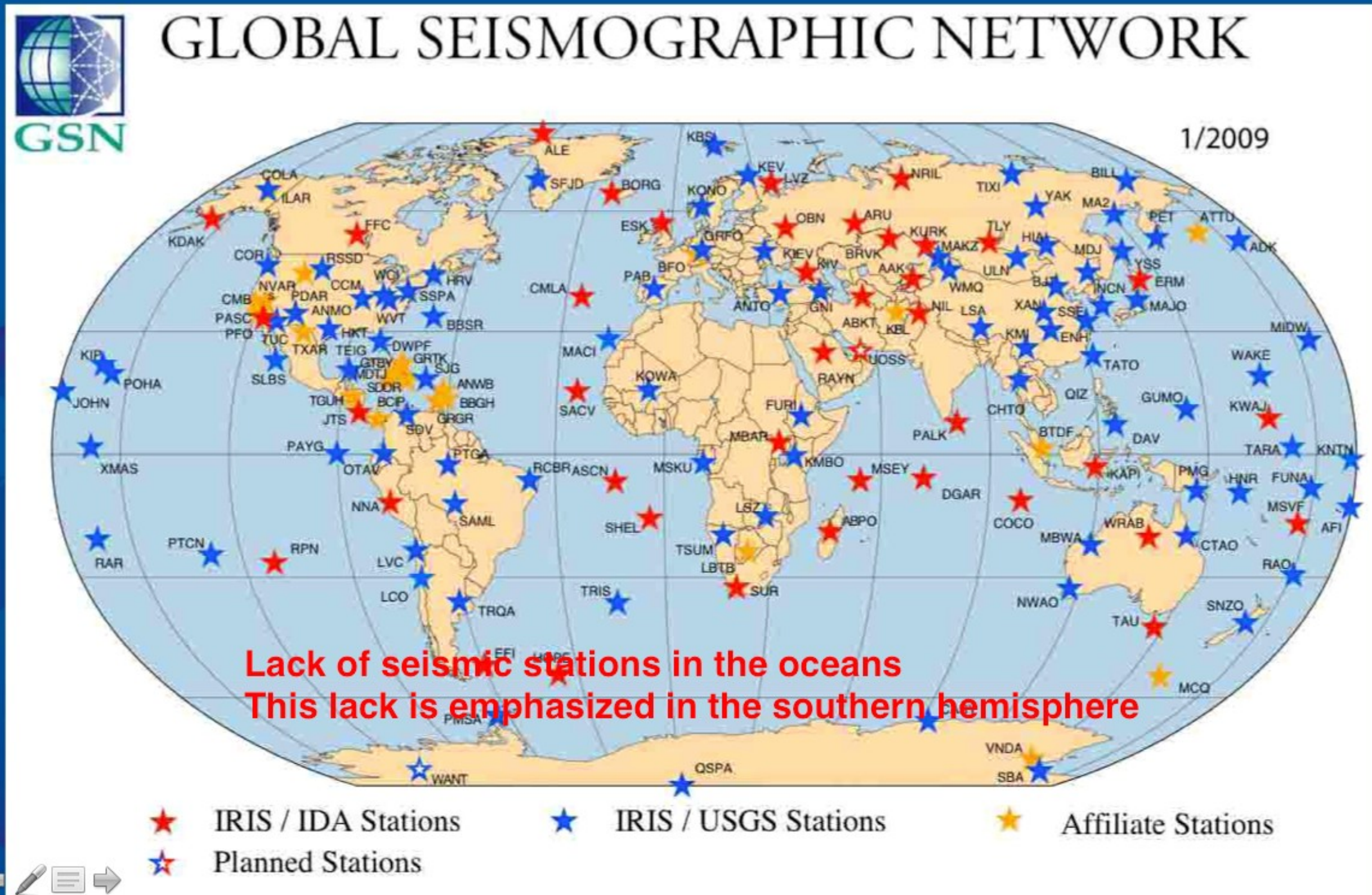
Mermaid

Mobile **E**arthquake **R**ecording in **M**arine **A**reas by **I**ndependent **D**ivers to Earthscope-Oceans

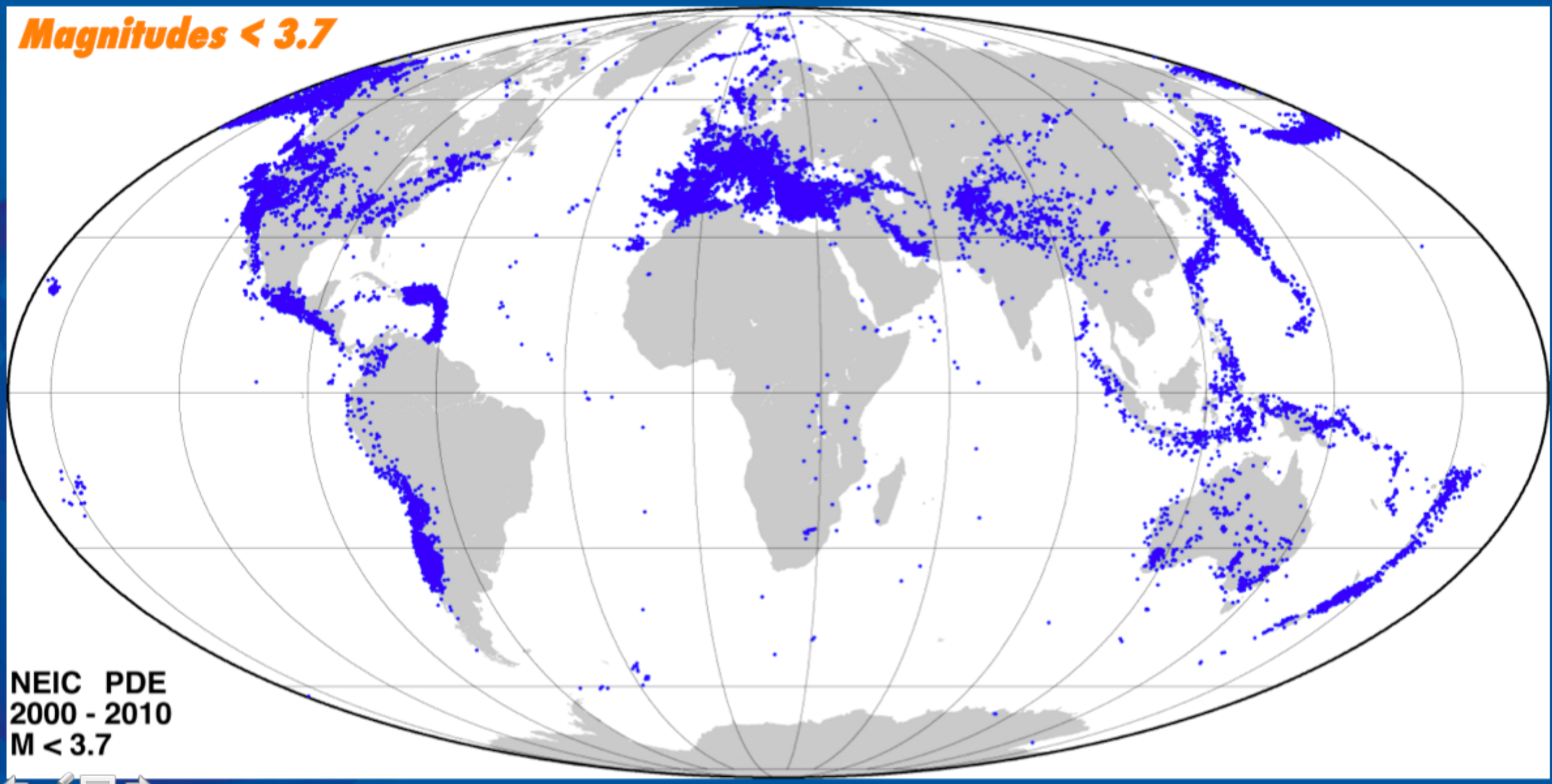
Guust Nolet, Yann Hello (Geoazur),
Olivier Philippe, Manuk Yegikyan (Osean).

Global network of permanent broadband seismic stations



World-wild seismicity 2000-2010

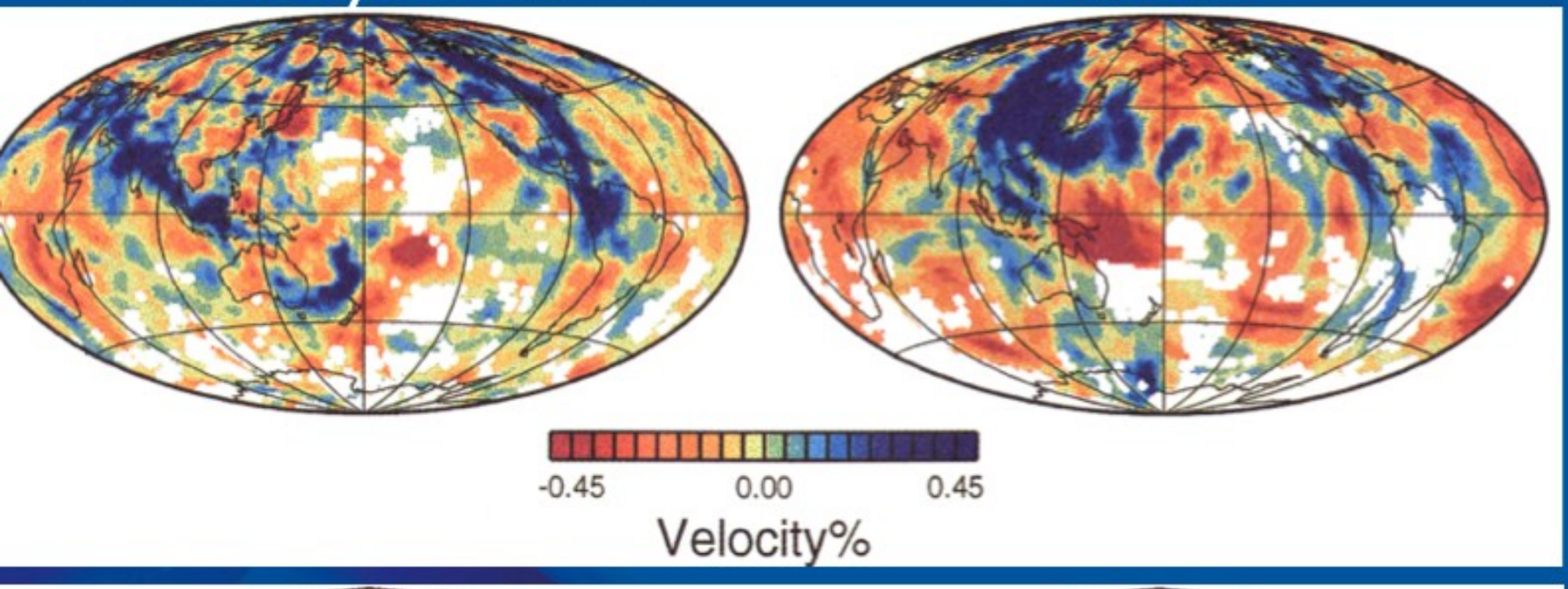
Localized by land stations network

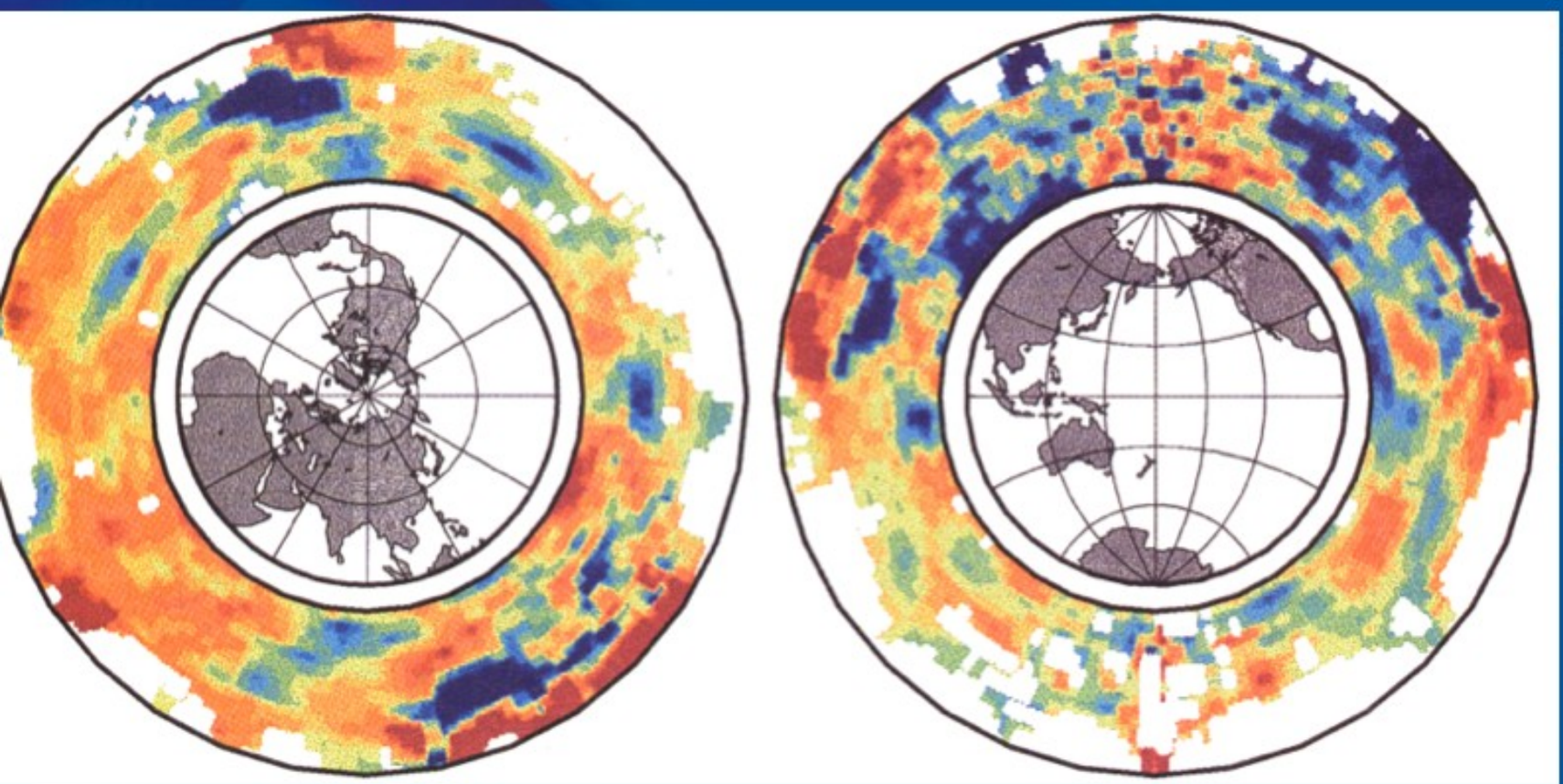


Global and local seismic tomography

Mantle velocity at 2700 km

1300 km





Equatorial cross-section

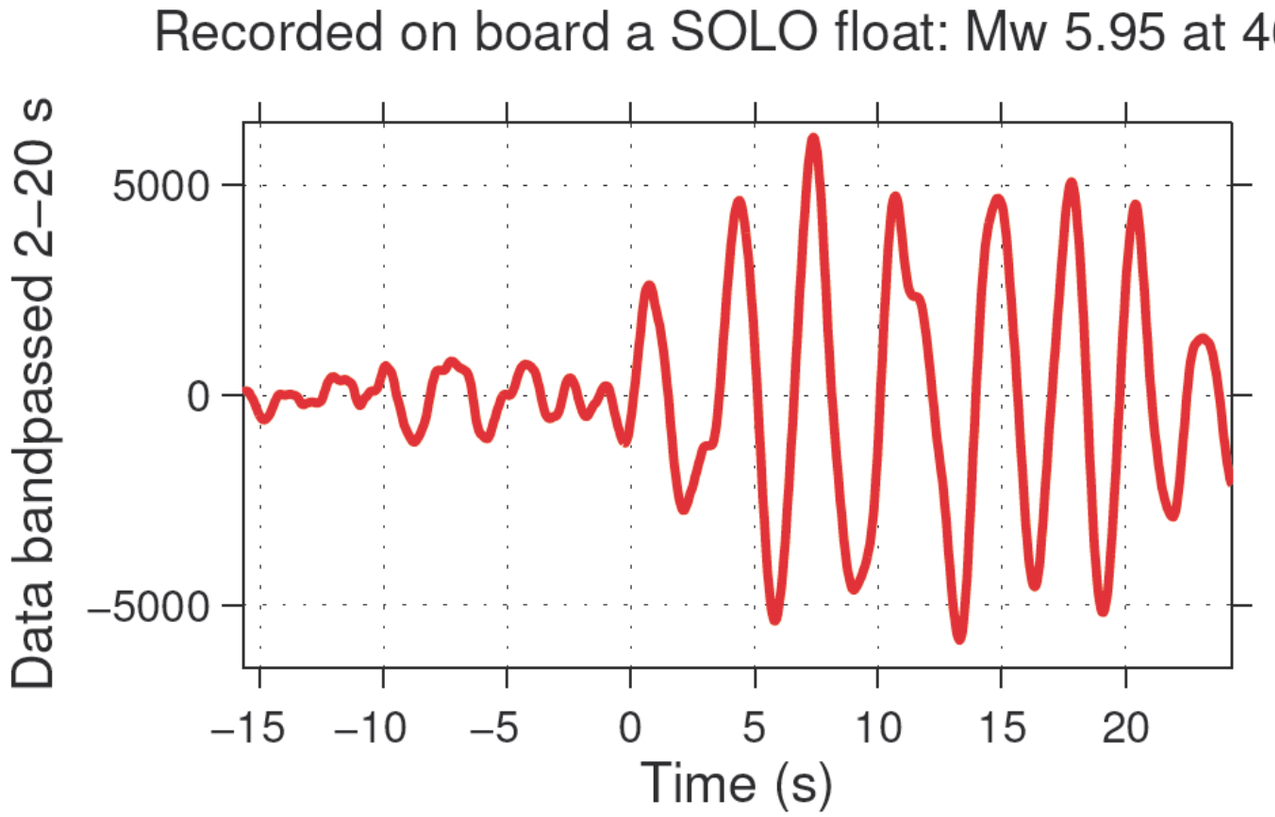
Polarcross-section

- Traveltimes and waveforms of recorded seismograms are used to reconstruct 3D wave speed distribution in the earth
- Provides information on the composition, thermal structure and origin of our planet
- Red for low velocities (compare to an average model) and blue for high velocities
- Under-sampled regions in white
- The poor data coverage in southern hemisphere limits the quality of tomographic reconstruction

Mermaid - A bit of history

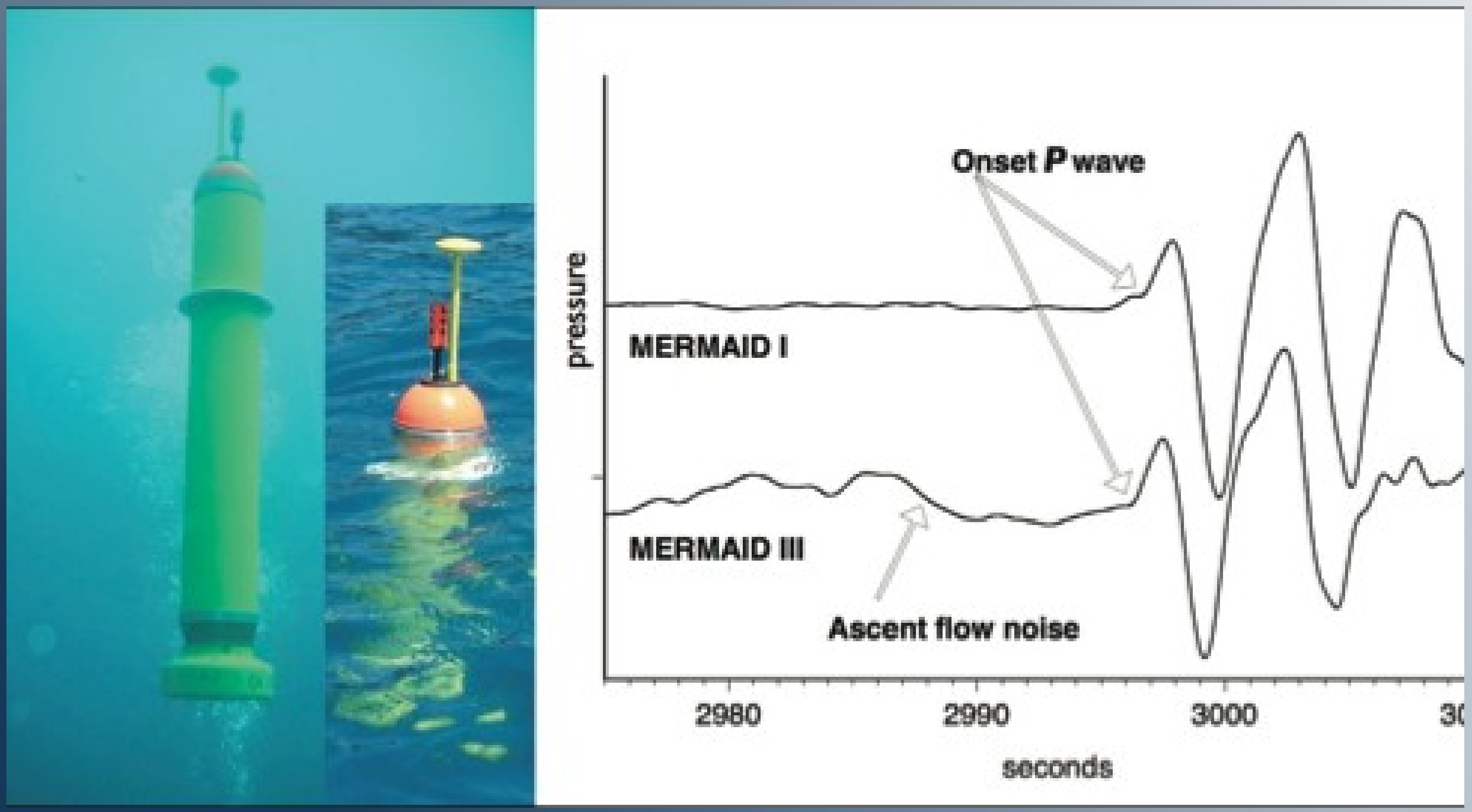
Mobile **E**arthquake **R**ecording in **M**arine **A**reas by **I**ndependent **D**ivers

Nov 5, 2003: Frederik Simons' prototype Mermaid records Mw=5.9 quake at 46º



Simons et al., JGR **114**, B05307, 2009

Geoazur
First recording of a telesismic event June 24, 2011(MW 7.4)



Fox Islands, distance 85°

From an article published in ELSEVIER September 1st 2006 – Frederik J.Simons & al.

Automatic detection and rapid determination of earthquake magnitude by wavelet multiscale analysis of the primary arrival F.

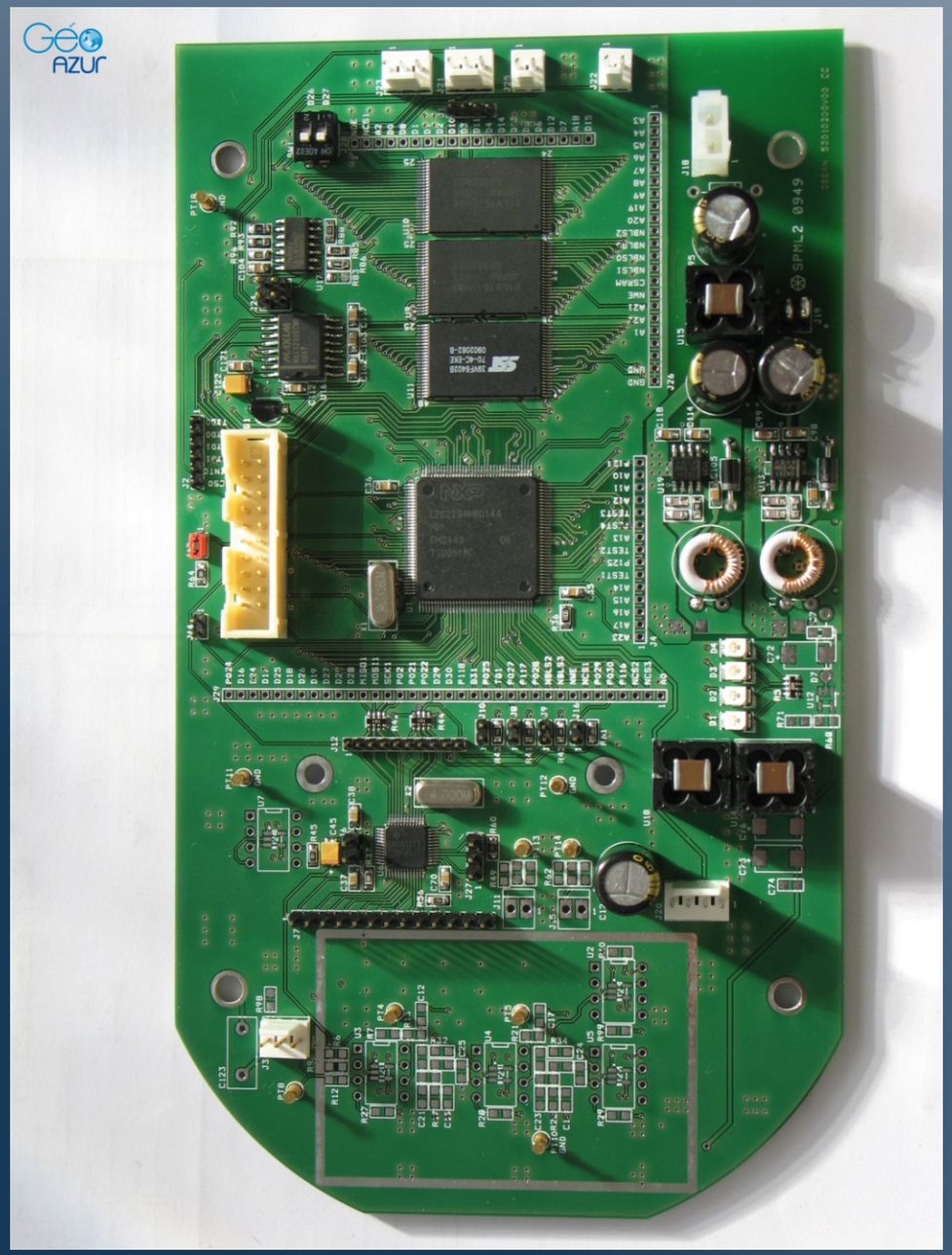
And from a Matlab wavelet transform algorithm :

```
lx = length(x);□for j=1:5;□  for n=2:2:lx−2□                    x(n)=x(n)−[x(n−1)+x(n+1)]/2; end□          f
x(n)−3*[x(n−3)+x(n+3)]/64 +19*[x(n−1)
                +x(n+1)]/64; end□   x = [x(1:2:lx) * sqrt(2); x(2:2:lx)/sqrt(2); x(lx+1:end)];□lx=length
```

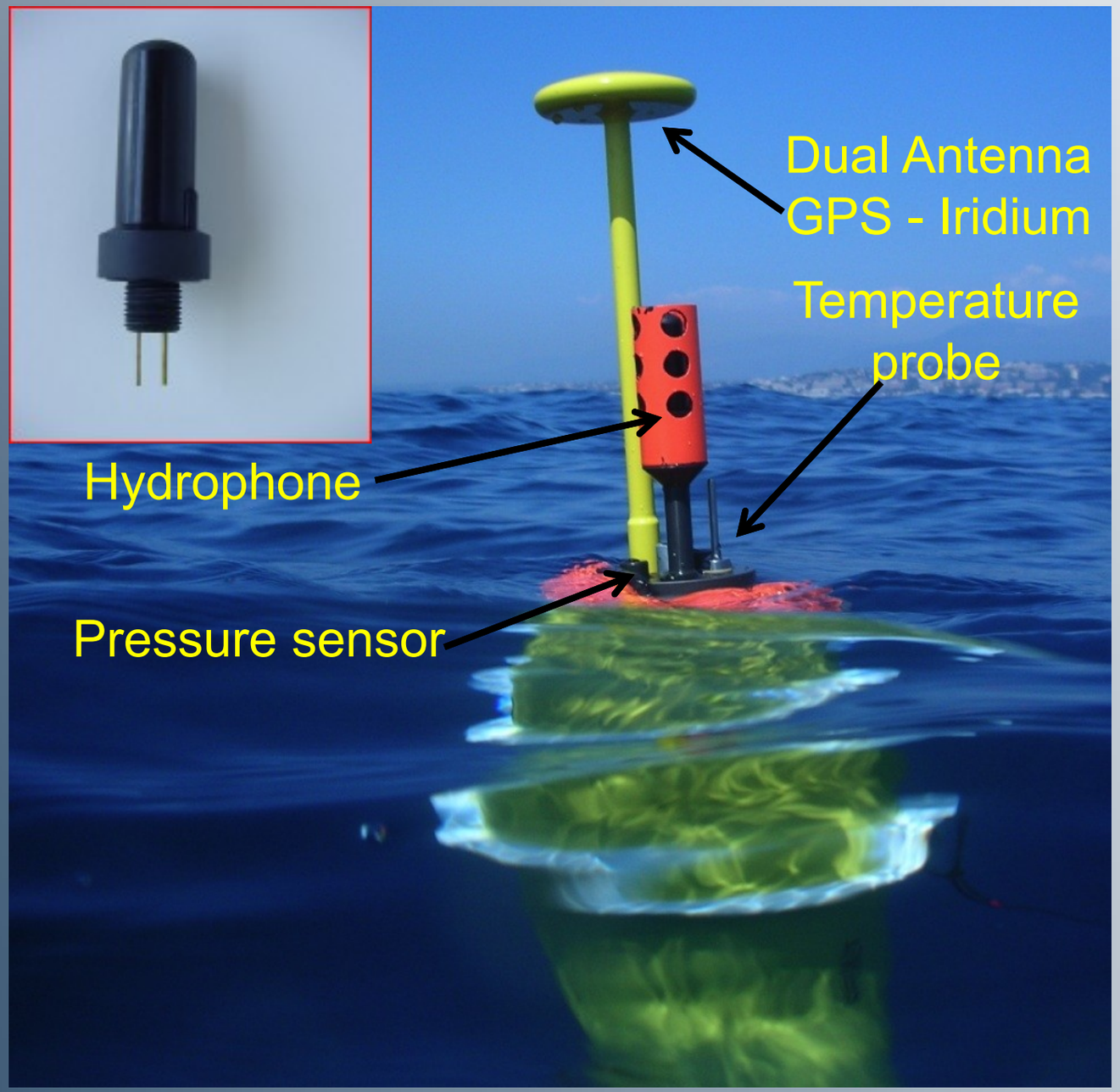
Automatic discrimination of underwater acoustic signals generated by teleseismic P-waves: A probabilistic approach

GRL 2011 – Alexey Sukhovich & al

Sukhovich's algorithm integrated in Mermaid

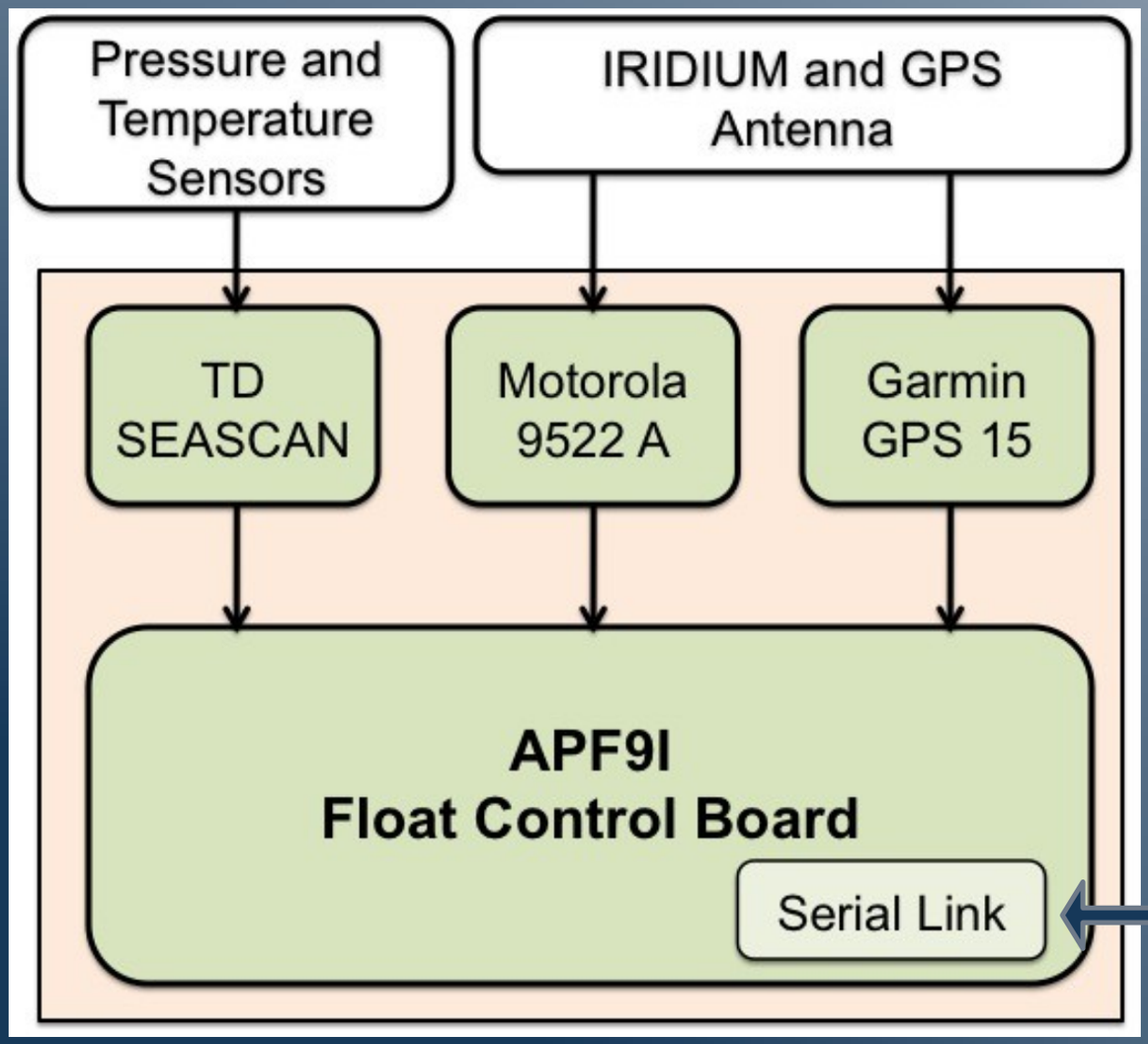


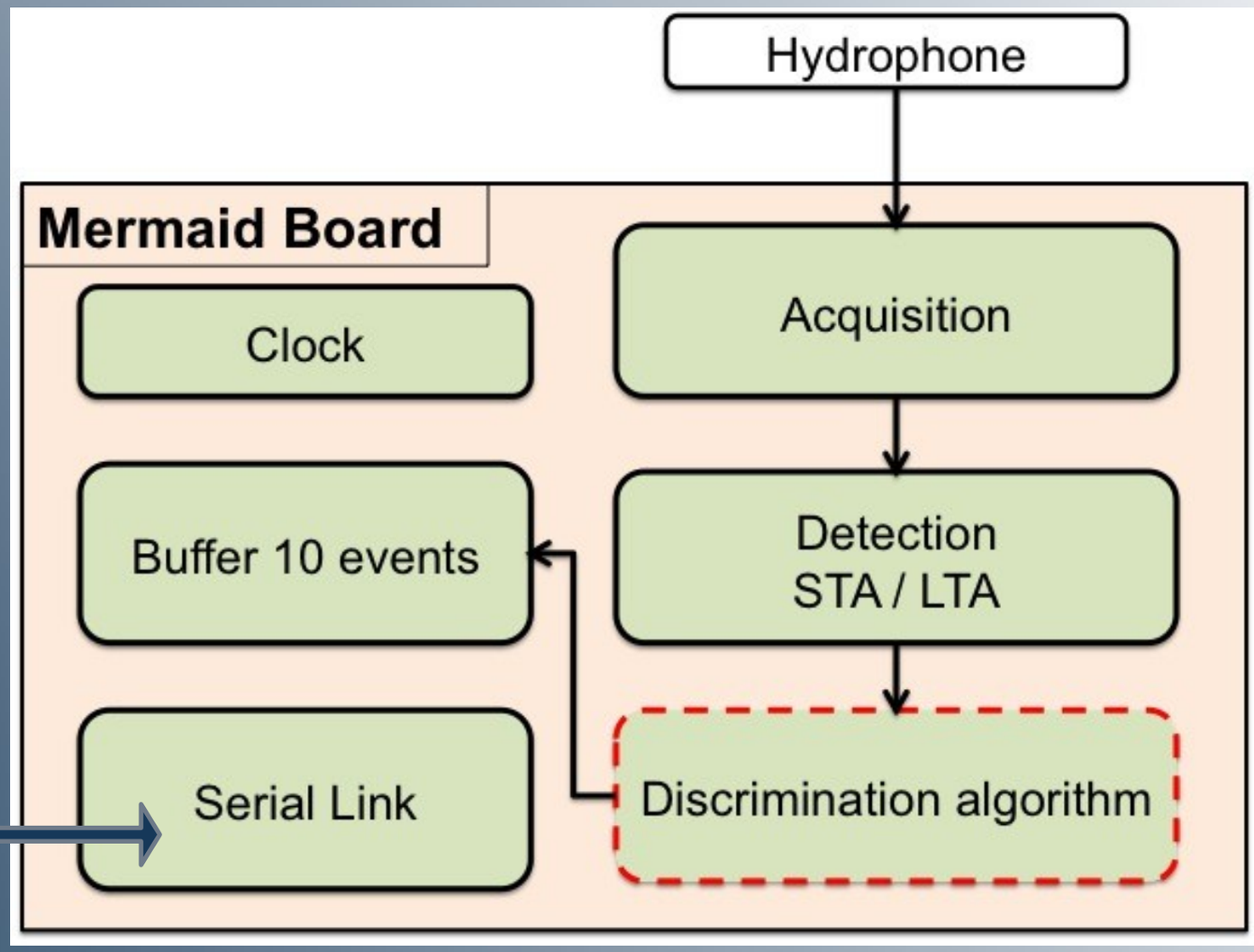
Mermaid board developped by Osean



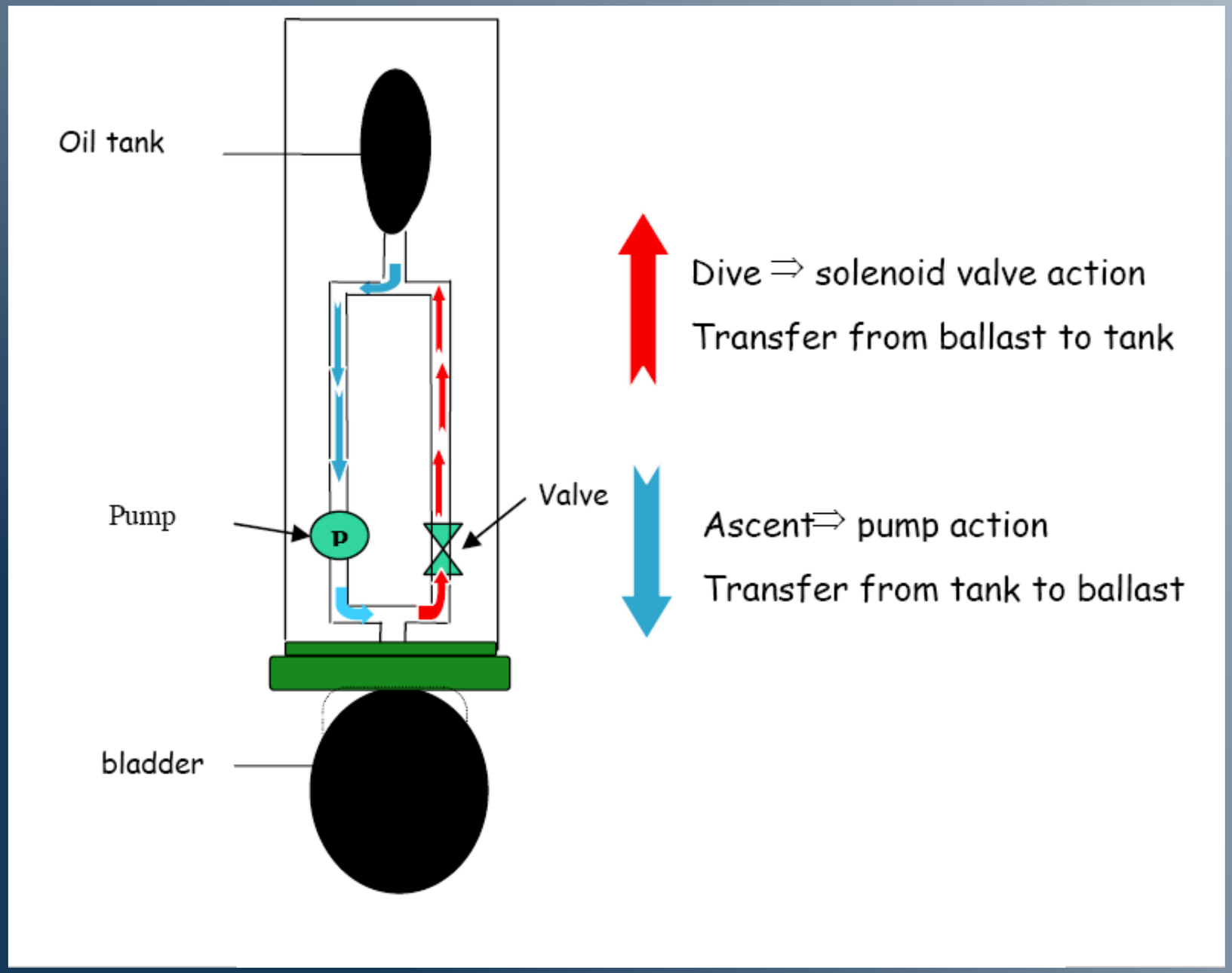
Mermaid in Apex from TWR.

Electronic Synoptics for Mermaid.

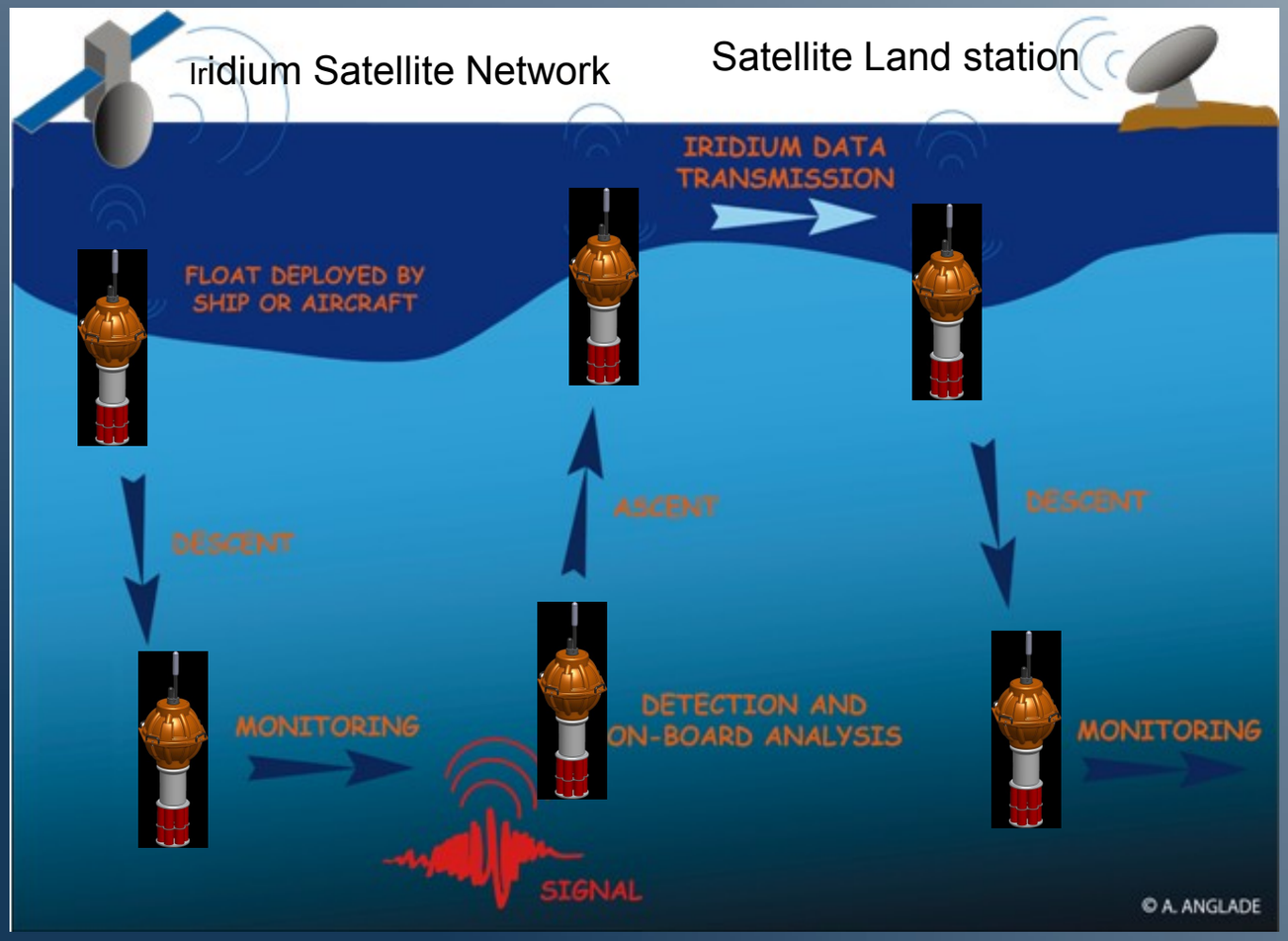


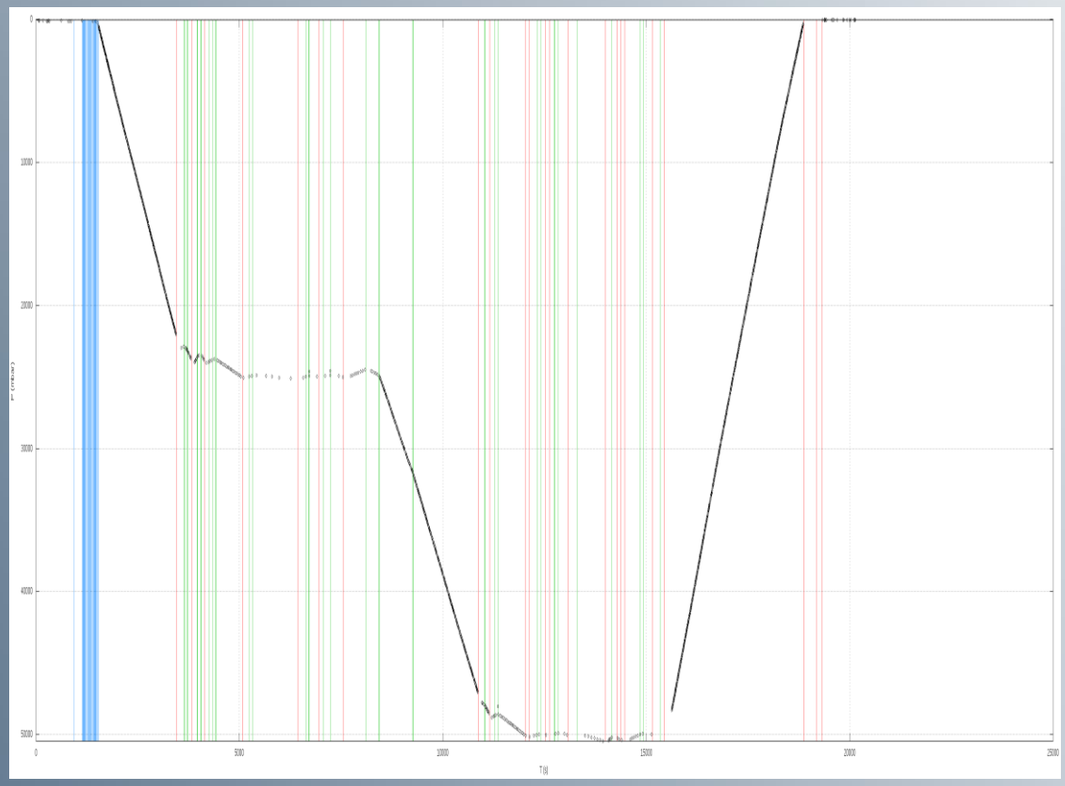


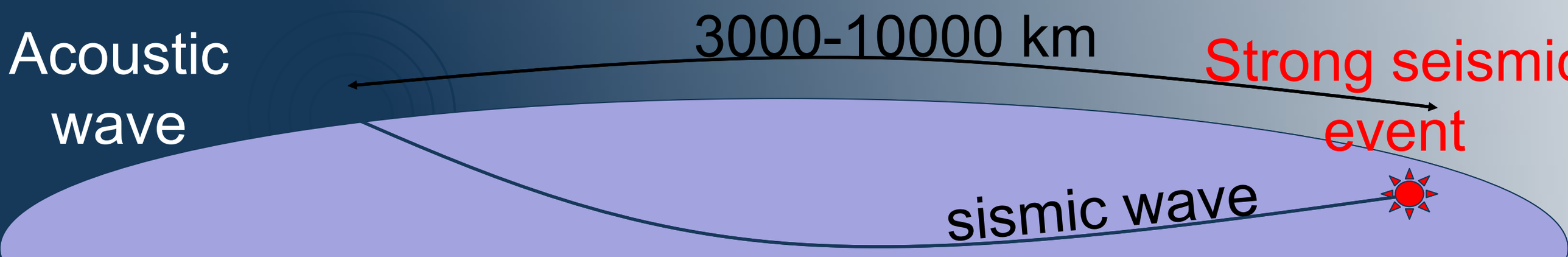
How does works an OSEAN MERMAID Lagrangien float?

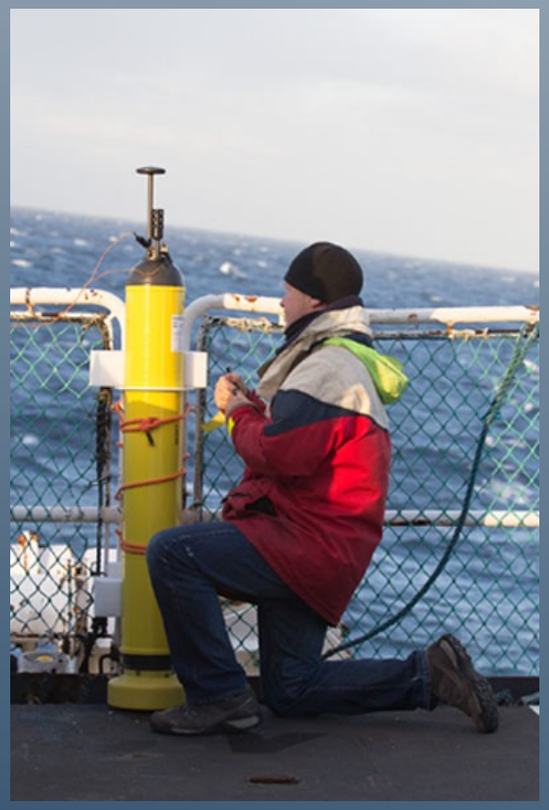


MERMAID: detection of long distance seismic event





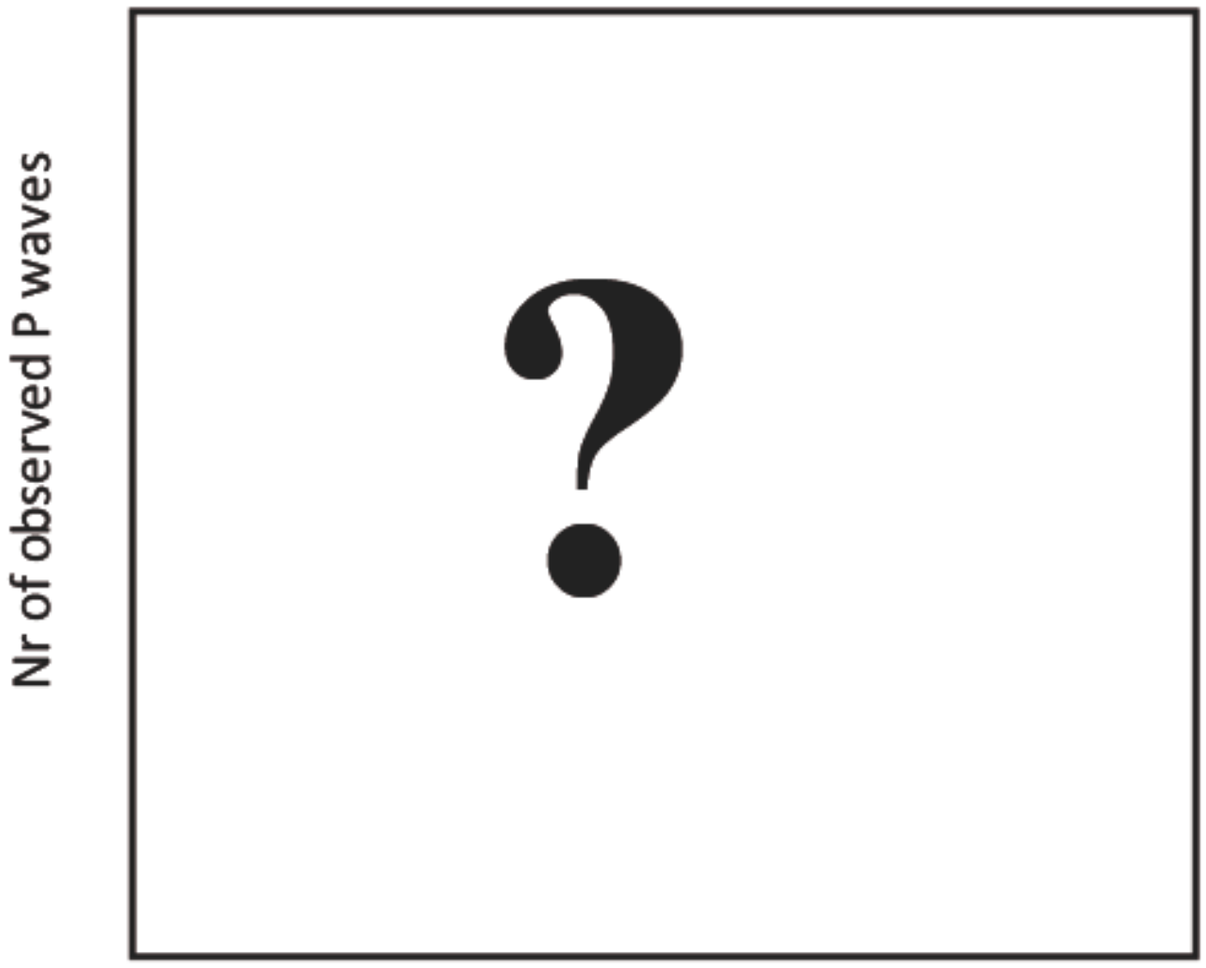


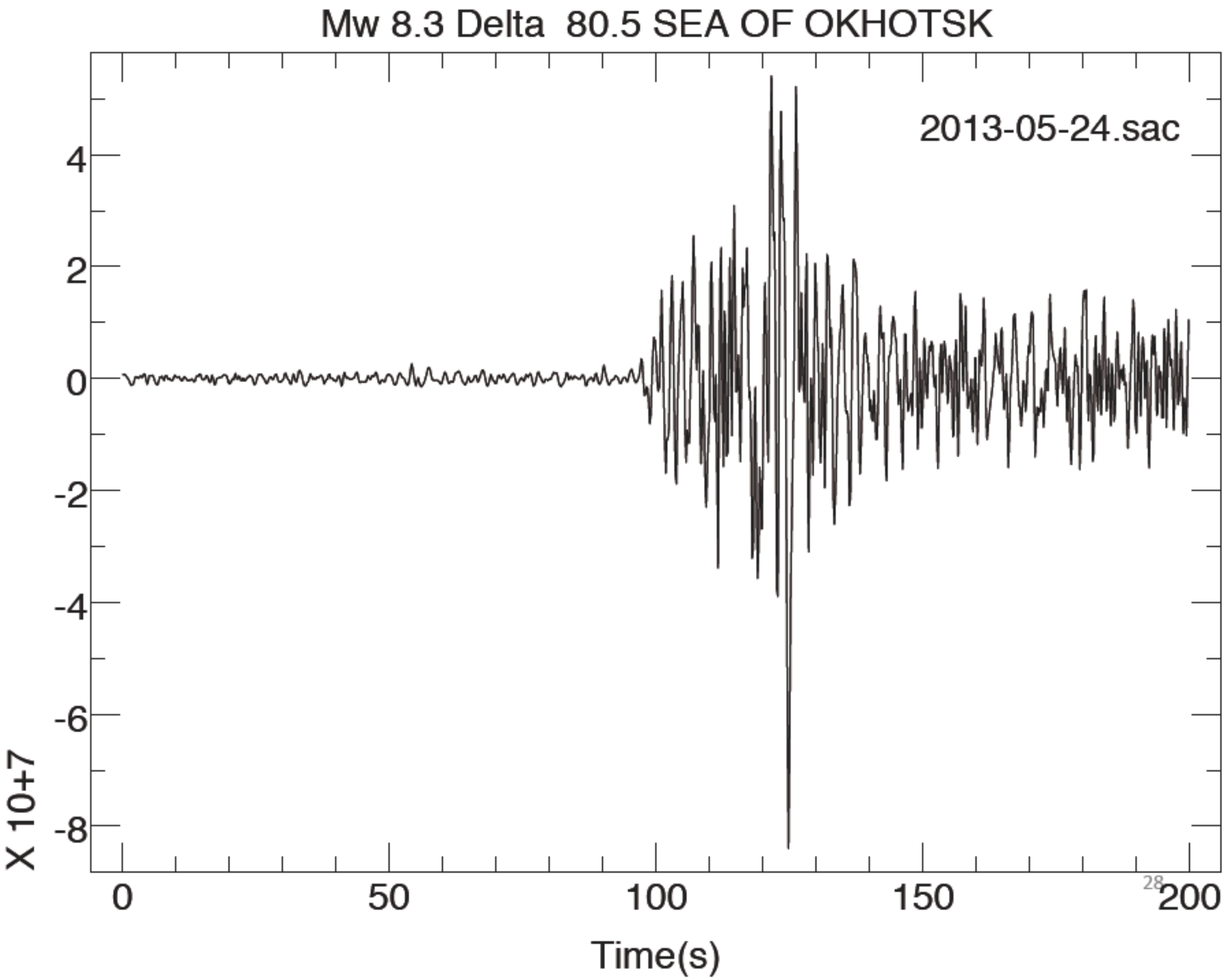


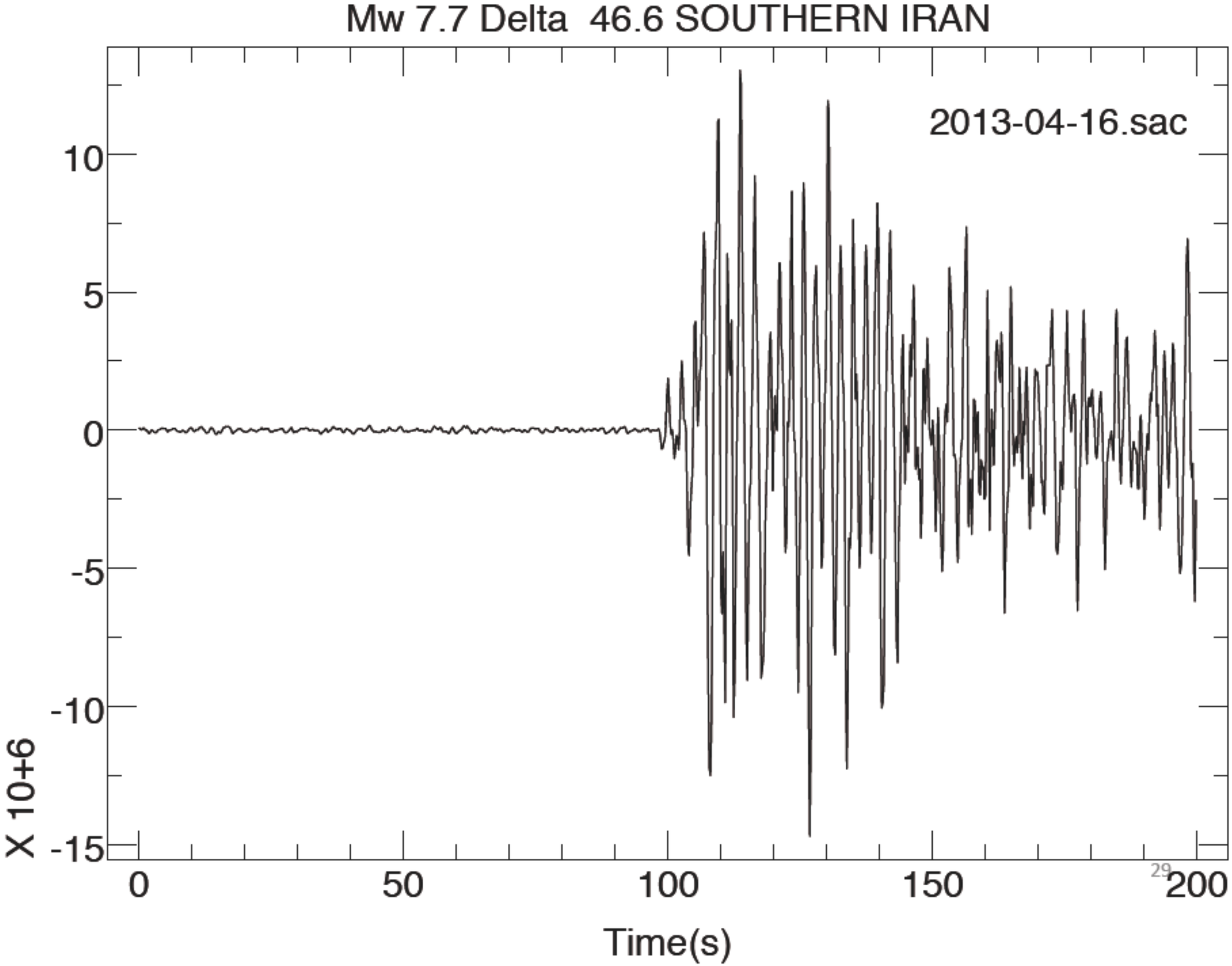
Mermaid Deployments

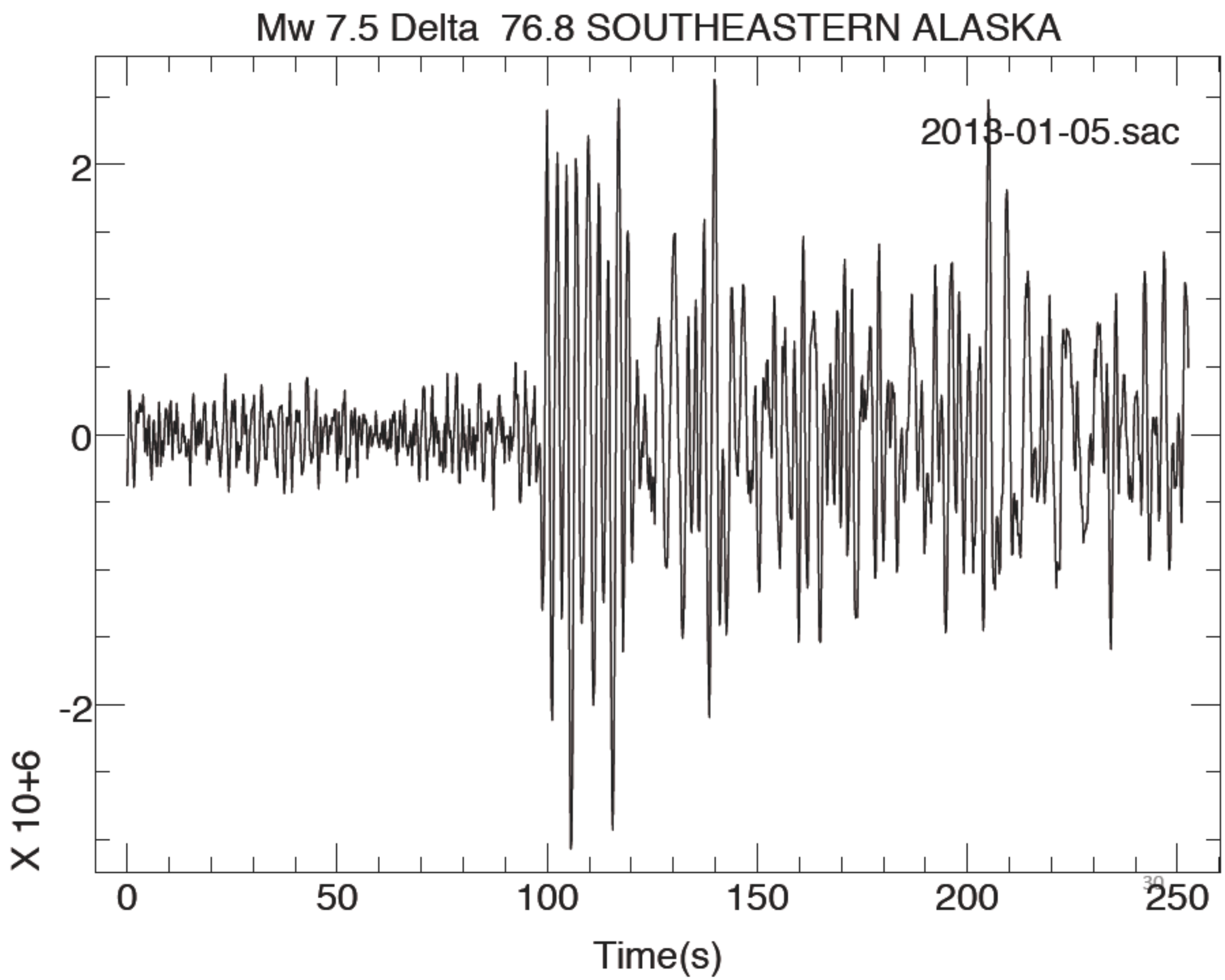
2012 - Mediterranean – (3 +2) Floats 2013
Indian Ocean – (3 +2) Floats
2014 - Galapagos – 10 Floats

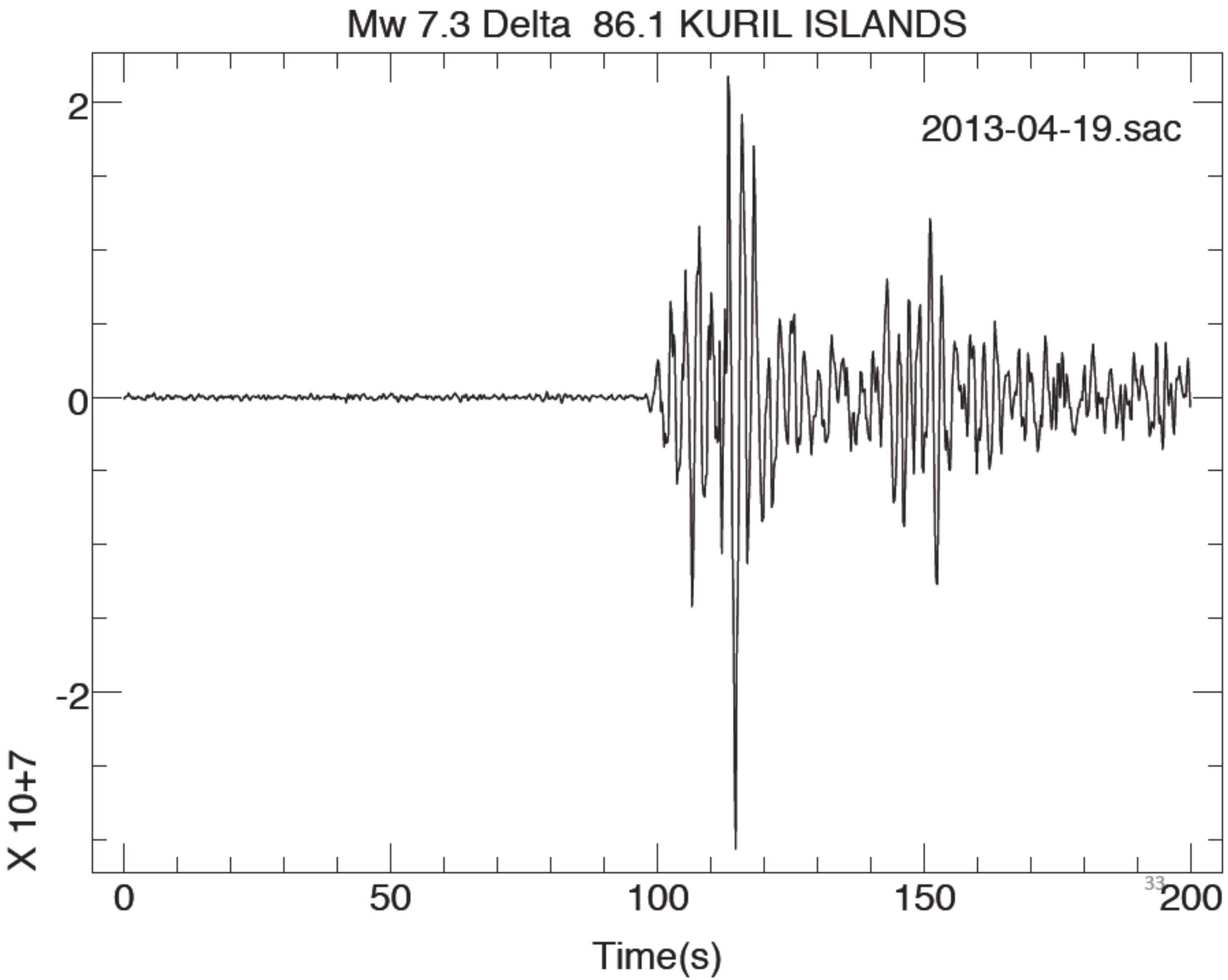
How far can we go down in magnitude?

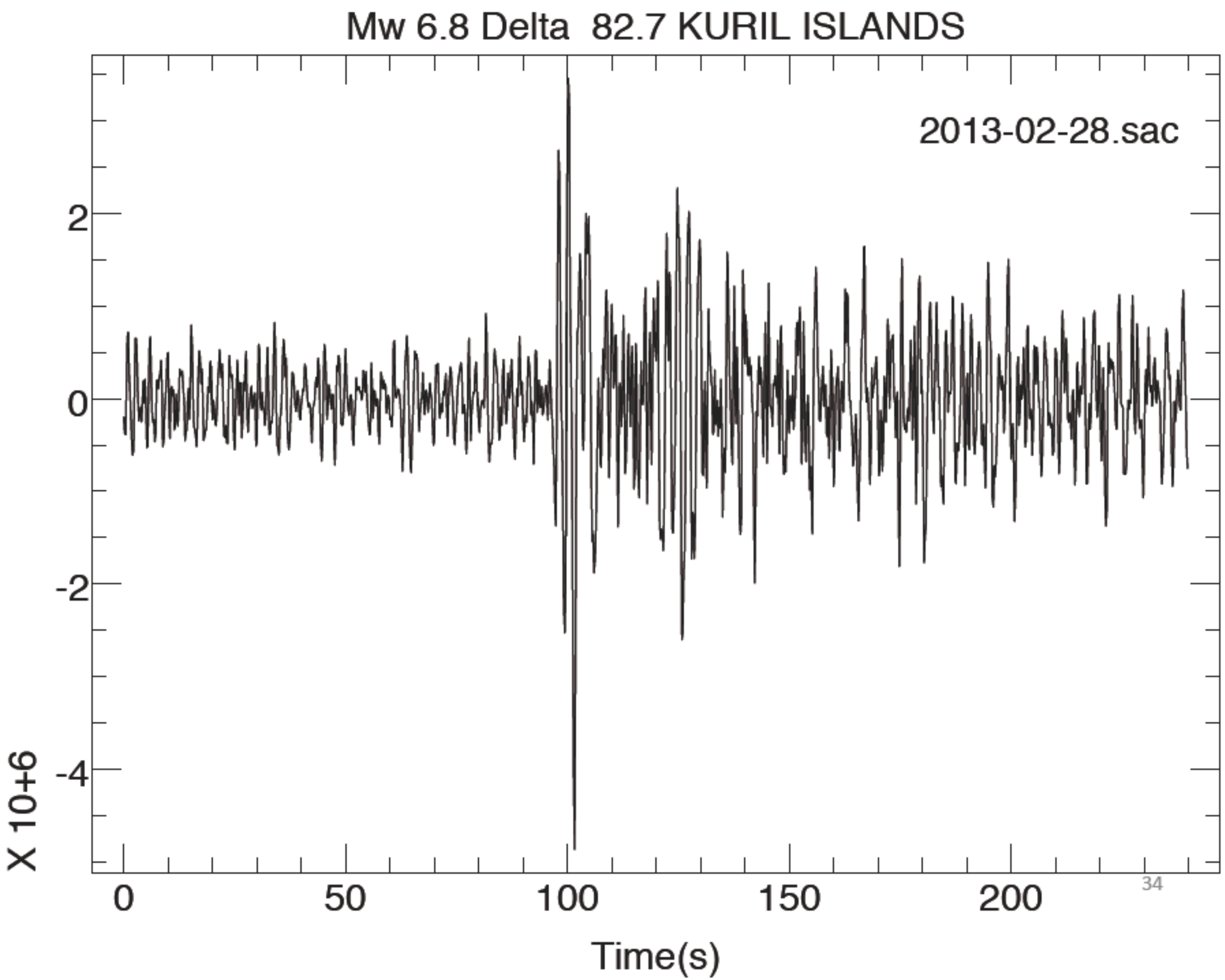


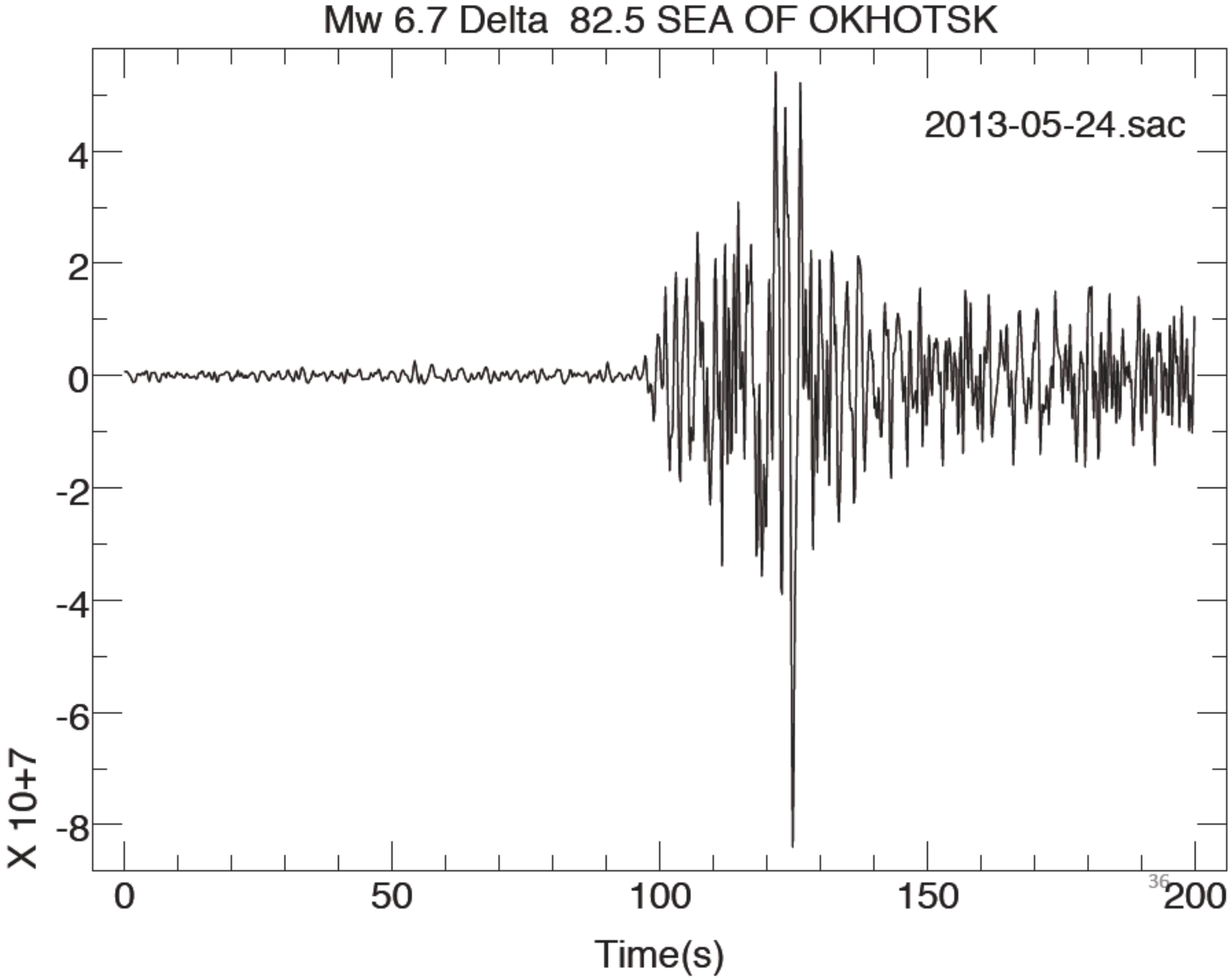

Mw 8.3 Delta 80.5 SEA OF OKHOTSK
2013-05-24.sac
4
2
0
-2
-4
-6
-8
X 10+7
0
50
100
150
200
Time(s)

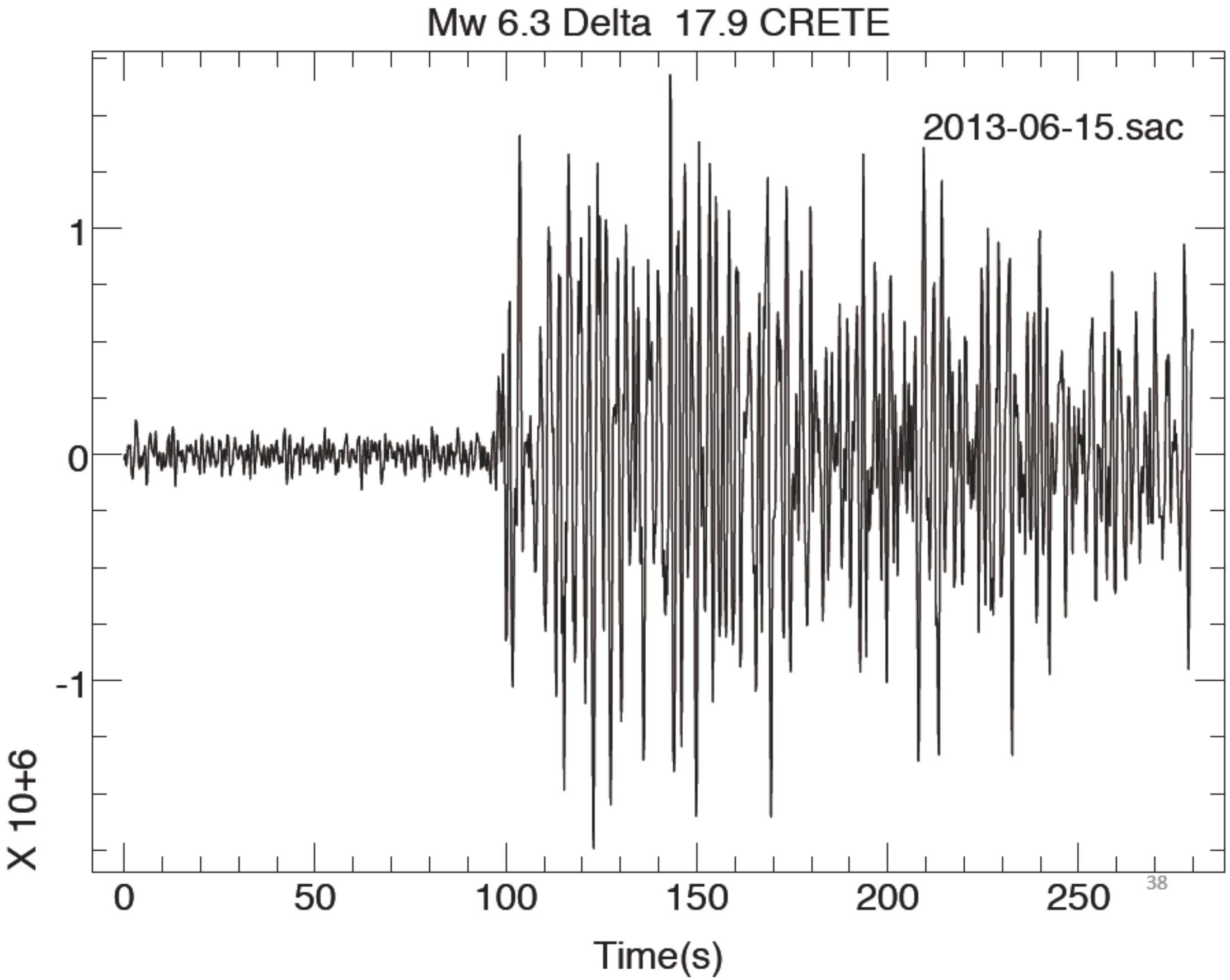

Mw 7.7 Delta 46.6 SOUTHERN IRAN
2013-04-16.sac
10
5
0
-5
-10
-15
X 10+6
0
50
100
150
200
Time(s)

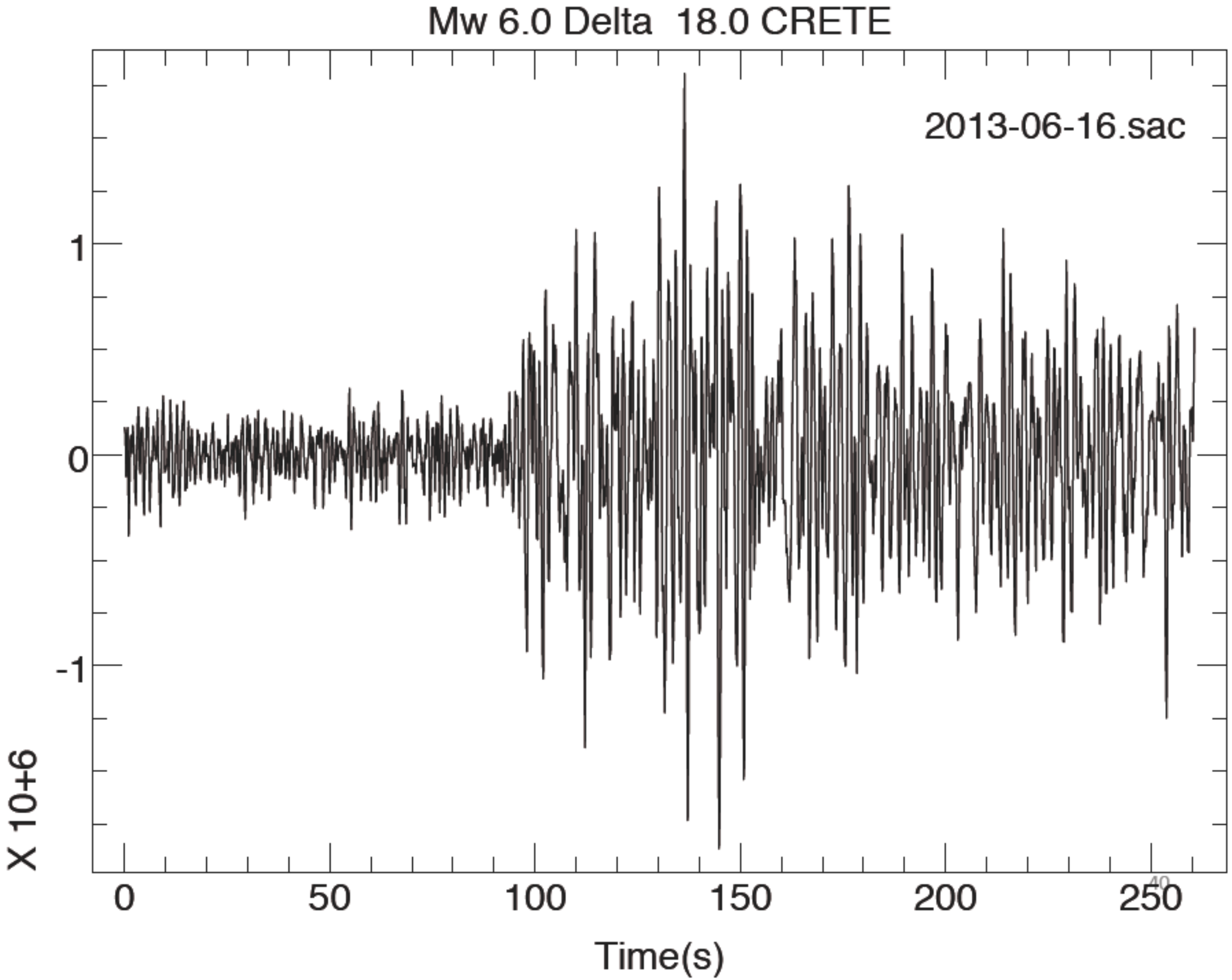

Mw 7.5 Delta 76.8 SOUTHEASTERN ALASKA
2013-01-05.sac
2
0
-2
X 10+6
0
50
100
150
200
250
Time(s)

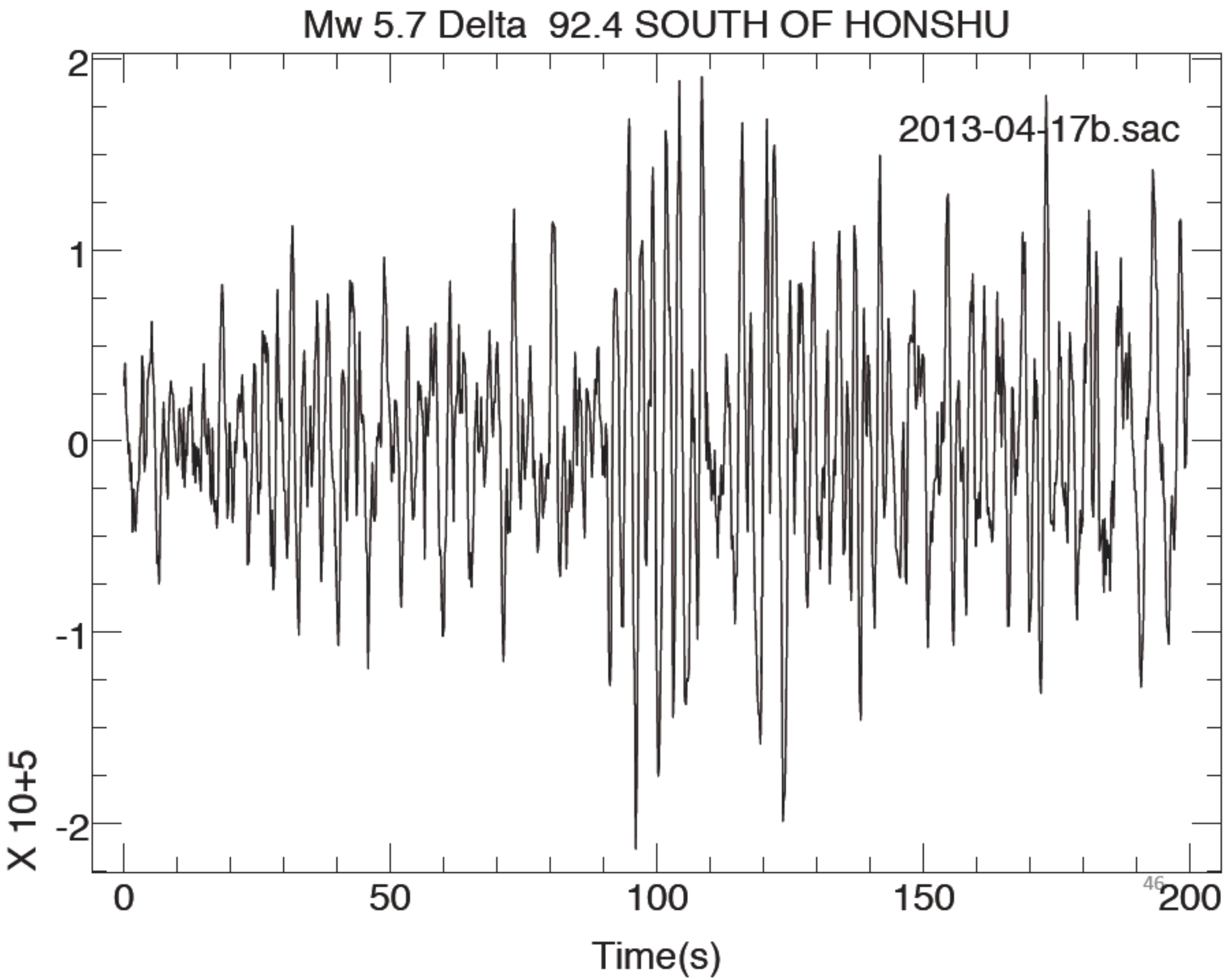

Mw 7.3 Delta 86.1 KURIL ISLANDS
2013-04-19.sac
2
0
-2
X 10+7
0
50
100
150
200
Time(s)


Mw 6.8 Delta 82.7 KURIL ISLANDS
2013-02-28.sac
2
0
-2
-4
X 10+6
0
50
100
150
200
Time(s)


Mw 6.7 Delta 82.5 SEA OF OKHOTSK
2013-05-24.sac
4
2
0
-2
-4
-6
-8
X 10+7
0
50
100
150
200
Time(s)


Mw 6.3 Delta 17.9 CRETE
2013-06-15.sac
1
0
-1
X 10+6
0
50
100
150
200
250
Time(s)


Mw 6.0 Delta 18.0 CRETE
2013-06-16.sac
1
0
-1
X 10+6
0
50
100
150
200
250
Time(s)

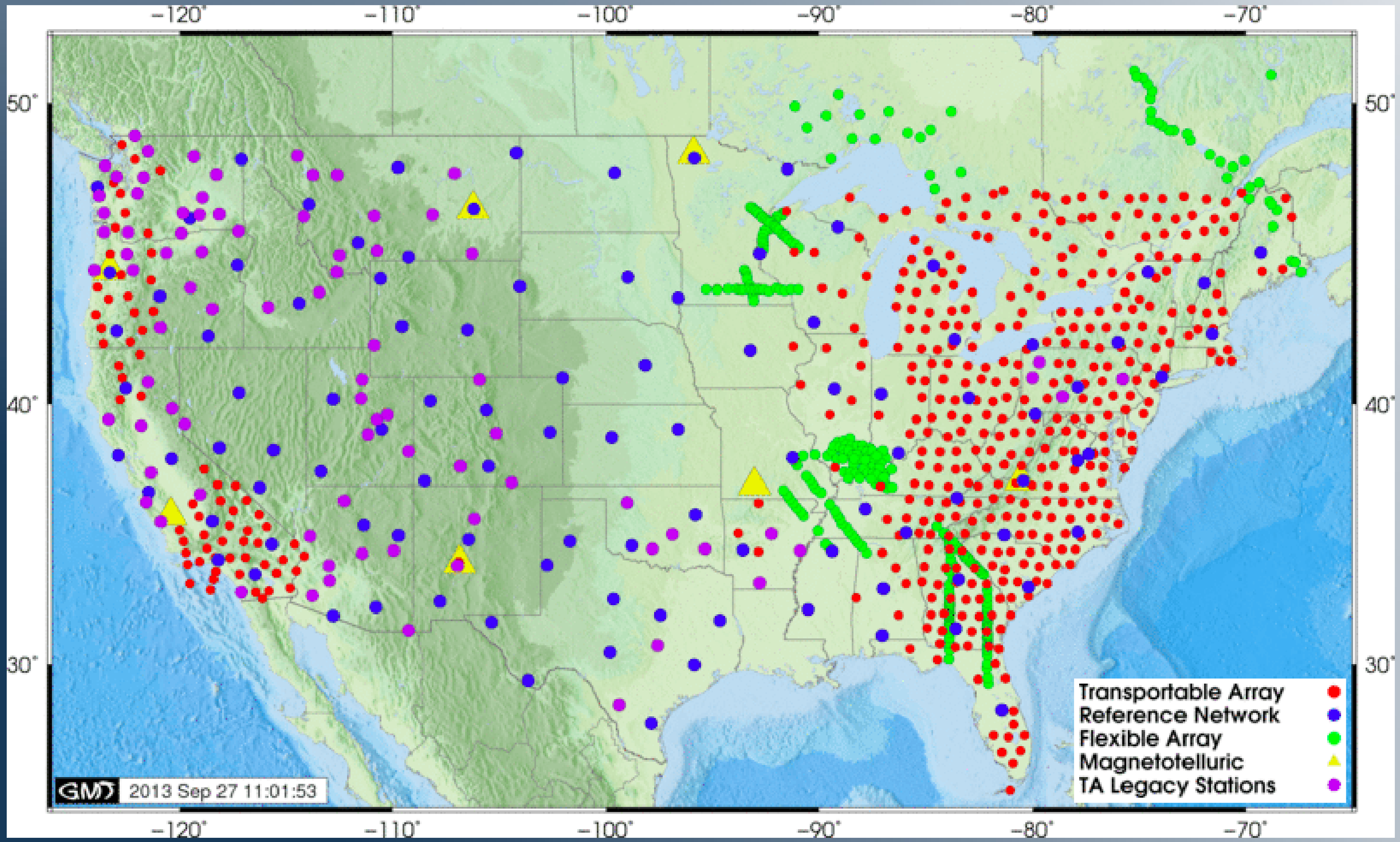

Mw 5.7 Delta 92.4 SOUTH OF HONSHU
2013-04-17b.sac
2
1
0
-1
-2
X 10+5
0
50
100
150
200
Time(s)

Visibility of P Waves

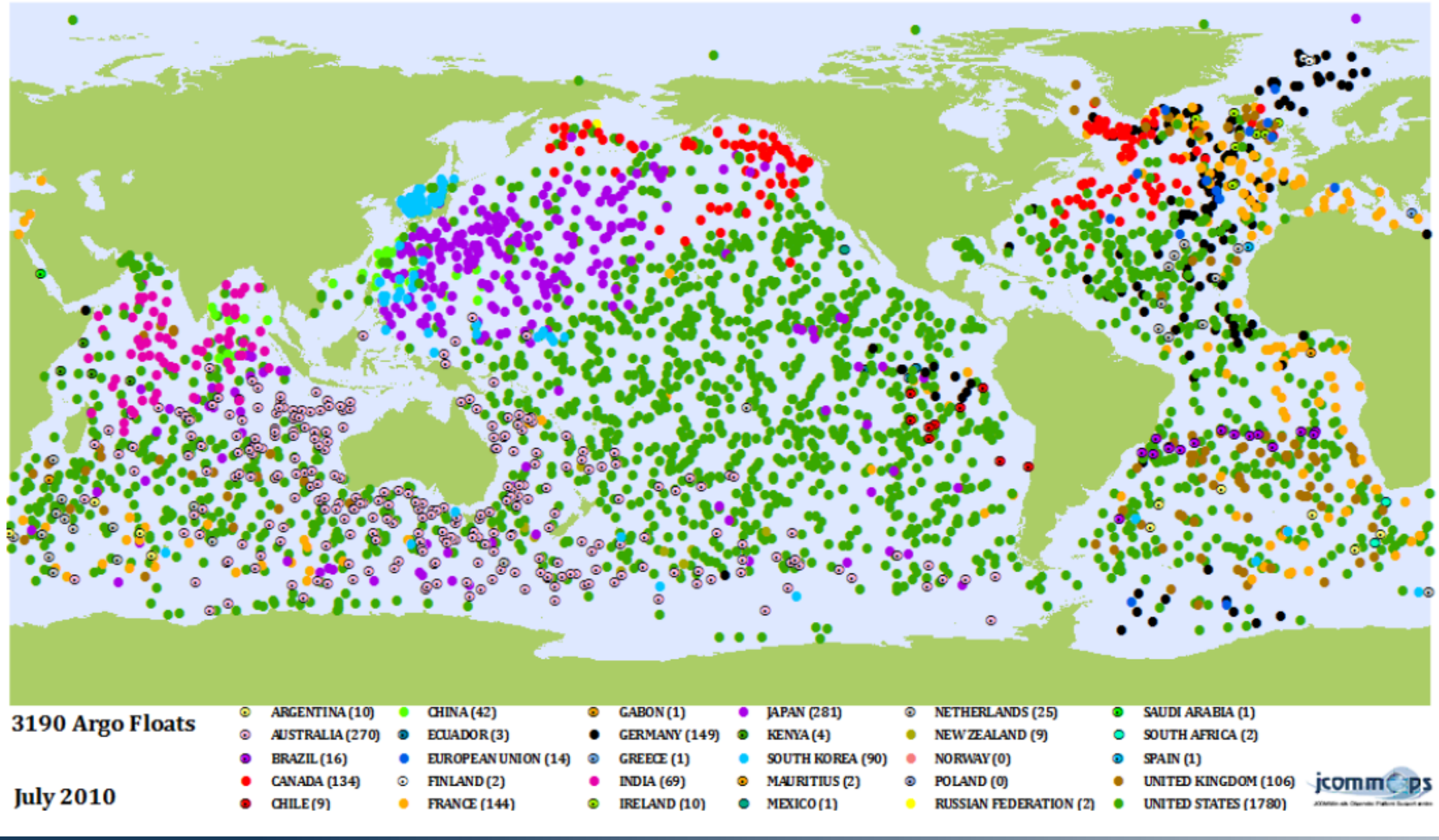
- Below Mw 5.8 under good conditions
- Above Mw 6.5 in bad weather
- Small magnitudes (~2) if close

Can we do at SEA what we now do on LAND?

IRIS Moving ARRAY through Northern America

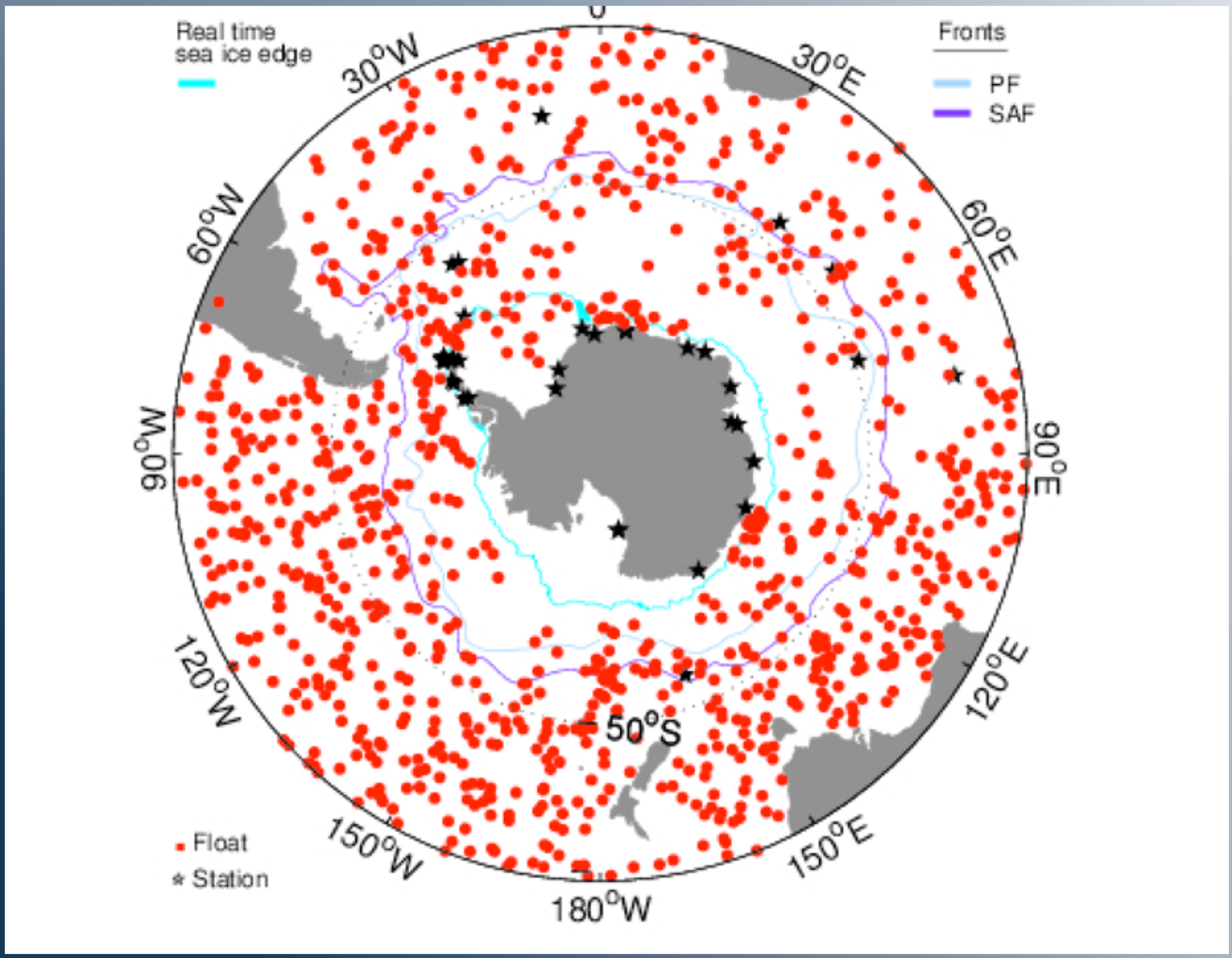


We are not the first to want to cover the oceans....

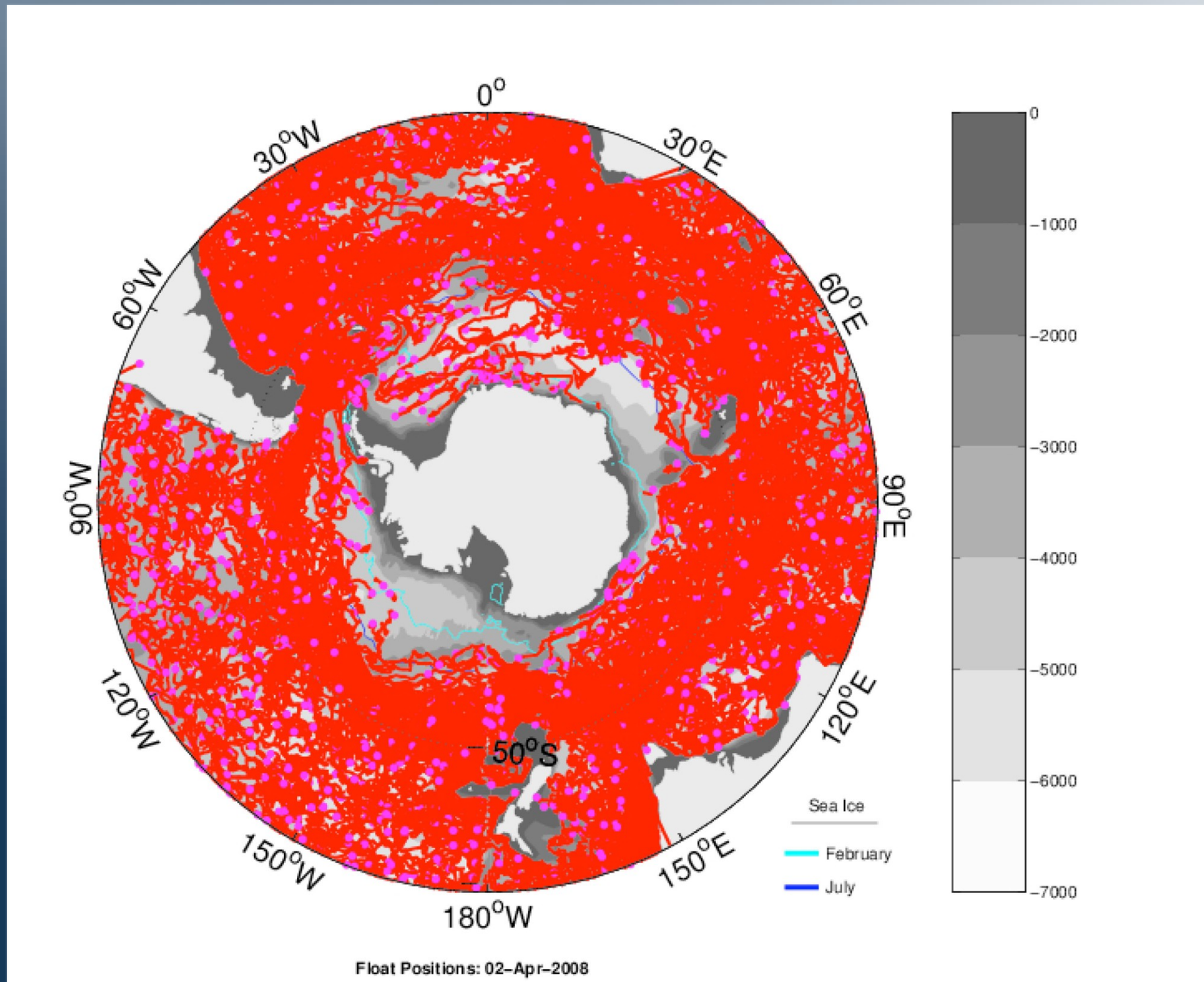


ARGO floats coverage density (soon 4000)
[observing sea current, temperature, salinity, oxygen]

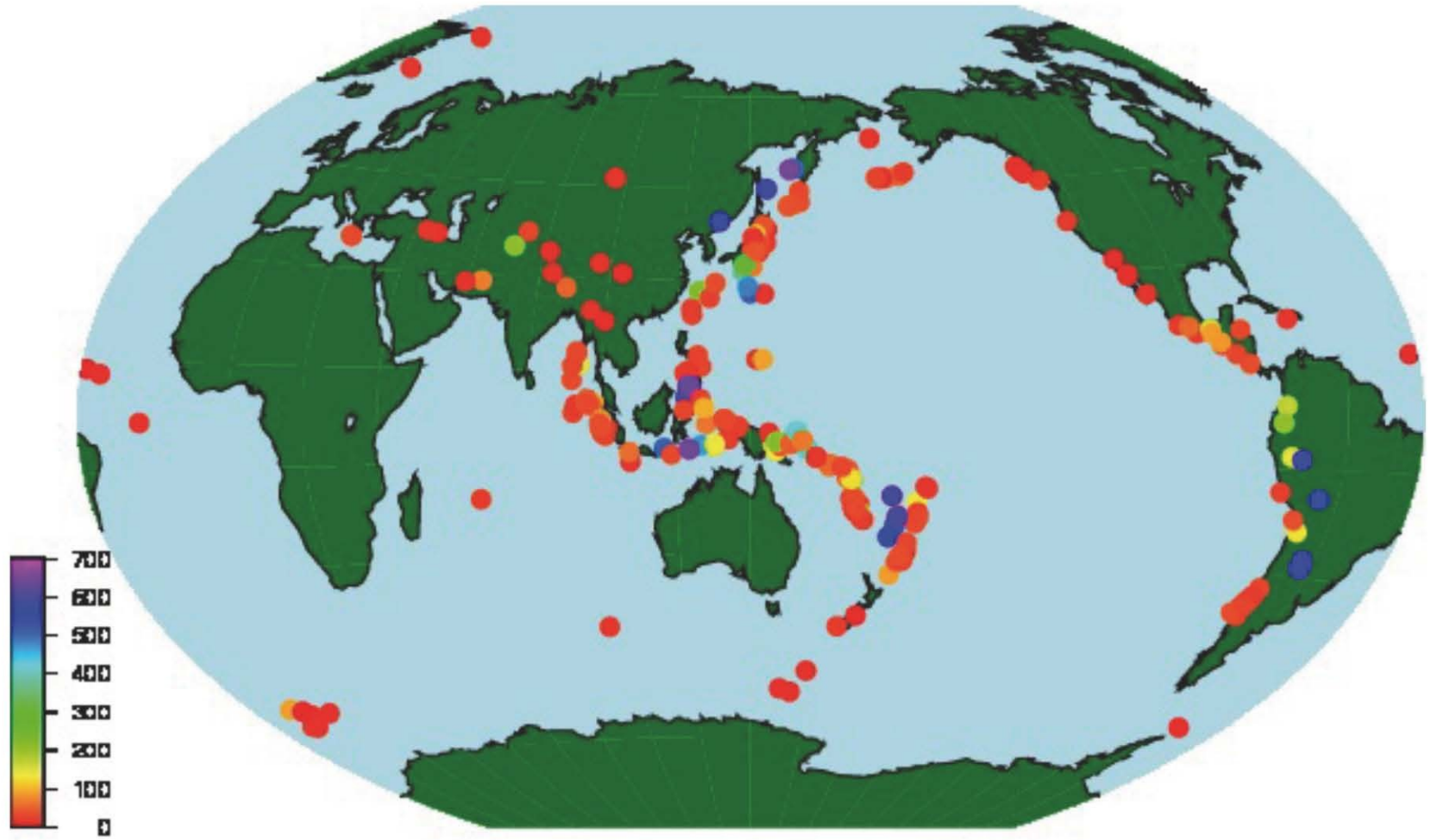
Southern Argo array: snapshot



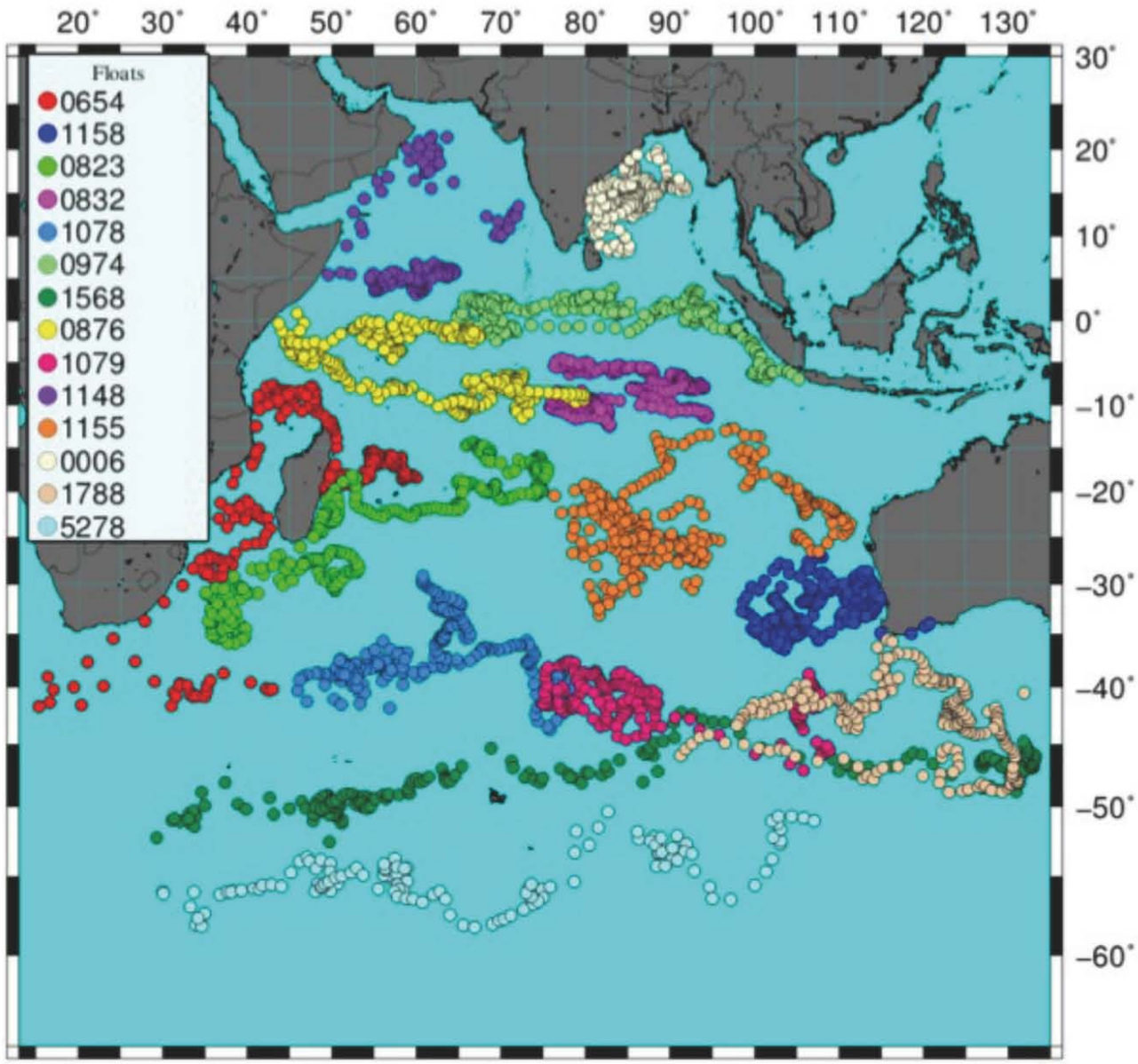
Southern Argo array after 6 months

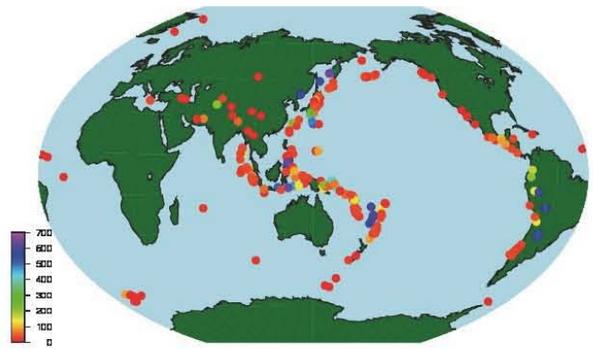


past 5 years: 257 events with magnitude > 6.5



What one PI can do with 14 floats (~ € 500,000)

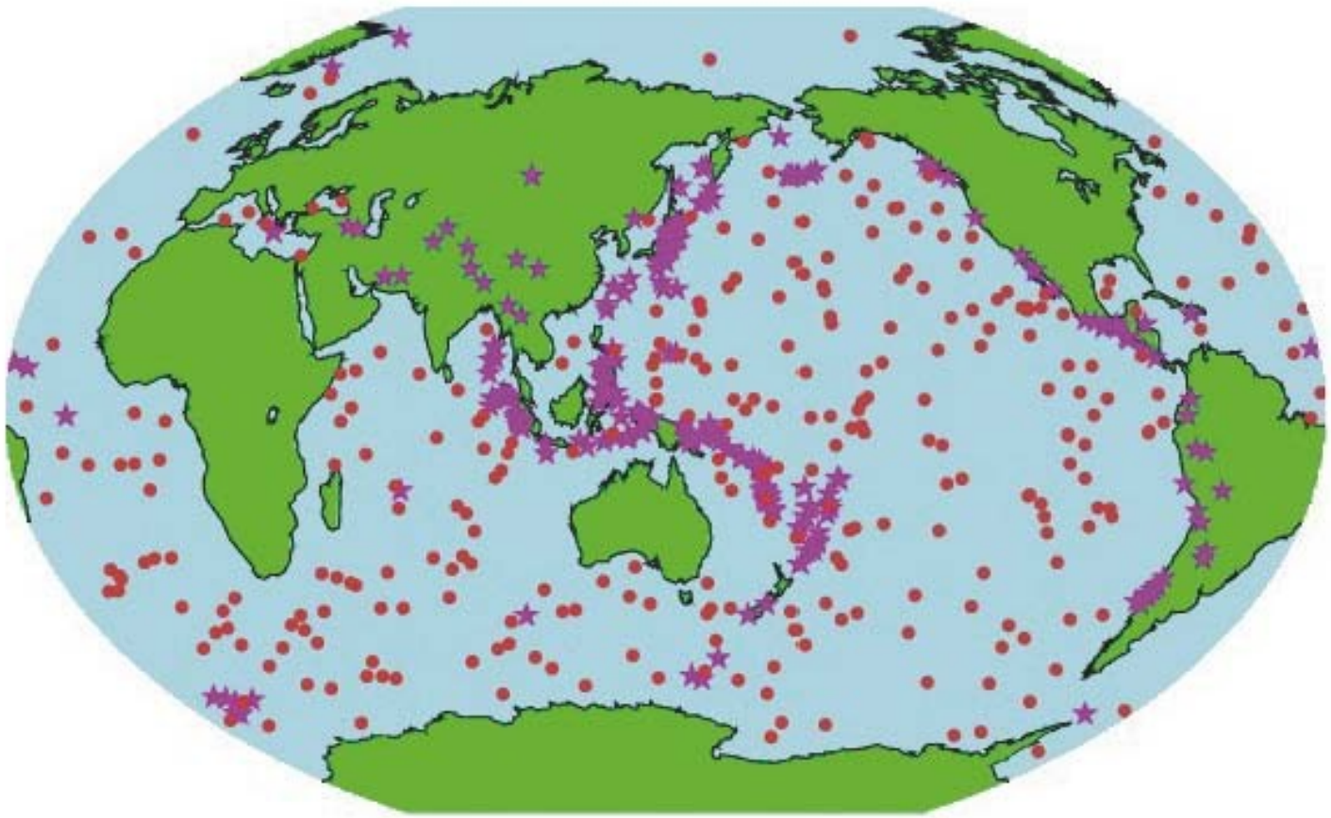




~ 3600 delays
in 5 years

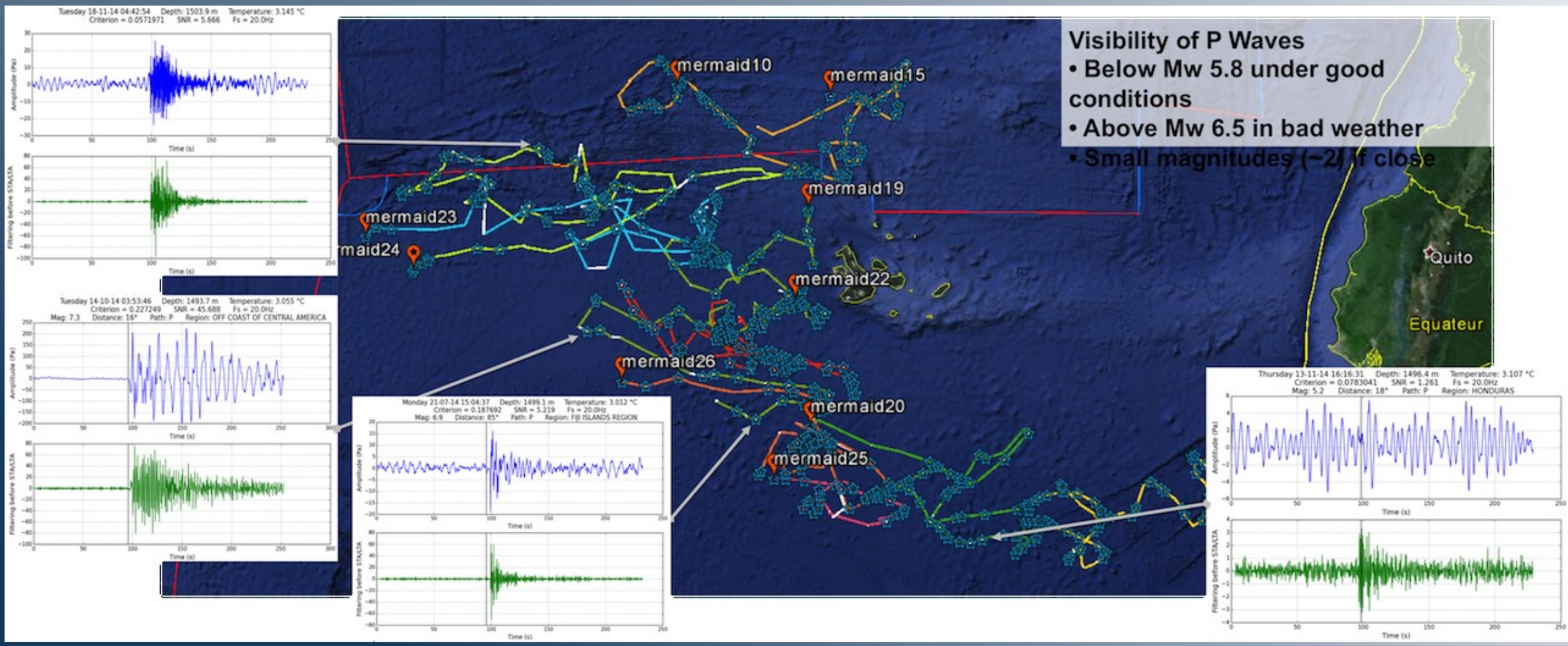
Figure courtesy Xavier Heris

MariScope: what 20 PI's with 300 floats can do

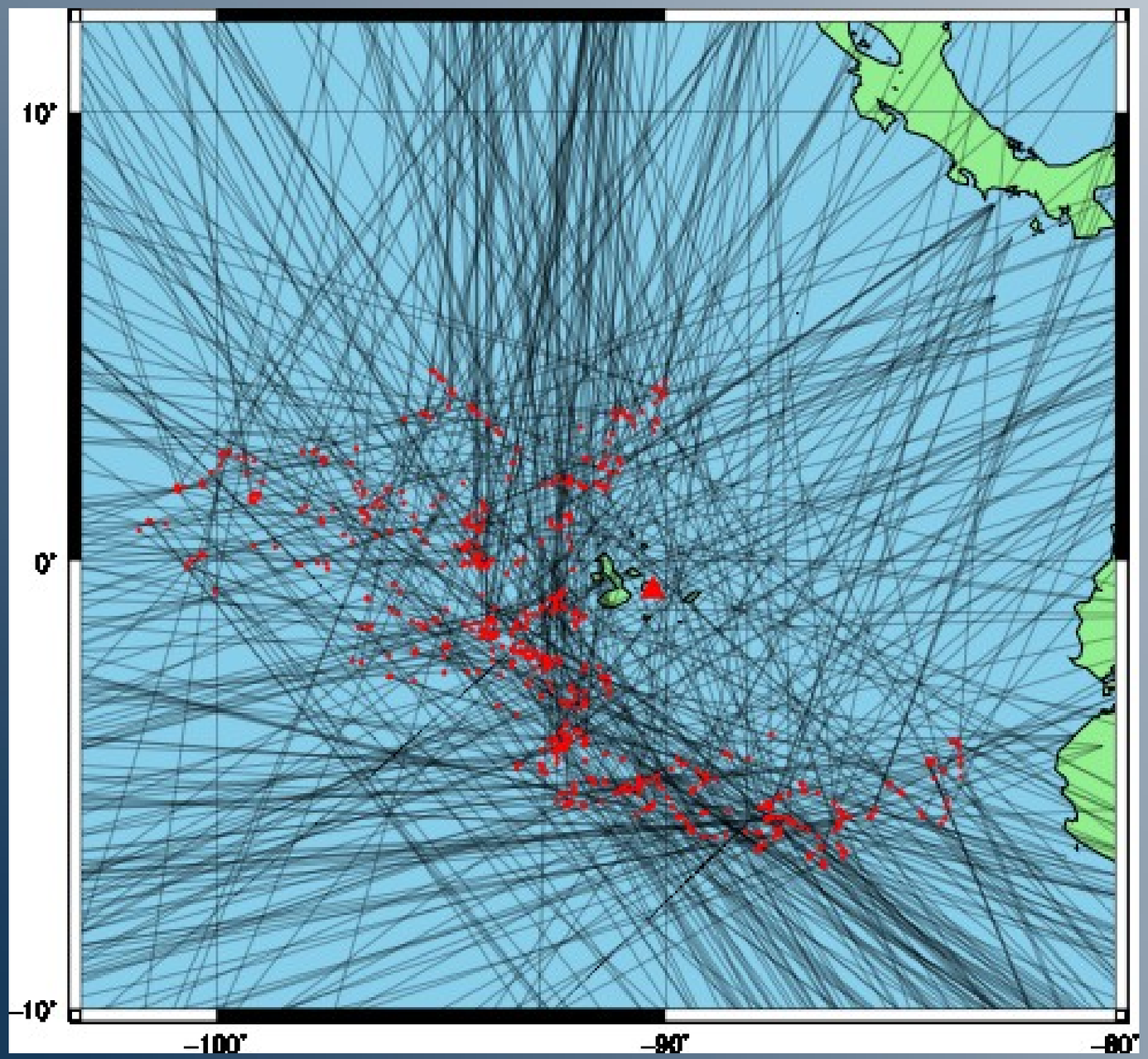


300 floats x 257 events = 77000 delays

Mermaid Network coverage in the Galapagos after 18 months.

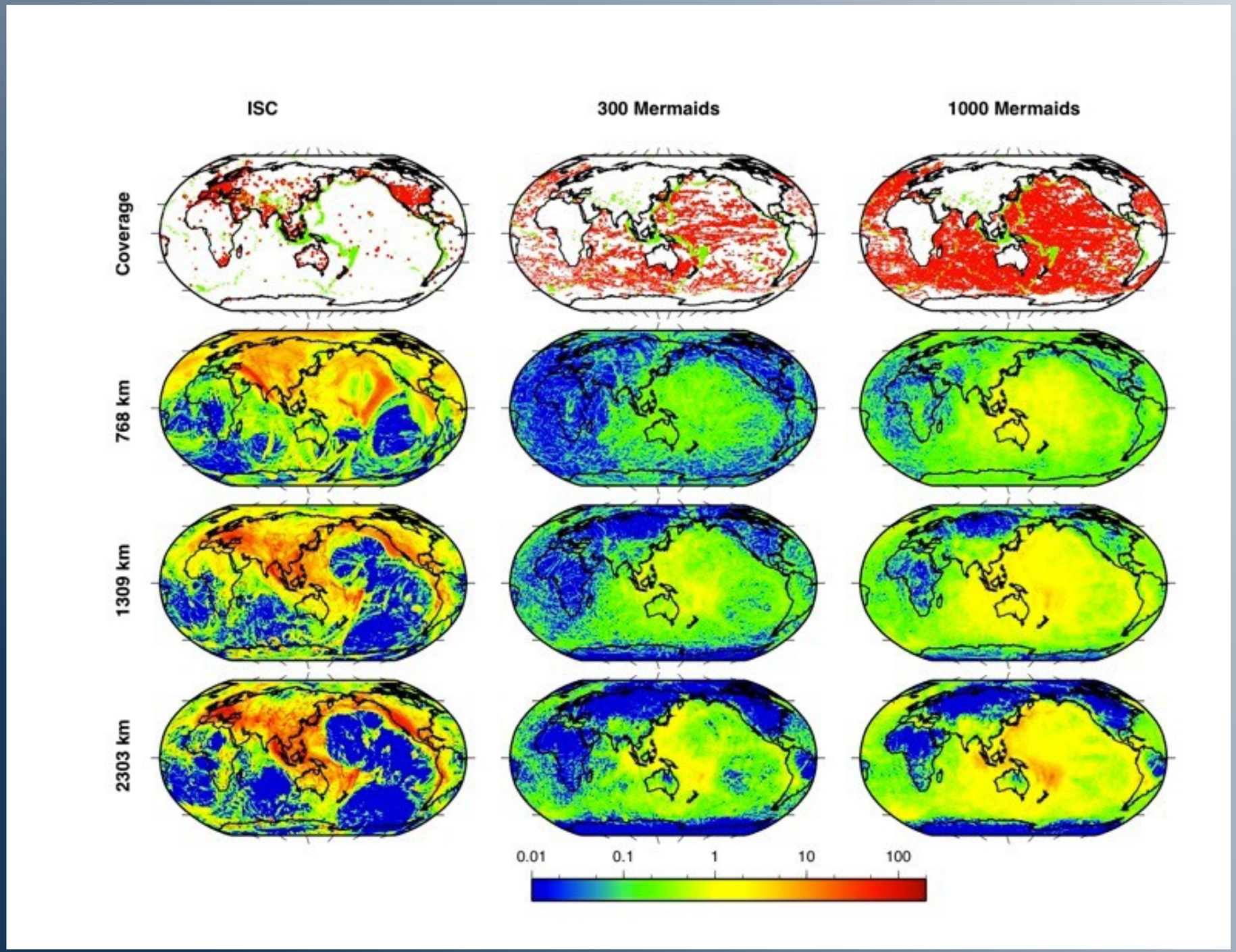


Coverage of rays for seismic tomography after 9 mermaids operated for 18 months near the Galapagos Islands.



703 seismograms

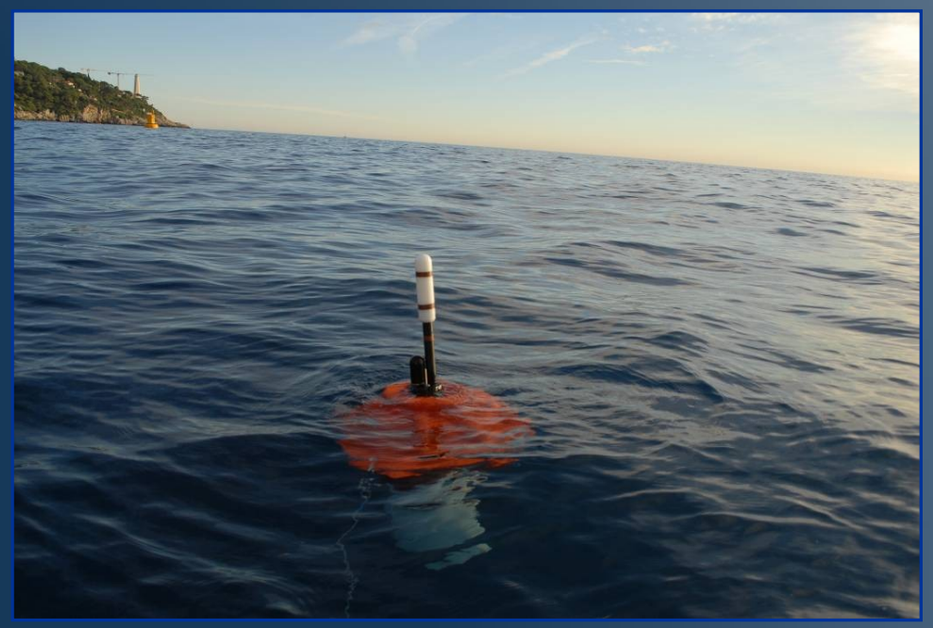
A simulation of the ray coverage for seismic tomography at three depths.



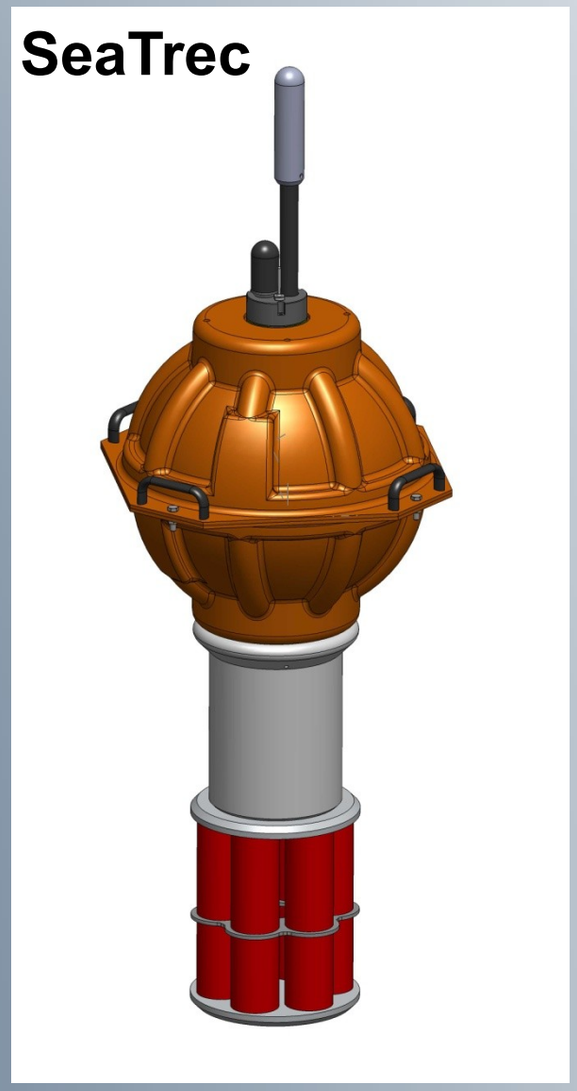
Sukhovich et al., *Nature Comm.,* 2015.

Large Autonomy

- Based on OBS sphere (17”)
- More batteries (5.5 KW
3 times more than current floats)
- Larger life time (5-6 yr)
- Remotely programmable
- *Multidisciplinary*:
- Temperature,
- Conductivity,
- High frequency acoustics
- Low frequency acoustics
- Green Energy

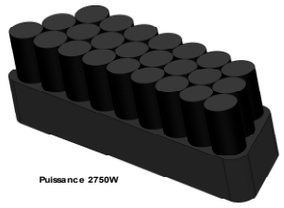


Multimermaid, a multidisciplinary float resulting from an ERC Proof-of-concept and collaboration with local industry Osean

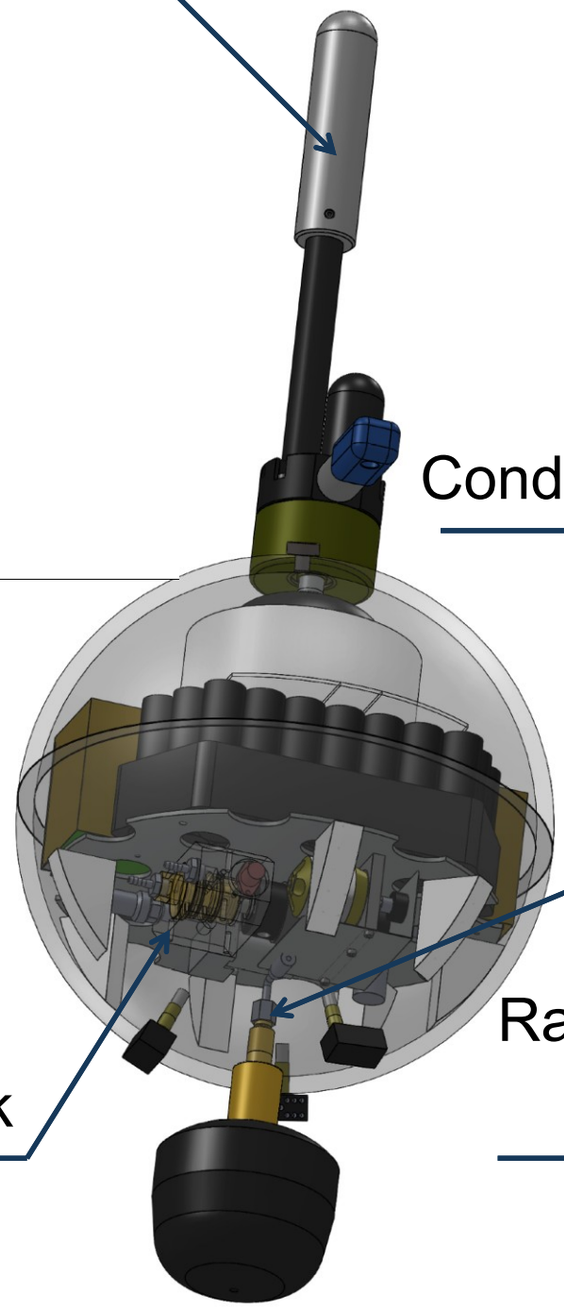


Thermal Recharging Battery

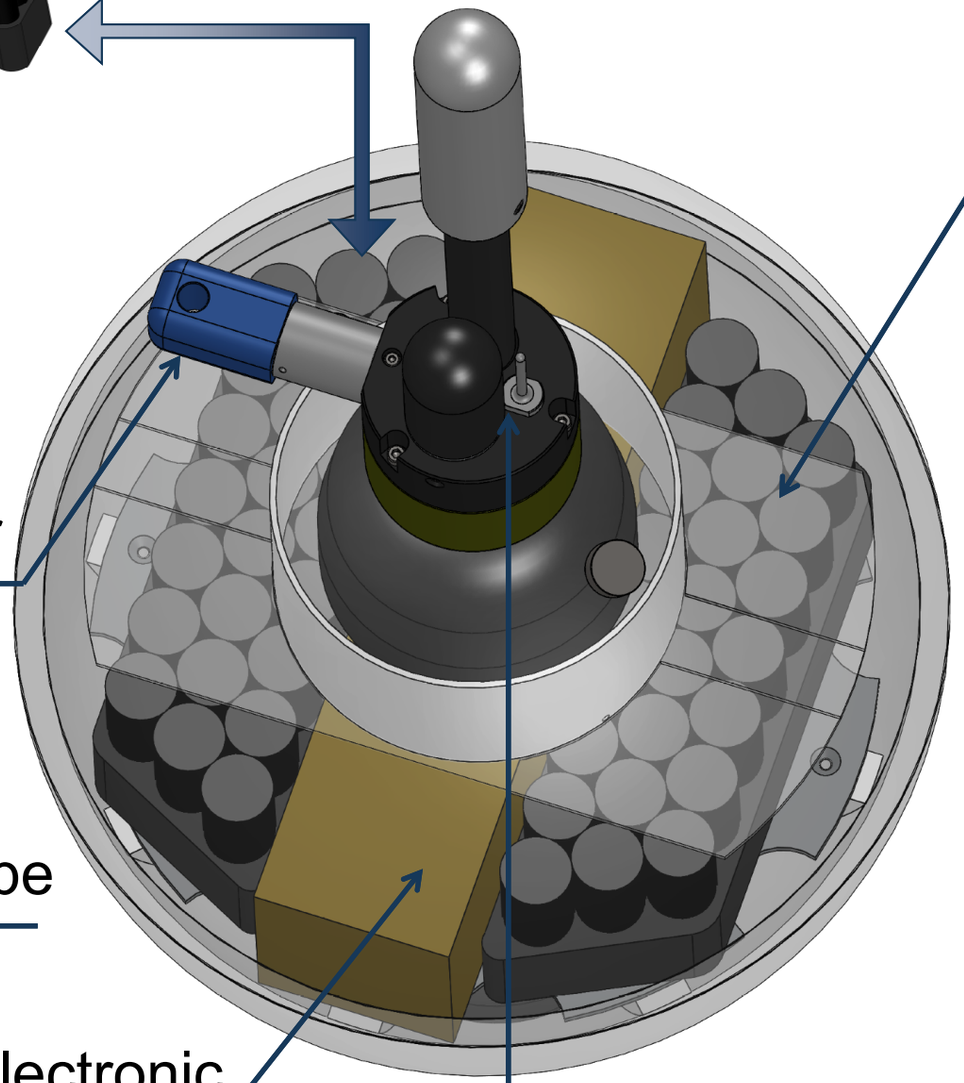
Antenna Dual GPS/Iridium



2 x Battery packs of 36 DD cells for a total amount of 5.5 Kw



Conductivity sensor



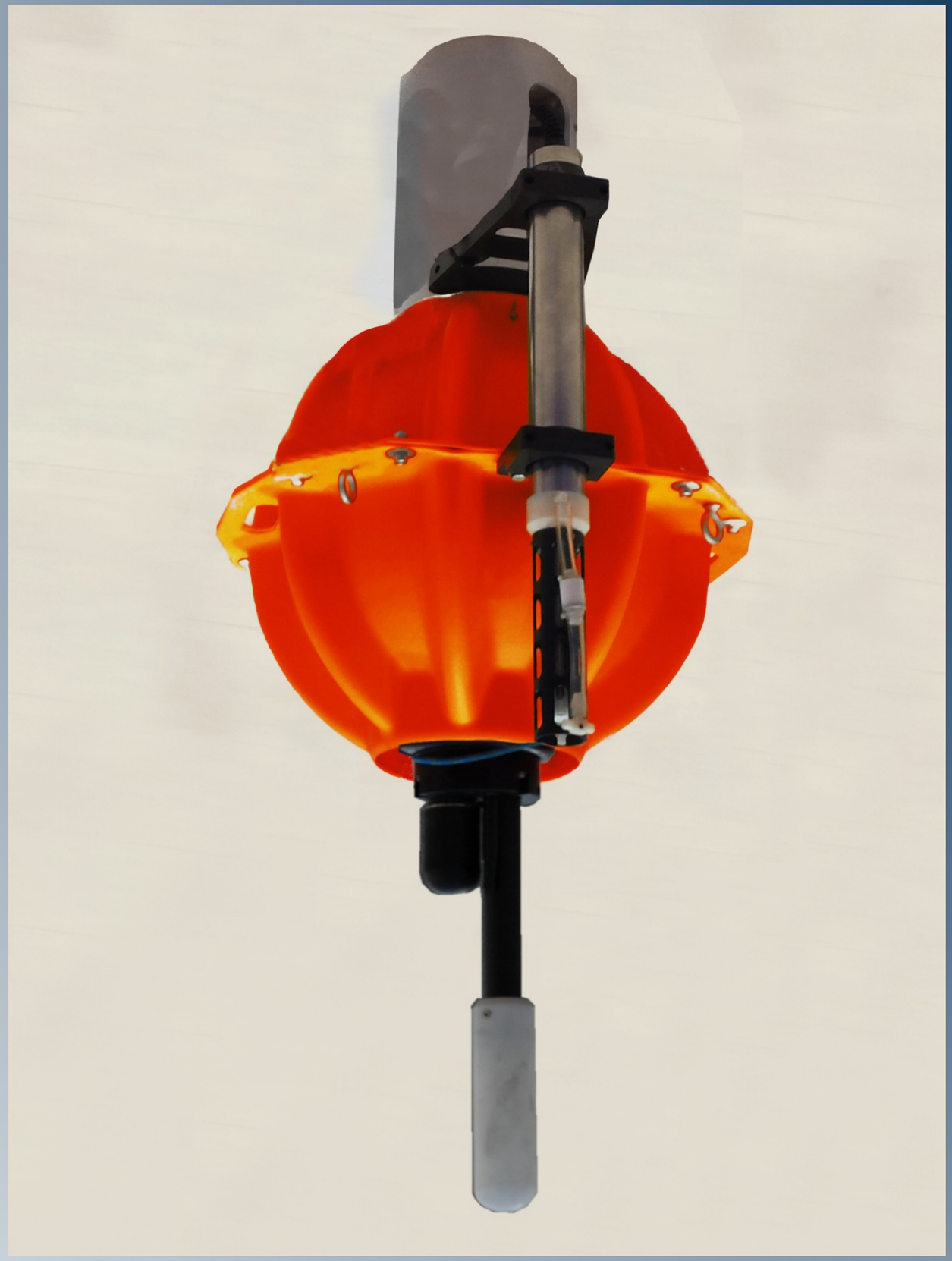
Pressure probe

Hydraulic block

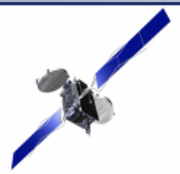
Rack mounted Electronic boards

Temperature Probe

Details of the constituent components of Mermaid



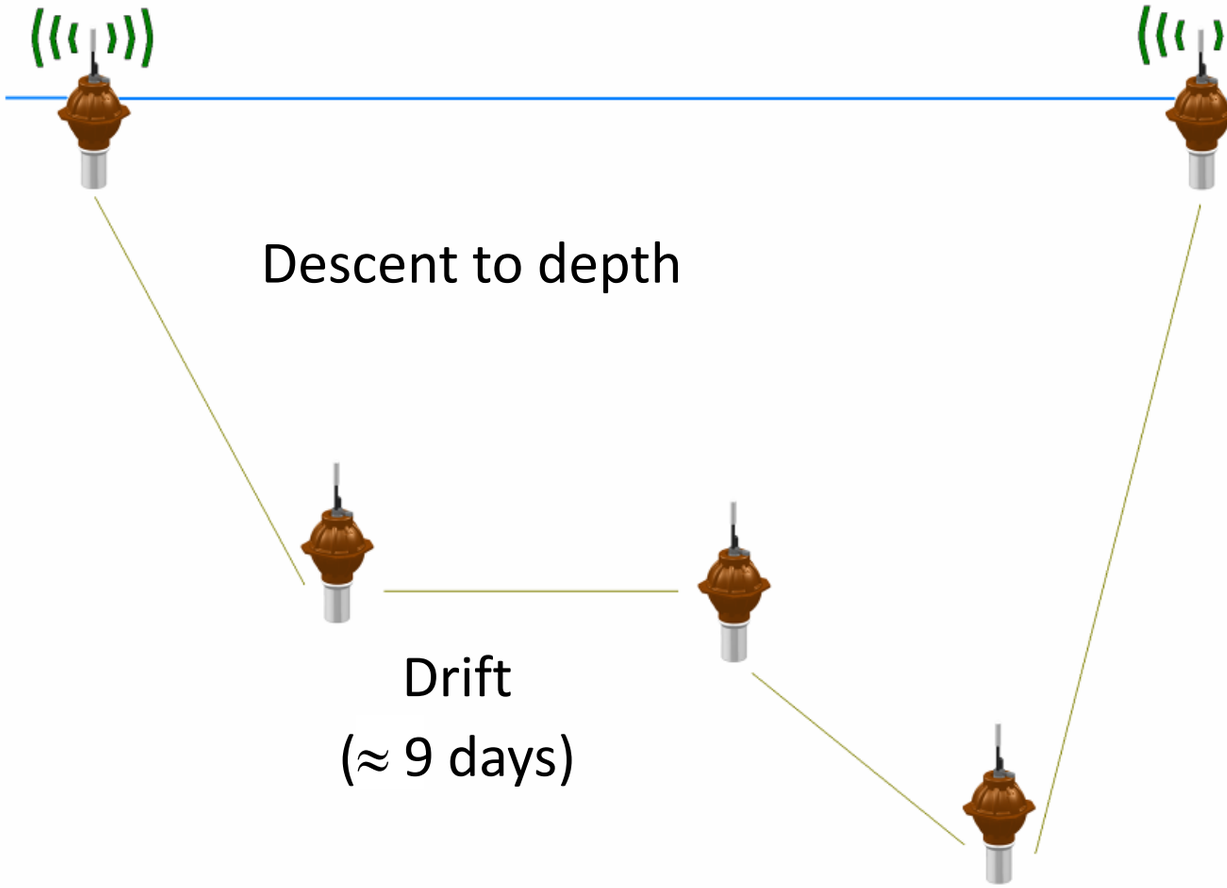
MERMAID: Deep CTD profile



IRIDIUM Satellite

At surface to transmit data to satellites

IRIDIUM Satellite Land Station



Descent to depth

CTD measures during ascent
(up to 12 hours)

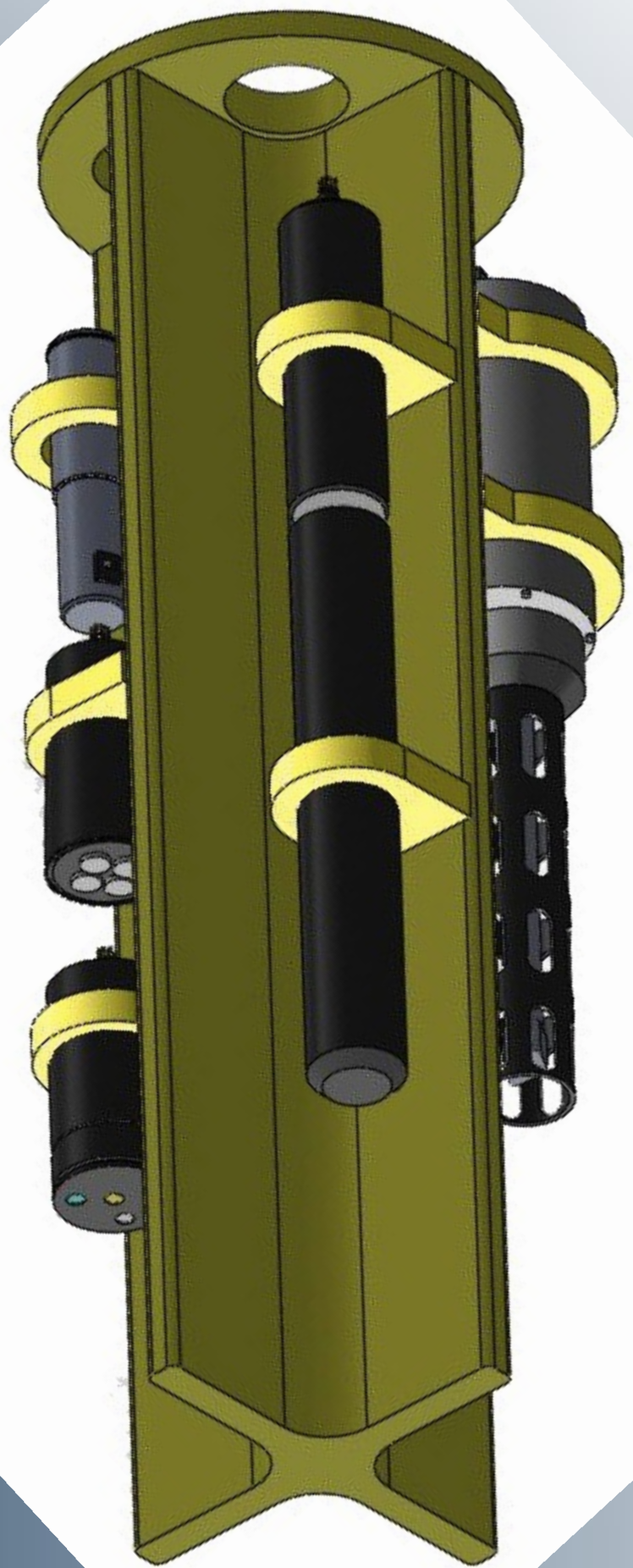
Drift
(≈ 9 days)

Float descends to begin profile
from greater depth (up to 3000 m)

Multi-mermaid float can carry up to 8 extra sensors.

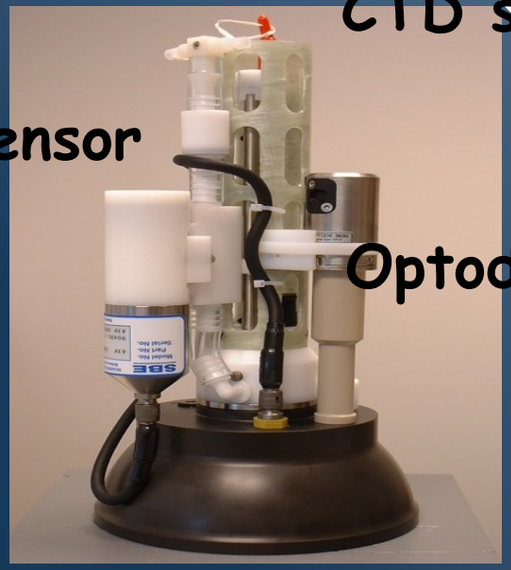
Ed-Lu sensor (7 λ 400-665 nm)

Chlorophyll-a sensor



CTD sensors

SBE O2 sensor



Optode sensor

Nutrients sensor

Green Renewable Energy

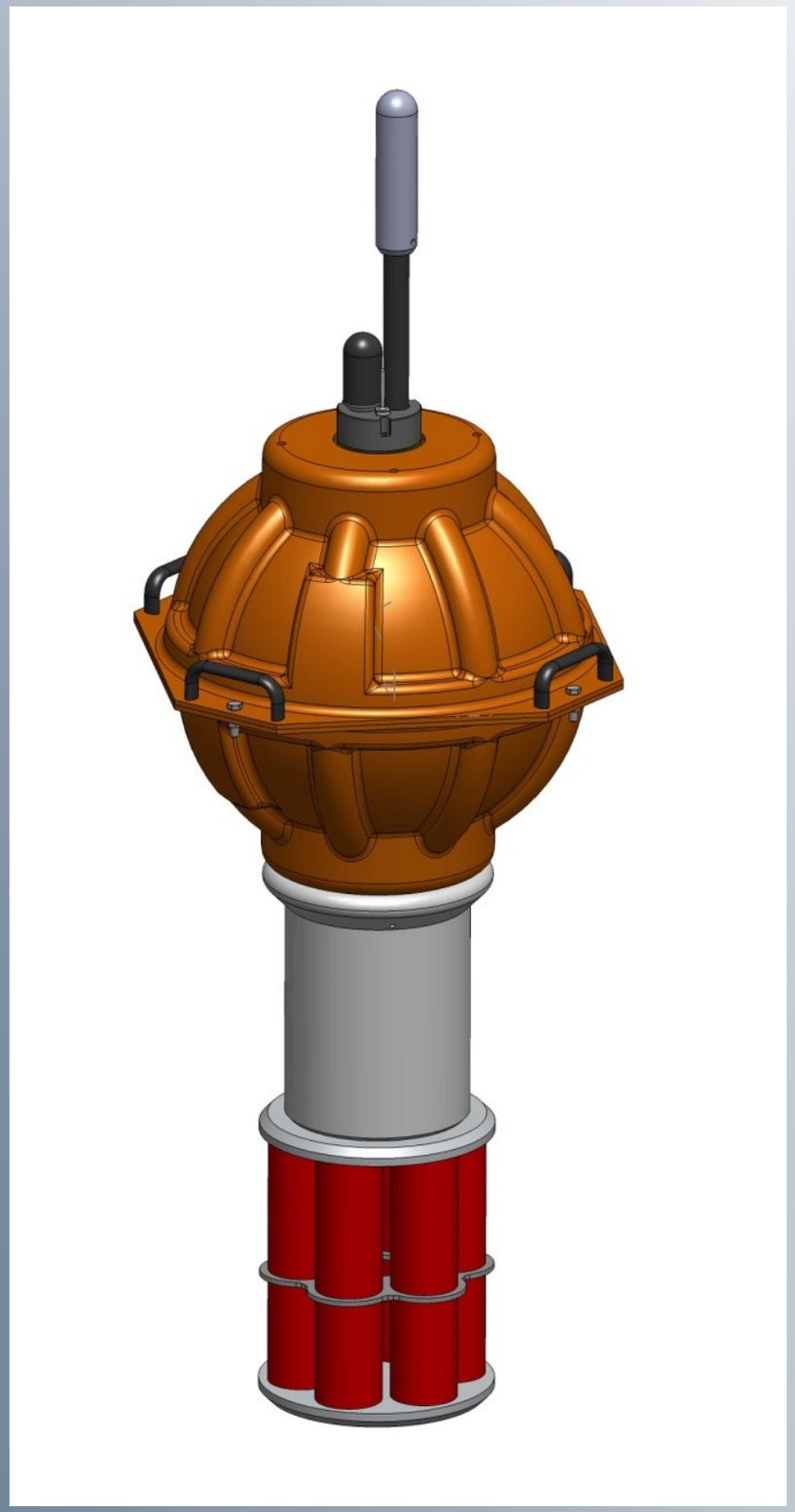
PROFILE COST REDUCTION

- Multi-disciplinary Floats
- Extra sensors: Bio Argo's….

But Extra Payload & Energy

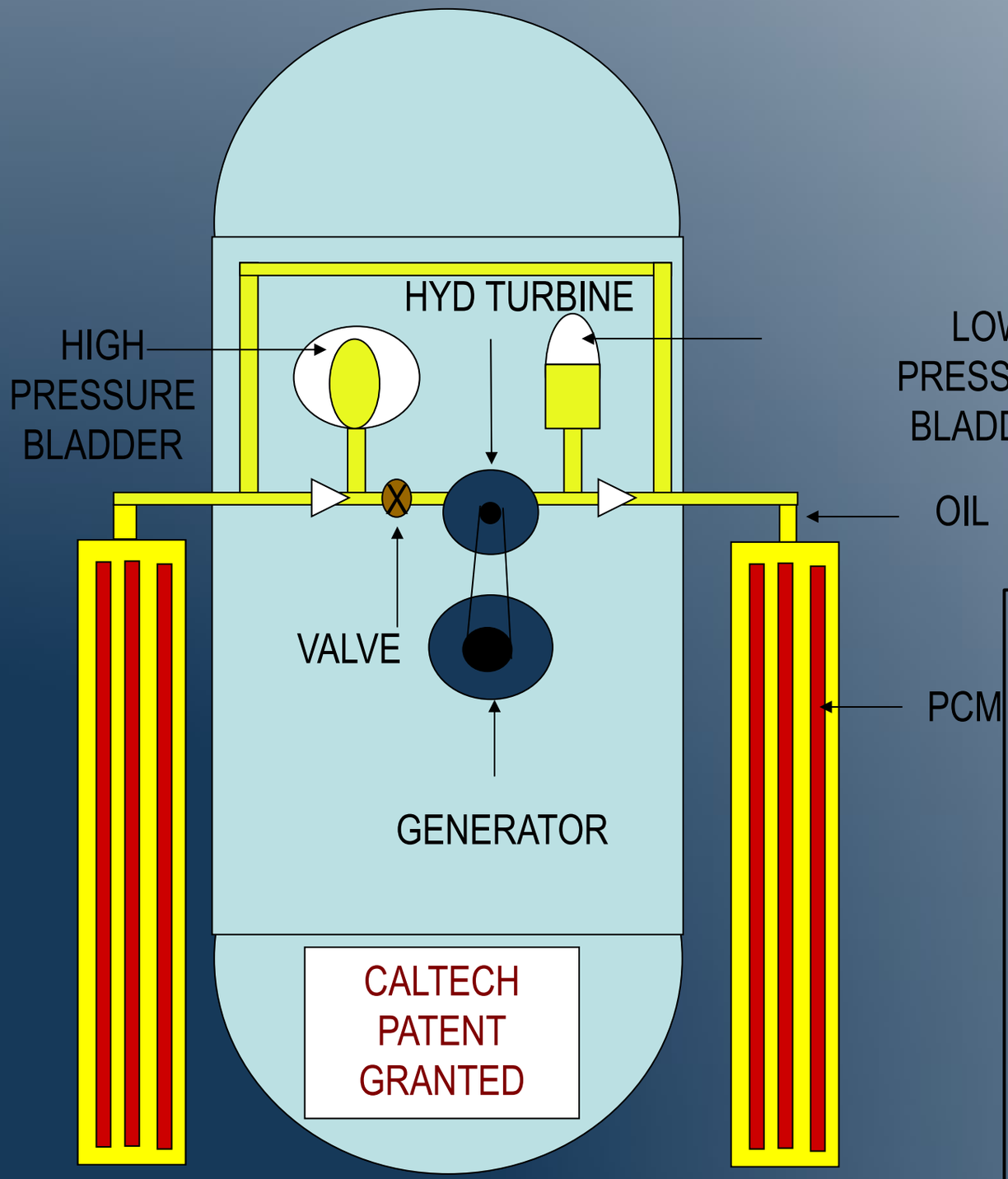
Our GREEN SOLUTION
Supplying new green/renewable energy source for underwater applications with Partner SEATREC

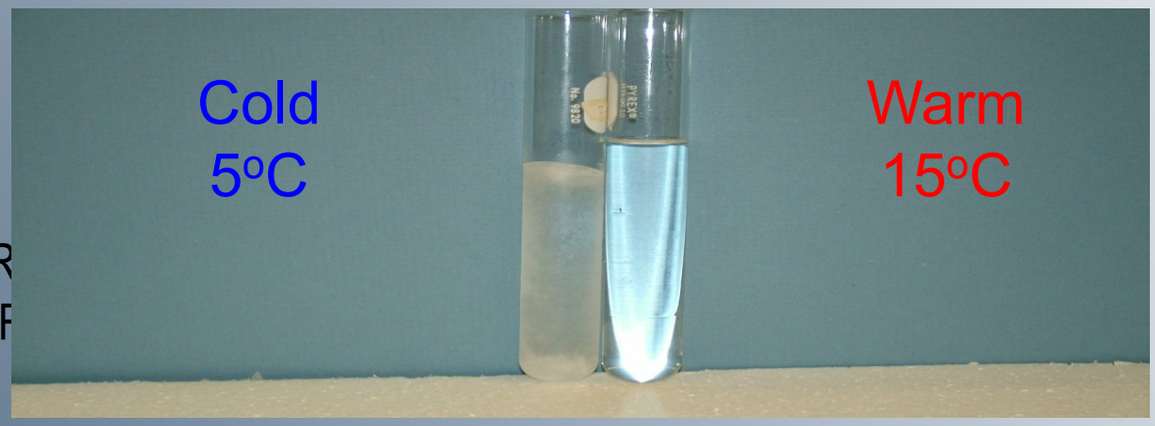
SEATREC



Technology Innovation

Temperature Difference → Volume Change → Pressure Difference → Battery Recharging

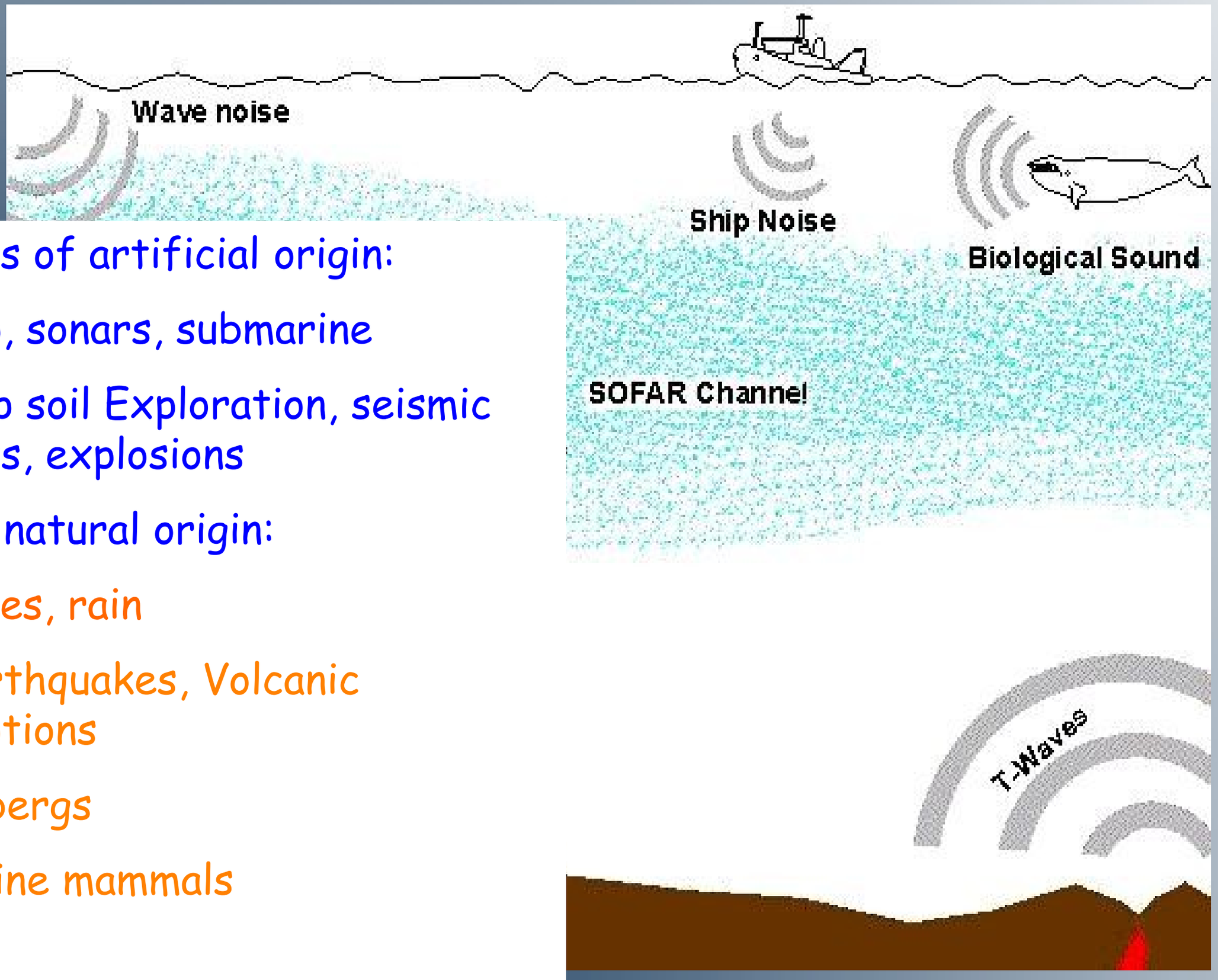




Phase Change Material (PCM)

PCMs expand/contract as they encounter warm/cold waters at surface/depth, and create a pressure differential, which will drive a hydraulic motor to generate electricity and charge battery.

Ocean: a "silent world" but also noisy !



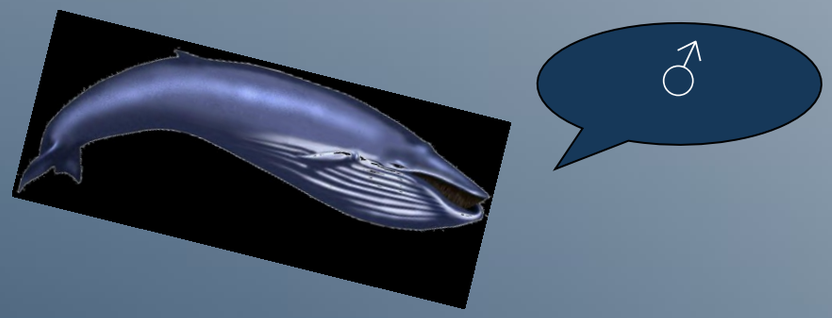
Sounds of artificial origin:

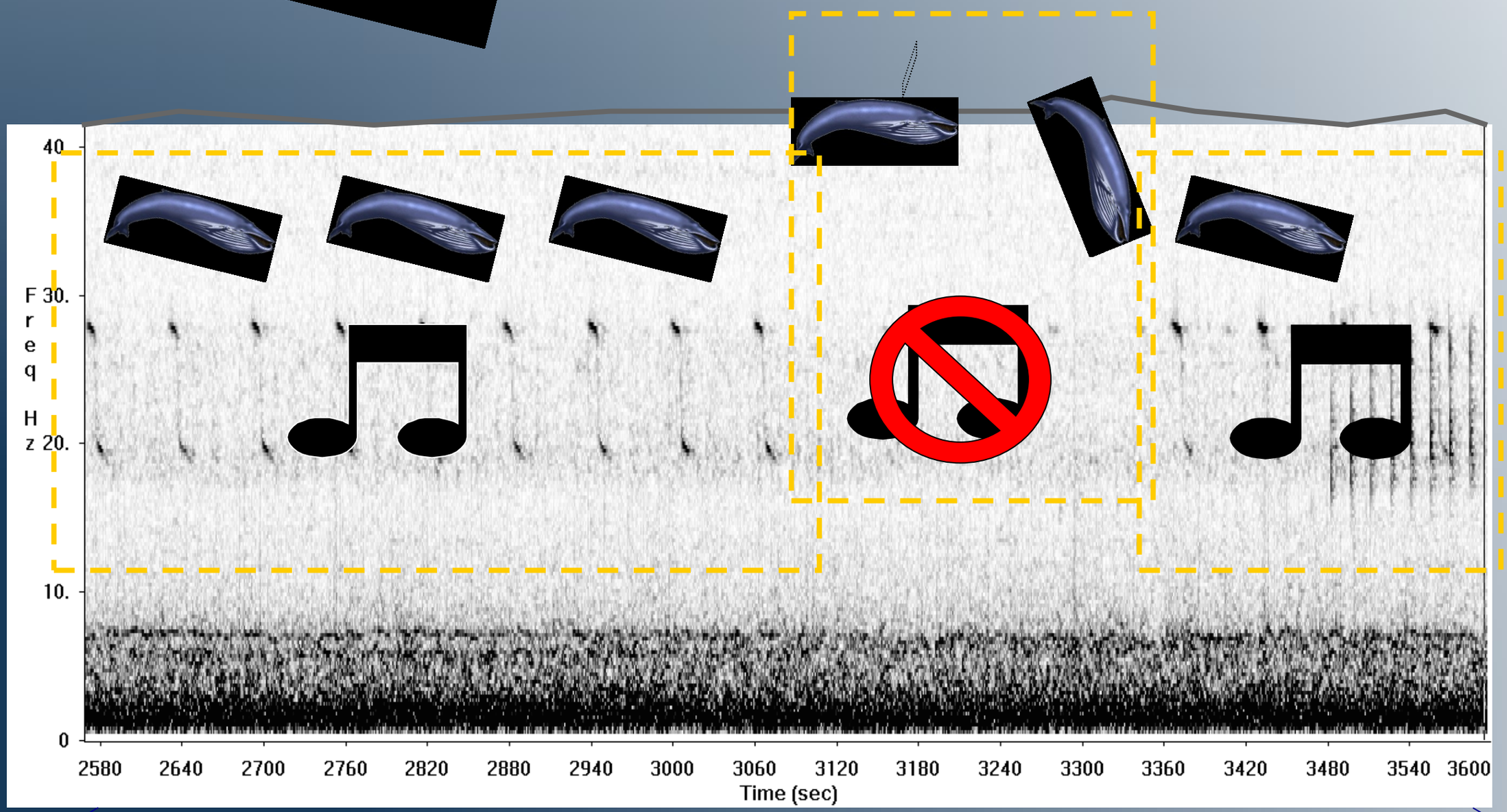
- Ship, sonars, submarine
- Deep soil Exploration, seismic shots, explosions

Or of natural origin:

- Waves, rain
- hearthquakes, Volcanic eruptions
- Icebergs
- Marine mammals

Sounds for blue whales





17 minutes

Samaran, 2010

Identifying Mamals

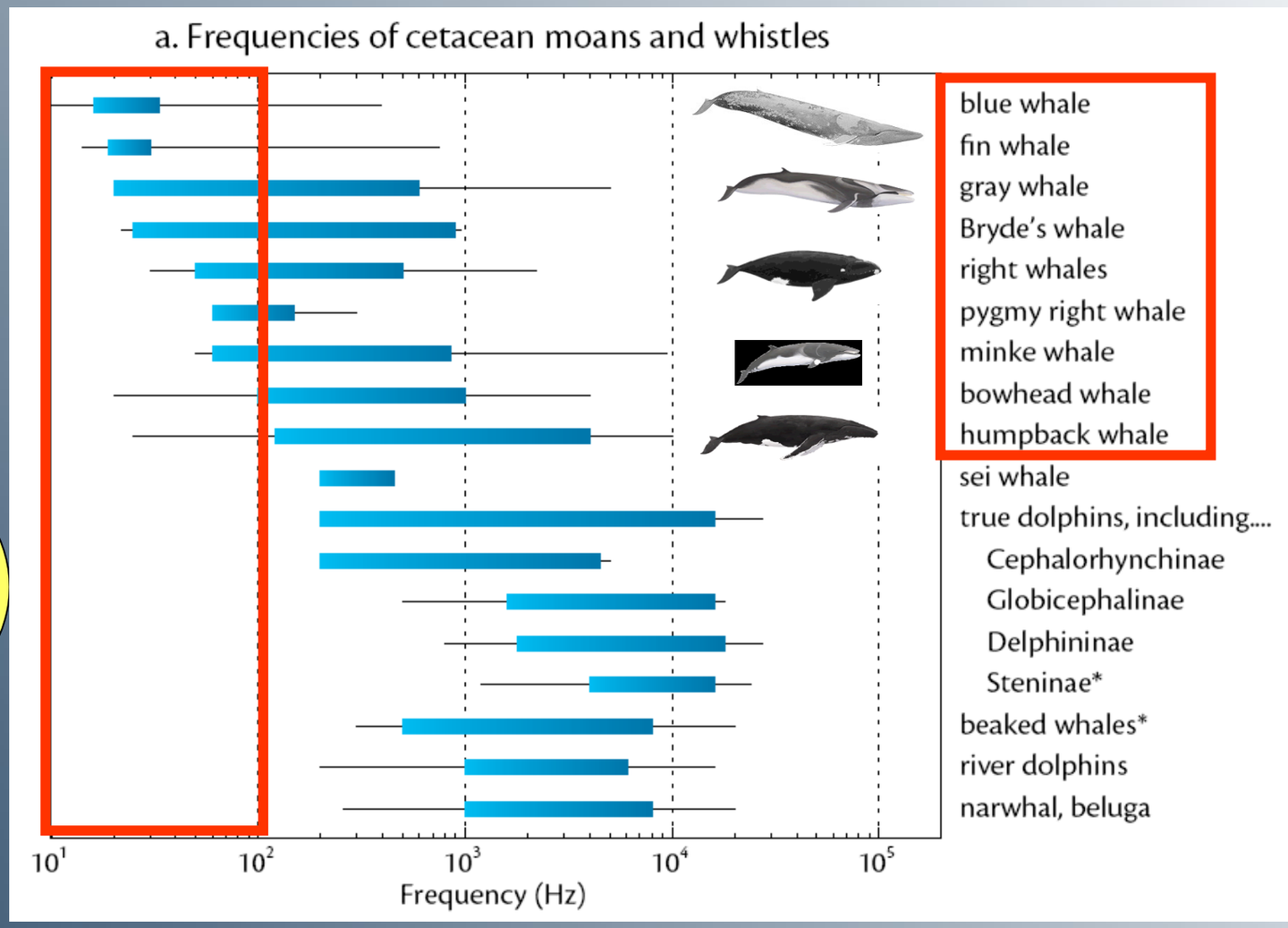
♫

Stereotypical sounds

Low frequencies

Strong intensity

regular interval



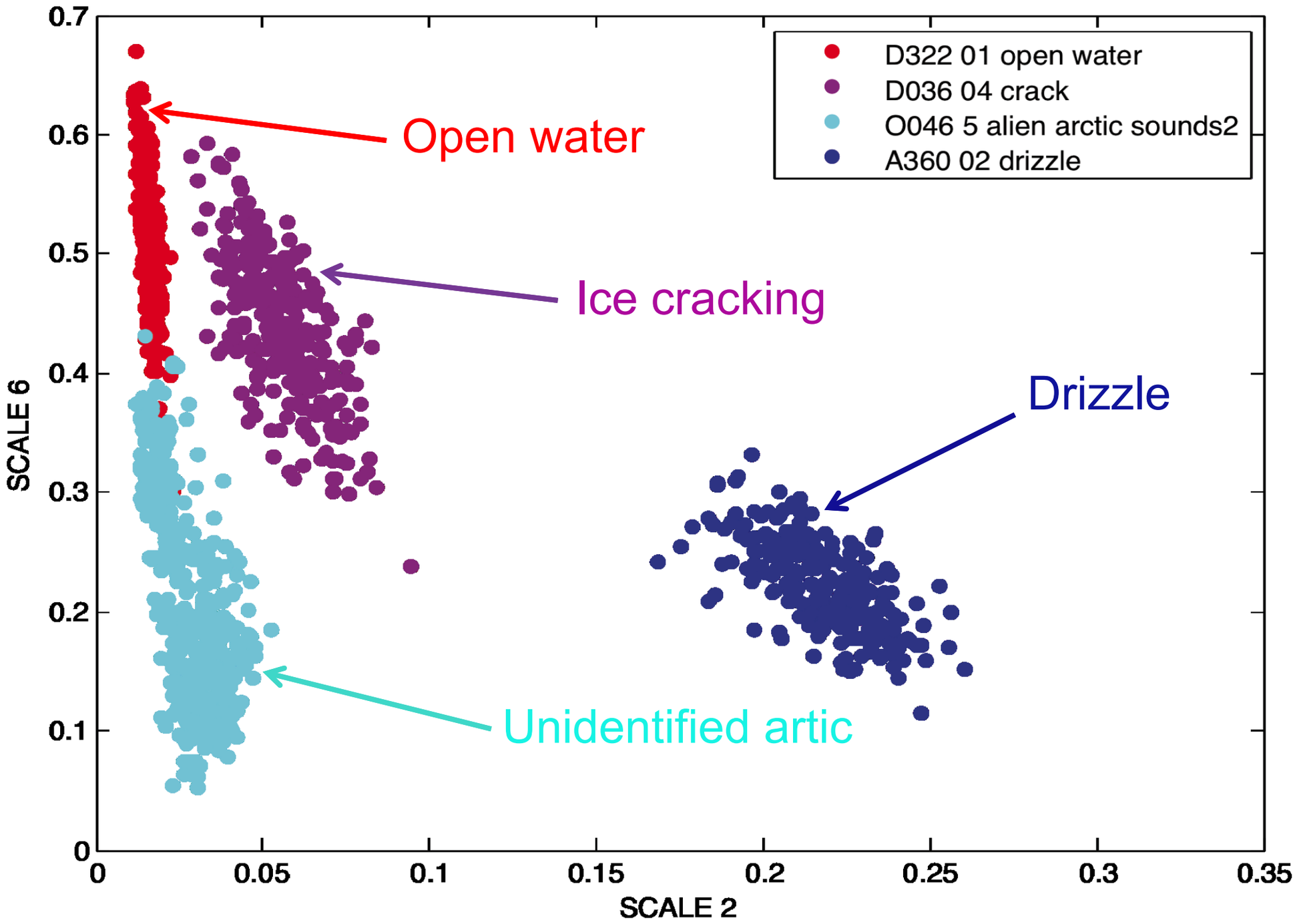
Distribution on long distances

(Hundreds of miles)

17/11/2016

Mellinger et al. 2007

the Sukhovich discriminator applied to meteorological data



EarthScope-Oceans

- P delays can be observed under water
- Robots are affordable
- A network of about 300/1000 Mermaids would fill the ‘ocean gap’ for seismic tomography
- Efforts can be shared between three continents. China can lead EarthScope in Pacific an Indian Ocean.
- Financing can be divided over at least three disciplines (meteorology, biology, solid earth

Thank you

MERMAID Most Advanced Float available

Large Autonomy

- Based on OBS sphere (17”)

- More batteries (5.5 KW
3 times more than current
floats)
Larger life time (5-6 yr)

- Remotely programmable
- *Multidisciplinary*:

- Temperature, Conductivity,

- High and Low frequency acoustics

Floats are intelligently distributed in a small array configuration,

Floats have a landing Capability to monitor after-shock,

Mermaid, a multidisciplinary float resulting from a fruitful collaboration between an experienced company in Marine development “Osean” and “Geoazur” a scientific laboratory specialized in Marine Geophysics

O S E A N

www.osean.fr

Geo AZUR

TERRE - OCÉAN - ESPACE