoon, at Carlsbad, California. Within this research project, Prof. Todd Martz's group is continuously monitoring those parameters that are related to the CO2 flux between the atmosphere and the water of the lagoon. These include pH, alkalinity, pCO2, dissolved inorganic carbon (DIC) and other physico-chemical variables, e.g., temperature salinity, dissolved oxygen and dissolved nutrients. On the other hand, at CNR-ISMAR in Venice, a leading team led by G. Umgiesser constructs numerical (mathematical) models of coastal seas and lagoons, principally applying and continuously developing the open source numerical model SHYFEM (https://github.com/SHYFEM-model/shyfem).

The main focus of this first Short Term Mobility was to establish a permanent connection and collaboration with the MESOM Laboratory on the flux of CO2 issue.

- At the first stage of collaboration the task of ISMAR is to provide the necessary knowledge of the principal hydrodynamic characteristics of the Agua Hedionda Lagoon, that will allow the MESOM and ISMAR researchers to model the temporal evolution of the CO2 flux accurately.
- The challenge is to (ultimately) model the full carbon cycle within the SHYFEM code, fully connected with the hydrodynamic module and the nested biogeochemical module BFM.

Moreover, the implementation of a SHYFEM - based mathematical model of the Agua Hedionda Lagoon will be an important component of two Ph.D. dissertations.

Activities

The daily progress of the activities was discussed jointly with Prof. Martz, and with Dr. Alberto Zirino, a well-known marine researcher in the Martz Laboratory.

Theory and practice of the CO2 system

The relationship between pH, water temperature and TCO2 was first investigated by analyzing the paper by Zirino et al. (1988) 'Surface pH, satellite imagery and vertical models in the Tropical Ocean' referring to oceanographic data collected during a cruise in the Gulf of California. Then, a simple vertical model (Keir and Fiedler, 1988) was used to calculate the vertical profiles of pH, nutrients, phytoplankton and temperature, (all part of the biogeochemical cycle of CO2).

A theoretical paper, by P. Kilho Park (1969), "Oceanic CO2 system: an evaluation of ten methods of investigation" dealing with the methods of evaluation of CO2, was analyzed and its major findings were verified using the calculator CO2SYS by Lewis and Wallace (URL?). A comparison between the modeled CO2 components and actual measured CO2 profiles was conducted using data from XIXIMI3 (Gulf of Mexico) cruise profiles.

Some time was spent studying the results of the application of the ROMS 3D model coupled with the biogeochemical model BioEBUS (Gutknecht et al., 2013) on the Gulf of Mexico. The calculated (BioEBUS) profiles of pH, tALK, and DIC were compared with the analytical results of bottle samples and found to be in considerable error. An investigation is being conducted to find the source of the errors.

Agua Hedionda Lagoon Modeling

The application of the mathematical model SHYFEM to the Agua Hedionda Lagoon started with the collection of the general information on the lagoon, mainly archived in the Technical Report by Elwany et al. 2005 (presence and location of fishery activities, location and magnitude of water intakes of the power plant and desalinization plant). For the model grid design, the internal coastline of the lagoon was digitized from Google Satellite Imagery. Since no bathymetric dataset of the lagoon was found, the isobaths of the bathymetric maps of the 3 lagoon's basins contained in the report, were digitized and converted into bathymetric points. Finally the numerical grid of the model was created with the Gmsh software (Fig.1). Inside the lagoon the resolution of the grid was set to a maximum of 5-7 meters in the inlet and the passages between the basins, and a minimum of 50 meters. In the shelf area the resolution is diminishing seaward from 50 to 250 meters. The resulting grid is composed by 9761 triangular elements and the smallest (area < 10 m^2) are located in the passages between the basins.

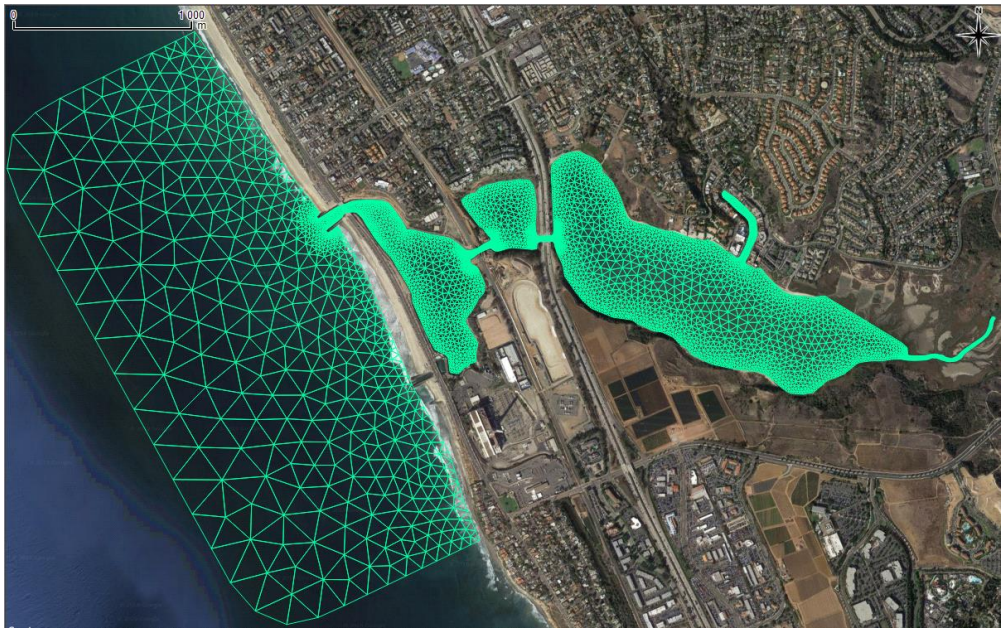


Figure1.

The bathymetric dataset of the shelf area was downloaded thorough the Bathymetric Data Viewer service of the National Centers for Environmental Information (https://maps.ngdc.noaa.gov/viewers/bathymetry/) and refers to the 2013 NOAA Coastal California TopoBathy Merge Project. Both bathymetric datasets (shelf and lagoon) were vertically aligned on the La Jolla MSL (https://tidesandcurrents.noaa.gov/datums.html?id=9410230). Figure 2 shows the result of the bathymetry interpolation on the numerical grid.

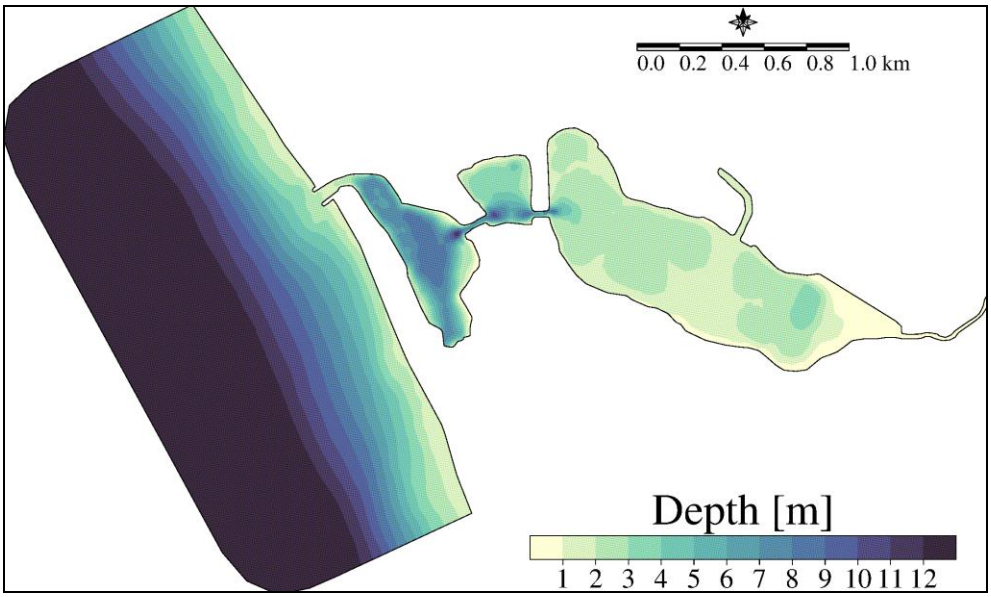


Figure 2.

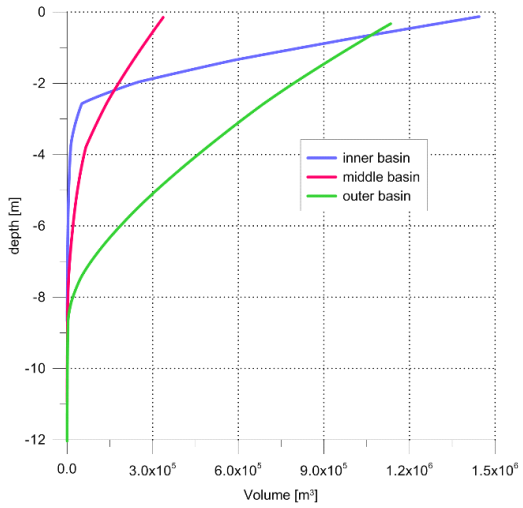


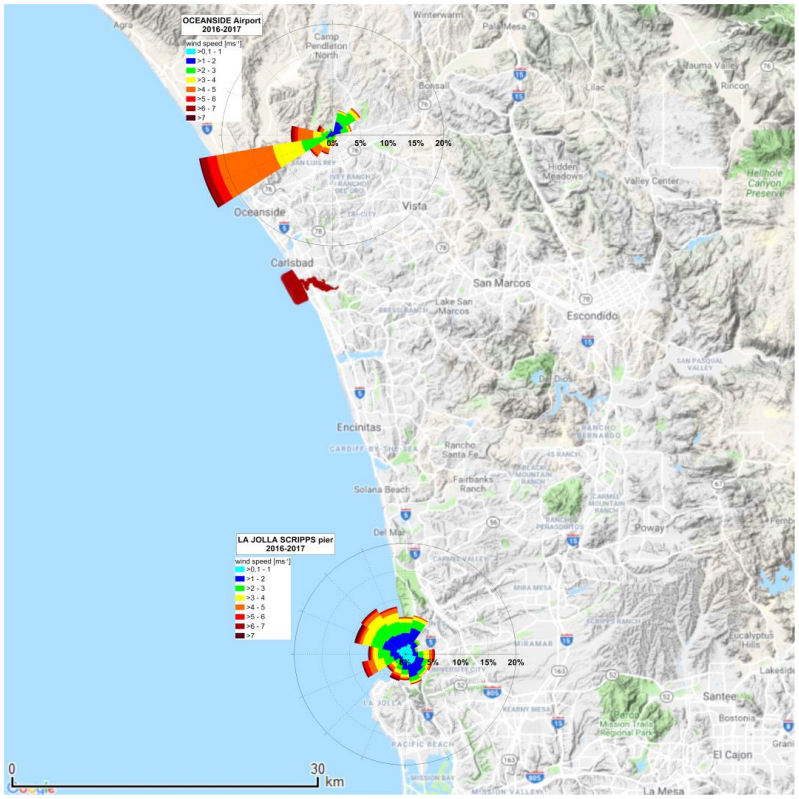
Figure 3.

Finally, with the shybas utility routine of the SHYFEM model, the depth-volume curves of the lagoon's basin where computed and reported in Figure 3. The subdivision of areas and volume of the lagoon is reported in Table 1

	area [m^2]	vol. [m^3]	avg.depth [m]
inner basin	7.8E+05	1.4E+06	1.84
middle basin	9.1E+04	3.4E+05	3.72
outer basin	2.2E+05	1.1E+06	5.22
lagoon	1.1E+06	3.0E+06	2.71

Table 1

We also looked for meteorological data to force the hydrodynamic model, basically at this stage the wind. The nearest stations with available hourly wind speed where La Jolla pier (on the coast, 30 km south the lagoon, (https://tidesandcurrents.noaa.gov/met.html?id=9410230) and Oceanside Municipal airport (4 km from the coast along the San Louis Rey creek, 8 km north the lagoon, https://www.ncdc.noaa.gov/cdo-web/datasets/LCD/stations/WBAN:53121/detail). The data were collected, filtered and the wind roses were drawn (Figure 4) to assess the wind regime of the area and evaluate which of the 2 stations is more representative of the area. For the years 2016-2017 the La Jolla dataset contains the 93% of valid data, while the Oceanside dataset only the 63%.



The orography of the coast area between Del Mar and Oceanside is composed by a series of canyons and small creeks perpendicular to the coastline, so that, despite their limited number, the observations the Oceanside airport seem to be much more compliant with the local orography than those of the La Jolla dataset.

The tide recordings of La Jolla pier were downloaded to force the sea boundary of the model, with the same datum of the bathymetry (La Jolla MSL), the dataset contains 100% of valid data.

Fig.4

Future activities

The preliminary tests on the model performances has already started in Venice and the roadmap outlined with the hosting researchers expects to achieve some basic hydrodynamics results by the next 3 months.

We hope that a new Short Term Mobility could be funded in order to strengthen the collaboration, and move to a full baroclinic simulation of the lagoon and the coastal area (we already detected the sea boundary condition from the Southern California Coastal Ocean Observing System http://sccoos.org/data/roms-3km/).

In the perspective of a continuous collaboration supported both from CNR Short Term Mobility Program and from SIO founding, we hope to come to the full simulation of the carbon cycle within the SHYFEM model in the next 2 years.

References

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