

COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

# SPHERES

Edition 09 • 2015

## Space Perspectives

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New satellite aims to improve crucial solar storm warning

### Mars with a Dash of Salt

Chemistry helps illuminate "water streaks" on planet

### Earth at Night

More than just a pretty view

### From Big Data to

Better Forecasts

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An artist’s rendition of the Orbiting Carbon Observatory-2.  
Image: NASA-JPL

**ON THE COVER:**  
Southern lights and the Southern Cross  
from McMurdo Station, Antarctica.  
Photo: John Cassano/CIRES

## SPHERES

Cooperative Institute for Research  
in Environmental Sciences

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# Hot Stuff!

Teachers: Energize your students' learning with the cool Sun and space weather curriculum from the CIRES Education and Outreach program:

<http://bit.ly/1VN5hU>

NASA

A yellow background featuring a Godzilla-like dinosaur on the left and a Spinosaurus on the right.

**Godzilla  
VS.  
Spinosaurus**

"Godzilla El Niño" may not mean what you think, page 20.

A dark space background with a starry field and a bright nebula.

**WHERE  
IN THE  
WORLD?**

Learn about our illuminating work with nighttime light data, page 6.

NASA & NOAA

A dark grey background with a large, dark silhouette of a volcano erupting.

More than **35,000 years ago**, Campi Flegrei in modern-day Italy erupted catastrophically. Scientists study current risk with satellites, page 8.

A colorful nebula background with a rainbow-like glow.

**150<sup>±38</sup> tons**

That's how much cosmic dust enters Earth's upper atmosphere every day, according to a new paper by CIRES researcher Wentao Huang, CIRES Fellow Xinzhao Chu, and colleagues. DOI: [10.1002/2014GL062390/](https://doi.org/10.1002/2014GL062390)

NASA

**4 observatories,  
8 tall towers,  
50 flask sites...**

These data-collecting platforms are critical for verifying or "ground-truthing" new satellite data, page 17.



NOAA

CIRES

NOAA

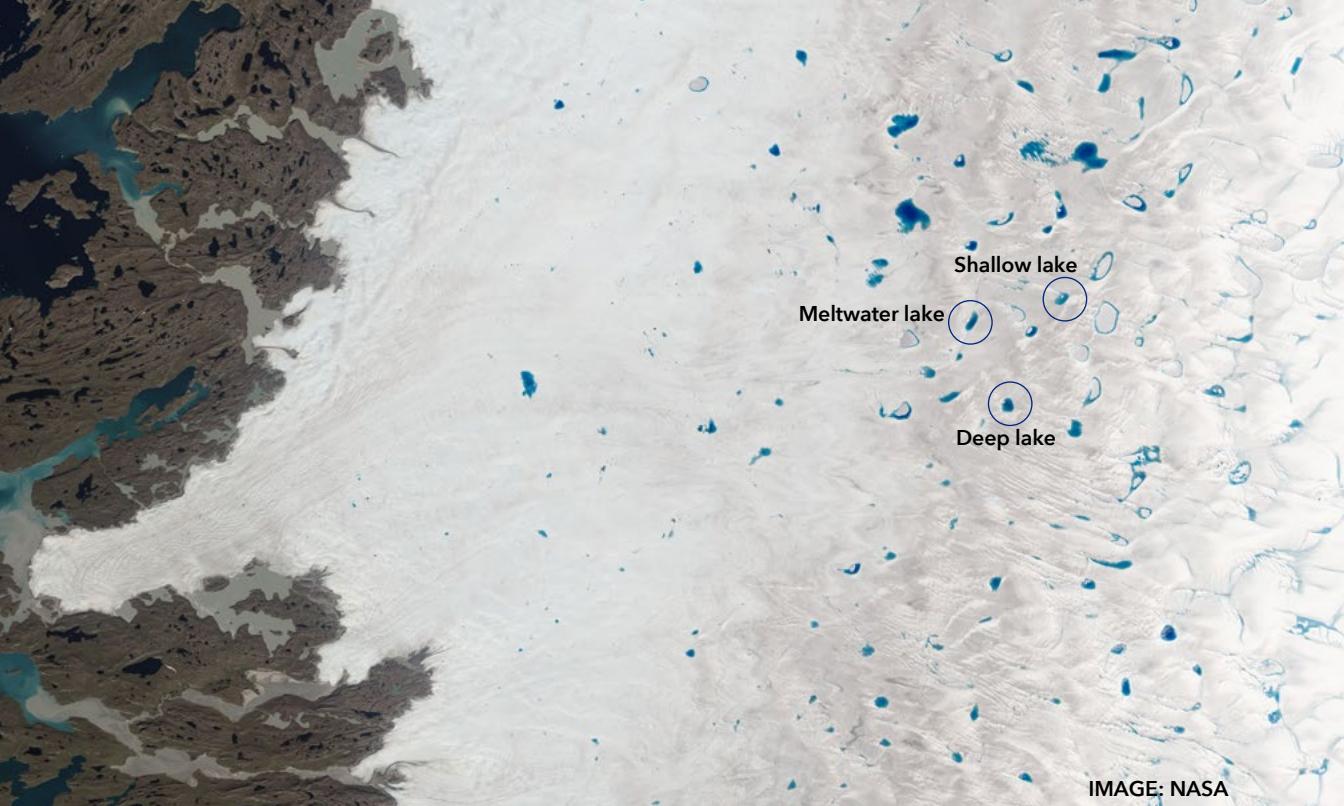


IMAGE: NASA

Imagine being able to measure the depth of a lake simply by looking at its color.

That's basically what Allen Pope, a postdoc working in the National Snow and Ice Data Center (part of CIRES) is doing with supraglacial lakes on top of the Greenland Ice Sheet. Pope uses images from NASA's Landsat 8 satellite and is analyzing the color of these lakes to decipher their depth. Darker blues and greens indicate deeper lakes. The deepest can reach eight meters, and Pope is finding he can measure depth within a 4-foot accuracy (and even better when averaged over large areas).

These lakes are important to the study of ice sheet dynamics because they can force open crevasses to the bottom of the sheet, lubricating the base with water and speeding the ice sheet's journey to the sea. Pope hopes his work will lead to more accurate climate modeling of ice sheet dynamics, and ultimately,

a better understanding of global sea level rise.

"Having better constraints on not just the area of the lakes, but also the depths, will help those models better predict exactly what's going to happen to the ice," said Pope.

With a Ph.D. in glaciology from the University of Cambridge in the U.K. and a productive term at NSIDC under his belt, what's next for Pope?

"I would love to find a teaching position that still lets me get to continue some cool research," he said. "As long as I have some pretty satellite pictures to work with, I'll be happy." ■

—Paul McDivitt/CIRES intern

## The COLOR of Water

**Follow** @PopePolar on Twitter or for news, videos, and photos of the changing Arctic and Antarctic ice, and check out his award winning video, "What Color is a Glacier?" at <http://bit.ly/20AYO5j>. A NASA video also features some of his work: <http://bit.ly/1MMhq8j>.



**Did you know** CIRES is dedicated to training tomorrow's geoscientists? Allen Pope is a CIRES postdoc at the National Snow and Ice Data Center, NSIDC. More information on our graduate and postgraduate opportunities:

<http://cires.colorado.edu/education/>.

# Sufficient for Life?

If life existed on a distant planet circling a faraway star, how could we know?

Today, planet hunters look for evidence that such exoplanets can sustain liquid water, considered necessary for life as we know it. Planetary scientists can pick up clues about this basic level of habitability from the size of a planet and the distance from its star.

Beyond necessary conditions are *sufficient* ones. From a distance, could we spy more than the presence of liquid water? Could we also discern the chemical cycles that are a natural prelude to life?

CIRES Fellow and atmospheric chemist Veronica

Vaida (CU-Boulder Chemistry and Biochemistry) suspects it could be possible. With three years of funding from NASA just awarded, she and her team plan to conduct a series of laboratory-based studies designed to examine how energy from starlight could be used to build the complex chemical systems of life.

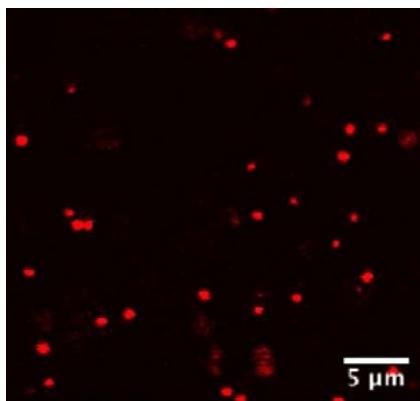
The team will focus on the light-initiated chemistry of pyruvic acid which, on Earth, has been important in metabolism even from the earliest days of life. They will examine reactions of pyruvic acid and related compounds in a variety of conditions, with a focus on the role of water in all its phases.

The ultimate goal, said Vaida, is “to identify potential

spectroscopic signatures of metabolites that may be used in the search for habitable environments on exoplanets.”

This project expands upon recent work in the Vaida lab, using sunlight to drive the formation of complex structures relevant in the origin of life on Earth (Griffith, Rapf, Shoemaker, Carpenter and Vaida et al., *JACS* 2014). ■

—Katy Human



Could lab experiments with tiny vesicles like these (left), formed in the Vaida laboratory through photochemistry, help us search for life elsewhere in the universe, as in these distant galaxies (right)? Images: *JACS* 2014 and NASA

## Setting National Satellite Science Priorities

Every 10 years, the National Research Council conducts the Decadal Survey for Earth Science and Applications from Space, a broad national effort to develop U.S. priorities for observing our atmosphere, oceans, and land surfaces by satellite. Next up: the decade 2018-2028.

What systems can best improve weather forecasts that help save lives and property? Which ones can best help us understand changes in climate, freshwater resources, and other environmental variables?

CIRES Director Waleed Abdalati, also a professor of geography at the University of Colorado Boulder, will co-chair the prestigious national committee charged with answering those questions. He and Antonio Busalacchi of the University of Maryland will spend the next two years leading a team of scientists, engineers, and policy experts from around the country to develop satellite science priorities for NASA, NOAA, the U.S. Geological Survey, and other federal agencies. ■ —Laura Krantz



CIRES Director  
Waleed Abdalati



University of Maryland's  
Antonio Busalacchi

Satellite images of Earth at night, sprinkled with lights, evoke a sense of beauty and awe. Thanks to recent innovations by NOAA and CIRES scientists, these images are also increasingly useful; they're rich with data invaluable to policy makers, geographers, resource managers, and other researchers.

"Nothing tells us more about the spread of humans across the Earth than city lights," said NOAA's Chris Elvidge. Elvidge leads a team of CIRES and federal scientists at the National Centers for Environmental Information, who process and make useful to others satellite data that illuminate our planet at night.

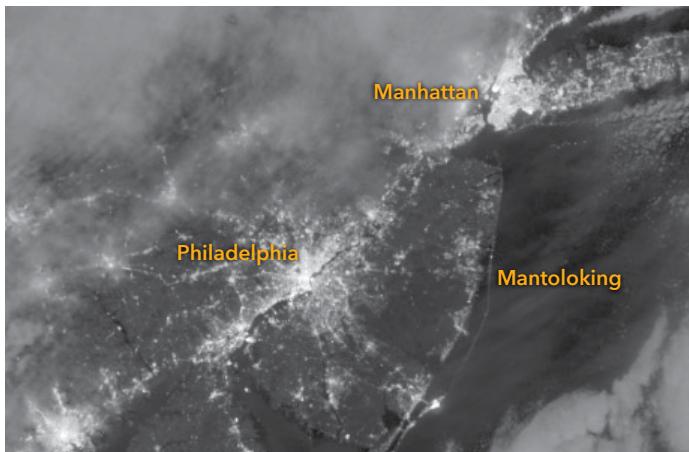
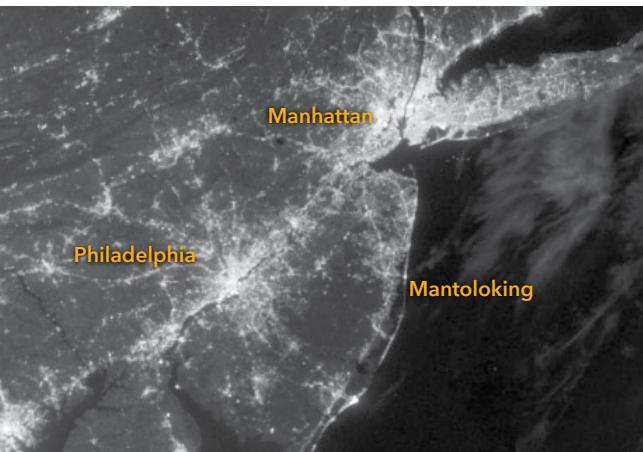
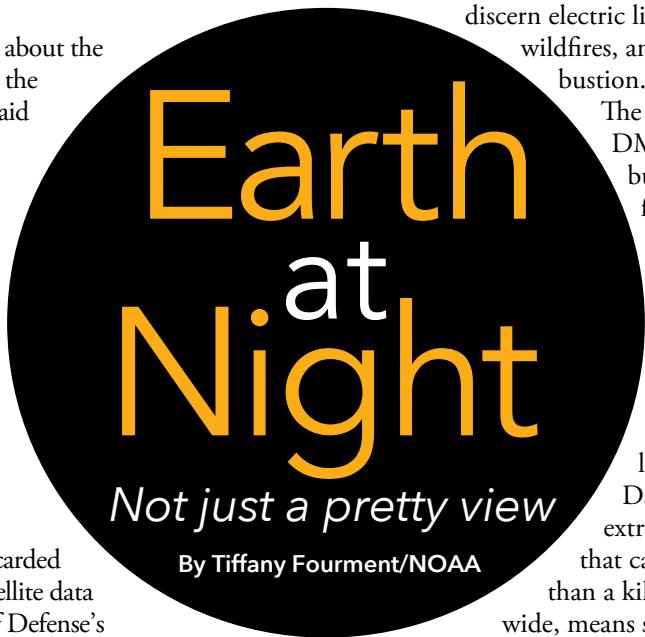
The lightbulb moment happened more than two decades ago, when Elvidge realized that discarded cloud-free nighttime satellite data from the Department of Defense's Meteorological Satellite Program (DMSP) could be put to use for a different purpose—tracking the human footprint on Earth. DMSP originally used those satellite data for strategic weather prediction. Elvidge and his colleagues "rescued" the information captured by DMSP instruments, such as the Operational Linescan System (OLS), and set to work trying to learn something from glimmers of light on the dark

side of our planet.

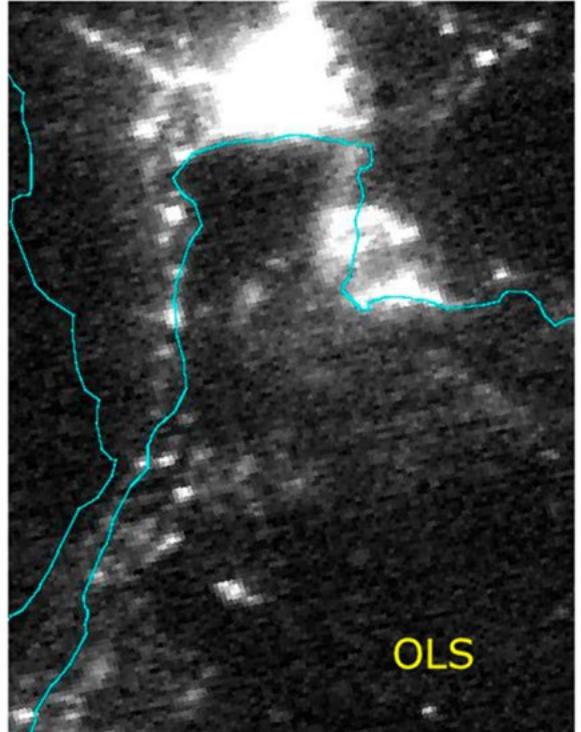
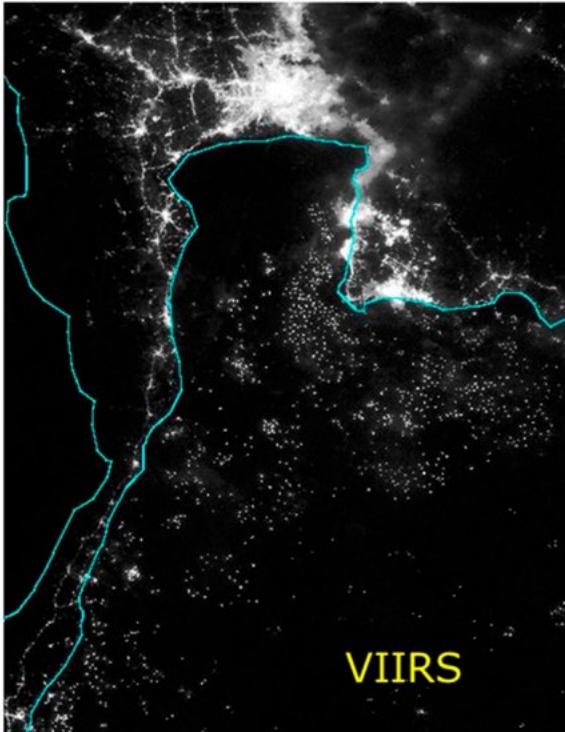
The NOAA and CIRES researchers (and others around the world who could now access the data) quickly learned to track changes in electrical lights over time, for example, to understand development and energy consumption trends. They learned to discern electric light from gas flares, wildfires, and other types of combustion.

The older images from DMSP were fascinating, but today the team focuses on analyzing data from the even more illuminating Visible Infrared Imaging Radiometer Suite (VIIRS) instrument, launched on a NASA/NOAA satellite in late 2011. The VIIRS Day-Night band, with extraordinary resolution that can capture features less than a kilometer (0.6 miles) wide, means scientists can more accurately detect lights of varying brightness, heat, and source.

"The improved global nighttime lights products from VIIRS will lead to major advances in each of the application areas demonstrated with DMSP data," Elvidge said in early 2013, about a year after the new VIIRS data began coming in. A few years later, it has become clear that prediction was accurate.



These images showing New Jersey, New York, and eastern Pennsylvania at night, were captured by the VIIRS instrument in August of 2012, when conditions were normal (left), and on November 1 that year, just after Hurricane Sandy swept through, triggering power outages. Images: NASA



Electric lights in Bangkok (upper center) are captured in far greater detail by the newer VIIRS instrument (left), and fishing boats in the Gulf of Thailand appear as defined pinpricks of light. Images: Elvidge et al., *Remote Sensing* 2015.

### Electric power

The images above, showing electric lights at night in Bangkok, Thailand, demonstrate the improvement in resolution between older DMSP data and VIIRS data. Scientists use this information to observe human population dynamics over time, estimate greenhouse gas emissions associated with power production, and can even gauge the effects of a natural disaster on crucial infrastructure.

### Fishing boat detection

In many parts of the world, fisherman shine bright lights into the water to lure squid and fish to nets, sometimes illegally. These lights can also be detected from space with satellite-based imaging systems, but users need up-to-date, accurate data, and until recently, that's not been available. Now, with the high-powered resolution of VIIRS and algorithms developed by Elvidge and his colleagues, scientists and resource managers can automatically detect fishing activity, even pinpointing the light from individual boats. Fisheries managers and other decision makers can use these data to monitor and protect sensitive fishing areas from illegal, unre-

ported, and unregulated fishing, and for ongoing management of fisheries and fish stock.

### Gas flaring

NOAA and CIRES scientists have also built VIIRS data processing algorithms that distinguish light from burning (combustion) and other sources such as electrical power, and that can even discriminate between lower-temperature combustion, such as biomass burning, and higher-temperature gas flares.

Across the world, gas flaring is commonly used as a way to get rid of the cheap natural gas that is sometimes a byproduct of oil production. This practice can waste usable fuel, and it can release both greenhouse gases (e.g., carbon dioxide) and other pollutants (e.g., black carbon) into the atmosphere. The Global Gas Flaring Reduction Partnership is an effort between many governments, institutions, and oil companies to reduce gas flaring. Using VIIRS data, researchers can measure and monitor gas flares around the world, producing monthly estimates of flared gas volumes and CO<sub>2</sub> emissions by country to inform initiatives such as the partnership. ■

From page 3, **WHERE IN THE WORLD?** Brightly-lit fishing boats line up along an invisible border in the Yellow Sea off South Korea.

# Warnings from

## *Using satellites to track potential seismic and volcanic*

By Laura Krantz

**T**hink of Italy and the mind conjures up thoughts of wine, food, artwork, a stunning coastline, and rolling hills. But CIRES Fellow Kristy Tiampo thinks of volcanos. Not towering Vesuvius, whose famed eruption in A.D. 79 buried the cities of Pompeii and Herculaneum. Or Etna, the Sicilian peak that's one of the most active volcanos in the world. No, Tiampo's thoughts are on Campi Flegrei—less a looming mountain than a collection of craters, nestled into a large caldera on the western side of Naples.

Tiampo, a professor of Geological Sciences at CU-Boulder, heads the Earth Science and Observation Center at CIRES and her research is centered around understanding natural and anthropogenic hazards, specifically earthquakes. To do so, she relies on something called InSAR—interferometric synthetic aperture radar—to create images of the Earth's surface. "Many things that go on underground have a physical expression on the surface," says Tiampo. "With earthquakes, you'll see fault slips, ground surface changes. Volcanoes are even easier to see: as magma fills chambers below the surface, it pushes up the surface of the Earth."

Of all the eruptions in Europe in the past 50,000 years, Campi Flegrei has provided two of the biggest, events on par with the catastrophic eruption of Krakatoa. The volcano has also erupted multiple times in a smaller way, most recently in 1538.

Recent evidence suggests that Campi Flegrei is stirring again. "It's inflating," says Tiampo, talking about the caldera. "It's been inflating since 2007 and it's been getting faster since

2010." With nearly a million people living in the Naples vicinity, 300,000 in the caldera alone, this kind of activity means scientists like Tiampo are using every tool available, including InSAR, to keep an eye on the volcano.

### **InSAR's beginnings**

InSAR got its start in the 1960s, only back then it was just called SAR. Like any other radar, it uses radio waves transmitted via an antenna; a more detailed image requires a bigger antenna. Images (which are topographical) are created by recording the echoes that bounce back to a receiver. However, unlike terrestrial radar, SAR is mounted on a satellite, which limits how long its antenna can be. To compensate for that, SAR creates a "synthetic antenna" through movement. As the satellite moves, so does the antenna location, allowing multiple, successive radar echoes to be recorded and combined into one image. The result has a finer resolution than would be possible with a standard antenna.

InSAR is an extension of SAR technology: the satellite flies over a specific location multiple times to capture multiple images over time. Those images can be superimposed on top of each other, which allows scientists to see if there's been a change in the height of the Earth's surface—also known as interferometry. "InSAR really came into its own when one of these satellites passed over Mt. Etna," says Tiampo. "You could see the edifice going up and down by several centimeters. The other event was the Landers Earthquake in 1992, when images were taken over the Mojave Desert a few days before and again a few days after."

Since the Tohoku Earthquake—the earth-

# Space

## events

quake and subsequent tsunami that destroyed the Fukushima Daiichi nuclear plant—scientists and policymakers have looked to InSAR for insight. In Northern California, Tiampo and her colleagues have been using InSAR to image the Hayward Fault. “We know where the fault is locked and where it’s slipping,” explains Tiampo. “The information on where it’s slipping tells you what the motion of the entire fault should be, so you know how much energy is being stored in the parts that are locked. And while we can’t say when an earthquake will happen, we can estimate how big it will be.”

### Applied science

Additionally, InSAR can be helpful for forensics. Images from before and after the Tohoku Earthquake showed big changes on shore, which allowed scientists to estimate how much of the fault broke and where it broke, providing information about what the rupture looked like in ways that seismic data alone couldn’t. Beyond natural earthquakes and volcanos, this technology can also be used to look at phenomena like subsidence—the gradual sinking of land—and the effects of fracking and wastewater injection wells. Wastewater wells have been the primary cause of induced seismicity (human-caused earthquakes).

All of this provides officials with information necessary to make smart policy decisions. Back at the Campi Flegrei site, researchers are using those InSAR images to make sense of what’s happening inside the volcano and help policymakers know when they might need to evacuate people. ■



**Please welcome** Kristy Tiampo, new director of CIRES' Earth Science and Observation Center. ESOC's mission is to advance scientific and societal understanding of the Earth system based on innovative remote sensing research. <http://cires.colorado.edu/esoc/>

# Raiders of the Lost Data

By Katy Human

## *Recovering old satellite archives to better understand the future*

In 1964, the Beatles took the world by storm, Lyndon Johnson won his second term as U.S. President—and NASA launched the first of seven Nimbus spacecraft to study Earth from space. Fifty years later, experts at the National Snow and Ice Data Center (NSIDC), part of CIRES, are recovering long-lost images from old Nimbus data tapes and black and white film, and finding treasures in the pictures.

“By extending the satellite record back to the 1960s, we can understand more about the history and natural variability in things like sea ice extent in the Arctic and the Antarctic,” said David Gallaher, technical services manager at NSIDC. The modern satellite record of sea ice goes back only to 1979.

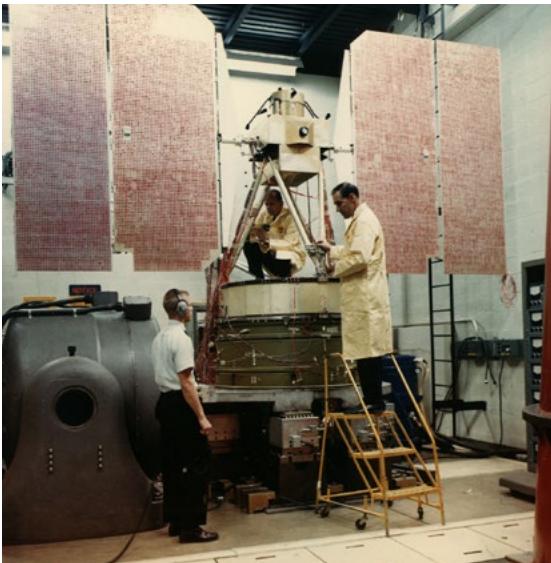
In the Arctic, sea ice extent was larger in the 1960s

**Learn more** about the NASA-supported data rescue mission online—including where Gallaher and Campbell and their NASA colleagues finally found the old Nimbus tapes and films, and what it took to read and digitize the fragile films online and in a short video:

- A CIRES news item: <http://bit.ly/1Nry6H1>
- A short video with NASA and NSIDC experts: <http://bit.ly/1QcpgO6>
- Nimbus data: <http://nsidc.org/data/nimbus/>

than it is these days, on average. “It was colder, so we expected that,” Gallaher said. What the researchers didn’t expect were enormous holes in the sea ice, still under investigation. “We can’t explain them yet,” Gallaher said.

“The Antarctic blew us away,” added Garrett Campbell, the NSIDC research scientist on the project. In 1964, sea ice extent in the Antarctic was the second largest ever recorded (it was surpassed in 2014), according to Nimbus data. Two years later, Antarctic sea ice reached a record minimum, and in 1969, sea ice appears to have reached the earliest date for a maximum ever—three see-sawing records in five years. ■



Vibration testing on a Nimbus satellite at NASA’s Goddard Space Flight Center, circa 1967.  
Photo: NASA



David Gallaher,  
technical services  
manager at NSIDC



Garrett Campbell,  
NSIDC research scientist.  
Photos: IEDA

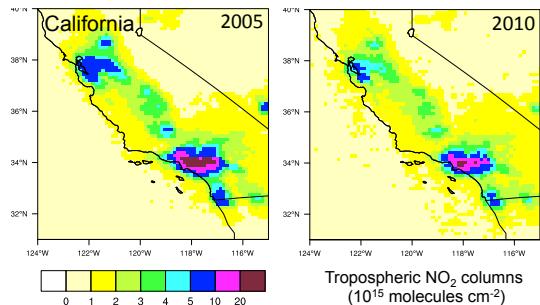
# Clearing the Air

## Satellite observations suggest a drop in Los Angeles NO<sub>x</sub> pollution

One type of pollution from cars and trucks—nitrogen dioxide (NO<sub>2</sub>)—fell by approximately 40 percent in the Los Angeles Basin from 2005 to 2010, according to results from scientists in the NOAA Earth System Research Laboratory (ESRL).

Using data from several U.S. and European satellites, including NASA's Aura, which carries the Ozone Monitoring Instrument (OMI), Si-Wan Kim and colleagues from CIRES and NOAA evaluated the effect of pollution control measures in the region. "By combining these satellite data with other information, we can confirm that emission controls and the economic recession played roles in reducing the abundance of NO<sub>2</sub> in the atmosphere," says Kim, a CIRES scientist working in ESRL's Chemical Sciences Division.

ESRL researchers use air and ground measurements, computer models that simulate atmospheric chemistry, and satellite data to track long-term changes in nitrogen oxide (NO<sub>x</sub>) emissions, which contribute to the production of ground-level ozone and aero-



Cleaner California air as seen from space.

sols. "Satellite data are especially useful for deriving trends and changes in air pollution and for improving estimates of how much is emitted by sources in the L.A. Basin," says Kim. Those emissions estimates, called inventories, are essential elements for studies of climate change and air quality.

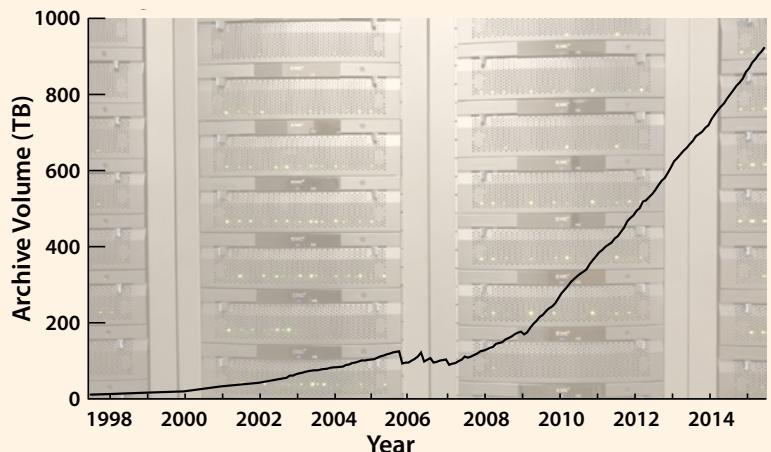
Future studies will look at different sources of NO<sub>x</sub>, including agriculture, and will evaluate NO<sub>x</sub> on other continents, including Asia. ■ —Karin Vergoth

## 50 Years, 1000 Terabytes

This fall, NOAA's National Centers for Environmental Information (NCEI) celebrated its first 50 years as a national archive of geophysical information—previously as the National Geophysical Data Center and now as NCEI. In the last five decades, NCEI's digital holdings in Boulder, Colorado, have expanded from less than 1 TB to nearly 1,000 TB (one Petabyte or PB), and they include data that inform our understanding of Earth at night, the U.S. continental shelf, our planet's magnetic field, tsunamis and natural hazards, space weather, and much more.

These data are collected by ship and by airplane, by scientists coring layers of limestone and mud, and from satellites that scan our planet from above or peer out into space. ■

—Karin Vergoth and Chuck Anderson **Check out this video on NCEI's 50 years:** <http://bit.ly/1NnBVbR>



NCEI's digital data archives in Boulder, Colorado. Satellite data embedded in these numbers include magnetic measurements, nighttime lights and gas flares, and information about space weather and solar storms and their effects.

An aerial photograph of a Martian canyon, showing a network of dark, narrow streaks (recurring slope lineae) that run down the slopes of the canyon walls. The terrain is reddish-brown and appears to be composed of sand and silt. The lighting creates strong shadows, highlighting the ruggedness of the canyon walls.

Ephemeral dark streaks on Mars.  
Image: NASA, JPL-Caltech, Univ. of Arizona

# Mars

## with a Dash of Salt

*Chemistry helps illuminate “water streaks” on Red Planet*

By Laura Krantz

Let’s start by introducing a word that’s going to get a lot of use in this article: Deliquescence. It sounds vaguely French, like a dessert or a ballet position. But it’s very much a scientific word, and one that Raina Gough says repeatedly. The chemistry Ph.D. is a research associate at CIRES, working in the lab of CIRES Fellow Margaret Tolbert (a Distinguished Professor of Chemistry at CU-Boulder).

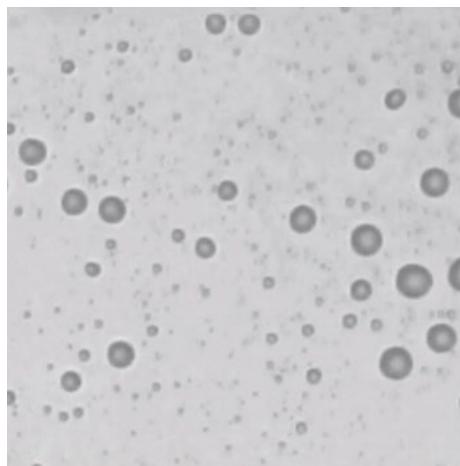
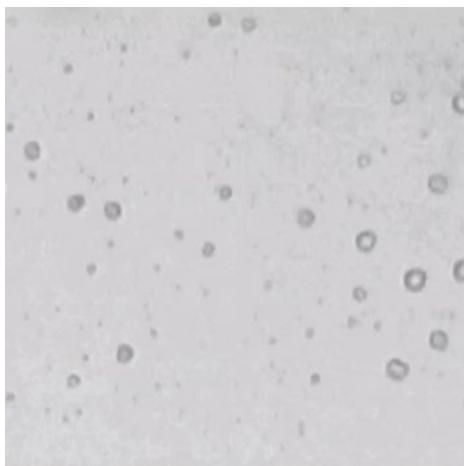
Tolbert and Gough spend a lot of time thinking about deliquescence, which is when a substance like, say, a salt, suddenly absorbs moisture from the atmosphere and becomes a liquid droplet. For example, if you’re in a humid place like Florida, this process happens in your salt shaker. To prevent the salt grains from absorbing water and clumping together, restaurants often add grains of rice.

In the case of Florida, we’re talking about table salt—sodium chloride—and it requires a relative

humidity of about 75 percent to deliquesce. But other types of salts, known as perchlorate salts, absorb water vapor at a much lower relative humidity and can even deliquesce when temperatures are below freezing. In 2009, perchlorates were found on Mars.

And then, in September 2015, new research from NASA suggested deliquescence of perchlorates was actually occurring on the Red Planet. NASA scientists announced they’d found chemical evidence of liquid water in a series of dark streaks that appear on a crater wall every Martian spring and summer. This doesn’t mean they found actual liquid water, but they did find what are called hydrated perchlorates—salt crystals infused with water molecules. These are the kinds of crystals Gough studies in the laboratory.

Now Mars, with its low temperatures and low atmospheric pressure (less than 1 percent of Earth’s), is a tough place for liquid water. “Pure liquid water isn’t stable on Mars,” says Gough. “It would rather be ice or water vapor.” But the nature of perchlorate



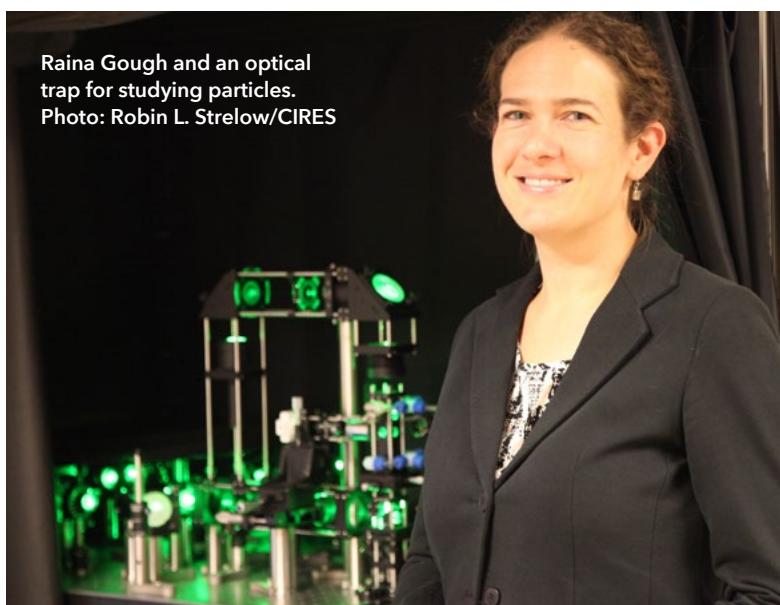
The photo on the left shows solid salt particles as they start to deliquesce into liquid brine. As water vapor is added, in the photo on the right, the particles continue to take up liquid water and grow in size. Image: Margaret Tolbert Lab @ CIRES

salts makes a liquid solution more possible, she points out. The implications of this recent discovery are that those crystals might have formed a liquid recently and that deliquescence might be how that liquid formed. “These new results are really exciting,” Gough says. “They connect these really fundamental lab studies to the actual observation of those mysterious dark streaks on Mars.”

Tolbert’s group has done studies to see how perchlorates interact with water vapor at temperatures as low as  $-50\text{ }^{\circ}\text{C}$ , and she and her colleagues were the first people to experimentally observe perchlorates deliquescing at low Martian temperatures and low relative humidity. In the lab, they use devices that allow them to control temperature and relative humidity and the results of their experiments are visible through an instrument known as a Raman microscope.

Gough brings up a video of perchlorate crystals taken using the microscope. The perchlorate starts out as a crystal but, as the relative humidity increases, the form changes dramatically, into swollen, round droplets. “Somewhere between 40 and 44 percent relative humidity,” she says, “the perchlorate salt particles go from being a crystal—a solid—to being a liquid, pulling water vapor from the atmosphere and forming brine droplets.” Additionally, once perchlorate has deliquesced, it doesn’t go back to crystal form easily. Relative humidity has to drop to about 15 percent before the perchlorate recrystallizes.

Back in the lab, two of Tolbert’s graduate students are now trying to figure out under what conditions



Raina Gough and an optical trap for studying particles. Photo: Robin L. Strelow/CIRES

there could be liquid perchlorate brine on Mars. Experiments in the lab have thus far been with pure perchlorate salts, bought from a chemical company, and pure water—mixed together, they create a pure brine. But Mars is a dusty planet and it’s likely that there are dust particles mixed into the brine as well. “So we’re putting more dust particles in our brine,” says Gough. “We’re inching closer to Mars relevance.”

Results from those tests could demonstrate if there’s a significant window of time on Mars where liquid water could exist. That could mean big things for astrobiologists looking for life on Mars. Liquid water is believed to be key to life on other planets. “The fact that liquid hangs around as long as it does,” says Gough, “has potential.” ■



# Incoming!

*New satellite aims to improve crucial solar storm warning*

By Paul McDivitt/CIRES intern

In May 1921, a massive geomagnetic storm temporarily wiped out the top technology of the day, telegraph service. Today's technology is just as susceptible to space weather events, which periodically sweep from the Sun toward Earth and can trigger geomagnetic storming. We are arguably more dependent than ever on technology, and more vulnerable to geomagnetic storms that can disrupt communication and navigation systems.

So a team of CIRES and NOAA researchers working at NOAA's Space Weather Prediction Center (SWPC)—the nation's official source of warnings and alerts about space weather and its impacts on Earth—are excited about a new satellite. The Deep Space Climate Observatory (DSCOVR) is poised

to improve the advanced warning systems that tell us when potentially destructive space weather is heading our way.

The team developed a ground processing system for the DSCOVR satellite, helping to ensure that space weather data from the new satellite flows 24/7 for users around the world who rely on it. The team completed the project on time and under budget, said NOAA's Doug Biesecker, who successfully nominated the team for a CIRES Outstanding Performance Award. Biesecker is the DSCOVR program scientist in SWPC.

Geomagnetic storms occur when Earth's magnetosphere is temporarily disturbed by a coronal mass ejection—a huge burst of magnetic field and plasma



Michael Burek



Michele Cash



Tom DeFoor

from the surface of the Sun. These storms create beautiful aurorae, but can also cause harm: power outages; disrupted radio transmissions impacting airlines, mariners, and emergency responders; damaged satellites; and interrupted or degraded GPS navigation, which affects oil drilling, surveying, precision agriculture, and aviation.

NASA’s Advanced Compositional Explorer (ACE) was previously the only satellite providing early detection of imminent geomagnetic storming. The agency designed ACE for a lifespan of only three years—it’s 18 today.

“In spacecraft years, that’s pretty ancient,” said CIRES scientist Alysha Reinard, who worked on the team that developed DSCOVR’s ground processing system. “We rely on it [ACE] heavily, so having a replacement for it has been very important,” said Reinard. “DSCOVR is that replacement.”

DSCOVR launched in February 2015 on a SpaceX Falcon 9 rocket, and it reached its intended position between the Sun and Earth, dubbed the Lagrangian Point, or L1, in early June. Now, the satellite is working through required testing and evaluation before going operational in March 2016.

Similar to ACE, DSCOVR will be able to provide 15- to 60-minute advance warnings of solar storms, but the new satellite will offer more robust data and better continuity of coverage than ACE. SWPC scientists believe the new satellite will improve geospace models, which space weather forecasters use to

model Earth’s magnetosphere.

“Your model is only as good as what you’re putting into it,” said Michele Cash, also a CIRES scientist who works in SWPC. Cash is developing operational products that will use real-time DSCOVR data to enhance space weather forecasting. These products include an estimate of L1-to-Earth propagation time (the time it will likely take a blast of solar wind or a coronal mass ejection to get from DSCOVR to Earth) and also a geomagnetic storm prediction product, which can identify and predict the occurrence, duration, and strength of large geomagnetic



NOAA’s Monty Spencer inside the Space Weather Prediction Center in Boulder, Colorado. Photo: Will von Dauster/NOAA

storms—a first for SWPC.

The full award-winning team is: Michael Burek, Michele Cash, Tom DeFoor, Ratina Dodani, Richard Grubb (not shown), Jeff Johnson, and Alysha Reinard, all CIRES scientists working in SWPC. ■

**Read more:** <http://bit.ly/1SWj1h5>



Ratina Dodani



Jeff Johnson



Alysha Reinard

# Fire's Future

Scientists planning major study on western wildfire impacts in 2018

By Karin Vergoth

The U.S. West faces a future with more frequent and intense wildfires, according to climate projections and because of policies that have long encouraged fire suppression.

Against that backdrop, NOAA and CIRES scientists in the NOAA Earth System Research Laboratory (ESRL) will launch a large-scale field study during the 2018 wildfire season. FIREX (Fire

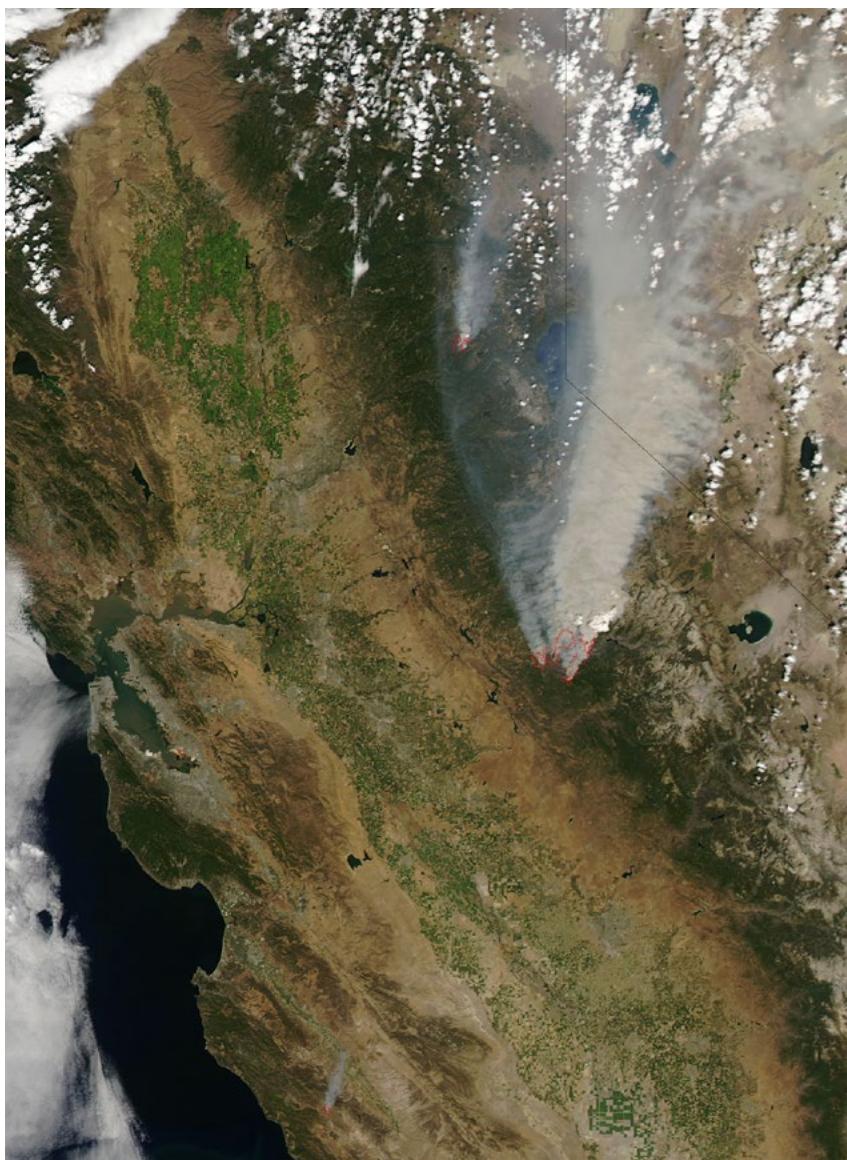
Influence on Regional and Global Environments Experiment) will examine the emissions created when different fuel sources burn, how those emissions are transformed chemically, and how they affect air quality, health, and even climate.

NOAA aircraft will fly over wildfires and prescribed fires to sample emissions, while stationary instruments and mobile labs will collect samples on the ground. To help track emissions on a regional

and even global scale, researchers will also tap into satellite data.

“Satellites can provide information about a fire’s radiative power—how big and intense it is,” said James Roberts, a scientist in the ESRL Chemical Sciences Division and a member of the study’s steering committee. Satellites can also track a fire’s smoke—where it is, where it goes, and its aerosol and optical properties, said Roberts. Finally, satellites can detect chemical signals coming from fires and can track emissions regionally and globally.

Several polar-orbiting satellites, which make one or two measurements per day, will help with these efforts: NASA’s Aura, Aqua, and Terra orbiters, and the Cross-track Infrared Sounder (CrIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) instruments on the Suomi NPP satellite, one of several orbiters planned for the NASA-NOAA Joint Polar Satellite System. ■



California's Rim Fire on August 22, 2013. Red marks hotspots where an instrument on NASA's Aqua satellite picked up unusually warm surface temperatures. A thick smoke plume is visible to the northeast. Image: NASA

# Tracking CO<sub>2</sub> from Space

*Global greenhouse gas measurements as ground truth for NASA satellite data*

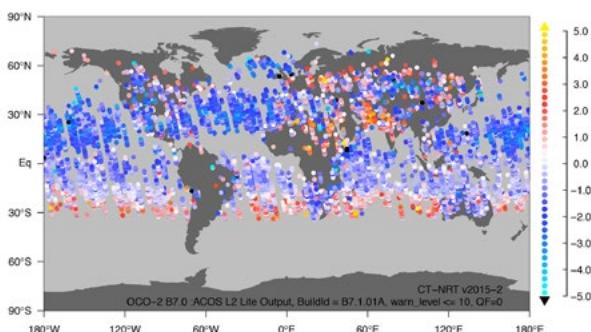
By Karin Vergoth

**H**ow well can carbon dioxide be measured from space? That's what a team of NOAA and CIRES scientists from the NOAA Earth System Research Laboratory (ESRL) is helping NASA and the international scientific community figure out.

NASA launched the Orbiting Carbon Observatory-2 (OCO-2) satellite in 2014 to measure carbon dioxide (CO<sub>2</sub>) from space and help detail sources and sinks of the greenhouse gas. Each day, the satellite orbits Earth 14 times and collects up to 60,000 usable measurements.

Scientists in ESRL's Global Monitoring Division (GMD) are validating OCO-2 measurements with ground- and air-based measurements from a network of instruments managed by NOAA and its international partners, including global surface sites, tall towers, and small aircraft (see sidebar) in NOAA's Global Greenhouse Gas Reference Network.

CIRES scientist Andy Jacobson, who works in GMD, tracks differences between the OCO-2 observations of carbon dioxide and a model constrained by these surface CO<sub>2</sub> measurements (see figure). "Our model bridges the gap between the surface network sites and the satellite observations," says Jacobson. His comparisons suggest that OCO-2 is consistently underestimating carbon dioxide levels over the oceans and might be producing unrealistic



OCO-2 observations compared with NOAA's CarbonTracker for May 2015. Each sounding made by the satellite is represented by a dot, color-coded to show the difference in column-average CO<sub>2</sub> abundance (ppm) between the satellite measurements and those simulated by NOAA's CarbonTracker model. Blue shows places where the satellite estimates less CO<sub>2</sub> than the model.

land-ocean differences in the greenhouse gas.

Other scientists are doing their own analyses and while many studies are underway, none are finished yet. "Our initial comparisons between satellite measurements and ground- and air-based measurements suggest the satellite-based measurements aren't yet at the level of accuracy needed to help us understand CO<sub>2</sub> sources and sinks," says John Miller, a CIRES scientist in GMD.

Miller and Brazilian colleagues are also investigating carbon dioxide over the Amazon—an important region for carbon sources and sinks, but one that's not well sampled from space (see the absence of data over South America in the figure, below left).

Understanding global carbon dioxide and its sources and sinks is a tough task. Because of its long lifetime and its tiny fluctuations relative to a big atmospheric background, progress is expected to be slow. Miller and his colleagues' analyses will be a critical component of knowing how well OCO-2 is working. ■

## AirCore

**P**art of this team's validation work includes an atmospheric sampling technology that captures and preserves a profile of trace gases from the atmosphere.

AirCore is a long coiled tube open on just one end, lofted up by helium balloon to 100,000 feet, and then dropped down. As it falls, the tube captures layered air samples that can be measured in the lab for gases, such as the key greenhouse gas CO<sub>2</sub>, and how their concentrations change during descent.

Because AirCore and other reference network instruments provide reliable measurements of CO<sub>2</sub> and other gases, scientists can compare those measurements with what the OCO-2 satellite sees. Without this important calibration step, OCO-2 measurements are vulnerable to bias.



Photo: Anna Karion/CIRES

# Cutting

## *CIRES scientists, colleagues improve daily sea ice forecasts for the Arctic*

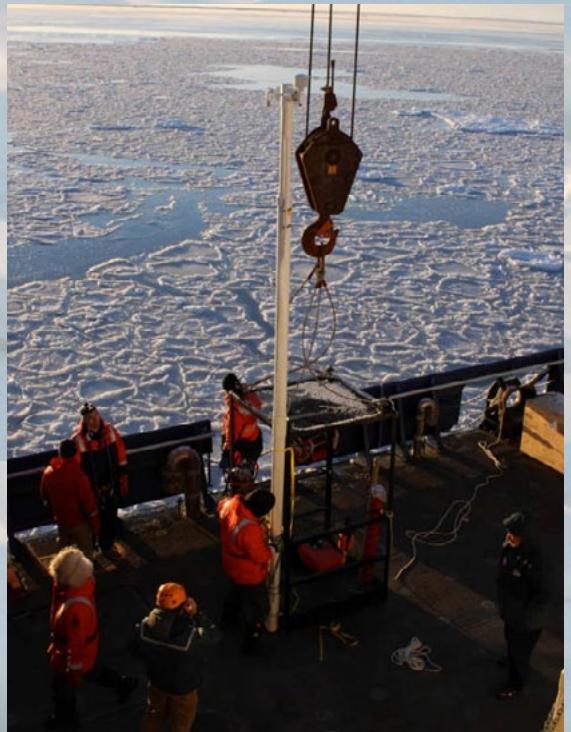
By Laura Krantz and Katy Human

In September 2012, just one day after beginning to drill, Shell Oil temporarily abandoned an Arctic Ocean well site because of fast-approaching sea ice. The company had already spent years and billions of dollars securing drilling rights in the Chukchi Sea. There was limited time remaining to drill that summer, so Shell's decision to pull back from the well was a serious one for the company.

Unanticipated sea ice has been an ongoing problem far north, not only for oil companies but also for research vessels and the military. So the Navy and NOAA have been looking for ways to improve sea ice forecasts. "You don't want to just know where the ice is today, you want to know where it will be tomorrow," says Florence Fetterer with the National Snow and Ice Data Center. "Winds may change and you can get into a bind quickly."

In 2015, the interagency team had a breakthrough, coming up with a new technique to estimate sea ice concentrations in the Arctic Ocean. The result has been a dramatic improvement in the six-hour sea ice forecast. "On average, it's about 40 percent better," Fetterer explains. "If before, the ice was predicted to be a mile from where it really turned out to be, now it's only going to be six-tenths of a mile. In the summer, it's up to around 60 percent better." That kind of accuracy makes it safer to operate in the Arctic Ocean.

The solution grew out of a realization that, while sea ice forecast models had improved—becoming more detailed—actual observations of sea ice had not kept pace with the models. To get that more precise sea ice information, Fetterer and her colleagues combined two types of measurements: high-resolution satellite data and human interpretation of sea ice data from



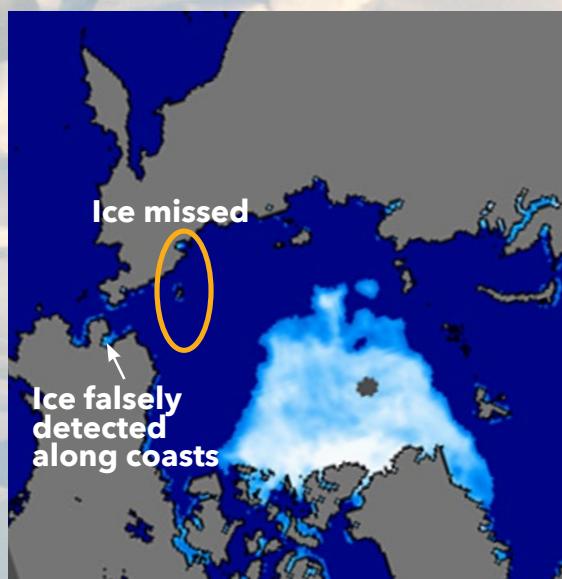
Researchers on a 2015 mission in the Arctic used new sea ice forecasts from NSIDC and partners.

Photo: Ola Persson/CIRES @ NOAA

other satellite sources. This blended approach catches ice that some sensors miss on their own. This is especially true in summer, when melted water on the surface of the ice appears as ocean to some instruments. And, in cases where ice is present, the satellite quickly provides a more accurate estimate of the amount of ice than humans can.

The new system (MASIE-AMSR2) can capture

# Edge



This image is from a satellite-only product. It misses some ice because, in the summer, ponds that form on top of the ice are mistaken for open water. Along coastlines, it sometimes finds ice that's not really there because the resolution isn't fine enough to differentiate land from water.

Images: NSIDC

even small patches of sea ice a few miles across, which are easy to miss using other systems. That means better input into forecasts, and more accurate output, too. "We expect this combined product is going to do a much, much, much better job," Fetterer says.

"It's especially important to have accurate forecasts given how fast conditions change in the Arctic," says Pamela Posey, a computer scientist with the U.S. Naval Research Laboratory in



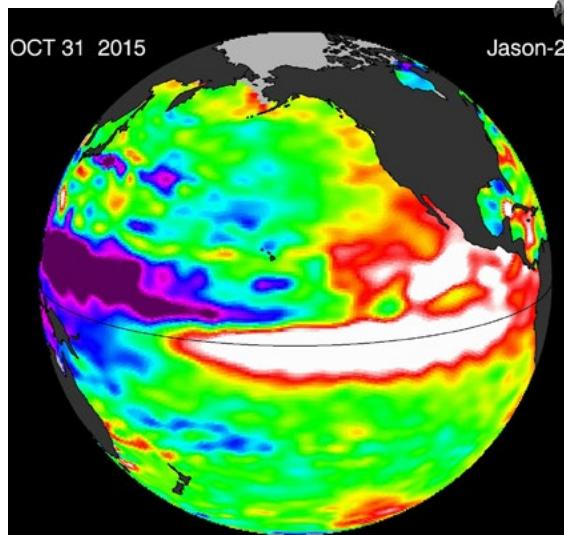
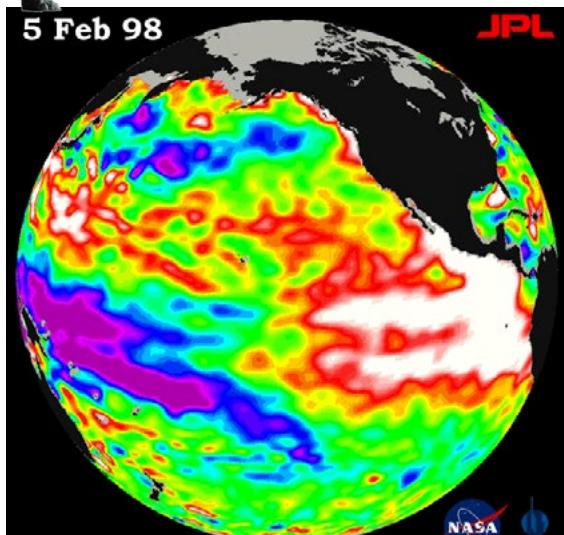
A blended approach involving satellite data and human interpretation results in this improved map. An island of ice north of Siberia (circled) was missed almost entirely in the satellite-only product. Additionally, the blended method recognizes the difference between land and water, so coastlines in the image on the right are clear of ice.

Mississippi, who worked with Fetterer and others on MASIE-AMSR2. "We're now seeing improved forecasts because we're starting the model with more realistic depictions of the current conditions. Similar to a weather forecast, getting that starting point right is important." ■

**More:** <http://nsidc.org/data/g10005>

**Background image:** Sea ice north of Greenland.  
**Photo:** Andy Mahoney/CIRES @ NSIDC

# Godzilla and Other Faces in the Sea



Godzilla (1998) and spinosaurus (2015) in sea surface temperatures measured by satellite. Images: NASA-JPL

After another national El Niño expert referred to the 2015 El Niño as “Godzilla,” Klaus Wolter, a CIRES researcher in the Earth System Research Laboratory’s Physical Sciences Division (PSD), dug up the backstory: “*This* was Godzilla,” Wolter said, pointing to a monster’s face in a 1998 satellite image of sea surface temperatures (SSTs) in the eastern equatorial Pacific Ocean. Then he pointed to a current SST map. “Today, it’s more like a spinosaurus.”

Wolter and colleagues working in PSD rely on a three-legged stool for their work assessing weather and climate: observations—including those satellite-derived SSTs—models, and evaluation.

Overall, the research group serves to help NOAA provide early warning of impending weather- and climate-related events. Better warnings require a better understanding of the physical conditions that lead to serious floods, prolonged droughts, crippling snowstorms, and more. Often, the researchers find, global SST patterns are critical in shaping extreme events:

- During El Niños, which can send rain to California and drought to India, altered global circulation patterns start with warmer-than-usual sea surface temperatures in the equatorial Pacific Ocean. Different “flavors” of El Niño, with ocean warming in slightly different regions, can produce different global effects.
- SST patterns can help explain rainfall variability (including drought) in East Africa, where October-December wet seasons have become wetter, and March-May has become drier.
- When dissecting the reasons behind the warming of the Arctic atmosphere, PSD scientists find a significant role of long-term SST temperature changes in parts of both the Atlantic and Pacific.

“This kind of diagnostic research exemplifies the work our division does to advance our understanding and prediction of weather and climate extremes,” said Robin Webb, director of PSD. “Our work supports NOAA’s responsibility to provide the early warning needed to manage risk and to prepare for, if not mitigate, impacts.” ■ —Katy Human

# From BIG DATA to Better Forecasts

**F**armers, pilots, students, highway patrolmen... they're all potential sources of weather data. Highway and agricultural departments collect daily weather data, so do many universities. If you could gather up all that information and make sure it's accurate, could you use it to make weather forecasts better?

Yes. That's exactly what the scientists at NOAA and its cooperative institutes in Colorado did with the Meteorological Assimilation Data Ingest System (MADIS). The system, which was handed over to

**"MADIS data has proved incredibly helpful in increasing our overall awareness of major weather, especially wind, cold temperatures, and storm systems."**

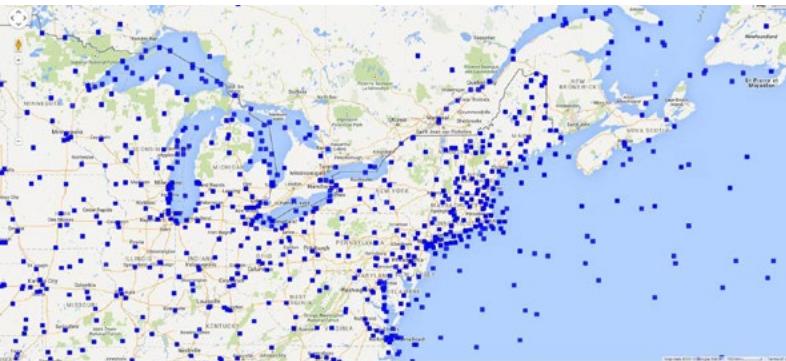
*—Chris Thompson, Virginia Department of Emergency Management*

the National Weather Service earlier this year, takes advantage of a treasure-trove of meteorological information gathered from around the globe, checking it to ensure accuracy, and organizing it in a way that's accessible to National Weather Service (NWS) forecasters, weather prediction models (both research and operational versions), NWS hydrometeorological applications, and the general public.

The result is a collection of more dense, more frequent weather-related observations—including temperature, pressure, humidity, wind, and radiance—many of these gathered by NOAA satellites. Where before, about 20,000 surface data sources were scattered across the world, now there are more than 67,000, most in the United States, making a more tightly packed network. MADIS helps meteorologists develop more accurate forecasts and communities and organizations plan for and respond to extreme weather events. ■

*—Laura Krantz and Monica Allen/NOAA*

**Sources of weather data before and after MADIS. Images: NOAA**

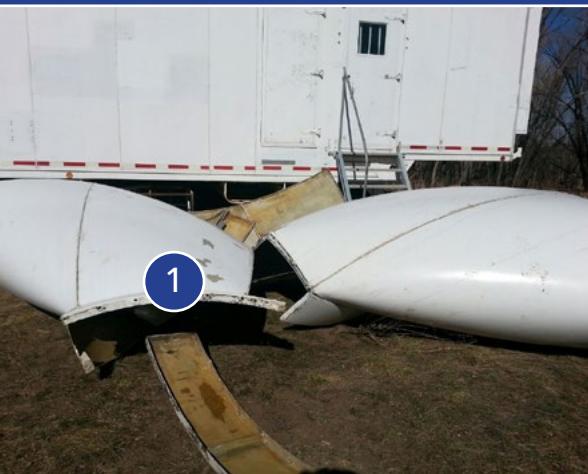


# my SPHERE



To see a video about this project,  
go to: <https://www.youtube.com/CIRESvideos>

CU-Boulder senior engineering students—whimsically called Team Jackalope—spent 2014-2015 designing and building a satellite ground station to support a small satellite called PolarCube: Jake Cazden, Patrick Harrington, Brian Lamb, Seth Meirs, and Topher Pollard. Photo: Kenna Bruner/ CU-Boulder

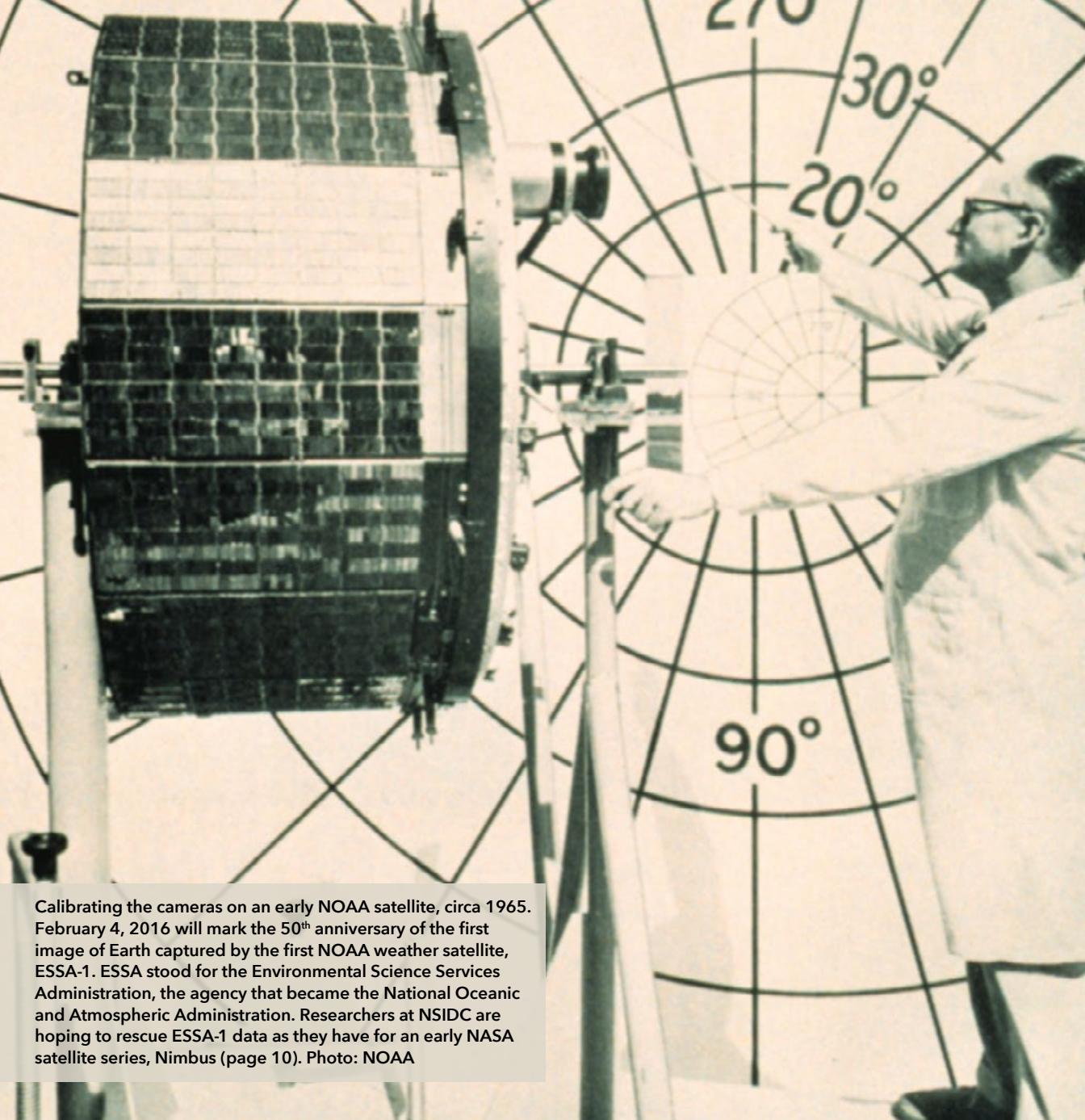




CIRES' Dave Gallaher (NSIDC), Al Gasiewski (Center for Environmental Technology), and Brian Sanders (Colorado Space Grant Consortium) are leading student engineers in designing and building the 10-pound satellite PolarCube and its tracking station. PolarCube will gather weather data over the Arctic, to improve weather forecasts and better understand Arctic sea ice changes.

- 1 A wind storm damaged half of a fiberglass sphere that protects the 2-ton, satellite-tracking antenna salvaged from NOAA.
- 2 Students rebuilt the sphere and retrofitted an old trailer with new electronics to create the ground station.
- 3 A crane positions the top hemisphere over the antenna.
- 4 The inside of the trailer, mid-retrofit.
- 5 Team Jackalope, after putting the antenna's housing back together again.





Calibrating the cameras on an early NOAA satellite, circa 1965. February 4, 2016 will mark the 50<sup>th</sup> anniversary of the first image of Earth captured by the first NOAA weather satellite, ESSA-1. ESSA stood for the Environmental Science Services Administration, the agency that became the National Oceanic and Atmospheric Administration. Researchers at NSIDC are hoping to rescue ESSA-1 data as they have for an early NASA satellite series, Nimbus (page 10). Photo: NOAA



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CIRES, a partnership of the University of Colorado Boulder and NOAA, is dedicated to fundamental and interdisciplinary research targeted at all aspects of Earth system science and to communicating these findings to the global scientific community, to decision makers, and to the public. Our environmental scientists explore many aspects of Earth system sciences: the atmosphere, cryosphere, hydrosphere, geosphere, and biosphere. These spheres of expertise give our magazine its name.

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