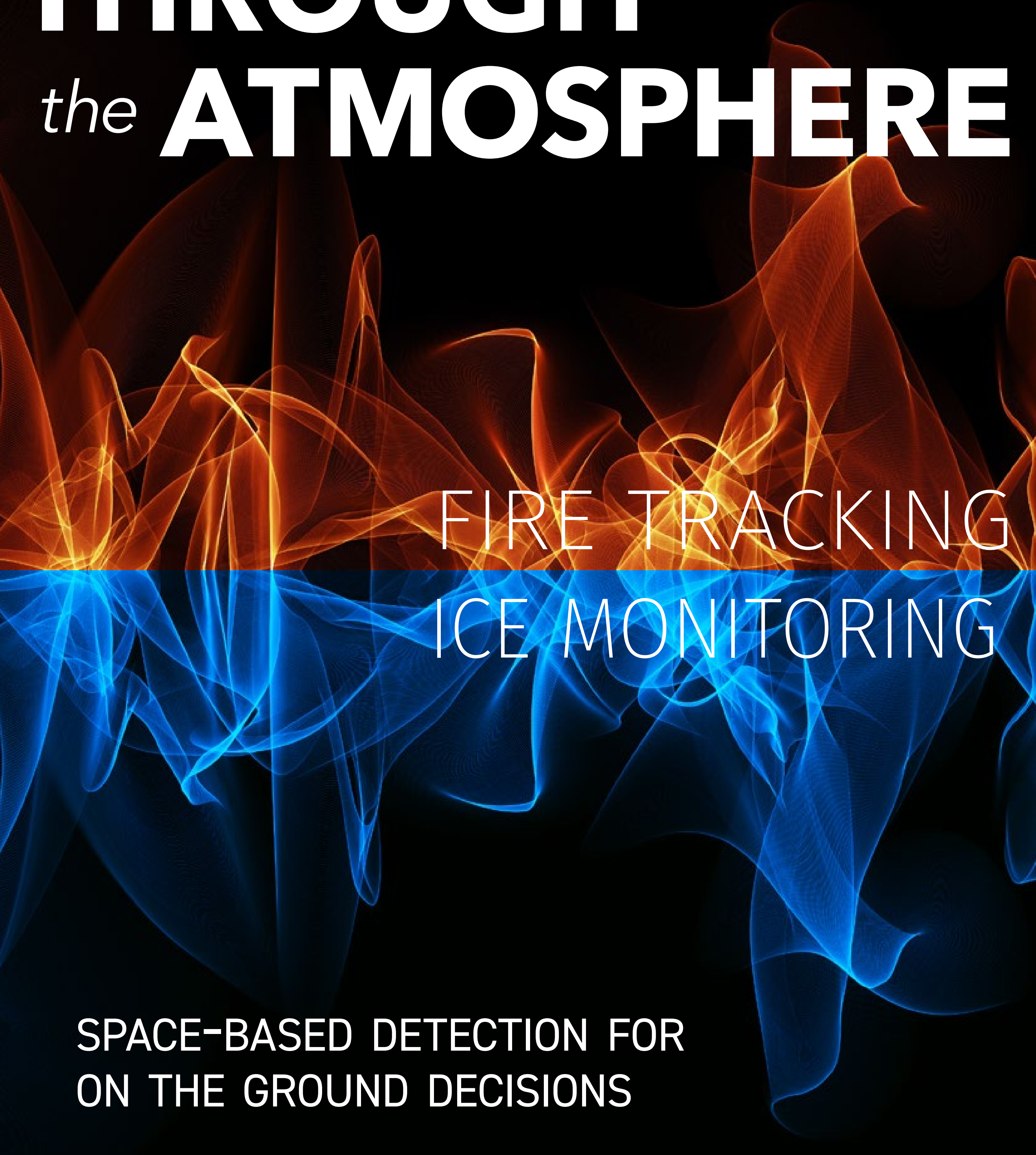
# THROUGH *the* ATMOSPHERE



## FIRE TRACKING
## ICE MONITORING

### SPACE-BASED DETECTION FOR ON THE GROUND DECISIONS

**Summer/Fall 2022**
Space Science and Engineering Center | Cooperative Institute for Meteorological Satellite Studies | University of Wisconsin–Madison

Credit: Carolyn Lipke

# Director's note

Environmental extremes exacerbated by a changing climate are accelerating sea ice melt and sea level rise while at the same time prolonged drought in the mid-latitudes is creating perfect conditions for wildfires.

These fire and ice processes may seem unrelated but we live on an interconnected planet with interconnected atmospheric circulation patterns. In fact, recent research reveals that diminishing ice may alter atmospheric circulations — specifically, the polar jet — preventing Pacific moisture from reaching the Western U.S. and reinforcing the warm and dry conditions that make those areas vulnerable to wildfires.

We need more information about these forces at work in our changing climate in order to predict and adapt to these changes.

Among the stories in this issue are four programs at SSEC and CIMSS that are adding to what we know about environmental changes, not only in the northernmost latitudes where ice covers the landscape, but also in the middle latitudes where drought and wildfire are increasingly making headlines.

The common denominator to all of these programs is environmental satellites.

Two involve using new satellite technologies to study sea ice in the Arctic aiming to improve climate models and measurements. And the other two, again using new satellite instruments, are developing tools to identify the locations of wildfires faster. In addition, they are building a database of fire attributes so that researchers can study conditions that spawn fires over time, using the past to inform future science, and future policy.

Our world is full of interdependencies where a change in one ecosystem can trigger unexpected changes in another. With the benefit of environmental satellites, researchers at SSEC and CIMSS are continuing to do what they do best: pursuing novel approaches to novel problems to support societal needs.

Tristan L'Ecuyer

**Tristan L'Ecuyer**
**CIMSS Director**

# THROUGH *the* ATMOSPHERE

## SUMMER/FALL 2022



Through the Atmosphere is a biannual publication featuring atmospheric, space science, and engineering research and education accomplishments of the University of Wisconsin–Madison's Space Science and Engineering Center (SSEC) and its Cooperative Institute for Meteorological Satellite Studies (CIMSS).

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**Cover image credit**
Gerd Altman

Credit: SSEC

# The air we breathe

## Increasing the tempo of air quality measurements

by Jean Phillips

We expect to breathe clean air, but pollutants from fossil fuels, ozone, car exhaust and other sources continue to be a threat to human health and the environment.

Despite improvements in air quality, the U.S. Environmental Protection Agency estimates that in 2021 about 102 million people lived in states with pollution levels that exceeded the National Ambient Air Quality Standards, the standards that set limits on certain pollutants such as ozone and carbon monoxide. People who live in these areas are at a higher risk for heart disease, lung cancer and other respiratory diseases like asthma.

Brad Pierce, director of the University of Wisconsin–Madison Space Science and Engineering Center and professor of atmospheric and oceanic sciences, has spent the better part of his career developing capabilities to use satellite data in air quality modeling systems in order to improve emission inventories and global air quality predictions. In short, to provide more up-to-date information to decision makers in public health, weather forecasting and other areas as they assess air quality risks to the public.

"Better and more frequent emissions data will give us a better handle on ways to improve air quality and public health," says Pierce.

Pierce is a member of the science team on the NASA — Smithsonian Astrophysical Observatory Tropospheric Emissions: Monitoring of Pollution mission. When launched, the TEMPO sensor will deliver hourly, daytime measurements of air pollution over North America from geostationary orbit at a frequency and resolution not possible with current instruments in polar orbit that provide measurements only once per day.

"The global emissions inventory we are using right now is from 2010 and the most recent U.S. inventory from the EPA is from 2017," says Pierce. "This is a pretty big lag in the frequency of our data."

With TEMPO, Pierce expects emissions updates with a latency of one year or less.

The TEMPO mission has the research community excited because it will be the second in a trio of satellites, joining an international push to improve air quality science and forecasting around the world. The first, South Korea's Geostationary Environment Monitoring Spectrometer, reached its orbit in 2020 and is making air quality measurements over Asia. TEMPO is expected to launch in early 2023 while the third, the European Space Agency's Sentinel-4 satellite, is also scheduled for launch in 2023 and will measure pollutants over Europe and North Africa.

Pierce and other science team members expect the TEMPO data will help them focus on identifying pollution-producing problems like exhaust from rush-hour traffic in heavily populated urban areas. Among the pollutants in car exhaust are carbon dioxide that contributes to climate change as well as nitrogen oxides and sulfur dioxide, both of which contribute to the formation of smog.

"We'll have better data on rush hour traffic and energy use," says Pierce. "We'll be able to measure pollutants from these sources as they increase and decrease throughout the day. Right now, we don't have satellite-based information on how they vary."

Previous satellite data were only available at one time each day for a given location due to the timing of polar-orbiting satellite orbits. Since GEMS is already in orbit, Pierce and other scientists are taking advantage of its more frequent measurements and developing tools to assimilate them into forecast systems.

"The frequency of the data from geostationary orbit is unprecedented," says Pierce.

This constellation of satellites, along with data from existing instruments in polar orbit, will provide a full suite of instruments measuring atmospheric composition around the world for the first time, he says.

**▲ Before its integration onto the satellite, the TEMPO instrument was tested to ensure that it could withstand the space environment. Credit: Ball Aerospace**

The TEMPO sensor has been tested in a vacuum chamber to be sure it can withstand the extreme space environment and it has been integrated onto the satellite ahead of launch.

Like much of science, TEMPO is related to a mission that preceded it: the Geostationary Coastal and Air Pollution Events Mission or GEO-CAPE that measured atmospheric composition. NASA conducted the design studies for both missions in response to recommendations from the 2007 decadal survey, *Earth Science and Applications from Space*, says Pierce. Pierce, who was also involved with GEO-CAPE, says that these mission design studies helped to formulate the TEMPO instrument.

A future mission, called Geostationary Extended Observations or GeoXO, is being planned by the National Oceanic and Atmospheric Administration and is expected to provide an operational follow-on to TEMPO. It will include other instruments important to monitoring Earth's atmosphere, such as a hyperspectral infrared sounder that will further realize the original GEO-CAPE mission design.

"It is kind of a nice circle," says Pierce. "The decadal survey recommends GEO-CAPE which forms the foundation for NASA's development of TEMPO, which in turn, provides vital operational information for NOAA's GeoXO."

This process demonstrates the importance of research missions during which scientists can refine and test instruments before using them operationally. It also demonstrates how long it takes — and the patience scientists must exhibit — to perfect an operational instrument.

*This work is supported by NASA.*


Credit: Bryce Richter


Credit: Margaret Mooney

**$4.5**
million
total funding


Credit: Bill Bellon

**53**
proposals funded
2019-2022


Credit: Eric Verbeten

**40+**
external partners and collaborators

# SSEC2022

## Center-wide investments lay groundwork for new research

by Eric Verbeten

SSEC2022 was a three-year, $4.5 million investment in the University of Wisconsin–Madison Space Science and Engineering Center's research, infrastructure and outreach — the internal funds serving as a catalyst for external opportunities.

From 2019 to 2022, more than 50 internal proposals were funded that are representative of the center's diverse research and engineering portfolio — while promoting education and outreach initiatives aimed at inspiring the next generation of scientists.

"SSEC2022 covers nearly every aspect of our work here at the center," says Brad Pierce, SSEC director. "It was part of the design to update our infrastructure and to build upon current research and engineering projects and to find new research avenues."

All proposals over the three-year period were peer reviewed by members of the SSEC Advisory Council, a board consisting of SSEC staff and affiliates.

Pierce says the first year in 2019 focused largely on SSEC's infrastructure to improve physical spaces and technological capabilities. Projects included upgrading shared computing resources, refurbishing spaces within the building and hosting an education and outreach program.

### Computing resources

Upgrades to SSEC Satellite Data Services' computing resources were installed to provide researchers with powerful GPU computing to develop new machine learning techniques for predictive weather models using satellite data. Other investments included building a cloud-based framework for future collaborations and data sharing with NOAA and the Geostationary Extended Operations or GeoXO program.

### Physical spaces

The Atmospheric Oceanic and Space Sciences Library underwent a transformative remodeling to better serve the AOSS community at UW–Madison. The remodeling project, guided by focus group feedback, has created a welcoming study space for students and staff. Phase two of the project will create a classroom for lectures, tours and presentations. Beyond providing research resources, the library's shared spaces serve as a way to build community.

### Education and outreach

The SSEC Tech Camp was a five-day program with a focus on diversity that brought six students and five teachers from surrounding Madison, Wisconsin schools to learn about weather, satellite meteorology, numerical weather prediction and computer programming. The following year, the Tech Camp was adopted as part of the campus-wide University of Wisconsin–Madison Badger Summer Scholars Precollege Program.

Pierce says the SSEC2022 investments have helped elevate SSEC and CIMSS science to address worldwide challenges like natural disasters, climate change and severe weather. The funded proposals have also helped the center be more competitive for future grants by improving SSEC's infrastructure and laying the engineering and research groundwork to compete for external opportunities.

Looking back, Pierce notes an unforeseen benefit that became integral to the SSEC2022 proposals.

"During the pandemic-related lockdowns that we experienced here and across the UW campus, SSEC2022 helped bring a sense of unity while we were working apart from one another," he says. "These projects provided a way forward through those very uncertain times."


▲ **The Scanning-High Resolution Interferometer Sounder is a compact remote sensing instrument designed to fly aboard high-altitude aircraft such as NASA's ER-2 (left) and others. Data from the S-HIS are used to study Earth's atmosphere and weather. Credit: Joe Taylor**

# High-altitude science

## SSEC2022 investments serve as catalyst for external opportunities

by Eric Verbeten

The National Oceanic and Atmospheric Administration has awarded the University of Wisconsin–Madison Space Science and Engineering Center $1.2 million for the development and testing of the next generation Scanning-High Resolution Interferometer Sounder, or S-HIS. Developed at SSEC, the S-HIS is a remote sensing instrument that makes precision measurements of key atmospheric variables important for weather and climate research.

SSEC engineers and scientists first designed the S-HIS as a compact instrument mounted underneath the wings of high-altitude aircraft. Its compactness allows for testing and refining the instrument on Earth with an eye towards adapting it for future spaceflight missions.

Traditional weather satellites are packed with earth-observing instruments that provide meteorologists 24/7 data to monitor the atmosphere and predict severe weather. One drawback; however, is that it is difficult, if not impossible, to service those instruments if they malfunction after launch.

"For more than two decades we've flown the S-HIS on these high-altitude aircraft as a way to develop new instrument technologies," says Joe Taylor, SSEC scientist and principal investigator. "These remote sensing measurements act as a bridge to in situ measurements and you have the flexibility to look at specific cases."

The instrument is designed to measure infrared radiation in the atmosphere. Earth's surface and air radiate energy across the electromagnetic spectrum, but certain features, like clouds or water vapor, absorb and reflect energy in the infrared. These measurements yield useful information about the formation of hurricanes, tornadoes, floods and other severe weather.

Taylor credits investments from the SSEC2022 initiative in helping the S-HIS project respond quickly and efficiently to this funding opportunity.

SSEC2022 was a three-year, $4.5 million investment in SSEC's research and engineering portfolio. The S-HIS project was selected for SSEC2022 support in 2019 and 2021. The first award was used to support a design study which focused on identifying a modular approach to upgrade and replace key components and systems, while reducing size, mass, and power needs. The following grant in 2021 was dedicated to the development of critical subsystems needed to advance the S-HIS capabilities. This included the imaging interferometer, along with an upgraded blackbody controller, and a real-time instrument controller which serves as the brain of the instrument to coordinate the sub-systems to work in unison.

"The SSEC2022 investments allowed us to be agile and move forward with this NOAA opportunity," says Taylor.

Satellites offer unprecedented views of changing atmospheric conditions from a vantage point of 800 km (500 miles) to more than 36,000 km (22,000 miles) away from Earth; however, given the construction costs and build times, these satellites must undergo rigorous testing before launch to ensure their payloads and systems are ready for orbit.

In contrast, high-altitude aircraft such as NASA's ER-2, Global Hawk and WB-57 provide a unique platform to test these satellite-bound remote sensing technologies for future missions. Once in flight, these aircraft can mimic the vantage points seen by satellites from orbit. An important difference; however, is that once the planes land, the instruments can be refined or repaired.

By comparing atmospheric data collected on the ground such as temperature, humidity and water vapor to S-HIS data gathered from the air, researchers are able to verify the calibration of space-bound detectors to ensure their accuracy in orbit. This also includes validation of data from satellites already in orbit such as SNPP, NOAA-20, GOES-16, GOES-17 and the latest GOES-18 which launched in 2022.

"This is how scientific instruments are developed — over time and with ingenuity and continuous improvements," says Taylor. "Each step allows us to envision new uses and this is an exciting aspect of our work."

*This work is supported by SSEC and NOAA.*

Credit: Jeff Miller

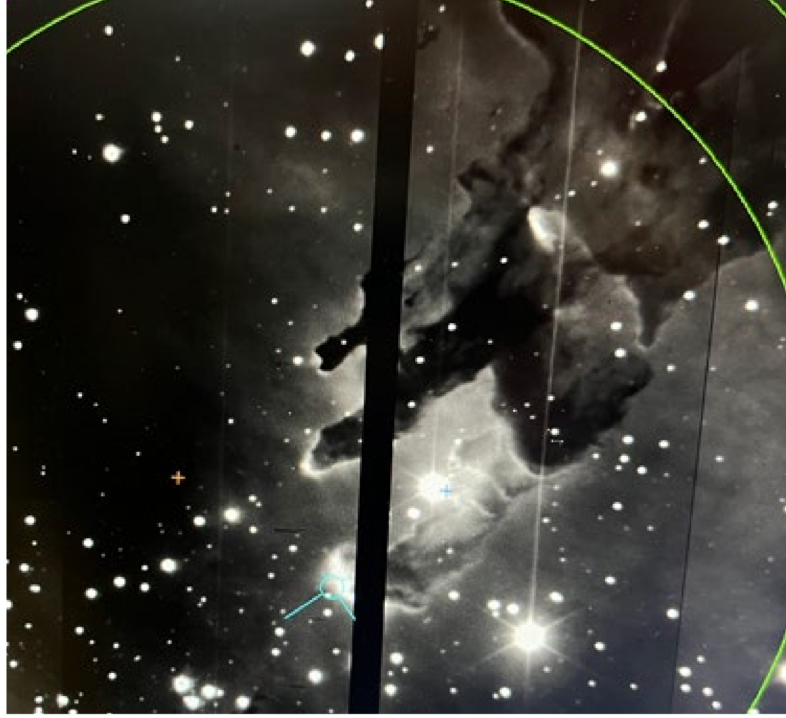
# SALT

## Southern African Large Telescope sees first infrared images

On a remote South African plateau, the passing of day into night reveals a cosmos awaiting discovery. The rural village of Sutherland, located four hours away from the capital city Cape Town, offers some of the darkest skies in the country. For this reason, it is home to the Southern African Large Telescope — an 11-meter (36-foot) telescope designed to peer deep into the cosmos and study our universe.

by Eric Verbeten

◀ The SALT is an 11-meter (36-foot) telescope that uses an array of 91 hexagonal mirrors to collect cosmic light and focus it toward three detectors, including the SALT Imaging and Acquisition Camera or SALTICAM, the Robert Stobie Spectrograph and the NIRWALS.



▲ The Southern African Large Telescope captured its first infrared light imagery by observing the Eagle Nebula located in the constellation Serpens. Credit: Lisa Crause

In Summer of 2022, SALT achieved a milestone by observing its first celestial object in the infrared. The target was a familiar one, the Eagle Nebula — made famous by the Hubble Telescope's imagery that revealed its unfathomable size and active stellar nursery. The nebula is located in the constellation Serpens and made for an ideal first target because of its intriguing structure and many star-forming regions.

"People came out of the woodwork for this momentous occasion. They had logged many long-hour days helping us prepare for this moment and weren't going to miss the event, even though it meant staying even longer into the night," says Marsha Wolf, senior scientist at the University of Wisconsin–Madison Department of Astronomy and principal investigator for the SALT Near-Infrared Washburn Astronomical Laboratories Spectrograph. "There were lots of high-fives going around the room."

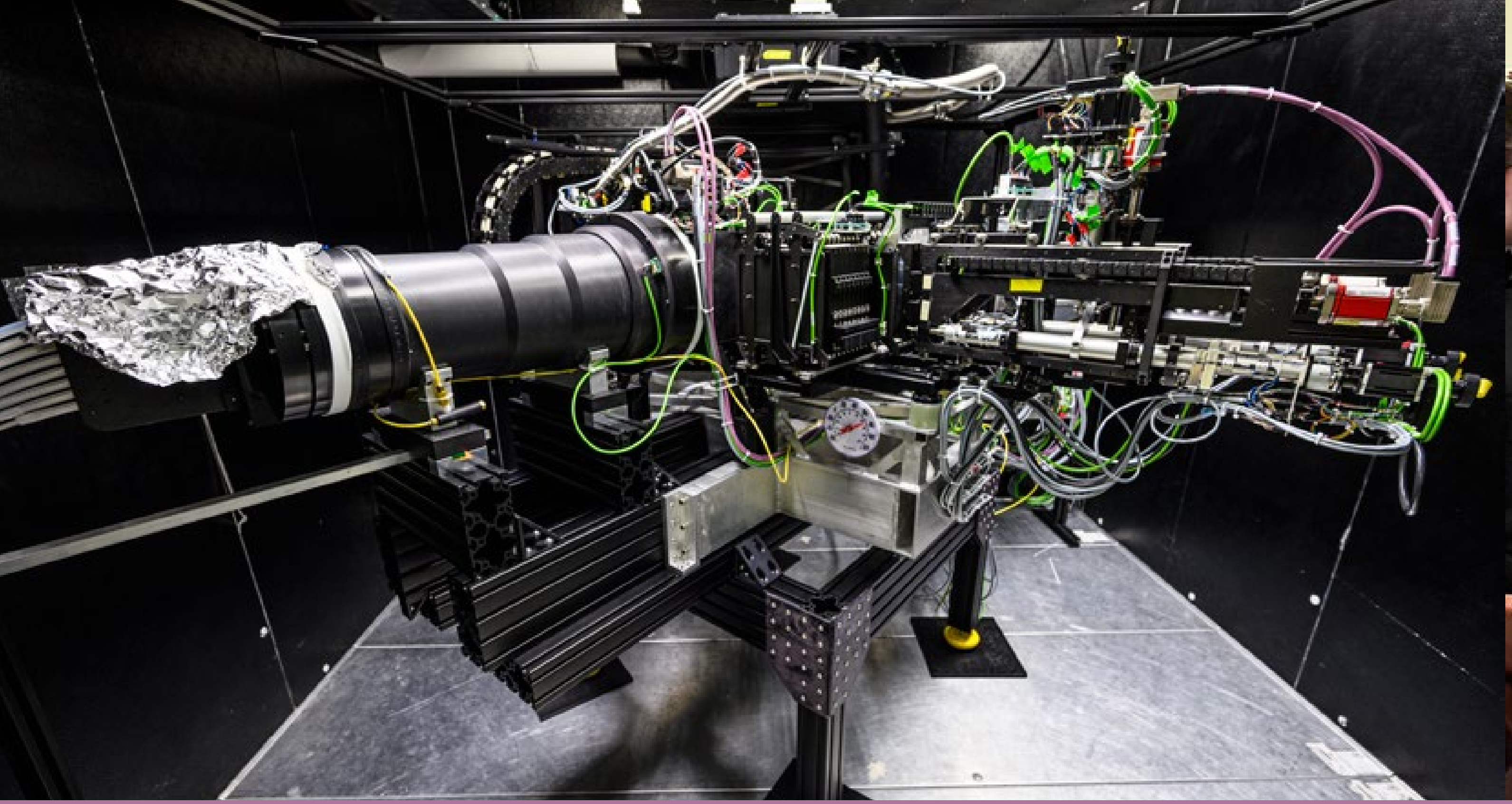
The SALT telescope is led by the South African Astronomical Observatory in partnership with more than 10 universities and observatories, including the UW–Madison Department of Astronomy and the Space Science and Engineering Center who helped design and build the NIRWALS.

The SALT uses an array of 91 hexagonal mirrors to collect cosmic light and focus it toward three detectors: the SALT Imaging and Acquisition Camera or SALTICAM, the Robert Stobie Spectrograph, and the NIRWALS. Each is sensitive to different wavelengths of light, including the visible and the near-infrared spectrum. Astronomers use both types of light to observe and study all aspects of celestial objects like stars, galaxies and nebulae.

Wolf's research focuses on galaxy formation and evolution. By using both the infrared and visible light gathered by the telescope, she and her team are able to witness changes in the structure of galaxies over time. In particular, they study galaxies that have active supermassive black holes at their center, known as active galactic nuclei. When these black holes feed on nearby matter like gas and stars, much of the matter is ejected far away from the center at blistering speeds. The resulting shockwaves can be forceful enough to disrupt the formation of nearby stars within the galaxy. These violent interactions emit light in the visible and infrared frequencies that are captured by the SALT telescope detectors.

"Stars form through the gravitational collapse of gas, so one way to stop this process is to heat the gas enough so that thermal motions of its particles overpower gravity and prevent it from condensing into stars," says Wolf. "One proposed feedback culprit is the supermassive black hole at the center of nearly every galaxy."

The idea is that the hot gasses and matter that are not consumed by the black hole collide with other particles in the galaxy, causing those areas



▲ **The Near-Infrared Washburn Astronomical Laboratories Spectrograph transforms incoming infrared light captured by the SALT into data and imagery used to study our galaxy. Credit: Marsha Wolf**

▲ **Marsha Wolf (right) gathers with NIRWALS team to witness the first infrared images captured by the SALT in July 2022. Credit: Lisa Crause**

to heat up. This redistribution of energy could interrupt a nearby star's formation and better match observations with computer simulated galaxy formations.

Wolf and her team will use the SALT to investigate hundreds of nearby galaxies to search for evidence of black hole disruptions and outflows of energy away from the center. According to Wolf, a large sample size is needed because each galaxy observed by the SALT provides only an instantaneous snapshot of a process that takes place over millions of years. Image by image, the team will be able to witness different phases of a galaxy's evolution and the activity from its black hole.

"The near-infrared spectra from our new instrument will give information on shocks in the gas from active galactic nuclei outflows, past supernovae, and the very youngest stellar populations," says Wolf. "Putting these data all together, this will paint a clearer picture of if and how the nuclei have regulated the star formation histories of galaxies."

## What is NIRWALS?

Telescopes have evolved significantly over the last century. While amateur astronomers and the public can enjoy seeing objects like the Moon or Saturn in our galactic backyard, modern telescopes reveal hidden objects located deep within our galaxy and beyond. Not only do they show us beautiful images of distant stars and planets, but they can tell us what they are made of, their age and how quickly they are moving away from us or toward us.

Observations in the infrared are responsible for this level of detail. Although invisible to the human eye, infrared detectors like the NIRWALS are sensitive enough to collect these data and reveal a wealth of knowledge about our universe.

The NIRWALS was designed by the UW–Madison Space Science and Engineering Center and the Department of Astronomy in partnership with the South African Astronomical Observatory.

"The NIRWALS allows us to compare the light signals from galaxies at large distances to galaxies nearby that have been observed at visible wavelengths. Because the universe is expanding the signals from distant galaxies get doppler-shifted into the near-infrared where we can observe them," says Matthew Bershady, UW–Madison astronomy professor and lead on the NIRWALS fiber optic system. "It also can be `cloudy' in space, particularly in star-forming galaxies where there is a lot of dust. The NIRWALS probes through more layers of dust to uncover the stars."

The instrument consists of three primary components: the payload, the fiber-optic cables and the spectrometer. The payload is located 13 meters (42 feet) above the ground level where it collects the light from the mirrors and then transfers that information to a spectrometer beneath the telescope structure.

A 43-meter (141-foot) bundle of sensitive fiber-optic cables connect the payload to the spectrometer and transfer the light signals. The spectrometer below is chilled to a constant temperature of -40 C (-40 F) and allows the device to detect subtle temperature differences throughout a galaxy or nebula. Ultimately, the NIRWALS collates those signals and sends them to a computer system in the control room to convert that information into bar-code-like images known as spectra. These spectral images contain a wealth of information about a celestial target such as temperature and composition.

The NIRWALS will enable astronomers around the world to identify key features of a galaxy like the nucleus around the active galactic nuclei, the surrounding stellar disk and any potential outflows of gas both in and beyond the galaxy.

SSEC scientists and engineers provided end-to-end development support for the NIRWALS, which began conceptually in 2008. They contributed detailed mechanical design of power, control and thermal systems, thermal analysis and project management. Final assembly began in Summer 2022 ending with the NIRWALS' six-week journey from Madison, Wisconsin to South Africa via trucks, ships and aircraft.

"SALT has a very bright future and this instrument is part of it," says Bershady. "For us, we could not have done it without SSEC. Their project management and engineering has allowed the UW–Madison Astronomy Department to successfully deliver and realize the intellectual capital that went into building the instrument."

*This work is supported by the SALT Foundation, NSF, UW–Madison, WARF and SSEC.*

# Assessing potential flood damages in warmer, wetter Wisconsin

by Jean Phillips

Since 1950, Wisconsin's average daily temperature has increased by 1.6 C (3 F). The state's average annual precipitation increased by 17 percent or about 13 cm (5 in) from 2010-2019 making it the wettest decade since 1900 when record-keeping began. Overall, the southern half of Wisconsin is seeing the largest increases in precipitation.

The relationship between atmospheric warming and precipitation is well understood: A warmer atmosphere can hold more water vapor which in turn can trigger more, and in some cases, heavier, rainfall and flooding.

"We have a changing climate with changing rainfall and these changes in precipitation, while they may seem insignificant, are amplifying the impact," says Shane Hubbard, a researcher with the University of Wisconsin–Madison Cooperative Institute for Meteorological Satellite Studies. He says that we need to adjust to this new normal by changing our building practices.

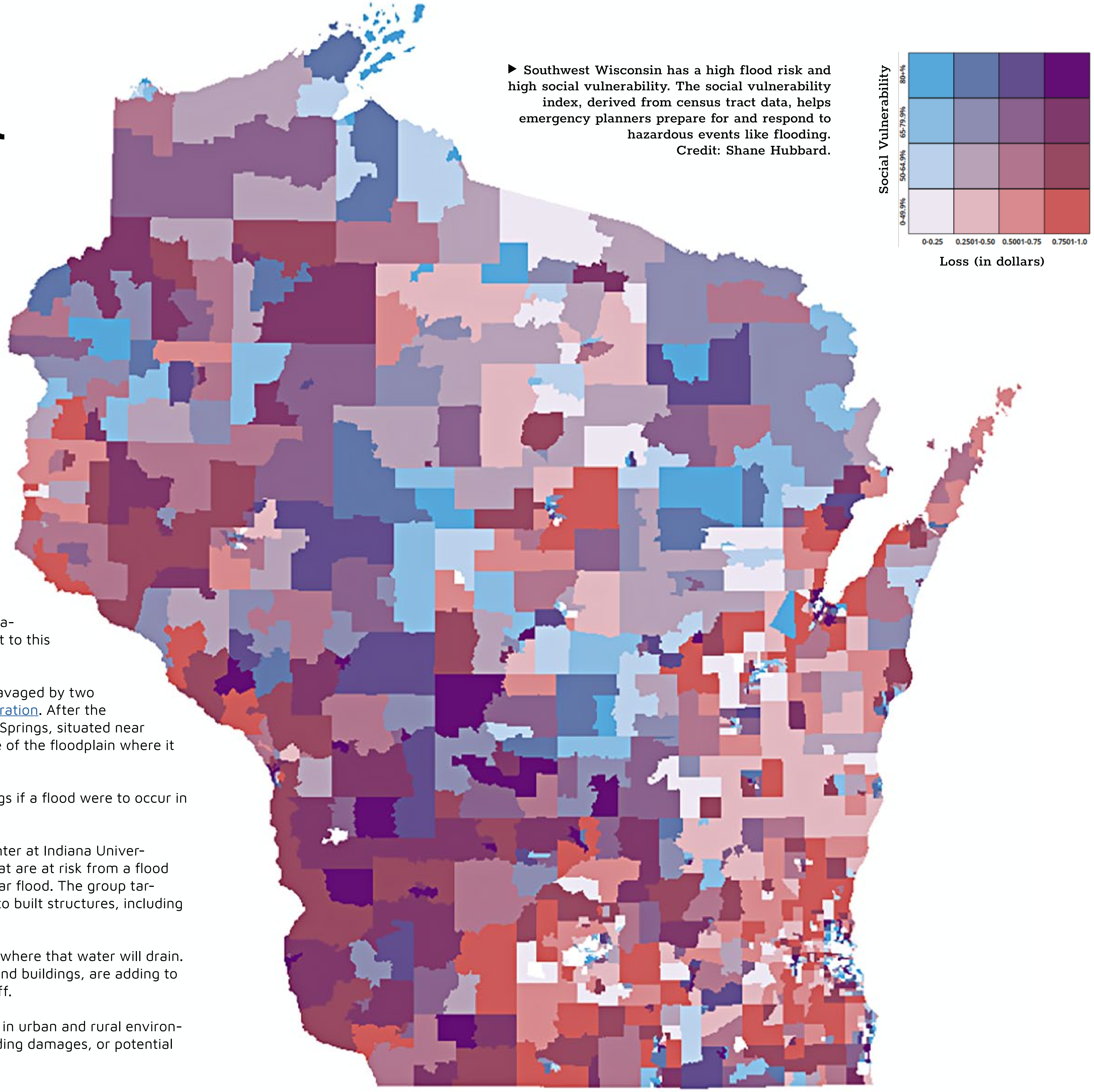
The increase is particularly apparent in places like Sauk County that has been ravaged by two major floods since 2008, both of which resulted in a Presidential Disaster Declaration. After the disastrous flood of 2018 that displaced people and businesses, the city of Rock Springs, situated near the Baraboo River, decided to move its downtown to higher ground and outside of the floodplain where it had been located for 140 years.

Hubbard has developed tools to help communities estimate damages to buildings if a flood were to occur in a certain area, like in or around designated floodplains along a stream or river.

Over the last year, he and a team of researchers from CIMSS and the POLIS Center at Indiana University gathered data on the locations of buildings in every county in Wisconsin that are at risk from a flood of a magnitude that statistically would occur once every 100 years or a 100-year flood. The group targeted buildings because the biggest financial losses come from water damage to built structures, including houses, and these data were readily available.

Any calculation about flooding must consider not just the volume of water, but where that water will drain. The growing number of impervious surfaces in cities, like parking lots, streets and buildings, are adding to the drainage problem as are farming practices such as tilling that result in runoff.

Taking into account all buildings across the state — commercial and residential, in urban and rural environments — Hubbard projects that Wisconsin is facing $2.7 billion of potential building damages, or potential




▶ Southwest Wisconsin has a high flood risk and high social vulnerability. The social vulnerability index, derived from census tract data, helps emergency planners prepare for and respond to hazardous events like flooding. Credit: Shane Hubbard.

▲ **Shane Hubbard specializes in geospatial modeling of hazard events like floods, tornadoes and hurricanes as well as estimating damages and losses from those events. Credit: Shane Hubbard**

risk from a 100-year flood.

Another recent study by Hubbard shows that a 10 percent increase in rainfall can result in three times as much damage to buildings. This is because rainfall is distributed equally across a watershed and the streams, rivers and lakes moving that water can only funnel so much before flooding, he says.

"...these changes in precipitation, while they may seem insignificant, are amplifying the impact." — Shane Hubbard

Armed with information about building locations and the potential financial impact of a flood, the state can help communities to lower, or mitigate, their risk.

This won't always mean moving the heart of a community's town to higher ground, but it may mean developing communities with an eye toward greener landscapes that absorb water and building practices that allow for water retention, like rain gardens, rain barrels and other drainage techniques: in general, more pervious landscapes.

Hubbard's statewide flood report was included in the [2021 State Hazard Mitigation Plan] that was developed by Wisconsin to meet Federal Emergency Management Agency requirements on how communities plan for and mitigate natural hazards. Many counties lack the resources to undertake this type of assessment, making Hubbard's work and collaborations with the state all the more important.

"Wisconsin is lucky because [Wisconsin] Emergency Management is especially good at developing mitigation strategies to address flooding," says Hubbard. "We are considered one of the leaders in this area."

*This work is supported by Wisconsin Emergency Management and FEMA.*



# Science Expeditions Open House

After a two-year hiatus, the UW–Madison Science Expeditions Open House was a huge success with more than 300 guests visiting us at the Atmospheric, Oceanic and Space Sciences building. Both kids and adults took part in a variety of hands-on weather activities, 3D globe presentations and rooftop tours. These were led by students and staff from the Department of Atmospheric and Oceanic Sciences, the Antarctic Meteorological Research and Data Center, SSEC and CIMSS. Thank you to all those who made this year a success and especially the AOS students whose enthusiasm helped revive the annual event.



Credits: Margaret Mooney

Credit: CIMSS

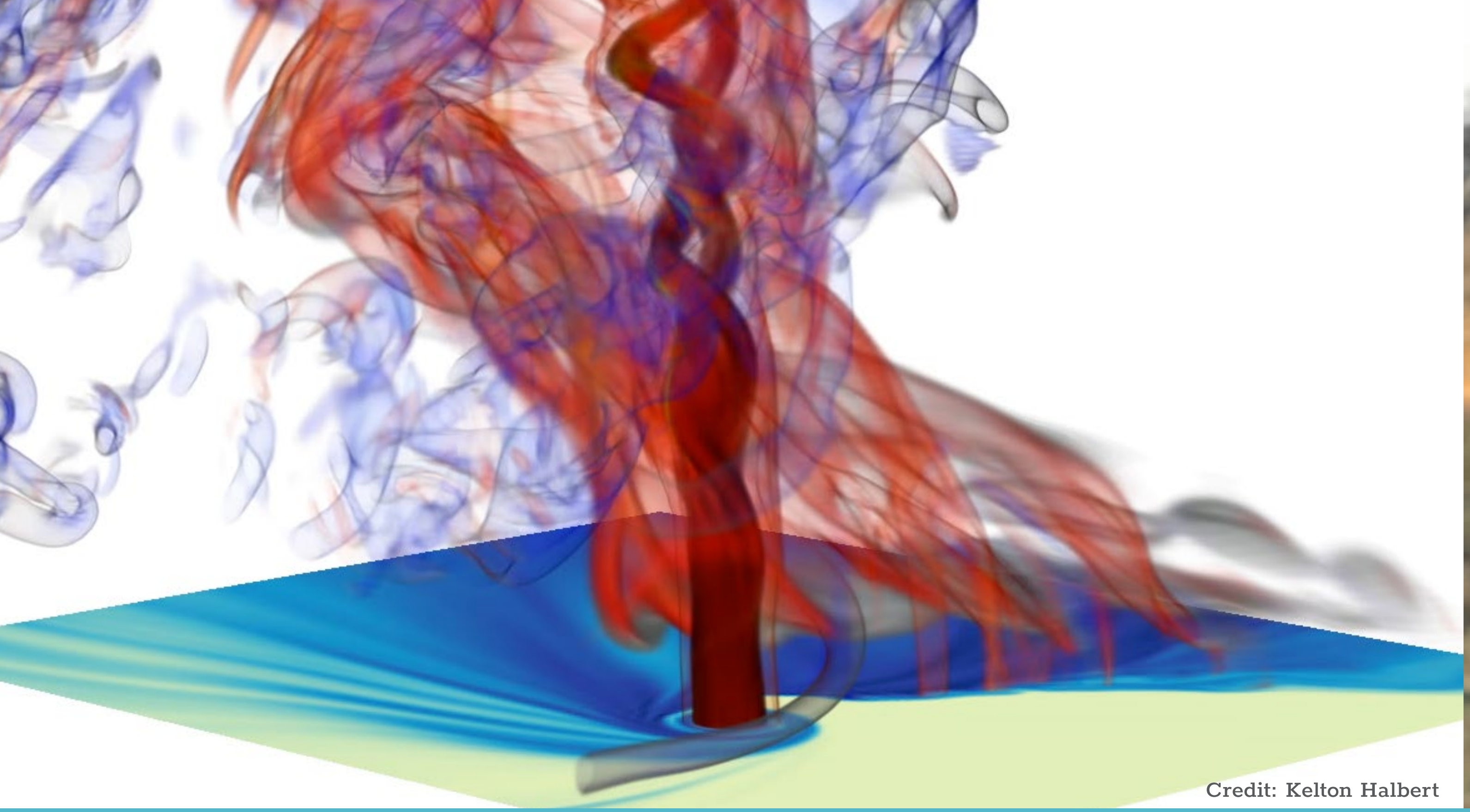
# GOES-18

Soon after its launch, researchers at the Cooperative Institute for Meteorological Satellite Studies processed this first, beautiful image of our blue planet from the latest geostationary satellite, GOES-18. Launched March 2022, GOES-18 is the third in a series of four satellites and will become operational in 2023, replacing GOES-West.

The Earth-facing instruments aboard the satellite include the Advanced Baseline Imager and the Geostationary Lightning Mapper. They deliver images as frequently as every 30 seconds and provide crucial data for forecasters monitoring the development of tornadoes, hurricanes or winter storms that might endanger safety or require evacuations.

"We are aptly named the birthplace of satellite meteorology because we've been involved since the late 1950s when the field emerged," says CIMSS Director and Atmospheric and Oceanic Sciences Professor Tristan L'Ecuyer. "In fact, the proof-of-concept missions — that demonstrated we could monitor Earth's climate and weather from space — were developed here."

by Jean Phillips



Credit: Kelton Halbert

# Supercells, supercomputers and tornadogenesis

## Graduate student Kelton Halbert

by Eric Verbeten

Through lines of code, Kelton Halbert simulates some of the world's most violent thunderstorms to date. Long-lived, violent tornadoes — like those that devastated cities in El Reno, Oklahoma or Mayfield, Kentucky — are recreated in a supercomputer to better understand how and why tornadoes form, or why they don't.

"Whether you get a supercell that spawns a tornado or not, it's all useful information in our simulations," says Halbert, graduate student at the University of Wisconsin–Madison Department of Atmospheric and Oceanic Sciences.
Halbert came to UW–Madison in 2017 after receiving his undergraduate degree in meteorology from the University of Oklahoma in Norman, Oklahoma.

With plans to complete his Ph.D. in 2023, Halbert has already accepted a position with the NOAA Cooperative Institute for Severe and High-Impact Weather Research and Operations (CIWRO), also in Norman. He will continue his research investigating severe weather and the formation of tornadoes or tornadogenesis. The position is a research-to-operations job working closely with the NOAA National Weather Service Storm Prediction Center. Halbert says he will be developing new forecast tools and techniques related to severe weather and tornadoes and working with the annual NOAA Hazardous Weather Testbed to evaluate those tools in an operational setting.

"I am using the expertise I've gained from my grad work with UW," says Halbert. "Specifically working with super computers and modeling to create new forecasting tools with real world impacts."

A supercell simulation begins with what is known as a "sounding" or physical measurements of atmospheric conditions like temperature, humidity, air pressure, wind speed and direction. The measurements are sometimes derived from actual events like those that spawned deadly tornadoes in 2013 and 2021.

With these values uploaded, a powerful supercomputer at the Texas Advanced Computer Center at the University of Texas at Austin plays out the scenarios of turbulent air resulting from these conditions that are the seeds of severe weather. Each simulation takes anywhere from six hours to three days to run, with no guarantee of a tornado forming. Halbert says the randomness of the simulations mirror reality where conditions may or may not be conducive to forming tornadoes.

"It goes right back to principles of the chaos theory by Lorenz, where small perturbations in an initial state can expand in a lot of different directions," says Halbert.

The simulations allow Halbert to rewind the storm scenes and investigate frame-by-frame the dynamics at play. Previous tornado research by UW–Madison Cooperative Institute for Meteorological Satellite Studies scientist Leigh Orf has revealed key structures such as inlet flows of cold air that are essential for starting and sustaining a tornado on its path.

Halbert plans to continue his research into severe weather while working with forecasters at the Storm Prediction Center to develop and improve tools and techniques, ultimately to improve weather forecasts and provide people more advanced warning time.

*This work is supported by CIMSS and UW–Madison.*

**▲ UW–Madison Atmospheric and Oceanic Sciences graduate student Kelton Halbert uses super computers to simulate some of the world's most destructive supercells and tornadoes. Credit: Kelton Halbert**

# New streamlined approach to detect and monitor wildfires

by Leanne Avila

Wildfires in the Western U.S. in 2021 burned millions of acres of land, damaging homes and businesses and decreasing air quality across the region. According to the National Oceanic and Atmospheric Administration's National Centers for Environmental Information, these wildfires were responsible for more than $11 billion in damages.

Credit: sippakorn yamkasikorn



PI Brad Pierce (left) leads new research to streamline the nation's satellite-based fire detection and monitoring systems. Mike Pavolonis (right) serves as the NOAA program manager for this effort. Credit: Bryce Richter, Mike Pavolonis

"Fires are becoming more of a national concern with climate change and drought in the Western U.S. that is unprecedented in the last 1800 years," says Brad Pierce, director of the University of Wisconsin–Madison Space Science and Engineering Center.

To combat this growing problem, NOAA has awarded nearly $3 million to SSEC for research led by Pierce that will streamline the nation's satellite-based fire detection and monitoring systems. These improvements will lead to more timely information for forecasters tasked with alerting the public about fires and fire managers responsible for extinguishing them.

Current satellite fire detection approaches are fragmented, with separate systems for separate satellites. There is no national system to seamlessly merge the information from these disparate systems to issue timely alerts and information about potential and growing fire threats.

To address this gap, Pierce and his team will establish a proven satellite-based system that, regardless of sensor type, will deliver real-time warning and monitoring of wildfires across the U.S. By combining observations from different satellite platforms, the system will take advantage of the spatial resolution of polar sensors and the temporal resolution of geostationary sensors to more precisely determine where and when fires may be occurring. The team also plans to expand the system to include a nowcasting capability.

"One of the primary goals is the development of a really robust algorithm for automated detection of fires that can be applied to any weather satellite," says Mike Pavolonis, who serves as the NOAA program manager for this research and is stationed at SSEC's Cooperative Institute for Meteorological Satellite Studies.

"Fires are becoming more of a national concern with climate change and drought in the Western U.S. that is unprecedented in the last 1800 years." — Brad Pierce

Improving satellite-based fire detection is critical because satellite sensors may provide the first eyes on new fires, as humans and cameras cannot see everywhere. And with the amount of satellite data now available, machine learning techniques are needed to quickly identify potential fire ignition sources, such as lightning, and predict which fires might intensify. The sooner fires are found, the sooner fire managers can develop plans and allocate resources to manage and extinguish them.


▲ Fire life cycle from a NOAA science and service perspective (From Pavolonis, M, "NESDIS Fire Product & Service Development Strategy in Support of Closing Critical Capability Gaps") Credit: Mike Pavolonis

The team has already developed a prototype fire detection system. The prototype is based on previous CIMSS work creating an operational volcanic cloud monitoring software system known as the VOLcanic Cloud Analysis Toolkit. VOLCAT detects volcanic eruptions, tracks the evolution of volcanic plumes and issues alerts to its users.

As Pierce explains, "Detecting fires is a very similar problem from a physics perspective."

This initial VOLCAT Wildfire prototype will be refined, as the team continues to evaluate and upgrade the underlying algorithm, as well as adding more useful information to the dashboard. CIMSS plans to transition the VOLCAT Wildfire system from the research environment to operations by use of a DevOps framework, "which means that there's continuous interaction between the science developers and operational implementation," as Pierce explains. In addition to bringing in experts in DevOps, SSEC has assembled a team of experts in data science, fire research, web development, software engineering and geographical information systems.

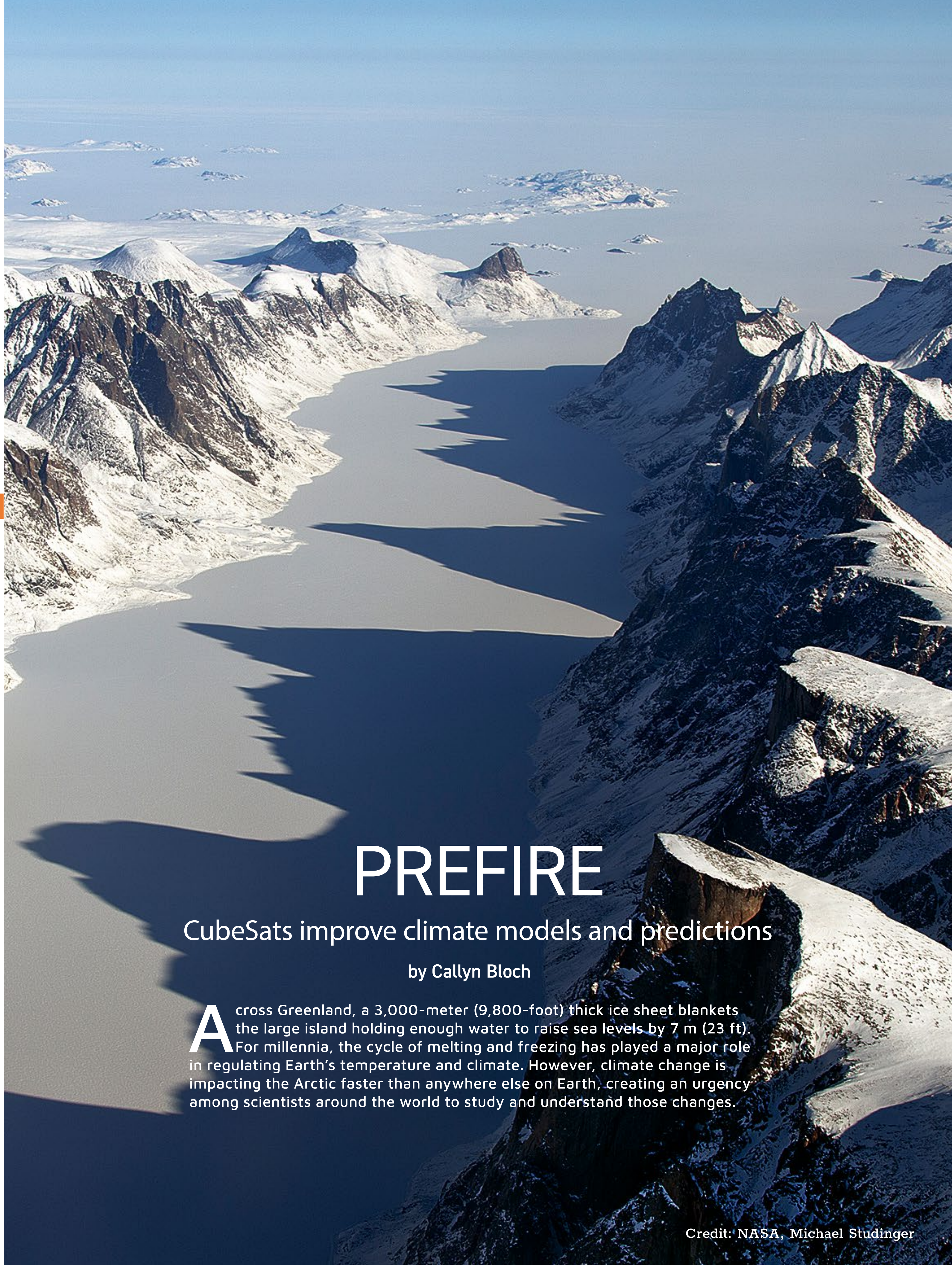
Over time they will develop a fire database, containing parameters such as fire detection, soil moisture, fuel moisture, terrain slope, local winds, humidity and temperature that will allow researchers to study fire behavior and create nowcasting models.

Both Pavolonis and Pierce emphasized the importance of partnerships to developing the new fire detection system, including with other cooperative institutes, university research centers and federal agencies such as the National Weather Service and the U.S. Forest Service. In addition, users will provide feedback to help shape it to their needs and priorities, while partners will continue to contribute from their areas of expertise to strengthen the system.

"This opportunity is an example of why cooperative institutes like CIMSS where federal researchers are working in partnership with academic researchers are a key to standing up something like this new capability in a short time," says Pierce.

*This work is supported by NOAA.*





# PREFIRE

## CubeSats improve climate models and predictions

**by Callyn Bloch**

Across Greenland, a 3,000-meter (9,800-foot) thick ice sheet blankets the large island holding enough water to raise sea levels by 7 m (23 ft). For millennia, the cycle of melting and freezing has played a major role in regulating Earth's temperature and climate. However, climate change is impacting the Arctic faster than anywhere else on Earth, creating an urgency among scientists around the world to study and understand those changes.

Credit: NASA, Michael Studinger

◀ **Nicole-Jeanne Schlegel is a NASA JPL scientist and a co-investigator for the PREFIRE project, using computer models to study glaciers and the Greenland Ice Sheet. Credit: Nicole-Jeanne Schlegel**

A collaborative research project aims to answer pivotal questions about how Arctic ice like the Greenland Ice Sheet and sea ice will respond to a warming climate. The Polar Radiant Energy in the Far InfraRed Experiment, or PREFIRE, is led by Tristan L'Ecuyer, professor of Atmospheric and Oceanic Sciences and director of the University of Wisconsin–Madison Cooperative Institute for Meteorological Satellite Studies. The project seeks to fill missing informational gaps in climate models through the use of satellite observations.

"Changes at the poles are driving global changes," says L'Ecuyer. "Melting glaciers are causing sea levels to rise while changing energy flows are influencing global weather patterns."

The PREFIRE project will gather data with CubeSats, which are shoebox-sized satellites with sensitive detectors used to measure infrared light. More than 60 percent of Earth's energy is emitted at the poles in the far-infrared; however, this part of Earth's energy spectrum has not been measured previously. By collecting accurate measurements of these emissions, the PREFIRE project seeks to improve climate models used to predict future changes in sea ice and glacial ice.

Climate models are foundational for climate studies. They can help understand variability and aid scientists in identifying where changes can occur due to a warming climate. These models answer complex questions about the climate and can be used to test different climate scenarios and interactions. This information plays a critical role in developing policies to respond to future changes. The National Science Foundation and National Center for Atmospheric Research Community Earth System Model is a global, coupled climate model that includes sea ice simulations as well as ocean and atmospheric circulations around the world. A key component of the CESM is a smaller scale climate model, the Ice-sheet and Sea-level System Model. These models work together to understand changes in the polar regions.

The ISSM, developed by the NASA Jet Propulsion Laboratory and University of California Irvine, was created to understand the formation and flow of ice sheets, the effect of ice on the water cycle and how climate forcings can affect sea level.

Nicole-Jeanne Schlegel is a scientist with JPL and PREFIRE co-investigator who works with the ISSM to study sea level and ice sheets, specifically focusing on the Greenland Ice Sheet. This model replicates the Greenland Ice Sheet's fluctuations and can predict how the snow changes through time depending on atmospheric conditions.

"PREFIRE will offer us new opportunities to monitor a region that is changing dramatically before our eyes, though we don't know the full impact of how, and what consequences it will bring," Schlegel says.

Ice sheets and sea ice respond very differently to changes in global temperature. Sea ice can change quickly based on ocean and atmospheric temperatures with response times of less than a decade. In contrast, snow landing on the Greenland Ice Sheet becomes a part of the ice sheet over many centuries due to the force of gravity squeezing out air pockets. This ice is then gradually pushed toward the edges of the sheet over thousands of years and eventually flows, breaks off and melts into the ocean. It takes far longer to make an ice sheet than it does to melt it.

▲ **The PREFIRE mission will provide frequent observational measurements each time its CubeSats pass over the Arctic and Antarctic — enabling scientists to further understand the future of polar ice conditions and the impacts of a warming climate. Credit: NASA/John Sonntag**

Historically, the relationship between snow accumulation and melting has been in balance and the Greenland Ice Sheet has maintained its thickness. However, in recent years, climate change has disrupted its equilibrium.

"Just 30 years ago, people thought that this ice sheet was in equilibrium," Schlegel explains. "Now, there is much more melt happening than what snow is replacing into the reservoir."

Because ice sheets and glaciers in the polar regions regulate sea level rise, and ice sheets, glaciers and sea ice are regulators of the Earth's heat budget, there is a growing urgency to monitor changes as average global temperatures increase. It is difficult to observe activity below the ice surface, but models can help explain what is happening and how the ice flows. However, there is still a great deal of uncertainty in models.

The PREFIRE mission can help reduce the uncertainty in these climate models by filling in missing information in the polar regions, especially information in the far-infrared. This missing information can help scientists understand more about the radiation balance of the ice and determine how much energy is absorbed and emitted. These measurements of the surface of the ice, when incorporated into models, can help predict the temperature beneath the surface.

"As scientists, we're supposed to put the story together with the smallest amount of uncertainty," says Schlegel.

Due to the vastness and remoteness of Greenland, observational data can be sparse, but is necessary for evaluating how models are performing. Once compiled, these pieces of information will begin to tell the story of the region's climatological history as well as its future. The PREFIRE mission will provide frequent observational measurements each time its CubeSats pass over the Arctic and Antarctic — enabling scientists to further understand the future of polar ice conditions and the impacts of a warming climate.

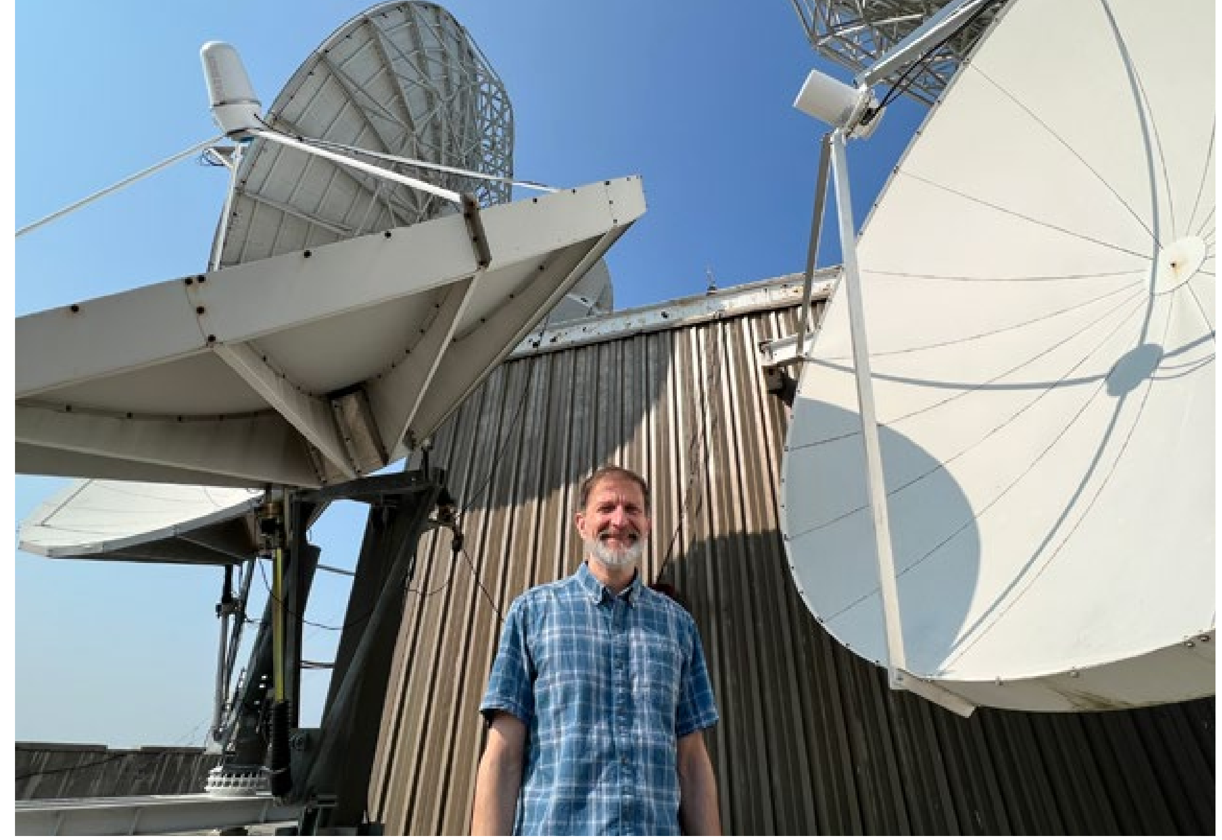
*This work is supported by NASA.*

Credit: NASA/Kathryn Hansen

# A new focus on Arctic sea ice

by Leanne Avila

For decades, scientists around the globe have watched as Arctic sea ice has changed. Whether the ice is growing or shrinking, those changes can affect industries such as commercial fishing and maritime shipping of goods, not to mention indigenous communities living on the coasts whose people rely on fishing and hunting and may be trapped on the ice in poor conditions.



▲ CIMSS scientist Tom Greenwald is the principal investigator on a three-year research project to improve the spatial resolution of Arctic sea ice imagery. Credit: Bill Bellon

These drastic shifts over the years also serve as evidence of climate trends. While scientists started monitoring sea ice changes with satellite sensors in the 1970s, until recently they had to contend with images of lower resolution that are less detailed.

Tom Greenwald, a scientist at the University of Wisconsin–Madison Cooperative Institute for Meteorological Satellite Studies, is the principal investigator on a three-year research project to improve the spatial resolution of Arctic sea ice imagery, in order to paint a clearer picture of environmental change. This research is part of the larger NOAA Joint Polar Satellite System Proving Ground and Risk Reduction program, which brings together developers and users to improve polar satellite products and applications.

Greenwald aims to improve the spatial resolution of the sea ice imagery to between 3 and 6 km (1.8 and 3.7 miles), which is a significant upgrade over the current 15 km (9 miles) or more for operational sea ice products using microwave measurements. These observations are from the Advanced Microwave Scanning Radiometer 2, a Japanese sensor that is capable of imaging during nearly all weather conditions, unlike visible and infrared sensors that are hindered by clouds.

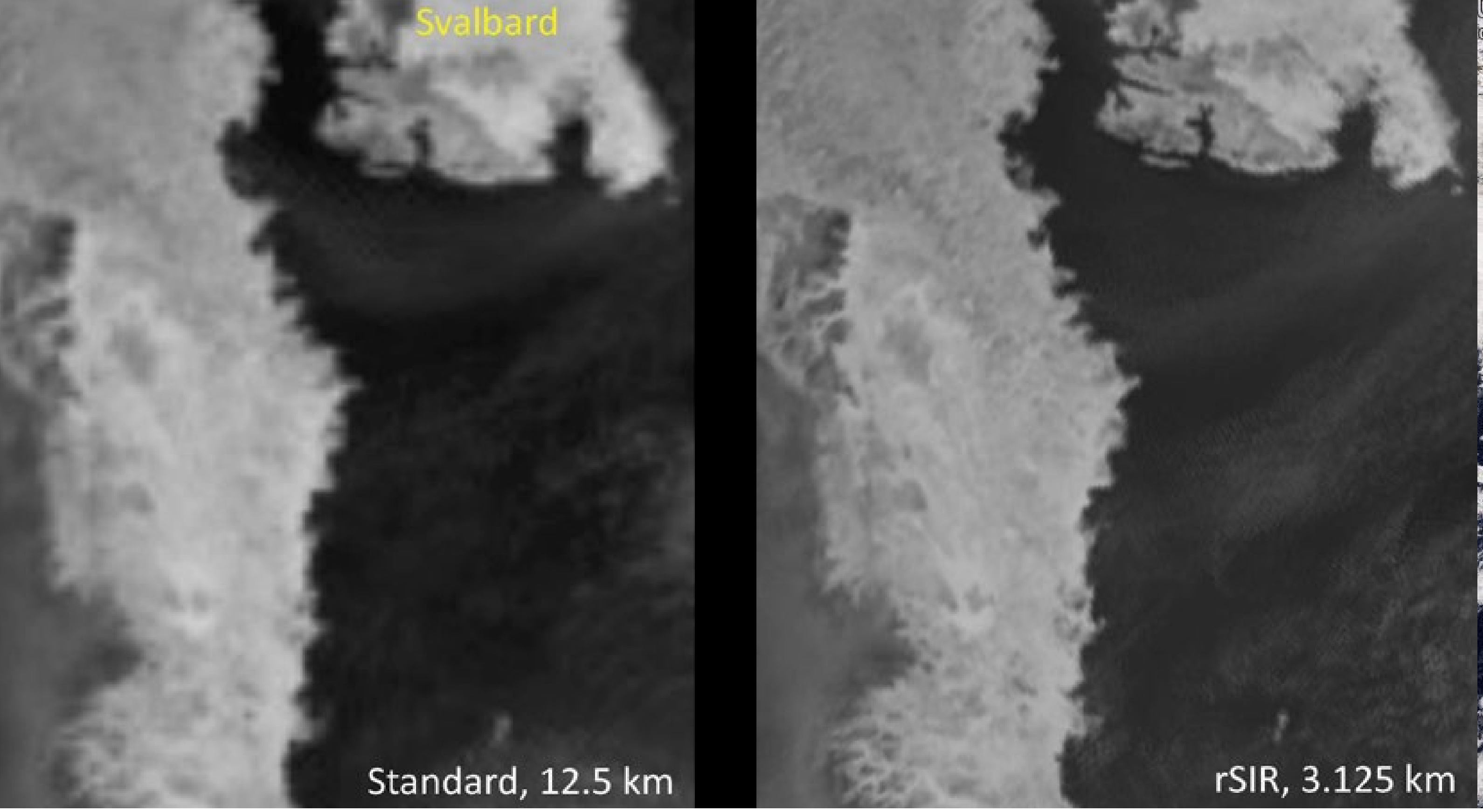
Greenwald's team includes collaborators at the University of Colorado, Mary Brodzik and Walter Meier, who have developed and refined the image processing software to sharpen the images of the Arctic sea ice using the AMSR2 data.

"We're taking advantage of these overlapping fields of view, the overlapping data in the polar regions. We use that information to sharpen a blurry image using image processing techniques," says Greenwald.

But it's about more than just creating highly detailed images. The enhanced imagery is used to produce high resolution products, such as sea ice concentration or even ice thickness, that are useful to forecasters and other researchers studying Arctic sea ice.

The enhanced imagery is available online, with images produced twice daily in GeoTiff format.

As the first year of research has finished, it is already receiving positive feedback from users




▲ **AMSR2 36.5H GHz imagery at native (left) and enhanced (right) spatial resolution on Jan. 10, 2022 over the Greenland Sea. Credit: National Snow and Ice Data Center**

at the National Weather Service Alaska Sea Ice Program in Anchorage. Greenwald noted that they appreciated being able to "see more fine-scale structure in the ice, especially the ice edge." Greenwald plans to connect with potential users at the U.S. National Ice Center to provide further evaluations of the images and products.

As they move into the second year, the team will continue to focus on producing high spatial resolution images as close to real-time as possible. They will also transfer the processing software from University of Colorado to the supercomputer housed within the Space Science and Engineering Center at UW–Madison for testing before delivering the software to the NWS Arctic Testbed and Proving Ground. At the ATPG it will be tested extensively in an operational system. Ultimately, Greenwald looks forward to seeing the research transferred into operations, making the images and products available to forecasters on a routine basis.

Until then, Greenwald and his team will continue to improve the algorithms and software to produce more highly detailed images and more useful products. They will validate their work using data from other sources, such as the Visible Infrared Imaging Radiometer Suite in clear skies, and Synthetic Aperture Radar which is very high resolution, as well as Landsat.

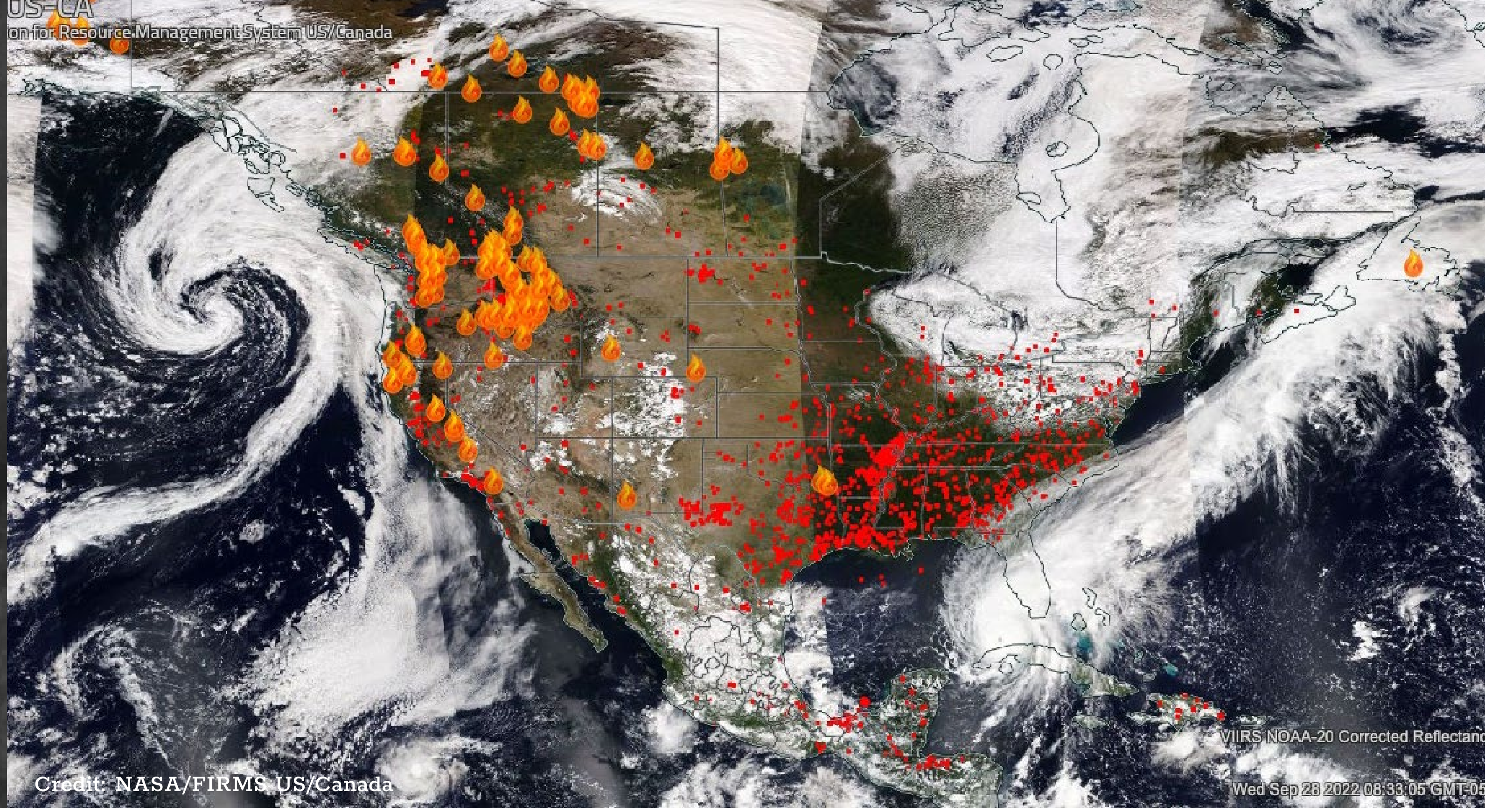
Creating the products is important but training forecasters on how to use them is a crucial piece of this project. With that in mind, Greenwald has enlisted SSEC's Scott Lindstrom to create training materials to teach users how best to use their products and images and their benefits. Broadening the reach of their research and sharing its value for forecasting and monitoring will be critical to its success.

As Greenwald notes, "The JPSS Proving Ground/Risk Reduction program is all about helping users, making sure they get the products that they need and eventually get these products into operations."

Providing users with more detailed observations and images of Arctic sea ice will lead to better analyses of current ice conditions and forecasts for safer navigation by industry, as well as indigenous people.

*This work is supported by NOAA.*






# One-minute data helps NASA detect wildfires faster

by Jean Phillips

The University of Wisconsin–Madison Space Science and Engineering Center is providing ultra-low-latency satellite data — within 60 seconds of observation — to NASA as part of a push for timelier tracking and monitoring of wildfires.

SSEC Distinguished Scientist Liam Gumley is leading the program at UW–Madison. "We've refined our ability to obtain data directly from the satellite and receive it on the ground, a process known as direct broadcast," says Gumley. "Now, from Earth observation to wildfire detection is less than 60 seconds."

Satellite data for this project are received via a specialized satellite ground station on the UW–Madison campus and at four other ground stations across the U.S.

These low-latency data from U.S. Earth observation satellites are a new addition to the NASA Fire Information for Resource Management System. FIRMS was developed by NASA for providing satellite-based detections of active fires in the U.S. and Canada. Once a fire is detected, NASA can coordinate with decision makers at other agencies to respond to, and continuously monitor, the fire and inform the public.

An expert in satellite data, including algorithm development and real-time data receiving and processing, Gumley has been on the leading edge of getting satellite-derived information to those who need it sooner.

Read more about NASA fire detection.

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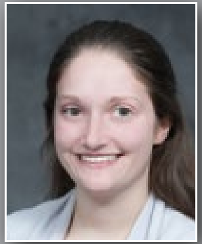
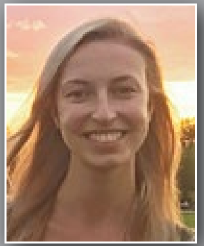
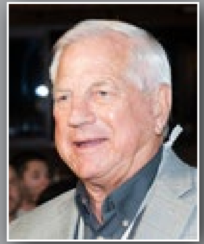
# AWARDS



**STEPHANIE ORTLAND**
1st place oral presentation at the NOAA Corp Symposium



**CALLYN BLOCH**
2nd place poster presentation Joint Conference Student Competition AMS Annual Meeting



**WILLIAM SMITH**
Gold Medal Award of the International Radiation Commission

**DANICA FLISS**
1st place Outstanding Poster Presentation 25th Conference on Satellite Meteorology, Oceanography, and Climatology / Joint 2022 NOAA Satellite Conference

**JONGJIN SEO**
2nd place Outstanding Poster Presentation 25th Conference on Satellite Meteorology, Oceanography, and Climatology / Joint 2022 NOAA Satellite Conference


# Smith honored with IRC Gold Medal Award

by Jean Phillips

Many in the atmospheric science community consider William L. Smith to be the father of satellite atmospheric sounding The International Radiation Commission agrees.

This summer, Smith received the IRC Gold Medal Award, recognizing his contributions of lasting significance to the field of radiation research — contributions that have spanned more than 50 years.

“Bill’s leadership is largely responsible for the evolution of the satellite radiance observation framework and associated applications from their beginnings in the late 1960s to today,” writes Dave Tobin, distinguished scientist at the University of Wisconsin–Madison Space Science and Engineering Center who nominated Smith for the award.

Smith, who bears many titles, currently is a senior scientist at SSEC, professor emeritus at UW–Madison and distinguished professor at Hampton University. His trajectory has included leadership positions as a government scientist as well as university faculty. These connections have strategically positioned him to collaborate between and across organizations, facilitating the pipeline of ideas that migrate from university laboratories to government operations in the process.

From the earliest days of his career as a scientist in the National Oceanic and Atmospheric Administration’s Radiation Branch, Smith could see the possibilities inherent in satellite observations of the Earth’s atmosphere. He also recognized their limitations.

"Because I had developed the operational retrieval processing system, I soon realized that clouds were the major obstacle to atmospheric profile accuracy,” says Smith.

So, beginning with NASA’s Nimbus 5 polar-orbiting satellite in the 1960s, Smith embarked on a path to design and build a radiometer with high horizontal resolution that could sample above and between clouds to accurately measure temperature and water vapor, especially of mesoscale features that range in size from several to several hundred kilometers. Such features, like thunderstorms, snowstorms or hurricanes had evaded understanding because there wasn’t an effective method of gathering detailed information about them. These early Nimbus radiometers led to the first high resolution and accurate temperature and water vapor data that established a baseline for forecasting and studying these storms.

By 1975, Smith was leading the development of a scanning radiometer — the High-resolution Infrared Radiation Sounder — that flew on Nimbus 6 the same year. Like its predecessor, the instrument delivered vertical measurements of temperature and water vapor, but with even greater precision. The HIRS flew on NOAA operational satellites for 40 years.

The Nimbus experiments marked the beginning of Smith’s quest to uncover new information about the vertical structure of the atmosphere. In doing so, he joined forces with colleagues at SSEC to help refine the ground-based Atmospheric Emitted Radiance Interferometer and the aircraft-based High-resolution Interferometer Sounder to improve vertical temperature and water vapor measurements from those instruments — measurements that have been vital to validating the accuracy of satellite measurements for several decades.

“As Bill envisioned, radiance observations from the HIS, and the AERI, demonstrated the measurement concepts that have led to today’s international constellation of Low Earth Orbit satellites that now carry hyperspectral sounders,” says Tobin.

The lineage is clear and direct: These include the U.S. Cross-track Infrared Sounder on Suomi NPP and NOAA-20 developed by Smith and colleagues as a replacement for the HIRS, the European Space Agency’s Infrared Atmospheric Sounding Interferometer on the Met-Op series of satellites and the Chinese Meteorological Agency’s Hyperspectral Infrared Atmospheric Sounder on the Feng-Yun series of polar orbiting satellites. Not only are these sensors crucial as data sources for numerical weather forecasts, they are providing information on greenhouse gases and Earth’s changing climate.

Smith’s work with polar-orbiting instruments and sensors has been balanced by, and often conducted in tandem with, pioneering work on geostationary radiance observations since the 1970s. In fact, success of the airborne HIS — and collaborative enhancements to it over three decades with partners at NASA and SSEC — produced a prototype instrument known as the Geostationary Imaging Fourier Transform Spectrometer. GIFTS demonstrated that it was possible to gather hyperspectral radiance measurements from geostationary orbit.

▲ **William L. Smith received the International Radiation Commission’s Gold Medal Award, recognizing his contributions of lasting significance to the field of radiation research. The award was presented to him at the International Radiation Symposium held in Thessaloniki, Greece, July 4-8, 2022. Credit: Bill Smith**

While the U.S. has not launched such a sounder on its satellites, international partners, recognizing the myriad applications of precise temperature, moisture and winds data in the horizontal and vertical domains as well as over time, have adopted the measurement technique for their own geostationary satellites. The Geostationary Interferometric Infrared Sounder or GIIRS, on CMA’s Feng-Yun–4D and -4E satellites are already in orbit and returning data. They will be followed in 2023 by the InfraRed Sounder on the EUMETSAT-European Space Agency’s Meteosat Third Generation-S geostationary satellite.

Smith exhibits the same enthusiasm today as he has throughout his career, an enthusiasm that continues to lead to improvements in weather forecasting through innovations in the science of measurement technology. He has his sights set on, and is demonstrating the potential value of, a new U.S. satellite system known as Geostationary Extended Observations that will include a hyperspectral sounder and is slated to launch within the next decade.

“My many mentors, students and colleagues with whom I’ve worked over six decades have made these accomplishments possible,” says Smith. “We’ve had an amazing ride.”

◀ While in Madison for her internship, Peyton Camden (center-front) engaged in a Q&A with NOAA Administrator Richard Spinrad and other graduate students in the UW–Madison Department of Atmospheric and Oceanic Sciences.
Credit: Bill Bellon

**120+**
undergraduate students per year receive support and paid summer internships with NOAA across the US

**1,930**
Hollings Scholarship alumni from more than 350 universities

**75%**
Hollings Scholarship alumni go to graduate school

Credit: NOAA

# Hollings Scholarship

## Undergraduate research opportunity at CIMSS

by Callyn Bloch

As a child learning to read, Peyton Camden stumbled upon a news article about the devastating tsunami that struck Indonesia on Dec. 26, 2004, killing more than 100,000 people. That event left an impression on her, sparking an interest in weather and earth sciences aimed at understanding the how and why of catastrophic events like tsunamis.

Now, Camden is an undergraduate meteorology student at Valparaiso University, and a 2022 NOAA Hollings Scholar. The Ernest F. Hollings Undergraduate Scholarship recipients receive financial support for two years and participate in a hands-on summer internship at a NOAA facility. The scholarship is named after South Carolina Senator Ernest Hollings who "was a champion for ocean policy and conservation" according to NOAA.

This summer, Camden's internship brought her to Madison, Wisconsin to work with NOAA scientists Mark Kulie and Andrew Heidinger both of whom are stationed at the University of Wisconsin–Madison Cooperative Institute for Meteorological Satellite Studies.

"Everyone was very responsive, and the environment is more collaborative and interconnected than I expected," she says.

Kulie and Heidinger enlisted her help to identify relationships between GOES cloud products, which provide information on cloud conditions and types, and lightning observations provided by the Geostationary Lightning Mapper. The project intrigued Camden especially when she realized it combined cloud research with her growing interest in coding: a perfect opportunity to push the boundaries of her comfort zone and skills.

Another recent catastrophic event — a derecho that swept across Nebraska, South Dakota and Minnesota on May 12, 2022 — served as a case study for her work. Derechos are characterized by strong, destructive winds that sometimes spawn tornadoes.

As Camden examined the GOES cloud products and the accompanying GLM data for the storm, she discovered that lightning occurred more frequently in ice clouds than in other cloud types. This discovery was especially rewarding for Camden because it confirmed that her results were consistent with previous research.

Camden also observed firsthand how research often takes longer than anticipated. While this was unexpected, it was the first time she had learned, and incorporated Python into her research. Learning this new language and how it could facilitate the cloud data analysis took time, strengthening her resolve to allow even more time for the next project.

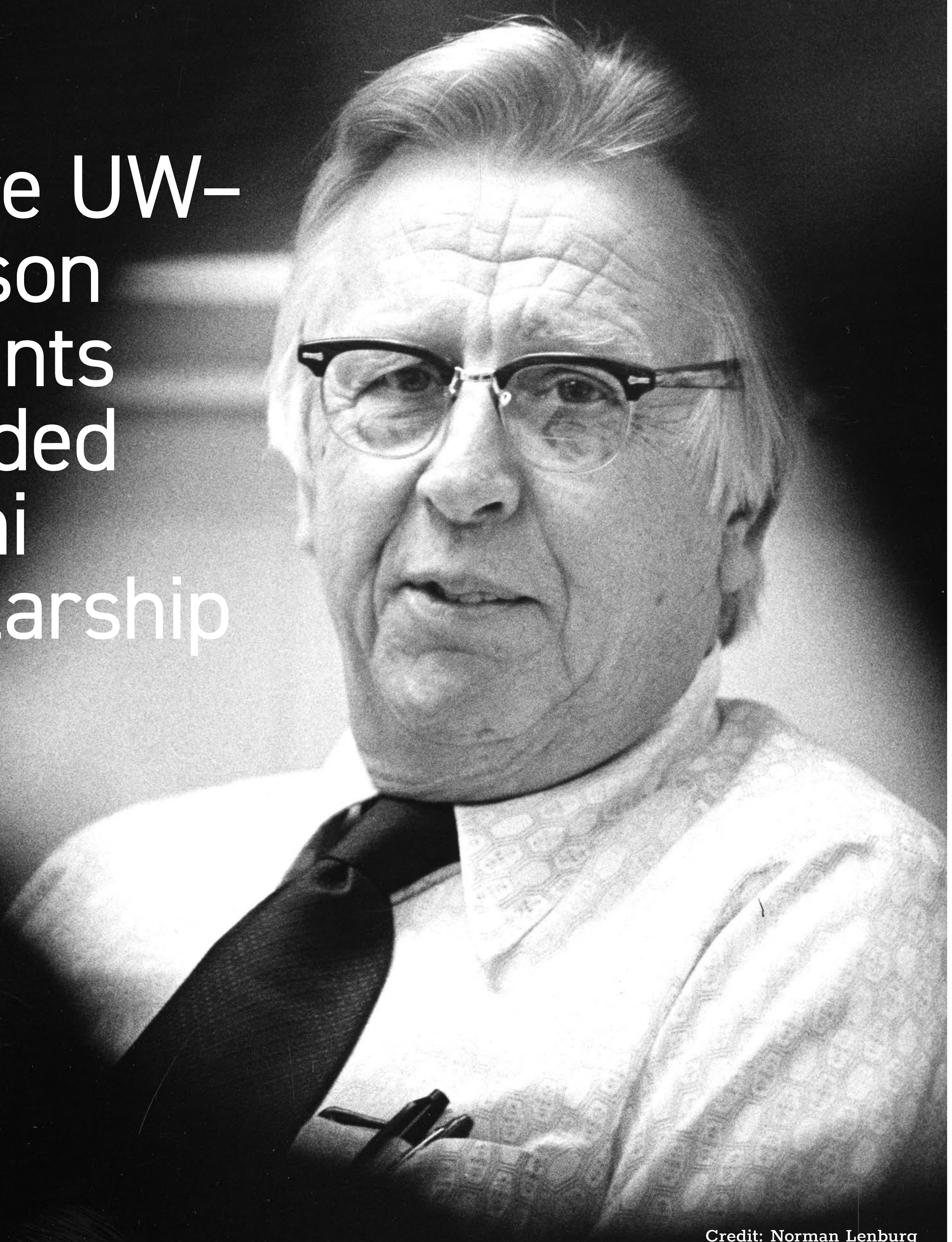
In addition to her research with Kulie and Heidinger, Camden learned more about forecasting careers through a visit to the NOAA National Weather Service Milwaukee/Sullivan Office Around the same time, NOAA Administrator Richard Spinrad visited CIMSS and invited her to participate in a student panel discussion. The experience provided her with new insights into possible meteorology careers.

"There is incredible variation in the meteorology job sector," Camden says. "I'm trying to stay open minded about my career."

Camden is planning to present her research results at the 2023 American Meteorological Society Annual Meeting in Denver, Colorado in January. She hopes that her research will help others. "There is so much data and so many ways to analyze it," she says. "This is just the beginning of this project."

# Future UW–Madison students awarded Suomi Scholarship

by Callyn Bloch



Credit: Norman Lenburg

Two high school seniors were awarded the Verner E. Suomi Scholarship for the 2022-2023 academic year at the University of Wisconsin–Madison in recognition of their academic excellence as well as service, mentorship and extracurricular activities. The scholarship is offered each year by the Cooperative Institute for Meteorological Satellite Studies.

## Katharine (Maggie) Wells

Credit: Katharine Wells

Katharine Wells from Saint Paul, Minnesota is passionate about physics and the environment. She aims to pursue these passions by studying civil and environmental engineering at UW–Madison.

As an engineer, Wells hopes to contribute to sustainably designed and purposefully built city buildings and serve as a role model for other women in STEM.

"As a female engineer, I hope to see a shift towards a more balanced workplace because civil engineering has typically been a male-dominated field," says Wells.

She hopes to break the barrier and gain recognition as a leader in the industry while inspiring young women in engineering.

Wells prepared for the rigors of college, in and out of the classroom, by excelling in advanced placement courses and participating in her school's math team, Knowledge Bowl and varsity volleyball. She volunteered in high school leadership roles and served as a mentor to younger students.

## Lily Thatcher

Lily Thatcher from Eau Claire, Wisconsin has always been fascinated by the world around her. Science proved to be a natural way to explore this interest and it is why she chose to study chemistry at UW–Madison.

"A degree in chemistry will allow me both the knowledge and flexibility to pursue my goals," says Thatcher.

Credit: Lily Thatcher

Those goals include using her degree to make an impact on the environment by creating more sustainable products and to help transition away from non-renewable energy. "I want to be part of our energy transition by improving options for renewable energy."

Each step in Thatcher's high school career set her on a path to studying science, from taking advanced placement courses to becoming a member of her school's environmental club. Thatcher's contributions have not gone unnoticed: she received the Gregor Mendel Award for Excellence in the biological sciences and has been recognized for her academic performance by her high school science teachers.

Thatcher rounded out her high school years by participating in extracurricular activities like Key Club and Link Crew where she learned leadership skills and mentored incoming freshman.

The $2,000 Suomi Scholarship, named after the "father of satellite meteorology," supports a new generation of earth and physical scientists at the start of their undergraduate careers. Suomi was passionate about teaching undergraduate students, and the recipients of this award share his passion for science.

# 2022 AOSS PHOTO CONTEST

For the 12th year, the Atmospheric, Oceanic and Space Sciences Photo Contest at the University of Wisconsin–Madison showcases stunning photographs of weather phenomena on Earth — and beyond.

University students, scientists, staff and professors share what they see when they peer through the camera's lens. Each picture tells a story.

**1st place**
Isaac Schluesche
EF1 @ F/4.5

**2st place**
Isaac Schluesche
Earth

**3rd place**
Jonathan Gero
Ice rift on
Lake Mendota


# The State of the Climate in 2021

by Jean Phillips

Each year the NOAA National Centers for Environmental Information leads an analysis of the global climate system. Their report, *The State of the Climate*, is published as a supplement to the *Bulletin of the American Meteorological Society*. This year, researchers from the Cooperative Institute for Meteorological Satellite Studies and the Space Science and Engineering Center contributed to sections on global cloudiness and Antarctica.

CIMSS researchers Mike Foster and Coda Phillips analyzed global cloudiness records from the NASA Aqua satellite. Their findings showed that 2021 was the third cloudiest year since 2003 (see pS59-S61).

Matthew Lazzara, Taylor Norton and Linda Keller, researchers with the UW–Madison Antarctic Meteorological Research and Data Center, reported on Antarctic conditions, including the coldest measured average temperature in winter of -61 C (-78 F) at the Amundsen-Scott South Pole station in 2021 (see pS313-S321).

Read the full report.

Credit: Tatlin

Credit: UW—Madison

# MAKE A GIFT

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