2014 ROMS User Workshop

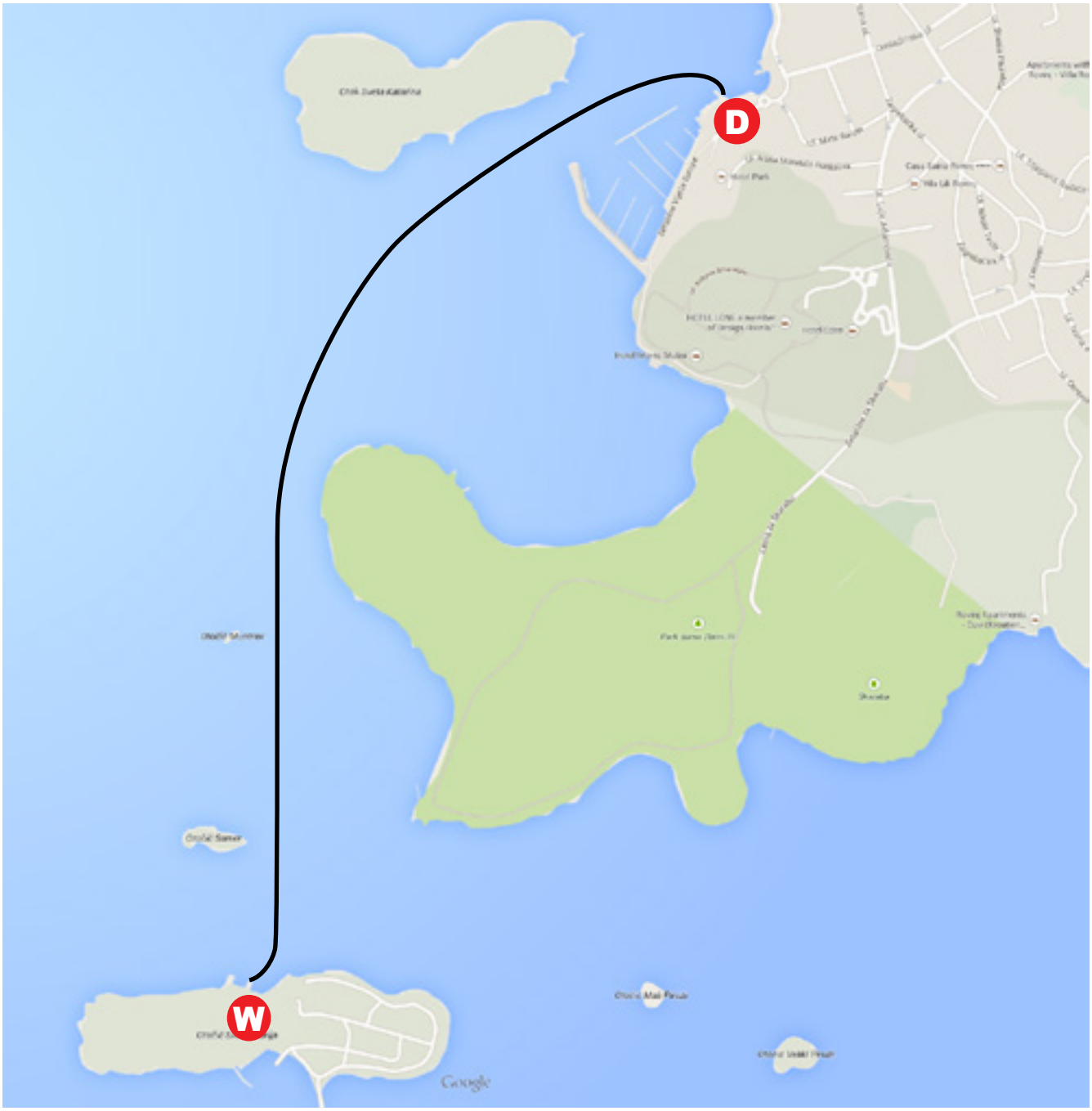
Island Hotel Istra, Island of St. Andrew's, Rovinj, Croatia, May 26 - 29, 2014

Organized by: Hernan G. Arango, John L. Wilkin, Andrew M. Moore, and Ivica Janekovic

http://www.myroms.org/croatia_workshop

Getting to the Workshop

The workshop is on the Island of Saint Andrew at the Island Hotel Istra, in the Huetterott Conference Room. The conference room is located within the hotel and can be reached via the main entrance, you can't miss it.



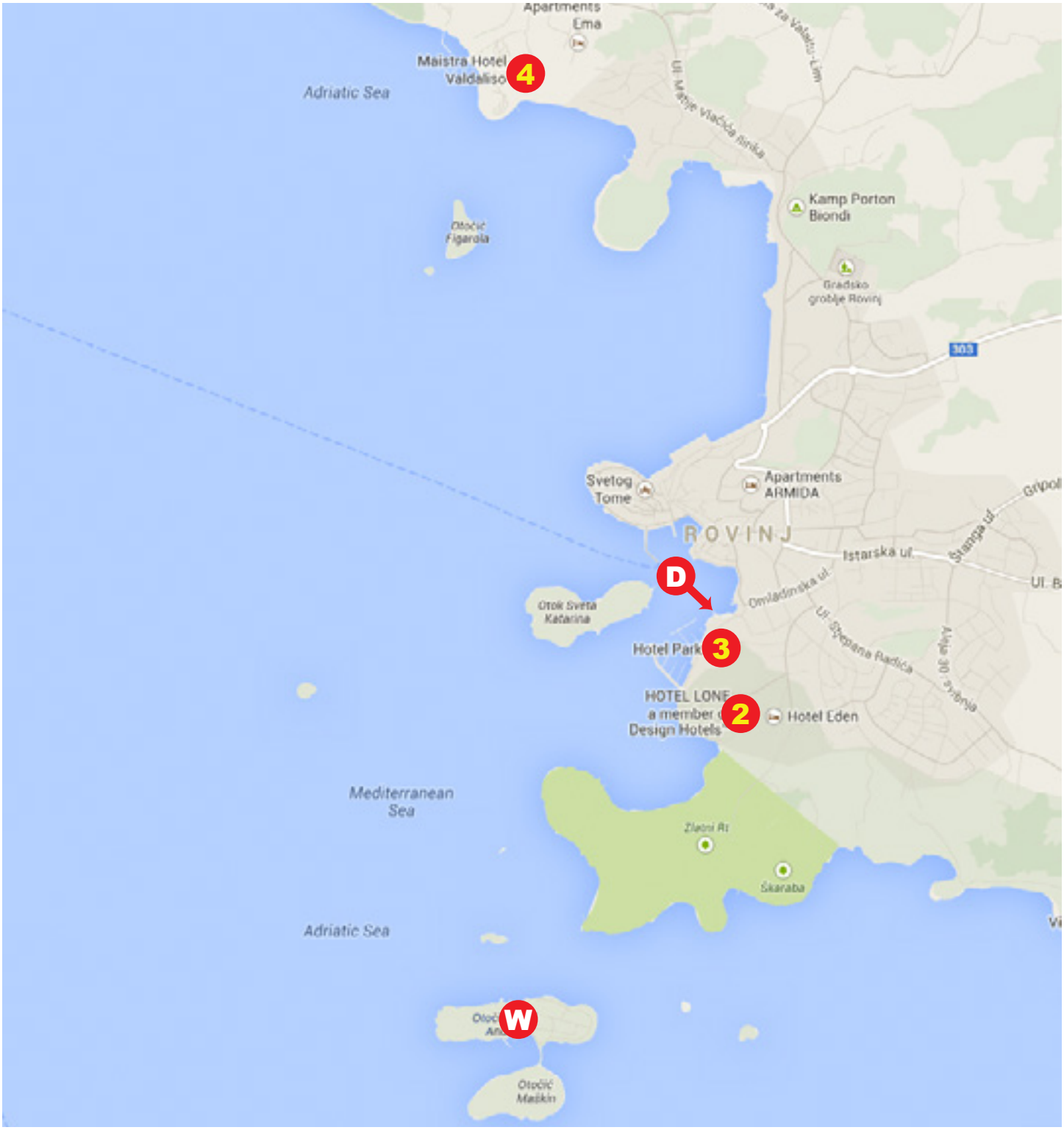
Island Hotel Istra

Boat:

The boat to the hotel leaves from Delfin pier (D) hourly starting at 5:30 am. The information booth of the hotel is located at Delfin pier, right next to the roundabout, where you will see "Hotel Istra" written in blue. If you are not staying at the Island Hotel Istra (W), on the first day of the workshop tell the boat staff that you are attending the ROMS workshop to avoid paying the 40 kn fare. On the first day of the workshop you will receive a name tag, which will allow you to ride the boat for free for the remainder of the workshop.

Map 3: Rovinj Hotels and Workshop Location

D. Delfin Pier
W. Island Hotel Istra
2. Hotel Lone
3. Hotel Park
4. Hotel Valdaliso



Rovinj attractions:

1. **Red Island (Crveni Otok):** One of the most renowned tourist locations in Rovinj, it actually consists of two artificially connected islands: St. Andrew's Island (Otok Sv. Andrije) and Maškin Island (Otok Maškin). Dense Mediterranean underbrush and old coniferous forest are predominant on the island, as well as cultivated flower parks with paths near the hotel and annexes.

2. **Golden Cape (Zlatni Rt/Punta Corrente):** Apart from thousands of indigenous and domesticated plants, such as the groves of holm oaks and Alpine pines, the deep shade in this age-old park is also created by many foreign plants, such as the cedar, the pine and some ten species of cypress, which all contribute to the park's distinctly Mediterranean atmosphere. There are numerous beaches and throughout the park as well as a restaurant, snack bar, and a large, open field for recreational activities.

3. **Sail the Archipelago:** Enjoy spectacular views of Rovinj, one of the most beautiful cities on the Adriatic coast. Excursions vary from 2-6 hours and depart from the Rovinj marina.

4. **Port of Rovinj:** Relax by the water, sip some wine, and enjoy the wonderful boats and sailing vessels that visit the port each day, or get out on the water yourself on one of the many boat tours, including glass bottom boats. There are also many restaurants near by.

5. **Katarina Island:** If you take a boat trip while in Rovinj, take it to Katarina Island. It is very easy to reach it by taxi-boats which leave every hour from Delfin the little pier (same as the workshop). On the island you'll find everything from ruins to beaches to cafes to a vineyard, not to mention spectacular views of Rovinj.

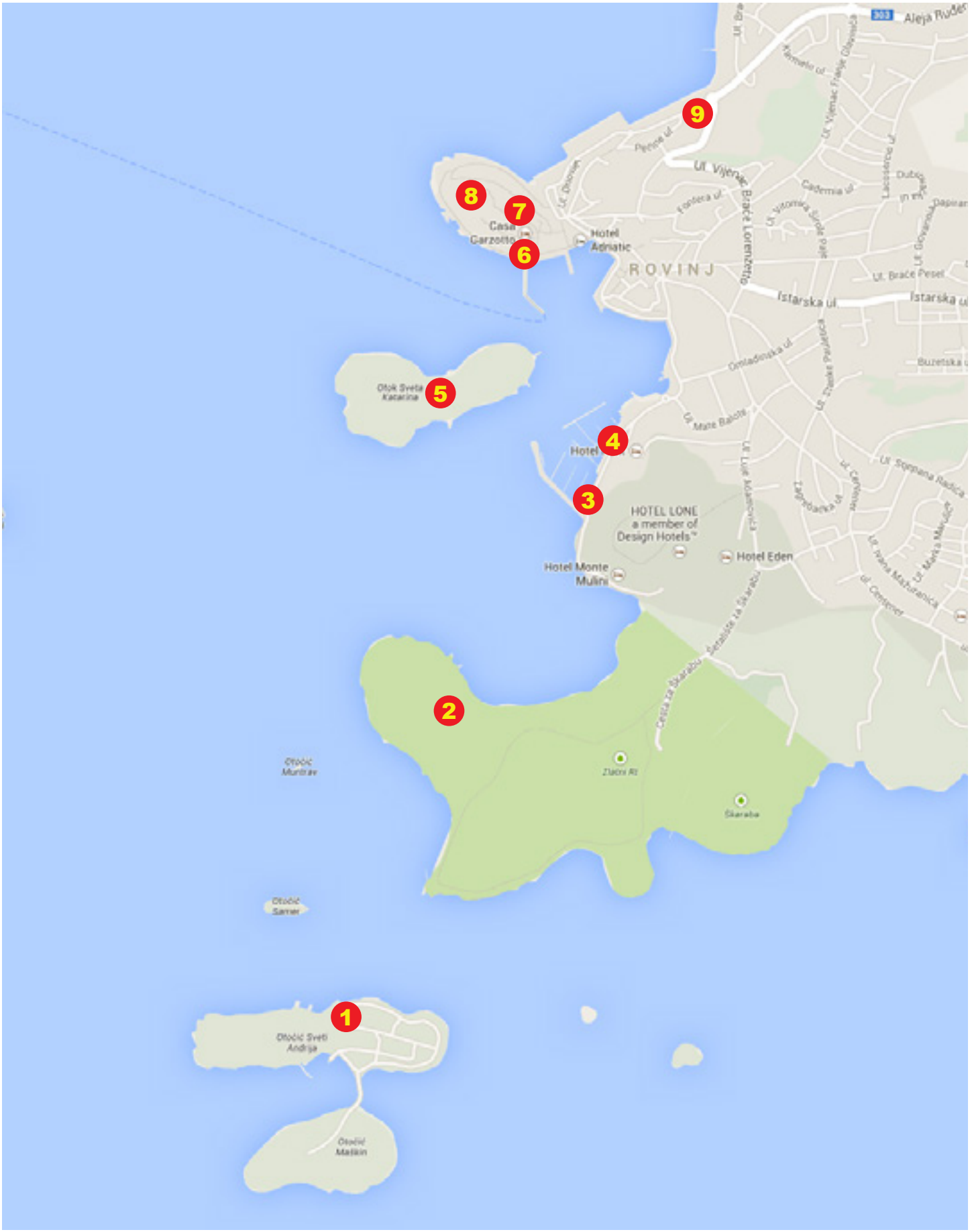
6. **Batana Eco-museum:** The Batana Eco-museum has 3 parts: the House of Batana, the Spacio Matika, and the Mali Škver. The House of the Batana, or Muòstra, contains the permanent exhibition. The Spacio Matika, or Spàcio, is actually a localized version of a tavern or wine cellar and is another peculiarity of Rovinj which helps shape the town's identity and its people. The Mali Škver, or Peîcio squèro (Little Shipyard), is the small square on the Riviera, directly in front of the House of Batana, where outdoor events and programmes of the Eco-museum are held. It is also where batanas are built and repaired with traditional methods.

7. **Old Town:** The old town of Rovinj is the protected historical center of Rovinj, the most appealing part of the town for visitors. The narrow cobbled alleyways and the small squares which have witnessed the turbulent history of the town are full of medieval, gothic, renaissance, and baroque buildings and terraces.

8. **Saint Euphamia Cathedral:** Named for the patron-saint of Rovinj, the bell tower of this church dominates the skyline of old town. This three nave church is a Venetian Baroque building and the largest monument in the city. It was restored between 1725 and 1736.

9. **Rovinj Aquarium:** In this centuries-old building located inside the Maritime Research Center of the Ruđer Bošković Institute, you can experience all the diversity of the Adriatic underwater world. It was opened in 1891 as the Zoological Station of the Berlin Aquarium and it is among the oldest institutions of that kind in the world. The aquarium is open to visitors and abounds in specimens of the local flora and fauna presenting the typical communities that live in our undersea area.

Map 4: Rovinj Tourist Attractions



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PROGRAM

2014 ROMS User Workshop

---------- Monday, May 26, 2014 AM ----------

08:00-08:50 Registration

08:50-09:00 Welcome and Logistics

Chairperson: Hernan G. Arango

09:00-09:30 (30 min) Andrew M. Moore, UC Santa Cruz, USA
Forecasting Forecast Error

09:30-10:00 (30 min) Ilaria Iermano, DiST - Parthenope U., Italy
Preliminary applications of the ROMS 4D-Var data assimilation to a Tyrrhenian Sea coastal region

10:00-10:30 Break (30 min)

Chairperson: Andrew M. Moore

10:30-11:00 (30 min) Mauricio Fragoso, PROOCEANO, Brazil
4DVAR Data Assimilation on Southeastern Brazilian Basin in the Scope of Project Blue

11:00-11:30 (30 min) Ivica Janekovic, IRB, Croatia
Estimation of ocean dynamics in coastal regions using advanced ROMS capabilities

11:30-12:00 (30 min) Carlo Brandini, CNR Ibimet - LaMMA, Italy
A Prediction and Observing System for the Ligurian and the North Tyrrhenian Sea

12:00-15:00 Lunch Break

---------- Monday, May 26, 2014 PM ----------

Chairperson: Brian Powell

15:00-15:30 (30 min) John L. Wilkin, IMCS, Rutgers University, USA
Coastal Mean Dynamic Topography Computed Using ROMS Variational Assimilation of Long-Term Mean Observed Currents and Hydrography

15:30-16:00 (30 min) Gildas Cambon, LEGOS, France
The ROW regional coupled system

16:00-16:30 (30 min) Mathieu Dutour Sikiric, IRB, Croatia
Coupling of the Regional Ocean Modeling System (ROMS) and Wind Wave Model

16:30-17:00 Break (30 min)

17:00-18:30 Poster Session I

PROGRAM

---------- Tuesday, May 27, 2014 AM ----------

Chairperson: Arthur J. Miller

09:00-09:30 (30 min) Brian Powell, University of Hawaii, USA
Improving Model ENSO Validation by Constraining Isotopic Signatures of Extreme Events

09:30-10:00 (30 min) Hrvoje Mihanovic, IOF, Croatia
Extreme cooling and dense water formation in the Adriatic during the winter of 2012

10:00-10:30 (30 min) Sandro Carniel, CNR-ISMAR, Italy
Sub-surface and near-bottom thermohaline circulation of a shallow sea during a dense water production event: a case study from the northern Adriatic Sea

10:30-11:00 Break (30 min)

Chairperson: John L. Wilkin

11:00-11:30 (30 min) Art Miller, Scripps Inst. of Oceanography, USA
The physical oceanographic environment of the southern California Current during the past decade: Changes in climate and concepts

11:30-12:00 (30 min) Farshid Daryabor, U. of Malaya, Malaysia
Modeling of circulation, tides, and thermohaline stractures of the southern region of the south china sea using Regional Ocean Modeling System (ROMS)

12:00-12:30 (30 min) Moninya Roughan, UNSW, Australia
Cold Core Frontal Eddies in the East Australian Current. Formation, Entrainment and biological significance

13:30-18:00 Lim Channel Cruise Reception

Lim Channel Cruise Reception

There will be a reception cruise on Tuesday, May 27th, 2014. The boat will Leave from Rovinj harbor. We have scheduled an hour between the end of the day's presentations and the boat's departure to allow ample time for attendees to get from the Island hotel Istra to the harbor. The boat will leave at 13:30. Average afternoon temperatures in late May are 20 - 26°C (68 -79°F) so be sure to wear appropriate attire. We will take a 1 hour 30 minute cruise from Rovinj harbor to Viking restaurant near the end of Lim Channel (approximate cruise track is shown below). There will be light refreshments on the boat with lunch at the Viking restaurant. After lunch we will re-board the boat back to Rovinj Harbor. The Lim Channel is a 10 km long estuary that has been declared "a special maritime reserve" and "an area of outstanding natural beauty" and is a testimony to the climatic changes and geological evolution of Istria.

PROGRAM

--------- Wednesday, May 28, 2014 AM ---------

Chairperson: Ivica Janekovic

09:00-09:30 (30 min) Robert Hetland, Texas A&M University, USA
Baroclinic instability along the Mississippi/ Atchafalaya plume front

09:30-10:00 (30 min) Francesco Marcello Falcieri, CNR-ISMAR, Italy
Northern Adriatic Dense Waters and Po River Plume interaction from a modelling and statistical point of view

10:00-10:30 Break (30 min)

Chairperson: Robert Hetland

10:30-11:00 (30 min) Jihène Abdennadher, IPEIT, Tunisia
Numerical simulation of the M2 Internal Tide in the Strait of Sicily

11:00-11:30 (30 min) Jordi Solé, CSIC, Spain
Quantifying the ocean velocity contribution to the Alboran Sea primary production

11:30-12:00 (30 min) Luz María García-García, IEO, Spain
A biogeochemical model for North and Northwest Iberia: some applications

12:00-15:00 Lunch Break

--------- Wednesday, May 28, 2014 PM ---------

Chairperson: Moninya Roughan

15:00-15:30 (30 min) Tomasz Dabrowski, Irish Marine Inst., Ireland
Shellfish growth and bacterial contamination model embedded in ROMS

15:30-16:00 (30 min) Chan Joo Jang, KIOST, Republic of Korea
Seasonal and interannual variability in the East Sea ecosystem: effects of nutrient transport through the Korea Strait

16:00-16:30 Break (30 min)

16:30-18:00 Poster Session II

PROGRAM

---------- Thursday, May 29, 2014 AM----------

Chairperson: Mauricio Fragoso

09:00-10:00 (60 min) Andrew M. Moore, UC Santa Cruz, USA

Lecture I: ROMS 4D-Var: Past, Present and Future

A review of the current systems, how and where it is being used, know issues and bugs, and where would like to take the system in the future.

10:00-10:30 Break (30 min)

10:30-11:30 (60 min) Hernan G. Arango, IMCS, Rutgers U., USA

Lecture II: ROMS Nesting: Composite and refined grids

A detailed overview of algorithms and current capabilities

11:30-12:30 (60 min) John L. Wilkin, IMCS, Rutgers U., USA

Lecture III: ROMS Nesting: Applications

An overview of pre- and post-processing Matlab scripts, grid setups, and realistic examples

12:30 **Adjourn**

PROGRAM

Posters

1. Ådlandsvik, Bjørn, IMR, Bergen, Norway
   NorKyst-.800 and the Norwegian Current Information System

2. Amorim, Fabiola, REMO/UFBA, Salvador - Bahia, Brazil
   Influence of river discharge on the seasonal circulation of the Eastern Brazilian Shelf (8°S - 19°S)

3. Barton, Ben, Knowtra Ltd, UK
   Modelling a Nigerian estuarine creek system combined with opportunistic in-situ data collection

4. Berry, Alan, Irish Marine Institute, Ireland
   ROMS Applications at the Irish Marine Institute

5. Brandini, Carlo, CNR Ibimet - LaMMA, Italy
   Optimal sampling of a regional sea for ocean forecasting, physical and numerical experiments

6. Cambon, Gildas, LEGOS, France
   New features in ROMS_AGRIF v3.1

7. Carniel, Sandro, CNR-ISMAR, Italy
   Modelling the exceptional Winter 2012 conditions in the Northern Adriatic Sea

8. Da Silva, Meyre, U. Federal do Espírito Santo, Brazil
   Dynamics of the Upwelling System Along the Eastern Brazilian Shelf

9. Džoić, Tomislav, IOF, Croatia
   Modelling physical-biological interactions in the dynamics of the Adriatic sardine ichthyoplankton

10. Gronholz, Alexandra, U. of Bremen / MARUM, Germany
    Application of a Coupled Ocean – Atmosphere – Wave – Sediment Transport (COAWST) system to assess wind-induced coastal changes

11. Kim, Chang S., KIOST, South Korea
    Numerical Modeling of Coastal Water Quality Accounting for Groundwater in Tidal Lake

12. Lim, Hak Soo, KIOST, South Korea
    Operational Coastal Modeling System of Korea

13. Marta-Almeida, Martinho, REMO-UFBA, Brazil
    Sensitivity experiments in a 1/24° ROMS configuration along the Southeast Brazilian region

14. Olita, Antonio, CNR - IAMC, Italy
    Impact of surface fluxes formulation on modeling the circulation of the Sardinian seas (Western Mediterranean)

15. Ramirez, Sergio, CMIMA, Spain
    Numerical Study of the Mediterranean Outflow with a Simplified Topography

16. Sims, Holly, Australian Bureau of Meteorology, Australia
    Storm Surge Modelling for the Australian Bureau of Meteorology

17. Tang, Cheng, Yantai Inst. of Coastal Zone Research, China
    Sediment accumulation and bottom morphology change in the west Hainan Island, Northern South China Sea

18. Valentini, Andrea, ARPA-SIMC, Italy
    Operational Oceanography to support Emilia-Romagna regional activities and the Italian National Civil Protection System

19. Zong, Haibo, East China Normal University, China
    Tidal cooling effect on SST and its influence on typhoon simulation over the East China Sea

Talk Abstracts

Numerical simulation of the M2 Internal Tide in the Strait of Sicily

Jihène Abdennadher and **Moncef Boukthir**
Institut Préparatoire aux Etudes d'Ingénieur de Tunis, University of Tunis, Tunisia

We have investigated the spatial distribution of the M2 internal tide in the Strait of Sicily using the ROMS. Realistic topography and stratification from existing observational data were used. The numerical simulations show that there are three distinct sites of strong M2 internal tide generation, namely, the western sill of the Adventure Bank, northwest of Sicily, and north of Pantelleria isle. The conversion rate of energy from the M2 surface to internal tide integrated over the whole model domain amounts to 47.5 MW, 75% of which are found to be generated over the three prominent topographic features mentioned above. The depth-integrated baroclinic energy flux depicts the propagation away from these sites, particularly toward the north and southwest. The maximum flux amplitudes are found in the three main generation sites identified, with the largest value occurring at the narrowest passage through the western sill.

A Prediction and Observing System for the Ligurian and the North Tyrrhenian Sea

Carlo Brandini, **Maria Fattorini**, **Stefano Taddei**
CNR Ibimet & Consorzio LAMMA, Firenze, Italy

In recent years, a number of critical environmental issues between the Ligurian and the North Tyrrhenian Sea have motivated the need for systems to monitor and predict the sea state in this region. A numerical forecasting system has been implemented by the LAMMA Consortium using a chain of models (WRF- ROMS – WW3 - SWAN) over a large regional area. This system has been used for coastal monitoring and managing the environment and coastal operations like navigation, search and rescue, and other emergencies. As in any ocean prediction system, observations and data assimilation are required to reduce the uncertainties in the predictive fields, especially in the coastal areas. An observation network is currently under development to support and improve this forecasting system. However, this observation network is limited by the high cost of the instruments required.. ROMS adjoint algorithms can be used to help design such an optimal observation network by determining where and what type of observations are needed to reduce the uncertainties in the forecasting product.

The ROW regional coupled system

Gildas Cambon[1], **Serena Illig**[1], **Patrick Marchesiello**[1], **Katerina Goubanova**[1], **Sylvie Le Gentil**[2], **Christophe Messager**[2], **Yumi Yamashita**[2], **Sebastien Masson**[3], **Guillaume Samson**[3], and **Boris Dewitte**[1]

1. LEGOS, Toulouse, France
2. LPO, Brest, France
3. LOCEAN, Paris, France

To study the detailed patterns of mesoscale air-sea interaction, we developed a regional coupled ocean-atmosphere system. The system is comprised of the ocean model ROMS_AGRIF (http://www.romsagrif.org), the atmospheric model WRF (ARW core; http://wrf-model.org) coupled together using OASIS3-MCT (developed at CERFACS; https://verc.enes.org/oasis). A notable strength of our coupled system is the 2-way nesting capability offered by both WRF and ROMS_AGRIF. This will allow us to undertake long-term, high-resolution, coupled studies of dynamical systems with downscaling and upscaling properties. Here, we will describe the implementation of the system and the preliminary results over the Peruvian upwelling system.

Sub-surface and near-bottom thermohaline circulation of a shallow sea during a dense water production event: a case study from the northern Adriatic Sea

Alvise Benetazzo, **Sandro Carniel**, **Andrea Bergamasco**, **Davide Bonaldo**, **Francesco Falcieri**, and **Mauro Sclavo**
CNR-ISMAR Venice, Italy

Cold, dry, and intense winds blowing over shallow sea shelves produce favorable conditions for water column cooling and evaporation: the newly formed water is denser than the out-shelf environmental water and thus is forced to move away from the production basin. The semi-enclosed Adriatic Sea is a representative domain to investigate the dynamics of this gravity flow. Indeed, such a flow (the so-called Northern Adriatic Dense water, NADW) originates in the northern shallow Adriatic and moves southeastward along the Italian coast, in quasi-geostrophic conditions, strongly modulated by ocean circulation (tide and wind driven) and pressure gradients. Along its way southward, NADW partially slide into sea bottom depressions and promote renewal of deeper and older water masses. Production and spreading of dense water in the northern Adriatic Sea were simulated by means of an eddy-resolving high-resolution (1.0 x 1.0 km^2) numerical

model, which relied on the Coupled-Ocean-Atmosphere- Wave-Sediment-Transport (COAWST) system, based on the 3-D ocean model ROMS (Regional Ocean Modeling System) and the wave model SWAN (Simulating Waves Nearshore). To drive COAWST, the atmosphere forcings provided by the meteorological model COSMO-I7 (an atmospheric mesoscale model developed in the framework of the COSMO Consortium) were used. Initial and boundary conditions were derived from numerical models operational in the Adriatic and Mediterranean Sea. An observational dataset has been also used with the dual purpose of describing the NADW formation process and assess numerical model solutions.

The selected period for the analysis brackets early February 2012, an exceptionally cold period during which the northern Adriatic Sea experienced a Cold Air Outbreak (CAO) that forced water temperature to drop to about 6°C, with water density exceeding 1030 kg/m^3. Results presented reveal some new insights on how NADW generates in the northern Adriatic Sea, triggered by tidal and wave forcing. Results also support a quantitative characterization of the NADW mass formation in the northern basin, by estimating volumes that leaves the production area and contribute to its water renewal.

Shellfish growth and bacterial contamination model embedded in ROMS

Tomasz Dabrowski[1], **Kieran Lyons**[1], **Marcel Curé**[2], **Alan Berry**[1], and **Glenn Nolan**[1]

1. Marine Institute, Rinville, Oranmore, Co. Galway, Ireland
2. The Numerics Warehouse Ltd., Tyrone, Kilcolgan, Co. Galway, Ireland

The authors developed a Fortran 90 implementation of the dynamic energy budget (DEB) model for *Mytilus edulis*. The model has been further developed to include physiological interactions with the ecosystem and has been coupled to a biogeochemical nitrogen-based model (ROMS Fennel model). Phytoplankton and detritus uptakes, oxygen utilization, CO_2 production, NH_4 excretion, egestion of faeces, and assimilation of food are modelled. A novel approach was derived that accounts for the allocation of C and N in mussel flesh and shell organic fraction. The microbial module has also been developed for predicting the level of mussel contamination by coliforms; this model has two state variables, namely, the concentrations of *E. coli* in water and in the mussel tissue. Novel formulations to calculate the filtration rates by mussels and the resulting uptake of bacteria are proposed; these rates are updated at every computational time step. Concentrations of *E. coli* in seawater are also updated accordingly taking into account the amounts ingested by mussels.

The above model has been embedded in ROMS (Fennel) and applied to the south-west coast of Ireland, where approximately 80% of national rope mussel is produced annually. It is a full 3D implementation, whereby a standing stock of mussels can be specified at any of the model's computational cells. Simulations have been carried out for the time period July 2010 – June 2011, for which the field data on mussel biometrics, ambient seawater properties and bacterial contamination were collated. The model accurately reproduced the spatio-temporal variability in blue mussel growth. It is also shown that the ecosystem dynamics are affected by the presence of aquaculture farms. Furthermore, it successfully reproduced the official classification of shellfish waters in the bay based on monthly sampling at several stations. The predicted filtration rates and ratios of *E. coli* in water and mussels also compare well with the literature.

The modelling system presented allows for the assessment of the impacts of aquaculture activities on water quality, quantification of the production and ecological carrying capacities and improvement of our understanding of the ecosystem functioning with particular emphasis on interactions between various trophic levels. The model also forms a tool that may be used to assist in the classification of shellfish waters (level of bacterial contamination) at much greater spatial and temporal detail than that offered by a field monitoring programme. Moreover, it can also aid in designing an efficient monitoring programme. The model can also be utilised to determine the contribution of individual point sources of pollution on the microbial loading in mussels and, when incorporated into an operational framework, it can provide a short-term forecasting of microbial contamination in a shellfishery. One of the key advantages of the presented model is that it can be easily extended to include other filter-feeder and pathogen species.

Modeling of circulation, tides, and thermohaline structures of the southern region of the south china sea using Regional Ocean Modeling System (ROMS)

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ROMS was used to investigate the dynamics of circulation and thermohaline structures of the southern region of the South China Sea covering Peninsular Malaysia's eastern continental shelf sea and coastal waters of western Borneo. The first part of the study considered the wind-driven circulation and associated thermohaline structure. The simulated surface circulation was generally cyclonic during the winter season and anticyclonic during the summer monsoon period with strong western boundary currents at Peninsular Malaysia's eastern continental shelf. The maximum speed was about 1m/s (0.5m/s) and extended the depth to around 30m (40m) during winter (summer) season. During summer, the western boundary currents split and partially leave the coast. The bifurcation point is roughly 4°N in June and shifts north to ~8°N in July. The simulated isotherm structures for summer and winter were nearly horizontal from east to west except at

the coastal regions. Based on different sensitivity experiments, such as the removal of surface wind, freshwater and shortwave radiation fluxes, it was found that the instability of the coastal currents generate the coastal eddies. Strong alongshore wind was responsible for stronger currents and upwelling along the eastern coast of Peninsular Malaysia during summer. This suggests net off-shore transport and the occurrence of weak upwelling. Results were confirmed by the high concentration of phytoplankton biomass at the sea surface due to nutrient rich water (e.g., enough phosphate and dissolved oxygen). It was also found that the surface freshwater and shortwave radiation fluxes play a secondary role in variations of the mean seasonal cycle in this region.

The second part of the study dealt with the modeling of tidal currents and amplitudes. Eight major constituents (M2, S2, K1, O1, N2, K2, P1 and Q1) were considered. Surface height and tidal currents of the TPXO.6 solution (global tidal model) were added to the 2D momentum through boundary conditions. The simulation period covered the period of 15th January to 15th March 2000 and the model was integrated for these two months. Observations from 19 tide gauge stations were used to validate the model. The results indicated that the 3D modeled tides compared well with observations. The southern region was mostly influenced by K1 as shown in the K1 tidal ellipse patterns.

Coupling of the Regional Ocean Modeling System (ROMS) and Wind Wave Model

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In this work the structured grid circulation model ROMS is coupled with the unstructured grid Wind Wave Model II. The physics of the model have been completely reformulated using Vortex Force formulation. The surface stress is consistently computed from the wave model.

The chosen models and coupling approach, allows the grids of both models to be chosen independently. However, we also introduced a systematic approach of generating unstructured grids from finite difference grids, while preserving the structure of the flow near islands and coasts.

The influence of different wave model grids on the coupling was investigated and found to be quite small, whereas the computational time can be drastically reduced. A new parallel coupling library was developed in order to couple the models. The benefit of the new coupling library is that it gives an almost optimal data exchange between different domain decompositions originating from the different discretization/parallelization of the different models. The coupled modeling system was validated on the analytical test case of the radiation stress induced wave setup. Finally, the coupled model was applied to the Adriatic Sea to investigate the wave-current dynamics during a bora and a sirocco event. The model was forced using data from the ALADIN atmospheric model. As a possible source of error, the model wind field was validated against QuikSCAT data and ENVISAT data indicating that ALADIN wind speeds are likely underestimated. The wave model consistently shows a negative bias with respect to the *in situ* measurements and altimetry but producing overall comparable results as in previous studies. The influence of the currents was evaluated with respect to significant wave height and zero down crossing periods, revealing strong interactions especially in the regions of strong current gradients as observed in the north and south-Adriatic gyre systems. The modulations based on the given setup show up to 10% variations during the subsequent events.

Northern Adriatic Dense Waters and Po River Plume interaction from a modelling and statistical point of view

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The Northern Adriatic Sea (NA) is a semi-enclosed basin located in the northernmost part of the Mediterranean Sea. This shallow sub-basin is strongly influenced, both in its physical and biogeochemical features, by the Po River plume. The buoyancy inputs partially drive the circulation of the sub-basin and impact the Northern Adriatic Dense Waters (NAdDW) formation processes, while the riverine nutrients and sediment loads can cause increased algal blooms, eutrophication processes and hypoxic or anoxic events.

The NAdDW is a very dense water mass that forms in the shallower part of the NA during the winter months; its formation is a consequence of heat losses during cold wind outbreaks (most commonly of North-Eastern Bora) with a significant preconditioning by fresh water inputs into the NA. The NAdDW then travels southward along the Italian Coast reaching, in a few months time, the Southern basin where it partially falls into the Southern Adriatic Pit.

To deepen the knowledge of the preconditioning and interaction between the Po Plume (PP) and the NAdDW formation process, an 8 year (2003-2010) hydrodynamic simulation of the Adriatic Sea has been implemented using ROMS. The model was run with high horizontal resolution (2km), measured riverine inputs (when available) and one open boundary at the Otranto Strait with forcing conditions from the Mediterranean Ocean Forecasting System.

The ocean-atmosphere fluxes are computed through the bulk formula forced by means of the high resolution meteorological model COSMO I7.

To extract a synthesis of the most common distribution, a 2x3 Self-Organizing Map (SOM) analysis was performed on the modelled surface salinity fields. Two antithetic patterns where found: i) a small plume confined to the coastal area, and ii) a wide plume that extends up to the basin mid-line. Moreover, four intermediate patterns with different degrees of spreading where highlighted.

The SOM maps were then compared to the dense water production computed as dense water transport across three transects (threshold density of 1029.3 km/m^3). Results show different types of interaction between plume distribution and dense water formation. As a general point, if freshwater inputs are low and basin salinity is higher, even low heat fluxes can trigger NadDW formation, while in case of high discharges very strong heat losses are needed.

4DVAR Data Assimilation on Southeastern Brazilian Basin in the Scope of Project Blue

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The Ocean Observing System for Santos Basin also known as AZUL Project is a pioneer operational oceanography project in Brazil. It started in August 2012 and its main goal is the development of an ocean observing system for Santos Basin region (Southeast Brazil) based on ocean modeling and real time systematic ocean data collection. The data collection program makes use of satellite remote sensing and *in situ* sensors such as surface drifters, floats and gliders. All the information that has been acquired during the project is fully available for the community. To date, 1 year of continuous glider transect, 22,054 drifter data (TSM, velocity and atmospheric pressure) and 44 ARGO floats profiles were collected already.

Within the AZUL Project scope and for the first time in Brazil, the Incremental Strong constraint 4D-Variational data assimilation system of ROMS was implemented in a southeast Brazil ocean model.

Strong constraint I4DVAR was performed sequentially for one year on a 1/3 degree model, starting on January 1st 2010, using 7 day assimilation windows adjusting only the initial conditions. The background initial conditions for the first assimilation cycle was taken from a long free run of the same model spanning 14 years (1995 – 2009). The model background initial conditions for each subsequent data assimilation cycle was taken from the last record of the previous I4DVAR cycle.

The model assimilates SST data from POES (Polar Operational Environmental Satellites), gathered by the AVHRR (Advanced Very High Resolution Radiometer), with daily global coverage and 0.1 degree resolution.

This experiment represents a step towards a full operational forecast system, with a 1/12 degree model assimilating weekly data from gliders, SVPs drifters, ARGO floats, and satellite SST and SSH.

Results from this experiment will be presented, discussed and analyzed.

A biogeochemical model for North and Northwest Iberia: some applications

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The Coastal and Ocean modeling group at the Spanish Institute of Oceanography (IEO) has a broad experience in hydrodynamic modeling with ROMS in the area of West and North Iberia. Our main task consists of providing insight on the coastal and ocean dynamics in support to the intense IEO ecosystem and fisheries research in the area.

The NW coast of Iberia is characterized by high levels of primary production that result from relatively frequent and intense inputs of nutrients caused by upwelling, especially in spring and summer. Primary production sustains wealthy fisheries and aquaculture industries, which constitute a prime economic activity in the region.

As a first approach to understand the ecosystem variability in the area we focused on the spring bloom. A high resolution (~3 km) configuration of the ROMS physical model with atmospheric forcing coming from the regional agency Meteogalicia (http://www.meteogalicia.es), which has shown to represent the main features of the shelf and slope circulation in the area, was run coupled to the Fasham-type Fennel biogeochemical model (N2PZD2).

Any biogeochemical model aimed at providing a reliable representation of the dynamics of a certain area should be tuned according to its characteristics. In an upwelling system, the composition of phytoplankton varies from the beginning to the end of the bloom. When nutrients and irradiance are high, diatoms are the dominant group, whereas flagellates become more important when upwelling relaxes and, consequently, nutrients and light intensity decrease. In the NW Iberian coast, it has been found that *Chaetoceros socialis* is the dominant diatom species during the spring bloom (Bode *et. al*, 1996, 1998). For this reason, we have decided to use parameters that are characteristic of plankton at the spring bloom. In particular, the parameters of *Chaetoceros socialis* have been considered for the unique phytoplankton class of the model.

We will show comparisons of the model results for 2006 and 2007 with observations at weekly and daily time scales (MODIS

chlorophyll-a images, *in situ* observations from the "Instituto Español de Oceanografía" Pelacus cruises). The spring bloom is reasonably reproduced in the NW and N coasts in time, space and intensity. The variability between the primary production in 2006 and 2007 can be related to the oceanographic conditions thanks to the use of a numerical model. The results are promising and encourage us to move forward to increase the complexity of our models and broaden their range of application. We will show some examples of the use of the IEO models to get some insight on sardine recruitment variability and harmful algal bloom prediction.

Baroclinic instability along the Mississippi/ Atchafalaya plume front

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Classic models of baroclinic instability, notably the Eady model, depend on the Rossby (or Richardson) number as the sole non-dimensional parameter. Inclusion of a sloping bottom requires an additional parameter, the slope Burger number, $Bu = \alpha N f^{-1}$, where α is the bottom slope. Numerical simulations of the evolution of instabilities along the edge of a coastally trapped buoyant flow suggest that the slope may help to stabilize the flow when the deformation radius is similar to or larger than the with of the buoyant flow, that is, the flow is stable when the slope Burger number is larger than about 0.3. In unstable cases, $Bu < 0.3$, baroclinic instabilities in the flow cause the isopycnals to relax, thereby increasing the local Burger number until the critical condition, $Bu \simeq 0.3$, is met. At this point the instabilities no longer grow in time, preventing further offshore buoyancy flux by the eddies. This final state corresponds approximately to the case where the slope of the ground is similar to the slope of the mean isopycnal surfaces. The nonlinear, three-dimensional numerical simulations are in basic agreement with one-dimensional linear stability analysis, with a few key exceptions. Notably, numerical simulations suggest that cross-shelf buoyancy fluxes are strongest within the bottom boundary layer, showing a similar pattern to continental shelf waves in the vertical structure of current and tracer variability. Idealized simulations show a marked similarity to instabilities along the Mississippi/Atchafalaya plume front, as seen in observations and realistic regional models. These eddies have been shown to be important in Lagrangian transport of surface particles, notably oil spill trajectory prediction, and create patchiness in bottom dissolved oxygen distributions during periods of summertime seasonal hypoxia.

Preliminary applications of the ROMS 4D-Var data assimilation to a Tyrrhenian Sea coastal region

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Among the Italian coastal zones, the Gulf of Naples (GoN) is a particularly interesting and at the same time critical area, influenced by numerous environmental, socio-economic and cultural factors (strong anthropogenic impact, intense maritime traffic, presence of the polluted Sarno river, relevant tourist and economic activities and four marine protected areas).

The GoN is one of the very few sites along the Italian coast that can benefit from the availability of real-time surface velocity data provided by a system of high frequency (HF) coastal radars. A Sea Sonde CODAR has been operating in the GoN since 2004 providing real-time hourly surface current fields with a resolution of 1.0 x 1.0 km over almost the entire GoN. These data have already been used to partially validate, semiquantitatively, a ROMS application of the region.

We applied the advanced 4-dimensional variational data assimilation method (4D-Var) to a limited area 3 km resolution ROMS in the Gulf of Naples and adjacent Tyrrhenian deep sea region to adjust initial temperature, salinity, and velocity, hourly temperature, salinity and horizontal velocities at the open boundaries, and hourly surface fluxes of heat and momentum.

4D-Var was applied in the ROMS domain using initially different types of data (e.g. satellite sea surface height (SSH) and surface temperatures (SST), and *in situ* data) to preliminarily assess the skill of the data assimilation procedure, and at a later time HF radar data were assimilated into the coastal model and preliminary results are here showed.

The activity was supported by the National Flagship Project "RITMARE" (SP3-WP4-AZ6).

Estimation of ocean dynamics in coastal regions using advanced ROMS capabilities

Ivica Janekovic and **Mathieu Dutour-Sikiric**
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Coastal regions, characterized with strong freshwater inflow, winds and tidal dynamics represent challenge for numerical modeling. Today, advanced techniques such as data estimation via 4D-Var, 1 or 2 way nesting, coupling with wave and atmosphere models, are available to advance our knowledge of the fast changing environment. In this talk I will show some examples and highlight important aspects related to high resolution modeling,

data assimilation across nested grids, boundary errors, problems with 2 way coupling for ocean/wave/atmosphere system, real time operational modeling and at the end data dissemination using OPeNDAP – THREDDS approach.

Seasonal and interannual variability in the East Sea ecosystem: effects of nutrient transport through the Korea Strait

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There has been a long debate about the roles of nutrient supply through the Korea Strait (KS) on the East Sea (Japan Sea) ecosystem. Although a considerable amount of nutrients are supplied to the East Sea through the KS, the nutrient concentration appears to be relatively low compared to the concentration in the East Sea. In this study, we investigated the effects of the nutrient supply through the KS on the seasonal and interannual variability in the southern East Sea ecosystem. By using a four-compartment NPZD model coupled with a three-dimensional circulation model, numerical experiments were conducted with three different conditions of nutrient flux through the KS: noflux, seasonally-varying flux with and without year-to-year variation. The results suggest that the nutrient flux through the KS contributes to the primary productivity in the southern East Sea. The magnitude of the phytoplankton blooms is also influenced by the nutrient transport. We will also present the indirect contribution of the nutrient flux through KS to the primary productivity of the southern East Sea.

Extreme cooling and dense water formation in the Adriatic during the winter of 2012

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Dense water formation (DWF) that occurred in open and coastal waters of the Adriatic Sea during an extreme cooling event in January/February 2012 was reproduced by the one-way coupled high-resolution ALADIN/ROMS modeling system. Two model experiments were conducted with simulations starting in 2008. The first experiment used real river fluxes from the January 2011 – July 2012 period for the Po River, all available Croatian rivers and power-plants outflows and recently compiled Slovenian river data, together with mean-year daily fluxes for other Adriatic rivers. The second experiment used climatological perpetual river fluxes computed from all available hydrological data throughout the model run. Eastern Adriatic coastal river fluxes turned out to be dramatically lower both for perpetual and real freshwater data compared to traditionally used climatological river fluxes documented by Raicich (1994) and typically used in previous Adriatic modeling studies.

Model results showed that aside from the 'convenient' DWF area located at the northernmost Adriatic shelf, a similar amount of dense water with slightly lower densities was formed in the eastern Adriatic coastal area. This area was subjected to extreme heat losses during peak cooling periods (up to 2000 W/m^2), while cumulative heat losses estimated for some locations during the whole cooling episode (24 January – 14 February 2012) reached 1.8 GJ/m^2. Transport of dense water (PDA > 29.2 kg/m^3) towards the middle Adriatic had a peak value of about 0.6 Sv, while the speed of initial bottom density current surpassed 40-50 cm/s, several times larger than during past events. The contribution of the dense water coming from the coastal eastern Adriatic through connecting channels was about 40%. This equals the amount of dense water generated in the northernmost part of the Adriatic shelf, while the rest of dense waters were formed in deeper parts of the northern Adriatic shelf. By comparing model runs using climatological versus real river discharges, we found a slight decrease (10-30%) in DWF when climatological river fluxes were used instead of real river discharges. Therefore, the contribution of the coastal eastern Adriatic waters to the DWF is expected to be significant not only during the dry years, but also during normal years with large cooling wintertime events occurring in the area.

The physical oceanographic environment of the southern California Current during the past decade: Changes in climate and concepts

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The California Current System (CCS) has been studied by CalCOFI for many decades. Since 2004, the Southern California Bight (SCB) and the oceanic region offshore has also been the site for the California Current Ecosystem (CCE) Long-Term Ecological Research (LTER) program, which has established long-term observational time series and executed Process Cruises to better understand physical-biological variations, fluxes and interactions. Since the inception of the CCE-LTER, many new ideas have emerged about what physical processes are the key controls on

CCS dynamics. These new perspectives include obtaining a better understanding of what climate patterns exert influences on CCS physical variations and what physical controls are most important in driving CCE ecological changes.

Physical oceanographic and climatological conditions in the CCS varied widely since the inception of the CCELTER observational time series, including unusual climate events and persistently anomalous states. These broadscale climate variations that occurred over the North Pacific and CCS during this time period are discussed here to provide physical context for the CCE-LTER time series observations and the CCE-LTER Process Cruises. Data assimilation fits, using the ROMS 4DVAR framework, were successfully executed for each 1-month period of the Process Cruises. The fits provide information about how the physical flows evolve during the multi-week Process Cruises. Relating these physical states to biological measurements of CCE-LTER will yield vital longterm perspective of how changing climate conditions control the ocean ecosystem in this region and information on how this important ecosystem can be expected to evolve over the coming decades.

Forecasting Forecast Error

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Singular value decomposition has been used to estimate the most rapidly growing directions of the expected forecast error covariance matrix for forecasts initialized using 4D-Var circulation estimates. Forecast error covariance information is confined to the sub-space spanned by the 4D-Var circulation estimate, and a potentially useful predictive relationship for the forecast error has been identified based on the mean eccentricity of the hyper-ellipsoid that describes the expected forecast error covariance matrix in this sub-space. Examples are presented for a baroclinically unstable jet.

Improving Model ENSO Validation by Constraining Isotopic Signatures of Extreme Events

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Oxygen isotope (delta-18O) records from tropical coral skeletons are widely used for reconstructing tropical climate variability, particularly the El Nino/Southern Oscillation (ENSO). However, the exact relationship between such large-scale modes of variability and isotopic variations local to the reef is poorly quantified. As such, climate reconstructions from delta-18O are subject to uncertainties whose extent has yet to be determined. To address this issue, a new, isotope-enabled version of the Regional Ocean Modeling System ("isoROMS") has been developed, providing the capability of simulating seawater oxygen isotope anomalies during historical El Nino and La Nina events at a variety of spatial scales. Preliminary results from isoROMS downscaling experiments for the Line Islands in the central Pacific are presented, covering the 1990s and 2000s. The extreme El Nino and La Nina of 1997-98 and 2010-11 are chosen for case studies, and the expected isotopic signals predicted from isoROMS at known proxy collection locations are computed during these events. Implications for validation of general circulation model performance are discussed.

Cold Core Frontal Eddies in the East Australian Current. Formation, Entrainment and biological significance

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Cold core eddies frequently form on the inshore edge of western boundary currents. They range in size from sub-meso- to meso-scale and they can exist from anywhere from 24 hrs to a matter of weeks or even months. Little is known however about their formation mechanisms, for example the role of the wind, the balance between baroclinc and barotropic instabilities and how they are sustained. Cold core eddies rotate in a cyclonic (clockwise) sense in the southern hemisphere, thus on the inshore edge of a WBC they have the ability to entrain shelf waters into the core of the eddy. These coastal waters likely possess different watermass characteristics, and have the potential to contain seed populations of plankton and larval fish. In this study we use a twofold approach, combining a number of numerical modelling simulations to investigate the role of wind forcing, and the energy balance during eddy formation, spin up and evolution. We diagnose the source waters of such a cold core eddy, and investigate the biogeochemical properties using a combination of observations from autonomous gliders, moored instrumentation and towed bodies alongside numerical tracer experiments. The results show that entrainment of preconditioned shelf waters into a cold core frontal eddy allows for retention in the vicinity of the EAC separation zone, and highlights the potential for these eddies

to play a significant role in providing nursery habitat for larval and juvenile fish.

Quantifying the ocean velocity contribution to the Alboran Sea primary production

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This work uses ROMS ocean circulation model coupled with Fennel biochemical model to relate the surface Chlorophyll (Chl) with ocean velocities in the Alboran Sea (Western Mediterranean). The influence of zonal wind on the primary production in the area is documented in previous works. Here we analyze how the wind can affect the Chl through the different ocean velocity components and what spatial and temporal patterns are more important to produce the observed chlorophyll blooms. To carry out such analyses we correlate the ocean velocity components with the chlorophyll concentration coming all from model simulations. The simulations use a grid of 2 km resolution with a climatology in both, meteorological forcing and boundary conditions. First, the spatial and temporal variability of Chl and ocean velocities have been characterized using standard statistics. Second, the original time series are separated in annual cycle and residual, and both are submitted to an EOF computation scheme. Then, the correlations between the amplitudes of the first temporal modes of Chl-velocities couple have been quantified. Using the most correlated pair in the annual cycle and residual we quantify which percentage of Chl biomass production is due to long term (monthly or seasonal) or short-term (days to weeks) ocean velocities.

Coastal Mean Dynamic Topography Computed Using ROMS Variational Assimilation of Long-Term Mean Observed Currents and Hydrography

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The across-shelf momentum balance of the Mid Atlantic Bight (MAB) coastal ocean is predominantly geostrophic and the associated sea level gradient is evident in coastal corrected altimetry. However, the mean along-shelf momentum balance involves a significant contribution from an along-shelf sea surface tilt (sea level decreasing toward the southwest). This sea level slope (~10-7) is not captured well in mean dynamic topography (MDT) fields derived from direct observations or hydrography, and is poorly represented in global and basin scale dynamical models. We have produced an MAB region MDT for use in conjunction with coastal corrected along-track altimetry in a real-time data assimilative ocean prediction system. The MDT was computed using the ROMS 4D-VAR data assimilation (DA) scheme in its strong constraint formulation with open boundary sea level among the control variables. The long-term mean observations assimilated were currents from (i) ~4 years of surface current observations from HF-Radar from the coast to approximately 150 km offshore, (ii) 10 years of monthly shipboard ADCP currents on an across-shelf transect (the Oleander Line), (iii) 40 moored current-meter deployments on the shelf, and (iv) a regional hydrographic climatology of temperature and salinity computed by locally weighted least squares to preserve anisotropic length scales resulting from the constraints of steep bathymetry on the flow. Climatological mean atmospheric forcing and river sources were applied to force the DA solution. The analysis was conducted for annual mean, and seasonal mean conditions. In the latter case, the seasonal cycle of along-track altimetry was included as a further data constraint. The dynamics embodied in the 4DVar solution introduce the anticipated mean slope that was absent from the prior solution for sea level boundary conditions adopted from a global data assimilative model. Various features of the monthly 3-dimensional climatological circulation of the MAB are presented.

Poster Abstracts

NorKyst-.800 and the Norwegian Current Information System

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Norway has the longest coastline in Europe, a zone with high ecological and economical importance. In a national cooperation, a ROMS-based model system, NorKyst-800, has ben setup covering the whole Norwegian Coast with resolution 800m. As the model domain is rather large, 2600x900 grid cells, a flexible system for automatic generation of grid files, initial fields and forcing for subdomains has been developed.

As a tool for management and regional development of the coastal zone, a web-based information system for current and spreading statistics is under development. Given an archive of model results, this allows the user to view statistics and plots of the current at any location, produce horizontal maps and soon spreading maps of pollution or contagious substances such as salmon lice. Presently this is based on Norkyst-800, but fjord archives with higher resolution will be included.

Influence of river discharge on the seasonal circulation of the Eastern Brazilian Shelf (8°S - 19°S)

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A regional model based on ROMS-RUTGERS, configured with a refined grid (1/36°) and realistic forcings (6-hourly winds and surface fluxes, daily large scale oceanic forcing and tides), was implemented to investigate the seasonal circulation within the Eastern Brazilian Shelf (EBS). The EBS is a passive continental margin forced by a combination of Western Boundary currents (which flow at the slope), winds, and local topography. The control experiment (with no river discharge) shows that for the northern limit (8-10°S) the northward North Brazil Current/Undercurrent (NBC/NBUC) system is the dominant pattern at the shelf-break/slope and the surface circulation at the inner and mid shelves is more influenced by the wind forcing. At the middle (14°S) and southern (16-18°S) domains, there is an alternating dominance of the southward Brazil Current (BC) and the northward NBC for the first 150 m of the water column. However, the annual net transport is southward oriented despite the change of the mean shelf circulation, which experiences a complete reversal of the mean flow between spring/summer (southwards) and autumn/winter (northwards) seasons, as a response to a similar change in the wind field. With the addition of the river discharges we identified that three main rivers interact with the local circulation, mainly during the summer season when the net discharge is about two times the winter one. For instance, at the northern limit, the density gradient associated with the Sao Francisco (SF) river discharge during summer generates a northward flow near the coast and a southward flow at the outer-shelf. The northward flow opposes the mean southward local circulation and decreases the velocity near the coast. On the other hand, the outer shelf flow increases and seems to accelerate the coastal border of an anti-cyclonic eddy, which is a recurrent feature in the central part of the domain during the summer season. During the winter season, the SF river discharge decreases and is deflected to the north, following the forcing balance between the density gradient and the preferential northward wind and current circulation. The southward density flow due to the river discharges in the middle and southern domains increases the local southward circulation, which did not change significantly between seasons, due to the topographic circulation constraint in these regions.

Modelling a Nigerian estuarine creek system combined with opportunistic in-situ data collection

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The tidal creek systems around Bonny River (near Port Harcourt) in Nigeria experience dry and intense wet seasons (average June rainfall accumulation of 480 mm) and annual rainfall comparable to western areas of the UK. This is believed to produce seasonality in sedimentation rates. By modelling the creek system, dredging can be optimised as it is possible to determine where sedimentation is occurring and when. This is beneficial to a client of Knowtra. The 3-D ROMS (Regional Ocean Modelling System) model used here has 18 by 18 metres resolution and 10 vertical levels. Tide height is forced by measurements from a local tide gauge and one boundary is forced by currents from harmonic analysis of an Acoustic Doppler Current Profiler (ADCP) survey. The upstream boundaries are fitted with two basins with similar surface area to the unmodelled river outside the domain. In-situ temperature, salinity, turbidity and weather measurements are being collected in a semi-automated way, to address the challenges of a remote location where there are no historical data records.

ROMS Applications at the Irish Marine Institute

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The Irish Marine Institute runs a suite of hindcast/forecast ROMS models providing a range of services to local, national

and international bodies. Our suite of operational ROMS model domains include ~5km NorthEast Atlantic, ~2km North East Atlantic, ~250m offline nested Bantry Bay, and ~200m offline nested Connemara models.

Details of the Irish Marine Institute's: (1)Model configuration(s), (2)Model validation, (3)Harmful Algal Bloom modelling, (4) Oil spill modelling, (5)Storm surge forecasting, and (6)Initial experiments in IS4DVAR, are presented.

Optimal sampling of a regional sea for ocean forecasting, physical and numerical experiments

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Due to the high cost of ocean sensors and related platforms compared to the societal benefits, the optimization of sea observational systems is a central issue for ocean forecasting centers. The goal of this work is to find, on a regional scale, operational criteria to identify suitable instrument types, their number, and improved sampling strategies to significantly enhance the quality and reliability of ocean forecasts.

The impact of any set of measurements on an operational forecasting system may be evaluated using data assimilation techniques to measure the quality of forecasts starting from different initial/forcing conditions. In the present work, such improvement in model forecast is assessed by a combined OSE and OSSE approach, and using the ROMS-4DVAR algorithm in different model configurations.

A first study was conducted in idealized model configurations, like a well organized hydrodynamic system (such as a double-gyre model), and a more chaotic field of mesoscale eddies (Q-G turbulence), analysing the impact of both standard in-situ measurements and lagrangian devices (drifters, floats). Different localizations of sensors (or deployment positions, in case of lagrangian tools) are compared, both choosing them randomly or concentrated on the most unstable directions.

Our analysis is also conducted on an operational forecasting system for the Tyrrhenian Sea, with a major focus on finding an optimal set of parameters for lagrangian floats (number of floats, release depth, frequency of profiles). A number of physical experiments are in course of realization in the area, and related data are assimilated into this model. Results of assimilation of such physical data are used to validate a larger set of numerical experiments in order to extend the range of validity of our study.

New features in ROMS_AGRIF v3.1

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A selection of the main features of ROMS_AGRIF V3.1 release (February 2014, http://www.romsagrif.org) will be detailed. We will present the implementation of the generic coupler OASIS3-MCT for ocean-atmosphere coupled simulations using ROMS_AGRIF with the Weather Research and Forecasting model (WRF). OASIS3-MCT was implemented in the pre-release WRF3.6. The coupled system was applied for testing in the Humboldt upwelling system (Illig *et. al*, in prep.). Technical details and preliminary results using oceanic and atmospheric nested domains will be presented.

A new biogeochemical model, called BioEBUS (Gutknecht *et. al*, 2013) is now part of ROMS_AGRIF. It is a 12 component nitrogen-based model including Nitrate, Nitrite, Ammonium, Dissolved Organic Nitrogen, 2 Phytoplankton (Small and Large), 2 Zooplankton, and 2 Detritus, as well as oxygen and nitrous oxide components. It is an advanced code of moderate complexity particularly suited to upwelling regions and minimum oxygen zones. BioEBUS flow charts and published results will be presented.

The Wave-Current interaction formalism of McWilliams *et. al* (2004) was also implemented in ROMS_AGRIF following Uchiyama *et. al* (2010). It includes a ray-theory spectrum-peak propagation and refraction model (WKB) for coupled studies but can use a forcing data set obtained from stand alone wave models. Some illustration of rip current modeling will be presented.

Modelling the exceptional Winter 2012 conditions in the Northern Adriatic Sea

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During late January and early February 2012, the Mediterranean Sea was characterized by a persistent cyclonic circulation associated with an exceptional cold anomaly. Large energy losses in the northern Adriatic sea (NA sea) were induced by resulting atmospheric patterns, mostly due to intense and cold Bora winds blowing from NE and producing a sea water temperature drop down to 6°C. We investigated these series of exceptionally cold air outbreak episodes by means of the Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) Modeling System. In the NA sea configuration, particular emphasis was devoted to the atmosphere-ocean interactions, i.e. on analyzing results obtained using the atmosphere model (WRF) in stand-alone configuration, the one-way forced situation (no feedback to the atmosphere from the ocean model ROMS) and the two-way coupled case.

The work aims at disentangling the different contributions of the interplay between ocean-atmosphere. Although uncoupled models were able to capture the cold air intrusion and the evolution of the heat fluxes, their magnitude was overestimated when compared to values derived from observations. The heat fluxes and air temperature at sea level, heavily affected by the SST used to force the atmospheric model (especially in a shallow, semi-enclosed basin such as the NA sea), reconciled better to observations when the atmosphere and the ocean were mutually coupled.

The activity was supported by the National Flagship Project "RITMARE" (SP3-WP4-AZ2).

Dynamics of the Upwelling System Along the Eastern Brazilian Shelf

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The Regional Ocean Modeling System (ROMS) coupled to a biogeochemical model (PISCES) has been used to study the upwelling system along the Eastern Brazilian Shelf and its impact on the local primary production. The model domain covers the continental shelf and oceanic plain from 10°S to 26°S and from 49°W to 30°W, with spatial resolution of about 7 km. The grid resolution seems adequate to resolve eddies and filaments, which are characteristic features observed in the region and may have an impact on the short-term variability of primary production. In a first approach only large-scale and seasonal variations are forced and the results compared to satellite and in situ observations. Simulated results suggest that two different seasonal cycles of primary production occur in the region. In the upwelling areas, entrainment of colder water in the shallower and depleted mixed layer result in biomass increase in summer. On the continental shelf and oceanic region adjacent to the upwelling areas, high biomass occurs in winter and is associated with the deepening of the mixed layer. Mixing brings nutrients from depths below the euphotic zone to levels where they may contribute to phytoplankton growth.

Modelling physical-biological interactions in the dynamics of the Adriatic sardine ichthyoplankton

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Investigations of the spawning grounds of the commercially important fish species play an important role in upgrading purse seine fisheries regulation and accompanied protection measures. In order to fill some gaps in the knowledge of the spawning ecology in the Adriatic, a series of numerical experiments with coupled modelling system ROMS-ICHTHYOP was conducted.

ICHTHYOP is an individual-based model (IBM) designed to study the dynamics of fish eggs and larvae (Lett *et. al*, 2008). In our numerical simulations ICHTHYOP model was initialized using published investigations of the Adriatic sardine, which provided necessary information such as spawning and recruitment areas, initial ichthyoplankton lengths and stages, dependence of their growth and stage changes or temperature, lethal temperatures etc.. The physical environment characteristics crucial for the sardine early stages (currents, temperatures and salinities) were obtained by a realistic month-long ROMS model simulation. Three-dimensional daily averaged ROMS output fields with a horizontal resolution of 2.5 km were used in the ICHTHYOP simulations to reveal the role of physical processes in the early life history of the Adriatic sardine and to estimate success of larvae transport from major spawning grounds to nursery areas. Numerical experiment results were related to the spatial distributions of the early sardine stages deduced from samples collected during January 2013 in the Croatian part of the Adriatic.

Application of a Coupled Ocean – Atmosphere – Wave – Sediment Transport (COAWST) system to assess wind-induced coastal changes

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Storm events have a strong influence on coastal areas. Regarding western Europe, and in particular the North Sea region, some projections indicate an enhanced occurrence of strong storm events or a change in the direction of extreme wind events is related to global warming. The aim of this study is to gain an improved understanding of the impacts of historical and future storm events. Interactions between regional atmosphere, ocean circulation and sediment transports are taken into account regarding the following questions: How strong is the influence of single extreme storm event compared to atmospheric mean conditions on the sediment transport and distribution in the southern North Sea region? What could be the effects of future changes in atmospheric conditions?

To answer these questions, the Coupled Ocean - Atmosphere – Wave – Sediment Transport (COAWST) modeling system is applied. It consists of the atmospheric model WRF, the ocean model ROMS, a sediment module and the wave model SWAN. To set up the coupled system, first the components are tested separately.

A comparison of the ROMS test results with data of the World Ocean Atlas (WOA) shows two main features: First, the vertical temperature distributions of the ROMS application and the WOA data generally reach similar ranges and secondly, the ocean mixing during winter and the stratification during summer are captured.

In the WRF stand-alone test case, one historical strong storm event which took place in December 1999 is simulated. The WRF results show a clear signal of the passing cyclone. The applied WRF setup combined with the used forcing data seems to be able to capture strong and fast storm events in the North Sea region.

After testing the coupled system, it will be applied to a strong historical storm event.

Numerical Modeling of Coastal Water Quality Accounting for Groundwater in Tidal Lake

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A new method for prediction of temporal and spatial variation of water quality accounting for groundwater effect has been proposed and applied to a water body partially-connected to macro-tidal coastal waters in Korea. The method is comprised of direct measurement of environment and water parameters, nutrient budget analysis to estimate indirectly the submarine groundwater fluxes, and three-dimensional numerical modeling of water quality using the directly collected data and indirectly estimated groundwater fluxes. The applied area is Saemangeum tidal lake that is enclosed by 33km-long sea dyke with tidal opening at two water gates of 240 meters and 300 meters wide. Due to the constraint of water exchange and nutrient loading from the land-side, the future condition of water quality is a serious concern. Especially the unknown but significant contribution of groundwater to the surface water quality has been an environmental issue.

Temporal and spatial variability of nutrients in the lake have been predicted using the results of the budget study that gives estimation of flushes of groundwater. The prediction was implemented by the three-dimensional numerical model (ROMS-ICM) consisting of hydrodynamic model of ROMS and eutrophication model of CE-QUAL-ICM (Kim et al., 2011). More detailed structure of the variability of nutrients, including the groundwater effect, could be achieved with mass balance in the tidal lake.

The results show that groundwater influx during the summer monsoon contributes significantly (20% more than during dry season) to the nutrient concentrations of TN, TP and SiO_2-Si. Consideration of groundwater effect on the nutrient budget provides a more precise amount of excess deposit over conventional mass balance using surface flow analysis.

Operational Coastal Modeling System of Korea

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We have developed a down-scaled high-resolution operational coastal modeling system for the coastal waters of Korea to support the major ports of Korea. For the operation of this system, we use a high-resolution coastal modeling system with 300 m grid size, for the western ports of Incheon and Gunsan, and southern ports of Yeosu, Masan, Busan, and Ulsan. The modeling system consists of operational coastal modeling and web-GIS modules. The modeling system uses ROMS, which is coupled with wave model SWAN, using Model Coupling Toolkit (MCT), to exchange data fields between the ocean model ROMS and wave model SWAN. The wave-current coupled model ROMS-SWAN is internally nested with the Community Sediment Transport Modeling System (CSTMS), and is externally nested with the water quality model CE-QUAL-ICM. For the surface forcing, we use predicted results derived from an operational atmospheric model WRF, which has been operated for the East China Sea and East Sea. The open boundary condition of the coupled model ROMS-SWAN is nested with predicted results from an operational model coupled ROMS and SWAN, which is in operation for the

East China Sea. For the tides at the open boundary of ROMS, we use 8 major tidal constituents with semi-diurnal tidal constituents (M2, S2, N2, K2) and diurnal tidal constituents (K1, O1, P1, O1) derived from the regional ocean tide model NAO.99jb with 5Œ resolution. The system predicts hydrodynamic variables twice a day on a 72-hour basis, including sea surface elevation, currents, temperature, salinity, storm surge height, sediment transport and wave information, for the coastal waters of major ports in Korea. The hydrodynamic variables were calibrated with tidal surface elevation, and verified with current data observed by a bottom-mounted AWAC. To validate the predicted results, we use real-time monitoring data transferred from a buoy system with specially designed bottom-mounted AWAC, 1-h averaged surface currents measured by HF-Radar system, and suspended sediment concentration (SSC) and ocean current vector (OCV) obtained hourly, and derived from the Geostationary Ocean Color Imager (GOCI), the world's first geostationary ocean color satellite. The system will provide monitoring and predicted data to government port agencies and to the public, to support ship navigation and marine activity, and also to solve problems associated with coastal accidents, such as storm surge, inundation, wave-setup, oil-spills, and search and rescue, as part of the Korea Operational Oceanographic System (KOOS).

Sensitivity experiments in a 1/24° ROMS configuration along the Southeast Brazilian region

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A set of sensitivity tests were conducted to study the model response to different data forcing sources and temporal and spatial resolution, for the Southeast Brazilian region. The chosen period of simulation was 10 years, from 2004 to 2013. The objectives were: i) to identify the best combination of available oceanic and atmospheric forcings and ii) to access the model response to events resolved at different temporal and spatial scales. The control run was forced with lateral data from the global model HYCOM/NCODA 1/12, with tides from TPXO and surface data from ERA-INTERIM. The sensitivity experiments included the periodicity of the lateral forcings, the absence of tidal forcing and changes in the sources of atmospheric data to include CFSR and CCMP (wind only). The model response to regional and seasonal aspects were analyzed. The results were validated against sea surface satellite temperature and salinity as well as available ARGO profiles during the simulation period.

Impact of surface fluxes formulation on modeling the circulation of the Sardinian seas (Western Mediterranean)

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The impact of different surface flux formulations [A) momentum, heat and freshwater as prescribed by the atmospheric model or B) interactively computed by the model through the classical Bulk formulae] on the circulation of the seas around Sardinia island (Western Mediterranean sea) is investigated trough a set of experiments performed with ROMS. The area is characterized by a very complex circulation including a quasi-stable southward current and intermittent coastal upwelling along the SW coast, a wind driven cyclonic circulation east of the narrow Strait of Bonifacio (NE of the domain), the presence of several anticyclonic eddies formed locally or remotely often approaching the SW Sardinian coast, and a cyclonic gyre in the SE area. Strong wind forcing with particular reference to mistral (NW) winds also characterize the area and are responsible for intense surface cooling during winters and for the above cited upwelling in summer.

ROMS is implemented in the domain (7.3° E - 10.5° E; 37.7° N – 42.5° N) with a horizontal resolution of 2 km (1.8 -2.2) and 30 terrain following levels. Bathymetry is the US Navy Digital Bathymetry DataBase at 1/60°. At open boundaries the model receives 3D (2D) fields from MFS (Mediterranean Forecasting System) analyses (T, S, U, V, ETA) gathered and distributed through MyOcean portal. A twin experiment has been performed simulating the first 6 months of 2012. In experiment A) momentum, heat and freshwater fluxes are directly prescribed by ECMWF ERA-interim data while in B) they are interactively computed trough the bulk formulae from atmospheric boundary layer variables. In B) winds, humidity and other relevant atmospheric variables for flux computations are also obtained from ERA-interim dataset. Then, the two experiments are analyzed to shed some light on pros and cons of the two adopted approaches. Results are also compared with satellite measurements of SST to accomplish a qualitative validation of the two setups.

Numerical Study of the Mediterranean Outflow with a Simplified Topography

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A 3D numerical model is used to setup a simplified scenario on the Atlantic side of the Strait of Gibraltar. This scenario simulates

an Atlantic Water (AW) flowing into Mediterranean basin along the surface and a Mediterranean Outflow Water (MOW) escaping to the Atlantic near the sea bottom. The MOW has two different main paths: northwards, along the Iberian slope, reaching as far as the Scandinavian Peninsula, thereby influencing the formation of North Atlantic Deep Water (NADW), and southwestwards propagating into the Atlantic Ocean. In this simplified scenario we want to study the way a gravity current, like the MOW, behaves for different outflow conditions. The emphasis is on understanding how distinct outflow conditions lead to different propagating depths and mixing that may affect NADW formation under predicted global change future scenarios. The ROMS model domain is centered in the area of the Gulf of Cadis. The northern and southern boundaries are delimitated by the Iberian Peninsula and the Moroccan coast, while the eastern boundary is at 6ºW, near the Camarinal Sill, and the western boundary is open, reaching as far as Cape San Vicente. The imposed boundary conditions consist in two layers of different density, the upper one simulating the AW and the lower simulating the MOW. The grid has 96 X 64 grid points with a resolution of about 3 km and 36 sigma levels. The complex topography of the area is simplified through a slope with two different zonal dependences: the initial (1/3 of the domain) decay of the bathymetry at the east is adjusted by a hyperbolic tangent function, followed by a constant slope. Initial conditions are setup as follows. The western part of the basin is filled with AW, and the eastern part of the domain is filled with AW from the surface to 150 m and with MOW from 150 m to the sea bottom. The open boundary conditions for temperature, salinity and velocity are specified using climatological vertical profiles. In particular, the velocity profiles have been adjusted and calculated with a positive velocity for the inflow and negative one for the outflow, such that mass is conserved within the model domain. Forcing conditions are setup with winds and atmospheric pressure fields.

Storm Surge Modelling for the Australian Bureau of Meteorology

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Storm Surge Modelling for the Australian Bureau of Meteorology, Australia

Australia has a vast coastline with many stretches vulnerable to storm surge. These events often occur over the tropical and subtropical regions in conjunction with cyclones. The Australian Bureau of Meteorology operates a cyclone warning system that uses the NWP (Numerical Weather Prediction) components of ACCESS (Australian Community Climate and Earth-System Simulator). Damage caused by previous storm surge events has highlighted the need to develop an operational storm surge warning system. Ensemble predictions for probabilistic products and services is considered essential. ROMS was chosen as the underlying hydrodynamic modelling software for several reasons including; open source code, incorporation of MPI and large user community. ROMS has been tested on the NCI (National Computational Infrastructure) super-computer where developments will occur before porting to an operational environment. The challenges building an operational storm surge system include simulating the large coastal area and diverse atmospheric conditions. Initial development has been on a Queensland domain with a 5km resolution. Two events; tropical cyclone Yasi (2011) and tropical cyclone Tim (2013), have been used to verify the model. Model Developments are currently focused on higher resolution grids up to 1km, rotated domains and the inclusion of new bathymetry data. Here we show the prototype system and some early results.

Sediment accumulation and bottom morphology change in the west Hainan Island, Northern South China Sea

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A small mud wedge shape in the seismic image was found close to the western shelf of Hainan Province in 2009 in a joint geophysical survey in the Gulf of Beibu. The clinothem-like profiles are similar to those which have been found on the shelf outside the Yellow and Yangtze River mouths. One possible explanation is that the sediment accumulation comes from the Pearl River transport though the Qiongzhou channel. A general 3D hydrological model using ROMS was set up to simulate and test the idea of water exchange and sediment transport in the Gulf of Beibu, in the Northern South China Sea. The hydrodynamic environment of the Beibu Gulf is mainly controlled by the tidal force, the sediment depocenter formation may due to the different water mass mixing.

Operational Oceanography to support Emilia-Romagna regional activities and the Italian National Civil Protection System

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The Hydro-Meteo-Climate Service of ARPA (ARPA-SIMC) acts as a Support Centre for the Civil Protection Agency of Emilia-Romagna, and is one of the Centres of Competence of the national civil protection system since 2005. In particular, ARPA-SIMC maintains a hierarchy of operational numerical models used for

supporting several activities in the field of environmental and civil protection. Presently, the numerical models run in sequence: every day, outputs of the atmospheric model are used by the hydrodynamic and wave models, while dedicated sub-models (oil spill, morphodynamic, saline wedge, water quality, sediment transport) rely on the outputs from the previously cited models.

Atop the hierarchy there is COSMO-I7, a non-hydrostatic limited-area atmospheric model, that represents one of the Italian operational implementations of the former COSMO model (Steppeler et al., 2003), developed by the Consortium for Small-scale Modelling (COSMO, www.cosmo-model.org). COSMO-I7 has been operational since 2001 and is managed by the Italian COSMO partners: Meteo Service (USAM) of the Italian Air Force, SIMC and the Environment Protection Agency of Piemonte Region. It is implemented over a domain covering the whole of Italy and a wide surrounding area with horizontal resolution of 7 km and 40 terrain-following vertical levels. Boundary conditions are provided by the ECMWF IFS and initial fields are obtained with a 'nudging' (Schraff and Hess, 2003) data assimilation technique. Observations provided by USAM are continuously assimilated in 2 daily cycles of 12 hours each. It supplies 72-hour forecasts twice a day with hourly output. COSMO-I7 operational outputs feed two operational marine models (and another one in case of accidents at sea).

The first model is AdriaROMS, an Adriatic implementation of the ROMS (Haidvogel et al., 2008). AdriaROMS has been operational at ARPA-SIMC since 2005 (Chiggiato & Oddo, 2008), and in 2010, thanks to a scientific and technical collaboration with the DISVA Polytechnic University of Marche and CNR-ISMAR Venice, a new configuration at 2 km horizontal resolution and 20 terrain-following vertical levels became operational (Russo et al., 2013). Air-sea heat, momentum and water fluxes are interactively computed from the COSMO-I7 hourly outputs. GNOO-MFS (the Italian Operational Oceanography Group's Mediterranean Forecasting System) are used for supplying tracers and velocity conditions at the open-boundary (Otranto Strait), where main diurnal and semidiurnal tidal components are imposed. Po River discharge is introduced using direct reading of Pontelagoscuro gauge station, whereas runoff of other rivers is introduced using monthly climatology derived from the literature. Analysis of the previous 24 hours and forecasts at +72 h are produced every day at hourly frequency.

The second marine model is the sea-state forecasting system called MEDITARE (Valentini et al., 2007), based on the SWAN model (Simulating Waves Nearshore; Holthuijsenet al., 1989; Booijetal., 1999; Riset al., 1999). The system is composed of three model implementations with nested domains at increasing horizontal resolutions, from about 25 km over the whole Mediterranean domain to about 0.8 km in the Emilia Romagna coastal area, passing through about 8 km on the whole Adriatic Sea. The three SWAN models are run daily in sequence from the wider to the finer, passing boundary conditions.

The described operational system outputs feed specific, operational (or ready to be activated in case of emergency) models. Currents and sea temperature forecasts produced by AdriaROMS as well as wind forecasts produced by COSMO-I7 are converted daily to a format used by the General NOAA Oil Modeling Environment (GNOME; http://response.restoration.noaa.gov/oil-and-chemical-spills/oil spills/response-tools/gnome.html). GNOME is used to produce forecasts of oil spill transport and dispersion at sea in case of accident.

A coastal morphodynamic model (XBeach; Roelvink, 2009) has been implemented as part of the EU-FP7-MICORE project activities along the Emilia Romagna coast and is being used to provide early warning about coastal risks deriving from approaching storms. XBeach produces daily operational forecasts for the next 72 hours in 8 sites along the Emilia-Romagna coast, relying on AdriaROMS and SWAN operational forecasts of sea level and waves, respectively.

Finally, AdriaROMS and SWAN forecasts have further uses, as saline wedge operational forecasts for the Po River (and other minor rivers of Emilia-Romagna region) and bathing water quality studies in Emilia Romagna coast.

Tidal cooling effect on SST and its influence on typhoon simulation over the East China Sea

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Each summer, tropical cyclones (including typhoon) frequently travel across the East China Sea (ECS), beating the surrounding regions with massive damages. Therefore, it is very important to predict their intensities and tracks by using numerical models. Unfortunately, forecasting the typhoon track is still a big challenge for a couple of reasons.

To numerically predict the typhoons, an atmosphere-ocean coupling model is often required. Researchers have done many efforts on the atmosphere part to improve the accuracy, while the ocean part was often treated simply. For example, many models include an ocean model that considers the air-sea exchange of heat and momentum, as well as large-scale ocean motions like circulation. However, in the shallow coastal oceans like the ECS, tidal forcing also plays an important role that modulates the vertical exchange to adjust the SST. So far no atmosphere-ocean coupling model in this region considers the tide. In this study, we use the coupled ocean–atmosphere–wave–sediment transport (COAWST) modeling system to simulate typhoons in the ECS. With numerical experiments, we have found that 1) Accuracy of SST is essential to correctly predict the intensity and track of typhoons; 2) It is important to include the tide to correctly simulate the SST in the shallow oceans like the ECS.