

# EMSO

## A Distributed Infrastructure for Addressing Geohazards and Global Ocean Change

The European Multidisciplinary Seafloor and water-column Observatory (EMSO; <http://www.emso-eu.org>) is addressing the next challenge in Earth-ocean science: how to coordinate data acquisition, analysis, archiving, access, and response to geohazards across provincial, national, regional, and international boundaries. Such coordination is needed to optimize the use of current and planned ocean observatory systems to (1) address national and regional public safety concerns about geohazards (e.g., earthquakes, submarine landslides, tsunamis) and (2) permit broadening of their scope toward monitoring environmental change on global ocean scales.

### SCOPE AND PARTNERS

EMSO is a large-scale European Research Distributed Infrastructure of the European Strategy Forum on Research Infrastructures (ESFRI) roadmap. It is composed of fixed-point, seafloor, and water-column observatories with the basic scientific objective of (near)-real-time, long-term monitoring of environmental processes across the geosphere, biosphere, and hydrosphere. This infrastructure is geographically distributed in key sites in European waters, from the Arctic through the Atlantic and Mediterranean to the Black Sea (Figure 1). EMSO ended its Preparatory Phase Project of the EU 7th Framework Programme in 2012 and is now in the Interim Phase, transitioning to the formation of the legal entity for managing the infrastructure: the EMSO

BY MAIRI BEST, PAOLO FAVALI, LAURA BERANZOLI, MATHILDE CANNAT, NAMIK CAGATAY, JUAN JOSE DAÑOBEITIA, ERIC DELORY, HENKO DE STIGTER, BÉNÉDICTE FERRÉ, MICK GILLOOLY, FIONA GRANT, PER O.J. HALL, VASILIOS LYKOUSIS, JUERGEN MIENERT, JORGE MIGUEL ALBERTO DE MIRANDA, GHEORGHE OAIÉ, VLAD RADULESCU, JEAN-FRANÇOIS ROLIN, HENRY RUHL, AND CHRISTOPH WALDMANN

European Research Infrastructure Consortium (herein, EMSO-ERIC). A phased implementation will characterize EMSO site extension, construction, and operation. Countries currently participating in EMSO are Italy, France, Ireland, Spain, Greece, United Kingdom, Portugal, Romania, Norway, Sweden,

Turkey, Germany, and the Netherlands. Participation is open to all (both individual scientists and institutions), and will be coordinated through an association called ESONET-Vi (European Seafloor Observatory NETwork—The Vision), following the extensive scientific community planning



Figure 1. Map of current EMSO nodes. Yellow dots indicate testbeds.

contributions of the ESONET-NoE FP7 project (see Priede et al., 2005; Favali et al., 2006, 2010, 2014; Ruhl et al., 2011; Person et al., 2014).

## DESIGN AND TECHNOLOGY

The most striking characteristic of observational design is that it allows addressing interdisciplinary objectives simultaneously across temporal and spatial scales. Data are collected from the surface ocean through the water column and the benthos to seafloor. Depending on the application, in situ infrastructures can either be attached to a cable, which provides power and enables data transfer, or they can operate as independent, stand-alone benthic and moored instruments. Data, in both cases, can be transmitted in real time either through fiber-optic cables or through cable and acoustic networks that are connected to satellite-linked buoys. Cabled infrastructure provides important benefits such as high power and bandwidth to support real-time data transfer for processing of large data sets (e.g., for bioacoustics and high-definition cameras), for real-time integration with land-based networks (e.g., for seismology), and for rapid geohazard early warning systems.

## RESEARCH

EMSO provides power, communications, sensors, and data infrastructure for continuous, high-resolution, (near)-real-time, interactive ocean observations across a truly multi- and

interdisciplinary range of research areas, including biology, geology, chemistry, physics, engineering, and computer science; from polar to tropical environments; and from surface waters down to the abyss. Such coordinated data allow us to pose multivariate questions in space and time, rather than focusing on single data streams (Figure 2).

In addition to generic sensors contributing to the monitoring of environmental change on global ocean scales, questions specific to each site's environment can be addressed by specific sensor modules set up in varying combinations depending on objectives for the site (Ruhl et al., 2011). For example, for geohazard early warning capability, measuring seismic motion, gravity, magnetism, seafloor deformation, sedimentation, pore-water properties, gas hydrates, and fluid dynamics all at once results in a more comprehensive understanding of the system than would more isolated measurements (e.g., Monna et al., 2014; Sgroi et al., 2014, in this issue). Many physical and biological applications require instruments throughout the water column for recording high-resolution time-series data over long periods. Depending on the specific application, these data can be drawn from profiling sensor arrays, sensors placed along mooring lines, or even mooring arrays. Such systems can, for example, detect variations in deep ocean currents and in the surface ocean or the bottom boundary layer. These

specialized systems can include the capability to synoptically measure physical parameters such as temperature, salinity, and current velocity, and biogeochemical and ecological parameters such as concentrations of oxygen, nutrients, chlorophyll, and pH. Other more specialized biogeochemical systems include sediment traps, pigment and hydrocarbon sensors, and in situ mass spectrometers. Systems for marine ecological research include time-lapse and video imaging, active acoustic recording, plankton sampling, holographic plankton imaging, in situ respiration measurements, and in situ molecular and genetic analysis.

## DATA

Continuous data are required to document episodic events, such as earthquakes, submarine slides, tsunamis, benthic storms, biological community shifts, pollution, and gas hydrate release. Long-term time series are relevant for monitoring global change. EMSO provides pan-European power, communications, sensors, and data infrastructure for continuous, high-resolution, (near)-real-time, coordinated, interactive ocean observations that allow the scientific community to address these challenges. It not only brings together countries and disciplines, but also allows pooling of resources and coordination for assembling harmonized data into a comprehensive regional ocean picture that EMSO will then make available to researchers and stakeholders worldwide on an open access and interoperable basis.

## GLOBAL CONTEXT

EMSO is the European counterpart to similar large-scale systems in various stages of development around the world (see Favali et al., 2010): United States (Ocean Observatories Initiative; <http://oceanobservatories.org>), Canada (Ocean Networks

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**Mairi Best** ([mmrbest.interimoffice@emso-eu.org](mailto:mmrbest.interimoffice@emso-eu.org)) is *Ocean Observatory Consultant*, **Paolo Favali** is *Coordinator*, and **Laura Beranzoli** is *Program Manager*, all at the *European Multidisciplinary Seafloor and water column Observatory (EMSO) Interim Office, Rome, Italy*. **Mathilde Cannat** (France), **Namik Cagatay** (Turkey), **Juan Jose Dañobeitia** (Spain), **Eric Delory** (Spain), **Henko de Stigter** (The Netherlands), **Bénédicte Ferré** (Norway), **Mick Gillooly** (Ireland), **Fiona Grant** (Ireland), **Per O.J. Hall** (Sweden), **Vasilios Lykousis** (Greece), **Juergen Mienert** (Norway), **Jorge Miguel Alberto de Miranda** (Portugal), **Gheorghe Oaie** (Romania), **Vlad Radulescu** (Romania), **Jean-François Rolin** (France), **Henry Ruhl** (UK), and **Christoph Waldmann** (Germany) are all *coordinators for EMSO partners*.

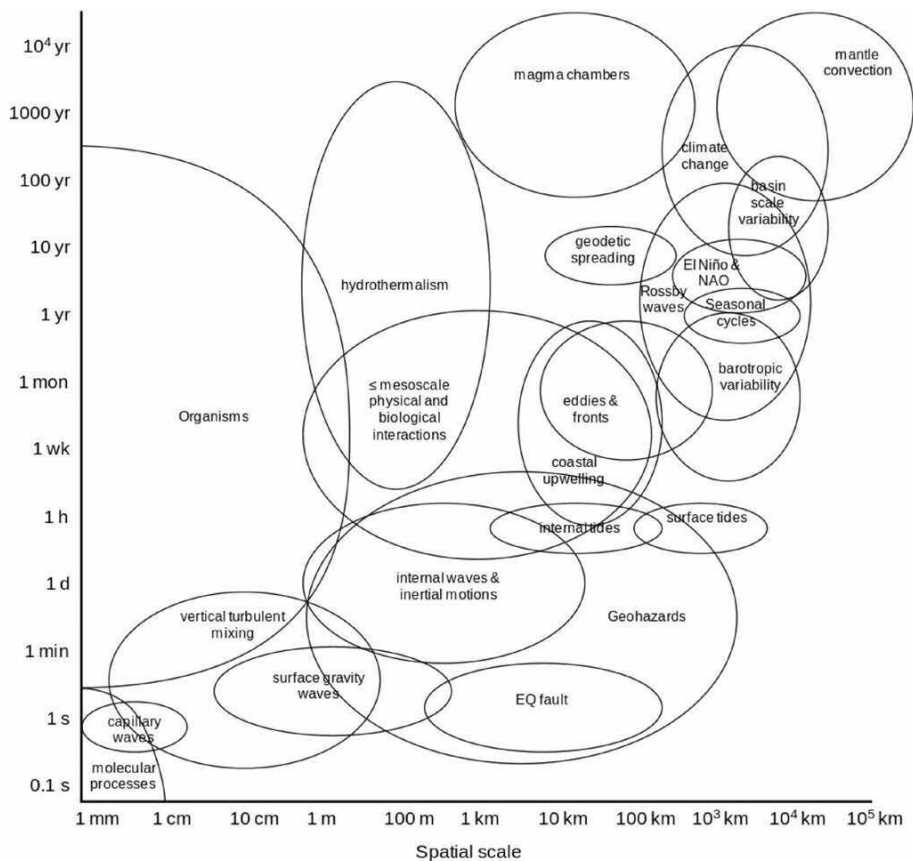



Figure 2. Temporal and spatial scales of ocean processes. From Ruhl et al. (2011)

Canada; <http://oceannetworks.ca>), Japan (Dense Oceanfloor Network System for Earthquakes and Tsunamis; <http://jamstec.go.jp/donet>), China (East China Sea Seafloor Observation System), Australia (Integrated Marine Observing System; <http://imos.org.au>), and Taiwan (Marine Cable Hosted Observatory; <http://scweb.cwb.gov.tw/macho-web>). Compared to above-mentioned national initiatives, EMSO has the challenge of dealing with harmonizing the different research interests and governmental regulations of several European nations. The experience gained within EMSO in transcending national boundaries provides valuable experience for further integration of the various ocean observation systems around the world into a single powerful integrated global ocean network.

## ACKNOWLEDGMENTS

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