Broad Coordination Needed to Address Atmospheric and Coupled-system Gaps in the Central Arctic

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With increased global focus on Arctic sea ice and its dramatic recent changes, there is a growing community recognition of the need to improve coupled system understanding in the central Arctic. Moreover, it is becoming clear that the most impactful deficiencies in this domain are related to atmospheric processes. While there are many stakeholders for an improved Arctic coupled-system understanding, the modeling community is one of the strongest drivers of this need. Coupled system numerical models are the new frontier, with major efforts underway in many countries to develop fully coupled models for numerous forecasting applications. In light of the broad global interest in sea-ice forecasting, sea ice is a particularly good example of these primary deficiencies. Sea ice is an integrator of energy in the central Arctic system. Variability in the sea ice mass budget cannot be understood without also understanding energy fluxes from the atmosphere and ocean, energy exchange processes at crucial interfaces, interseasonal processes of heat storage and release, precipitation on sea ice, momentum transfer, ice deformation, and other processes. Simply observing sea ice in isolation does not provide the foundation needed to improve predictive skill for sea ice.

In recent years, some lines of disciplinary research have found great success in the Arctic Ocean domain, with significant advances in autonomous observations that allow for year-round, routine measurements of numerous ice and ocean properties (e.g., ITP and IMB buoys and others). These measurements are sometimes made together in clusters, facilitating studies of some aspects of the coupled system. However, similar advances have not been made in the realm of autonomous atmospheric measurements. While buoy-based systems exist for basic surface meteorology and some atmospheric gases, robust autonomous measurements are not currently available for the surface energy budget nor the processes responsible for its variability such as clouds and atmospheric thermodynamic profiles. These measurements are exceedingly difficult to make in an autonomous fashion due to extreme conditions, riming, the sophistication of necessary instruments, and other issues. Ultimately the atmosphere is the driver of most variability in the Arctic cryosphere; it is involved in most climate feedbacks, and atmospheric greenhouse gases are the root cause of climate change. To understand the central Arctic climate system, and improve sea-ice forecasting, requires an improved ability to obtain long-term atmospheric measurements in the central Arctic domain and to conduct the inter-disciplinary research that will provide a coupled system understanding.

Due to the complexity, expense, and scale of the deficiencies outlined here for the central Arctic system a legitimate attempt to address these issues requires significant national and international cooperation. There are two current promising pathways for progress where investment and coordination will lead to substantial advancement in both the short- and long-term.

1) *The Multidisciplinary drifting Observatory for the Study of Arctic Climate* (MOSAiC, www.mosaicobservatory.org). To make large advances in understanding many aspects of the coupled central Arctic system requires comprehensive, interdisciplinary observations, some of which use sophisticated instruments that cannot currently be operated in an autonomous fashion. While the movement towards autonomous sensors is important for continuity (see below), the scale of our current deficiencies and urgency with which they must be addressed warrant intensive, manned observations.

MOSAiC will be a drifting, manned station to facilitate coupled system observations of the atmosphere, ice, ocean and ecosystem in the central Arctic, surrounded by a constellation of autonomous sensors to capture spatial heterogeneity and variability. These assets will be installed in the newly forming autumn sea ice and drift for a full year with that ice, supporting coupled system observations over the annual cycle. Observations of many critical parameters such as cloud properties, surface energy fluxes, atmospheric aerosols, biological processes in the ice and ocean, and others have never been made in the central Arctic in all seasons, and certainly not in a coupled system fashion. The international scientific community recognizes that, if manifested, MOSAiC will provide an unprecedented step change in coupled system understanding and a foundation for coupled system research and modeling for the foreseeable future.

MOSAiC is an example where the scientific drivers are exceedingly strong and the potential for scientific advancement is high. As a result, there has been substantial excitement throughout the community on the potential it holds. The International Arctic Science Committee (IASC) has adopted MOSAiC as a key international activity, the German Alfred Wegener Institute has made the huge contribution of the icebreaker Polarstern to serve as the central drifting observatory for this yearlong endeavor, and the US Department of Energy has committed a comprehensive atmospheric measurement suite. MOSAiC will be an observational centerpiece for the WMO-sponsored Year of Polar Prediction (YOPP), which will bring together numerous enhanced observational and modeling activities over a multi-year period towards the advancement of polar prediction capabilities. Many other nations and agencies have expressed interest in participation and in gaining access to the unprecedented observational datasets that MOSAiC will provide. However, international coordination is not yet sufficient to support this groundbreaking endeavor and it likely will not be possible without substantially more US leadership and formal engagement from additional nations.

2) *Development of autonomous atmospheric systems.* To develop a longer-term understanding of the central Arctic coupled system that represents multiple years and diverse conditions also requires making sustained autonomous atmospheric measurements along with those that are currently made in the Arctic ocean and sea ice. Prior attempts to routinely measure atmospheric radiation faced difficulties related to riming and leveling, but these are solvable problems. Profiling atmospheric thermodynamic and dynamic structure, and observing cloud properties are substantially more difficult, but obtaining some estimate of how these interact with the surface is critical for understanding the current and evolving Arctic state. Various groups are currently working on buoy-based atmospheric observations, with leadership from the French and Norwegians. Further investment in robust technologies for obtaining reliable atmospheric measurements in the central Arctic are needed, and international coordination is imperative to provide the requisite financial backing, system development, network deployment and logistics support, and integration with other autonomous measurement systems. Manned campaigns like MOSAiC can serve as an important platform for development of such systems by providing a platform for all-season, in-the-field testing and adaptation of equipment.

To manifest MOSAiC and long-term autonomous atmospheric measurements, and maximize their benefit for stakeholders, these significant activities must rely on national and international coordination. To date there has been little coordination on “coupled system” observations in the central Arctic with an emphasis on better integrating atmospheric measurements. As a result these are the most significant gaps that inhibit shared priorities like sea ice forecasting. With a wealth of experience and capability, and the potential for strong collaborations with many nations, the US should provide leadership in this direction. Organizations such as the US Interagency Arctic Research Policy Committee (IARPC) must stand up to its mandate and develop truly interagency coordination on these important topics, rather than providing simply a collection of disparate individual agency contributions to Arctic research. Through IARPC, US agencies can and should formulate a cross-agency plan for committing specific resources to the MOSAiC and YOPP initiatives; moreover, this plan must take shape in 2016 to provide ample time for planning and coordination. Internationally, nations must develop the ability to more effectively coordinate their contributions through joint funding mechanisms and formalized leveraging of resources. Prioritization of joint research on key Arctic themes can capitalize on guidance from international organizing bodies such as IASC.