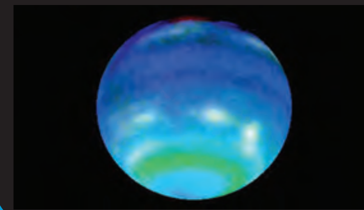
SPACE SCIENCE AND ENGINEERING CENTER • COOPERATIVE INSTITUTE FOR METEOROLOGICAL SATELLITE STUDIES • UNIVERSITY OF WISCONSIN-MADISON

TtA 2013
Summer / Fall



SSEC

through the atmosphere

Breaking Records at the Poles

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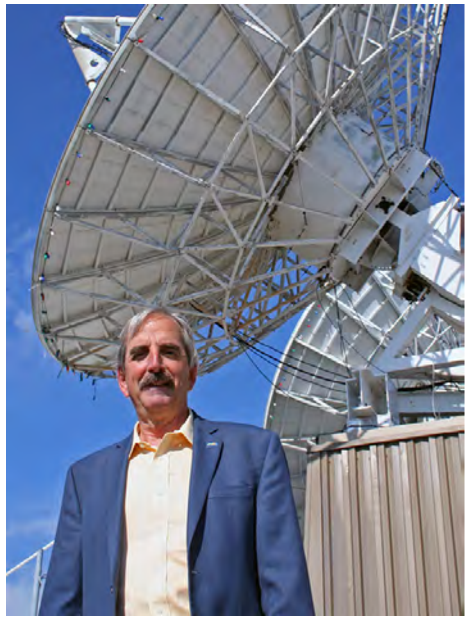
Fogbow at Summit Camp in central Greenland on 15 June 2011.
Photo credit: Nate Miller, SSEC

DIRECTOR'S Note



In addition to its fundamental role in establishing and maintaining the Earth's climate, ice enhances nature's magnificent beauty. While investigating the role of ice in weather and climate, we are fortunate to also experience the beauty of its sun dogs, solar pillars, and yes, even the unusual fog bow in Greenland.

This issue focuses on our polar regions research where understanding the role of ice in the form of both surface cover and cloud particles is key to explaining the mysteries of the Earth's climate. The tools of this research are diverse, ranging from the satellite's view from above, to observations from the surface upward, to capturing the Earth's past below the surface, and even delving into the microphysics of cloud particle structures and their interaction with electromagnetic radiation.

The importance of this broad perspective toward the fields of weather and climate is certainly recognized by the new director of the National Weather Service, Dr. Louis Uccellini (see first article). Dr. Uccellini's statement that "it's not just the weather anymore" refers to that need to take a larger view and to connect with society to save lives. Louis has also shown a long-term commitment to bringing the research and operational communities together.

The articles on polar research and ice begin with recent observations of an extensive surface melt event in Greenland and of the declining Arctic sea ice extent. Both illustrate the role that clouds can play in enhancing surface warming, as well as the cooling that we often associate with a cloudy day.

We also report on two very different endeavors in the south polar regions of Western Antarctica. The long commitment to deploying Automatic Weather Stations on the surface in Antarctica is playing a key role in detecting West Antarctica warming. Also, temperature trends over the scale of tens of thousands of years are being pursued by removing ice core samples throughout the depth of the ice sheet. Following a record setting coring achievement in the 2011/2012 drilling season, this season brought a new first by resampling critical regions using a new replicate drilling technique.

I invite you to read more about these exciting research programs and other endeavors at SSEC in the pages that follow.

Hank Revercomb

Hank Revercomb
Director, SSEC

It's Not Just the Weather Anymore

An Interview with Dr. Louis Uccellini

by Leanne Avila and Jean Phillips

Dr. Louis Uccellini was appointed the 16th director of the National Weather Service in February 2013. Prior to this appointment, he led the National Centers for Environmental Prediction (NCEP) for 14 years. Uccellini is a fellow of the American Meteorological Society and served as the Society's president in 2012.

"Go, Badgers!"

In just two words Dr. Louis Uccellini, the recently appointed Director of the National Weather Service (NWS), conveyed his longstanding connections and affection for his alma mater, the University of Wisconsin-Madison. As a student in the 1970s, Uccellini was inspired by his mentors, especially professors Charles E. Anderson and Donald R. Johnson of the UW-Madison's Department of Meteorology (known today as the Department of Atmospheric and Oceanic Sciences). Later, collaborations with researchers at the Space Science and Engineering Center (SSEC) gave him the opportunity to put theory into practice. Uccellini has since dedicated his life's work to improving weather forecasts. Now, as NWS Director, he sees new challenges and opportunities for the future of the discipline.

We interviewed Dr. Uccellini in February, just weeks after his appointment. He shared stories from his time at the UW-Madison, as well as his thoughts about the science of weather forecasting and just what it means to be a "weather-ready nation." Despite the many advances in our nation's ability to forecast severe weather events with precision and accuracy, injuries and death as a result of severe weather remain an unsettling fact. Communicating well with decision makers and the public is critical. Unfortunately, "we still have situations in which the message we give is not equal to the message received." Using Hurricane Sandy as a successful example, Uccellini noted how the forecasts focused on impacts and extent, rather than on whether or not the storm system would make landfall as a hurricane or post-tropical storm.

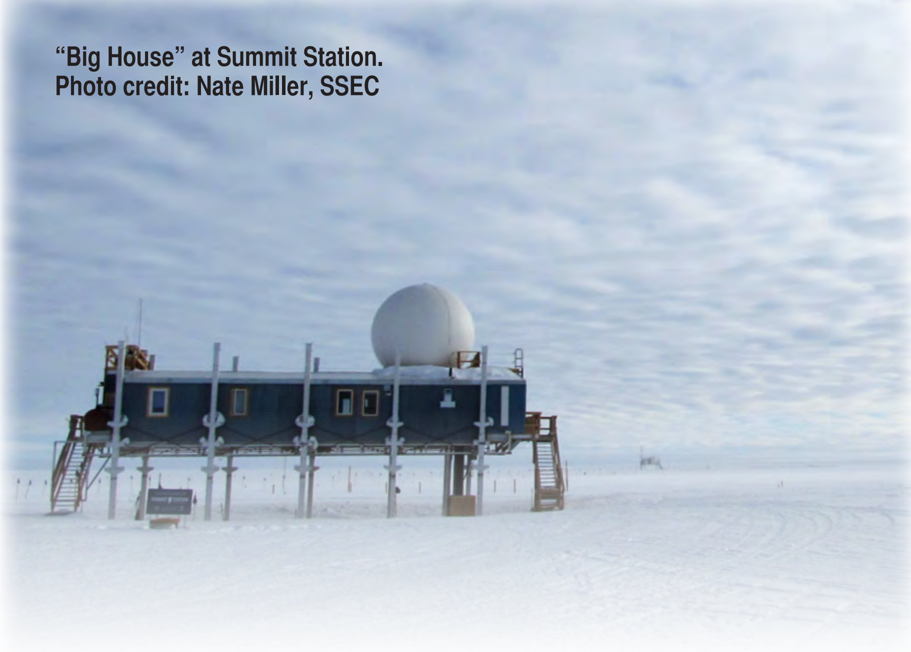
Collaboration among many groups is key to continued improvements in forecasts. Uccellini commented on the need for the research and operational communities to work together and noted how Wisconsin is "usually at the front of the line in terms of being able to affect the transition from research into operations." Specifically, Uccellini mentioned SSEC's satellite research and work with the National Hurricane Center. According to Dr. Uccellini, the NWS relies on university research programs, like those at the UW, for improvements and advancements in technologies related to enhancing forecast skill.

In addition, Uccellini urged those involved in weather forecasting to look outside their discipline. Weather impacts every facet of human life, from the spread of disease to the economy to agriculture and beyond. Taking an interdisciplinary approach, examining more than just the atmosphere, but also looking at oceans, land surface, the cryosphere, biological and hydrological systems, and chemistry, Uccellini maintains that forecasts can only become more accurate. "We also know that to make predictions, it's not just the weather anymore."

In fact, Uccellini expects many more groups to work together in the future to leverage one another's efforts, given the current economic difficulties that may result in a gap in satellite coverage. Maintaining the availability of satellite data in real time, sharing this data, and a free flow of information are fundamental to the global satellite observing system. SSEC, and its founder, Verner Suomi, made the case early on for such collaboration, and Uccellini is keen to see it continue.

Despite the budget challenges and need to improve communication, Uccellini is optimistic about the future, seeing opportunities for growth. Further, Uccellini sees the ultimate goal of saving lives and mitigating property loss as a worthwhile venture extending far beyond the science. It seems only fitting that this philosophy mirrors SSEC's mission for its research to be of benefit to all, serving, too, as a perfect example of the Wisconsin Idea, the UW-Madison's mission to "improve people's lives beyond the classroom." §

Read the full transcript of the interview at: http://goo.gl/f2Glo



“Big House” at Summit Station.
Photo credit: Nate Miller, SSEC

Finding the Cause

Greenland’s Record-Breaking Ice Melt of 2012

by Mark Hobson

If the Greenland Ice Sheet (GIS) were to melt in its entirety tomorrow, it would raise global sea levels by 24 feet. Second in volume only to ice-covered Antarctica, the GIS is 2400 kilometers (1500 miles) long, 1100 kilometers (680 miles) wide, and as much as 3 kilometers (1.8 miles) thick. That’s nearly 3 million cubic kilometers of ice.

It won’t melt overnight, of course, but researchers are following record-breaking melting events that have been observed across most of the GIS.

In an April 2013 paper published in “Nature,” Ralf Bennartz, a professor in the Department of Atmospheric and Oceanic Sciences and scientist with the Space Science and Engineering Center at the University of Wisconsin-Madison, examines one part of the complicated puzzle that Greenland’s climate presents.

“In July 2012,” Bennartz says, “a historically rare period of extended surface melting raised questions about the frequency and extent of such events. Of course, there is more than one cause for such wide-spread change. We focused our study on certain kinds of low-level clouds.”

The University of Wisconsin, together with other institutions, maintains an atmospheric research experiment at the National Science Foundation’s Summit Station, a research facility located on top of the GIS at a height of 3200m above sea level. This experiment, which is known as ICECAPS (Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit), provided invaluable data and insights into the different factors causing the melt event.

“You can say we were really lucky to be right there when the melt happened,” Bennartz continues.

Satellite observations show an increase in the extent of the GIS melt since at least 1979, but the July 2012 event set a new record in melt extent. Examination of long-term melt records obtained from ice-core projects at Summit Station indicate that such events occurred only about once every 150 years over the last 4000 years.

“The July 2012 event,” explains Dave Turner of NOAA-NSSL, one of the lead investigators, “was triggered by an influx of unusually warm air, but that was only one factor. In our paper we show that low-level clouds were

Low-level, liquid-bearing clouds over the Mobile Science Facility at Summit Station in central Greenland. Photo credit: Ed Stockard, SSEC

instrumental in pushing temperatures up above freezing."

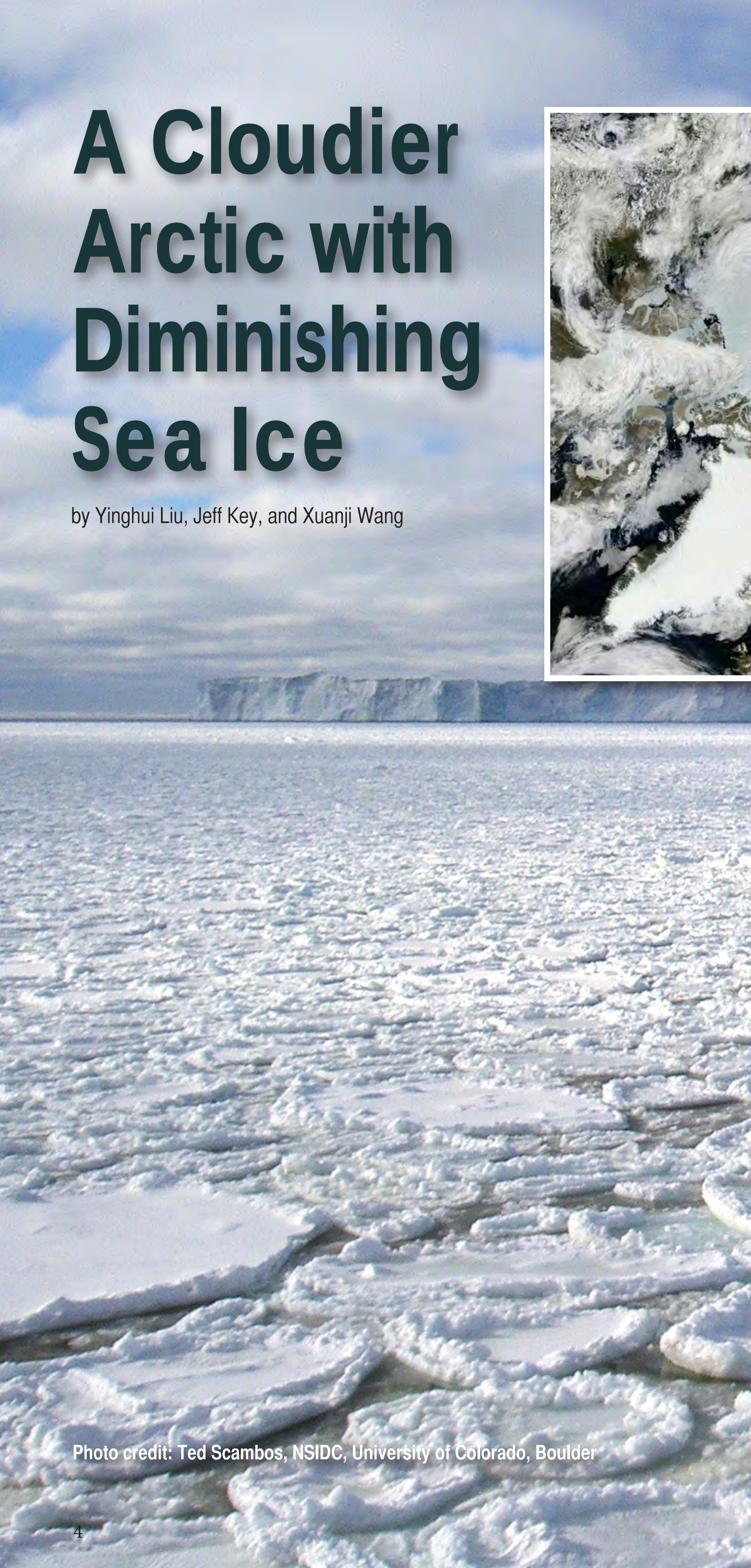
Low-level clouds usually reflect solar energy back into space, while also radiating infrared energy downwards, back to the surface. That is only one element within a complex interaction of many conditions, such as wind speed, turbulence, temperature, and humidity. In addition, heat transfer on the surface depends upon the snow's ability to conduct the heat received from solar radiation as well as the heat exchange between different layers of snow.

When cloud thickness and temperature conditions are right, these clouds can be thin enough that, instead of reflecting most of the solar energy away from the surface, they allow some of it to pass through, while still "trapping" infrared radiation at ground level. The extra heat energy available at the surface pushes temperatures above freezing. That is exactly what happened in July 2012 over large parts of the GIS.

Current climate models tend to underestimate the occurrence of this particular cloud type, thus limiting those models' ability to predict cloud response to Arctic climate change and possible feedback mechanisms. By using a combination of surface-based observations, remote sensing data, and surface energy-balance models, this study not only delineates the effect of clouds on ice melting, but also shows that this type of cloud is common over both Greenland and across the Arctic.

> *"The July 2012 event was triggered by an influx of unusually warm air, but that was only one factor... low-level clouds were instrumental in pushing temperatures up above freezing."*

"We know that these thin, low-level clouds occur frequently," says Bennartz. "Our results may help to explain some of the difficulties that current global climate models have in simulating the Arctic surface energy budget. Above all, this study highlights the importance of continuous and detailed ground-based observations over the GIS and elsewhere. Only such detailed observations will lead to a better understanding of the processes that drive Arctic climate." §



A Cloudier Arctic with Diminishing Sea Ice

by Yinghui Liu, Jeff Key, and Xuanji Wang

Photo credit: Ted Scambos, NSIDC, University of Colorado, Boulder

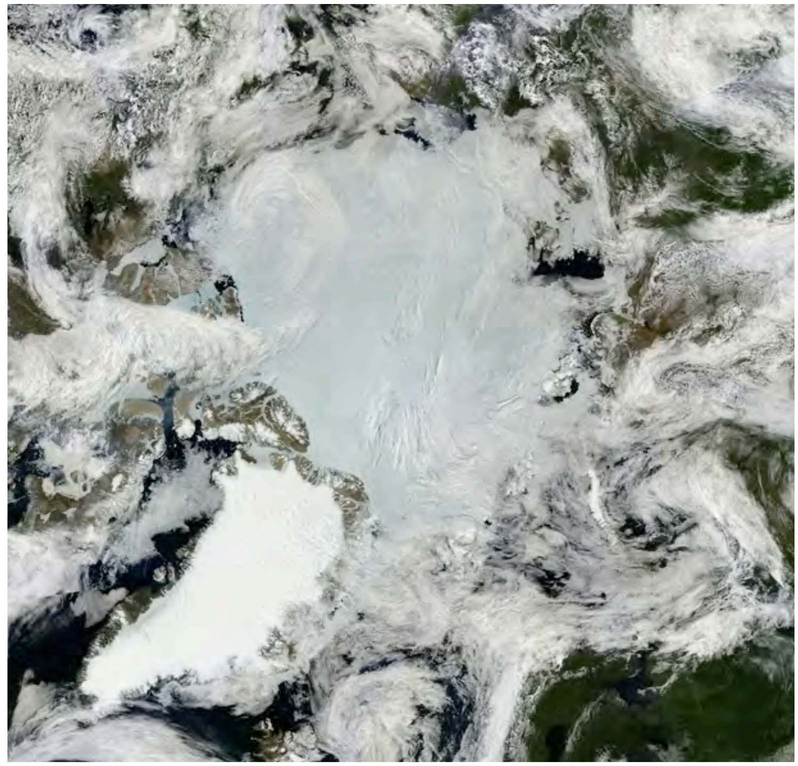


Figure 1. True color composite of Moderate Resolution Imaging Spectroradiometer (MODIS) imagery over the Arctic acquired on 30 June 2011. Greenland is in the lower left; Alaska is under cloud cover in the upper left. Figure credit: Jeff Schmaltz, NASA MODIS Land Rapid Response Team

Arctic sea ice (Figure 1) has been shrinking for the past three decades with the summertime extent declining over 30%. With continued increasing temperatures, ice-free conditions in the summer are likely in the coming decades. Changes in Arctic sea ice are already having an impact on regional flora and fauna. Some species will face increasing challenges in the future, while new habitats will open up for other species. The changes are also affecting the living and working conditions of people who live in the Arctic in negative as well as positive ways. While the way of life for native communities is being threatened, there will be new opportunities for shipping, fishing, and natural resource extraction.

Climate model simulations have captured the general downward trend in Arctic sea ice extent but with considerable variability. In almost all climate model simulations, the predicted decrease in Arctic sea ice is slower than that observed by space-based passive microwave instruments. The implication is that some processes controlling Arctic sea ice are not well represented in climate models. Cloud feedback is the primary source of uncertainty in model simulations, especially in the polar regions.

Clouds are a key factor in the radiative components of the surface energy budget, and as a result they significantly influence sea ice melt and growth. CIMSS and NOAA scientists observed a trend in the radiative effect of Arctic clouds during the 1980s and 1990s, such that changes in cloud cover resulted in increased cooling during summer and decreased warming during winter, possibly suppressing Arctic warming to some degree.

Changes in sea ice, in turn, are very likely to cause changes in cloud cover and other cloud properties. Areas of increased total cloud cover tend to be collocated with declining ice concentration over the Arctic Ocean. Positive cloud cover anomalies (more clouds) correspond to negative sea ice concentration anomalies (less ice). An example for September 2012 is shown in Figure 2. The most likely reasons behind this relationship are the increased availability of moisture for cloud growth and the decreased stability of the lower troposphere resulting from a warmer surface. Recent studies suggest the importance of cloud-sea ice interaction in the changing Arctic climate, and in turn emphasize the need to further quantify the feedback of sea ice changes on cloud cover using longer observations with more advanced analysis tools.

Given that climate models may not adequately capture the feedback between sea ice and clouds, how can we quantify this relationship? A statistical method called the equilibrium feedback assessment (EFA) was applied to multiple years of satellite data, providing an observational assessment of the degree to which cloud cover responds to changes in Arctic sea ice. Passive microwave data were used to characterize the sea ice cover, while visible and thermal infrared data were used to estimate cloud properties. Results suggest a positive feedback between sea ice and cloud cover; that is, lower sea ice concentration (or more open water) favors increased cloud cover possibly through stronger surface evaporation. The increased cloud cover, in turn, tends to trap (emit) more longwave radiation and thus warm the surface resulting in further sea ice shrinkage. Quantitatively, a 1% decrease in sea ice concentration leads to a 0.36-0.47% increase in cloud cover. This seemingly simple result may help explain the discrepancy between the observed and modeled decline in Arctic sea ice extent. Additionally, it suggests that a further decline in sea ice cover – which is likely over the coming decades - will result in an even cloudier Arctic. §

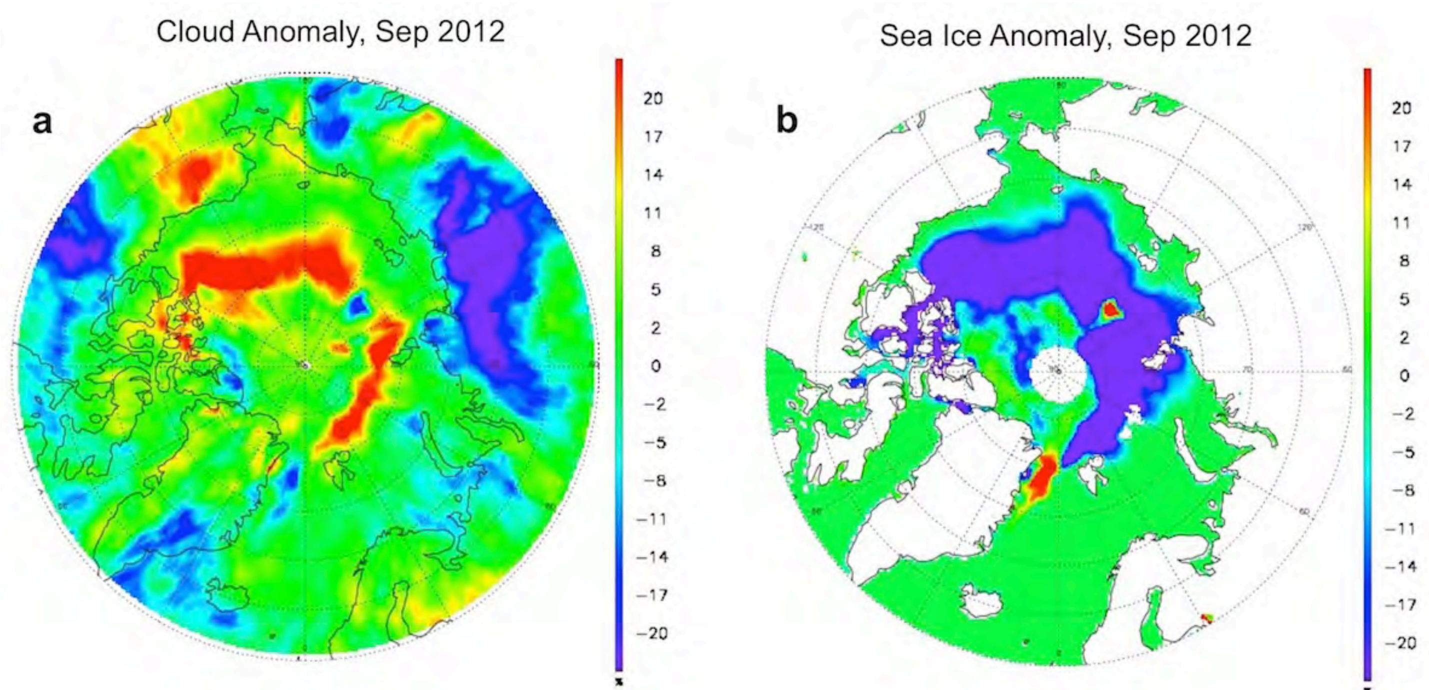


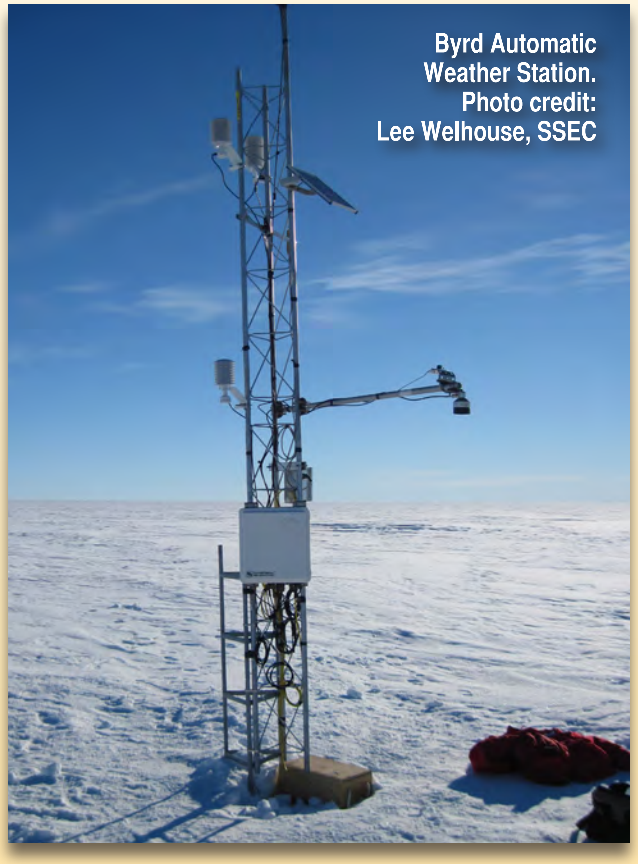
Figure 2. Cloud cover (a) and passive microwave sea ice concentration (b) anomalies (%) in September 2012 relative to the corresponding monthly means for the period 2002-2010. Cloud data are from Aqua MODIS.

Statistically Significant Warming

AWS Data Supports Study of Central West Antarctica Warming

by Matthew Lazzara and Jean Phillips

Central West Antarctica is warming. In fact it has warmed almost 4.3 degrees Fahrenheit in the last 50 years. A study led by David Bromwich, Ohio State University (*Nature Geoscience*, 2012), along with collaborators from SSEC's Antarctic Meteorological Research Center (AMRC), found "statistically significant warming during the austral summer" which is the peak of the melting season on the continent. Matthew Lazzara, who heads the AMRC, along with his colleagues Linda Keller and George Weidner, provided the corrected Byrd Station dataset that was to form the backbone of the study.


Byrd Automatic Weather Station. Photo credit: Lee Welhouse, SSEC

Until 2011, polar researchers at Ohio State and the UW worked in parallel as they examined various aspects of Antarctic weather and climate. Eventually, some of the work initiated at Ohio coincided with the AMRC's work on legacy calibration of station data. The Bromwich team had been looking at warming over a longer time scale, using Automatic Weather Station (AWS) data from the AMRC, among other datasets. Their work indicated unusually high levels of warming in Central Western Antarctica. Coincidentally, and as part of routine evaluation, George Weidner and others in the AWS field team had recovered the electronics from a number of weather stations over the years, including Byrd AWS, and had begun to test the hardware to check function and performance in order to confirm the accuracy of the calibrations.

Weidner's examination of the actual hardware and electronics at Byrd Station uncovered two important problems. The first involved an offset in temperature that had been programmed into the original software. Researchers had added this offset originally to correct the temperature calibration at Byrd, but neglected to remove it when it was no longer needed. This offset continued to be added to the temperature readings from Byrd for many years giving erroneously high readings.

A second problem came to light only because Weidner was looking at the electronics in the laboratory and by doing so, was able to simulate what the sensors would read at certain values or temperatures. The Byrd Station electronics began to exhibit degraded temperature calibrations because of exposure to Antarctic weather extremes. By placing the electronics into a cold chamber in the lab, they were able to prove that the error worsened as temperatures decreased. Temperatures were being altered. This problem might not have been discovered had AMRC researchers not already been evaluating performance in the controlled environment of the lab. Weidner was able to modify the code to correct for the temperature error.

These two errors were in opposite directions; that is, the first offset was consistent over time, but the second varied with temperature and thus would be different over a segment of the archived data record. Despite the issues of data error and subsequent correction, the combined Wisconsin and Ohio team still arrived at a significant warming in Central Western Antarctica. Removing the offset from the code and adjusting for the equipment error did not negate results of the study that indicated temperatures were warming, but the warming was not as extreme as originally thought. Both research teams, at the UW and at Ohio, checked the data independently, verifying that each could correct the data and arrive at the same results.

Researchers now have a dataset that is more complete and accurate and can be drawn upon to support future studies.

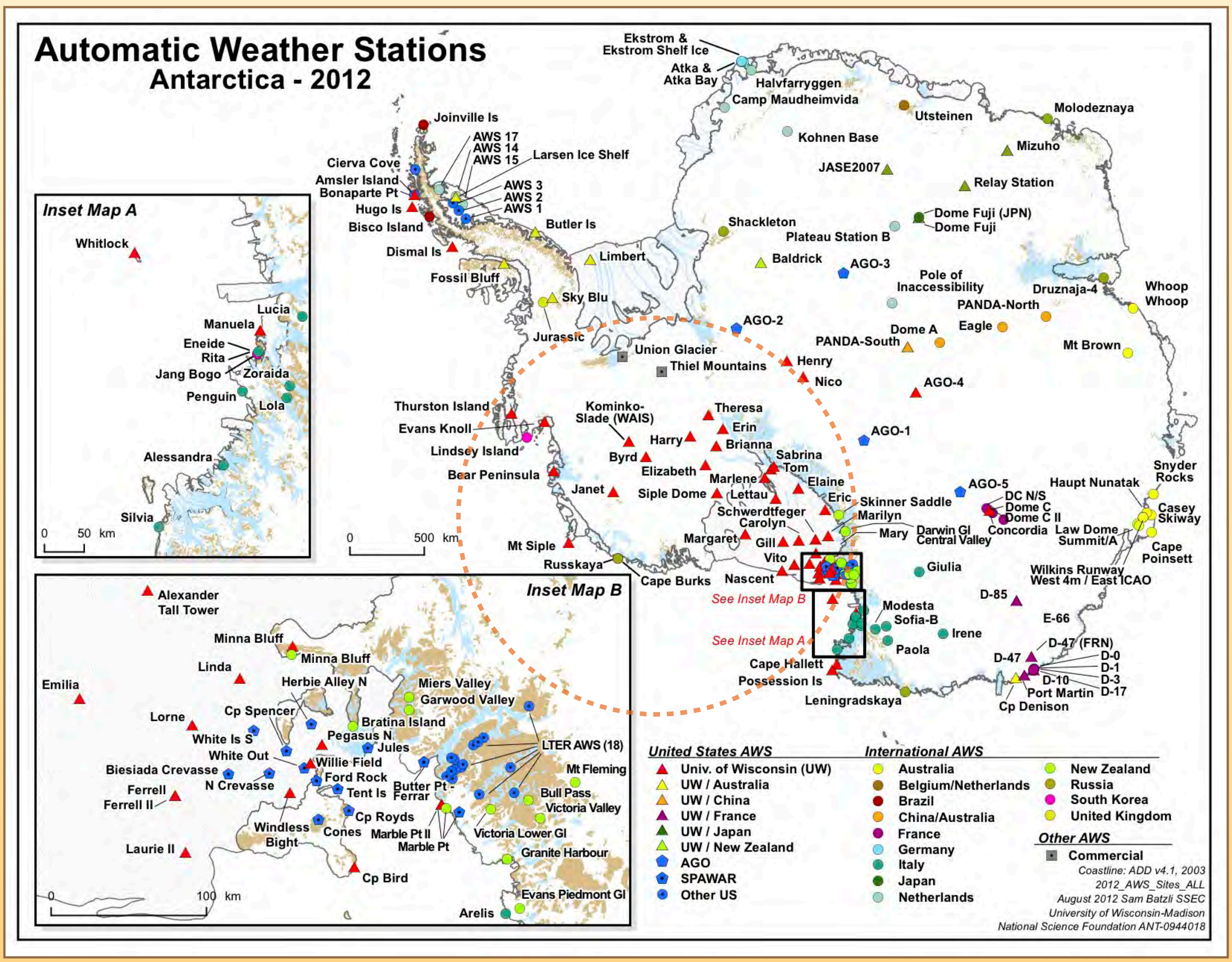
The Bromwich study shows warming in Central Western Antarctica, corroborating other studies such as that by Eric Steig (*Nature*, 2009), that showed warming "beyond the Antarctic Peninsula to cover most of West Antarctica," and the British Antarctic Survey documenting the Antarctic Peninsula as rapidly warming over the last half-century (http://www.antarctica.ac.uk/bas_research/science/climate/antarctic_peninsula.php).

The network of Automatic Weather Stations (AWS) was initially installed to collect weather data, such as temperature and wind speed, but as more and more stations reach the thirty year point, scientists can utilize the longitudinal data to support climate studies. Lazzara would like to install stations in areas that do not currently have them – between the peninsula and Byrd – in order to collect more data.

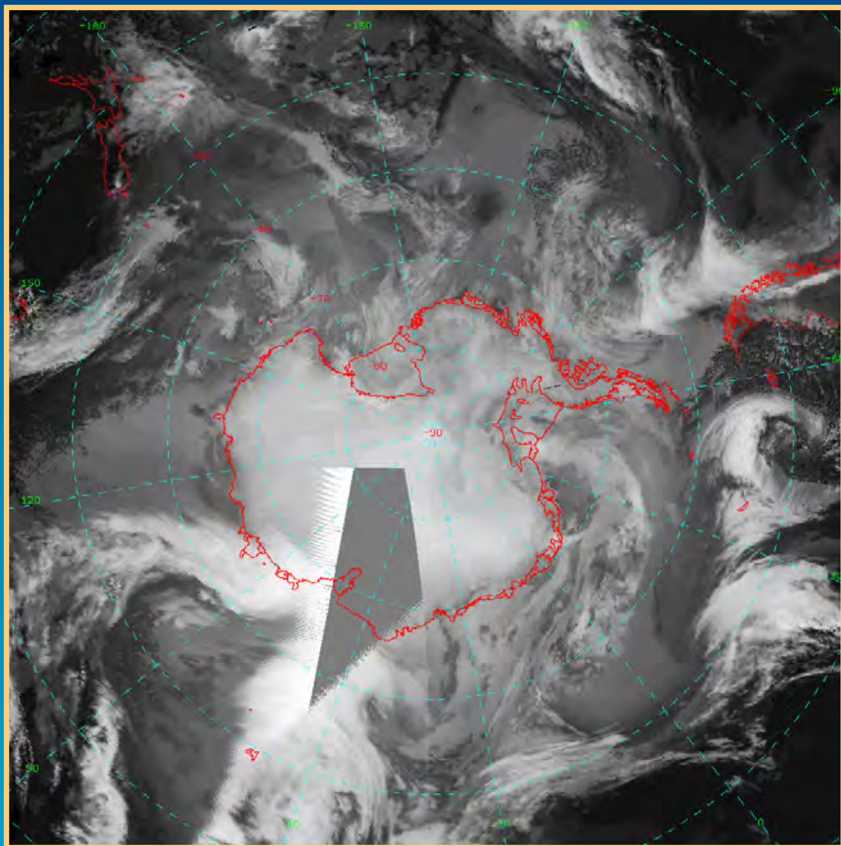
He and other scientists have been able to construct some boundaries on what is happening in the Antarctic and elsewhere. For example, while the peninsula and Central Western Antarctica are warming, the region around the South Pole is not changing much. Studies by Lazzara and Keller have reviewed 50 years of South Pole surface observations and determined that South Pole temperatures are not significantly warming. If the pole is not warming, will the warming move toward the east?

Scientists now know that Western Antarctica is warming. Whether this will change over time or continue at the same pace is unknown. Rising temperatures will not melt the ice immediately, but warmer temperatures allow the atmosphere to hold more moisture, creating the potential for snow farther inland. Will the continent melt at the edges and grow in the center? How will this process affect the global hydrological cycle?

These questions, currently without answers, can begin to be analyzed using current studies as benchmarks and with the collection of more data to develop larger, more comprehensive datasets, such as that of Byrd Station. §



Automatic Weather Stations on the Antarctic continent in 2012. Figure credit: Sam Batzli, SSEC



20 Years of the AMRC

Antarctic Meteorological Research Center

by Jean Phillips

The development of Antarctic satellite composite imagery at SSEC's Antarctic Meteorological Research Center (AMRC) in 1992 revolutionized the view of weather systems around the Antarctic, especially for weather forecasting. The late Professor Charles Stearns, having been introduced to the Antarctic by Werner Schwerdtfeger, saw the utility in making satellite composites from both geostationary and polar-orbiting satellites over the Antarctic and adjacent Southern Ocean. The composite products became routinely available. These observations have supported meteorological research and other science investigations for over two decades, inspiring a variety of applications.

Today, the AMRC is led by Dr. Matthew Lazzara who continues the legacy of improvements to the Antarctic and Arctic satellite composites. Composites now incorporate additional spectral channels, such as water vapor and experimental visible, expanding the utility of the initial infrared composite. §

Source: Lazzara, Matthew, 2010. Picture Composition: The University of Wisconsin-Madison Antarctic Meteorology Program, Launch Issue, Meteorological Technology International, 88-92.

Highlights

♦ **Smith, Nadia; Menzel, W. Paul, Weisz, Elisabeth; Heidinger, Andrew K., and Baum, Bryan A.** A uniform space-time gridding algorithm for comparison of satellite data products: Characterization and sensitivity study. Journal of Applied Meteorology and Climatology v.52, no.1, 2013, pp255-268.

Introduction of a statistical gridding algorithm for projecting data from unique instrument domains to a uniform space-time domain. The sensitivity of the gridding algorithm is demonstrated using one month of level 2 Aqua/MODIS cloud-top pressure (CTP) retrievals. The authors conclude that this greatly facilitates the intercomparison of CTP and algorithms in a dynamic environment. Its simplicity makes it useful for both research and operational use.

♦ **Sieglaff, Justin M.; Hartung, Daniel C.; Feltz, Wayne F.; Cronce, Lee M., and Lakshmann, Valliappa.** A satellite-based convective cloud object tracking and multipurpose data fusion tool with application to developing convection. Journal of Atmospheric and Oceanic Technology v.30, no.3, 2013, pp510-525.

Discussion of the need to fuse data sets of different temporal and spatial resolutions used to study deep convective clouds into a single framework. The authors introduce a methodology to identify and track convective cloud objects from infancy into the mature phase using only geostationary imager IR window observations. The system uses the Warning Decision Support System-Integrated Information (WDSS-II) framework and a UW-CIMSS-developed postprocessing algorithm, demonstrating that the system output is an effective means for fusing a variety of meteorological data for studying the initial growth of deep convective clouds and temporal trends.

♦ **Roebeling, Rob; Baum, Bryan; Bennartz, Ralf; Hamann, Ulrich;**

Heidinger, Andy; Thoss, Anke, and Walther, Andi. Evaluating and improving cloud parameter retrievals. Bulletin of the American Meteorological Society v.94, no.4, 2013, ppES41-ES44.

Summary of the Third Cloud Retrieval Evaluation Workshop. About 70 research scientists and students from Europe and the United States reviewed existing and new approaches to infer cloud parameters from passive and active satellite observations. The priorities were to compare products from different teams, increase traceability of results, and discuss scientific issues common to all teams.

♦ **Pavolonis, Michael J.; Heidinger, Andrew K., and Sieglaff, Justin.** Automated retrievals of volcanic ash and dust cloud properties from upwelling infrared measurements. Journal of Geophysical Research v.118, 2013, doi:10/1002/jgrd.50173.

Presentation of a fully automated, globally applicable algorithm to retrieve ash and dust cloud properties from infrared satellite measurements which will serve as the official operational algorithm of the next generation Geostationary Operational Environmental Satellite (GOES-R).

♦ **Mielikainen, Jarno; Huang, Bormin; Wang, Jun; Huang, H.-L. Allen, and Goldberg, Mitchell D.** Compute Unified Device Architecture (CUDA)-based parallelization of WRF Kessler cloud microphysics scheme. Computers and Geosciences v.52, 2013, pp292-299.

Development of an efficient Weather Research and Forecasting (WRF) Kessler microphysics scheme which runs on Graphics Processing Units (GPUs) using the NVIDIA Compute Unified Device Architecture (CUDA). Discussion of the significant speedup over CPU based single-threaded version.

♦ **Hyer, Edward J.; Reid, Jeffrey S.; Prins, Elaine M.; Hoffman, Jay P.; Schmidt, Christopher C.; Meittinen, Jukka I., and Giglio, Louis.** Patterns of fire activity over Indonesia and Malaysia from polar and geostationary satellite observations. Atmospheric Research v.122, 2013, pp504-519.

Biomass burning patterns over the Maritime Continent of Southeast Asia are examined using a new active fire detection product based on the application of the Wildfire Automated Biomass Burning Algorithm (WF-ABBA) to data from the images on MTSAT geostationary satellites. Preliminary sampling demonstrates that fire activity sampled by the two MODIS sensors varies significantly by region and vegetation type. Based on the results, a series of steps is outlined to account for some of the systematic biases in order to produce a successful merged fire detection product.

♦ **Hartung, Daniel C.; Sieglaff, Justin M.; Cronce, Lee M., and Feltz, Wayne F.** An intercomparison of UW cloud-top cooling rates with WRD-88D radar data. Weather and Forecasting v.28, no.2, 2013, pp463-480.

Discussion of the University of Wisconsin Convective Initiation (UWCI) algorithm which utilizes geostationary IR satellite data to compute cloud-top cooling (UW-CTC) rates and assigns CI nowcasts to vertically growing clouds. An objective validation of UW-CTC rates using a satellite-based object-tracking methodology is presented, along with a prognostic evaluation of such cloud-top cooling rates for use in forecasting the growth and development of deep convection.

♦ **Foster, Michael J and Heidinger, Andrew.** PATMOS-x: Results from a diurnally corrected 30-yr satellite cloud climatology. Journal of Climate v.26, no.2, 2013, pp414-425.

Satellite drift is a historical issue affecting the consistency of the few satellite records capable of being used for studies on climate time scales. The authors address this for the Pathfinder Atmospheres Extended (PATMOS-x)/Advanced Very High Resolution Radiometer (AVHRR) cloudiness record, which spans three decades and 11 disparate sensors.

♦ **Bromwich, David H; Nicholas, Julien P.; Monaghan, Andrew J.; Lazzara, Matthew A.; Keller, Linda M.; Weidner, George A., and Wilson, Aaron B.** Central West Antarctica among the most rapidly warming regions on Earth. Nature Geoscience v.6, 2013, pp139-145.

Presentation of a complete temperature record for Byrd Station in central West Antarctica in which observations have been corrected and gaps filled using global reanalysis data and spatial interpolation. In contrast to previous studies, the authors report statistically significant warming during austral summer. The results argue for a robust long-term meteorological observation network in the region.

♦ **Bennartz, R.; Shupe, M. D.; Turner, D. D.; Walden, W.P.; Steffen, K.; Cox, C. J.; Kulie, M. S.; Miller, N. B., and Pettersen, C.** July 2012 Greenland melt extent enhanced by low-level liquid clouds. Nature v.496, no. 7443, 2013, pp83-86.

Discussion of how the radiative effects of low-level clouds consisting of liquid water droplets played a key part in the July 2012 melt event by increasing near-surface temperature. The results may help explain the difficulties that global climate models have in simulating the Arctic surface energy budget, particularly as models tend to under-predict the formation of optically thin liquid clouds at super-cooled temperatures – a process potentially necessary to account fully for temperature feedbacks in a warming Arctic climate. §

Record Broken, Cores Intact, at

Breaking Trail 3,400 Meters Down

by Mark Hobson

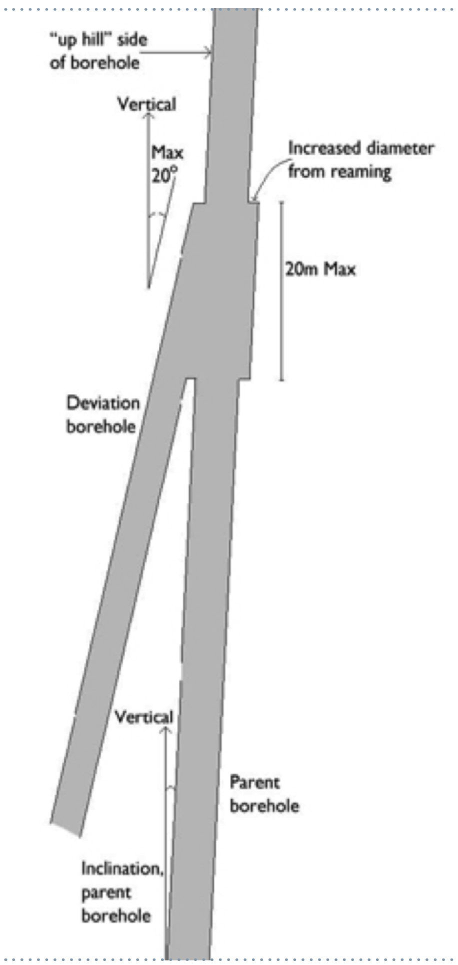
An amazing achievement has changed the look of drilling in Antarctica. The SSEC designed and built replicate core ice drill cut its way to record depths, proving that, at depths of over 3,000 meters, it can actually deviate from its main path and carve out new, branching avenues and gather multiple cores at the same level.

The ice cores brought up from the frozen depths are filled with a valuable resource – bubbles of air trapped thousands of years ago. To access older ice cores, we need to drill ever deeper into the ice. To scientists studying the ancient atmosphere of Earth these cores are priceless, and yet difficult to obtain. Time, money, harsh climate – all stand in the way of reaching this archive of the atmosphere's past.

Normally it takes years to drill thousands of meters down into the nearly impervious ice sheet as the drilling season in Antarctica is limited to the height of the Antarctic summer – mid-November through January.

With these limitations in mind and in response to the needs of researchers, SSEC's Ice Coring and Drilling Services (predecessor to the current Ice Drilling and Design Operations (IDDO)) designed and built the Deep Ice Sheet Coring (DISC) drill. Incorporating the best features of existing drills and adding new technologies to increase its capabilities, engineers designed an innovative drill system capable of initiating new boreholes at depth.

No longer limited to one main borehole, the replicate drill could alter its course and create new boreholes, as many as three at any depth in the main borehole. Researchers could multiply the amount of usable core they received, without having to go through the time and expense of drilling a completely new hole.



Cross sectional view of parent and deviation boreholes. Figure credit: Nicolai Mortensen, IDDO

Replication at depth had been attempted before by using a wood block placed in a main borehole to force the drill to alter course. This method effectively closed the main borehole and did not achieve the goal of creating the deviation on the uphill side of the borehole and keeping the main borehole open for future scientific study.

To solve this problem, a team, including SSEC lead engineers Nicolai Mortensen, Chris Gibson, and Jay Johnson, led by Project Manager Alex Shturmakov, Program Director Don Lebar, and Principal Investigator Charlie Bentley, implemented actuators on the side of the drill itself – levers that extend on command, exerting force against the side of the main borehole and forcing the drill to gradually start a new hole. Two sets of actuators were added to the existing DISC drill so that the drill could be pushed against the top side of the hole, working against gravity, when it carved its new path. The new process left the main hole open, the new hole always accessible, and space for more new deviations.

The DISC drill was placed on the West Antarctic Ice Sheet (WAIS) Divide in 2007. Through the next several seasons researchers cut the main borehole, recovering ice cores the entire way. Completed in the 2011-2012 season, the hole reached an American record depth of 3405 meters, and is the second deepest hole ever drilled in ice.

the WAIS Divide

The WAIS Divide Camp (right) and Drilling Site (left). Photo credit: Jay Johnson, IDDO

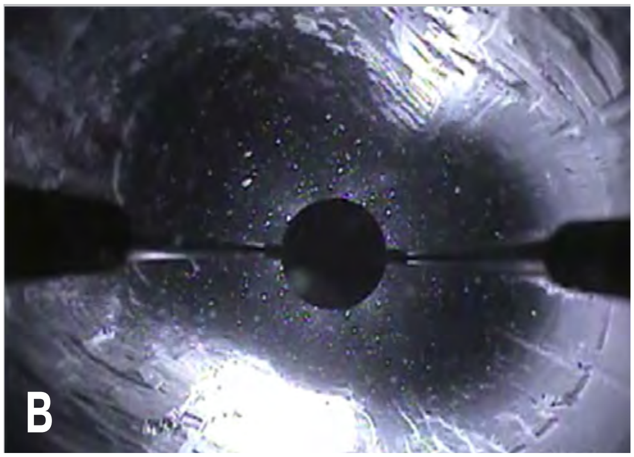
Initial testing of the replicate coring system was conducted at WAIS Divide during the 2011-2012 season. After some adjustments over the (Northern Hemisphere) summer, the IDDO team returned the drill to Antarctica for the 2012-2013 season, obtaining the first replicate core sample on Monday, 17 December 2012. In the course of the season, the drilling team achieved five deviations, at depths ranging from 2,000 meters to 3,100 meters, and all on the uphill side, a first in ice coring.

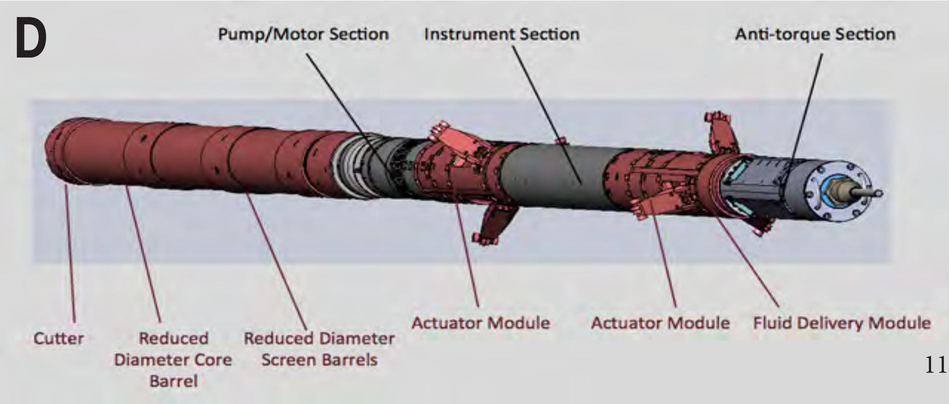
The WAIS Divide is a source of ice core samples for researchers studying the Earth's atmosphere and its history. The area receives abundant snowfall which rarely melts. Each year the snow is compacted into ice, burying the ice further below the surface. Air trapped in the ice is compressed into bubbles and held, completely isolated and pristine, until drills cut their way into the depths, encircle and break off a core sample, and haul it back to the surface.

SSEC's IDDO team was successful in securing 285 meters of core from five separate deviations, with only two broken in the process. The multiple cores obtained will supply researchers with abundant study materials, providing insights into times of abrupt climate change and records of greenhouse gas quantities that will inform future climate studies. §

Watch the incredible footage of the drill's journey two miles beneath the surface at: http://youtu.be/BMGPMbz5op8

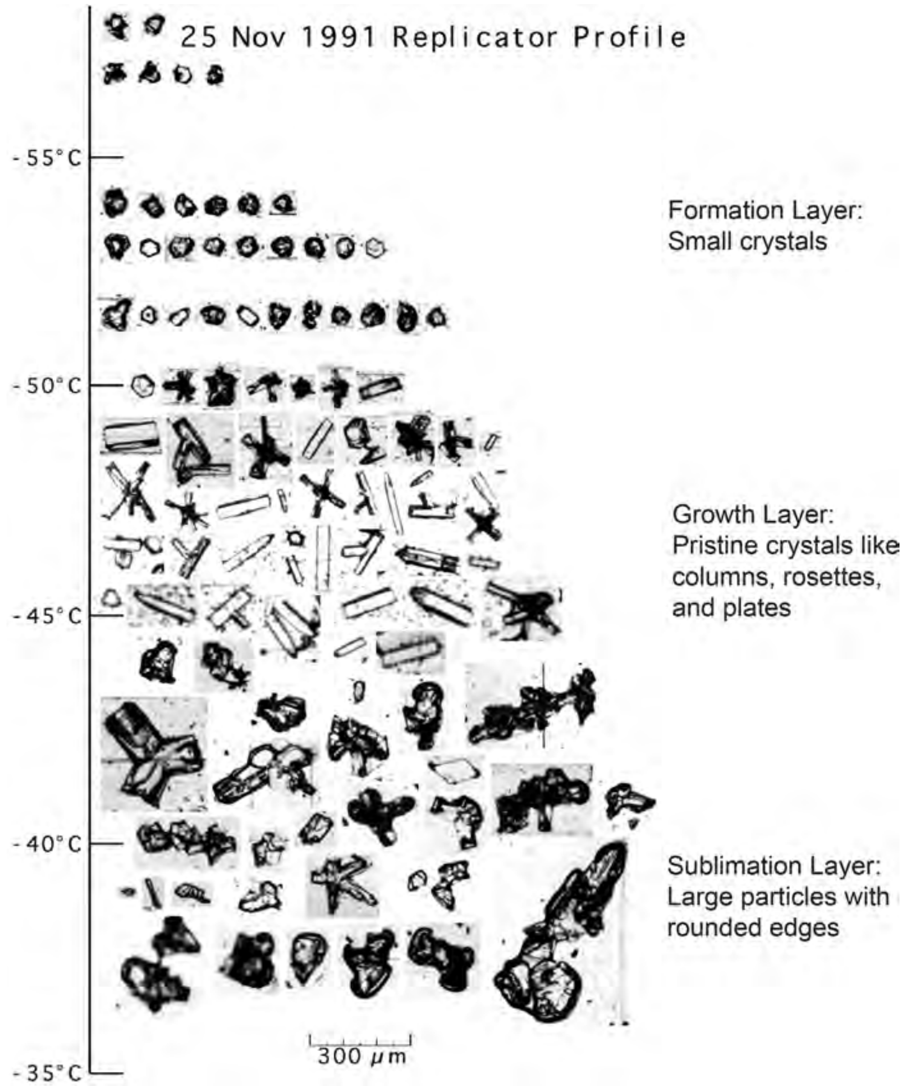
(A) Actuators extended from the barrel of the replicate drill. Photo credit: Jay Johnson, IDDO (B) A video camera attached to the replicate drill sonde provides this image of the parent hole (left) and the first deviation off of this hole (right) at a depth of nearly two miles. Photo credit: Jay Johnson, IDDO (C) The actuators extended, applying lateral pressure to change the course of the drill at depth. Photo credit: Jay Johnson, IDDO (D) The major components of the replicate sonde. Figure credit: Chris Gibson, IDDO





Building
A Better Ice Cloud Model

by Leanne Avila and Bryan Baum

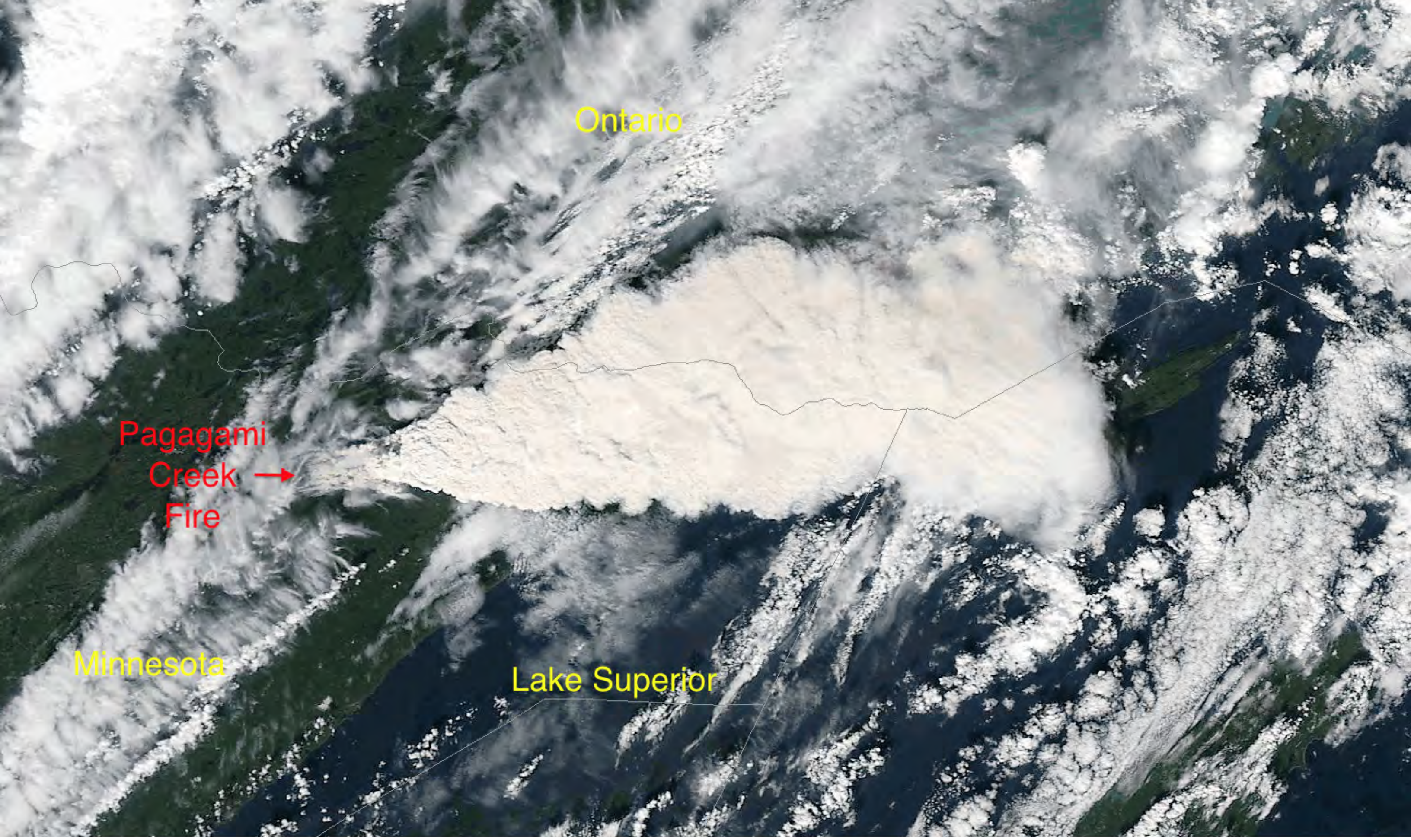


Cirrus ice particles from balloon-borne replicator data from 25 November 1991 from the FIRE-2 field campaign held in Coffeyville, Kansas. The updraft velocity is very low, which allows a process called "size sorting." The smallest particles are at the cloud top. As the particles grow, in this case into columns, bullet rosettes, and plates, they become heavier and tend to fall to a lower level. The largest and most complex particles are at the bottom of the cloud and show signs of sublimating (i.e., moving directly from ice to gas phase) so the edges become rounded. Figure courtesy of Andy Heymsfield, NCAR.

Until the late 1980s, scientists simulated the radiances that various sensors would observe from ice clouds as if they contained only perfectly spherical water droplets. It was a simple view, albeit unrealistic given the variety of sizes and shapes (habits) of ice particles in nature. No one at the time understood quite how to work with ice clouds because of the complexity in figuring out the treatment of light scattering through these particles. Even in the late 1990s, each satellite team employed a different way of treating ice clouds in their data reduction process, which made it incredibly difficult for teams to compare their results.

Knowing that there had to be a better way to deal with ice clouds, SSEC's Bryan Baum (with NASA Langley at the time) and colleague Ping Yang of Texas A&M University set out over a decade ago to develop models that handle the unique characteristics of ice particles, in particular the different ways they scatter light. "When you're working with satellite data, you infer cloud properties by comparing measurements to simulations," stated Baum. So he and Yang sought to "beef up the simulation side…to take out the mystery."

They first tackled ice cloud models for the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument before continuing on to the remaining sensors on the NASA A-Train and beyond. To date they have created models for each of the polar-orbiting and geostationary imagers, as well as polarization models to work with a relatively new type of sensor called the Polarization and Directionality of the Earth's



Annotated MODIS true-color image showing a large pyroCb and smoke plume from the Pagami Creek wildfire that was burning in northeastern Minnesota on 12 September 2011.

Reflectances (POLDER).

The models take into account nine different ice particle shapes or habits. Cirrus particles can take the form of pristine habits, like the hexagonal columnar crystal or a bullet rosette (a particle that is similar to a bunch of sharpened pencils sticking out of a common core). However, some habits defy description, like aggregates that form in intense convection with riming. Each scattering model has been created consistently from short (ultraviolet) to long (far-infrared) wavelengths using microphysical data collected over a lifetime in different parts of the world by NCAR colleague, Andy Heymsfield.

Baum and Yang have been keen to make the models available on the Web so that they get used in the scientific community and so that they get valuable feedback for continued improvements. (Version 3 of the models may be found online: http://www.ssec.wisc.edu/ice_models/).

With new generation sensors and their data now available, Baum and Yang will add to the collection of models by including what's necessary for polarization and hyperspectral calculations, supporting new sensors in development, and moving towards broadband shortwave and infrared (IR) models for use in numerical weather and climate models.

Looking further into the future, Baum is moving away from working with pristine ice clouds to polluted ice clouds. Specifically, he's interested in investigating pyrocumulonimbus (also called pyroCb) events. These are incredibly severe events where biomass burning may be influenced by an approaching front, stoking the fires such that in the space of a few hours the smoke plumes can reach the troposphere and even move into the stratosphere. The pyroCbs tend to occur at high latitudes in each hemisphere. The smoke plumes can interact with ice clouds and influence the weather downstream for many days in areas far from the original pyroCb location.

In anticipation of this new research direction, Baum has begun networking with the pyroCb community and collaborating with Michael Fromm of the Naval Research Laboratory. With SSEC's Scott Bachmeier and help from SSEC Webmaster Bill Bellon, a PyroCB blog (http://pyrocb.ssec.wisc.edu/) is now in operation to catalog pyroCb events around the globe.

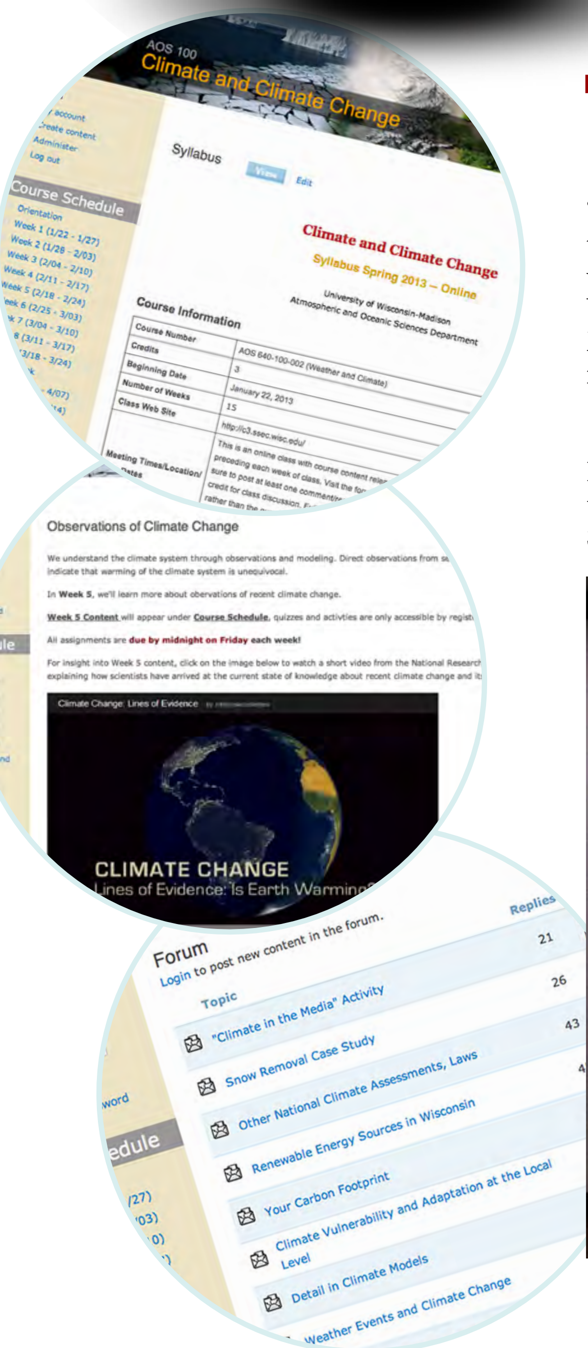
This new effort to catalog the occurrence and impact of pyroCbs will improve the treatment of ice clouds when they are impacted by heavy aerosol events in numerical models, which is currently quite rudimentary. As the influence of pyroCbs on ice clouds is still unknown, Baum and his colleagues are eager to tackle this new challenge. §

Version 3 of the Ice Cloud Bulk Scattering Models may be found at : http://www.ssec.wisc.edu/ice_models/

AOS 101 (Weather and Climate) Debuts

Teaching Climate Change Online

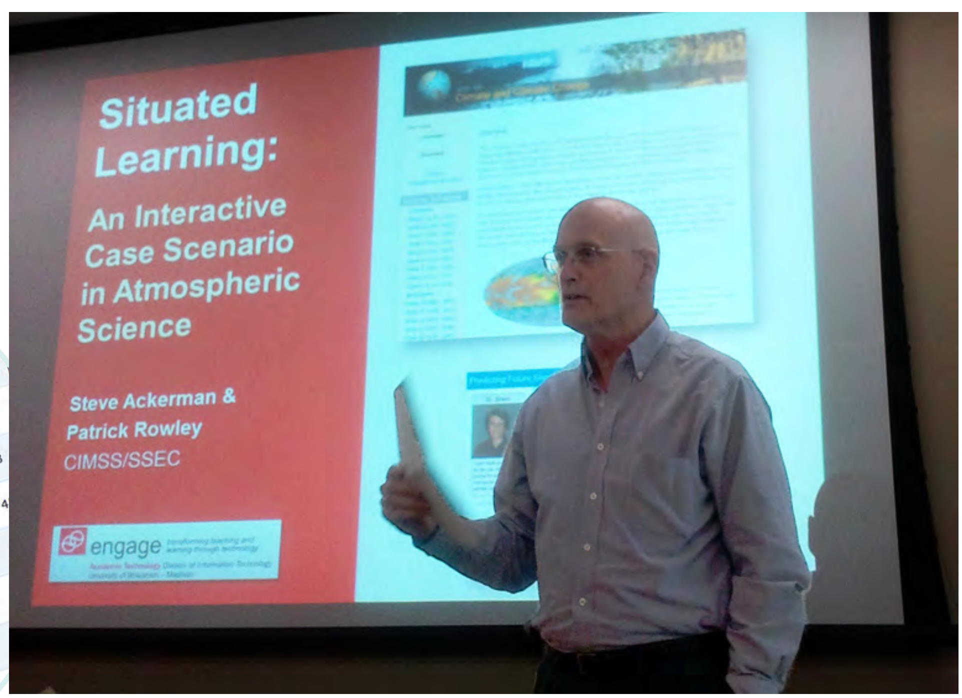
by Mark Hobson and Margaret Mooney



The UW-Madison Atmospheric and Oceanic Sciences (AOS) Department debuted a 100-level online course, "Climate and Climate Change," during the 2013 spring semester. The course was a NASA-funded collaboration between Madison College (formally MATC) and the Cooperative Institute for Meteorological Satellite Studies (CIMSS).

In the sixteen weeks of AOS 100, under the guidance of CIMSS Director Steve Ackerman and AOS graduate student Zak Handlos, students learned about Earth's climate system and regional impacts of climate change. They examined the history of the Earth's climate, how climate is studied, what steps might be taken to mitigate climate change, and how to communicate effectively the facts of climate change as they are known.

Weekly assignments and activities included investigations of ice formation and melting on the Madison lakes, web-based field trips, and an interactive, immersive snow removal



Steve Ackerman presents the online Situated Learning scenario at a DoIT seminar.

project scenario created specifically for the course and delivered through the DoIT Engage Case Scenario tool. Patrick Rowley of CIMSS developed the project, in which students attended virtual town hall meetings and gathered information from experts in order to make their own decisions about how to handle snow emergencies in a fictional town.

An integral part of the course was its online forum, enabling students to create a community of fellow class members where they could interact quickly and at their convenience.

The 2013 release of this web-based course coincided with the current UW-Madison Educational Innovation initiative aimed at customizing learning experiences in the digital age. Several students cited the flexibility of online learning as a main reason for taking the course. In addition, internet delivery of educational content doubled as a climate mitigation strategy, which perfectly fit the theme of the course.

Course content highlighted concepts presented in the 2007 Intergovernmental Panel for Climate Change (IPCC) Summary for Policymakers, the newest National Climate Assessment and a multi-agency climate education document called "*Climate Literacy: The Essential Principles of Climate Sciences.*"

The videos, webinars, stories, and activities assembled for the course came primarily from NASA, NOAA, the National Research Council, and CIMSS/SSEC. The climate research highlighted was regionally focused, featuring work by AOS professors and findings from the Wisconsin Initiative on Climate Change Impacts. Scott Lindstrom and Margaret Mooney from CIMSS worked with Ackerman and Handlos to incorporate Madison College material into the new UW course. §

The New CIMSS Education and Public Outreach Office and Its New Director

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has established an Education and Public Outreach (EPO) Office, tapping its own Margaret Mooney, an outreach specialist, to serve as the first Director.

Margaret Mooney, New Director of CIMSS EPO Office.

For more than 30 years, CIMSS has developed and supported educational and outreach programming to fulfill its mission. In 1991 CIMSS established a summer workshop for high school students, one of the first in the country, encouraging students to follow climate studies into college and their careers. And, in 2002, CIMSS began offering workshops for science teachers covering the topics of satellite remote sensing, climate literacy, and climate change. These workshops, having developed a reputation for quality programming, continue today.

CIMSS has been a leader in educational software design for several decades, pioneering distance learning software and computer-based education tools. Recently, the Institute launched an innovative technology lending library from which middle and high school science teachers can borrow specially equipped iPads to use in their classrooms and to participate in weather experiments.

The CIMSS EPO is committed to promoting satellite meteorology resources and advancing weather and climate literacy through national initiatives like the American Meteorological Society's Weatherfest, Earth Science Information Partners (ESIP) meetings, Science-on-a-Sphere (SOS) docent support, and local events like student and teacher workshops. Above all, the new CIMSS Education and Public Outreach Office will strive to maintain excellence in education and outreach while working to ensure that CIMSS research products continue to provide maximum benefits to society.

Integral to the success of the new CIMSS EPO office will be the addition of Patrick Rowley who joined CIMSS in 2011 to develop and write the CIMSS EarthNow blog (http://sphere.ssec.wisc.edu/), a resource for SOS docents.

Margaret Mooney, the new director, is a former National Weather Service meteorologist with wide-ranging local and national expertise in geoscience educational initiatives. She served on the White House Council on Environmental Quality roundtable in 2010 and participated in the 2013 Climate Science Day on Capitol Hill. Given Mooney's experience and connections with the outreach community, the CIMSS EPO office is poised to not only continue but expand the CIMSS legacy of successful programming. §

SSEC Partners with GeoMetWatch on STORM Program

by Mark Hobson

The University of Wisconsin-Madison, Space Science and Engineering Center (UW-SSEC) has entered into a partnership to be the prime contractor for data processing associated with GeoMetWatch's first hyperspectral Sounding and Tracking Observatory for Regional Meteorology (STORM) sounder, a series of six geostationary satellite instruments that will collect critical weather data not currently available to weather forecasters.

The STORM system is based on the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) that was developed from 1999 to 2006 under the NASA New Millennium Program administered by NASA with key technical leadership from Utah State University and UW-SSEC. Bill Smith and Allen Huang of UW-SSEC provided pioneering science and implementation techniques for GIFTS and will continue as key members of the STORM team.

GIFTS was originally meant to pave the way for a sounder on the new GOES-R spacecraft planned for launch in 2015. Budgetary issues cancelled the GIFTS program and the GOES-R sounder, leaving the GOES-R without the capability to sense rapidly changing atmospheric stability that will enable advanced severe storm warnings from space.

GeoMetWatch, a private commercial venture that two years ago obtained a licensing agreement from the Department of Commerce to place hyperspectral instruments in six geostationary satellite slots around the world, has now announced its partnership with AsiaSat, a major satellite communications company. The partnership plans to launch its first STORM instrument in 2016, and GeoMetWatch will eventually launch a minimum of five more. Fabrication of the first STORM instrument has already begun at Utah State University's Advanced Weather Systems Foundation (AWS) in North Logan, Utah.

"STORM will provide significantly earlier warning for severe weather and climate instability, and it will do so faster, more frequently, and with finer detailed measurements than any capability in orbit today," said David Crain, Chief Executive Officer of GeoMetWatch.

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STORM is designed to make effective use of the key developments of the GIFTS program to minimize program risks. The goal of the STORM constellation is to improve the prediction of localized severe weather, provide more accurate tropical cyclone path forecasts, and use its unprecedented spatial and temporal resolution to more accurately pinpoint the location and onset of major storms.

"I view this as a very exciting opportunity for SSEC," says Hank Revercomb, Director of SSEC. "This is a timely opportunity to apply SSEC's expertise to help ease the

Photo credit: GeoMetWatch

global human- and societal-level disruptions posed by severe storms. This effort will produce a very valuable resource for greatly improving severe weather warnings and much more, and will thereby be a great asset to NOAA and to the world-wide mission of SSEC."

Crain added, "We are very appreciative of our relationship with UW-SSEC, and recognize the significant contribution they will make to the success of our overall project. UW-SSEC has a truly unique capability in developing the science and operational algorithms for hyperspectral sensors like STORM as well as the processing, distribution, and data center tools needed for a mission such as this. We truly look forward to our ongoing partnership."

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SSEC, the birthplace of geostationary weather observing which was initiated by Professor Verner E Suomi, is the world leader in developing algorithms and software for processing the high-volume geostationary atmospheric data that will be collected by the STORM hyperspectral sounder.

"The plan is for SSEC to play similar roles it originally was to play for the GIFTS program," Revercomb says, "namely responsibility for the Data Center and Data Processing, in addition to supplying calibration Blackbody systems and Testing/Engineering support. It is very exciting to see this hyperspectral technology effort brought back and set on the track to launch again." §

Honors and Awards

Fred Best, Bob Holz, Bob Knuteson, Hank Revercomb, Joe Taylor, Dave Tobin

CLARREO Group Achievement Award from 28 August 2012

Jordan Gerth

First place, Graduate Student Oral Presentation, National Weather Association, 2012

Wisconsin Space Grant Consortium Graduate Fellowship Award

Bormin Huang

SPIE Fellow, 2013

Jun Li and Zhenglong Li

NOAA/NASA Joint Polar Satellite System Program Office Certificate of Recognition for contributions to the successful launch and commission of the Suomi National Polar-orbiting Partnership Satellite System

Bill Line

First place, Graduate Student Poster Presentation, National Weather Association, 2012

2012 Unidata Users' Workshop student stipend

Graeme Martin and Dave Tobin

Individual "Best Poster" awards at the 18^{th} International TOVS Study Conference in Toulouse, France

Christopher Moeller and Dan LaPorte

NASA Group Achievement Award as members of the Suomi NPP Mission Development Team

Christopher Velden

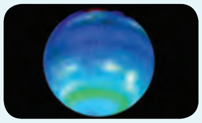
UW Chancellor's Award for Excellence in Research: Independent Investigator

Tom Whittaker

Appreciation for Service as Co-Chair of the Committee on Environmental Information Processing Technology (formly IIPS)

United Way of Dane County Community Volunteer Award as a high school math tutor

through the atmosphere



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Through the Atmosphere is a semiannual publication that features atmospheric and space science research, engineering projects, and accomplishments at University of Wisconsin-Madison's Space Science and Engineering Center (SSEC) and its Cooperative Institute for Meteorological Satellite Studies (CIMSS).

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