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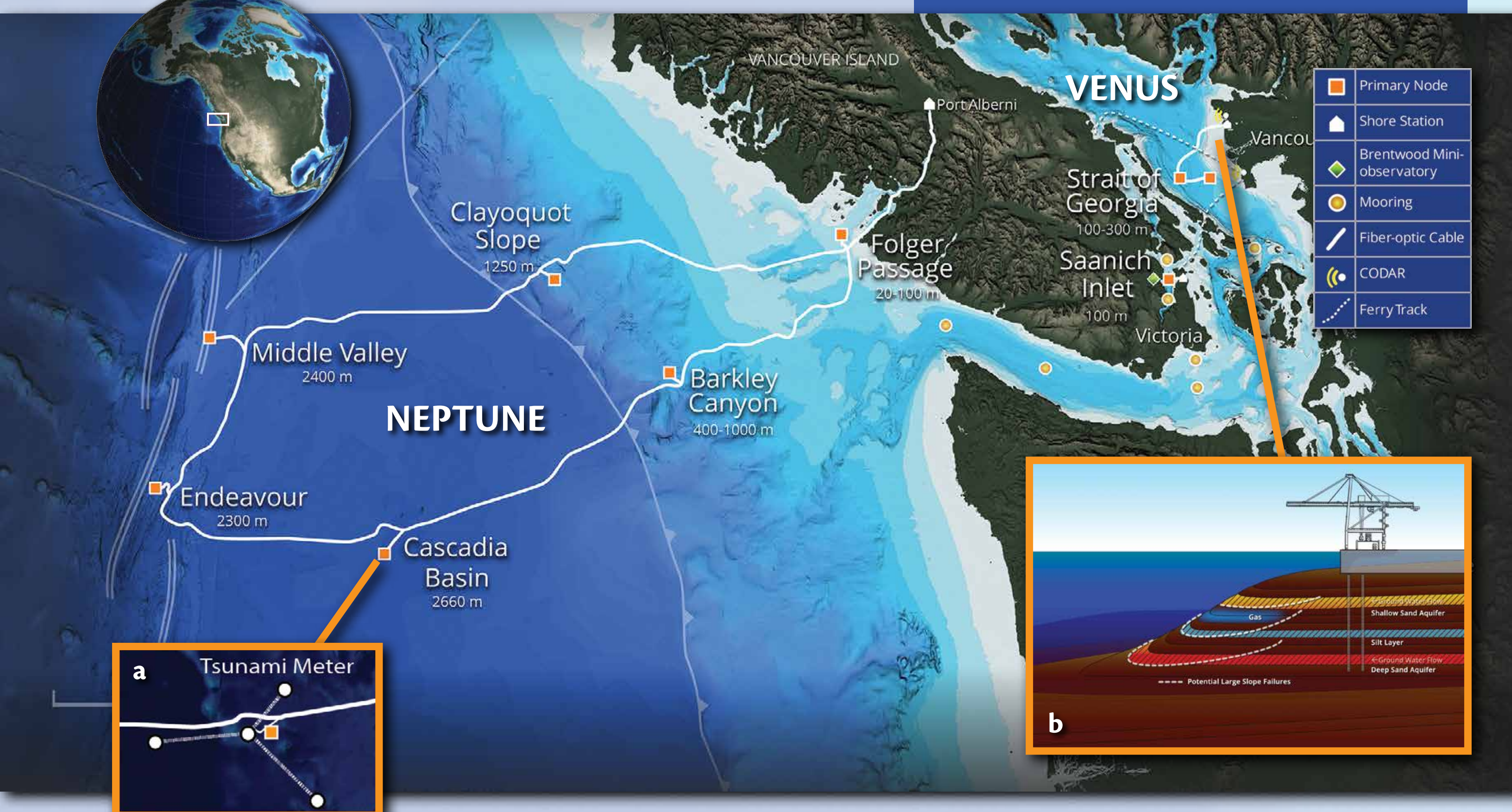
Ocean Networks Canada

From Geohazards Research Laboratories to Smart Ocean Systems

BY MARTIN HEESEMANN, TANIA L. INSUA, MARTIN SCHERWATH, S. KIM JUNIPER, AND KATE MORAN

Ocean Networks Canada (ONC; http://www.oceannetworks.ca) operates the NEPTUNE and VENUS cabled ocean observatories off the western coast of Canada (Figure 1) and an increasing number of miniature ocean observatories, such as in the Canadian Arctic. These observatories collect data on physical, chemical, biological, and geological properties of the ocean and seafloor over long time periods, supporting research on complex Earth processes in ways not previously possible (Taylor, 2009; Barnes et al., 2012, 2013). All recorded data are permanently archived and publicly available in real time through ONC's Oceans 2.0 data portal. Much of the data collected by ONC is related to marine geohazards, such as earthquakes, tsunamis, submarine landslides, waves, and gas hydrate stability. These real-time data are used by early warning centers and could be made available to decision makers through Smart Ocean Systems (http://www.oceannetworks.ca/technology-services/smart-ocean-systems).

Figure 1. Overview map showing the locations of Ocean Network Canada's NEPTUNE and VENUS cabled ocean observatories. Primary nodes that provide power and Internet to connected junction boxes and instruments are shown as orange squares. The NEPTUNE observatory covers the northern part of the Juan de Fuca Plate and of the Cascadia subduction zone, where the Juan de Fuca Plate subducts beneath the North American Plate. The insets highlight (a) the tsunami meter that is arranged around the Cascadia Basin node, and (b) the Delta Dynamics Laboratory at the mouth of the Fraser River. *Bathymetry Data Sources: Saanich Inlet and Strait of Georgia bathymetry from Canadian Hydrographic Service; USGS Cascadia DEM report 99-369; University of Washington (UW), School of Oceanography, R/V Thomas G. Thompson, multibeam cruise data (funding provided by KECK Foundation and UW). Plate Boundaries: Adapted from Dragert et al. Science, May 2001. Map Creation: Center for Environmental Visualization, UW School of Oceanography.*



NEPTUNE: AN EARTHQUAKES AND TSUNAMI RESEARCH LABORATORY

The NEPTUNE cabled observatory monitors the continental shelf and slope off the west coast of Vancouver Island as well as the complete northern part of the Juan de Fuca Plate. Its cable loop is more than 800 km long and covers the coastal zone, the northern part of the Cascadia subduction zone, Cascadia Basin, and the Endeavour Segment of the Juan de Fuca Ridge (Figure 1).

Currently, seismometers installed at each of the NEPTUNE nodes (except for the shallow Folger node) are recording relatively little seismic activity on the northern Cascadia subduction zone (Figure 1), consistent with a fully locked seismogenic zone (Scherwath et al., 2011). However, geological evidence suggests a 25–40% probability of a magnitude 8 or greater megathrust earthquake occurring along the Cascadia subduction zone in the next 50 years (Goldfinger et al., 2012). Sedimentary records of episodic coastal subsidence and offshore turbidites confirm that the interface between the Juan de Fuca and North American Plates has produced numerous great megathrust earthquakes and tsunamis, with an average recurrence interval of about 500 years (Goldfinger, 2011). The most recent great earthquake, with an estimated magnitude of about 9.0, occurred in 1700 and caused widespread tsunami damage in Japan (Atwater et al., 2005).

Most of the tsunamis that arrive along the west coast of North America originate from distant sources around the Pacific (Clague et al., 2003). Over the last 100 years, about 500 major tsunamis have occurred in the Pacific Ocean, killing tens of thousands of people (Lockridge, 1988; Clague et al., 2003), and the probability of a potentially damaging tsunami (runup ≥ 1.5 m) for the Canadian outer Pacific coastline is ~ 40–80% in 50 years (Leonard et al., 2014). To monitor these tsunamis, the NEPTUNE observatory also includes high-precision bottom pressure recorders at each of its nodes and a tsunami meter consisting of three additional bottom pressure recorders arranged on an ~ 20 km radius circle around the flat Cascadia basin site (Figure 1). On September 30, 2009, just days after the first instruments were installed, the first tsunami waves of 2.5 to 6 cm amplitude associated with the transoceanic tsunami generated by the M_W 8.1 Samoa earthquake in the South Pacific were recorded by six instruments (Thomson et al., 2011). The Samoan tsunami was followed by several other events recorded by the network, including the 2010 Chilean tsunami, the 2011 Tōhoku-Oki earthquake and tsunami (Figure 2), and the 2012 Haida Gwaii tsunami (Fine et al., 2013; Rabinovich et al., 2013a, 2013b; Leonard and Bednarski, 2014). These open ocean observations were uncontaminated by complex bathymetry or coastal reflections, demonstrating that NEPTUNE

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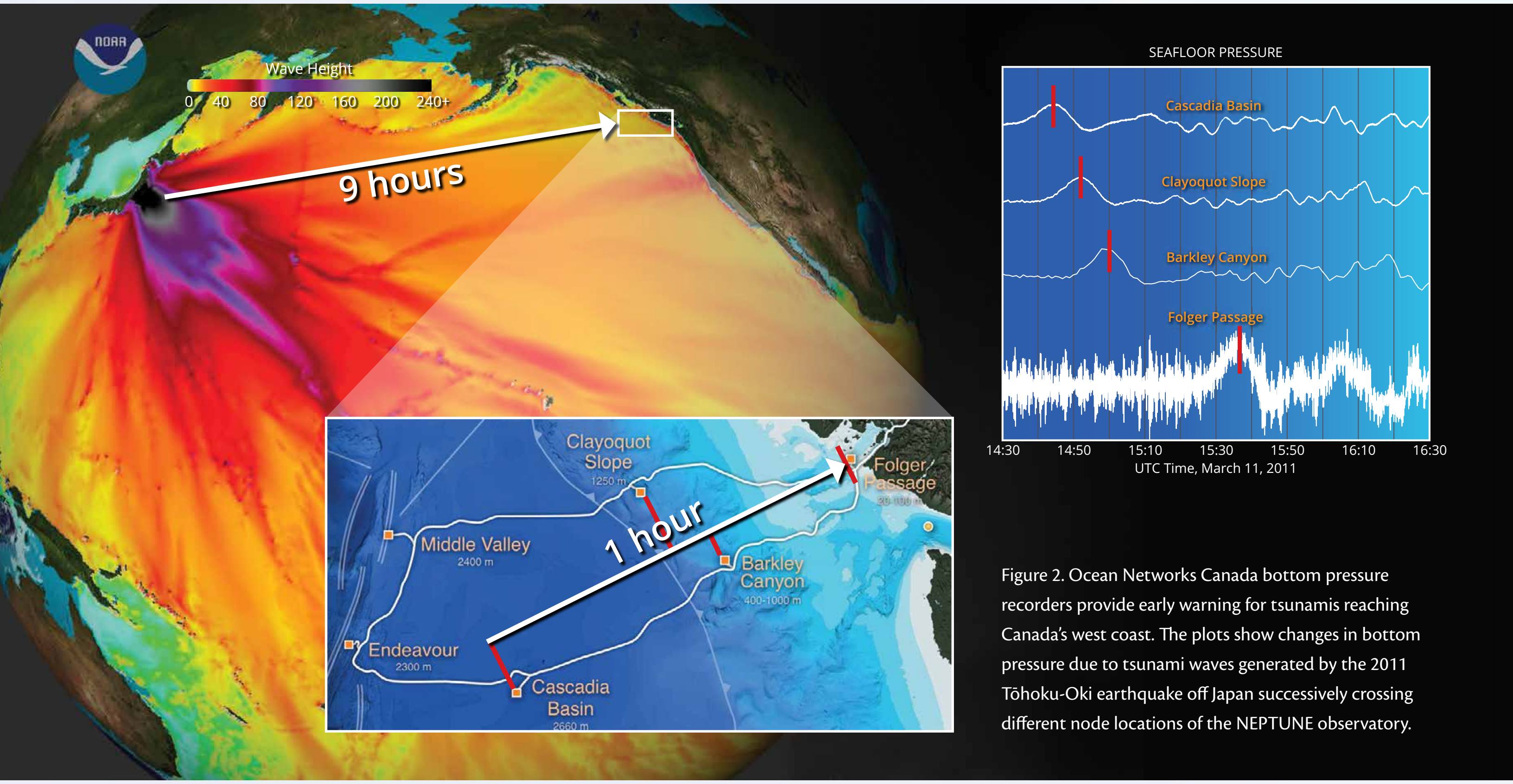

Figure 2. Ocean Networks Canada bottom pressure recorders provide early warning for tsunamis reaching Canada's west coast. The plots show changes in bottom pressure due to tsunami waves generated by the 2011 Tōhoku-Oki earthquake off Japan successively crossing different node locations of the NEPTUNE observatory.

records from future tsunami events can be effectively used as real-time input to regional numerical tsunami forecast models. In fact, real-time data from NEPTUNE seismometers and bottom pressure recorders already feed into the tsunami early warning systems operated by the National Oceanic and Atmospheric Administration (NOAA) Pacific and West Coast and Alaska Tsunami Warning Centers.

VENUS: AN UNDERWATER LANDSLIDE RESEARCH LABORATORY

An important purpose of the VENUS cabled observatory is monitoring the Fraser River delta's main channel off of Vancouver, BC (Figure 1). With a peak discharge of nearly 10,000 cubic meters of silt-laden water per second in May and June, sediments rapidly accumulate in the Fraser River delta, often resulting in unstable slopes that can fail catastrophically as underwater landslides. Because the delta is located near important coastal infrastructure including the Vancouver Airport, the deep-sea Deltaport container terminal, and the Tsawwassen ferry terminal, it is critical to gain a proper understanding of this dynamic coastal region.

One type of instrument currently deployed on the VENUS Observatory to monitor slope stability—known as a Seismic Liquefaction In Situ Penetrometer—uses piezometers (to measure pressure in the water column and seabed), accelerometers (to measure seismic activity), and inclinometers (to measure sediment movement through strain) to gather data on the conditions associated with slope failure. Another instrument package, the Delta Dynamics Laboratory, provides additional environmental information concerning water properties, turbidity, and currents for the slope stability studies. Additionally, hydrophones are installed to listen for undersea landslides and earthquakes (Lintern and Hill, 2010).

SMART OCEAN SYSTEMS

Ocean Networks Canada actively pursues opportunities to make sure that its extensive research observatories provide socio-economic benefits. For instance, the new Smart Oceans BC program (http://www.oceannetworks.ca/about-smart-oceans-bc) aims to provide online and real-time management portals to industry, government, First Nations, and local stakeholders for preventing accidents, responding to situations as they arise, forecast and warning of natural hazards, and supporting overall marine operational situational awareness.

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