THROUGH *the* ATMOSPHERE

Shared data Shared discovery with NOAA-20

Winter/Spring 2018

Space Science and Engineering Center | Cooperative Institute for Meteorological Satellite Studies | University of Wisconsin–Madison

Director's note

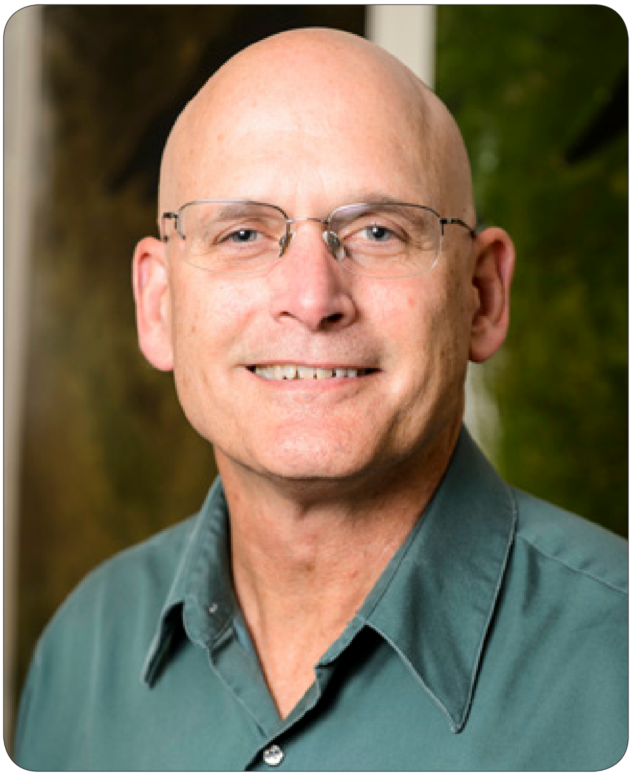
Shared data, shared discovery with NOAA-20: The tag line on the cover of this issue of *Through the Atmosphere* says it all. Our research is grounded in the idea that the global scientific community—and all of society—benefits when research results, and the data that support them, are shared.

All of the stories between the covers of this magazine are linked by their attachment to the principles of shared data. The cover story, for example, highlights the US role, and SSEC's, in promoting a satellite data policy with no restrictions or encryption. Liam Gumley's research illustrates the ways NOAA-20 is improving forecasting, how and where his team, and others, are making weather satellite data accessible to anyone, and how they are connecting decision-makers with the data they need, when they need it.

Hurricane Maria left a path of destruction in its wake when it hit Puerto Rico. Fortunately, CIMSS scientist Shane Hubbard had been sharing his knowledge and tools for some time to help communities understand their risks related to natural hazards like hurricanes and ever present flood dangers. His niche research area includes models that not only visualize the effects of these natural disasters, but also helps emergency managers and planners develop mitigation plans.

After learning of her work at an international conference in 2010, the UK Met Office approached CIMSS scientist Eva Borbas about sharing her land surface emissivity global database so that it could be incorporated into the UK's radiative transfer model. And she did. Her database has provided the UK's model with more accurate temperature and water vapor retrievals, along with better radiance simulations over clear skies, resulting in an on-going collaboration. Just last year, Borbas oversaw an upgrade to the database, leading to an improved emissivity product.

A little closer to Madison, and to Earth, the UW–Madison Department of Atmospheric and Oceanic Sciences professors Grant Petty, Tristan L'Ecuyer, and Ankur Desai, have partnered with SSEC to purchase, and build, an ultralight, low-altitude aircraft. With instruments onboard, the aircraft will help gather measurements of the lower atmosphere, providing clues to where turbulence might form—sharing their data with researchers across campus.



Another UW–Madison alumnus and pioneer with early connections to SSEC, Terry Kelly was honored last year by the American Meteorological Society for his revolutionary work in computerized weather: work that charted a new course for real-time television weather broadcasting. His goal, like the others featured in this issue, was to get timely weather information to the public and industry, and he has done so quite successfully.

Finally, we include a synopsis of the new biography of SSEC's founder, *Verner Suomi: The Life and Work of the Founder of Satellite Meteorology*, which brings us full circle to the visionary who believed so strongly in the value of international cooperation and shared data. Among the SSEC co-authors are Paul Menzel and Jean Phillips who researched with John Lewis of NOAA's National Severe Storms Laboratory, (formerly at CIMSS during the Suomi era), to present a picture of the man who launched the field of satellite meteorology.

I hope you enjoy these stories and more in the Winter/Spring 2018 issue of *Through the Atmosphere*.

Steve Ackerman
Interim SSEC Director

THROUGH *the* ATMOSPHERE

WINTER/SPRING 2018

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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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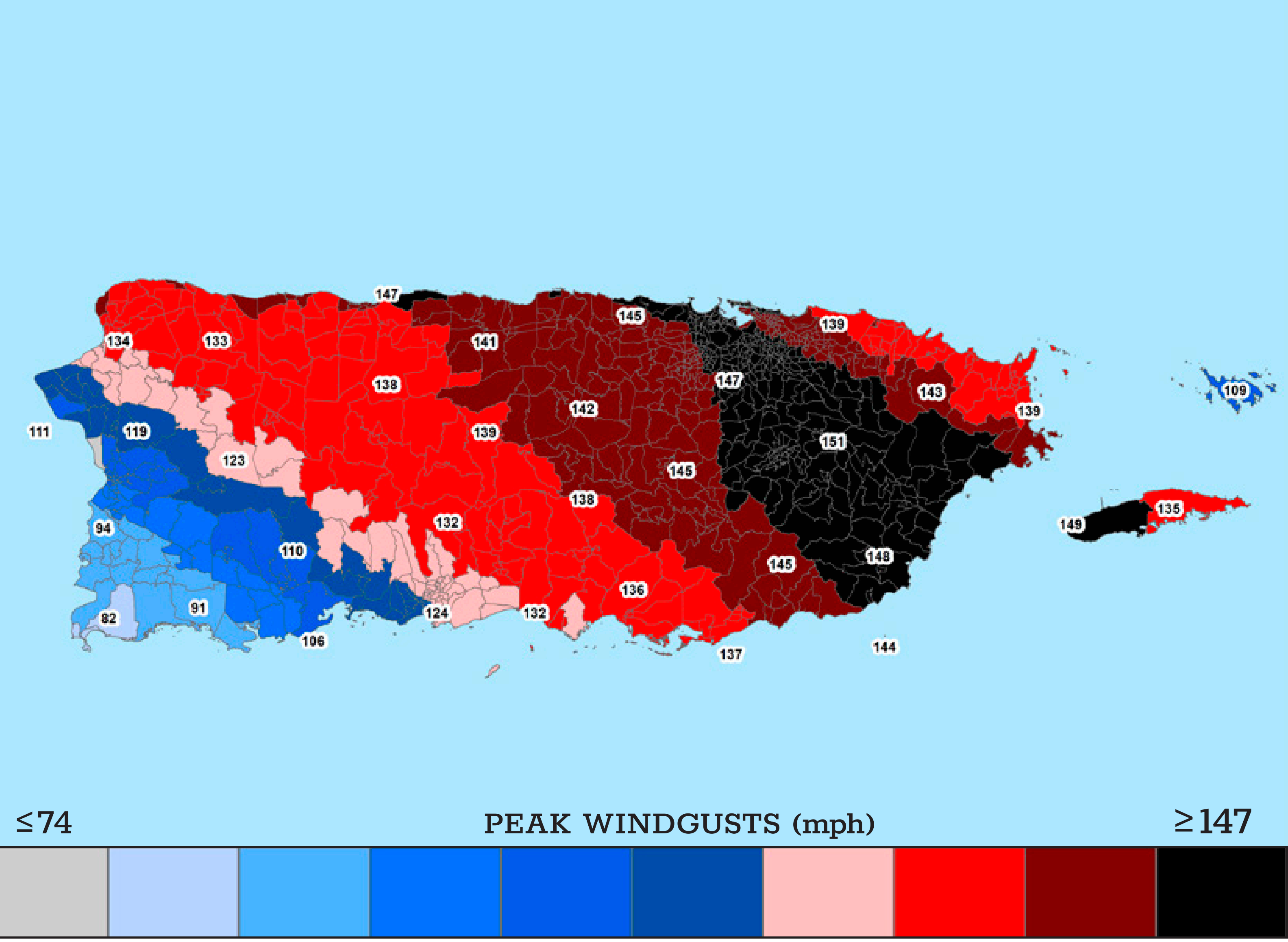
Cover image: Satellite composite image from Suomi NPP VIIRS imager, similar to the detector onboard NOAA-20 that provides global visible and infrared observations of land, ocean, and the atmosphere.



Hurricane Maria

Modeling towards resilience and supporting Puerto Rico after major hurricane

by Leanne Avila

Researchers at the University of Wisconsin-Madison Space Science and Engineering Center (SSEC) have dedicated their careers to helping others anticipate severe weather events. But sometimes professional work can become personal, like when a scientist has an opportunity to see firsthand the human impacts of storm systems—as devastating as a hurricane—on a community, as SSEC researcher Shane Hubbard did in 2017.

Hubbard has long been working to help emergency managers and their communities understand their risks with respect to natural hazards, such as tornadoes and flooding, so that they can develop mitigation plans and manage during severe weather. In particular, he has developed computer models to help visualize the effects of such hazards.

All of his knowledge and tools were quickly put to use as Hurricane Maria, a powerful category 5 hurricane, approached Puerto Rico in September 2017.

Scenes from Hubbard's October 2017 visit to Puerto Rico: Roofs damaged by the hurricane and subsequent tornado (top). The contaminated water of Laguna San José adjoining a San Juan neighborhood (middle). Credit: Shane Hubbard

(Opposite) Based on the likely track for Hurricane Maria, Hubbard produced a map of estimated windspeeds, representing the estimated peak winds within each census tract. Local effects (e.g., topography, buildings, trees, open terrain) will impact speeds locally. Credit: Shane Hubbard

Hubbard already had a history working with and in Puerto Rico. Through collaborations with the US Federal Emergency Management Agency (FEMA) on modeling natural hazards, he first began working with the Commonwealth of Puerto Rico Planning Board in 2011 to assess the island's risks for flooding and hurricanes. As part of this effort, he would travel there once or twice a year.

Prior to Hurricane Maria, Hubbard had visited and worked in Puerto Rico in January and March of 2017 through funding from the Rockefeller Foundation's Climate Resilience Office in San Juan. A private philanthropic foundation, it had developed an initiative known as 100 Resilient Cities, targeting 100 cities around the world to help them better meet challenges in three particular areas: physical, social and economic.

While it could be heart-breaking work, especially in the wake of Hurricane Maria, Hubbard could also see his research supporting the community, playing a positive role in its plans for the future.

"What we were doing there was some really neat—probably some of the neatest or coolest research I've ever been a part of," said Hubbard.

Hubbard noted that they were looking at San Juan neighborhoods with significant populations living in poverty. As they were analyzing the risks and potential problems within various neighborhoods, a colleague of his who is the City of San Juan's Chief Resilience Officer under the city's partnership with 100 Resilient Cities, Alejandra

In March 2017, representatives from the community, 100 Resilient Cities, Deltares, and the City of San Juan, along with Hubbard (far right), are discussing flood maps that had been created to find out from the community leaders if the maps accurately represent the flooding that typically occurs. Credit: Gabriela Fernandez Nieves

As part of a collaboration with the US Geological Survey, Shane Hubbard takes a water sample from Laguna Los Corozos in San Juan, Puerto Rico. Credit: Félix Aponte-González

Castrodad-Rodríguez, observed that one neighborhood appeared particularly vulnerable and suggested that they visit and investigate further.

What they found is that these neighborhoods are situated very close to a large body of water contaminated by wastewater that is not filtered out but rather merges with the area's stormwater system. That proximity can lead to disaster in times of severe weather and floods as the water strays beyond its normal boundaries.

"And when it floods, that body of water that is contaminated goes into the community, and people get very sick," said Hubbard.

In January 2017, Hubbard and students from the University of Puerto Rico went into the neighborhood with two aims: to create an inventory of buildings, as well as the building materials used, and to gather information on past flooding via visible high water marks or by asking people directly, "where on your body was the water."

"The Climate Resilience Office brought in an engineering firm from the Netherlands [Deltares] to develop detailed flood maps of the communities under various flooding scenarios. We used the information that I had collected on buildings and previous flooding. We linked that with their flood mapping, and we created what past floods and future flood impacts would look like," said Hubbard.

Out of those analyses came ideas for low-cost strategies to mitigate the effects of flooding: from rain barrels to rain silos that could hold thousands of gallons of rain water, preventing it from becoming a flooding hazard. The team presented their research and suggestions to the community in San Juan during the March 2017 visit.

Less than six months later—and just two weeks before Hurricane Maria hit—Hurricane Irma appeared to threaten Puerto Rico. As the tropical cyclone tracked closer to the island, Hubbard provided assessments of potential damages and losses based on what they had learned. While Puerto Rico was mostly spared, Irma still provided a preview of the devastation that was to come.

"San Juan, the largest city, lost power for about 10 days. They got power back for two days, and

Based on the flood modeling completed by Dutch engineering firm Deltares and Hubbard, he created 3D flood depth grids, which were then draped over the 3D Google Earth View of San Juan's Playita neighborhood.
Credit: Shane Hubbard

then Maria came," said Hubbard.

Once again, Hubbard was carefully watching Maria's approach and providing updates on San Juan's risks based on the hurricane track forecasts. He kept in close contact with Castrodad-Rodríguez and was soon warning her that the flood waters might reach eight feet high. At the same time, Castrodad-Rodríguez was actively working in the neighborhood to encourage residents to evacuate to a safer location.

"For the first time they were able to get about 150 people to evacuate. Generally, nobody will leave," said Hubbard.

Hubbard also noted that while the community was inundated with flood waters deeper than they had previously experienced—anywhere from four to six feet deep—they were spared the eight feet as the hurricane path had shifted 10 miles south. That minor change in course meant that the hurricane weakened as it spent more time over land before reaching San Juan.

On Oct. 3, 2017, less than two weeks after Maria made landfall, Hubbard traveled to Puerto Rico to see the aftermath of the hurricane and collect additional data points to improve future analyses of flooding and hurricane risks so that these communities can better prepare.

"One of the other things that had become very clear is the way that we model the damages from winds and flooding in the continental United States is different than how these impacts should be modeled in San Juan. Almost 90 percent of their residential construction is concrete block… no drywall on the walls… concrete floors," said Hubbard.

Through community engagement, Castrodad-Rodríguez was able to build relationships and organize a team of volunteers that could support recovery efforts within the neighborhoods. These connections made it possible for Hubbard to visit homes and see the damage, as well as the ongoing repairs. He commented on how this particular community worked for "days and days" using Clorox to remove contamination caused by raw sewage in the floodwater.

According to Hubbard, of the roughly 2,000 buildings in that community, close to 50 percent had been flooded and around 30 percent had roof damage. At the same time Puerto Rico was entering its rainy season, September to December, which compounded the damage and hampered recovery efforts. In spite of these devastating scenes, people within the neighborhood were coming together to help each other, and community leaders were developing solutions and plans to mitigate the effects of future hurricanes and floods.

Hubbard was glad to be a part of the team working to make a difference—sharing knowledge, data, and tools.

"All this work that we've been doing in this small community for the last year is now going to be considered during the recovery efforts that will lead to resilience initiatives," he said.

This work was supported by FEMA, the Rockefeller Foundation, and SSEC.

Ultralight science

Boundary layer measurements from low-flying source

by Eric Verbeten

On a grassy runway just outside of Madison, Wisconsin, Grant Petty makes the final checks on his skeleton-framed airplane. Once ready, he hits the throttle and lurches forward, slowly at first. After a few hundred feet the aircraft is airborne and climbing steadily, with the scenery miniaturizing beneath his feet. This flight is more than a hobbyist's joyride however, the onboard instruments strapped to the wings and the cockpit collect atmospheric data during the flight and are part of a UW–Madison research project aimed at better understanding the Earth and its atmosphere.

Petty is a professor at UW–Madison's Department of Atmospheric and Oceanic Sciences (AOS) and principal investigator for the UW Ultralight project. Started in summer 2017, it is the creation of Petty and other AOS and Space Science and Engineering Center (SSEC) staff including professors Ankur Desai, Tristan L'Ecuyer and researcher Jonathan Thom who hope to use the versatile platform to make boundary layer measurements.

"The ultralight, low-altitude aircraft can capture what's happening in the lower atmosphere where much of the turbulence is," says Desai. "It's key to understanding coupling of the surface to the atmosphere in an experimental way."

Scientists continue to study this exchange of heat and moisture between the Earth's surface and the atmosphere, known as coupling, because it provides

▲ **The UW Ultralight project uses a Zigolo M12 aircraft to make boundary layer measurements over the Wisconsin landscape. Pilot Grant Petty (above) takes the first test flight in the hand-assembled craft before reaching an elevation of 1,100 feet. Credits: Jonathan Thom, Eric Verbeten**

a window into our climate system. At a cruising speed of around 40 mph (64 kmph), the instruments can peer into parts of the atmosphere and capture measurements not otherwise possible with tools like satellites, ground-based instruments, or NASA's high-altitude, high-speed aircraft, the ER-2. The team sees the ultralight as a way to fill gaps in our understanding about atmospheric physics and behavior.

The ultralight Zigolo MG12 craft is owned and operated by UW–Madison AOS and SSEC and was built by Petty and Thom in the summer of 2017. After three weeks of careful hand-assembly, Petty took the first test flight in August with a couple of "crow hops," short takeoffs and immediate landings until he felt comfortable ascending higher. Petty is currently the only pilot for the project but hopes to expand the program to include other experienced (and brave) pilots to help collect atmospheric data needed by scientists around UW–Madison for their research.

The craft usually flies between 150 ft. (45m) to 1,500 ft. (457m) and can remain airborne for a little more than four hours on a full tank of gas. Weighing in around 485 lbs. (220kg), the aircraft can also take off from short, unpaved runways less than 200 ft. long.

"Although the initial measurements will be focused on land-atmosphere couplings in Wisconsin, the

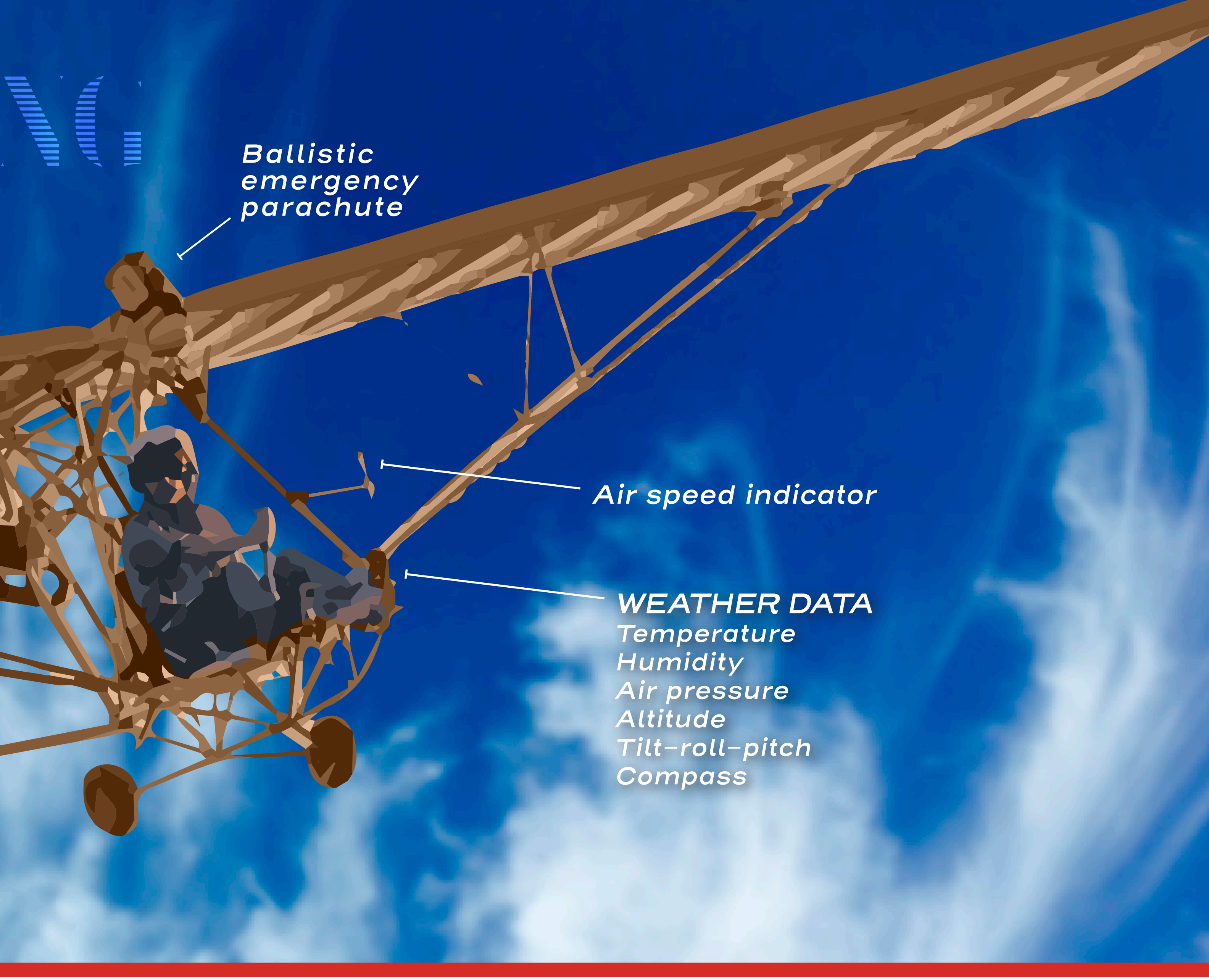
ULTRALIGHT SENSI

goal is to eventually collect a diverse sample that can tell us, in greater detail, how the surface interacts with the atmosphere," says L'Ecuyer. "We're excited about the simplicity and ability to quickly adapt the instruments, flight paths, and science objectives based on what we're learning."

With a load capacity of only 260 lbs. (118kg), heavy onboard instruments present an engineering challenge of their own. It is a challenge that requires researchers to either design new instruments from the ground up or reconfigure pre-built instrumentation to shed excess weight. Fortunately, SSEC and AOS have a long history of DIY aviation projects and instrument building dating back to the 1950s. Petty plans to tap this local expertise to adapt instruments to the craft, including plans to involve students in a hands-on curriculum for instrument testing and calibration, which he sees as a great way to engage students in the field of remote sensing.

"The onboard equipment includes ones similar to what you might find in a home weather-station; tools like an anemometer, thermometer, pressure and humidity sensors," says Desai. "Other equipment allows us to measure water fluxes, or evaporation off the surface, in addition to collecting data on land and surface properties"

The team plans to eventually convert the plane's 25 horsepower gasoline engine into an all-electric motor through a conversion kit, which will allow them to collect accurate pollution and particulate measurements without interference from exhaust. Other experiments include measuring



evapotranspiration rates over agricultural fields, radiances over nearby lakes (buoy transects), and winter flights over Lake Mendota's frozen surface.

Using a new type of infrared measuring device, the ultralight will also serve as a testbed for NASA's Polar Radiant Energy in the Far Infrared Experiment (PREFIRE). Currently in the planning stages, PREFIRE will involve CubeSats to collect data over the Arctic and measure frequencies in the far infrared (wavelengths longer than 15 micrometers), a unique part of Arctic emissions that have not previously been captured with other detectors. By flying winter transects over Madison's frozen lakes, L'Ecuyer says the ultralight will be used to collect the data needed for calibration and other comparative studies as the PREFIRE program is developed.

At a peak altitude of 1,100 ft. Petty makes the final maneuvers in his test flight and banks toward the landing strip where the ultralight comes to a gentle stop. Satisfied with the test results, Petty and Thom put the craft away in a storage hangar for the winter. Petty says he looks forward to Spring 2018 and beyond and the new experiments to come.

"We are looking forward to accommodating researchers across campus who maybe can't afford projects with high-end planes but could use the data available to us," he says. "We're excited to see what people come up with for ideas and uses for this platform."

This project is supported by UW–Madison's SSEC and Department of Atmospheric and Oceanic Sciences.

Publications & Awards

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▶ Li, J. and W. Han. 2017. **A step forward toward effectively using hyperspectral IR sounding information in NWP.** *Advances in Atmospheric Sciences* 34:1263-1264.

▶ Otkin, J. A., R. Potthast, and A. S. Lawless. 2018. **Nonlinear bias correction for satellite data assimilation using Taylor series polynomials.** *Monthly Weather Review* 146:263-285.

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▶ Wang, P., J. Li, Z. Li, A. H. N. Lim, J. Li, T. J. Schmit, and M. D. Goldberg. 2017. **The impacte of Cross-track Infrared Sounder (CrIS) cloud-cleared radiances on Hurricane Joaquin (2015) and Matthew (2016) forecasts.** *Journal of Geophysical Research-Atmospheres* 122:13201-13218.

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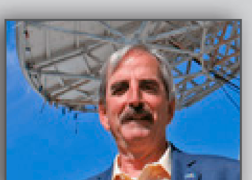
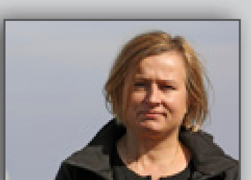
See all publications: go.wisc.edu/Lx74ac

AWARDS

MARGARET MOONEY
UW Chancellor's Award for Excellence in Public Service and Outreach



HANK REVERCOMB
ITSC-21 Gold for Best Oral Presentation



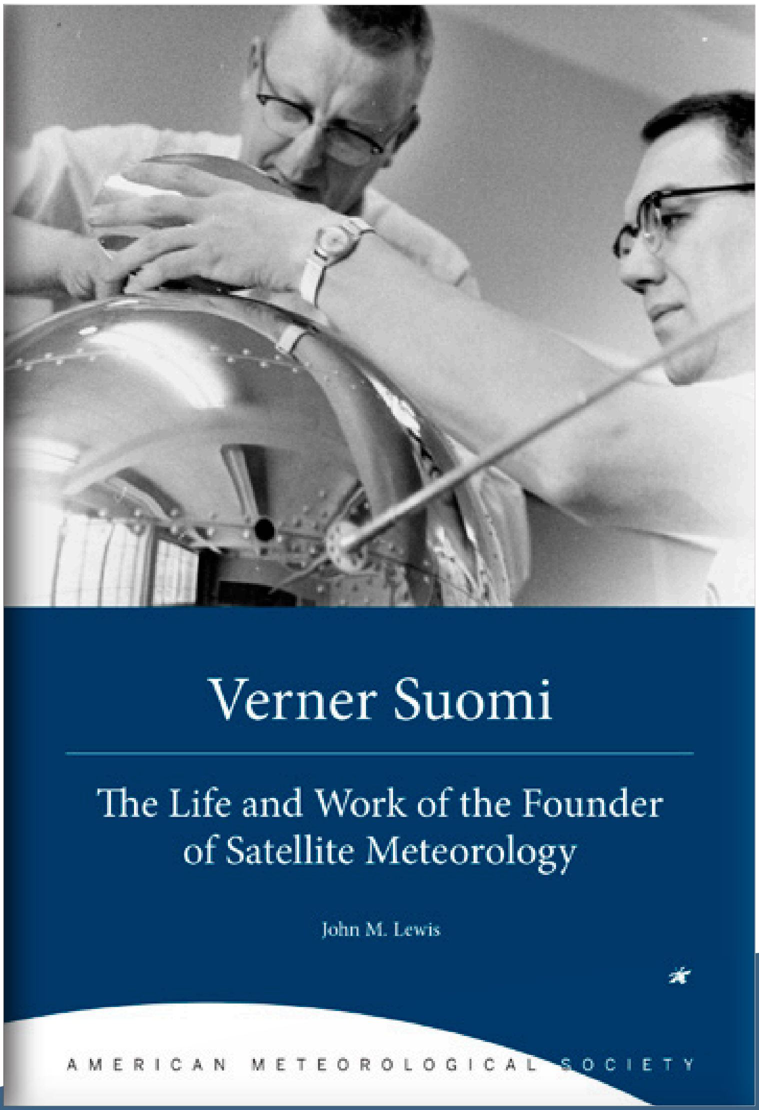
EVA BORBAS
ITSC-21 Gold for Best Poster Presentation

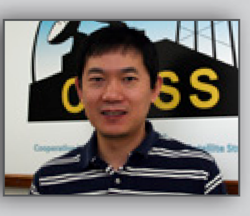
RECENTLY PUBLISHED—VERNER SUOMI

THE LIFE AND WORK OF THE FOUNDER OF SATELLITE METEOROLOGY

As the space age got underway in the wake of Sputnik, one of the earliest areas of science to take advantage of the new observational opportunities it afforded was the study of climate and weather. This book tells the story of Finnish-American educator, inventor, and scientist Verner Suomi, who, in those early days of space science, brought his pragmatic engineering skills to bear on finding ways to use our new access to space to put observational instruments into orbit. In 1959, Suomi's work resulted in the launching of Explorer VII, a satellite that measured the earth's radiation budget, a major step in our ability to understand and forecast weather. Drawing on personal letters and oral histories, the book presents a rounded picture of the man who launched the field of satellite meteorology—in the process changing forever the way we understand and interact with the weather around us.

Available through the American Meteorological Society bookstore.

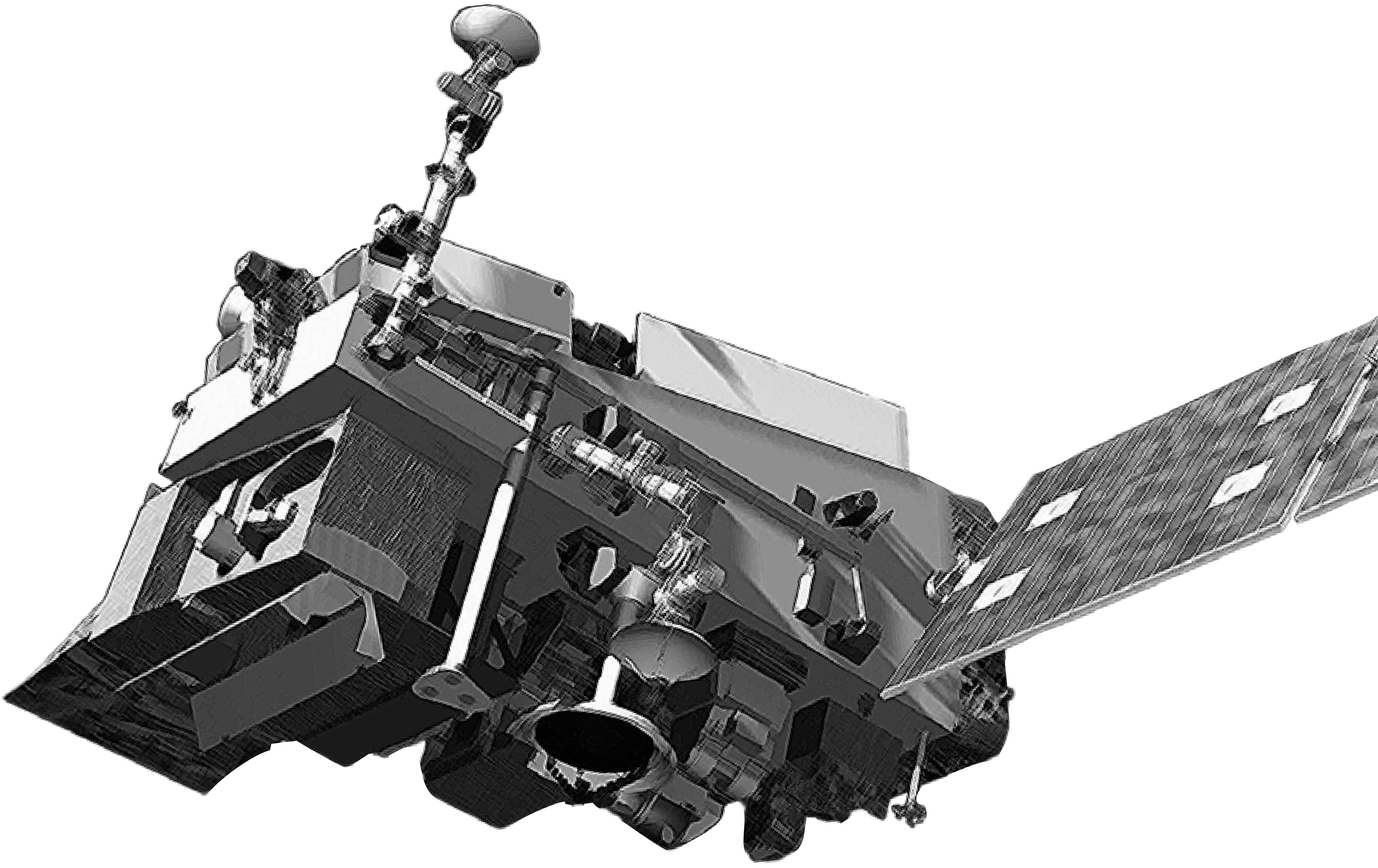


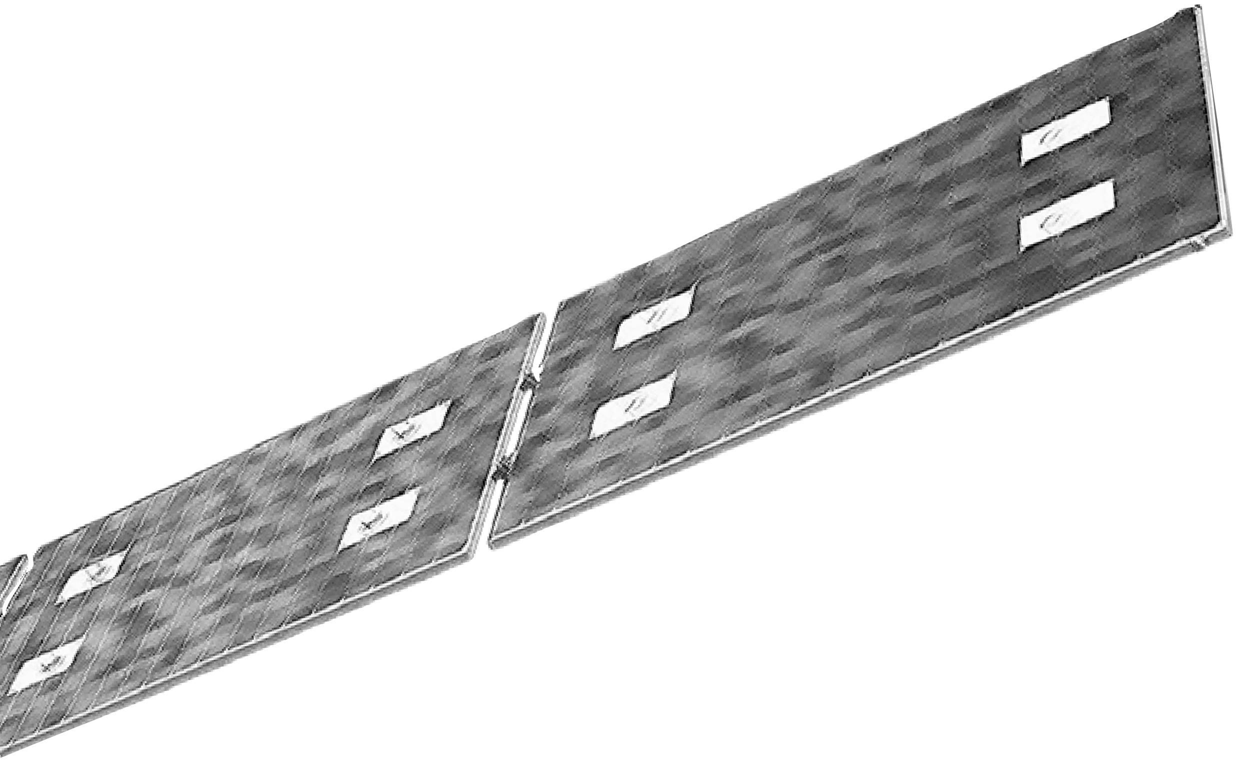


ZHENGLONG LI
ITSC-21 Bronze for Third Best Poster Presentation

JIM KOSSIN
NESDIS Award for Outstanding Science & Data Management

WILLIAM STRAKA
JPSS Program Office Extra Mile Award





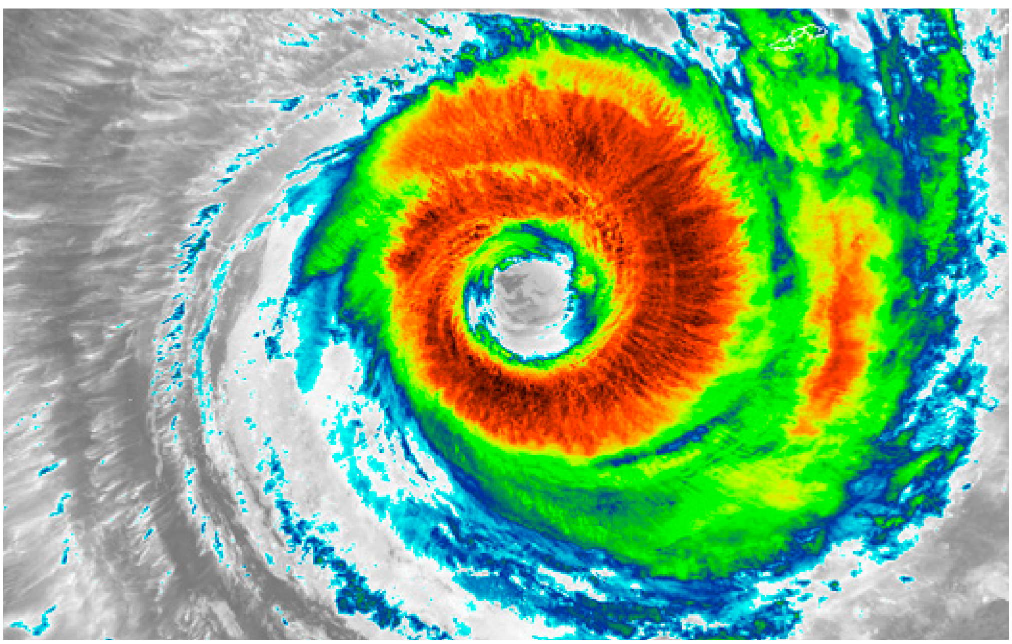
SHARED DATA SHARED DISCOVERY

SSEC's continued commitment to open research and data

by Jean Phillips

For decades, the world meteorological satellite community has operated under a policy of freely shared data – no restrictions and unencrypted – available at no cost. It is a philosophy and model of cooperation, first promoted by the United States and adopted by global satellite agencies, that endures regardless of political or national persuasion.

It is also a model embraced and facilitated by Liam Gumley, a scientist at the University of Wisconsin–Madison Space Science and Engineering Center (SSEC). Users, from scientists to the general public, can access these weather satellite data in a couple of ways, says Gumley.



◀ Early NOAA-20 imagery, capturing California wildfires (top), the beginning of the 2018 Pacific tropical cyclone season with Hurricane Gita (middle), and nighttime imagery over the continental US. Credits: NOAA, CIMSS, SSEC

With a career that has spanned nearly 25 years at SSEC, Liam Gumley has lent his expertise to everything from algorithm development and testing to real-time data reception and processing to big data systems, in addition to international collaboration. Credit: Bill Bellon

Data collected from all United States' geostationary and polar orbiting environmental satellites are stored in the National Oceanic and Atmospheric Administration's (NOAA) Comprehensive Large Array-Data Stewardship System (CLASS) archive within about 10 hours of collection on the satellites. Anyone can visit CLASS and download these data.

Those with an interest or need to obtain the data sooner, like weather agencies for forecasting purposes, can install an antenna and appropriate hardware to receive data in real-time, directly from the satellite. Within minutes of digitization on the spacecraft, this direct broadcast data is transmitted to receivers below.

Gumley notes that developing countries can receive the data at a lower cost through a process known as re-broadcast. In this case, NOAA or EUMETSAT, the European satellite agency, receive and process the data, uplink it to a telecommunications satellite, and then beam it back down on a signal similar to that of a digital television. For less than a thousand dollars, anyone with a small antenna or a computer can receive the re-broadcast data, says Gumley.

"We are not doing rebroadcast directly at SSEC," says Gumley, "but we do have an agreement with EUMETSAT, to work with data that it rebroadcasts over Europe as part of a system called EUMETcast." It, too, uses telecommunications satellites to disseminate near real-time delivery of satellite data and other products. Launched as the first in an advanced series of polar-orbiting weather satellites on Nov. 18, 2017, JPSS-1 (named NOAA-20 post-launch) offers these users another unique opportunity to gather timely data critical to their work. From its low orbit, just over 500 miles above the Earth, NOAA-20 will circle the planet 14 times each day, collecting high resolution data in consecutive swaths in order to construct a picture of the planet twice a day. It forms the backbone of the global observing system, delivering detailed information on the state of the atmosphere, land, and oceans.

NOAA-20 joins its predecessor, Suomi-NPP (so-named for SSEC's founder, Verner Suomi), as well as satellites operated by other countries, in making important measurements of Earth's environment. According to Gumley, these data are being used in three distinct ways by his team, scientists at SSEC, and worldwide: to improve forecasts, to assist in real-time decision-making, and to analyze global environmental processes over longer periods of time.

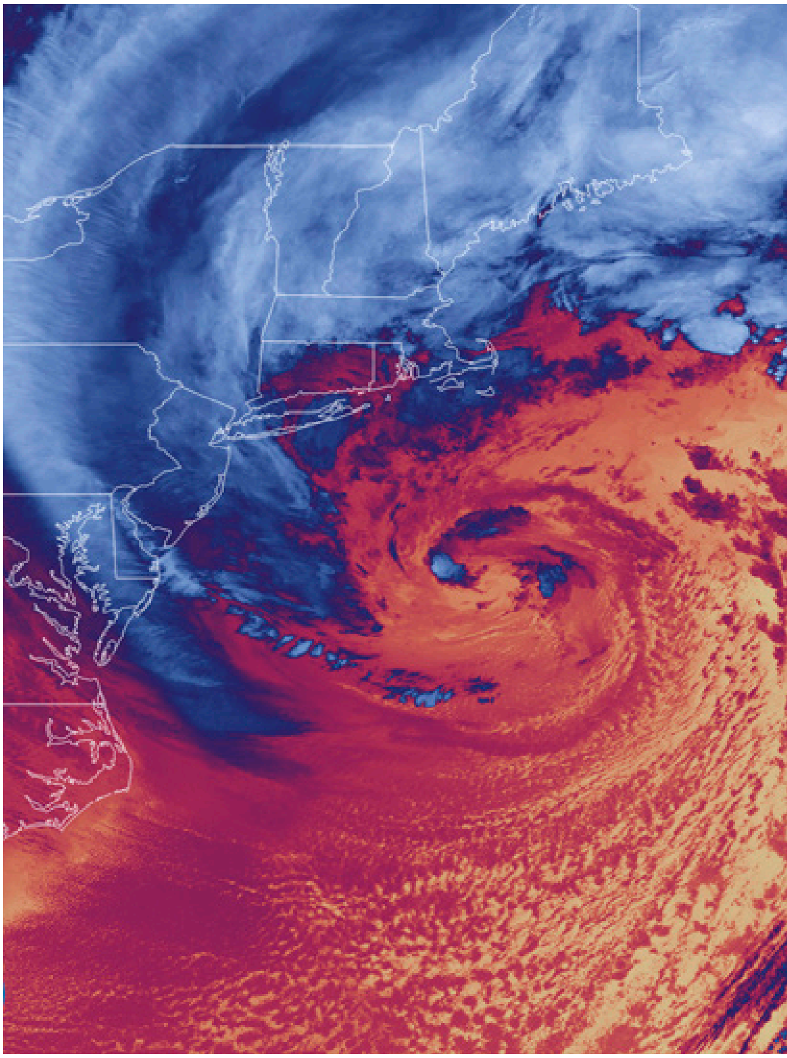
Improving forecasts is paramount to scientists like Gumley. The data from these satellites—all of which have infrared and microwave sensors onboard—are crucial to weather prediction models, or numerical weather prediction (NWP), that are at the heart of U.S. forecasting. NWP harnesses the power of computers to run algorithms that process massive amounts of satellite data. Data from other sources, such as weather balloons, aircraft, and ground-based instruments, are also processed in NWP models, but "by far, the most important data source is the satellite data," says Gumley.

> "It is gratifying to see that all of the money, expertise, and hard work that goes into building these systems results in something that is shared for the global good."

In addition to improving forecasts, these data play a role in decision-making, especially when time is of the essence. Scientists at the UW have the advantage of access to SSEC's Satellite Data Services where satellite data from numerous satellites are ingested and archived daily. With nearly immediate access, scientists like Gumley can view and analyze satellite data streams and imagery in 15 minutes, sometimes less. Getting that information to decision-makers as soon as possible is key.

To support the process of decision-making in the U.S. and to make it more economical for other countries, Gumley's team has developed a suite of software called the Community Satellite Processing Package (CSPP) that can be downloaded by anyone, without cost or restriction, from the program's website. As part of a community effort, SSEC and partner sites have developed CSPP products that convert the digital satellite signal to useable information.

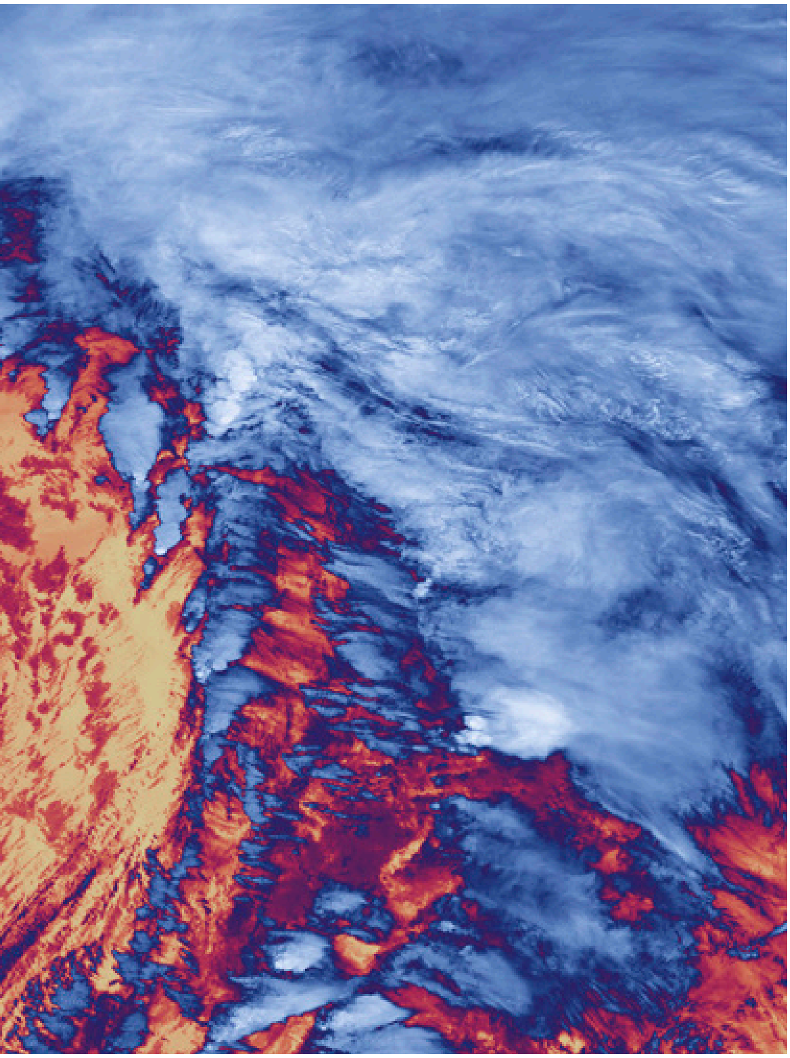
By running any of the CSPP products users can detect fires, calculate cloud heights, analyze sea or land surface temperatures, read temperature and water vapor information, or assess vegetation,



▲ **Thermal infrared image taken by NOAA-20 of the powerful nor'easter generated heavy snowfall and strong gusts up to 80 mph in a 24-hour period. It ranks as one of the strongest observed**

and much more, to aid in weather forecasting and disaster response. CSPP can help keep real-time decision-making under local control.

That immediacy allows users, such as forecasters at other agencies, like the NOAA National Weather Service, to quickly assess situations that might affect public safety. For example, the VIIRS Day/Night Band on NOAA-20 can detect nighttime fog in valleys. If the low-level fog is blanketing a highly traveled interstate, forecasters could quickly inform the state highway patrol or other relevant agencies to alert drivers to the diminished visibilities. Or, notes Gumley, "fires can be spotted from satellite images, too. If we see a fire at a particular latitude and longitude, we can notify fire protection agencies so that they can dispatch personnel."



'bomb cyclone' that hit the US East Coast January 2018. The due to the rapid intensification, dropping 59 millibars of pressure storms to hit the East Coast. Credit: NOAA

Collaborating with others to make these polar-orbiting satellite data available, and constructing pathways to understanding them, has deep roots at SSEC, dating back to the early 1980s. At that time, SSEC scientists developed the first International TOVS Processing Package to process data from instruments on NOAA's early polar-orbiting satellite series known as TIROS.

Finally, researchers are using these data to study global processes over an extended period of time, 20-30 years, to determine climate trends.

Scientists have already determined that clouds are one important variable in the global radiation budget. For today, says Gumley, the question is: "Are we seeing more or less high clouds as a result of climate change?" The opportunity to amass more data over longer periods of time, makes identifying trends more reliable.

NOAA-20 will continue these and other types of observations that have been collected from previous generations of satellites and archived for the last 25 years.

But before the data can be used for climate research, Gumley's group is part of the ground team that has been tasked with characterizing the data from NOAA-20 in terms of its completeness, validity, accuracy, and consistency. Starting three days after launch, and as sensors onboard the spacecraft were turned on, his team has been working with NASA and NOAA to ensure the integrity of several terabytes of data each day.

"Now that NOAA has given the go-ahead," says Gumley, "we are supplying it to NWP centers so they can start evaluating the NOAA-20 data, too."

To support long-term climate study, SSEC had a contract with NASA to create atmosphere products—known as Science Investigator-led Processing Systems or SIPS—from the Suomi-NPP VIIRS sensor. That agreement extends to data from NOAA-20 as well. These datasets are processed over the course of a mission, reprocessed from time-to-time, and forwarded to NASA for archiving and distribution. Only one of the six groups involved in the SIPS development is based at an organization outside of NASA: the one based at SSEC.

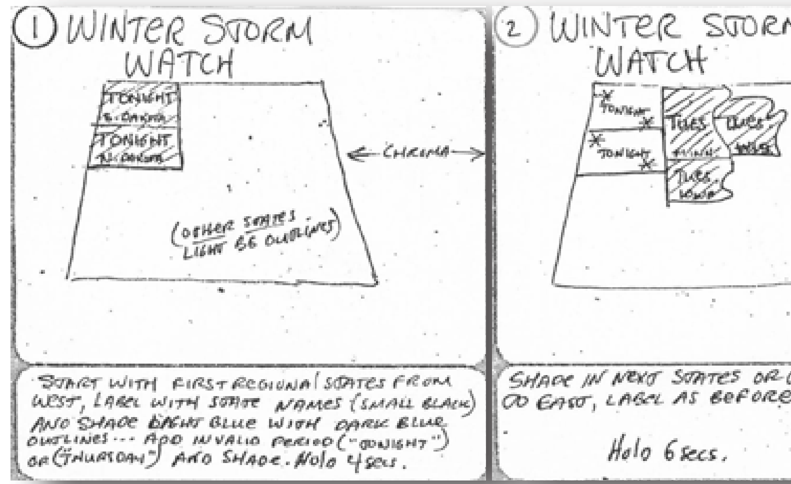
For Gumley, it is rewarding to work within a global collaboration where despite differing environments and locations, everyone is receiving the same data and is interested in using it for improving forecasts and studying environmental conditions.

"It is gratifying to see that all of the money, expertise, and hard work that goes into building these systems results in something that is shared for the global good," says Gumley. And furthermore, he continues, "it's not just the U.S., but because of its example, all the major satellite operators are participating."

This work was supported by NASA and NOAA. Story cover image: A graphic rendering of the NOAA-20 polar orbiting satellite launched Nov. 18, 2018. Credit: NOAA

Terry Kelly

Visionary of computerized weather, elected Fellow of the American Meteorological Society



by Jean Phillips

Before the era of computer-generated images, television weather forecasts required hand-drawn and colored graphics painstakingly aligned on a wall in the studio so the camera could pan from picture-to-picture, or they used "pull-up boards" and magic marker.

Terry Kelly, University of Wisconsin-Madison alumnus and entrepreneur, turned consulting and television weathercasting on its end through his revolutionary work in computerized weather. Last year, the American Meteorological Society (AMS) honored Kelly with its highest distinction — Fellow of the AMS — for his leading role in charting a new course for real-time television weather broadcasting.

Like another UW visionary, Verner Suomi, Kelly brought timely weather information in visual formats out of the research laboratory and into the homes of the public. As SSEC worked to provide satellite and radar imagery in real time and in higher resolution, Kelly and his team invented the real-time weather displays required to make such data useful.

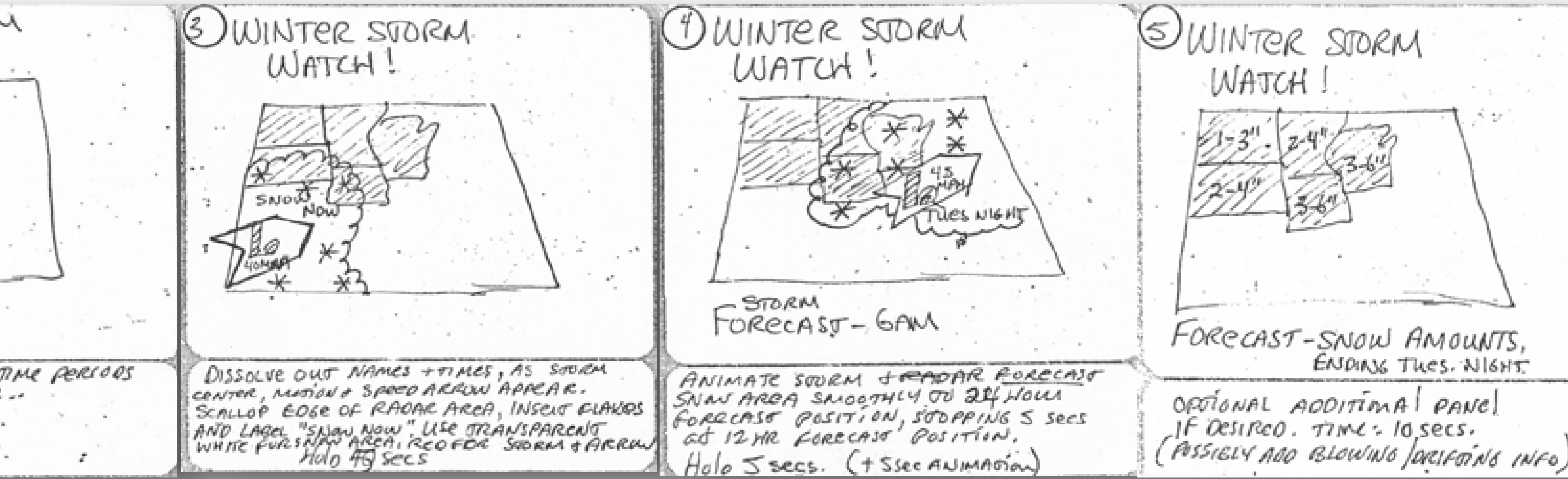
According to Kelly, though, finding his path to meteorology was anything but straightforward. His journey took him from learning to fly airplanes through dangerous weather, to pairing television weather broadcasts with computer advancements.

In fact, he took a leave-of-absence from college because he was undecided about a major. By chance, he saw a tiny ad in the Boston Globe that said, "Come work for us and we'll teach you to fly!" "Well, I thought it sounded like fun to learn how to fly a Piper Aircraft but in less than a week on the job, I had caught my hair in the drill press!" says Kelly. Rather than fire him, the union machinist crew took Kelly under their collective wings, situating him at the end of the assembly line where he was involved with quality control — removing bad rivets from planes and replacing them with good ones — rather than operating heavy machinery.

As promised by his employer, Kelly learned how to fly, earning instrument and multi-engine ratings in the process. It was during his flights along the US east coast that Kelly encountered severe weather situations, "at least one or two of which I probably should not have survived," he notes.

> "These early systems became a realization of Dr. Suomi's dream to make geostationary satellite imagery television-compatible, becoming the 'eyes' of the weather for scientists and the public."

From his vantage point above (and in) the clouds and storms, Kelly remembered his childhood fascination with the beauty of the skies and the early days of television weather. According to Kelly, whenever the weather segment aired on television, he would place plastic wrap over the screen, draw the fronts with markers and check his predictive accuracy the next day. Although he recalls being teased about his preoccupation with the weather, it finally dawned on him many years later when flying



a Piper Aircraft that he could be a meteorologist, the notion "hitting him on the back of the head," he says.

So, Kelly arrived at UW–Madison in 1969 to pursue a degree in meteorology. There he met meteorology professor Frank Sechrist, a synoptician who developed early television forecasts for Wisconsin Public Television's Target program and who became one of Kelly's mentors. Those 1970s forecasts used SSEC's Man-computer Interactive Data Access System (McIDAS), a first-of-its-kind system for the display and animation of satellite data. Even with McIDAS, preparation still required hours of graphics development before each broadcast.

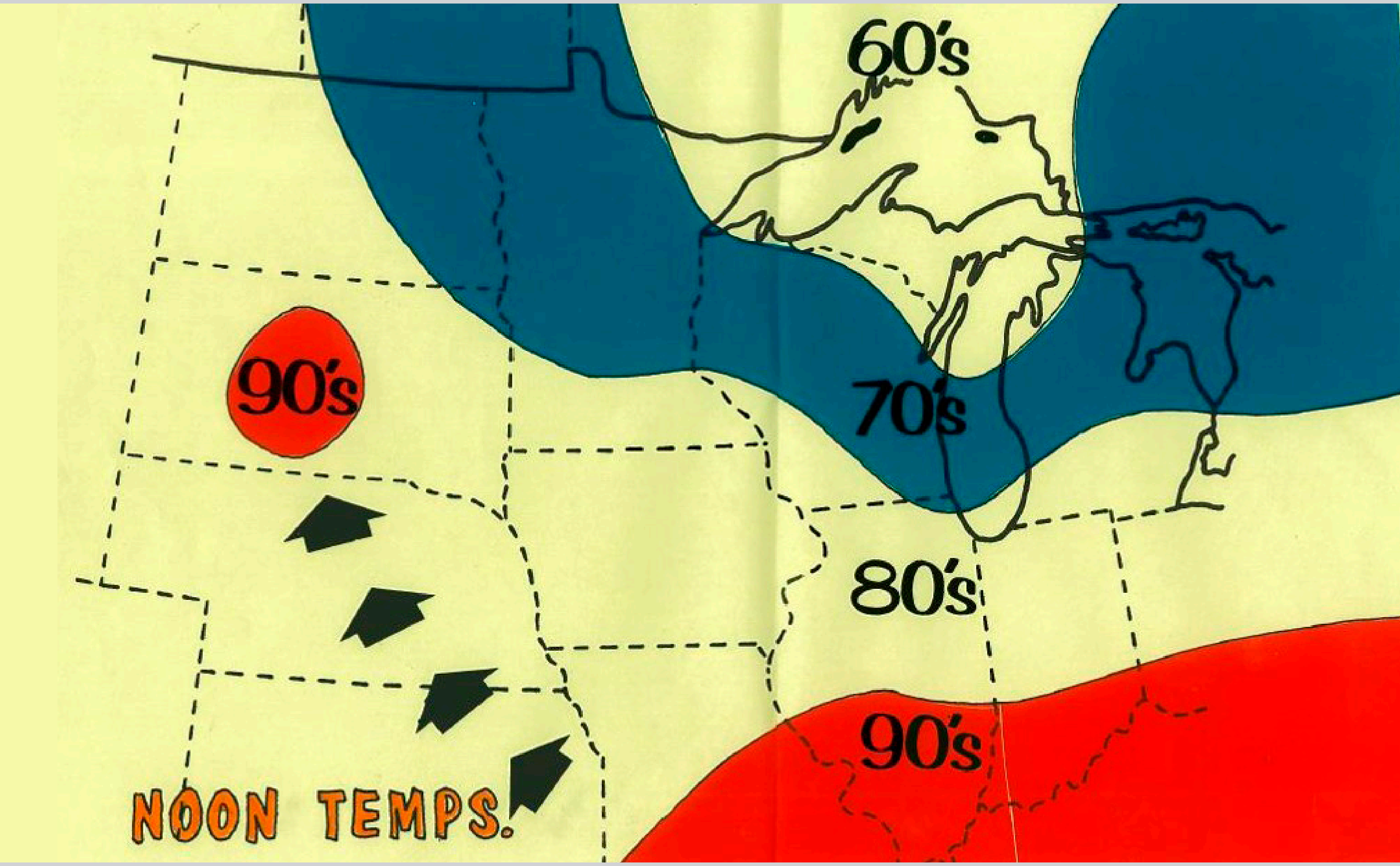
"Everyone who goes to college should have this good fortune," says Kelly, "as I found a mentor in Sechrist." One summer, Sechrist asked Kelly to do the broadcast program while he was on vacation. It intrigued Kelly, and was the beginning of a sustained interest in television weather.

He would, in fact, later pursue a career in broadcast meteorology while simultaneously developing new computer systems, landing a role at Madison's WKOW Channel 27 where he became the face of television forecasting for a decade. As the first on-air meteorologist in the state, he was awarded the AMS Seal of Approval and later the AMS Award for Outstanding Service by a Broadcast Meteorologist.

However, Kelly's initial attempts to find a meteorology job in 1972, post-graduation, proved challenging. His persistence and networking first led him to a job seeding clouds with silver iodide flares and rockets and running a rain gauge network at seven thousand feet in the Sierra Nevada Mountains. It is one of the few areas, says Kelly, where weather modification has been shown to work. The additional snowpack realized from cloud seeding generated hydro-electric power, he says, helping to provide clean hydropower electricity to Southern California. While the pay was low, only $700 per month, Kelly kept the job for two winters. He and his new wife, Mary, lived in a mobile home provided for them in the mountains.

Having endured the hardships of high-altitude living with low pay, Kelly returned to Madison in 1973 to

▲ Terry Kelly, UW—Madison alumnus and entrepreneur, charted a new course for real-time television weather broadcasting. Credit: Bryce Richter, UW—Madison



Two graphical representations of weather systems, both created by Kelly and his team, but decades apart. Prior to the team's pan the camera from left to right to show the sequence of predicted weather. Side-by-side, they show advances in the process of

work with Bob Wollersheim who was the program manager for a new federally funded project at SSEC called Innovative Video Applications in Meteorology (IVAM). The opportunity to work alongside Suomi and Wollersheim allowed Kelly to focus on applied meteorology, an area that fueled his passion for the intersection of technology and meteorology.

The IVAM program was intended to implement the new concept of "nowcasting" by harnessing the latest data processing techniques and information dissemination technologies to provide a forecast to the public while the weather events were still on-going or imminent.

Kelly's brain was spinning with ideas to put the IVAM concepts into action. He envisioned taking the rapidly evolving tools, displays and output in meteorology to make them useful to ski areas, power utilities, farmers, aviation, and food production and insurance companies — any of the weather-dependent industries. And for the public.

During this time, writes Mike Nelson, another UW alumnus, mentee, and colleague who led Kelly's nomination for the AMS Fellow honor, Kelly began to explore using emerging lower cost computer systems to display weather graphics for television, drawing inspiration from McIDAS that was becoming more sophisticated each year.

Kelly landed funding from the UW's University-Industry Research (UIR) Program to conduct a nowcasting experiment with Madison Gas and Electric Co., the City of Madison Streets Department, and a local construction company to test the

work on computerized weather graphics, newscasters would use several hand-drawn pictures like the one featured left, and generating these types of graphics. Credit: Terry Kelly

value of better short-range forecasts that could help companies and cities anticipate the weather and craft plans to work safely around it. UIR was established to encourage connections between university researchers and industry and Kelly's idea was a perfect fit for UIR's mission.

These early systems became "a realization of Dr. Suomi's dream to make geostationary satellite imagery television-compatible, becoming the "eyes" of the weather for scientists and the public," says Nelson.

Early computers were expensive, says Kelly, "but when the Apple II was released, we knew we could bring this weather technology into the world in a practical way." With the new computer, Apple introduced a capability of displaying six-color graphics. The image resolution, adds Kelly, was practically nothing in terms of today's standards, but it was a first step, and systems could be produced and sold at a fraction of McIDAS costs.

Beyond solving the problem of color graphics, the system would need to comply with existing television broadcast standards that dictated everything from frame size and rate to the process for interweaving video and audio. Kelly's team devised a specialized video conversion box that would convert the nonstandard video into standard video so that it could be used on-air.

Priced at $11,900, Kelly's new system generated considerable interest at trade shows, but surprisingly few sales. A repeat visitor to their booth suggested to Kelly that in order to be taken seriously, he should increase the "perceived value" to the buyer by increasing the price of his system. He did, tripling the sales price, and in very short order, selling 50 units: they were well on the way to becoming a multi-million dollar company.

Kelly founded Weather Central in 1974. The company was later purchased by Dynatech Corporation in 1982, though Kelly and his colleagues stayed on to expand the weather graphics industry under the new ownership. Before long, they'd sold graphics systems to hundreds of television stations in the US market, as well as around the world.

During his tenure at Dynatech, Kelly became a group vice president. He credits this era with honing his acumen for managing and developing technology companies and assessing teams, skills that he would rely on again and again.

Under his leadership, Kelly and colleagues invented a suite of tools for modeling and visualizing the weather in 3D. By the late 1990s, Kelly says that he, chief scientist Richard Daly and the Weather Central team demonstrated the first high definition graphics on the air.

The advancements kept coming as they unveiled tools that enabled a localized preview of tomorrow's weather. Known as futurecast, it used National Weather Service radar and other data to extrapolate storm development or tracks into the future. "It takes a tremendous amount of computing power to model the atmosphere down to 1km square," says Kelly. That early prediction work proved to be of great benefit to insurance companies, he adds, because they were keenly interested in knowing when and where hail storms would form so that adjusters could assess damage with more certainty and rein in claims costs.

MyWeather LLC, a start-up within Weather Central, was established to further develop and commercialize micromodelling and intelligent, instantly available forecasts.

Kelly sold Weather Central to The Weather Company in 2012. The combined companies remain in Madison under IBM Watson, the artificial intelligence wing of IBM.

After years of innovation, Kelly has 13 US patents in his name or as co-inventor, spanning from an array of systems and methods for presenting wind speed and lightning strike information to personalized storm warnings, though he is quick to point out that while many of these advances were based on his ideas, just as many resulted from group efforts.

Currently, Kelly is founder and partner of Venture Management LLC that invests in technology companies, many of which are affiliated with the UW–Madison and are located in Wisconsin. Looking back, says Kelly, his work with Dynatech, and the skills he developed there for assessing and gauging the potential of start-ups, foreshadowed his current endeavors.

Beyond solving the problem of color graphics, the system would need to comply with existing television broadcast standards that dictated everything from frame size and rate to the process for interweaving video and audio.

Outside of pursuing his continued interest in improving weather forecasts, Kelly spearheaded the establishment of the Climate Science Education Center at the Aldo Leopold Nature Center in Madison to encourage visitors — students, families, teachers — to think and learn about Earth's climate in an informative, but neutral environment. He served as the Center's chairman and CEO for more than 20 years.

Kelly's fingerprints can be seen in other philanthropic gestures, such as his founding investment in Air America Radio, a national progressive network, and Madison's Rhythm and Booms Independence Day celebration which spanned nearly two decades. Kelly has spent his career on the leading edge of computerized weather, providing critical information and predictive capabilities for people and industries around the world.

"One thing you'd like to see about the work you do in your life is that it mattered," he says.

AMS Fellow and past President Bob Ryan adds, "Terry Kelly is an example of what is best about our science and our society … his election as a Fellow [is] as much an honor to the AMS as it [is] to Terry."

Science Expeditions Open House

Every year for the last decade, the Atmospheric, Oceanic and Space Sciences building has opened its doors as part of the campus-wide Science Expeditions Open House. This year was no different.

CIMSS Education and Public Outreach Director Margaret Mooney spearheaded this fun and informative event, along with staff and graduate students from SSEC, CIMSS and the Department of Atmospheric and Oceanic Sciences.

Families and friends from around the area were invited to engage with our scientists and their research in order to get to know the people, places and science outreach programs of our land-grant university.

Interactive educational displays, presentations, and rooftop tours to see the satellite antennas—and the beautiful view of Madison—showcased our passion for science, our rich history, and our commitment to sharing our research with Wisconsinites and beyond.

This year we welcomed more than 300 attendees who joined us to learn about satellite meteorology, weather, climate and the instruments we use to collect our data.


Credit: Bill Bellon

MODIS +ASTER CAMEL

A land surface emissivity upgrade for UK radiative transfer model

by Leanne Avila

Networking and making connections at conferences isn't unusual. And in that regard, the International TOVS Study Conferences (ITSC) organized by the International TOVS Working Group (ITWG) are no different. However, attending the 16th ITSC in Angra dos Reis, Brazil in May 2008 proved pivotal for University of Wisconsin-Madison Space Science and Engineering Center (SSEC) scientist Eva Borbas.

Following her presentation on the land surface emissivity global database that she had developed in collaboration with late SSEC colleague Suzanne Wetzel Seemann, Roger Saunders of the United Kingdom's Met Office tracked Borbas down to discuss incorporating it into the UK's radiative transfer model (RTTOV); RTTOV is widely used in Europe in numerical weather prediction (NWP) to assimilate satellite data. More accurate land surface emissivity leads to more accurate temperature and water vapor retrievals and radiance simulation over clear skies.

The UW–Madison emissivity database (UWIREMIS) was initially included in RTTOV, version 10, released in January 2011. Because of his familiarity and experience with RTTOV, Ben Ruston of the Naval Research Laboratory (NRL) was instrumental in helping Borbas integrate and test the emissivity database. This collaboration between SSEC, NRL, and the Met Office was supported by EUMETSAT's NWP Satellite Application Facility (NWP-SAF).

In 2017 with help from SSEC and NASA Jet Propulsion Laboratory colleagues, Glynn Hulley and Simon Hook, Borbas provided a significant upgrade for the most recent RTTOV release, version 12. They replaced the UWIREMIS database — which uses laboratory measurements and data from the MODerate-resolution Imaging Spectroradiometer (MODIS) — with the Combined ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and MODIS emissivity over Land (CAMEL) product. According to Borbas, merging the UW database with JPL's ASTER emissivity database allowed them to highlight their advantages, leading to an improved emissivity product.

"ASTER is more accurate in the 8.3–12 micron region, especially on non-vegetated areas, and MODIS is more accurate on the vegetated areas. In addition, MODIS provides emissivity values in the midwave IR region while ASTER does not," stated Borbas.

Despite the complementary nature of the two datasets, combining them required navigating a few challenges, some of which they are still resolving – such as how this monthly database can accurately characterize emissivity in areas with snow coverage that is not constant throughout the month.

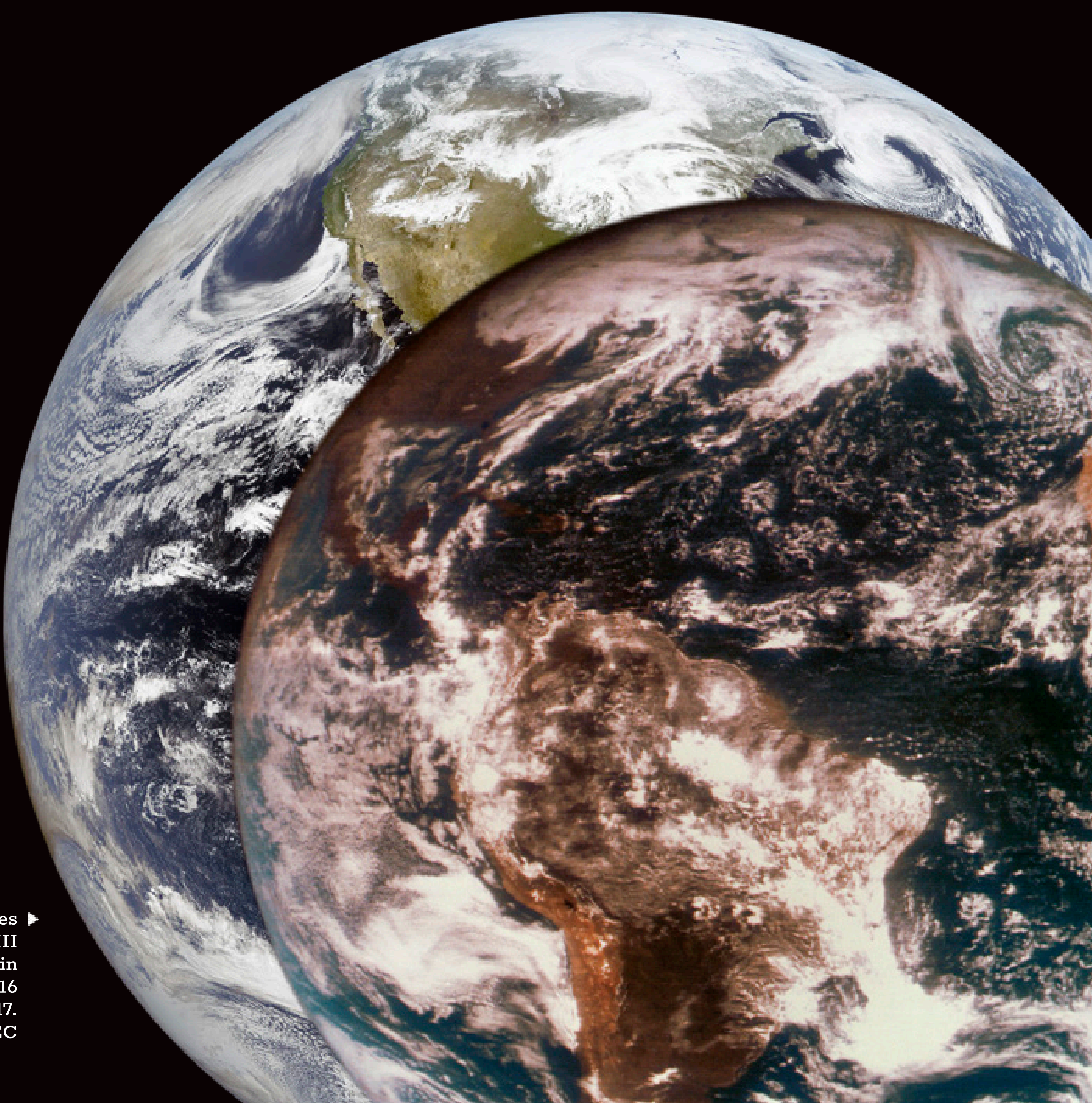
Borbas and SSEC colleagues, Michelle Feltz and Bob Knuteson, are continuing to improve the CAMEL product, in particular the error uncertainty estimates. They are taking into account improvements in spatial resolution from 50km to 5km, as well as providing the user with more flexibility and control in managing the uncertainty estimates. With more flexibilityand control in managing the uncertainty estimates.

This work was supported by EUMETSAT's NWP Satellite Application Facility (NWP-SAF).

50 years ago

The world as we'd never seen before

Just a few weeks after its launch, NASA's third installment of the Applications Technology Satellite (ATS-III) sent back some of its best Earth images on November 18, 1967. Later compiled into animations by then SSEC director Verner Suomi, and his team of scientists, the subsequent videos revealed the complex motions of our planet's clouds and allowed continuous viewing of weather from space—in true color—for the first time. Suomi's legacy, and that of ATS-III, can be seen today through the succession of geostationary and polar orbiting satellites: generations of satellites that built on his innovations. UW–Madison, the birthplace of satellite meteorology, is so-known because of Suomi's vision to use satellites as a platform for viewing and advancing our understanding of Earth and its atmosphere.



Full-disk images taken by ATS-III (foreground) in 1967 and GOES-16 in 2017. Credit: SSEC

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