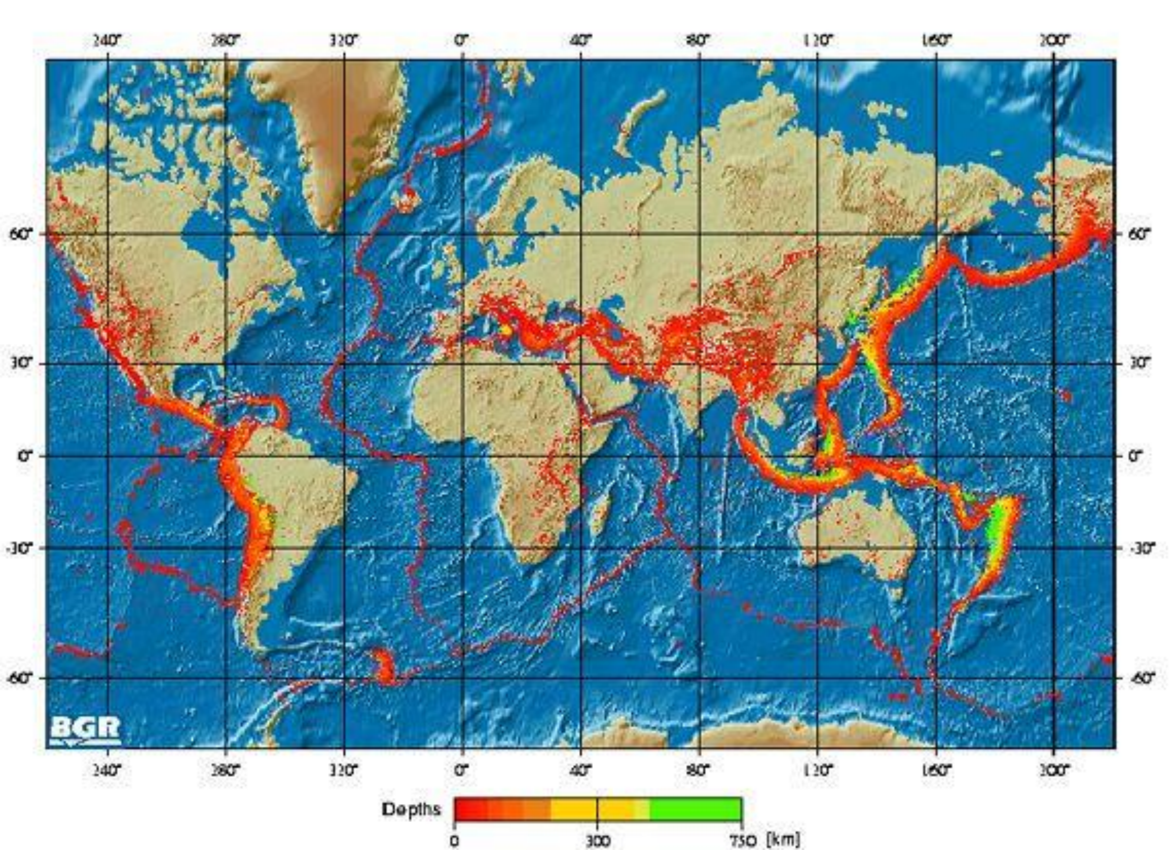
Seismology on sea floor: why and how.

Anne Deschamps, Géoazur, CNRS/UNS,IRD,OCA

The main questions in seismology

1a: Earthquakes understanding

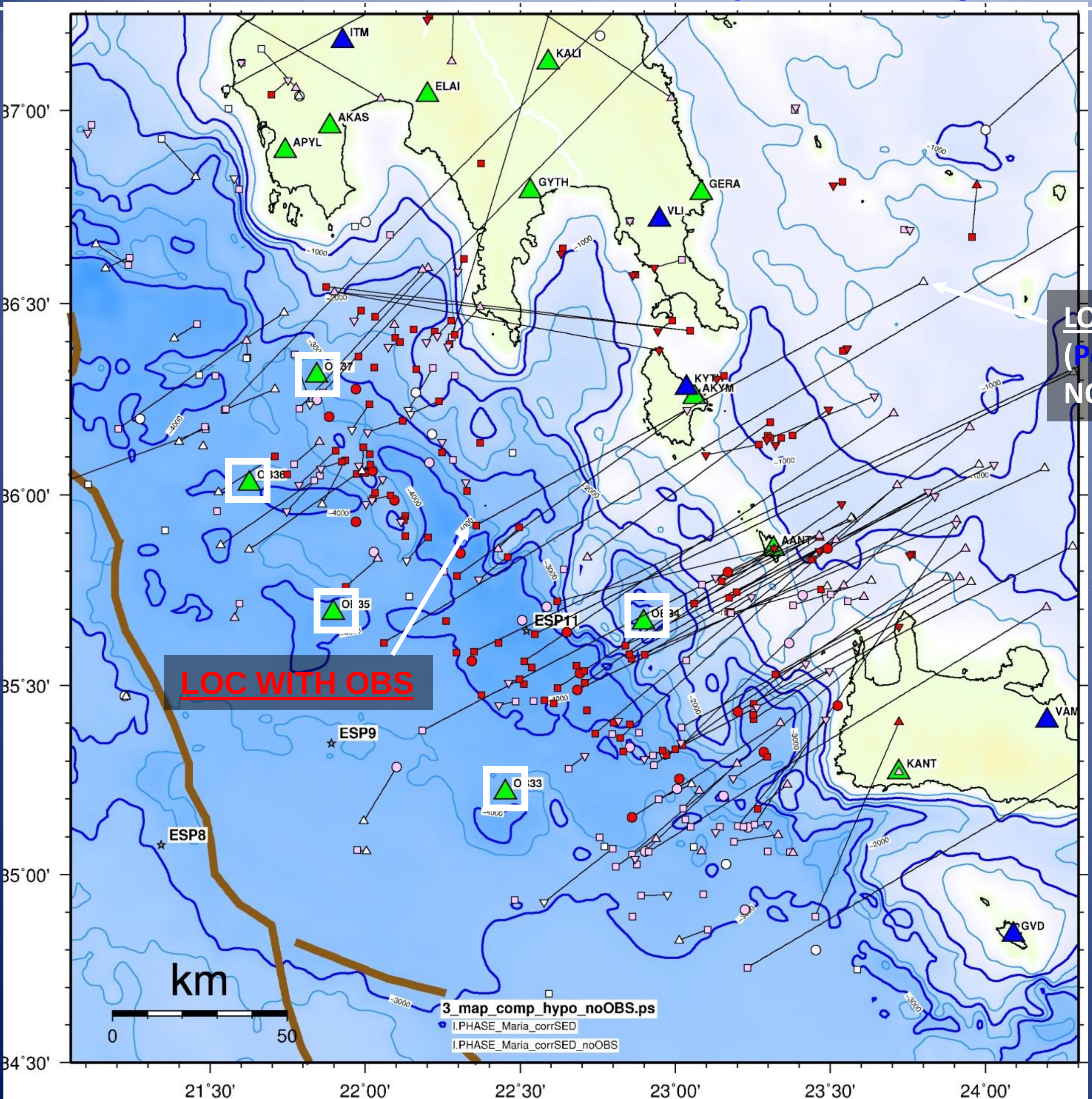
where do they occur?



Location from land based instrumentation

A pilot Ocean Bottom Seismometer and land array location of earthquakes in the pre-seismic context to the 2008, M=6.9 Methoni major earthquake of the Hellenic subduction in the decade.

Sachpazi, M., M. Laigle et al. In preparation, 2011



THALES WAS RIGHT EU project

Offshore EQs located by 5 OBS and ~10 land-stations (6 months)

LOC WITHOUT OBS (Permanent network, NOA catalogues)

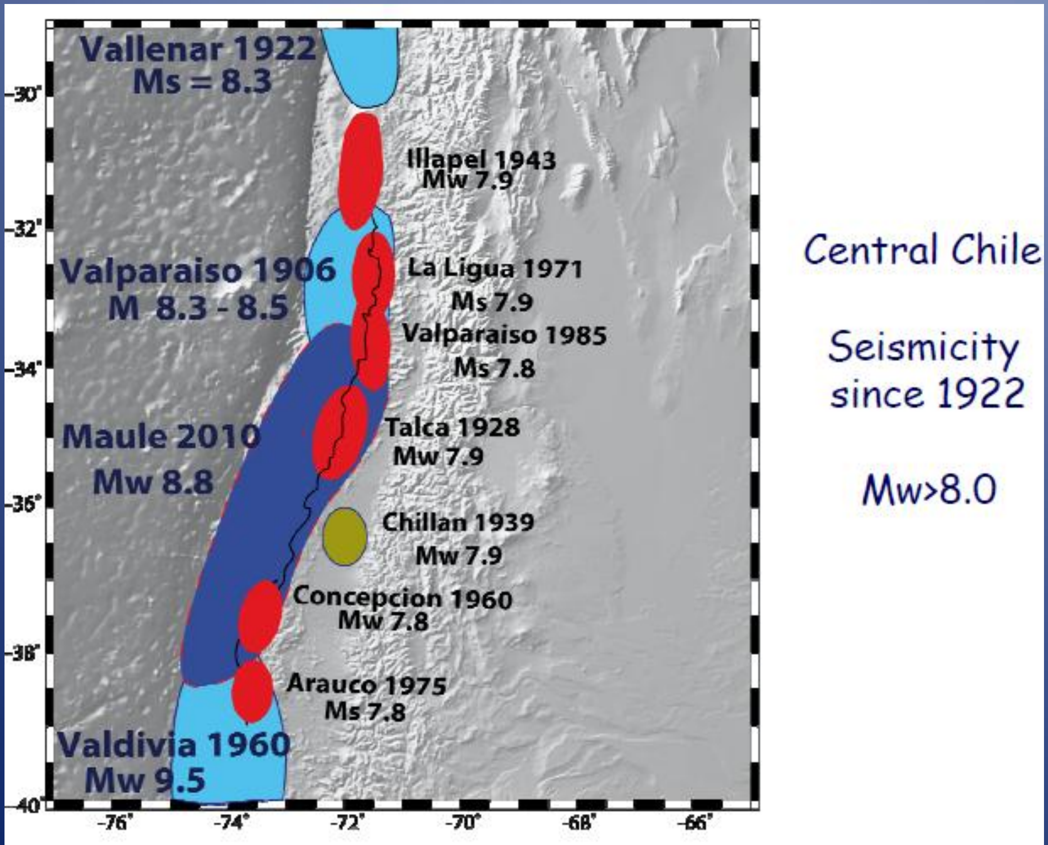
⇒ Shift in location to the SW reaching ~100 km !

Previously located "Aegean Sea events" are in fact : "Ionian Sea subduction events"

The main questions in seismology

1b: Earthquakes understanding

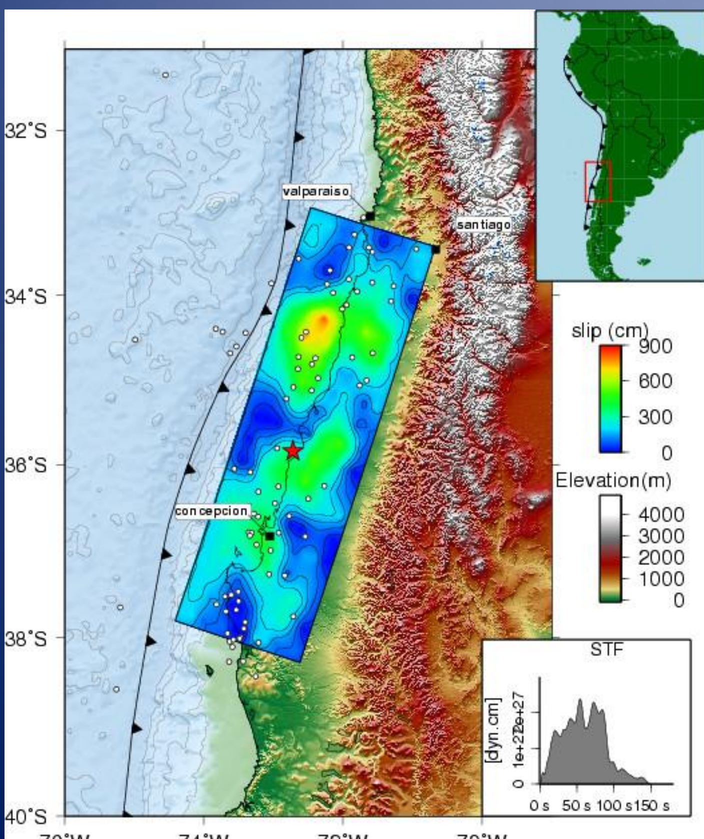
how big will be the earthquake?



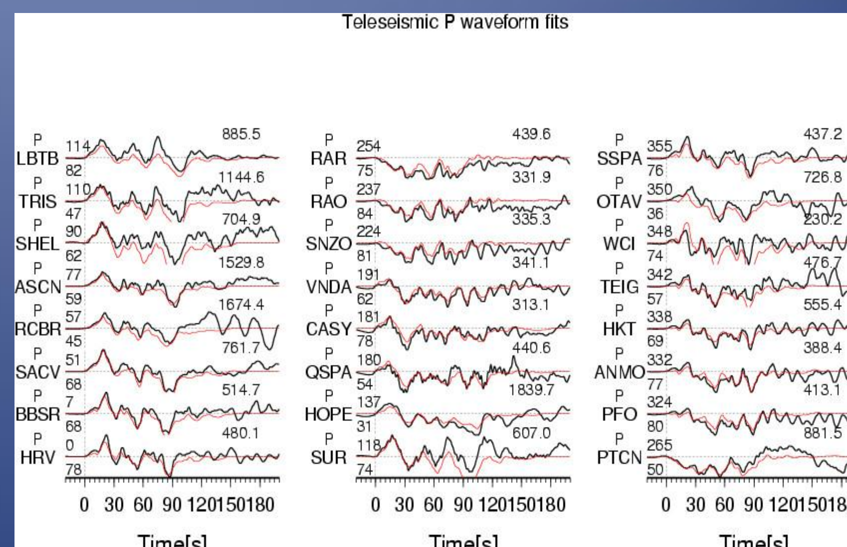
The main questions in seismology

1b: Earthquakes understanding

how big will be the earthquake?



Maule, 27 february 2010, Mw =8.8



The main questions in seismology

1b: Earthquakes understanding

Geometry of Landers fault system

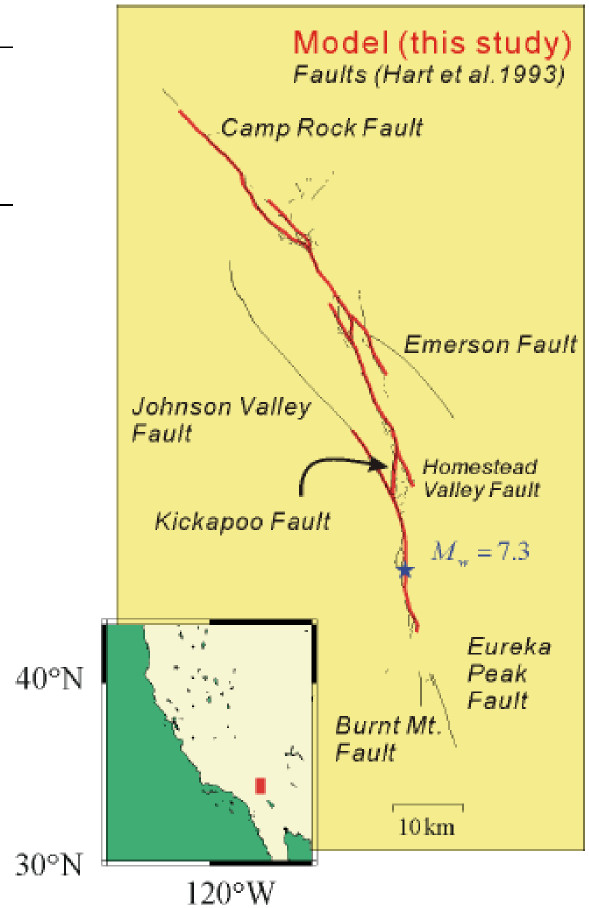
Figure shows the fault traces

(Hart et al., 1993)

which ruptured during

the 1992 earthquake,

and those which did not break then

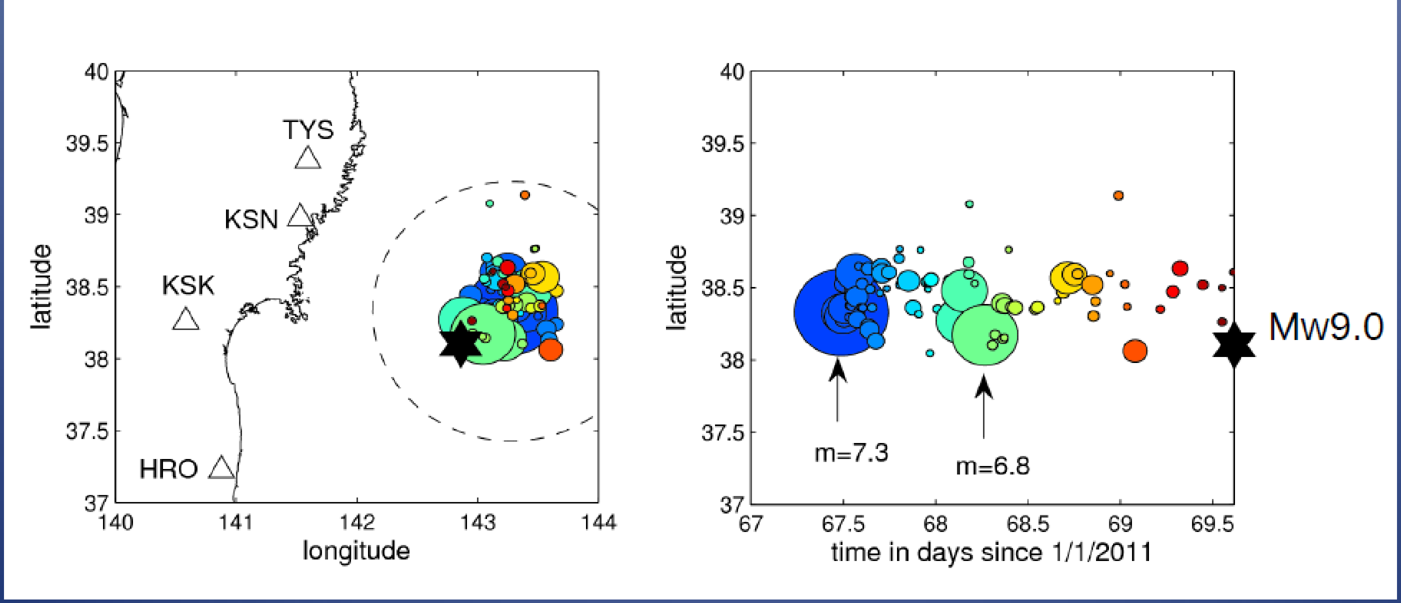


The main questions in seismology

1c: Earthquakes understanding

when will the earthquake occur?

Precursors observed before Tohoku 11 march 2011 event

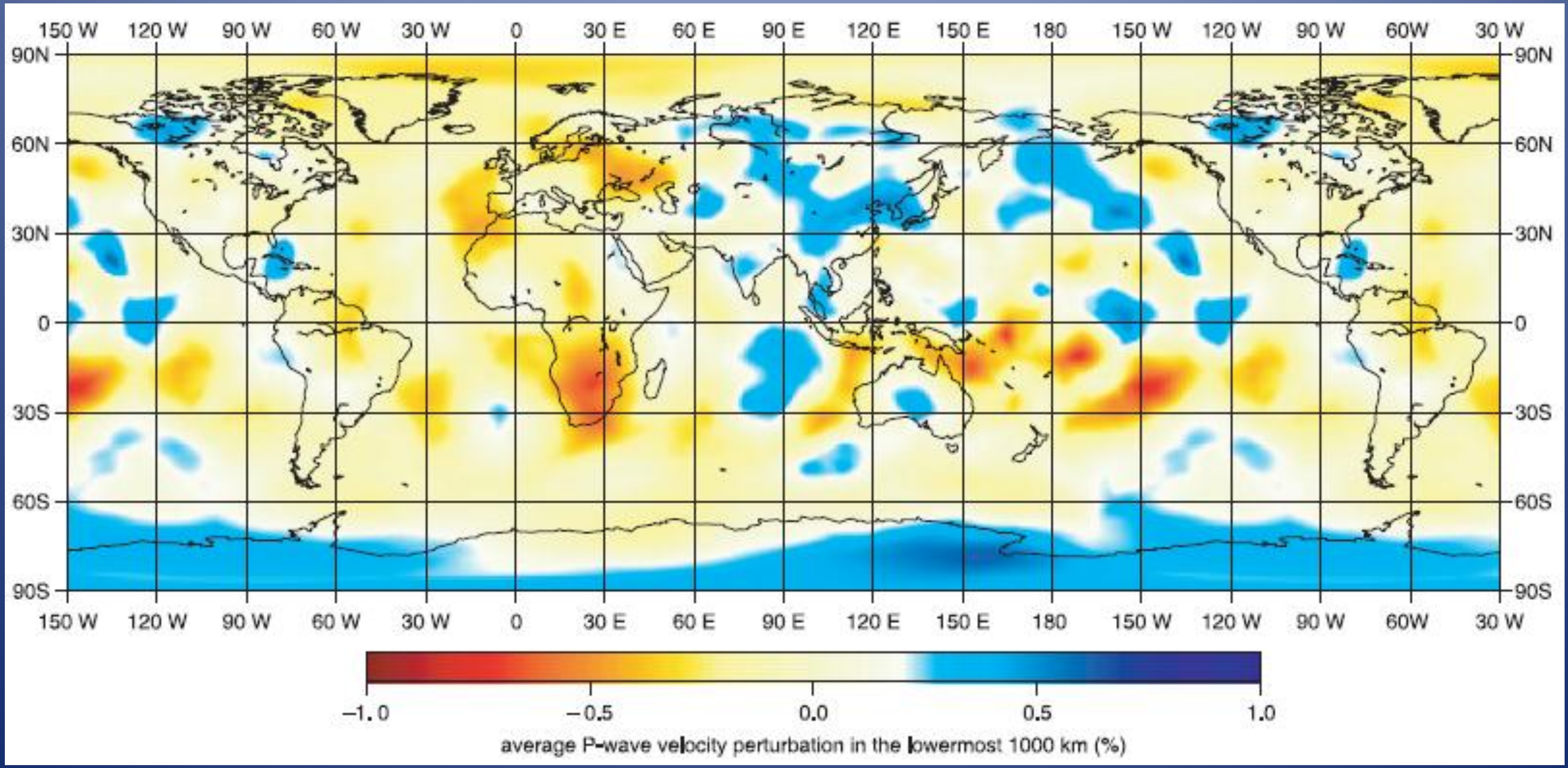


Need of near field observation

The main questions in seismology

2. Structure of the Earth at different scales

Global Earth P waves velocity variation at a depth of 1000km

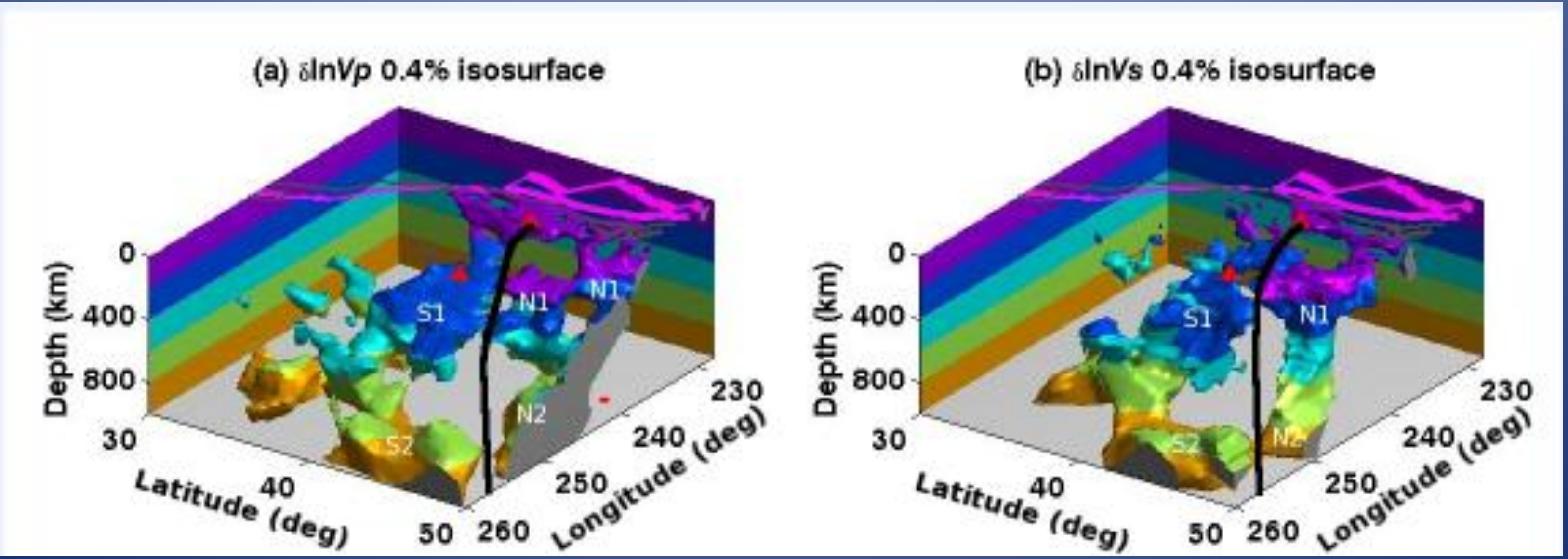


Montelli et al., 2004

The main questions in seismology

2. Structure of the Earth at different scales

Regional scale: P and S waves velocities beneath North American plate



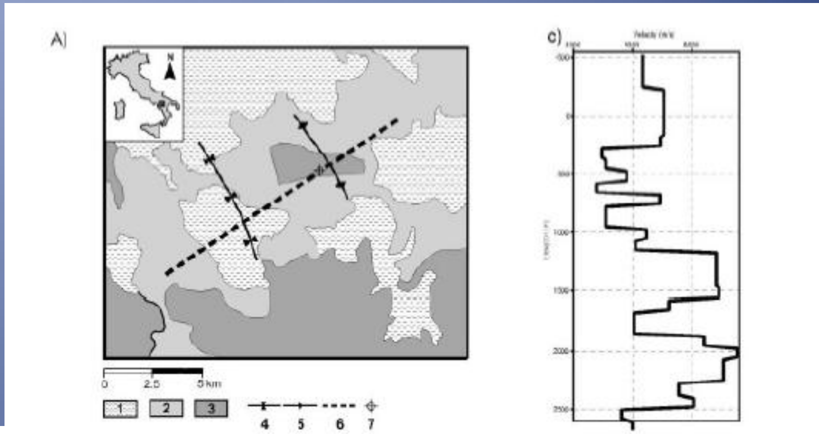
Sigloch et al. (2008), Tian et al. 2009

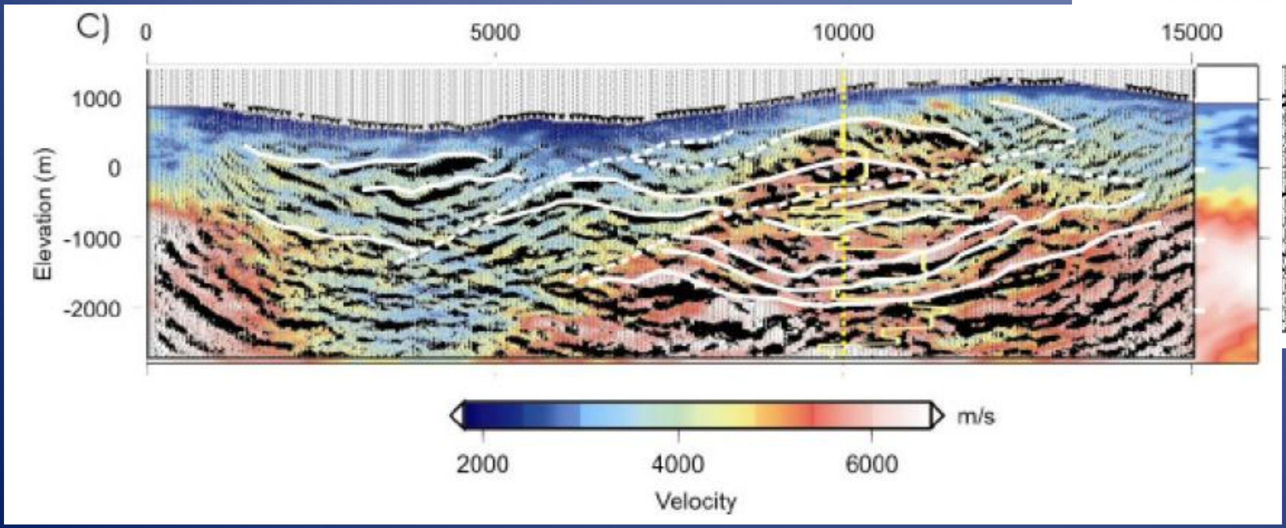
The main questions in seismology

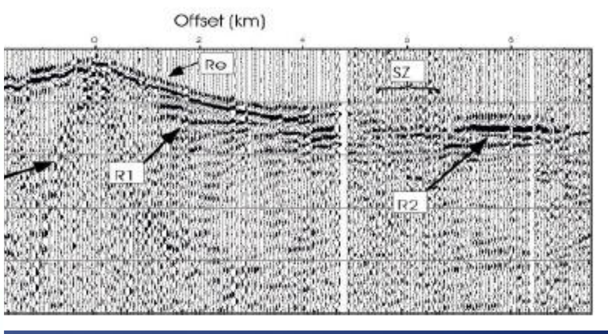
- Structure of the Earth at different scales

Local scale: ressources prospecting

seismic profile in Italy

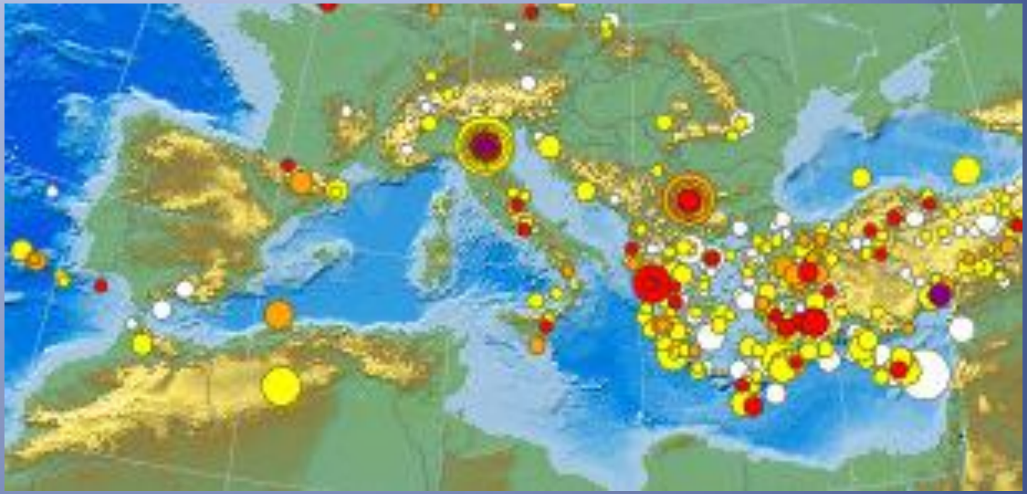






Operto et al., 2006

In Mediterannean area



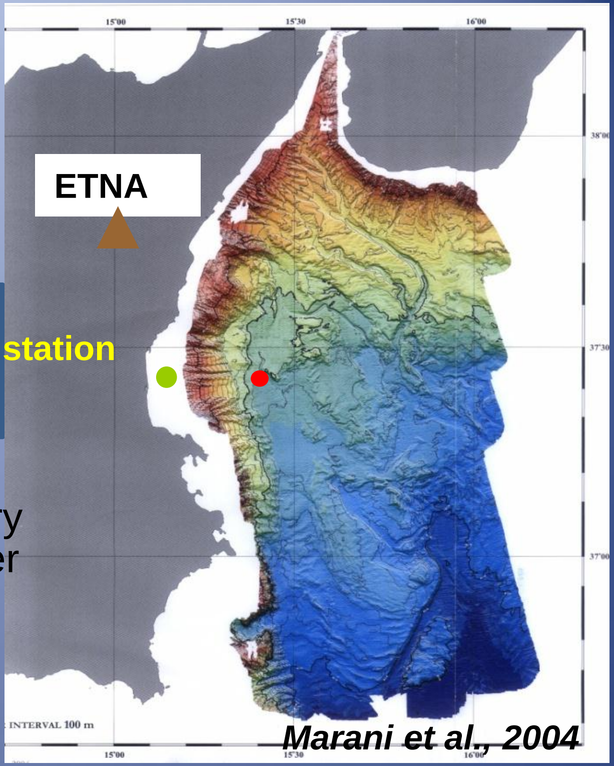
Last 10 days of seismicity

Seismicity is mainly moderate
But, for a large part, just offshore along coasts.

Installing permanent seismological observations is important for some specific studies

WESTERN Ionian Sea – NEMO-SN1

The Obs. Is 2100 bsl, 25 km from the Sicilian coast at about 50 km from Mt. Etna volcano



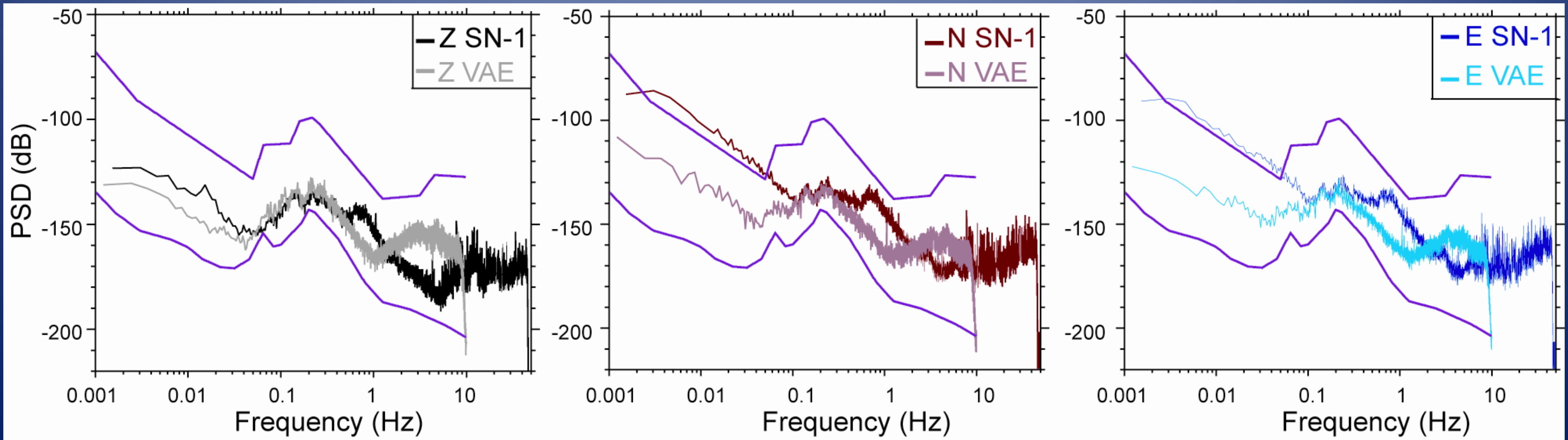
Marani et al., 2004

VAE land station

Broad-band Seismometer: Guralp CMG-1T- 100 Hz sampling rate, 0.0027 to 50 Hz

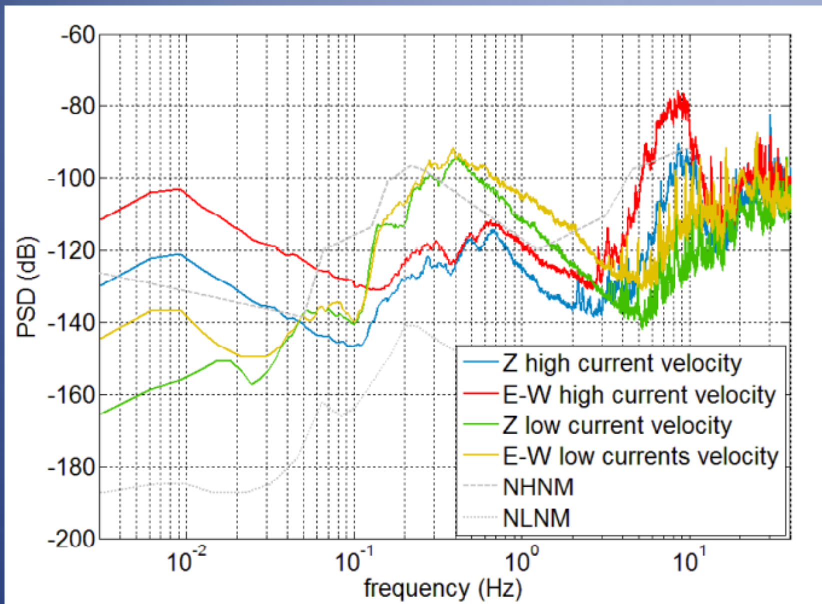
- SN-1 observatory
- Buoy wave-meter

Comparison between the background seismic noise at NEMO-SN1 and at VAE land station (Peterson HNM and LNM s model is also shown): good coupling of the NEMO-SN1 seismometer with the seafloor

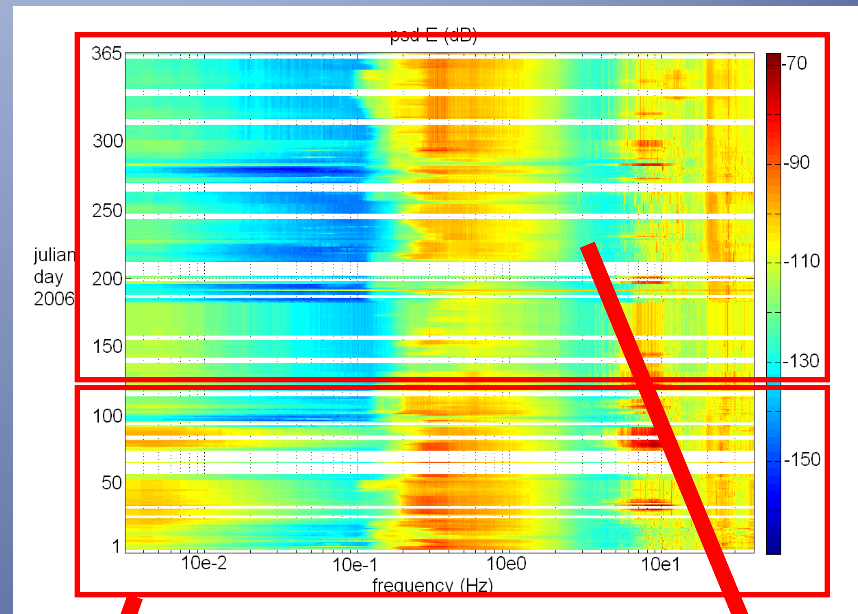


Monna et al., 2005

At Antares Site in 2005/2006:



Current speed influence on seismic noise.

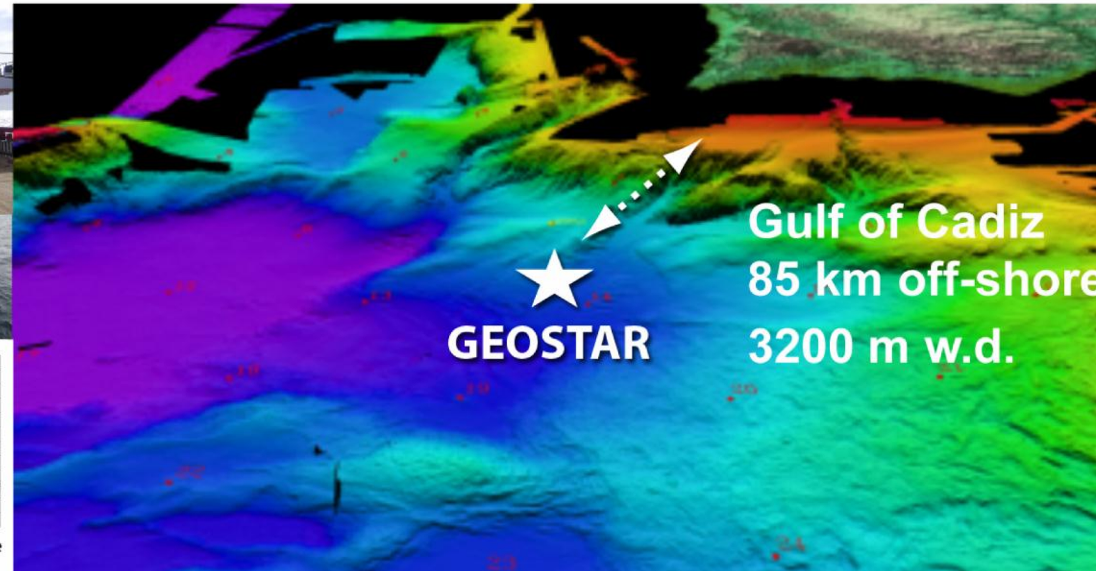


Variation of the DSP of the EW acceleration of sea bottom (12 hours periods)

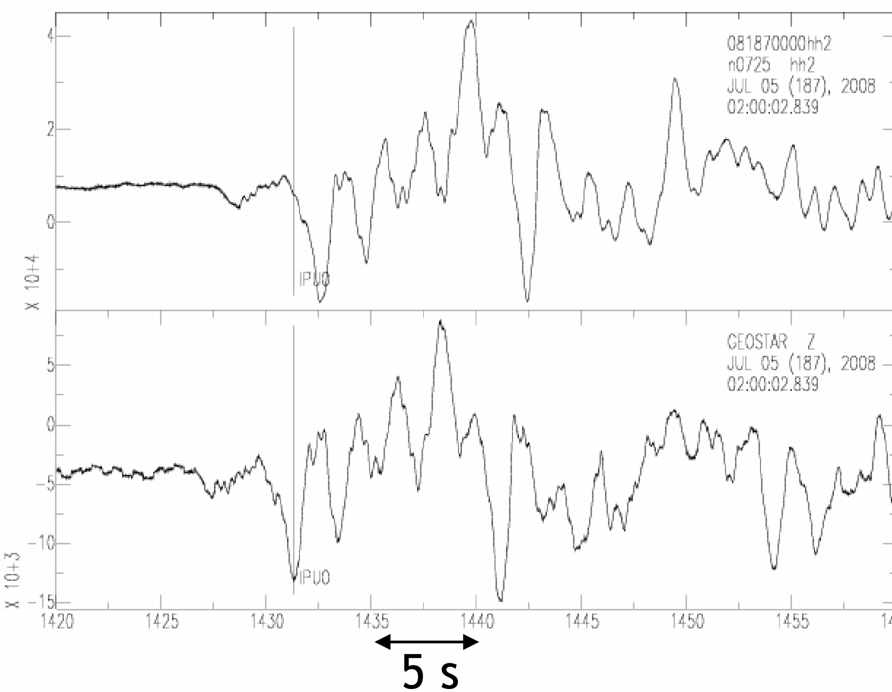
- Burying the sensor improve the signal/noise ratio at low frequency
- Noise is lower during summer

* DSP = spectral density

NEARES
T EC
Project

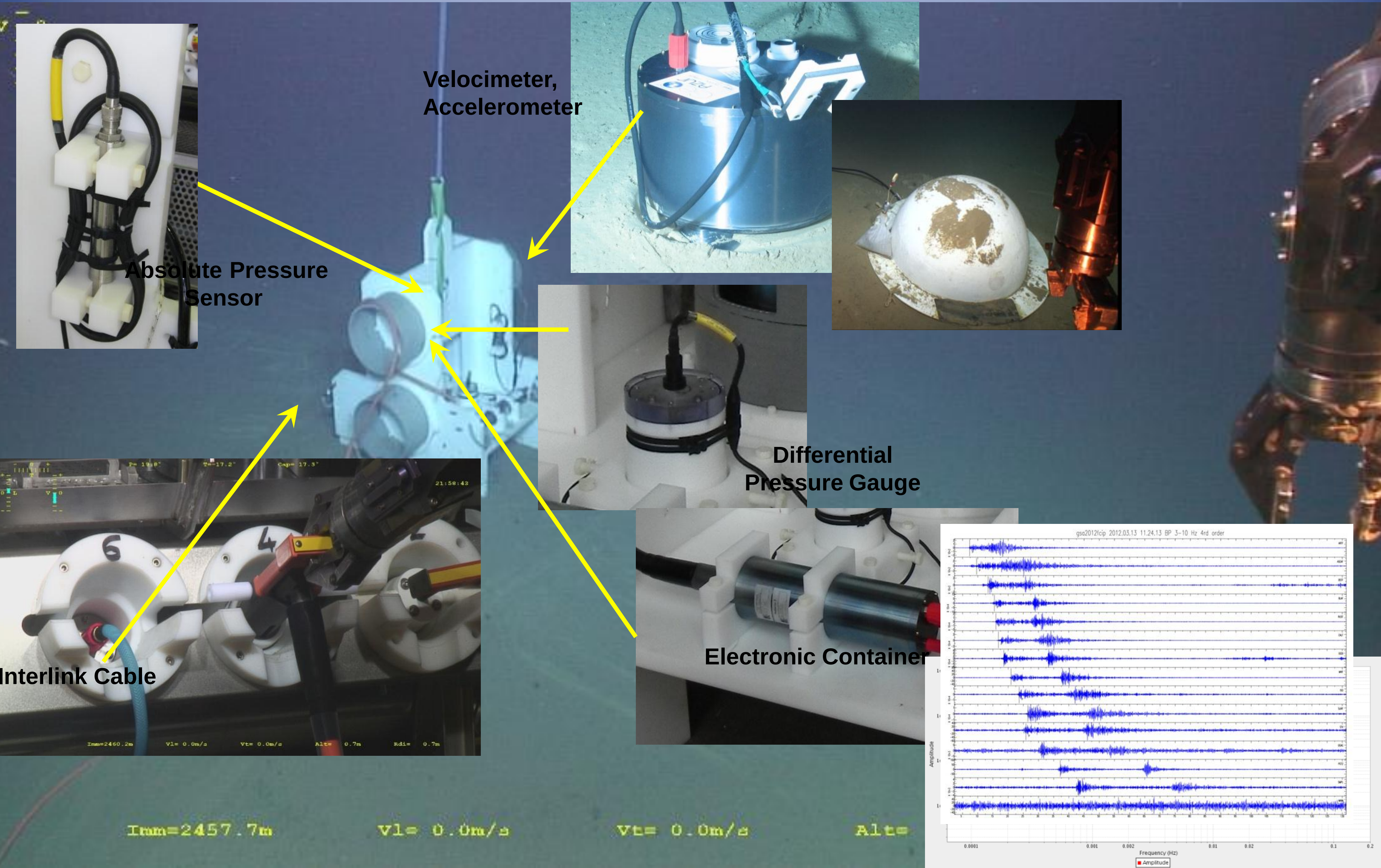


Teleseismic event: Sea of Okhotsk M

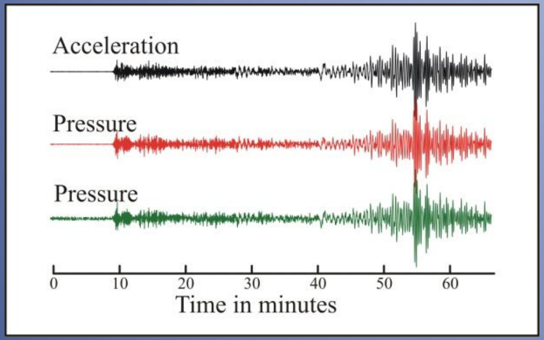


Comparison between of GEOSTAR recording with a nearby OBS (distance about 9 km): GEOSTAR seismometer signal is richer in high frequency than the OBS one because of the difference in the ground coupling quality.

At Antares site TEXREX experiment: geophysical instrumentation 2010/2012 ASEAF station.

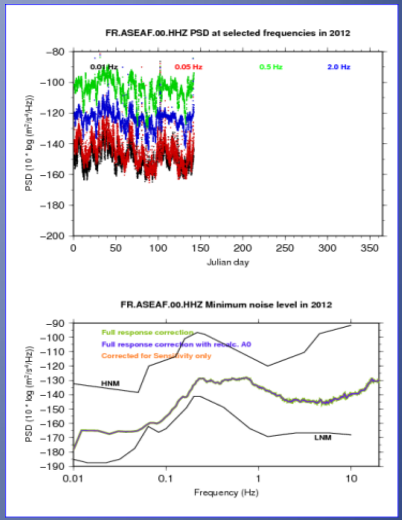


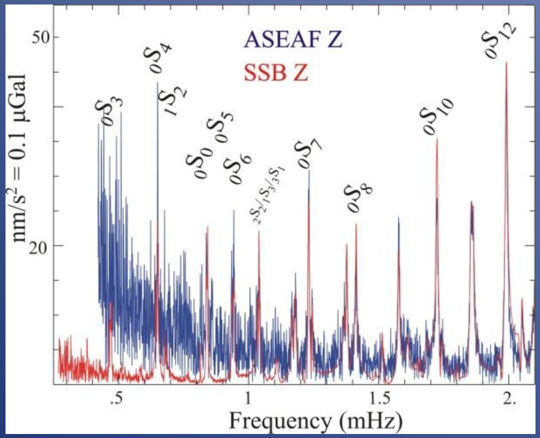
At Antares site 2010/2012 ASEAF station:



Japan 2011 Mw=9 event: ground acceleration, différential pressure gauge, absolute pressure sensor

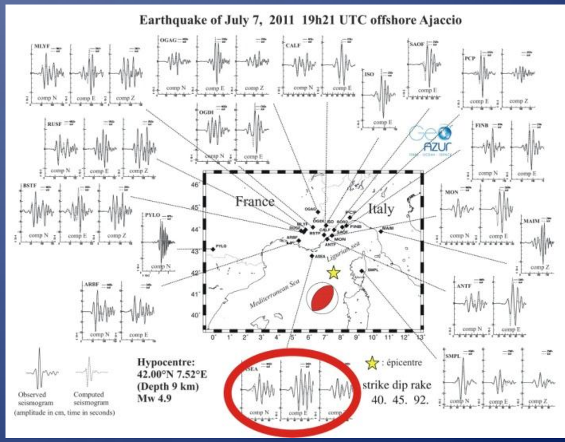
Data send continously to Orfeus to be integrated in European seismological data base where the quality control is assured.





Sumatra 2012 Mw=8.7 event: Earth normal modes compared at ASEAF and SSB (Massif Central, France)

Real time data flow is used to detect and analyse events in Ligurian Sea. ex: 7 July 2011 Ligurian ASEAF data are integrated with the land observations



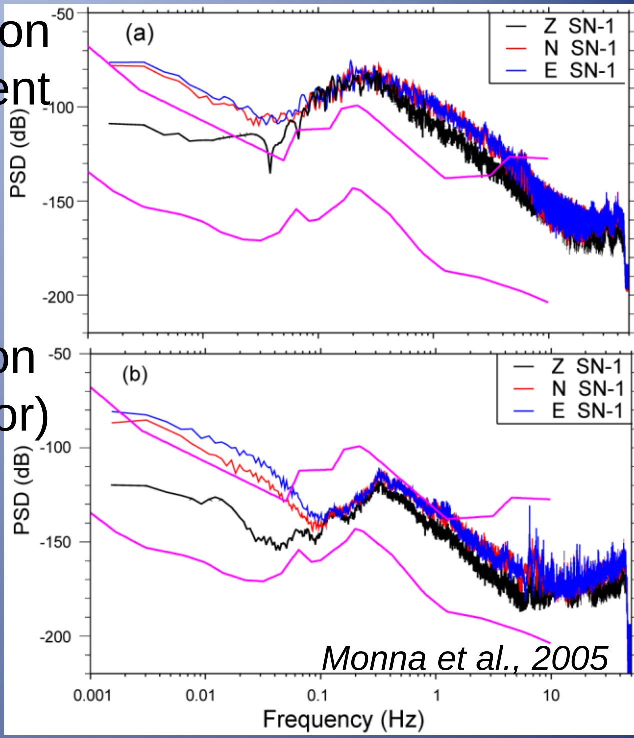
Delouis et al., 2009

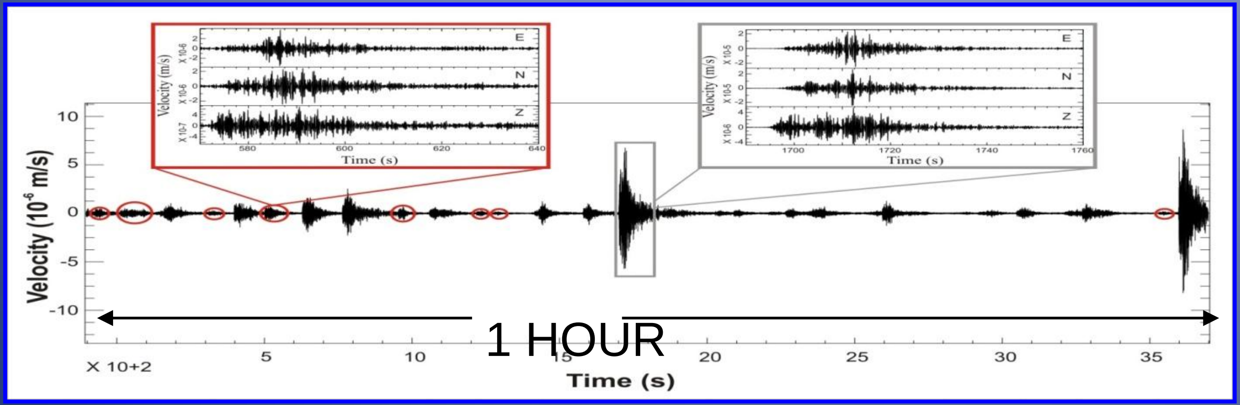
WESTERN Ionian Sea – NEMO-SN1

Mt. Etna eruption 2002-2003

Intense eruption including Ml 4.8 event

End of the eruption (mainly tremor)





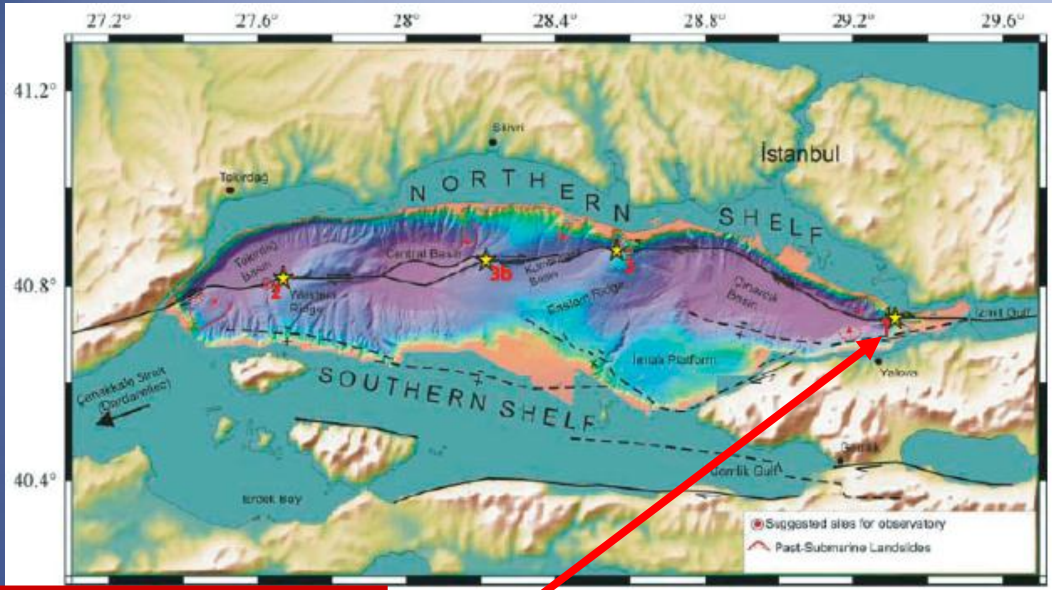
(Right upper panel) - The volcanic tremor was the main feature of the final phase of the 2002-2003 eruption. The tremor is related to fluid circulation in the volcanic feeding structure. The tremor is well visible on NEMO-SN1 seismic noise signal in comparison with ‘quite conditions’ as shown in the previous slide.

(Bottom left panel) Differently from land recordings, seismic events occurring during the tremor phase were observable in spite of the tremor.

Sgroi et al., 2007

Marmara SN-4 Experiment

Partners: Turkey, Italy, France



Main goals:
Relationship between Seismicity & Gas seepage

SN-4

The site:
eastern part of the sea at the westernmost end of the fault rupture caused by the 1999 Izmit earthquake. It is rich of gas-charged sediments and episodic fluids emission related to the fault activity

Multiparameter seafloor station for long-term monitoring of seismicity, oceanographic and gas-seepage processes

GURALP CMG-40T broadband SEISMOMETER — 100Hz

METHANE SENSORS (Franatech) — 1 Hz

AANDERAA OXYGEN SENSOR Optode 3820 — 1 Hz

Acoustic Current Meter MAVS-3 NOBSKA — 5 Hz

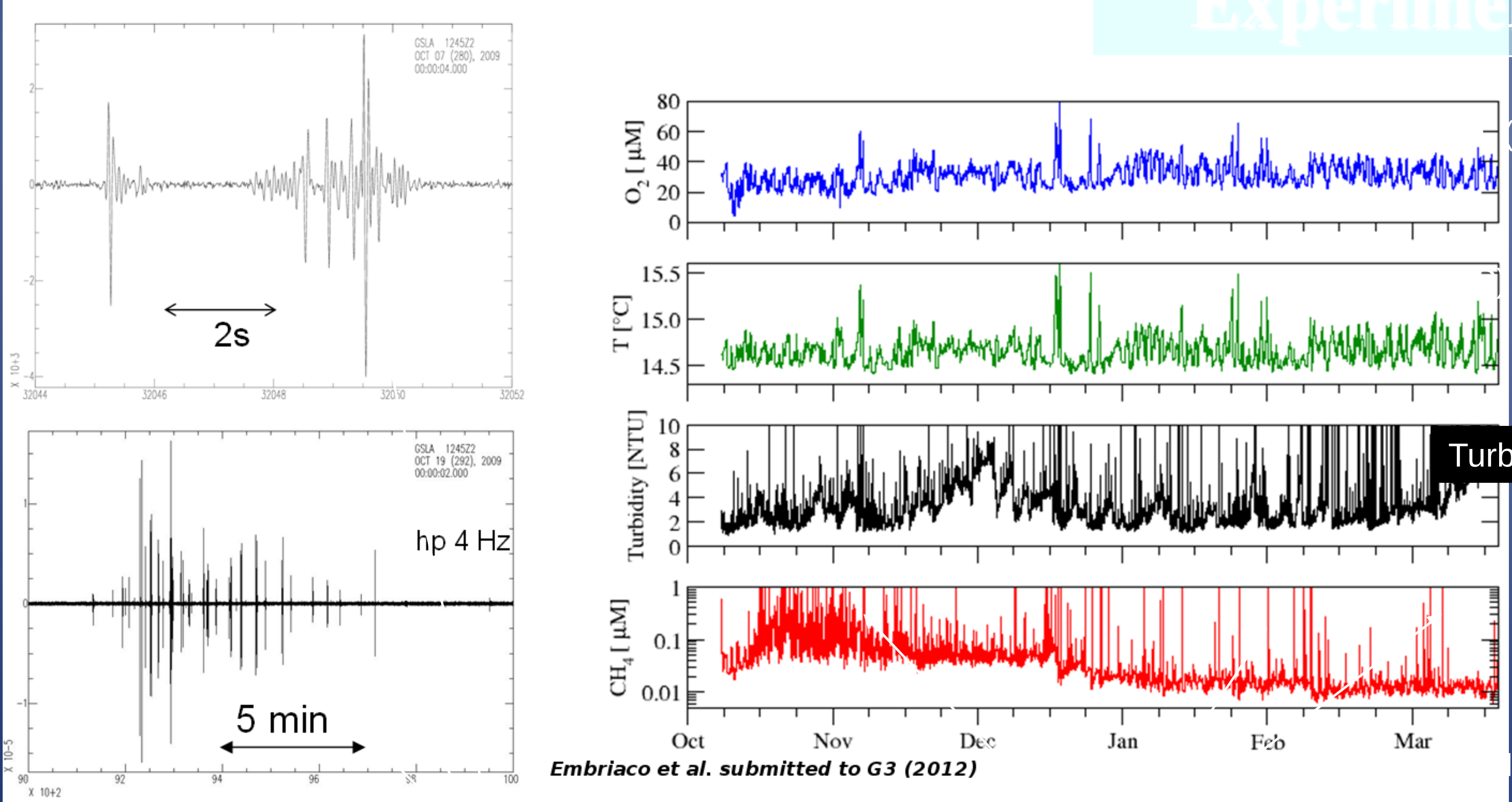
CTD (Seabird) 16 Plus — 1sample / 10 min

Backscattering Meter ECO BB - WET Labs — 1sample /10 min

All sensors are managed by a data acquisition and control system, with the same time reference (Rubidium Clock)

SN-4 Multiparametric approach

Marmara SN-4 Experiment



Embriaco et al. submitted to G3 (2012)

Seismic Short Duration Events linked to methane degassing

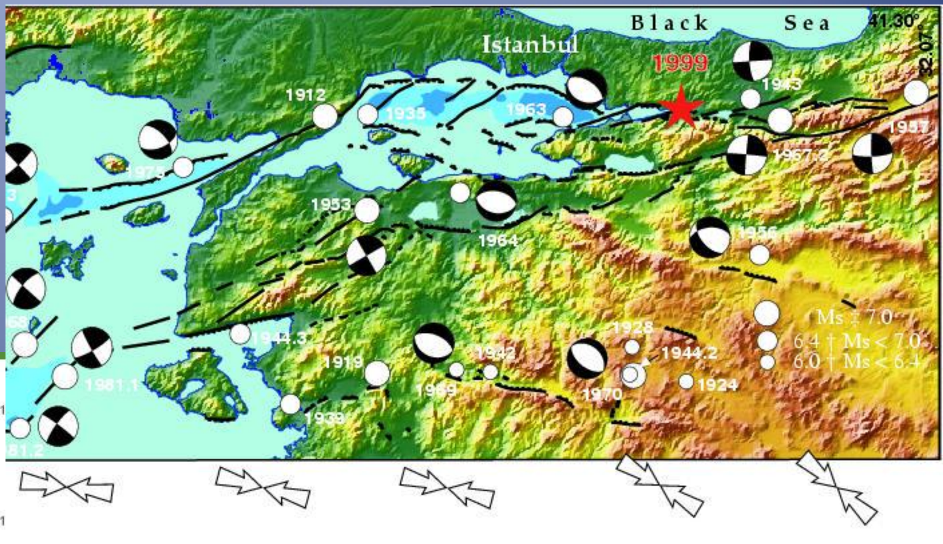
(CTD, oxygen and current meter data are useful to describe methane detection process)

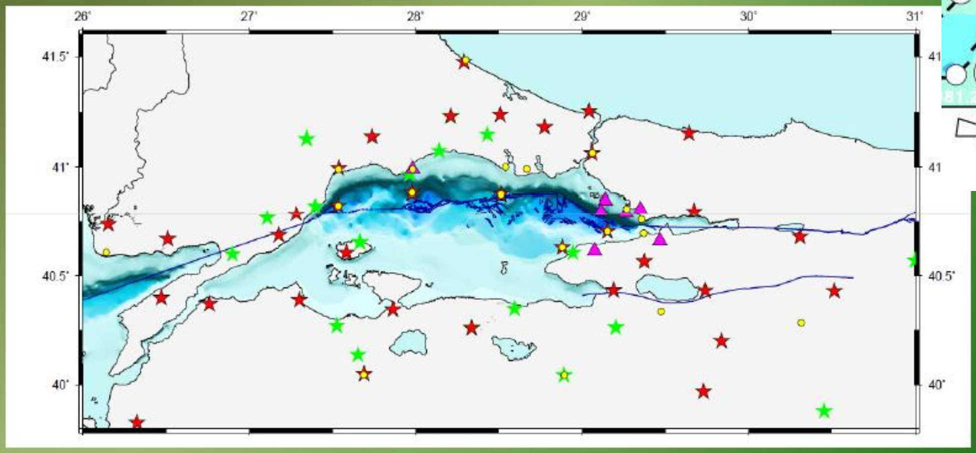
5 October 2009-15 March 2010 (**161 days**)

It is the longest monitoring of temperature + gas + seismicity at seabed, ever done

In this area a large event which can strongly destroy Istambul is expected:

The turkish groups have deployed 5 cabled seismological instruments for activity monitoring

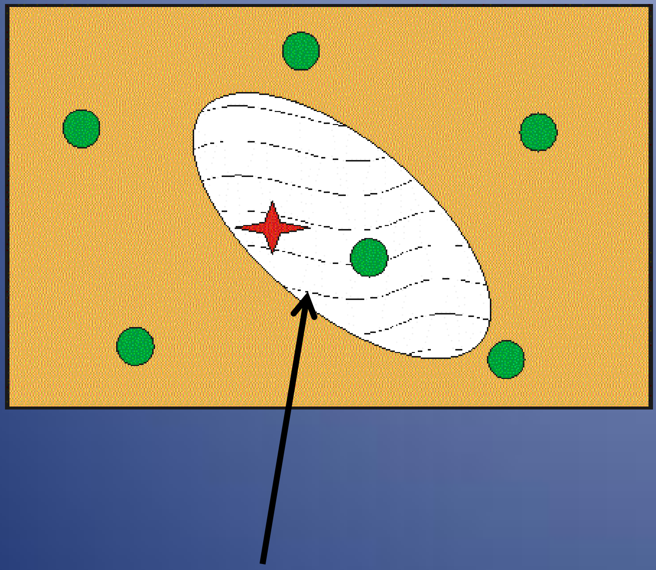




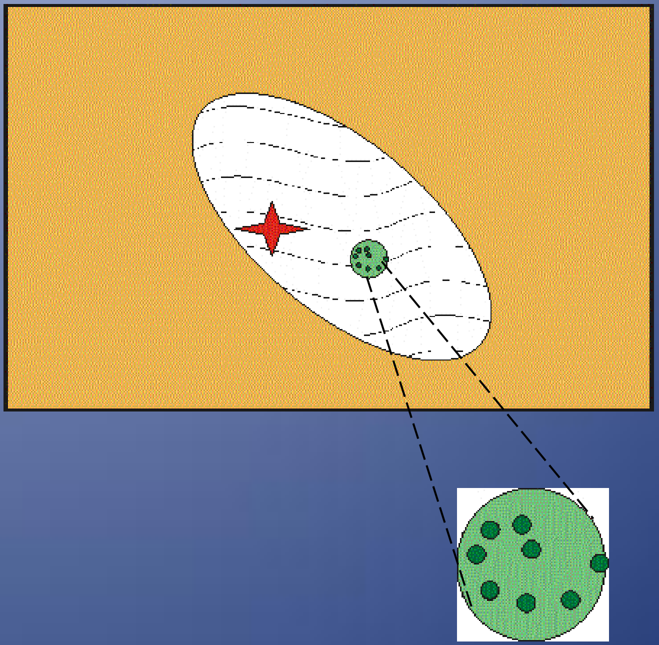
Networks : KOERI-NEIC, AFAD, Cinnet (Koeri-CNRS)

Dispersed versus concentrated instrumentation

Common seismological networks



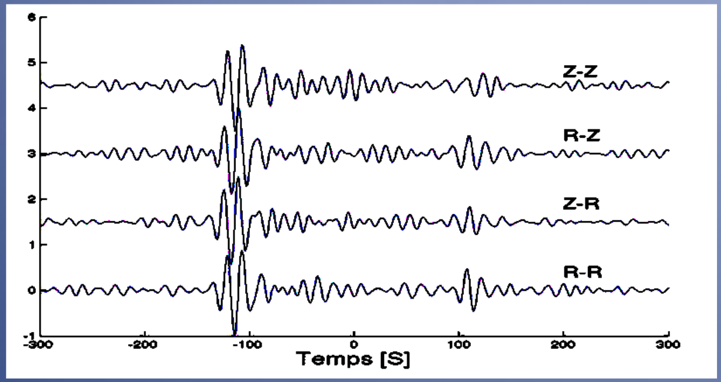
Seismic area of interest

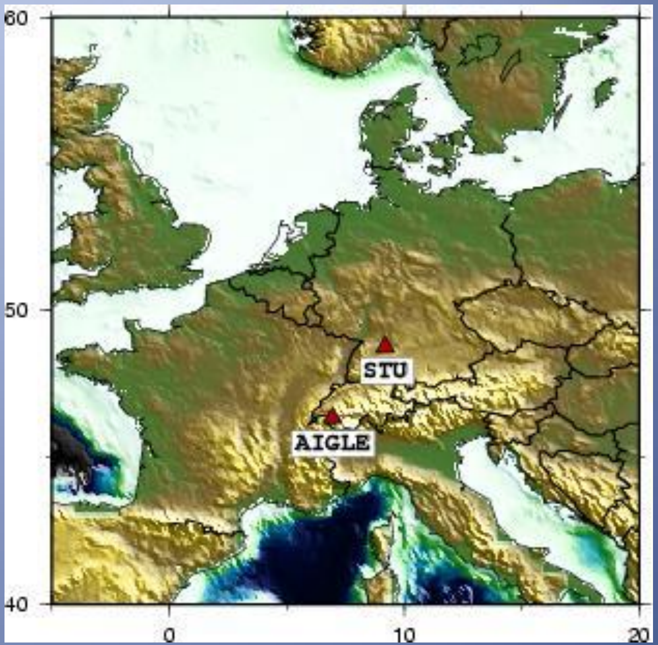


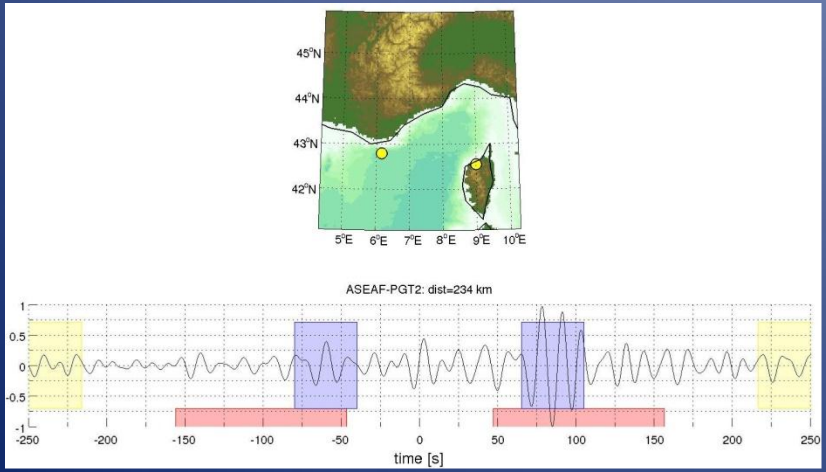
Datation better than 1ms
High sampling rate (200 sps)

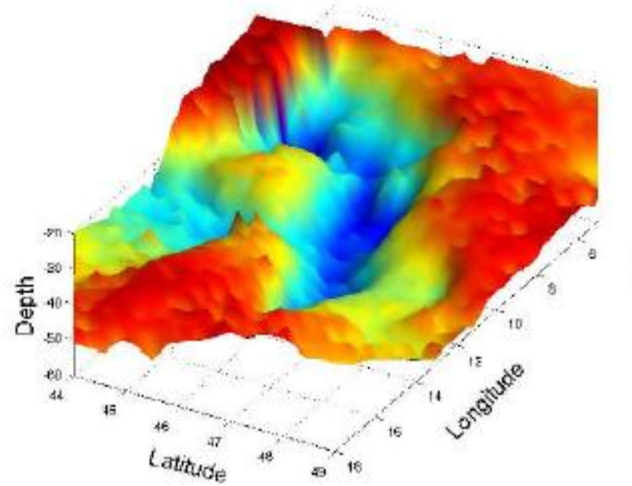
Data from Antares station will provide possible extension of the Alps study

Ondes de Rayleigh from ambient noise correlation









'Noise' tomography
Stehly et al. 2008

Conclusions

Seismological studies are relevant to the Mediteranean context.

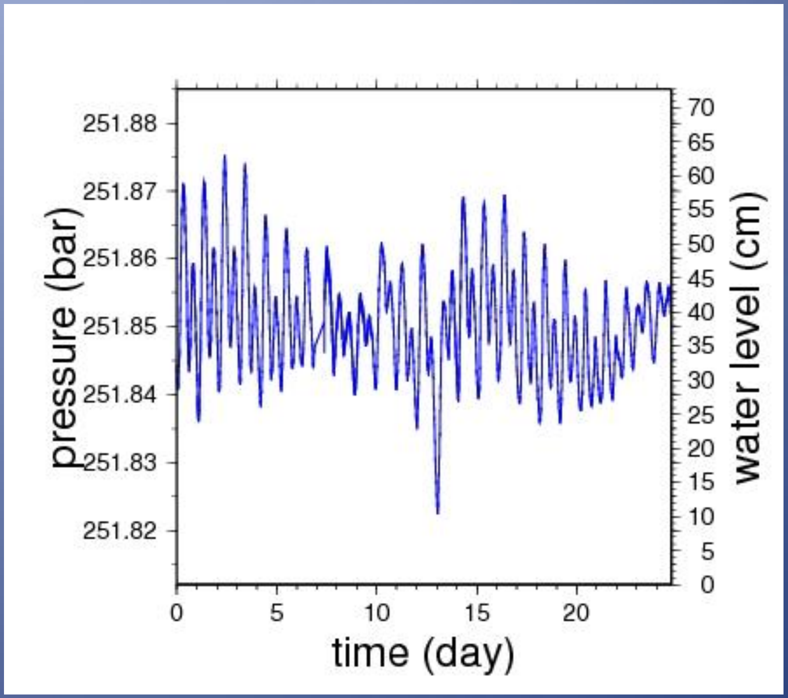
The deployment of the sensor must be done carefully to insure good signal to nois e ratio and good soil coupling.

A long term observation is necessary to structures studies but even more for earthquakes understanding and monitoring. Continuous recording is very important.

Multiparameter observations help to the interpretation of seismological dadata (current, pression, temperature, geochimistry…)

The difficulty to build a distributed network around the sources can be overcome using a set of 6 to 8 velocimetric sensors acting as an antenna to locate the sources.

Tsunami observation : a pressure gauge



Pressure 2010

Real time observation needed

The available tools

- Observations
  - Seismic waves (seismometers, accelerometers)
  - Ground deformation: geology, GPS, satellite imagery
  - Ambient noise
- Formal theories
  - Plate tectonics
  - Wave propagation
  - Rocks mechanics
  - Inverse problems
- Numerical modelling
  - 3D wave form modelling
  - Rupture modelling