ADDOS: Autonomous Deployed Deep-Ocean Seismic System

Communications Gateway for Ocean Observatories
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ABSTRACT
We describe an autonomously deployable, communications gateway designed to provide long-term and near real-time data from ocean observatories. The key features of this system are its ability to telemeter sensor data from the seafloor to shore without cables or moorings, and to be deployed without a ship, thereby greatly reducing life-cycle costs.

The free-floating surface communications gateway utilizes a Liquid Robotics wave glider comprising a surfboard-sized float towed by a tethered, submerged glider, which converts wave motion into thrust. For navigation, the wave glider is equipped with a small computer, a GPS receiver, a rudder, solar panels and batteries, and an Iridium satellite modem. Acoustic communications connect the subsea instruments and the surface gateway while communications between the gateway and land are provided by the Iridium satellite constellation.

The acoustic communications package is mounted in a shallow, towed “tender,” which utilizes a WHOI micro modem and a BenthoS low frequency, directional transducer. A matching modem and transducer will be located on the ocean bottom package. Tests of the surface gateway in 4350 m of water demonstrated an acoustic efficiency of approximately 396 bits/s. For example, it has the ability to send 4 channels of compressed, 1 sample per second data from the ocean bottom to the gateway with an average power draw of approximately 0.015 W and a latency of less than 3 minutes.

This gateway will be used first to send near real-time data from a broadband ocean bottom seismic observatory designed for a two year operational life. Such data from presently unobserved oceanic areas are critical for both national and international agencies in monitoring and characterizing earthquakes, tsunamis, and nuclear explosions.

We present initial results from an actual 2-week OBS deployment.

PROOF-OF-CONCEPT DEPLOYMENT OFF-SHORE LA JOLLA

RESULTS ON DATA TRANSMISSION

BEST RECORDS

Data Transmission Rate

Typical hydophone record with large “acoustic pulses” caused by modern transmission. Real-time monitoring of OBS transmission through acoustic pulses on DPG. More in-depth analysis through recovered hydophone data transmission every 32s (for a 512-byte block a filled) packet sent wirelessly. Analysis of complete records 19 - 25 May: duty cycle (time fraction the modem transmitted data) varied from 2.76 to 2.84%; at 12W power draw during transmission, this gives 6W/day.

SEISMIC DATA

• Due to failure of seismometer, we were unable to collect high-quality real-time data.
• Second test completed in July. Confirmed that transmission pulses insignificant on seismometer, at least for this environment.
• DPG is subject to ocean wave noise at shallow depths, not ideal for a seismic sensor.
• Nine teleseismic earthquakes with Mw>5.0 during deployment; two with Mw>7.0 discernible in raw data. A Mw>7.5 event in Okhotsk was not detected.
• A Mw=5.7 event in Northern California also discernible in raw telemetered data.
• 1 Hz data not suitable for detection and analysis of local earthquakes, so no local earthquake recorded in near-real time, but the recovered hydophone recorded 7 of 9 local event with Mm>3.0 reasonably well and between stations, wave gliders have very clear detection thresholds at ML=3.0 for a distance of 235 km and Mh=3.3 for a distance of 265 km.

CONCEPT

Ocean Surface Gateway

Ocean Bottom Package

Top: Two-part wave glider pulling payload in “tender”, e.g. acoustic modem. The WG can be deployed from a ship, or from shore, before it travels at typically 1.2 knots. The WG itself uses only renewable energy: Solar to transmit data, to control navigation and some payloads; wave energy for propulsion. The satellite link provides constant, near-real-time access to scientific data collection.

Bottom: Wave glider propulsion: A passing wave lifts the float and pulls the glider upward. Passive fins below are pushed downward. As the glider moves up, the fins generate thrust to pull the vehicle forward, both upward and downward motion produces thrust; a rudder at the tail of the glider steers the vehicle in any direction.

WG progress can be monitored by customers through LRI mission control (red are given way, green is wave glider track). The WG senses approaching vessels and sends alarms. LRI can verify the WG.

We experimented with three different octagon routes for data transmission with the least losses:
1. Radius 250 m led to many transmission dropouts due to receiver saturation.
2. Radius 1000 m also led to dropouts due to transducer directivity.
3. Radius 500 m was optimal and kept for the remainder of the deployment.

ADDOS communications system latency: OBS data were transmitted with a time stamp and end users at IGORP compared when these data were received. From this we determined the typical latency time of about 5 min.

Typical contributions are: OBS data logger: 62s; A/D filters for 1Hz: 34.52 s; WG modem: 3s; SBD channel: 55s; Iridium Gateway: 15s.

Raw records of the 24 May 2013 Mw=7.4 Fiji earthquake this is the first ever near-real time telemetered seismic record from the ocean.
Floor top: recovered hydophone middle: recovered DPG; bottom: telemetered DPG; a 34.5 s delay in the telemetered DPG was not corrected

Raw records of the 24 May 2013 Mw=8.3 Ssea of Okhotsk earthquake. Top: telemetered DPG; Middle: recovered DPG; Bottom: recovered hydophone; a 34.5 s delay in the telemetered DPG was not corrected

Raw records of the 24 May 2013 Mw=6.9 Greenville, Northern California earthquake. Top: recovered hydophone middle: recovered DPG; bottom: telemetered DPG; a 34.5 s delay in the telemetered DPG was not corrected

Raw records of the 16 May 2013 Mw=3.2 Rancho Palos Verdes earthquake. Top: recovered hydophone middle: recovered DPG; bottom: no telemetered data for this event, as we were still optimizing the WG route.