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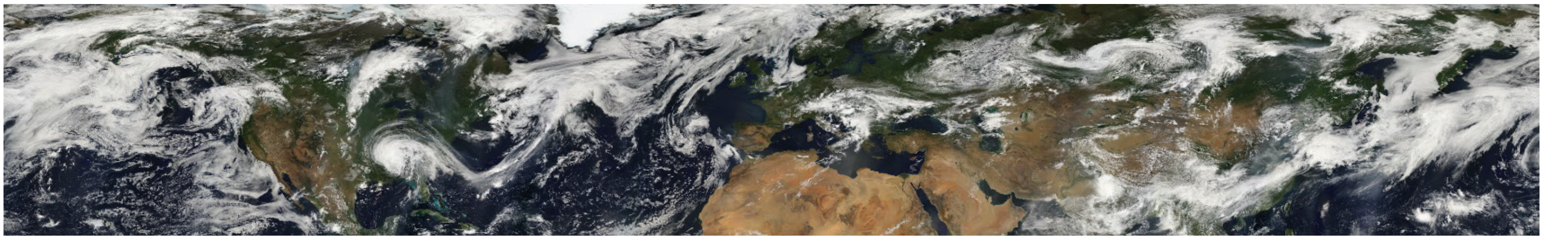
Earth Science Data and Information System (ESDIS) Project

National Aeronautics and Space Administration



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New Data From Old Satellites: A Nimbus Success Story

After being in storage for more than 40 years, data recovered from NASA's Nimbus I, II, and III missions are extending the polar sea ice record back to the 1960s and giving scientists new views of this changing environment.

Archaeologists hunt for relics in an effort to shed light on the past. For techno-archaeologists, these relics are data, and Dave Gallaher and Dr. Garrett Campbell are in a race against time to uncover data that have not seen the light of day in almost a half-century. They are searching for polar sea ice data collected by NASA satellites launched in the 1960s. It has been a long time since these data were collected and last seen. And time is running out.

You see, data, especially data from the 1960s and early 70s, are fragile. After 30 or 40 years the iron ferrite particles that magnetically hold bits of data can separate from the acetate holding the particles in place on the large data spools used at the time. When this happens, the data can disappear. Forever.

So when Gallaher heard in 2009 that scientists at NASA's Goddard Space Flight Center (GSFC) in Greenbelt, MD, had successfully recovered high resolution infrared radiometer (HRIR) data from NASA's Nimbus I (1964), II (1966), and III (1969) missions, he had an idea.

"I noticed that some of the satellite swaths went over the poles," says Gallaher, the Technical Services Manager at the National Snow and Ice Data Center (NSIDC), the home of NASA's Distributed Active Archive Center (DAAC) specializing in snow and ice data. "I asked if they could detect sea ice with these data, because one of the major gaps we have in sea ice data is that the sea ice data record starts in 1979. Wouldn't it be amazing if we could use the data from these early satellite missions to find out what the

In This Issue:

Articles written by Josh Blumenfeld, EOSDIS Science Writer ice looked like and extend the sea ice record back a full 50 years?"

More than five years later, after manually searching through more than a quarter-million individual Nimbus images with a small team using equipment that is no longer manufactured, these early polar sea ice data are now available at the touch of a button. This is a data success story; a story about bringing dark data back into the light.

Sensing the 60s

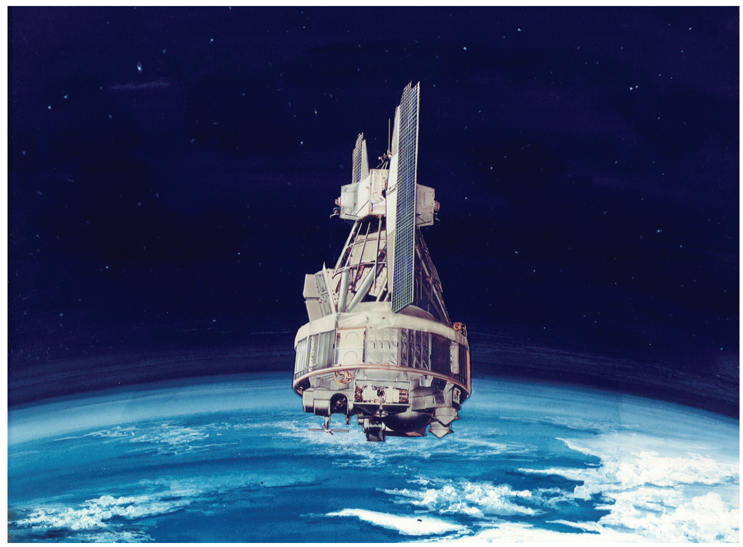
From the viewpoint of the 21st century, when a cell phone has more processing power than the computers that helped land astronauts on the moon, it is easy to look back and ask why the data from these early satellite missions were not actively processed, analyzed, and stored as an integral part of the climate record.

As Campbell, the NSIDC scientist who worked with Gallaher on the Nimbus data recovery effort, notes, the primary objective of these early satellite missions was not to collect long-term climate data. "Climate monitoring from satellites really didn't get started until the mid- to late-70s," he says. "The original NASA instruments and missions were more engineering missions to figure out how to make measurements and get them distributed the day they were taken so you could look at that day's weather. The idea of a climate trend or keeping long-term climate records just wasn't understood as a standard practice back then."

In addition, the computers of the mid-1960s and early-1970s simply did not have the power to efficiently process and store the amount of data these missions produced. "The Nimbus user guide from 1966 says that this data set is so large and so vast that no one will ever be able to look at all of it," says Gallaher. "In order to process these data, they had to print out photos and lay them out on a gymnasium floor. This was the only way to look at this stuff. It was hard! At the time, NASA played the data back over a TV screen and took pictures of the TV screen and this became the archival record."

Finally, the Earth's climate simply was not understood as well. "These records occur really before CO2 and global warming really got going," Campbell says. "El Niño had been scientifically described, it was a known event, but the causes were not well-researched. Even the ozone hole [over Antarctica] happened after these data."

As a consequence, the spools of data from Nimbus along with 70mm reels of film with hundreds of thousands of images were boxed up after the individual missions ended and sent to government warehouses in Maryland and North Carolina. The Nimbus data were never lost, but, as Gallaher observes, they became "dark." "This means that the data are there, but you can't easily use them," he says. "Remember, the Nimbus images are just images; there's a time stamp on them, but that's it. In order to make any sense of the Nimbus data, you had to be able to put the data back in their correct order to determine what the image showed."



Nimbus I launched on 28 Aug. 1964 and operated until 22 Sept. 1964. Along with the HRIR instrument, the spacecraft also carried an advanced vidicon camera system (AVCS) for recording and storing remote cloud cover images and an automatic picture transmission (APT) camera for providing real-time cloud cover pictures. NASA graphic

Even when confronted with this reality, Gallaher and Campbell realized that if they could get the Nimbus polar data this could add 10 to 15 years to the sea ice data record. By 2009, the National Oceanic and Atmospheric Administration (NOAA) had ownership of the Nimbus data collection, and Gallaher contacted them to request the polar data.

The Challenges of "Dark" Data

"I called down to NOAA and asked them to send us Greenland and Antarctica," recalls Gallaher. "There was a pause at the other end of the line and the NOAA representative said I didn't understand. And I said, you have these data, I have the document that says you have these data. And he said, yes, we have these data, but the data are in boxes, the boxes have canisters, each canister has about 200 feet of film in it, and it's by orbit. We don't have any idea what's on that film. Oh, and these canisters have been sealed for at least 40 to 50 years."

The only way Gallaher and Campbell could get the images they wanted was to scan all of the data and look at each individual frame of film, more than 250,000 images.

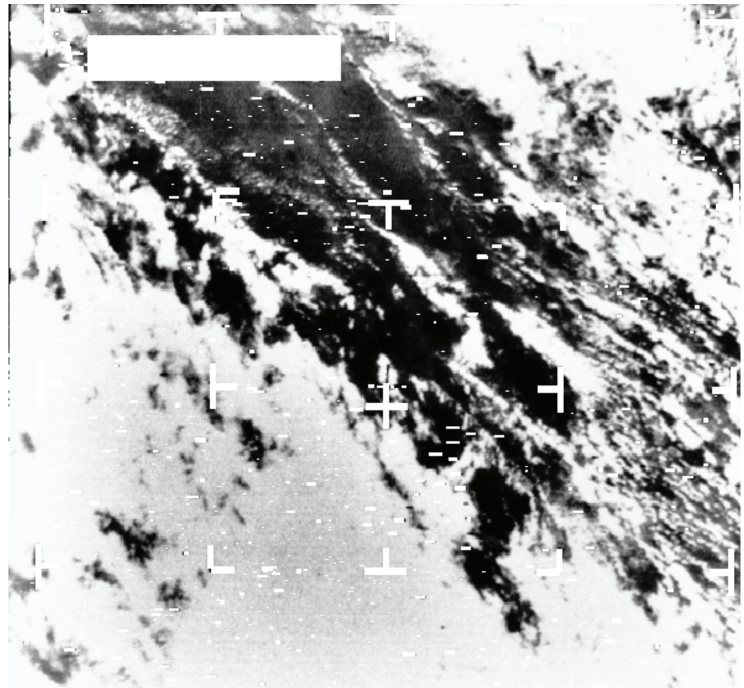
Gallaher notes that while many people had inquired about the data, no one wanted to take any of the data after hearing about the state the data were in. "These data were inherently dark data—they were too tough to use to be of any value," he says.

But Gallaher and Campbell, along with their NSIDC colleague Dr. Walt Meier, a sea ice specialist and currently a research scientist at the GSFC Cryospheric Sciences Laboratory, knew the Nimbus data could answer many questions about polar sea ice and, perhaps, solve some mysteries in the process.

"The current sea ice record starts in 1979, right about when temperatures are really starting to rise and we're beginning to see the downward trend in Arctic ice starting to hit," Meier says. "The Nimbus data come in at 1964, so it extends our record back another 10 to 15 years. Nimbus really fills in the gaps."

And there are a lot of gaps in sea ice data. Prior to the late-1970s, polar sea ice records were spotty at best. "There are no records in the 1960s and even for much of the 1970s of where the sea ice was—not from the Air Force, not from anybody," Gallaher says. "The Russians had some ships that tried to take a stab at this for a few months at a time, but it is really incomplete data."

With funding from a small grant through the Innovative Research Program (IRP) at the Cooperative Institute for Research in Environmental Studies (CIRES), Gallaher and Campbell broke the seals on the canisters and began to reconstruct the Nimbus sea ice record.



A Nimbus I image acquired 14 Sept. 1964. Nimbus I images are 4 bit images, and each image is displayed in only 16 shades of gray. Trying to distinguish clouds, ice, and open water was difficult; in some images this was impossible. Image: Gallaher, D. & Campbell, G. 2013. Nimbus Advanced Vidicon Camera System Visible Imagery L1, HDF5, Version 1.1964.09.14. Boulder, Colorado. NASA NSIDC DAAC [doi: http://dx.doi.org/10.5067/NIMBUS/NmAVCS1H]. Accessed 26 May 2016.

Bringing Nimbus Dark Data Back into the Light

After an initial assessment of the tapes and images, Gallaher and Campbell still were not sure whether the data would be useful. While each image had a time stamp, it was almost impossible to determine the location of specific images without orbital information. Then they caught a lucky break. As it turns out, the North American Aerospace Defense Command (NORAD) still had the Nimbus orbital data from the 1960s. This was the Rosetta Stone Gallaher and Campbell needed. "If you know the orbit and you know the time, you can figure out what the satellite was looking at," explains Gallaher.

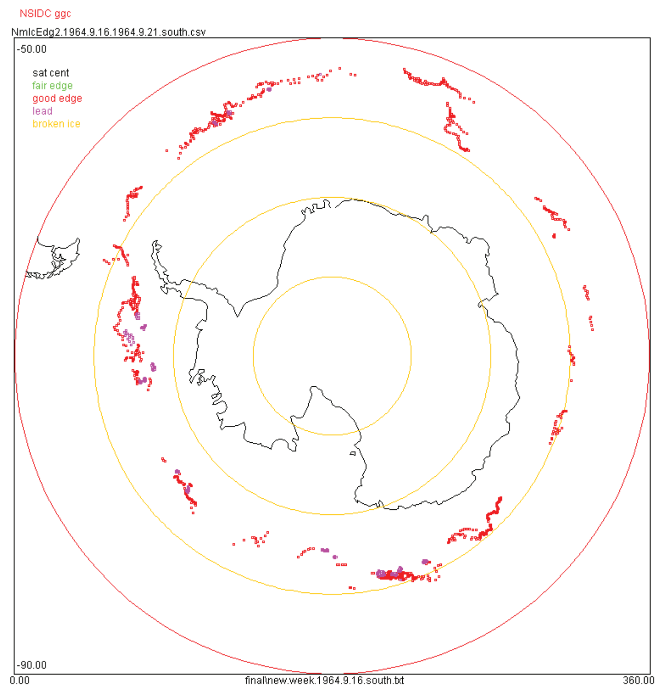
Now it was time to use the Nimbus images to determine the ice edge. However, this was easier said than done. Unlike sea ice data collected in the later 1970s and through today that use passive microwave sensors, the Nimbus data are visible images. This distinction is important. Passive microwave sensors detect energy radiated from Earth and are able to produce images based on this radiated energy independent of a source of illumination (such as the sun) or a barrier between the sensor and the ground (such as clouds). Visible images, on the other hand, require a source of illumination—an obvious hindrance during the dark polar winter—and cannot "see" through clouds. "Cloud cover is a major factor," says Meier. "Cloud cover of 80% of the region is not uncommon. You're really limited to the amount of data you can get compared with the passive microwave sensor."

Campbell and a rotating team of students from the University of Colorado spent approximately four years analyzing the ice images from Nimbus I, II, and III to determine the ice edge and create composite images of both poles. They initially did this manually before Campbell developed a program to automate this process. "Garrett created an algorithm to look at the images and pick out the darkest pixel, which likely is water," Meier says. "Over a seven day period the ice is there and it's going to stay there or move around very little, but the ice is not going to get any darker. If you pick the darkest pixel, you're likely to get the ice and the ocean, but you're likely not to get cloud. This makes the ice show up much better. Once you have the composite image of the region, you can mark out the ice edge."

Another challenge for the team was the sheer tedium of entering the hundreds of thousands of time stamps from individual images into an electronic database. "Garrett wrote a brilliant piece of software where if a student could figure out one time in an orbit, they could key that time in," says Gallaher. "The software was designed to recognize that the images were taken roughly 91 seconds apart. So if the orbit is correct and the timing is correct, this image should show this specific location. The program would then simply inquire if the location shown was what was expected and the student could validate it."

A final challenge was that the large reel scanners needed to read the Nimbus tapes were no longer being produced. Gallaher and Campbell acquired a Kodak scanner built in 2000 that would do the job. The team still has this scanner, and plans to use it for future data recovery efforts.

Today, NASA's NSIDC DAAC distributes 16 data sets from the Nimbus Data Rescue Project, 15 of which are available in both HDF5 and GeoTIFF format; the Nimbus Ice Edge Points data set is distributed in CSV format. Nimbus data also are available through NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC).



Antarctic ice edge plot from 16 Sept. 1964 derived from Nimbus I imagery. Image: Gallaher, D. & Campbell, G. 2014. Nimbus Ice Edge Points from Nimbus Visible Imagery L2, CSV, Version 1. 1964.09.16. Boulder, Colorado USA. NASA NSIDC DAAC [doi: http://dx.doi.org/10.5067/NIMBUS/NmIcEdg2]. Accessed 26 May 2016.

The Nimbus Time Machine

The Nimbus data recovered by Gallaher, Campbell, and their small team of students is shedding new light on the polar sea ice record—and uncovering some mysteries as well.

"We were shocked by what we discovered in these images," says Gallaher. "We thought, OK, all reports from the 1960s were that it was colder, so we expected to see a lot more sea ice. In fact, 1964 was the largest sea ice extent until 2014. Then in 1966 we saw the lowest ice extent that was ever seen. This was totally unexpected. There's a lot more variability in sea ice extent than we ever could have imagined."

Meier agrees. “Even in the passive microwave record for the Antarctic you see these seesaws where the ice concentrations go up and down, so extreme high or extreme low are not that unusual,” he says. “What the Nimbus data tell us is that there’s variability in the Antarctic sea ice that’s larger than any we had seen from the passive microwave data. Nimbus helps put this in a longer term context and extends the record.”

The Nimbus data from the Arctic also validate the average sea ice concentrations established by the 1979 to 2000 passive microwave record. This is a good indication that the Arctic was fairly stable in the mid-60s and remained stable until about 1979, which is when data indicate that sea ice concentrations began gradually decreasing before a more rapid decline in sea ice began in the 1990s.

And then there’s the mystery of the missing polynya. A polynya is a large area of open water that is surrounded by sea ice. Passive microwave imagery detected a large polynya in the Weddell Sea in Antarctica between 1972 and 1977, but scientists have not seen this feature since. “The data from Nimbus I or II had some indications in the imagery that this polynya might be there to some extent [between 1964 and 1966],” says Meier. “There are signs of open water in this area, but it’s not totally clear. Was this a glitch? Or was this a feature that persisted from the 1960s into the 1970s and then faded away? We don’t have the imagery to prove this conclusively, but there are indications in the [Nimbus] imagery.”

Looking Ahead by Looking Back

For sea ice researchers like Meier, the recovered Nimbus data open up many avenues for new research. “The Nimbus data give a longer term context of the sea ice record,” he says. “We might say a year is a record year, but we’re really only talking about the years covered by the passive microwave record. Now we can take into account the Nimbus data record.”

Gallaher points out that the Nimbus data also will aid in climate modeling. “If you’re trying to build a climate model you now have access to 50 years of data. This will improve the accuracy of these models quite a bit,” he says. “One thing I’ve been advocating is to run these models backwards. If you can predict what we saw [in the Nimbus data], you now have handled all the extraneous characteristics of what was there [in the 1960s] and what has changed. This would be an excellent validation of these models. If you can predict back 20 years, you can predict forward 20 years or longer.”

While Gallaher and Campbell concentrated on sea ice, Nimbus has other data that also can be used for research. “The potential exists to get sea surface temperature, cloud distributions, tropical storm images,” Campbell says. “We have not really mined the data for all the possible uses. We’ve just focused on sea ice since this is our area of interest at NSIDC.”

The Nimbus Data Rescue Project remains a popular NSIDC DAAC data set, with the Nimbus Advanced Vidicon Camera System Visible Imagery L1 and the High Resolution Infrared Radiometer Digital Swath Data L1 being the two most heavily downloaded products, based on NSIDC volume metrics from 2015 and 2016.

In addition, the Nimbus Data Rescue Project received the 2013 International Data Rescue Award in the Geosciences. This award, presented by Integrated Earth Data Applications and Elsevier Research Sciences, encourages improvements in the preservation and access of research data, particularly data that have not been analyzed or processed.

And there are more dark data out there.

Gallaher and Campbell currently are organizing the rescue of data from the Environmental Science Services Administration (ESSA) Satellite Program, specifically the ESSA 1, 3, 5, 7, and 9 missions, which launched between 1966 and 1969 and provided sea ice data similar to Nimbus. They also want to attempt a rescue of data from NOAA-2, which launched in 1972 and was the first operational weather satellite to rely solely on radiometric imaging to obtain cloud cover data.

Gallaher, Campbell, and Meier note that there are some good lessons from the Nimbus data recovery effort. “Nimbus is a lesson in don’t throw anything away,” Meier says. “The longer-term context that the Nimbus data provide is really valuable and useful for the science community.”

Gallaher agrees, and notes that if they had not acted when they did, the Nimbus data may have been lost forever. “These canisters were held together with cloth tape, so when you open the canisters the tape disintegrates into dust," he recalls. "You're opening these things up and it's odd to think about how old this stuff is. We're the first ones to really look at these data. There are some amazing images. It really was man's first look at our own planet."

A first look that is finally seeing the light of day.

Explore NASA Nimbus Data

Nimbus data at NASA's NSIDC DAAC:
http://nsidc.org/data/nimbus/data-sets.html

Nimbus Data Rescue Project:
http://nsidc.org/data/nimbus

Nimbus data at NASA's GES DISC:
http://disc.sci.gsfc.nasa.gov/nimbus

Earthdata Webinar: *https://youtu.be/5bImuoROpd0*
Satellite Techno-Archeology: Old Data Answers New Questions

User Profile: Dr. Erricos C. Pavlis

Who uses NASA Earth science data? Dr. Erricos C. Pavlis, to help accurately measure Earth.

Dr. Erricos C. Pavlis with a Global Navigation Satellite System (GNSS) receiver. This receiver was later deployed as part of a sea-level monitoring network in the southeastern Aegean Sea

Dr. Erricos C. Pavlis, Associate Research Scientist, Joint Center for Earth Systems Technology (JCET) at the University of Maryland, Baltimore County (UMBC)

Research interests: Applications of space techniques in geodesy and geophysics.

Current research: For most of us, knowing where we are to within a few meters is fine for everyday activities, such as finding an address or driving. For Dr. Erricos C. Pavlis, knowing where he is to within a few millimeters is critical to his research. As a geodesist, a key element of Dr. Pavlis' research is accurately measuring and mapping Earth's surface to better understand how our planet works and to predict its future state.

Until about a half-century ago, these measurements were difficult to conduct beyond a local or regional level. The advent of the space age finally gave scientists the ability to precisely measure and map the entire planet. For example, geodetic techniques such as Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) (where laser beams are bounced off a satellite in a stable orbit [SLR] or a reflector on the moon [LLR] and their return time precisely measured) helped provide definitive proof of plate tectonics. Today, an international network of geodetic stations continuously collect measurements to determine the International Terrestrial Reference Frame, or ITRF. NASA contributes about one third of the stations in the global network that are used to establish and monitor the evolution of the ITRF.

As the Technique Analysis Coordinator for the International Laser Ranging Service (ILRS), Dr. Pavlis contributes to the definition of the ITRF and helps develop new models to describe satellite orbits, Earth processes like plate tectonics, and interactions among various components of the Earth System. The extremely precise measurements conducted by Dr. Pavlis and his colleagues ensure that the ITRF is as stable and accurate a reference as possible.

Dr. Pavlis also uses SLR and LLR to test fundamental physics theories. He is part of an international team led by Dr. Ignazio Ciufolini (University of Salento, Italy) that is using SLR data to test a prediction of the theory of general relativity—the existence of a "gravitomagnetic" field around a massive rotating body like Earth. This effect, also known as “frame-dragging,” is due to the fact that a large rotating mass (in this case Earth) warps space-time in its neighborhood and “drags” it along near itself in the direction of rotation. This, in turn, affects the movement of smaller objects nearby (such as satellites in orbit around Earth). Initial research by Dr. Pavlis and his colleagues used SLR data from NASA’s two Laser Geodynamic Satellites (LAGEOS and LAGEOS-2) along with improved gravitational models from the joint NASA/German Aerospace Center Gravity Recovery And Climate Experiment (GRACE) mission to demonstrate that the orbits of these satellites were dragged by almost 2 meters (6.56 feet) per year due to the gravitomagnetic field created by the rotating Earth.

Following these initial observations using the LAGEOS satellites, the team worked with the Italian Space Agency (ASI) to build the Laser Relativity Satellite (LARES), which improved on the LAGEOS design. LARES was placed in orbit by the European Space Agency (ESA) on February 13, 2012.

Data products used:

- SLR data from NASA’s Crustal Dynamics Data Information System (CDDIS)
- GRACE gravity models from NASA’s Physical Oceanography Distributed Active Archive Center (PO.DAAC)

Research findings:

Dr. Pavlis and his colleagues published the initial results of their “frame-dragging” observations in 1998 and a much more accurate result in 2004 using improved GRACE models. These results provided good evidence for the existence of gravitomagnetic fields. However, the research team wanted to be able to refine their results to an even higher accuracy.

The launch of LARES provided a better platform to continue this research. Although LARES has not yet provided enough data for the final test envisioned by the research team, the initial results published in 2016 indicate that they are very close to verifying this aspect of the theory of general relativity to within 1 percent. Dr. Pavlis notes that a key point in the team’s approach is that their test can be repeated and will only improve with time as more SLR data from these satellites are accumulated and as gravitational models improve. The team is currently in discussions with ASI for the launch of an additional satellite, LARES-2, by 2019.

Read about the research:

Ciufolini, I., Paolozzi, A., Pavlis, E.C., Koenig, R., Ries, J., Gurzadyan, V., Matzner, R., Penrose, R., Sindoni, G., Paris, C., Khachatryan, H. & Mirzoyan, S. (2016) “A test of general relativity using the LARES and LAGEOS satellites and a GRACE Earth gravity model: Measurement of Earth’s dragging of inertial frames.” The European Physical Journal C, 76(3) [doi: 10.1140/epjc/s10052-016-3961-8].

Ciufolini, I. & Pavlis, E.C. (2004). “A confirmation of the general relativistic prediction of the Lense-Thirring effect.” Nature, 431(7011) [doi: 10.1038/nature03007].

Altamimi Z., Angermann, D., Argus, D., Blewitt, G., Boucher, C., Chao, B., Drewes, H., Eanes, R., Feissel, M., Ferland, R., Herring, T., Holt, B., Johannson, J., Larson, K., Ma, C., Manning, J., Meertens, C., Nothnagel, A., Pavlis, E.C., Petit, G., Ray, J., Ries, J., Scherneck, H.-G., Sillard, P. & Watkins, M. (2001). “The Terrestrial Reference Frame and the Dynamic Earth.” EOS, Transactions, AGU, 82(25) [doi: 10.1029/EO082i025p00273-01].

Ciufolini, I., Pavlis, E.C., Chieppa, F., Fernandes-Vieira, E. & Pérez-Mercader, J. (1998). “Test of General Relativity and Measurement of the Lense-Thirring Effect with Two Earth Satellites.” Science, 279(5359) [doi: 10.1126/science.279.5359.2100].

ESDIS Project Summer Interns Balance NASA Work with Making Connections for Future NASA Careers

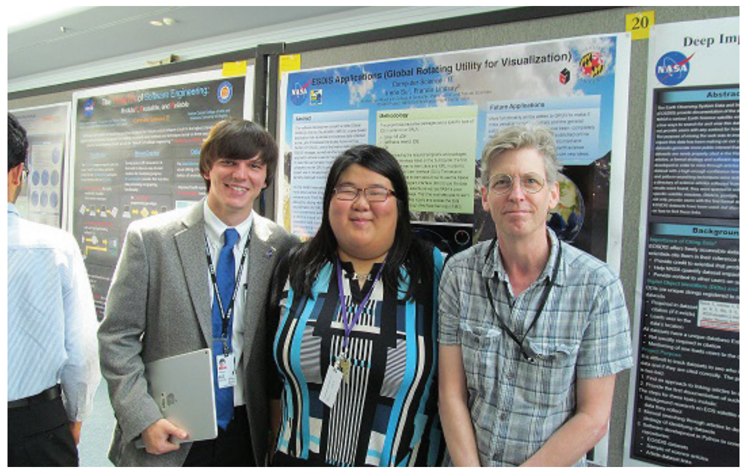
More than 25 high school, college, and graduate students supported the ESDIS Project at DAACs across the country as summer interns in 2016.

The road to a NASA career may run through Metropolitan State University in Minneapolis, MN. Or perhaps Stevens Institute of Technology in Hoboken, NJ. Or even Poquoson High School in Poquoson, VA. Students from these schools, and from high schools, colleges, and universities across the country, supported NASA Earth Observing System Data and Information System (EOSDIS) projects this summer as interns at EOSDIS Distributed Active Archive Centers (DAACs) and NASA centers and facilities.

NASA's Goddard Space Flight Center in Greenbelt, MD, hosted 425 interns this summer, including three working on projects in the Earth Science Data and Information System (ESDIS) Project office and two working on projects at the Goddard Earth Sciences Data and Information Services Center (GES DISC) DAAC. Before heading back for their fall semesters, the Goddard interns gathered in the atrium of Building 28 for an Intern Showcase to show off a summer of hard work.

Jacob Moore, a rising sophomore at Northern Kentucky University majoring in computer science, is one of three interns supporting the ESDIS office. Jacob spent the past 10 weeks working on a mobile application developed by NASA's Land Processes DAAC (LP DAAC) to enhance user interfaces with their data. "I worked on the iOS-based LandCast application," he says. "It was almost finished, but I had to go in and fix a few bugs. I also developed a user guide for the application that details everything the application does."

Around the corner from Jacob, Irene Su, a rising sophomore computer science major at the University of Maryland-College Park and another ESDIS office intern, describes her project to a small group of NASA scientists and engineers. Like Jacob, Irene also is working on an application developed by LP DAAC, the Global Rotating Utility for Visualization, or GRUV. GRUV is a graphical user interface (GUI) that allows users to explore various Earth data layers collected from LP DAAC. "I originally was going to work on the Android version of LandCast, but after the first few weeks I branched off to work on GRUV," she says. "I've mostly been fixing various bugs, adding new functions to make GRUV more user-friendly, and also making the GUI compatible for both Windows and Mac operating systems."



Left to Right: ESDIS Project interns Jacob Moore and Irene Su with their mentor, Dr. Frank Lindsay. ESDIS Project image.

Next to Irene, Sameena Bajwa, a rising junior computer science major at Boston University and the third summer intern supporting the ESDIS office, describes her work developing software to help solve an ongoing problem—determining specific ESDIS datasets referenced in scientific articles in the absence of proper dataset citations. "Right now, the only way for the ESDIS Project to track who is writing about our data is to use citations, but we can't rely on authors to properly cite our data," she says. "Once I found enough of a trend [in the data], I wrote programming in Python to find links to the datasets."

The work of Jacob, Irene, Sameena, and other NASA interns is critical to moving projects forward or laying the groundwork for new missions. "[Sameena's] data citation project is one we've been wanting to start on and work on, but everyone is so busy that we just haven't been able to get to this," says Evelyn Ho, an ESDIS systems and software engineer and the ESDIS liaison with Goddard's Office of Education. "We'll be able to work off of what she's done and move this project forward."

In fact, the efforts and insight of summer interns are a key element in moving hundreds of NASA projects forward. Each fall, NASA puts out a call for projects to be added to the NASA Interns, Fellows & Scholars One Stop Shopping Initiative (NIFS/OSSI) website. Through the NIFS/OSSI website, students can search and apply for all NASA internship, fellowship, and scholarship opportunities in one location. A single application places a student in the applicant pool for consideration by all NASA centers.

NASA internships are available for high school, undergraduate, and graduate students. High school interns must be at least 16 years old and a current sophomore, junior, or senior; undergraduate and graduate students must be accepted or enrolled full-time in an accredited U.S. college or university. Along with a GPA of 3.0 on a 4.0 scale, perspective interns must be U.S. citizens. (NASA internships for international students from select countries are available through the NASA International Internship Program.)

Competition for the limited number of NASA internships is strong. "For each ESDIS opportunity [at Goddard] this year, we had about 20 applicants," says Ho. "It was a difficult decision to narrow these applicants down to the top candidates since all our applicants were very qualified and had good relevant experience."

Every intern works under the supervision of a mentor, and sometimes more than one mentor. Mentors play an important role in not just helping interns with their assigned projects, but also passing along the experience and knowledge they have acquired through their years at NASA. Dr. Frank Lindsay, an ESDIS Project systems engineer, is the mentor for Jacob and Irene, and notes that part of his role is to help students understand how their work fits into the larger NASA and ESDIS Project missions.

"It's important for them to know what the ESDIS Project does and why it's important for NASA to be collecting these data," says Lindsay. "We are a science agency, so everything we do relates back to the science. It's critical for them to understand the reasons behind why they're working on the project they've been given and the reasons behind why the app was developed and the scientific questions the app helps answer. I want them to take away this knowledge."

Along with the ESDIS and GES DISC interns at Goddard, more than 25 interns supported projects at many of the EOSDIS' 12 discipline-specific DAACs around the country.

This includes 13 interns at NASA's Atmospheric Science Data Center (ASDC) DAAC at NASA's Langley Research Center in Hampton, VA, the highest number of interns at any DAAC this summer.

2016 ASDC summer interns. Front row (Left to Right): Patrick Rea, Asher Mazaika, Nicole Raftery, Aoade Balogun, Rachel Erb, Preston Callaway, Gabe Perez. Back row (Left to Right): Joe Koch, Oliver Hamilton, Abigail Chen, Noah Dunn, Forrest Knight, I'Ran James. Photo by Kathleen Stevens.

"When we bring in an intern, we're bringing them in to serve a specific purpose. This is work that needs to be done and projects that help us accomplish our mission," says Walt Baskin, lead scientific programmer/analyst at ASDC and a mentor to four ASDC interns. "The beautiful freedom of this internship program is that our focus is not just limited to the specific task; it's to expose them to as much as they're able to take in."

ASDC also has the highest number of high school student interns of any DAAC: six. "I don't treat my high school students any differently than I would treat a graduate student," Baskin says. "What I've noticed this year is that our high school students are able to do more technical computer programming. Some of my high school students have accomplished tasks I would normally expect from a graduate student."

Back at the Intern Showcase in Goddard's Building 28, Elaine Keim, who recently received her bachelor's degree in geosciences with a minor in atmospheric science from Texas Tech University, describes her work supporting a GES DISC project. Elaine developed a climatology for the Giovanni data visualization and analysis system using data from the Atmospheric Infrared Sounder (AIRS) instrument aboard NASA's Aqua Earth observing satellite. "I looked at the difference between two averaging methods for these data: a weighted and an unweighted average," she says, pointing to her analysis on the large poster behind her. "I found that there is a significant difference between the data produced using these two methods."

While continuing her GES DISC work this fall, Elaine also will be taking graduate-level classes at the University of Maryland-College Park toward a master's degree in atmospheric science.

Nearby, Kush Bhakta, a rising junior mechanical engineering major at the Missouri University of Science and Technology, describes how he was able to combine his academic studies with his interest in unmanned aerial systems (UAS) to support a GES DISC data management project. As Kush notes, one problem with UAS or drone data is that while a lot of data are being produced, there are as yet no formal standards for organizing and preserving these data.

Kush created two databases. The first is a catalog of drone aerial data, which currently holds aerial photography. The other is a database of how people are using drones in the Earth sciences, including information about pre- and post-flight software used in the drone community. Along with GES DISC staff, Kush also worked with members of the Earth Science Information Partners (ESIP) Drone Cluster on his project. "The purpose [of this project] is to answer several questions: who is collecting data, how are they collecting these data, where are these data being collected, and what data are they collecting," he says. "Answering these questions will give us a real good view of the landscape of drones and from this we'll get a better idea about how these data are being collected and how the data are being used in the Earth sciences."

Of course, the intern experience involves more than simply working on tasks. Interns participate in many enrichment, networking, and social activities. Walt Baskin notes that the ASDC interns have tours and other activities every afternoon, including social gatherings where interns, mentors, and ASDC staff talk about issues as colleagues and developers. Intern activities at Goddard include a lecture by Nobel laureate and NASA astrophysicist Dr. John Mather, tours through laboratories and facilities, and participation in programming boot camps. "Interns certainly aren't stuck in a cubicle working on a project for 10 weeks," says Evelyn Ho. "We encourage them to network and build connections and really see how things go on here at NASA."

If the reaction of the interns to their summer at NASA is any indication, the program is accomplishing its goals. "This is where I want to work someday," says Jacob Moore. "It's great to learn how NASA employees interact with their colleagues and how work is done in this environment. To just experience this puts me light years ahead of where I was before this internship." Like Elaine Keim, Jacob is continuing his NASA internship in the fall, this time at NASA's Kennedy Space Center in Cape Canaveral, FL, where he will work on flight software for the Orion spacecraft.

Irene Su and Sameena Bajwa agree with Jacob. "You know that if you're working on a NASA project, then you're making a large impact at NASA," says Irene. "I feel that if you work here you just get really inspired, especially when you hear about other people's stories and their experiences working here."

"Everything was brand new to me and I've learned a lot," says Sameena. "I really like how you're doing something worthwhile that's going to be important."

For this summer's ESDIS and DAAC interns, all roads led to a valuable experience that they will take with them not only back to their campuses across the country, but, possibly, back to NASA as the next generation of NASA employees.

Additional Information

For more information about the NASA internship program and to search available internship opportunities, visit the NASA NIFS/OSSI website: *https://intern.nasa.gov/ossi/web/public/main*

Data Chat: Dr. Gail Skofronick-Jackson

Talking about NASA precipitation data with GPM Project Scientist Dr. Gail Skofronick-Jackson.

Dr. Gail Skofronick-Jackson at the Tanegashima Space Center in Japan for the GPM launch in February 2014. Photo by Warren Shultzaberger, NASA.

Since the launch of the joint NASA/Japan Aerospace Exploration Agency (JAXA) Tropical Rainfall Measuring Mission (TRMM) in 1997, NASA has continually collected global precipitation data using orbiting satellites. The most recent precipitation mission, the joint NASA/JAXA Global Precipitation Measurement (GPM) Core Observatory, launched in 2014. GPM expands NASA precipitation data to the mid-latitudes, and includes measurements of both liquid and frozen precipitation. Ensuring that these data meet GPM mission requirements as well as user needs in terms of content, quality, and availability is a critical task that is managed by GPM Project Scientist Dr. Gail Skofronick-Jackson. As Dr. Skofronick-Jackson observes, NASA precipitation data have far ranging uses for both science and society.

Your Ph.D. is in electrical engineering, yet a majority of your GPM work involves meteorology and physical processes. Do you see yourself as an electrical engineer, a meteorologist, or a combination of these two fields?

My background is all electrical engineering. But I don't build instruments. I'm a pure scientist who looks at science from a modeling point of view, an engineering point of view, an instrument point of view. I think this is my greatest strength—knowing how the instruments take these data and how these measurements relate back to the physical properties that are being measured. I understand how to take the physical measurements and model these into what the satellite sees. This is a really important aspect, because if you don't understand this relationship, you can't have good algorithms.

What is the significance of TRMM and GPM data?

We can use these data for scientific research and societal applications. Scientifically, this is really important information. We can put it into weather forecast models and climate change models because both of these [models] have a fairly simplistic representation of the snow and the ice within the cloud.

On the societal benefit side, the more data that you have in terms of where, when, and how precipitation—rain and snow—is falling, the better idea you have of where floods might occur, where landslides are more probable, and where there are droughts. With the data we get over the oceans you can see exactly where the hurricane eyes are located and where they are likely to make landfall.

How are these precipitation data collected?

TRMM and GPM data are collected using two different instruments that help us understand the storms, precipitation, and storm structure. One instrument is a radiometer. With the radiometer, the measurements are integrated through the precipitating cloud, so you can see total columnar intensities of rain and ice that provides horizontal structure of the precipitating event.

The other instrument is a radar. The radar allows us to see layer-by-layer within the storm. Every 250 meters vertically you can see the characteristics of the precipitating particles; essentially their size distributions. Through the radar data you can tell where the melting layer is because these frozen drops, which tend to be bigger than the liquid drops, get coated with liquid and appear like large raindrops leading to this big bulge in the data identifying the melting layer. You can tell different parts of the storm with the radar and you can see the storm three-dimensionally. Now, I've made this all seem so easy! In reality, the radar and radiometer measure reflectivities and brightness temperatures, respectively, that need sophisticated retrieval algorithms to convert them into precipitation information.

How does NASA's Precipitation Processing System aid in producing precipitation information?

Our Precipitation Processing System, or PPS, takes the data and converts them into the rain rates. Since the measurements from the radar are radar reflectivities and the measurements from the radiometer are brightness temperatures, you need to have an algorithm that converts these measurements into rain rates. There are science teams and algorithm teams leading investigations to develop the algorithms. PPS puts these algorithms into production so you can get rain rates.

The other really important thing through PPS is that we have near real-time products. This started with TRMM. It was not part of the TRMM requirements, but it is part of the GPM requirements. Our products are out anywhere from an hour to four hours after we get the data. These near real-time products are very helpful for monitoring on-going storms and for short-term forecasting.

Tell me about your data users.

We have two user communities. We have the sophisticated science users who have been working with satellite data forever and they know exactly how and where to go to get their data and analyze these data. These science users may want 25 flavors of the precipitation data. But there's a whole other community out there that is the applications community. They are used to their own applications area; they know they want precipitation data, but they don't necessarily know all the very fine attributes that the hard-core science users are requesting. The applications users just want to know what the rain rate is right now and which rain rate is the best to use for their specific application. It's interesting to work with two different user communities. The users have been very receptive to our intensive efforts to communicate how to access the data.

What can data users expect in terms of new GPM data enhancements or products?

The snow algorithm has fairly high error bars right now since snow retrievals from space are in their infancy and [snow] rates are very difficult to measure on the ground so you can actually validate [the GPM data]. These snow particles are all different shapes and sizes and they flutter as they fall. This makes it very difficult to accurately determine snow rate. We're trying to improve this algorithm to eliminate some of these error bars.

In terms of new products, we're looking more at applications-related products and application activities. We're also trying to get data to these types of users so they understand how to use it. We have workshops for applications users about once a year where we say here are the data, here's how you can go and get them, here are some plotting routines, and here are some completed plots. Our overall goal is to make sure that the science and application communities know how to use the data and get to the data.

Along with your work on GPM, you also are Chief of the Mesoscale Atmospheric Processes Laboratory. Tell me about this lab and the products available through this lab.

This lab is an interesting mix of people. We have the hard-core GPM scientists who are developing algorithms for GPM and TRMM and who are using the data scientifically. We have a group of modelers who develop cloud models that are used for GPM and to predict the weather for field campaigns and other modeling projects. One of our lab groups developed the CATS [Cloud-Aerosol Transport System] instrument on the International Space Station, which is looking at cloud particles. We also have a group looking at aerosols and the whole spectra of how clouds form. We have people building instruments for air and space, we have people doing science with satellite data, and we also have some ground validation people. There also are four labs within our lab where equipment is tested and built.

As an electrical engineer, do you ever want to get more hands on in the lab?

Oh yes, I love this! I'd like to think that the engineers in this lab appreciate that I understand some of these things.

Do you ever miss not being as hands-on as you were as an electrical engineer?

I really enjoyed the days when GPM was being built here at Goddard. I was much more immersed in the engineering and the science. I understood what was going on with the engineering. I was the [GPM] deputy project scientist at the time, and the current project scientist was much more of a pure scientist who did not have engineering training. I could sit on the fence and say, oh, engineers are having a problem and I think this is how this problem might affect the science. So I was a translator between the engineers and the science team.

What are the next steps in using satellites to measure global precipitation? Where do we go from GPM?

The GPM team submitted a recommendation to the 2017 Earth Science Decadal Survey for a new precipitation mission that is not a GPM follow-on, but a step beyond GPM in that we would look at clouds and precipitation. In TRMM and GPM, the instruments were only sensitive to precipitation-sized particles; we couldn't see stuff that's not precipitating. So we put in a request for a mission to look at cloud particles and the precipitating particles. You want to know what water is being retained in the atmosphere and what falls out. What's retained is what affects the cloud patterns which, in turn, affects the energy budget. Depending on the type of cloud, sunlight gets trapped or it gets reflected. This tells us more about both the hydrologic cycle and the energy budget cycle for global warming and the role that clouds play with that.

The next step beyond GPM also would be to sample at even higher latitudes. TRMM covered the tropics, GPM covers the mid-latitudes. The next step is to measure from pole-to-pole the sources of precipitation contributing to glaciers and sea ice.

What are some of the highlights of your role as GPM project scientist?

My professional background is falling snow, so I'm really excited that GPM can measure falling snow. In fact, just two-and-a-half weeks after launch we got one of the most visually compelling snow estimates we've ever seen during [a] snowstorm in the Washington, D.C., area. It's just really rewarding to see the snow!

Also, there's a large GPM science team out there. We have 60 principal investigators who are using TRMM and GPM data to further precipitation science and benefit society. Every time one of these scientists makes a new discovery or publishes a paper using these data it's really rewarding to know that I had a small part in making this happen.

Sharing GPM with the science community and the public through outreach events and through Hyperwall presentations is also a highlight of my work. People understand the importance of precipitation; it's essential for life on Earth.

You attended the GPM launch. Tell me about that experience.

My gosh, it was great! It was the first NASA launch I had ever seen and it was in Japan, a nighttime launch. My heart was pounding. It was beautiful; it was absolutely beautiful.

A Japanese H-2A rocket launches NASA's Global Precipitation Measurement Core Observatory satellite toward orbit from Tanegashima Space Center in Japan early Feb. 27, 2014 local time.
Credit: JAXA/NASA TV

Explore Current Natural Hazards with the new NASA Worldview/EONET Events Feature

Imagery and information about current natural hazard events are only a click away thanks to a collaboration between Worldview and the Earth Observatory Natural Event Tracker (EONET).

Users of NASA's Worldview (https://worldview.earthdata.nasa.gov) application may have noticed a new "Events" tab sandwiched between the "Layers" and "Data" tabs in the upper left home page window. Clicking on the Events tab reveals a list of natural events, including wildfires, tropical storms, and volcanic eruptions. Selecting one of these events transports users seamlessly back in time to imagery and data about the selected event. Almost 50 events currently are part of the Worldview Events feature.

Viewing an event is simple. Click on the Worldview Events tab in the upper left corner of the Worldview home page to bring up a chronological list of events. Once an event is selected, Worldview zooms to the location and date of the event. In the animation below, California's Gap Fire from August 27 is first selected. Immediately, Worldview zooms to the Terra/MODIS (true color) image of Northern California for August 27, which also includes the Fire and Thermal Anomalies (day and night) Terra/MODIS layer with red dots indicating the fire's detected hot spots. Next, Hurricane Hermine is selected, which brings up four separate images showing the progression of this recent storm.

Additional data layers can be added to a selected event's imagery with a few mouse clicks through the existing Worldview functionality.

In addition, each event has a link to information about the event. For example, clicking on the Events tab for the Gap Fire near the California/Oregon border provides a link to the Incident Information System web page about this fire.

The Events feature is a collaboration between Worldview and NASA's Earth Observatory Natural Event Tracker (EONET). EONET is an application program interface (API) that provides a continually curated list of natural events. In addition, each event has links to related near real-time image layers for viewing in client applications such as Worldview.

Worldview is a natural partner with EONET since it already provides access to hundreds of imagery layers created from data collected by instruments aboard Earth observing satellites. Many of these images are available within three to four hours of a satellite overpass, making

Clicking on the InciWeb link in the Gap Fire Event takes you to additional information about this event.

these near real-time images an invaluable tool for managers, forecasters, and researchers needing a quick view of an event without the need for the more heavily processed data required for scientific research.

Check out the new Events feature in Worldview and explore your dynamic planet!

NASA's fleet of Earth observing satellites collect data about our planet 24/7. Images produced from these data become part of NASA's Global Imagery Browse Services (GIBS). GIBS is part of NASA's Earth Observing System Data and Information System (EOSDIS), and provides access to over 240 trillion pixels' worth of imagery designed to provide a quick overview of an event or a summary of atmospheric data for rapid analysis. GIBS images can be browsed interactively through clients such as Worldview, which also allows users to download the underlying data.

NASA's EOSDIS provides end-to-end capabilities for managing NASA's Earth science data. The primary services provided by EOSDIS are data archive, management, and distribution; information management; product generation; and user support services. These services are managed by NASA's Earth Science Data and Information System (ESDIS) Project

User Profile: Dr. John Fasullo

Who uses NASA Earth science data? Dr. John Fasullo, to track changes in Earth's climate

Dr. John Fasullo in Jamaica pointing out NASA's ability to determine global mean sea level to within 1mm given the complicating effects of tides, waves, and sampling challenges. Image courtesy of Dr. John Fasullo.

Dr. John Fasullo, Project Scientist, National Center for Atmospheric Research (NCAR)

Research interests: Climate variability and change with a focus on the energy and water cycles.

Current research: Earth's climate is changing, and NASA has the numbers to prove it. According to data from NASA's Global Climate Change website based on studies by NASA/NASA's Goddard Institute for Space Studies (GISS), NOAA, and the University of East Anglia, global mean surface temperature has risen about 0.78˚C (about 1.4˚F) since 1880 (with 9 of the 10 warmest years ever recorded occurring since 2000) and Arctic ice reached its lowest extent ever recorded in the satellite era on September 16, 2012.

As also noted on the Global Climate Change website, global mean sea level is rising about 3.4 mm per year. This is why a drop in global mean sea level of roughly 7 mm during 2010 and 2011 was an unexpected event, and an event well-suited to Dr. John Fasullo's research interests.

Dr. Fasullo uses NASA Earth observing data to characterize Earth's climate and test various theories about the effects of climate change on Earth processes, particularly effects on the energy and water cycles. Changes in global mean sea level are indicative of variability of both cycles due to the ocean's large role distributing global heat and moisture. If global sea level falls, such as in 2010-2011, this means that water was prevented from entering the ocean. For Dr. Fasullo, this raised the obvious question: Where did this water go and where was it stored?

Much of the data used by Dr. Fasullo for monitoring global mean sea level come from Earth observing missions. These include the joint NASA/German Aerospace Center Gravity Recovery and Climate Experiment (GRACE) satellite mission, which studied Earth's gravity field, and the joint NASA/French Space Agency (CNES) TOPEX/Poseidon mission and Jason series of satellite missions, which study ocean surface topography.

Dr. Fasullo also relies on climate models. These models use complex algorithms and high power computers to analyze Earth observing data collected over many years by satellite, airborne, and ground-based instruments. Models such as NASA's Goddard Earth Observing System Model, Version 5 (GEOS-5), NCAR's Community Earth System Model version 1 (CESM1), and the World Climate Research Programme's Coupled Model Intercomparison Project Phase 5 (CMIP5) attempt to simulate and predict climate responses to events, such as an increase in carbon dioxide or a volcanic eruption. These models are constantly checked against data collected by Earth observing missions and real-world events to ensure that their projections accurately reflect actual environmental responses.

These models sometimes are found to contain biases. Along with monitoring global mean sea level, Dr. Fasullo also looks at these biases. In one recent study, Dr. Fasullo and his colleagues identified major differences in how some climate models simulate clouds, which are notoriously difficult to simulate due to their complexity. Not only are clouds difficult to track and detect, they also differ in microphysical properties. These microphysical properties include the condensation nuclei around which water vapor adheres to form clouds and water droplets. As a result, cloud processes in models are more general than exact, which can lead to different models returning different simulations of environmental conditions.

In order to minimize potential model bias, Dr. Fasullo and his colleagues developed an approach to look at the environment in which clouds occur, rather than the clouds themselves. This approach relies on relative humidity, which is easily tracked and measured in the atmosphere by instruments aboard satellites, such as the Clouds and the Earth's Radiant Energy System (CERES) instrument aboard NASA's Tropical Rainfall Measuring Mission (TRMM, which ended in 2015), Terra, Aqua, and Suomi-NPP satellites.

Data products used:

- GRACE gravity field measurements, available through NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC)
- Sea Level Rise from Satellite Altimetry data available through NASA's Global Climate Change portal
- Various products from TRMM, which are available through NASA's Precipitation Measurement Missions portal
- Various data sets from NASA's Global Precipitation Climatology Project (GPCP), which is part of the Mesoscale Atmospheric Processes Laboratory located at NASA's Goddard Space Flight Center
- Various cloud and flux data sets produced from data collected by the CERES instrument

Research findings:

So where did water go that did not end up in the ocean in 2010-2011? The answers found by Dr. Fasullo and his colleagues involve several contributing factors that occurred over an 18 month period, among which were La Niña conditions in the Eastern Pacific Ocean (that is, cooler than normal ocean water, which is the opposite of El Niño conditions) and the unique nature of Australia's rivers. The end result was a rare combination of climatic factors that led to historically heavy rainfall in Australia that was prevented from flowing into the ocean long enough to cause a drop in global sea levels.

During 2010-2011, La Niña conditions transported moisture from east to west, resulting in heavier than normal rainfall in the western Pacific Ocean. Meanwhile, an atmospheric circulation pattern called the Indian Ocean Dipole, or IOD, had entered a negative phase. A negative IOD phase is characterized by warmer than normal water in the eastern Indian Ocean and cooler than normal water in the western Indian Ocean. This negative IOD led to heavier than normal precipitation in the western Pacific, especially over Australia. In addition, another atmospheric circulation pattern called the Southern Annular Mode (SAM) had entered a negative phase and was drawing moisture and storm systems from the western Pacific southward. These factors led to the heaviest rainfall ever recorded in many parts of Australia.

Over most land regions, this excess water would simply drain into the ocean. However, Australia has two unique characteristics that prevent water from easily running to the sea. When rain falls in Australia, particularly in the eastern part of the continent, it runs inland and is collected in basins that trap water. This type of basin is called an endorheic basin. The only way water leaves an endorheic basin is through evaporation or slow seepage. Compounding this, Australia also has very low runoff ratios due to its large expanse of desert. These areas with very low runoff are called arheic, and also prevent moisture from easily escaping.

Dr. Fasullo and his colleagues found that these factors led to heavier than normal precipitation falling on an area that trapped this water and prevented it from flowing easily to the sea, leading to a decrease in global mean sea level. Dr. Fasullo's research also found that simply having La Niña conditions in place is not enough to cause such a large decrease in global mean sea level; a number of other climate factors (such as the negative phase of the IOD and the SAM) also need to be present to cause substantially heavier than normal precipitation to fall in areas that prevent this water from running into the sea, such as in Australia.

In their work on minimizing model biases through the use of the cloud/relative humidity relationship, Dr. Fasullo found that the tropics and subtropics both show seasonal variations in relative humidity that correlate strongly with the formation of clouds and the warming projected by models in response to increases in carbon dioxide in the 21st century. Adjusting climate models to use observed variations in relative humidity gathered from Earth observing satellites that can sense moisture in the troposphere should help lower model biases and enable these models to make better predictions of future climate trends.

Read about the research:

Fasullo, J.T., Lawrence, D. & Swenson, S. (2016). "Are GRACE-era terrestrial water trends driven by anthropogenic climate change?" Advances in Meteorology, 2016 [doi: 10.1155/2016/4830603].

Fasullo, J.T., Boening, C., Landerer, F.W. & Nerem, R.S. (2013). "Australia's unique influence on global sea level in 2010-2011." Geophysical Research Letters, 40(16) [doi: 10.1002/grl.50834].

Fasullo, J.T. & Trenberth, K.E. (2012). "A less cloudy future: The role of subtropical subsidence in climate sensitivity." Science, 338(6108) [doi: 10.1126/science.1227465].

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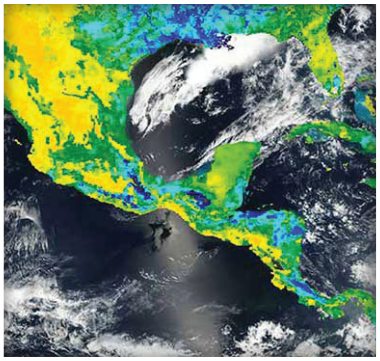

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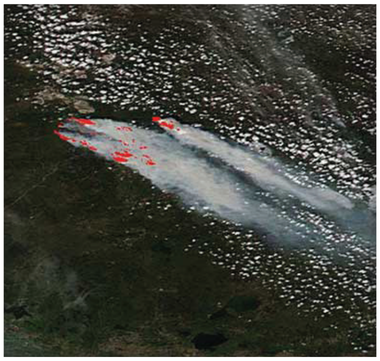

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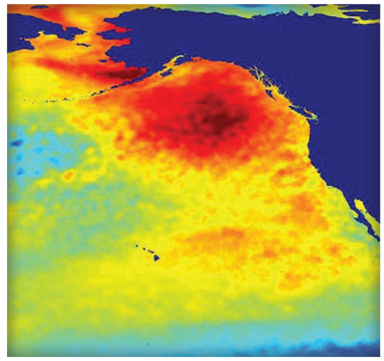

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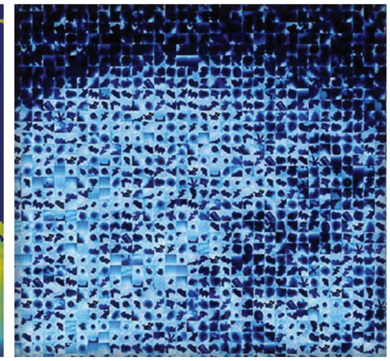

Mid-latitude Continental Convective Clouds Experiment (MC3E)

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Phytoplankton bloom in Lake Erie

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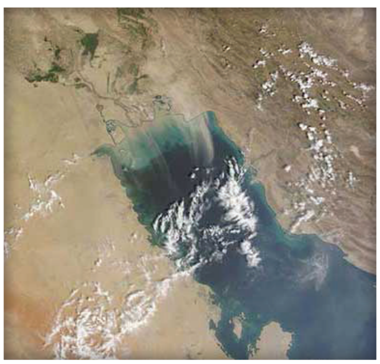

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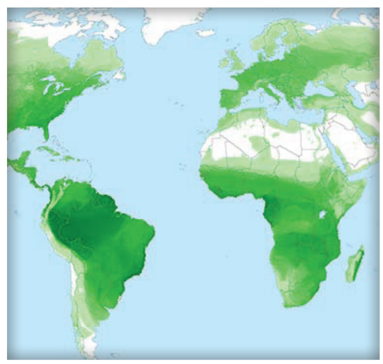
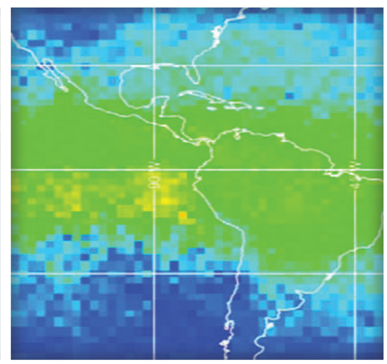


Looking at Global Amphibian Density

https://earthdata.nasa.gov/mastheads

Published on August 22, 2016



Sensing Ice Clouds

https://earthdata.nasa.gov/mastheads

Published on August 29, 2016