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Slip Magnitude Along Thrust Faults

Student Travel Grant Challenge

PREDICTING SEA ICE EXTENT

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On the Cover

Scientists study Arctic sea ice and melt ponds in the Chukchi Sea. Credit: NASA/Kathryn Hansen

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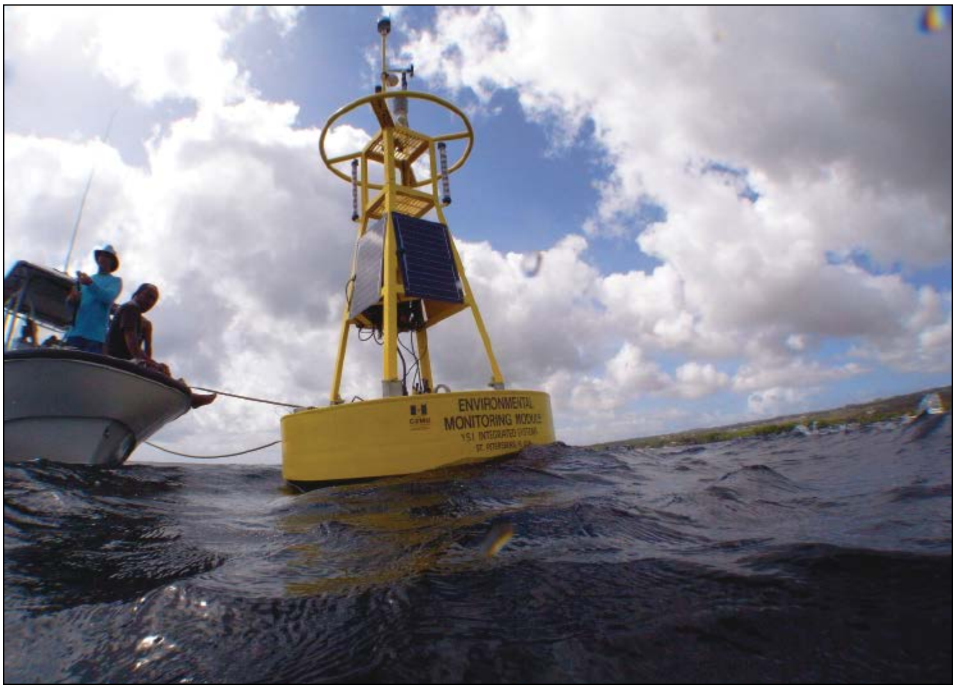
Global Warming "Hiatus" Never Happened, Study Says



NOAA/CREWS

The number of buoys measuring sea surface temperatures has increased in recent decades. Their readings tend to be lower than those taken by ships at a given location. For these reasons and others, a team of scientists has adjusted data sets to provide a more accurate measurement of average global temperature.

A presumed pause in the rise of Earth's average global surface temperature might never have happened, according to new research published in early June in *Science.*

The apparent hiatus, first reported by the Intergovernmental Panel on Climate Change (IPCC) in 2013, instead resulted from a shift during the past couple of decades to greater use of buoys for measuring sea surface temperatures. Buoys tend to give cooler readings than measurements taken from ships, explained Thomas Karl, director of the National Centers for Environmental Information of the National Oceanic and Atmospheric Administration (NOAA) and lead author on the research paper. Uncorrected, those discrepancies led to the apparent slowdown since 1998 in the long-observed rise of Earth's average surface temperature.

"The biggest takeaway is that there is no slowdown in global warming," Karl said. Global warming over the past 15 years is the strongest it's been since the latter half of the 20th century, he added.

Measurement Bias

To measure how Earth's average global temperature is changing, scientists combine hundreds of thousands of measurements from Earth's surface, taken by land instruments, ships, buoys, and orbiting satellites. Scientists must comb through these data to eliminate random errors and correct for differences in how each type of instrument measures temperature.

Global warming over the past 15 years is the strongest it's been since the latter half of the 20th century.

In the paper, published on 4 June (see http://bit.ly/4JuneScience), Karl and his colleagues report that they dug into NOAA's global surface temperature analysis to examine how sea surface temperatures (SSTs) were being measured. Scientists measure SSTs in several ways—by collecting ocean water in a bucket and measuring its temperature directly, measuring the temperature of water taken in by a ship's engine as a coolant, or using floating buoys moored at locations scattered around the planet's oceans.

Each technique records slightly different temperatures in the same region, so scientists have to adjust the data. In the past couple of decades, the number of buoys has increased, Karl explained, adding coverage to 15% more of the ocean. Because buoys tend to read colder temperatures than do ships in the same places, Karl and his team corrected for this bias by adding 0.12°C to each buoy measurement.

By combining the ocean data with improved calculations of air temperatures over land around the world, Karl and his colleagues found that overall global surface warming during 2000–2014 was 0.116°C per decade, more than twice the estimated 0.039°C per decade, starting in 1998, that IPCC had reported. Further, having reexamined global temperatures as far back as 1880, Karl and his team found that from 1950 to 1999, the rate of warming was 0.113°C per decade.

"The [new] data still show somewhat slower warming post-2000 than in the preceding decades, but the difference is no longer statistically significant, which means it is no longer justifiable to say that there was a 'hiatus,'" said Steven Sherwood, director of the Climate Change Research Centre at the University of South Wales, Australia. He was not involved in the study.

"The fact that such small changes to the analysis make the difference between a hiatus or not merely underlines how fragile a concept [the hiatus] was in the first place," said Gavin Schmidt, director of NASA's Goddard Institute for Space Studies in New York City.

Faux Pause?

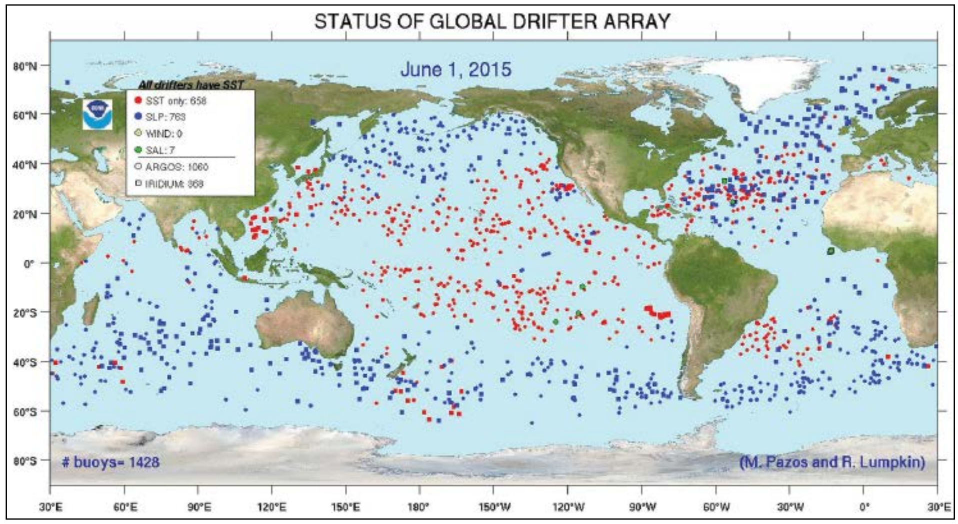
Since the IPCC report came out, scientists have been investigating what was causing the supposed hiatus. Some studies found evidence that the leveling of global temperature rise resulted from absorption of the "missing" heat by the world's oceans.

Other research indicated that although there was no pause in global temperature rise, there might have been a temporary slowdown of warming for the Northern Hemisphere. Michael Mann, director of the Earth System Science Center at Pennsylvania State University, and his colleagues found earlier this year that natural fluctuations in the Pacific and Atlantic oceans led to cooling of the tropical

Even as perceptions of a global warming pause remained widespread, some scientists were finding evidence to the contrary.

Pacific, driving down average temperatures for the northern half of the globe. Mann calls this phenomenon a "faux pause."

"The slowdown, which appears to relate to internal oscillations with an origin on the tropical Pacific, primarily impacts Northern Hemisphere mean temperature and is barely evident in global mean temperature," Mann told *Eos.*



NOAA

Locations of NOAA's ocean buoys as of 1 June.

Even as perceptions of a global warming pause remained widespread, some scientists were finding evidence to the contrary. A paper in *Nature Climate Change* last year reported that there was "no pause" in heat extremes around the world. What's more, NOAA concluded that 2014 was the planet's hottest year on record.

According to the new analysis, Karl said, global average temperature rise between the years 2000 and 2014 is virtually indistinguishable from that which occurred over the latter half of the 20th century.

By **JoAnna Wendel,** Staff Writer

Building a Better Glacial Speedometer

A stream carves ice on its way to a lake perched on the ice sheet in Greenland.

Greenland is the land of escaping lakes. In the summer, when soot lands on the ice sheet's snowy surface and the Sun begins to melt the snow, bright blue lakes form on top of the ice. Just as on land, the water seeks a way down.

Sometimes, instead of carving surface channels, water trickles into the ice sheet through crevasses and vertical shafts called moulins. In the most dramatic cases, a lake can burst through a kilometer-thick ice sheet and rush to the bottom of the glacier in a forceful waterfall. There, under high pressure, water may help the glacier glide a little faster over the rock below.

Just how fast, however, is the subject of an ongoing debate.

More Ice Sheet Lakes, Farther Inland

Geoscientist Kate Briggs of the University of Leeds predicted that such lakes will advance from around 50 to more than 100 kilometers inland on Greenland over the next few decades. She presented evidence for this, based on a study she and her colleagues published earlier this year in *Nature Climate Change,* during a session at the 2015 European Geosciences Union (EGU) meeting in Vienna, Austria.

If such lakes begin to cover more of the Greenland ice sheet, they could play a growing role in the speed with which it moves, Briggs said.

However, there may be natural brakes built into the system. Physical geographer Jonathan Bamber of the University of Bristol commented during the session that lakes forming on the even thicker ice sheet in the middle of Greenland may not be able to escape all the way to the rock bed below the glacier. The deepest ice is under even more pressure and may resist the hydraulic fracturing that enables surface lakes to break through the ice sheet closer to Greenland's edge.

Briggs and her colleagues assumed in their model that the water did eventually reach the rock bed and that the additional pressure helped it speed up the ice sheet's motion. Nonetheless, the net effect of how glacial lakes affect ice flow is "still very much an open question," Briggs said.

Many Methods, Many Answers

Other scientists installed GPS and tilt sensors for short periods on and inside the ice sheet to examine how it moves. They found a caterpillar-like movement in fits and starts, according to research reported earlier this year in the *Journal of Geophysical Research: Earth Surface.*

It is useful information, but generalizing any local observation about the ice sheet is difficult: Greenland spans 18° of latitude and hosts differing microclimates, and its ice sheet encounters chaotic mountains and sea conditions at its edge. The ice sheet's interaction with the Earth's climate is complex, session speakers noted.

Still, tracking its speed is a good place to start, explained ice sheet researcher Twila Moon of the University of Colorado Boulder. "Understanding ice velocity is fundamental to understanding how much ice we're going to lose," she told *Eos.*

During the same EGU session as Briggs's talk, Moon presented preliminary data from the Landsat 8 series. Some of Moon's previous work shows that the ice sheet's velocity changes over the course of the seasons and varies by location. Landsat 8 offers more frequent sampling than previous satellite ice sheet mapping: up to every 16 days. That means she will be able to create maps of the ice sheet's speed with unprecedented time coverage.

"Her data will add a lot," said applied mathematician Ian Hewitt of the University of Oxford in the United Kingdom. Hewitt creates computational models of how water, glaciers, and the rock bed interact.

Perhaps, over the course of the season, Hewitt explained, water carves out channels below the ice sheet, and over time, more of the glacier's weight settles onto the rock bed between the channels. That might explain why researchers have detected both speedups and slowdowns of the ice sheet after surface lake disappearances. The new density of time sampling will enable him and other modelers to put better limits on their models.

More Data, More Modeling

Briggs and others also examine the ice sheet's topography using radar from CryoSat-2. She presented some preliminary data on ice sheet thickness during her talk, including more evidence that some of the Greenland ice sheet is thinning in ways not captured by existing regional climate models. Similar to the GPS and optical data, the radar data raise more questions.

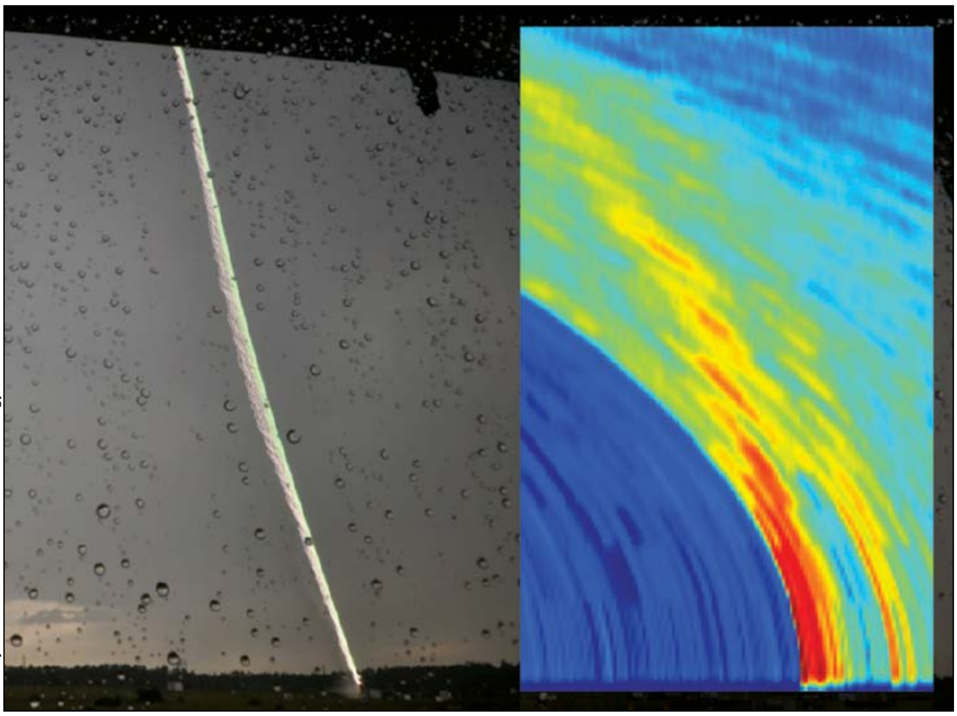
It is tempting to argue that the growing density of aerial coverage could mean there is less need for slow, expensive GPS surveys, Moon told *Eos.* However, some of the finer movement, as shown by the GPS surveys, occurs on time scales too short for satellites to reliably detect.

"We would need subdaily resolution to capture the sudden fits and starts," Hewitt told *Eos.* "We won't get that from satellites." Instead, it may take a lively combination of more on-the-ground instrumentation, more remote sensing, and more modeling to see into the future of Greenland's ice sheet and its disappearing lakes.

Hewitt explained, "To really work out what's going on, we'll have to integrate subglacial processes into those models and then run them long term."

By **Lucas Laursen,** Freelance Writer; Twitter: @lucaslaursen

Experiment Captures First Image of Thunder


University of Florida, Florida Institute of Technology, and Southwest Research Institute

(left) Lightning generates (right) thunder, seen here through a technique that images the bolt's acoustic signature.

A rainy and windy midsummer Monday in north Florida was a good day to catch an artificially triggered lightning bolt. It also turned out to be the perfect day to image thunder for the first time by visually capturing the sound waves created by the bolt.

Although the physics behind lightning strikes remains poorly understood, imaging the acoustic signature of thunder "provides new tools to further understand the origins of thunder and the energetics of the lightning channel," explained Maher Dayeh, a research scientist in the space science and engineering division of the Southwest Research Institute in San Antonio, Texas. Dayeh, who presented his research in May at the 2015 Joint Assembly in Montreal, Canada, provided insight into the research in an interview with *Eos.*

"Literally seeing what we hear" is the most exciting part of the research, Dayeh told *Eos.* "It is amazing to pinpoint the acoustic sources along the lightning channel," he said, referring to the irregular path along which a lightning discharge occurs.

"Every person perceives thunder differently, since it all depends on how far you are from the lightning channel. Close to it, the sound is sharper and louder. Far away, you hear long-lasting rumbles. This work provides a better idea on where sound comes from."

The imaged thunder "provides new tools to further understand the origins of thunder and the energetics of the lightning channel."

Pulling Off the Experiment

Dayeh conducted the research with help from a rocket with a grounded copper wire launched on 14 July 2014 into thunderclouds above the International Center for Lightning Research and Testing (ICLRT) in Gainesville, Fla. The center is jointly operated by the University of Florida and the Florida Institute of Technology.

To "image" the sound, an array of 15 microphones—laid out along the ground 95 meters from the rocket launch pad—served as an "acoustic camera" to analyze the bolt. Dayeh said that the original constructed image looked less like thunder and more like a "wiggly and colorful" painting. However, at higher-frequency bands of sound, the image showed a distinct signature of thunder generated by a lightning strike, seen in the image to the left.

Resolving Pieces of Lightning

Previously, scientists typically reconstructed a lightning channel using just the sound of thunder. The technique usually involves triangulation of three or more microphones spread around the lightning source, Dayeh said. Although the recorded signals could be traced back to their source locations, no information could be inferred about the loudness along the channel, individual return strokes, or the full frequency content of the event, he explained.

Now the new technique could help reveal many traits previously unknown about lightning. ICLRT director of operations Doug Jordan and his team triggered the lightning and set up the microphones for Dayeh's experiment. He noted that although artificially triggered lightning differs from natural lightning at the beginning of a strike, subsequent portions are "a good proxy" for studying natural lightning.

Before, "nobody had been able to have the processing and the data to actually be close enough to things that they could resolve various pieces of lightning. So we were pleased with that, that they could even do it," Jordan said.

Lightning Studies: Still in Infancy

Joseph Dwyer, a professor at the University of New Hampshire, Durham, and a leading expert on lightning, was surprised that the experiment by Dayeh, who is his Ph.D. student, actually worked.

"His is one of those things that seemed like a good idea, but you never know until you actually try it," Dwyer told *Eos.* "You know, you've got microphones sitting outside. This is a thunderstorm. It's windy. It's rainy. There's a lot going on. Plus you have lightning nearby, which can cause lots of problems if you have sensitive electrical equipment. So getting it all to actually work in practice was quite a challenge."

Overcoming these challenges and then producing an image "that you can recognize and say 'Wow, I can actually see the lightning there in sound'—which is like [what] a bat would do or a dolphin—it's pretty cool," he continued.

This new tool for studying lightning "shows the infancy of the field," Dwyer said. "Here, in 2015, we're just now getting around to making the first acoustic images of lightning."

"We don't understand how it gets started up inside thunderstorms," he said. Plus, "we don't understand very well how it propagates. And we don't understand how it strikes things on the ground."

New advances in the study of lightning can lead to important societal benefits, Dwyer explained. Lightning kills people and causes property damage, but it is a fact of life that people accept and get used to, he added.

However, its frequent occurrence is no reason for complacency, Dwyer said. "Suppose just randomly," he continued, "every afternoon pianos fell from the sky and crashed to the ground. You would say, 'Hey, somebody's got to do something about this.' Right? 'Where's all the research money to stop these pianos falling from the sky or at least predict where they're going?'"

"There are at least four million lightning strikes a day to the planet," Dwyer said. "We know very little about how it actually works."

> Producing an image "that you can recognize and say 'Wow, I can actually see the lightning there in sound'…it's pretty cool."

By **Randy Showstack,** Staff Writer

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Obama Links Climate Change to National and Global Security

Pablo Martinez Monsivais/Associated Press

President Obama spoke about climate change and national security at a 20 May commencement speech at the U.S. Coast Guard Academy.

Climate change "constitutes a serious threat to global security, an immediate risk to our national security. And make no mistake, it will impact how our military defends our country. And so we need to act, and we need to act now," U.S. president Barack Obama said in a commencement speech at the U.S. Coast Guard Academy in New London, Conn., on 20 May.

"If you see storm clouds gathering, or dangerous shoals ahead, you don't sit back and do nothing. You take action—to protect your ship, to keep your crew safe. Anything less is negligence. It is a dereliction of duty. And so, too, with climate change. Denying it, or refusing to deal with it endangers our national security. It undermines the readiness of our forces," he said as he addressed the 217 cadets who received their commission as officers in the Coast Guard.

New Report

Obama's remarks came on the same day that the White House issued a report about the connections between climate change and national security.

Findings from Select Federal Reports: The National Security Implications of a Changing Climate, which draws on other recent reports by the administration, states that the national security implications of climate change impacts are far-reaching within the United States and abroad (see http://1.usa.gov/1FuyKvR). The report also says that these impacts may exacerbate existing stressors;

> "Denying [climate change], or refusing to deal with it endangers our national security. It undermines the readiness of our forces."

contribute to poverty, environmental degradation, and political instability; and provide "enabling environments" for terrorist activity abroad.

Climate Change and Conflict

Obama told the cadets that their generation needs to lead the way to prepare for climate change and to prevent its worst effects in the future. He said that climate change increases the risk of instability and conflict around the world and that it could lead to a rise in "climate change refugees."

Climate change—especially rising seas—also is a threat to Americans' health and safety, the nation's economic infrastructure, and homeland security, he said. In addition, Obama noted that climate change "poses a threat to the readiness of our forces." He said that many military installations are on coasts, whereas others face the potential risk of thawing permafrost or deeper droughts and longer wildfires.

"Politicians who say they care about military readiness ought to care about this as well," Obama said.

"Fighting climate change and using energy wisely also makes our [military] forces more nimble and more ready. And that's something that should unite us as Americans," Obama said. "This cannot be subject to the usual politics and the usual rhetoric. When storms gather, we get ready."

By **Randy Showstack,** Staff Writer

Communicating Uncertainties in Sea Surface Temperature

Sea Surface Temperature User Workshop on Uncertainties
Exeter, UK, 18–20 November 2014

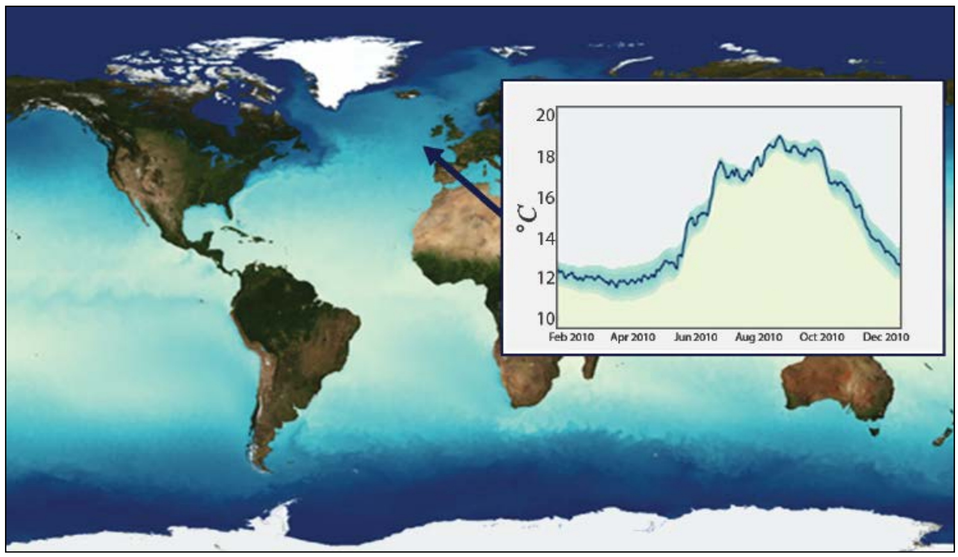
A project on sea surface temperature is generating new climate data records from satellite observations. The data are independent of in situ observations and are harmonious across satellite sensors to maximize stability and have realistic, context-sensitive uncertainty estimates at all spatial and temporal scales.

The project, part of the European Space Agency Climate Change Initiative (SST CCI), now seeks to establish a useful method for communicating uncertainty in sea surface temperatures. This goal was the impetus for a workshop held in November 2014 in Exeter in the United Kingdom.

Participants' backgrounds spanned a range of interests in weather and climate research. A key focus of the workshop was to clarify the distinction between error (mistakenness) and uncertainty (doubt). Uncertainty is typically quantified as the standard deviation of an estimated error distribution. However, errors in measurements from different effects have different correlations in space and time, so they cannot be expressed simply as a standard deviation.

Instrumental noise is usually modeled as independent random error between measurements. Calibration drift produces error that is highly correlated over global scales and years. Earth observation data sets will usually include errors on intermediate scales, which may be termed locally systematic. In the case of sea surface temperature, these are generally related to ambiguity from atmospheric variability and therefore correlate on synoptic scales. The current SST CCI approach is to specify components of uncertainty from random, locally systematic, and systematic effects separately.

In deriving uncertainty estimates across scales, these different components need to be propagated according to their correlation structure. Participants recommended that full characterization and clear documentation of the error model are needed and that these uncertainty components should be provided together with correlation information or that their complex behavior should be encapsulated in an ensemble as currently done by some providers of centennial-scale sea surface temperature data sets.



Example day from a sea surface temperature product of the European Space Agency's Climate Change Initiative. Inset shows a time series of sea surface temperature from one location, together with an indication of its uncertainty (illustrative only).

Because error covariance matrices can be large and difficult to use, workshop attendees recommended that these be parameterized to allow easy communication. The Climate Forecasting conventions—the community-accepted standards for providing metadata—require extension to accommodate more nuanced uncertainty information. Participants agreed that use of uncertainty information would be facilitated by providing tools for appropriate uncertainty propagation, ensemble selection, or the creation of user-defined flags.

Researchers do not necessarily use uncertainty estimates at face value, and trust in their realism has to be established. Workshop participants concluded that uncertainty validation and verification are welcomed, but more reference data are needed.

Participants noted that in addition to other factors, two major influences that govern how data are used are the scientific reputation of the producer and precedent of successful exploitation. Because precedent is persuasive, data producers may be able to promote uptake of products by engaging trailblazer users with their improved uncertainty information.

Attendees also felt that data producers need to address uncertainty estimation in a rigorous, defensible manner by defining uncertainty traceability chains. Tracing an uncertainty budget through processing levels from instrumental measurement to geophysical product can be based on metrological norms, e.g., from the Bureau International des Poids et Mesures's guide to the expression of uncertainty in measurement.

Recommendations will be used to update the SST CCI user requirements document. A full report is available at the workshop's website (http://www.esa-sst-cci.org/PUG/workshop.htm). The organizers thank all participants for their enthusiastic contributions.

By **Nick A. Rayner,** Met Office Hadley Centre, Exeter, UK; email: nick.rayner@metoffice.gov.uk; **Christopher J. Merchant,** Department of Meteorology, University of Reading, Reading, UK; and **Gary K. Corlett,** Earth Observation Science, Space Research Centre, Department of Physics and Astronomy, University of Leicester, Leicester, UK

IMPROVING PREDICTIONS
SEA ICE

By Julienne Stroeve, Ed Blanchard-Wrigglesworth, Virginie Guemas, Stephen Howell, François Massonnet, and Steffen Tietsche

Scientists study Arctic sea ice and melt ponds in the Chukchi Sea in 2010. Sea ice observations from studies like this one by NASA's Impacts of Climate Change on Eco-Systems and Chemistry of the Arctic Pacific Environment (ICESCAPE) project and many other Arctic investigations are providing new data that may help improve the forecasting skill of models that predict the extent and other characteristics of Arctic sea ice cover.

OF ARCTIC
EXTENT

NASA/Kathryn Hansen

In Arctic regions, marine transport operations, tourism businesses, resource extraction operations, and local communities rely on accurate reporting and forecasting of sea ice conditions. For example, recently, several coastal communities experienced critical shortages of heating fuel and gasoline during the winter months because an unforeseen early freeze-up cut short barge delivery of fuel.

Arctic sea ice reaches its maximum extent each March and its minimum extent each September. In addition to the yearly trends, routine satellite monitoring of polar regions has documented a decline in total Arctic sea ice extent since 1979. The largest and most widespread losses, which occur in September, affect an area as large as Ireland (a loss of 86,000 square kilometers per year, or 13.3% per decade).

The eight lowest September sea ice extents have all occurred within the past 8 years. As a result, Arctic

Shipping and hydrocarbon industries in Alaskan and Canadian waters are particularly interested in improved sea ice information and predictions.

resource extraction and ship traffic have increased [*Pizzolato et al.*, 2014], leading to growing interest in developing reliable methods to predict the summer minimum sea ice extent a few months in advance.

Starting in 2008, the Study of Environmental Change (SEARCH) program began collecting, from the sea ice forecasting community, summertime estimates of the upcoming September Arctic sea ice extent and synthesizing them in monthly reports called the Sea Ice Outlook (SIO). Contributors to the reports use a wide variety of methods to generate their estimates, including heuristic forecasts, statistical and/or dynamical models, ice-ocean coupled models, and fully coupled ice-ocean-atmospheric models.

Results from the SIO are shared with other researchers and interested members of the general public through the Arctic Research Consortium of the United States.

Interest in the SIO is substantial, with more than 192,740 unique views since the outlook began. In 2013, a newly funded interagency project, the Sea Ice Prediction Network (SIPN), took over SEARCH's synthesis effort.

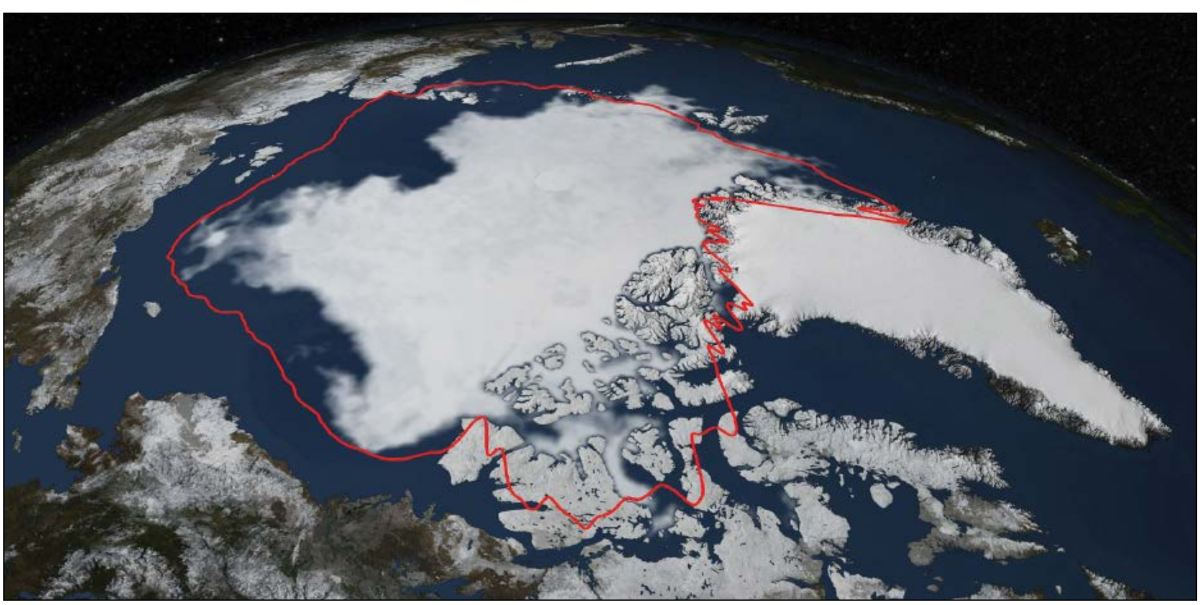
The Need for Forecasts of Sea Ice Conditions

Information on ice conditions is extremely important to local communities and industries. Because of this, spatial maps on the probability of timing of ice-free conditions provided in the 2014 SIO were an important addition to the standard pan-Arctic sea ice extent forecasts originally solicited for the SIO. In 2015, SIPN will consider adding additional metrics, such as the timing of ice breakup, freeze-up, and thickness.

Shipping and hydrocarbon industries in Alaskan and Canadian waters are particularly interested in improved sea ice information and predictions over several time scales. For example, barge and vessel traffic and oil fields on the North Slope rely on forecasts of ice conditions and potential hazards on synoptic time scales (a few days to a week), as they are relevant to ice closing in toward the coast.

Variations in the distribution of ice thickness and perennial ice—ice remaining from previous years—are hazards of particular concern, requiring forecasts at the onset of the operational season as well as synoptic and subseasonal forecasts over the course of the season. Seasonal predictions of breakup, freeze-up, and overall ice regimes provide an overview for conditions lasting several months. The need for ice thickness assessments, multiyear-ice assessments, and seasonal-scale forecasts dovetails with data needs for initialization and validation of predictions based on coupled ice-ocean and ice-ocean-atmosphere models.

Stakeholders in coastal communities place a high priority on improved predictions of fall freeze-up at the seasonal to submonthly scale. The presence of sea ice in the fall is a key constraint for a range of activities, including resupplying northern communities. Sea ice also affects potential hazards such as the exposure of coastlines to fall storms.



NASA/Goddard Scientific Visualization Studio

Arctic sea ice hit its annual minimum on 17 September 2014. The red line in this image shows the 1981–2010 average minimum extent. Data provided by the Japan Aerospace Exploration Agency GCOM-W1 satellite.

Searching for Meaningful Diagnostics

In April 2014, SIPN hosted its first sea ice prediction workshop. Scientists from around the world attended, with representation from the modeling and observation communities, as well as operational forecast centers. These scientists put forward several recommendations to improve predictions. They placed the highest priority on model intercomparison projects, improvements in ice thickness data retrieval, and assimilation of observations into models.

The need for more-sophisticated diagnostics was a recurring theme in the discussions. For the first few years of the SIO, ice extent was almost exclusively the only metric considered, yet it is clear that such a spatially integrated metric is of little use to most stakeholders.

Five groups responded to a 2014 request for submissions of spatial predictions of the date of ice loss and the probability that September sea ice concentration (the fraction of a given area that is covered by ice) will be greater than 15%. Although these results show varying degrees of skill in capturing the ice edge location (Figure 1a), the multimodel mean yields a more skillful outlook than any individual dynamical model, a feature also seen in other climate forecasts [e.g., *Krishnamurti et al.,* 1999].

General agreement across models shows that the most unpredictable feature of the September 2014 ice cover was the significant loss of ice in the Laptev Sea and the above-average ice cover in the Barents Sea (Figure 1b). It is telling that these are the regions within the Arctic where summer atmospheric forcing was most extreme, with warm southerly winds over the Laptev Sea and cold northerly winds over the Barents Sea. Because the atmosphere is mostly unpredictable beyond 1 or 2 weeks, the sea ice forecasts initialized in late spring may not be able to accurately predict sea ice features that develop as a result of extreme summer atmospheric conditions.

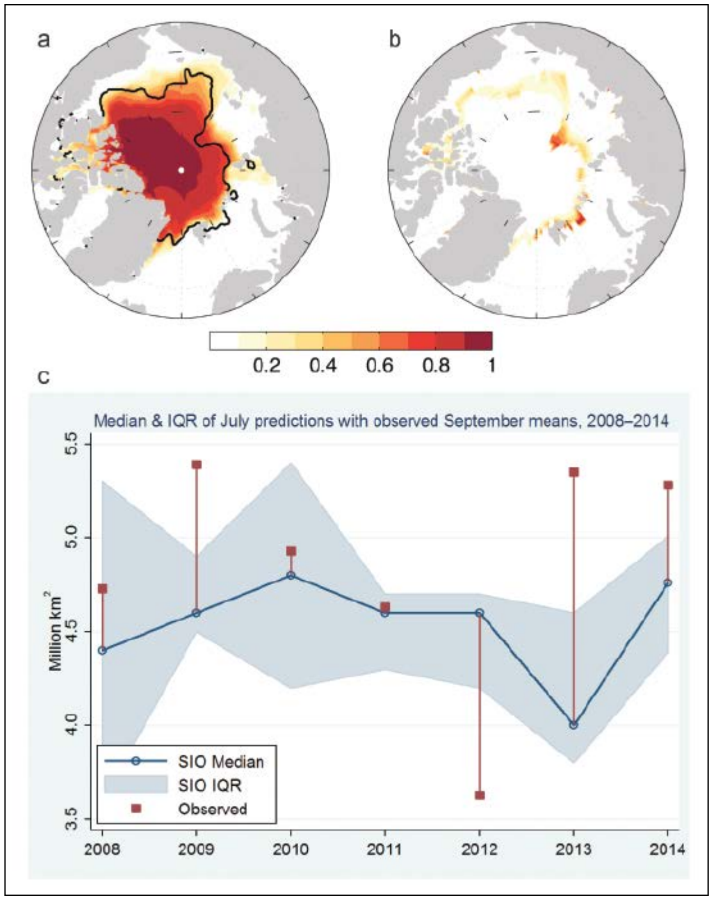


Fig. 1. (a) Multimodel ensemble mean sea ice probability. A value of 0 represents 0% probability that September sea ice concentration will be greater than 15%, and 1 represents 100% probability. The black contour indicates the observed September 2014 sea ice edge. (b) Depiction of forecast skill of the multimodel ensemble mean. Colors represent skill ratings calculated as Brier scores (see http://bit.ly/1fcFx71). A value of 0 (shown as white) represents a perfect forecast, and 1 (dark red) represents a completely erroneous forecast. (Credit for models that contributed to Figure 1a and 1b: Blanchard-Wrigglesworth et al., NCAR CESM; Cullather et al., NASA GMAO; Wang et al., NOAA CFS; Zhang and Lindsay, UW PIOMA; Slater) (c) Median and interquartile range (IQR) of July Sea Ice Outlook (SIO) predictions compared to observed September extent.

Which Models Are Most Accurate?

We evaluated SIO contributions from 2008 to 2013 and found that median predictions tended to be accurate in years when the extent followed the long-term accelerating trend [*Stroeve el al.,* 2014]. For example, the observed September 2014 extent was 100,000 square kilometers less than that observed in 2013, and the median of the current sea ice extent estimations in the SIO is closer to the observed sea ice extent than the median for contributions in 2013 (Figure 1c).

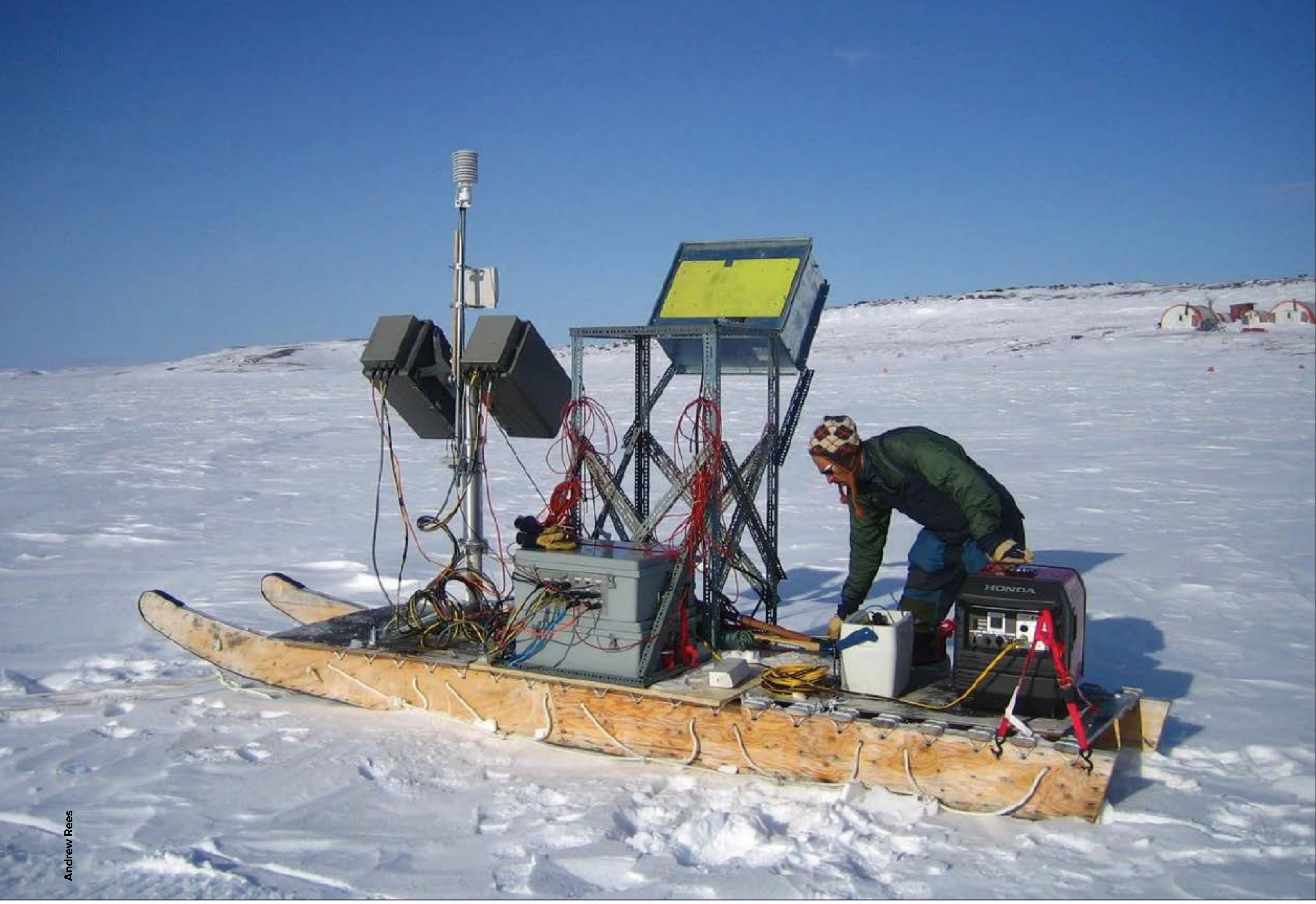
In 2014, about one third of contributions came from dynamical climate models that, as a multimodel ensemble, bracketed the observed value for each month the forecasts were issued. These forecasts were more accurate for start dates closer to September, that is, when the models were initialized using the most recent observations.

An analysis of the differences between predicted and observed sea ice extents using various methods suggests that the SIO forecasts capture accelerating rates of ice loss better than a linear trend approach, although only slightly better.

Limitations of Predictability

Given inherent uncertainties, what are the limits that determine how well any predictive model can perform? Several studies have used a "perfect model" approach to estimate the limit of Arctic sea ice predictability. These idealized prediction studies suggest that skillful forecasts for monthly pan-Arctic sea ice extent should be possible up to 24 months in advance (see *Guemas et al.* [2014] for a review).

However, skillful forecasts extend only 2 to 5 months during summer, when scientists use the same type of dynamical models and statistical forecast systems to predict observed ice conditions. This gap may originate from limitations of the forecast systems, such as insufficient or



To improve Arctic models, scientists conduct fieldwork to record observations under shifting arctic baselines. Here a scientist readies instruments for a surface-based passive microwave survey on Daring Lake in Canada's Northwest Territories. The survey will help researchers learn more about snow cover properties over multiple years at a scale appropriate for comparison with satellite passive microwave remote sensing data and regional climate and hydrological models.

poor-quality initial conditions for data assimilation, insufficient or inadequate model physics, and a potential for climate models to drift toward a state that's not a real feature of the climate system.

Ultimately, inherent predictability may be quite a bit lower in nature than in dynamical models. However, new model physics developments that address important sea ice processes, such as the life cycle of melt ponds on sea ice, demonstrate promising results in enhancing predictive skill in a statistical forecast model [e.g., *Schröder et al.,* 2014].

How Do Shifting Baselines Further Limit Predictability?

Additional complexity arises from the lack of knowledge about how the intrinsic predictability may be affected by a change in the climate's mean state [*Holland et al.,* 2010]. Scientists find this question particularly relevant given the fast pace of change in the Arctic.

Despite the fairly short satellite sea ice record, it is sufficiently long to conclude that the summer ice loss has accelerated [*Stroeve et al.,* 2012]. Yet superimposed on this accelerating downward trend are large year-to-year variations. Interannual variability of summer sea ice extent will likely increase in coming decades, and some scientists suggest that this might lead to a reduction in predictability [e.g., *Tietsche et al.,* 2013]. However, few modeling studies of future potential predictability have been performed to date.

Future Directions

The sea ice prediction modeling community must act on several fronts to analyze future contributions efficiently and extract reliable information relevant for stakeholders. Priority lies in designing a stringent common protocol for seasonal prediction systems so that the uncertainty contributions from imperfect knowledge of initial conditions, chaotic summer atmospheric forcing, and imperfect model physics can be quantified in a realistic framework. Eventually, this will help identify where efforts should be placed to improve SIO forecast skill.

Modeling groups must also be prepared to incorporate an increasing number of available sea ice observations in their models for initialization. Data on ice concentration and thickness, snow cover, spring melt pond fraction, and ice drift are already available or will become routinely available in the near future.

Evaluation of statistical models is also complex because there is no consensus on the overall structure of these models. Currently, statistical model users favor ordinary regression, but there are a number of alternatives. Because statistical models are fixed mathematical relationships between climate variables constructed from past data, scientists will need to address if and how these relationships might change under a changing climate.

In addition, a framework should be designed so that statistical model predictions can be compared with predictions from coupled models. We have received statistical predictions of regional and stakeholder-relevant sea ice parameters, such as the Barnett severity index [*Drobot,* 2003]. Comparing these with coupled model predictions is a challenge.

Statistical modelers should also work toward producing spatial maps so that these can be interpreted relative to the coupled models. A noteworthy result of the 2014 SIO is that a statistical model yielded the best spatial forecast skill. Whether this result holds only for 2014, when the extent fell near the long-term trend, remains to be seen.

Finally, there is substantial value in fostering communication between observers, modelers, and various stakeholder groups to better define data utility, information needs, and priorities. This requires effective communication pathways, such as presentations directly to stakeholder groups, translation of research findings into brief summaries, and the creation of a forum for informal exchange. Toward that end, SIPN has begun hosting bimonthly webinars (http://www.arcus.org/sipn/meetings/webinars) and has created a LinkedIn forum (http://linkd.in/1TgpzIE) for informal exchange among stakeholders and climate forecasters.

Acknowledgments

SIPN is funded by the National Science Foundation, NASA, the U.S. National Oceanic and Atmospheric Administration, the Office of Naval Research, and the Department of Energy.

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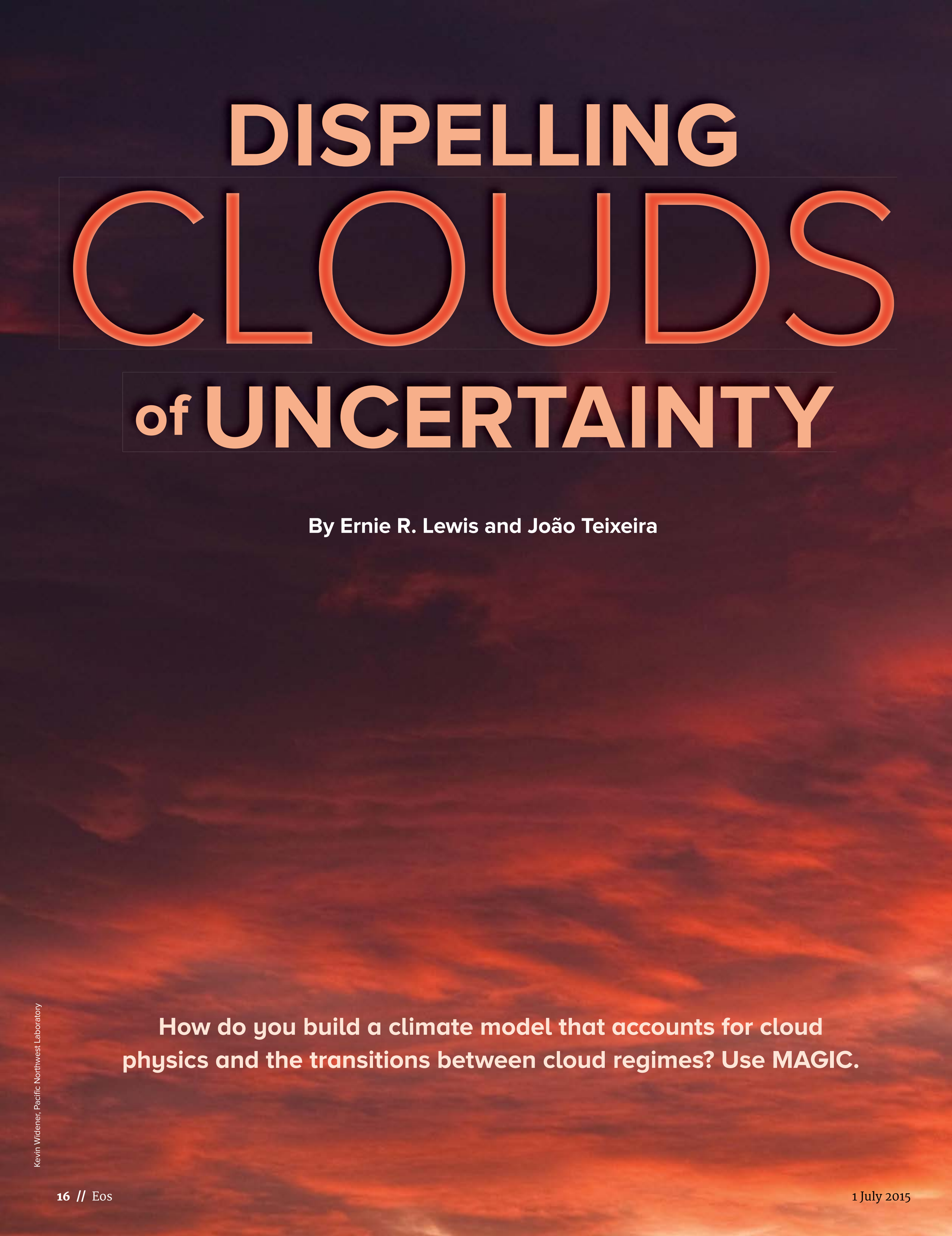
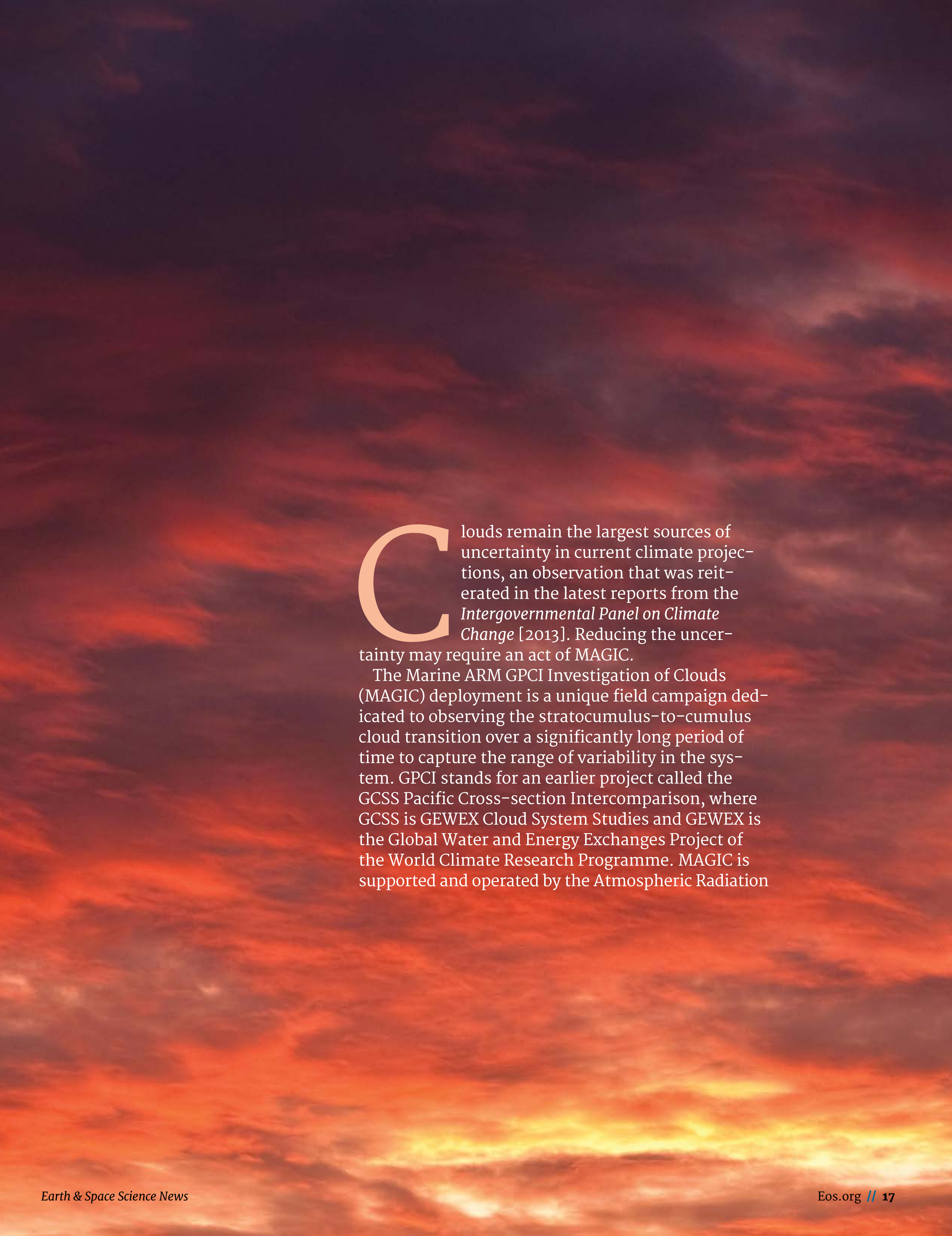


DISPELLING CLOUDS of UNCERTAINTY

By Ernie R. Lewis and João Teixeira

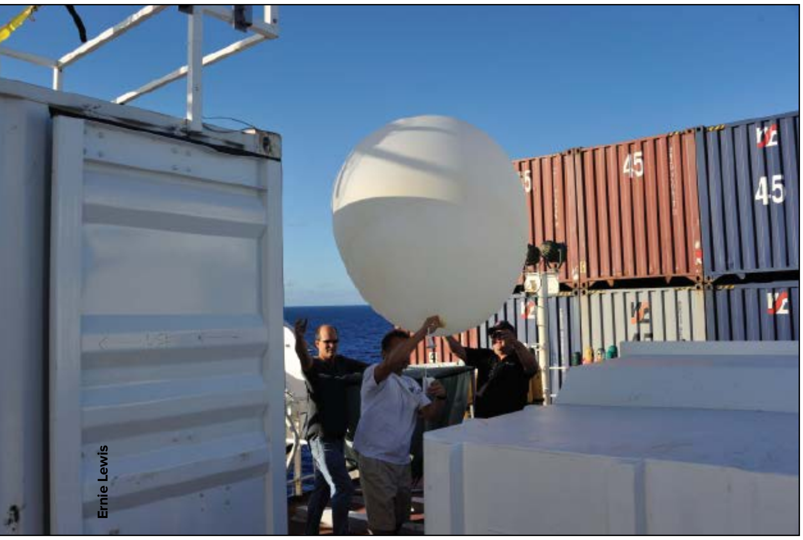
How do you build a climate model that accounts for cloud physics and the transitions between cloud regimes? Use MAGIC.

Kevin Widener, Pacific Northwest Laboratory



Clouds remain the largest sources of uncertainty in current climate projections, an observation that was reiterated in the latest reports from the *Intergovernmental Panel on Climate Change* [2013]. Reducing the uncertainty may require an act of MAGIC.

The Marine ARM GPCI Investigation of Clouds (MAGIC) deployment is a unique field campaign dedicated to observing the stratocumulus-to-cumulus cloud transition over a significantly long period of time to capture the range of variability in the system. GPCI stands for an earlier project called the GCSS Pacific Cross-section Intercomparison, where GCSS is GEWEX Cloud System Studies and GEWEX is the Global Water and Energy Exchanges Project of the World Climate Research Programme. MAGIC is supported and operated by the Atmospheric Radiation



On the bridge deck of the Spirit *cargo ship, members of the Marine ARM GPCI Investigation of Clouds (MAGIC) research team prepare to launch a balloon-borne radiosonde to take atmospheric measurements.*

Measurement (ARM) Climate Research Facility of the U.S. Department of Energy.

A Shift in Cloud Cover

The MAGIC approach took advantage of the mobile nature of the Second ARM Mobile Facility (AMF2) by deploying its suite of marine-capable instruments on board the Horizon Lines cargo container ship *Spirit* as it plied its regular route between Los Angeles and Honolulu from September 2012 to October 2013. This route transects two cloud regimes that are of great interest to climate modelers, and it lies near a transect previously used to evaluate climate models during the GCPI project [*Teixeira et al.,* 2011]. The clouds are primarily stratocumulus near the coast of California and transition to shallow cumulus clouds, which are the dominant type near Hawaii.

Boundary layer clouds (those within the atmospheric turbulent layer, which is adjacent to the surface and roughly 1 kilometer deep) have a particularly important role in the climate system because of their complex interactions with turbulence, convection, radiation, precipitation, surface fluxes, and large-scale circulation. Stratocumulus clouds, which are often found off the west coast of continents, have high reflectivity (albedo) and large horizontal extent. These clouds transition to a cumulus regime as the boundary layer moves horizontally over warmer waters along the trade winds toward the equator.

Although cumulus clouds play a crucial role in atmospheric vertical transport and in modulating surface evaporation, because of their low areal coverage, their direct interactions with radiation are much less significant for the climate system than those that occur in the stratocumulus regime.

Because of this remarkable contrast in terms of the interaction with radiation (stratocumulus regimes strongly reflect solar radiation, whereas cumulus regimes do not), the transition from stratocumulus to cumulus is an important element of the climate system. It turns out that this key cloud transition could play an essential role in cloud-climate feedbacks. For example, in a future climate it is conceivable that the characteristics of the stratocumulus and cumulus regimes will remain fairly similar to those in the current climate. On the other hand, the transition between them may be quite different: It may occur farther north or farther south, or it may be more abrupt. A significant change in the location of the transition, for example, would have a tremendous impact on the feedbacks between clouds and climate. However, the physical mechanisms responsible for the transition are not fully understood. In particular, current climate and weather models fail to reproduce many of the key properties of the stratocumulus-to-cumulus cloud transition [e.g., *Teixeira et al.,* 2011].

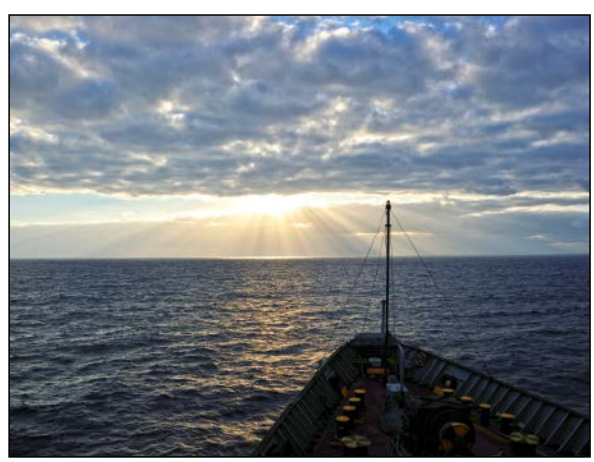
Models and Satellites Provide a Start

The "purest" version of the stratocumulus-to-cumulus transition is arguably the one that occurs over the eastern North Pacific, as the air flows from California toward Hawaii. At this location, the size of the ocean basin and the shape of the adjacent continents allow for a clear transition between the two cloud regimes.

This specific transition was investigated by *Teixeira et al.* [2011], who compared a variety of weather and climate models against satellite observations along the GPCI transect, which provides a representative cross section extending from the coast of California southwest to the equator (Figure 1). The study helped characterize the main deficiencies of models in representing this transition but did not allow for a detailed understanding of the physics involved.

Achieving this understanding requires dedicated high-resolution modeling—large-eddy simulation models, for example—and observations of the transition from within the boundary layer. Although some field experiments have been dedicated to studying this cloud transition in the Atlantic [e.g., *Bretherton and Pincus,* 1995], they were of limited duration—days to weeks.

Some detailed studies have also incorporated observations from field experiments, high-resolution models, and single-column versions of weather and climate models [e.g., *Bretherton et al.,* 1999]. Before MAGIC, however, no



A heavy cloud layer darkens the sea off the bow of a cargo ship laden with instruments used to collect data on the stratocumulus-to-cumulus transition.

long-term field experiment had been dedicated to studying the stratocumulus-to-cumulus transition.

Measuring the Clouds

The mobile instrument facility for the MAGIC field study, AMF2, consists of three 20-foot (6.1-meter) cargo containers housing instruments, computers, and supplies. To measure the properties of clouds and precipitation during MAGIC, scientists used three radars, two lidars, two microwave radiometers, a ceilometer to measure the height of the cloud base, a total-sky imager, disdrometers to measure precipitation drop size distribution and velocity, and other instruments.

A suite of instruments measured direct and diffuse incoming solar radiation. Other instrumentation measured key aerosol properties such as concentrations of condensation nuclei, concentrations of cloud condensation nuclei at various relative humidities, aerosol particle size distributions, light scattering and absorption by aerosols at multiple wavelengths, and the extent to which aerosol particles absorb moisture with changing relative humidity.

In addition, scientists collected aerosol samples for later analysis of bulk and individual particle composition, individual particle morphology, and ice-nucleating ability. They also measured basic meteorological quantities and sea surface temperature, enabling computation of surface energy fluxes that can serve as boundary conditions for models attempting to represent processes occurring in the marine boundary layer.

Shipboard researchers launched radiosondes with weather balloons every 6 hours (every 3 hours for the period of 6–18 July 2013) to provide detailed information on atmospheric vertical structure (i.e., temperature, relative humidity, and wind speed and direction). They completed more than 550 successful radiosonde launches.

Clearing Away the Uncertainty

In total, MAGIC completed nearly 20 round trips and 200 days at sea, yielding an unparalleled data set over a region that is vastly undersampled. The data have been ingested and deposited in the ARM data archive (http://www.archive.arm.gov/), where they are freely available to all.

The extent of temporal and spatial sampling within the marine boundary layer as it flows from the cold waters off California to the warmer waters around Hawaii produced an unprecedented observational data set. MAGIC data have the potential to lead to major breakthroughs in our understanding of the physics of the stratocumulus-to-cumulus cloud transition and to the accurate representation of this essential transition in future weather and climate models.

For more information on MAGIC, contact Ernie Lewis or visit the MAGIC website (http://1.usa.gov/1QPyD38).

Acknowledgments

We thank Horizon Lines and the captain and crew of the *Spirit* for their support and hospitality during MAGIC. E.R.L. was supported by the U.S. Department of Energy's Atmospheric System Research Program (Office of Science, OBER) under contract DE-SC00112704. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

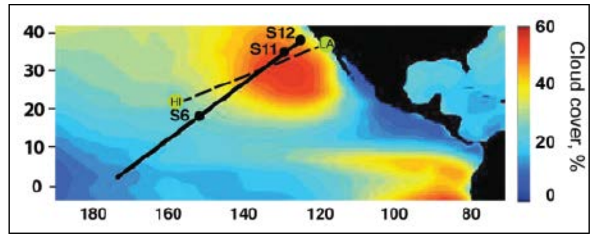


Fig. 1. False colors show average June-July-August low-level cloud cover from the International Satellite Cloud Climatology Project (ISCCP), with the GPCI transect (solid line) and MAGIC route (dashed line) between Los Angeles and Honolulu marked. Points S6, S11, and S12 used in the Cloud Feedback Model Intercomparison Project (CFMIP)–GCSS Intercomparison of Large-Eddy and Single-Column Models (CGILS) are also shown (based on Figure 1 of Teixeira et al. *[2011]).*

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AGU's 2015 Mass Media Fellow to Report for *National Geographic*

Courtesy of Maya Wei-Haas

Maya Wei-Haas, AGU's 2015 Mass Media Fellow, is spending her summer working as a science reporter at National Geographic.

Geologist and environmental chemist Maya Wei-Haas defended her thesis on flame retardants in lakes and streams of Arctic Alaska in May. Rather than set off on new studies with her Ph.D., though, Wei-Hass is spending her summer on a different kind of adventure: working as a science reporter at *National Geographic* in Washington, D. C.

AGU is sponsoring Wei-Hass's tenure at the magazine as the organization's 2015 AAAS Mass Media Science and Engineering Fellow. The program, run by the American Association for the Advancement of Science (AAAS), places about a dozen scientists at news media outlets around the United States each year to get immersive experiences in science journalism and to bring scientific expertise into newsrooms.

Along with her love for science, Wei-Haas has "always had a passion for art and storytelling," she said. "In part, that's why I've always loved geology. There's something artistic about rocks...they're just very beautiful." This passion led her to the Mass Media Fellowship program. She hopes to put her experiences to use at *National Geographic.*

Those experiences have included several field-research stints above the Arctic Circle and in Antarctica in pursuit of scientific knowledge. In her junior year at Smith College, Wei-Haas traveled to Svalbard, a Norwegian island chain northeast of mainland Norway, as part of an undergraduate research experience program run by Mount Holyoke College. The students sailed to the island over waters so cold that each passenger was required to wear a survival suit. This field site was where Wei-Haas did "real" research for the first time.

"They introduced us to the field sites...and what instrumentation was available and said 'Ask questions,'" Wei-Haas said. "It was pretty amazing. It felt like an old-school adventure of Arctic explorers."

Research on Brominated Flame Retardants

Ultimately, Wei-Haas graduated with a B.A. in geology and then moved to the Ohio State University, where she earned her doctorate in geology this May for her work on brominated flame retardants. These chemical compounds are found in many common household products and are neurotoxins that have become ubiquitous in the environment.

The compounds degrade slowly, Wei-Haas said, and escape into the environment by clinging onto dust particles or simply evaporating into the air. Some scientists believe that these chemicals become more toxic over time, so Wei-Haas studies how long they stick around, to better understand their environmental impact.

"My research is looking at their fate in the Arctic," she said, where the flame retardants are suspected of causing renal lesions in polar bears, for example, and other health problems affecting Arctic animals. "It's an interesting and slightly scary topic," she said.

> "I can't wait to learn all I can from the amazing [*National Geographic*] staff about both science journalism and scientific graphic design."

Scientific Images and Illustrations

While pursuing her doctorate, Wei-Haas also nurtured an interest in creating scientific illustrations, graphics, posters, and images. "I am so excited and honored to have been selected to work at *National Geographic,*" she said. "I can't wait to learn all I can from the amazing staff [there] about both science journalism and scientific graphic design."

Wei-Haas will be working with Erika Engelhaupt, the online science editor for the *National Geographic* website, who was the AGU-sponsored Fellow in 2006.

"We're really excited to have her at *National Geographic,*" Engelhaupt said. "As a former AGU-sponsored Mass Media Fellow, it's really nice to be able to see the next generation of science writers and communicators coming up through the [program]."

AGU has sponsored at least one fellow from the Earth and space sciences in the program every year since 1997.

To see some of Wei-Haas's science illustrations and graphics and to read some of her journal stories from the field, visit her website (http://www.mayaweihaas.com/). For more information about AGU Mass Media Fellows and how to apply for the fellowship, visit http://news.agu.org/mass-media-fellowship/.

By **Mary Catherine Adams,** Public Information Specialist, AGU; email: mcadams@agu.org

Take the Student Travel Grant Challenge

Gary Wagner

Students gain valuable experience through collaboration with senior leaders and scientists at AGU's Fall Meeting.

Since its inception, the Student Travel Grant program has helped more than 1000 students enrich their careers and expand their scientific networks by attending the AGU Fall Meeting and other scientific gatherings, such as the Joint Assembly, Meeting of the Americas, and Ocean Sciences meetings.

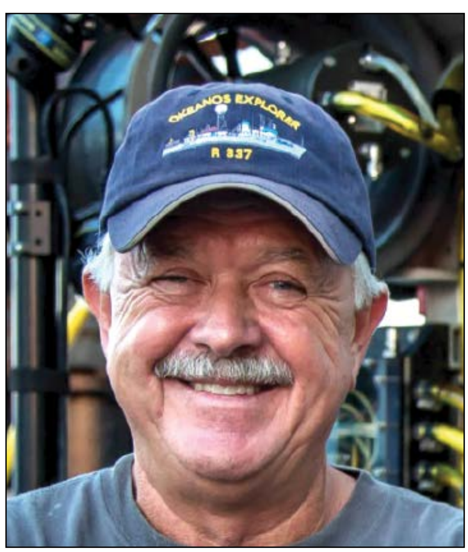
Now more than ever, the program needs your support—and a new challenge issued by its founder will help to meet the program's goal of providing assistance to every student who needs it.

Founding the Program

The Student Travel Grant Program was founded in the early 2000s, largely through the efforts of Jamie Austin, senior research scientist at the University of Texas Institute for Geophysics.

As a student member in the 1970s, Austin attended Fall Meetings and began to see them as transforming experiences. The meetings connected him with senior leaders and scientists, helping him gain experience and lay the groundwork for his future career.

In the early 2000s, as a member of AGU's Budget and Finance Committee (now the Finance and Investment Committee), Austin worked with AGU leadership to create the first Development Board, a team of AGU members and other volunteers charged with helping to codify and support the work that the Development Department was doing to advance the growth of new programs.



J. Austin

Jamie Austin, senior research scientist at the University of Texas Institute for Geophysics and founder of AGU's Student Travel Grant program.

As chair of the first Development Board, Austin could see that AGU's student members were becoming a force within the membership, and he wondered what he could do to support them and to connect them with the breadth of expertise that AGU's members have to offer. He set to work to create the first Student Travel Grant program, generously founding the program with a large donation to inspire AGU's members and donors.

The Goal: Assistance to Every Student Who Requests It

Today Austin continues to see the Student Travel Grant program as something that is intrinsically valuable to AGU's membership and corporate sponsors. "Growing talent pool is one of the clearest ways that AGU can help impact the future of the Earth and space sciences and of the planet," he said.

In 2014, the Student Travel Grant program received nearly 1000 applications from students who needed assistance to attend Fall Meeting. However, AGU was able to award grants to fewer than 20% of applicants.

"Ideally, we should be awarding assistance to every student who requests it," said Austin, "but the cost is high."

A Challenge to AGU Members

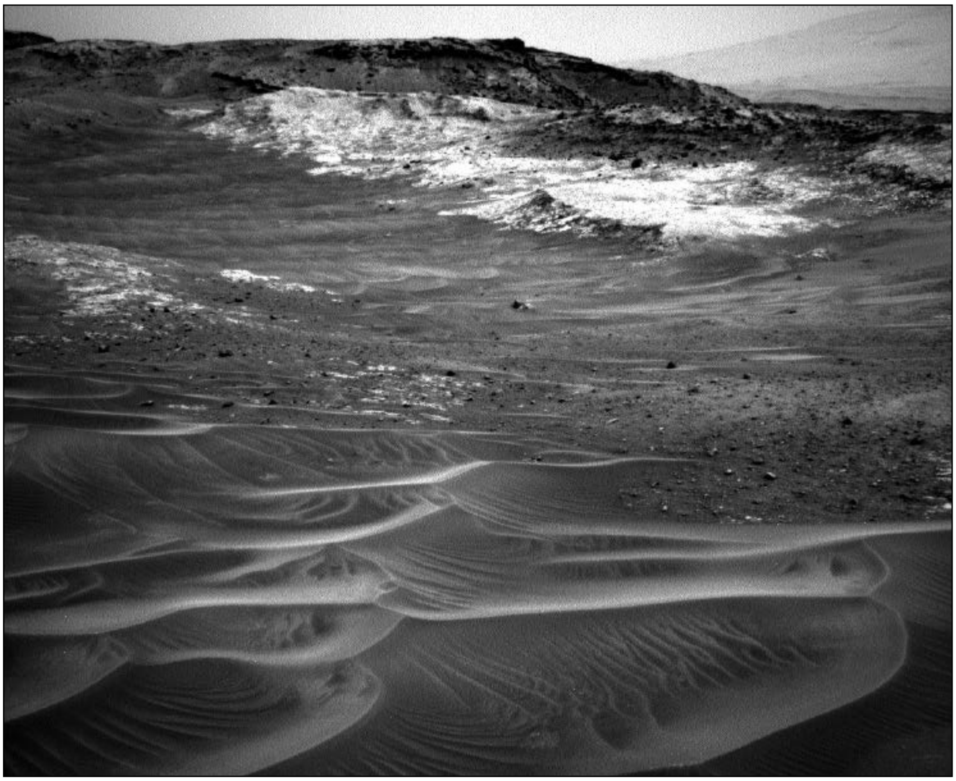
As AGU's student member constituency continues to grow, AGU must find a way to alleviate the financial burden of attending national and international meetings for our young members. With nearly a $500,000 annual shortfall between Student Travel Grant applications and awards, Austin is issuing a challenge to all AGU members and organizational partners.

In a recent conversation with AGU's senior staff, Austin pledged, "For every $9 committed by AGU donors, I will contribute an additional $1, up to a total of $50,000 to address this shortfall. It will take the collective resources of all Earth and space science stakeholders, but I am certain by AGU's centennial in 2019, we can bridge the funding gap and award Student Travel Grants to all applicants."

Join Austin in supporting Student Travel Grants this year by visiting http://giving.agu.org/ or contacting Development staff at +1-202-777-7434 or development@agu.org to make your gift.

By **Jeff Borchardt,** Development Director, AGU; email: jborchardt@agu.org

What's New in the AGU Blogosphere



USGS/NASA

Curiosity used its Mast Camera to map out a path around slippery sands to "Mt. Stimson," the dark ridge in the background, writes Ryan Anderson in a recent Martian Chronicles *blog post. Every Curiosity-related post includes a fresh image from Mars.*

This spring the AGU Blogosphere saw the awakening of a long-dormant planetary science blog as well as the addition of a new blog about glaciers.

In March the Blogosphere welcomed back *Martian Chronicles* (see http://blogs.agu.org/martianchronicles/), which had been inactive for almost 2 years. The original blogger, Ryan Anderson, has brought with him two fellow U.S. Geological Survey (USGS) scientists who work on the Curiosity Mars Rover team.

For some time, Anderson, Ken Herkenhoff, and Lauren Edgar have been posting brief updates on the USGS Astrogeology Science Center website about what the Curiosity rover is up to. Now those updates are being posted, with fresh images from Mars, on *Martian Chronicles* as well.

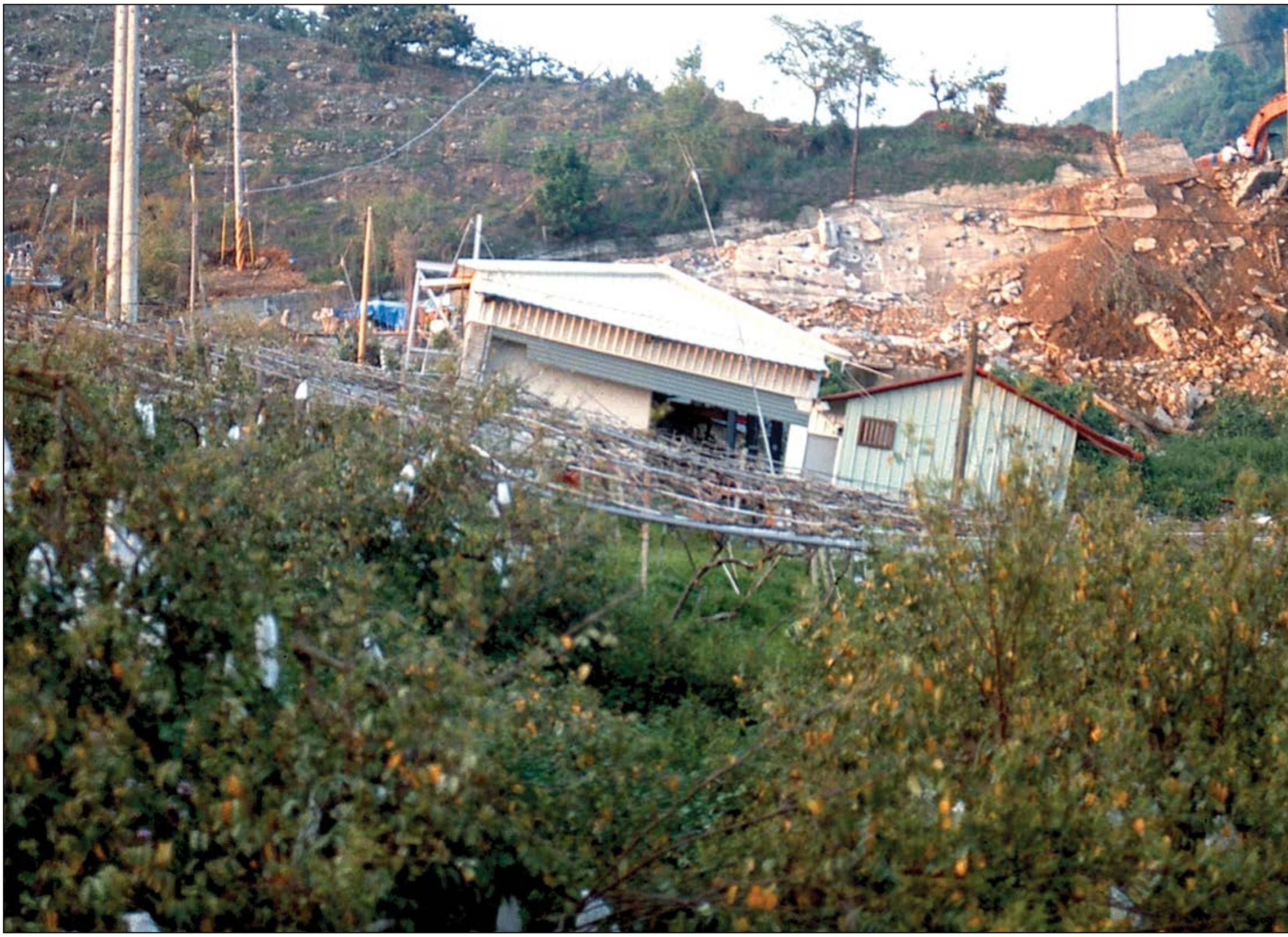
"We hope you will enjoy following along with Curiosity's daily activities as we explore the foothills of Mt. Sharp," Ryan wrote in his first post to the revived blog. "It's good to be back!"

March also saw *From a Glacier's Perspective* join the AGU Blogosphere (see http://blogs.agu.org/fromaglaciersperspective/). The blog was created in 2009 by glaciologist Mauri Pelto of Nichols College and the North Cascade Climate Project.

Pelto's posts focus on studies of how glaciers are changing around the world, one glacier at a time. He includes in his posts historical and current images of glaciers with written explanations. Sometimes these posts also feature videos documenting changes.

Recent posts give a look at the mountain glaciers of the recently erupting Calbuco Volcano and changes to the Greenland Ice Sheet in 2014.

By **Larry O'Hanlon,** Blogosphere Manager and Social Media Coordinator, AGU; Twitter: @Earth2larryo



John Suppe

A house tilted during the 1999 Chi-Chi earthquake (M_w 7.6, which struck central Taiwan) as it was dragged across a fold hinge. See larger electric poles on the left of the house for vertical reference.

Surface Folds Hint at Magnitude of Slip Along Thrust Faults

Reconstructing the long-term history of fault movement where tectonic plates collide is important for assessing seismic hazard, but it has proven challenging to accomplish in practice. Many methods use the deformation of sediments deposited on top of faults to extract information about past earthquakes and slip rates.

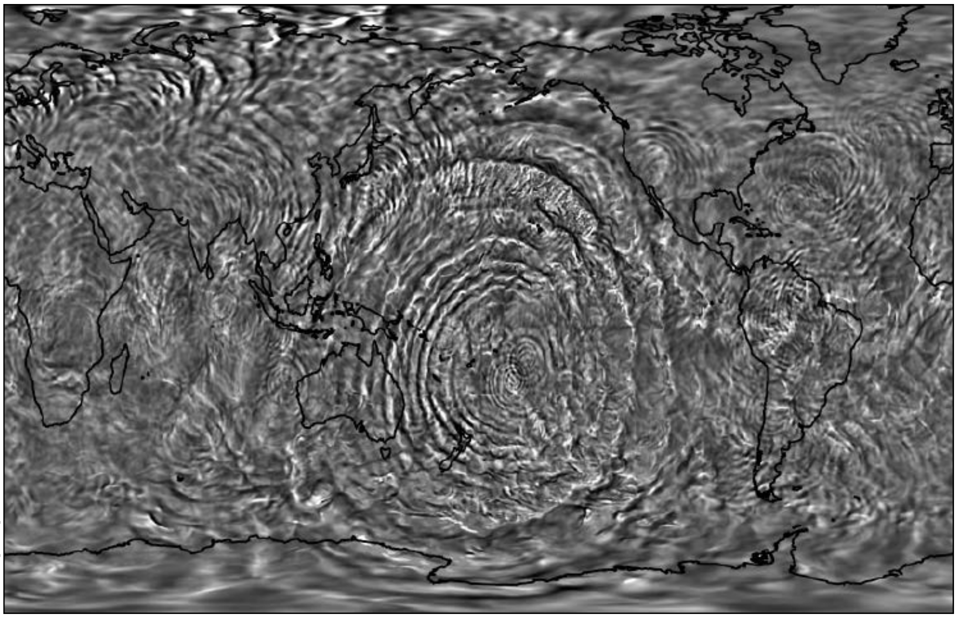
However, obtaining robust estimates from these techniques requires understanding the link between sediment disturbances and fault geometry. *Le Béon et al.* propose a conceptual model based on previous research that employs a specific kind of deformation—fault-bend folding—to understand the slip history of thrust faults. They applied their method to the Chelungpu fault in Taiwan.

Fault-bend folding occurs as a consequence of the underlying geometry of a fault; below the surface, many fault planes lie relatively flat and then climb toward the surface at a steeper angle. When slip occurs, the bottom of the upper block runs into the steeper slope of the lower block, deforming the sediments that sit on top of the fault planes and producing a topographic kink at the surface. The researchers developed mathematical relationships that use the three-dimensional shape of this kink to determine the amount and direction of slip that has occurred along the fault.

By combining their new approach with observations of the Chelungpu fault, including extensive structural geology data and a topographic analysis of abandoned river terraces, the researchers estimated the slip history of this feature. They found that the fault has slipped obliquely at a rate of nearly 18 millimeters per year for the past 30 thousand years.

They also found that the M_w 7.6 earthquake that occurred along the fault in 1999, the largest earthquake in the 20th century to strike Taiwan, appears to be a typical event throughout the region's history, recurring approximately every 470 years. (*Journal of Geophysical Research: Solid Earth*, doi:10.1002/2013JB010794, 2014) **—Julia Rosen, Freelance Writer**

Global Atmospheric Model Simulates Fine Details of Gravity Waves



Liu et al. [2014]

Concentric gravity waves in the lower thermosphere (at roughly 100 kilometers in altitude) excited by a tropical cyclone to the east of Australia.

When a stable atmosphere is disturbed vertically, gravity tries to restore equilibrium, producing a wave, similar to what happens when a rock is dropped in water. So-called gravity waves play a number of important roles in the middle and upper atmosphere, where the wave amplitudes become increasingly large with decreasing air density. These roles include transferring energy and momentum from one atmospheric region to another, perturbing the densities of ions and neutral molecules, and inducing instability.

However, scientists still struggle to quantify how gravity waves are distributed and structured and how they change over time. They operate on such a large range of scales—from several kilometers to thousands of kilometers—that any one observational technique cannot completely capture them.

Liu et al. use a whole-atmosphere general circulation model that for the first time resolves gravity waves on the mesoscale—down to the tens of kilometers level—from Earth's surface to the lower thermosphere to try to better understand these waves' structure, function, and impacts. This model, developed from the National Center for Atmospheric Research's Whole Atmosphere Community Climate Model, simulates a number of gravity wave features, including their spectra, intensity, and distribution both horizontally and vertically. The authors also used the model to assess the resulting impacts on larger-scale Earth conditions such as temperatures, tides, and easterly and westerly zonal winds.

The resulting simulations suggest that the modeling generally produced realistic results. The spatial structure and magnitudes of gravity waves generally echoed those derived from temperature observations in the Sounding of the Atmosphere using Broadband Emission Radiometry satellite mission, the authors found.

Vertical winds, a proxy for gravity wave activity, grew stronger and more widespread at higher levels in the simulations, suggesting that the same holds true for gravity waves. Moreover, the model simulation also yielded daily and semidaily tides that agreed with observational data, an improvement from previous models. However, the model still could not resolve many mesoscale waves on the smallest scales (less than 100 kilometers) very well, which the authors suggest means that their model can only partially capture the mesoscale waves in the middle and upper atmosphere. (*Geophysical Research Letters,* doi:10.1002/2014GL062468, 2014)

—Puneet Kollipara, Freelance Writer

Dynamics of the Earth's Surface in the Eastern Tibetan Plateau

The evolution of mountains is written in the histories of the rocks that make up their ranges. Scientists have long used areas where rivers cut deep incisions in rock to study the patterns of how the Earth's surface rose toward the sky—a geological process termed uplift—but this strategy assumes that there is very little lag time between uplift events and river-induced erosion.

A new study set out to test this assumption in the eastern Tibetan Plateau, where the Dadu and Min rivers carve deep gorges into the land. According to the authors, the relatively uniform rates of erosion in the region imply that the plateau was formed by a rapid uplift of rock in the late Miocene, but until now, the timing of river-induced erosion there had not been pinned down.

Tian et al. used fission track dating, which measures the number of fission events from the decay of uranium-238 in the mineral apatite, in two vertical rock profiles from areas where the two rivers have worn chasms into the plateau. These fission events are temperature sensitive, which makes the method a useful way to track the thermal history of rocks, and help scientists estimate when the rock became exposed at the Earth's surface.

The authors found that river erosion rates increased fourfold to eightfold in the late Miocene, roughly 10 to 12 million years ago. The study indicates that the lag time between rock uplift and river erosion in the Tibetan Plateau was just 2 million years or so, making them relatively synchronous events—at least on geological timescales. (*Geophysical Research Letters,* doi:10.1002/2014GL062383, 2015)

—Kate Wheeling, Freelance Writer

JialiangGao, CC BY-SA 3.0 (http://bit.ly/ccbysa3-0)

A picture of the town of Aba located within the Tibetan Plateau.

What Causes Extreme Hail, Tornadoes, and Floods in South America?

Kristen Rasmussen

An aerial view of a flood-prone river in the foothills of the Andes near San Miguel de Tucuman, Argentina.

Subtropical South America is host to a tornado alley in the Pampas lowlands, flash floods in the Andes foothills, and the highest frequency of large hail (≥2.5 centimeters in diameter) in the world. Their cause is clear: The region is home to some of the world's deepest convective storms, which are triggered in proximity to the Andes and driven by heat and moisture arriving from Amazonia. Improved forecasting of the factors that lead to headline-making, disruptive natural events is needed.

Rasmussen et al. advocate that understanding and predicting these extreme weather events is important for economic security and public safety of this region. In a new paper, the authors used local media reports of tornadoes, floods, and hail, combined with more than a decade of satellite radar data on atmospheric precipitation systems and lightning sensor data. They mapped the climatology of lightning and then calculated the average lightning flash rates within deep convective cores. They also mapped the instances of extreme weather, as reported in Argentina and Uruguay newspapers, creating the first systematic summary of extreme weather reports in the region.

Combined, the maps of convective storms and local effects reveal several seasonal and spatial patterns. For example, the tornado alley over the Pampas is not where the high frequency of hail occurs. Summer flash floods are usually associated with larger-scale storms. The authors say that greater understanding and forecasting of these South American weather events could be vital to saving lives and minimizing damage to property. (*Geophysical Research Letters,* doi:10.1002/2014GL061767, 2014) **—Shannon Palus, Freelance Writer**

New Insights into Currents in Earth's Magnetic Field

Charged particles from space are often trapped by Earth's magnetic field. The particles bounce back and forth between the two hemispheres of the planet along the field lines like beads on a string, creating the vibrant auroras that illuminate the night sky at high latitudes. These field-aligned currents (FACs) have been of interest to scientists studying space weather phenomena since they were discovered in the late 1960s.

Until now, everything scientists have learned about these intense currents has come from observations from lone satellites, which are subject to two "crippling assumptions," according to the authors of a new study: that the currents are static and that they have a simple, sheet-like geometry.

To find out if those assumptions are warranted, *Lühr et al.* used data from the early days of the European Space Agency's Swarm constellation mission to observe how FACs of various sizes change over time. The authors looked at measurements collected during the first 3 months after the satellites launched in November 2013, when the three spacecraft were still relatively close together.

They found that small-scale currents, extending up to 10 kilometers, are highly variable. Smaller-scale FACs remain stable only for periods up to 10 seconds, and their spatial structure could not be determined. Large-scale FACs, which extend up to 150 kilometers, were stable for up to 60 seconds and were roughly 4 times longer along their longitudinal axis than they were wide, confirming their sheet-like structure. The study shows that large FACs are likely both stable and sheet-like, meaning that single-satellite estimates of larger currents at auroral latitudes are relatively accurate. (*Geophysical Research Letters,* doi:10.1002/2014GL062453, 2015) **—Kate Wheeling, Freelance Writer**

The highly structured and dynamic phenomena of auroras result from charged particles traveling along the lines of Earth's magnetic field.

Inflexibility of Some Hydrological Models Limits Accuracy


Ahodges7, CC BY-SA 3.0 (http://bit.ly/ccbysa3-0)

The Animas River in Durango, Colo., part of the Colorado River basin. Scientists used the basin to test how fixed inputs affect the accuracy of hydrological models.

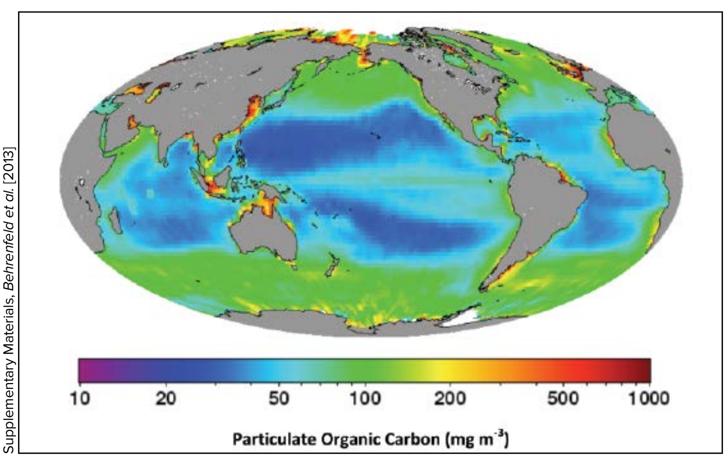
Hydrologists and geologists have increasingly relied on highly complex, process-based models to simulate how water flows locally, regionally, and globally. Although these models seek to provide detailed, realistic representations of various hydrological processes and interactions, they often do not perform better than more traditional modeling approaches. As *Mendoza et al.* argue, complex process-based models are limited in that they make fixed assumptions about input parameter values and physical processes that can actually vary across space and time, rendering them inflexible and useful only in limited environments and time periods.

To test this argument, the authors analyzed how physically based model simulations performed against observational data and how sensitive the results were to changes in parameter values. For their model, the authors chose Noah-MP, which can simulate large-scale hydrologic and biophysical processes in a variety of conditions and climates, and they tested its ability to simulate total runoff in three headwater catchments of the Colorado River basin. A number of Noah-MP parameters, ranging from the runoff decrease rate to the maximum fraction of the surface that is saturated, are hard coded in the model. Not only were the simulations inaccurate when default values were used for these parameters, but the authors also found that changes in the hard-coded parameters made the biggest difference in model accuracy.

Compounding this issue, many of the physical processes implicitly lumped into hard-coded parameters depend on location properties or hydroclimatic conditions that can vary over space and time; therefore, oversimplifying these scalable variables can introduce errors to model predictions. The authors argue that these models should have the flexibility to vary input parameter values and to adapt the equations used to represent hydrological processes, spatial variability, and other details depending on the situation. (*Water Resources Research,* doi:10.1002/2014WR015820, 2015)

—Puneet Kollipara, Freelance Writer

Hacking a Climate Satellite to See Beneath the Ocean's Surface



Supplementary Materials, *Behrenfeld et al.* [2013]

Global distributions of surface particulate organic carbon from CALIPSO lidar measurements.

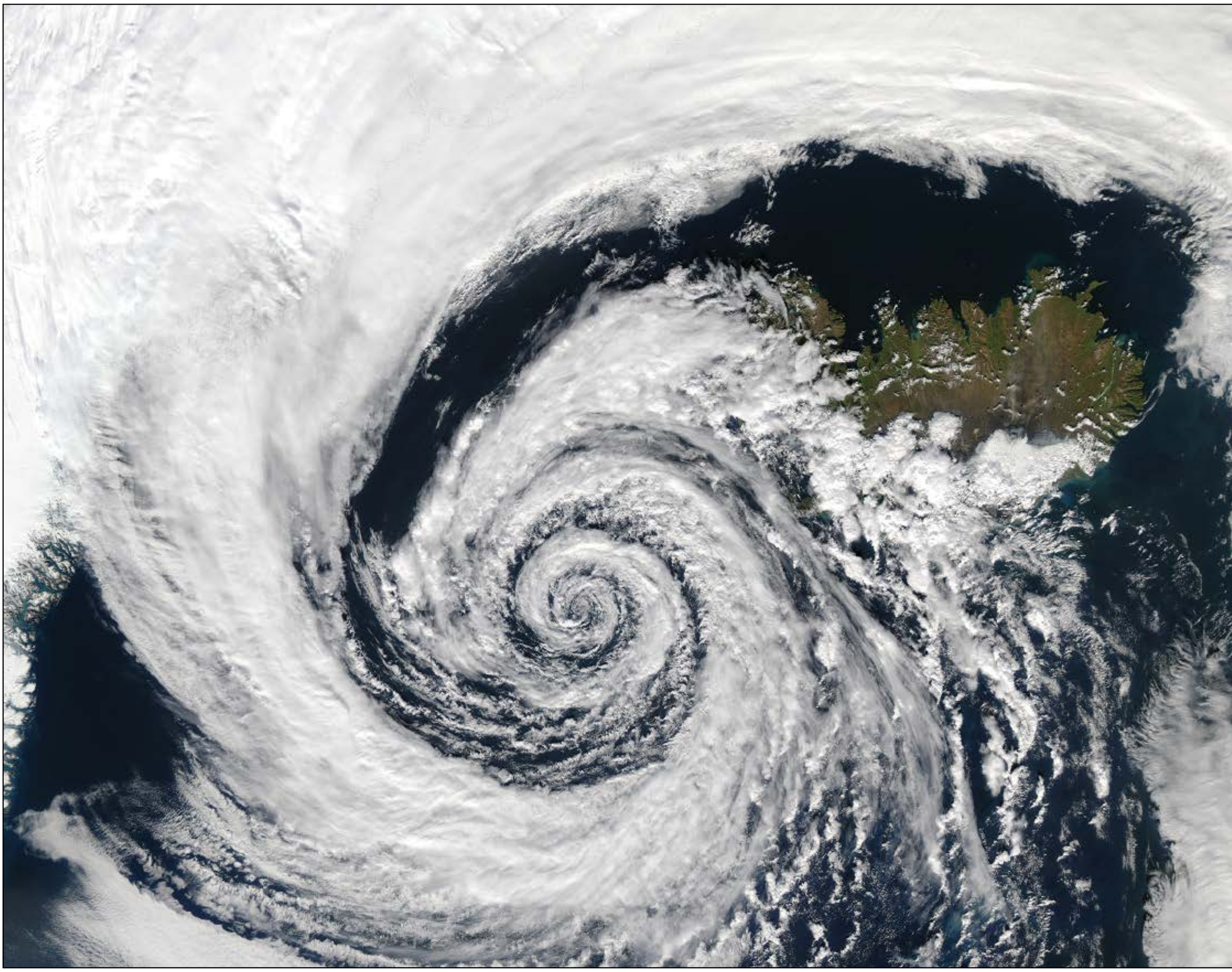
NASA launched its Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission in 2006 to study the impact of clouds in the atmosphere. The climate satellite uses lidar, which shoots laser light pulses at Earth's surface and measures how they bounce back to measure the distance to objects below. The space agency's goal is to combine that information with data from other satellites to show vertical structures, water content in clouds, and other climate indicators.

Lidar is not a new tool for ocean research. Scientists have used it to profile schools of fish and ocean surface roughness and even to detect waves by interpreting phytoplankton signatures. Recent studies found that CALIPSO is also capable of capturing data from below the surface of the ocean. In 2008, a pair of researchers compared CALIPSO data taken before and after Cyclone Nargis to show how the storm vertically mixed sediments. More recently, scientists also showed that the spacecraft had potential to estimate the global carbon stocks in Earth's oceans.

Lu et al. wanted to estimate exactly how much subsurface backscatter they could pick up from the spacecraft's lidar measurements to more precisely determine its usefulness.

First, the team had to remove the signals they did not need from the lidar observations. Once that was accomplished, the backscatter signal showed significant correlations with chlorophyll *a* concentrations, an indicator of phytoplankton presence. They also found that the signal was sufficient to estimate particulate organic carbon, a combination of living and dead organic material. The researchers say that the two measurements taken together would allow scientists to calculate the ocean's global carbon stock. (*Journal of Geophysical Research: Oceans,* doi:10.1002/2014JC009970, 2014)

—Eric Betz, Freelance Writer


NASA's Aqua/MODIS Satellite

A cyclone that formed near Iceland in 2003. Research shows that thanks to climbing temperatures, cyclones similar to this one that form outside of tropical zones may generate significantly more rain in the future.

Historic Warm Periods Shed Light on Future Cyclones

It is well established that planet Earth is heating up, but how a warmer climate will affect weather events and human life often remains unclear. Cyclones are particularly difficult to assess in this respect: Numerous competing factors drive the storms, such as air pressure, atmospheric temperature gradients, and moisture—all of which may be influenced by the warming climate.

Recently, *Li et al.* analyzed historic weather data and sea surface temperatures from the 1940s through 2011 to contrast how cyclones that occur outside of the tropics in the northern Atlantic Ocean behaved in warmer versus cooler periods. Specifically, they used the periods 1948–1963 and 1997–2011 as analogues for the warmer future and 1979–1993 as a cooler baseline period. The researchers concede that the historic conditions do not match perfectly with predictions for the future; nevertheless, their analysis revealed that cyclones during warmer periods generated significantly more precipitation but did not exhibit increased intensity otherwise.

Because a warmer climate can lead to more evaporation and thus greater humidity, previous research has sought to understand how the added moisture would affect cyclones. The increased levels of precipitation detailed here support the theory that added moisture increases the efficiency of poleward heat transport by the storm track, as opposed to increasing wind speed or vorticity through latent heat release. The researchers suggest that this finding affirms the current cyclone models, which have arrived at similar conclusions. (*Geophysical Research Letters,* doi:10.1002/2014GL062186, 2014) —**David Shultz, Freelance Writer**

Ocean Sciences

Assistant Professor (Coastal Physical Oceanography) Tenure Track

Department of Oceanography Graduate School of Engineering and Applied Sciences Naval Postgraduate School, Monterey, CA

The Oceanography (OC) Department in the Graduate School of Engineering and Applied Sciences at the Naval Postgraduate School (NPS) invites applications for the position of tenure track Assistant Professor in the field of coastal physical oceanography. We are seeking candidates with core strengths in areas such as: coastal and nearshore processes; field experimentation; and coastal modeling and data assimilation. The successful candidate is expected to develop an externally funded research program that spans basic to applied research areas and involves graduate students. The candidate must have a strong commitment to graduate teaching.

We are seeking a colleague to join our vibrant OC Department, which has a long history of excellence in physical oceanography, ocean acoustics, ocean dynamics, nearshore processes, ocean waves and turbulence, ocean analysis and prediction, and high latitude ocean dynamics. The OC Department has a strong research infrastructure, such as facilities and vessels located in close proximity to Monterey Bay, CA, an experienced group of technical staff, and computational resources. The OC department promotes interdisciplinary research and encourages research collaborations with the number of oceanographic institutions located around the bay. Additional information can be found online at http://nps.edu/Academics/Schools/GSEAS/Departments/Oceanography/index.html

Minimum qualifications:

- Requires an earned doctoral degree in coastal physical oceanography or related field that supports the OC Department's instructional needs
- Evidence of teaching aptitude
- Evidence of potential to advise student theses and dissertations
- Evidence of strong potential for scholarship leading to scholarly publications
- Must currently hold or be eligible for a Secret clearance
- U.S. citizenship preferred

A letter of application including CV, statement of teaching and research interests and philosophy, and the names of three referees should be sent by July 31, 2015 to:

Dr. Jamie MacMahan, Faculty Search Committee Chair
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943
831-656-2379
jhmacmah@nps.edu

Salary is commensurate with qualifications and experience. Relocation package, including recruitment/relocation incentive may be authorized. The position will remain open until filled.

The Naval Postgraduate School is an equal opportunity employer. For additional information about NPS, please refer to the website at http://www.nps.edu

Post-doctoral position in ocean ensemble prediction

A Post-doctoral research position in oceanography is available at NRL, Stennis Space Center. The objective of this project is to develop a state of the art global ensemble forecast system based on the Navy's operational HYbrid Coordinate Ocean Model (HYCOM) model. The system is expected to provide ocean forecasts and the associated uncertainty estimates that are critical to the US Navy's future missions. The technology to be used is based on the ensemble Kalman filter (EnKF) theory. The ensemble system is expected to be implemented for operation in the future. It will adequately represent the initial state uncertainties and accurately predict the ocean state and probabilistic information up to months. A stochastic forcing model is expected to be developed to account for the model-related uncertainties. This position is full time with a duration of one year initially and can be extended for further years. Applications will be reviewed immediately until the position is filled. Salary and benefits are highly competitive, relocation will be paid. Please email a resume and description of interest to Mozheng Wei (Mozheng.Wei@nrlssc.navy.mil; 228-688-4493).

Solid Earth Geophysics

Postdoctoral Research Associate/ Mineral Physics/Princeton University

16Applications are invited for a post-doctoral or more senior research position in high-pressure mineral physics in the Department of Geosciences at Princeton University. Qualifications include a Ph.D. in Geoscience, Physics, Materials Science or a related field as well as relevant experience such as in high-pressure experimental techniques. Some research will take place at the Argonne National Laboratory. The position will involve studies of geological materials under dynamic compression using synchrotron X-ray techniques (diffraction and imaging). The candidate will design and carry out shock compression experiments using gun and laser drivers and perform all associated data analysis and modeling. The position requires a strong research background and hands-on experimental skills and analytical ability. We are seeking a creative, self-motivated individual with excellent written and oral communication skills who can work successfully in a fast-paced interdisciplinary research environment. The anticipated start date is September 1, 2015. Initial appointment is a one year term renewable depending upon available funding and satisfactory performance.

Inquiries about the position can be sent to Prof. T. Duffy (duffy@princeton.edu). Applicants should include a cover letter, a curriculum vitae including a publication list, a short statement of research interests and goals, and name, address and email address of three referees familiar with their work by applying on the Princeton University jobsite at https://jobs.princeton.edu. Princeton University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law. This position is subject to the Universityís background check policy.

Interdisciplinary/Other

Executive Director, PAGES
The PAGES (Past Global Changes) project supports and facilitates international and interdisciplinary past global change research. We are seeking a new Executive Director to coordinate the project's activities from our office in Bern, Switzerland. Applications close 26 July 2015.

Learn more about the role, PAGES, and how to apply at: www.pages-igbp.org/my-pages/paleo-jobs/118-other/1191-ed

Faculty Position in Earth and Planetary Science At Rice University Department of Earth Science

We seek creative and promising candidates across the broad spectrum of earth and planetary science who complement the disciplines represented in our department.

Successful candidates are expected to direct an active research program, supervise graduate research, and teach courses for undergraduate and graduate students. Details about the department and its facilities can be found at http://earthscience.rice.edu

Please send a CV, research and teaching statements, and names of four or more references to esci-search@rice.edu.

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Postdoctoral fellowships in interdisciplinary research relating to origins of life, spending 50% of time in Tokyo, Japan

The ELSI Origins Network (EON) announces the availability of post-doctoral research fellowships for research related to the Origins of Life. Ten two-year positions will be funded, to take place within the period 2016-2018.

THE UNIVERSITY OF QUEENSLAND

SCHOOL OF EARTH SCIENCES

ASSOCIATE LECTURER / LECTURER / SENIOR LECTURER POSITIONS
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The role The School of Earth Sciences at The University of Queensland is undergoing a significant expansion through the hiring of three early career academics in the areas of Geochemistry and Geochronology, Igneous Petrology/Volcanology, and Geostatistics/Mining Geology. The School offers the undergraduate Major in Geological Sciences, Honours in Geology, Geophysics, and Computational Earth Sciences, and a comprehensive postgraduate program in all areas of Earth Sciences. The School also hosts a range of state-of-the-art analytical facilities, including modern sample preparation laboratories; ICP-OES, ICP-MS, TIMS, MC-ICP, noble gas, and stable isotope (H, C, O, S) mass spectrometry facilities; organic petrology and geomicrobiology laboratories; and major computational infrastructure. The successful candidates will engage in undergraduate teaching, postgraduate supervision, research, and other activities associated with the School. The successful applicants will complement existing School strengths, and they are also expected to help promote and expand our world-class analytical and computational facilities.
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Applications close 15 August 2015
Job No 497190 + 497192 + 497194

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UNIVERSITIES AUSTRALIA UNIVERSITAS 21 GROUP OF EIGHT AUSTRALIA

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Successful candidates will split their time between the Earth-Life Science Institute (ELSI) in Tokyo and another institution of the candidate's choice, anywhere in the world. The fellowship will pay a salary for two years, which covers the time spent at both locations, as well as a generous research budget. The positions will start on or before 1st April 2016.

EON is an interdisciplinary international network which seeks to foster dialogue and collaboration within the Origins of Life community to articulate and answer fundamental questions about the nature and the reasons for the existence of life on Earth, and possibly elsewhere in the Universe. Its goal is to bring together leading-edge research in all areas of the physical, mathematical, computational, and life sciences that bears on the emergence of life. ELSI is chartered as a Japanese World Premier International Research Center, to study the origin of Earth-like planets and the origin of life as inter-related phenomena. ELSI is located at the Ookayama campus of Tokyo Institute of Technology.

EON-supported research addresses three overarching questions:

1. How did life emerge on Earth?

2. How common is life in the universe?

3. What fundamental principles explain the emergence of life?

Due to the split-time nature of these fellowships, the application process requires the applicant to choose a supervisor and host institution outside ELSI who will support the proposal. EON is designed to promote collaboration across disciplinary boundaries, and host institutions in all fields are welcome.

The goal of the fellowships is cross-fertilization between specialists in Origin of Life research around the world, with a central collaborative hub at ELSI. EON aims to build a research community in which postdoctoral fellows benefit from facilities not only at ELSI but also among the centers throughout the network.

The first deadline for applications is August 1st 2015, with a second deadline on 1st October to fill any remaining places. Please check our web site for more details, including the application procedure.

Details of the fellowships are as follows:

Duration - 2 years, with a start date no later than April 1, 2016.

Salary - USD 70,000.00/yr. (approximate equivalent, paid in JPY.)

Research Budget - USD 30,000.00/yr. (approximate equivalent, paid in JPY.)

For more details, including the application procedure, please visit eon.elsi.jp

Student Opportunities

Synthesis Post-doc program, National Center for Earth-surface Dynamics 2, University of Minnesota

Applications are now being accepted for the 2015/2016 National Center for Earth-surface Dynamics 2 (NCED2) Synthesis Post-doc program. This program aims to create a small, highly interactive community of post-docs and mentors who collaborate on a research theme in Earth-surface processes. The research theme for 2015/2016 is Earthcasting: case studies in predicting Earth-surface response to change. Proposed research must directly address the current theme and each post-doc must have at least two advisor-mentors. NCED2 will provide 50% of post-doc salary support while advisor-mentors must provide the other 50% of support. The post-doc will network with other selected post-docs through workshops, webinars/web discussions, participation in the Summer Institute on Earth-surface Dynamics (SIESD), joint experimental work at the St. Anthony Falls Laboratory at the University of Minnesota, and field work at affiliated sites such as the Wax Lake Delta observatory. The post-doc must be based at a US institution but is not required to be a US citizen or permanent resident. Applications will be reviewed starting July 1st, 2015 in the order in which they are submitted until all positions are full. Funding will commence in September 2015. Learn more and apply at: www.nced.umn.edu/synthesis-post-doc-program

NANYANG TECHNOLOGICAL UNIVERSITY

Asian School of the Environment,
Nanyang Technological University, Singapore

Young and research-intensive, Nanyang Technological University (NTU Singapore) is the fastest-rising university in the world's Top 50 and ranked 39th globally. NTU is also placed 1st amongst the world's best young universities.

FOUR FACULTY POSITIONS

The Asian School of the Environment (ASE) at NTU Singapore seeks to hire faculty for four professor-level positions (rank commensurate with experience) as part of a terrestrial and marine initiative in Southeast Asia. ASE, a new interdisciplinary School, focuses on Asian environmental challenges integrating Earth systems, environmental life sciences, ecology, and the social sciences to address key issues of the environment and sustainability. Strong interdisciplinary links between ASE and the Singapore Centre on Environmental Life Sciences Engineering (SCELSE), the Earth Observatory of Singapore (EOS) and the Complexity Institute provide an excellent community for tackling large, cutting-edge research questions. Successful candidates will also contribute to development and execution of new undergraduate programmes.

1. Aquatic Chemistry (open professor rank)

We seek a creative and cutting edge aquatic chemist who focuses on environmental sustainability of natural systems and who has an interest in addressing research questions in Southeast Asia. Research interests may include but are not limited to, natural and anthropogenic contaminants of fresh water systems, nutrient cycling and the carbon cycle, redox chemistry using tools such as stable isotopes and water sediment interactions amongst other areas.

2. Environmental Organic Chemistry (open professor rank)

We seek a creative and cutting-edge marine chemist focusing on environmental sustainability of natural systems and who has an interest in addressing research questions in Southeast Asia. Research interests may include but are not limited to, organic contaminant fate and transport, synthesis and processing of organic molecules in the environment, stable isotope techniques to evaluate the sources, sinks and cycling of organic matter in aquatic or marine environments.

3. Environmental Microbiology (open professor rank)

We seek a creative and cutting-edge microbiologist exploring microbial diversity and activity in natural systems and their implications on ecosystem functions and services. The successful applicant should have a clearly defined interest in addressing research questions in Southeast Asia. Research interests may include but are not limited, to microbial physiology, environmental virology, bacterial genetics and diversity, microbe-host interactions using tools such as genomics and metagenomics amongst other areas.

4. Biogeochemistry (open professor rank)

We seek a creative and cutting-edge biogeochemist investigating biological, chemical and geological processes on societally relevant time-scales in wetlands, rivers, soils or oceans. The successful applicant should have a clearly defined interest in addressing research questions in Southeast Asia. Research interests may include but are not limited to, global carbon and nutrient cycling, ocean-atmosphere interactions, and microbial or organic biogeochemistry amongst other areas.

The candidates are expected to:

- Establish a world-class research programme
- Play a leading role in the formation of the new Asian School of the Environment
- Enhance the new School's visibility as an international leader in education and research in Environmental Earth System Science
- Teach undergraduate and graduate classes in Environmental Earth System Sciences
- Actively collaborate with NTU faculty and researchers with existing strengths in Earth Systems Science and Environmental Life Sciences

Applications, including the applicant's experience/ philosophy of research, teaching, a CV, and contact information for two professional references should be sent to Chairman of Search Committee, NTU, at ASE-EnvSc@ntu.edu.sg.

Review of applications will begin in August 2015 and will continue until the positions are filled. NTU offers highly competitive salaries and on-campus housing. A start-up package will be available. NTU is an equal opportunity employer.

More information can be found at:
www.ase.ntu.edu.sg
www.earthobservatory.sg
www.scelse.sg
www.complexity.ntu.edu

www.ntu.edu.sg

Postcards from the Field

Dear science enthusiasts,

The 2015 endless springtime in Nevada continues as we begin summer season fieldwork! We camped here in the Pahroc Range with petroglyphs, roadrunners, and rainstorms before continuing up to our climate monitoring sites in the Snake Range. I snapped this pic Wednesday evening from a perch on some Hiko Tuff boulders, simply amazing light. This season in the Great Basin simply cannot be missed for beauty.

Cheers, all,
Scotty Strachan
Department of Geography, University of Nevada

View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.

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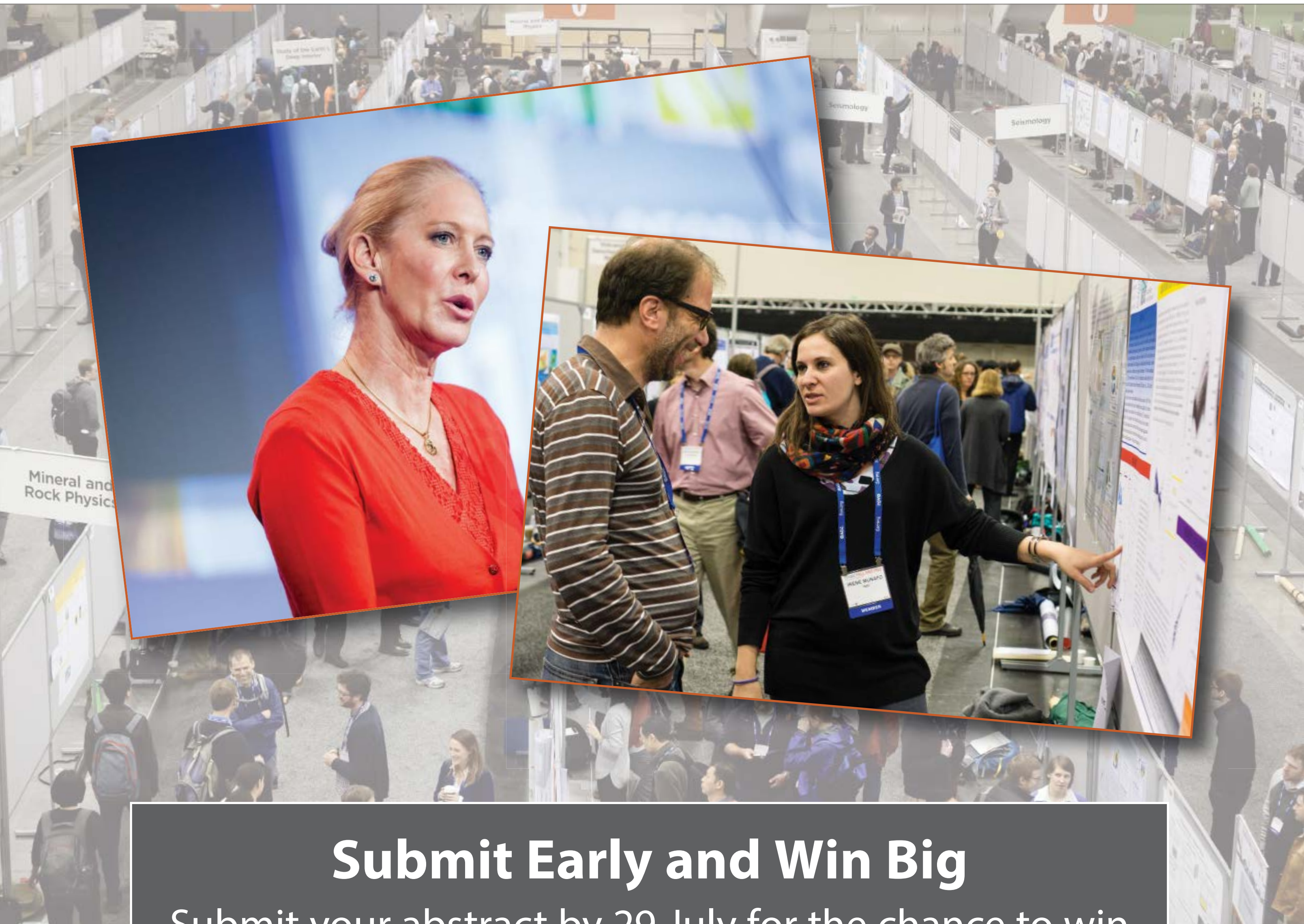

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