SMART Subsea Cables for Observing the Global Ocean

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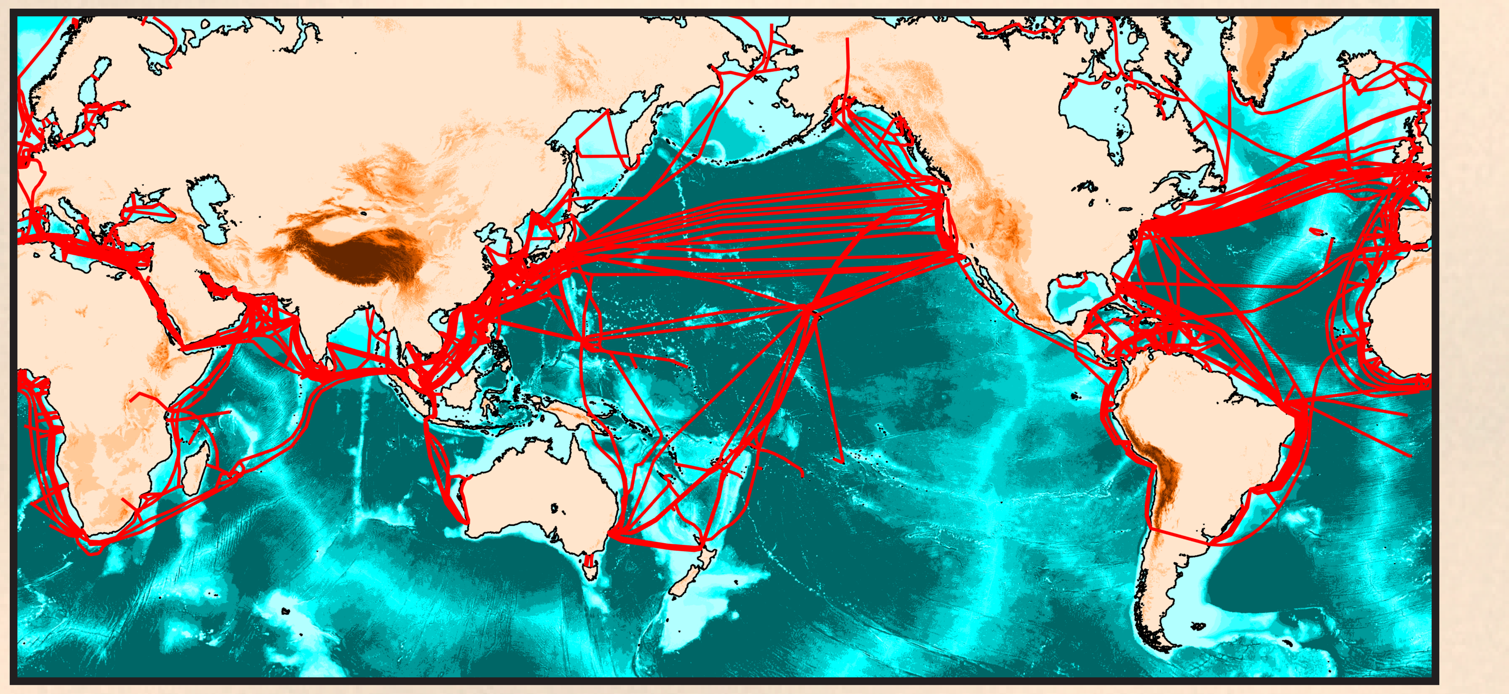


Map of existing and projected cable routes. *data source : cablemap.info*

Overview

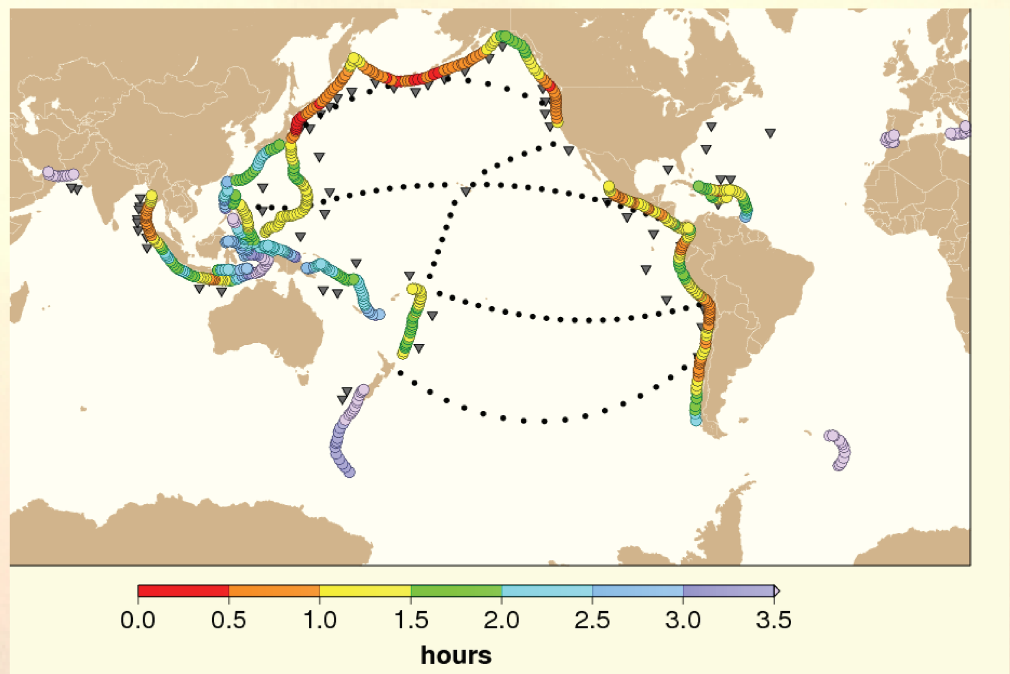
"The deep ocean is key to understanding environmental and societal threats, from climate and ocean warming to rising sea level, ocean acidification, and tsunamis. Because the deep ocean is difficult and costly to monitor, however, we lack fundamental data needed to adequately model, understand, and address these threats. One solution is to integrate sensors into future undersea telecommunications cables. This is the mission of the SMART cables initiative (Science Monitoring And Reliable Telecommunications), a Joint Task Force (JTF) sponsored by three UN agencies. SMART sensors would "piggyback" on the power and communications infrastructure of a million kilometers of undersea fiber optic cable and tens of thousands of repeaters, creating the potential for global coverage at modest incremental cost. Initial sensors would measure temperature, pressure, and acceleration. The resulting data would address two critical scientific and societal issues: a) the long-term need for sustained climate-quality data from the under-sampled deep oceans, and b) the near term need for improvements to global tsunami warning networks. This poster explores the ocean observing improvements available from SMART cables. Simulations show deep ocean temperature and pressure measurements can improve estimates of ocean circulation and heat content, and cable-based pressure and acceleration sensors can improve tsunami warning times and earthquake parameters. The technology of integrating sensors into fiber optic cables are discussed, addressing sea and land-based elements plus delivery of real-time open data products to end users.

SMART cables have been endorsed by major ocean science organizations. JTF is working with cable suppliers and sponsors, development banks and end-users to incorporate SMART capabilities into future cable projects. By investing now, we can build up a global ocean network of long-lived SMART cable sensors, creating a transformative addition to the global ocean observing system."

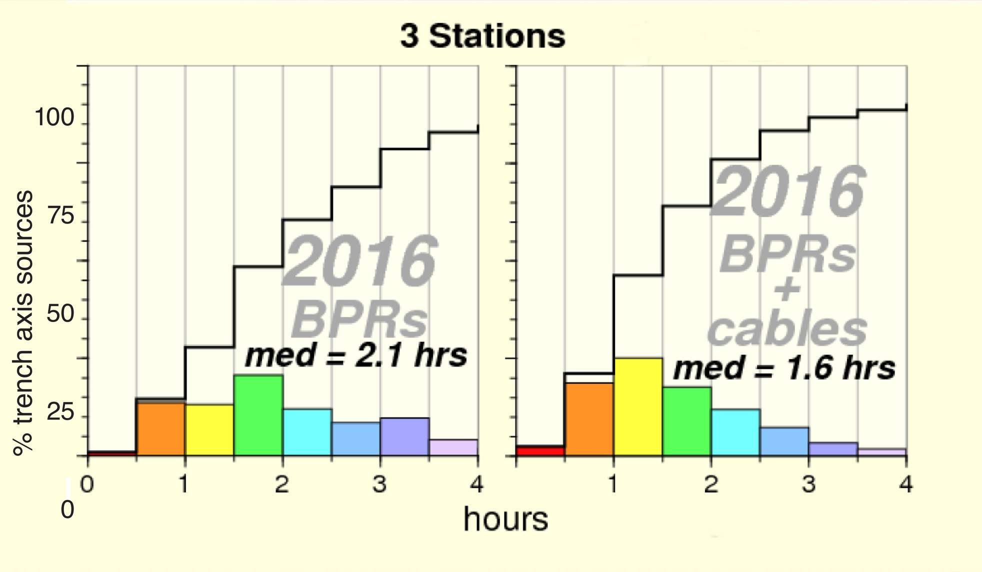
Tsunami detection

Using the addition of deep ocean pressure sensors along hypothetical transpacific cable routes, the time-to-issue a tsunami warning can be reduced from 2.1 to 1.6 hours (a 25% reduction), which can be critical for the evacuation of at-risk areas.

The specific improvement of tsunami warning times at a particular site due to SMART cables is obviously highly dependent on the cable locations.

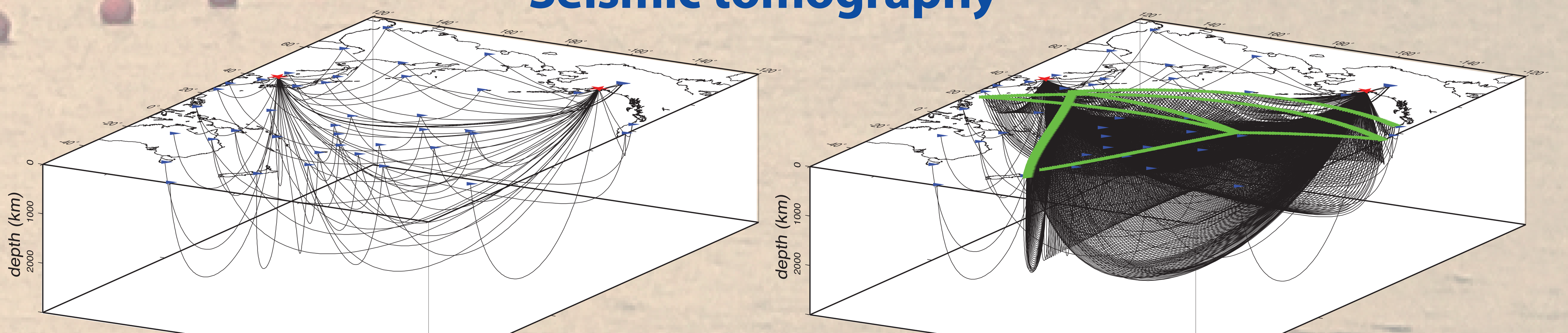


Time elapsed (color) between an earthquake at the circle location and until the tsunami is detected at three bottom pressure sensors. *Courtesy N. Becker and S. Weinstein (NOAA/NWS/PTWC, Honolulu USA)*



Distribution of elapsed times between earthquake and tsunami detection, currently (left), and with the addition of hypothetical transpacific SMART cables (right). *Courtesy N. Becker and S. Weinstein (NOAA/NWS/PTWC, Honolulu USA)*

Seismic tomography



Direct P-wave arrivals , with the current seismic array (left) or with the addition of smart sensors (right). *(from Ranasinghe , Rowe , et al 2017)*

The addition of the SMART cables will, over time, provide significantly improved seismic ray coverage for global velocity and attenuation models, allowing seismic tomographers to improve currently undersampled areas.

In the existing global seismic dataset, resolution of the structure near the transition zone and upper part of the lower mantle suffers from poor coverage beneath the major ocean basins, in particular the Pacific. A dramatic improvement is obtained by assuming some of the currently laid cables already possess sensors. Here direct P waves are modeled. Adding later arriving phases could mitigate current gaps, but the sensitivity regions of indirect phases are more complicated, and their observations are far less numerous than direct P. Accelerometers must be sufficiently sensitive to record regional and teleseismic P, but advances in solid state devices are promising. *Credit: Charlotte Rowe and Nishath Ranasinghe (LANL)*

For more information, International Telecommunication Union (ITU) Website: http://www.itu.int/en/ITU-T/climatechange/task-force-sc

Deep ocean Temperature

Deep ocean temperature observations are currently extremely limited in space and time. From the limited ship based repeat hydrography, we know the global deep ocean is currently warming at an average rate of ~5 m°C per decade, with the strongest (order 50 m°C/decade) magnitudes found in the Southern Ocean. After 5-10 years, the deep SMART cable temperature sensors should be able to detect any decadal temperature changes in the deep ocean, supplementing the other deep observing systems with the only long-term high temporal resolution deep ocean temperature record and contribute to more accurate estimates of deep ocean heat content and steric sea level rise.

In addition to the long-term climate trends, the deep observations will offer a unique look at local deep temporal variability. At a given location in the ocean, local fluctuations in temperature are dominated by vertically homogenous isotherm heave from passing eddies, tides, and shifting fronts. Therefore, temperature measurements at the single depth at the bottom can give accurate information about horizontal and temporal variability throughout much of the deep ocean. Using the high temporal sampling of ocean bottom temperature collected along transocean bottom cables throughout the world, it would be possible to evaluate high to low frequency variability at many locations throughout the global ocean.

Sea Level

Sea–level is a key parameter of the climate system. It has been extracted from satellite altimetry data from successive missions since 1993. Raw satellite altimetry data undergoes various corrections to account for tidal and atmospheric effects. SMART cables would provide bottom pressure data that can be used to improve de-aliasing tidal models. This tidal de-aliasing will in turn improve past satellite altimetry products and facilitate the identification of drift or biases. SMART cable pressure data will also allow a realistic representation of the ocean's response to atmospheric pressure variations dispensing with oversimplified inverse-barometric model assumptions, especially on short time scales.

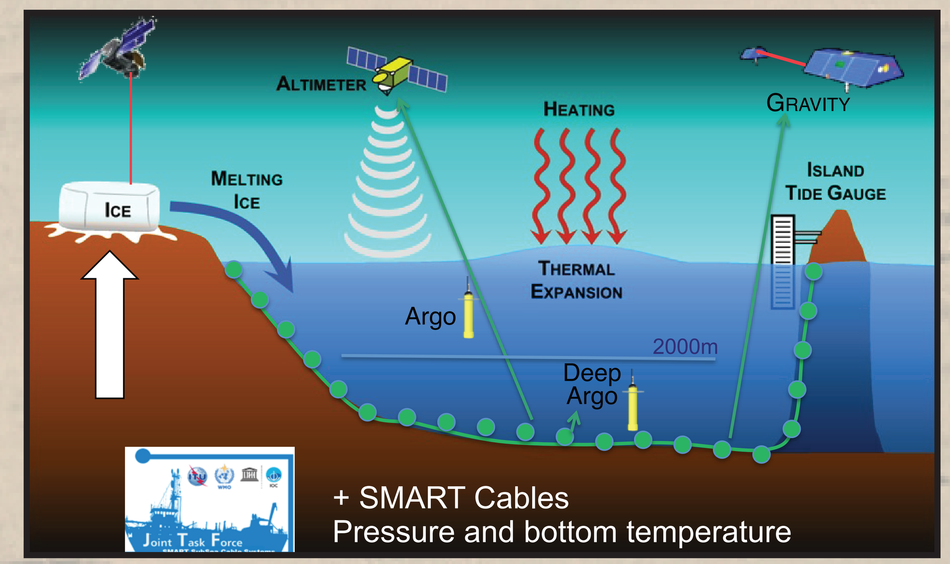
Ocean mass

Ocean mass changes and redistribution and associated variations in the mass component of sea level and the Earth's gravity field are important key parameters of the climate system and are observed by the satellite gravity mission GRACE since 2002.

Complementary continuous ocean bottom pressure measurements from SMART cable systems will provide valuable information on sub-monthly variability that is presently not resolved by GRACE. The observations of short-term ocean bottom pressure variability will not only be an important ground-truth of remotely sensed gravity fields, but are also expected to substantially improve the de-aliasing and correction products, the separation of non-ocean gravity signals, and, thus, final global gravity fields derived from ongoing and future gravity field missions.

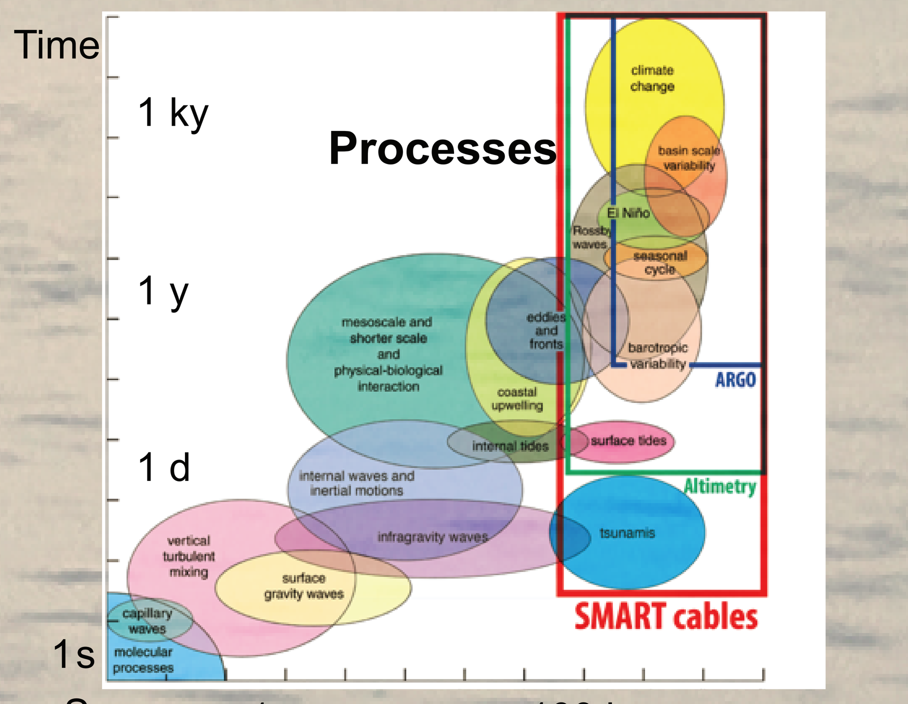
Large scale ocean volume transport

Through the topics discussed above, bottom pressure and temperature from SMART cables will advance our understanding of large scale ocean circulation. The bottom measurements will provide estimates of barotropic flow and deep advective-diffusive balance, related to overturning circulation, temperature content, and mass redistribution in the ocean. The cables may also sample along continental slope boundaries and provide insight into intensified boundary currents, mixing, and boundary processes. Indirectly, improvements in altimetric and gravimetric satellite products through better tidal and high-frequency corrections will translate into more accurate low-frequency circulation from surface geostrophic velocities and horizontal pressure gradients. Thus, even though they are point measurements along a line, SMART cable measurements will improve our understanding of global circulation.



Adapted from Nerem, 2016

Basic elements of the ocean observing systems for temperature, sea-level and ocean mass, with the addition of SMART cable sensors.



Time and space scales of processes in the ocean.

References

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