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COASTAL CRETE: A HIGH-RESOLUTION OPERATIONAL FORECASTING SYSTEM FOR THE COASTAL AREA OF CRETE, EASTERN MEDITERRANEAN

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Abstract

A high-resolution operational ocean forecasting system, namely COASTAL CRETE, has been developed for the coastal area of Crete. COASTAL CRETE implements advanced numerical hydrodynamic and sea state models, nested in CMEMS Med MFC products and produces 5-day hourly and 6-hourly averaged forecasts of important marine parameters, such as sea currents, temperature, salinity and waves. The COASTAL CRETE high-resolution (~ 1km) hydrodynamic model is based on a modified POM novel parallel code implemented by CYCOFOS in the East Med and the Levantine Basin, while for wave forecasts, the ECMWF CY46R1 parallel version has been implemented with a resolution of ~1.8 km. The hydrodynamic model has been evaluated against its parent model and with satellite Sea Surface Temperature data with good statistical estimates. Similarly, the wave model is calibrated with in-situ data provided from the HCMR buoy network operating in the area. Nested, finer grid (~250 m) hydrodynamic and wave models are also implemented to provide on demand information and services to local end users. COASTAL CRETE products are made available through ADAM (Advanced geospatial Data Management platform) developed by MEEO S.r.l. (<https://explorer-coastal-crete.adamplatform.eu/>).

Keywords: operational oceanography, Cretan Sea, wave model, WAM cycle 4

1. Introduction

The island of Crete is known to be at the crossroads of the Eastern Mediterranean Sea routes that served as conveyors of trade, knowledge and culture, linking some of the world's earliest civilizations, while nowadays attracts millions of tourists and cruise passengers. Currently, in view of the oil/gas exploration in the broader coastal sea area of Crete, the approved by EU EastMed gas pipeline layout that will cross Crete offshore and the enlargement of the Suez canal that will increase the maritime traffic in the area, the National and local authorities in Crete, like ports and the coast guard, who are involved in maritime safety, the tourism industry and the policy makers, are key end users who can benefit from high spatial and temporal resolution forecasting products and information to support their offshore activities. To support local end users and response agencies to strengthen their capacities in maritime safety and marine conservation, the high-resolution, operational forecasting system COASTAL CRETE has been developed for the coastal area of Crete. COASTAL CRETE implements advanced numerical hydrodynamic and sea state models, nested in CMEMS Med MFC products and provides high-resolution forecasts of important marine parameters, such as sea currents, temperature, salinity and wave characteristics. The COASTAL CRETE hydrodynamic model has been evaluated against its parent model at various depth levels and with satellite Sea Surface Temperature data with good statistical estimates. Similarly, the wave model is calibrated with in-situ data provided from the HCMR buoy network operating in the area. The downscaled high-resolution COASTAL CRETE forecasts are used to deliver on demand services to local end users, particularly for oil spill and floating objects/marine litter predictions. Nested, very fine grid hydrodynamic and wave models are also implemented to provide information for day-to-day operation of ports, such as the Port of Heraklion.

2. Methods

The development and implementation of COASTAL CRETE operational forecasting system consists of downscaling from regional to coastal scale, nesting fine resolution models within regional configurations. COASTAL CRETE integrates Copernicus Marine Service Analysis and Forecast model products, satellite data and in-situ observations to produce short-term (5-days) hourly and 6-hourly-averaged high-resolution forecasts of sea temperature, salinity, currents and wave parameters – which are updated on a daily basis – for local authorities, scientists and business users, strengthening their maritime safety capabilities. The COASTAL CRETE high-resolution (~1km) hydrodynamic model, nested in CMEMS Med MFC products, is based on a modified POM (Princeton Ocean Model, <http://www.ccpo.odu.edu/POMWEB/>) novel parallel code, previously implemented by the CYCOFOS in the Eastern Mediterranean and the Levantine Basin (Zodiatis *et al.*, 2016), while for wave forecasts, the latest ECMWF CY46R1 parallel version (ECMWF, 2019) including a number of new features, a state-of-the-art wave analysis and prediction model with high accuracy in both shallow and deep waters has been implemented with a spatial resolution of ~1.8 km. Atmospheric forcing for

the hydrodynamic and sea state models is provided by SKIRON modelling system (<https://forecast.uoa.gr/en/forecast-maps/skiron>) developed by the Atmospheric Modeling and Weather Forecasting Group (AM&WFG) of the Department of Physics of National and Kapodistrian University of Athens (NKUA). The area of interest is shown in Figure 1.

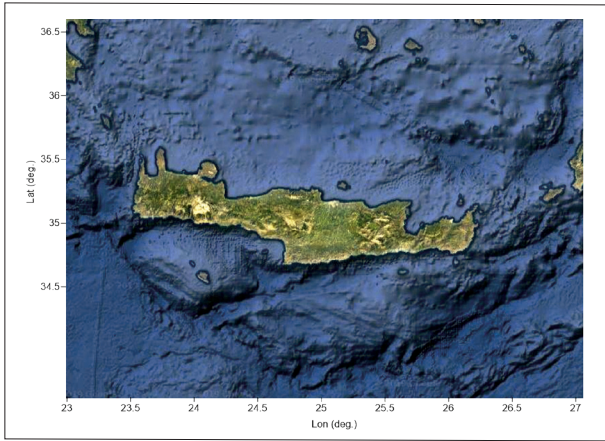


Fig. 1. The COASTAL CRETE computational domain.

An initial evaluation of the COASTAL CRETE hydrodynamic model has been performed with the comparison of the produced temperature, salinity and sea current fields against the hourly produced CMEMS Med MFC model products. Bias and RMSE statistical values have been estimated. It should be noted that for the estimation of statistical metrics, COASTAL CRETE model results have been interpolated to the resolution of CMEMS Med MFC products. Comparison of results produced at 09:00 UTC for the COASTAL CRETE hydrodynamic model and 09:30 UTC for CMEMS Med MFC model on October 3rd, 2020 for the surface layer (~ 1 m) and at the depth level of 300 m shown in Figure 2-7.

The comparison between COASTAL CRETE and CMEMS Med MFC hydrodynamic models' results shows similar hydrodynamic features. Differences at the surface and the near surface (up to 50 m depth) levels are observed as anticipated and are gradually reduced with depth increase. These are due to: the more detailed bathymetry of the higher resolution COASTAL CRETE model, which causes significant variations in the flow field; models' output is sampled with a half an hour difference; the CMEMS Med MFC data used for downscaling are daily averaged, while the CMEMS Med MFC data used for comparison are hourly; different meteorological forcing is used for the CMEMS Med MFC and the COASTAL CRETE hydrodynamic models.

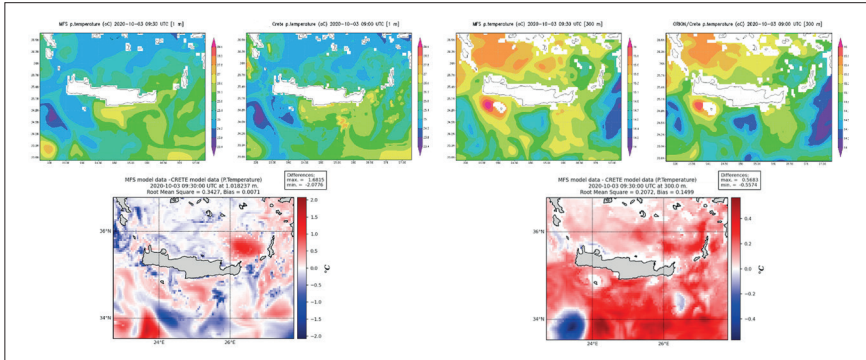


Fig. 2. CMEMS Med MFC and COASTAL CRETE model temperature for the surface layer (~ 1 m) and at the depth level of 300 m on October 3rd, 2020.

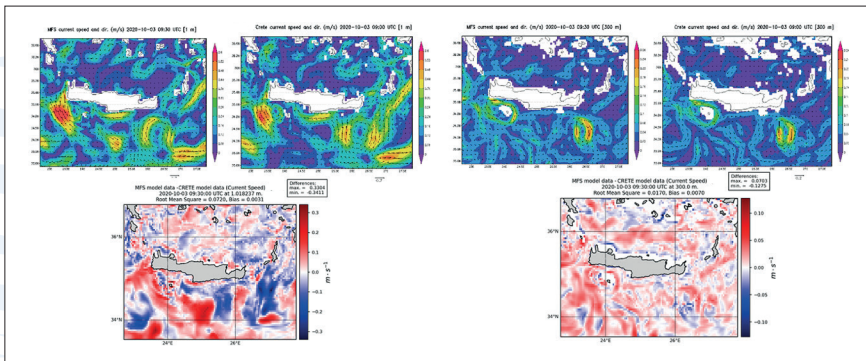


Fig. 3. CMEMS Med MFC and COASTAL CRETE model currents magnitude and direction for the surface layer (~ 1 m) and at the depth level of 300 m on October 3rd, 2020.

The COASTAL CRETE hydrodynamic model has been calibrated and validated mainly with Sea Surface Temperature (L3) satellite data (SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012). Figure 4 shows the comparison between model results and satellite data for the period August 2020 – November 2020 for 2 randomly selected points in the computational domain.

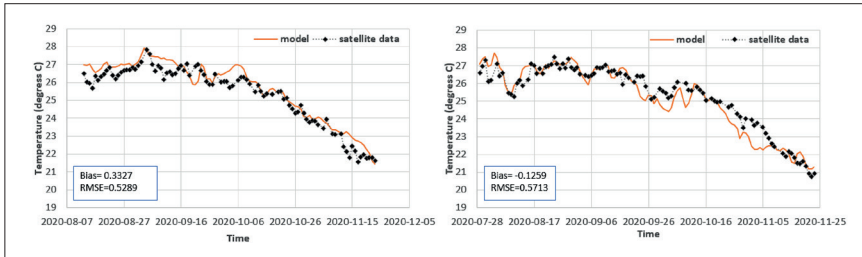


Fig. 4. Inter-comparison of COASTAL CRETE model (red line) with satellite SST observations (black dots), for 2 selected points (1st point long. 25.95°, lat. 34.68°, 2nd point long. 23.73°, lat. 35.11°) at the south of COASTAL CRETE domain for a period of 3 months from 13/8/2020 to 23/11/2020.

The COASTAL CRETE wave modelling system has been calibrated and validated using in-situ data for significant wave height and wave period data from the HCMR buoy network operating in the area. The calibration period was 1-1-2017 to 12-31-2017, while several short-term validation experiments have been performed to evaluate the model's forecasting ability.

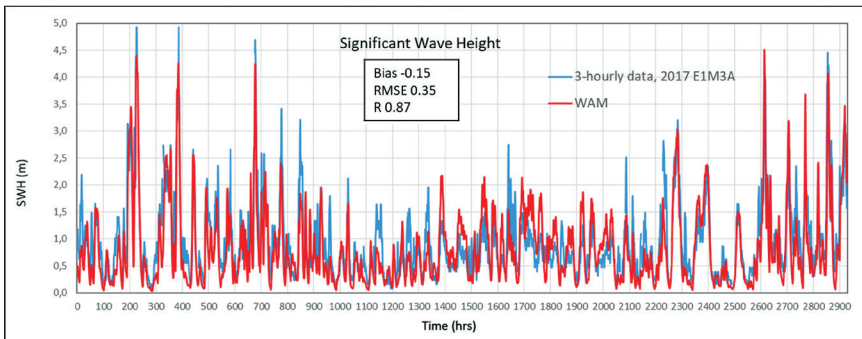


Fig. 5. COASTAL CRETE wave model: Calibration with HCMR buoy E1M3A significant wave height data.

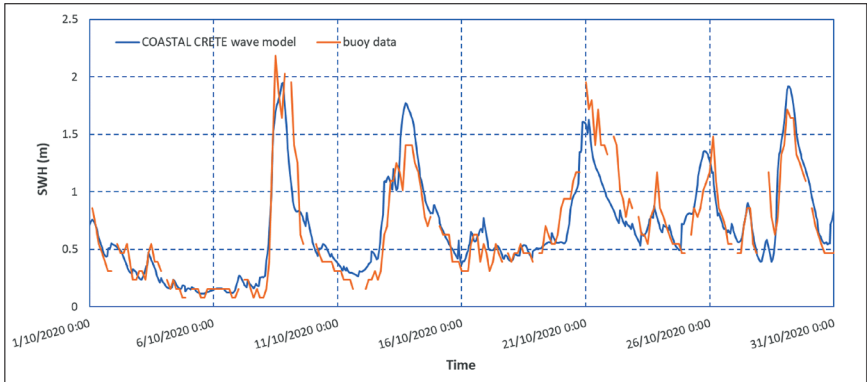


Fig. 6. COASTAL CRETE wave model: Validation experiment with HCMR buoy E1M3A significant wave height data for October 2020.

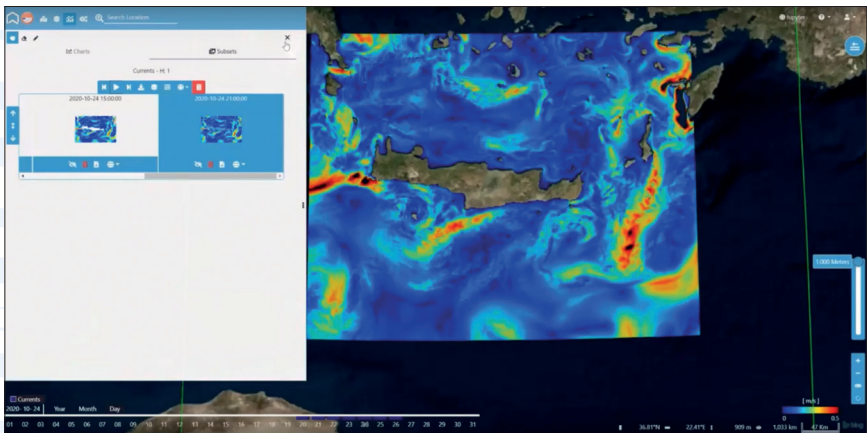


Fig. 7. Visualisation of currents forecast in COASTAL CRETE.

3. Coastal Crete service implementation

Both the CMEMS Med MFC products and COASTAL CRETE forecasts are made available through a customized instance of ADAM (Advanced geospatial Data Management platform) developed by MEE0 S.r.l. (<https://explorer-coastal-crete.adamplatform.eu/>). This application provides automatic data exchange management capabilities between the CMEMS Med MFC and the COASTAL CRETE models, enabling data visualization, combination, processing and download through the implementation of the Digital Earth concept. Among the numerous functionalities of the platform, a depth slider allows to explore the COASTAL CRETE products through the depth dimension, and

a sea current magnitude feature enables the visualization of the currents vectors by overlaying them to any available product/parameter, thus allowing comparisons and correlations.

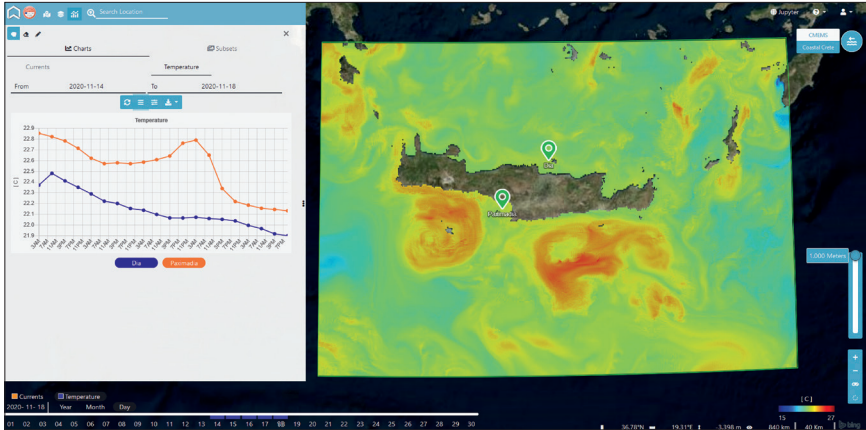


Fig. 8. Visualisation of temperature forecast in COASTAL CRETE.

4. Conclusions

COASTAL CRETE high-resolution forecasting system integrates Copernicus Marine Service Analysis and Forecast model products, satellite data and in-situ observations to produce 5-day forecasts of sea temperature, salinity, currents and wave parameters to address the needs of local end users. COASTAL CRETE service also delivers (on demand), user-tailored information and derived products for maritime safety, readily available and easily understandable for users' operation, planning and management requirements. Examples of such services, (provided at the moment for the Port Authority of Heraklion and the Hellenic Coast Guard, and planned to be extended for other users in the near future) include: Very high-resolution wave and currents forecasts (~ 150 m), support to the response to environmental hazards such as oil spills and personalized early warnings and alerts. The enhancement vision of the system considers integration of earth observation and in-situ data assimilation algorithms to further improve the initial conditions used by the models and thus, the models' accuracy.

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