SECTION NEWS

HiSeasNet: Oceanographic Ships Join the Grid

OCEAN SCIENCES

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HiSeasNet, the communications network providing full-period Internet access for the U.S. academic ocean research fleet, is an enabling technology that is changing the way oceanography is done in the 21st century. With the installation in March 2006 of a system on the research vessel (R/V) *Seward Johnson* and the planned installation on the R/V *Marcus Langseth* later this year, all but two of the Universities National Oceanographic Laboratories System (UNOLS) fleet of large/global and intermediate/ocean vessels will be equipped with HiSeasNet capability.

HiSeasNet is a full-service Internet Protocol (IP) satellite network utilizing Cisco technology. In addition to the familiar IP services—such as e-mail, telnet, ssh, rlogin, Web traffic, and ftp—HiSeasNet can move real-time audio and video traffic across the satellite links. Phone systems onboard research ships can be connected to their home institutions' phone exchanges. Video teleconferencing with the current 96 kilobits per second circuits supports compressed video frame rates at about 10 frames per second, allowing for effective conversations and demonstrations with ship-to-shore video.

Typical uses include transmitting near-real-time data gathered on the ships to scientists and engineers on shore; providing basic communications—e-mail, voice, and video conferencing—between the research vessel's scientists, engineers, and crew; and providing valuable tools for real-time educational interactions between shipboard scientists and teachers and the classroom. Below are some examples of recent uses of the network.

- As part of the U.S. National Oceanic and Atmospheric Administration's Teacher at Sea Program, middle-school science teachers Debra Brice of San Marcos Middle School, San Diego, Calif., and Viviana Zamorano of Escuela America, Arica, Chile, took part in a three-week research cruise on the R/V *Roger Revelle*. While on board, Brice and Zamorano connected with their classrooms, hosted Web broadcasts, videoconferenced, maintained daily online logs, posted pictures of the shipboard operations, interviewed scientists, and answered students' e-mail messages (http://www.ogp.noaa.gov/ootas/).
- Because of changing schedules, a principal investigator was recently unable to sail on the R/V *Knorr* to direct a multibeam bathymetry, magnetic, and gravity survey. However, she was able to direct the cruise from shore because of the ability to stream large quantities of data from ship to shore. Over the three-week cruise, two gigabytes of multibeam data were telemetered to shore for analysis by the 'virtual' scientific team both in Woods Hole, Mass., and in Paris, France (see *Eos 86*(37) 2005).
- The Research Channel (a cable channel similar to C-SPAN but with the emphasis on research; see http://www.researchchannel.org/) broadcast a live high-definition television (HDTV) feed from a deep-sea, high-temperature venting system associated with an active underwater volcano off the Washington–British Columbia coastlines. Images from the seafloor robot JASON were transmitted to the R/V *Thompson* through an electro-optical tether. An onboard engineering-production crew delivered a live HD program using both shipboard and live subsea HD imagery. The program was transmitted via a modified HiSeasNet system to the University of Washington, Seattle. The resulting HD stream was mixed in real time with live two-way discussion and HD imagery from participating land-based researchers working in a studio with undergraduates, kindergarten through 12th grade students, and teachers.

HiSeasNet began in 2002 with a prototype system, installed on the R/V *Roger Revelle*, funded by the state of California and the Office of Naval Research. This system operated in the C-band (4-6 GHz) on the global beam of Inteldsat Pacific satellite. During 2003, a second ship, the R/V *Thomas Thompson*, was outfitted with a similar system and a hub teleport was established at University of California, San Diego on the roof of the San Diego Supercomputer Center (Figure 1).

Under a 2005 two-year grant from the U.S. National Science Foundation (NSF) to the Joint Oceanographic Institutions, Inc., and separate funding to the University of Miami, Fla., hub service has been expanded to cover the southeastern Pacific and Atlantic oceans, and eight more ships of the UNOLS feet have been equipped with HiSeasNet systems (Table 1). Ku-band (12–18 GHz) service was also introduced for the UNOLS ships operating primarily in the coastal waters of North America and the Caribbean. The Pacific and Atlantic subnets, which include all of the ships operating in those basins at a particular time, utilize 7.2-meter hub antennas to transmit data to satellite systems. For coverage of North American coastal and Caribbean waters, a 3.8-meter Ku-band hub antenna provides sufficient gain.

Fig. 1. One of the 7.2-meter HiSeasNet hub antennas being installed atop the San Diego Supercomputer Center (SDSC) building on the campus of the University of California, San Diego in La Jolla, Calif. The SDSC is the major regional node for the Internet.

Table 1. Timeline indicating when U.S. research vessels installed HiSeasNet and when ocean basin hubs were established

Milestone	Date
Roger Revelle	Jan 2002
Pacific hub at SDSC	Sep 2003
Thomas Thompson	Dec 2003
Melville	Dec 2003
Atlantis	Jan 2005
Atlantic hub at SDSC	Feb 2005
Kilo Moana	Mar 2005
Knorr	Mar 2005
Ku-band hub at SDSC	Apr 2005
Endeavor	Jun 2005
South Georgia Island IDA station	Oct 2005
New Horizon	Nov 2005
Seward Johnson	Mar 2006
Marcus Langseth	mid-2006

The ships' antenna systems are equipped with a three-axis, servo-controlled stabilization system that locks onto the satellite to a precision of better than 0.2 degrees under most conditions. For the large ships, which use C-band, the antenna is housed in a 3.7-meter-diameter dome. For intermediate ships, which use Ku-band, domes are two meters, and for the smaller regional ships (yet to be equipped), a new generation system is available housed in a dome of only 1.2 meters and weighing only about 100 kilograms.

To reduce the required satellite resources (and thus the recurring cost), HiSeasNet is configured with a shared shore-to-ship channel for each of the subnetworks. Local routers on each ship extract data packets addressed to them from the shared, received stream. Currently, ship-to-shore channels are 96 kilobits per second, and a point-to-multipoint channel from shore to ship is currently 160 kilobits per second for the Pacific satellite and 64 kilobits for the Atlantic satellite.

The hub facility provides bandwidth management, ensuring that the available bandwidth is efficiently shared among all of the ships. For example, when ships transit from one satellite footprint to another, the hub facility manages the reassignment of bandwidth to another satellite. When ships are in port for extended periods, their bandwidths can be reassigned temporarily to other ships.

HiSeasNet can also provide IP services to remote areas not normally covered by commercial Internet service providers. As an example, in October 2005 a service was initiated for the Incorporated Research Institutions for Seismology/International Deployment of Accelerometers Global Seismographic Network station on South Georgia Island and for the resident scientific community of the British Antarctic Service. The global component of the NSF-sponsored Ocean Observatories Initiative comprises both low- and high-bandwidth buoys for collecting observations. The high-bandwidth buoys are large enough to integrate the C-band or Ku-band antennae used in HiSeasNet. For these larger systems, land-based researchers would then have full access to their instruments in the water column and at the seafloor.

The HiSeasNet 'fleet' includes ships operated by Scripps Institution of Oceanography, University of Washington, University of Hawaii, Woods Hole Oceanographic Institution, Lamont-Doherty Earth Observatory, University of Rhode Island, and Harbor Branch Oceanographic Institution. Through the Joint Oceanographic Institutions, Inc., Scripps Institution of Oceanography operates the HiSeasNet hub and manages shipboard installations and maintenance. CommSystems of San Diego (http://www.comm-systems.com) is the principal subcontractor for HiSeasNet, providing system integration, installation, and maintenance services for both the hub and the shipboard systems. More information about HiSeasNet is available at http://www.hiseasnet.net

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MEETINGS

High Resolution Simulations of Atmospheric and Oceanic Circulation

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The pursuit of fine spatial representation in models of the atmospheric and oceanic circulation has been a theme running through the development of the field of numerical simulation. For example, in studies of the global ocean circulation, a long-standing concern has been the issue of adequately resolving particularly energetic eddies, such as Gulf Stream rings. In global and regional atmospheric models, a key issue has been resolving mesoscale circulations that organize clouds and convection.

With the recent advent of a new generation of high-performance computing systems, such as the Japan Agency for Marine-Earth Science and Technology's (JAMSTEC) Earth Simulator, some notable thresholds in terms of model resolution have been approached or, in some cases, surpassed. For example, the first long integrations with genuine eddy-resolving global ocean models were reported in 2003. On the atmospheric side, decadal integrations with global models with effective horizontal resolution of approximately 20 kilometers have now become possible, and very short integrations of models that explicitly resolve scales approaching those of individual convective elements were first reported in 2005. These developments in global models have been paralleled by rising research activity with increasingly fine resolution regional atmospheric models for climate and short-range forecasting applications.

Producing fine-resolution simulations is a fairly straightforward task, given the availability of suitably powerful computers. However, there are many interesting issues related to the optimal model formulation and the interpretation of results from high-resolution models that remain to be explored. To assess some of these issues, an international workshop was held recently at the JAMSTEC Yokohama Institute for Earth Sciences, where the Earth Simulator is housed.

Twenty-two speakers were invited from Australia, Canada, Japan, the United Kingdom, and the United States, and more than 60 scientists attended. The speakers presented results from various regional atmospheric, global atmospheric, global ocean, and global coupled models.

New Discoveries

A number of exciting new findings were reported during the workshop. One example was the discovery of a meridionally-banded structure of numerous narrow zonal jets in the deep ocean in a global ocean simulation employing the Ocean General Circulation Model for the Earth Simulator (OFES) run at 0.1-degree horizontal resolution. As reported by Kelvin Richards (University of Hawaii at Manoa), this aspect of the simulation appears to be analogous to the well-known multiple jet structures observed at the cloud-top level in the atmosphere of Jupiter, but occurs at a much reduced horizontal scale consistent with the ocean's small Rossby radius. As also reported by Richards, these new ocean model results motivated his colleagues to examine the limited relevant real-world observations available for model validation. At least some hints of similar behavior can be identified in the real ocean. Given the lack of detailed observations of deep oceanic circulation, high-resolution explicit modeling may play an important role in discovering some basic features of the circulation.

At least some global atmospheric models with effective horizontal grid spacing of the order of about 20–30 kilometers were shown to be able to simulate a realistic overall horizontal and vertical spectrum of motions down to the smallest resolved scales, i.e., down to those variations with horizontal wavelengths twice the effective grid spacing. Such results were reported by Kevin Hamilton (University of Hawaii at Manoa) for the Atmospheric General Circulation Model for the Earth Simulator (AFES) spectral model run at T639 resolution (roughly equivalent to a 20 km horizontal grid spacing), as well as for the U.S. National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory SKYHI grid-point model run at one-third-degree resolution. The simulated flow fields include representations of prominent mesoscale phenomena such as tropical cyclones and fronts that appear to be realistic in many respects.

A particularly exciting development was the first application of such extremely high resolution global models to climate change problems, as reported by Akira Noda (Japan Meteorological Research Institute, Tsukuba). A global model with 20-kilometer grid spacing was integrated for 10 years with sea surface temperatures (SSTs) taken from a control run of a lower-resolution coupled atmosphere-ocean model, and then for 10 years with SSTs taken from the end of a twenty-first century global warming scenario run with the same coupled model. Since the model is able to simulate a fairly realistic climatology of tropical cyclone numbers, paths, and intensities, this allowed an assessment of the effects of global warming on the tropical cyclones. A significant decrease (~30%) in the global numbers of tropical cyclones occurred in the simulated warmer world. However, the simulations produced an increase in the number of the most intense storms in some regions. The effect of global warming on tropical cyclone climatology is currently a subject of great controversy. The