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The Development and Implementation of an Environmental Coastal Observatory focused on semi-enclosed Gulfs

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Abstract. The structure of a Coastal Observatory for the North Aegean Sea is described in this work. The Observatory AEGIS is focused on the semi-enclosed Gulfs of the islands of Lemnos and Lesvos, with emphasis on the Kalloni Gulf. The Observatory includes both an observing and a forecasting component, and incorporates a three-stage forecasting system composed of three numerical domains, one extending throughout the North and Central Aegean Sea, the second covering the sea around Lesvos island, and the third composed of very high-resolution models of the three Gulfs, of Gera and Kalloni in Lesvos and Moudros in Lemnos island. The observational component includes a meteorological / oceanographic mooring deployed in the middle of the Kalloni Gulf and sea-level gauges at the Kalloni and Gera Gulfs, while submarine telephone cables extending across the Straits of the above Gulfs permit the measurement of net exchanges with the open sea. The above observations enable the validation of the forecasts of the Gulf-level models, while the North-Central Aegean (large-domain) forecasts employ data assimilation to achieve high forecasting skills. The implementation of biochemical models will enable to assess the impact of anthropogenic interventions in these very sensitive areas.

Keywords: semi-enclosed, North Aegean, Coastal Observatory

1. Introduction

The North and Central Aegean Sea, being the first receptor of Black Sea Waters through the Dardanelles Strait, exhibits very high stratification in the upper part of the water column, and less oligotrophic character than the South Aegean, been continuously fertilized by the “richer” Black Sea. Despite its high stratification, it also exhibits the densest waters of the Aegean, clearly being a dense-water formation site. Observational evidence has shown that the eastern shores of the Central and North Aegean sea can contribute significantly in the dense-water production of the basin (Sayin et al., 2011), a fact raising questions about the role of the semi-enclosed Kalloni, Gera and Moudros Gulfs of the two major islands of the North-Central Aegean.

The above Gulfs are ancient mountain valleys that sank during the major sea-level rise that marked the beginning of the Holocene period. As such, they are characterized by gradual deepening towards the Strait connecting them to the open sea, and the lack of a sill in the Straits. They can be considered as typical Mediterranean islands embayments with the potential to exhibit quite variable and complex behaviour regarding their thermohaline functioning and contribution to the open sea (Petalas *et al*., 2020). Especially Kalloni Gulf is characterized by high productivity and biodiversity, supporting the competitive viability of coastal fishing.

The eastern shores of the Aegean Sea also exhibit very strong signals of seasonal coastal upwelling due to the strong summer northerlies known as Etesian winds (*Mamoutos et al*., 2021 and therein references).

Thus, thus the North Aegean Sea hosts a wide range of oceanographic processes that can and need to be studied and monitored, The short distance of the Gulfs of Gera and Kalloni to the premises of the Department of Marine Sciences of the University of the Aegean in Mytilene, enable the design and implementation of a Coastal Environmental Observatory that can be supported and maintained at low operational cost.

This Observatory has been devised and initiated in 2008, and gradually materialized through a series of research / infrastructure projects. The aim is to support Blue Growth in the North Aegean Region, contribute to the National Operational Oceanographic Research Infrastructure coordinated by the Hellenic Centre for Marine Research and provide state-of-the-art training for future marine and coastal scientists.

In the next sections, the current state of the AEGIS Coastal Environmental Observatory is presented and its prospects are discussed.

2. The Observational Component

A well-equipped oceanographic and meteorological platform (**Figure 1**) has been deployed in the Kalloni Gulf, at a depth of approximately 10 m.

2.1. Meteorological Measurements

To enable air-sea exchange studies, the mooring is equipped with the following meteorological sensors:

Gulf mouths via recording electric voltage differences between the opposiet coasts with the help of underwater telephone cables (Petalas *et al.*, 2020).

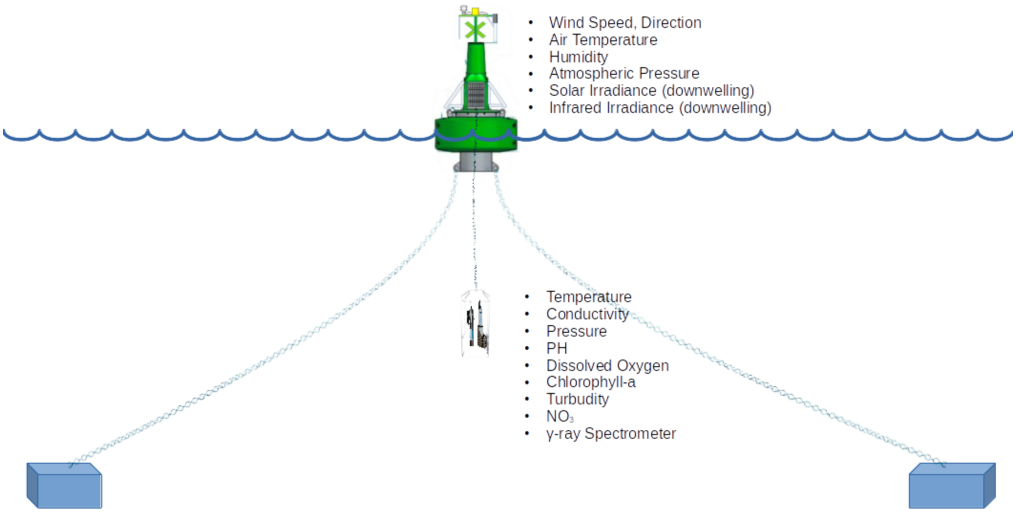

Figure 1. Realistic schematic diagram of the mooring deployed in the middle of Kalloni Gulf, Lesvos island. Two anchors are used, and the cage with the oceanographic instruments is attached from the buoy at a depth of 3-4 m below the sea-surface.

- a Gill GMX500 Compact Weather Station, making ultrasonic measurements of true wind-speed and direction, air-temperature, humidity and atmospheric pressure.
- An Eppley Precision Infrared Pyranometer (PIR) and a Standard Precision Pyrgeometer (SPP), providing downwelling long-wave and solar irradiance respectively.
- A Young 50202 Precipitation Gauge.

The above instruments have no moving parts and are considered ideal for oceanographic purposes.

2.2 Oceanographic Measurements

The oceanographic instruments currently incorporated to the platform are the following:

- A Seabird HydroCAT-EP, measuring Conductivity, Temperature, Pressure, Dissolved Oxygen, pH, Turbidity and Chlorophyll-a concentration.
- A Seabird SUNA V2 submersible Ultraviolet Nitrate Analyzer and a
- HORST KATERINA II underwater in-situ gamma-ray Spectrometer.

In order to meet the challenge of biofouling on a mesotrophic environment, the oceanographic instruments have been attached on a single cage that can be easily retrieved from the water (**Figure 1**).

2.3 Sea-level data and water exchanges

Two OTT Radar Level Sensors (RLS) sea-level gauges have been installed at two ports inside the Kalloni and Gera Gulfs, reporting at 10 min intervals. These data are used to calibrate the estimation of net water transports through the

2.4 Offshore Components

The offshore observational components of the AEGIS Coastal observatory include a WERA-type High-Frequency radar, monitoring the surface circulation of the region where Black-Sea waters enter the Mediterranean, and an ALSEAMAR SeaExplorer Ocean Glider, recently integrated in the infrastructure.

3. The Forecasting Component

3.1. The Central - North Aegean-Sea model (CNAG)

The Regional Ocean Modeling System (ROMS: Shchepetkin and McWilliams *2003, 2005*) is used for the ocean simulations in the domains of (a) the Central and North Aegean Sea and (b) the sea around Lesvos (**Figure 2**) . An orthogonal grid covering the Central and North Aegean was developed with a horizontal resolution of 2.5 km in both horizontal directions and 20 unevenly-spaced vertical sigma (σ) levels. The bathymetry came from GEBCO (General Bathymetric Chart of the Oceans, Weatherall *et al., 2015*) data set and interpolated linearly on the grid with minimal smoothing applied. Boundary conditions at the southern limit came from the Mediterranean basin scale MED-MFC model (Escudier *et al., 2020*) freely distributed by CMEMS (Copernicus Marine Service), while the exchanges through the Turkish Straits System (TSS) follow the work of Maderich et al. (2015). Finally atmospheric forcing and riverine inputs data sources are the SKIRON (Kallos *et al., 1997)* daily forecasts and the SHMI E-HYPE hydrological model (Lindstrom *et al., 2010*) daily climatological estimates from 1981 to 2010 respectively.

An analysis procedure is conducted daily in order to produce optimal initial conditions for a 5-day forecast

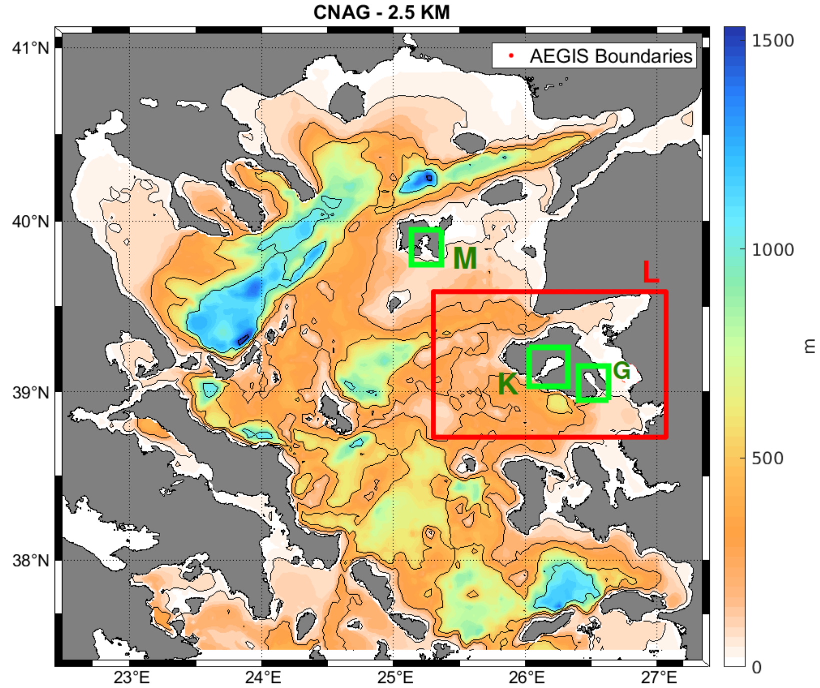

Figure 2. Geographical coverage of the four forecasting circulation models of the Observatory: The bathymetry shown corresponds to the full CNAG domain. The domain of the Lesvos sea model is shown as a red rectangular (identified by "L"), the domains of the three Gulfs (Moudros "M", Kalloni "K", Gera "G") by the green rectangulars.

using using model's native 4DVAR data assimilation scheme (Fisher *et al., 1998;* Tshimanga *et al., 2008*). The window length for each analysis cycle is 3 days and all available data per cycle from various platforms is used: Sea Surface Temperature Level 3S super – collated data (SST L3S) from the CMEMS European service, AVISO Sea Level Anomaly Level 3 swaths (SLA L3) and T/S ARGO profiles.

The wave model of our choice was SWAN (Simulating Waves Nearshore, Booij *et al.*, 1999) on the same orthogonal rectangular grid as the ROMS ocean model. For the wind input we choose exponential wind growth (Janssen *et al.*, 1991) and for bottom friction Collins *et al.* (1972) formula. For depth-induced breaking the Battjes and Janssen (1978) option is enabled and triad wave – wave interactions are simulated as in Eldeberky *et al.* (1996).

CMEMS Mediterranean Sea Waves Reanalysis (product id MEDSEA_MYLTIYEAR_WAV_006_012 – Korres *et al.*, 2021) is used combined with a JONSWAP (Hasselmann *et al.*, 1973) approximation for the ocean wave spectra for boundary conditions for the south open boundary of our computational grid.

3.2 The Lesvos sea model

The output of CNAG's forecast provides initial and boundary conditions for the Lesvos area model to produce forecasts via a 1-way offline nesting procedure employed for the dynamical downscaling to the higher spatial resolution (450 m) grid (**Figure 2**). The CNAG model provides two-dimensional wave spectra at 1-hr intervals and short spatial intervals along the south, north and west sides of the Lesvos wave model grid to be used as boundary conditions. The model setup, in terms of physics and wind input is identical with Central North Aegean's wave model setup and a 5-day forecast is produced on a daily basis.

3.3 The three semi-enclosed Gulfs models

Simulations and forecasting of the hydrodynamics of the Kalloni, Gera and Moudros Gulfs are based on the FLOW module of the Delft3D modelling system (Lesser *et al.*, 2004; Gerritsen *et al*., 2008), implemented in a 3D, σ-layer configuration. These models use curvilinear grids to achieve maximum resolution in the narrow Straits (of the order of tens of meters), while retaining reasonable simulation speeds. All three models use 15 σ layers. The biochemical module Delft3D-WAQ is being implemented on the Kalloni Gulf simulated fields.

4. Discussion

The AEGIS Coastal Environmental Observatory is a comprehensive coastal operational oceanography system providing research, monitoring and educational services. The future challenges are related to long-term funding, securing data quality through the further of regular calibration and maintenance procedures, and national / international networking.

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