East of Korea and West of Japan... The Very Model of Modern Major Oceanography

BY KENNETH H. BRINK AND STEPHEN P. MURRAY

THE OCEAN

The Japan/East Sea* is often described as a miniature ocean, and the characterization is apt. The relatively small basin (about 1000 km by 800 km) spans conditions from subarctic to subtropical and so involves many of the features found in larger oceans: deep water formation, subduction, boundary inputs, fronts, eddies, ocean jets, and biological zonations. The basin, although oceanographically diverse, is surprisingly tractable for oceanographic studies with our modern oceanographic tools.

This *Oceanography* issue describes results from a 1999–2001 oceanographic study in the Japan/East Sea sponsored by the United States Office of Naval Research (ONR). The program was born as a logical result of the very important ground work done over the preceding decade under the auspices of CREAMS (Cooperative Research in East Asian Marginal Seas), a remarkable international effort that unified scientific efforts in Japan, the Republic of Korea, and Russia in an area where they had not previously worked productively together. The CREAMS effort (see Danchenkov et al., this issue) enabled new levels of scientific insight, while at the same time it lowered political barriers that had severely restricted international research efforts, such as where a given group could work. The CREAMS findings, as well as the CREAMS organization, then made it very attractive, and feasible, for a group of U.S. scientists to join in the study of this fascinating miniature ocean.

Perhaps even more than the compactness of the ocean under study, a striking feature of the papers that follow is the extent to which they demonstrate that the future has arrived. We can compare what was possible two decades ago against today's reality as demonstrated by the Japan/East Sea program.

- *Technological advances*: Moored physical systems are now survivable even in this hostile, heavily fished environment, making long, continuous time series, previously only a pipe dream, available. Towed undulating platforms now allow horizontal resolution of a kilometer or two for physical measurements—and are obtained without slowing down (let alone stopping) the ship. Genuinely synoptic surveys have become routine. Similarly, and even more strikingly, the towed Video Plankton Recorder is capable of detecting individual zooplankters, and, using an expert system, identifying them and counting them at a spatial resolution comparable to that resolved by physical oceanographers. The simultaneous and synoptic resolution of both physical and biological structures opens entire new possibilities for developing a genuinely quantitative understanding of physical-biological coupling.
- *Remote sensing*: Satellite information has become completely integrated into the data streams throughout the Japan/East Sea program. Satellite color or temperature data guide sampling in real time and they make *in situ* observations intelligible after the fact. Satellite ocean wind data are recognized as extremely high-quality information and are now critical to modelers. Rather than remote sensing being a specialized add-on to a field program, it has become so tightly integrated that we often lose sight of its presence and of the way it has revolutionized our view of the sea.
- *Scale interactions*: The breadth, resolution, diversity, and durability of present observing systems now allow serious study of scale interactions (such as between eddies and internal

* One might wonder how such a small body of water would have such a complex name. The explanation lies in its smallness, and in that the adjoining countries each have their own names for it historically. At present the name is under dispute with international bodies, and until the matter is settled more firmly, the accepted protocol is to use both of the alternative names: hence "Japan/East Sea."

tides) that appear to be so important for determining dissipation, patterns of variance, and smaller-scale structures. The more we learn of these scale interactions, the more we appreciate the inability of understanding a single scale window in isolation.

- *Models*: In the distant past, numerical modeling components were included with a clear understanding of their potential value, but that value was often not realized because of limitations associated with computing capabilities, lack of data and information for inclusion, and the dearth of tools for facilitating display and interpretation. Those days are past. Numerical modeling efforts are now integrated into the field programs and produce results that can be compared very plausibly with observations. Thus, they play a central role in explaining the realities of the ocean and in pointing out unobserved features that are likely to exist.
- *Interdisciplinary*: New doors have been opened by new capabilities, new intellectual frameworks, and, especially, the development of observing systems and models that resolve physical, chemical, and biological systems on the same scales. A new mindset is growing from this new capability, which has all ocean-science disciplines thinking much harder about the broad context of their work and about how their own specialized subject affects processes described by other disciplines.
- *International*: All of the components of the core ONR Japan/East Sea program were, of themselves, international. It is only natural that this should be so in the context of this particular body of water, given that the key insights leading to this program were derived from decades of important work carried out by Japanese, Korean, and Russian investigators. This international flavor is likely to grow in the future for all oceanographic research. Needs for pooled physical and intellectual resources have become more apparent. Together these resources are capable of dealing with the magnitude of the increasingly ambitious problems envisioned by all.

The results here convey a remarkably comprehensive physical oceanographic understanding of the Japan/East Sea.

We have thus taken stock of this program and so recognize that the future of oceanographic research has, in many ways, arrived. Yet, we can expect even greater changes over the coming decades. One obvious change is the growing importance of international ocean observing systems that will provide the context and many of the routine measurements required by process-oriented programs. These observing systems will likely become just as integrated as satellite remote sensing has become. Numerical models, and their ability to replicate more aspects of the actual ocean, will continue to improve. Finally, communications and data-transmission capabilities will improve to the point that most data sets will become broadly available in virtually real time. This communication speed will facilitate the expansion of existing remarkable feedbacks that allow, for example, models to help shape adaptive sampling schemes. Certainly, the science and its expanding capabilities will continue to take our breath away.

THIS ISSUE

This *Oceanography* issue describes dramatic advances from the recent ONR-sponsored Japan/East Sea program. The intent here is to present an easily accessible overview of the project's accomplishments. More detailed results are presented in a 2005 special issue of *Deep-Sea Research II* (volume 52) and numerous other journal articles. The papers here provide insights into the historical context (Danchenkov et al., this issue) and into most of the major facets of the program.

To a large degree, processes and properties inside the Japan/East Sea are controlled by boundary conditions at the entry portal—the Tsushima Strait—and at the air-sea interface. Long-term measurements in the southern, Tsushima Strait, entrance had been sparse due to incredibly intense bottom fishing and

Kenneth H. Brink *(kbrink@whoi.edu) is Senior Scientist, Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA, USA.* **Stephen P. Murray** *is Program Officer, Physical Oceanography, Office of Naval Research, Arlington, VA, USA.*

trawling. The introduction of trawl-resistant bottom mounts for acoustic profiling current meters by the Naval Research Laboratory has dramatically rectified this situation, resulting in a number of publications describing these new results (Teague et al., this issue). The lateral inflow transport, its thermohaline properties, and its seasonal and monthly variability are thus now well known, a boon to our modeling colleagues. Dorman et al. (this issue) describe the several components of a study of the marine atmospheric boundary layer by aircraft, ship observations, and modeling techniques. Emphasis is on the generation and impact of severe cold-air outbreaks from Siberia as they move over the Japan/East Sea. The mesoscale response to these outbreaks is very dependent on pre-conditioning, resulting from the interaction of Siberian air motions with an impressive coastal mountain barrier along the Korean/Russian rim. The Vladivostok Gap, the major break in this barrier, is shown to be critical in localizing a center of intense heat loss conducive to water-mass modification.

Just inside the Tsushima Strait, the Ulleung Basin, well known for its intense eddy activity, was examined in great detail with an extensive array of advanced inverted echo sounders. Watts et al. (this issue) and Park et al. (this issue) show how this new data set has completely reshaped our many prior branching scenarios of the Tsushima Current inflow into a new understanding that acknowledges the dominance and the presence and persistence of warm and cold eddies. These eddies in turn affect the "beaming" and steering of internal tides emanating from the north end of the Tsushima Strait.

Warm, saline Kuroshio water passing north from the Tsushima Strait impacts cold south-flowing water on the western side of the Japan/East Sea to form one of the most dramatic features in the Sea, a distinct subpolar front that extends across the basin near 40°N. Lee et al. (this issue) use a high-resolution towed profiler to show how the front responds to energetic wind forcing as well as to the intense buoyancy loss, both associated with the Siberian cold-air outbreaks. They detect vertical velocities that are ten times larger than expected from conventional meander-driven frontal models and that draw low-salinity, chlorophyll-rich surface water downward in the frontal zone.

Basin-scale process studies involved extensive observations of physical and chemical property distributions (Talley et al., this issue). Results confirm that deep convection associated with buoyancy loss induced by the Siberian cold-air outbreaks and brine rejection accompanying sea-ice formation cause deep- and bottom-water formation, respectively. Observations indicated that during winter 2000, at most a weak ventilation of bottom waters occurred, but that the severe winter of 2001 saw brine-rejected waters spread down the continental slope and begin to fill a bottom pool in the Japan Basin. Thus, even a short, two-year study demonstrates that ventilation events are sporadic and driven by climate-time-scale events and that bottom-water formation has indeed not ceased despite previous conjectures. To complement and exploit the physical studies at the basin scale and the Subpolar Front, Ashjian et al. (this issue) describe major advances not only in understanding biological distributions but, as a result of the integrated aspect of the field program, how their seasonal and spatial differences are driven by the physical processes.

Modeling is seen to be a double-edged sword: both an integrator and a process tool. Mooers et al. (this issue) not only execute innovative evaluations of simulated three-dimensional circulation using profiling floats, drifters, and current meters, but also study the rate and location of subduction zones. Their models point to several candidate areas for downward motions that were not touched by our observationalists. Hogan and Hurlburt (this issue), inspired by Gordon et al. (2002), focus here on the conundrum of the formation of the intrathermocline eddies. Their results suggest the process described by Lee et al. (this issue) is but one of several possible formative mechanisms for these subsurface eddies in the Japan/East Sea.

The results here convey a remarkably comprehensive physical oceanographic understanding of the Japan/East Sea. This new understanding would not have been possible without the results and international partnerships fostered by the preceding CREAMS program. Although the miniature aspect of this ocean undoubtedly contributes to the ability to reach a new level of understanding, the decisive factors are really the modern tools and insights brought to bear in this international context.

REFERENCES

Gordon, A.L., C.F. Giulivi, C.M. Lee, H.H. Furey, A. Bower, and L.Y. Talley. 2002. Japan/East Sea Thermocline Eddies. *Journal of Physical Oceanography* 32:1,960–1,974.