SCOR Working Group Proposal

Climate and tsunami science with green repeaters on submarine cable systems

Summary

The goal of this SCOR working group is to promote the development of a new modality of ocean observing – the integration of sensors into commercial submarine telecommunication cable systems – by providing a cogent analysis of the scientific benefits, providing science guidance for the larger effort, and engaging the scientific community. Such new dual-use systems combining the communications arteries of our planet with environmental sensing will ultimately form an enduring global network that fills crucial gaps in current sampling, knowledge and application.

Current planning efforts have attracted significant commercial and government interest. The UN International Telecommunication Union (ITU) with UNESCO-IOC and WMO are leading the overall coordination effort that includes engineering, business and legal aspects; the SCOR Working Group (WG) will provide the crucial science review and guidance. The makeup of the WG reflects the international participation and cooperation needed to accomplish the goal. As this is a new, developing observing modality, entraining younger people to plan, develop, and eventually use it, is essential. We will produce a review of the science enabled by this technology including expected quantitative impacts on observing capability on implementation time scales of years to centuries. In addition to group telecommunications, a workshop and conference will be held.

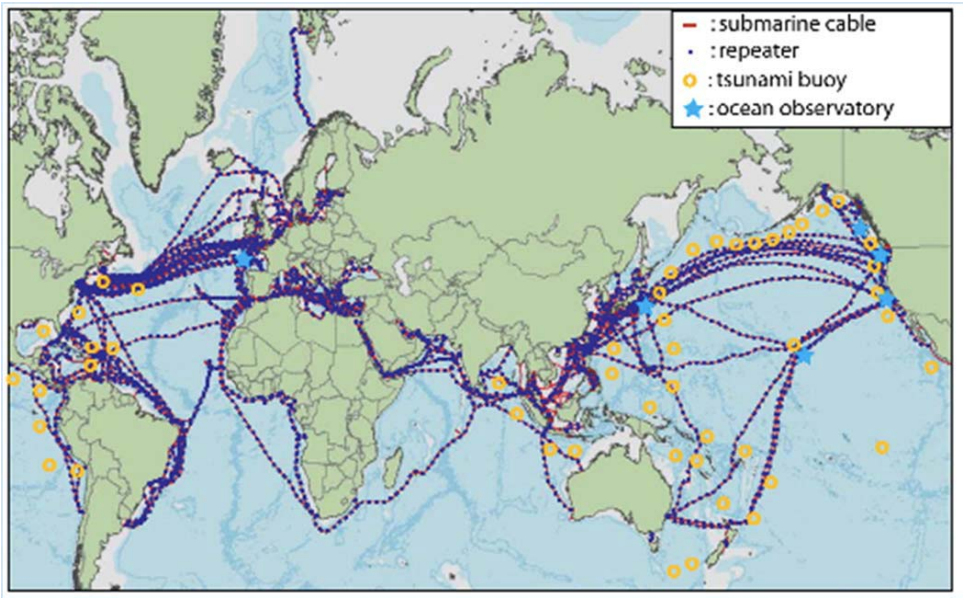

Figure 1: Abridged map of current submarine cable routes (red), with cable repeaters (dots, x4 less than actual). Tsunami buoys and other ocean observatories are also plotted. Initial plans call for pressure, temperature and acceleration sensors to be incorporated into repeaters of new "green" systems as they are deployed; subsequent systems could have additional sensors, with expected lifetimes of decades. Note, new systems are planned for the Arctic and the South Atlantic to reduce latency and improve spatial diversity.

SCOR Working Group

Developing a real-time global deep ocean system for understanding climate change and tsunami processes is a bold vision that has a high probability of success at this particular time given recent technology developments. Local and regional scale science cabled ocean observatory systems are now proven, e.g., NEPTUNE Canada, DONET in Japan, MACHO in Taiwan (Favali et al., 2010; Barnes et al., 2013). You (2010) proposed the much more global concept of incorporating sensors into repeaters on trans-ocean telecommunication cable systems.

The International Telecommunication Union (ITU), the World Meteorological Organization (WMO), and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO IOC) have joined together to promote, develop and transition this concept to reality (see ITU references and web pages below). Workshops (Submarine Cables for Ocean/Climate Monitoring and Disaster Warning: Science, Engineering, Business and Law) were held in Rome and Paris in 2011 and 2012, respectively, and the next workshop will be within the third ITU Green Standards Week in Madrid 19-20 September 2013. A Call to Action resulted in a Joint Task Force (JTF; 2012-) to explore the potential of a submarine climate monitoring and disaster warning system.

The JTF is composed of over 80 experts from the science, engineering, business, marketing and law communities. Six committees have been established: Executive, Science and Society, Engineering, Business Model, Legal, and Publicity, and Awareness and Marketing. The JTF currently has limited financial support but does have the secretariat support of ITU. It is developing a pilot project to design, build and test a new repeater with a simple suite of sensors (pressure, temperature, acceleration), with possible partnership with industry (a multi-million dollar project over 2-3 years). In parallel, the JTF needs to see the science framework and international relationships established. We are requesting SCOR fund and oversee this activity over a four-year period. The resulting progress reports, publications, final reports and both a workshop and conference will be integrated with the parallel progress made by the other JTF committees. The current JTF plan calls for the green system to be developed and accepted by the telecommunications industry by 2017 and then implemented on an ongoing basis. Some companies have already expressed an expectation of being required to provide such environmental data, e.g. Arctic Fibre Inc. proposing a system from Japan to Europe through the Canadian Arctic Islands with science sensors and links with remote communities, arcticfibre.com; and a cable linking Australia, New Zealand and the United States, hawaikicable.co.nz.

Science Background

While there have been significant advances in ocean observing, the ocean remains poorly sampled, and the sampling that does occur is often aliased and incoherent. Consequently, there is a poor understanding of the ocean science and ocean processes in the vast areas of particularly the deep oceans, which is critical for issues of climate change and tsunamis dynamics. Dual-use commercial telecommunication cables provide an opportunity to rectify this situation. Below we highlight the science and operational observing that can be accomplished, emphasizing longer-term observations for climate and shorter-term tsunami detection.

The role of the deep ocean in climate change. The deep ocean is largely unknown. Understanding the deep ocean is indispensable to sustaining humankind on planet Earth and avoiding major disruptions to the climate and life systems. The oceans are the primary driver of

climate change, representing the largest store of energy and absorbing a third of the anthropogenic CO_2 produced.

Still largely unknown is the rate of temperature and circulation change in the bottom of the oceans, especially those areas affected by deep ocean meridional overturning circulation (MOC) such as in the North Atlantic and Southern Hemisphere around Antarctica (Stouffer et al., 2006; Purkey and Johnson, 2012). Descending cold, salty polar waters sink to the bottom of the ocean and circulate throughout the world ocean as part of the now well-know global ocean conveyor belt (Broecker, 2005, 2010). Studies have shown that the broad current patterns are rather more complex that first envisaged with many deflected side currents and influenced by seabed and ocean ridge topography (Richardson, 2008). Concerns about the more rapid than expected melting of Arctic sea ice and the Greenland ice cap (Alley, 2002) suggest that the models of climate change are not precise and need more input of observational data (Wijffels et al., 2010). A fundamental missing portion of critical climate observational data is the precise and changing temperature and pressure (measure of circulation) of ocean bottom waters along a variety of transects across the world's oceans. This is the *first key focus of this WG proposal*, using these new cable systems with added sensors to measure key variables such as ocean floor water temperatures.

Tsunami dynamics: much improved tracking of tsunamis across the world's oceans. The *second key focus of this WG proposal* is to use the same approach to better understand ocean hazards such as tsunamis generated by both large earthquakes and seabed slope failures. Major tsunamis have occurred several times in the last decade, most notably associated with megathrust earthquakes between M_w 7.7 and 9.1 in Sumatra (2004), Java (2006), US Samoa (2009), Mantawai (2010), Chile (2010) and Japan (2011) resulting in severe loss of life and billions of dollars of anthropogenic and environmental damage. Reducing such losses and mitigating damage is a key factor in developing tsunami warning systems (Bernard and Robinson, 2009; Whitmore, 2009). The offshore tsunami buoys (see Figure) provide some measure of warning but are widely spaced and prone to vandalism and failure (often only 60 percent available; National Academy of Science, 2010). This second focus of the WG includes using the network of sensor-equipped green repeaters located about every ~50 km along submarine cables to measure pressure and acceleration and thus establish a network of mini-observatories across many ocean transects that could map out in real time the speed, track and pattern of tsunamis.

Ocean floor topography and ridges, both in the open ocean and along continental margins and coasts, affect the speed and track of major tsunamis. Computer simulation models developed to help predict the affects of tsunamis along particular coastlines are constrained by variable previous and present tsunami data. The new data established by the many sensor-equipped trans-ocean cables could substantially improve the models and generate social and economic benefits, especially to non-developed countries (such as many Pacific Ocean and Indian Ocean island states).

Other science topics

While this four year WG project would emphasize the science of climate change and tsunamis using new bottom sensors (p,T,a) on green repeaters and with an initial pilot project, we emphasize that this could evolve into a long-term effort to include others sensors (inverted echosounder/acoustic modem, salinity, O_2, CO_2, pH, bio-optics, etc.) that enable much broader spatial coverage and diversity of science.

Also, there are too few environmental measurements made consistently over many years, especially long-term measurements at the bottom of the oceans. Many of these sensors cut across and support different science topics and disciplines. A comprehensive modeling and observing system simulation will be required to quantify absolute and relative value of these measurements.

Terms of Reference

The Terms of Reference for the Working Group are:

1. Evaluate the scientific opportunities for understanding ocean circulation and climate change, and tsunami dynamics, using new green repeaters on submarine telecommunication cables.
2. Develop a science strategy and schedule to adopt modified submarine systems equipped with scientific sensors such as pressure, temperature, acceleration, salinity/conductivity, and hydroacoustic. Review future opportunities for acoustic monitoring of marine life, earthquakes, and volcanism.
3. Identify specific types of sensors currently available, or in development, that could meet the needs of the scientific community, be reasonably inexpensive, small, integrative, robust, reliable, long-lasting, and readily deployable to meet the design connections within, or connected to, the green repeaters. The aim is to establish a new and increasing global network of ocean environmental sensors for ocean climate and tsunami research and warning systems.
4. Analyze the development of current and planned commercial and major scientific repeatered ocean observatory projects that could include new, renovated, and relocated retired out-of-service cables that could host the new network.
5. Cooperate closely with the ITU/WMO/UNESCO IOC Joint Task Force (JTF) and the International Cable Protection Committee (ICPC) to support dual-use of cables by safely incorporating the required scientific sensors into green submarine repeaters without affecting normal cable systems and telecommunication signals (http://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx; http://www.iscpc.org/).
6. Organize teleconferences, symposia and workshops to report on progress, engage with interested and vested research communities. Two to three such meetings would be arranged over the four years. Produce journal publications as well as formal interim and final reports to SCOR, JTF and ICPC.

List of Products from the WG

1. Introductory article in *Eos.*
2. Article(s) on science potential in a peer-reviewed journal.
3. Report on recommendations for future directions and guidance for the larger effort, for dissemination to ITU, WMO, UNESCO IOC, as well as CLIVAR, GOOS, GEOSS, and others.
4. One early workshop and a final conference.

Collaboration and Capacity Building

As noted in several places in this proposal, the WG will be well connected into agencies that can assist with capacity building, such as SCOR, ITU, WMO, UNESCO IOC, as well as POGO.

Collaboration with scientific programs is noted (e.g. CLIVAR, GOOS, GEOSS) and with the JTF and ICPC. Committee members are already well connected into relevant networks and programs.

Timeline

We will begin immediately with an *Eos* article to encourage participation and interaction in the scientific community.

1. The first meeting will be held in conjunction with the AGU Ocean Sciences Meeting in Honolulu, Hawaii in February 2014. At this meeting we will:
    a. Outline the project: schedule, opportunities, networking strategy and planned publications and meetings
    b. Encourage WG members to participate in related activities in home countries/institutions and with dissemination
    c. Identify strategies for further study (e.g., observing system simulation experiments) and promotion of concept
    d. Address interaction with ITU/IOC/WMO and related programs.
    e. Develop a detailed capacity-building plan
2. A second meeting, as a workshop, will be held in 2015, possibly in conjunction with an ITU Green Week and/or a JTF meeting. Students and alternates will be invited to attend. We will:
    a. Finalize paper(s) for submission
    b. Prepare the conference proposal and funding requests
    c. Outline the Report for recommendations
3. In the third meeting (possibly by telecommunication) in 2016, we will
    a. Finalize the report
    b. Finalize conference planning
4. The conference (and associated report) in 2017 will be the final activity of the WG.

Chairs and Working Group Members

The proposed working group (table below) has extensive field, analysis, and modeling expertise: all readily have agreed to serve. The two co-chairs are Bruce Howe at the School of Ocean and Earth Science and Technology, University of Hawaii, and John Yuzhu You at the Institute of Marine Science, University of Sydney. Howe has worked on basin-scale acoustic thermometry, the NEPTUNE cabled observatory systems, and now is now operating the ALOHA Cabled Observatory. You has worked on a broad range of topics including paleo and present climate, general ocean circulation, and mixing; he organized the PACSWIN (Indonesian Throughflow: PACific Source Water Investigation) Submarine Cable Workshop 2009 from which this current effort has evolved. The seven other members of the proposed WG represent a balance of expertise, national representation, seniority and gender.

Name	Seniority/ Gender	Affiliation	Expertise
Bruce Howe (co-chair)	sr/m	University of Hawaii, USA	Physical oceanography, ocean heat content, cabled ocean observatories
John Yuzhu You (co-chair)	sr/m	University of Sydney, Australia	Climate and ocean data analysis and modeling
Jerome Aucan	jr/m	IRD-LEGOS, France	Physical oceanography, tides, bottom pressure, tsunamis
Molly Baringer	mid/f	NOAA-AOML, USA	Abyssal temperature, cable-measured transport, meridional overturning circulation

Gerard McCarthy	jr/m	National Ocean Center, UK	Meridional overturning circulation
Wahyu Pandoe	mid/m	BPPT, Indonesia	Indonesian Tsunami Program, deep sea tsunami detection
Jae-Hun Park	mid/m	KIOST, Korea	Physical oceanography, bottom pressure, internal tides and mixing
Hanne Sagen	mid/f	Nansen Center, Norway	Polar oceanography and observing systems
Rick Thomson	sr/m	Fisheries and Oceans, Canada	Coastal and deep-sea physical oceanography, tsunami propagation physics

We have six volunteer Associate members who will support the effort with their particular expertise: Juliet Hermes, physical oceanography, long term observations of the southern oceans, member GCOS steering committee and Ocean Observations Panel for Climate (OOPC), South African Environmental Observation Network, South Africa; Steven Jayne, ocean and climate modeling, data assimilation, WHOI, USA; Janet Sprintall, physical oceanography, ocean observations and network design, SIO, USA; Fadli Syamsudin, physical oceanography, Indonesian Through Flow, BPPT, Indonesia; Ikuko Wada, subduction zone geodynamics, International Research Institute of Disaster Science, Tohoku University, Japan; and Jing Zhang, chemical oceanography and ocean circulation, University of Toyama, Japan.

SCOR support through the Working Group

SCOR is the most logical organization to support this proposal given the vital scientific issues, global approach, and socio-economic benefits. It is not surprising that the proposal is not too closely allied to earlier WGs. With the onset of a new era of cabled ocean observatories and real-time data, it is likely that SCOR will receive an increasing number of WG proposals related to cabled observatory science. The science supported through a SCOR WG would provide excellent arms-length oversight and credibility.

References

ITU References

Call for Action http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B0400000D0001PDFE.pdf

Joint Task Force http://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

Workshops as part of ITU Green Week:

"Submarine Cables for Ocean/Climate Monitoring and Disaster Warning: Science, Engineering, Business and Law"

2011, Rome, www.itu.int/ITU-T/climatechange/gsw/201102/program.html.

2012, Paris, www.itu.int/ITU-T/climatechange/gsw/201209/programme-009.html

Reports:

Strategy and Roadmap, R. Butler, 2012. http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000150001PDFE.pdf

Engineering, P. Phibbs and S. Lentz, 2012. http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000170001PDFE.pdf

Legal Issues, K. Bressie, 2012. http://www.itu.int/dms_pub/itu-t/oth/4B/04/T4B040000160001PDFE.pdf

Alley, R.B., 2002, The two-mile time machine: ice cores, abrupt climate change, and our future, Princeton University Press, Princeton NJ and Oxford, England.

Barnes C.R., Best, M.M.R., Johnson, F.R., Pautet, L. and Pirenne, B., 2013, Challenges, benefits and opportunities in installing and operating cabled ocean observatories: perspectives from NEPTUNE Canada, *IEEE Journal of Oceanic Engineering*, v. 28. no. 1, p. 144-157.

Bernard, E.N. and Robinson, A.R. 2009. Introduction: emergent findings and new directions in tsunami science. In: Bernard, E.N. and Robinson, A.R. (eds.) Tsunamis. The Sea, v. 15, p. 1-22. Harvard University Press, Cambridge MA and London, England.

Broecker, W.S. 2005. The ocean's role in climate: yesterday, today and tomorrow. Eldigio Press, New York.

Broecker, W.S. 2010. The great ocean conveyor belt: discovering the trigger for abrupt climate change. Princeton University Press, Princeton, NJ and Oxford, England.

Favali, P., Person, R., Barnes, C.R., Kaneda, Y., Delaney, J.R. and Hsu, S-K. 2010. Seafloor observatory science. In Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.28.

National Academy of Science, 2010. Tsunami warning and preparedness. Report of the Committee on Review of the Tsunami Warning and Forecast System and Overview of the Nation's Tsunami Preparedness, J. Orcutt, Chair, 4p.

Purkey, S.G. and Johnson, G.C. 2012. Global contraction of Antarctic Bottom Water between the 1980s and 2000s. Journal of Climate, 25, 5830-5844: 120315135854004 DOI: 10.1175/JCLI-D-11-00612.1

Richardson, K. et al. (11 authors). 2009. Climate Change: Global Risks, Challenges & Decisions.. Synthesis Report of the United Nations Framework Convention on Climate Change (UNFCCC) meeting, Copenhagen, 10-12 March 2009. www.climatecongress.ku.dk

Richardson, P.L. 2008. On the history of meridional overturning circulation schematic diagrams. Progress in Oceanography, v. 76, p. 466-486.

Rintoul, S. & Co-Authors (2010). "Deep Circulation and Meridional Overturning: Recent Progress and a Strategy for Sustained Observations" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 1), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09, 32p.

Stouffer et al. (23 authors). 2006. Investigating the causes of the responses of the thermohaline circulation to past and future climate changes. Journal of Climate, v. 19, p. 1365-1387.

Whitmore, P.M. 2009. Tsunami warning systems. In: Bernard, E.N. and Robinson, A.R. (eds.) Tsunamis. The Sea, v. 15, p. 401-442. Harvard University Press, Cambridge MA and London, England.

Wijffels, S. & Co-Authors (2010). "Progress and Challenges in Monitoring Ocean Temperature and Heat Content" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 1), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.pp.40

You. Y. 2010. Harnessing telecoms cables for science. Nature, v. 466, p. 690-691.