EMSO ERIC, THE PAN-EUROPEAN INFRASTRUCTURE OF SEAFLOOR AND WATER-COLUMN OBSERVATORIES AROUND THE EUROPEAN SEAS, EXTENDS ITS COVERAGE TO THE ARCTIC

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Abstract

EMSO is a distributed Research Infrastructure currently comprising nine Regional Facilities (RFs) and three shallow water test sites, strategically located all the way from the southern entrance of the Arctic Ocean across to the North Atlantic through the Mediterranean to the Black Sea. Since the beginning of 2021 Norway has been integrated as a new EMSO ERIC member, extending the geographical coverage to the Nordic Sea and the Arctic. EMSO's extension will benefit from an experienced team managing moored observatories, ocean gliders and the Mohn Ridge Seafloor and Water Column Observatory.

Keywords: European Research Infrastructure, ocean observation systems, interdisciplinarity, deep seafloor and water column

1. Introduction

The European Multidisciplinary Seafloor and water column Observatory (EMSO) European Research Infrastructure Consortium (ERIC) distributed infrastructure, currently comprises of 9 Regional Facilities (RFs) and three shallow water test sites, strategically located all the way from the southern entrance of the Arctic Ocean across to the North Atlantic through the Mediterranean to the Black Sea (Figure 1). Since the beginning of 2021 Norway has been integrated as a new of EMSO ERIC member, extending the geographical coverage to the Nordic Sea and the Arctic. Other three RFs are going to be added soon, two in Italian waters and one in Greek waters. EMSO's expansion will benefit from an experienced team managing moored observatories, ocean gliders and the Mohn Ridge Seafloor and Water Column Observatory.

EMSO ERIC is in transition to implement the full operation of all services, which will be completed in 2022, with the goal to harmonize quality-controlled data, to achieve interoperability across the infrastructure and easy access for data aggregators, in the EOOS framework; to extend the infrastructure and strengthen international collaboration with special emphasis on Polar observations; to establish strong links with key marine industries.

EMSO aims at stimulating new technologies and knowledge that will promote European excellence in marine research. It sets the perspective for the position and role that EMSO ERIC must achieve in the coming years to ensure long-term sustainability of the infrastructure operations and the continuous update of its cutting-edge technology. Overall EMSO infrastructure offers scientists a powerful new tool for understanding ocean dynamics driving Earth's ecosystems and the complex forces controlling climate on a global scale, and observing natural risks such as earthquakes, tsunamis and steep-slope sliding (Ruhl *et al.*, 2011; Favali *et al.*, 2015).

2. EMSO DISTRIBUTED infrastructure around European Seas

EMSO ERIC RFs include open-ocean, water column and seafloor observatories in water depths from a few meters down to 4,850 m, and shallow-water test bed sites in the North East Atlantic and the Mediterranean Sea (Best *et al.*, 2016). Although each observatory provides essential services and products on an individual basis, but as a distributed infrastructure, EMSO has the potential to increase data availability and continuity throughout the European seas, and address broader questions. Furthermore, the integrated observatory infrastructure can enhance collaboration among the nodes to provide wider-reaching and higher-impact services.on a global scale, and observing natural risks such as earthquakes, tsunamis and steep-slope sliding (Ruhl *et al.*, 2011; Favali *et al.*, 2015).

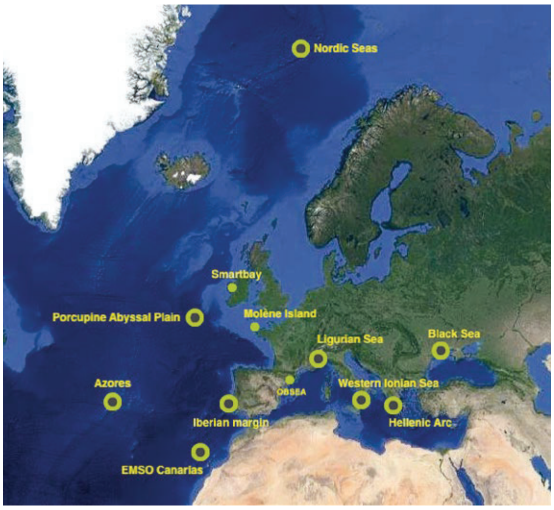


Fig. 1. EMSO Regional Facilities deep-sea observatories (empty circles) and shallow water depth test sites (solid circles).

2.1 Atlantic coverage

EMSO is moving towards site specialization at the RFs as an efficient and beneficial advance that provides added value. In the Atlantic Ocean from North to South EMSO covers key environmental areas like the newest incorporation of Norway that will fill the gap in the Nordic Seas (Figure 2), as the gate to the Arctic and a key environmental site to understand the climate system and global ocean circulation better.

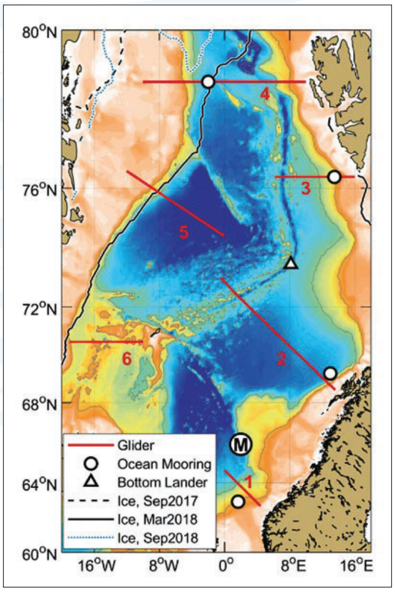


Fig. 2. Norwegian Nordic-seas RF component made up of three main components: (a) ocean gliders (tracks in red), (b) deep-sea moorings (white circles), and the Mohn deep-sea observatory (triangles) (Barreyre, Fer and Ferré, 2020).

In the Atlantic, several RFs have the capacity to record biodiversity and ecological data, for example, the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) is located at 49.0°N-16.5°W, which is about 560 km SW of Ireland, it is a place of growing interest as it has large collections of data series for interdisciplinary research and the monitoring of the functioning of the oceanic ecosystem from the surface to the seabed. Another key environmental location at the EMSO-Azores (37.5°N-33.0°W) is the Lucky Strike hydrothermal (Figure 3a) vent field at 1,700 m depth on the mid-Atlantic ridge, an exceptional place to study extreme deep-sea habitats live. These hydrothermal vent-based faunal and microbial communities can sustain vast amounts of life because by using chemosynthetic bacteria. Data are produced through several arrays of connected and autonomous sensors while the whole infrastructure comprises two seafloor junction boxes communicating with a buoy at the surface, with (near) real-time satellite data transmission from buoy to shore. A mooring equipped with autonomous sensors measuring physical parameters is deployed/recovered every year.

At the western African coast (29°10'N-15°30'W) there is the EMSO-Canarias (PLOCAN) observatory ESTOC (Figure 3b), which has over 20 years of observations. The installation includes a full depth (3,630 m) mooring with a surface buoy measuring meteorological and surface oceanographic variables.

(a)

(b)

Fig. 3. (a) EGIM deployed at EMSO-Azores (b) Mooring maintenance at ESTOC.

SmartBay is located 4.5 km east of County Galway 1.5 km offshore. A subsea cabled observatory is deployed (25 m depth) and powered by a hybrid optical/electrical cable that provide high-speed communications data. A number of autonomous sensors record physical and biogeochemical parameters along the water column from 1 to 25 m depths. The buoy also includes a meteorological station.

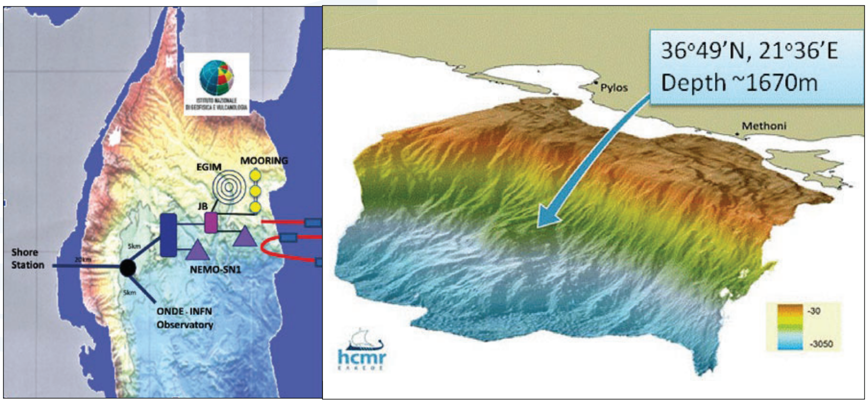
2.2 Mediterranean and Black seas coverage

In the Mediterranean and Black seas, from West to East, all of the EMSO RFs are designed for Operational Oceanography. EMSO's main scientific objective is to help scientists to understand global environmental processes by building of time-series on

EOVs and stimulating new technologies and knowledge by adopting of standards in sensors and measurement methodologies increasing interoperability (Dañobeitia *et al.*, 2020). EMSO RFs offer a wide variety of oceanographic data services as detailed in the previous section. EMSO temperature and salinity time-series data are key in the context of deep ocean processes, climate variability, at regional (Mediterranean Sea), European and global scale. Changes have been documented in the last decades in Mediterranean Sea providing evidence that the deep ocean is accumulating heat. Understanding the underlying dynamics is crucial in defining future climate variability scenarios.

Geophysical data from different type of sensors are collected at several EMSO RFs. Geo-hazards include earthquakes, tsunamis, volcanic eruptions, and landslides. These geological hazards can have a significant socio-economic impact. Most of Europe's geographical hazard data available in Europe are collected in terrestrial environments by Geological Surveys or National Geophysical Institutions. EMSO with its distributed RFs can augment with unique information in the ocean and fill the gap by developing methodologies to detect the trigger of geo-hazards and improve the capacity of early warning to mitigate the impact. The shallow water EMSO-OBSEA provides real-time seismic data, and deliver on near-real time to the National and Regional Seismic Networks. The EMSO-Ligurian cabled observatory is composed of three main locations with two cabled in open sea at Western Ligurian (2,400 m) and coastal at Eastern Ligurian (near Nice), together with a stand-alone mooring (DYFAMED).

The EMSO Western Ionian Sea (Figure 4a) is a cabled observatory that splits in two branches at 20 km off the Eastern Sicily coast down at ~2,100 m depth. The North branch hosts the geophysical and oceanographic station SN1, managed by INGV, while the South branch hosts a tetrahedral antenna of hydrophones, managed by INFN.

(a)


(b)

Fig. 4. (a) EMSO Western Ionian Sea, (b) EMSO Hellenic Arc location.

The EMSO Hellenic Arc is located in the South East Ionian Sea (Figure 4b), offshore Peloponnese, at a depth of 1670 m. It comprises of three major parts:

1. An open sea surface buoy with a 1000 m water column component;
2. An autonomous seabed platform with hydro acoustic relay to the surface buoy;
3. A cabled multidisciplinary seafloor observatory.

The EMSO Black Sea is located in a geological complex area, where three major tectonic plates (Eurasian, Anatolian, Arabian) interact. Geo-hazards, such as earthquakes, submarine landslide, displacement along active faults, are present and are possible triggers of tsunami, potential gas eruptions from sea bottom sediments. Today the system consists of three offshore moored observatories, each including underwater modules. The offshore observatories are moored 160 km from the Romanian coast at about 90 m water depth. EMSO RF delivers near real-time data on geophysical processes for scientific research purposes to databases for purposes of earthquake monitoring and academic studies.

EMSO bottom pressure data, acquired at the Western Ionian and Ligurian Seas, Azores, Hellenic arc and the Black Sea, can contribute to tsunami warning systems, particularly in the Mediterranean region. However, efforts are still requested to achieve this objective.

3. EMSO deliver services from a multinode approach

A key objective of the EMSO ERIC is to provide stakeholders with data quality with FAIR principles, based on continuous and sustained monitoring of environmental processes, and physical and virtual access to RFs. Stakeholders include marine scientists and engineers, policy makers, marine industries and the wider public. The EMSO ERIC conceptual workflow and value chain in providing high-quality multidisciplinary environmental data is shown in Figure 5.

Despite the technological developments in ocean observations, significant challenges still exist as described in OceanObs'19 white paper (Speich *et al.*, 2019). EMSO ERIC has participated in the scientific and engineering community's efforts to better establish future ocean observation requirements for future ocean observation, in particular in respect to the GOOS EOVs (Miloslavich *et al.*, 2018). Moreover, in the framework of EMSO-Link project work has focused on best practices in ocean observation (Pearlman *et al.*, 2019). EMSO ERIC has established plans for Geo-hazards, Oceanography and Climate, and Environmental Indicators workflows to support its RFs to deliver complex services and products.

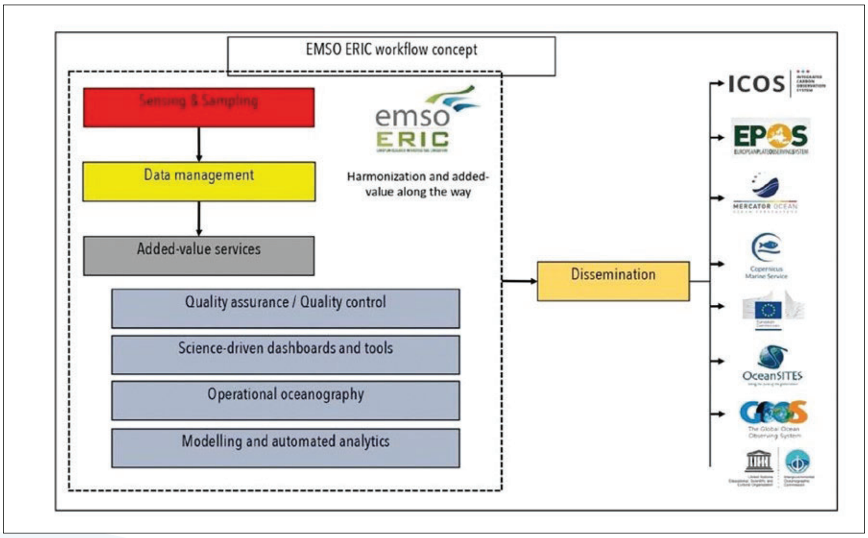


Fig. 5. EMSO ERIC conceptual workflow.

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