A Decade of High-resolution Ocean Bottom Pressure Measurements in the Northeast Pacific — The NEPTUNE Observatory Turns 10 years old

Martin Heesemann[1], Joseph Farrugia[1], Earl Davis[2], Richard Thomson[3], Steven Mihaly[4], Alexander Rabinovich[5], and Isaac Fine[6]

[1]Ocean Networks Canada
[2]Geological Survey of Canada, Pacific Geoscience Centre
[3]Inst Ocean Sciences
[4]University of Victoria
[5]Instituto de Estudos do Mar Almirante Paulo Moreira
[6]Institute of Ocean Sciences

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Abstract

Ocean Networks Canada (ONC; http://www.oceannetworks.ca/) operates the multidisciplinary NEPTUNE and VENUS cabled ocean observatories off the west coast of Canada and an increasing number of miniature ocean observatories, such as in the Canadian Arctic. All data collected by these observatories are permanently archived and publicly available through ONC's Oceans 2.0 data portal. Much of the data are related to marine geohazards, such as earthquakes, submarine landslides and tsunamis and are delivered in real-time, including to early warning centers. The NEPTUNE cabled observatory consists of an approximately 800-km long cable loop deployed off the west coast of Vancouver Island that covers the coastal zone, the northern part of the Cascadia subduction zone, Cascadia Basin and the Endeavour Segment of the Juan de Fuca Ridge. The observatory includes several high-precision bottom pressure recorders (BPRs) at each of its five active nodes. On September 30, 2009, just days after the first instruments were installed, six BPRs on the array recorded tsunami waves of 2.5 to 6 cm amplitude originating with the Mw 8.1 Samoa earthquake. The Samoan tsunami was followed by several other events recorded by the network, including those of the 2010 Chilean tsunami, the 2011 Tōhoku-Oki tsunami, and the 2012 Haida Gwaii tsunami. We will review the decade of open-access bottom pressure recorder data, instrument development, and research findings across many disciplines and give an outlook for future developments.

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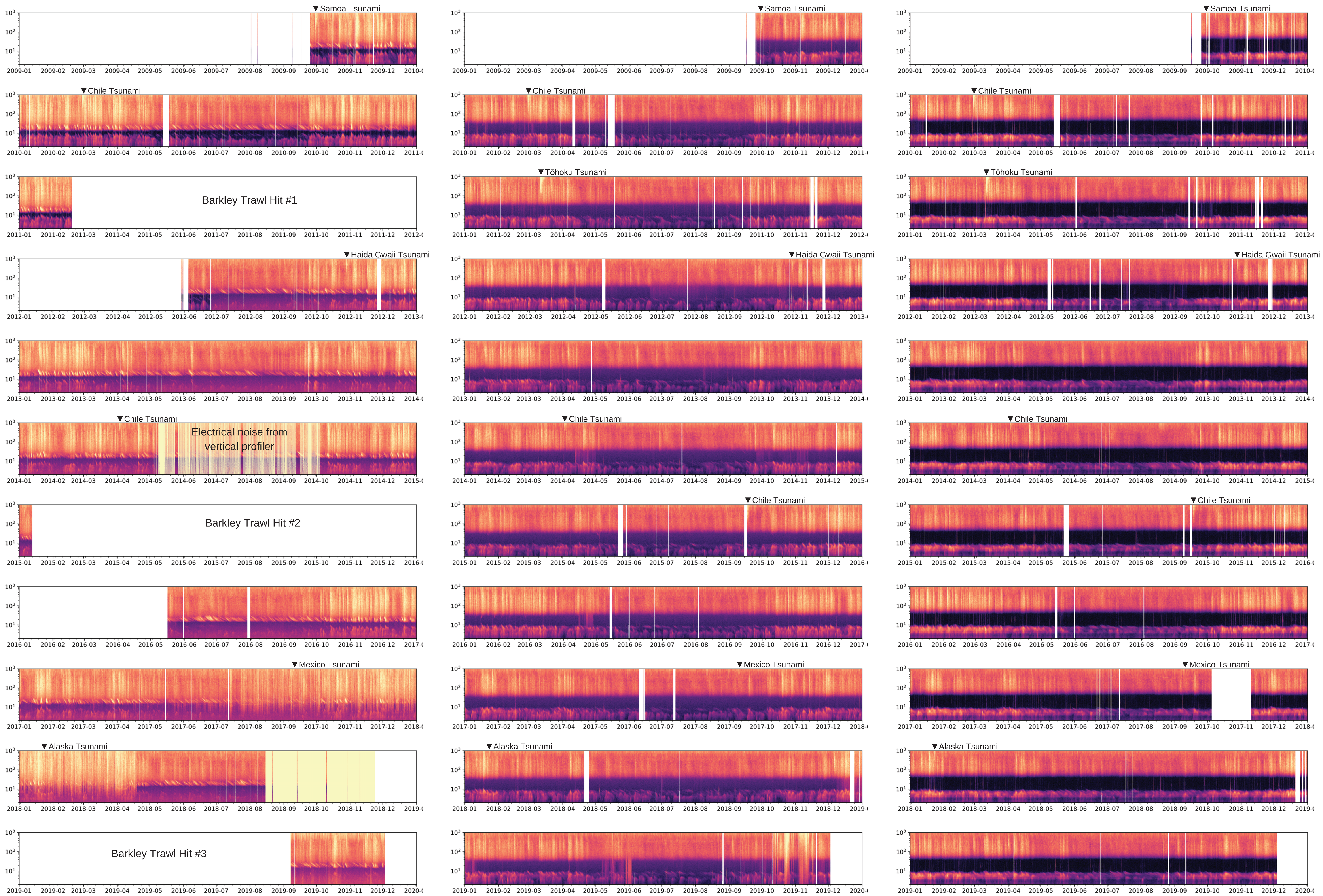
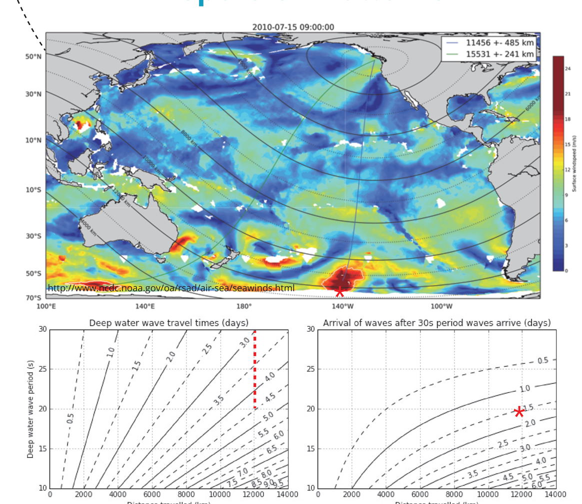
[1]Ocean Networks Canada, University of Victoria, Victoria, BC, Canada | [2]Pacific Geoscience Center, Sidney, BC, Canada | [3]Institute of Ocean Sciences, Sidney, BC, Canada

OCEAN NETWORKS CANADA

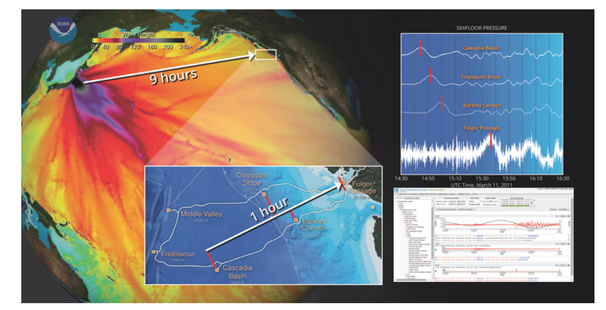


Dispersion Patterns



Swells (deep water waves) are dispersive. Longer period waves travel faster than shorter period waves. By comparing the difference of arrival between different period waves we can estimate the distance the swells travelled since they were generated. In the summer months, most swell originate from the southern hemisphere; a common time difference of about 1.5 days between 30s and 20s swells indicates that the waves travelled for about 12,000 km.

Earthquakes and Tsunamis



On September 30, 2009, just days after the first NEPTUNE instruments were installed, the first tsunami waves of 2.5-6.0 cm amplitude generated by the Mw 8.1 Samoa earthquake were recorded by six BPRs. More tsunamis we recorded in the following years as indicated in the spectrograms to the right. The figure above shows the 2011 Tōhoku-Oki earthquake and tsunami recorded be the ONC infrastructure.

Bottom Pressure Recorders

The Bottom Pressure Recorders (BPR) deployed on the observatory consist of DigiQuartz pressure sensors built by Paroscientific Inc. and low-power , high-precision frequency counters developed for the Pacific Geoscience Centre. They provide observations of nano-resolution pressure variations which correspond to millimeter scale surface height variations in several kilometers of water. RBR Ltd. took on the challenge to develop an off-the-shelf instrument based on the same technology (http://www.rbr-global.com/products/bpr).

Overview

The high-precision Bottom Pressure Recorders (BPRs) deployed on the Ocean Networks Canada NEPTUNE Observatory are capable of detecting a wide range of phenomena related to sea-level variations and hydro-acoustic waves.

Detected signals include Tides, storm surges,

- Tsunamis and Earthquakes,
- Infragravity Waves, Swells and Microseisms

As observed in the example from the BPR at Barkley Upper Slope shown above

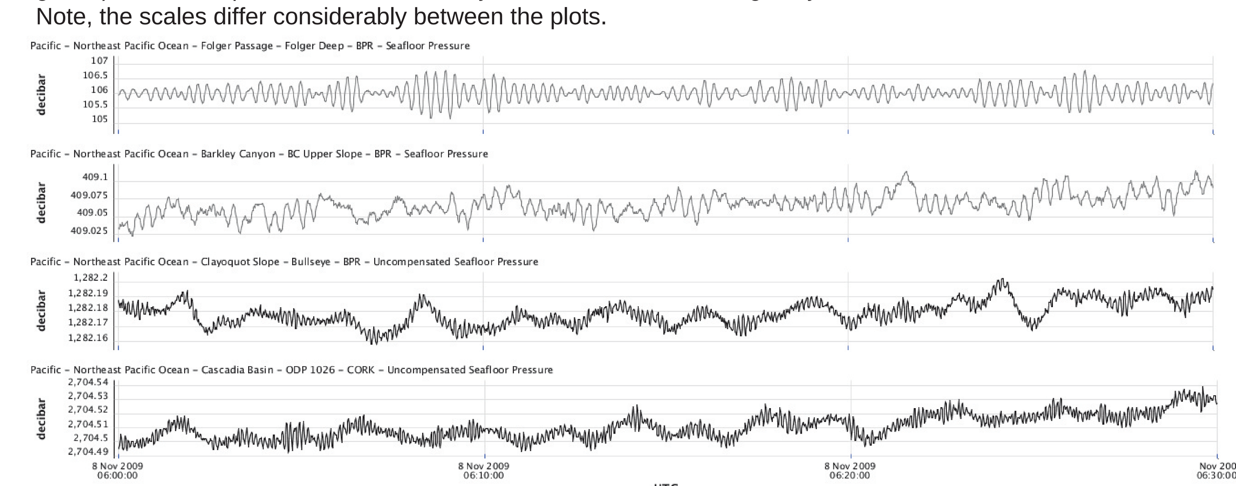
- infragravity waves (>30 s periods),
- swells (14-30 s periods),
- double frequency microseisms (2-10s), and
- earthquakes (stripes visible in the low energy band from ~8-14 s)

get recorded at about 400m water depth.

Dispersion Pattern from swells generated in the southern hemisphere are prominent during summer month in the swell and microseism band. Higher frequency microseisms in the range between 2-7 s period, indicative of regionally generated wind waves, are used to define a Microseism Based Upwelling Index.

Infragravity Waves, Swells, and Microseisms

Apart from tides, different pressure signals dominate the data depending on the water depth. The plots below show that Folger Deep (100 m) is dominated by swells. Infragravity waves and microseisms (at double the swell frequency) become noticeable in the unprocessed data at Barkley upper slope @400 m (see also spectrograms). At the deeper sites, swells are fully attenuated and the infragravity waves and microseisms dominate. Note, the scales differ considerably between the plots.



Microseism Based Upwelling Index

The biological productivity of coastal upwelling regions undergoes marked interannual variability as marine ecosystems respond to changes in the prevailing winds. Determination of the principal metrics that define the upwelling cycle—the spring transition, when ocean conditions switch from downwelling- to upwelling-favorable, and the fall transition, when conditions return to downwelling-favorable—is essential for understanding changes in coastal productivity. Thomson et al. (2014) argue that upwelling in the northern California Current System may be delineated by changes in microseism activity.

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