# Climate Matters

USGS science for a changing world

*News from the* USGS Climate Research & Development Program

**Volume 1, Summer 2014**

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Climate Research & Development Program Coordinator introduces the "Climate Matters" newsletter.

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## Science Highlights

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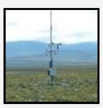
Planning for effective restoration in the Everglades



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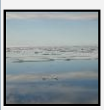

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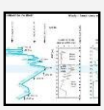

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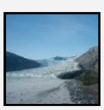

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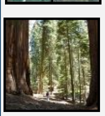

Climate effects on western US forests

## New and Noteworthy

"National Climate Change Viewer" Enables Focus on Future Climate-Driven Changes for U.S. Watersheds at Local Levels

By Jay Alder, Steve Hostetler and Catherine Pucket

## Recent Meetings

Ecological Society of America 98th Annual Meeting, Minneapolis MN, August 4-9, 2013

The theme of the 98th meeting of the Ecological Society of America was developing and maintaining sustainable trajectories in the midst of highly unpredictable, changes that affect and interact with ecological systems. USGS Climate and Land Use Research and Development participated by holding workshops chairing sessions and lecturing.

2013 GSA Annual Meeting and Exposition, Denver, Colorado, October 27-30, 2013

The Geological Society of America (GSA) 125th annual meeting themed Celebrating advances in Geoscience, featured a broad array of special technical sessions, field trips, short courses, and lectures. USGS Climate and Land Use Research and Development Scientists participated by chairing sessions, making presentations on their research and providing posters.

American Geophysical Union 46th Annual Fall Meeting, San Francisco, California, December 9-13, 2013

The American Geophysical Union's (AGU) annual fall meeting covered a wide range of research topics, including climate. The meeting featured several themed sessions, called SWIRLs, to promote interdisciplinary collaboration. This meeting's SWIRLS were (1) Characterizing Uncertainty, (2) Dust and Aerosols, (3) Computational Methods across Scales: from Personal to High Performance Platforms, (4) Global Soils, and (5) Urban Systems.

## Upcoming Meetings

Ecological Society of America Annual Meeting 2014 in Sacramento, CA, August 10-15, 2014

Geological Society of America Annual Meeting 2014 in Vancouver, BC, Canada, October 19-22, 2014

American Geophysical Union 47$^{th}$ Annual Fall Meeting in San Francisco, CA, December 15-19, 2014

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## About this issue

Cypress tree at Cypress Bridge Swamp Natural Area in central Virginia.

Welcome to the first edition of Climate Matters, a newsletter dedicated to disseminating information on current activities in the USGS Climate Research & Development Program. The newsletter is intended to highlight recent research findings from the program and their relevance to societal needs and issues important to resource managers, policy makers, and the general public.

The Climate R&D Program supports interdisciplinary research designed to improve our understanding of how the Earth system responds to climate and land use change over multiple temporal and spatial scales. The Program is one of four programs within the USGS Climate and Land Use Change Mission Area, and projects funded by Climate R&D conduct the unbiased, foundational research needed to develop sustainable management strategies.

The Climate R&D Program currently funds research projects that examine patterns of climate and land use change in all fifty states and across the globe. These projects integrate expertise in paleoclimate, ecology, hydrology, modeling, geography, biogeochemical cycling, and geology to understand how changes in climate and land use affect the processes that shape the Earth.

In this and future newsletters we include a feature article that highlights recent field excursions and the important research questions that they address. We also include summaries of recently published papers from a cross section of Climate R&D projects (a complete list of publications can be found on our website). The newsletter provides information on contributions by Climate R&D scientists to national meetings. Finally, the newsletter includes links to Climate R&D research in the news that may be of interest to our readership.

Our goal is to produce the newsletter on a semiannual basis, and we welcome feedback and comments to help shape future issues.

Debra Willard

Program Coordinator

Climate Research & Development Program

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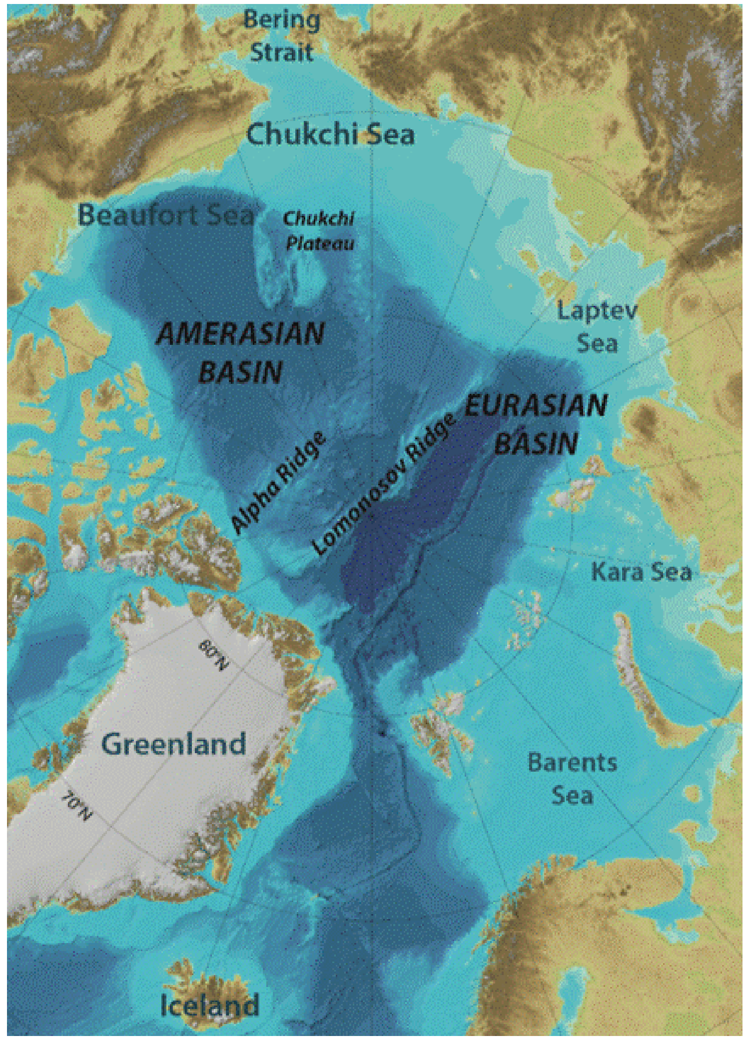
# Studying Arctic Sea Ice Ecosystem Change

Laura Gemery, USGS Ecologist




Map of Arctic Ocean, showing bathymetry and location of subsurface features and seas. Modified from International Bathymeteric Chart of the Arctic Ocean, courtesy of M. Jakobssen, Stockholm University.

**Overview**

The Arctic is undergoing a rapid environmental transformation such that the Arctic is warming faster than other regions and loss of snow and ice cover is causing more solar radiation to be absorbed, compounding the warming and melting. Such changes have the potential to alter terrestrial and marine habitats and ecosystems, affect permafrost and carbon cycling, and affect people, industry, and commerce in the Arctic.

**Arctic sea-ice loss and ecosystem change**

Sea ice is a critical feature of the Arctic Ocean and surrounding regions. Mammals and birds rely on sea ice for resting, hunting, and reproduction. Alaskan native communities depend on ice for subsistence fishing, whale and seal hunting. The annual cycle of Arctic and subarctic springtime ice melt initiates phytoplankton blooms that drive annual ecosystem functioning. Many regions in the Arctic, such as the Chukchi and Bering Seas off Alaska, are experiencing earlier spring sea-ice retreat and later autumn sea-ice formation affecting the timing of food and habitat availability for animals and humans.

Since 1979, when satellite-based measurements began, Arctic sea ice cover and thickness has been decreasing in most regions of the Arctic and researchers have also documented changes in the abundance and distribution of key marine species. Although there is a large amount of uncertainty in predictions of future sea ice, there is nonetheless concern that these trends will continue. As a consequence, the United States has developed a National Strategy for the Arctic Region which positions the country for future challenges and opportunities in the Arctic. Similarly, the Department of Defense



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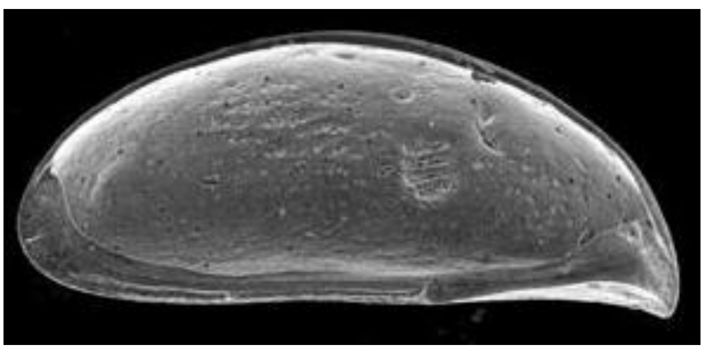
Arctic Strategy addresses potential security issues stemming from Arctic environmental change.

### Paleo-records help understand Arctic ecosystem variability

Most instrumental records of Arctic ecosystems extend back only a few decades, and historical climate recordkeeping began just over a century ago. This short time frame of study limits our understanding of natural climate, sea-ice and marine ecosystem variability. To more fully understand the baseline variability in Arctic climate, researchers use paleoclimate records preserved in natural archives such as sediments deposited in lakes and oceans, tree rings, glacial ice and speleothems. By analyzing paleo-records from critical sites in the Arctic Ocean, researchers are developing a more complete understanding of regional patterns of sea-ice variability over decadal, centennial and millennial time scales.

Sea ice in March aboard U.S. Coast Guard Cutter (USCGC) *Healy* in the northern Bering Sea. During the past 30 years, decreasing summer sea ice caused the northern Bering Sea to gain 25 days of open water. Photo courtesy of T. van Pelt, North Pacific Research Board.

### How do scientists reconstruct long climate records?



Scanning electron microscope photo of shell of the ostracode *Acetabulastoma*, which inhabits perennial sea ice and whose fossils from sediment cores provide a history of sea ice in the Arctic Ocean and adjacent seas.

Researchers use a variety of proxy methods to reconstruct past climates and environments in the Arctic Ocean and other regions. Proxies typically involve measurements of physical, biological or chemical features of sediments that have accumulated over thousands to millions of years. For example, reconstructing past changes in Arctic Ocean temperature, circulation, sea level and sea ice involves the use of small microfossil groups including ostracodes, a group of small, shelled Crustacea , and foraminifera, single-celled protists that secrete calcareous shells. The ability to use ostracodes, foraminifera and other biological groups to reconstruct past environments relies on understanding their geographic and depth distribution and other ecological requirements in the modern Arctic environment. Especially important are the temperature, depth, salinity, and oxygen levels that species can tolerate. Similarly, the chemistry of microfossil shells and the sediment in which they are preserved yields quantitative information about past ocean temperature, salinity, sea ice cover, and ocean chemistry. On



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land areas, pollen and various lake-dwelling microfossil groups are used to reconstruct terrestrial environmental change. The USGS Arctic Paleoceanography website provides more information about paleoclimatology and the Arctic's climate history.

### Arctic research cruises

Given the challenges of working in the Arctic, scientific expeditions are usually carried out aboard specially outfitted research vessels. The USGS and other federal agencies have operated cruises to the Arctic since the 1950s. Early research missions focused on surveying the ocean floor and creating seismic profiles to collect information about energy resources. In addition, USGS and other agencies also conducted expeditions to map the bathymetry of the seafloor and gather geophysical data about the geology and composition of the sediments and seafloor, including oceanographic measurements. Collectively these cruises provide samples and data that can be studied for many scientific purposes.


Early USGS research cruises, such as those aboard the research vessel *Samuel Phillips Lee*, focused on understanding the geology for potential oil resources and assessing geologic risks associated with resource development, such as seafloor stability, permafrost, habitats and coastal erosion.

### Case Study: 2012-2013 Chukchi Sea Cruises


USCGC *Healy* conducted BOEM- and NSF-sponsored cruises during summer 2012 and 2013 in which USGS scientists participated.

During the 2012 and 2013 field seasons, the Bureau of Ocean and Energy Management (BOEM) sponsored research expeditions on the United States Coast Guard (USCG) Icebreaker Healy to the Hanna Shoal region of the Chukchi Sea to examine ecosystem trophic structure, sediments, and anthropogenic chemicals (http://www.comidacab.org/hannashoal/index.html; http://www.doi.gov/pmb/ocean/news/newswave/upload/NewsWave-Fall-2012-7.pdf). Led by chief scientists Drs. Lee Cooper and Jackie Grebmeier, University of Maryland, and Dr. Kenneth Dunton, University of Texas at Austin, the Hanna Shoal cruises included scientists from government organizations including USGS and several academic institutions conducting multi-disciplinary studies of marine life in the Hanna Shoal region.



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These cruises collect baseline data on biological resources that may be at risk from energy exploration and other human activities in the Arctic. Scientists aboard the Healy aimed to document the biodiversity and distribution of zooplankton and benthic invertebrates, such as clams and crabs. Planktonic and benthic organisms are essential links in marine sea-ice ecosystems that also support populations of sea birds and marine mammals like walrus, seals and gray whales.

The Van Veen grab sampler is designed to recover sediment and associated faunas from the seafloor. These surface sediments are used to assess faunal changes due to climate-driven changes in temperature, salinity, productivity, and sea ice.

Sediment is collected in a variety of ways during research cruises. Some devices, such as a Van Veen grab sampler, collect only the uppermost seafloor sediment, whereas longer coring devices capture deeper columns of sediment that provide records of the past hundreds to thousands of years. On board, scientists wash and sieve samples to isolate the organisms from sediment. Additional study is then conducted after the cruise in government and university laboratories where scientists sort, identify and count faunal collections for studies of changes in ecosystem structure and biodiversity.

One focus of USGS research is the documentation of the distribution and composition of benthic ostracode assemblages in the Bering and Chukchi Seas during the last 40 years. Because ostracode shells are preserved long after the animal's soft parts degrade, researchers can acquire data from archived surface sediments from prior Arctic cruises dating back to the 1960s. Analysis of ostracode assemblages show that changes in the abundance of dominant species appear to be related to changes in temperature and sea ice over the last few decades. In addition to documenting recent ecosystem changes, these faunal analyses provide baseline ecological data that can be used in future studies of the response of Arctic ecosystems to long-term climate variability and change.

**Future Arctic Research**

Continued observation and paleoclimate reconstruction at various temporal scales will improve scientific understanding of the Arctic's natural variability. More generally, scientific investigation in the Arctic Ocean can help establish the impacts of climate-related environmental change that help decision-makers and planners in developing mitigation and adaptation plans for changes in the future.

For more information, contact: lgemery@usgs.gov

For additional information on USGS research on Arctic paleoclimatology: http://www.usgs.gov/climate_landuse/clu_rd/projects/artic_paleo.asp

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## Sea level rise and nutrient cycling in coastal wetlands

Coastal wetlands and swamps are vulnerable to increased salinity from sea level rise. Cypress trees that dominated this site are dying and being replaced by brackish marsh.

Sea level rise and land use changes are causing salt water to encroach into many formerly freshwater tidal wetlands along the US coast. In many areas, this process, known as salinification, is converting freshwater-forested wetlands to low-salinity marshes with distinctively different plant and animal communities.

While species shifts along salinity gradients have been well-documented, other less well-known impacts may also be important. For example, salinification-induced changes in cycling of nutrients such as phosphorous and nitrogen can affect primary productivity in terrestrial habitats. They can also fuel excessive nutrient build-up (eutrophication) in adjacent aquatic habitats, altering water quality and triggering algal blooms.

In a new paper by USGS research scientists and university colleagues, changes in soil nitrogen and phosphorus cycling were measured in response to salinification of tidal freshwater-forested wetlands and their subsequent conversion to more saline marshes in South Carolina and Georgia. Salinification was found to increase the rates with which these key soil nutrients changed chemically. These increases in soil nutrient availability likely lead to nutrient export to estuaries and fueled the migration of marsh plants into salt-stressed tidal forests. The findings from this research advance our understanding of coastal wetland response to sea level rise. These data are critical to improve our capabilities to model and forecast impacts of future climate and sea level scenarios.

The paper, published in Biogeochemistry, is available at http://link.springer.com/article/10.1007/s10533-012-9805-1#page-1



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## Planning for effective restoration in the Everglades

For the last century, water flowing through the Florida Everglades has been managed to address the dual goals of facilitating urban and agricultural development and protecting coastal communities from flooding and drought.

In this photograph, USGS CLU R&D scientists collect a sediment core from Arthur R. Marshall Loxahatchee National Wildlife Refuge, Florida. Proxy records from wetland sediments provide an archive of past climate and land use change.

Resource managers control water levels in the Everglades based on water regulation schedules, which define water depths in different parts of the system throughout the year. These schedules are intended to provide flood control, manage water supply, and maintain a healthy ecosystem.

These schedules were developed when water conditions became either too wet or too dry. In some cases, they resulted in degradation of the wetland ecosystem. In an effort to optimize their water regulation schedules, managers at the Arthur R. Marshall Loxahatchee National Wildlife Refuge in the northeastern Everglades decided to include information on predrainage hydrology in their decision-making process. Because historical records were limited, they approached USGS scientists to use paleoecological methods to reconstruct Refuge hydrology over the past few centuries.

In a joint USGS and USFWS research effort, scientists analyzed fossil pollen from ten sediment cores collected in the Refuge to reconstruct the vegetation and hydrologic conditions of the last 300 years. Their results showed that plant communities and hydrology have been altered significantly since implementation of water regulation schedules.

Their results also highlighted the considerable spatial impact of water management practices that began in the mid-20th century. Sites in the northern part of the refuge are now much drier, whereas those in the southern part are much wetter. These changes have affected the distribution of plant communities and associated wildlife.

This information helps managers design new water regulation schedules that meet the needs of the urban and agricultural communities, while providing a healthy habitat for wetland wildlife and plant communities.

The paper, published in Wetlands in 2013, can be found at: http://link.springer.com/content/pdf/10.1007%2Fs13157-013-0469-y.pdf



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## New climate dataset available from the National Petroleum Reserve–Alaska and the Arctic National Wildlife Refuge, 1998–2011

Climate model projections for this century consistently suggest that rapid rates of warming will continue in the Arctic, especially in Alaska and the adjacent Bering, Beaufort, and Chukchi Seas. Climate data to support Arctic research has been difficult to acquire due to the remoteness of the region and its harsh environmental conditions. Continuous climate measurements are now available from an array of climate observing stations in northern Alaska.

One of 16 stations in the DOI/GTN-P climate network monitoring environmental changes in arctic Alaska in support of the U.S. Department of the Interior's land-management mission. This station, U31 in the Global Terrestrial Network for Permafrost (GTN-P), is located at Marsh Creek in the Arctic National Wildlife Refuge.

The projected Arctic warming is expected to degrade permafrost (ice-rich soil frozen for two or more years) and have significant impacts on terrestrial and marine habitats, wildlife, indigenous people, commerce, and human infrastructure. Permafrost degradation also has significant implications for carbon cycling and changes in the release and storage of $CO_2$, methane, and other greenhouse gases.

The USGS Permafrost- and Climate-Monitoring Network (DOI/GTN-P) consists of two primary observing systems: 1) A deep borehole array used to monitor the thermal state of permafrost, and 2) the climate-station network being reported on here. DOI/GTN-P is part of the Global Terrestrial Network for Permafrost, an international data network designed to improve our understanding of climate change throughout the Arctic and the Northern Hemisphere. The DOI/GTN-P network is located on DOI-managed lands on the Arctic Slope of Alaska, specifically within the National Petroleum Reserve-Alaska and the Arctic National Wildlife Refuge. These stations continually record air and ground temperatures, wind speed and direction, solar radiation, snow depth (during the cold seasons), rainfall, and soil moisture. Most stations transmit their data in near real-time in support of arctic research and DOI land management decisions. All data acquired by the DOI/GTN-P climate network between 1998 and 2011 have recently been released in an online USGS Data Series. The report includes hourly, as well as monthly, seasonal, and annual climate summaries.

The report, published in 2013, is available at http://dx.doi.org/10.3133/ds812

Near real-time data from most of the DOI/GTN-P stations can be found at: http://data.usgs.gov/climateMonitoring/region/show?region=alaska

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## *Long-term arctic sea ice variability*

Much of the Arctic Ocean is covered by perennial sea ice, but in marginal regions near North America and Eurasia, sea ice melts during summer and reaches a minimum cover each year in September. During the past 20 years, satellite and instrumental measurements have shown that average sea-ice thickness and extent have decreased. Some of the most notable changes have occurred off the coasts of western and northern Alaska in the Bering and Chukchi Seas.

Sea ice in Chukchi Sea off north coast of Alaska, August 2013.

New research is underway to improve our understanding of how sea ice varied over long time periods and whether recent trends are human-induced or represent one extreme of natural climate variability.

Instrumental records extend back only a few decades, so they are insufficient to understand natural variability in sea ice, ocean temperature, circulation and ecosystems, or the impacts of a warming climate on the Arctic. Scientists from USGS CLU R&D collaborated with an international team of scientists to reconstruct a history of Arctic sea ice for the past 600,000 years. They used data on past sea ice conditions preserved in a sediment core from Mendeleev Ridge in the western Arctic Ocean.

The results indicate that perennial sea ice developed about 350,000 years ago during a major global climate transition. Since then, the Arctic has experienced large glacial-interglacial climate oscillations with highly variable sea ice cover during the warm interglacial periods. Notable periods of seasonally sea-ice free conditions occurred at 5,000-10,000, 125,000 and 400,000 years ago. These results demonstrate that Arctic sea ice is extremely sensitive to climate changes and that Arctic Ocean marine ecosystems have experienced repeated short and long-term climatic cycles.

The paper, published in *Quaternary Science Reviews*, is available at http://www.sciencedirect.com/science/article/pii/S0277379112005380.



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## Improving models of the future with data from the past

A better understanding of the Pliocene Earth through paleoenvironmental reconstructions and computer simulations is providing insight on future climate projections.

In May 2013, atmospheric carbon dioxide ($CO_2$) concentrations measured at the Mauna Loa Observatory in Hawaii exceeded 400 ppm. The upward trend of this greenhouse gas has important implications for the Earth's climate in the near term and for hundreds to thousands of years into the future.

The last time that $CO_2$ levels were this high was ~3 million years ago, during the geologic period known as the Pliocene Epoch. Because the Pliocene climate was in many respects similar to climate projections for the end of this century, USGS researchers and colleagues have reconstructed aspects of Pliocene climate (including ocean temperature, land cover, and sea level). The climate modeling community is using this data to test the capabilities of different models to simulate climatic conditions significantly different from present day.

USGS scientists and colleagues compared a reconstruction of Pliocene ocean temperatures to model simulations. Most simulations capture the overall warmer ocean of the Pliocene, but they differ from the reconstruction in three areas: the mid- to high latitude North Atlantic, the tropics, and in mid-latitude upwelling systems.

In the North Atlantic, multiple techniques indicate a larger magnitude of warming than is shown in the simulations. Conversely, in the tropics, the simulations show more warming than is detected by paleontological or geochemical techniques. Model simulations disagree with each other in upwelling regions, and the available data is inconclusive.

Eliminating the data-model discrepancies is critical to improving model projections of future climate conditions. Both data analyses and model performance continue to be refined.

The paper, published in *Scientific Reports*, is available at: http://www.nature.com/srep/2013/130618/srep02013/full/srep02013.html



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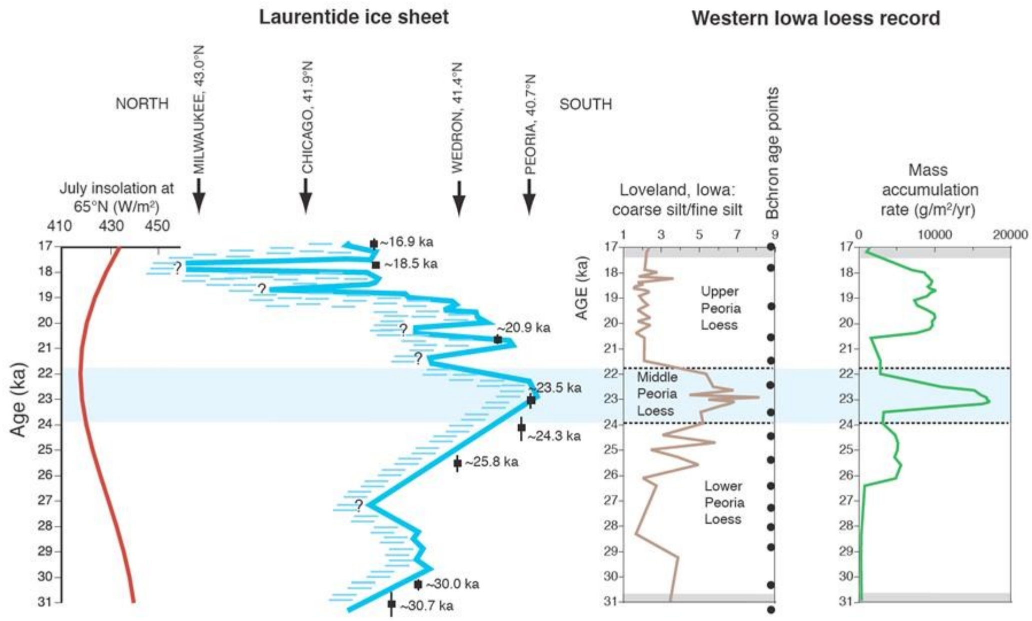
## *Western Iowa loess records stronger last-glacial winds*




Left to right: insolation from 31 ka to 17 ka at the top of the atmosphere at 65°N in July (from Berger and Loutre, 1991); time–distance diagram showing the southerly extent of the Laurentide ice sheet in the mid-continent of North America from ~31 cal ka BP to ~17 cal ka BP (redrawn from Johnson et al., 1997; their radiocarbon ages converted to calendar-year ages using Fairbanks et al. (2005)); stratigraphy, coarse/fine silt ratios in loess at Loveland, Iowa (particle size data from Muhs and Bettis (2000)); and loess mass accumulation rates (green line) at Loveland, calculated using a Bayesian reconstruction of OSL ages based on the 15 points (solid circles) shown.

Scientists have hypothesized that atmospheric dust concentrations may change under different climate scenarios, affecting planetary radiation balance, cloud dynamics, and dust inputs to oceans and terrestrial ecosystems. USGS CLU R&D scientists are exploring sources and concentrations of dust during past extreme climates to better understand causes of increased dustiness in the past. A recent study examines the hypothesis that stronger, more frequent winds increased dustiness during the last glacial period (28,000 – 10,000 years ago), when geologic records on land, in deep-sea cores, and in ice cores show that the Earth was a dustier planet.

A site at Loveland, Iowa, along the Missouri River, contains one of the thickest deposits of last-glacial-age dust (loess) in the world. Based on several geochemical "fingerprinting" techniques, this loess was determined to have derived not only from glacial sources near the Missouri River, but also from non-glacial sources in Nebraska. Dating of these deposits using a technique known as Optically Stimulated Luminescence (OSL) has resulted in the first detailed chronology of last-glacial-age loess at Loveland. Deposition began after about 27,000 years ago and continued until about 17,000 years ago, when the initial glacial retreat began.



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OSL ages also indicate that accumulations rates of loess were not constant. Accumulation was highest and grain size was coarsest approximately 23,000 years ago, when about 10 m of loess accumulated in no more than 2,000 years and possibly much less. The timing of this accumulation period, indicating strongest winds, coincides with a period of low summer solar radiation reaching the earth's surface at high latitudes in North America and the maximum southward extent of the last-glacial ice sheet. Such conditions would bring about a larger temperature contrast between the northern and southern regions in North America. An enhanced temperature contrast would result in more frequent strong winds. Many past climate models have not been able to produce a dustier last-glacial Earth. The results of this study show how geologic records can help to "fine-tune" climate models that are used for forecasting possible future climates.

The paper was published in *Quaternary Research* and can be found at: http://dx.doi.org/10.1016/j.yqres.2013.06.006



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## Warming ocean waters: impacts on tidewater glaciers

During the summer in the northeast Pacific Ocean, the Alaska Coastal Current sweeps water with temperatures in excess of 12°C (~54°F) past the mouths of glaciated fjords and bays along the northwestern coast of North America. These warm waters contribute to net ice loss from Alaskan tidewater glaciers, however the details of this interaction remain uncertain. Understanding ice discharge from marine-terminating glaciers such as these is important because it is the primary mechanism responsible for sea level rise.

Yahtse Glacier, Alaska discharges ice into Icy Bay both by calving, as evidenced by the ice covered fjord, and submarine melt. In late summer, submarine melt matches the pace of incoming ice flow, which at Yahtse Glacier exceeds 17 m/d.

A team of NSF researchers including USGS CLU R&D scientists combined glaciological and oceanographic measurements to demonstrate that a large fraction of the rapid mass loss from Alaska's tidewater glaciers is a result of submarine melt, that is, by ice melting below the sea surface. This important process, now on the edge of scientific discovery, has for decades been obscured by logistical challenges in making measurements. Their results support the idea that tidewater glaciers are strongly sensitive to changes in ocean temperature (i.e. two-way communication exists between glaciers and the oceans; each system is capable of triggering large scale changes in the other). The research took place at Alaska's Yahtse Glacier in Icy Bay, one of the most remote sections of the Gulf of Alaska coastline.

The team used passive seismology to measure iceberg calving, GPS and time-lapse photography to measure ice speeds, and oceanographic measurements of water column properties such as temperature and depth. The data showed that freshwater subglacial meltwater (which is less dense than seawater) provides the 'engine' by which warm ocean water is brought to the glacier terminus where it can melt ice rapidly during the late summer and fall.

This research provides much needed understanding of marine-glacier instability and how these processes influence sea level rise. Additionally, the work will help to improve the accuracy and validity of models designed to predict future sea level change.

The article "Does calving matter? Evidence for significant submarine melt," was published in *Earth and Planetary Science Letters* and can be found at: http://dx.doi.org/10.1016/j.epsl.2013.08.014

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*News from the* USGS Climate Research & Development Program

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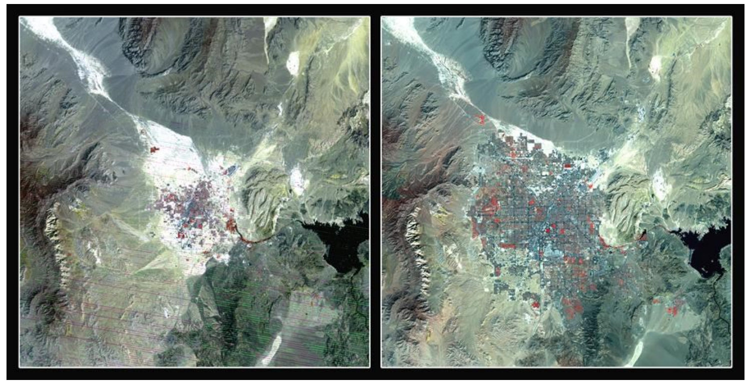
**Volume 1, Summer 2014**

## *Land use and Land cover change in the conterminous United States from 1973 to 2000*



This image shows the City of Las Vegas using data from Landsat 1 and 8. Landsat multispectral scanner data from Landsat 1 was acquired on April 12, 1974. The color infrared image shows a "young" Las Vegas at the time. The image on the right reveals the substantial urban growth that has occurred in the city over the past 40 years. Data from the Landsat 8 Operational Land Imager was acquired October 6, 2013.

Land Use Land Change (LULC) management often leads to changes that compromise human needs and ecosystem functioning. These LULC changes have been shown to have impacts at the local to global scale, directly affecting the cycling of chemicals and nutrients (e.g. carbon), functioning of ecosystems, water quality, and climate and weather systems. For example, LULC changes have been shown to alter the regional carbon budgets of forested ecosystems, resulting in increased flux of $CO_2$ to the atmosphere.

Despite broad acceptance in the scientific community of LULC change as a significant cause of environmental change, there has been a lack of integrated studies conducted at sufficient spatial, temporal, and thematic scales needed to comprehensively characterize LULC change at the national scale. A recent USGS CLU R&D study used nearly 30 years of Landsat satellite observations to measure spatial and temporal patterns of LULC changes in the conterminous United States.

The study divided the nation into 84 conterminous ecoregions and used a random sampling approach that included 2688 sample sites imaged by Landsat over five periods (see figure). This methodology enabled the direct comparison of estimates of change in LULC across time periods and ecoregions. The researchers found that LULC is a pervasive and variable phenomenon with considerable geographic and temporal variability. For example, the southeast and northwest have undergone almost continuous change while southwest deserts have been relatively stable. The most dynamic regions are those in which environmental conditions such as climate, soils, and topography are suitable for productive and relatively intensive resource-based land uses, such as urbanization, cultivation, and timber extraction.

The findings from this research provide important baseline data on LULC change by ecoregion over time, which can be used to assess the impacts on other environmental processes such as assessing regional water quantity and quality, analyzing the health of ecosystems and critical habitat needed by imperiled species, and the cycling of energy between the ocean, land and sea.

This paper, published in Global Environmental Change in 2013, can be found at: http://www.sciencedirect.com/science/article/pii/S0959378013000538



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Debra Willard, Managing Editor
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## Climate effects on western US forests

In order to forecast how forests will change in the future, we need to understand how climate affects tree mortality. Indeed, we will likely get substantially different forest landscapes depending on which mechanism or combination of mechanisms are driving tree death.

Forests are a critical component of the terrestrial biosphere, and changes in forests can have substantial effects on the cycling of carbon, energy, and water. To forecast how forests may change in the future, it is important to understand how climate affects tree mortality. Indeed, we may see substantially different forest landscapes depending on which mechanism or combination of mechanisms play a role in tree death.

The rate of tree mortality in western forests has more than doubled in the past few decades, and that increase appears to be related to a warming climate. It is unclear, however, whether those warming-related increases are driven by increasing drought stress in trees, more favorable conditions for tree-killing organisms, or some combination of the two.

USGS CLU R&D scientists and colleagues attempted to identify which mechanism dominates climate-related changes in tree mortality across the landscape. Using data from a long-term study of tree demography in the Sierra Nevada of California, they found strong evidence that the drivers of changing mortality rates differ between forests where growth is limited by energy (colder, wetter areas with shorter growing seasons) and forests where growth is limited by water (hotter, drier areas where water is more scarce). In water-limited forests, drought stress on trees seems to dominate changes in mortality rate, while in energy-limited forests climatic effects on tree-killing organisms also appear to play a key role. However, they also discovered that currently available data are inadequate to clearly forecast how these mechanisms will affect tree mortality in the future, with different (and equally supported) models giving radically different outcomes.

As the climate continues to warm, tree mortality will likely continue to increase. How severe those increases will be and how they will be distributed across the landscape remain key questions.

The paper was published in the journal *PLOS One* and is available at: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0069917



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## "National Climate Change Viewer" Enables Focus on Future Climate-Driven Changes for U.S. Watersheds at Local Levels

***By Jay Alder, Steve Hostetler and Catherine Pucket***

Secretary of the Interior Sally Jewell unveiled the National Climate Change Viewer, a climate-visualization website tool from the Interior Department's U.S. Geological Survey. The new tool gives citizens and resource managers the opportunity to look at climate-driven impacts on watersheds.

"The new USGS National Climate Change Viewer shows projected climate-driven challenges to watersheds and future water supplies across the United States," said Secretary Jewell. "This information will be valuable to the work of scientists, water and land managers, farmers and ranchers — as well as all interested citizens. As we carry out the President's Climate Action Plan, this will be a useful tool for planning how to manage, adapt to and mitigate climate change."

This is the second phase of the National Climate Change Viewer project, which aims to make climate model results more accessible and understandable. In the first phase, the climate change viewer provided information on projected temperature and precipitation for the United States, states and counties through the 21st century in 25-year periods as part of an effort to visualize some climate model simulations being used by the IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report.

In this second phase, the climate change viewer has been expanded to provide information on associated projected changes in snowpack, soil moisture, runoff and evaporative deficit for U.S. states and counties and for USGS Hydrologic Units or watersheds as simulated by a simple water-balance model. The model provides a way to simulate the response of the water balance to changes in temperature and precipitation in the climate models. Combining the climate data with the water balance data provides further insights into the potential for climate-driven change in water resources.

USGS scientists Steve Hostetler and Jay Alder, who developed the tool in collaboration with the College of Earth, Oceanic and Atmospheric Sciences at Oregon State University, said they believe that the water balance modeling will provide a broader perspective on climate change. "For example," said Alder, "in addition to temperature and precipitation, farmers and land and water managers can use the website to help guide their thinking and actions concerning adaptation and mitigation strategies, and educators can use it to teach students about some of the implications of climate change."

The National Climate Change Viewer and data are already being used by federal agencies, including the USGS and the National Park Service, to examine the potential effects of climate change on aquatic and terrestrial ecosystems in the Greater Yellowstone Area and elsewhere.

The first phase of the project had more than 12,000 users that generated more than 100,000 maps. Phase 2, which began on May 8, 2014, has had more than 2,000 unique users that generated more than 26,000 maps to date. The viewer was featured under "Emerging Tech" in Government Computing News (GCN) see: http://gcn.com/blogs/emerging-tech/2014/06/usgs-climate-change-viewer.aspx?admgarea=TC_BigData

The National Climate Change Viewer maps and summaries are available here, along with a tutorial and illustration of how the viewer can be used.

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