Parallel Session Summary

The Fate of Sea Ice

Session Chairs: Ron Kwok and Axel Schweiger
Rapporteur: Alice Bradley

Overview. Arctic sea ice extent and thickness are declining, and the expectation that current trends will continue portends a future with larger expanses of open-ocean, longer durations of ice-free conditions, and a more accessible Arctic. However, our limited understanding of the coupled interactions among the sea ice, ocean, atmosphere, and land hinders our ability to predict the rate and magnitude of future change and its impact on physical, biological, and human systems. The need to understand, adapt to and take advantage of a changing sea ice cover places new demands on the research community and observational systems. Discussions were broadly organized around the three questions listed below. The answers point to the crucial need for long-term coordinated observation networks to address the needs of scientific understanding, short-term predictions, climate projections, planning and operations.

<u>Question 1:</u> What scientific or operational advances have been facilitated by the network(s) of Arctic observations?

While the observational systems of sea ice were not initially conceived as a coordinated network, these systems (supported by different agencies) have produced observations that have benefited the broader understanding of coupled Arctic ice/ocean/atmosphere interactions. The plenary talk and discussions highlighted a number of specific thematic areas/programs of success based on observations from instruments deployed on satellite, airborne, submarine and in situ platforms (this is not an all-inclusive list). Also, the sea-ice observation programs (examples below) would benefit from increased 'networking' even though a broad range of science investigations already benefit from their results.

- Satellite ice concentration and extent (since 1978). The multidecadal record of satellite observations has been the driver to better understand arctic climate and global change.
- International Arctic Buoy Programme (since 1978). The program maintained a network of drifting buoys to provide meteorological and oceanographic data for real-time operational requirements and research purposes (Sea level pressure; Surface air temperature; ice drift.). It has contributed to understanding of air temperature, changes in large-scale sea level pressure, and the spatial and temporal variability of ice drift.

- Maps of ice age (since 1985). The estimates from ice drift and ice concentration highlighted the large increase in the coverage of younger seasonal ice in the Arctic, and decrease in overall ice age within the basin.
- NSF AON: Sea ice deformation array provided time-varying strain rates at sub-daily time scales sufficient to resolve tidal and inertial effects.
- Ice Mass balance (IMBs) from buoys. IMBs are the only instruments capable of providing a time-series of surface and bottom melt – not available elsewhere. The contributions of the IMB observations in advancing the state of knowledge, as part of AON, have been clearly demonstrated over the last decade.
- Seasonal Ice Zone Observing Network (SIZONet): Coordinated airborne, field, under-ice surveys of the seasonal ice zone.
- NASA IceBridge Mission. The seasonal campaigns have documented seasonal and interannual changes in spring ice thickness and snow depth.
- ICESat /CryoSat-2 Satellite Missions. Basin-scale ice thickness and ice volume estimates are now available from satellite measurements on a monthly time scale.
- Submarine ice draft and thickness. The combined submarine ice draft and satellite data have documented the decrease in Arctic ice thickness since the 1950s.
- New satellite observations of dynamic topography that allow the estimation of time-variable geostrophic circulation in the Arctic Ocean.

<u>Question 2:</u> What opportunities exist to address new science questions, operational challenges, or questions of Arctic communities through enhanced collaboration and a robust interagency observing system?

Addressing the questions of Arctic sea ice changes and predictability depend on a robust program of well-planned and coordinated observations. Improving short- and long-term forecasts will require better models, with fully coupled ice-ocean-atmosphere processes that assimilate advanced observations and generate time-varying sea-ice concentration, thickness, and ice-edge location at high temporal and spatial resolution. Continuous or frequently repeated data collection will be needed, including broad surveys of ice conditions over the annual cycle to initialize forecasts. Furthermore, data – especially satellite data - should be returned in near real-time to support forecasting at shorter time scales and to verify sensor performance.

Significant key points for a robust interagency observing system: 1. Complementary platforms and field activities at different time and length scales (field programs, airborne and satellite remote sensing) are key to producing relevant basin-scale scientific results; 2. Development of programs for comprehensive process studies driven by well-posed scientific questions (e.g. ONR MIZ and Sea State DRIs). 3. Joint support of modeling efforts that address improvement in process understanding and impact on predictability. 4. Sharing of new observational capabilities for measurement of ice parameters.

Another broad opportunity, in addition to interagency activities, is the leveraging of international collaborations to advance our knowledge of the polar-regions. For example, organizations in the European Union, Canada, Japan, S. Korea and China are interested in the Arctic and collaborative programs that facilitate the exchanges of data and sharing of resources would benefit the international Arctic community.

Question 3: How have observing activities contributed to the science needs of mission agencies or stakeholders?

There is a distinction between mission driven agencies (e.g., NASA, NOAA, ONR, etc.) and NSF, which has a broader mandate to promote the progress of science. Thus the contributions to NSF needs are not as well defined even though observational networks implemented for understanding of changes in the Arctic require dedicated programs and long-term commitment of resources, and perhaps more difficult for NSF. But, long-term observations with well-defined objectives are required to document and understand the changes, and to improve operational planning on seasonal-to-decadal time scales.

An example of long-term observations is the record of ice extent acquired by the series of space-based radiometers that started with NASA's Nimbus-7 SMMR in 1979. The observations have been maintained by successive SSM/Is launched by the Defense Meteorological Satellite Program (DMSP). Without these assets, the time series for monitoring of the Arctic sea ice cover, used in a broad range of applications (from operational to scientific research), would not have been available - this includes the multi-decadal record of ice extent that has served to document the dramatic decline in the Arctic Ocean sea ice coverage.

Long-term coordinated observational networks are crucial for advancing our knowledge in the coming decades.