MEETINGS

An Array of Ice-Based Observatories for Arctic Studies

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The Arctic Ocean's role in global climate—while now widely appreciated—remains poorly understood. Lack of information about key processes within the oceanic, cryospheric, biologic, atmospheric, and geologic disciplines will continue to impede physical understanding, model validation, and climate prediction until a practical observing system is designed and implemented.

A review of recently observed changes in the physical and biological state of the Arctic and a justification for future Arctic observations are contained in the supporting document of the U.S. National Science Foundation's (NSF) "Study of Environmental Arctic Change" program (SEARCH, http://psc.apl.washington.edu/search/). Comparable Arctic study programs have been conceived as an international contribution to the proposed International Polar Year 2007–2008 (http://www.aosb.org/ipy.html). Future directions in instrument development for Arctic studies were also considered at a workshop at the Monterey Bay Aquarium Research Institute in October 2002 (http://www.mbari.org/rd/ArcticInstrumentationWorkshop).

An outcome of these ongoing discussions is an increasingly focused vision for future Arctic research. Three main components of this vision have been identified: (1) manned expeditions with enhanced capabilities; (2) basin-wide networks of autonomous ice-based instrument systems and autonomous vehicles; and (3) cabled oceanographic observatories.

Following up on the second of these themes, an international workshop was held this summer. The assembly of 55 workshop participants that included Arctic scientists, engineers, industry representatives, and program managers from eight countries was tasked with detailing the next generation of ice-based technologies that could contribute to a future observing system and begin coordinating plans and instrument development.

Ice-Based Instrument Systems

The idea of ice-mounted instruments or drifting ice-anchored buoys is certainly not new. The first scientific drifting platform was Nansen's Fram (1893–1896) that, over a 3-year period, drifted with the ice across the Arctic while making atmospheric and oceanic observations. A similarly remarkable scientific expedition that involved drifting on a sea ice floe was accomplished by the USSR in 1937. That drift continued for 274 days, during which time the station traveled more than 2600 km. This began the "North Pole" station investigations that opened a new era in Arctic studies.

During their history (1937 to present), Russian and U.S. drifting stations, ice camps, and icebreaker programs have provided important information from the Arctic. Autonomous instruments have become an increasingly significant source of Arctic data. Since 1978, observations from the International Arctic Buoy Program (IABP) have contributed to polar science by returning meteorological and sea ice drift data for real-time operational requirements and research purposes (http://IABP.apl.washington.edu/).

Buoys with subsurface instrumentation have also been used with great success. Between 1985 and 1994, the Polar Science Center, University of Washington, deployed 24 Polar Ocean Profiler (or SALARGOS) data buoys. And during 1992–1997, WHOI in collaboration with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) developed and deployed six Ice-Ocean Environmental buoys (http://ioeb.whoi.edu/index.htm).

Since 2000, JAMSTEC Compact Arctic Drifter (J-CAD) buoys (http://www.jamstec.go.jp/arctic/J-CAD_e/jcadindex_e.htm) have been measuring the structure of upper ocean currents and water properties under multiyear ice floes. Also beginning in spring 2000, an international research team supported by NSF has conducted annual expeditions each April to the North Pole to service and install an ensemble of autonomous scientific platforms, collectively called the North Pole Environmental Observatory (NPEO, http://psc.apl.washington.edu/northpole/).

Requirements and Challenges for Ice-Based Observatories

Experience gained in previous studies was brought to bear by workshop participants to develop the concept of an array of ice-based instrument systems, or Ice-Based Observatories (IBOs), necessary to satisfy the needs of international Arctic science programs. Workshop participants identified IBOs as automated, drifting, ice-based sensor systems providing comprehensive data from the Arctic environment and incorporating the multidisciplinary needs of biological, chemical, and physical oceanography, as well as different aspects of atmospheric and sea ice studies. Moreover, in addition to supporting suites of sensors, these observatories may also act as a network of tomographic receivers, data transmission nodes, and navigation beacons for autonomous vehicles operating between the stations.

The basic requirements identified at the workshop for a future generation of ice-based unmanned platforms are:

- Observation and real-time reporting, with high vertical resolution and high accuracy, of an interdisciplinary suite of parameters from the near-surface atmosphere, sea ice, and upper ocean for multiple years (assuming deployment on robust ice floes) at temporal resolution appropriate for each parameter;
- Ease of deployment from landed aircraft and helicopters in addition to deployment by icebreaker;
- Modest cost, allowing them to be deployed in large numbers (analogous to the present IABP) and, in some cases, to be considered expendable;
- Accommodation, through standard interface and communication protocols, of future surface and/or subsurface instrumentation, including acoustic communication (for data transfer and navigation) with autonomous vehicles.

Although much of the necessary IBO technology already exists and routine observa-tions are presently underway using the IBO concept, there are a variety of challenges that must be addressed en route to a comprehensive observing system. Workshop participants agreed that platform instrumentation should be improved by continued development of profiling systems for atmosphere, ice, and ocean with the goal of sampling biological and chemical variables on the same spatial and temporal scales as physical variables in order to separate biological and/or chemical transformations from changes due to physical mechanisms.

Profiling systems for many physical variables are presently available or easily adapted for routine use in the Arctic, whereas biochemical profiling systems will require additional development effort. Relating to the platforms themselves, it was noted that IBOs will be best suited to deployment in perennial pack ice. However, the seasonal sea ice zone accounts for a majority of the northern marine cryosphere, and most of this is in shallow water (< 500 m). Specialized IBO designs will likely be needed for the seasonal ice zone, platform lifetimes will be short, and frequent redeployments will be required. Alternate technology (e.g., profiling floats) may also be required.

Finally, the integration of mobile assets with IBOs needs to be addressed in design studies. There are specific technological issues (e.g., navigation, communication, and energy transfer) relating to interactions among IBOs, floats, gliders, and AUVs that should be addressed concurrently with an IBO array implementation.

Workshop Conclusions and Recommendations

Ice-based instrument systems are a proven means of acquiring unattended high-quality air, ice, and ocean data from the central Arctic during all seasons. Arctic change is ongoing, and measurements need to begin now. An array of IBOs maintained throughout the Arctic Ocean is envisioned to observe the spatial structure and temporal variability of the polar atmosphere-ice-ocean environment. Practical, cost-effective, and proven IBO designs presently exist, can be readily extended to provide interdisciplinary observations, and should be implemented expeditiously as part of a coordinated Arctic observing system.

Specific recommendations were:

- A relatively simple and robust IBO array, based on presently available technology, should be implemented immediately as part of a stepwise ramp-up to a multicomponent, interdisciplinary Arctic observing system. An international body will be required to coordinate the various national programs (to eliminate overlap, and ensure no data holes) and ensure compatibility of data and their widespread distribution.
- The 25 years of IABP drift trajectories, existing data climatologies, and available numerical simulations should be exploited to derive insight into optimal array design, deployment strategies, sampling intervals, and expected performance of an IBO array.
- Since ice-based observations at a given site may consist of a distributed set of subsystems developed by multiple principle investigators, the logistics infrastructure for getting to the deployment sites is one of the most important shared assets of the observing system. A long-term, internationally coordinated logistics plan should be implemented as an essential complement to scientific and technical plans for an IBO array.
- IBO designs should provide accommodation for novel sensors, tomographic receivers, and communication and navigation capabilities for autonomous vehicles. Emerging technologies for Arctic observation (including but not limited to unattended biological and chemical sensors, electromechanical sensors, autonomous oceanographic vehicles and drifters, and unmanned aerial and micro aerial vehicles) should be developed within the framework of an integrated Arctic observing system.

The Arctic Observing Based on Ice-Tethered Platforms workshop was held at the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts, 28–30 June 2004.

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BOOK REVIEWS

An Introduction to the Environmental Physics of Soil, Water and Watersheds

CALVIN W. ROSE
Cambridge University Press, New York; 454 pp.; ISBN: 0-521-53679-0; 2004; $60.
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An Introduction to the Environmental Physics of Soil, Water and Watersheds presents an easy approach to understanding physical processes associated with the land surface and subsurface water and energy balance, with a brief treatment of transport.

The book begins with a treatment of soil, its formation and composition, and properties associated with soil strength and characterization with moisture. Next is a description of the properties of liquids wherein concepts such as pressure, energy, buoyancy, and waves are addressed. This is followed by the treatment of evapotranspiration and infiltration. The book then discusses overland flow, erosion and deposition, and transport by rivers. The behavior of flow in the subsurface, namely, saturated and unsaturated flow and contaminant transport, completes the book.

Environmental physics is truly an interdisciplinary subject. It is used by professionals and students whose expertises range from agriculture to zoology, and hence a good introductory text is a blessing. Most current texts are either too heavy on the mathematical treatment or have too much prose without a good quantitative approach. This book treads a fine line between these two aspects, with a balanced approach to verbal and quantitative description.

However, the author delves into long-winded descriptions at the beginning of many chapters (e.g., chapter 6 on infiltration has seven pages of prose before the author gets to a figure). There are two suggestions for improvement. First, the author should have organized these ideas into numbered paragraphs or bulleted points, which would help beginning readers to follow his train of thought. Second, many of the figures are repetitive; the book would be served better with fewer figures but better labels and descriptions (e.g., Figures 1.7, 1.8, and 1.9 could be combined into one neat, well-labeled figure).

Hydrology is a very integrated science. Even though for sake of order, the book is organized as chapters on infiltration or evapotranspiration, a synthesized chapter at the end which features an end-to-end problem solution would greatly benefit the reader. This could be precipitation excess calculation (rainfall minus infiltration), calculation of evapotranspiration given the net radiation, and computation of the overland and stream flow, followed by the groundwater flow and the moisture content in the unsaturated zone. Such an end-to-end problem would display the scope of the material by illustrating what occurs in nature.

The book is suitable for undergraduate students in their junior or senior year and for graduate students beginning courses of study related to hydrology, ecology, agricultural sciences, meteorology, or climate.

The author contends in his preface that no prior knowledge of physics or mathematics is required. This is not true. Students need to understand scientific thought processes as well as have taken high school physics and mathematics (at the very least). Knowledge from a university-level first course in math and physics is definitely preferable. The book has a reasonable price ($60 for paperback), and the list of exercises at the end of each chapter complements fully the material in the text and also builds on more concepts.

On the whole, this book is a good read for students and professionals who need to refresh their knowledge of hydrology and hydrogeology and the environment.

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