Applications of Cabled Observatories to Earthquake and Tsunami Research and Early Detection: Experience from Canada and Europe.

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“The last century of oceanography is marked most by the degree of undersampling” Walter Munk (2001)
Florida Population and Major Hurricanes

Category 3, 4 and 5 Major Hurricane Strikes in Florida

Millions of Coastal Residents

Decade

Projected
Challenges

• range of spatial and temporal scales at which processes occur

• their complex interconnectedness,

• and in many cases their catastrophic episodicity.
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cabled ocean observatories offer:

- 24/7/365/25 presence, variety of sensors, selected locations
- Sampling frequencies of subseconds for most parameters
- Real-time multidisciplinary, interactive experiments

All this is possible with:

- Abundant power (up to 9kW) and high bandwidth (up to 4 Gb)
- Remote control of observatory network and instruments
- Real-time high data/imagery return
- A vast interactive data archive
Cabled Ocean Observatories around the World: Power and Internet to the deep sea
Ocean Networks Canada
Internet controlled mobile seafloor observations on temporal and spatial variations around gas hydrates

Thomsen, Barnes, Best, Chapman, Pirenne, Wagner and Vogt 2012
Internet controlled mobile seafloor observations on temporal and spatial variations around gas hydrates, Geophysical Research Letters.
COVIS – Grotto Vent, Endeavour Ridge

Earthquakes in western Canada
Power Spectral Density of Land vs. Seafloor Seismometers
Calm vs. Stormy
Tsunamis

Thomson et al. 2011 – Samoan tsunami
Chilean Tsunami and Seismic waves on NC BPR sensors

Realtime crustal fluid changes, Abyssal Plain (ODP 1026B) @ 1Hz

Tides: 12-25 hr period

Infragravity waves: 2 min period

Ocean surface waves: 7 s period

Tsunamis: 15 min period
Info available though oceannetworks.ca and ibook
Data available publicly through ONC Oceans 2.0 and IRIS
EMSO, an ESFRI Research Infrastructure

EMSO, a Research Infrastructure of the ESFRI Roadmap, is the European network of fixed seafloor and water column observatories constituting a distributed infrastructure for long-term monitoring of environmental processes, including geo hazards.
The EMSO-ERIC (European Research Infrastructure Consortium) will be the legal entity in charge of coordinating the distributed research infrastructure.
EMSO nodes: present status

**INFRASTRUCTURE** SEAMON nodes, two stand-alone acoustic observatories and their transmission BOREL buoy are operating since ESONET demo mission (MoMAR, Monitoring MidAtlantic Ridge) in 2010.

**RESEARCH** Lucky Strike hydrothermal vent field, geophysical movements of Earth (seismicity and vertical deformation); water, heat and mineral flow through vent system; behaviour of physical and chemical elements in vent fluid; variations in biogeochemistry and the ecological hotspots in vicinity of vents.

**PREVIOUS/RECENT ACTIVITIES** Mid-Atlantic Ridge work part of the InterRidge programme, MarBEF-DEEPSETS, HERMIONE, and Coralfish programmes among others; site of the ESONET demonstration mission Monitoring the Mid-Atlantic Ridge, MoMAR.

**FUTURE ACTIVITIES** Yearly maintenance is scheduled for the next 5 years. Data transmission to shore through the buoy. New generation of stations planned for 2015.
EMSO nodes: present status

**INFRASTRUCTURE** GEOSTAR observatory, seafloor station with acoustic connection to a surface buoy and satellite connection from buoy to shore.

**RESEARCH** Eurasian and African plate boundary off Portuguese coast, Mud volcanoes, pockmarks, mud diapirs, carbonate chimneys, hydrocarbon venting and faulting; prototype tsunami meter; passive acoustics related to marine mammals and anthropogenic noise.

**PREVIOUS/RECENT ACTIVITIES** part of HERMIONE research; NEAREST and NEAMTW geo-hazard early warning efforts; ESONET demo mission Listening to the Deep Ocean environment (LIDO); near real-time data transmission through acoustic link from seafloor observatory to surface buoy and through satellite link from buoy to shore based on GEOSTAR platform;

**FUTURE ACTIVITIES** Installation of an observatory starting in 2013, with communication by satellite link, in the same site or a neighbouring place.

Gulf of Cadiz
85 km off-shore
3200 m w.d.
EMSO nodes: present status

Nice slope is planned to be cabled in 2014, Var canyon will be monitored by stand alone stations again in 2013.

**INFRASTRUCTURE**  
East Ligurian sea: a) DYFAMED (DYnamics of Atmospheric Fluxes in the MEDiterranean Sea); b) Var canyon monitoring; c) Nice slope monitoring of geohazard;  
West Ligurian Sea: ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch) Earth-Sea science extension of astrophysics underwater telescope  

**RESEARCH** coastal upwelling, particle plumes, nutrient benthic exchange, bottom boundary layer processes, seismic monitoring; sub-sea geophysics; slope stability; biogeochemical fluxes and marine ecology  

**PREVIOUS/RECENT ACTIVITIES** EuroSITES, JGOFS, International Ocean Drilling Program (IODP)  
**FUTURE ACTIVITIES** Stand-alone observatory at Nice (Var-Dyfamed) area from 2012 to 2016. Cabled extension of ANTARES/KM3NET cable from 2010. New cable with two nodes.
**EMSO nodes: present status**

**INFRASTRUCTURE** NEMO-SN1 seafloor observatory, cabled to laboratory in the harbour of Catania by electro-optical cable

**OPERATING IN REAL TIME SINCE 2005** Integrated with land-based networks by transmitting real-time data to National Seismological Service Centre in Rome; Test site for realisation of the underwater neutrino telescope

**RESEARCH** Geohazards, tsunami, climate change, bioacoustics and ambient noise.

**PREVIOUS/RECENT ACTIVITIES** LAMS and SIRENA FESR projects (national), GNDT-SN1 (national), PEGASO project (Structural funds), ESONET demo missions (LIDO, Listening to the Deep Ocean environment), GENESI-DEC, SCIDIP-ES (FP7 infrastructures), KM3NET, TRANSFER

**FUTURE ACTIVITIES** Extension of the Catania 30-km cabled; Off Capo Passero 100-km cabling, it has been operating from 2011; Further implementation adding water column and data management
EMSO nodes: present status

INFRASTRUCTURE Cabled system NESTOR, Stand alone Poseidon Pylos and Poseidon E1-M3A (35°06'N, 24°09'E), Proposed drilled observatory BUTT

RESEARCH Geohazards, tsunami, climate change, bioacoustics and ambient noise, biogeochemical fluxes, benthic-pelagic interactions; benthic respiration; biogeochemical fluxes; photography-based ecology; seabed methane fluxes; oil and gas industry activities

PREVIOUS/RECENT ACTIVITIES EuroSITES, IODP, HERMES-HERMIONE, SEAHELLARC, TRANSFER, KM3NET
Continuity of stand-alone observatory over to 2014.

FUTURE ACTIVITIES Implementation of a new cabled observatory within the frame of EMSO (EMSO-Hellenic) near Poseidon-Pylos site (about 15km from shore and in 1600m depth) with equipment according to ESONET standards. Project funded by the Greek government (EMSO contribution).
Estimated budget 3.7MEuro (2012-2015).
**EMSO nodes: present status**

**INFRASTRUCTURE** Five cabled observatories are under test after deployment. They include seismometers, accelerometers, current-meters and temperature sensors.

**RESEARCH** Regular tectonic activity because of its location on the North Anatolian Fault; Natural gas fields with hydrocarbon seeps on seafloor from the fault; relationship between gas seepage and earthquake occurrence; pore pressure, bubble detection.

**PREVIOUS/RECENT ACTIVITIES** Research and monitoring activities under ESONET demo mission (Marmara-DM) with several cruises and sensor deployments, including the deployment of SN4 multidisciplinary seafloor observatory during 2009-2010 in eastern part of the fault that ruptured during the 1999 Izmit earthquake, and deployment of bubble observatory, piezometers and OBSs.

**FUTURE ACTIVITIES** Design of the future multi-disciplinary cabled observatory in three locations along fault.
Example: Western Ionian Sea (East-Sicily)

Core infrastructures realised by INFN
Funds by EU, Regione Sicilia and MIUR

Catania Test Site:
25 km East offshore the Catania harbour, > 2000-m depth – EMSO module

Capo Passero Site:
85 km South East offshore Capo Passero, 3500-m depth
SN1 Upgrade - 2012

Cable interface
OAS hydrophone
APG
CTD
Gravity meter
SMID hydrophone
Bioacoustic bentosphere
3-C current meter
ADCP
Broad-band seismometer
Scalar & Vectorial magnetometers module

2002-3 Autonomous data
2005-8 Real-time data transmission
Fluxgate Data from 8.00 of 9 Jun to 7.59 of 10 Jun 2012 (24h)

Vect. magnetometer
10/06/2012 (24h)

Local event (M 2.2)
20/06/2012 - Ionian Sea

Regional Event (M 6.0)
10/06/2012 - Greece

Temperature (°C)

Conductivity

Pressure (dBar)

CTD 12-14/06/2012
SN1 1\textsuperscript{st} stand-alone experiment 2002-2003

East Sicily seismicity not-recorded inland

213 events

Mt. Etna bilateral eruption

Southern Calabria

Continental-ocean boundary

Malta Escarpment

Deep Ionian Basin (subduction)

Sgroi et al., 2007
http://www.emso-eu.org
Real Challenge

Integrating

• Hardware
• Software
• and People

Networks