

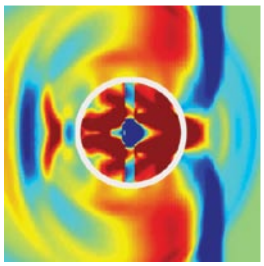




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A Smart Sensor Web for Ocean Observation

Ship surveys, autonomous floats, instrumented moorings, cabled sensor systems powered from shore, land-based radar, and orbiting satellites are some of the many assets deployed to observe and understand the ocean environment. NASA's goal is to establish an ocean observing system that uses satellites in an integrated web of sensors distributed from space to the Earth's subsurface. Knit together by a communications fabric, the sensor web is made 'smart' by combining autonomy with adaptive control and dynamic configurability.

Senior Engineers Payman Arabshahi and Warren Fox, Principal Oceanographer Bruce Howe, and colleagues at the UW Department of Electrical Engineering and the Jet Propulsion Laboratory are designing and deploying a first-of-its-kind sensor web with support from NASA's Earth Science and Technology Office – Advanced Information Systems Technology program. The system incorporates dynamic reconfiguration of sensor assets, adaptive sampling, and high-bandwidth, high-power observations. The Laboratory's horizontal and vertical integration of science and technology expertise is uniquely suited to the task. Satellite data analysis, signal processing, acoustical oceanography, and mechanical, software, and electrical engineering are all components of the sensor web.

One component of the network, a moored sensor system, is designed for use with a range of ocean observatories. It is connected to shore by an electro-optical cable for power and Ethernet communications. The mooring's three main parts work synergistically to sample the ocean with high temporal and vertical resolution: a subsurface float at a depth of 165 m is outfitted with sensors; an instrumented, motorized vertical profiler collects oceanographic data as it crawls up and down the mooring line between the float and the bottom; and a secondary fixed node on the seafloor is replete with sensors. During summer 2007 the cabled node system providing seafloor power and Ethernet communications and a short version of the subsurface mooring were installed in Puget Sound. Another test version will be deployed in 900 m of water in Monterey Bay in spring 2008.

Seagliders, autonomous undersea vehicles developed by the UW School of Oceanography and APL-UW, are robust and operate on modest power; they are capable of profiling in a local area or surveying across ocean basins. Seaglider's standard oceanographic sensors complement those on the mooring and the bottom fixed nodes, extending the web's horizontal range. While on the surface Seagliders obtain GPS fixes and use the Iridium satellite system to pass data to the pilots on shore and to receive mission commands. The vehicle's sensor payload now includes a passive hydrophone to record ambient noise and an acoustic modem developed by the Woods Hole Oceanographic Institution. With these sensors Seagliders can, for example, record nearby marine mammal vocalizations and transfer commands to an acoustic bottom array, as well as relay remote sensor status information and data to the shore via the cable system.

If Seagliders are to be used effectively in concert with other subsurface fixed and mobile sensors, a robust underwater acoustic communications network is needed. The difficulties are well known: overall bandwidth is limited due to acoustic absorption that increases with frequency, and typical shallow water regions where communications are desired have high degrees of spatial and temporal variability.

The Sonar Simulation Toolset (SST), developed by Senior Physicist Robert Goddard, allows assessment of a wide range of proposed undersea acoustic communication scenarios for the sensor web. Users specify an ocean environment in SST with a wide variety of parameters relevant to acoustic signal propagation and reception: sound speed profile, bathymetry, surface and bottom characteristics, ambient noise levels, and others. The user also specifies locations and trajectories of acoustic sources and receivers within that environment, and signals to be transmitted by the sources. SST then uses acoustic propagation models and time series simulation techniques to produce properly calibrated digital time series of the signals that would be 'heard' by the receivers. These received time series are used to test acoustic modem processing algorithms, or to estimate the communications capabilities between two modems as a function of the transmitter and receiver locations in a variety of environmental conditions.

In the envisioned sensor web system, satellites would be used to relay data gathered by sensors to scientist workstations, to download mission commands from shore or ship to the Seaglider, and to collect their own mission data to be assimilated with those from all other sensors into a regional ocean modeling system (ROMS). With a real-time view of the ocean state, the mobile sensor platforms can be redirected to adaptively sample ocean sub-volumes that have greater degrees of uncertainty, are rapidly changing, or

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have features of specific interest. In this way, satellite remote sensing data are validated and regularly calibrated against the in situ data to increase accuracy and value.

When deployed in Monterey Bay, the mooring system will be near whale feeding grounds in an area of periodic intense upwelling of nutrient-rich water. Here Seagliders might be directed in real time to specific locations to better track the whales, using their hydrophones to triangulate on vocalizations. The oceanographic and biological data collected by the mooring system and the Seagliders will expand understanding of the ocean conditions that give rise to this patch of intense ocean life.

The undersea sensor web system will also be able to conduct acoustic tomography experiments using the Seagliders as moving receivers of low-frequency signals. These acoustic travel time data will be assimilated in the ROMS model; in concert with other sensor data, such as shore-based high-frequency radar surface current measurements, the ROMS output may lead to better forecasts of all oceanographic variables. The bottom line is that a smart sensor web will maximize the science return on investment as sensors and their platforms are able to adjust their data collection parameters to optimize their own performance and return measurements requested by science users.

Team members: Payman Arabshahi, Warren Fox, Bruce Howe, and Timothy McGinnis

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