Tools of the Trade – Then and Now

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John Knauss' career is the subject of this issue, and to put his career in perspective, consider how the oceanographic world has changed during his time. In the early 1950s, sailing vessels still provided the sampling platform, and the tools were essentially free of electronics. Water properties were measured by lowering bottles, separately attached to a cable, over the ship's side. Reversing thermometers were the standard tool for observing water temperature, and salinities were measured using wet chemistry on board ship. Simple net tows captured some of the marine organisms living in the water column to provide an estimate of biomass. The word "computer," in the oceanographic world, meant a person who did computations using pencil, paper, a slide rule or mechanical calculator. Modern satellite communications and navigation capabilities existed only in science fiction novels.

The evolution and revolution of observing capabilities is evident by our widespread use of electronics, spacefaring, communications and computing capacity. We now use electronic devices to measure water properties (such as salinity) on scales down to centimeters. We deploy moored current meters for years at a time and measure air-sea heat fluxes to within a few percent accuracy. Just in the last decade or two, biological sensing capabilities caught up to physical capabilities with the evolution of the Video Plankton Recorder ("zooplankton CTD"), sophisticated optical sensors, and high frequency acoustical systems. *In situ* chemical sensors for pCO_2 and nutrients either exist today or are far down the development path. Sea floor observatories are moving towards implementation.

Our ability to see the ocean synoptically has exploded. Satellite imaging systems for ocean color or sea-surface temperature yield true snapshots of the ocean's state on scales ranging from the basin to a few kilometers. Other satellite systems, such as the altimeter yield global coverage on repeat times of a few days. But remote sensing need not be only from space: systems such as acoustic tomography allow detail study of the subsurface ocean over a range of scales.

Finally, it goes without saying that the computer has changed from a person to a machine. The implications of this are tremendous in terms of what we can measure, how we can analyze the results, and how theory advances. The combination of *in situ* sensors, remote sensing systems, communications and real time modeling capability makes possible a comprehensive global ocean observing system, accessible to anyone with web access.

With all of these incredible capabilities, what have we gained? From the researcher's perspective, we have a far richer, more accurate view of the ocean. We begin to understand, for example, the relative strength of mean flow and eddies and the role played by each. We can place the ocean in the context of the broader earth system, and understand the role that the ocean plays in climate fluctuations. We now measure well enough to begin to see through the noise of multiple ocean phenomena and quantify those which are important to us as scientists and as a society. More importantly, we are on the verge of a new era in oceanography–a coming age of routine and continuous ocean observations and predictions to form an oceanographic analogue of the National Weather Service.

John Knauss presently chairs the Ocean Research Advisory Panel (ORAP) of the National Ocean Partnership Program. One of ORAP's responsibilities is to provide advice on the development of the ocean observing system, including the advanced technologies with potential to become routine observational tools. In the post-war years, John Knauss and others of his generation developed our current system of support for basic oceanographic research and founded the basic research institutions in the U.S. Now John and others in this same generation are among those helping to lead oceanography from basic research towards applications. When one considers the changes in our field that occurred during just one generation, developing and implementing a comprehensive and international ocean observing system during the next few years seems a very manageable task.