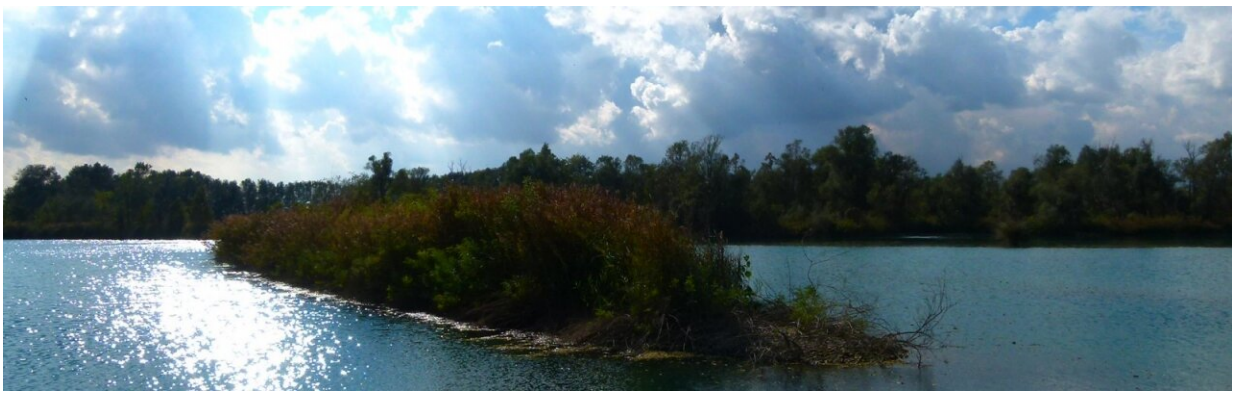
Rivers: How they contribute to better understand Mediterranean Sea dynamics

March 5 2020



Credit: CMCC Foundation - Euro-Mediterranean Center on Climate Change

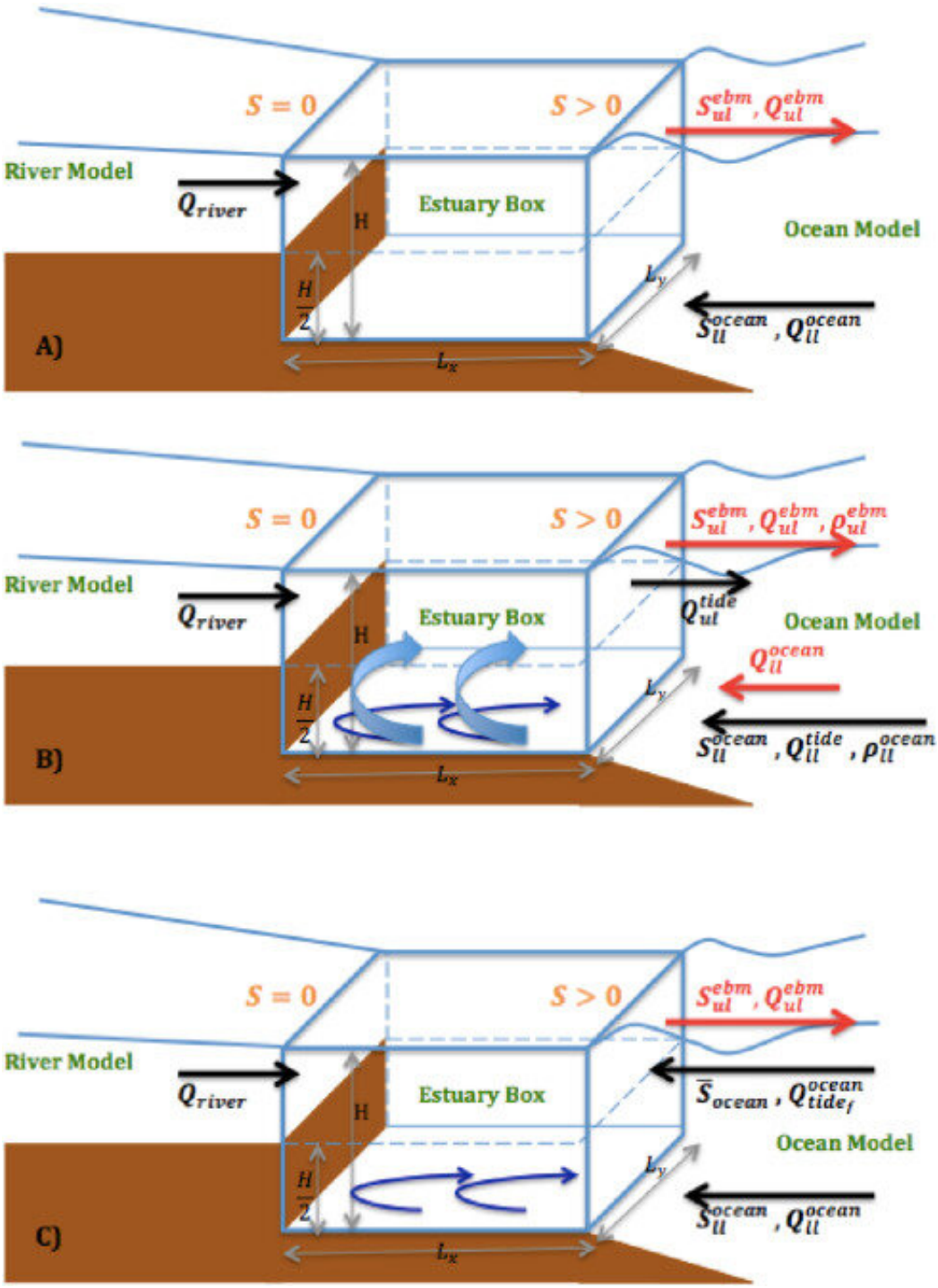
Do rivers play a significant role in ocean circulation and dynamics? Do we need a fine representation of river release into regional ocean models?

Rivers are well known to affect both coastal and basin-wide ocean circulation and dynamics, but representing the net freshwater flux at river mouths is still challenging for global and regional scale ocean modelling. Several studies have demonstrated that the freshwater discharge dominates the dynamics of the shelf areas adjacent to estuaries by producing a typical "buoyant river plume," which consists of an offshore bulge and a coastal alongshore current. Other studies have

highlighted the role played by ocean salt waters intruding into the estuaries, demonstrating that this intrusion drives the estuarine water exchange thus affecting the net estuarine outflow and salinity values.

Regional and global ocean models cannot resolve estuarine dynamics, and they parameterize the river release in an oversimplified way, with climatological runoff and zero or constant salinity values.

A new study just published on *Ocean Modelling* tried to solve this problem while providing a more realistic representation of the estuarine water inputs and developing proper interfaces between mesoscale eddy-resolving models and estuaries in order to simulate the ROFI (i.e. Regions Of Freshwater Influence) dynamics. The study, led by scientist Giorgia Verri, ocean modeler at the CMCC Ocean Predictions and Applications Division, and co-authored by CMCC scientists Nadia Pinardi, Giovanni Coppini and Emanuela Clementi, tested and compared three different approaches (the three following models: Knudsen's relation, the UCONN-NCAR Estuary Box Model and the CMCC Estuary Box Model, called CMCC-EBM, developed by researcher G. Verri) to represent the river volume transport and salinity values at the outlets and reconstruct the estuarine dynamics.



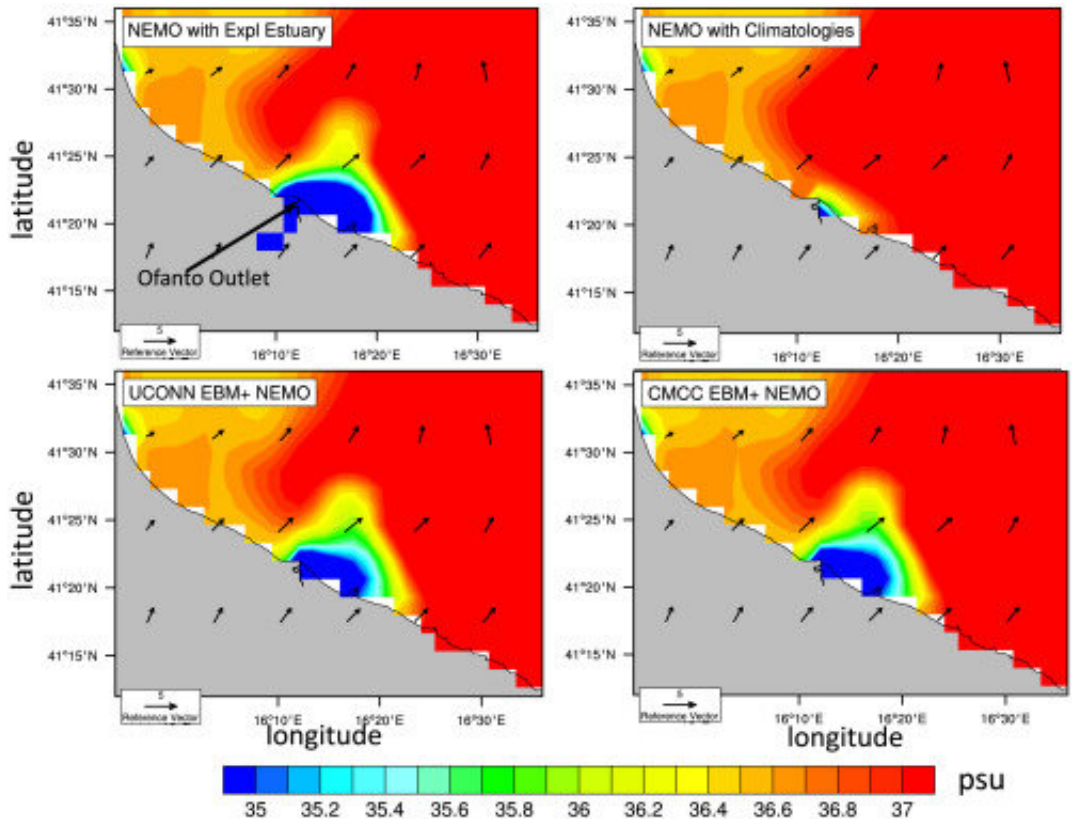
Knudsen relations model (top panel A), UCONN-NCAR EBM (middle panel B) and CMCC EBM (bottom panel C). The volume fluxes entering or exiting the box along with their salinities and densities are represented by arrows. Black arrows stand for input values from the ocean and river models, red arrows for the unknowns solved by the EBM. The pairs of blue arrows represent the tidal

mixing, pairs of upward light-blue arrows stand for the shear mixing at the layer interface. Credit: Creative Commons CC-BY-NC-ND G. Verri, N. Pinardi, F. Bryan et al., A box model to represent estuarine dynamics in mesoscale resolution ocean models. Ocean Modelling (2020), doi: 10.1016/j.ocemod.2020.101587

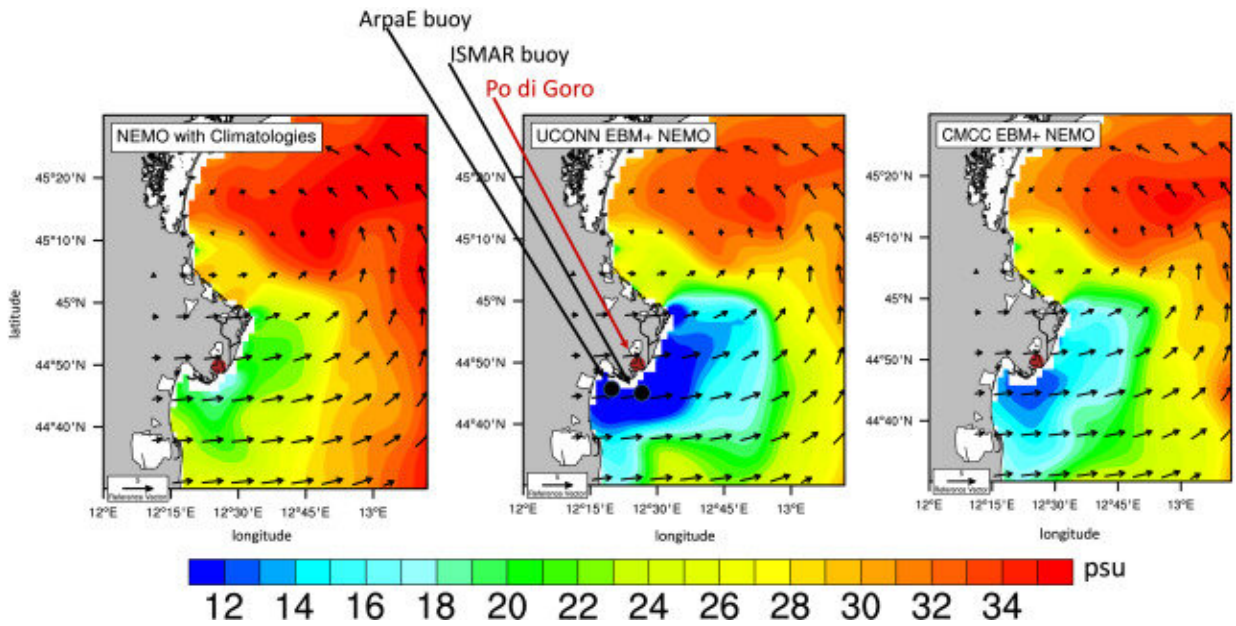
"The study," explains Giorgia Verri, "is placed in the framework of developing a conceptual and numerical modelling approach to simulate the effects of river release on the coastal to open sea circulation and dynamics. The few km resolution of mesoscale ocean models cannot explicitly resolve estuary dynamics; thus, the idea of an "estuary box model" that gives reasonable values of water volume flux and salinity at the river mouth, which in turn affects the ocean dynamics.

Therefore, CMCC EBM has been conceived to represent the estuarine processes coupled to an eddy resolving regional ocean model (based on NEMO code).

To show the impact of the EBM volume flux and salinity values on the quality of an ocean simulation, researchers applied the results of the EBMs to a regional ocean model in the central Mediterranean Sea and in particular to two estuaries in this area: the highly-stratified estuary of the Ofanto river, which flows through Apulia in southern Italy and ends in the Southern Adriatic Sea, and the partially mixed delta of the Po river, one of the main rivers in Europe which discharges into the northern Adriatic Sea.



Daily SSS (psu) of the Ofanto ROFI when upwelling wind regime (black arrows), i.e. on March 3rd 2011. Top Left: Exp1, NEMO with explicit estuary set-up. Top Right: Exp2, NEMO with climatological river release. Bottom Left: Exp3, coupled UCONN-NCAR EBM NEMO Bottom Right: Exp4, coupled CMCC EBM NEMO. Credit: Creative Commons CC-BY-NC-ND G. Verri, N. Pinardi, F. Bryan et al., A box model to represent estuarine dynamics in mesoscale resolution ocean models. Ocean Modelling (2020), doi: 10.1016/j.ocemod.2020.101587



Daily SSS (psu) of the Po ROFI when upwelling wind regime (black arrows), i.e. on May 20th 2009. Left: Exp1, NEMO with climatological river release. Middle: Exp2, coupled UCONN-NCAR EBM NEMO. Right: Exp3, coupled CMCC EBM NEMO. Dots and arrows indicate the locations of Po di Goro mouth and ISMAR and ARPAE buoys. Credit: Creative Commons CC-BY-NC-ND G. Verri, N. Pinardi, F. Bryan et al., A box model to represent estuarine dynamics in mesoscale resolution ocean models. Ocean Modelling (2020), doi: 10.1016/j.ocemod.2020.101587

The study highlighted that the coupled systems are capable to reconstruct well defined river plumes and outperform the climatological approach which neglects the estuarine water exchange while improving the performance of ocean models. Moreover, the coupling of the eddy resolving ocean model to the CMCC EBM is found to outperform the one with the UCONN-NCAR EBM in the region of freshwater influence on the shelf areas.

"The research is not only interesting from an academic point of view,"

highlights Prof. Nadia Pinardi, oceanographer at the CMCC Foundation, "but also for its practical application: introducing an information on river release into ocean models, from regional to global scale, can improve their performance and produce more realistic operational forecasts or climate scenarios. The EBM-CMCC model will be first coupled to the models currently used to produce operational forecasts in the Mediterranean or in the Black Sea, that is to the Copernicus Mediterranean and Black Sea Forecasting Systems (CMEMS Med MFC and CMEMS BS MFC), to improve their outputs."

"The Copernicus Marine Service (CMEMS) has been designed to respond to issues emerging in the environmental, business and scientific sectors. Using information from both satellite and in situ observations, it provides state-of-the-art analyses and forecasts daily, which offer an unprecedented capability to observe, understand and anticipate marine environment events. This study adds a key piece of information to oceanographic models used by this service," comments Giovanni Coppini, Director of the CMCC Ocean and Predictions Applications Division. "The CMCC estuarine model adds in fact increased realism to the ocean models while providing more accurate simulations and forecasts."

CMCC researchers are already working to upgrade the model. The further development of the model will support the understanding of another key issue: the study of salt water intrusion and salinization processes in coastal areas. "The upgraded version of our model," Verri adds, "will be used to assess the level of salt wedge intrusion in the Po river delta in the framework of OPERANDUM, a project aiming at reducing hydro-meteorological risks in Europe through the design and development of innovative Nature Based Solutions. Modelling the level of salt water intrusion will support in particular a study for the design and development of Natural based solutions to improve the environmental resilience of the area. The scenarios produced will help in

particular the activities of the project aimed at introducing herbaceous perennial deep rooting plants as coverage of earth embankments for the mitigation of flood risk and salt wedge intrusion in the Po delta."

More information: Giorgia Verri et al, A box model to represent estuarine dynamics in mesoscale resolution ocean models, *Ocean Modelling* (2020). DOI: 10.1016/j.ocemod.2020.101587

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