Investigating Extreme Marine Environments through the NEPTUNE Canada Cabled Ocean Observatory

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Summary

A range of extreme and dynamic marine environments, from the coast, to continental slope, to abyssal plain, to oceanic spreading ridge, are being examined through the world's first regional cabled observatory. This NEPTUNE Canada (NC) observatory has an 800km backbone cable loop off the west coast of Vancouver Island that links five nodes with several hundred sensors and instruments. The abundant power and high bandwidth Internet connectivity through a Port Alberni shore station and a University of Victoria data and control centre facilitate real time multidisciplinary experiments and collaborations with a data flow of 60TB/yr. The newly constructed NC, VENUS and MARS observatories are leading others being planned in the US, Japan, Taiwan, China, and several in the European Union that together represent a new era of wiring the oceans and quantitatively studying and generating long decadal time series for most of the extreme environments in the marine realm.

Introduction

The marine realm includes many diverse extreme environments that have posed severe challenges to adequately investigate them and understand the various processes. A new generation of observatories – cabled ocean observatories – are just being planned or installed (e.g. in Canada, US, Japan, China, Taiwan, and in the European Union). Typically, a backbone cable network adopts sophisticated telecommunications cable technology combined with complex new technologies for power transmission and communications. This system delivers abundant power (up to 10kV DC) and high bandwidth communication (10Gbsec) to support a network of scientific instruments, sensors, and robotics. The network can generate continuous time series of data over the typical design life of 25 or more years of the observatories. These systems transform the ocean sciences through the volume of real time data delivered on a 24/7/365/25 basis, by building a vast repository of data, by allowing real time multidisciplinary studies, and by enabling worldwide scientific collaborations. This innovation heralds a new era of wiring the oceans. This paper focuses on the development of NC as the world's first regional cabled ocean observatory and briefly illustrates the novel approaches and technologies applied to investigate the complex processes in a variety of extreme environments, from coast to deep sea.

NEPTUNE Canada cabled ocean observatory: investigating extreme environments with novel technologies

NEPTUNE Canada (NC), installed in 2009, is the world's largest cable-linked ocean observatory. It will expand the boundaries of ocean exploration and provide a new way of studying and understanding our planet. The observatory has a design life of at least 25 years and consists of an 800 km ring of powered fibre optic cable on the seabed in the north-east Pacific from the coast and across the northern part of the Juan de Fuca tectonic plate, a 200,000 sq km region off the coasts of British Columbia, Washington and Oregon (Figure 1). Funding to date to NC has been approximately $100M for the subsea infrastructure (including $20M in-kind) and $40M for operating funds that covers the project through to 2012. The US component to install a cabled observatory on the southern part of the plate and adjacent coastal regions was funded by NSF as part of the Ocean Observatories Initiative in September 2009 ($376M/5 years).

The NC cable network consists of six "laboratories", or experimental environments: mid-ocean ridge (Endeavour and the partly installed Middle Valley), central abyssal plain (ODP 1027), mid-continental slope (ODP 889), upper continental slope and submarine canyon (Barkley Canyon) and inner continental shelf (Folger Passage) (Figure 1). Instrumentation at all but the Endeavour site was installed in 2009; the instrumentation at Endeavour will be deployed in mid 2010. Additional funding is being sought for an instrumented node at Middle Valley, Juan de Fuca Ridge. From these locations, land-based scientists control and monitor instruments, video cameras and remotely operated vehicles as they collect data from the ocean surface to within the seafloor. Instruments are interactive—scientists can instruct them to respond to events such as storms, plankton blooms, fish migrations, earthquakes, tsunamis, and underwater volcanic eruptions, as they happen. Information is available to researchers, educators, students, policy makers and the public via the Internet; new work flow tools have been developed by the Data Management and Archive System group through an Oceans 2.0 Web Services framework.

Through NC, scientists can observe and interact with the complex earth and ocean processes that occur on, above and below the seafloor. The five major research themes of NC are:

- ocean climate change and its effects on marine life at all depths
- diversity of deep sea ecosystems
- engineering and computational research
- structure and seismic behaviour of the ocean crust
- seabed chemistry and geology

NC's unprecedented access to a spectrum of coastal to deep sea environments will increase our understanding of the oceans through study of continuous time series of a wide variety of phenomena. This new knowledge will address many global problems and opportunities, such as tsunami measurements and warnings, better location and characterization of earthquakes, improved understanding of marine food chains, better models for climate and ocean change including ocean acidification and regional nutrient fluxes, and potential new energy sources. Many of these processes occur in or affect extreme marine environments in the Northeast Pacific, with examples briefly outlined below.

The coastal Folger Passage node site will have instruments at 100m and 17m, the latter being on a pinnacle that has a rich biota in a high energy surf environment. Instruments include an arc of 8 cameras to monitor biotic changes with variable diurnal, tidal and storm conditions that will record environment/biotic interrelationships through time.

At Barkley Canyon and ODP 889 node sites on the continental slope, one important feature being examined are the gas hydrates that outcrop in the canyon wall (Barkley Canyon) and occur regionally in the shallow subsurface (ODP 889). The methane hydrates appear to occur in a dynamic environment in which methane is streamed off periodically in bubble curtains, possibly tied to forcing by tidal, earthquake, major storm and tsunami processes. This environment fosters chemosynthetic biotas (clams, microbial mats) and instrumentation needs titanium housings to reduce corrosion. At Barkley Canyon, NC is deploying a crawler (about the size of an all-terrain vehicle) designed by researchers at Jacobs University, Bremen, hosting a camera, methane sensor, temperature sensor, among others (Figure 2). At ODP 889, a research team at the University of Toronto has designed a Controlled Source Electro Magnetic (CSEM) sonar, in cooperation with Shell Oil, which with a sensitive gravimeter will determine the controlling factors, scale and flux of methane release over time. The physical, chemical and biological properties of the shelfbreak water column in this area are being measured by a 400m vertical profiler system (VPS) that has 10 instruments within a float that descends over two hours, repeatedly, from the surface to the sea floor.

The deepest node site is ODP 1027 in 2660 water depth. This extreme environment encompasses the flat abyssal plain with the top of sea mounts emerging out of the sedimented ocean crust. Recent work has shown that the fractured ocean crust provides an extensive subsea aquifer where fluids are forced regionally by volcanic and tectonic/earthquake events at the ocean spreading ridge over 100km to the west. The subsurface environments can now be monitored in real time through connecting the downhole ODP instrumentation to the NC observatory. Also connected are three 12 km radiating secondary cables terminating at sensitive bottom pressure recorders that establish an array to determine the speed, direction and height of tsunamis and major storms.

The extreme environments at the ocean spreading Endeavour segment of the Juan de Fuca Ridge will be studied at the Mothra and Main Endeavour vent fields with four adjacent instrumented vertical moorings about 250m high monitoring physical and chemical fluxes in this region of active volcanic venting. Black smoker faunas characterize these environments (Figure 3) and their development and variability will be examined with new technologies including real time microbial incubators, scanning sonars, cameras, and the Tempo-Mini instrument platform designed at Ifremer, France, which includes temperature, oxygen and iron sensors and a video camera (Figure 4).

The NC observatory is one of Canada’s Major Science Initiatives and has brought together scores of researchers and technologists from the academic, government and industry sectors in a venture that will transform the ocean sciences. It represents a huge national investment in the ocean sciences and NC is also a participant in the complementary Ocean Tracking Network led by Dalhousie University.

Acknowledgements

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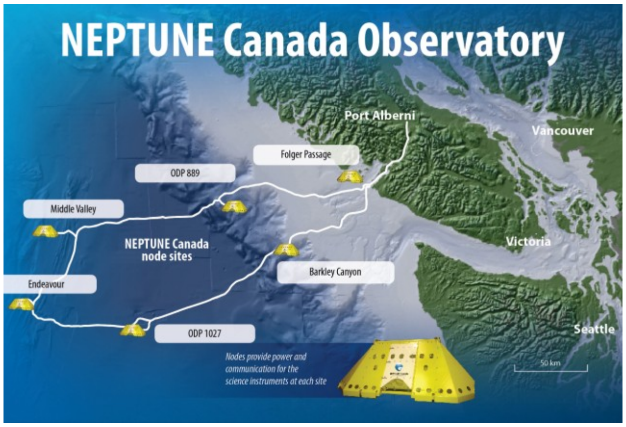

Figure 1: Map of the NEPTUNE Canada cabled ocean observatory

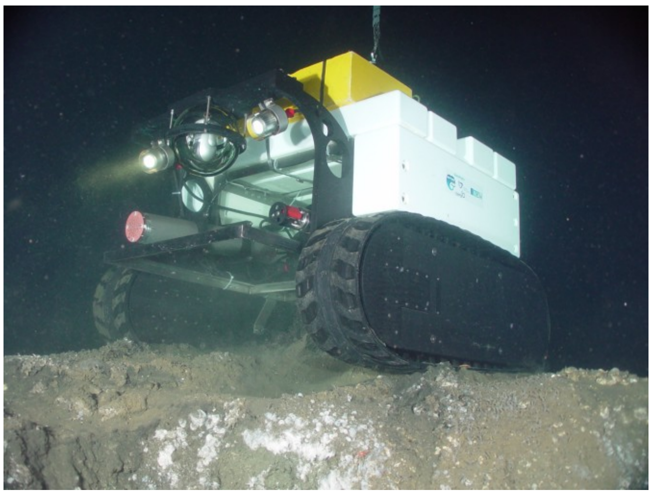

Figure 2: Crawler (Jacobs University, Germany) being deployed at Barkley Canyon gas hydrates

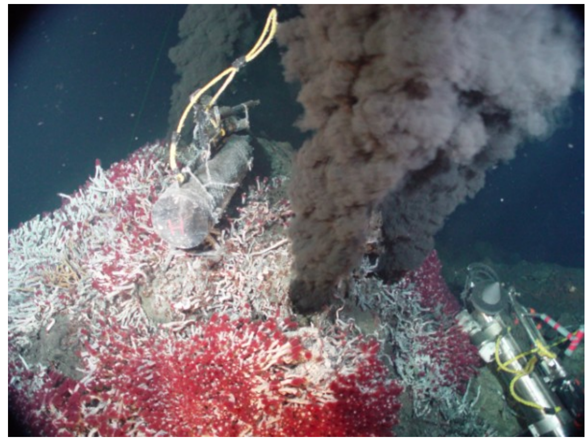

Figure 3: Hot fluids vent from the seafloor in volcanically active Endeavour Ridge. Photo taken from ROPOS by University of Washington researchers.

Figure 4: Tempo-Mini (Ifremer, France) being tested for deployment at the Endeavour ocean spreading ridge