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Around the Americas Expedition: Instrumenting a Sailboat for Science

A Sailing Expedition Around the American Continents Conducts Studies To Increase Knowledge and Raise Awareness of Ocean Conservation

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The recent Around the Americas (AtA) expedition, a 12.5-month, 28,000-nautical-mile sailing voyage around North and South America, was designed to raise public awareness about the health of the global oceans and how they are impacted by human activities.

The scientific component of the voyage sought to obtain measurements that would illustrate the expedition's educational concepts and to use the unique attributes and perspective of the expedition to complement ocean research programs.

As the project objectives became more clearly defined and science partners and appropriate instrumentation were identified, a suitable boat, the *Ocean Watch*, was found. The team undertook a complete refit to prepare it for the voyage and to add and integrate the necessary sensors to meet the objectives of the expedition's science plan.

Developed in coordination with a team of investigators from around the United States, the AtA's scientific goals included making various *in-situ* observations from a system of sensors on the sailboat.

The expedition's main observations included taking meteorological data; video and still images of the sea surface; aerosol optical depth (AOD) measurements; jellyfish samples; conductivity, temperature and depth (CTD) and pH measurements; and underwater noise data.

Educational Goals

The AtA project was conceived and developed by three well-known ocean conservationists: David Rockefeller Jr., David Treadway and Mark Schrader. Rockefeller and Treadway had recently founded Sailors for the Sea, a not-for-profit organization with the mission of inspiring members of the boating community to serve as ambassadors to help protect and restore the oceans. Though it was clear that the AtA expedition would generate considerable interest within the boating and adventure communities, the voyage also needed to feature strong linkages to current ocean science research and education to advance its primary mission of public education and engagement.

The Pacific Science Center (PSC) joined the venture to support the scientific and educational goals of the program. The center developed and operated the educational component of the AtA project, which included a portable exhibit space that served as a venue for educational activities adjacent to the boat, featuring printed educational content as well as information about the voyage. Trained bilingual educators also traveled with the voyage and offered lessons and presentations on ocean health to school groups, families and community organizations in port cities.

The center also created a free online curriculum for the use of educators in formal (classroom-based) and informal (after-school program administrators, science museum personnel, etc.) settings. The curriculum was designed for students in kindergarten through eighth grade and was aligned with national educational standards of the U.S. and Canada. Lessons focused on the health of the global oceans, with topics such as ocean acidification, sea level rise and pollution.

In addition, PSC leveraged its strong relationships with several groups active in oceanographic and atmospheric research, such as the University of Washington's Applied Physics Laboratory, the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) and the Massachusetts Institute of Technology's Sea Grant Program, to foster linkages between the project and a range of science partners.

Observational Goals

Compared to most modern oceanographic research, the AtA effort was modest. Space and power constraints, as well as a strict schedule, significantly restricted the AtA scientific agenda. The expedition needed to closely adhere to its schedule of port calls, and as a result, scientific observations needed to be made on the fly. *Ocean Watch* was either underway or in port, so the emphasis was on acquiring "datasets of opportunity." The single onboard scientist, with assistance from the crew, was responsible for all scientific activities. There were only limited opportunities to stop and monitor interesting developments.

Creativity was required for selection, location and installation of instrumentation. The deck was generally crowded with lines and rigging. Furthermore, the deck and superstructure were covered in salt spray and often submerged. Motion on such a small sailboat was much more violent than on a large research vessel. Inside there was almost no available space, and equipment needed to be compact and easily adapted to fit into unusual spaces such as the head, a former liquor cabinet, under bunks and in the crew's closets. Power consumption and power uncertainty were other serious issues.

The science plan was divided between taking survey data and performing satellite validation/calibration. The team took advantage of the remote locations to observe, collect and document what they saw. A second use of the AtA observations was for validation, correction and calibration of model and satellite products. Improvement in model performance depends on accurate initial data fields. Many observations acquired en route were used to support model and/or satellite programs.

Meteorological reports were communicated to the NOAA National Weather Service as part of the NOAA Volunteer Observing Ship program. Oceanographic data were transmitted by Inmarsat plc's (London, England) Inmarsat-C service to the NOAA Shipboard Environmental Data Acquisition System (SEAS) software program. Daily cloud observations were sent to NASA's Students' Cloud Observations On-Line (S'COOL) project to support satellite cloud studies. Aerosol observations were sent to NASA in support of their Aerosol Robotic Network (AERONET) global aerosol sensing program.

Underway Instrumentation

There were three autonomous systems on board *Ocean Watch*: a climate quality meteorological station, a flow-through water sampling station and a downward-pointing hemispherical camera. Data from these systems were recorded onto computer hard drives and returned to shore for subsequent analysis. These continuously acquired, high-resolution datasets will provide the backbone for all future data analyses by providing environmental context for the other observations.

The meteorological system was designed to provide climate quality measurements. These measurements—wind speed and direction, air temperature, humidity, barometric pressure, solar radiation, infrared radiation, precipitation and sea-surface temperature, along with pitch, roll and heading—can be processed using standard algorithms to compute the amount of energy (through heat measurements) and water (through evaporation measurements) that passes from the sea to the atmosphere and vice versa. The tolerance for measurement uncertainty for these observations is very tight, and it remains unresolved whether the AtA measurements will have sufficient accuracy for this purpose; not because of the sensors themselves, but because of the considerable potential for external contamination from motion, tilt, spray and salt.

Water measurements were made with a YSI Inc. (Yellow Springs, Ohio) SeaKeeper 1000 pumping system, which used an IDRONAUT S.r.l (Brugherio, Italy) multisensor to measure conductivity, temperature, pH and oxygen concentration. The SeaKeeper computer also prepared an hourly data message which it sent to the SEAS volunteer ship observation program. A second thermosalinograph, contributed by Sea-Bird Electronics Inc. (Bellevue, Washington), was added to the pumping manifold for the last third of the voyage, from Costa Rica to Seattle. The redundant measurements provided a valuable comparison to the SeaKeeper system.

Both the SeaKeeper and the meteorological system made use of the NOAA-produced Scientific Computer System (SCS) data-collection software. SCS is the data management workhorse for the NOAA research fleet and for many other research vessels and related programs worldwide.

Ocean surface video images were recorded continuously by a downward-looking Ladybug®2 spherical digital video camera system from Point Grey Research Inc. (Richmond, Canada). This system was composed of six cameras and provided a 360° panoramic view of the ocean surface from nadir to within 50° of zenith. The system was mounted on the arch at the stern, approximately two meters outboard of the starboard side. The output data from the Ladybug2 were recorded by a notebook computer. In normal operation, the video system recorded one set of six images every 10 seconds.

Video of the sea surface was acquired during the AtA cruise to perform wide-latitudinal surveys of two particular issues: the variation of whitecap coverage as a function of wind speed and the extent of jellyfish populations.

Acquiring these data was motivated by the importance of whitecaps, or visible breaking waves on the sea surface, and their role in the air-sea transfer of kinetic energy, latent heat and momentum in the production of atmospheric aerosol particles. Whitecaps are also a key consideration for many types of ocean remote sensing due to their impact on visible albedo and microwave emissivity of the sea surface. Jellyfish blooms, which are becoming increasingly common in coastal waters, are thought to be a symptom of anthropogenic ocean stress and climate change. Reports of human problems with jellyfish have increased in recent years and have captured the public's attention. Such problems come mainly from jellyfish stinging swimmers and interfering with fishing, aquaculture and power plant operations. A video survey such as this has not been attempted previously, and it has the potential to uncover new and exciting information about the distribution of these animals.

Spot Measurements

Spot measurements were taken at moments of opportunity, usually without interrupting the boat operations. As a rule, spot measurements were collected and sent to the principal investigators at the first convenient time, usually over the Internet.

Cloud observations were made at overpass times for the NASA Terra and Aqua satellites in a validation program for NASA's Clouds and the Earth's

Radiant Energy System experiment. Observations were forwarded to the S'COOL project.

When there were clear skies, measurements of the AOD were made with a handheld Microtops sun photometer from Solar Light Co. Inc. (Glenside, Pennsylvania). These measurements were forwarded to the University of Washington and to NASA to supplement is network of land-based sun photometers, the AERONET.

Whenever possible, jellyfish were sampled when they were observed as part of a global survey of their coastal distributions. Studies on jellyfish have been limited mainly to coastal areas near the few scientists who study them. The AtA voyage enabled huge ocean areas to be examined for jellyfish where they have likely not been collected before. Captured jellyfish were photographed and flesh samples were reserved for subsequent DNA identification.

Additionally, the *Ocean Watch* hydrophone project was devised to provide the crew with a simple, uncomplicated means by which they could record underwater sound. One of the scientific goals of this project was the measurement of ambient noise in ports-of-call and other protected and sheltered waters. It is of interest to understand the variation of sound level with latitude, as it is influenced by snapping shrimp populations that are more prevalent within tropical latitudes.

Finally, the Sea-Bird Seacat CTD-pH probe was used to sample the top 50 meters of the ocean. The probe casts were an important tool to double check the accuracy of the underway pumping system and to investigate the influence of the ongoing El Niño circulation along the western coasts of Central and North America.

Conclusions

The AtA expedition was unique in scope, purpose and execution. As an adventure, it was already in rarefied company by crossing the Northwest Passage and rounding Cape Horn in the same cruise. But it was the educational and scientific missions of this voyage that truly distinguished it as much more than an adventure and brought it home to a much larger audience, particularly families and children. The project used the excitement associated with the voyage as an opportunity to raise awareness of ocean health and environmental conservation, both of which are crucial to the future.

All instruments operated almost perfectly (greater than 95 percent) throughout the voyage, surviving extreme seas and climates, power interruptions and minimally trained operators, and data-quality assurance and post-processing are now being undertaken.

The challenges of conducting reasonably complicated scientific measurements on such an expedition—a small boat with an alternating crew of differing skill levels and with an unforgiving port schedule—were severe, and the success of the measurement program is in debt to the enthusiastic crew and contributors along the way.

Acknowledgments

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Previously the assistant director of education and outreach and senior oceanographer for the Applied Physics Laboratory at the University of Washington, Dr. Ellen Lettvin joined the Pacific Science Center in late 2008 as vice president for science and education.

Mark Schrader has completed two single-handed circumnavigations of the world and was the first American to singled-handedly circumnavigate the globe via the five Southern Capes from 1982 to 1983. An avid marine conservationist and wildlife advocate, he was one of the founders of the Around the Americas expedition.

[Fig 1]

The underway instruments were, from left to right, the climate station at mast top, the SeaKeeper ocean pumping system and the LadyBug2 all-view camera.

[Fig 2]

Two examples from the LadyBug2 camera show a hemispheric inverted profile (top) and a downward-facing hemispheric view. Images will be used for air-sea interaction studies and, hopefully, to monitor jellyfish populations.

[Fig 3]

Spot measurements taken included (clockwise, from top left) cloud observations at satellite overpass times, AOD measurements using a handheld sun photometer, jellyfish samples and CTD-pH profiles.