Northern Climate ExChange

Independent Information - Shared Understanding - Action on Climate Change

NCE Update January 13, 2010

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Announcements

1. Canadian Geographic: Special Arctic International Polar Year (IPY) Issue - January/February 2010

"The January/February 2010 issue of *Canadian Geographic* contains a polarpalooza of stories, ranging from an intimate portrayal of life at the Yukon's Kluane Lake Research Station to a profile of a student geographer from Labrador on exchange in Norway. We shine a spotlight on the largest ever Inuit health survey and the mysterious disappearance of mercury from the atmosphere when the Arctic sun rises. It's all part of our crucial quest to understand the North".

www.canadiangeographic.ca

2. Call for Proposals 2010-2011: The Climate Change and Health Adaptation Program - Northern First Nations and Inuit Communities.

The Climate Change and Health Adaptation Program is accepting proposals from Northern First Nations and Inuit Communities for the 2010-2011 fiscal year.

The Climate Change and Health Adaptation Program funds community-centred research, where the research is done by community members/organizations for the benefit of their community.

Application Deadline: January 24th, 2010

For more information and how to apply, contact:
Erin Myers, Program Officer, Health Canada
(613) 957-2490 or e-mail erin_myers@hc-sc.gc.ca

3. WhiteCAP - Whitehorse Community Adaptation Project Community Vulnerability Scenarios: Open House

Date: January 14, 2010
Time: 5:00 - 9:00 pm.
Where: Whitehorse, Yukon, Canada Games Centre, Meeting Room #2

Northern Climate ExChange is hosting an open house to review and obtain feedback on the community climate change vulnerability scenarios that we have developed for the **Whitehorse Climate Change Adaptation Plan**. The scenarios explore how climate change may affect residents in the Whitehorse area.

If you are concerned about how climate change may affect Whitehorse, please come out and share your thoughts with us.

For more information contact: Ryan Hennessey, Community Adaptation Project Manager, 867-668-8874, rhennessey@yukoncollege.yk.ca.

Snacks, tea and coffee will be provided.

www.taiga.net/nce

4. Arctic Change Speaker Series: Climate Change and Rising Sea Levels - Jan 2010

Join **Dr. Shawn Marshall**, **Canada Research Chair in Climate Change and Geography Professor at the University of Calgary**, as he discusses glacier response to climate warming and its implications for future sea level rise.

The public is welcome to attend this free talk at the **University of Calgary**, **Room ES 162, on Wednesday, January 20 from 4 p.m. to 5 p.m**. The talk is sponsored by the **Arctic Institute of North America** as part of its Arctic Change Speaker Series.

www.arctic.ucalgary.ca

5. Energy Solutions Centre: Northern Energy Solutions Conference: Practical and Current Energy Solutions for the North - February 2010

The **Energy Solutions Centre** will host the **Northern Energy Solutions Conference** on February 15 - 19, 2010 at the Yukon Inn in Whitehorse Yukon. The conference will focus on practical and current Energy Solutions for commercial and institutional structures. It will also touch on transportation, residential housing and other energy issues.

The North has remote regions and different energy scenarios, weather trends and population bases, with energy issues requiring unique solutions. Together, we will learn the best practices and solutions for energy issues in the north.

What are the solutions that can be implemented now to conserve energy, reduce costs and limit GHG emissions? Delegates from Nunavut, Northwest and Yukon Territories and some southern regions will attempt to answer this question.

Date: February 15-19, 2010
Contact: Sean MacKinnonby e-mail at sean.mackinnon@gov.yk.ca or by phone (867) 393-7067.

Website: www.yukonenergyconference.ca

www.esc.gov.yk.ca

6. New Website: Arctic Stories

"Video footage of life near the North Pole can be found on a new Web site that showcases the research, climate and culture of the Arctic region.

Co-developed by Purdue University atmospheric chemist **Paul Shepson** and collaborating author **Peter Lourie**, the site takes visitors on a digital journey of life in the Arctic, describing how it may be changing and highlighting research under way in the Arctic Region near Barrow, Alaska.

Included is Shepson's own work with a solar-powered ozone buoy that collects atmospheric data from the frozen surface of the Arctic Ocean".

The **Arctic Stories** website can be found online at www.arcticstories.net

www.purdue.edu

Articles

1. Melting Tundra Creating Vast River of Waste Into Arctic Ocean

ScienceDaily
January 12, 2010

The increase in temperature in the Arctic has already caused the sea-ice there to melt. According to research conducted by the University of Gothenburg, if the Arctic tundra also melts, vast amounts of organic material will be carried by the rivers straight into the Arctic Ocean, resulting in additional emissions of carbon dioxide.

Several Russian rivers enter the Arctic Ocean particularly in the Laptev Sea north of Siberia. One of the main rivers flowing into the Laptev Sea is the Lena, which in terms of its drainage basin and length is one of the ten largest rivers in the world. The river water carries organic carbon from the tundra, and research from the University of Gothenburg shows that this adds a considerable amount of carbon dioxide to the atmosphere when it is degraded in the coastal waters.

Increased temperatures

The increase in temperature in the Arctic, which has already made an impact in the form of reduced sea-ice cover during the summer, may also cause the permafrost to melt. "Large amounts of organic carbon are currently stored within the permafrost and if this is released and gets carried by the rivers out into the coastal waters, then it will result in an increased release of carbon dioxide to the atmosphere," says Sofia Hjalmarsson, native of Falkenberg and postgraduate student at the Department of Chemistry.

Study of two areas

In her thesis, Sofia Hjalmarsson has studied the carbon system in two different geographical areas: partly in the Baltic Sea, the Kattegat and the Skagerrak, and partly in the coastal waters north of Siberia (the Laptev Sea, the East Siberian Sea and the Chukchi Sea). The two areas have in common the fact that they receive large volumes of river water containing organic carbon and nutrients, mainly nitrogen.

The thesis *Carbon Dynamics in Northern Marginal Seas* was publicly defended on 18 December.

www.sciencedaily.com

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2. Extreme negative phase of the Arctic Oscillation yields a warm Arctic

NSIDC
Arctic Sea Ice News and Analysis
January 5, 2010

Arctic sea ice extent at end of December 2009 remained below normal, primarily in the Atlantic sector of the Arctic. Average air temperatures over the Arctic Ocean were much higher than normal for the month, reflecting unusual atmospheric conditions. Finally, we provide a review of 2009 Arctic sea ice conditions.

Overview of conditions

Arctic sea ice extent averaged over December 2009 was 12.48 million square kilometers (4.82 million square miles). This was 920,000 square kilometers (350,000 square miles) below the 1979 to 2000 average for December, but 210,000 square kilometers (81,000 square miles) above the record low for the month, which occurred in December 2006. Ice extent was less than normal over much of the Atlantic sector of the Arctic, including the Barents Sea, part of the East Greenland Sea, and in Davis Strait.

image 1

Conditions in context

During December 2009, ice extent grew at an average of 68,000 square kilometers (26,000 square miles) per day. Sea ice extent increased at a fairly steady rate throughout the month, staying slightly above the levels observed in December 2007.

image 2

December 2009 compared to past years

December 2009 had the fourth-lowest average ice extent for the month since the beginning of satellite records, falling just above the extent for 2007. The linear rate of decline for December is now 3.3% per decade.

image 3

Warm air keeps ice extent low

December air temperatures over the Arctic Ocean region, eastern Siberia, and northwestern North America were warmer than normal. In contrast, temperatures in Eurasia, the United States, and southwestern Canada were below average. The strongest anomalies (more than 7 degrees Celsius/13 degrees Fahrenheit) were over the Atlantic side of the Arctic, including Baffin Bay and Davis Strait, where ice extent was below average.

image 4

Negative phase of the Arctic Oscillation

These regional contrasts in temperature anomalies resulted from a strongly negative phase of the Arctic Oscillation (AO). The AO is a natural pattern of climate variability. It consists of opposing patterns of atmospheric pressure between the polar regions and middle latitudes. The positive phase of the AO exists when pressures are lower than normal over the Arctic, and higher than normal in middle latitude. In the negative phase, the opposite is true; pressures are higher than normal over the Arctic and lower than normal in middle latitudes. The negative and positive phases of the AO set up opposing temperature patterns. With the AO in its negative phase this season, the Arctic is warmer than average, while parts of the middle latitudes are colder than normal. The phase of the AO also affects patterns of precipitation, especially over Europe.

The phase of the AO is described in terms of an index value. In December 2009 the AO index value was -3.41, the most negative value since at least 1950, according to data from the NOAA Climate Prediction Center.

While a negative AO leads to warmer temperatures over the Arctic, it also tends to reduce the flow of sea ice out of the Arctic by affecting the winds that can export the ice to warmer waters, where it melts. In this way, a negative AO could help retain some the second- and third-year ice through the winter, and potentially rebuild some of the older, multiyear ice that has been lost over the past few years. However, we do not yet know if the strongly negative AO will persist through the winter, or what its net effect will be.

image 5

For more information on the AO, see the NSIDC Arctic Meteorology and Climatology Primer.

2009 year in review

The minimum ice extent in September 2009 was greater than the past two Septembers, but again fell below the long-term average. The melt season began with a young, thin Arctic sea ice cover, suggesting that significant amounts of ice would be lost during the melt season. However, a cooler summer with favorable winds helped preserve the ice.

Despite the cool summer, the ice remained thin and vulnerable at the sea ice minimum, with little of the older, thicker ice that used to characterize much of the Arctic. Recently published research by Barber and colleagues shows that the ice cover was even more fragile at the end of the melt season than satellite data indicated, with regions of the Beaufort and Chukchi Seas covered by small, rotten ice floes.

In the fall, the sea ice froze up in fits and starts. The Northern Sea Route opened in October, even after sea ice extent for the Arctic as a whole had begun to increase. The annual average extent for 2009 was 11.18 million square kilometers (4.32 million square miles), 970,000 square kilometers (375,000 square miles) or 8.0% below 1979 to 2000 average and 740,000 square kilometers (286,000 square miles) or 6.2% below the 1979 to 2008 average.

image 6

References

Barber, D. G., R. Galley, M. G. Asplin, R. De Abreu, K.- A. Warner, M. Pucko, M. Gupta, S. Prinsenberg, and S. Julien. 2009. Perennial pack ice in the southern Beaufort Sea was not as it appeared in the summer of 2009. *Geophysical Research Letters* 36, L24501, doi:10.1029/2009GL041434.

www.nsidc.org

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3. Polar Bears Changing Habitat in Response to Sea Ice Conditions

ScienceDaily

January 7, 2010

A long-term study showing the changes in habitat associations of polar bears in response to sea ice conditions in the southern Beaufort Sea has implications for polar bear management in Alaska.

Karyn Rode, a polar bear biologist with the U.S. Fish and Wildlife Service in Anchorage, Alaska and one of the study's authors, says data collected between 1979 and 2005 show that polar bears in the region are occurring more frequently on land and in open water and less frequently on ice during the fall. This means there are increased chances for human/bear interaction. The paper was published in the December issue of Arctic -- the journal of the Arctic Institute of North America.

Polar bears were observed over the 27-year period by U.S. government Minerals Management Services staff as part of the fall bowhead whale aerial survey conducted annually in the southern Beaufort Sea. Ice conditions were also recorded.

Data showed that as ice conditions changed, bears were being found on different habitats. Between 1979 and 1987, 12% of bear sightings were associated with no ice. Between 1997 and 2005 however, 90% of bear sightings were associated with no ice.

"When bears were seen, they were more often seen in open water and on land than on sea ice. At the same time, changes were observed in ice, suggesting that these observations are connected," says Rode.

In addition, the number of bears sighted steadily increased from 138 bears in the years 1979-1987, to 271 bears between 1988 and 1996, and finally to 468 bears between 1997 and 2005. Rode warns that this study was not designed to estimate the number of bears using the nearshore area. Data were drawn from studies created to track bowhead whale migration routes, not polar bear populations. Therefore, it should not be concluded that more bears are occurring in the nearshore waters off the Southern Beaufort Sea coast.

However, Rode states that "Our results do suggest that bears that use the nearshore area are more likely to occur on land in recent years because their preferred habitat, sea ice, is unavailable.

"This is one of the few data sets available over such a long time frame. It shows there has been a shift in habitat use," she says.

In the Beaufort Sea region, there was less ice in 2005 than when the study period began in 1979. In general, freeze up is later and spring melt comes earlier with measurements showing since 1979 the summer melt period has increased by 13 days per decade. This is one reason for the region's rapid retreat of multi-year ice, which provides a thicker, more stable platform for hunting and denning.

This work is helpful in highlighting the need to proactively develop programs to manage bear-human interactions in coastal areas. Bear-human interactions in Native villages and with industry in Alaska have been on the rise in recent years.

This media release is part of the Promotion of Arctic Science, an Arctic Institute of North America project made possible with the generous support of the Government of Canada Program for International Polar Year.

The mission of the Arctic Institute of North America at the University of Calgary is to advance the study of the North American and circumpolar Arctic and to acquire, preserve and disseminate information on physical, environmental and social conditions in the North. More information can be found at www.arctic.ucalgary.ca

Adapted from materials provided by Arctic Institute of North America, via EurekAlert!, a service of AAAS.

www.sciencedaily.com

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4. Bering Strait influenced ice age climate patterns worldwide

University Corporation for Atmospheric Research (UCAR)
January 10, 2010

In a vivid example of how a small geographic feature can have far-reaching impacts on climate, new research shows that water levels in the Bering Strait may have helped drive global climate patterns during ice age episodes dating back more than 100,000 years.

The international study, led by scientists at the National Center for Atmospheric Research (NCAR), found that the repeated opening and closing of the narrow strait due to fluctuating sea levels affected currents that transported heat and salinity in the Atlantic and Pacific oceans. As a result, summer temperatures in parts of North America and Greenland oscillated between warmer and colder phases, causing ice sheets to alternate between expansion and retreat and affecting sea levels worldwide.

While the findings do not directly bear on current global warming, they highlight the complexity of Earth's climate system and the fact that seemingly insignificant changes can lead to dramatic tipping points for climate patterns, especially in and around the Arctic.

"The global climate is sensitive to impacts that may seem minor," says NCAR scientist Aixue Hu, the lead author. "Even small processes, if they are in the right location, can amplify changes in climate around the world."

The study is being published this week in Nature Geoscience. Funded by the Department of Energy and the National Science Foundation, NCAR's sponsor, it used the latest generation of supercomputers to study past climate at a level of detail that would have been impossible just a few years ago.

New clues to an ice age mystery

Hu and his colleagues set out to solve a key mystery of the last glacial period: Why, starting about 116,000 years ago, did northern ice sheets repeatedly advance and retreat for about the next 70,000 years? The enormous ice sheets held so much water that sea levels rose and dropped by as much as about 100 feet (30 meters) during these intervals.

In other cases, scientists have associated such major oscillations in climate with fluctuations in Earth's orbit around the Sun. But in the time period that the research team looked at, the orbital pattern did not correspond with the geologic movement of the ice sheets and associated sea level changes.

The study team considered an alternative possibility: that changes in the Bering Strait, the main gateway in the Northern Hemisphere between the Atlantic and Pacific oceans, might have affected ocean currents across much of the globe. Although small-the strait is currently about 50 miles (80 kilometers) wide between Russia and the westernmost islands of Alaska-it allows water to circulate from the relatively fresh north Pacific to the saltier north Atlantic via the Arctic Ocean. This flow is instrumental to regulating the strength of a current known as the meridional overturning circulation, a key driver of heat from the tropics to the poles.

Supercomputers reveal a pattern of warming and cooling

Using the NCAR-based Community Climate System Model, a powerful computer tool for studying worldwide climate, the researchers compared the responses of ice age climate to conditions in the Bering Strait. They ran the model on new supercomputers at NCAR and the Department of Energy's Oak Ridge National Laboratory, enabling them to focus on smaller-scale geographic features that, until recently, could not be captured in long-term simulations of global climate.

The simulations accounted for the changes in sea level, revealing a recurring pattern-each time playing out over several thousand years-in which the reopening and closing of the strait had a far-reaching impact on ocean currents and ice sheets.

- As the climate cooled because of changes in Earth's orbit, northern ice sheets expanded. This caused sea levels to drop worldwide, forming a land bridge from Asia to North America and nearly closing the Bering Strait.

- With the flow of relatively fresh water from the Pacific to the Atlantic choked off, the Atlantic grew more saline. The saltier and heavier water led to an intensification of the Atlantic's meridional overturning circulation, a current of rising and sinking water that, like a conveyor belt, pumps warmer water northward from the tropics.

- This circulation warmed Greenland and parts of North America by about 3 degrees Fahrenheit (1.5 degrees Celsius)-enough to reverse the advance of ice sheets in those regions and reduce their height by almost 400 feet (112 meters) every thousand years. Although the Pacific cooled by an equivalent amount, it did not have vast ice sheets that could be affected by the change in climate.

- Over thousands of years, the Greenland and North American ice sheets melted enough to raise sea levels and reopen the Bering Strait.

- The new inflow of fresher water from the Pacific weakened the meridional overturning circulation, allowing North America and Greenland to cool over time. The ice sheets resumed their advance, sea levels dropped, the Bering Strait again mostly closed, and the entire cycle was repeated.

The combination of the ocean circulation and the size of the ice sheets-which exerted a cooling effect by reflecting sunlight back into space-affected climate throughout the world. The computer simulations showed that North America and Eurasia warmed significantly during the times when the Bering Strait was open, with the tropical and subtropical Indian and Pacific Oceans, as well as Antarctica, warming slightly.

Learning from the past

The pattern was finally broken about 34,000 years ago, the point in Earth's 95,000-year orbital cycle at which the planet was so far from the Sun at certain times of year that the ice sheets continued to grow even when the Bering Strait closed. When the orbital cycle brought Earth closer to the Sun in the northern winter, the ice sheets retreated sufficiently about 10,000 years ago to reopen the strait. This helped lead to a relatively stable climate, nurturing the rise of civilization.

"This kind of study is critical for teasing out the nuances of our climate system," says NCAR scientist Gerald Meehl, a co-author of the paper. "If we can improve our understanding of the forces that affected climate in the past, we can better anticipate how our climate may change in the future."

In addition to NCAR, the study team included researchers from the National Center for Scientific Research (CNRS) in France, University of Colorado in Boulder, Catholic University of Louvain in Belgium, Australian National University, and Harvard University.

About the article:

Title: Influence of Bering Strait flow and North Atlantic circulation on glacial sea-level changes

Authors: Aixue Hu, Gerald A. Meehl, Bette L. Otto-Bliesner, Claire Waelbroeck, Weiqing Han, Marie-France Loutre, Kurt Lambeck, Jerry Mitrovica, and Nan Rosenbloom
www2.ucar.edu

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5. Wireless sensor to monitor glaciers

The Engineer
January 13, 2010

Bristol University scientists have been awarded £225,000 to develop a wireless sensor that will monitor ice sheets in Greenland and the Antarctic for the effects of climate change.

The two-year project will develop an autonomous capsule, dubbed Cryo-Egg, which will be placed on the bed of ice sheets. It will return data from the bottom of the ice sheets to scientists on the surface as it monitors this largely uncharted landscape.

'The engineering challenges for Cryo-Egg are vast,' said project leader Dr Jemma Wadham, from the university's School of Geographical Sciences. 'In addition to the need to survive crushing by ice and extreme cold, the probe must be able to communicate with scientists on the surface through kilometres of ice. This will be the first goal of the project and is the focus of the current funding.'

Glacial ice deforms and slides over its bed, a scenario that makes a probe linked by cables impractical.

Prof Ian Craddock, from the university's Department of Electrical & Electronic Engineering Centre for Communications Research, said: 'Trying to communicate data through several kilometres of glacial ice is a major technical challenge. It will require highly novel solutions using a suite of communications technologies, along with innovative methods to unscramble the data.'

This multidisciplinary collaboration between glaciologists, Earth scientists and engineers at the university aims to overcome the immense technical challenges involved.

The data transmitted back will help them understand one of the most important processes associated with climate warming.

www.theengineer.co.uk

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6. Ocean Conveyor's Pump Switches Back On
How will climate warming affect ocean circulation? The answer isn't so simple.

By Lonny Lippsett
Woods Hole Oceanographic Institution
January 9, 2010

One of the "pumps" that helps drive the ocean's global circulation suddenly switched on again last winter for the first time this decade. The finding surprised scientists who had been wondering if global warming was inhibiting the pump and did not foresee any indications that it would turn back on.

The "pump" in question is in the western North Atlantic Ocean, where pools of cold, dense water form in winter and sink beneath less-dense warmer waters. The sinking water feeds into the lower limb of a global system of currents often described as the Great Ocean Conveyor. To replace the down-flowing water, warm surface waters from the tropics are pulled northward along the Conveyor's upper limb.

The phenomenon has far-reaching impacts on climate. It transports tropical heat to the North Atlantic region, keeping winters there much warmer than they would be otherwise. And it draws down the man-made buildup of carbon dioxide from air to surface waters and eventually into the depths, where the greenhouse gas is stored for centuries and offset global warming.

The pump is driven by the contrast between warm water and frigid, dry winter air, which draws heat from the ocean into the atmosphere and leaves ocean water colder and denser. Over the last 15 years, the sinking of cold water in the North Atlantic has been either absent or too shallow to feed into the deep Conveyor. Scientists have speculated that a cause could be generally warming air temperatures, which also melts polar ice and adds less-dense fresh water to the ocean. That overall trend didn't change in 2007, and in fact, Arctic Ocean sea ice disappeared to a record minimum in the summer of 2007.

Yet the sinking of cold water in the North Atlantic resumed vigorously, a research team led by Kjetil Våge and Robert Pickart of Woods Hole Oceanographic Institution reported in the Dec. 23, 2008 issue of *Nature Geoscience*. "The obvious question is, why?" wrote Våge, Pickart, and colleagues.

A fleet of floats

Their investigations turned up a myriad of interrelated, nuanced factors that make it difficult to predict future changes in ocean circulation and climate, concluded the research team, which also included Virginie Thierry (Laboratoire de Physique des Océans), Gilles Reverdin (Laboratoire d'Océanographie Dynamique et de Climatologie), Craig M. Lee (University of Washington), Brian Petrie (Bedford Institute of Oceanography), Tom A. Agnew and Amy Wong (Meteorological Service of Canada), and Mads H. Ribergaard (Danish Meteorological Institute).

The researchers examined new data collected by robotic floats that have been drifting for several years in the Labrador and Irminger Seas around southern Greenland. These Argo floats-part of a fleet of 3,000 dispatched since 2000 through the world's oceans-descend to depths of 1.25 miles (2,000 meters), collect temperature and salinity data as they periodically rise toward the surface, and then transmit the data via satellite before descending again. Unlike ships that usually (and wisely) avoid rough North Atlantic seas in winter, the Argo floats provide a way to detect the sinking of cold waters in the season that it occurs.

The Argo float data showed that in the winter of 2007-2008, cold water sank significantly beyond .62 miles (1,000 meters) deep in northern seas for the first time in eight years and for only the second time since the mid-1990s. Beyond that depth, waters can be swept into lower limb of the Conveyor and carried around the world.

Sinking was undoubtedly enhanced last winter by air temperatures over the North Atlantic that were 9° to 11°F (5° to 6°C) colder than in the previous seven years. That often occurs when a seesawing pattern of high- and low-pressure air masses, called the North Atlantic Oscillation, is in its "positive" position, bringing frigid westerly winds from Canada streaking across the North Atlantic. But, curiously, that was also the case in 2006-2007, in which sinking did not occur.

The lack of substantial sinking throughout the decade meant that there was no "preconditioning"-that is, colder waters could not build up from previous winters to a point where they are easily pushed over a density threshold and sink the following year, the research team said. That made the sudden reappearance of sinking in 2007-2008 all the more surprising.

Tip jets and exported ice

Digging deeper, the researchers found that local wind patterns, which occurred in 2007-2008 (but not the preceding winter), may have played a role. In particular, storms tended to track farther to the south, pulling cold air off the ice edge of eastern Canada into the Labrador Sea. The same storms also continued past Cape Farewell at the southern tip of Greenland, creating a phenomenon known as Greenland tip jets: High winds from the west deflect around the glacial slopes of Greenland, accelerating as they draw cold, ocean-chilling air into a relatively small area over the southern Irminger Sea.

A final clue emerged. Analyzing satellite and in-situ ocean data, the researchers said a large amount of pack ice and fresh water was exported into the northwest Labrador Sea in the summer of 2007. This froze the following winter, significantly extending the ice edge farther offshore. As a consequence, cold air from the North American continent traveled farther over ice, instead of warmer ocean waters, remaining cold until it hit warmer open water in the middle of Labrador Sea. The resulting temperature contrast helped trigger the sinking process.

The scientists noted "that the increased liquid and frozen freshwater flux into the Labrador Sea was probably tied to the large export of sea ice from the Arctic Ocean that contributed to the record minimum in sea-ice extent observed in the summer of 2007. Ironically, this disappearance of Arctic sea ice, which has been linked to global warming, may have helped trigger the return of deep wintertime [water sinking] to the North Atlantic."

www.whoi.edu

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7. Tipping Elements in the Earth System: How Stable Is the Contemporary Environment? Canada

ScienceDaily
January 6, 2010

A Special Feature of the *Proceedings of the National Academy of Sciences* presents the latest scientific insights on so-called tipping elements in the planetary environment. These elements have been identified as the most vulnerable large-scale components of the Earth System that may be profoundly altered by human interference. If one or more of those components is tipped -- especially in the course of global warming -- then the age of remarkably stable environmental conditions on Earth throughout the Holocene may end quickly and irreversibly.

This Special Feature was designed and edited by Hans Joachim Schellnhuber of the Potsdam Institute for Climate Impact Research (PIK). It is meant to make a major contribution to the emerging field of sustainability science. The authors involved analyse altogether eight Earth System components. Three of them, the biggest dust source on our planet, oceanic biogeochemical cycles, and marine methane hydrates, are discussed in depth as potential tipping elements for the first time ever.

"It is the cardinal question of Earth System and sustainability science whether global warming actually triggers singular transformations of crucial components of the planetary machinery," says Schellnhuber. Singular transformations -- as opposed to smooth linear and nonlinear ones -- would dramatically alter the environment in which human civilisations have developed and thrived over many millennia. "Currently, the climate system still operates in the Holocene mode, but the research presented here underlines that a rise of the global mean temperature beyond two degrees Celsius might push the world into singular-change terrain and therefore needs to be avoided," Schellnhuber adds.

The PIK scientist has introduced the tipping-elements concept into the research community some ten years ago. It describes components of the Earth System that could be pushed past critical thresholds by anthropogenic forcing, so that they may "tip" into qualitatively different modes of operation. In a recent seminal paper, Tim Lenton from the University of East Anglia, Hans Joachim Schellnhuber and an international group of colleagues presented a formal definition and compiled a short-list of the nine tipping elements ranked as the most policy-relevant. The current Special Feature examines five of these in much more depth: the El Niño/Southern Oscillation phenomenon, Arctic sea-ice and the great polar ice sheets, the Amazon rainforest, the major monsoon systems, and the circulation of ocean currents in the Atlantic Ocean.

In their article, Matthias Hofmann and Stefan Rahmstorf, also from PIK, discuss the last topic, i.e. the stability properties of the Atlantic Meridional Overturning Circulation (AMOC). The authors present new model simulations of the AMOC response to increased freshwater inflow into the North Atlantic. These challenge the hypothesis that the resulting circulation weakening and the possibility of abrupt oceanic change are just artefacts arising from model flaws. Rather, improving the physical realism of the model leads to a greater vulnerability of the projected AMOC stability.

A group of PIK scientists led by Anders Levermann show that every monsoon circulation inherently bears the possibility of an abrupt collapse. The reason is the moisture-advection feedback which is the core of any monsoon system and was captured in a conceptual model by the authors. The monsoon rains are essential for agriculture as the source of livelihood for several hundred million people in the pertinent regions, the authors state.

David Archer from the University of Chicago and his co-authors provide evidence that methane hydrates in ocean sediments should be regarded as a "slow tipping element" in the Earth's climate system. Global warming of some three degrees Celsius could lead to the escape of more than half of the relevant methane stocks, estimated 940 billion tons of carbon, on a millennial time-scale. This hydrate leakage could cause an additional rise in planetary temperature by 0.5 degrees Celsius. The authors tie this increase in global mean temperature to the methane, but it would persist through many millennia because methane is oxidised in about a decade to carbon dioxide, which continues to impact climate for many millennia.

Ulf Riebesell and colleagues from the Leibniz Institute of Marine Sciences (IFM-GEOMAR) describe the oceans as a climate-system component which is presently undergoing major changes. The sea is not only warming, it is also becoming more acidic. Unbridled anthropogenic emissions of greenhouse gases could alter the cycling of carbon and nutrients in the surface ocean and might damage entire marine ecosystems. The authors conclude that the current level of knowledge allows no clear answer on whether tipping points in the marine ecosphere exist, but they regard some of the projected shifts in oceanic biogeochemistry and their impacts as severe.

Mojib Latif and Noel Keenlyside, also of IFM-GEOMAR, present a review of the complicated mechanisms ruling the El Niño/Southern Oscillation (ENSO) phenomenon. It leads to strong temperature and precipitation fluctuations in the Equatorial Pacific from one year to another and has widespread effects on the global climate system. However, current climate models cannot capture the potential tipping point behaviour of the ENSO phenomenon, the authors resume. Given the potentially huge impacts on biological, chemical and socio-economic systems, the question whether global warming will fundamentally alter the ENSO dynamics in the future has to be investigated further.

A research team led by Richard Washington from the University of Oxford qualifies the biggest dust source on our planet, the Bodélé Depression in Chad, as a potential tipping element. This area in the southern Sahara releases huge plumes, which carry about 700,000 tons of dust towards the Atlantic and the Amazon basin. The authors explain that the so-deployed mineral aerosols play a vital role in transcontinental climatic and biophysical feedbacks. If regional wind patterns or surface erosivities changed due to anthropogenic interference, the dust export from the Bodélé Depression could be substantially modified at time scales as small as one season.

A research team headed by Yadvinder Malhi, also of the University of Oxford, has employed nineteen different global climate models to investigate, whether climate change could cause a large-scale dieback of Amazonian rainforest. The analysis based on a scenario with continuously increasing global emissions of greenhouse gases over the 21st century suggests that dry season water stress is likely to increase in parts of Amazonia. The researchers provide evidence that the Amazonian rainforest could reveal characteristic properties of a tipping element with the tendency to change into a seasonal forest.

In his paper on potential threshold behaviour of sea-ice and continental ice-sheets, Dirk Notz of the Max Planck Institute for Meteorology concludes that tipping points more likely exist for the loss of the Greenland ice sheet and the West-Antarctic ice sheet than for the loss of Arctic sea-ice, which could recover rapidly in a cooler climate. Inland ice could be much more vulnerable to regional warming due to the lack of large internal stabilizing feedbacks as existing for the Arctic sea-ice dynamics. Melting of the continental ice-sheets could lead to rapid multi-meter rise in mean sea level over the coming centuries.

Finally, Nobel Laureate Mario Molina and his co-authors demand fast action from political and economic decision makers to avoid activation of tipping elements. They propose to strengthen the Montreal Protocol regarding substances that have high global-warming potentials. In particular, the scientists make strong cases for an accelerated phasing out of hydrochlorofluorocarbons and a massive reduction of the emissions of soot.

"After two decades of failed climate protection since the 1990 IPCC Report it is more doubtful than ever whether society will manage to confine global environmental change to sub-dangerous levels," says Hans Joachim Schellnhuber. The tipping-elements field is developing quickly into a broad and relevant research frontier domain, but the issues pose tough challenges for contemporary science. Practically none of the planetary cases studied can be either dismissed now -- by firmly ruling out a possible anthropogenic triggering of irregular dynamics -- or settled by providing reliable estimates for activation temperatures and reaction time scales. "Many of the papers sketch the research way forward, but it seems that we will have to live with at least another decade of tantalising ignorance concerning the most worrying potential impacts of global warming," says Schellnhuber.

Adapted from materials provided by Potsdam Institute for Climate Impact Research (PIK), via AlphaGalileo.

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8. Arctic Tundra is Being Lost As Far North Quickly Warms

The treeless ecosystem of mosses, lichens, and berry plants is giving way to shrub land and boreal forest. As scientists study the transformation, they are discovering that major warming-related events, including fires and the collapse of slopes due to melting permafrost, are leading to the loss of tundra in the Arctic.

By Bill Sherwonit
Yale - Environment 360
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During the summer of 2007, lightning strikes sparked five tundra fires on Alaska's North Slope. Two of the fires - rare events north of the Arctic Circle - began in neighboring drainages, only a couple of days apart. That, in itself, might have gained the attention of tundra researchers. But the 2007 fire season would ultimately burn a record swath across the North Slope, while reshaping the way scientists think about the Arctic's response to global warming.

Researchers have known for years that the Arctic landscape is being transformed by rising temperatures. Now, scientists are amassing growing evidence that major events precipitated by warming - such as fires and the collapse of slopes caused by melting permafrost - are leading to the loss of tundra in the Arctic. The cold, dry, and treeless ecosystem - characterized by an extremely short growing season; underlying layers of frozen soil, or permafrost; and grasses, sedges, mosses, lichens, and berry plants - will eventually be replaced by shrub lands and even boreal forest, scientists forecast.

Much of the Arctic has experienced temperature increases of 3 to 5 degrees F in the past half-century and could see temperatures soar 10 degrees F above pre-industrial levels by 2100. University of Vermont professor Breck Bowden, a watershed specialist participating in a long-term study of the Alaskan tundra, said that such rapidly rising temperatures will mean that the "tundra as we imagine it today will largely be gone throughout the Arctic. It may take longer than 50 or even 100 years, but the inevitable direction is toward boreal forest or something like it."

Dominique Bachelet, a climate change scientist at Oregon State University, forecasts that by 2100 tundra "will largely disappear from the Alaskan landscape, along with the related plants, animals, and even human ecosystems that are based upon it." She made that prediction in 2004, and now says "the basic premise still holds, but the mechanism of change may be different than we thought." Instead of long-term, incrementally complex changes caused by gradually warming temperatures, "extreme events will be the important triggers for change." Hot-burning fires or slumping hillsides tied to melting permafrost could "clean the slate and allow new species to establish themselves," Bachelet said.

The transformation of the tundra - the word comes from the Finnish, *tunturia*, meaning "treeless plain" - will have a profound impact on the creatures that live and breed there, including grizzly bears, wolves, foxes, and many species of waterfowl and migratory songbirds. Especially hard-hit could be caribou, which depend heavily on lichen as a food source.

Increased burning and thawing of the tundra also is expected to accelerate global warming. Scientists point out that huge amounts of carbon - and substantial amounts of methane, an even more potent greenhouse gas - are tied up in the permafrost that underlies most Arctic tundra. Michelle Mack, an ecosystems ecologist at the University of Florida in Gainesville, notes that "twice as much carbon exists in the world's permafrost as in the atmosphere. So as they melt, these soils will add immensely to the carbon dioxide in the air."

Many scientists are now researching the role that fire plays in altering the landscape of the far north. The North Slope's 2007 mid-July fires were a seminal event, especially the blaze that began on July 16 in the Anaktuvuk River valley and turned into a full-blown conflagration. Abnormally high late-summer temperatures, unusually low summer rainfall, a late-season high-pressure system over the nearby Beaufort Sea, the autumnal senescence (aging and drying) of tundra plants, and the record retreat of sea ice in the Arctic Ocean - which contributed to the warmth - created prime conditions for a large and intense fire.

By the time early winter snows put out the fire, it had burned an area about 40 miles long by 10 miles wide, or more than 250,000 acres, making it the biggest fire in Alaska that year and historically the largest by far ever to burn across the North Slope. It was also more intense than normal tundra fires, severely charring much of the landscape through which it swept. Bowden said the fire "was both a really rare and huge event, and because it burned with several levels of intensity, the Anaktuvuk River has given us a natural laboratory" to study Arctic tundra ecosystems and how they're responding - and contributing - to changes in the Earth's climate.

While the Anaktuvuk River burn has gained widespread attention because it is a North Slope rarity, there is plenty of evidence that, elsewhere in Alaska, large, hot-burning fires have been transforming the tundra for decades.

Randi Jandt, a fire ecologist with the Bureau of Land Management and one of many researchers studying the aftermath of the Anaktuvuk River fire, has seen the proof a few hundred miles to the southwest, on the Seward Peninsula. There, a team of researchers has been systematically investigating a tundra landscape that caught fire in 1977. Because a portion of the burn area had been studied prior to the blaze, they've been able to compare before-and-after plant assemblages. Thirty-three years after the fire, a place that formerly contained substantial moss (20 percent) and fruticose lichens (7 percent) remains almost free of those species. Meanwhile shrubby willows have increased from 5 to 40 percent.

"Obviously the landscape has already changed a lot and it's continuing to change," Jandt says. "Shrubs are increasing at the expense of lichens and mosses, and as willows take over, they're going to transform the landscape even more. The key is that the soil is warming. It really doesn't matter whether that happens gradually or dramatically, through fire." As the warming of the soil increases, it favors the shrubs because they can more easily take root and then grow substantially faster in milder conditions, eventually "shading out" and outcompeting mosses and lichens.

The lichen decline has serious implications for Alaska's Western Arctic Caribou Herd, whose core wintering ground includes much of the Seward Peninsula. Lichens comprise up to three-fourths of the caribou's winter diet, notes Kyle Joly, a National Park Service researcher who has studied the herd since 2004. A permanent shift to shrub-rich, lichen-poor tundra in its winter range "could be really bad news" for the caribou, Joly says.

After peaking at nearly 500,000 caribou in 2003, the Western Arctic Herd - Alaska's largest - dropped significantly, to an estimated 377,000 animals in 2007. This has alarmed some native Alaska residents, whose subsistence lifestyle depends heavily on caribou.

In the course of studying caribou, Joly has also learned a great deal about the role of fire in "low," or sub-Arctic, tundra, where for several decades at least it has been a much more significant factor than on the North Slope's "high Arctic" landscape. About 9 percent of Alaska's lower latitude tundra burned between 1950 and 2007, whereas only 7 percent of the North Slope caught fire during that period. That could change as the region warms and fires become more frequent farther north.

Joly's and Jandt's overlapping interests and study areas have prompted them to jointly analyze several interrelated factors - fires, caribou foraging, global warming, and shrub expansion - that appear to be acting "unidirectionally" to reduce lichen cover in northwest Alaska, a change likely to have substantial ripple effects.

Jandt's fascination with tundra wildfires has now led her northeast, to the Anaktuvuk River burn, where in 2008 she and several research partners established transects to study burn severity, plant community shifts, and the effects of fire on permafrost and active soil layers. Among the team's observations so far: virtually no lichen cover remains in the burn area; willows have begun re-sprouting, and by 2009 some were already more than a foot tall; and tundra slumping and collapse has occurred.

Many other scientists have also begun studies in the Anaktuvuk burn, which has become part of the Arctic Long Term Ecological Research (LTER) program. Based at the Toolik Field Station, in the Brooks Range's northern foothills, the LTER study is funded by the National Science Foundation. Among the many researchers working out of Toolik is Mack, who characterized the tundra as "a very resilient plant community." But for all its resilience, Mack wonders if North Slope tundra is headed for substantial and perhaps irrevocable change, particularly if "fire starts the ecosystem on a new trajectory," as has happened on the Seward Peninsula.

Another researcher, Adrian Rocha of The Ecosystems Center in Woods Hole, Mass., found that a year after the fire, severely burned tundra *released* nearly twice as much carbon into the air as unburned tundra absorbed. Two years later, the burned tundra continues to release carbon.

Other scientists are looking at a different, but related, extreme Arctic event: the development of "thermokarst failures" within the burn area and in other parts of the North Slope. Nearly 20 research groups are involved in the thermokarst project, a collaborative effort supported by the National Science Foundation's Arctic System Science Program.

A thermokarst is uneven terrain produced by thawing permafrost, and recent studies have revealed many more thermokarst features than anyone expected. On flat ground, that may mean bumps and hollows. But on sloping ground, it can create huge slumps in which tons of soil move downhill. Such thermokarst failures can lead to high carbon dioxide and methane emissions from newly exposed and thawing soils, thus contributing to atmospheric warming. The thermokarsts provide niches for new plants and shrubs, which add to the "greening" of the tundra and warming of the soil, which in turn favors even more shrub growth. And in moving huge amounts of sediments and nutrients, thermokarsts can have "enormous impacts" on tundra streams and lakes, Bowden says.

Anything that warms tundra and thaws permafrost - from fires to milder annual temperatures and increased rainfall, particularly in winter - can contribute to thermokarst failures. Because climate change models predict a warmer and wetter Arctic with increased summer thunderstorms and lightning, thermokarsts are likely to occur on an ever-larger scale.

Already, Bowden says, thermokarst failures similar to those in Alaska - and in some cases much larger - have been reported in Siberia and Canada: "It's a pan-Arctic phenomenon, with the exception of a few areas that haven't warmed," says Bowden.

As with fires, thermokarst failures result in a "positive feedback" loop: The release of greenhouse gases, warmer Arctic soils, and shrubbier tundra all contribute to increased warming, which in turn make thermokarst failures more likely, releasing even more greenhouse gases. The result is not only a rapidly transformed landscape, but accelerated warming.

Even in areas unaffected by fires and thermokarst failures, there's evidence that tundra itself is warming. Canadian researcher Greg Henry of the University of British Columbia has reported that tundra in his Nunavut study area has on average warmed 1 degree Celsius (1.8 F) per decade since 1970. He attributes that largely to a greener, "weedier" tundra.

As Bowden, Bachelet, and other researchers have pointed out, the transformation of the tundra will have huge ripple effects, not only upon plant communities, but also upon the landscape, insect populations, wildlife, and human communities. Unless there's some dramatic and unexpected shift, the world's northern regions will be changed drastically, likely for hundreds or thousands of years.

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