NUMERICAL MODELLING OF SUB-MESOSCALE CIRCULATION PROCESSES IN COASTAL AREAS OF THE BLACK SEA

VASSILI BALTIKAS[1], CHRISTOS MAKRIS[1], NIKOLAOS NAGKOULIS[1], THEOFANIS KARAMBAS[1]

[1] School of Civil Engineering, Aristotle University of Thessaloniki, Greece, emails: vmpaltik@civil.auth.gr, cmakris@civil.auth.gr, nikolaosn@civil.auth.gr, karambas@civil.auth.gr

Abstract

The setup and calibration of an advanced 3-D ocean circulation model is presented to seek its potential for operational forecasting applications and investigate the hydrodynamic processes in selected coastal areas of the Black Sea. The extents of the studied areas refer to local scales of typical mid-range depths in a microtidal open coast environment up to the shelf-break. The effects of short-term changes in meteorological conditions on the coastal eddies' anticyclonic dynamics are explored in conjunction with the effects of the eastern and western cyclonic gyres of the Rim Current in the Black Sea basin (boundary conditions derived from Copernicus operational forecast platform). Field data of *in situ* oceanographic observations in coastal waters are employed for the validation of high-resolution hydrodynamic simulations in operational forecast mode to detect the sub-mesoscale effects of prevailing coastal circulation patterns.

1. Introduction

The Black Sea (BS) is a globally important ecosystem susceptible to both natural and anthropogenic pressures from significant drainage basins of 24 countries, while affecting the coastal zone of six of them (Bulgaria, Georgia, Romania, Russia, Turkey, Ukraine). To support the efficient management of BS fisheries and aquaculture comprehensive data repositories are imperatively required for a) forecast modelling of marine water circulation and quality with focus on selected case study areas, b) linkage between numerical simulations and environmental monitoring, and c) development and testing of web-based platforms and databases for stakeholder interaction with key research processes, tools, methods, and frameworks. Two pilot test cases on zonally opposite Pontic littorals are investigated, *i.e.*, one in the western continental shelf (Varna, Bulgaria) and one in the eastern coastal zone (Batumi, Georgia). The goal is to increase availability of cross-border compatible marine data to address the public needs of society and stakeholders.

2. Methodology

The assessment and recommendation of advanced hydro-environmental numerical tools for real-time data control and forecasting of marine conditions in the Black Sea is based on the following.

2.1. Coastal circulation model

The hydrodynamic circulation simulations in the coastal environment are implemented with the Delft3D-FLOW modeling system (https://oss.deltares.nl/web/delft3d) in a 3-D σ-layer configuration (e.g., Androulidakis et al., 2021) with a very fine discretization down to dx=50m locally in the coastal zone. Herein we present the operational model setup and parameterizations in terms of bathymetric, initial, boundary, forcing, and river input conditions to validate its performance.

2.2. Bathymetric data

The model bathymetries are built upon a combination of GEBCO (https://www.gebco.net/), EMODnet (https://www.emodnet-bathymetry.eu/) and Navionics (https://www.navionics.com/) detailed geospatial datasets of various resolutions inserted in the *rgfgrid* module of Delft3D-GUI.

2.3. *Atmospheric input*

The atmospheric forcing is derived from available open-access meteorological forecast databases, i.e., NOAA (https://www.ncdc.noaa.gov/) and ECMWF (https://www.ecmwf.int/en/forecasts/datasets/set-i) in a 3-hourly interval and 0.25-0.5° resolution concerning wind velocities, sea level pressure, air temperature, relative humidity, cloudiness, and precipitation over the BS basin. Data are retrieved via specific API services for accessing servers in the form of *python* libraries.

2.4. *Boundary conditions*

We further make use of the Copernicus (https://resources.marine.copernicus.eu/products) *python* motu-client API for automated downloads integrated in *Linux* bash scripts for reading, translating, and preparing *NetCDF* files of oceanographic forecasts for salinity, temerature, sea surface height, ocean mixed layer thickness, and seawater velocities, in a 0.025° gridded resolution up to 121 vertical levels and an hourly mean temporal resolution.

2.5. *River outflow data*

The main local freshwater outflows in the study areas are based on available data by the respective Bulgarian and Georgian River Basin Management Plans concerning rivers Batova, Kamchia-Grozdiovo, Chorokhi-Ajaristskali, etc., and their runoff systems in the BS coastal waters.

3. Results

Characteristic output for 2-D horizontal maps of Sea Surface Salinity (SSS) by Delft3D-BS model in late November 2021 and typical input of SSS boundary conditions in cross-sectional depiction by post-processed Copernicus datasets during early July 2021 are presented in Fig. 1.

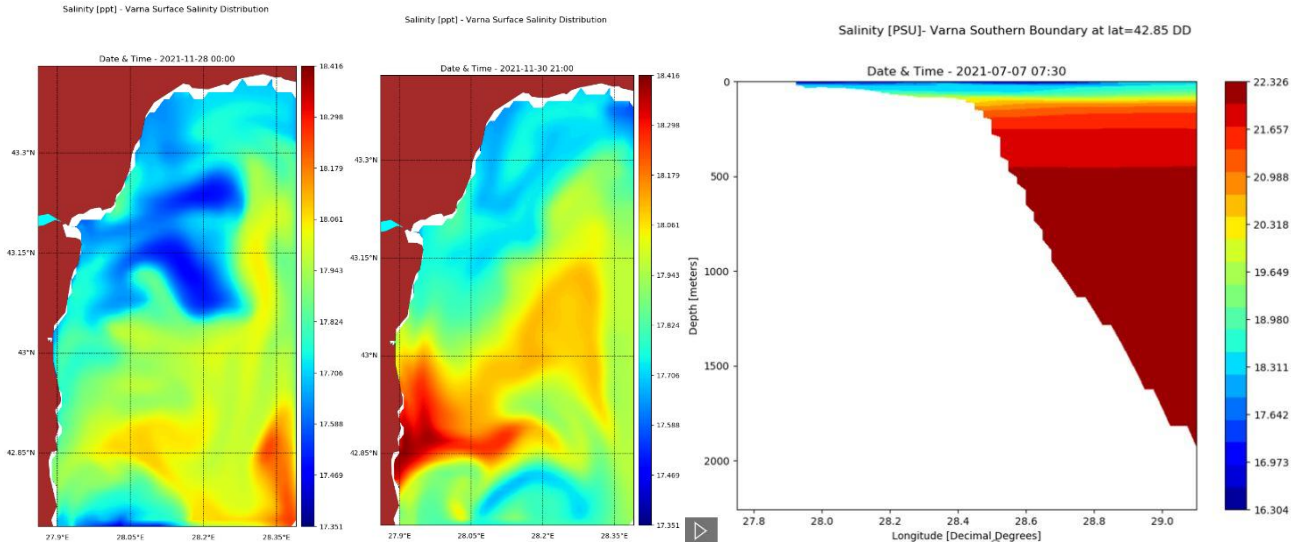

Fig. 1. Typical 2-D horizontal maps of Sea Surface Salinity (SSS in psu; 28-30/11/2021; two left graphs) in Varna coastal area by Delft3D model results and cross-section of SSS boundary conditions (right graph) in the southern margin of Varna Bay during early July of 2021.

4. Conclusions

An initial operational forecast output of simulated coastal circulation hydrodynamics is provided by the Delft3D ocean model, set up in characteristic case study areas of the Black Sea continental shelf. The influence of brackish waters on the sea surface and the upper layer of the water column is apparent. The model results are disseminated to the public and involved stakeholders via the TIMMOD project website's web-GIS tool (http://timmod.org/index.php/en/ict-tools/timmod-open-gis-platform) providing updates of the Operational Forecast Platform. The created TIMMOD Information and Communication Technology (ICT) solutions consist of integrated model simulation

outputs, a data-sharing platform, and a database management tool for operational oceanographic forecasts and monitoring datasets to end-users. New insight is currently produced about the sub-mesoscale marine effects on coastal circulation at the BS coastal zone.

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References

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