Marine Magnetotelluric Instrumentation

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A short history of marine magnetotelluric (MMT) methods

- **1965**, **Charles Cox and Jean Filloux** deploy electric and magnetic field recorders in 4,000 m water off California. The first MMT response is calculated.
- **1976**, Mobil attempt one site of MMT in 20 m water in the GoM, collecting data telemetered to an acquisition hut on a work boat.
- **1980**'s, **Laurie Law, Jean Filloux, Antony White, Jiro Segawa, et al.** collect MMT data using ring-core fluxgates and torsion fiber magnetometers (Filloux).
- **1994**, I test BF-4 coils on an SIO Mk-I CSEM receiver (16 bit VCO), with help from AOA and LBL.
- **1995**, Industry consortium funds development of Mk-II MT instrument (16 bit ADC, later 24 bit). Build up a fleet of instruments by commercial rents through AOA.
- **2001**, ExxonMobil funds the development of SIO Mk-III instrument (24 bit ADC), I start making my own coils using aluminium wire to save weight. Continue to build instruments through rentals.
- **2002**, AGO and EMGS start commercial MMT acquisition.
- **2004**, Schlumberger buys AGO.
- **2014**, Schlumberger stands down marine EM operations and donates equipment to Scripps.

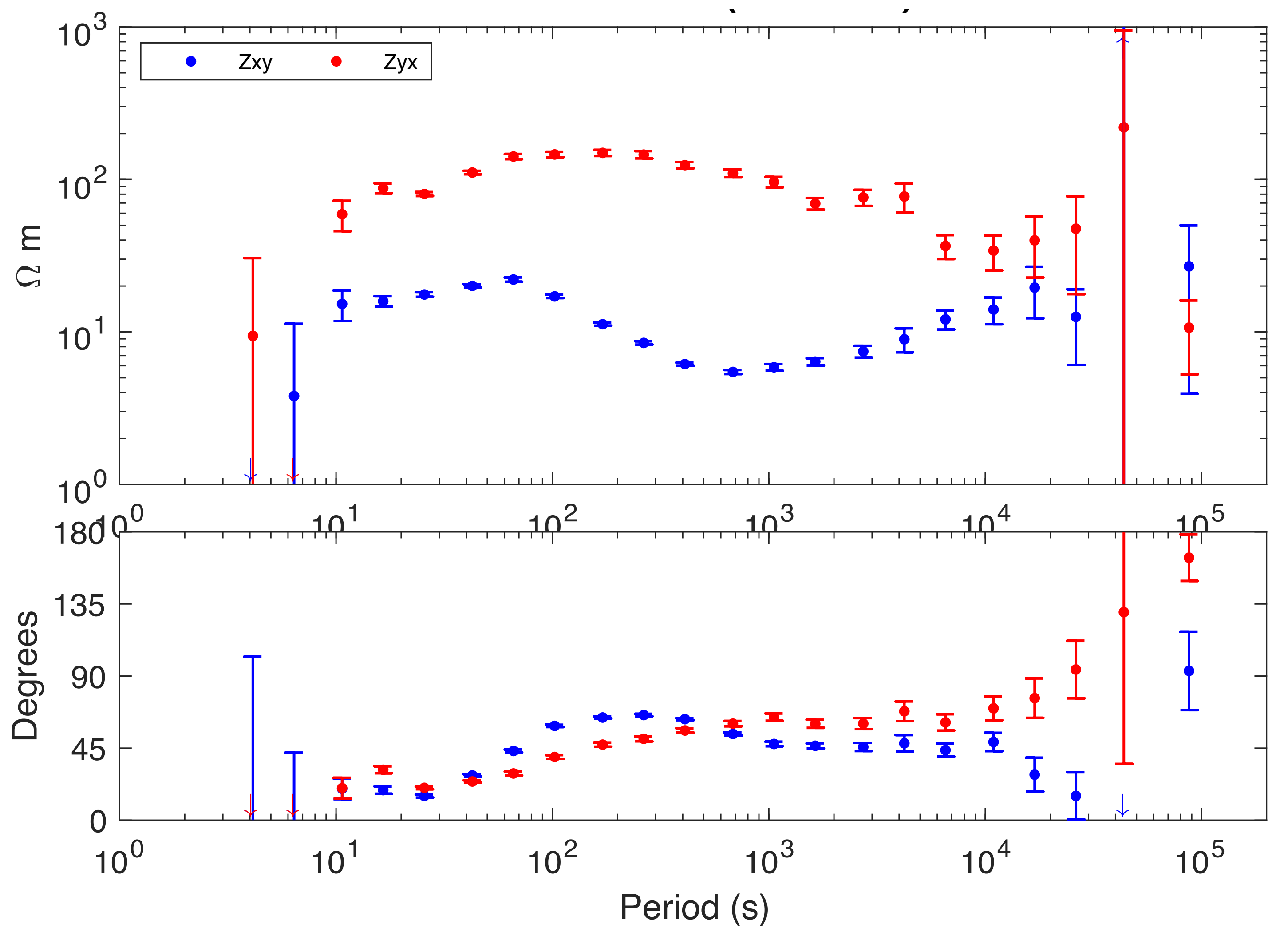
SIO Magnetotelluric/CSEM receiver:

- Uses induction coils to maximize HF response
- Loss rate < 1% of deployments
- Uses rechargeable NiMH or alkaline batteries

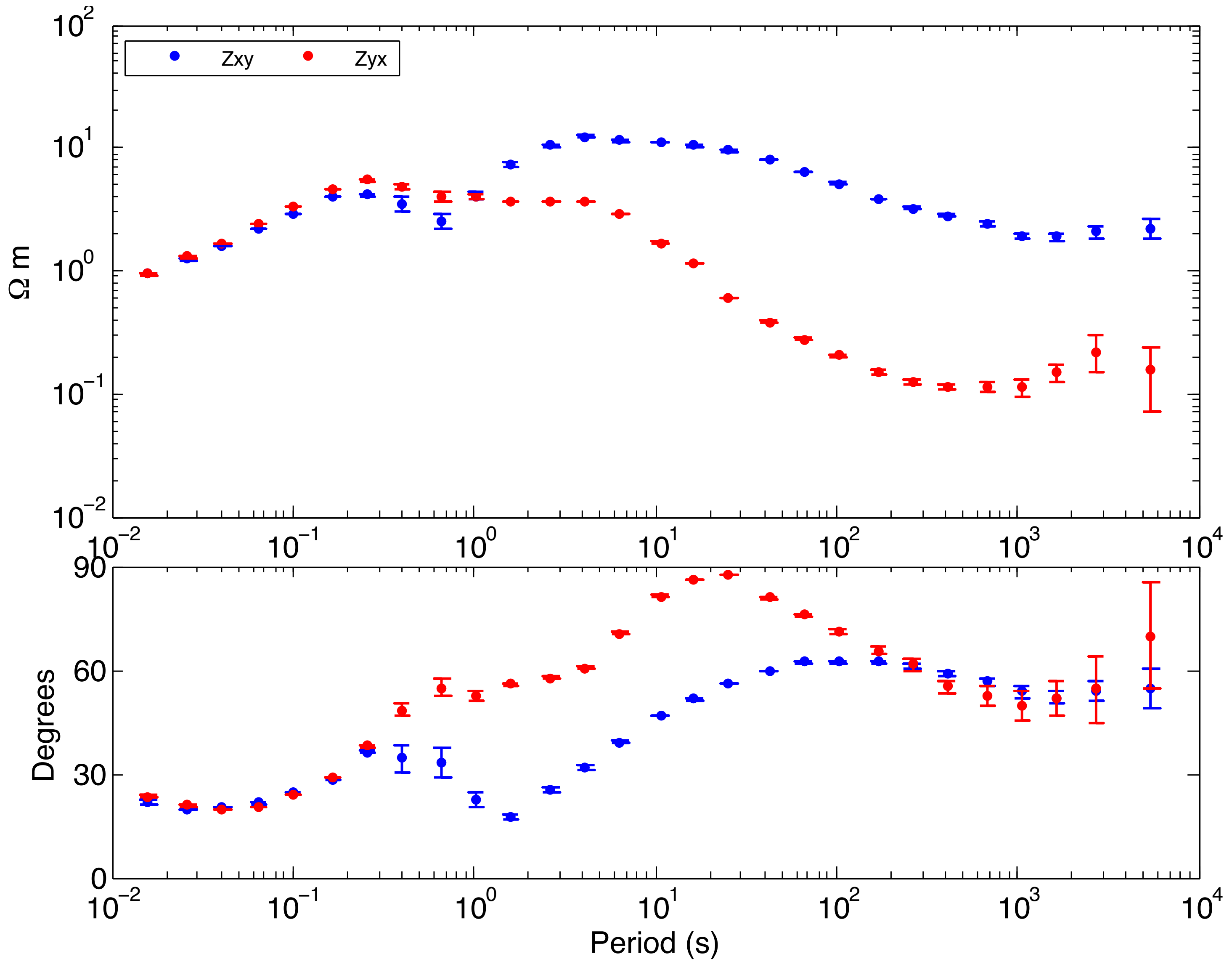
8 channels of data
24 bit ADC
64 GB data capacity
< 500 mW

Timing ~1 ms/day
Records for ~ 70 days
Endurance > 1 year
Max sample rate 1 kHz

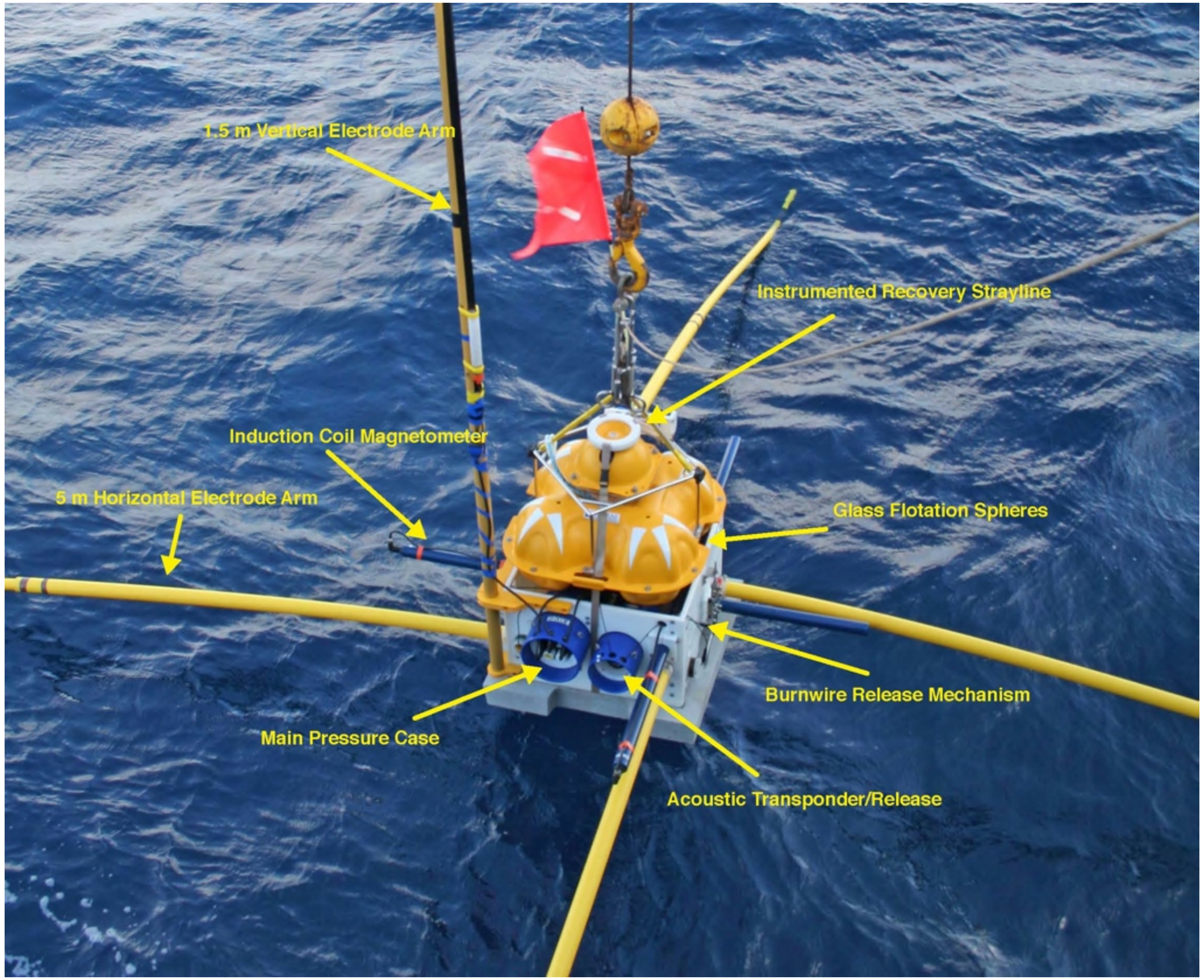
Max depth 6,000 m
E_{noise} 10^{-20} $(V/m)^2/Hz$ at 1 Hz
B_{noise} 10^{-8} nT^2/Hz at 1 Hz



MT responses 10 s to >10,000 s in deep water

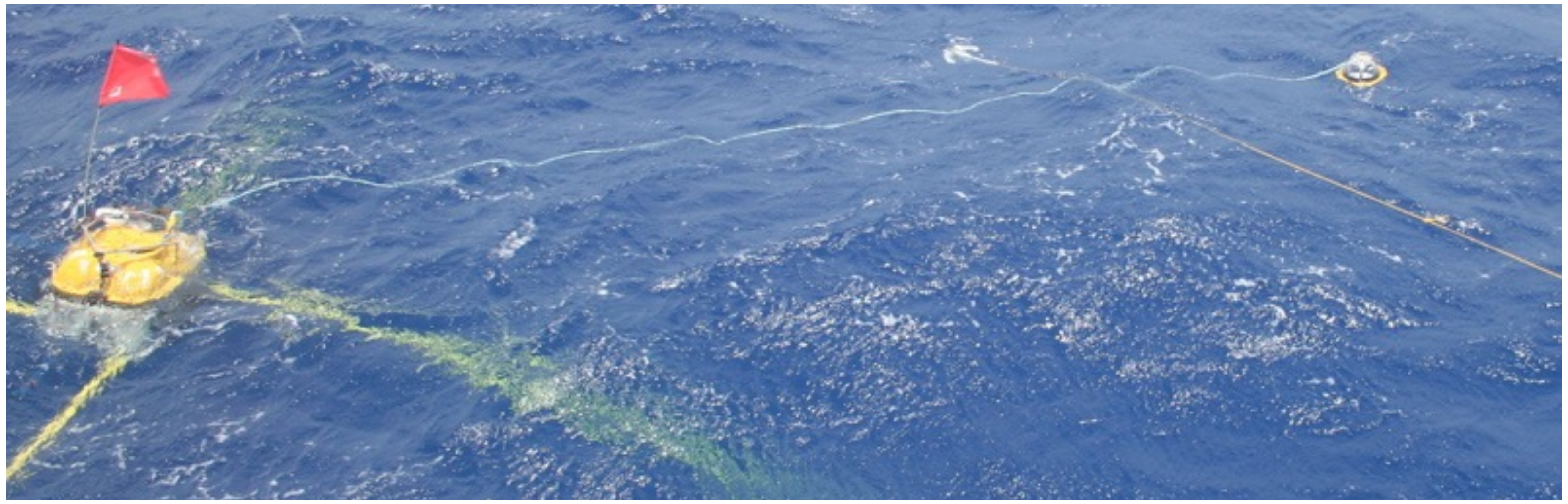


MT responses to 100 Hz in shallow water



Constable, 2013

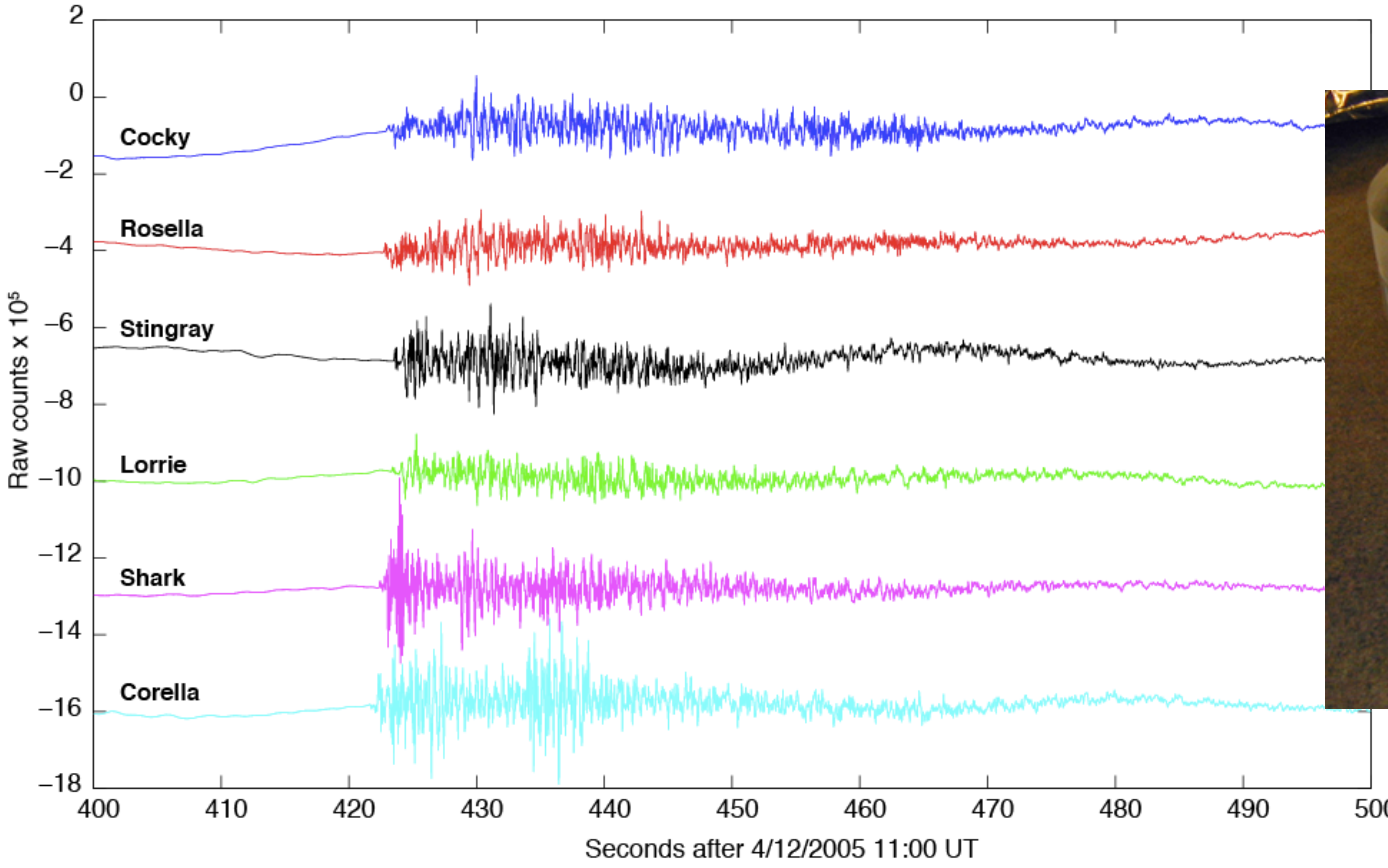
We have ~150 seafloor receivers, about half built by Scripps through industry funding, and about half donated by Schlumberger after they stood down their marine CSEM operations.



The instruments use a mix of commercial and home-brewed 12 kHz acoustic releases. A custom stray-line buoy instrumented with GPS, 900 MHz modem, and strobe light assists recovery.

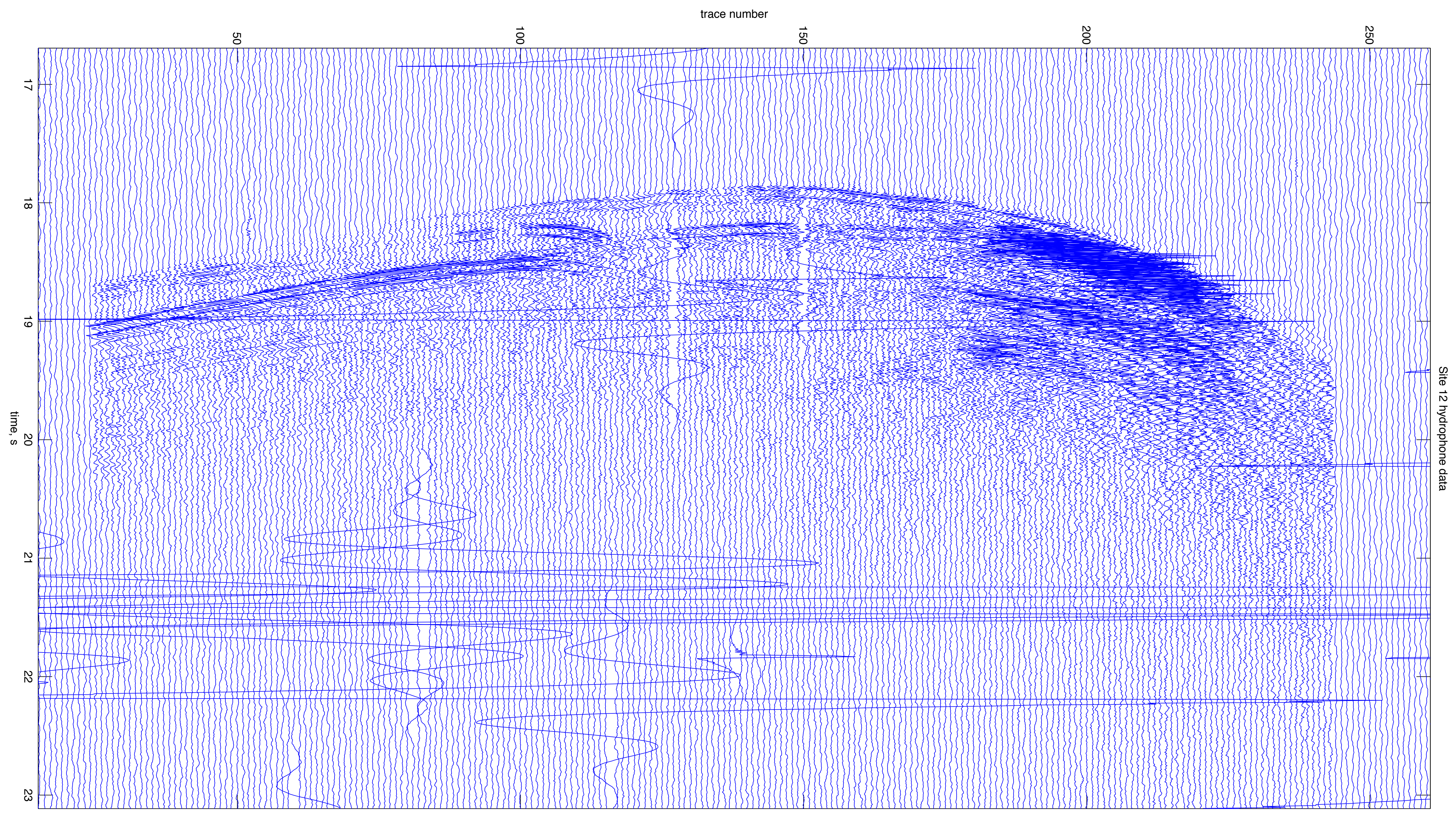
Deploy about 24/day, recover about 12/day in deep water.

A logger is a logger… It is pretty easy to add seismic sensors. I think joint acquisition is the way of the future.

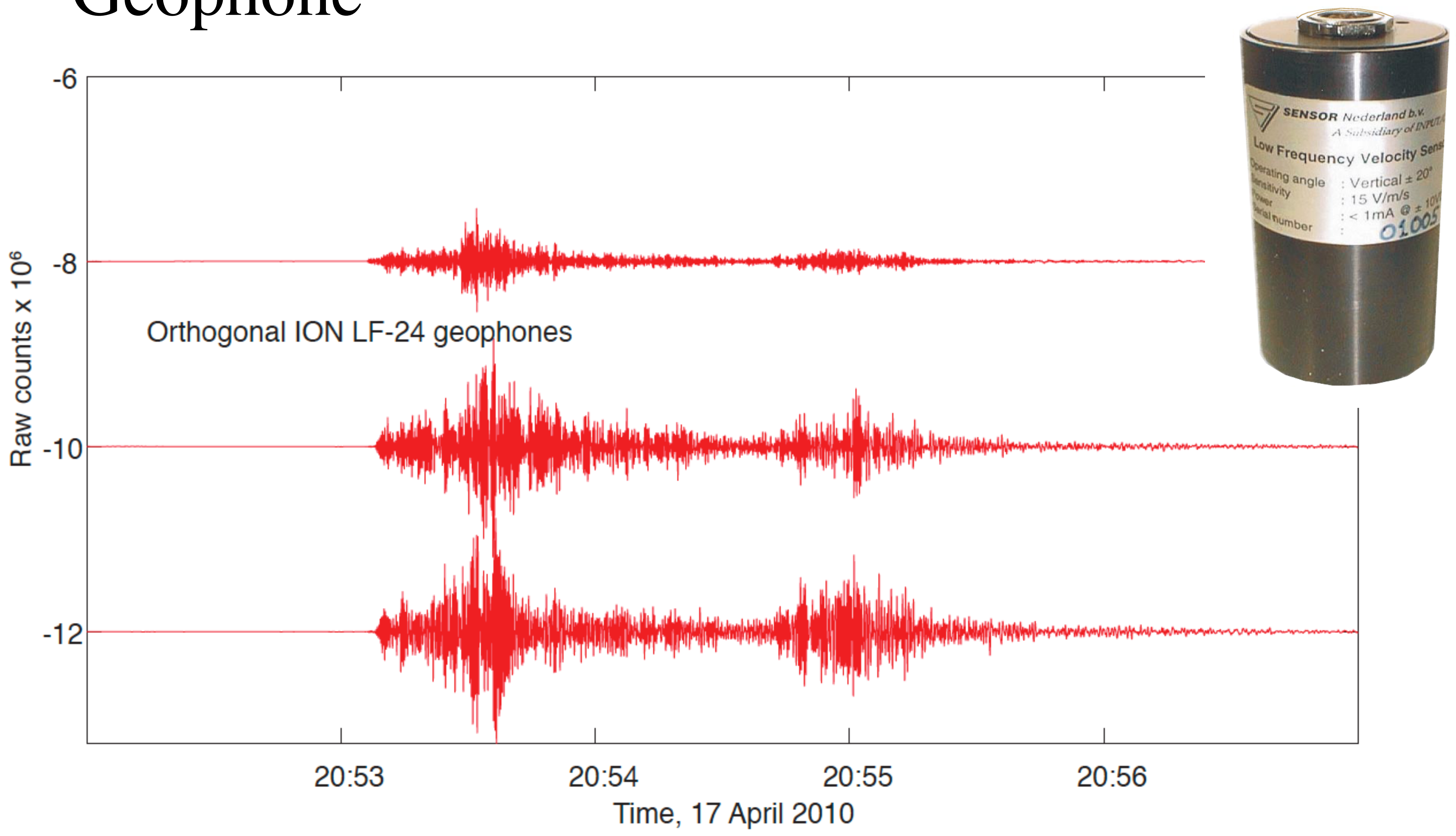


DPG

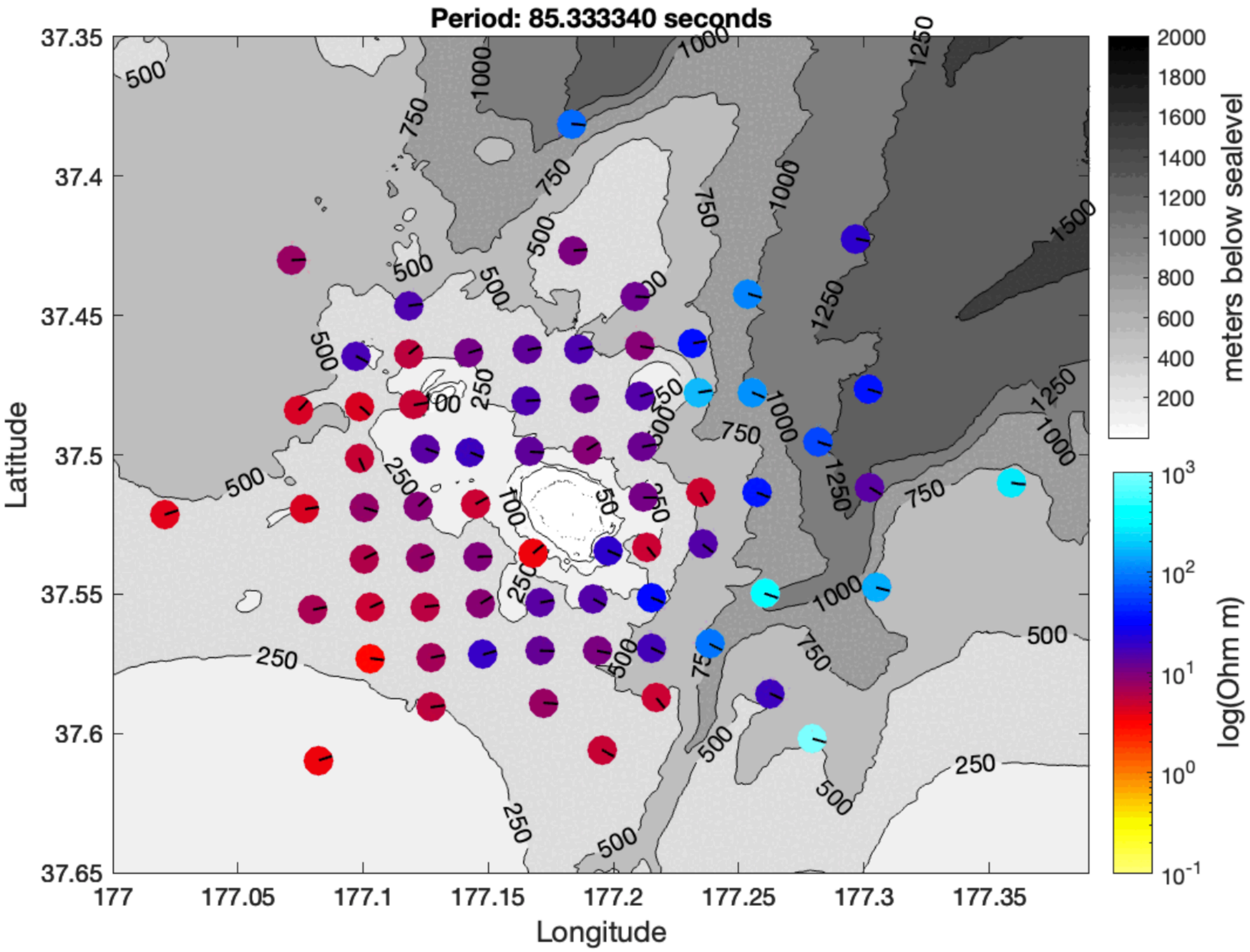
Hydrophone

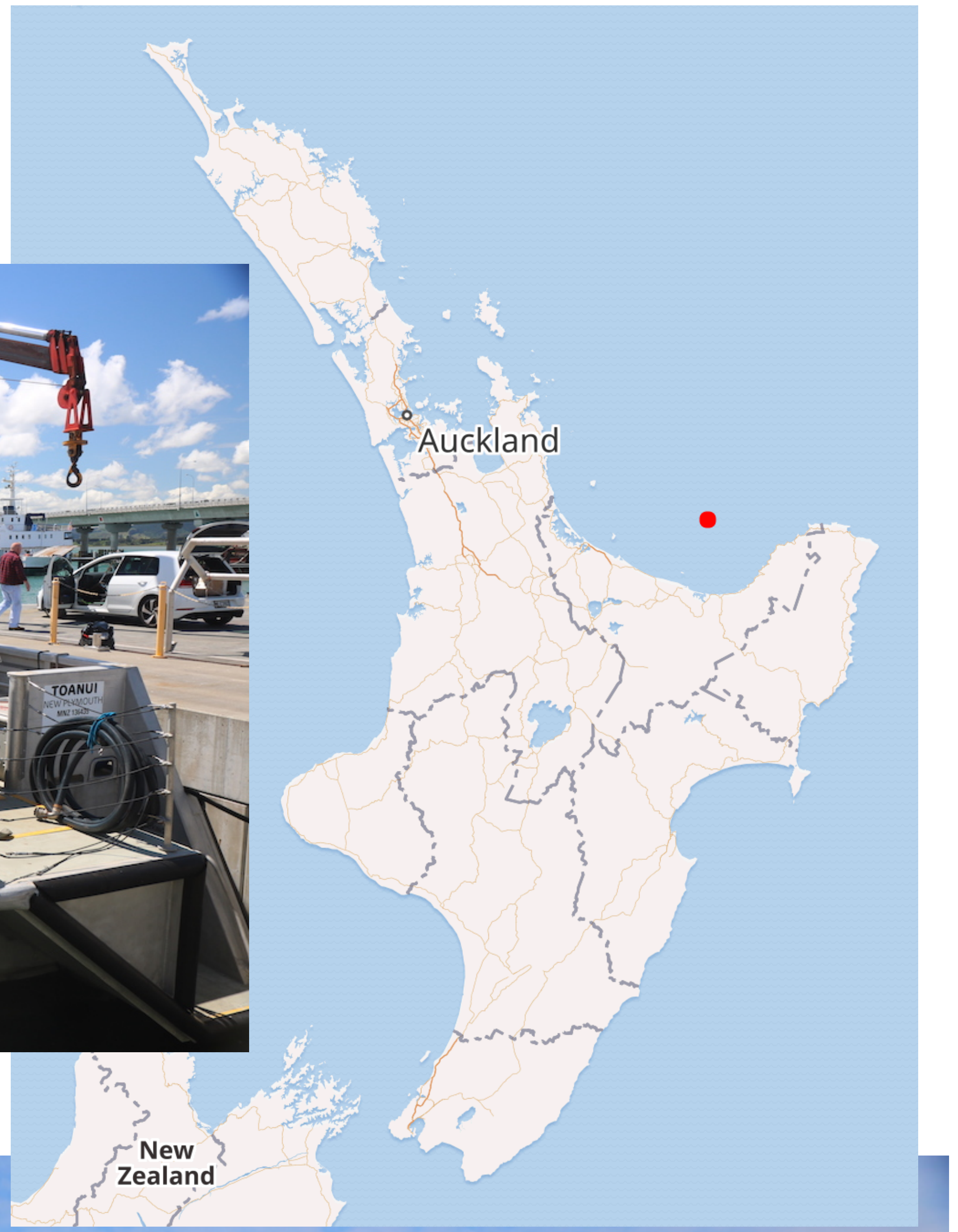


Geophone



A recent example from White Island New Zealand, 73 sites deployed and recovered, lost only 2 channels due to failed cables/sensors. Total ship time 7 days.





A de facto NSF marine EM instrumentation facility:

- 2012, **K. Key, S. Constable. G. Egbert, A. Schultz, D. Livelybrooks,** *Collaborative Research: Onshore-offshore MT Investigation of Cascadia Margin 3D Structure, Segmentation and Fluid Distribution,* OCE-1053207
- 2015, **R. Evans, K. Key,** *Collaborative Research: A Pilot Study for Electromagnetic Surveying of Freshwater Resources Beneath the US Atlantic Continental Shelf, OCE-1459035*
- 2015, **K. Key, N. Bennington**, *Collaborative Research: Magnetotelluric and Seismic Investigations of Arc Melt Generation, Deliver and Storage Beneath Okmok Volcano*, OCE-1456710.
- 2015, **S. Constable and K. Key**, *Central Atlantic Lithosphere-Asthenosphere Boundary Study*, OCE-1536400
- 2016, **G. Jacobs et al.**, *`Ike Wai: Securing Hawai`i's Water Future Award,* OIA-1557349 (subcontract).
- 2017, **S. Constable and D. Sandwell,** *The Mendocino Fracture Zone: A Natural Laboratory to Study Aging of he Lithsophere and Asthenosphere*, OCE-1736590
- 2018, **S. Naif, K. Key**, *Hikurangi Trench Regional Electromagnetic Survey to Image the Subduction Thrust,* OCE-1737328
- 2018, **K. Key, S. Naif, R. Evans, S. Constable**, *Marine EM Survey of Fluids in the Alaskan Megathrust*, OCE-1654652
- 2019, **S. Constable,** *Marine CSEM Study of the Southern Hikurangi Margin: A First Step Towards Estimating the Global Gas Hydrate Carbon Budget,* OCE-1916553
- 2020, **R. Evans,** *Porosity Structure and Earthquake Rupture Dynamics at the GOFAR Fracture Zone,* OCE-1922528
- 2020, **T. Minshull and S. Constable,** *Quantifying Evolution of Magmatism and Serpentinization During the Onset of Seafloor Spreading*. NSF/NERC OCE-2026866
- 2021, **A. Husker and S. Constable**, *Collaborative research: A better understanding of seismic hazard in Tehuantepec, Mexico, using amphibious MT studies*, OCE-2105740
- 2022, **S. Naif**, *Collaborative Research: Quantifying melt in the mantle and controls on lithosphere-asthenosphere dynamics and intraplate magmatism: a joint seismic and EM survey of the Cocos plate,* OCE-2146896
- 2022, **D. Sandwell and S. Constable**, *Determining the origin of Haxby lineaments using magnetotelluric and bathymetry data*, OCE-2211895

We have ~150 seafloor receivers, all designed, tested, and built with industry support (~$20M). While functionally state of the art, this equipment is now ~20 years old and industry isn't funding marine EM much any more. Flash cards, CPUs, and ADCs are all obsolete. Our 2 technicians and 2 engineers have over 100 years experience with marine EM systems.

Going forward, we will need support to keep this instrument fleet fully functional. NSF is aware of this, and have suggested that I increase my "drop fees", which cover maintenance and losses.