Workshop W4 on "*Networking ocean observatories around the North Pacific Ocean*"

by Ken Denman, Jack Barth, S. Kim Juniper, Jae Hak Lee and Hidekatsu Yamazaki

Around the North Pacific Ocean, various coastal ocean observatories are operating or under development. These observatories include cabled systems as well as integrated observing systems that employ buoys, Autonomous Underwater Vehicles (AUVs), gliders, moorings, satellite imagery, and other observing tools. In addition, there exist several long-term time-series programs, and the Argo drifter program. The primary objective of the Workshop (W4) on "*Networking ocean observatories around the North Pacific Ocean*" was to bring together operators of these observatories to discuss how to make progress on the following issues:

- Set up plans for coordinated data sharing, data standards, common sampling protocols, and open access on the Internet;
- Set out a timeline for developing an integrated (nearly) real-time synthesis of observations in the North Pacific by linking coastal and open ocean observatories as well as Argo;
- Define a specific science challenge/question that could be best addressed through a network of observing systems in the Pacific Ocean;
- Discuss the requirements for assimilating data from ocean observatories into multidisciplinary models.

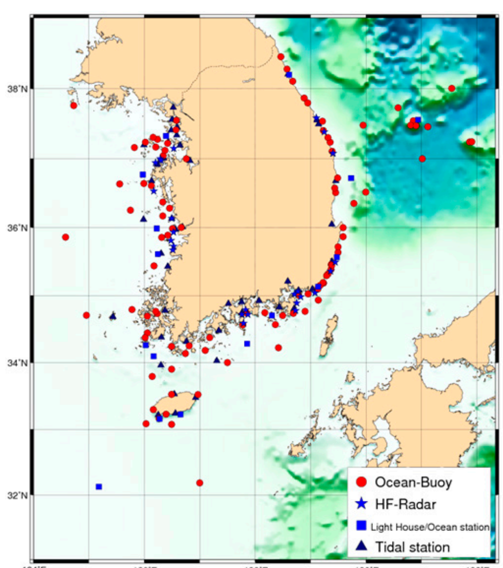
Most of these facilities are regional and coastal in scope, making PICES the ideal organization to host such a workshop. The need for a network of observing facilities was articulated in the conference description of the joint PICES/ICES Workshop on "*Global assessment of the implications of climate change on the spatial distribution of fish and fisheries*" that was held in May 2013 in St. Petersburg, Russia: "… observations and model projections (are) needed to develop a global synthesis of the implications of climate change on fish and fisheries".

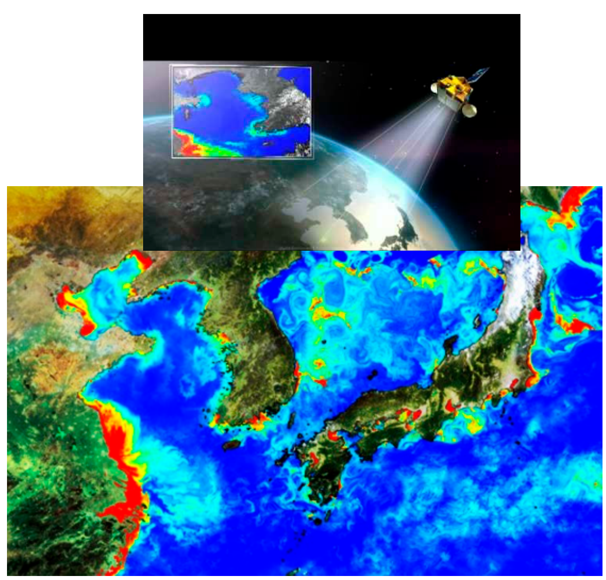
Between 15 and 20 people attended W4 (held October 17 at PICES-2014, Yeosu, Korea). Seven presentations were provided, followed by a discussion on common issues, the need for a group that would meet annually, and recommendations for how to form such a group. Ocean Networks Canada was a co-sponsor of the Workshop.

Short descriptions of presentations

The session consisted of one invited 30-minute address and six contributed 20-minute talks, summarized here in order of presentation.

Jae Hak Lee from the Korea Institute of Ocean Science and Technology (KIOST) described '*The status of ocean monitoring in Korea*'. He first reviewed Korean real time ocean monitoring activities stressing the coastal oceans and the integration of many different observing platforms, including a Geostationary Ocean Color Imager launched in 2010. Coverage is 8 times/day over an area 2500 km by 2500 km centered over Korea, with resolution of 500 m by 500 m. Contributing to international programs, Korea has launched 302 Argo floats since 2001 – in the East Sea/Sea of Japan, the Pacific Ocean, and the Southern Ocean – of which approximately 75 are still active. In the OceanSites program, Korea currently maintains three sites: one in the East Sea/Sea of Japan, and two sites in the equatorial western Pacific. Korea is experimenting with subsea and wave gliders.





(Left) Real time monitoring sites around the Korean peninsula, (right) KIOST's Geostationary Ocean Color Imager.

Jack Barth from Oregon State University, USA, presented a '*Ten-year retrospective of the Northwest Association of Networked Ocean Observing Systems (NANOOS)*' on behalf of Jan Newton (NANOOS Executive Director) and many other NANOOS colleagues. NANOOS is one of approximately 10 regional components of the U.S. Integrated Ocean Observing System (IOOS). The stakeholder priorities for NANOOS are maritime operations, ecosystem impacts (including hypoxia and HABs), fisheries, mitigating coastal hazards, and climate (including ocean acidification). Major observational systems include HF radar for mapping surface currents and waves, buoys in the Pacific Northwest, buoys and moorings in the Columbia River estuary and Puget Sound, long-term coastal glider programs, and monitoring beach and near-shore bathymetry. In order to meet the different data delivery needs of a variety of user groups, substantial effort has gone into development of the online NANOOS Visualization System (NVS), including the NVS Data Explorer.

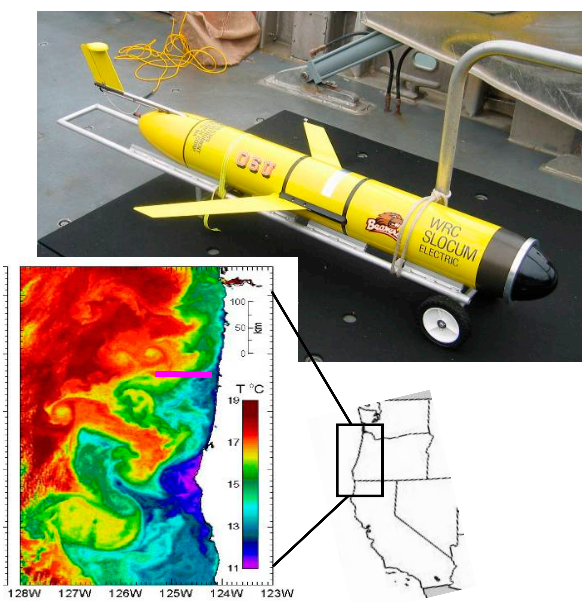
Mary Grossmann from the Okinawa Institute of Science and Technology, Japan, described the OIST Cabled Teleoperational Observatory Performing Undersea Surveillance (OCTOPUS), a new coastal observatory deployed since August 2013 at about 20 m depth on a coral reef in the nearshore zone off Okinawa. In addition to measuring standard oceanographic and biochemical variables, the focus is on biological imaging with several cameras, a passive hydrophone (for cetaceans and vessel traffic). Results were presented from the Continuous Plankton Imaging System (CPICS), a fixed station Visual Plankton Recorder, deployed in cooperation with Scott Gallager of Woods Hole Oceanographic Institution (WHOI; USA). Using five-minute temporal resolution, counts of six predatory plankton groups show day–night transitions, and hourly counts of 10 classes of plankton show strong presence–absence changes with the passage of two typhoons during October 2013.

Hidekatsu Yamazaki of the Tokyo University of Marine Science and Technology, Japan, described the Joint Environmental Data Integration (JEDI) System which employs novel observational and modeling technologies to evaluate multi-scale variations of pelagic marine communities and biodiversity under the influence of the Kuroshio and internal waves in coastal habitats. The JEDI System includes deployment of a cabled observatory and a moving AUV platform MEMO-pen. The cabled observatory, the Oshima Coastal Environmental data Acquisition Network System (OCEANS), was deployed from Oshima Island southwest of Tokyo Bay. Also conducted in cooperation with Scott Gallager of WHOI, OCEANS employs a full suite of physical, biological and chemical instrument systems operating from an underwater cabled node. The AUV has a specially-designed low vibration propulsion system with a pump jet system rather than a rotating propellor, which allows microstructure turbulence measurements and use of a plankton microscope camera (CPICS). Measurements are interpreted in the context of a high resolution numerical model of the area that shows spatial and temporal patterns of internal waves at tidal frequencies in the vicinity of Oshima Island.

Holger Brix (with Burkard Baschek) from the Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Germany, presented an invited talk on the multi-platform Coastal Observing System for Northern and Arctic Seas (COSYNA), mostly focused on the German Bight in the North Sea west of Hamburg. The mission of COSYNA is the development and testing of analysis systems, consisting of observations and numerical modelling, for the operational synoptic description of the environmental status of the North Sea and Arctic coastal waters. COSYNA aims to provide knowledge tools that will help authorities and other stakeholders manage routine tasks, emergency situations and evaluate trends. Types of observations include: i) point measurements, including buoys, fixed stations and underwater nodes, ii) surface transects on ferries with FerryBox systems, and on research vessels, iii) 3D transects with SCANFISH and gliders, and iv) mapping of spatial fields using optical remote sensing (satellite) and radar (HF and X-band). Several of these systems and example observations were presented in addition to examples of the comparison of regional model results and measurements. An end-to-end sensor to user(s) data flow chart was shown and the COSYNA Data Portal was described. Two applications were introduced – offshore 'windparks' and hunting gyres with 3D real time mapping. One outreach project of COSYNA is the Global Coast to link expertise from different coastal observatories around the globe.

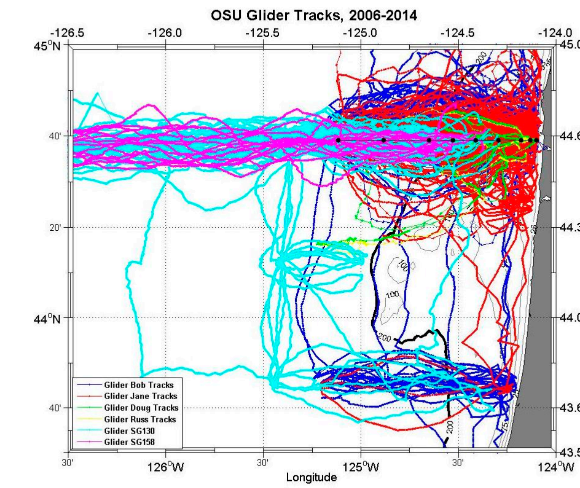
Kim Juniper, from Ocean Networks Canada (ONC) located at the University of Victoria, gave a talk on '*Cabled ocean observatories as tools for studying biodiversity change*'. He presented six Essential Biodiversity Variables (EBVs) developed by the Biodiversity Observation Network of the Group on Earth Observations (GEO BON): Genetic composition, species populations, species traits, community composition, ecosystem function, and ecosystem structure. Information on all of these variables except the first can now be obtained from cabled observatories. He presented several examples of EBV studies at ONC cabled sites around Vancouver Island and in the Canadian Arctic. Time-series video imagery coupled with oceanographic sensors are used to study temporal and spatial changes in benthic community composition and ecosystem processes in a variety of near-bottom environments: i) hydrothermal vent sulphide worms, ii) an epibenthic megafaunal community in a submarine canyon, iii) epibenthic community responses to severe hypoxia in a coastal inlet, iv) surface-sediment bioturbation rates over a fixed area, and v) seasonal faunal dynamics at a shallow coastal Arctic site. He concluded with two issues that require attention: First, the need for more efficient tools to extract biological data from imagery (ONC has a growing archive of over 10,000 hours of HD video imagery), which include computer algorithms for automated counting of fish and other animals, and 'citizen science' using a video game 'Digital Fishers' to 'pre-analyze' hundreds of video clips; second, the opportunity for collaboration between ocean observatories using EBVs as a tool for structuring biological observations between different research groups.

Jack Barth from Oregon State University, USA, gave a talk that described the use of autonomous underwater gliders to observe continental margins and ocean boundary currents. His results were from the California Current upwelling system, one of four major coastal upwelling systems that together comprise on 1% of the global ocean surface area but which provide more than 20% of wild caught seafood globally. During some summers over the Oregon shelf, hypoxia develops at depths below 30 m causing stress and mortality to sea life. To monitor changes in upwelling and hypoxia, AUV gliders equipped with a CTD and sensors for dissolved oxygen, chlorophyll and CDOM fluorescence, light backscatter and depth-averaged velocity have been traversing a cross-shelf section twice per week since April 2006. Through September 2014, there have been 3485 glider-days, and 260,190 vertical profiles covering a horizontal distance of over 82,000 km. The gliders have documented upwelling episodes, development of upwelling fronts, subsurface hypoxia and buoyant fresh water plumes from the Columbia River. Significantly, the gliders generate data even during severe storms that generate 10-m seas, when oceanographic research vessels, if present, would suspend *in situ* sampling. There are plans to add new sensors, including bioacoustics.



Autonomous Underwater Vehicle Glider, and cross-margin transect conducted twice per week since April 2006 off the coast of Oregon.

Gliders can be operated from just about any size boat, from (left) OSU's 16-m R/V Elakha, (right) from a rowboat off the Chilean coast.



OSU Glider operations from April 2006 to September 2014.

Discussion issues

During the discussion following the presentations, a number of common issues emerged, which include:

- Excepting dissolved oxygen, biochemical sensors continue to be unreliable for long-term deployment.
- For groups who make much of their data available online in 'near real time', there appear to be no common automated quality assurance, quality control techniques.
- Groups who make much of their data available online in 'nearly real time' need to develop effective methods for correcting/calibrating the data, after they have been posted initially, and for notifying users of these data corrections/updates.
- The usual manner in which data are presented on-line for researchers is completely inadequate for 'operational' users of the data – fisheries managers, environmental quality managers, controllers of safe marine traffic and transport, *etc*. How different groups attempt to adapt their data displays to their users' needs differs from group to group – again, sharing experiences can lead to development of common 'best practices'.
- There is a general sense that obtaining funding for developing and installing ocean observatories is easier than maintaining funding for operating the facilities,

partially because we have underestimated the human resources required for long-term operation and data management, *e.g.*, operating gliders continuously over many years, rather than for limited time 'missions'.

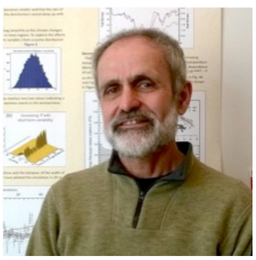
Recommendation and response

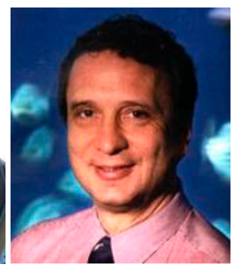
There was broad agreement that the 'operators' of coastal observing systems around the North Pacific would benefit from meeting on a regular basis and developing an evolving set of 'best practices' – basically sharing experiences on 'what works and what does not work', and working towards common data formats such as NetCDF file formats.

Our formal recommendation was to propose that the PICES Technical Committee on Monitoring (MONITOR) and Technical Committee on Date Exchange (TCODE) set up an Advisory Panel for 'Developing Best Practices and Common Data Protocols for Coastal Ocean Observing Systems' (AP-COOS). Such a structure would allow this AP to hold focused workshops at PICES on topics like those described earlier under 'Discussion issues'. Once this working format has been established, it may be advisable to make contact with similar entities within ICES and IOC.

The proposal was considered by the Science Board and submitted to Governing Council at the end of the PICES 2014 Annual Meeting. Council approved the establishment of an Advisory Panel on *North Pacific Coastal Ocean Observing Systems* (AP-NPCOOS), under the direction of MONITOR and TCODE. Initial Terms of Reference have been drawn up: the Advisory Panel will have Co-Chairs – one from the western North Pacific and one from the eastern North Pacific, with 2 to 4 members from each Contracting Party. The Terms of Reference include:

1. Develop and advise about best practices for coastal ocean observing systems;
2. Convene workshops/sessions to engage those involved in coastal ocean observing systems from around the North Pacific; and
3. Advise on linkages between coastal ocean observing systems and both PICES activities (*e.g.*, FUTURE Science Program, North Pacific Ecosystem Status Report) and open-ocean observatories (*e.g.*, Argo).





Dr. Kenneth Denman (denmank@uvic.ca) is Adjunct Professor in the School of Earth and Ocean Sciences at the University of Victoria. Most recently he was Chief Scientist with Ocean Networks Canada. Until 2010 he was Senior Scientist with Fisheries and Oceans Canada (DFO), seconded since 2000 to Environment Canada's Canadian Centre for Climate Modelling and Analysis (CCCMA). Dr. Denman's research interests include current and future impacts of climate change, including ocean acidification, on marine ecosystems and fish populations. He was a Coordinating Lead Author of the Second and Fourth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC).

Dr. Jack Barth (barth@coas.oregonstate.edu) is a Professor of Oceanography and Associate Dean for Research in the College of Earth, Ocean, and Atmospheric Sciences (CEOAS) at Oregon State University. His research seeks to understand the spatially and temporally variable ocean circulation, water mass structure and ecosystem response in coastal waters including a focus on low-oxygen zones off Oregon. Within PICES, Dr. Barth is a member of the Technical Committee on Monitoring (MONITOR).

Dr. S. Kim Juniper (kjuniper@uvic.ca) is Chief Scientist for Ocean Networks Canada. He has been a Professor in the School of Earth and Ocean Sciences and the Department of Biology at the University of Victoria, and holder of the British Columbia Leadership Chair in Ocean Ecosystems and Global Change since 2006. He came to the University of Victoria from the Université du Québec à Montréal where he was Professor of Biology and Director of the GEOTOP Research Centre. He received his BSc from the University of Alberta (1976) and a PhD from Canterbury University in Christchurch, New Zealand (1982). The primary focus of his research is the biogeochemistry and ecology of submarine hydrothermal systems.

Dr. Jae Hak Lee (jhlee@kiost.ac) has been working at the Korea Institute of Ocean Science and Technology (KIOST) as a Research Scientist since 1992. He received his BSc and MSc from the Seoul National University (1978, 1982) and a PhD from Yale University (1991). The primary field of his research is observational physical oceanography. Within PICES, he is a member of the Advisory Panel for a CREAMS/PICES Program in East Asian Marginal Seas.

Dr. Hidekatsu Yamazaki (hide@kaiyodai.ac.jp) is Professor in the Department of Ocean Sciences, Tokyo University of Marine Science and Technology. He received PhD in ocean engineering from Texas A&M University in 1984. He worked at the Department of Oceanography, Naval Postgraduate School (NPS) and switched his expertise from ocean engineering to oceanography. His interest in oceanic microstructures, particularly turbulence and plankton, started at NPS. He also worked at Chesapeake Bay Institute, Johns Hopkins University, and School of Earth and Ocean Sciences, University of Victoria, before he returned to Japan in 1993. His research spans from oceanic microstructures to fisheries ground environments as well as various biophysical coupling problems. As Associate Editor of Limnology and Oceanography: Fluids and Environments, he handles small-scale physical-biological interaction subjects and mixing problems.