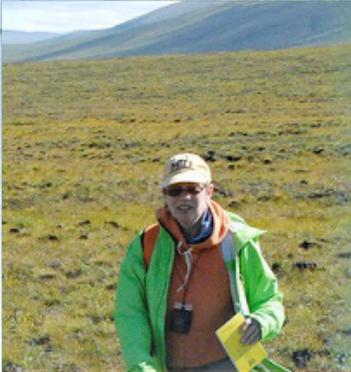
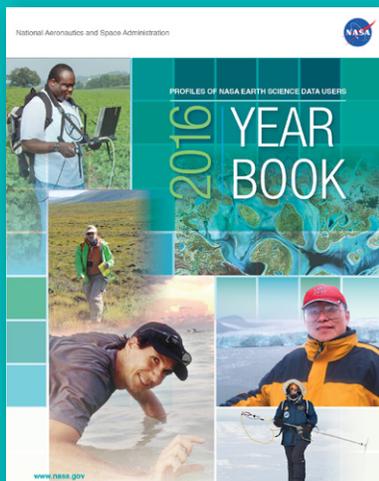




PROFILES OF NASA EARTH SCIENCE DATA USERS

2019 YEAR BOOK

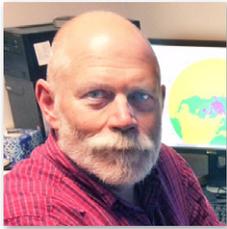




**COVER:** (Counterclockwise from upper left) Dr. Bernard Hubbard, Dr. Nancy French, Dr. John Fasullo, Dr. Gina Henderson, and Dr. Xiaofeng Li.

NASA's Earth Observing System Data and Information System (EOSDIS) is pleased to present the 2016 EOSDIS Data User Profile Yearbook. From investigating the effects of biomass burning in Sub-Saharan Africa to testing predictions of the theory of general relativity, EOSDIS data users are applying NASA Earth observing data to a wide range of research. The EOSDIS Data User Profile series showcases these scientists, researchers, managers, and educators along with the data products that make their work possible. Our Data User Profile Yearbook gives you a taste of the breadth of research enabled by the vast NASA EOSDIS data collection.

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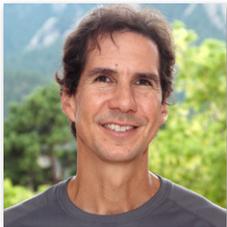
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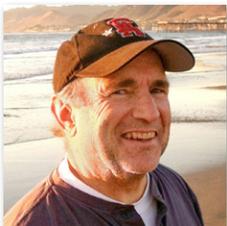
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# Who Uses Earth Science Data?

Dr. Mark Anderson, to better understand how frozen surfaces react to changing atmospheric conditions.



## Dr. Mark Anderson

**Associate Professor,**  
Department of Earth and  
Atmospheric Sciences,  
University of Nebraska-Lincoln

**Research interests:** Water is an incredible substance. It exists in three separate states—solid (frozen), liquid, and gas (water vapor) — and can change from one state to another at normal Earth temperatures. This is especially true in the atmosphere, where water vapor rises, cools, condenses back into a liquid, and then (if chilled enough) re-freezes back into a solid.

Dr. Mark Anderson's research looks at how frozen precipitation (snow and ice) forms and falls through the atmosphere and how frozen surfaces react to atmospheric conditions. This research has important implications in areas that undergo seasonal periods of melting and re-freezing, such as the open waters of the Arctic.

As surface ice in the Arctic starts to melt in the spring, the crystalline structure of the ice changes. This structural change can be detected by passive microwave sensors carried on orbiting satellites, such as the [Advanced Microwave Scanning Radiometer-Earth Observing System \(AMSR-E\)](#) instrument aboard NASA's [Aqua satellite](#). The dates that sea ice begins to melt and break apart, along with when this water begins to re-freeze, impacts global climate, sea level, and, through the availability of shipping lanes, commerce. Remotely-sensed data from Earth observing satellites are a key tool Dr. Anderson uses for determining when snow or ice-covered surfaces are melting and the start of this melting and re-freezing.

**Research highlights:** Dr. Anderson is studying whether ice surfaces in the Arctic Ocean and surrounding northern hemisphere bays and seas are melting earlier than before, how much the date of first melt has changed over time, and how rapidly the onset of first melt may be changing.

Since 1979, remotely-sensed passive microwave ice melt data have been collected by instruments on various satellite platforms. Along with AMSR-E, these instruments include the [Scanning Multichannel Microwave Radiometer \(SMMR\)](#) on NASA's Nimbus-7 satellite and the [Moderate Resolution Imaging Spectroradiometer \(MODIS\)](#) instrument on NASA's Terra and Aqua satellites. These data are distributed through NASA's [Earth Observing System Data and Information System \(EOSDIS\) Distributed Active Archive Centers \(DAACs\)](#), and can be accessed through NASA's [National Snow and Ice Data Center \(NSIDC\) DAAC](#).

### **Data products used (all data sets are available through NASA's NSIDC DAAC):**

#### **Data sets with melt onset dates:**

- MEaSUREs Arctic Sea Ice Characterization Daily 25km EASE-Grid 2.0, Version 1 [doi: [10.5067/MEASURES/CRYOSPHERE/nsidc-0532.001](https://doi.org/10.5067/MEASURES/CRYOSPHERE/nsidc-0532.001)]
- Snow Melt Onset Over Arctic Sea Ice from SMMR and SSM/I-SSMIS Brightness Temperatures, Version 3 [doi: [10.5067/22NFZL42RMUO](https://doi.org/10.5067/22NFZL42RMUO)]

#### **Data sets used to determine melt onset dates:**

- NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 2 [doi: [10.7265/N55M63M1](https://doi.org/10.7265/N55M63M1)]
- Nimbus-7 SMMR Polar Gridded Radiances and Sea Ice Concentrations, Version 1 [doi: [10.5067/QOZIVYV3V9JP](https://doi.org/10.5067/QOZIVYV3V9JP)]

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# Who Uses Earth Science Data?

- DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures, Version 4 [doi: [10.5067/AN9AI8EO7PX0](https://doi.org/10.5067/AN9AI8EO7PX0)]

**Data sets developed by Dr. Anderson as part of NASA's Making Earth System Data Records for Use in Research Environments (MESEDR) Program:**

- Northern Hemisphere State of Cryosphere Daily 25km EASE-Grid 2.0, Version 1 [doi: [10.5067/MEASURES/CRYOSPHERE/nsidc-0534.001](https://doi.org/10.5067/MEASURES/CRYOSPHERE/nsidc-0534.001)]
- Northern Hemisphere State of Cryosphere Weekly 100km EASE-Grid 2.0, Version 1 [doi: [10.5067/MEASURES/CRYOSPHERE/nsidc-0535.001](https://doi.org/10.5067/MEASURES/CRYOSPHERE/nsidc-0535.001)]

**Research findings:** Through an analysis of almost 35 years of Arctic microwave data, Dr. Anderson and his colleagues found that there is about a 10-day earlier melt onset than at the beginning of the data collection period. Even more significantly, Dr. Anderson found that regional differences can be greater. For example, the mean melt onset date for the Arctic region is 13 May ( $\pm 7.3$  days). Regionally, mean melt onset varies from 15 March in the St. Lawrence Gulf to 10 June in the Central Arctic. Dr. Anderson's next steps are to examine the differences in atmospheric conditions for these locations that might contribute to the differences in melt onset along with overall changes in atmospheric conditions over time.

## Read about the research:

Bliss, A.C. & **Anderson, M.R.** (2014). "Daily Area of Snow Melt Onset on Arctic Sea Ice from Passive Microwave Satellite Observations 1979–2012." *Remote Sensing*, 6(11) [doi: [10.3390/rs61111283](https://doi.org/10.3390/rs61111283)].

Bliss, A.C. & **Anderson, M.R.** (2014). "Snowmelt onset over Arctic sea ice from passive microwave satellite data: 1979–2012." *The Cryosphere*, 8 [doi: [10.5194/tc-8-2089-2014](https://doi.org/10.5194/tc-8-2089-2014)].

Anderson, M.R., Busse, J.L. & Drobot, S.D. (2012). "A comparison between SSM/I passive microwave melt onset dates and satellite-derived albedo melt onset dates in the Arctic." *International Journal of Remote Sensing*, 33(2) [doi: [10.1080/01431161.2010.542198](https://doi.org/10.1080/01431161.2010.542198)].

# Who Uses Earth Science Data?

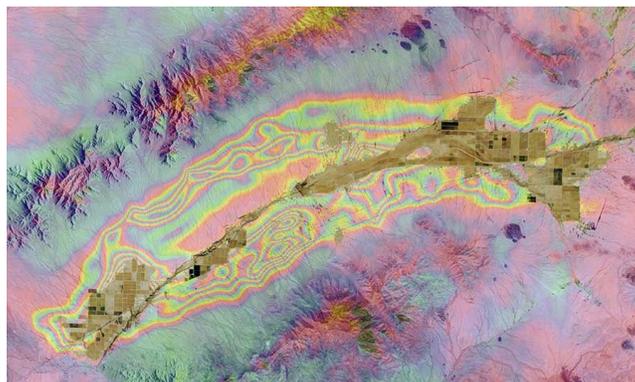
Brian Conway, to monitor land subsidence and the impacts of this on Arizona's water resources.



## Brian Conway

**Hydrologist and Supervisor,**  
Geophysics/Surveying Unit,  
Arizona Department of Water  
Resources (ADWR)

**Work and research highlights:** Brian Conway spends his days monitoring the sinking of Arizona. The area Conway monitors, which is mainly in south-central and southern Arizona, has been sinking since the mid-1900s. In fact, the elevation of some areas of Maricopa and Pinal Counties in south-central Arizona has decreased more than 5.5 meters (18 feet) over more than 60 years—an amount slightly less than the height of a two-story building. This is generally due to the compaction of the sub-surface alluvium, which is a mixture of clay, silt, sand, and gravel. As the groundwater within the alluvium is removed through pumping for agriculture, development, and other uses, the pore spaces in the alluvium collapse, leading to a lowering in land elevation. This lowering is referred to as land subsidence. Subsidence also can lead to earth fissures, or hairline cracks that grow and widen as surface water erodes material from the sides and bottom of the earth fissure. Some earth fissures can be more than 10 meters (33 feet) deep and several meters wide. Land subsidence and earth fissures cause millions of dollars in damage to private property and infrastructure (such as roads, railroads, canals, pipelines, and bridges), and can lead to changes in drainage patterns and weaken water retention features like dams and levees. Conway has been monitoring land subsidence in Arizona since joining the [ADWR](#) in 1999, shortly after the start of the ADWR land subsidence monitoring program. The Arizona land subsidence monitoring program is mandated by state statute.



An InSAR image of the McMullen Valley groundwater basin in south-central Arizona showing the colored fringes indicating changes in elevation between 2010 and 2015. Each complete color sequence fringe in this image, from blue to blue, indicates 2.8 cm (1.1 in) of elevation change. Image courtesy of ADWR.

depict these small land changes as colored fringes on an image called an interferogram. An interferogram shows the location of subsidence and allows you to estimate the magnitude of subsidence based on the number of complete fringe cycles. Conway supplements InSAR images with global navigation satellite system (GNSS) data, which provide pinpoint measurements of locations anywhere in the world. He also uses relative and absolute gravimeters to monitor aquifer storage changes. Gravimeters are instruments used to measure local gravitational fields. These gravitational fields are affected by changes in the amount of water contained in aquifers, and measurements of these gravity changes provide information about aquifer water resources. Finally, Conway uses depth-to-bedrock modeling and aquifer storage estimates to keep track of Arizona's water resources.

An important technology Conway uses to monitor land subsidence is synthetic aperture radar (SAR), which uses radar pulses to produce high resolution images of Earth's surface 24/7. By comparing images of an identical area captured days, months, or years apart, slight shifts in the land surface on the order of centimeters or millimeters can be observed. This technique, called interferometry, uses interferometric synthetic aperture radar (InSAR) images to

(Continued)

# Who Uses Earth Science Data?

**Current research focus:** Conway uses InSAR and GNSS data to determine the spatial extent, magnitude, and rate of historical and current land subsidence. The majority of the InSAR data that ADWR collect, process, and analyze are for areas in south-central and southern Arizona, which is at the northern edge of the Sonoran Desert. This region is home to not only Phoenix and Tucson, the two largest cities in the state, but also the location of extensive agriculture. This combination of high water demand and low annual precipitation leads to significant areas of subsidence.

Conway also monitors aquifer storage using gravimeters to acquire micro-gravity measurements, which provide data about aquifer storage and dynamics. Since 1999, he has focused this research in the Pinal and Phoenix Active Management Areas in the central and south-central areas of the state. These data, along with depth-to-groundwater data, are used by ADWR's groundwater modelers for the calibration and validation of models describing water resources.

## **Data products used (all are available through NASA's [Alaska Satellite Facility](#) & [Distributed Active Archive Center](#) (DAAC):**

- [ALOS-1 PALSAR](#), 10 to 100 meters resolution; each satellite frame is 40 to 70 kilometers; 46-day repeat [doi: [10.5067/JBYK3J6HFSVF](#) and [10.5067/Z97HFCNKR6VA](#)]
- [Radarsat-1](#), 10 to 100 meters resolution; each satellite frame is 100 kilometers; 24-day repeat
- [Sentinel-1A](#), 20-meter resolution; each satellite frame is 250 kilometers; 12-day repeat

**Research findings:** A comparison of historical InSAR data with more recent data shows that land subsidence rates have decreased between 25% and 90% in groundwater active management areas where imported Colorado River water has been used to offset groundwater pumping. As a result, groundwater levels in these areas have been recovering since the mid 1990's. In addition, areas that are either outside groundwater active management areas or that do not have access to imported Colorado River water to offset groundwater pumping are experiencing increased land subsidence rates as much as three to four times higher when compared with historical InSAR data.

## **Read about the research:**

Conway, B.D. (2014). "Arizona Department of Water Resources Land Subsidence Monitoring Report No 2." [http://www.azwater.gov/AzDWR/Hydrology/Geophysics/documentsADWRLandSubsidenceMonitoringReport\\_Number2\\_Final.pdf](http://www.azwater.gov/AzDWR/Hydrology/Geophysics/documentsADWRLandSubsidenceMonitoringReport_Number2_Final.pdf)

Conway, B.D. (2014). "Monitoring Land Subsidence and Floodplains in Arizona." *Alaska Satellite Facility News and Notes*, 10(2). [http://www.azwater.gov/AzDWR/Hydrology/Geophysics/documents/ASFNewsandNotes\\_2014\\_Fall.pdf](http://www.azwater.gov/AzDWR/Hydrology/Geophysics/documents/ASFNewsandNotes_2014_Fall.pdf)

Conway, B.D. & Cook, J.P. (2013). "Monitoring Evaporite Karst Activity and Land Subsidence in the Holbrook Basin, Arizona using Interferometric Synthetic Aperture Radar (InSAR)." Proceedings for the 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst. [http://www.azwater.gov/AzDWR/Hydrology/Geophysics/documents/2013\\_SinkholeConference\\_HolbrookKarst.pdf](http://www.azwater.gov/AzDWR/Hydrology/Geophysics/documents/2013_SinkholeConference_HolbrookKarst.pdf)

# Who Uses 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.

**Research highlights:** 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.

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# Who Uses Earth Science Data?

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 \(PMM\)](#) 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.

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# Who Uses Earth Science Data?

In his 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 21<sup>st</sup> 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:

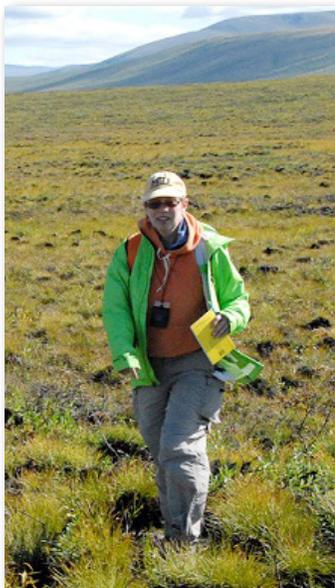
Fasullo, J.T., Lawrence, D. & Swenson, S. (2016). "Are GRACE-era terrestrial water trends driven by anthropogenic climate change?" *Advances in Meteorology*, 2016 [doi: [10.1155/2016/4830603](https://doi.org/10.1155/2016/4830603)].

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](https://doi.org/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](https://doi.org/10.1126/science.1227465)].

# Who Uses Earth Science Data?

Dr. Nancy French, to study the effects of wildfires on forest ecosystems.



Dr. Nancy French walking a sampling transect at a burn site in Noatak National Preserve in the Alaskan tundra in August 2011. Image courtesy of Dr. Nancy French.

## Dr. Nancy French

**Senior Scientist,**  
Michigan Tech Research  
Institute; Adjunct Professor,  
School of Forest Resources  
and Environmental Science,  
Michigan Technological  
University

**Research interests:** Applications of remote sensing to ecology and vegetation studies.

**Research highlights:** The ingredients necessary to create a wildland fire are simple: a source of fuel, heat to bring the fuel to its ignition temperature, and oxygen to sustain the resulting combustion. As the fire burns, it releases smoke and other emissions. One of these emissions is carbon, the sixth most abundant element in the universe and an essential component of life on Earth. Carbon is continually cycled through processes such as burning and the decay of organic material. The integrated processes of wildland fire and carbon cycling form the cornerstones of Dr. Nancy French's research.

Dr. French uses remote sensing data and the application of remote sensing techniques to study forest ecosystems. More specifically, her research focuses on wildfires and the effects of these fires on the structure and function of ecosystems along with the impacts of wildfires to carbon cycling, energy balance, and air quality. Her research relies on a variety of remote sensing techniques to study vegetation, including synthetic aperture radar (SAR) images and data from multi-spectral sensors such as the joint NASA/USGS Landsat series of satellites and the [Moderate Resolution Imaging Spectroradiometer \(MODIS\)](#) instrument aboard NASA's [Aqua](#) and [Terra](#) Earth observing satellites. Dr. French also works with modeling experts to use NASA-developed models, such as the [Carnegie-Ames-Stanford Approach \(CASA\) biosphere model](#), to predict future impacts on ecosystems based on past fire and ecosystem observational data. Examples of her recent research show the application of these various components.

In one NASA study, Dr. French used geospatial and remote sensing methods to better understand, verify, and quantify expected increases in the number of wildfires in tundra ecosystems due to global climate change and predict future fire potential in northern Alaska. Data from MODIS along with Landsat optical imagery were used to assess changes in burn scars over time. In addition, SAR imagery from the European Space Agency's [European Remote Sensing Satellite \(ERS-1/2\)](#) and the Japan Aerospace Exploration Agency's [Advanced Land Observing Satellite-1 \(ALOS-1\)](#) were used to assess burned areas and the impacts of fire on changes in the amount of radar energy reflected from the land surface. The use of MODIS, Landsat, and SAR imagery enabled a broad assessment of fire-impacted areas using a wide range of spectral bands (infrared, visible, and microwave). Images produced from these data allowed changes in these burn areas to be tracked over time as vegetation recovered. This research continues as part of NASA's [Arctic-Boreal Vulnerability Experiment \(ABoVE\)](#).

Dr. French also received NASA funding to develop methods for evaluating wildland fire emissions and fuel consumption. Prior to the development of satellite-based instruments to study vegetation and burned areas, assessments of emissions from biomass burning were based on fragmentary data from fire-activity reports submitted by land managers and government agencies. The value of these fire-activity reports was limited, though, due to their lack of detailed land use and land cover type data. As a result, these reports generally had overly broad assessments of the amount and type of vegetation burned and the characteristics of the burning. Through the use of remotely sensed data, Dr. French and her colleagues were able to more accurately assess vegetation type and ecological conditions in a burn area. These

(Continued)

# Who Uses Earth Science Data?

observations, combined with field data, led to the development of more precise methods for understanding the variability in wildfire emissions arising from the type of vegetation that is burned and the proportion of this fuel that is consumed.

Finally, Dr. French participated in several studies evaluating the effectiveness of satellite-based data (such as SAR and multi-spectral optical data) in assessing fire extent and severity, mainly in boreal, tundra, and peat environments. The multi-spectral optical data used included the Landsat-derived Normalized Burn Ratio (NBR) and differenced Normalized Burn Ratio (dNBR) algorithms, which use [Landsat Thematic Mapper \(TM\)](#) and [Enhanced Thematic Mapper Plus \(ETM+\)](#) imagery to map the variability of vegetation cover at burn sites. The research team specifically looked at the effects of fire on soil water status, surface fuel consumption, and post-fire vegetation recovery. They compared data derived from remotely-sensed metrics (such as NBR and dNBR) with data derived from field metrics (such as the Composite Burn Index [CBI], which is a measure of burn severity based on ground observations that attempts to numerically describe the ecological consequences of a fire). This research was mainly focused on fires in Alaska, but also included sites in Russia and in western U.S. states.

## Data products used:

### ■ MODIS data sets:

- Vegetation Continuous Fields, [MOD44A](#) (Terra, composite) and [MOD44B](#) (Terra, annual), both of which are available through NASA's [Land Processes Distributed Active Archive Center \(LP DAAC\)](#)
- Level 3 8-Day Daily Composite Fire Product, [MOD14A1](#) (Terra) and [MYD14A1](#) (Aqua), both of which are available through LP DAAC
- Burn Area (MCD64A1); available through the [Wildland Fire Emissions Information System \(WFEIS\)](#) website
- Albedo ([MCD43A3](#)) at 1000 m; available through LP DAAC

### ■ Various data sets from the [Advanced Spaceborne Thermal Emission and Reflection Radiometer \(ASTER\)](#) instrument; available through LP DAAC

### ■ [ERS-1/2 SAR data](#); available through NASA's [Alaska Satellite Facility \(ASF\) DAAC](#)

### ■ [ALOS-1 PALSAR data](#); available through ASF DAAC

### ■ Landsat TM and ETM+ data; available through the U.S. Geological Survey's [Earth Explorer](#) interface and [GloVis](#) data viewer

**Research findings and outcomes:** In her work investigating potential changes in the number and scope of tundra wildfires due to global climate change, Dr. French and her colleagues found that small tundra fires, defined in their research as those with a mean size of 2,452 acres (almost 10 km<sup>2</sup>) and a median size of 16 acres (0.06 km<sup>2</sup>), are common. As a rough size estimate, one acre is slightly smaller than the size of an American football field. With an increase in warmer summers and an extended period of vegetation drying, fire activity is expected to increase in this region. Another tundra study used MODIS data to assess changes in the amount of light and radiation reflected from a surface, or albedo. Wildfire has a strong impact on albedo since burned vegetation darkens the surface, which leads to less light and radiation being reflected and more solar radiation being absorbed. This, in turn, can lead to greater warming of the upper soil layers in these darker, burned areas that can impact productivity. Dr. French found that there was a marked decrease in the

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# Who Uses Earth Science Data?

amount of reflected light from a burned area in the year following a fire, but that areas in her study returned to pre-fire albedo levels in roughly four years.

Through her NASA-funded fire emissions and fuel consumption research, Dr. French and her colleagues note that remotely-sensed data provide information about several factors that are required for estimating carbon emissions from wildfires: the fire's spatial extent; the fuel type, fuel load, and plant physiological and moisture conditions; site characteristics before and after the fire event; and environmental factors during the fire that can influence fire intensity and severity (such as wind speed and direction, changes in humidity, and atmospheric temperature profiles). This work led to the development of the [Wildland Fire Emissions Information System \(WFEIS\)](#). WFEIS provides a simple interface for computing wildland fire emissions across the continental U.S. and Alaska at landscape to regional scales. WFEIS also provides access to the spatial data and models needed to compute emissions from fires within the WFEIS fire database. Using MODIS burn area products or Landsat-based burn perimeters mapped by the USGS, which are available through the [Monitoring Trends in Burn Severity \(MTBS\)](#) project. WFEIS is able to compute emissions for anywhere within the U.S. that is known to have burned.

Dr. French's work evaluating the benefits of using remotely sensed data for assessing fire and fire effects showed the necessity of combining remotely-sensed data with field measurements. As she and her co-authors note, while satellite data can be invaluable for mapping and determining variables such as fire perimeters, especially in remote areas, a combination of satellite images and data gathered from field investigations is necessary for a complete understanding of fire effects. Dr. French notes that MODIS products provide information on the spatial locations of fires and burn areas that are essential for quantifying fire emissions and for mapping the ecological consequences of fire. Vegetation mapping and monitoring from MODIS, ASTER, and Landsat provide important information about site ecology as well as actual and potential fire emissions that can be combined with data from field investigations to create a more precise, ecologically-based assessment of fire effects. Dr. French and her colleagues also developed ways to use SAR imagery for mapping soil moisture in areas of low stature vegetation and for assessing soil moisture in sites within boreal Alaska where permafrost is present.

## Read about the research:

French, N.H.F., Whitley, M.A. & Jenkins, L.K. (2016). "Fire disturbance effects on land surface albedo in Alaskan tundra." *Journal of Geophysical Research: Biogeosciences*, 121(3) [doi: [10.1002/2015JG003177](#)].

French, N.H.F., Jenkins, L.K., Loboda, T.V., Flannigan, M., Jandt, R., Bourgeau-Chavez, L.L. & Whitley, M. (2015). "Fire in arctic tundra of Alaska: past fire activity, future fire potential, and significance for land management and ecology." *International Journal of Wildland Fire*, 24(8) [doi: [10.1071/WF14167](#)].

French, N.H.F., McKenzie, D., Erickson, T., Koziol, B., Billmire, M., Endsley, K.A., Scheinerman, N.K.Y., Jenkins, L., Miller, M.E., Ottmar, R. & Prichard, S. (2014). "Modeling regional-scale fire emissions with the Wildland Fire Emissions Information System." *Earth Interactions*, 18 [doi: [10.1175/EI-D-14-0002.1](#)].

French, N.H.F., de Groot, W.J., Jenkins, L.K., Rogers, B.M., Alvarado, E.C., Amiro, B., de Jong, B., Goetz, S., Hoy, E., Hyer, E., Keane, R., McKenzie, D., McNulty, S.G., Law, B.E., Ottmar, R., Perez-Salicrup, D.R., Randerson, J., Robertson, K.M. & Turetsky, M. (2011). "Model comparisons for estimating carbon emissions from North American wildland fire." *Journal of Geophysical Research*, 116 [doi: [10.1029/2010JG001469](#)].

French, N.H.F., Kasischke, E.S., Hall, R.J., Murphy, K.A., Verbyla, D.L., Hoy, E.E. & Allen, J.L. (2008). "Using Landsat data to assess fire and burn severity in the North American boreal forest region: an overview and summary of results." *International Journal of Wildland Fire*, 17(4) [doi: [10.1071/WF08007](#)].

# Who Uses Earth Science Data?

Dr. Chelle Gentemann, to study the effects of sea surface temperature on the ocean and atmosphere.



## Dr. Chelle Gentemann

**Physical Oceanographer** at Earth and Space Research, a nonprofit research institute

**Research interests:** Air-sea interactions, upper ocean physical processes, and microwave remote sensing.

**Research highlights:** From space, the predominant color of Earth is blue. In fact, one of the most famous NASA images of our planet, a full-disk image taken by Apollo 17 astronauts in 1972, is called the “[Blue Marble](#).” This blue is thanks, in part, to the high amount of water surrounding our world that absorbs and scatters light passing through it. According to the U.S. Geological Survey (USGS), water covers 71% of Earth’s surface, with 96.5% of this water held in the oceans. This vast amount of open ocean water has a correspondingly large impact on global weather, climate, and circulation, primarily through the exchange of heat between the ocean and the atmosphere. Dr. Gentemann’s sea surface temperature (SST) research is helping to fill in the gaps in our understanding of how SST affects Earth.

With such a wide area over which to collect data, SSTs can be studied most efficiently using data collected by instruments aboard satellites, such as the [Moderate Resolution Imaging Spectroradiometer \(MODIS\)](#) instrument aboard NASA’s [Aqua Earth observing satellite](#). As a member of the [Group for High Resolution Sea Surface Temperature \(GHRSSST\)](#) science team, Dr. Gentemann is helping to improve satellite SST data and analysis. Her work as part of the the [Multi-sensor Improved SST \(MISST\)](#) project team focuses on improving the quality of satellite-generated SSTs, producing multi-sensor SST data using a blend of U.S. and international data sets, and broadening the use of SST products within targeted coastal applications and the [Integrated Ocean Observing System \(IOOS\)](#).

Improvements in SST data also will lead to improvements in models designed to simulate Earth processes. One NASA model is the [Goddard Earth Observing System Model, Version 5 \(GEOS-5\)](#), which is a collection of models designed to simulate Earth climate variability on a wide range of time scales. Dr. Gentemann and her colleagues are developing and testing an advanced GEOS-5 model interface to improve representations of SST along with representations of the ocean and atmospheric surface boundary layers. This, in turn, will enable the creation of better models of Earth’s atmosphere and help produce more accurate weather and climate predictions.

Dr. Gentemann also is studying cold wakes generated by tropical cyclones. As these strong storms move across the ocean, colder SSTs are pulled in behind the storms due to the storm’s rotation. Since warm SSTs are what power tropical cyclones, colder SSTs can rob the storm of the energy it needs to survive. Finally, Dr. Gentemann is working on a project examining the causes of the abnormally high SSTs in the northeast Pacific Ocean and the relationship between this anomaly (which also has been called the “Warm Blob”) and the persistence of blocking high pressure contributing to drought conditions in California.

### Data products used:

- Several data sets available through NASA’s [Physical Oceanography Distributed Active Archive Center \(PO.DAAC\)](#), including:

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# Who Uses Earth Science Data?

- Cross-Calibrated Multi-Platform (CCMP) Ocean Surface Wind Vector Analyses, daily 25km [doi: [10.5067/CCF30-01XXX](https://doi.org/10.5067/CCF30-01XXX)]
- Daily ocean salinity data from the [NASA Aquarius mission](#), 1 degree resolution [doi: [10.5067/AQR40-3S1CS](https://doi.org/10.5067/AQR40-3S1CS)]
- [Ocean Surface Current Analysis Real-time \(OSCAR\) surface currents](#), daily 1/3 degree resolution
- [GHRSSST SSTs](#) at various spatial/temporal resolutions
- [Multi-scale Ultra-high Resolution \(MUR\) SST Analysis](#), daily 1km global SST data, which are available through NASA's Jet Propulsion Laboratory (JPL)
- [Estimating the Circulation and Climate of the Ocean, Phase II \(ECCO2\)](#) ocean model data available through NASA's JPL
- [Ocean color data](#) available through NASA's [Ocean Biology DAAC \(OB.DAAC\)](#)
- A variety of sea surface height anomaly data sets (including data from the [Ocean Topography Experiment \(TOPEX\)](#)); these data sets are available through the Centre national d'études spatiales (CNES) AVISO website at <http://www.aviso.altimetry.fr/en/data.html>

**Research findings:** Dr. Gentemann found that the primary sources of uncertainty in satellite SST retrievals are due to errors in spacecraft navigation, sensor calibration, sensor noise, retrieval algorithms, and incomplete identification of corrupted retrievals. Looking at retrieval accuracies of microwave (MW) SSTs acquired by the [Advanced Microwave Scanning Radiometer-Earth Observing System \(AMSR-E\)](#) and infrared (IR) SSTs acquired by MODIS, she identified errors in both the MW and IR SST data sets, including significant cloud contamination of nighttime MODIS retrievals at SSTs less than 10°C (50°F). Her research also revealed significant differences between SST products in coastal and open ocean areas. Differences of more than 2°C (about 1.1°F) are often observed at high latitudes partly due to the different treatment of the sea-ice transition zone by the algorithms used to generate SST data products.

In another project, Dr. Gentemann and her colleagues investigated Category 4 Hurricane Kenneth, which experienced unpredicted rapid weakening when it stalled over a cold core eddy on 19-20 September 2005, 2,800 km SE of Hawaii. Although the storm's weakening was attributed to wind shear, research by Dr. Gentemann and her colleagues indicates that the slow movement of the storm and consequent intense SST cooling were the main causes of the storm's rapid weakening.

Finally, in her investigation of the Pacific Ocean warm SST anomaly, Dr. Gentemann and her colleagues found that the 2013-2015 warm anomaly was unprecedented. Both a long-term *in situ* SST time series and a more recent NASA satellite time series show the warming in the eastern Pacific and along the West Coast is the largest in the historical record. The satellite data, which have a higher temporal and spatial resolution, show an even larger anomaly than the *in situ*-based time series.

## Read about the research:

Gentemann, C.L. & Hilburn, K.A. (2015). "In situ validation of sea surface temperatures from the GCOM-W1 AMSR2 RSS calibrated brightness temperatures." *Journal of Geophysical Research*, 120(5) [doi: [10.1002/2014JC010574](https://doi.org/10.1002/2014JC010574)].

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# Who Uses Earth Science Data?

Gentemann, C.L., Hilburn, K. & Mears, C. (2015). "The 2013-Present Pacific SST anomaly." Oral presentation Wednesday, July 22, at GHRSSST XVI, 20-24 July, 2015. Available online at <https://www.ghrsst.org/documents/q/category/ghrsst-science-team-meetings/ghrsst-xvi-esa-estec-the-netherlands/g-xvi-presentations/wednesday-22nd-july-2015/>.

Gentemann, C.L. (2014). "Three way validation of MODIS and AMSR-E sea surface temperatures." *Journal of Geophysical Research*, 119(4) [doi: [10.1002/2013JC009716](https://doi.org/10.1002/2013JC009716)].

Walker, N.D., Leben, R.R., Pilley, C.T., Shannon, M., Herndon, D.C., Pun, I.-F., Lin, I.-I., & **Gentemann, C.L.** (2014). "Slow translation speed causes rapid collapse of northeast Pacific Hurricane Kenneth over cold core eddy." *Geophysical Research Letters*, 41(21) [doi: [10.1002/2014GL061584](https://doi.org/10.1002/2014GL061584)].

# Who Uses Earth Science Data?

Dr. Gina Henderson, to better understand the connections between tropical and Arctic weather and climate.



Gina Henderson on the north slope of Barrow, Alaska, in March 2013. She is holding a snow probe, which is used to measure snow depth and record the GPS location of each measurement. Image © Chris Linder.

## Dr. Gina Henderson

Assistant Professor,  
Oceanography Department,  
U.S. Naval Academy

**Research interests:** Dr. Henderson's research seeks to develop a better understanding of the role of snow cover in the hydrologic and global climate system. In particular, she studies the influences of snow on atmospheric circulation and climate change through surface-atmosphere interactions using both climate data records and global climate models.

**Research highlights:** Dr. Henderson's current research focuses on the connections between tropical and extratropical weather patterns by examining variability within the Arctic system and how this variability is linked to tropical deep convection (known as the Madden-Julian Oscillation [MJO]) on intraseasonal (30-60 day) time scales. The MJO is an eastward moving disturbance of clouds, rainfall, wind, and pressure that is observed mainly over the Indian and Pacific Oceans. It consists of two parts, or phases: an enhanced rainfall (or convective) phase and a suppressed rainfall phase. The MJO traverses the planet in the tropics and returns to its initial starting point generally within 30 to 60 days. The movement of the MJO in the tropics influences both precipitation and temperature in the Northern Hemisphere, and MJO-influenced changes in the jet stream can lead to heavy precipitation along the U.S. West Coast along with colder than normal surface temperatures in Alaska and the Arctic. Few studies have related the intraseasonal variability of the MJO and its effect on Arctic sea ice concentrations or the extent of Northern Hemisphere snow. Understanding the connections among the tropics, the Arctic, and the mid-latitudes is crucial to understanding and predicting global climate.

### Data products used:

- Northern Hemisphere Terrestrial Snow Cover Extent Daily 25km EASE-Grid 2.0 [doi: [10.5067/MEASURES/CRYOSPHERE/nsidc-0530.001](https://doi.org/10.5067/MEASURES/CRYOSPHERE/nsidc-0530.001)]; available through NASA's [National Snow and Ice Data Center \(NSIDC\) Distributed Active Archive Center \(DAAC\)](#) and created as part of a NASA [Making Earth System Data Records for Use in Research Environments \(MEaSUREs\)](#) project.
- MODIS/Terra Snow Cover Monthly L3 Global 0.05 Deg Climate Modeling Grid (CMG), Version 5 [doi: [10.5067/IPPLURB6RPCN](https://doi.org/10.5067/IPPLURB6RPCN)], available through the NSIDC DAAC
- Modern Era Retrospective-analysis for Research and Applications (MERRA) snow depth data set [doi: [10.5067/XOHTIIK0W9RK](https://doi.org/10.5067/XOHTIIK0W9RK)]; available through the [Goddard Earth Sciences Data and Information Services Center \(GES DISC\)](#)

**Research findings:** Dr. Henderson and her colleagues explored variability in the Arctic atmosphere and sea ice concentrations, and connections of this variability with phases of the MJO. Principal findings include evidence that the MJO affects the Arctic atmosphere in both the Arctic winter and summer seasons. In addition, variability in sea ice concentrations by phase of the MJO is found in both the Arctic summer and winter seasons. This variability is supported by corresponding changes in the state of the atmosphere.

Dr. Henderson and her colleagues also examined the variability of snow depth in the Northern Hemisphere meteorological spring season (March, April, and May) by phase of the

(Continued)

# Who Uses Earth Science Data?

MJO. The team found statistically significant regions of daily snow depth change differences in both North America and Eurasia. The magnitude of the observed anomalies in daily snow depth in some regions was found to exceed 100% of the monthly mean change, indicating that intraseasonal variability of spring-season daily snow depth change is physically significant.

## Read about the research:

Barrett, B.S., **Henderson, G.R.** & Werling, J.S. (2015). “The influence of the MJO on the intraseasonal variability of Northern Hemisphere spring snow depth.” *Journal of Climate*, 28: 7250-7262 [doi: [10.1175/JCLI-D-15-0092.1](https://doi.org/10.1175/JCLI-D-15-0092.1)].

Henderson, G.R., Barrett, B.S. & Lafleur, D.M. (2013). “Arctic sea ice and the Madden-Julian Oscillation (MJO).” *Climate Dynamics*, 43(7): 2185-2196 [doi: [10.1007/s00382-013-2043-y](https://doi.org/10.1007/s00382-013-2043-y)].

Henderson, G.R., Leathers, D.J. & Hanson, B. (2013). “Circulation response to Eurasian versus North American anomalous snow scenarios in the Northern Hemisphere with an AGCM coupled to a slab ocean model.” *Journal of Climate*, 26: 1502-1515 [doi: [10.1175/JCLI-D-11-00465.1](https://doi.org/10.1175/JCLI-D-11-00465.1)].

# Who Uses Earth Science Data?

Ben Holt, to study polar sea ice, coastal oceanography, and marine pollution.



Ben Holt collecting snow and ice surface samples on thin first year Arctic sea ice, 29 October 2015. Photo by Madison Smith, University of Washington.

## Ben Holt

**Research Scientist,**  
Ocean Circulation Group,  
NASA's Jet Propulsion  
Laboratory (JPL)

**Research interests:** Ben Holt uses remote sensing data to study the geophysical state of polar sea ice and snow, investigate circulation along coasts, and detect marine pollutants. He also uses these data to develop new instruments and techniques for the microwave measurement of sea ice thickness.

**Research highlights:** Studying polar sea ice from the ground has never been easy. Winter Antarctic temperatures average about  $-50^{\circ}\text{C}$  ( $-58^{\circ}\text{F}$ ), while summer Arctic high temperatures struggle to reach  $0^{\circ}\text{C}$  ( $32^{\circ}\text{F}$ ). Along with frigid temperatures, the vast distances over which data must be collected can create logistical nightmares. Polar orbiting Earth observing satellites, such as NASA's [Terra](#) and [Aqua](#), and the use of [synthetic aperture radar \(SAR\)](#), which does not need illumination from the sun and can penetrate through clouds, ushered in a new era of polar data collection. Even with the benefits of satellites, though, researchers still need to conduct field campaigns at the poles to validate these remotely-sensed data.

For Ben Holt, field campaigns are an important aspect of his research into the impact of ocean waves on sea ice in the marginal ice zone in the Arctic Ocean, a project funded by the U.S. Office of Naval Research. Holt uses satellite data along with data collected by aircraft and during field campaigns to derive sea ice morphology, ice type, and floe size distribution over thousands of miles of Arctic ocean. A field campaign was conducted in fall 2015 in the Beaufort and Chukchi Seas to measure and observe waves and their impact on sea ice. Along with the use of multi-sensor SAR data collected by satellites (such as Canada's [Radarsat-2](#) and the European Space Agency's [ESA] [Sentinel-1A](#)), Holt also relies on data collected by instruments on aircraft (through campaigns such as NASA's [Operation IceBridge](#) and as flown by NASA's [uninhabited aerial vehicle SAR \(UAVSAR\)](#)) and other fine resolution imagery of sea ice, such as from the U.S. Geological Survey's (USGS) [Landsat 8](#) satellite. In addition, as a member of the science definition team for the upcoming joint NASA/Indian Space Research Organisation (ISRO) SAR, or [NISAR](#), mission, Holt is helping to define science and mission requirements for deriving SAR-based polar sea ice motion products.

Holt also is conducting research at lower latitudes. In the Great Lakes, he is part of a team studying seasonal patterns of thermal bar overturning and relationships to the lake circulation and the generation of small eddies. Thermal bars form in the Great Lakes in the spring when the water begins to warm. As this water warms above freezing, it becomes denser. This warmer, denser surface water sinks, and a curtain of water running parallel to shore that is  $4^{\circ}\text{C}$  ( $39^{\circ}\text{F}$ )—the temperature at which water has its highest density—develops. With continued summer warming, the thermal bar gradually moves farther offshore into deeper, cooler water. The difference in water density within the thermal bar restricts mixing between coastal and offshore waters. Thermal bars are areas of not only warmer water temperatures, but also elevated nutrient concentrations, which can make them areas in which fish congregate. On the other hand, thermal bars also can help retain pollutants in coastal waters. For this research, Holt and his colleagues are using a lake surface temperature product from the [Advanced Along-Track Scanning Radiometer \(AATSR\)](#) aboard the [ESA Envisat](#) satellite as well as SAR imagery from multiple sensors.

Finally, Holt uses remote sensing data to detect and track marine pollutants. In one study, he is using an analysis of NASA UAVSAR polarimetric SAR imagery to estimate the thickness

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# Who Uses Earth Science Data?

and transport properties of oil spills. This work is currently using data collected off Norway in June 2015 during a controlled spill experiment and is based on earlier work using UAVSAR collections from the Gulf of Mexico as a result of the Deepwater Horizon oil spill in 2010. Holt also uses sea surface temperature, optical properties and chlorophyll, and surface roughness data from multiple satellite sensors to detect coastal pollution in Southern California caused by stormwater runoff and wastewater plumes. The goal of this project is to identify sources of pollution impacting local water quality and the movement of this pollution.

## Data products used:

- SAR data sets available through NASA's [Alaska Satellite Facility \(ASF\) Distributed Active Archive Center \(DAAC\)](#), including:
  - [Seasat](#)
  - [European Remote Sensing Satellite-1 \(ERS-1\)](#) and [ERS-2](#)
  - [Radarsat-1](#)
  - [Advanced Land Observing Satellite-1 \(ALOS-1\)](#)
  - [Sentinel-1A](#)
  - [UAVSAR](#)
- [NASA Operation IceBridge data](#) available through NASA's [National Snow and Ice Data Center \(NSIDC\) DAAC](#)
- [Moderate Resolution Imaging Spectroradiometer \(MODIS\) sea surface temperature \(SST\)](#) data from NASA's Terra and Aqua Earth observing satellites and ocean color data from [Terra](#) and [Aqua](#) available through NASA's [Ocean Biology DAAC \(OB.DAAC\)](#)
- [ALOS-2 data](#) available through the Japan Aerospace Exploration Agency (JAXA)
- [Envisat data](#) available through ESA
- [Landsat 8 data](#) available through USGS

**Research findings:** In his research into the effect of waves on Arctic sea ice, Holt and his colleagues found that an increase in open water during the summer period in the Arctic Ocean has led to more ocean waves due to the increased fetch, or distance across the open ocean, that wind can blow. This increase in ocean waves impacts summer ice melt as well as the formation of young sea ice during the fall period of sea ice growth and advance.

While studying thermal bars in several locations in Lake Superior, Holt and his colleagues noted a thermal gradient between warmer nearshore waters and colder offshore waters that enhances cyclonic coastal currents. The research team observed small eddies, and identified and mapped basic eddy characteristics including diameter, location, and rotation. The eddies were located within the region of sharp thermal gradients (3-5°C [37.4-41°F] per 3 km [1.86 mi]). While the spatial and temporal coverage of the eddies were uneven, more eddies were seen in SAR images taken in late summer along the southern and eastern shores as well as areas where the boundary current interacts with topographic features such as islands and promontories.

Finally, in his pollution research, Holt and his colleagues were able to derive a method of identifying thicker emulsified oil from thinner oil using UAVSAR data. They are continuing to evaluate this method under varying ocean conditions and with varying oil properties.

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# Who Uses Earth Science Data?

## Read about the research:

Wang, Y., **Holt, B.**, Rogers, W.E., Thomson, J. & Shen, H.H. (2016). “Wind and wave influences on sea ice floe size and leads in the Beaufort and Chukchi Seas during the summer-fall transition 2014.” *Journal of Geophysical Research: Oceans*, 121(2) [doi: [10.1002/2015JC011349](https://doi.org/10.1002/2015JC011349)].

Holt, B., Johnson, M.P., Perkovic-Martin, D. & Panzer, B. (2015). “Snow depth on Arctic sea ice derived from radar: *In situ* comparisons and time series analysis.” *Journal of Geophysical Research: Oceans*, 120(6) [doi: [10.1002/2015JC010815](https://doi.org/10.1002/2015JC010815)].

McKinney, P., **Holt, B.** & Matsumoto, K. (2012). “Small eddies observed in Lake Superior using SAR and sea surface temperature imagery.” *Journal of Great Lakes Research*, 38(4) [doi: [10.1016/j.jglr.2012.09.023](https://doi.org/10.1016/j.jglr.2012.09.023)].

Minchew, B., Jones, C. & **Holt, B.** (2012). “Polarimetric analysis of backscatter from the Deepwater Horizon oil spill using L-band synthetic aperture radar.” *IEEE Transactions on Geoscience and Remote Sensing*, 50(10) [doi: [10.1109/TGRS.2012.2185804](https://doi.org/10.1109/TGRS.2012.2185804)].

# Who Uses Earth Science Data?

Dr. Bernard Hubbard, to help locate mineral resources and assess natural hazards.



Dr. Bernard Hubbard conducting fieldwork in Goldfield, NV, in 2009 to provide ground truth for mineral maps created using data collected by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on NASA's Terra Earth observing satellite. Image courtesy of Dr. Bernard Hubbard.

## Dr. Bernard Hubbard

**Research Geologist,**  
Eastern Mineral &  
Environmental Resources  
Science Center,  
U.S. Geological Survey  
(USGS)

**Research interests:** If you own a cell phone you also own a set of rare earth elements, or REEs. REEs are key ingredients in the circuitry and components of your phone. Actually, these elements are not that rare, but finding these elements in quantities large enough to justify the cost of mining them is, which makes them economically valuable. Identifying potential sources for these REEs in remote locations around the world is one facet of the work of Dr. Bernard Hubbard.

To identify specific minerals, Dr. Hubbard uses multispectral and hyperspectral instruments mounted on aircraft and satellite platforms (such as the Hyperion imaging spectrometer on NASA's Earth Observing-1, or EO-1, satellite). These instruments detect energy emitted in various wavelengths from ground objects. While humans can detect light in the visible band of the electromagnetic spectrum (0.45  $\mu\text{m}$  [blue] to 0.67  $\mu\text{m}$  [red]), multispectral and hyperspectral instruments detect a much broader range of radiated energy—from longwave infrared and microwave radiation to shortwave ultraviolet and X-ray radiation. The difference between multispectral and hyperspectral is the number of wavelengths, or bands, the instrument can detect. A multispectral sensor, such as Landsat 8, might have 3-10 wide bands; a hyperspectral sensor, such as Hyperion, has hundreds of narrow bands and is much more sensitive.

Individual minerals can be identified by the specific wavelengths in which they emit or reflect radiant energy. For example, REEs have unique spectral signatures, especially in the near-infrared portion of the electromagnetic spectrum. Hyperspectral instruments can reveal these unique spectral signatures and allow geologists to identify specific REEs present in rocks. If these rocks are well exposed, these spectral signatures may even be detected by sensors on orbiting satellites. Dr. Hubbard uses these sensor returns to map the spatial distribution of minerals and combines these maps with digital geographic information system (GIS) information to help locate mineral resources.

Along with his work in economic geology identifying REEs, Dr. Hubbard uses satellite and airborne remote sensors to assess hazards from landslides, volcano edifice failures, and related debris flows. Since joining the USGS in 2001, Dr. Hubbard's primary work has focused on using remote sensing to help assess mineral resources in areas that may be too remote (such as the Alaskan tundra) or dangerous (such as Afghanistan) for extended field campaigns.

**Research highlights:** Dr. Hubbard is working on several projects across the continent. In the Southern Appalachian Mountains, he is conducting spectral studies of potential REE deposits. In Alaska and the Canadian Yukon, he is using remote sensing to help distinguish areas of permafrost from wildfire burns and exposed bedrock. In southern California, Dr. Hubbard is studying landslide, debris flow, and flood hazards along the mountainous border areas surrounding the Salton Sea basin. Finally, he is working on global mapping of clay-rich altered rocks on volcanoes to help determine the possible source volumes and extents of large flows of water and rock fragments triggered by volcanic eruptions. These flows are called lahars. Large lahars can crush, bury, or carry away almost anything in their paths, including homes, roads, bridges, and slope-stabilizing vegetation.

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# Who Uses Earth Science Data?

## Data products used:

- Moderate Resolution Imaging Spectroradiometer (MODIS) Level 2 Total Precipitable Water Vapor product from NASA's Terra ([MOD05\\_L2](#)) and Aqua ([MYD05\\_L2](#)) Earth observing satellites available through NASA's [MODIS Adaptive Processing System \(MODAPS\) Services](#)
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Level 1B radiance data ([AST\\_L1B](#)) and Level 2 emissivity data ([AST\\_05](#)) available through NASA's [Land Processes Distributed Active Archive Center \(LP DAAC\)](#)
- Global Digital Elevation Models (GDEMs) from ASTER and the Shuttle Radar Topography Mission (SRTM), which can be accessed through LP DAAC using the [Global Data Explorer \(GDEx\)](#)
- Advanced Land Imager (ALI) and Hyperion instrument data from NASA's EO-1 satellite; these data are available through the USGS [Earth Explorer](#) data discovery and access tool, as well as the [GloVis](#) online search and order tool
- [Landsat Thematic Mapper](#), [Enhanced Thematic Mapper](#), and [Operational Land Imager](#) data available through the USGS Earth Explorer data discovery and access tool, as well as the GloVis online search and order tool
- [Landsat landcover data](#)

**Research findings:** Dr. Hubbard's research shows that REE deposits associated with lateritic soils and bauxite deposits can successfully be explored and mapped using hyperspectral instruments. Lateritic soils have high concentrations of aluminum and iron, and are predominately found between the Tropic of Cancer and the Tropic of Capricorn. Bauxite is an aluminum ore and the world's main source of aluminum. Bauxite deposits associated with lateritic soils are found primarily in the tropics. Dr. Hubbard also found that some of the same minerals that can be used to locate precious- and base-metal related ore deposits also can be used to assess slope stability and landslide hazards.

In his work in Alaska and the Canadian Yukon, Dr. Hubbard and his colleagues found that airborne electromagnetic (AEM) surveys and Landsat images can be used together to distinguish between exposed bedrock and dry and burnt vegetation as well as green vegetation. Exposed outcrops are crucial for evaluating mineral resources and collecting samples for analysis, and can be difficult to spot from helicopters since brown-colored moss or burned vegetation can be mistaken for rock outcrops. AEM data were processed to estimate electrical resistivity and this resistivity was found to correlate to specific areas of rock, vegetation, and permafrost, making identification of exposed bedrock in these remote locations much easier.

## Read about the research:

Mars, J.C., **Hubbard, B.E.**, Pieri, D. & Linick, J.L. (2015). "Alteration, slope-classified alteration, and potential lahar inundation maps of volcanoes for the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Volcanoes Archive." U.S. Geological Survey Scientific Investigations Report 2015-5035 [doi: [10.3133/sir20155035](https://doi.org/10.3133/sir20155035)].

(Continued)

# Who Uses Earth Science Data?

Hubbard, B.E., Smith, B.D., Day, W., Gough, L., Kass, M.A., Emond, A. & Caine, J.S. (2014). “Correlation of Alaska Landsat image analysis with airborne geophysical survey data: A promising tool of locating outcrops, monitoring burn recovery and assessing potential permafrost thaw.” Presentation at the 2014 Geological Society of America Annual Meeting, Paper No. 324-1. Available online at <https://gsa.confex.com/gsa/2014AM/webprogram/Paper245715.html>.

Hubbard, B.E., Sheridan, M.F., Carrasco-Núñez, G., Díaz-Castellón, R. & Rodríguez, S.R. (2007). “Comparative lahar hazard mapping at Volcan Citlaltépetl, Mexico using SRTM, ASTER and DTED-1 digital topographic data.” *Journal of Volcanology and Geothermal Research*, 160(1-2) [doi: [10.1016/j.jvolgeores.2006.09.005](https://doi.org/10.1016/j.jvolgeores.2006.09.005)].

# Who Uses Earth Science Data?

Dr. Charles Ichoku, to study the global and regional impacts of fires in Northern Sub-Saharan Africa.



## Dr. Charles Ichoku

**Research Physical Scientist,**  
Climate & Radiation Laboratory,  
Earth Science Division,  
NASA Goddard Space  
Flight Center

**Research interests:** Given that seasonal biomass burning is widespread in Sub-Saharan Africa, can the effects of this burning on the environment be measured regionally and globally? This is one of the questions NASA scientist Dr. Charles Ichoku seeks to answer in his research examining the effects of wildfires, agricultural burning, and the emissions associated with these activities. Through a variety of measurement and modeling approaches coordinated under an interdisciplinary framework, Dr. Ichoku is helping scientists, researchers, and natural resource managers gain a better understanding of environmental change and climate variability in Northern Sub-Saharan Africa (NSSA) caused by seasonal fires and how these changes may impact the water cycle and other processes not just in this diverse region, but around the world.

**Research highlights:** The NSSA region straddles the African continent from east to west, and is bounded on the north by the Sahara Desert and on the south by the equator. While the northern edge of this vast region is dry and sparsely populated, seasonal moisture becomes more abundant towards the equator. As the summer rains taper off and the dry season begins around November, wildfires and agricultural burning become common. Peak biomass burning generally occurs November through January, then tapers off in March and becomes virtually non-existent in the summer. These fires, most of which are human-set, are used to clear land for cultivation or other agricultural purposes as well as to help increase soil nutrients. This burning also contributes high quantities of fine particles, called aerosols, into the atmosphere. In fact, the NSSA region is estimated to contribute 20-25% of the global annual carbon emissions from open biomass burning. This seasonal burning not only impacts landcover, it also affects parts of the energy and water cycles and, through these, potentially also rainfall patterns.

Dr. Ichoku and his colleagues are exploring the effects of this seasonal biomass burning on land-cover and ecosystem changes, surface albedo, smoke and dust emissions, atmospheric heating rates, and how these factors in turn affect the difference between the amount of sunlight absorbed by this region and the amount reflected back into space. As part of this research, they developed a model of the NSSA regional climate system components that may be affected by biomass burning, and analyzed a variety of satellite data covering the years 2001 to 2014 along with relevant model-simulated data and data collected from field investigations.

Through the use of this interdisciplinary approach, the research team is conducting a comprehensive study of Sub-Saharan African biomass burning to understand and clarify the impacts of this on the region's water cycle. The team seeks to determine how the fire-induced surface and atmospheric changes affect rainfall variability, soil moisture content and retention, surface runoff, infiltration, and groundwater mass balance, particularly in the Lake Chad Basin and surrounding regions. The Lake Chad Basin alone covers an area of about 2,335,000 sq. km (902,000 sq. mi) across parts of seven countries in north central Africa, and is home to more than 30 million people.

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# Who Uses Earth Science Data?

## Data products used:

- NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Type product ([MCD12Q1](#)), which provides data characterizing five global land cover classification systems. These data are available through NASA's [Land Processes Distributed Active Archive Center \(LP DAAC\)](#).
- Fire detection and fire radiative power (FRP) data extracted from the MODIS Collection 5 thermal anomalies products from NASA's Terra ([MOD14](#)) and Aqua ([MYD14](#)) Earth observing satellites.
- MODIS/Terra ([MODVI](#)) and Aqua ([MYDVI](#)) Monthly Vegetation Indices Global 1x1 degree V005, both of which are available through NASA's [Goddard Earth Sciences Data and Information Services Center \(GES DISC\)](#)
- Precipitation data from NASA's [Tropical Rainfall Measuring Mission \(TRMM\)](#) obtained from the Version 7 [TRMM Multi-satellite Precipitation Analysis \(TMPA\)](#) products
- Aerosol optical depth (AOD) variables extracted as monthly averages of the MODIS Dark Target product from the NASA [GES DISC Interactive Online Visualization and Analysis Infrastructure \(GIOVANNI\)](#) website
- Surface evapotranspiration data from NASA's [Global Land Data Assimilation System Version 1 \(GLDAS-1\)](#) Noah Land Surface Model monthly data set at 0.25°x0.25° spatial resolution

**Research findings:** Using more than 10 years of MODIS fire and albedo data products, Dr. Ichoku and his colleagues were able to assess the areas burned throughout the NSSA region and the times these areas burned. The team found that the spatial-temporal extent of fires in Sub-Saharan Africa is widespread, and the disturbance rates from year to year remain fairly steady. The team determined that biomass burning in the NSSA produces a net decrease in surface albedo, meaning that the burned areas do not reflect as much incoming solar radiation, and that these albedo changes vary with the type of vegetation burned (woody savanna/savanna, evergreen broadleaf, cropland, etc.). The results of this research are useful in determining the effects of albedo changes caused by biomass burning on soil moisture budget, evapotranspiration, infiltration, and runoff, all of which affect the water cycle. In addition, the team's research indicates that humid West Africa shows an increasing trend of April biomass burning and that this increase in burning seems to delay the onset of daytime warm rain processes, which further impacts the region's water cycle.

Dr. Ichoku also determined that global fire emissions from biomass burning can be assessed through the use of remotely-sensed satellite data, such as the NASA MODIS aerosol and fire products. These research findings will help improve the estimation of emissions of various smoke constituents and their contributions to atmospheric aerosol concentrations.

## Read about the research:

Ichoku, C. & Ellison, L. (2014). "Global top-down smoke aerosol emissions estimation using satellite fire radiative power measurements." *Atmospheric Chemistry and Physics*, 14, 6643-6667 [doi: [10.5194/acp-14-6643-2014](#)].

Gatebe, C.K., **Ichoku, C.**, Poudyal, R., Roman, M.O. & Wilcox, E. (2014). "Surface albedo darkening from wildfires in northern Sub-Saharan Africa." *Environmental Research Letters*, 9(6) [doi: [10.1088/1748-9326/9/6/065003](#)].

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# Who Uses Earth Science Data?

Zhang, F., Wang, J., **Ichoku, C.**, Hyer, E. J., Yang, Z., Ge, C., ... da Silva, A. (2014). "Sensitivity of mesoscale modeling of smoke direct radiative effect to the emission inventory: a case study in northern Sub-Saharan African region." *Environmental Research Letters*, 9(7) [doi: [10.1088/1748-9326/9/7/075002](https://doi.org/10.1088/1748-9326/9/7/075002)].

Yang, Z., Wang, J., **Ichoku, C.**, Hyer, E. & Zeng, J. (2013). "Mesoscale modeling and satellite observation of transport and mixing of smoke and dust particles over northern Sub-Saharan African region." *Journal of Geophysical Research: Atmospheres*, 118(21) [doi: [10.1002/2013JD020644](https://doi.org/10.1002/2013JD020644)].

# Who Uses Earth Science Data?

Dr. Christian Kummerow, to study the water budget.



Dr. Christian Kummerow and an anteater in Alcantara, Brazil, as part of a tropical rainfall experiment. Image courtesy Dr. Christian Kummerow.

## Dr. Christian Kummerow

**Professor,**  
Department of Atmospheric Science  
and Director, Cooperative Institute for  
Research in the Atmosphere (CIRA),  
Colorado State University

**Research interests:** Satellite remote sensing of precipitation and global water and energy cycles.

**Research highlights:** By integrating observations of the components of the water budget (evaporation, water vapor, clouds, and precipitation), Dr. Kummerow and his colleagues hope to improve the consistency of estimates about the water budget and address the interdependencies of these components. Because evaporation minus precipitation within a closed system has to ultimately equal the transport of water vapor out of the system, a measure of the consistency of these three components adds confidence in each of these estimated parameters. The ultimate goal is not only to create better products to estimate the contributions of the components of the water cycle in specific regions, but to gain a better understanding of the current relationships among these components in order to make more reliable predictions of future relationships. Data from the recently launched joint NASA/Japan Aerospace Exploration Agency Global Precipitation Mission (GPM) is a critical element of this research.

### Data products used:

- Global Precipitation Climatology Project (GPCP) Combination Data, Version 2.2 [short name: [GES DISC GPCPRAIN V2.2](#)]. These data are available through NASA's [Mesoscale Atmospheric Processes Laboratory](#)
- Water vapor and wind products from NASA's [Modern Era Retrospective Analysis for Research and Applications \(MERRA\)](#), which are available through NASA's [Goddard Earth Sciences Data and Information Services Center \(GES DISC\)](#)
- Various products from the [SeaFlux Project](#), which produces and maintains a high-resolution satellite-based data set of surface turbulent fluxes over the global oceans under the auspices of the World Climate Research Programme (WCRP) Global Energy and Water Experiment (GEWEX) Data and Assessment Panel

**Research findings:** The research team has been surprised by how well evaporation and precipitation agree, even on a regional scale, when water vapor transport is accounted for. Over the Indian Ocean, for instance, monthly variations in evaporation minus precipitation match the water vapor transport out of this region to within a few percent, with only small, random errors in the three parameters (evaporation, precipitation, and water vapor). This adds a great deal of confidence in each of the variables since they are derived independently of one another.

While this balance is seen in other tropical basins the team examined, one unexpected finding is that the tropical West Pacific was not in balance, and in fact was trending so as to be less and less balanced in a 10 year time series from 1998 to 2008. This imbalance meant that there was an error in one of the derived

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# Who Uses Earth Science Data?

parameters. This error has been attributed to subtle changes in the structure of precipitation systems in this region, with larger, more organized storm systems becoming more prevalent in the last decade at the expense of more frequent isolated showers. Such subtle changes in precipitation not only cause problems for the retrieval algorithms, but are the real clues to how the climate system is currently changing.

## Read about the research:

Kummerow, C.D., Randel, D.L., Kulie, M., Wing, N., Ferraro, R., Munchak, S. & Petkovic, V. (2015). "The Evolution of the Goddard Profiling Algorithm to a Fully Parametric Scheme." *Journal of Atmospheric and Oceanic Technology*, 32(12) [doi: [10.1175/JTECH-D-15-0039.1](https://doi.org/10.1175/JTECH-D-15-0039.1)].

Brown, P.J. & **Kummerow, C.D.** (2014). "An Assessment of Atmospheric Water Budget Components Over Tropical Oceans." *Journal of Climate*, 27(5) [doi: [10.1175/JCLI-D-13-00385.1](https://doi.org/10.1175/JCLI-D-13-00385.1)].

Hou, A.Y., Kakar, R.K., Neeck, S., Azarbarzin, A., **Kummerow, C.D.**, Kojima, M., Oki, R., Nakamura, K. & Igushi, T. (2014). "The Global Precipitation Measurement (GPM) Mission." *Bulletin of the American Meteorological Society*, 95(5) [doi: [10.1175/BAMS-D-13-00164.1](https://doi.org/10.1175/BAMS-D-13-00164.1)].

# Who Uses Earth Science Data?

Dr. Xiaofeng Li, to study atmospheric and oceanic processes.



Dr. Xiaofeng Li on a 2013 research cruise in the Arctic Ocean. Image courtesy Dr. Xiaofeng Li.

## Dr. Xiaofeng Li

**Scientist,**  
National Oceanic and  
Atmospheric Administration  
(NOAA) National  
Environmental Satellite,  
Data, and Information  
Service (NESDIS)

**Research interests:** Using remote sensing data, primarily synthetic aperture radar (SAR) data, to study atmospheric and oceanic processes.

**Research highlights:** Radar is a simple concept—radio waves are sent out and their time and power of return are calculated to determine the range, angle, velocity, and characteristics of objects off of which the radar beam bounces. [Synthetic aperture radar \(SAR\)](#), bounces a microwave radar signal off Earth’s surface to detect physical properties. While the word “aperture” when used in reference to an optical instrument like a film camera refers to the size of an opening in a lens that lets light in, the term “aperture” in radar use refers to the antenna generating the microwave pulses. In general, the larger the radar antenna, the more information and better surface resolution the radar can produce. Since antenna size is limited on satellite instruments, scientists use the spacecraft’s motion along with advanced signal-processing techniques to simulate a larger antenna and create high resolution images. This is where the “synthetic aperture” comes from. Significant advantages of SAR are that it can create high resolution images without the need for illumination (such as from the sun) and can penetrate clouds, fog, tree canopies, or other obstructions to create these images. This makes SAR ideal for use in Earth observing satellites.

Dr. Xiaofeng Li uses SAR data to study a wide range of processes occurring in the atmosphere and ocean, including air-sea interactions, ocean surface winds, waves, coastal upwelling, oil slicks, and tropical cyclones. In fact, SAR has been used to observe tropical cyclones since the launch of the first satellite-borne SAR aboard NASA’s [Seasat](#) mission in 1978. SAR reveals tropical cyclone features like eye structure, rain bands, and arc clouds, as well as features that may not be visible, such as the presence of high winds within a cyclone’s eye. Dr. Li and his colleagues use SAR to better understand tropical cyclone morphology as well as to help determine physical parameters including wind speed and direction, rain rate, and eye location, all of which help improve cyclone tracking and intensity predictions.

In a recent study, Dr. Li and his colleagues combined SAR measurements of tropical cyclones with cloud pattern data from the [Moderate Resolution Imaging Spectroradiometer \(MODIS\)](#) instrument aboard NASA’s [Terra](#) and [Aqua](#) Earth observing satellites. The combination of these data allowed the team to study cyclone tilt, which is one indicator of storm intensity (strong, developing storms tend to tilt from the storm base to the storm top, generally tilting toward cooler upper-level air). For physical wind retrievals, conventional radar signals tend to produce ambiguous returns under hurricane conditions and very high winds. To alleviate this problem, Dr. Li and his colleagues developed high-wind retrieval algorithms using cross-polarization SAR measurements along with SAR-derived hurricane morphological information. These cross-polarization measurements exhibit less scattering at high wind speeds and allow for more accurate wind retrievals. The research team compared their SAR-derived hurricane wind measurements with wind measurements from the airborne [Stepped-Frequency Microwave Radiometer \(SFMR\)](#), which is part of NOAA’s Hurricane Research Division.

Dr. Li also uses SAR to develop algorithms for tracking changes in coastlines and the movement of oil spills. Since SAR images can be captured day or night and in almost all kinds of weather, long-term coastline changes can easily be observed and tracked over time.

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# Who Uses Earth Science Data?

In addition, oil slicks on the sea surface tend to damp, or flatten, surface capillary waves and make the sea surface smooth. These patches of oil-dampened water appear as dark features in SAR images and can be used to study ocean currents underneath the oil slicks as these currents move the slicks. Dr. Li and his colleagues used multiple SAR observations and oil drifting models to identify the movement of oil at sea and assess spots where oil might come ashore.

In another recent study, Dr. Li and his colleagues used SAR data to observe ocean waves called internal solitary waves (ISW), which are large amplitude ocean waves that tend to occur in areas where water density increases rapidly with depth. One area where these waves are common is the South China Sea. The specific waves Dr. Li and his colleagues studied are generated by internal tides occurring at the Luzon Strait in the South China Sea. These waves move westward toward mainland China at roughly 3 m/s toward the continental shelf.

Dr. Li and his colleagues chose to look at how the Dongsha Atoll affected the movement of these internal waves. The atoll (a ring-shaped island made of coral) is located at the edge of the continental shelf roughly 450 km (about 280 miles) west of the Luzon Strait. As these undersea waves hit and move around the atoll, the incoming wave is split and then re-joins on the western side of the atoll. This change in wave direction is called “refraction.” The research team used SAR imagery to map ISW signatures around the atoll in order to understand their generation mechanisms, type, spatial distribution, propagation speed, refraction, and other processes.

## Data products used:

- SAR data sets available through NASA’s [Alaska Satellite Facility \(ASF\) Distributed Active Archive Center \(DAAC\)](#):
  - [Seasat](#)
  - [European Remote Sensing Satellite-1 \(ERS-1\)](#) and [ERS-2](#)
  - [RADARSAT-1](#)
  - [Advanced Land Observing Satellite-1 \(ALOS-1\)](#)
  - [Sentinel-1](#)
  - [Uninhabited Aerial Vehicle Synthetic Aperture Radar \(UAVSAR\)](#)
- MODIS [sea surface temperature \(SST\)](#) and ocean color data from Terra [doi: [10.5067/TERRA/MODIS\\_OC.2014.0](#)] and Aqua [doi: [10.5067/AQUA/MODIS\\_OC.2014.0](#)] available through NASA’s [Ocean Biology DAAC \(OB.DAAC\)](#)
- [ALOS-2 data](#) available through the Japan Aerospace Exploration Agency (JAXA)
- [Envisat data](#) available through the European Space Agency (ESA)
- SST data available through NOAA’s [Comprehensive Large Array-data Stewardship System \(CLASS\)](#) and [CoastWatch](#)

**Research findings:** In his research into hurricane morphology, Dr. Li and his colleagues found that storm eye shapes in tropical cyclones can be categorized using SAR imagery and that stronger storms tend to have more symmetrical eyes. Also, heavy rain and atmospheric properties can interfere with the radar beam and cause false returns to appear over land and sea. Through the use of the high-wind retrieval algorithms developed by Dr. Li and his colleagues, the team was able to mitigate this beam interruption and reconstruct a complete tropical cyclone wind map, including both speed and direction.

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# Who Uses Earth Science Data?

In his work on oil slick tracking, Dr. Li and his colleagues developed new oil slick detection methods based on statistical and physical approaches. Using SAR oil slick images as a tracer, the research team found that the movement of oil seeps in the Gulf of Mexico is directed by currents that are affected by the Earth's rotation (Coriolis force). A sudden wind blowing over the water tends to cause surface water initially to move in the direction of the wind, but then turn this water to the right-hand side of the wind direction in the Northern Hemisphere because of the Coriolis force. Once this motion is established, the surface water continues moving in a circle. Oil slicks are carried along with this water, and can be more easily tracked. Algorithms developed by Dr. Li and his colleagues as a result of this research have been used in NOAA's daily oil slick monitoring operations.

Finally, in his research into internal waves near Dongsha Atoll, Dr. Li found unusual wave refraction patterns revealed by the SAR imagery. The research team noticed that after the wave hit the atoll and split, the wave closest to the atoll moved around the atoll in a circular pattern while the other side of the split wave continued moving west toward the continental shelf. Dr. Li and his colleagues found that this phenomenon was caused by the asymmetry of the tidal current near the atoll and hypothesize that the observed wave refraction is caused by changes in water depth around the atoll.

## Read about the research:

Li, X., Jackson, C.R. & Pichel, W.G. (2013). "Internal solitary wave refraction at Dongsha Atoll, South China Sea." *Geophysical Research Letters*, 40(12) [doi: [10.1002/grl.50614](https://doi.org/10.1002/grl.50614)].

Li, X., Zhang, J.A., Yang, X., Pichel, W.G., DeMaria, M., Long, D. & Li, Z. (2012). "Tropical cyclone morphology from spaceborne synthetic aperture radar." *Bulletin of the American Meteorological Society*, 94(2) [doi: [10.1175/BAMS-D-11-00211.1](https://doi.org/10.1175/BAMS-D-11-00211.1)].

Li, X., Li, C., Yang, Z. & Pichel, W. (2012). "SAR imaging of ocean surface oil seep trajectories induced by near inertial oscillation." *Remote Sensing of Environment*, 130 [doi: [10.1016/j.rse.2012.11.019](https://doi.org/10.1016/j.rse.2012.11.019)].

# Who Uses Earth Science Data?

Dr. Anne Nolin, to study mountain ecosystems.



Dr. Anne Nolin on Mt. Hood, Oregon, in July 2014. The instrument in her backpack is a snow tube, which is used to measure snow water equivalent (SWE). Image courtesy of Oregon State University.

## Dr. Anne Nolin

**Professor,**  
College of Earth, Ocean,  
and Atmospheric Sciences;  
Oregon State University

**Research interests:** Mountain hydroclimatology, remote sensing of snow, and mountain social-ecological systems.

**Research highlights:** It is impossible to underestimate the importance of mountain snowpacks and associated glaciers to water resources. As Dr. Anne Nolin notes, snowpacks and glaciers are the lifeblood of the western U.S. and similar regions around the world, storing water in winter and gradually releasing this water during spring (from snow) and summer (from glaciers) as the snow and ice melt. Dr. Nolin's work on snowpack and mountain environments attempts to map, monitor, and characterize these vital ecosystems.

Satellite remote sensing data are a critical component of Dr. Nolin's research. Not only do these satellite data provide imagery of remote, often inaccessible mountainous areas, they also provide data for computer models designed to mathematically represent environmental conditions and are used to update these models as they run. In addition, Dr. Nolin and her colleagues use remotely-sensed data to validate model output and augment snow information from ground-based mountain monitoring stations, which may be few in number, spread out over large distances, or difficult to reach.

Research by Dr. Nolin shows that global warming is leading to changes in these ecologically sensitive regions. These changes affect not only mountain ecosystems, but also the resources that flow from mountain regions. As Dr. Nolin and her colleagues observe, "Mountain snowpack is a key common-pool resource, providing a natural reservoir that supplies water for drinking, worship, hydropower, agriculture, ecosystems, industry, and recreation for over 1 billion people globally." Changes in these snowpack resources also affect the human mountain communities depending on these resources. Dr. Nolin's work seeks to understand mountain regions as a system that couples human dimensions with these biophysical areas.

In a recent study, Dr. Nolin and her colleagues looked at the impacts of climate and precipitation changes on maritime mountain snowpack in the McKenzie River Basin (MRB) in Oregon's Cascade Mountains. While about one-third of the annual mountain precipitation in this region falls as snow, much of this snowfall occurs at temperatures close to 0°C (32°F). This means that only a small increase in temperature is needed to change the precipitation from snow to liquid. Since the snowpack stores water in the winter and gradually releases this stored water during the melt season, an increase in temperature can significantly impact water for forests, fish, energy, production, and agriculture in this region. Through the use of model simulations and remotely-sensed data (including data from the [Landsat Thematic Mapper \[LTM\]](#)) coupled with ground-based observations of precipitation, temperature, and the amount of water contained in the snowpack (called "snow water equivalent," or SWE), Dr. Nolin and her colleagues evaluated the sensitivity of this snowpack to projected temperature increases of 2°C and variabilities in precipitation of ±10%.

As rising temperatures reduce snowpacks, research in the Western U.S. shows that one consequence is an increase in wildfire frequency, size, intensity, and duration. When a forest burns, charred debris (such as burned trees) falls onto the forest floor. Dr. Nolin and her colleagues investigated how this charred debris changes the amount of light and radiation

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# Who Uses Earth Science Data?

that is absorbed or reflected from the forest floor and the impact of these changes in reflectance on snowmelt rates and intensity.

The amount of light and radiation reflected by a surface is called albedo. Fresh snow reflects a high percentage of light and radiation that strikes it and has a high albedo. Charred debris, on the other hand, reflects much less light and radiation, and has a much lower albedo. Solar radiation that is not reflected by a surface (such as sunlight striking dirty snow) is absorbed, causing the upper layers of the surface to increase in temperature. Remotely sensed data, specifically a spatial analysis combining snow cover, fire, and forest cover data from the [Moderate Resolution Imaging Spectroradiometer \(MODIS\)](#) instrument, allowed the research team to calculate the amount of burned area in their study sites and monitor the changes in albedo in these areas as they recovered.

Dr. Nolin and her colleagues also are using MODIS snow cover data to develop new snow metrics as geospatial products to support the [National Climate Assessment](#). These snow data products will soon be available through [Google Earth Engine](#), which will allow users to tailor the web-based maps and data output to individual needs. In addition, Dr. Nolin and her colleagues developed a remote sensing glacier-mapping pilot project called [IceTrendr](#). IceTrendr uses Landsat time-series data to capture, label, and map glacier change for use in climate science, hydrology, and Earth science education. The interactive web interface the team developed allows them to map glacier change and label the change processes.

Finally, Dr. Nolin and her colleagues used data from the [Multi-angle Imaging SpectroRadiometer \(MISR\)](#) instrument aboard NASA's [Terra](#) Earth observing satellite to map and analyze Greenland ice sheet roughness. Since the surface of the Greenland ice sheet is shaped by wind, melting processes, and glacier dynamics, the roughness of this ice sheet causes changes in the amount of heat reflected or absorbed by the ice sheet surface and can impact ice sheet development.

## Data products used:

- MODIS/Terra snow cover, Daily, 500-m grid (MOD10A1, doi: [10.5067/MODIS/MOD10A1.006](https://doi.org/10.5067/MODIS/MOD10A1.006)), available through NASA's [National Snow and Ice Data Center \(NSIDC\) Distributed Active Archive Center \(DAAC\)](#)
- MODIS snow-covered area and grain size ([MODSCAG](#)) 500-m grid, available through the [Snow Data System](#) portal at NASA's Jet Propulsion Laboratory
- MISR Level 1B2 Terrain Data: terrain projected top of atmosphere radiance, resampled at the surface and topographically corrected (MI1B2T, doi: [10.5067/Terra/MISR/MI1B2T\\_L1.003](https://doi.org/10.5067/Terra/MISR/MI1B2T_L1.003)), available through NASA's [Atmospheric Science Data Center \(ASDC\)](#)
- Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) data, available through the U.S. Geological Survey's [EarthExplorer](#) and [Global Visualization Viewer \(GloVis\)](#)

**Research findings:** Results from Dr. Nolin's exploration into the effects of projected climate changes on maritime mountain snowpack in the Oregon Cascades found that this snowpack is highly sensitive to increasing temperatures, with snowpack between elevations of 1,000 and 2,000 meters (about 3,280 to 6,560 feet) being particularly sensitive. Specifically, she and her colleagues found that peak SWE decreases 56% when temperature increases by 2°C. Also, projected warmer temperatures hasten the snowpack melt cycle, with peak SWE occurring 12 days sooner. The research team found that while temperature increases are the

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# Who Uses Earth Science Data?

primary driver of diminished snowpack accumulation, variabilities in precipitation produce noticeable changes in the timing and storage of water in the snowpack. The combination of diminished snowpack resulting from projected temperature increases along with expected increases in the population that will depend on water from this snowpack could lead to water management concerns. Since maritime snow comprises about 10% of Earth's seasonal snow cover, Dr. Nolin and her colleagues observe that the results from this case study can be applied to areas of maritime snowpack around the world.

In her study of the effects of burned debris on snowmelt, Dr. Nolin found that snow accumulation was greater in a burned forest study area when compared with an unburned study area. However, the snowpack in the burned study area disappeared 23 days earlier and had twice the melting or evaporation rates than in the unburned forest. Snow albedo was 50% lower in the burned forest, leading to a substantial increase in heat absorbed by the upper layers of soil in the burned area.

Looking at the surface roughness of the Greenland ice sheet, Dr. Nolin and her colleagues found that the ice sheet's surface roughness changes significantly over the course of the melt season, primarily from April to July, and varies from year to year depending on the amount of melt and the dynamics of the outlet glaciers along the ice sheet margin. Dr. Nolin also found that roughness values are lower in the dry, snow-covered interior of the ice sheet and much higher along the crevassed margins of the ice sheet.

## Read about the research:

Gleason, K.E. & **Nolin, A.W.** (2016). "Charred forests accelerate snow albedo decay: parameterizing the post-fire radiative forcing on snow for three years following fire." *Hydrological Processes*, 30(21) [doi: [10.1002/hyp.10897](https://doi.org/10.1002/hyp.10897)].

Gleason, K.E., **Nolin, A.W.** & Roth, T.R. (2013). "Charred forests increase snowmelt: Effects of burned woody debris and incoming solar radiation on snow ablation." *Geophysical Research Letters*, 40(17) [doi: [10.1002/grl.50896](https://doi.org/10.1002/grl.50896)].

Nolin, A.W. & Mar, E. (2013). "Greenland Ice Sheet Surface Roughness and Glacier Zones from MISR, 2000-2013." American Geophysical Union, Fall Meeting 2014, abstract #GC51E-0468 [Bibliographic Code: [2014AGUFMGC51E0468N](https://doi.org/2014AGUFMGC51E0468N)]

Sproles, E., **Nolin, A.W.**, Rittger, K. & Painter, T. (2013). "Climate change impacts on maritime mountain snowpack in the Oregon Cascades." *Hydrology and Earth System Science*, 17(7) [doi: [10.5194/hess-17-2581-2013](https://doi.org/10.5194/hess-17-2581-2013)].

Nolin, A.W. (2012). "Perspectives on climate change, mountain hydrology, and water resources in the Oregon Cascades, USA." *Mountain Research and Development*, 32(S1) [doi: [10.1659/mrd-journal-d-11-00038.s1](https://doi.org/10.1659/mrd-journal-d-11-00038.s1)].

Nolin, A.W. & Payne, M.C. (2006). "Classification of glacier zones in western Greenland using albedo and surface roughness from the Multi-angle Imaging SpectroRadiometer (MISR)." *Remote Sensing of Environment*, 107(1-2) [doi: [10.1016/j.rse.2006.11.004](https://doi.org/10.1016/j.rse.2006.11.004)].

# Who Uses Earth Science Data?

Dr. Erricos C. Pavlis, to help accurately measure Earth.



## 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.

**Research highlights:** 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 \(ITRF\)](#). 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.

(Continued)

# Who Uses Earth Science Data?

## 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%. 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](https://doi.org/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](https://doi.org/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](https://doi.org/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](https://doi.org/10.1126/science.279.5359.2100)].

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