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Authors: Alexander, Clarence, Bynum, Nora, Johnson, Elizabeth, King, Ursula, Mustonen, Tero, et al.

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# Linking Indigenous and Scientific Knowledge of Climate Change

CLARENCE ALEXANDER, NORA BYNUM, ELIZABETH JOHNSON, URSULA KING, TERO MUSTONEN, PETER NEOFOTIS, NOEL OETTLÉ, CYNTHIA ROSENZWEIG, CHIE SAKAKIBARA, VYACHESLAV SHADRIN, MARTA VICARELLI, JON WATERHOUSE, AND BRIAN WEEKS

*We explore the connections among indigenous climate-related narratives, documented temperature changes, and climate change impact studies from the scientific literature. We then propose a framework for enhancing synthesis of these indigenous narratives of observed climate change with global assessments. Our aim is to contribute to the thoughtful and respectful integration of indigenous knowledge with scientific data and analysis, so that this rich body of knowledge can inform science and so that indigenous peoples can use the tools and methods of science for the benefit of their communities if they choose to do so. Improving ways of understanding such connections is critical as the Intergovernmental Panel on Climate Change Fifth Assessment Report process proceeds.*

*Keywords: climate change, observed impacts, indigenous knowledge, assessment, temperature change*

**I**ronically and tragically, climate change is being experienced by many indigenous communities that have not participated in the industrial activity that is its primary cause. Climate change's negative effects on indigenous communities go beyond immediate threats to food supply (Differbaugh et al. 2007, Parry et al. 2007) to encompass aspects of health such as susceptibility to diseases as epidemiologies are affected by environmental factors (McCarthy et al. 2001, NAST 2001) and as long-lasting cultural disturbances and losses affect well-being (Green et al. 2009, Sakakibara 2008, 2009).

In this article, we explore possible complementarities among indigenous and scientific knowledge systems and discuss the potential for enhancing integration of indigenous observations of climate change with global assessments such as those of the Intergovernmental Panel on Climate Change (IPCC). Because the IPCC is subject to intense public scrutiny, it tends to rely primarily on information from peer-reviewed scientific studies and, in the past, has largely excluded traditional indigenous knowledge as a source of information for its assessment reports as a result of a general bias against evidence from non-peer-reviewed sources. *Science*—here, defined as a set of statistically analyzed data or instrumental records—rests on precise definitions of independent and dependent variables that can be empirically measured and that demonstrate acceptable levels of reliability and validity. Such quantitative rigor is not necessarily at the core of *indigenous knowledge*, which can be defined as

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*“Traditional knowledge is still under-used by science, although it is of great value and can contribute significantly to the development of humankind.”*

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—Chief Vyacheslav Shadrin

“knowledge that an indigenous or local community accumulates over generations of living in a particular environment” ([www.unep.org](http://www.unep.org)).

However, we have found that indigenous knowledge can provide complementary information that has particular value in determining patterns of climate change for regions in which there are limited instrumental records. It can provide a broader picture of the impacts of climate change by putting scientific changes in the context of a human landscape. Although they are relatively limited in number, the indigenous knowledge records presented here represent different global regions and illustrate their general validity and potential usefulness.

## Traditional ecological knowledge

*Traditional ecological knowledge* (TEK) is a subset of indigenous knowledge that can be understood as “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment” (Berkes 1999, p. 8). TEK is often an integral part of the local culture and environment and sometimes includes management advisories adapted to specific areas. TEK can include diverse kinds of narratives or observations by an indigenous person or group (Menzies and Butler 2006). These narratives, in turn, can provide intergenerational observations of various kinds of natural resource phenomena.

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Since the 1980s, various forms of TEK have come to be commonly accepted by scientists in the fields of agriculture (Warren 1995), pharmacology (Schultes 1989), water engineering (Groenfelt 1991), architecture (Fathy 1986), ethnobotany (Nebhan 2002, Schultes and von Reis 2008), ethnozoology (Clement 1995), irrigation systems (Mabry 1996), soil and water conservation (Reij et al. 1996), and ethnoastronomy (Celi 1978) and by social scientists (Nelson 1980, Feld 1982, Freeman 1984, Allen 1998). TEK can be found all over the world, particularly within indigenous traditions across diverse geographical regions from the Arctic to the Amazon, and represents various understandings of ecological relationships, spirituality, and traditional systems of resource management. In recent decades, resource managers have gradually begun to embrace the usefulness of applying TEK to contemporary stewardship issues in various parts of the world (WCED 1987, UN 2008).

There are both similarities and differences between TEK and Western science (Berkes 1993, 1999, Ingold 2000). The recent and increasing academic and scientific interest in TEK has created a new reciprocal relationship that facilitates a synthesis of the two worlds through dialogue (Huntington 1992, Albert 2001, Fox 2003, Brewster 2004, ELOKA 2010). Although the path for integration of TEK with Western science for environmental management is new, there are now constructive opportunities for indigenous and scientific communities to collaborate, as in this case, on the crucial issue of climate change.

We are aware that any attempt to join scientific and indigenous knowledge systems may reflect the history of power relationships between indigenous groups and nonindigenous groups (Simpson 2004). We further recognize that traditional knowledge is not uniform, even within small communities, and that there can be substantial variation in the substance of TEK reported in what appear to be

homogenous indigenous communities. Our aim is to contribute to the thoughtful and respectful integration of indigenous knowledge with scientific data and analysis so that this rich body of knowledge can inform science, and science can in turn perhaps contribute tools and methods that will allow indigenous communities to make informed decisions about their current situations and future prospects. Faithfully representing the people, voices, and history that hold much of the richness of indigenous knowledge is difficult, but by opening a pathway for the meaningful exchange of information, we hope that efforts to understand, adapt to, and mitigate climate change will be strengthened. This is especially true if the intent is to develop a methodology that might serve as a building block for similar comparisons in the future, and in which findings may be aggregated to build a larger body of knowledge.

### Climate change

For many indigenous communities, climate change is already altering physical, biological, and social systems. Initiatives such as the *Stories of the Raven* detailed such changes in narratives set forth at a three-day meeting with representatives from all circumpolar nations and various indigenous peoples (Mustonen 2005). The Arctic Climate Impact Assessment (ACIA 2005), prepared by more than 300 participants from 15 countries, includes many examples drawn from the local traditional knowledge of Inuit, Sami, Athabaskans, Gwich'in, Aleut, and other Arctic indigenous peoples. These publications demonstrate some of the possibilities for bringing diverse groups together to frame challenges related to climate change.

To further explore the challenges that climate change poses to indigenous groups and the role of indigenous knowledge in responding to climate change, the Center for Biodiversity and Conservation of the American Museum of Natural History (AMNH) brought together a panel in 2008 on indigenous

#### Box 1. Participants in the Panel on Indigenous Peoples and Climate Change at the Sustaining Cultural and Biological Diversity in a Rapidly Changing World: Lessons for Global Policy Conference, American Museum of Natural History, 2–5 April 2008.

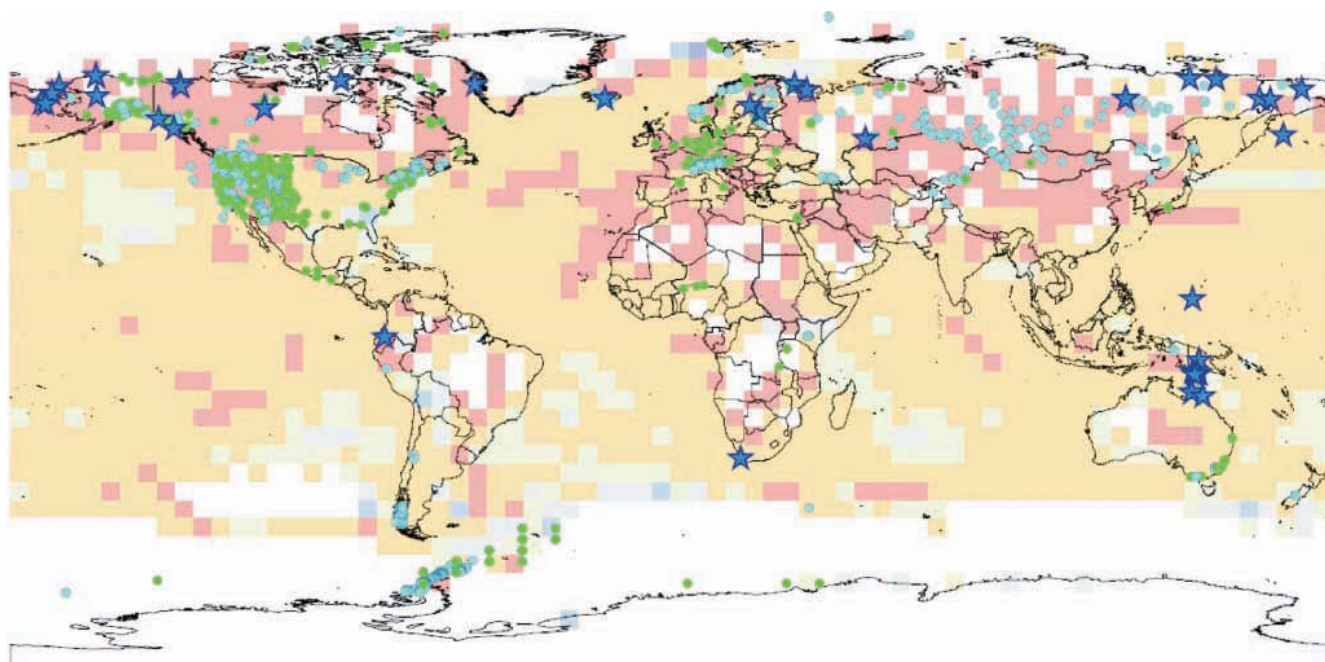
Chief Clarence Alexander, Yukon River Inter-Tribal Watershed Council, United States.  
 Nora Bynum, American Museum of Natural History, United States.  
 Violet Ford, Inuit Circumpolar Council, Canada.  
 Elizabeth Johnson, American Museum of Natural History, United States.  
 Ursula King, National Centre for Epidemiology and Population Health, Australian National University, Australia.  
 Tero Mustonen, The Snowchange Cooperative, Finland.  
 Peter Neofotis, Climate Impacts Group, Columbia University; and City University of New York, United States.  
 Noel Oettlé, Environmental Monitoring Group, Nieuwoudtville, South Africa.  
 Cynthia Rosenzweig, NASA Goddard Institute for Space Studies, United States.  
 Chie Sakakibara, Appalachian State University, United States.  
 Chief Vyacheslav Shadrin, Head of the Yukaghir Elders Council, Russia.  
 Marta Vicarelli, Columbia University, New York City.  
 Jon Waterhouse, Yukon River Inter-Tribal Watershed Council, United States.  
 Ellen Wiegandt, Graduate Institute of International and Development Studies, Geneva, Switzerland.

peoples and climate change as part of a larger conference titled Sustaining Cultural and Biological Diversity in a Rapidly Changing World: Lessons for Global Policy (April 2–5, <http://symposia.cbc.amnh.org/biocultural>). The panel consisted of indigenous group leaders, scholars of indigenous knowledge, and climate change impact scientists (box 1). The goal was to provide some initial findings regarding the following questions: (a) Are indigenous communities experiencing and responding to climate change? (b) Do indigenous narratives relate to observed changes in temperature and other climate variables and vice versa? (c) Do indigenous narratives relate to climate change impact studies and vice versa?

Fifty-seven indigenous narratives describing climate change and its impacts were gathered from sources provided by the panel participants at the AMNH conference. The sources were either formal presentations or papers contributed by some of the conference participants, representing observations from certain indigenous groups or communities (Mustonen 2005, Oxfam America 2007, Archer et al. 2008, Rhoades et al. 2008, Sakakibara 2008, 2009, 2010, Castillo 2009a, 2009b, Green et al. 2009). The narratives were

assembled in a database and characterized by source and indigenous group, as well as by latitude and longitude. The latter represents the central location of the climate change impacts, either provided by the participants or approximated using NASA World Wind (<http://worldwind.arc.nasa.gov/download.html>) (figure 1). The narratives provided by the indigenous conference participants add a needed human dimension to the scientific observations of climate change. We focused on compiling narratives relating to climate change and not on compiling those documenting factors at work other than climate change. The observations were categorized as to whether the reported changes were expected symptoms of regional warming or cooling.

A geographic information system (ArcView GIS 9.3.1; Esri, Redlands, California) was used to overlay the locations of the narratives with temperature changes from 1970 to 2004 and with data from peer-reviewed studies documenting physical and biological climate-related changes (Rosenzweig et al. 2008). Two different gridded observed temperature data sets were used: HadCRUT3 (Brohan et al. 2006) and GHCN-ERSST (Smith and Reynolds 2005).



Indigenous knowledge database:

- ★ Physical, biological, and social changes

Rosenzweig and colleagues (2008) database:

- Physical systems (cryosphere, hydrology, coastal processes)
- Biological systems (marine, freshwater, and terrestrial)

Temperature change (°C)  
1970–2004



**Figure 1.** Locations of physical and biological changes described in indigenous narratives and in peer-reviewed scientific studies overlaid on global HadCRUT3 temperature trends (Brohan et al. 2006). The circles represent locations of statistically significant trends in changes in either direction in systems related to temperature change or to other climate change variables and that contain data from at least 20 years between 1970 and 2004 (Rosenzweig et al. 2008). The stars indicate the central location of the climate change impacts described in the indigenous narratives provided by the panel participants.

### Narratives related to impacts and adaptation

The collected narratives were related to the impacts of and adaptations to changing climate in North America, Europe, Asia, Oceania, Latin America, and Africa, but in this article, we focus primarily on the Northern Hemisphere high latitudes, where the predominance of the indigenous narratives from the participants originated. The assembled knowledge indicates in an exploratory way widespread impacts on indigenous populations perceived to be caused by global climate change. We acknowledge that the individual holders of indigenous knowledge are diverse and that reports from a number of individuals might reveal a wide range of observations. Future work in this area should involve more narratives from a larger group of participants and should involve further qualitative analysis and synthesis of the narratives. If narratives are to contribute to specific resource-management decisions, interviews with multiple observers and experts should be conducted, and all available sources of information should also be synthesized. However, even in its present form, this means of gathering individual narratives and knowledge mapping from the perspective of indigenous communities offers a view of the impacts of climate change experienced by local communities, broadening the understanding of climate change beyond what is measured by instruments (e.g., sensors that monitor glacial wastage).

#### Northern high latitudes

In the northern high latitudes, particularly in North America and Asia, recent warming has resulted in physical, biological, and social changes in many communities (Parry et al. 2007). These alterations are often complex, and applying directional generalities can be difficult. However, changes in the northern high latitudes, found at multiple locations by multiple groups, have several shared characteristics:

**Many polar animals are being affected negatively.** The melting of snow and ice and increased variability has had a profound effect on the migration patterns of some birds and mammals, with several species of fauna particularly affected. These species include the bowhead whale (*Balaena mysticetus*) and the reindeer (*Rangifer tarandus*); the latter also shows signs of malnourishment (Mustonen 2005, Sakakibara 2009).

**Hunters are often having less success.** Changes in animal behavior, often accompanied by signs of stress, have caused problems for some indigenous hunters (Mustonen 2005, Sakakibara 2008, 2009).

**Hazards are increasing.** There are some reports that thinning ice jeopardizes modes of transportation, and that melting permafrost destabilizes community infrastructure (Mustonen 2005, Sakakibara 2008).

**Exotic species are appearing.** Rarely encountered or exotic species, such as willow trees (*Salix* spp.) and beavers (*Castor canadensis*), are migrating into some areas. Mosquitoes are increasing in abundance in some places. Some of these species

changes necessitate the development of new food-gathering strategies (Mustonen 2005, Sakakibara 2008, 2009, 2010).

**Forest fire frequency appears to be increasing.** In some places, adversely affected land mammals, such as caribou (*Rangifer tarandus groenlandicus*), are modifying their migratory patterns, and causing geographic and temporal changes in indigenous livelihood practices (Mustonen 2005).

#### Oceania, Latin America, and Africa

Some of the narratives from Oceania, Latin America, and Africa (which were of limited numbers in this collection) relate to impacts affecting health, coastal livelihoods, water resources, and food production, as well as adaptation to changes in climate regimes. For example, the impacts of climate change on the indigenous peoples in Australia may bring disproportionate burdens:

For many indigenous people, a connection with “country”—a place of ancestry, identity, language, livelihood and community—is a key determinant of “health”... Therefore, as ecosystems change due to biophysical impacts and extreme weather events, many traditional owners living in remote areas are likely to face increased physiological, psychological, economic and spiritual stress as it becomes more difficult to “look after their country.” (Green et al. 2009)

On the north coast of Australia, Aborigines have reflected on how climate change-induced animal migrations and sea-level rise threaten their own survival and identities (Castillo 2009a, 2009b). For example, saltwater intrusion threatens the Kowanyama, a coastal Aboriginal community in tropical Queensland, Australia. The delicate balance of freshwater from the rivers and ocean saltwater has in the past nurtured the life of the area. However, the Kowanyama report that the tide comes farther and farther inland each year, threatening terrestrial plant and animal life and freshwater ecosystems (Castillo 2009b). In the Torres Strait Islands, off the far north coast of Australia, the Saibai have adapted to higher sea levels by raising their homes on stilts, a return to traditional housing design (Green 2006). In Peru, changing climate regimes, a result of melting glaciers, have had detrimental effects on water supplies (Rhoades et al. 2008). In South Africa, droughts have had an influence on the methods of farming used to produce traditional teas (Archer et al. 2008).

#### Spatial correspondence of indigenous observations and temperature changes

To explore the complementarities of indigenous and scientific knowledge, we first overlaid the geographic locations of the narratives onto a map of observed temperature data. We found that the majority of the narratives were from indigenous communities located in temperature cells with measured temperature increases (figure 1).

Narratives of observed changes in the northern high latitudes coincide with instrumentally observed changing temperature trends for the region (Parry et al. 2007). For several decades, the surface air temperature in the Arctic has risen at approximately twice the global rate (Trenberth et al. 2007). The warming trend is strongest over the interior parts of northern Asia and northwestern North America (ACIA 2005, Trenberth et al. 2007). Together with the Antarctic Peninsula, these are the most rapidly changing areas on the globe (Turner et al. 2007).

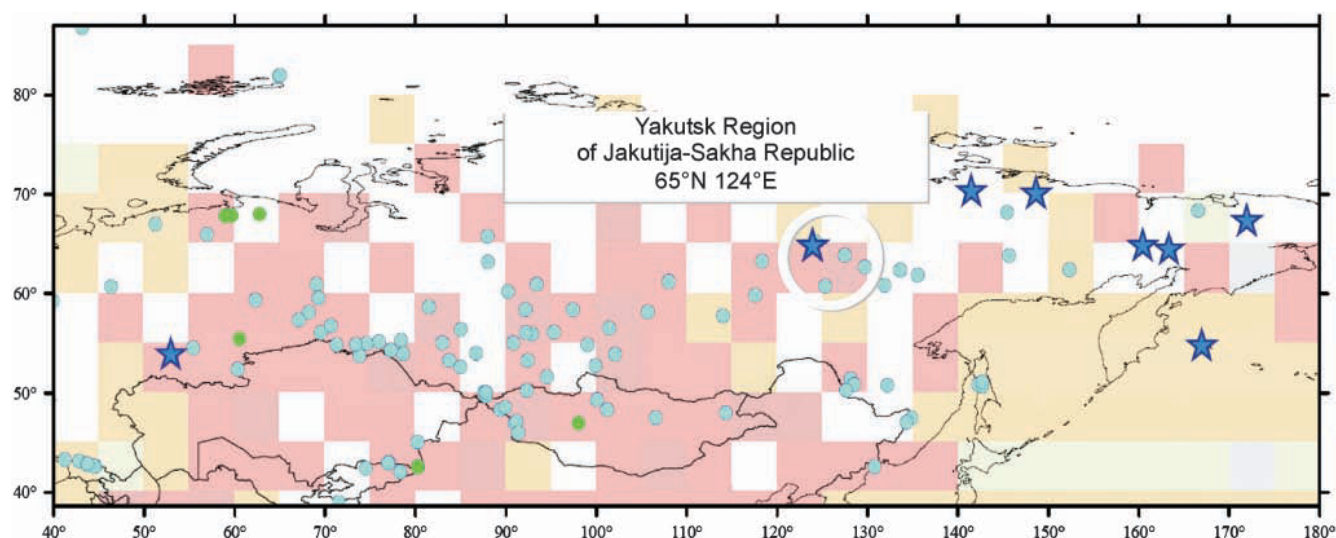
Narratives of warming effects that were located in cells with observed cooling may be a result of local warming's not being actively measured by scientific instruments and thus not contributing to aggregation at the  $5 \times 5$  grid-box scale or may be related to global effects of warming, such as sea-level rise, rather than to local warming per se. Indeed, the six narratives from the Torres Strait north of Australia from cooling cells were all related to sea-level rise. These are six of the eight narratives located in grid cells with significant cooling. The two other such narratives were located in cells in Europe with slight cooling ( $0^\circ$  to  $-0.2^\circ$  Celsius), and the observed impacts there—both in the direction of warming, despite the slightly cooling grid cell—were related to animal

migrations that could be influenced by the strong warming in adjacent grid cells.

### Linking to impact studies

To bring indigenous and scientific knowledge into a similar geographic context, we compared the locations of indigenous narratives with the locations of data series of observed changes included in peer-reviewed impact studies (Parry et al. 2007, Rosenzweig et al. 2008; figure 2; box 2). Many of these data series were over 35 years in length.

We found that the peer-reviewed observations of climate change impacts and the indigenous narratives located in the same cell were complementary, in that they both corresponded to system changes consistent with local-area warming temperatures. The presence of indigenous narratives in grid cells for which there may not be studies of climate change impacts showed that the indigenous narratives expand our knowledge of climate change impacts to regions that do not have scientifically documented changes. If this and other indigenous knowledge databases were to be expanded, more narratives from Oceania, Latin America, and Africa could prove very useful to climate science, since these are regions of the world



**Figure 2.** Observed climate change impacts in Yakutsk, Russia, where changes described by indigenous narratives were located within 250 kilometers of observations from the peer-reviewed scientific literature (white circle). The blue circles represent locations of statistically significant trends in changes in either direction in systems related to temperature change or to other climate change variables and that contain data from at least 20 years between 1970 and 2004 (Rosenzweig et al. 2008). The stars indicate the central location of the climate change impacts described in the indigenous narratives provided by the panel participants.

#### Box 2. Narratives and evidence from the Yakutsk region.

“Lakes are sinking as the permafrost melts, which means many fishing lakes have been lost. People have to go further, which is hard as the price of fuel goes up. Reindeer herders select routes based on weather forecasts so mistakes have detrimental effects.”

Source: Vyacheslav Shadrin, Head of the Council of Yukagir Elders, 2005.

Mean monthly soil temperature data for 1930–1990 indicate that as temperatures have been rising, the active layer of permafrost has been deepening and the freezing depth has become more shallow.

Source: Frauenfeld et al. 2004.

generally lacking extensive long-term scientific data records of climate change impacts. We hope that development of this complementary framework will foster narratives and studies from other places in the world.

### Side-by-side approach

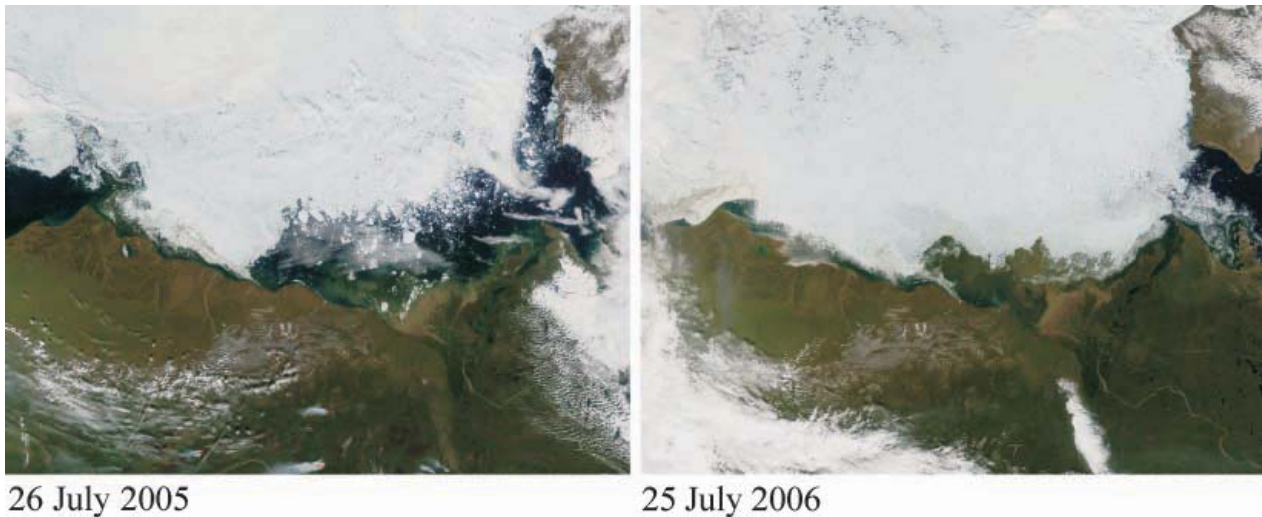
We next identified places where the indigenous knowledge observations were located within 250 kilometers (km) of data points from peer-reviewed studies. The stars on the map in figure 2 indicate the central location but do not cover the full extent of the region occupied by the indigenous groups and described in their narratives. For instance, the Iengra region, which is occupied by the 12 nomadic and seminomadic Yukaghir tribes, is a vast area covering multiple cells with significant warming (each cell being about  $500 \times 500$  km). These examples further demonstrate how the two knowledge systems can complement each other (box 2). In Russia, changes in the ice and water content of lakes and streams, along with detrimental impacts on reindeer herders, coincide with

climate-induced changes in seasonal freeze and thaw depths of permafrost (Frauenfeld et al. 2004). Further investigation into the relationships among these and other collocated reports is likely to yield more correspondences.

Indigenous narratives have also been linked with scientific data sets in other geographic areas (figure 3, box 3; Sakakibara 2009). In several Iñupiaq indigenous narratives, the changes in sea ice and whale migrations that have affected hunting success were described. This effect influences the Iñupiaq's spiritual and physical ties with the whale in relation to traditional musicmaking (Sakakibara 2009). These narratives were linked to NASA Earth Observations Records (NASA 2007). As time series of remotely sensed data become longer, further links between narrative and scientific observations may be found.

### Fostering connections

We found that indigenous knowledge can provide complementary information about climate change that has value in



**Figure 3.** Indigenous observations and remotely sensed data related to near-shore sea ice and whale hunting. Images of the Beaufort Sea, north of Alaska, and Canada's Yukon and Northwest Territories. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured these images on 25 July 2005 and 25 July 2006. Images: Courtesy of Jeff Schmaltz, MODIS Rapid Response Team at NASA Goddard Space Flight Center.

### Box 3. Narratives and evidence from the Beaufort Sea area.

Many Iñupiaq interviewees emphasized that the ice condition was out of the ordinary in both 2005 and 2006... An elderly captain stated that the 2006 spring season harvest in the North Slope Borough was the lowest in the past 35 years.

Source: Sakakibara 2009.

"Those poor whales out there in the ocean that we depend on. Are they going to come back to us? Are they going to really show up next year, like our ancestors always expected them for 20,000 years? We are heartily concerned."

Source: Earl Kingik, Iñupiaq tribesman.

Record melting during 2005 allowed old, thick ice from the north to drift into the Beaufort Sea. Some of this ice from the increased melting was pushed by wind toward the shore in 2006.

Though there was more ice in the Beaufort Sea at the end of July 2006 than there had been in previous years, the Arctic as a whole continued to melt at an ever-quickening pace. By June 2006, sea ice in the Arctic covered 1.2 million fewer square kilometers than the long-term average measured between 1979 and 2000. This put sea ice concentrations (the percentage of ice that covers a predefined area) at a record low for June, breaking the record set in June 2005, during which sea ice extent was down 0.8 million square kilometers from the average.

Source: NASA Earth Observatory 2007.

determining patterns for regions in which there are limited instrumental records. Furthermore, these narratives promote an expanded and multidimensional picture of the impacts of climate change by placing these changes in the context of a human landscape. Our indigenous knowledge assemblage is still at an embryonic stage, but we find these preliminary results promising and such linkages important to understanding climate change. Collating indigenous narratives in parallel with peer-reviewed studies represents a valuable approach to deepening assessments of the impacts of climate change and to sharing adaptive strategies. Indigenous knowledge, especially from remote areas, can contribute to a significant expansion of global knowledge and understanding of warming and sea-level rise that are already under way. This method of knowledge assemblage could also offer a voice to the larger universe of other resource-dependent communities beyond indigenous ones.

Currently, indigenous narratives are minimally included in the IPCC or other global assessments of climate change, because changes observed by local people are not frequently documented in peer-reviewed studies and are thus subject to the bias against non-peer-reviewed evidence. Yet indigenous narratives provide a rich source of information based on multi-generational knowledge about local climate that can contribute a great deal to science assessments, such as the IPCC, that provide policy-relevant information. Indigenous knowledge often deepens understanding about what climate change means for livelihoods, cultures, and ways of life beyond the understanding provided by statistically significant changes reported in the scientific literature. These narratives show that global climate change has already affected integrated physical, biological, and social ecosystems, especially in the northern high latitudes.

Guidance for the process of integrating indigenous narratives may be provided by the Convention on Biological Diversity (CBD), which has advanced a code of ethical conduct (a) to respect, preserve, and maintain the knowledge, innovations, and practices of indigenous and local communities embodying traditional lifestyles relevant to the conservation of biological diversity and sustainable use of natural resources; (b) to promote the wider application of indigenous knowledge with the approval and involvement of the holders of such knowledge; and (c) to encourage the equitable sharing of the benefits that arise from the utilization of such knowledge.

The IPCC could similarly provide guidance for how to include traditional knowledge in its assessments. Such a process of inclusion would enhance the IPCC Fifth Assessment Report process, which is now under way. Following and adding to the principles set forth by the CBD, this process could include (a) the full participation of indigenous and local communities in the detection and description of climate change impacts; (b) consideration and valuation of indigenous knowledge alongside scientific data obtained using statistically analyzed records; (c) a holistic approach that respects the spiritual and cultural values of

the communities and allows indigenous knowledge to be brought forth in the form and format identified by the communities themselves; (d) an appreciation that indigenous knowledge can involve an integrated awareness of the stewardship of land, water, and living resources and that this knowledge can contribute to conservation and the sustainable use of resources; and (e) an understanding that access to indigenous knowledge will entail informed participation and approval from the holders of such knowledge.

We believe that it is crucial to foster linkages among indigenous and scientific knowledge systems. For example, in remote areas that do not have temperature data, indigenous knowledge narratives may be able to serve as proxy records. On the other hand, point data and remote-sensing measurements may aid in explaining phenomena that may be difficult to observe through tactile or visual means (e.g., ocean current strength and direction changes, ocean temperature, atmospheric oscillations). Our hope is that the relationship between the two knowledge systems can be strengthened and that there will be wide benefits both to indigenous communities and to scientific study. In the examples shown in this article, temperature and sea-ice records provide links to the global climate system, which is inarguably changing. The indigenous narratives resonate with human voices and with deep understanding and concern for our changing planet.

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*Chief Clarence Alexander, former Grand Chief of the Gwich'in Nation, and Jon Waterhouse are on the Yukon River Inter-Tribal Watershed Council, in Fairbanks, Alaska. Nora Bynum, Elizabeth Johnson, and Brian Weeks are affiliated with the American Museum of Natural History, in New York, New York. Ursula King is affiliated with the National Centre for Epidemiology and Population Health, Australian National University, in Canberra. Tero Mustonen is the Leader of the Snowchange Cooperative in Tampere, Finland. Marta Vicarelli is affiliated with Columbia University and Peter Neofotis is affiliated with Columbia University and the City University of New York, both in New York, New York. Noel Oetlé is affiliated with the Environmental Monitoring Group, Nieuwoudtville, South Africa. Cynthia Rosenzweig (crosenzweig@giss.nasa.gov) is with the NASA Goddard Institute for Space Studies, in New York, New York. Chie Sakakibara is at Appalachian State University, in Boone, North Carolina. Chief Vyacheslav Shadrin is the Head of the Yukaghir Elders Council in Yakutia, Russia.*