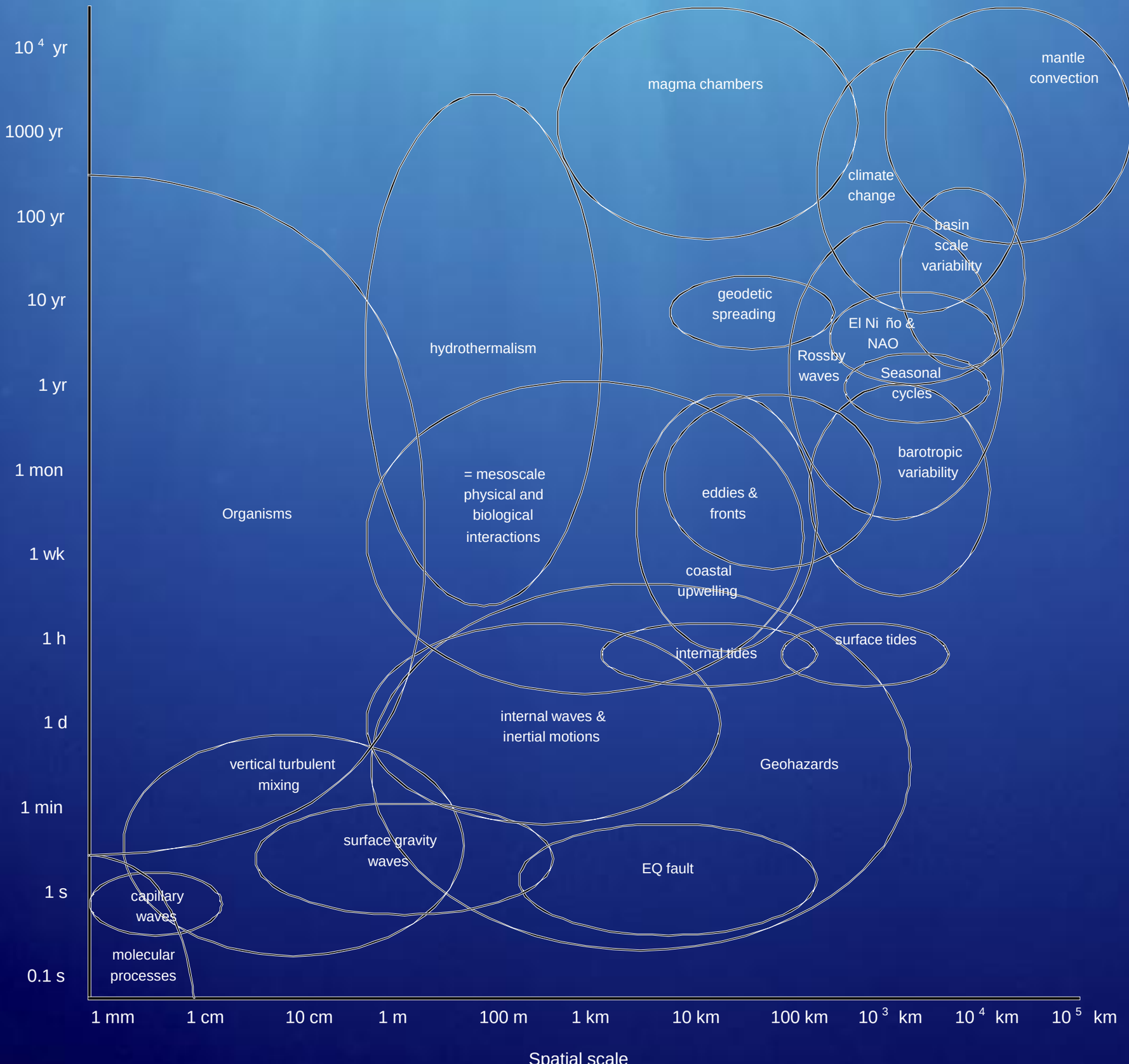
Applications of Cabled Observatories to Earthquake and Tsunami Research and Early Detection:

Experience from Canada and Europe.

Dr. Mairi Best,
Founding Associate Director Science, NEPTUNE Canada
Ocean Observing Consultant to EMSO

"The last century of oceanography is marked most by the degree of undersampling" Walter Munk (2001)

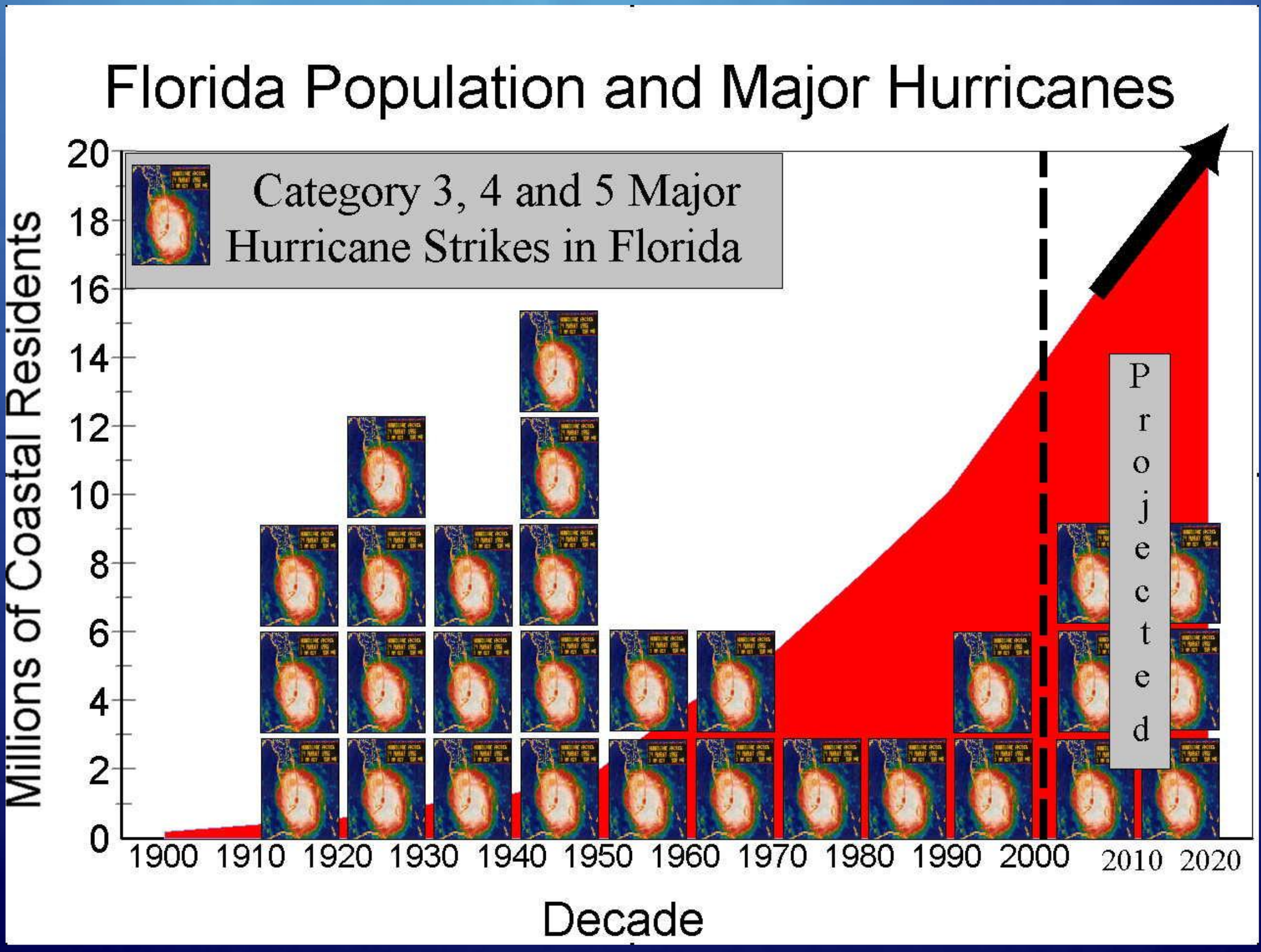
Temporal and Spatial Scales



Ruhl et al., 2011

Catastrophic Episodicity

aoml.noaa.gov



Challenges

- range of spatial and temporal scales at which processes occur
- their complex interconnectedness,
- and in many cases their catastrophic episodicity.

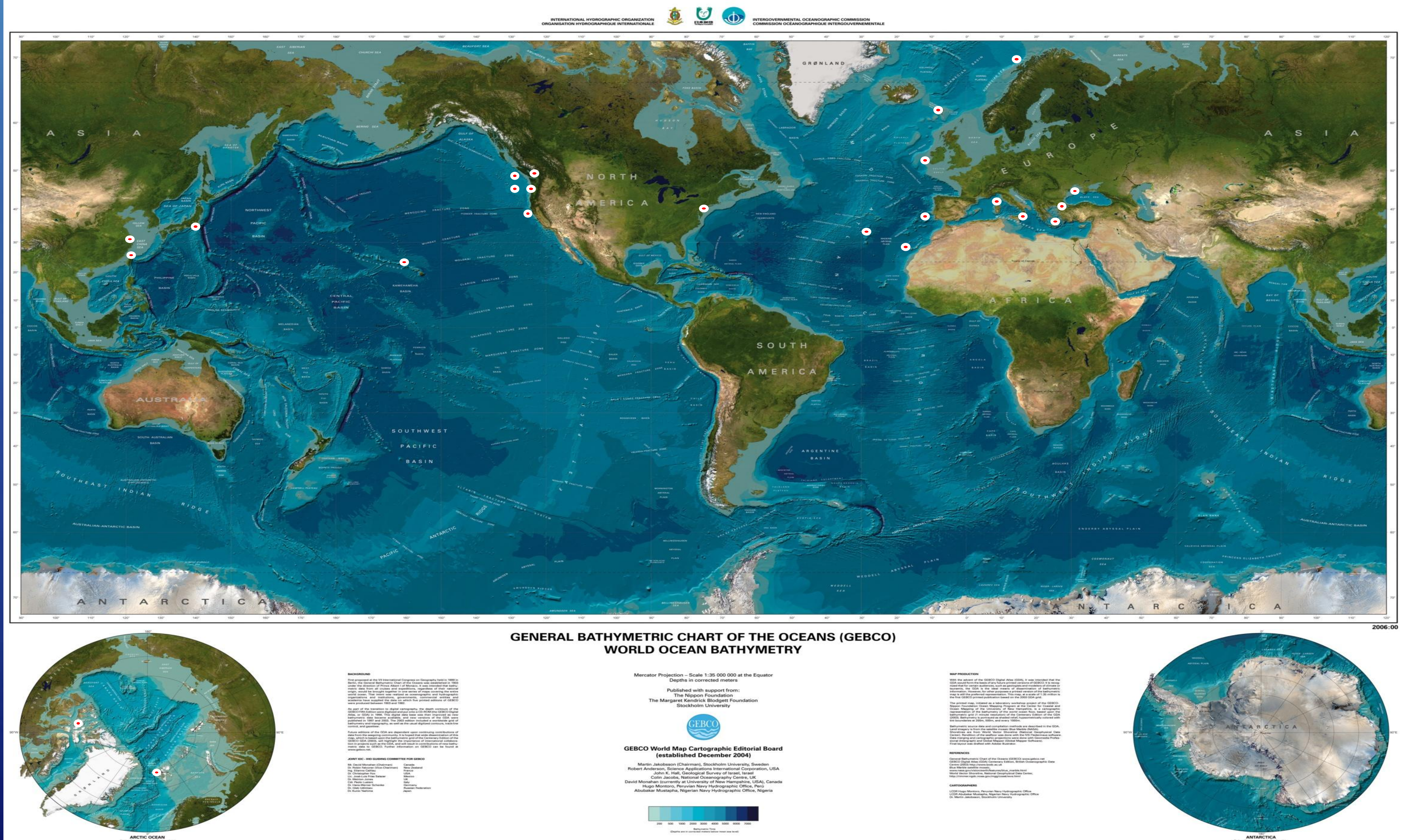
“The last century of oceanography is marked most by the degree of undersampling” Walter Munk (2001)

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



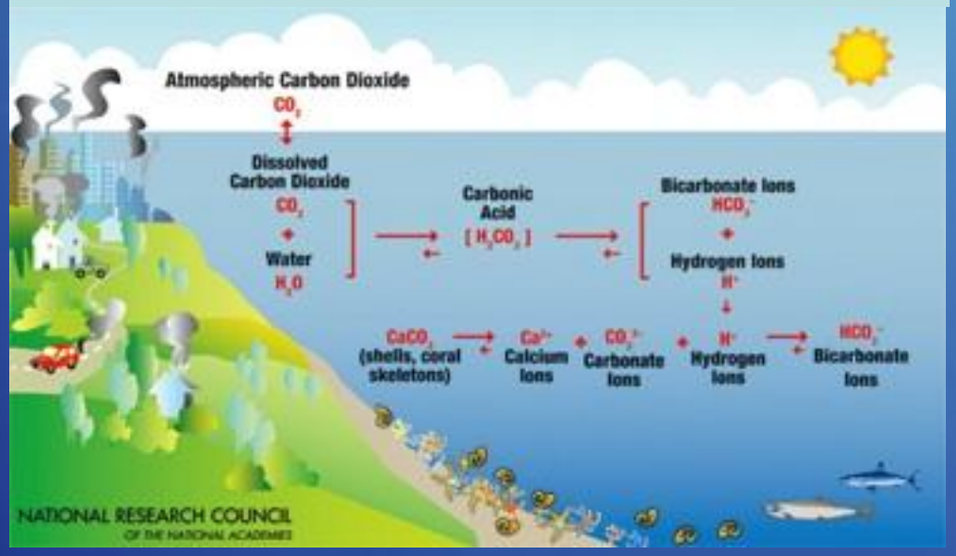
Cabled Ocean Observatories around the World: Power and Internet to the deep sea

OCEAN NETWORKS CANADA
EXPLORATION·INNOVATION·ACTION
For a Changing Planet
A University of Victoria Initiative

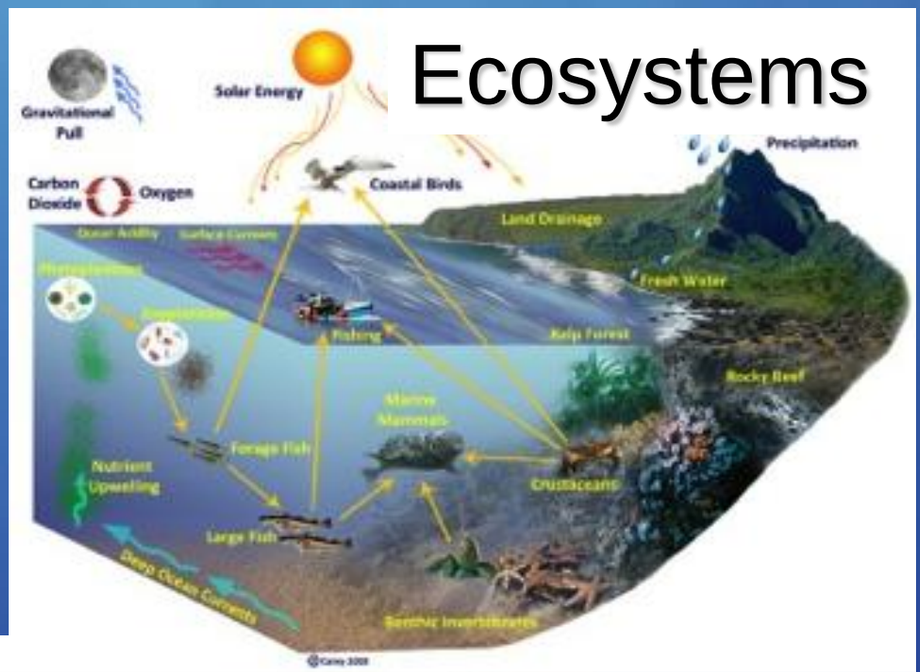
Ocean Networks Canada

Enabling Science

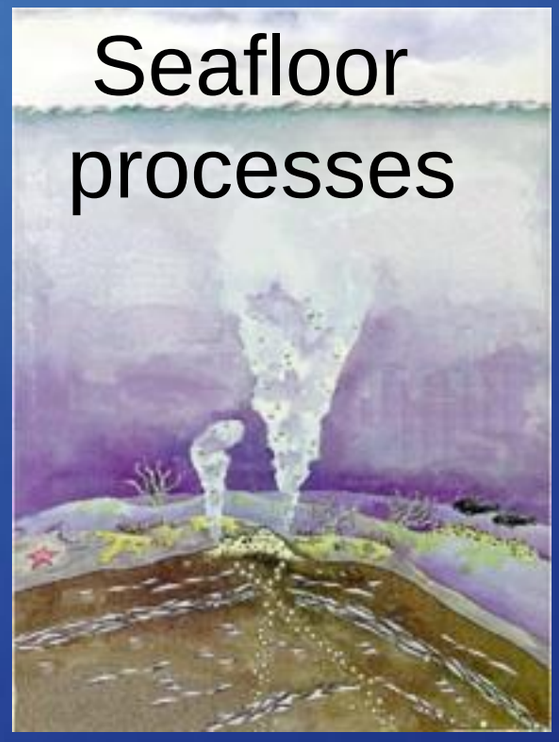
Climate & Marine Biota



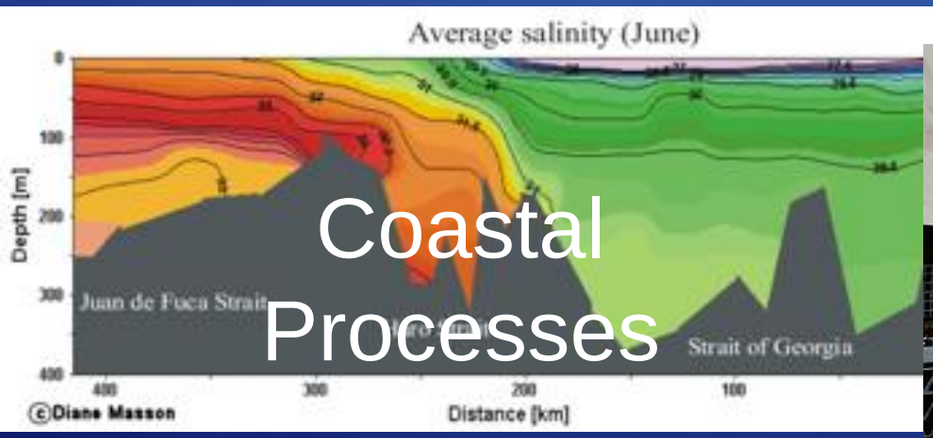
Ecosystems



Seafloor processes

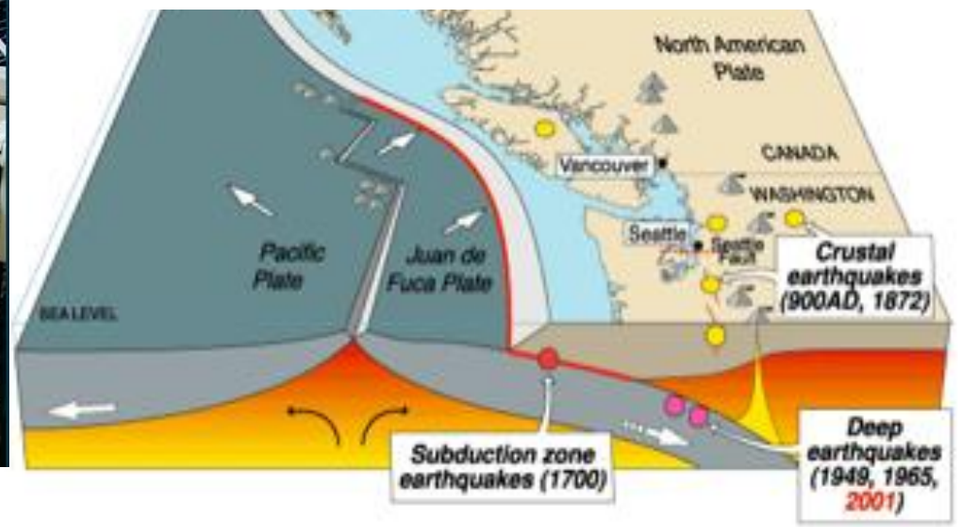


Coastal Processes

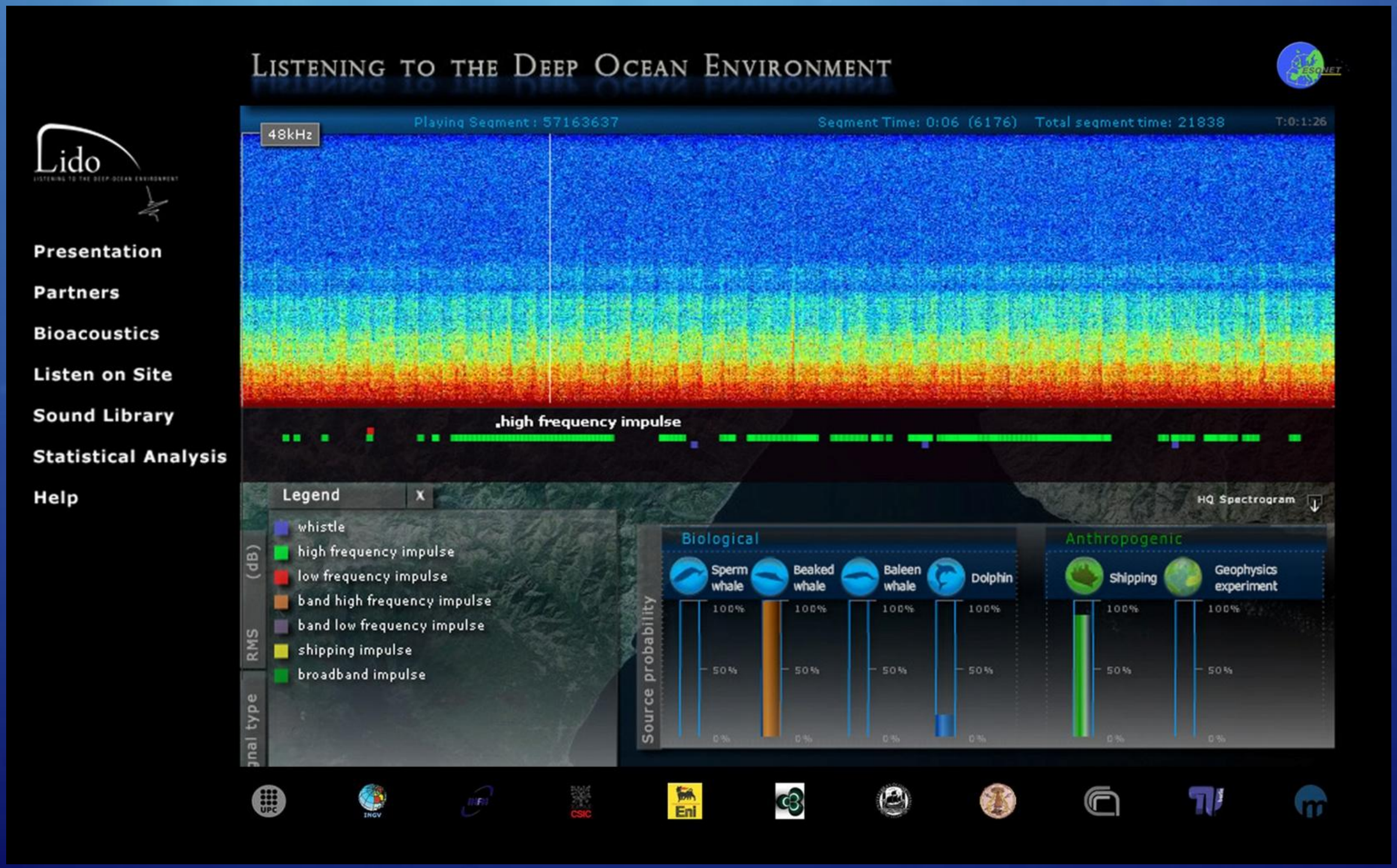


Technology

Earthquake dynamics

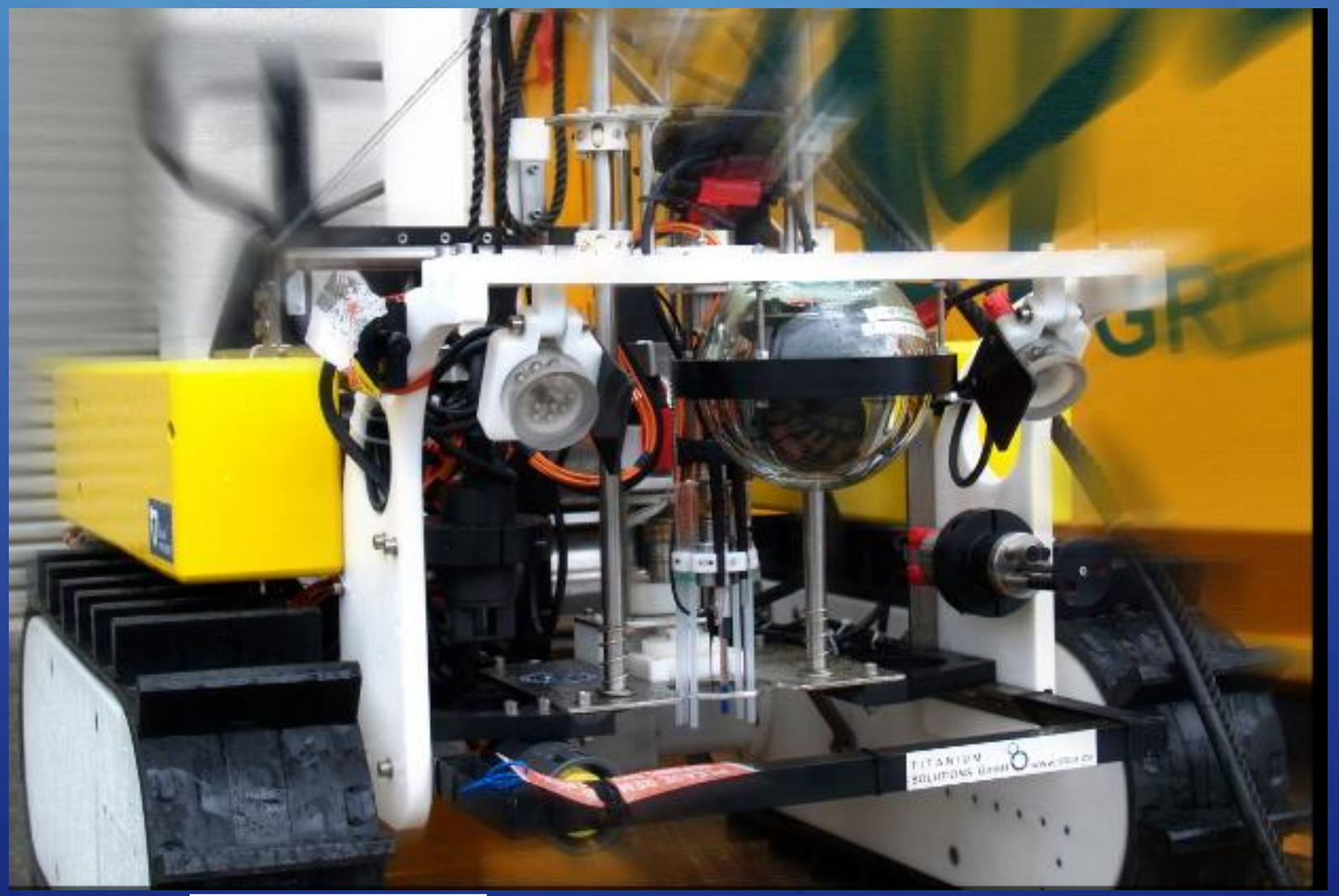


LAB UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA



http://listentothedeep.com

Internet controlled mobile seafloor observations on temporal and spatial variations around gas hydrates

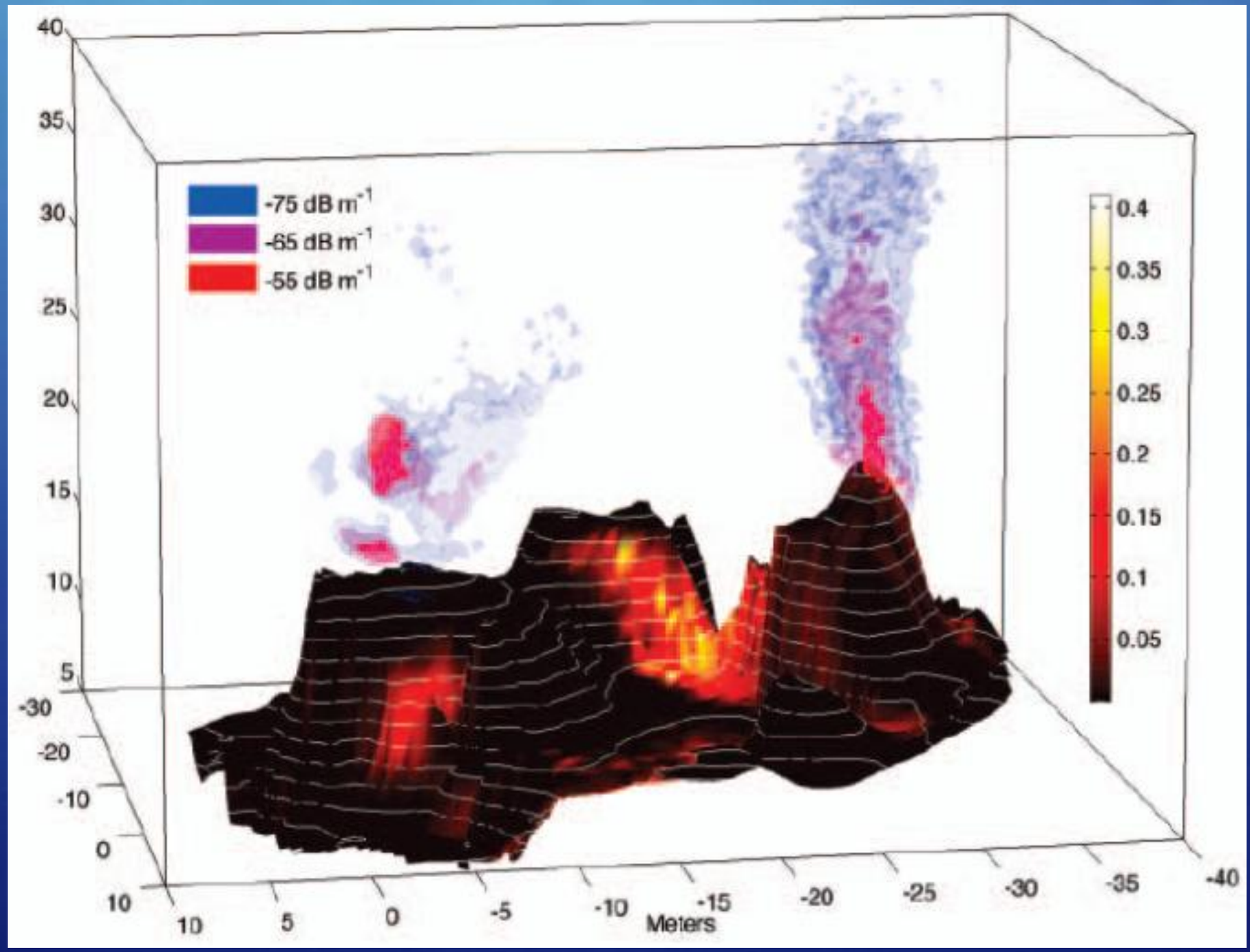


JACOBS UNIVERSITY

Max-Planck-Institut für Marine Mikrobiologie

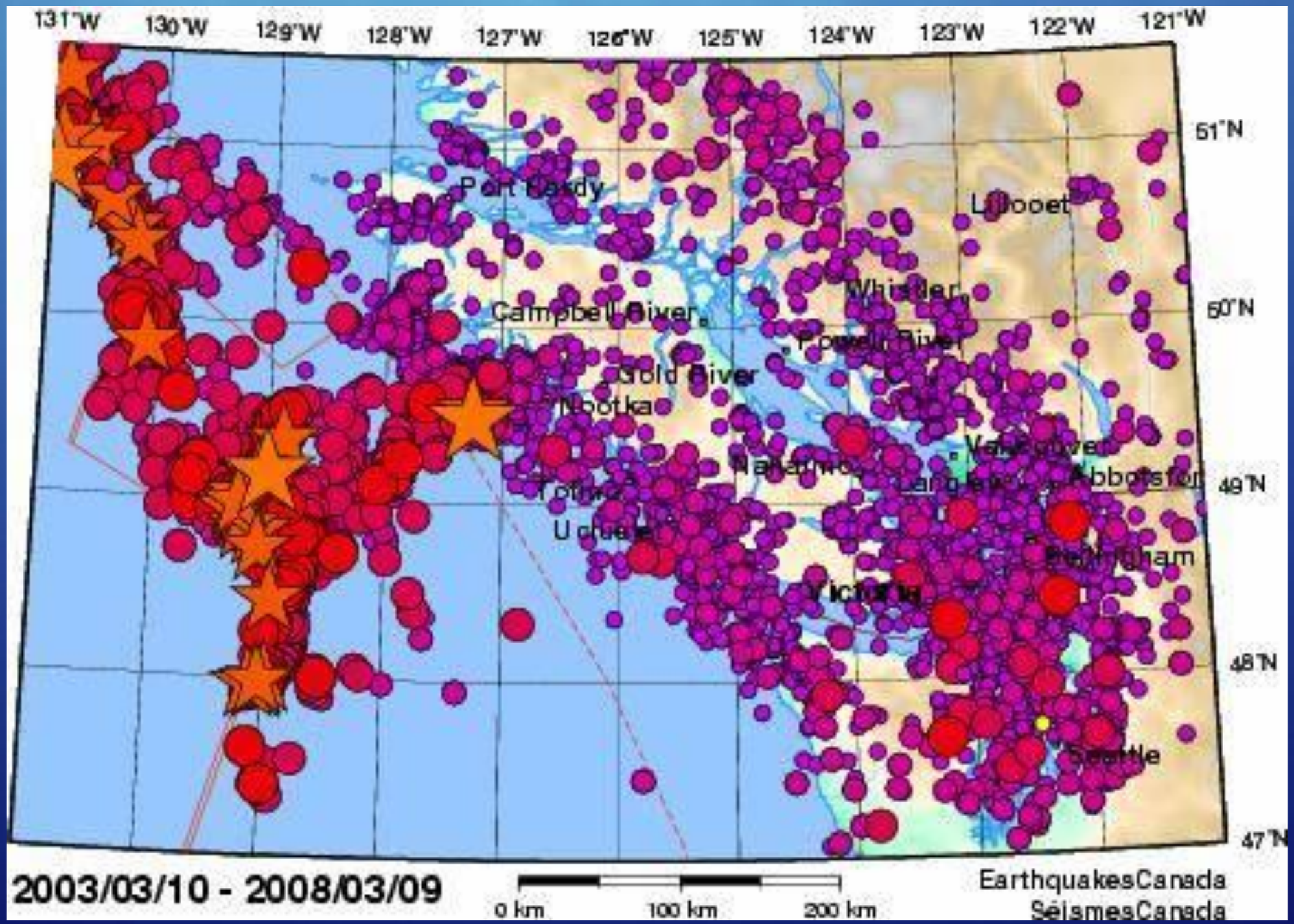
Thomsen, Barnes, Best, Chapman, Pirenne, Wagner and Vogt 2012
Internet controlled mobile seafloor observations on temporal and spatial variations around gas hydrates, Geophysical Research Letters.

COVIS – Grotto Vent, Endeavour Ridge



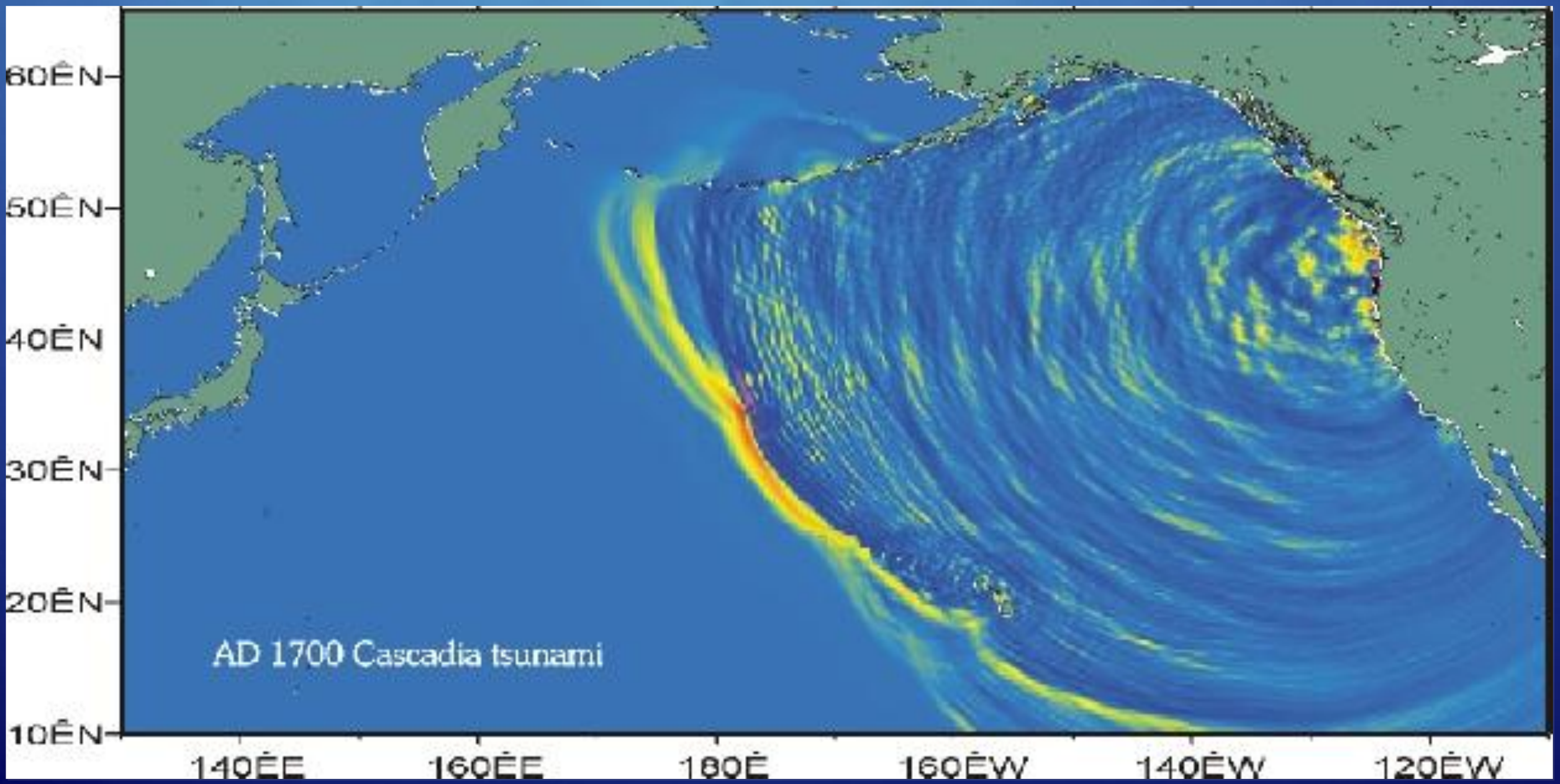
Rona, Peter, Russ Light, (and Team) 2011. Sonar Images Hydrothermal Vents in Seafloor Observatory, Eos, Transactions, American Geophysical Union, v. 92, Number 20, 17 May 2011, 169-170.

Earthquakes in western Canada

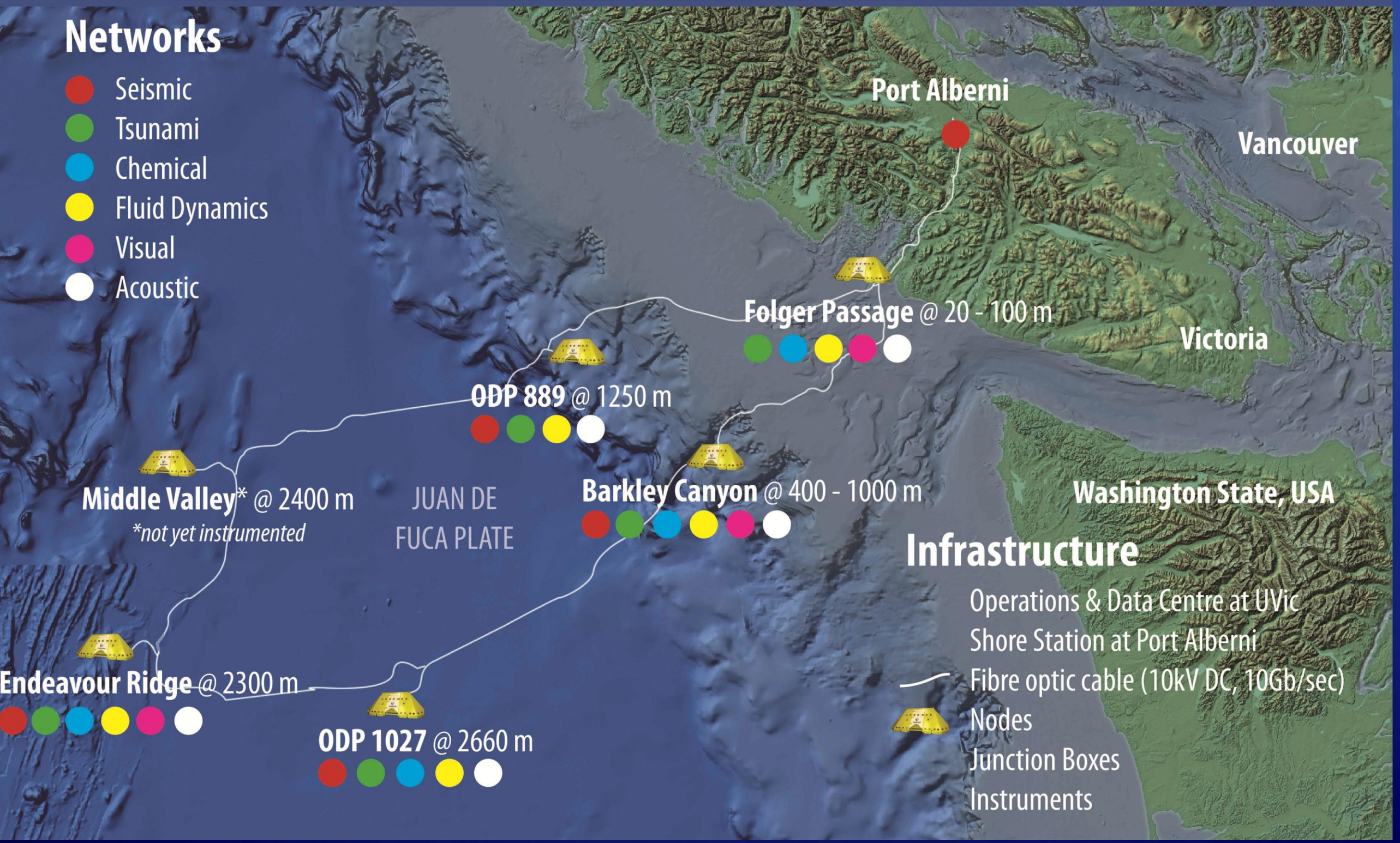


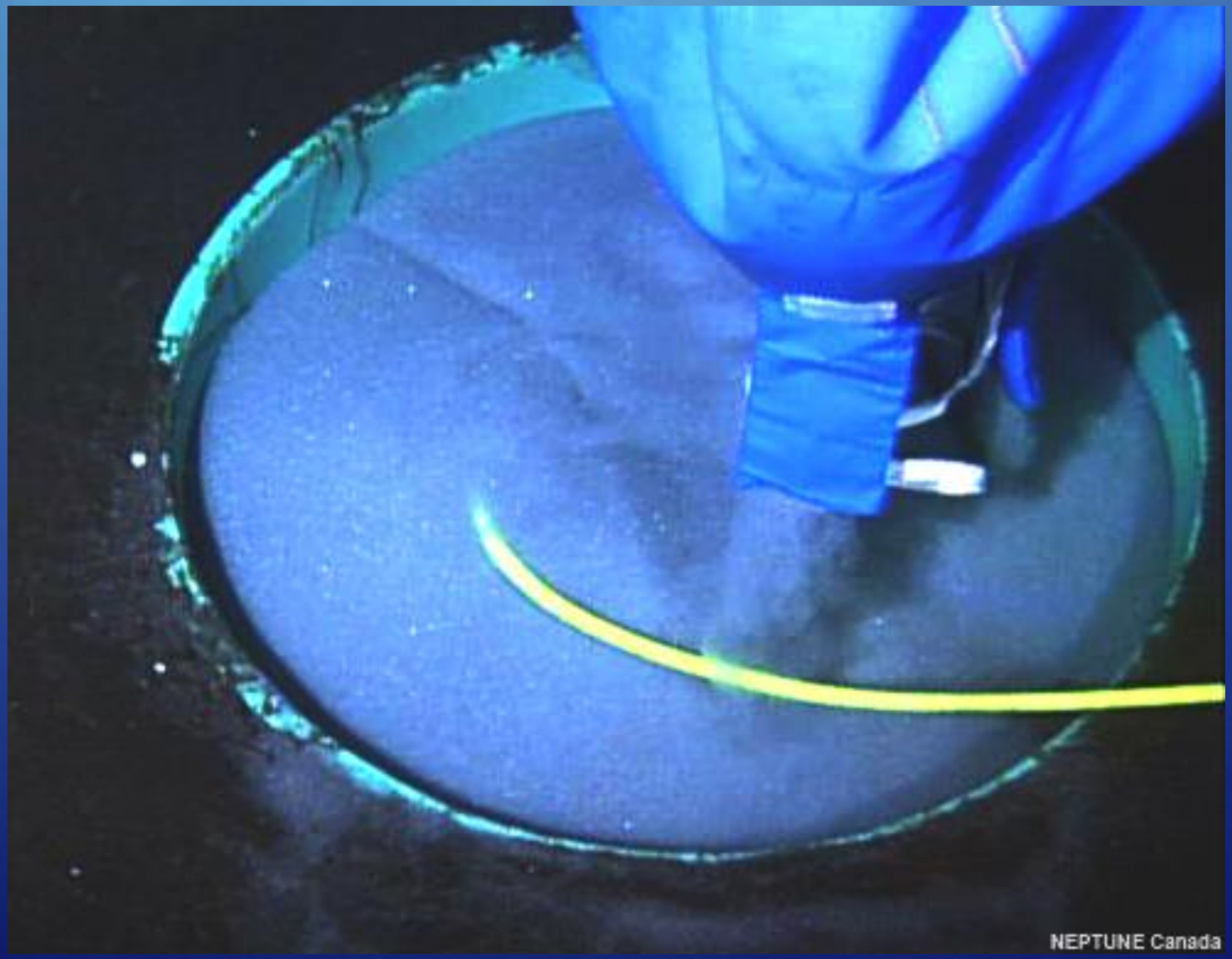
Recent earthquakes (most recent is shown in yellow)

M < 2.0 · M ≥ 2.0 · M ≥ 3.0 · M ≥ 4.0 · M ≥ 5.0 · M ≥ 6.0

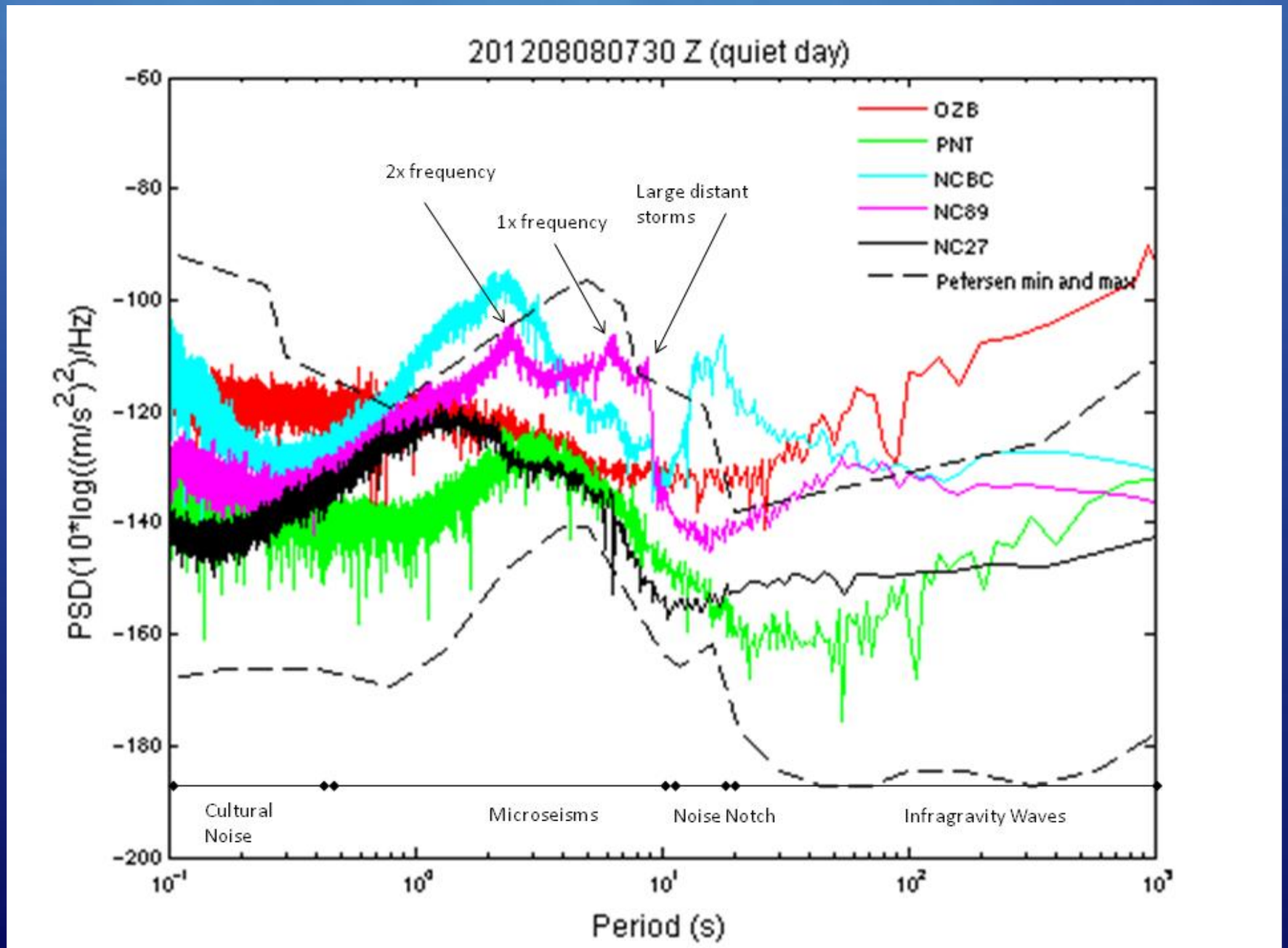

60ÊN
50ÊN
40ÊN
30ÊN
20ÊN
10ÊN
140ÊE
160ÊE
180Ê
160ÊW
140ÊW
120ÊW
AD 1700 Cascadia tsunami

NEPTUNE Canada
online since 2009

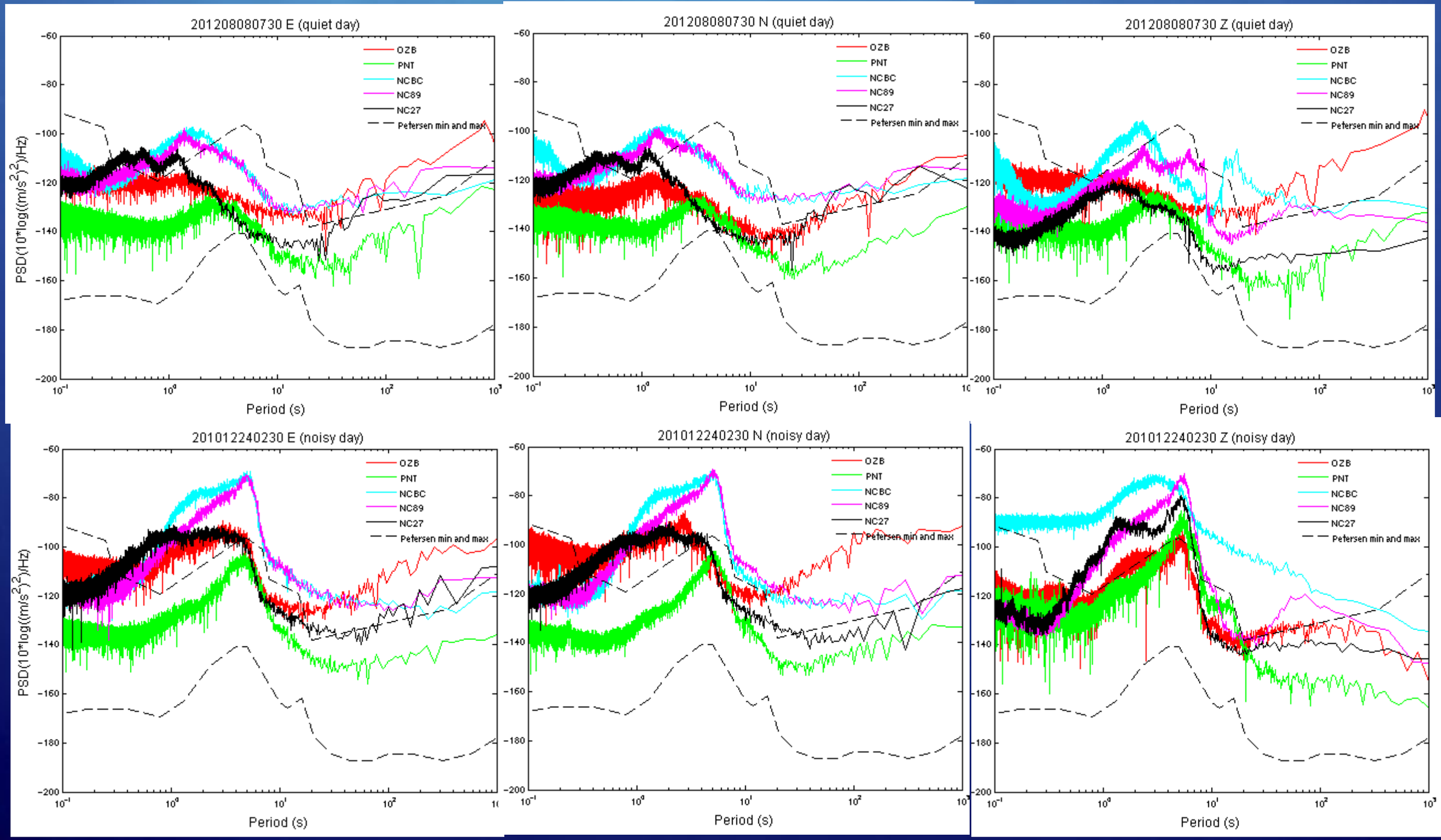



NEPTUNE Canada

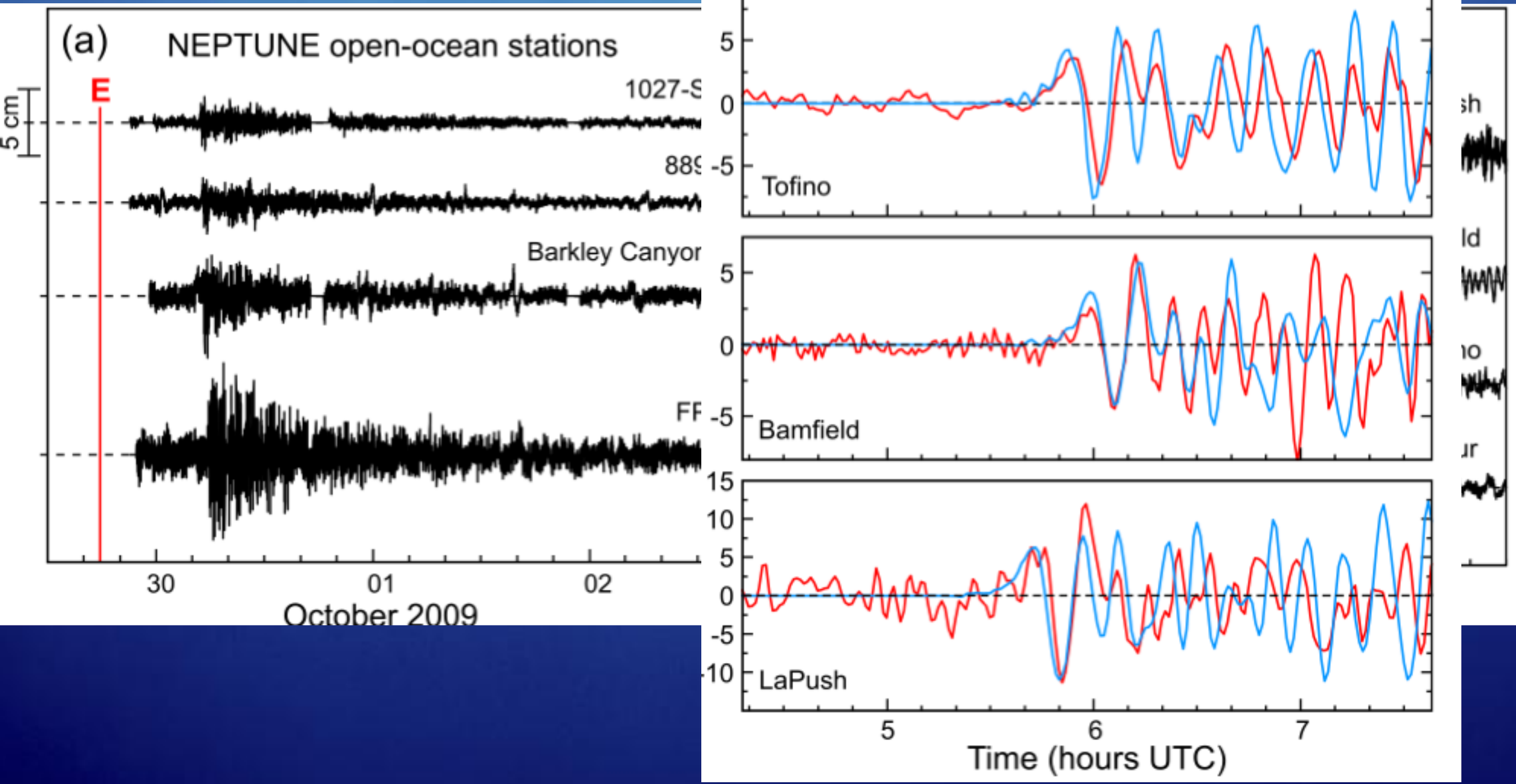
Power Spectral Density of Land vs. Seafloor Seismometers



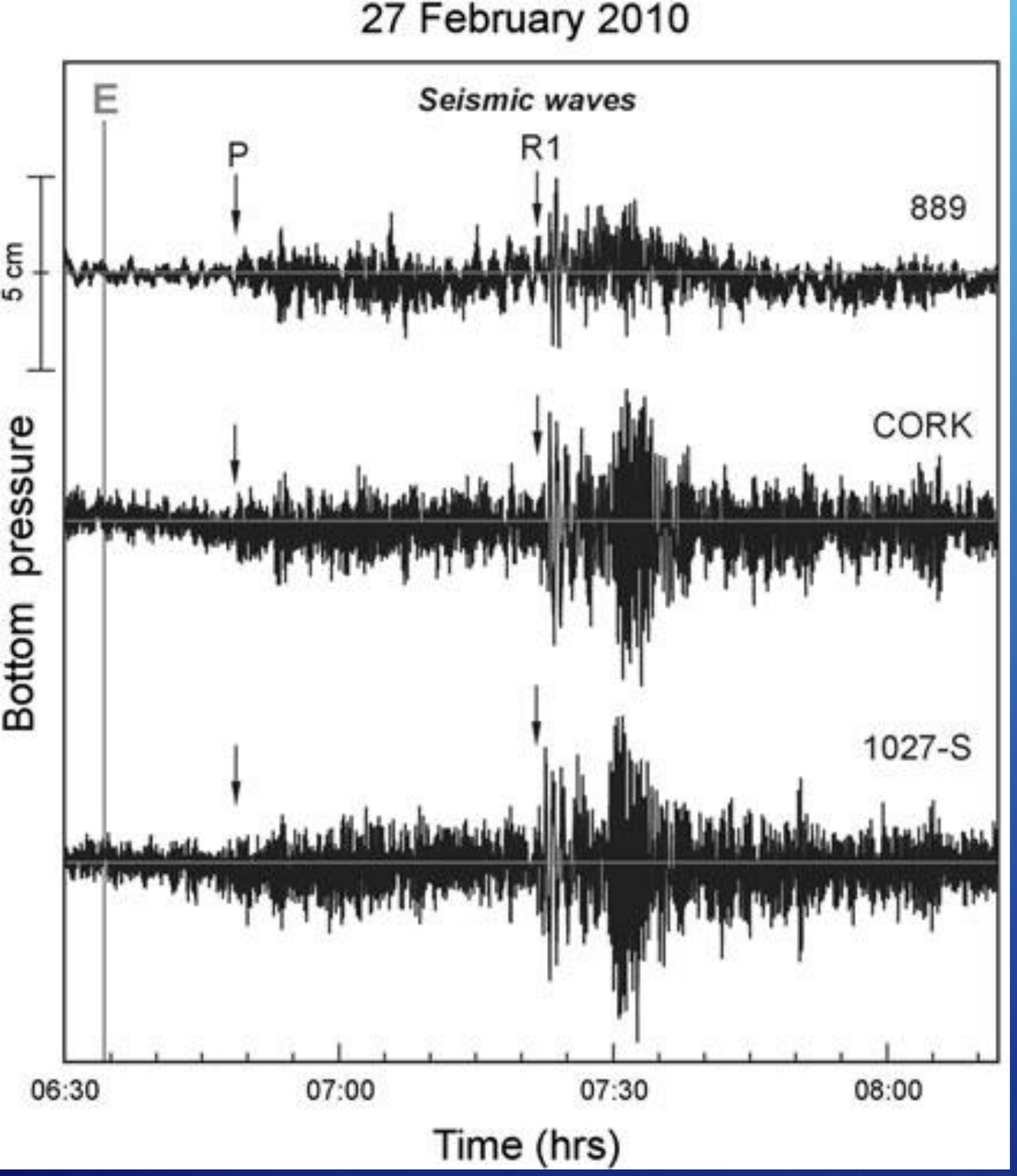
Calm vs. Stormy



Tsu



Thomson et al. 2011 – Samoan tsunami

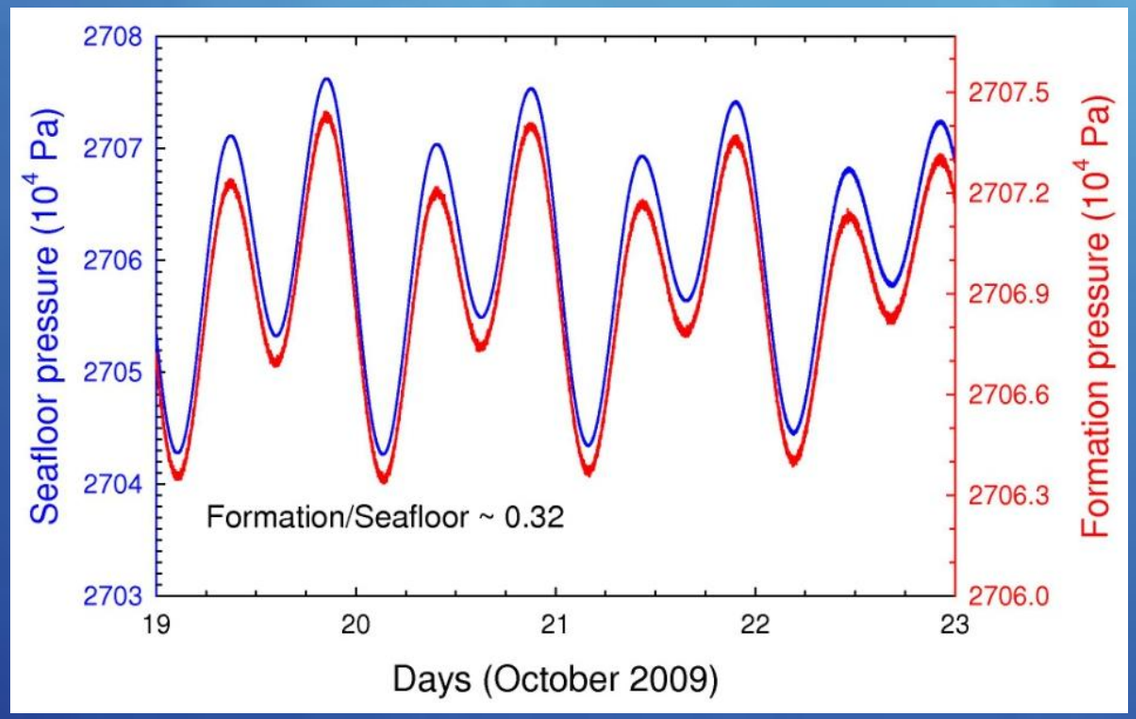


Chilean Tsunami and Seismic waves on NC BPR sensors

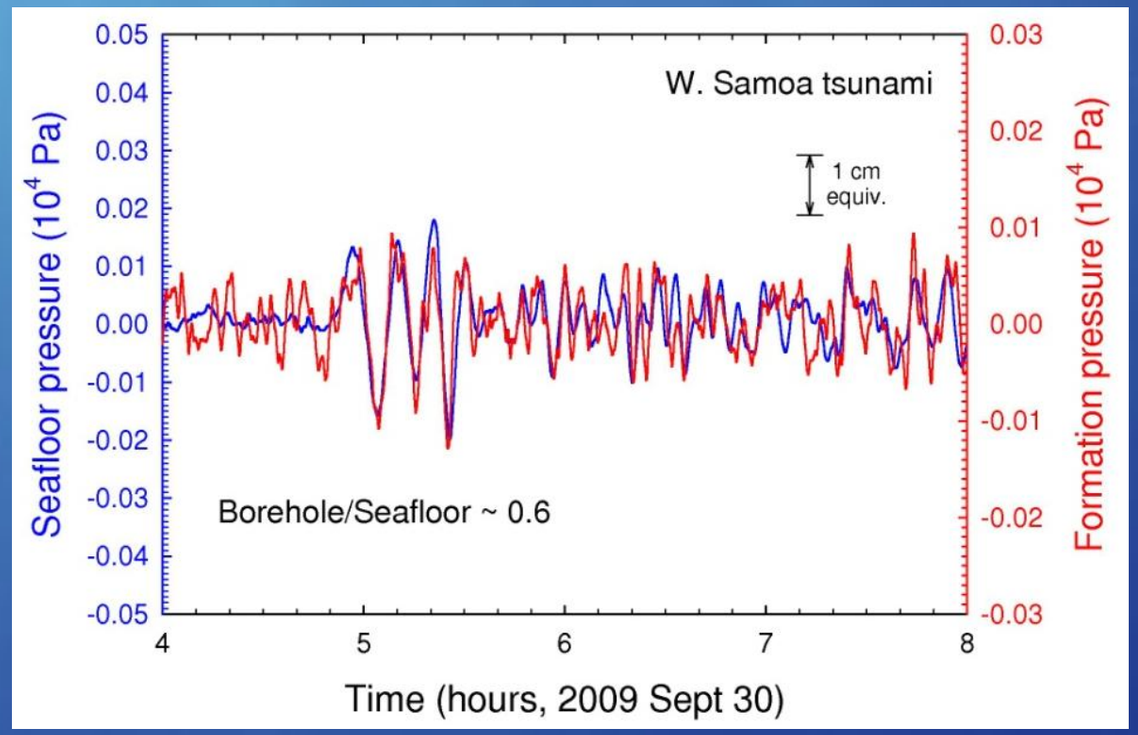
RABINOVICH, A.B., R.E. THOMSON, and I.V. FINE 2012. The 2010 Chilean Tsunami Off the West Coast of Canada and the Northwest Coast of the United States. Pure Appl. Geophys.

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

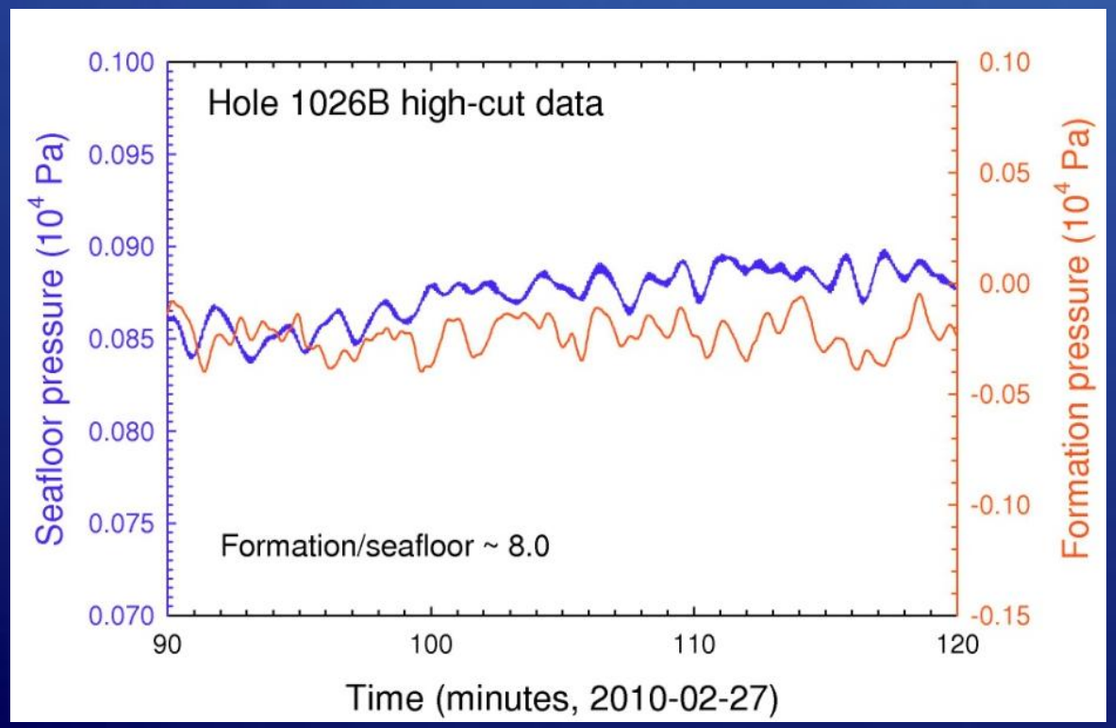
Tides: 12-25 hr period



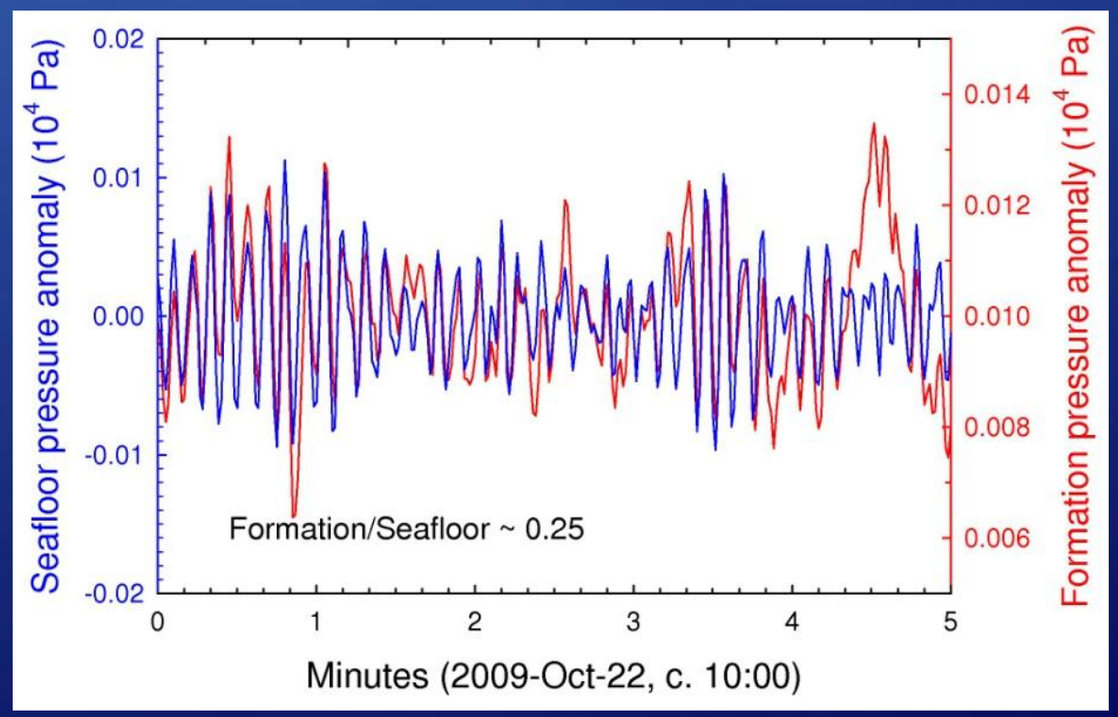
Tsunamis: 15 min period



Infragravity waves: 2 min period



Ocean surface waves: 7 s period



Earl Davis et al.

Info available though oceannetworks.ca and ibook

Data available publicly through ONC Oceans 2.0 and IRIS

european multidisciplinary seafloor observatory

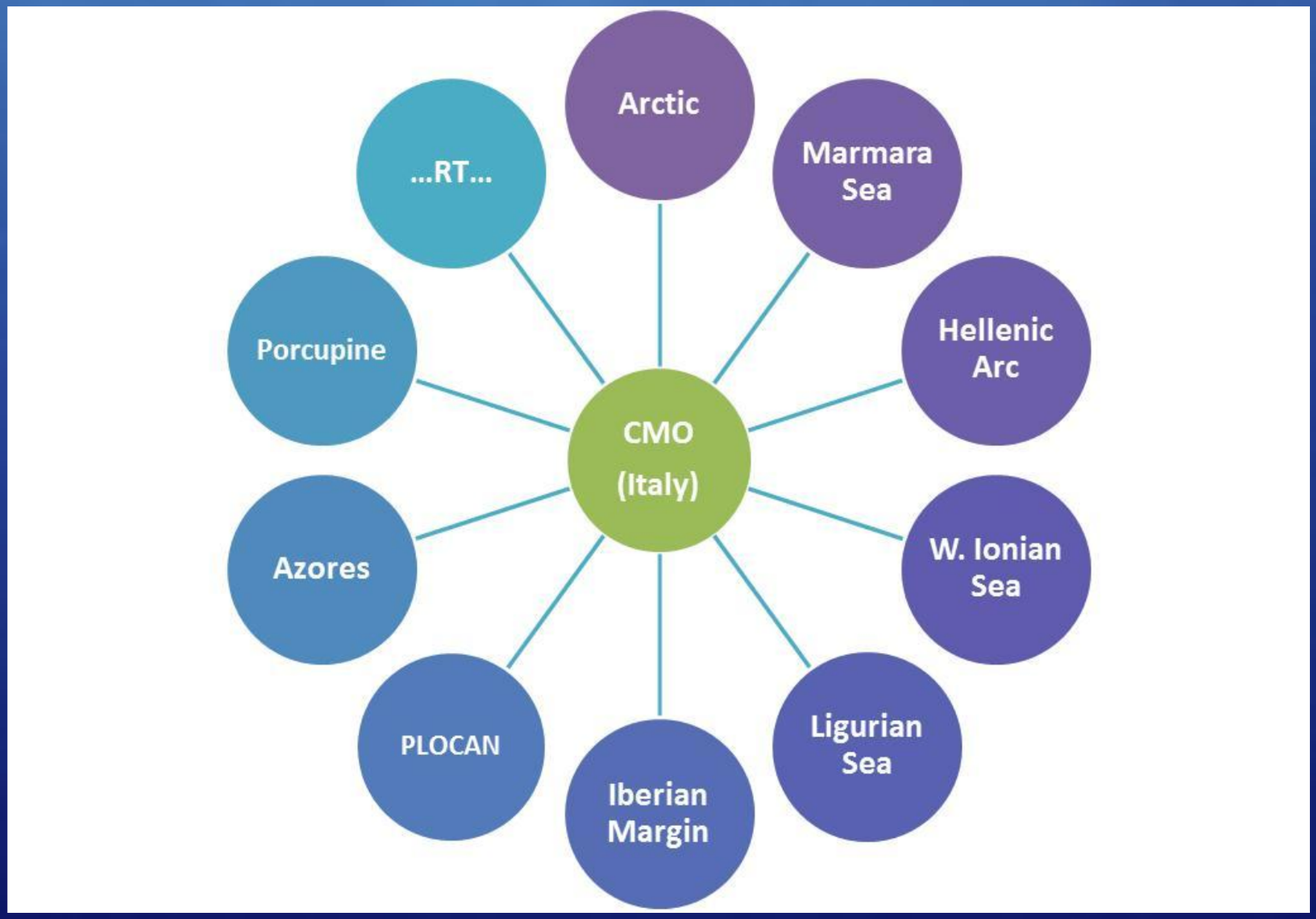
emso

EMSO, an ESFRI Research Infrastructure

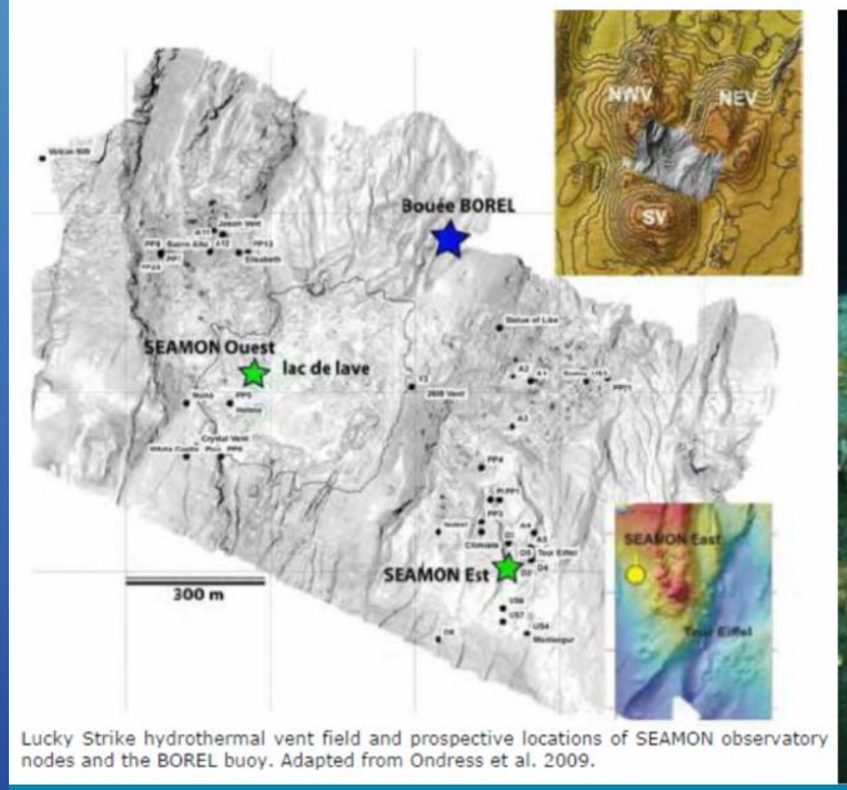
EMSO, a Research Infrastructure of the ESFRI Roadmap, is the European network of fixed seafloor and water column observatories constituting a distributed infrastructure for long-term monitoring of environmental processes, including geo hazards.

EMSO ERIC

The EMSO-ERIC (European Research Infrastructure Consortium) will be the legal entity in charge of coordinating the distributed research infrastructure.



EMSO nodes: present status



Lucky Strike hydrothermal vent field and prospective locations of SEAMON observatory nodes and the BOREL buoy. Adapted from Ondress et al. 2009.

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

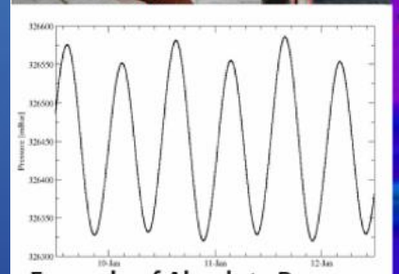
RESEARCH Lucky Strike hydrothermal vent field, geophysical movements of Earth (seismicity and vertical deformation); water, heat and mineral flow through vent system; behaviour of physical and chemical elements in vent fluid; variations in biogeochemistry and the ecological hotspots in vicinity of vents

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

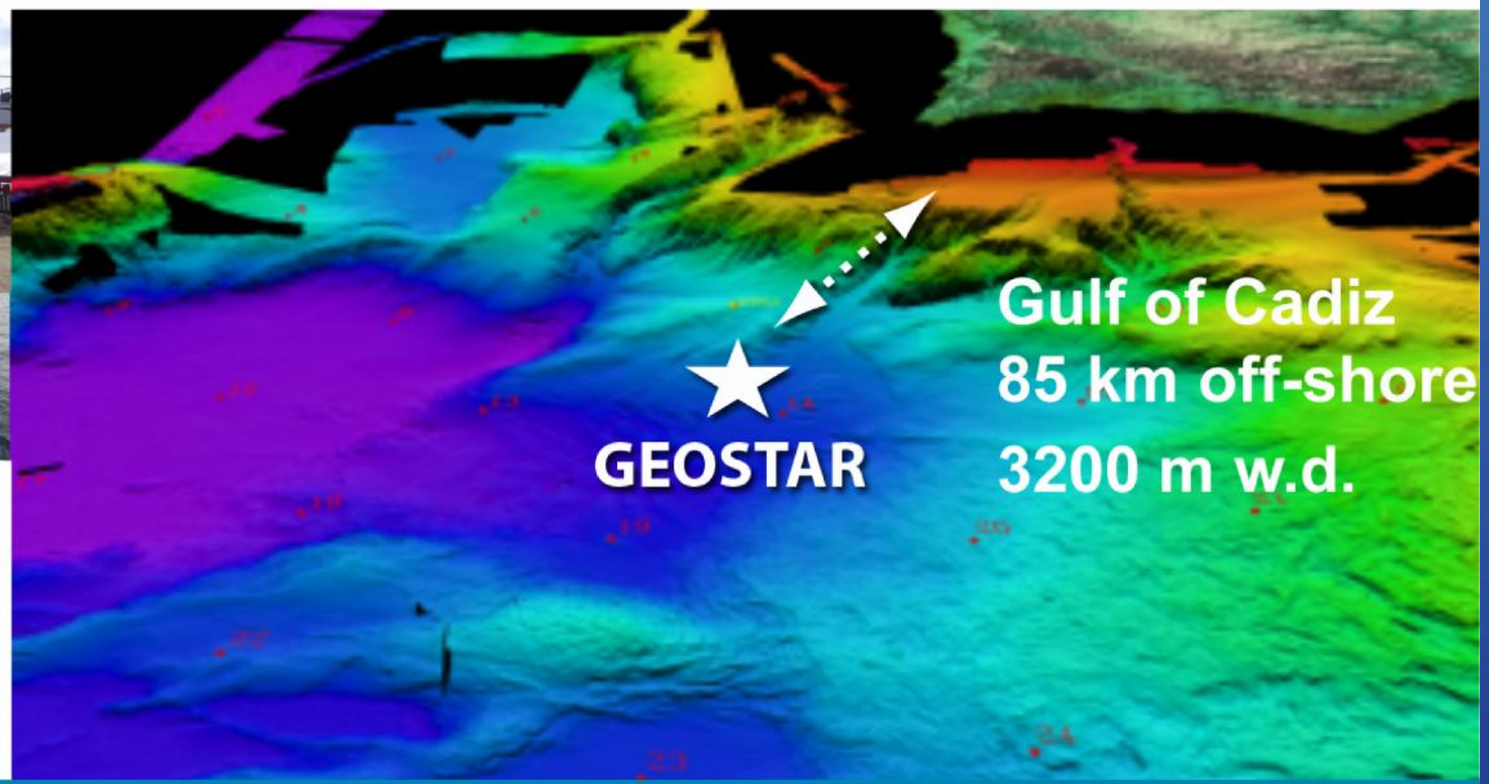
FUTURE ACTIVITIES Yearly maintenance is scheduled for the next 5 years.
Data transmission to shore through the buoy.
New generation of stations planned for 2015

AZORES ISLANDS

EMSO nodes: present status



Example of Absolute Pressure Gauge raw data recorded



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

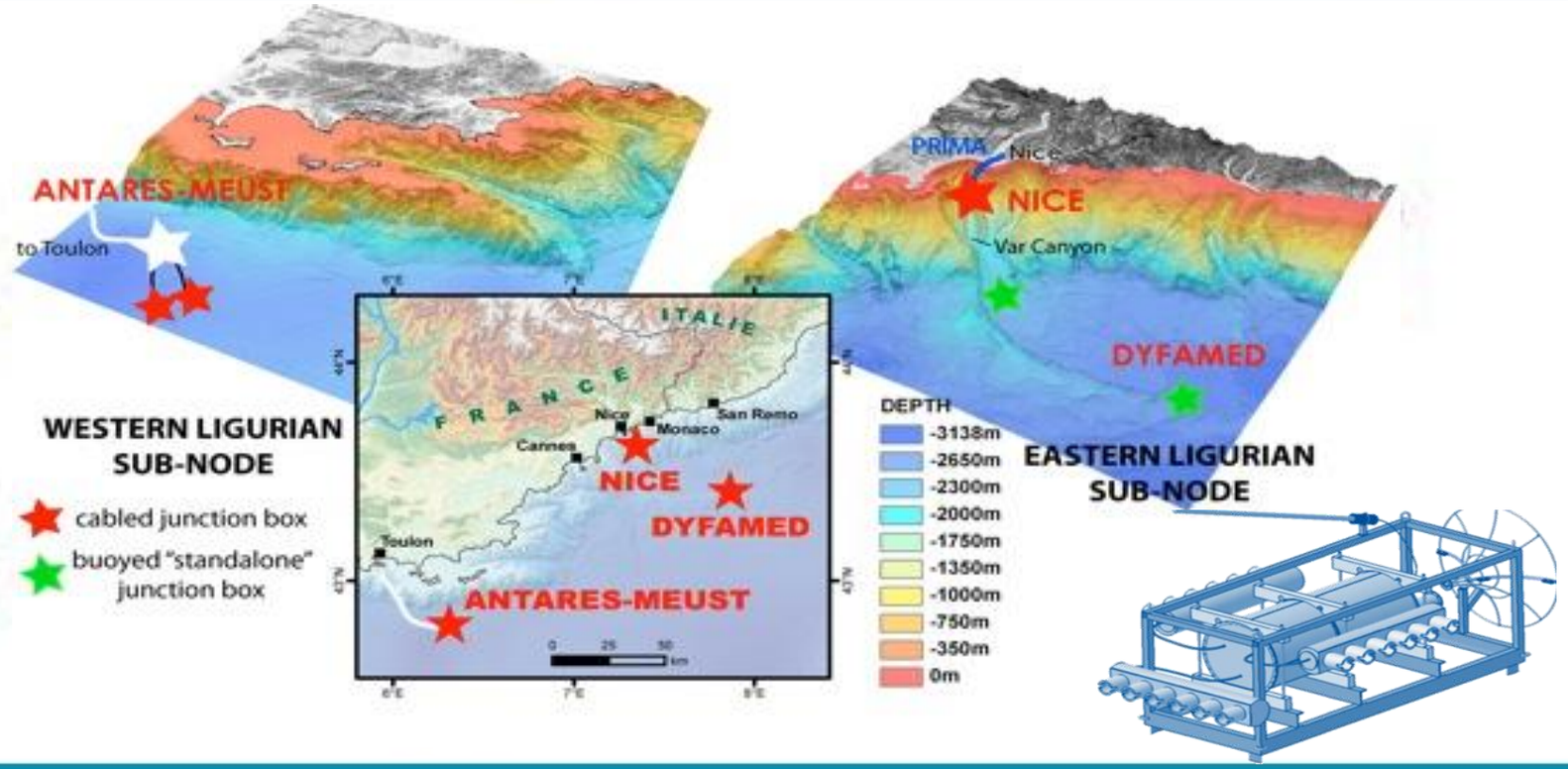
RESEARCH Eurasian and African plate boundary off Portuguese coast, Mud volcanoes, pockmarks, mud diapirs, carbonate chimneys, hydrocarbon venting and faulting; prototype tsunami meter; passive acoustics related to marine mammals and anthropogenic noise

PREVIOUS/RECENT ACTIVITIES part of HERMIONE research; NEAREST and NEAMTWS geo-hazard early warning efforts; ESONET demo mission LIstening to the Deep Ocean environment (LIDO); near real-time data transmission trough 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

IBERIAN MARGIN

EMSO nodes: present status



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.

LIGURIAN SEA

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

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

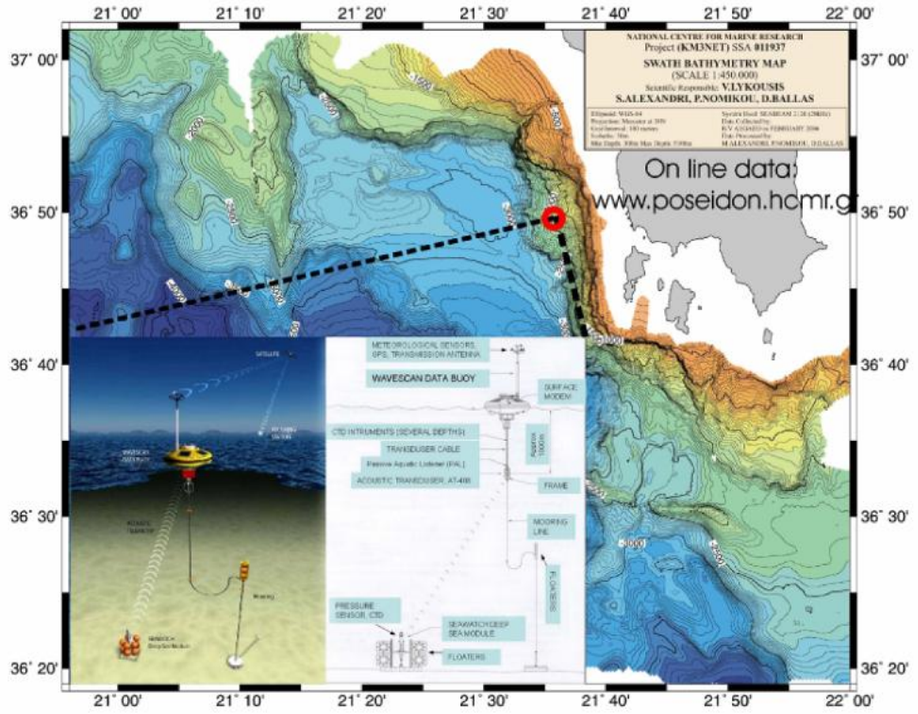
RESEARCH Geohazards, tsunami, climate change, bioacoustics and ambient noise.

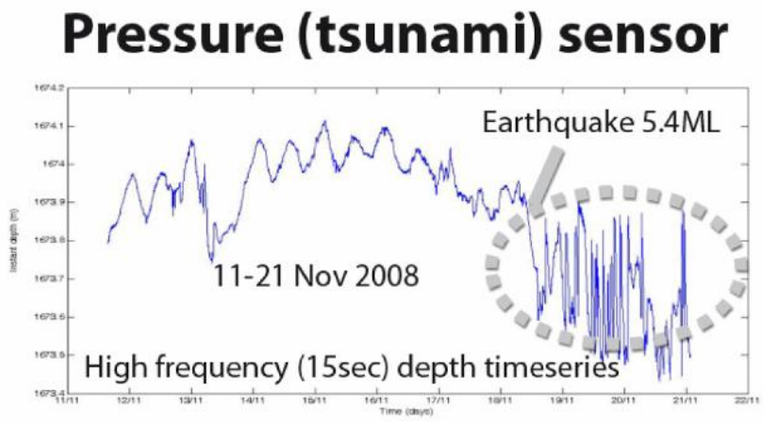
PREVIOUS/RECENT ACTIVITIES LAMS and SIRENA FESR projects (national). GNDT-SN1 (national). PEGASO project (Structural funds). ESONET demo missions (LIDO, LIstening to the Deep Ocean environment). GENESI-DEC, SCIDIP-ES (FP7 infrastructures), KM3NET, TRANSFER

FUTURE ACTIVITIES extention 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

WESTERN IONIAN SEA

EMSO nodes: present status





INFRASTRUCTURE Cabled system **NESTOR**, Stand alone **Poseidon Pylos and Poseidon E1-M3A** (35o66'N, 24o99'E), Proposed drilled observatory **BUTT**

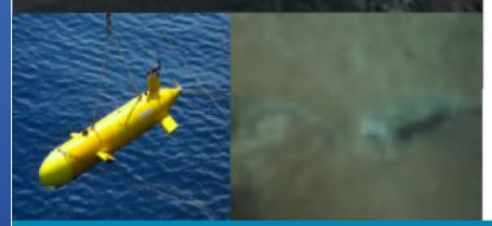
RESEARCH Geohazards, tsunami, climate change, bioacoustics and ambient noise, biogeochemical fluxes, benthic-pelagic interactions; benthic respiration; biogeochemical fluxes; photography-based ecology; seabed methane fluxes; oil and gas industry activities

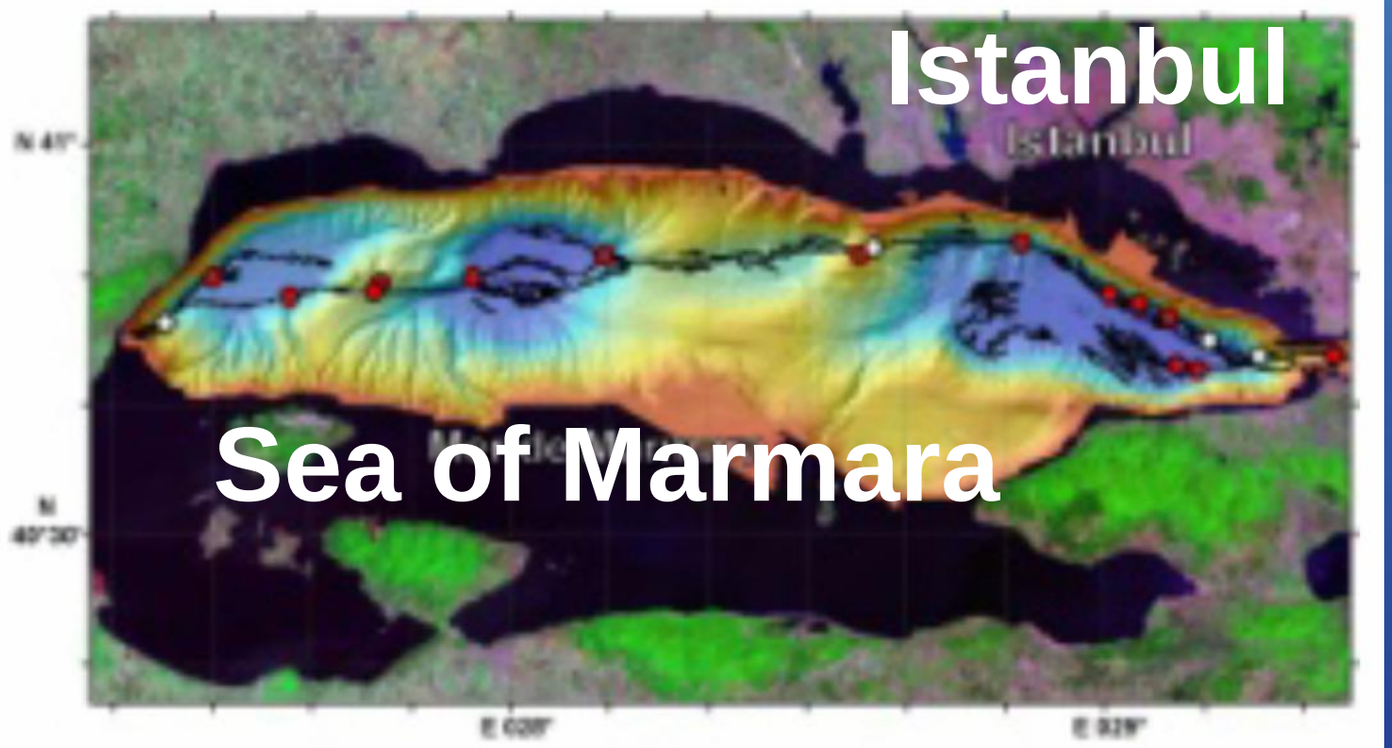
PREVIOUS/RECENT ACTIVITIES EuroSITES, IODP, HERMES-HERMIONE, SEAHELLARC, TRANSFER, KM3NET
Continuity of stand-alone observatory over to 2014.

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).

HELLENIC ARC

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

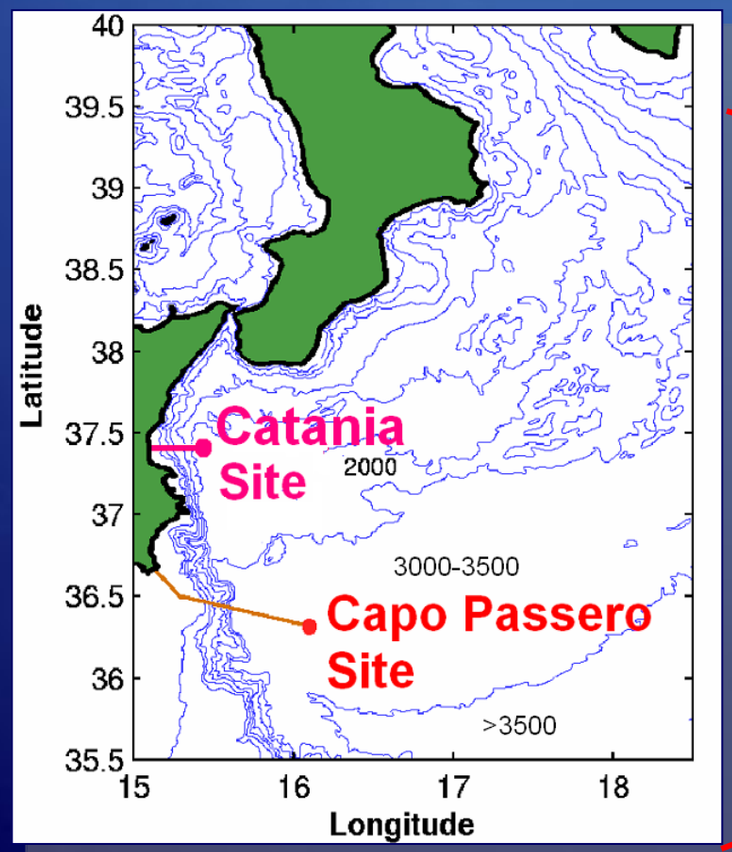
FUTURE ACTIVITIES Design of the future multi-disciplinary cabled observatory in three locations along fault

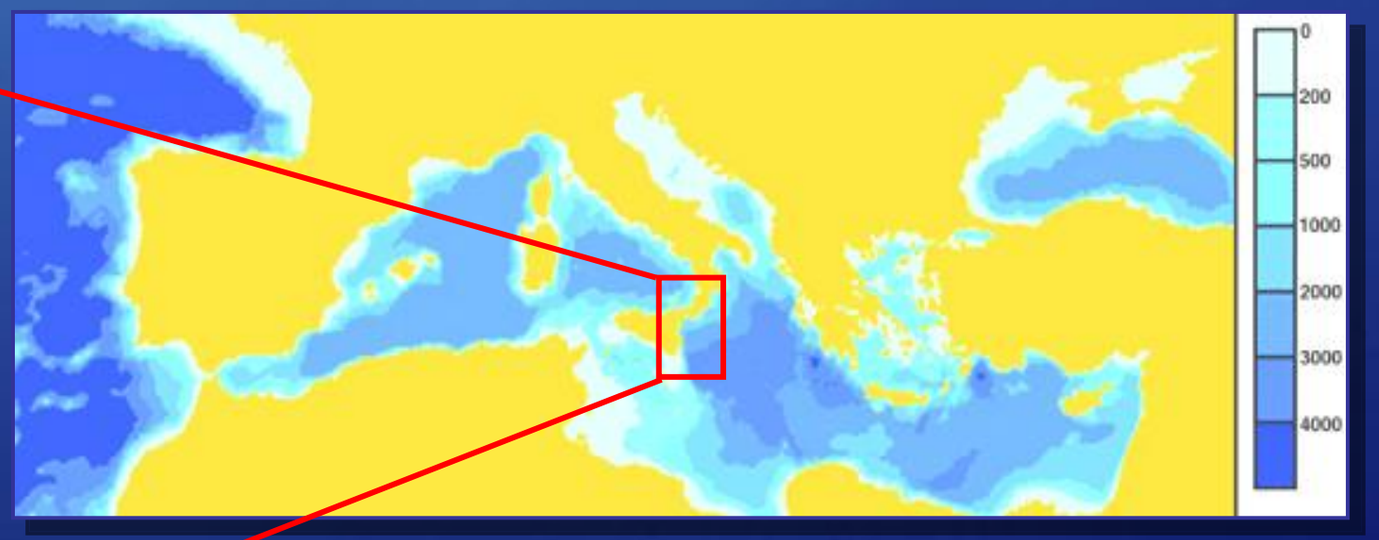
MARMARA

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



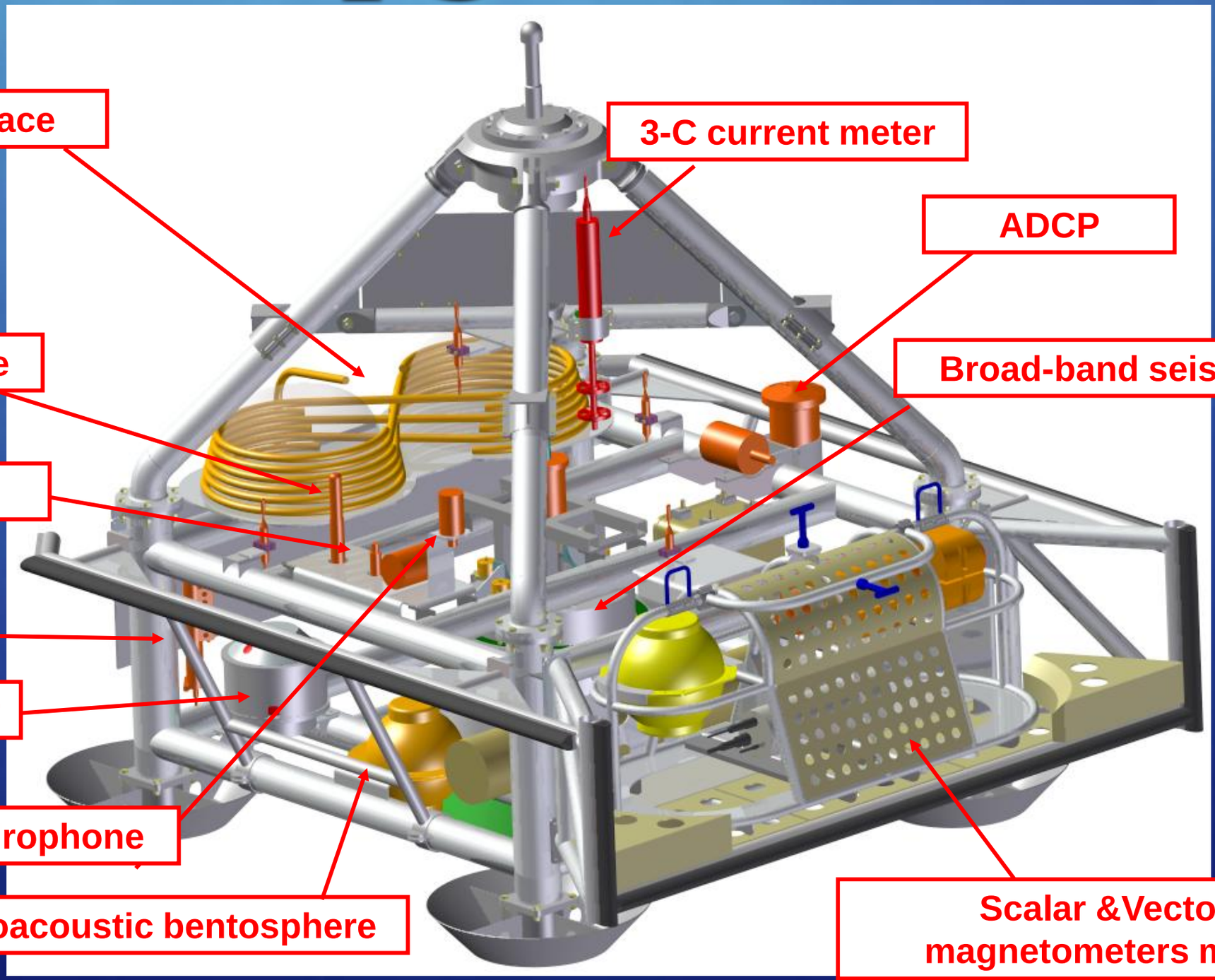


european multidisciplinary seafloor observatory emso

INFN

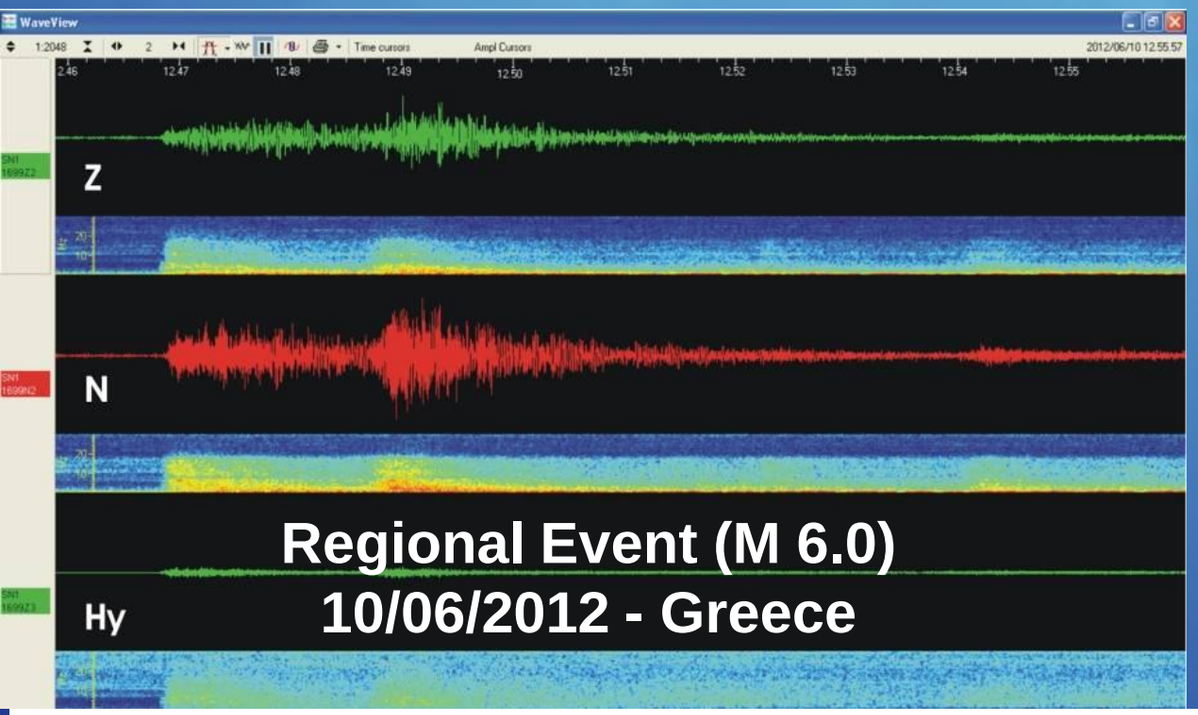
KM3NeT

SN1 Upgrade - 2012

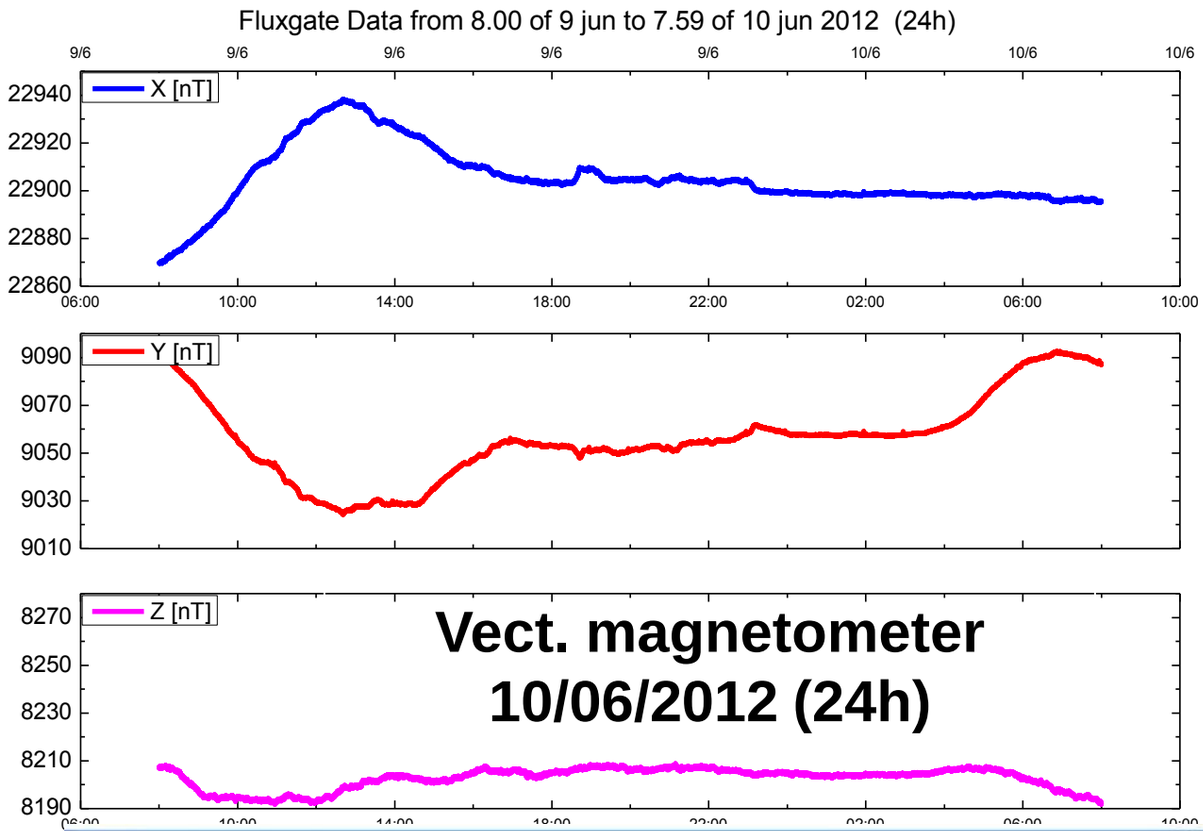


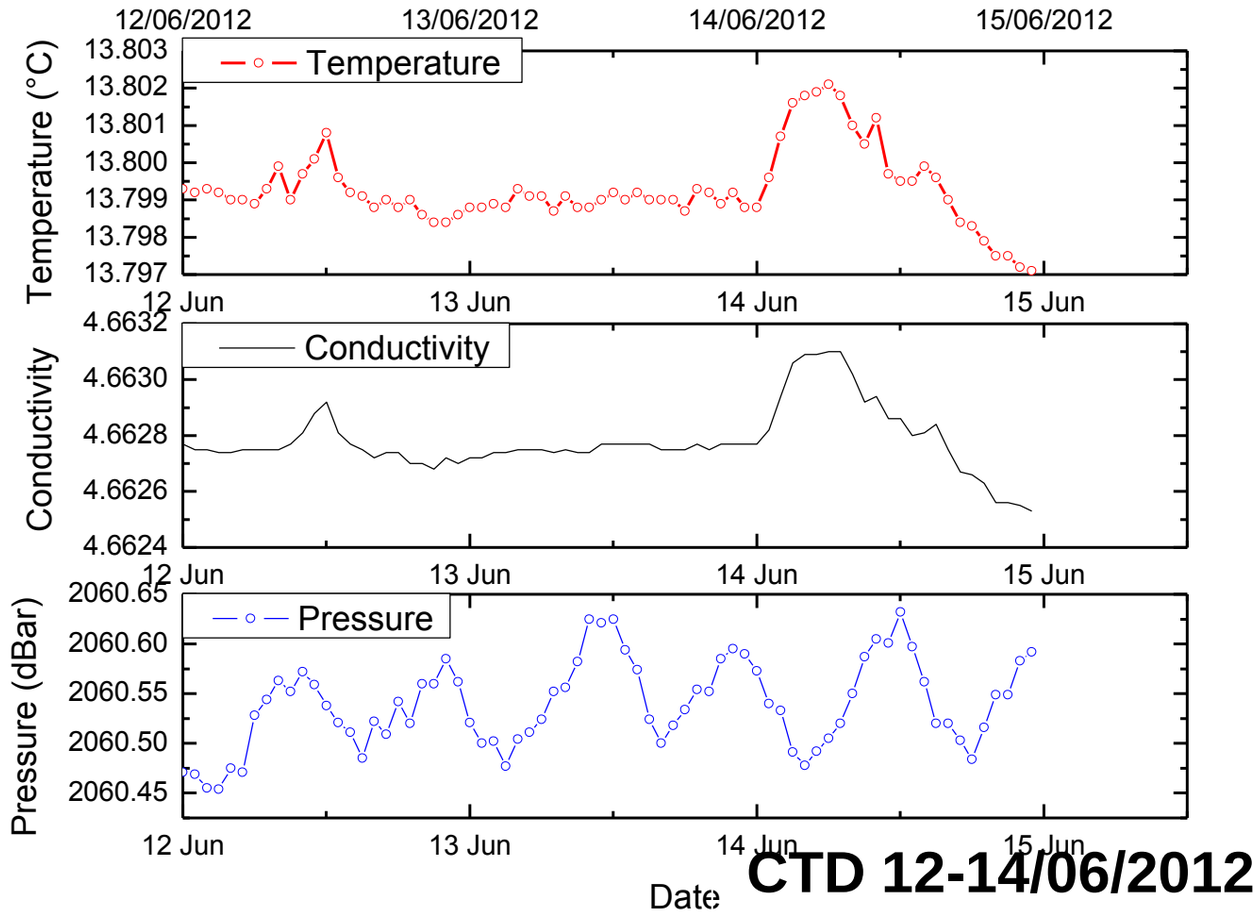
2002-3 Autonomous data
2005-8 Real-time data transmission

EMSO data examples



Western Ionian Sea





SN1 1st stand-alone experiment 2002-2003

East Sicily seismicity not-recorded inland

213 events

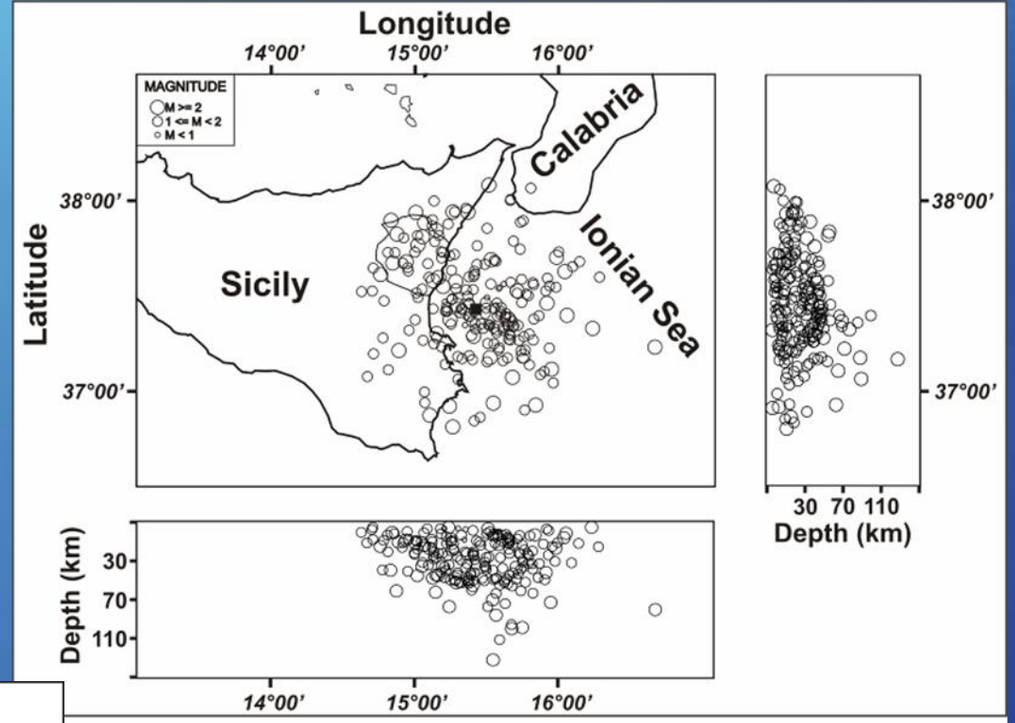
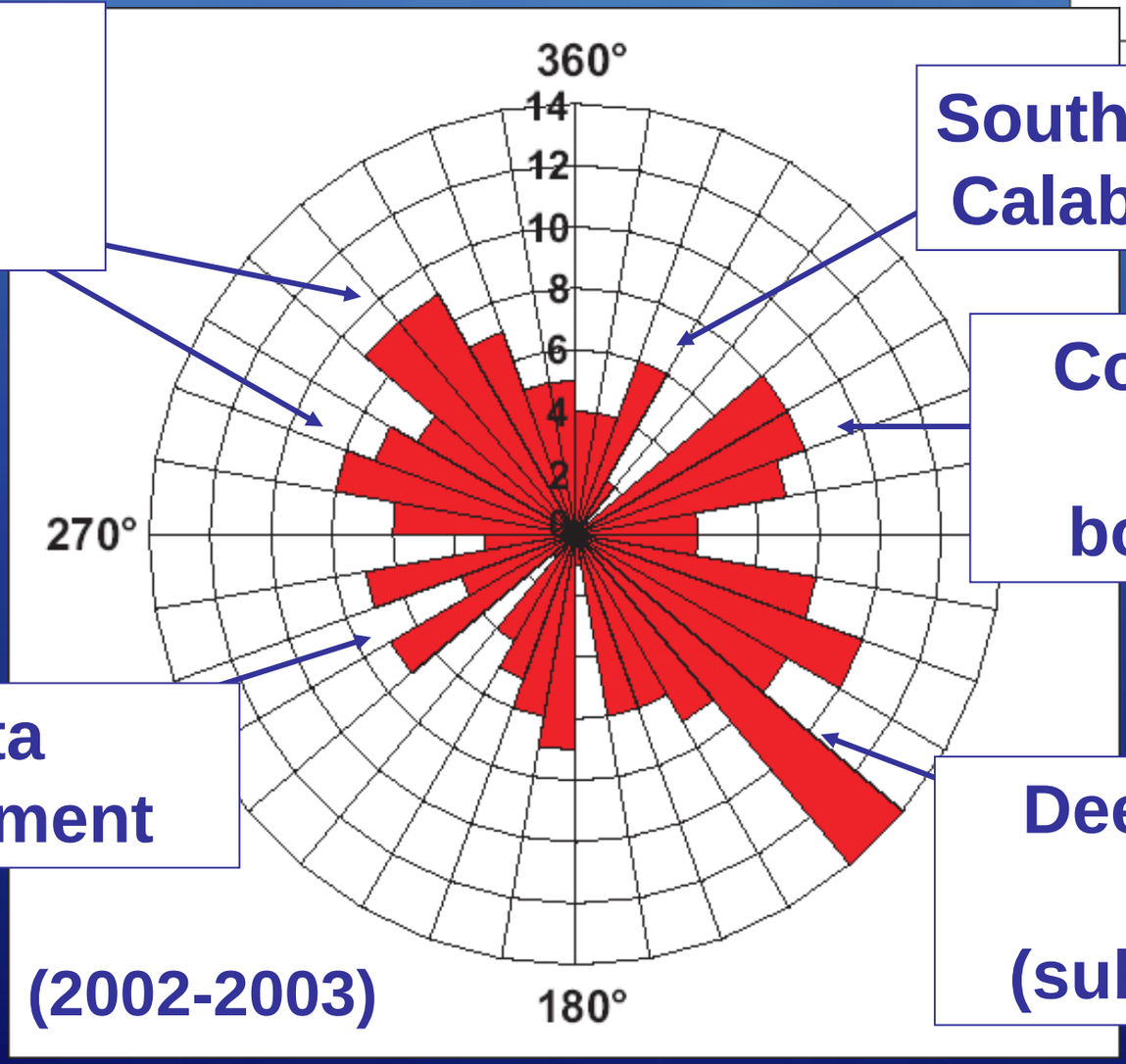


Figure 11

Mt. Etna bilateral eruption



Southern Calabria

Continent-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