SUBSEA OBSERVATORIES IN EUROPE: A LARGE RESEARCH INFRASTRUCTURE

Jean-François Rolin, Fiona Grant (Irish Marine Institute), Mick Gillooly (Irish Marine Institute), Paolo Favali (Istituto Nazionale de Geofisica i Vulcanologia), Nick O’Neill (SLR Consulting), Roland Person.
Email: <jrolin@ifremer.fr>
IFREMER / Centre de Brest BP 70 – 29280 Plouzané – France.

Abstract: The projects co-funded by the European Commission are preparing the construction of cabled observatories on key sites of scientific interest of the European ocean margins. The network of excellence ESONET joins the efforts of more than 200 scientists and demonstrates monitoring in the deep seas at 11 locations from Mediterranean sea, North-East Atlantic Ocean (Azores, Porcupine and Norwegian Sea) to the Arctic Sea.

The Preparatory Phase of a large research infrastructure called EMSO is performed by a consortium of scientific institutes representing their national funding agencies. It includes studies on governance, legal, financial, sea intervention logistic and technical aspects. EMSO is in the roadmap of large research infrastructures of the European Commission. A dedicated legal entity under a new European law is liable to be constituted.

The collaboration with similar infrastructures in North America and East Asia intends to address:
- Standardization of sensor interfaces
- Data exchange format
- Quality control procedures
- Procedures for deep-sea intervention
- Tests and calibration procedures
- Production of documents for diffusion towards the public to promote deep-sea observatory sciences (TV films, public conferences…).

1. INTRODUCTION

Research in Europe has been for a long time based on large infrastructures open to international collaboration. CERN for instance is the reference of a successful enterprise of knowledge acquisition, innovations in many disciplines and of how science may be active to participate to improve international relations and peace.

This model is now applied to the deep sea environment long term observatories, where subsea cables will play the role of a “backbone”.

The EMSO (European Multidisciplinary Subsea Observatory) research infrastructure preparatory phase is underway. It will meet the needs of a wide networked community built around ESONET Network of Excellence. The interests for this field of subsea observatories have been shown by a large group of stakeholders as demonstrated by a recent VISO workshop in Tromsø.[1]

2. DEEP SEA IN THE EUROPEAN RESEARCH INFRASTRUCTURE ROAD MAP

Europe, through the development of ocean observatory infrastructure will have the capacity to competitively deliver deep-
ocean data, knowledge, and services internationally. The European Union has been supporting deep-ocean scientific research for decades. Consecutive EU Framework Programmes have invested in the successful integration of the geoscience, physical oceanography, biogeochemistry, and marine ecology research community. The same programmes also invested through competitive calls in the standardisation of deep-ocean observatory infrastructure, protocols, data management and interoperability (GEOSTAR, ALIPOR, ASSEM, ORION, EXOCET/D). In Europe the effort to investigate a seafloor observation infrastructure was first supported by EU through ESONET-Concerted Action (European Seas Observatory NETwork-CA) followed by the European Seas Observatory Network Implementation Model [2]. Then the ESONET-NoE was created aiming at integrating together the community selected by the previous calls and interested in multidisciplinary ocean observatories.

The implementation of the European Strategy Forum for Research Infrastructures (ESFRI) Roadmap projects for the construction (or major upgrade) of research facilities of pan-European interest has led to increased attention to studies measuring the scientific, social and economic benefits deriving from these infrastructures. The disciplines related to environment and more particularly those dealing with marine sciences are not as accustomed as other disciplines such as physics to build trans-national infrastructures in common for long term operation. It is a challenge that EMSO as other projects of the first group of ESFRI Preparatory Phases is targeting to win.

EMSO Preparatory Phase (PP) project aims at establishing the legal entity charged of the construction and management of the observatory infrastructure. It includes studies on governance, legal, financial, sea intervention logistic and technical aspects. Several EC funded research projects are running in association with the ESONET NoE and EMSO(HERMES, HERMIONE, MERSEA, NEAREST, SeaDataNet, EuroSITES, HYPOX, MyOcean, KM3Net Design Phase). The projects have many participants in common. These efforts have demonstrated the maturity of the scientific case: the seas around European continent and islands provide the opportunity to address key scientific topics. It is worth developing an ocean observatory infrastructure to provide also obvious services to society such as environmental monitoring and earthquake and tsunami early warning systems.

It is now recognized that EMSO infrastructure will be a marine segment for in-situ measurements of the Global Monitoring for Environment and Security (GMES) and Global Earth Observation System of Systems (GEOSS) initiatives and will contribute to the provision of information on global change, natural hazards and sustainable management of the European Seas.

One of the Core Services of EMSO is defined as the capacity to deliver basic, established, standardized, data products and data services that will be provided on an operational basis by future operational deep-ocean observatories to international agencies responsible for Earth monitoring. It will feed into GEO, and other organizations to form and revise policy and legislation. The strategy of the European Union provides a major driver for EMSO and a schedule of implementation. EMSO open seas and margins seafloor data are needed to build the program of the Marine Strategy Framework Directive [3] before 2014 and operate the prescribed monitoring to ascertain a good environmental status from 2014 over to 2020.
It will provide the reference observation of eulerian (fixed) data away from the coast and should provide verification of the consistency of the oceanographic modelling of GMES.

The EMSO infrastructure is also the natural partner to ICG/NEAMTWS (Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected Seas) providing earthquake monitoring in marine seismogenic areas not covered at present by observations and accurate seafloor pressure sensors for real-time warning of tsunami. For example one of the ESONET/EMSO sites is in the Sea of Marmara, which connects the Black Sea to the Mediterranean south of Istanbul, Turkey. The site monitors underwater seismic activity and ESONET researchers will try to determine a possible link between seismicity and fluid expulsion along the North-Anatolian Fault (running through the Sea of Marmara), which triggered several devastating earthquakes in the recent past (1999 $M_W$ 7.4 Izmit and $M_W$ 7.2 Duzce earthquakes). Other sites are the Gulf of Cadiz where tsunamigenic earthquakes threaten the Portugal, Morocco and Spanish coast as in 1755 and Sicily, bearing in mind the volcanic activity and past seismic events (Catania, 1693; Messina, 1908).

### 3. LEGAL OPTIONS – ERIC REQUIREMENTS FOR EMSO

In order to support the development of new Research Infrastructures, a new legal framework was adopted by the European Council in May 2009 which will facilitate the setting up of a number of projects on the ESFRI Roadmap – a legal framework for a European Research Infrastructure Consortium (ERIC). The principal task of an ERIC is to establish and operate a research infrastructure. An assessment of European legal structures concluded that an ERIC is currently deemed the most suitable legal form for EMSO to adopt.

### 4. CURRENT AND PLANNED EMSO INFRASTRUCTURE

Eleven ESONET sites have been selected for their scientific, technological and socio-economic interests. The proposed network stretches from the Arctic Ocean near Svalbard to the mid Atlantic Ridge, and eastward through the Mediterranean to the Black Sea (see Figure 1).

![Figure 1 EMSO PP proposed sites](image)

**Figure 1 EMSO PP proposed sites (larger dots are corresponding to places of Demonstration missions underway).**

The network of proposed sites monitors abyssal plains, open slopes, seamounts, canyons, ridges, faults, fluid seeps, hydrothermal vents, gas hydrates, mud volcanoes, deep-sea corals, carbonate mounds, and marine areas affected by geohazards (earthquakes, tsunamis, volcanoes and slope instabilities). The sites also span the major biogeochemical provinces found in European waters. The modular design has two fundamental components with one addressing core services, which includes supplying data on standard generic physico-chemical parameters and another that incorporates the appropriate site specific data services such as seismic, biogeochemical fluxes, or faunal abundances.
The ocean observatories will use other supporting data including satellite oceanographic data, climatic data, air-sea interface data, and the known distribution and abundances of marine fauna. Exploiting the yearly maintenance cruises, the ROV and mobile systems like autonomous underwater vehicles (AUVs) will greatly improve the potential of an observatory. In situ infrastructures include sensors and samplers attached to seafloor cables, communicating moorings and communicating benthic stations. Seafloor cables provide substantial power and bandwidth for data transfer, and provide highly accurate time synchronization and real-time shore-side alerts to episodic events, such as seismic activity. Connected moorings provide a critical link to the water column that connects surface conditions to the solid Earth. Together these platforms provide a wide-ranging view of ocean dynamics over time. The modular and expandable network is adaptable and can also support highly specialized monitoring and experimental systems as needed.

The current infrastructure at each site on Figure 1 is listed hereunder:

**Arctic**

Hausgarten site is a deep sea observatory visited each year by German scientists. It is at the verge of the ice cover of the Arctic in Summer season. 15 permanent sampling sites are monitored along a depth transect from Vestnesa Ridge to the Molloy Hole (1000-5500m) using moorings and long-term lander systems since 2000. The Arctic (AOEM) Demonstration Mission of ESONET is integrating two experiments with long term observation potential. One of them monitors the whole Fram Strait with moorings, acoustic tomography and gliders. The other one, co-funded by Statoil-Hydro is performing a minimum of 2 years deployment to monitor rates and processes of Arctic methane dissociation in the same area.

**Norwegian**

The Snøhvit gas production field operated by Statoil-Hydro is equipped with a junction capacity for a scientific monitoring node several kilometres away. Haakon Mosby Mud Volcano is a unique fluid flow area. It is monitored by LOOME, an ESONET Demonstration Mission.

**Celtic**

EuroSITES deployed a stand-alone observatory on Porcupine Abyssal Plain. Since 2002, a mooring has been in place with sensors taking biogeochemical and physical measurements of the upper 1000m of the water column. Some of these data are transmitted in near real-time via satellite. It is the site of the MODOO ESONET Demonstration Mission. Cold coral sites are under study by HERMIONE and CORALFISH projects. SmartBay coastal observatory provides potential for onshore infrastructure, IT equipment, local data archive, personnel and associated expertise that may be in place from 2011 at Marine Institute.

**Azores**

The MoMAR scientific team was constituted in 1998 for the study and Monitoring of the Mid Atlantic Ridge hydrothermal site south of Azores. It organized one or two scientific cruises each year since 2006. The mapping of the Lucky Strike vent field area was performed at a decimetric scale with Victor 6000 ROV. Since 2006, the observatory included sismometers, temperature, pressure, current measurements. A camera and a chemical analyzer were also deployed during two years during the EXOCET/D project. MoMAR-D is a Demonstration Mission of ESONET. It deploys more instruments and will transmit data in near-real time through acoustic links, a buoy and satellite communication.
**Iberian**

The area is the Gulf of Cadiz (Portugal) in which the destructive and tsunamigenic 1755 earthquake occurred destroying Lisbon. During The EC NEAREST project, GEOSTAR was installed in August 2007 south-west of Cape St. Vincent at over 3200 m water depth and recovered in August 2008. In this experiment, GEOSTAR was equipped with geophysical instruments and oceanographic instruments, and with a new prototype of “tsunameter”. The tsunami meter is based on a double check of seismic and pressure signals and keeps into account the seafloor movements.

The infrastructure (seafloor observatory and surface buoy) was re-deployed to continue the experiment in the same site in November 2009 using the new Spanish ship, R/V Sarmiento de Gamboa, thanks to LIDO Demonstration mission of ESONET. Bio-acoustic issues are considered with antenna for mammal tracking.

**Ligurian**

The Var canyon is under monitoring with a communication link through a buoy since 2005. The unstable slope offshore Nice airport is under monitoring by a piezometer using a stand alone SEAMON station. The Dyfamed site has been monitored for a decade, it is a reference site for the validation of satellite sensors by European Space Agency.

The ANTARES neutrino telescope cabled site south of Toulon has been able to measure currents, temperature, acoustic and optical parameters during the past 5 years. A junction box is under construction in order to provide an Earth-Sea science extension 500m away in the vicinity of Antares. It is designed according to several of the ESONET label requirements. The Cabled observatory Test Demonstration of ESONET will use this infrastructure in 2010.

**Sicily**

The NEMO-SN1 seafloor observatory is connected to the Shore Station, a laboratory located in the harbour of Catania, by electro optical cable. (NEMO is a neutrino telescope infrastructure) The cable lies for 20 km towards East and then is split into 2 branches (5 km each): northern and southern. It is operating in real time since 2005 and is the first operative node. Northern branch is equipped with geophysical and oceanographic sensors and it is integrated in the Italian land-based networks, transmitting data in real time to the National Seismological Service Centre, in Rome. Southern branch hosts an acoustic station, equipped with hydrophones that characterise the acoustic environmental noise and records the “voices” of marine mammals. NEMO-SN1 is also a test site for the realisation of underwater neutrino telescope. Starting from April 2008, NEMO-SN1 was recovered and has been refurbished, adding sensors and functionalities, particularly taking into account geo-hazards, including sensors for tsunami prone signal detection, and bio-acoustics. The re-deployment and re-connection to the cable is planned early 2010. These activities are performed in the frame of the PEGASO project funded by “Regione Siciliana”, and the LIDO Demonstration Mission funded by ESONET-NoE. The test Demonstration of Esonet will use this site for interoperability tests in 2010.

**Hellenic**

A complete survey of the West Peloponese site was performed.

A stand alone station manufactured by Fugro-Oceanor is operated by HCMR for monitoring, it is integrated in the Poseidon data processing.. The NESTOR (neutrino telescope infrastructure) cable is announced to be soon in operation.

**Marmara**

In 2008 the Marmara Demonstration Mission was approved in the framework of ESONET-NoE. This DM entitled “Multidisciplinary Seafloor Observatories for Seismogenic Hazards Monitoring in the Marmara Sea” aims at contributing to the
establishment of optimized permanent seafloor observatory stations for earthquake monitoring in the Marmara Sea. A multidisciplinary seafloor observatory (SN4,) was deployed in October 2009 in the eastern part of the sea at the westernmost end of the fault rupture caused by the 1999 Izmit earthquake using the oceanographic vessel R/V Urania. Other devices were deployed like pore pressure sensors and bubble imaging station. Their major scientific goal is to contribute to the knowledge on the relationship between gas seepage and earthquake occurrence. KOERI institution has contracted Guralp to install four cabled observatories for seismic monitoring.

**Black Sea**

Cruises deploying landers and cooperation between oxygen depletion phenomenon specialists are planned within EC funded project HYPOX (2009-2012).

The eleven ESONET sites were assessed based on their defined architecture; maturity of planning; identified stakeholders, number of European countries supportive of the site and funding commitments.

Over the course of the next five years (see Figure 2), many sites will become fully operational as part of EMSO. Partners will build on projects and infrastructure already in-situ, by the deployment of stand-alone systems, extensions to cables currently in place, and by the deployment of new cabled systems. The timing and order in which each site will be developed will be dependent on partners and Member and Associate State ability to access a combination of national, European and Structural funding, and some anticipation capacity gained through European Investment Bank financial products.

![Figure 2: Estimated construction and operational costs across the 11 ESONET/EMSO sites for the first 5 years.](image)

**5. PHASED PROGRAMME OF IMPLEMENTATION**

Within FP7 the EMSO-Preparatory-Phase was launched in April 2008, to design and create the legal and organizational structure to coordinate the financial effort of the Member States in charge of managing EMSO. A coordinated phased implementation of the eleven sites can now start, taking into consideration the commitments and scientific interests already expressed through the regular
cruises or cabled sites, the concerted actions and the network of excellence. Each site will be progressively upgraded to a real-time observatory in a segmented manner. Preliminary scenario of planned development (used for the cost analysis and advisory meetings) is established, a large proportion of the infrastructure budget is dedicated to cable laying and operation and deep-sea underwater intervention.

6. INTERNATIONAL COMMITMENTS

The collaboration with similar infrastructures in North America and East Asia ([4],[5],[6]) intends to address:
* Standardization of sensor interfaces
* Data exchange format
* Quality control procedures
* Procedures for deep-sea intervention
* Tests and calibration procedures
* Production of documents for diffusion towards the public to promote deep-sea observatory sciences (TV films, public conferences...).

The constitution of an International Association of Subsea Observatory Operators is underway.

7. CONCLUSION

It is likely that the EMSO observatory infrastructure will be among the first marine environment research infrastructures in Europe meeting the criteria of an open access long term operation.

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9. REFERENCES


