Arctic Essays

Faster Glaciers and the Search for Faster Science

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During a 1979 research cruise in the Bering Sea, Conrad Oozeva, a Native hunter from St. Lawrence Island, shared dozens of Yupik words for sea ice (**Fig. 12.1**). I recently looked at my notebook from that period and realized that some of those terms—such as *tagneghneq* (thick, dark, weathered ice)—refer to types of sea ice that are rare or non-existent today. That some of those Yupik terms—probably in use for thousands of years—would become obsolete in just a few decades attests to the rapid pace of change in the Arctic and to the impacts on indigenous peoples (Berman 2004; Oozeva et al. 2004; Ford and Pearce 2010).

Fig. 12.1. Brendan Kelly (author) and Conrad Oozeva aboard the USCGC *Polar Sea* in 1979.

For Arctic researchers, communicating the impacts of our discoveries has taken on an unprecedented urgency in the face of environmental change that—in many instances—is outpacing our ability to understand and explain the changes we are witnessing. Accustomed to advancing our scientific disciplines at what is often called a 'glacial' pace, we recognize that glaciers are not so slow anymore (Arendt et al. 2002; Howat et al. 2008; Schild et al. 2016). Before long, we may need to redefine 'glacial' to mean something that is rapidly diminishing or employ a different adjective. Glacial melts are accelerating, and—to serve society—we need to accelerate our science. Of the many steps in creating new scientific knowledge, some are more amenable to acceleration than others. The final step—communicating new knowledge—certainly needs to be sped up.

Scientists working in the Arctic and elsewhere increasingly recognize the importance of becoming more timely and effective in conveying what we know. And, what we know often is most valuable to policy makers and affected communities when we synthesize across disciplines and succinctly communicate the policy-relevant points. For example, researchers are combining observations and models in oceanography, atmospheric sciences, sea ice physics, and glaciology to understand the impacts of diminishing sea ice on mid-latitude weather (Rahmstorf and Coumou 2011; Francis and Vavrus 2012, 2015; Swain et al. 2016) and the melting of glaciers and ice sheets (Rahmstorf et al. 2015). A series of cross-disciplinary workshops have accelerated the pace of synthesis (https://usclivar.org/meetings/2017-arctic-midlatitude-workshop) by providing important and timely fora for translation among scientists across disciplines. Yet, we still need further translation-and condensation-to convey the state of the science to policy makers (https://www.youtube.com/watch?v=5eDTzV6a9F4). Accelerating our science means speeding up syntheses and improving our ability to effectively convey what we know.

In the United States, the science community has increasingly recognized the value of making scientific results broadly accessible since 1997 when the National Science Foundation adopted the description of broader impacts as one of the criteria for funding. Subsequently, organizations such as COMPASS (http://www.compassonline.org/OurHistory), the Leopold Leadership Program (http://leopoldleadership.stanford.edu/about/mission), the Union of Concerned Scientists (http://www.ucsusa.org/action/science_network/science-network-workshop-series.html#.V-7LWZMrJsM), and the American Association for the Advancement of Science (https://www.aaas.org/pes/communicating-science-workshops) developed effective trainings that help scientists communicate more effectively with diverse audiences. Science agencies and organizations, including NOAA (http://www.arctic.noaa.gov/Report-Card/), NASA (https://science.nasa.gov/science-news), and the American Geophysical Union (https://sharingscience.agu.org/) now provide fora for disseminating digests of new science.

The evolution of Study of Environmental Arctic Change (SEARCH) is a good example of how Arctic scientists increasingly are accelerating their science and communication. SEARCH was founded to advance understanding of the Arctic system and its trajectory through synthesis and modeling. From a scientific perspective, synthesis is an important step in an iterative process. It "is the critical last step before the design of the next experiment" (Patrick Webber quoted in Overpeck 2003). At its inception, SEARCH recognized the need to include a focus on synthesis (Morison et al. 1998). That early vision of SEARCH described observing and process studies at length but devoted less than 10% of the text to synthesis. That disparate treatment reflected, perhaps, the program's nascency. Five years later, NSF sponsored the Arctic System Science Synthesis Retreat in Big Sky, Montana that began with a careful contrast between synthesis and analysis and resulted in the projection that the Arctic is headed for a "super interglacial state" (Overpeck et al. 2005).

Inspired by the Big Sky synthesis, SEARCH's early focus on the interaction of ocean and atmosphere (Morison et al. 1998; Wang and Key 2003; Liu et al. 2005; Wang and Key 2005a,b) expanded to facilitating syntheses considering freshwater (Serreze et al. 2006; Holland et al. 2007; White et al. 2007; Francis et al. 2009; Rawlins et al. 2010), terrestrial ecosystems (Hinzman et al. 2005), marine ecosystems (Huntington et al. 2014), connections between the Arctic and the broader earth system (Serreze et al. 2000; Chapin et al. 2005; Huntington et al. 2007a; Francis and Vavrus 2012), and human dimensions of change in the Arctic (Huntington et al. 2007b; 2015). Other recent examples of Arctic syntheses efforts include reports on the evolving science linking Arctic sea ice loss to changes in mid-latitude weather (National Academy of Sciences 2014; Jung et al. 2015) and marine ecosystems (Bellard et al. 2012; Carmack et al. 2012; Post et al. 2013).

SEARCH and many in the Arctic research community have become increasingly convinced, however, that additional important syntheses combining scientific research and Indigenous Knowledge are needed. From a scientific perspective, synthesis may be important for designing the next experiment, but policy makers, local communities, and others look to syntheses to answer specific questions. Syntheses framed in policy-relevant forms (e.g., how much and how soon will sea level rise? Or, how soon will coastal erosion undermine our village?) are more valuable to these user communities than are framings focused on advancing the state of knowledge. And, the policy questions are becoming increasingly urgent.

SEARCH now brings together scientists as well as stakeholders and agencies to synthesize knowledge from many disciplines—syntheses intended to simultaneously increase the body of knowledge and address stakeholder questions. Recognizing it is insufficient to say, "Science isn't done until the journal article is published," SEARCH also believes that science isn't done until stakeholders use the science.

Translating science into forms usable by stakeholders' calls for translating technical information into language accessible to diverse audiences. SEARCH recognizes that many interested audiences are sophisticated but not facile with technical jargon. To improve communication with all stakeholders, we are developing "knowledge pyramids." Each knowledge pyramid assembles the state of the science concerning a societally important Arctic question in multiple formats ranging from one-page, jargon-free summaries at the apex of the pyramid (https://www.arcus.org/search-program/products) to original research publications at the base (**Fig. 12.2**). Thus, when asked about the state of the science concerning—for example—melting ice sheets and their impact on sea level rise, we would point a geologist to primary literature at the base of the pyramid; a scientist from another discipline to a review article (mid pyramid); a science journalist to a more condensed synthesis (e.g., an *Arctic Report Card* essay); and a Congressional staffer to a briefing paper in the apex. Naturally, the level at which someone enters the pyramid is not fixed and will vary with their specific background and interests. Especially important in this regard is the potential for the one-page summaries to be useful not only for policy makers but also for efficient communication among scientists of different disciplines. We believe that giving specialists windows in to each other's science will facilitate the multi-disciplinary collaborations necessary for a fuller understanding of environmental change in the Arctic. We would argue further that translating our research in to common language deepens our own understanding of our results and their broader implications.

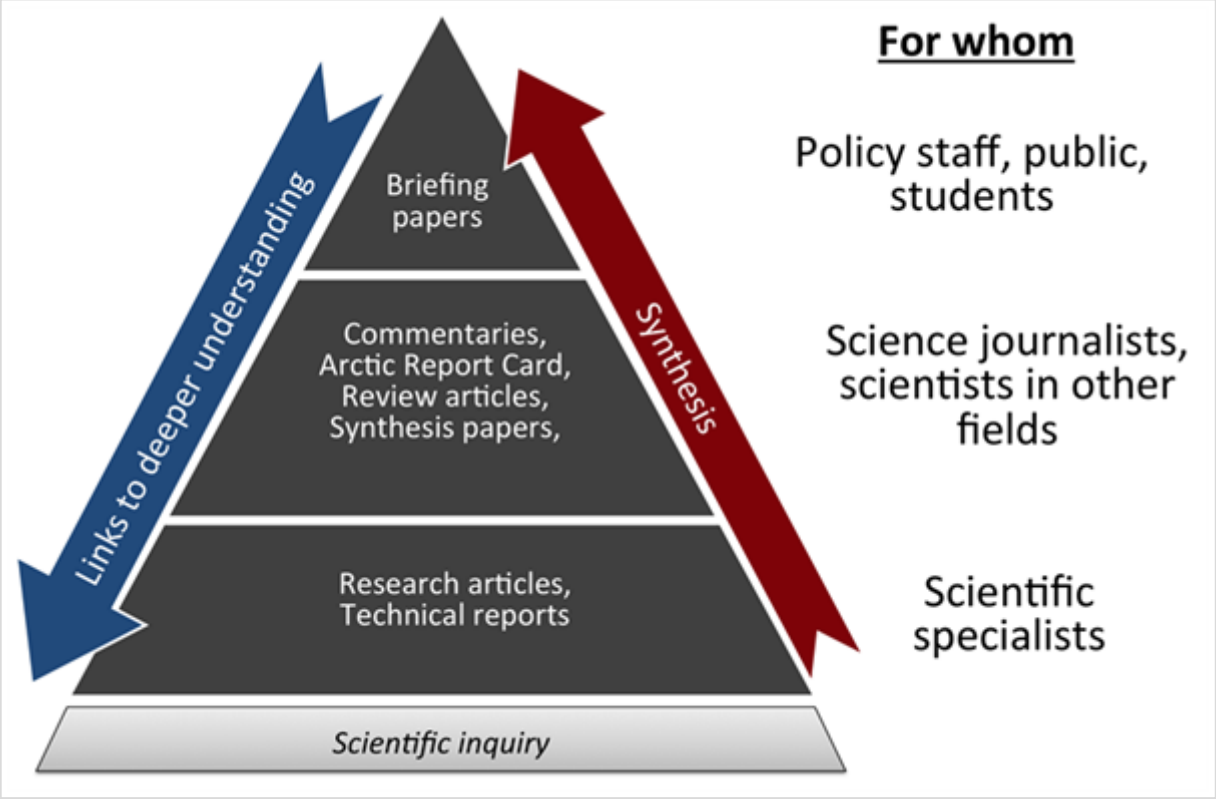

Fig. 12.2. SEARCH's concept of knowledge pyramids.

Similarly, we fully appreciate and honor the valuable information found in the differences between scientific and indigenous perceptions of the Arctic. When Conrad used numerous Yupik words to describe sea ice, which I would have referred to using a single term, he drew my attention to differences in ice characteristics that I had overlooked. Conrad's knowledge extends well beyond nouns; he is deeply knowledgeable about the exchange of energy and materials in the bio geophysical environment, as I learned when he and I co-taught a course in ecology. Our pupils were high school

students in a large wall tent on St. Lawrence Island. Early on, they expressed anxiety over choosing between Conrad's indigenous knowledge and my scientific knowledge. Conrad, however, disabused them of the notion that they faced a dilemma. He eloquently described how learning from his elders, his own observations, and the many scientists he had guided around the island expanded his understanding of his environment. You can apply all those types of information in your own understanding, he explained. Thus, he encouraged our students to synthesize.

The communities of St. Lawrence Island, like communities across the Arctic, are facing extremely rapid changes, some of which may make obsolete certain terms in their language. Such cultural losses may challenge those communities, but following Conrad's advice to synthesize—drawing on information from various sources—will likely enhance their resilience. The scientific community can also benefit from Conrad's advice to think across disciplines and his example of translating his knowledge for diverse audiences.

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