15 Years of Arctic Observation: A Retrospective

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First issued in 2006 to address the need for timelier communication of Arctic change to a broad audience, Arctic Report Card (ARC) 2020 marks the 15th anniversary of this annual, peer-reviewed publication. In recognition of this milestone, the ARC2020 editorial team has taken a step back to consider how observing, understanding, and communicating Arctic change have evolved over the course of the 15-year ARC series. To be clear, warming temperatures in the Arctic, and around the globe, were recorded decades before ARC2006 was published. A look back at ARC2006, however, reveals a community of observers who were just beginning to grasp the scope and persistence of the Arctic change we would witness and document over the next 15 years. Lost on most was the rapid rate of the changes to come. From the ARC2006 Executive Summary:

> *'...during 2000-2005 the Arctic system showed signs of continued warming. However, there are a few indications that certain elements may be recovering and returning to recent climatological norms (for example, the central Arctic Ocean and some wind patterns). These mixed tendencies further illustrate the sensitivity and complexity of the Arctic physical system. They underline the importance of maintaining and expanding efforts to observe and better understand this important component of the climate system to provide accurate predictions of its future state.'*

It did not take long into the ARC series to realize the Arctic region was on a path toward a 'new normal'. Dominating the 15-year storyline is the persistent and robust increasing trend in surface air temperature over the Arctic region. It is a trend that extends from the mid-1990s and continues to outpace the rate of increase in global temperatures by a factor of two. In response to the upward trend in air temperatures, there is an equally persistent and robust record of significant ice loss throughout the region during the 15 years of the ARC.

As it turns out, the first publication in 2006 coincided with a cusp of transformation in the sea ice cover, which is literally and figuratively central to the Arctic system. The 2007 September minimum sea ice extent stunned scientists and grabbed world-wide media attention with a new record minimum that was 23% below the previous record low set in 2005. Just five years later, in 2012, the 2007 record was overtaken by a September minimum sea ice extent that was 18% below 2007. The 2012 record low still stands as of 2020. However, in the 14 years since ARC2006 the late summer sea ice minimum extent has never returned to pre-2007 values. The impacts of this significant reduction in the extent of the summer sea ice cover, accompanied by equally notable changes in the thickness of the sea ice cover, reach well beyond the Arctic environmental system. Sea ice loss has significantly increased accessibility to Arctic waters for shipping and commercial enterprises. At the same time, these changes are challenging the traditional ways of life for coastal Indigenous communities. Reductions in the sea ice cover may also be linked to shifts in weather in the mid-latitudes.

There have been other consequential surprises. For example, 15 years ago, researchers were just beginning to see signals of rapid changes in the Greenland Ice Sheet, via the increasing rate of ice motion at glaciers on both coasts of Greenland. Currently, the Greenland Ice Sheet is losing ice mass at an average rate that is almost four times higher than reported at the turn of the century, just 20 years ago. At the current rate of ice melt, Greenland is the largest contributor to global sea level rise, increasing sea level 0.7mm/year. Arctic-wide glaciers and ice caps outside of the Greenland Ice Sheet also show a consistent trend of increasing ice loss, contributing approximately 0.4 mm/year. Taken together, these annual contributions add more to the global rise in sea level than Antarctica and are already acutely felt by coastal communities during storms, storm surges, and high tides. In the face of increasing air temperatures, changes to the Arctic snow cover over land during the past 15 years are in line with expectations: as air temperatures have warmed, snow cover has melted earlier in spring, and started to accumulate later in autumn. However, at -15.5% per decade over the period 1981-2020, the rate of loss of the terrestrial snow cover extent in June exceeds even the high pace of sea ice reduction in September, which is -12.8% per decade. Fifteen years ago, the notion that widespread degradation of permafrost on Alaska's North Slope would start before the end of the 21st century was still in question. Yet, as documented in ARC, permafrost loss in this region of the high Arctic is already widespread and impacting coastline stability, built infrastructure and terrestrial ecosystems. Today, it is anticipated that progressive deep thawing of permafrost in this region may begin in 30-40 years.

The ARC series has also exposed the connections and complexity within the Arctic environmental system. For instance, with each summer there has been a progressive warming of surface waters in the seas that surround the Arctic Ocean, which is associated with the decrease in sea ice extent. The loss of sea ice allows for increased solar energy absorption by the relatively dark ocean surface, leading to an increase in sea surface temperatures. The increase in sea surface temperatures, in turn, leads to more melting of the sea ice cover. Similarly, the increased melting of terrestrial snow and land ice, which reflect sunlight, increasingly exposes the darker land surfaces, which absorb the sunlight. Through these linkages, the sustained ice and snow melt and warming sea and land temperatures in the Arctic have drawn attention to the dominant role of the ice-albedo feedback, one of the most prominent global climate feedbacks. The ARC series also illustrates that changes in the characteristics of the sea ice cover, ocean, and land cascade into changes in the marine (e.g., increases in primary productivity, fish distribution, bowhead whale feeding behavior) and terrestrial ecosystems (e.g., increases in vegetation growth on the tundra, increasing wildfire activity, increasing coastal erosion).

The ARC series reveals a storyline that goes beyond long-term trends. Enveloping every strong trendline is the equally strong signal of interannual variability, evident by the year-to-year jumps that are ubiquitous throughout the climate records showcased by the ARC. It is these jumps, superimposed on the climate trends, that have often stolen the show during an ARC press release, especially when they are associated with new records (e.g., extreme air or ocean temperatures, extreme ice loss, etc.). Much research is concentrated around understanding the underlying causes behind interannual variability, realizing that this variability provides a window into the connections throughout the Arctic and global systems and the forces driving the observed trendlines. Connections throughout the Arctic system and linkages between the Arctic and global environmental systems are now much better recognized and understood than they were 15 years ago. However, much work remains to be done, motivated by the awareness that knowledge gained in understanding these connections and linkages is a key to improved predictions of future change, on seasonal to decadal time scales. Improved predictions enable improved planning capability for local, regional, and global populations who must anticipate, cope, and adapt to the warming environment.

The intensity of the change in the Arctic environment, peppered by numerous record setting events, has broadened the awareness of change and concerns around the associated impacts well beyond the Arctic research community. With the increased awareness has come increased resources, enabling more research, encouraging interdisciplinary project teams, improving research and communication networks, increasing access to data and commercial resources, and facilitating international and national cooperation. Important technological advances have also been made; chief among them are satellite-based observational capabilities. The Arctic is a harsh environment that challenges the deployment and maintenance of long-term in situ observational networks. Satellites offer a remote platform that allows a continuous pan-Arctic perspective, with many observations that are widely available in near-real time. For instance, development of gravity measurements from space (especially the GRACE and GRACE-FO satellites) have revolutionized measurements of changes in land-based ice masses. Similarly, advances in satellite-based altimetry, employed by CryoSat-2 and ICESat-2, are providing unprecedented new data on sea ice thickness and the depth and distribution of snow on the sea ice cover. High resolution satellite imagery is also proving an essential tool for daily wildfire management in Alaska and northwest Canada and for understanding the details of changes in tundra vegetation. With that said, in situ observations continue to provide an important complement to remote sensing observations, often providing insight on causality. The recent MOSAiC project, highlighted in ARC2020, is an excellent example of how resources and research can come together, across international lines, to provide step changes in documenting and understanding the changing Arctic. When it comes to documenting climate-related changes, it important to acknowledge the need for sustained observational records that extend for decades. The challenge standing in the way of achieving multi-decadal observational records is typically funding and coordination, as opposed to technology.

One of the most important changes to take place over the course of the ARC series is the increased recognition of the roles of Indigenous Peoples of the Arctic for understanding Arctic change. There is a growing appreciation for the deep and long-term knowledge of the environment held by those who have called the Arctic home for millennia, who are an integral part of the Arctic system on which their lives depend. Though this Indigenous knowledge base seems an obvious resource, respectful and equitable partnerships with Western scientists have been long in coming and are very much a work-in-progress. ARC2019 welcomed the first contribution from members of Indigenous communities, highlighting changing conditions in the Bering Sea region. The contribution was enthusiastically received. Having taken this first step, the ARC remains committed to routinely featuring the voices of Indigenous Peoples and knowledge from Indigenous-led research, helping to facilitate an increase in the exchange and inclusion of information from diverse knowledge systems.

Over the course of its 15 years, ARC has achieved the goal of providing timely updates on the state of the Arctic environment to an increasingly broad and diverse audience. The annual ARC press release has become highly anticipated by the national and international news media and generates one of the most widely viewed events on NOAA's Climate.gov website. This achievement reflects the work of hundreds of people. Many have contributed their time and expertise to the writing and editing of the essays, which form the core of every ARC. Behind the scenes are also teams producing the webpage, developing highlight videos, guiding the content format, organizing and promoting the public release, implementing the peer review, participating in the peer review…the list goes on. To each and every one of you, a hearty 'Thank you!' for your important contributions. The ARC team looks forward to continuing to provide annual updates on the state of the Arctic, documenting the condition of this unique and fascinating region that is an integral part of our planet.

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