SIDEBAR | The North Pole Environmental Observatory Mooring

By Knut Aagaard and James M. Johnson

Eulerian time series form an important element of the modern oceanographic toolbox. As part of the North Pole Environmental Observatory (NPEO; Morison et al., 2002; http://psc.apl.washington.edu/northpole), we therefore maintained a bottom-anchored, instrumented mooring within ~ 55 km of the North Pole from 2001 to 2010 (Aagaard et al., 2008). The mooring site was over the Pole Abyssal Plain in water ~ 4,300 m deep, a location that illuminated boundary current evolution along the Eurasian flank of the Lomonosov Ridge and events in the interior ocean away from the boundary. Standard measurements have included velocity, temperature, salinity, and pressure at various depths, as well as ice thickness (Morison et al., 2002). In 2005 and 2006, sensors for bio-optics and nutrients were added.

During the first five years, the mooring was replaced annually, then every second year after that. Deployment and recovery were from the drifting sea ice using aircraft and temporary ice camps. Developed during the mid-1970s (Aagaard et al., 1978), the methodology was first applied to the deep central Arctic Ocean during April and May 1979 when two moorings were deployed near the North Pole (Aagaard, 1981). Ice-based logistics offer greater flexibility and easier access than shipboard operations, but at the price of doing without the considerable infrastructure available on a ship. Indeed, the ice-based work has many of the joys and discomforts of winter camping trips.

For those early deployments, accurate positioning was problematic, but GPS now makes the task trivial. Determining depth during mooring deployments remains a challenge, requiring a heavy transducer for full ocean depths. Additionally, it is difficult to move short distances during deployment to compensate for changing depth over steep topography. Access to the ocean requires a hole somewhat greater than 1 m across; chisels, augers, and dynamite have been replaced with a melter system that uses water warmed in a small diesel-fired burner. To handle the heavy loads inherent in mooring work, we use a quadrapod with a large block and a capstan driven by gasoline-powered hydraulics, with a backup brake system (Figure 1). The capstan is fed from an axle-mounted spool, which is powered for retrieval purposes. For insertion of instruments and other mooring components during deployment, we secure the weight-bearing line at all junctions, making fine vertical adjustments of the mooring using either the capstan or two chain hoists. The system is readily transportable and handles up to ~ 650 kg. Once the hole is melted and the equipment set up, a 4,300 m deployment takes ~ 8 hours.

Recovery begins with locating the mooring, first with GPS and then by ranging and bearing on the various transponders in the acoustic releases or built into the upper 100 m of the mooring. The location of the mooring relative to that of the ice, ice drift, and ice conditions in the vicinity determine when to release the mooring. For example, if the ice is deformed, deep keels can significantly impede pulling in the mooring, and we may therefore delay release until conditions are judged favorable. Once the mooring is released, the whole array rises to the under-ice surface in about one hour and is distributed under the drifting ice (Figure 2). By then, a pressure-activated switch has turned on a radio-frequency avalanche beacon attached to the top float, and

Figure 1 (above). Re-deployment of the North Pole Environmental Observatory (NPEO) mooring in 2004. The hydraulic power pack is seen on the left through the quadrapod legs with hoses connected to the capstan in the lower center. The deployment hole through the ice is covered except when large items are passed through.

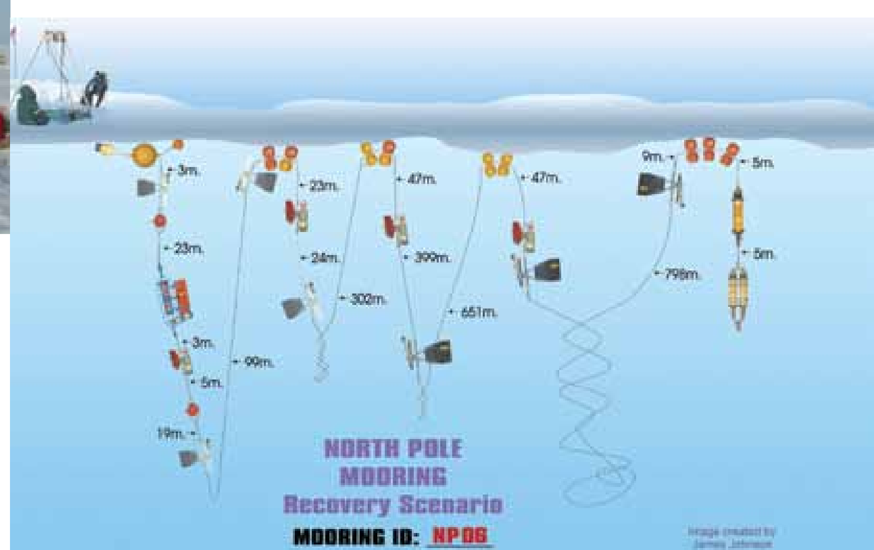

Figure 2 (right). Schematic representation of a released NPEO mooring after rising to the underside of the ice. Only some of the instruments and mooring components are shown. The mooring can be distributed laterally over hundreds of meters, depending on the ice drift during the mooring ascent.

the location of the top float under the ice can be determined to within ~ 1 m horizontally using a standard receiver. A recovery hole is melted and the quadrapod and capstan installed. Knowing the ice drift, we also know how the mooring is laid out relative to the hole. Frequently, we are able to reach down through the hole and snag the top of the mooring with a pole-mounted hook, although sometimes divers must attach the recovery line. If the underside of the ice is relatively smooth, the recovery is generally straightforward using the capstan for retrieval. Rough ice may require either diving to free individual mooring components, even melting additional holes to do so, or weighting the components down one at a time to get them past a keel—a time-consuming operation. All the flotation packages are color coded for mooring position and orientation, so that if the line tangles, we can readily identify where it leads. Once the mooring is recovered, the hole is used for the new deployment.

Most of the attention to changes in the Arctic Ocean has been focused on the extent and thickness of the ice cover, and on the variability of the halocline and the temperature of the Atlantic layer. A fuller analysis of the data from the NPEO mooring will add much to that discussion, in part because of the continuity and length of the time series, in part because of the location of the mooring, which allows views of both of signals carried by the boundary current and of changes in the interior ocean. Perhaps more important, the mooring provides coverage of other parts of the water column, both the mid-depth ocean, which oxygen profiles show to be remarkably well ventilated, and the deep ocean, which has hitherto chiefly been viewed through ship-borne profiles scattered widely in time. Both velocity and water properties at the mooring site show large variability on a range of time scales and at all depths. For example, the temperature and salinity in Figure 3 are representative of the lower halocline (115 m), the Atlantic layer (270 m), and mid-depth waters (1,005 m) during the first seven years of the mooring. Many of the features in Figure 3 represent perturbations by eddies, for example, the event centered near day 700 (gray, vertical bar), which Aagaard et al. (2008) describe in some detail. Other variability shown in Figure 3 reflects long-term changes in water properties, such as the cooling of the mid-depth waters that began in 2003, followed three years later by warming through the end of the record. All the NPEO mooring data from these seven years are available at the Cooperative Arctic Data Information Service (CADIS) of the Arctic Observing Network (http://aoncadis.ucar.edu/home.htm).

When we began this work, it was not obvious that a bottom-moored array in the interior Arctic Ocean could be reliably maintained and serviced over many years, especially absent ship support. We now know that it can be done.

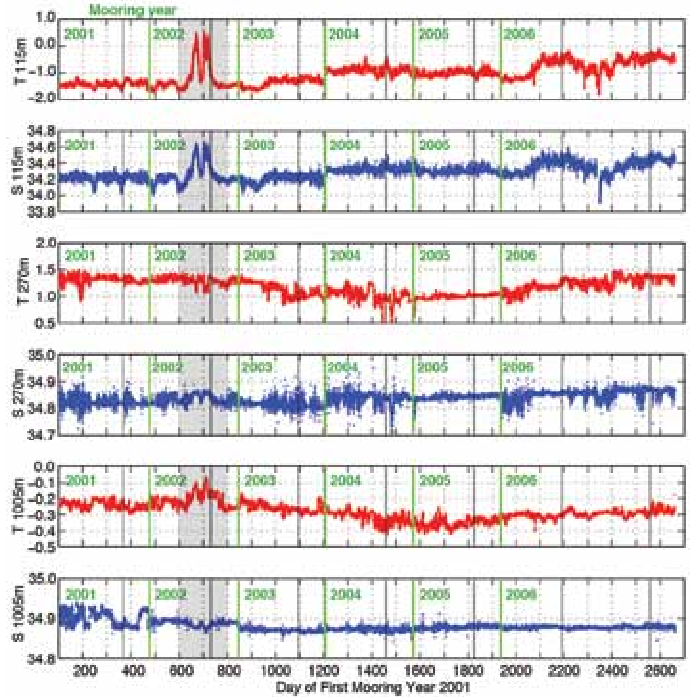

Figure 3. Temperature (red) and salinity (blue) at selected nominal depths at the NPEO mooring site 2001–2008. The vertical green lines mark a mooring recovery/redeployment (designated mooring year), and the thin black lines a calendar year. The vertical gray bar indicates an eddy event centered near day 700. The records have not been adjusted for depth differences between successive deployments nor for the effect on salinity of increased pressure during mooring pulldowns.

Indeed, as mooring technology and instrumentation continue to evolve, the demonstrated feasibility of long Eulerian time series from the deep Arctic Ocean using aircraft and ice-based logistics will likely prove one of many useful results from the North Pole Environmental Observatory.

Knut Aagaard *(aagaard@apl.washington.edu) is Professor Emeritus, School of Oceanography, University of Washington, Seattle, WA, USA.* **James M. Johnson** *is Senior Field Engineer, Applied Physics Laboratory, University of Washington, Seattle, WA, USA.*

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