DOWNSCALING CLIMATE PROJECTIONS TOWARDS COASTAL HYDRODYNAMICS MODELS

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INTRODUCTION

State-of-art modelling has shown a largely altered oceanographic environment as a consequence of climate change. The climate models implemented normally present low temporal and spatial resolutions as they aim at a general understanding on how large scale processes vary in a changing climate.

However, through projection models it is difficult to address the specific response at a local scale. For instance, shallow waters and coastal areas encompass several processes that are not resolved by large scale climate models. Hence, the interactions between atmosphere, ocean, waves, hydrology, sediment transport, and biogeochemistry are not always appropriately coupled.

Through downscaling projections towards coastal applications it is possible to reach higher resolutions and much more detailed information. If such an approach is performed using unstructured models instead of finite difference ones, it allows for an even better representation of complex morphologies. The latter enables studying more in depth the behavior of coastal environments, such as deltas, that heavily involve the oceanographic and hydrologic components. One of such areas is the Po Delta located in the Northern Adriatic Sea. With its complex system of lagoons and river branches (Maicu et al., 2018), downscaling is fundamental for representing the local processes driven by the interaction between the basin wide circulation and the freshwater inputs.

In the context of the European Strategic Italy-Croatia AdriaClim Project (ID 10252001), hydrodynamic downscaling from regional scenario projections to high-resolution coastal applications is undergoing. The final local, high-resolution implementation is a finite element hydrodynamic model that uses the atmospheric forcing, and hydrologic and oceanographic boundaries from the projections.

METHODOLOGY

The downscaling approach begins with the usage of a regional scale (Mediterranean basin) ensemble member (L'Hévéder et al., 2013) from a coupled air-sea model made available by the Med-CORDEX coordinated initiative. Its results are used to downscale from a regional to a subregional scale (Adriatic sea) using atmospheric (WRF), hydrologic (WRF-Hydro) and oceanographic (NEMO) models. It is important to emphasize here that the future projections followed the RCP 8.5 scenarios. From the subregional implementation, a further downscaling is conducted to the high-resolution, local Po Delta domain (Figure 1) using the System of HydrodYnamic Finite Element Modules (SHYFEM).

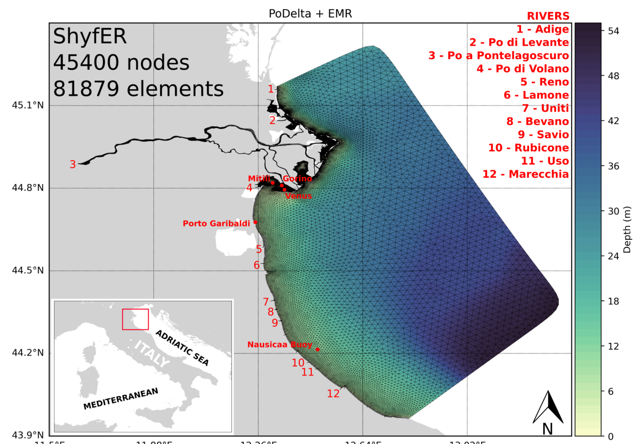

Figure 1 - numerical domain presenting the grid characteristics, most important coastal stations used for calibration and the rivers set as hydrologic boundary conditions.

SHYFEM is a 3D finite element model that solves the primitive equations using a semi-implicit scheme for integration in time (Umgiesser et al., 2004). Here, SHYFEM is applied in an unstructured domain covering the Po Delta and its adjacent coastal areas. The domain consists of 45400 nodes, 81879 elements with the maximum depth reaching 55m offshore (27 z levels in total). Its bathymetry has been generated combining in situ measurements (single and multibeam data) with the EMODNET2020 gridded values (≈115m).

Two sets of simulations are part of the Adriaclim project developments: the first one involves historical simulations and a second one the future projections. Additionally, sensitivity tests have been performed to reach the best possible parameter set and evaluate how the model reproduced a year-long simulation. The distinction between the historical run and the sensitivity tests rely on the computational burden that decadal simulations imply considering also the fact that only recently an MPI version of the model has been made available in the official GitHub repository (https://github.com/SHYFEM-model/shyfem). For the sensitivity tests, COSMO-2I (Steppeler et al., 2003) and Adriac (COAWST - Warner et al., (2010) - implementation to the Adriatic Sea) have been used as atmospheric forcing and oceanographic boundary conditions, respectively. Relative to the fluvial boundaries, 12 rivers were represented (Figure 1). Measured discharges were used for the Po at Pontelagoscuro (River 3 in Figure 1) while climatologies were used for the remaining ones. River temperatures were all from climatologies. The historical simulations and future projections use the outputs of the subregional NEMO and WRF previously mentioned. Some of the regional rivers have had projections performed in the context of the Adriaclim project. For the ones whose projections are not available, the already calculated climatologies are persisted in the future. In this abstract, only the results relative to the sensitivity analyses are shown as the historical simulations and future projections are still being carried out.

RESULTS AND DISCUSSION

Eight sensitivity tests were used to verify the model performance to varying bottom friction, air drag coefficients and oceanographic boundaries. The results were used to analyze the model when reproducing temperature, salinity and sea level covering March to December, 2021 (the simulation began on January 1st but two months of spin up were necessary for the model to reach an equilibrium). The results shown here comprehend the stations of Venus (temperature and salinity) and Porto Garibaldi (sea level) with their locations shown in Figure 1.

In Figures 2A, 2B and 2C, it is possible to see that Shyfem appropriately reproduces yearly temperature variations following the seasonal cycles for the Venus measuring station. A slight model underestimation can be seen during the period. This can be attributed partially to the climatological values used at the fluvial boundaries instead of the real measured river temperatures discharging close to the Goro Lagoon (where the Venus station is located) and/or to a lower temperature being downscaled from the oceanographic boundaries. Generally, the maximum and minimum values are well represented by the model as corroborated by the two model peaks being very similar to the observed peaks in the probability density functions (PDFs) in Figure 2C. The temperature mean absolute error (MAE) and root mean squared error (RMSE) are of 1.18 and 1.46°C, respectively, with a significant Pearson correlation coefficient of 0.99. The temperature average for the period was 19.38°C while the model average was 18.43°C.

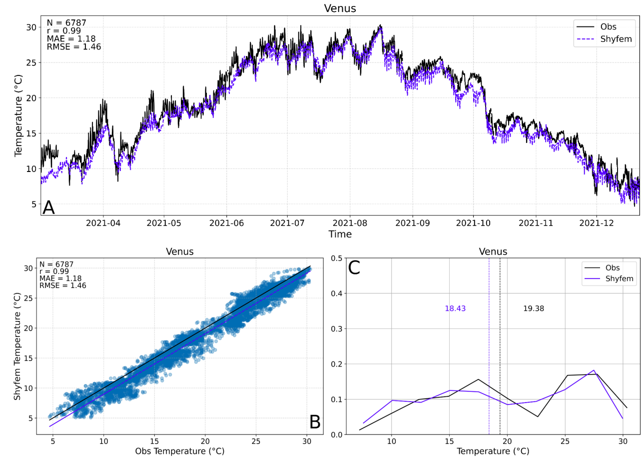

Figure 2 - Temperature measurements (in black) and Shyfem results (in blue) at the Venus station. A) Plot of the 2021 time series of observations and model results. B) Scatter plot of observation and model results. C) PDFs of observations and model results.

In Figures 3A, 3B, and 3C, salinity measurements and results at the Venus station are shown. The salinity reproduction has been characterized by a slight overestimation of lower measurements and an underestimation of higher observations. The more constant behavior is due in part to the salinity measurements not being hourly averaged as the model results. Furthermore, setting measured river discharges at the boundaries instead of the climatologies would provide a closer to reality representation of the local dynamics. Still, the main salinity patterns have been well reproduced even if not with the best possible amplitude relative to the measured dataset. The MAE and RMSE were of 3.81 and 4.85PSU, respectively, while the Pearson correlation coefficient was 0.52. The model average for the period was 21.52PSU while the average for the observations reached 22.71PSU.

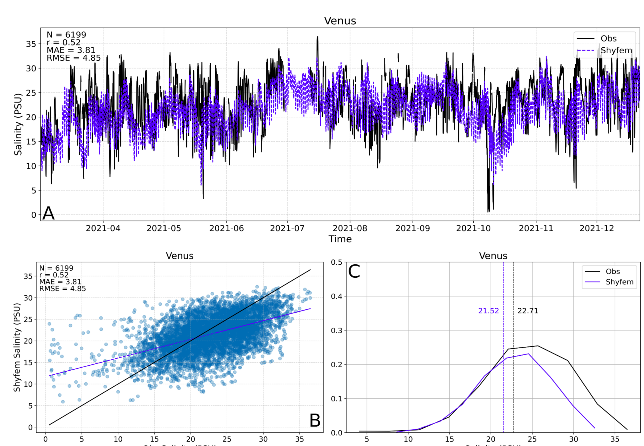

Figure 3 - Salinity measurements (in black) and Shyfem results (in blue) at the Venus station. A) Plot of the 2021 time series of observations and model results. B) Scatter plot of observation and model results. C) PDFs of observations and model results.

The general representation of the sea level by Shyfem follows accurately what is observed in reality as shown in Figure 4 and subfigures. A slight tidal amplitude overestimation can be observed as the model results are most of the time higher during the high tides and lower during the low ones. This can be explained by the oceanographic boundary conditions that have been set as the same behavior is observed when Adriac results are considered relative to tide gauge measurements. MAE and RMSE valued 0.10m and 0.12m, respectively, and the Pearson correlation coefficient was 0.92.

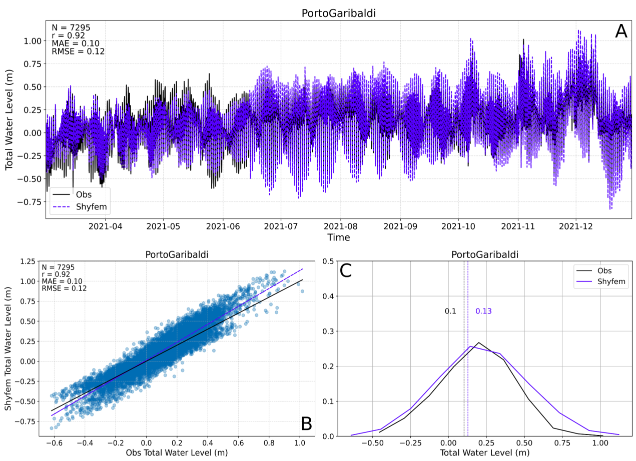

Figure 4 - Sea level measurements (in black) and Shyfem results (in blue) at the Porto Garibaldi station. A) Plot of the 2021 time series of observations and model results. B) Scatter plot of observation and model results. C) PDFs of observations and model results.

The sensitivity tests carried out to better understand the model behavior and limitations have been extremely important as, for the three variables considered, a reasonable agreement was found between the model results and the measurements. Using climatological values for most of the river discharges and all of their temperatures has proven to be an adequate way to proceed with both the historical simulations and future projections even if the high-frequency variations, mostly salinity, are not fully represented.

CONCLUSIONS

The results of the sensitivity tests performed so far made possible the definition of an optimal parameter set that proved accurate on reproducing year long temperature, salinity and sea level patterns even with river climatologies at the boundaries. With an optimal parameter set already chosen, the next steps involve proceeding with the historical simulations and future scenarios so climate indicators can be calculated having a standard value of what has happened in the past and what the future projections' outcomes will indicate.

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