Advancing Weather, Ice and Environmental Predictions in The Polar Regions: An IPY Legacy

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Introduction

In the justification for nearly every IPY project one can find, prominently, a description of an urgent polar process NOT adequately (if at all) represented in global models. Sea ice drift; aerosol production near polynyas; pulses of deep water formation; photochemical production of oxidants from snow; heat and momentum fluxes over a partially ice-covered ocean; carbon fluxes from degrading permafrost; the impact of dust and soot on snow albedo; the effects of basal melt waters on glacier velocities; the influence of stratospheric chemistry on surface winds; the list could easily fill this page. In practice, these polar 'deficiencies' very often derive from inadequate understanding, parameterization or extrapolation of the high latitude exchanges of heat, momentum and material among ocean, land, atmosphere and ice, for reasons unique to polar regions: logistical obstacles, extreme environmental conditions, intense internal temporal and spatial variability, and high sensitivity to external forcing. These polar deficiencies present serious barriers to improved weather, climate and environmental predictions, globally and for polar regions.

If most IPY projects identified improved models as a motivation, can we see, or foresee, improvements in predictive skill, for ice, ocean, atmosphere, or carbon cycling, for polar regions or globally? In additional to hoped-for improvements in prediction, what IPY-induced changes in operational systems or in research or operational collaboration might contribute to a positive long-term legacy of rapid incorporation of new knowledge into enhanced predictive skill?

Possible prediction outcomes from IPY-produced knowledge

We anticipate substantial, perhaps unprecedented, steps forward in knowledge of polar processes and polar systems. Ice, polar oceans, permafrost, marine and terrestrial ecosystems, health, and local, regional and hemispheric atmospheric processes all received substantial attention during IPY; the stimulus of funding in those research areas will produce a subsequent pulse of publications.

These scholarly publication processes represent scientific research following its philosophical roots. Despite the urgency inherent in many original proposals, most IPY research will not automatically lead to the rapid development of useful predictive skill. To reduce delays between research products and predictive applications, several national research agencies design funding programs to encourage observationalist-to-modeler interactions; many international research programs (e.g. WCRP) have a similar objective. The transfer of research model developments to operational modeling practice represents another essential and often missing step in developing useful predictive skill. This transfer does occur effectively in advanced numerical weather prediction centers of the WMO system, but many of those centers have ‘blind spots’ when it comes to polar regions. Here, as a thought process to help understand the potential impact of IPY research, we imagine three user groups, each group including researchers, operators, and decision makers, and then assess the IPY impact for each group. We use this approach to identify the potential for, or obstacles to, rapid development of polar prediction systems and skills.

Marine operations - Largely focussed on transportation and the Arctic, this group could include commercial shipping and resource (e.g hydrocarbon or fishery) extraction companies, insurance and regulatory bodies, port authorities, tour operators, and national policy- and decision-makers. IPY’s potential impact on this group would occur through improved predictive skills for ice, ocean, and marine weather, embodied in daily, monthly, seasonal and decennial forecasts. These forecast systems, probably with a national basis and focus (although necessarily with international data sources, and the Arctic Marine Shipping Assessment makes strong cases for pan-Arctic services and cooperation, noting, presciently, that less ice does not mean less danger), could and should make use of new IPY information on: sea ice formation, evolution and drift; ocean currents; high impact weather (including waves, storms, thaws, and surges); sea level; changes in hydrology and terrestrial water resources; aerosols, cloud systems and visibility; and seasonal to decennial trends for winds, currents and sea ice. In the near term, issues of year-to-year predicability will present large research and operational challenges, with a likely focus on vernal and autumnal transition seasons for both observations and predictions.

Carbon impact community - This group could include climate modelers, climate negotiators and regulators, national and international assessment groups, and a growing carbon-literate public. IPY’s potential impact on this group would occur largely through the development of improved global climate models, expressed through regular seasonal, decennial and centennial predictions and in periodic assessments. These modeling groups could and should use new IPY information on: ocean deep water formation and thermohaline circulation; northern terrestrial carbon sources and sinks; northern and southern oceanic carbon sinks and sources; polar wind regimes and upper ocean mixing; surface energy budgets over ice and snow; and changes in hydrology and snow cover and their influence on vegetation and fire. Predicting the timing and quantity of methane emissions from terrestrial and submarine permafrost would emerge as an issue of immediate urgency.

Natural resource managers - This group could represent present and future consumers and managers of polar marine and terrestrial ecosystem resources, health specialists, sociologists and community activists, economists, and local, regional and national governments. IPY’s potential impact on this group would occur through development of integrated ocean-atmosphere-ecosystem models with predictive skill for regional and local food abundance and quality; several models have emerged during IPY that show preliminary skill and great potential. These users could and should make use of new IPY information on: marine and terrestrial ecosystems; community adaptability and survivability; polar biodiversity; health impacts of regional (aerosols) or global (mercury, POPs) pollutants deposited in polar regions; condition, timing, and predicability of snow cover, lake and river ice, and sea ice; structural changes in permafrost;

options and mechanisms for local management and governance. Initial focus might turn toward food security in the Arctic and enhanced protection of key marine resource areas in the Antarctic.

Barriers to polar prediction skill

For each of our imaginary groups, we assign an urgency of need, and a probability of progress. Unfortunately, we score urgency as high but progress as slow or unlikely in every case. Why?

A challenging and urgent gap exists between the many observations and studies of polar systems undertaken during IPY and the development of useful predictive skill for integrated geophysical and biological (and Arctic social) systems. This gap has several causes. The natural tendency of science to focus on research publications represents a primary cause. A lack of suitable and capable predictive models for polar systems also contributes to the gap. Existing models may lack crucial types of polar observational data for input or verification. Or, models developed globally or for temperate regions may have substantial weaknesses (e.g. in surface flux parameterizations, in cloud properties, or in basic numerical design) when applied to polar regions. Even when good component models exist, the complexity of integrated geophysical, ecological and social linkages has generally deterred attempts at integrated modeling.

Meanwhile, our three user groups need robust predictive skill for key polar questions about ice, carbon and ecosystems; reliance on ‘climatologies’ or extrapolation of recent trends clearly will not provide sufficient guidance. IPY’s strength as an international program derives from its bottom-up and inclusive nature; in no other way would we have encouraged such broad scientific and political engagement. Now, however, IPY needs a prediction focus and framework, developed with leadership from and in partnership with organizations like the WMO, but covering the physical, biological and cultural features of polar systems, to quickly and effectively exploit IPY science for the benefit of imagined and real user groups, polar residents, and global citizens.

Several positive steps

One can easily identify positive accomplishments and trends across the range of IPY science and outreach activities. We focus here on integrating activities with potential utility to our three user groups, namely steps toward predictive skill for ice, carbon and ecosystems. Each of these skills includes direct linkages to and requirements for atmospheric science, but they also also broaden the prediction challenge by including biogeochemical, biological and human elements. We report several positive research, organizational and coordination steps within IPY, which develop from the inherent modeling interest and skills of many IPY researchers and from the high level of international cooperation.

During IPY, international groups (20 in 2008, 15 in 2009) have contributed monthly sea ice extent estimates leading up to the September Arctic sea ice extent minimum, sharing, freely and openly, their estimates as well as their techniques and reasoning. This collaboration, organized and compiled by the SEARCH program (http://www.arcus.org/search/seaiceoutlook/index.php), publicizes the skills of the groups and demonstrates the clear benefit of rapid sharing of information and ideas. It also will rapidly advance the understanding and prediction skill for Arctic sea ice!

In the Southern Ocean, observationalists and modelers (the distinction becomes less and less relevant) have cooperated to use the SOSE (Southern Ocean State Estimate, http://www.mit.edu/~mmazloff/SOSE.html) model to plan, guide and analyze an ocean tracer experiment. Using SOSE, an ocean observation assimilation system built around a state-of-the-art eddy-permitting ocean model, optimized to observations taken in 2005 and 2006, the DIMES (Diapycnal and Isopycnal Mixing Experiment, http://dimes.ucsd.edu/) investigators have deployed a tracer that will serve as the focus and target of international observational programs over the next three years. Using the SOSE assimilation framework to synthesize a wide range of IPY Southern Ocean observations seems quite feasible; analysis of such a state estimate will represent a hopeful step toward understanding and predicting the biology, chemistry, and dynamics of the Southern Ocean.

Through IPY-stimulated cooperation, operational weather and space agencies as well as national funding programs have produced some remarkable results. The WWRP-THORPEX cluster of IPY projects has generated new polar cloud, microphysics and surface flux data for improving physical parameterizations, improved high-latitude assimilation techniques for satellite data, advanced the use of ensemble simulations and observational targeting for high latitudes, and demonstrated the positive impact of increased Arctic and Antarctic observations on local and extratropical forecasting. The integrated observations of the Arctic Ocean during IPY, in which the combined international talents of chemical, biological and physical oceanographers has plausibly achieved the stated goal of "being able to measure almost any key environmental variable of interest almost anywhere and at almost any time" represents an extraordinary example of formal and ad hoc international cooperation among funding agencies of at least ten countries. The IPY Polar View project has established enhanced levels of integration among international sea ice services, making it easier for users to access sea ice information. Space agencies, particularly those operating synthetic aperture radars, have adjusted schedules, modified operational parameters, and offered enhanced free data access as they cooperated in the IPY Global Interagency IPY Polar Year Snapshot (GIIPSY) to produce unprecedented systematic coverage of ice sheets and ocean-ice margins. The European Centre for Medium-range Weather Forecasts (ECMWF) has made daily high resolution model fields available to IPY researchers through a portal at the Norwegian Meteorological Service. Many of these efforts would justify continuation if they could demonstrate useful predictive impact.

These examples of international cooperation and the examples of IPY sea ice and ocean mixing 'prediction' exercises represent just the tip of an iceberg. Many groups develop independent descriptions and models of regional ice-ocean-atmosphere coupling, permafrost degradation, vegetation propagation, snow accumulation, disease invasion, fishery adaptation, and human migration, to list only a few IPY activities. This abundance, this great variety of exploration and study, will lead to an improved and broadened knowledge of polar systems. However, without an an explicit prediction framework that continues to stimulate and support these efforts, that successfully draws them together, and that links them to operational observation and prediction services, this advanced and amazing IPY research and cooperation will not, or at least will not quickly, lead to integrated predictive skill.

IPY Legacy: A serious polar prediction effort

A WMO-organized network of national prediction centers routinely produce some useful forecasts of daily to weekly polar weather and weekly to seasonal ice conditions. These same groups work with the climate community of WMO to deliver some routine seasonal forecasts on a regional basis. Other groups produce global climate scenarios on multi-decadal to century scales. However, none of these products bring the full potential of IPY research together to addresses the topical needs or range of pertinent times scales envisioned for our polar user groups. We call for an immediate, high-level and sustained focus on polar prediction services, stimulated, led and coordinated by WMO, as the best way to integrate and synthesize the IPY observational efforts and to communicate and maximise the impact of IPY science. We encourage the Commission for Atmospheric Science of WMO, representing weather, climate, water and environmental prediction research, to find ways to do this. We believe that the WMO Executive Council Panel of Experts on Polar Observations, Research and Services has a mandate to help implement recommendations.

We suggest a prediction focus on snow, ice and air pollution (for weather, climate, sea level and transportation applications), carbon (for emission and ecosystem applications), and ecosystems (for future fisheries, forestry, biodiversity conservation, human and ecosystem health). Mutual dependencies will immediately emerge: prediction of carbon sources and sinks will require prediction of climate and ecosystem functions which will require predictions of sea and land ice. Producing polar predictions will entail risk (and require changes in thinking and funding), but will focus attention on quality and on understanding and meeting user (including public) expectations.

Predictions for polar regions will start from weather and climate. Very quickly, however, real prediction skill for snow and ice, carbon, and ecosystems will require assets of and cooperation from meteorology, hydrology, air chemistry, oceanography, glaciology, biology, ecology, physiology, sociology, and economics. While ability to model integrated physical-biological-human systems remains primarily a dream on global scales, polar systems represent a more geographically-manageable situation. Progress on prediction skill for integrated polar systems, while enormously difficult, will represent an important enabling step for other regional or global systems. A polar prediction system will force us to think operationally, to assess the timeliness and quality of observations (and, through simulation experiments, to determine elements of the IPY polar observations of greatest research and operational utility for sustained measurement), to develop and use polar data assimilation schemes, and to understand and meet user needs. The strengths of the WMO numerical weather prediction research and operational community at measuring prediction skill will apply here in a broader context. The joint verification research working group of the World Weather Research Programme and the Working Group on Numerical Experimentation of WMO and its co-sposored WCRP programme represents a useful place to start.

The design and development of a polar prediction system represents an appropriate and urgent task for the WMO Executive Council Panel of Experts on Polar Observations, Research and Services. A polar prediction system will draw and coordinate many research and operational elements of WMO and related agencies, of national modeling centers and of other polar science organizations into common purpose; the system will stimulate and support polar research in all it forms. A polar predictions system should represent the central motivating idea of a polar decade.

Source Materials

Arctic Marine Shipping Assessment 2009 Report. Arctic Council, April 2009.

High Latitude Ocean and Sea Ice Surface Fluxes: Requirements and Challenges for Climate Research. U.S. CLIVAR High Latitude Flux Working Group, 2009. Submitted.

Improvement of weather forecasts in polar regions. WWRP-THORPEX IPY activities in 2007-2008 (WMO Bulletin 56 (4) 2007).

ISAC 2009, The International Study of Arctic Change, Science Plan and Implementation Strategy. ISAC Program Office, Stockholm, Sweden. (M.S. Murray, editor).

The Integrated Arctic Ocean Observing System (iAOOS) in 2007. Arctic Ocean Sciences Board, 2008.

The Integrated Arctic Ocean Observing System (iAOOS) in 2008. Arctic Ocean Sciences Board, 2009.

THORPEX International Research Implementation Plan. Version 1, 14 February 2005. WMO/TD No. 1258

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