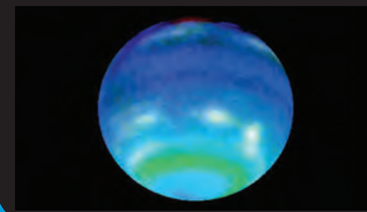
SPACE SCIENCE AND ENGINEERING CENTER • COOPERATIVE INSTITUTE FOR METEOROLOGICAL SATELLITE STUDIES • UNIVERSITY OF WISCONSIN-MADISON

TtA 2015
Winter / Spring





SSEC

through the atmosphere

R20: Past, Present, and Future

TtA
Winter / Spring
2014

INSIDE This Issue

Cover Image

A graphic of next-generation geostationary weather satellite, GOES-R, set to launch in 2016. Credit: Hayden Klabunde, CIMSS.

DIRECTOR'S Note

Each story in this issue demonstrates our commitment to exploring the atmosphere and environment, and using our discoveries to benefit society. SSEC's historic contribution to the 1959 Explorer 7 mission is early evidence of this process. In the years since, SSEC has played important roles in our nation's weather satellite programs, from designing instruments, to generating and analyzing data, and, ultimately, helping people understand and make use of the information.

This research-to-operations (R2O) approach continues with the next geostationary weather satellite program — GOES-R. SSEC and CIMSS scientists are working with our NOAA partners to develop techniques to transform satellite observations into useful information about the atmosphere to support decision-making.

The next generation of weather satellites will bring improved technologies, some of which were developed at SSEC. New analysis methods for atmospheric motion vectors build on earlier SSEC studies. We are also researching the new capabilities of the super rapid scan operations (SRSO-R) mode on GOES-14.

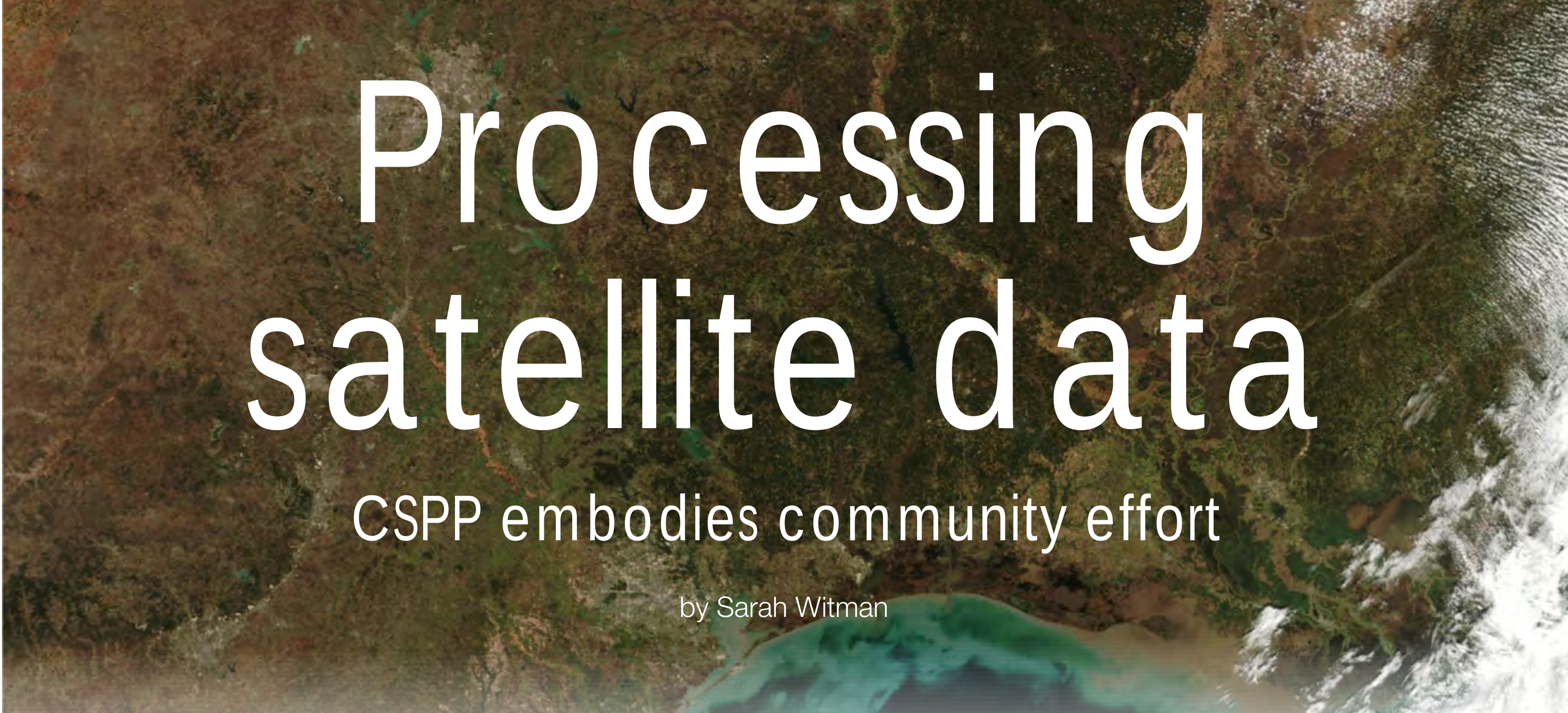
Our long history of producing and distributing high-quality research products was recently recognized by the American Meteorological Society's Special Award to the CIMSS Tropical Cyclones Group. In addition, our legacy of software development and distribution extends from the ITPP to today's CSPP. While our work with NOAA and the weather communities spans decades, we are establishing collaborations with the USGS, FEMA, and the UW Sea Grant Institute, to expand our R2O successes.

Young scientists and graduate students play a key role in our research and the future of SSEC and CIMSS as organizations. Read about the achievements of one of these students, Jacola Roman, in this issue. Our Education and Public Outreach programs are magnets tailor-made for younger scientists — from middle school to high school.

SSEC and CIMSS were founded during exciting scientific times. Looking ahead, our future holds new opportunities and challenges, leading to new discoveries for the benefit of society.

Steve Ackerman

Steve Ackerman
Director, CIMSS



Processing satellite data

CSPP embodies community effort

by Sarah Witman

The next few years promise multiple milestones in satellite science, as next-generation geostationary satellite GOES-R is set to launch in 2016, followed by the Joint Polar Satellite System-1 (JPSS-1), a collaboration between NASA and NOAA that will be the second in a three-part series of environmental satellites, beginning with the launch of Suomi NPP in 2011.

With this eventful era on the horizon, Earth and space scientists across the globe are in preparation mode, educating themselves on the new technologies and advanced capabilities these satellites will bring.

For the multidisciplinary, collaborative team working on the Community Satellite Processing Package (CSPP) at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), these advancements will mean vastly more, higher-quality data to be processed for its users.

Based at the University of Wisconsin-Madison and funded by JPSS, the mission of CSPP is to package and distribute free, open-source satellite science software, as well as provide training for local applications of the software. The communities it supports are twofold, mainly direct-broadcast meteorologists and environmental satellite scientists—global users that process satellite data for research or regional, real-time applications. Essentially, any organization with a receiving station can obtain and use satellite data at no cost, a main tenet of the project.

Already, CSPP has played a significant role in processing Suomi NPP data: Its software packages are used for processing a variety of raw, sensor, and environmental data records from instruments such as VIIRS, MODIS, AIRS, CrIS, ATMS, AMSU, IASI, and AVHRR. For the CSPP team, getting to this level has required years of groundwork.

CSPP can trace its lineage to 1982, when CIMSS scientists developed the International TOVS Processing Package (ITPP). This first-generation processing package, led by former UW-Madison professor and inaugural CIMSS director Bill Smith, dealt with an important set of instruments onboard NOAA's TIROS satellite series, called the TIROS Operational Vertical Sounder (TOVS). Then came an advanced version of TOVS, called A-TOVS, and ITPP became the International ATOVS Processing Package, or IAPP.

By the 1990s, the package incorporated two new NASA sensors, becoming the system of choice and named the International MODIS and AIRS Processing Package (IMAPP). The success of IMAPP, with more than 1,900 registered users from more than 90 countries, is what solidified the foundation for development of a community-oriented, real-time processing capability that could harness the technological advancements of NOAA's operational polar-orbiting weather satellites for years to come, Huang said.

It was not until 2011, with the launch of Suomi NPP, that CSPP adopted its current acronym. CIMSS scientist Allen Huang, who is PI for the project, says the new name embraces the collaborative, community-oriented spirit of the project.

"Instead of focusing on a particular

> "Our rich heritage is based on the strong support of NASA and NOAA over many years."
>
> -Allen Huang, CIMSS scientist and CSPP PI

Background image: VIIRS true color over Texas from POLAR2GRID. Credit: CIMSS.

▸▸ *continued from page 1*

sensor, we wanted to emphasize that this is a collective, partnership effort," Huang said. "Our rich heritage is based on the strong support of NASA and NOAA over many years."

Satellites transmit unprocessed, raw data to scientists who may process them down to different levels: At level 1, data such as visible, infrared, and color composite images are ready to be used by those less familiar with satellite operations. Level 2 data are usable products from several instruments, such as temperature, water vapor, aerosols, particulate matter, and sea-surface and land-surface temperatures, as well as derived products such as cloud thickness, precipitation, and soil moisture. By level 3, data are ready for weather nowcasting, nearcasting, forecasting, and air quality monitoring applications, and users such as the National Weather Service (NWS) are able to incorporate all three levels into their routine operations to make forecasts.

"The goal is to make satellite data meaningful, in order to make accurate forecasts," Huang said.

The software is so powerful that it can produce up to 35 products in 10 minutes, keeping pace with near-real-time satellite observations, he added.

Huang described a system that CSPP/IMAPP installed on the campus of East China Normal University, located in the city center of Shanghai, China — what the CSPP team calls a turn-key, end-to-end system.

"We deliver this one solution, put it in, turn the key, everything works," he said.

This example is a testament to what such a system can do for research and education, as well as local environmental and weather monitoring and forecasting, he added.

"They have everything they need to make a weather forecast in the next three hours, six hours, up to three days later," said Huang. "Information about wind temperature, precipitation, and more is all automatic."

CSPP has had 26 releases since 2011, and three more are in the works, including NUCAPS, a NOAA retrieval package for hyper-spectral sounders; support for the IAPP retrieval package; and ASCPO, a NOAA package that produces sea-surface temperature retrievals from a number of imagers.

"These packages produce the same output products using the same science algorithm for a number of different instruments," said CIMSS scientist Kathy Strabala, who has worked on processing packages since the project's early days in 1999.

The team is also working to make Microwave Integrated Retrieval System (MIRS) microwave products from NOAA available to CSPP direct broadcast users, particularly NWS forecasters, starting in Hawaii.

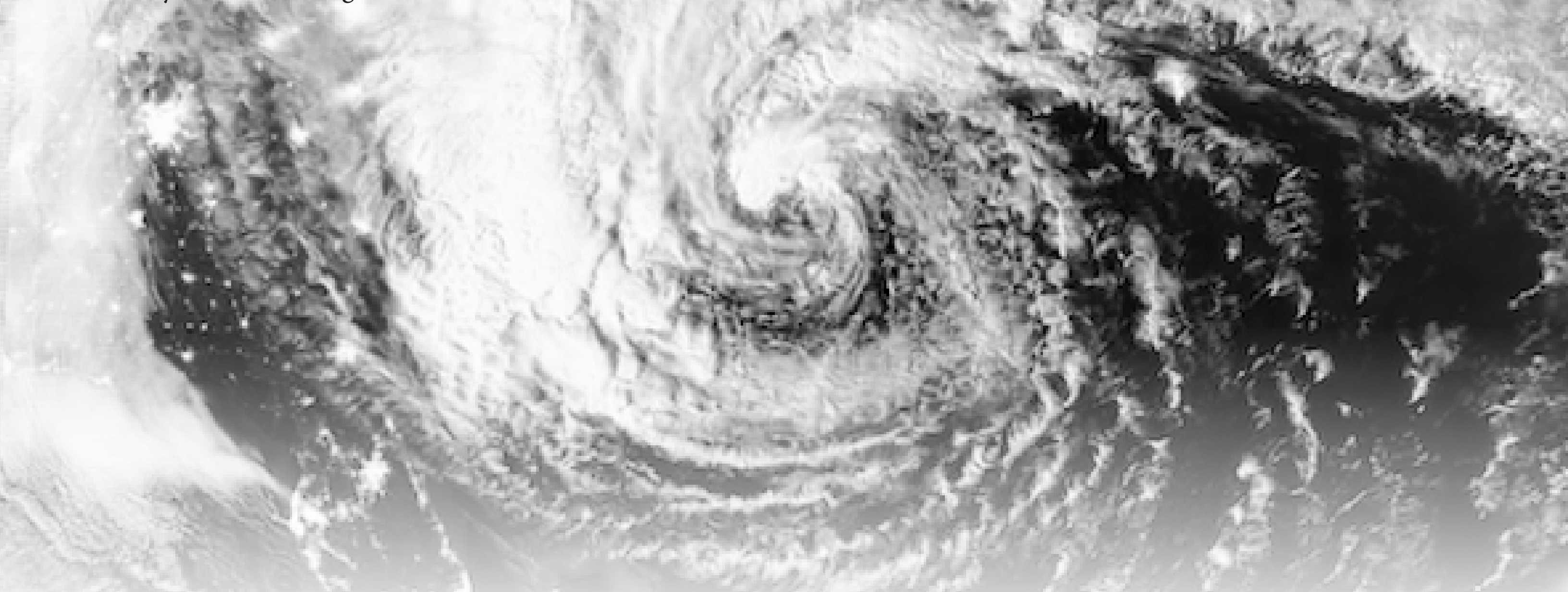
"We are really focused on the end users. The main goal is to make the data useful to people," Strabala said.

In addition to these releases, new updates are ongoing. An update to the CLAVR-x cloud and land-surface retrieval software, released in May 2014, is coming soon, Huang says, which will have more suites of products, a faster interface, and more reliability.

"New releases are based on the priorities we hear from users," he said.

The general philosophy for CSPP, Huang said, is building software that is easy to install, operate, verify, and run, and to provide training, support, and updates that are just as user-oriented and efficient. The CSPP team conducts training workshops around the world, on all five continents, the most recent of which was the CSPP IMAPP workshop in Madison. In April 2015, there will also be a users' group meeting in Germany, which will allow the team to interact with users from around the globe, and get feedback on possible improvements.

"We want our product to benefit society," Huang said. "It should be useful not only to our own community but society at large." ■



Background image: Hurricane Sandy in October 2012, VIIRS day-night band from CSPP direct broadcast. Credit: CIMSS.

GOES-R Proving Ground at CIMSS prepares educators, students for 2016 launch

by Margaret Mooney

With new satellite imagery and improved products coming in the GOES-R era, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) is heading an initiative called the GOES-R Education Proving Ground, connecting teachers and scientists to ensure that the education community is launch-ready for the next generation satellites.

▲ The 2014 GOES-R Education Proving Ground team at Space Science and Engineering Center in Madison, WI. From left to right, team-members include John Moore, Tim Schmit, Margaret Mooney, Vicky Gorman, Peter Dorofy, Craig Phillips, Brian Whittun, Charlotte Besse, and Amy Monahan.

For more than a year, six middle and high school science teachers from three different states have been collaborating with CIMSS Education and Public Outreach Director Margaret Mooney and Tim Schmit, a scientist from NOAA's Advanced Satellite Products Branch (ASPB) at CIMSS, to develop relevant lesson plans and new interactive WebApps.

Mooney and Schmit met the teachers in person for the first time at the 2014 Satellites & Education XXVII conference in Madison this summer. Teachers presented first drafts of their lesson plans, which included activities such as "Little League weather forecasting," to introduce the GOES-R Geostationary Lightning Mapper; "Tabletop Twitter," to build students' vocabularies of meteorological terms; and a "GOES-R Instruments" exercise, to promote comprehension of GOES-R's Advanced Baseline Imager (ABI). Each of the lesson plans incorporates relevant Next Generation Science Standards (NGSS) identified by the teachers.

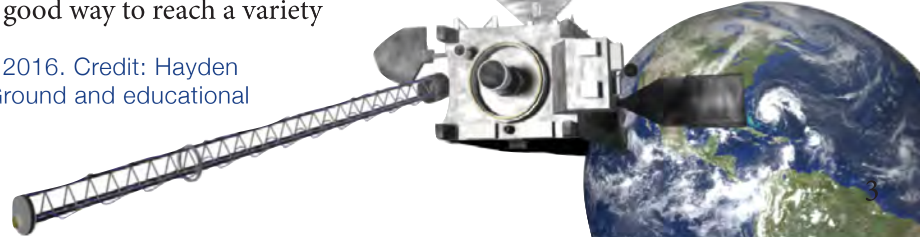
Schmit also shared two newly developed WebApps, co-developed with Tom Whittaker at CIMSS, which allow users to navigate time and space in the context of real satellite imagery. Super rapid scan data from the GOES-14 satellite emulates the improved temporal resolution planned for the ABI, Schmit says, providing a hands-on experience to better understand the instrument. Users can customize every detail: adjusting the sampling rate and pixel size of an animation while exploring hurricanes, storm convection, clouds, fires, smoke, and pyrocumulus formations.

Through the GOES-R Education Proving Ground, the WebApps have been tested in several classrooms and demonstrated at conferences. A teacher from Wisconsin is now collaborating with Schmit on a forthcoming WebApp to demonstrate the benefit of the increased number of spectral bands (16) available with GOES-R.

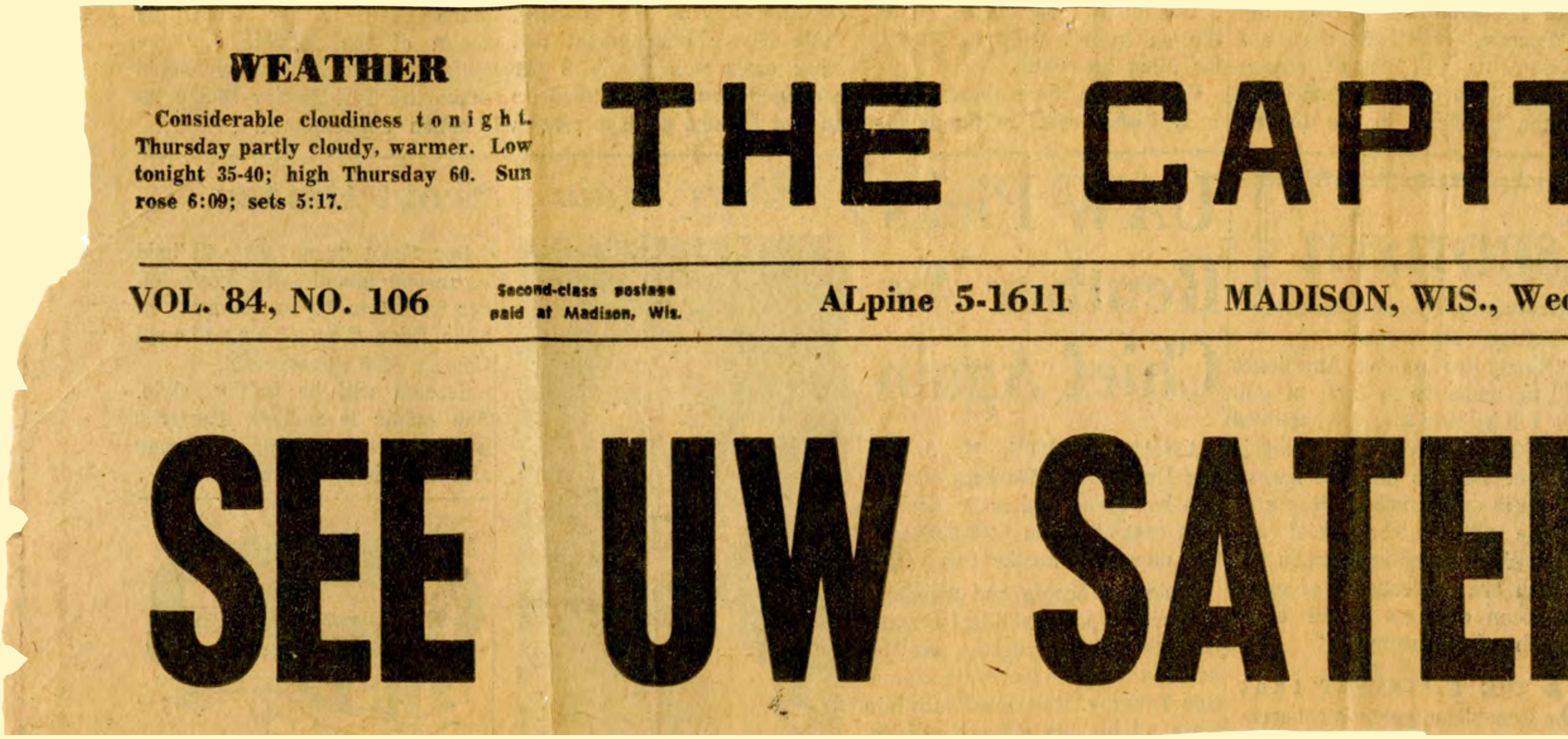
"Many groups will use the improved information from the next generation GOES satellite — not just NOAA's National Weather Service," Schmit said. "One good way to reach a variety of people is by educating students at several ages."

Mooney and Schmit have also been working with SSEC's Rick Kohrs to develop prototype videos for Science On a Sphere (SOS) exhibits that highlight GOES-R technology and products.

Both the WebApps and SOS videos demonstrate several basic remote-sensing concepts as well as specific attributes of the GOES-R series. Through these new resources, in concert with the lesson plans currently being tested in classrooms around the country, the GOES-R Education Proving Ground promises to reach a broad audience of formal and informal learners. ■



▶ A graphic of the GOES-R spacecraft, set to launch in 2016. Credit: Hayden Klabunde, CIMSS. Full details on the GOES-R Proving Ground and educational materials can be accessed on the project's website: *http://cimss.ssec.wisc.edu/education/goesr/.*



WEATHER

Considerable cloudiness tonight. Thursday partly cloudy, warmer. Low tonight 35-40; high Thursday 60. Sun rose 6:09; sets 5:17.

THE CAPIT

VOL. 84, NO. 106 Second-class postage paid at Madison, Wis. ALpine 5-1611 MADISON, WIS., We

SEE UW SATEL

Explorer VII: R2O begins at SSEC

by Jean Phillips

The Space Science and Engineering Center, under the early leadership of Verner Suomi, was (and continues to be) a pioneer in the research-to-operations process – successfully marshalling numerous instruments and algorithms from experimental to operational mode.

The International Geophysical Year, 1957-1958, set the stage for this process early on, creating opportunities for the development of instruments that would fly on the earliest earth-orbiting satellites. These instruments would provide, for the first time, measurements of the Earth's atmosphere from space.

As a dissertator at the University of Chicago in 1953, Suomi had considered The Heat Budget Over a Cornfield. His dissertation measured the difference between the amount of

continued on page 6

Suomi Tells High Hopes

1

Signals May Reveal Basic Weather Secrets

By JOHN PATRICK HUNTER
(University Editor)

PINE BLUFF—Data beeped back from Explorer VII may help man finally understand the weather, Prof. Verner Suomi, one of the developers of America's newest satellite, told The Capital Times today.

Wisconsin scientists, alerted early Tuesday, have been tracking the satellite on a panel of complicated electronic devices set up in the basement of the U. W. observatory here.

The first signal was picked up at 11:12 a. m. Tuesday and again at 3 p. m. and a team of scientists returned to this brand new observatory on a hill outside of Pine Bluff early today to begin monitoring the orbiting moonlet again.

Dr. Suomi said he has received reports from a listening station at Boulder, Colo. which bolsters his hopes that all the instruments "are working perfectly."

Prof. Suomi

"I am amazed to hear that people already have reported seeing the satellite," Dr. Suomi declared. He explained that no attempt had been made to polish the "package" and that visual sighting must be the result of sun rays reflecting on glass mirrors installed on the sides of the satellite.

\+ \+ \+

2

Researchers Pleased With 'Moon' Orbit

By HOWARD BENEDICT

CAPE CANAVERAL, Fla. (AP) — America's new Explorer VII satellite is spinning about the earth every hour and 41 seconds gathering data about space radiation and the weather.

A four-stage Juno II rocket lifted the gyroscope satellite into orbit Tuesday and it immediately began transmitting valuable information.

Space scientists were pleased with the orbit attained—which takes the Explorer VII 664 miles from earth at its farthest point and as close as 346 miles at its nearest point.

Dr. Homer Newell Jr. of the National Aeronautics and Space Administration reported this orbit is more nearly circular than hoped for and said it would be an advantage because of the nature of some of the seven experiments ca[illegible]ed in the ins[illegible]ument pack-

Listening to a welcome sound, the vo
Prof. Verner Suomi, U. W. meteorolog
Observatory, where a monitoring station
has been set up. Standing behind Dr. Suo
Weather Bureau meteorologist, who is
project to cross-check the results of the
by Carmie A. Thompson)

TAL TIMES

HOME EDITION

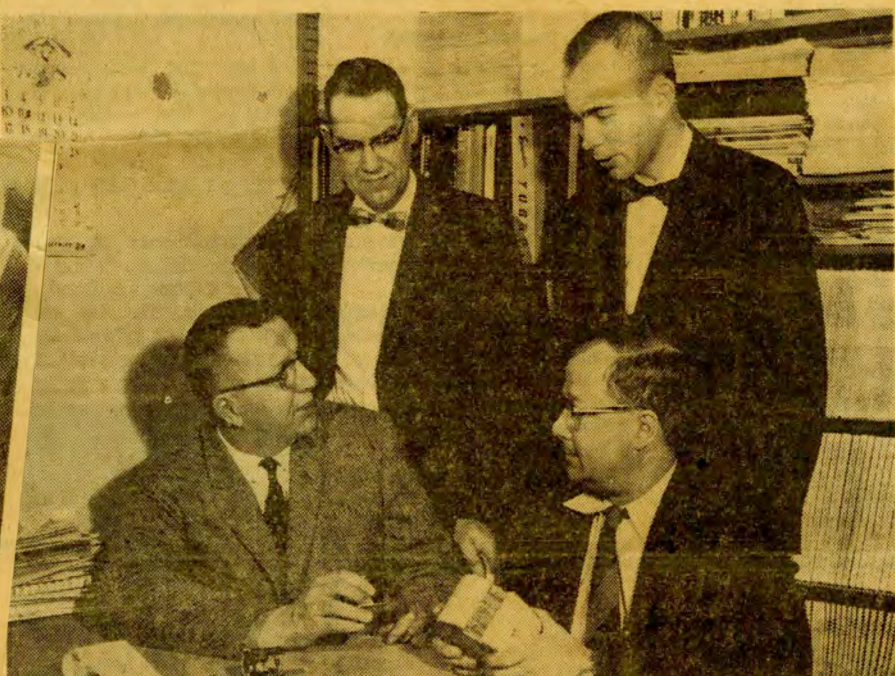
Tuesday's Circulation **45,642**

Largest net paid circulation of any evening paper in Wisconsin outside of Milwaukee.

dnesday, Oct. 14, 1959 ★★★ 38 PAGES PRICE 5c

LLITE TRIUMPH

U. W. Weathermen of Space



Here are some of Wisconsin's satellite scientists, men chiefly responsible for design and assembly of meteorological instruments included in the Army Ballistic Missile Agency's "Juno Satellite."

Seated on the left is Prof. Verner Suomi of the Meteorology Department. Behind him, left to right, are Prof. Robert J. Parent, Electrical Engineering, and Prof. Wayne B. Swift, Electrical Engineering, and, seated on the right, Prof. Harry H. Miller, project associate with the Meteorology Department Electrical Standards Laboratory.

oice of Explorer VII, is
gist, at the Pine Bluff
n to track the satellite
mi is Peter Kuhn, U. S.
working on another
satellite's data. (Photo

Researchers Pleased With 'Moon Orbit'

2

(Continued from Page 1)

designed for precision tracking of the satellite. Newell said, however, that when the radio stops, the satellite can be tracked by telescopic means.

Explorer VII is expected to stay aloft for 20 years, but it will relay information for only one year. After that period, an automatic device will shut off the second transmitter. This is to prevent the radio signals from cluttering up satellite broadcasting wavelengths.

The gyroscope gets its nickname because it looks and acts like the spinning devices that stabilize moving ships and planes.

The main mission was to study the lower levels of bands of radiation hovering above the earth. This data may help ease man's way to the moon.

Other instruments measure cosmic rays in and below the belt; Micrometeoric density; sun-produced ultra-violet radiation; and the heat balance between the earth and the sun. Meterologists believe the latter is responsible for most of our weather.

The Juno II was one of three rockets launched here Tuesday.

Earlier, a B-47 jet bomber fired a 37-foot Bold Orion missile across the path of the Explorer VI "Paddlewheel" satellite. The missile may be the forerunner of a weapon designed to knock down enemy satellites. Tuesday night the Air Force launched its dependable Thor intermediate range missile on a 1,500-mile test flight.

▸▸ *continued from page 4*

energy absorbed and the amount of energy lost in a cornfield. This led him to think about heat budgets on a much larger scale – the Earth's heat budget.

With the help of Harry Wexler, then chief of research at the Weather Bureau, Suomi and his engineering colleague, Robert Parent, submitted their idea for an instrument to measure the Earth's radiation budget. They secured a payload spot for their instrument on Vanguard SLV-6 in 1959.

The instrument consisted of a series of sensors designed to measure the amount of solar radiation absorbed on Earth and the amount of radiation reflected back into space.

This first mission was unsuccessful.

There were many setbacks in those early attempts to launch satellites into orbit around the Earth: explosions on the launch pad, wobbling satellites, unusable data. Suomi's own experiment, with three unprecedented launch attempts in 1959, wouldn't succeed until October of that year when it flew on Explorer VII.

Interviewed by the Capital Times newspaper in Madison, WI, after the launch, Suomi said, "data beeped back from Explorer VII may help man finally understand the weather."

Considered the first successful meteorological experiment conducted from a satellite, the data, when analyzed, would indeed show trends in observed weather patterns. The Earth's heat, or energy budget, drives global weather patterns and has become an important component of climate studies.

The Suomi-Parent radiometer – experimental on Explorer VII – would fly operationally on many polar-orbiting satellites until 1970.

It was the first of numerous research-to-operations programs undertaken with SSEC, industry, and government partners. ■

1

Satellite Success Is Forecast

(Continued from Page 1)

der the mass balloon launchings.

The balloons will rise to 21 miles and measure the infra red rays to get a radiation measurement of the earth and atmosphere. This data will be recorded and checked with information being sent back by Explorer VII.

The mass balloon launching has not been shceduled yet, but it may come at sunset tonight or tomorrow night, Kuhn revealed.

The balloons are set to explode after they reach a height of 21 miles and will parachute their electronic equipment back to earth. Kuhn said he expects to recover about half of the 20 devices.

The signal for the mass launching to be given by Suomi will be flashed from Madison simultaneously to all of the participating stations by the Weather Bureau "raywarc" network, Kuhn explained.

This reporter was on hand when the first signal or the orbiting moonlet was received here Tuesday. It sounded like a high strident pulsating but continuous shortwave radio signal.

✦ ✦ ✦

Dr. Suomi, U. W. meteorologist, returned to Madison late Tuesday from Cape Canaveral. He witnessed the successful launching of the Juno II rocket bearing instruments that were developed on the University campus by Dr. Suomi, Dr. Wayne Swift and a team of other U. W. scientists.

Interviewed today, Suomi, who had witnessed two earlier unsuccessful attempts to put Badger equipment into orbit in a rocket, sounded like a batter who had just hit a home run with the bases loaded after a prolonged batting slump.

Suomi said that he had talked to Cape Canaveral scientists this morning and they had reported the beeping signal of the satellite "appears to be getting stronger."

"They said they are getting a better signal from the Explorer than from the Sputniks," Suomi reported.

Among the data being flashed back to listening stations around the country is a measurement of the temperature of the shell of the satellite's 91-pound payload, Suomi explained. The instruments are gleaning information about the "heat budget" of the earth.

✦ ✦ ✦

The heat budget is a combination of the heat coming from the sun and light and heat reflected from the earth, Suomi explained.

Dr. Wayne Swift, 32, one of the dozen scientists who developed instruments during the past two and a half years at Wisconsin Electrical Engineering Department, reported today that the $150,000 package will also send back data offering an insight into the circulation of the atmosphere and the large scale changes in the earth's weather makeup.

The satellite will take a temperature reading every 42 seconds as it speeds around the earth, Swift said. These readings will tell scientists about the heat current close to the earth's surface.

Many scientists believe this heat current is the key to the atmospheric movements which change the world's weather patterns.

✦ ✦ ✦

Putting together the instrument packages for Vanguard III and Juno Satellite has been more than a one-man job. Prof. Suomi drew on the know-how of a number of University departments, including his fellow meteorologists, electrical engineers, and solar energy specialists.

He went first to the College of Engineering with an idea and a tentative design. The engineers took over from there, and "made it work," Suomi says.

Members of the team which helped him are:

Prof. Robert J. Parent, electrical engineering, specialist in electronics and communication and

Highlights of Recent Publications

July 2014 - December 2014

♦ Duncan, Bryan N.; Prados, Ana L.; Lamsal, Lok N.; Liu, Yang; Streets, David G.; Gupta, Pawan; Hilsenrath, Ernest; Kahn, Ralph A.; Nielsen, J. Eric; Beyersdorf, Andreas J.; Burton, Sharon P.; Fiore, Arlene M.; Fishman, Jack; Henze, Daven K.; Hostetler, Chris A.; Krotkov, Nicholay A.; Lee, Pius; Lin, Meiyun; Pawson, Steven; Pfister, Gabriele; Pickering, Kenneth E.; Pierce, R. Bradley; Yoshida, Yasuko, and Ziemba, Like D., 2014: Satellite data of atmospheric pollution for US air quality applications: Examples of applications, summary of data end-user resources, answers to FAQs, and common mistakes to avoid. *Atmospheric Environment* v.94, 647-662.

Full potential of satellite data for important air quality applications has not been realized due to inherent difficulties associated with accessing, processing and properly interpreting observational data, and with the technical skill required on the part of the data end-user at air quality agencies with limited resources. Goal of this review article is to close that gap and provide answers to common questions in plain language.

♦ Foster, Michael J. and Heidinger, Andrew, 2014: Entering the era of +30-year satellite cloud climatologies: A North American case study. *Journal of Climate* v.27, no.17, 6687-6697.

Length and quality of satellite-based cloud records have potential to improve climate model development, monitoring, and studies as these extended records may increase the understanding of the influence of cloud feedbacks. Specifics of the PATMOS-x AVHRR cloudiness record over North America are explored.

♦ Jie, Zhang; Li, Zhenglong, and Li, Jinglong, 2014: Ensemble retrieval of atmospheric temperature profiles from AIRS. *Advances in Atmospheric Sciences* v.31, 559-569.

This study lays the foundation for improving temperature retrievals from hyper-spectral infrared radiance measurements. An ensemble retrieval algorithm is presented that improves the accuracy of the physical retrieval, therefore improving weather forecasting.

♦ Liu, Yinghui and Key, Jeffery R., 2014: Less winter cloud aids summer 2013 Arctic sea ice return from 2012 minimum. *Environmental Research Letters* v.9, no.4, doi:10.1088/1748-9326/9/4/044002.

Importance of the influence of decreased wintertime cloud cover on the return of sea ice cover the following summer provides a significant factor in explaining large year-to-year variations in the otherwise decreasing Arctic sea ice cover.

♦ Price, Erik; Mielikainen, Jarno; Huang, Melin; Huang, Bormin; Huang, Hung-Lung Allen, and Lee, Tsengdar, 2014: GPU-accelerated longwave radiation scheme of the Rapid Radiative Transfer Model for General Circulation Models (RRTMG). *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* v.7, no.8, doi:10.1109/JSTARS.2014.2315771.

The feasibility of using Graphics Processing Units (GPUs) to accelerate the Rapid Radiative Transfer Model for General Circulation Model Long-Wave radiation schemes (RRTMG_LW) in weather research is examined. Speed and performance improvement are presented.

♦ Roman, Jacola; Knuteson, Robert, and Ackerman, Steve, 2014: Time-to-detect trends in precipitable water vapor with varying measurement error. *Journal of Climate* v.27, no.21, 8259–8275.

This study determined the theoretical time-to-detect (TTD) global climate model (GCM) precipitable water vapor (PWV) 100-year trends when realistic measurement errors are considered. Detailed case study analysis of four regions with high population density indicate that trend analysis on regional spatial scales may provide the most timely information when comparing detection time scales to global and zonal analyses.

For a complete list of 2014 publications, please see: *http://go.wisc.edu/lx74ac*

Honors & Awards

Chris Velden:
WMO THORPEX Certificate of Appreciation

Jim Kossin:
NOAA Administrator's Award

Steve Ackerman:
UW-Madison Associate Vice Chancellor for Research

Denis Botambekov, Corey Calvert, Richard Dworak, Richard Frey, Bob Holz, Hue Li, Yinghui Liu, Min Oo, Andi Walther, and Xuanji Wang:
NOAA-CIMSS Collaboration Award

Mathew Gunshor, Scott Lindstrom, and James Nelson:
NOAA-CIMSS Collaboration Award

Satellite history at UW-Madison comes full circle with NOAA David Johnson award

by Sarah Witman

Michael Pavolonis thinks of himself as a volcano guy. As a physical scientist with the National Oceanic and Atmospheric Administration (NOAA), based at the University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS), Pavolonis developed a satellite-based system to detect volcanic eruptions across the world. It enables more timely and accurate volcanic ash cloud advisories and is now used by NOAA Volcanic Ash Advisory Centers in Washington D.C. and Alaska.

"Volcanic Ash Advisory Centers are the front line of action in warning about volcanic-cloud hazards, and Mike's quantitative retrievals, corresponding training materials, and visits are in high demand," writes Marianne Guffanti, a U.S. Geological Survey volcanic ash expert, in a letter nominating Pavolonis for the 2015 NOAA David Johnson Award.

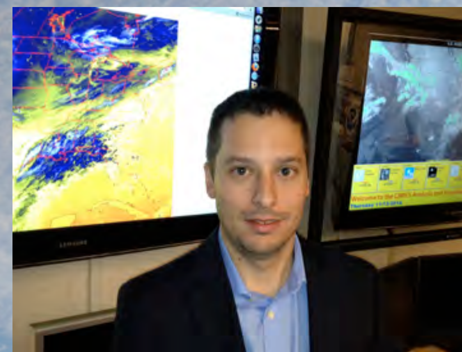
Pavolonis was chosen this month for the honor, sponsored by the nonprofit National Space Club and awarded in memory of the late Johnson, first assistant administrator of NOAA's Satellite and Information Service (NESDIS). Each year, the award is presented to a young professional in recognition of outstanding, innovative uses of Earth-observation satellite data for operations, in order to predict atmospheric, oceanic, or terrestrial conditions.

Earlier this year, Pavolonis briefed the United States House and Senate as well as NOAA senior leadership on the importance of satellites in mitigating volcanic hazards. He also runs the NOAA/CIMSS volcano imagery site, www.*volcano.ssec.wisc.edu*, and his volcanic eruption system has proved helpful for researchers around the world.

In addition to his volcano work, Pavolonis is leading the development of ProbSevere, a new weather prediction model that determines the likelihood storms will produce severe events like thunderstorms or tornados within a 60 minute window. When the NOAA/CIMSS team demonstrated ProbSevere at NOAA's Hazardous Weather Testbed this summer, the model added at least 10 minutes of lead time to severe weather warnings over half of the time.

"This product truly represents the future of forecast and warning products," Jeffrey Craven, science and operations officer for the Milwaukee/Sullivan National Weather Service Forecast Office, writes in Pavolonis' nomination letter.

Pavolonis got his start at UW-Madison, earning both his master's and doctorate degrees in atmospheric and oceanic sciences. He hasn't strayed far and his award, too, has UW-Madison ties.



▲ Physical scientist Michael Pavolonis is the winner of the 2015 NOAA David Johnson Award. Credit: NOAA.

In 1966, the late UW-Madison professor and Space Science and Engineering Center founder Verner Suomi – considered the father of satellite meteorology – collaborated with Johnson and the National Aeronautic and Space Administration (NASA) to launch the first spin-scan cloud camera into Earth's orbit. Suomi's camera enabled weather satellites to gather continuous images of weather as it happened, much like the weather loops we see today.

In 1977, Johnson teamed with Suomi once more, sending nine of his best people to Madison, bridging the gap between the operations of NOAA and the research at the university, and founding what would become CIMSS a few years later. The NOAA Cooperative Institute Program would evolve from these first arrangements with UW-Madison and other institutions. ■

Background image: Astronauts aboard the International Space Station photographed this view of Pavlof Volcano in the Aleutian Arc of Alaska on May 18, 2013. The volcano jetted lava into the air and spewed an ash cloud 20,000 feet high. Credit: NASA.

CIMSS Tropical Cyclones Group receives AMS award

by Jean Phillips

The Tropical Cyclones Group at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison, has been selected for an American Meteorological Society (AMS) Special Award.

The award is presented to groups or individuals that have made important contributions to meteorology, meteorological aspects of oceanography or hydrology, or the Society.

The AMS cited the CIMSS Tropical Cyclones Group for "providing the weather community with valuable tropical cyclone-related satellite information and derived products for over two decades," stating that the

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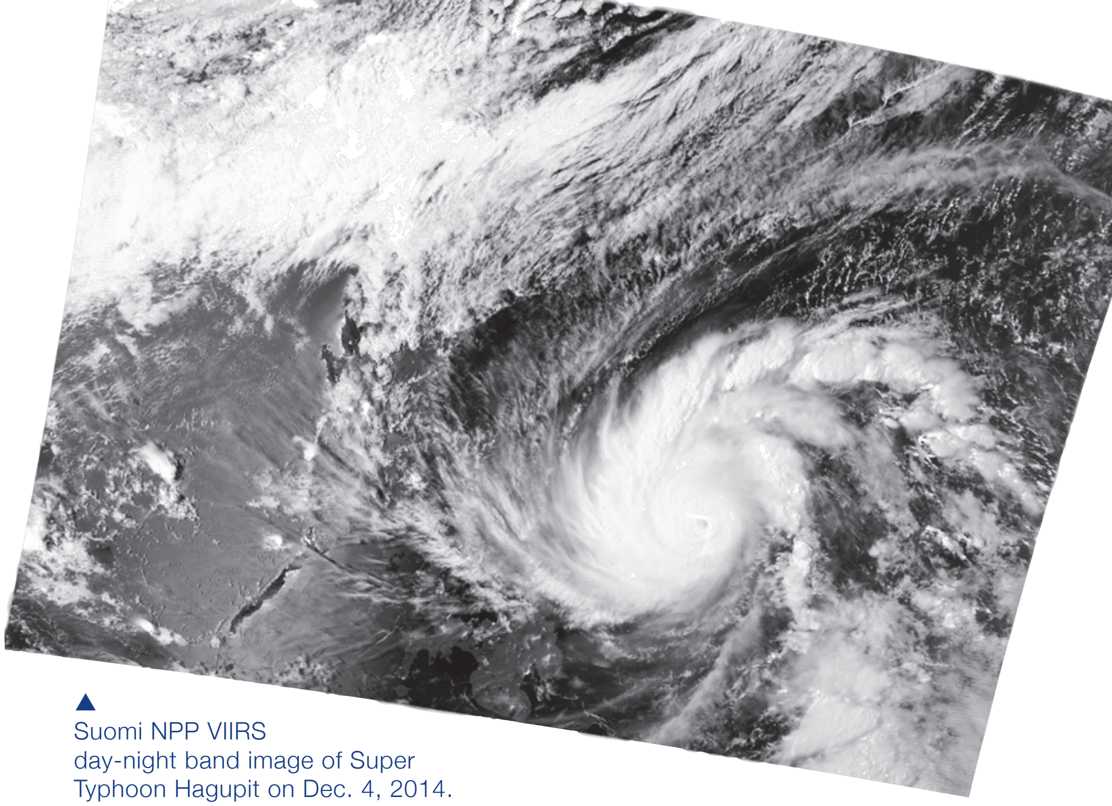


▲ Suomi NPP VIIRS day-night band image of Super Typhoon Hagupit on Dec. 4, 2014. Credit: Kathy Strabala, CIMSS.

award is "a reflection of [their] commitment to the Society and to the field."

The Special Award recognizes the scientific contributions of current and former members of the Tropical Cyclones team: Timothy Olander, Derrick Herndon, Anthony Wimmers, David Stettner, Steven Wanzong, Jason Dunion, Sarah Griffin, John Sears, and group founder Christopher Velden.

According to CIMSS Director Steve Ackerman, the group has worked with its operational partners – the National Hurricane Center (NHC) and the Joint Typhoon Weather Center (JTWC), along with many international centers – to deliver state-of-the-art, satellite-based tools and research directed toward applications to help monitor tropical cyclones.

The majority of tropical cyclone warning centers around the world rely on satellite-derived information to determine the position, intensity, and structure of tropical cyclones. The analysis aids developed by the CIMSS team are now almost universally applied at these centers.

For example, a CIMSS product or analysis (on shear measurements, thermal profiles, estimates of intensity) has been cited in nearly 60% of NHC Forecast Discussions since 2004, indicating the "robustness and growing impact on operations," notes Robert Hart, professor of meteorology at Florida State University.

"When considering that NHC forecasters typically have precious few minutes to examine data during a forecast cycle, these dominant statistics alone warrant an AMS Special Award," writes Hart in his nomination letter. "It is impossible to imagine the global tropical cyclone forecast process today without CIMSS research and associated operational products."

▲ CIMSS Tropical Cyclones Group. From left: Christopher Velden, Derrick Herndon, Steven Wanzong, Sarah Griffin, David Stettner, Timothy Olander. Credit: Sarah Witman. From upper right: Jason Dunion, Anthony Wimmers, John Sears.

Beyond research and development, the CIMSS Tropical Cyclones website has provided real-time satellite imagery during each hurricane season since 1994, and was the first to do so. This year the website is celebrating its 20th year of expanded service to the weather community and to the public.

Hurricane Sandy and Typhoon Haiyan were recent stark reminders of the need and societal benefit of the satellite imagery and derived products provided on the website. These two storms alone exceeded 4 million hits to the site per day, bringing with them countless media and public requests for information and graphics.

"Our outreach extends beyond the tropical cyclone forecast centers, to the research community and curious public," notes Velden. "We are honored to receive this award, knowing that we are contributing important information to our understanding of the global threat of tropical cyclones." ■

GOES-R ABI: Research to operations at its best

by Jean Phillips

During the summer of 2013, scientists at the UW-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) submitted several special requests to the National Oceanic and Atmospheric Administration (NOAA) to shift GOES-14 from its back-up mode to its experimental super rapid scan operations (SRSO-R) mode.

One of those requests occurred on August 21, on the heels of a NOAA Storm Prediction Center forecast that highlighted the potential for severe thunderstorms across the upper Mississippi Valley and the upper Great Lakes regions.

Having seen the forecast, GOES expert Tim Schmit, a NOAA Advanced Satellite Products Branch (ASPB) scientist working at CIMSS, anticipated a fast-moving cold front across Wisconsin.

As expected, the front triggered severe and rapidly evolving convection in the upper Midwest, providing a perfect opportunity to compare the routine scanning of operational satellites: relating GOES-13's 15-30-minute image refresh rate to the special rapid scan, one-minute imaging of GOES-14.

According to Schmit, one of the most exciting aspects of the newest geostationary weather satellite, GOES-R – set for launch in early 2016 – is the improved rapid scan imaging capability, particularly in the mesoscale, convective environment. It will be a standard option on GOES-R, delivered via the Advanced Baseline Imager (ABI), the satellite's primary instrument.

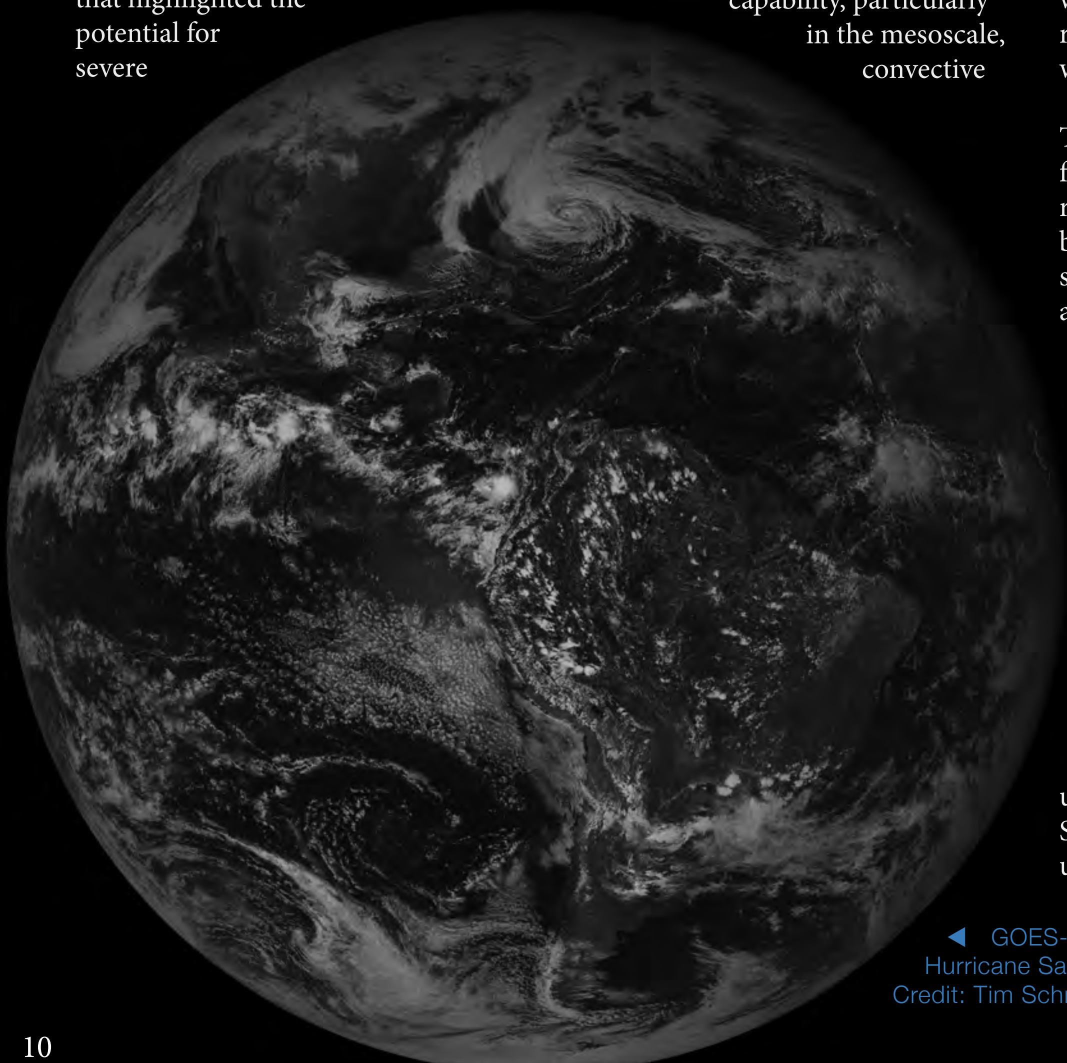
The ABI on GOES-R will provide enhanced and detailed imaging of Earth's weather and environment on an unprecedented scale.

"We'll be able to scan the continental United States (CONUS) every five minutes, but then also move to the mesoscale, where convection may be occurring, and get one-minute imagery with the rapid scan option," explains Schmit. "And, we'll still be able to capture full disk imagery of the hemisphere – all of this can happen nearly simultaneously because the scans are 'interwoven' in time. We can't do this with the current GOES satellites."

In contrast to the less frequent imagery of today, these rapid scan images will quickly prove their utility to researchers and forecasters dealing with weather events on the local scale.

The dramatic improvements in frequency, and spatial and spectral resolutions, will allow scientists to better predict the behavior of severe storms by combining satellite imagery and quantitative products with other technologies, such as radar, thereby increasing the accuracy of convective event forecasting.

With better satellite imagery, scientists can, for example, evaluate five-minute, ground-based radar alongside one-minute, satellite imagery in emerging convective environments. The satellite perspective can see rapidly cooling and expanding clouds, overshooting tops, and the development of rapid updrafts: Using the two tools together, Schmit explains, will increase our understanding and our ability to track



◀ GOES-13 Imager full disk visible image of Hurricane Sandy on 28 October 2012 at 18 UTC. Credit: Tim Schmit, NOAA ASPB.

storms with much more accuracy.

In the case of the August 2013 convection, notes Schmit, "We were able to see things with a much greater lead time." An image-refresh rate of 15-30 minutes is too long when time is of the essence, weather conditions are quickly changing, and forecasters need to alert the public to potentially dangerous conditions.

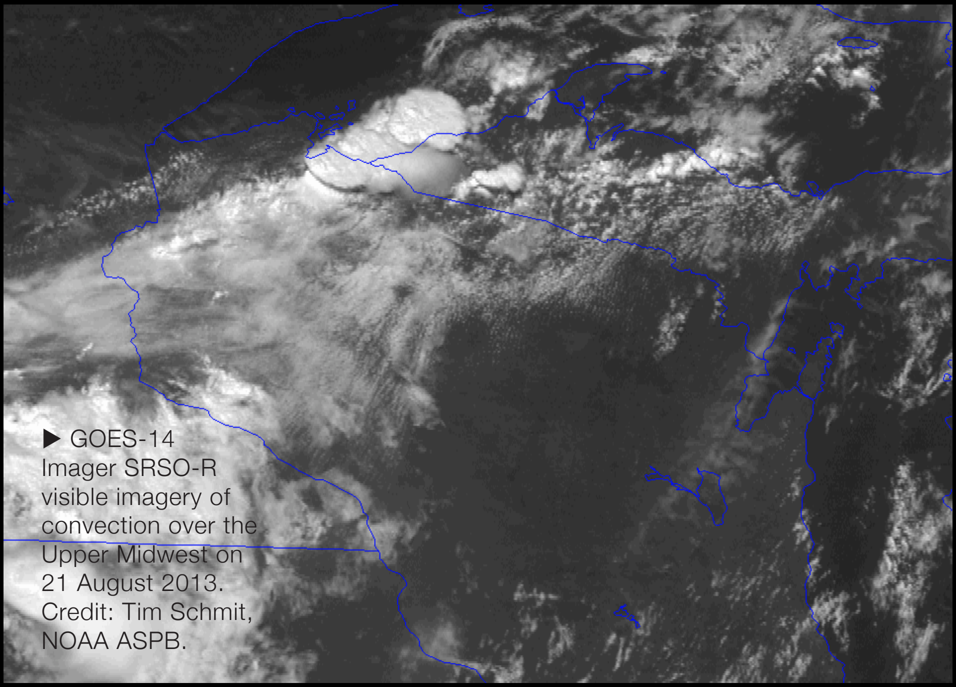
The ABI, developed collaboratively over the last decade by university researchers at institutes such as CIMSS, with NOAA and NASA scientists along with private industry partners, will include 16 spectral bands that will capture more data at different frequencies across the electromagnetic spectrum. In comparison, the current GOES imager has only five spectral bands.

Scientists have had just a taste of the SRSO-R capabilities because the current GOES satellite is acting as a proxy for the future ABI. The actual imager promises to be even better.

The anticipated imaging capabilities of GOES-R are exciting to CIMSS scientists because of the expected improvements in different areas of environmental remote sensing — for early detection of smoke plumes from fires and biomass burning; fast and continuous monitoring of hurricane intensification, as in the case of Hurricane Sandy; and monitoring the interactions between phenomena such as smoke, clouds, and precipitation, to name a few.

Another important instrument to be included on GOES-R is the Geostationary Lightning Mapper (GLM). The GLM will provide coverage of all lightning activity – cloud-to-ground as well as cloud-to-cloud.

Scientists have documented that rapid changes in lightning activity often accompany thunderstorms



▶ GOES-14 Imager SRSO-R visible imagery of convection over the Upper Midwest on 21 August 2013. Credit: Tim Schmit, NOAA ASPB.

and hurricanes. Adding the new GLM measurements to existing measurements will improve thunderstorm and tornado forecasts and warnings.

Looking beyond the regular scans of CONUS, Schmit says that with ABI-like imagers on the recently launched Japanese Himawari satellite and those slated for inclusion on the next Korean KOMSAT and European geostationary satellites, we will have the potential to piece together some current gaps in coverage: creating a better view of developing weather over most of the globe.

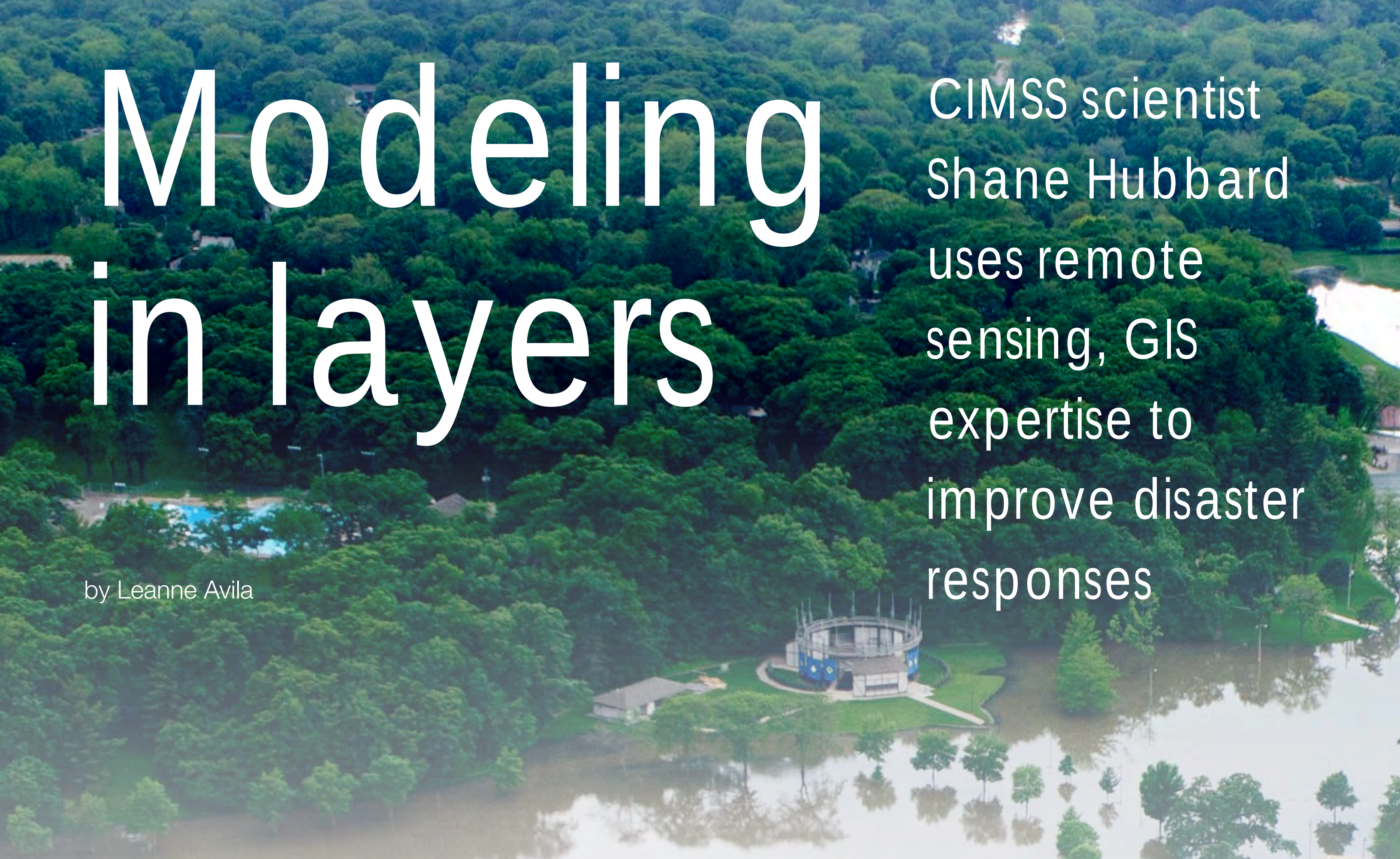
Schmit is certain that the success of the GOES-R mission, as with those that came before it, hinges on the pivotal, well-established, research-to-operations partnerships. "We have university researchers working independently and in collaboration with federal scientists to conduct the basic and applied research, and contribute the ideas," he says. "We have private industry to build the instruments, and we have government partners to provide oversight."

The ProbSevere model (see page 16), a recently developed product, is another important example of this cooperation at its best – NOAA and CIMSS scientists working with operational forecasters to perfect a new tool to predict the probability of severe weather occurring in the near-term. Forecasters provide direct feedback about overlays and desired features, which in turn are incorporated by researchers.

As a measure of the importance of the partnership, nearly all of the operational products on the current GOES series were developed at CIMSS or include significant contributions by CIMSS and/or NOAA ASPB scientists. In addition, nearly half of the expected ABI operational products on GOES-R have been developed by CIMSS scientists, frequently in collaboration with ASPB scientists.

NASA and NOAA estimate that economic benefits from the ABI, across its lifetime, will reach at least $4.6 billion, touching all those who are affected by hurricanes, tornadic storms, fires, and floods.

Adds Schmit, "We don't know all the things that we'll be able to do with the next generation satellites, instruments, and data, but this is an important time for forecasting that will provide many societal benefits." ■



Modeling in layers

CIMSS scientist Shane Hubbard uses remote sensing, GIS expertise to improve disaster responses

by Leanne Avila

Water is a vital resource, one that requires careful monitoring. Some areas do not have enough – California experienced a major drought in 2014 – while other areas receive too much – Buffalo, NY, was blanketed by a major snowstorm in November 2014. The storm resulted in deaths and structural damage as roofs collapsed, followed by concerns about flooding as temperatures quickly rose in the days afterward.

Whether it is one extreme or the other, getting information about water issues to emergency managers and other decision-makers is critical. What impact will the potential water shortage or flooding have on their community, and how significant will it be? What actions can they take to alleviate the problem?

Shane Hubbard of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) has been working to better connect the institute's remote sensing research and his own expertise in geographic information science (GIS) with groups interested in monitoring water issues, from local and state emergency management groups to the United States Geological Survey (USGS) and the Federal Emergency Management Agency (FEMA).

While hired by CIMSS in 2013, Hubbard brings with him years of experience collaborating with these groups, particularly the USGS and FEMA. His work straddles the research and real worlds, as he looks not only to study ways to better predict hazards, but also to help emergency managers as they plan and manage their responses.

"I have a research side of my life and a support side of my life. I'm trying to do both, integrating my research into real-world applications," he said.

Hubbard is working with the USGS on a number of different fronts, exploring ways to help them monitor water across the US. He noted their interest in using remote sensing to make observations of inland water temperatures, a significant input to their modeling work. The USGS could also use remote sensing data to better detect algal blooms, such as the one in Toledo this past summer.

"We've had a history of being able to do some identification and detection" of algal blooms, Hubbard said of the success of CIMSS and the Space Science and Engineering Center (SSEC) in this area.

Hubbard has also helped to connect other CIMSS scientists with the USGS. He mentioned using brownbag seminars at the USGS as a way to introduce their research – Christine Molling has presented on modeling agricultural runoff and Jason Otkin has presented on a flash drought index. Hubbard is hopeful these connections will lead to collaborative research.

Meanwhile, Hubbard is pursuing another, much larger-scale, collaboration with the USGS through the National Water Center (NWC), based at the University of Alabama. The NWC brings together a number of federal agencies, including the National Weather Service and the USGS, to examine all water

Background image: Severe flooding in Iowa in June 2013. Credit: Aneta Goska, Iowa Flood Center.

issues, from shortages to excesses, around the country. He anticipates the opportunity to leverage SSEC resources to help the NWC with modeling.

"We have a variety of experts in the building that can provide assistance in many areas of the NWC's mission: specifically, in the Data Center and supercomputing," Hubbard said.

Add to that Hubbard's experience with risk identification: experience that , in part, comes from years of working with state, local, and federal emergency management. Hubbard's links to state emergency management (Wisconsin Emergency Management) date back to his time as a master's student in the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin-Madison when he worked as a hazard mitigation planner.

"I have been supporting emergency management ever since," he said.

Since 2004 Hubbard has been involved with FEMA's HAZUS-MH software program. He has served as a beta tester, collaborated on writing the course curriculum with Kevin Mickey of the Polis Center at Indiana University-Purdue University Indianapolis, and taught HAZUS-MH to others out in the field as well as at FEMA's training facilities.

Hubbard described HAZUS-MH as a "damage and loss estimation software for hurricanes, floods, and earthquakes." Users input information about people and buildings and select the hazard they wish to simulate. HAZUS-MH outputs the damages and losses based on the chosen scenario. That information can then be used to identify risks and create plans to mitigate them.

While HAZUS-MH was developed as a mitigation tool, Hubbard began using it as a prediction tool in 2008. In the presence of a flood forecast, he would use the software as much as 10 days out to develop damage and loss estimates.

"It really helps give perspective to emergency managers and decision makers. It helps you identify who needs to be evacuated, because you're identifying the buildings that are in the floodplain. But it also gives a perspective on the magnitude of the event, the potential impacts of the event, and what the long-term recovery will look like," he said.

And the economic impact of lost businesses can be significant. Hubbard said that five or six businesses were unable to recover from the 2008 floods in Iowa City, IA, while others that were eventually able to relocate took months to reopen.

Hubbard's expertise has led him to work with Sandia National Labs. He helped them integrate HAZUS-MH into a tool they are developing for state and federal emergency management to run simulations. The simulations help managers to evaluate their preparations for various disaster scenarios.

Furthermore, based on his experience with HAZUS-MH, Hubbard is working with CIMSS' Tommy Jasmin to develop a tornado model. Similar to HAZUS, this model estimates

▸▸ *continued from page 13*

damage and losses based on a tornado path provided by the user. Hubbard explained that this model has been used in national-level exercises in Washington D.C.

Closer to home, Hubbard has been meeting with Johnson County (Iowa) Emergency Management to discuss building a model similar to one he helped create when he was a Ph.D. student at the University of Iowa. At that time he was tasked with modeling how to evacuate building contents during a flood. Now, Johnson County is focused on evacuating people – and not just who, but where and when.

As Hubbard explained, emergency management now wants to answer the question: "What's the spatiotemporal evolution of future evacuations?"

Hubbard described the need for emergency managers to know whether, and when, to close roads and bridges, or to respond with floodgates, sandbags, and pumps. Numerous pieces need to come together at the right time to construct an effective response.

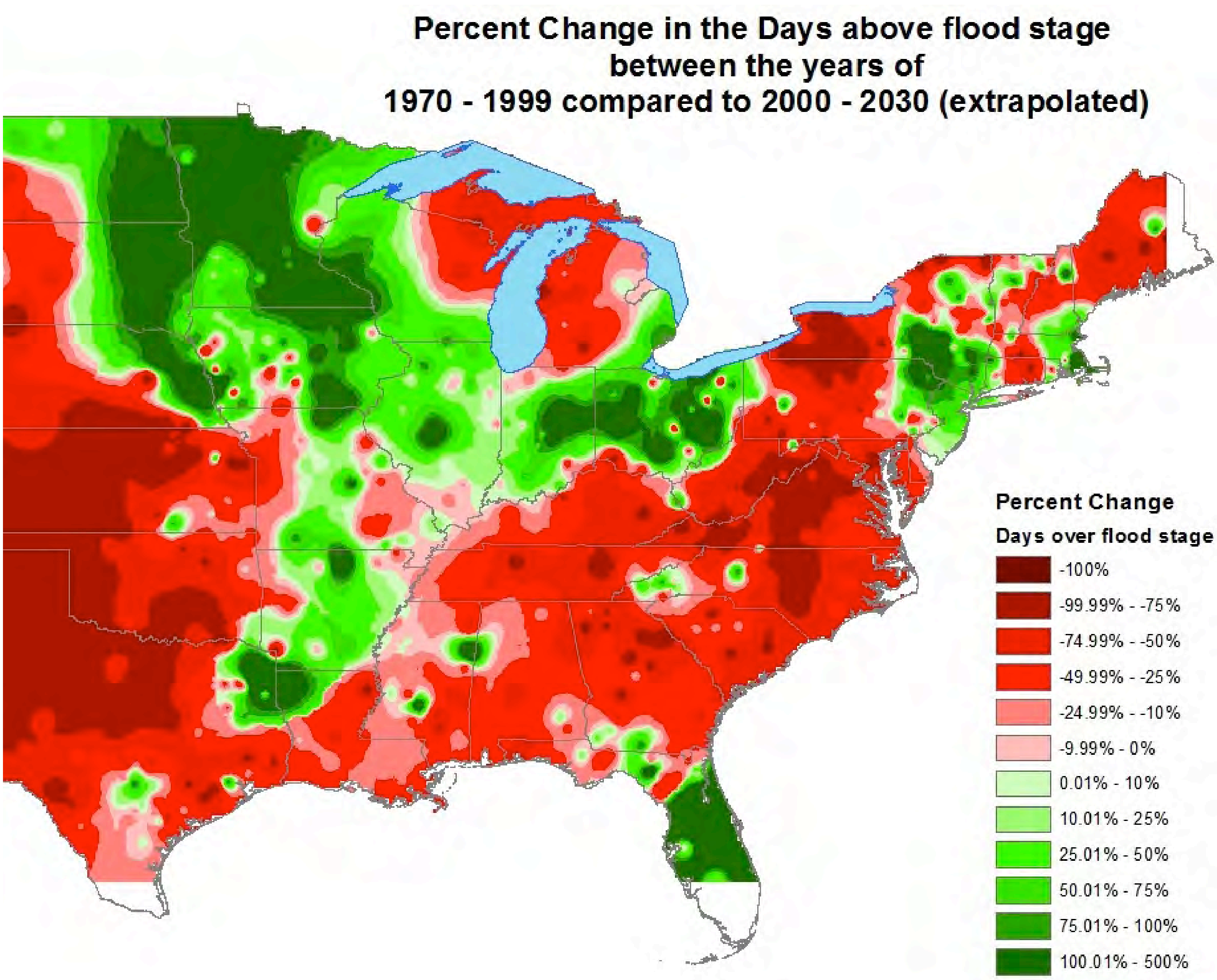
"[We are] trying to take the guesswork out of emergency response," he said. "And where it's not guesswork, where information is understood, [we are] trying to integrate this better into one place."

While some of the collaborations Hubbard has fostered for CIMSS might be new, using GIS in the institute's research is not as new as one might think.

"We've been doing GIS in this building, some of the same spatial concepts. It's just not called GIS," he said.

Layering brightness temperatures and doing comparisons is but one small example of these concepts at work, Hubbard noted, adding that

▼ This figure represents the percentage change in the number of days over flood stage from two 30-year time periods (1970-1999 versus 2000-2029). Future values are extrapolated from the 2000-2014 trend. This analysis includes 800 U.S. Geological Survey streamgage locations. Areas in red depict the decrease in the average number of days above flood stage, while areas in green depict an average increase in the days above flood stage. Credit: USGS.



▲ A screenshot from the spatiotemporal tornado-damage and loss-risk model that Shane Hubbard and Tommy Jasmin are developing. Credit: Shane Hubbard, CIMSS.

GIS analysis methods, such as spatial autocorrelation, could prove useful as another way to examine remote sensing data.

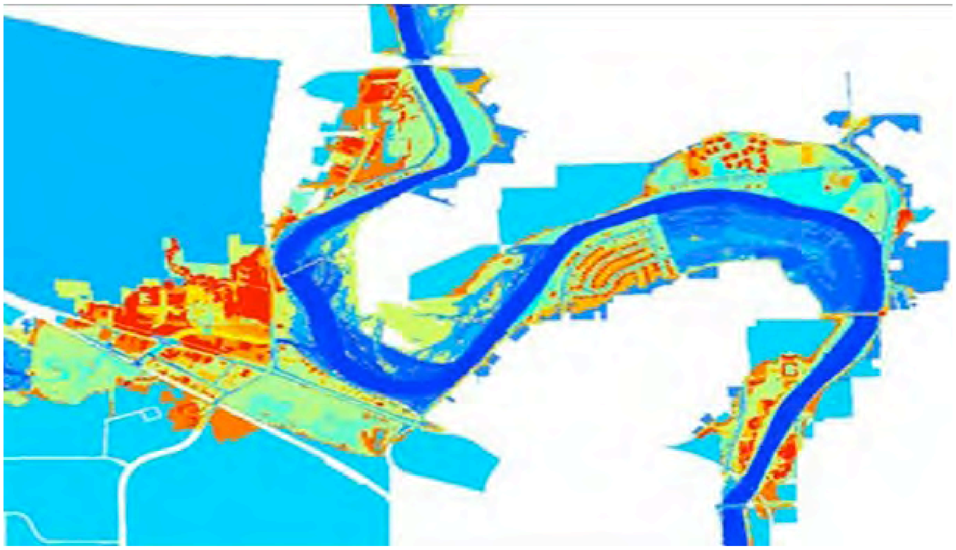
In addition to creating external collaborations, Hubbard has been working on a number of internal projects. Mike Pavolonis, a member of the local National Oceanic and Atmospheric Administration's Advanced Satellite Products Branch (NOAA ASPB), was eager to have Hubbard's input on improving his fog detection algorithm, specifically with regard to valley fog. CIMSS's Corey Calvert has been developing the algorithm, and the updated algorithm is "showing promise," said Hubbard.

"It's a really neat example of how my world and what we do in the Center, mostly atmospheric remote sensing, [intersect]. But there is really a connection between many of the things that can be going on in the atmosphere with things that are happening on the land. And we can use GIS to do some of that analysis," Hubbard said.

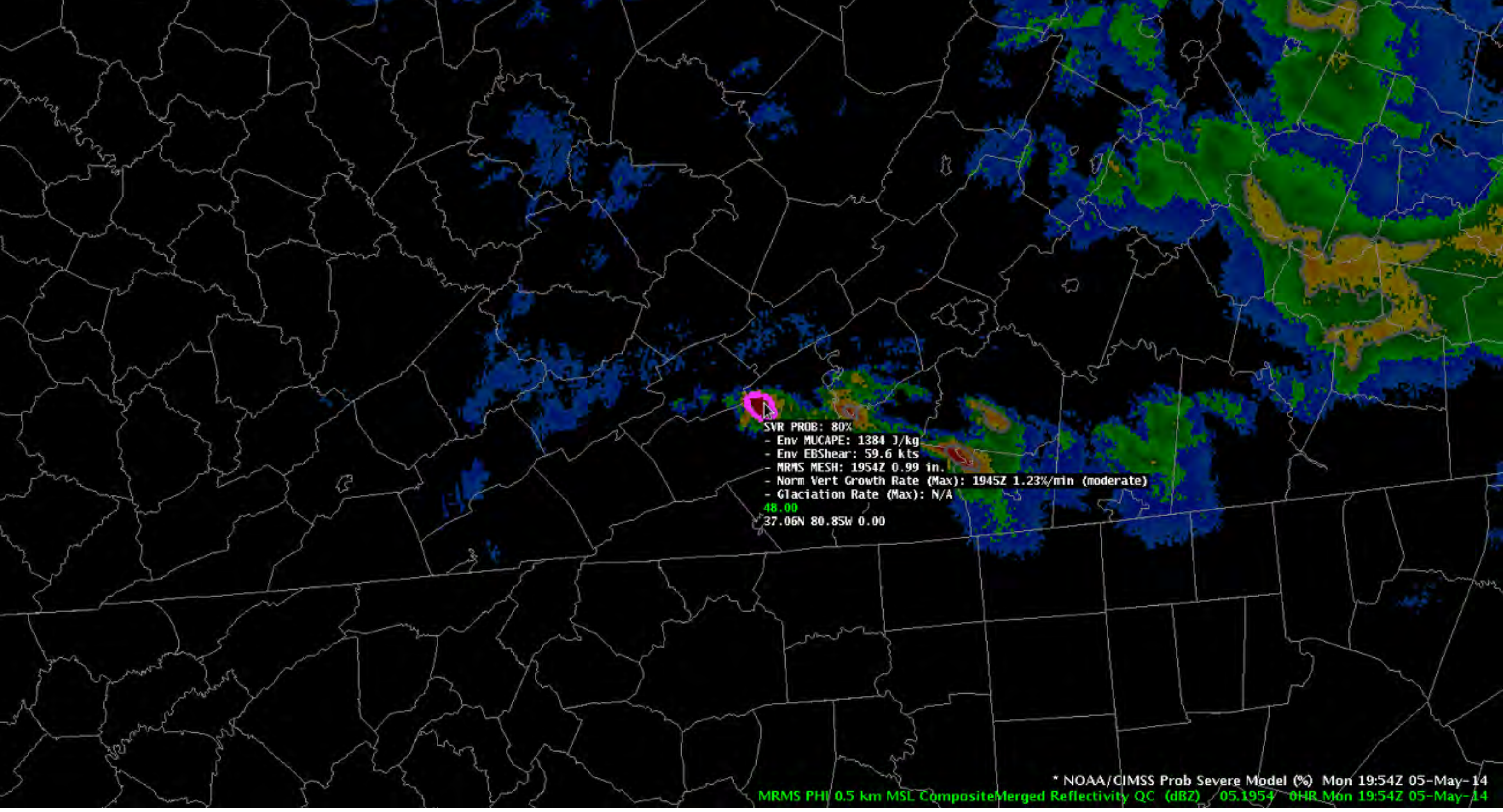
Looking back on his years of work, Hubbard noted that he has been involved in six flood responses, a tornado response, and two hurricane responses. Through those experiences, he has gained first-hand knowledge of the pressures facing emergency managers and their need for information.

"It's funny… I started off in mitigation, and I'm getting further and further away from that," he said. "There's just been this real need for spatiotemporal information during a disaster response."

Hubbard's response has been to dive into the work, creating successful collaborations that match the experts and data providers with the end users. ■



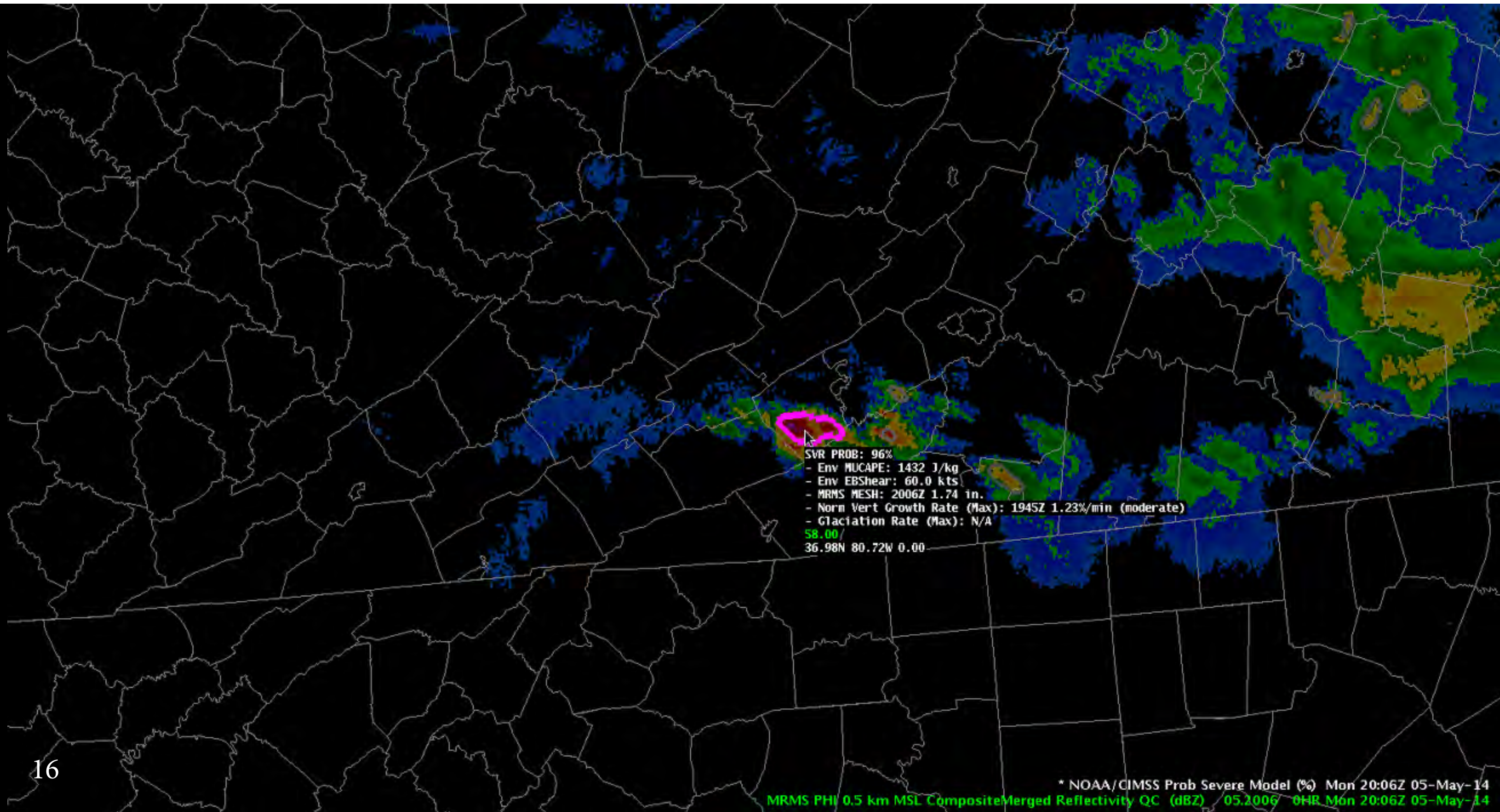
▲ A geospatial representation of flood-response event risk based upon decision-makers' priorities during flooding. Warmer colors represent higher risk values, and cooler colors represent lower risk values. Credit: Shane Hubbard, CIMSS.



ProbSevere shows promise

NOAA, CIMSS real-time statistical severe weather model highly regarded in test-runs over past year

by Sarah Witman



Scientists from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and the National Oceanic and Atmospheric Administration (NOAA) have developed a promising new storm-prediction model that would provide a supplement to radar, historically the most widespread and effective weather-monitoring tool for mesoscale disturbances since World War II. ProbSevere, a real-time statistical model, calculates the likelihood that a developing storm will first produce severe weather in the next 60 minutes.

"Nature, and weather, are chaotic," said CIMSS scientist John Cintineo, lead author on the ProbSevere paper published in Weather and Forecasting in 2014.

Severe thunderstorms — those that produce hail, strong winds, and even tornadoes — are common, but often rapidly evolving and complex, making it challenging to predict which storms will become severe. More accurate probabilities enable NOAA's National Weather Service (NWS) to issue better warnings to the public.

"Satellites have been greatly underutilized for severe weather applications," said Mike Pavolonis, a NOAA physical scientist who leads the ProbSevere research at CIMSS, and first developed the concept for a statistical model using various inputs in late 2011. "I felt that the largely unexplored combination of satellite and radar would be extremely beneficial for short-term severe weather prediction."

While weather radar functions by locating precipitation, calculating its motion, and offering some deductions about the type of weather that is present — rain, snow, or hail — ProbSevere is one step ahead, looking at the storm from multiple perspectives. It combines high-resolution numerical weather prediction data on environmental conditions from NOAA's Rapid Refresh (RAP) system, GOES satellite cloud tracking and cloud growth rates, as well as radar tracking and storm intensity data from a network of NWS radar called NEXRAD, to identify and track cloud objects.

These predictors allow ProbSevere to calculate a probabilistic "nowcast," which forecasters can analyze to determine how strong a thunderstorm might become in the next hour.

"So much of what we know about storms comes from radar. And, with radar, only when the storm has begun to produce moderate to heavy precipitation can we monitor it," said CIMSS scientist Justin Sieglaff, who works on ProbSevere.

"Knowing the history of how the storm grew, from a satellite perspective, can give us more confidence, and potentially more lead-time to predict severe weather hazards, than with radar alone," added Cintineo, whose background is in radar tracking.

CIMSS researchers tested ProbSevere all convective season in 2013-14, and its data have been used in forecasting imagery for several severe weather events, such as strong winds over Arkansas in July 2014, and a hail-producing storm in Texas in April 2014.

It has also been evaluated experimentally, in real time, at NWS weather forecast offices in Milwaukee/Sullivan, WI, as part of the GOES-R Proving Ground. The Proving Ground — a nationwide, collaborative effort between NASA, the GOES-R Program Office, NWS forecast offices, the National Center for Environmental Prediction, NOAA test-beds, and NOAA cooperative institutes, such as CIMSS — is intended to foster testing and feedback on experimental technologies that could be used in conjunction with the next-generation satellite, GOES-R, upon its launch in 2016. When GOES-R reaches orbit, ProbSevere will be one of the first physical science tools to deliver its benefits.

> *"ProbSevere was a smashing success this year; it was very encouraging and rewarding to see that kind of buzz and excitement."*
>
> *-Justin Sieglaff, CIMSS scientist*

At NOAA's Hazardous Weather Testbed (HWT) this summer, ProbSevere added at least 10 minutes of lead-time to severe weather warnings more than half of the time. The test-bed, jointly managed by NOAA's Severe Storms Laboratory, Storm Prediction Center, and Oklahoma City/Norman NWS forecast office, is an annual event in Norman, OK, bringing together scientists, engineers, and forecasters to demonstrate new technologies.

For many HWT attendees, this was their first time seeing ProbSevere in action. The team was able to get feedback directly from users on improving its capabilities. Each week, four forecasters would test ProbSevere and other products to help them make decisions in a mock severe weather warning exercise, recalled Cintineo, who was stationed at the test-bed for two weeks in May.

"It was really enjoyable to work with the forecasters, since the whole idea of the model is to make their jobs easier," he said. "Overall, there was a pretty favorable response."

In particular, he said, testers appreciated how the model tied different types of information together, and the calibration of the probabilities. For instance, the model's probabilities are given in the form of a percent — a

◀ ProbSevere displays during a demonstration to National Weather Service forecasters on 5 May 2014 at the Hazardous Weather Testbed. Top: At 1954 UTC, the model showed a probability of more than 80% for a thunderstorm in Virginia. Bottom: At 2006 UTC, the model exceeds 90% probability. The NWS office in Blacksburg, VA issued a severe storm warning at 1952 UTC, and the storm went on to produce one inch of severe hail at 2009 UTC. Credit: NOAA, CIMSS.

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▲ CIMSS scientist John Cintineo stands by while forecasters attending NOAA's Hazardous Weather Testbed try out the ProbSevere statistical model. The model added at least 10 minutes of lead-time to severe weather warnings more than half of the time at the test-bed this summer. Credit: James Murnan, NOAA.

straightforward way to communicate how many times out of 10 the user should expect a storm to produce severe weather.

"ProbSevere was a smashing success this year; it was very encouraging and rewarding to see that kind of buzz and excitement," Sieglaff said, adding that the GOES-R programming office named ProbSevere as one of its top five products to watch in the GOES-R era.

Others at the HWT noted the usability of the display interface, Cintineo said. ProbSevere shows the location of an individual storm in a series of images, allowing the user to follow its movement and monitor a variety of properties, which Sieglaff said is an ideal way to track clouds and cloud objects, especially in real-time displays such as the NWS' AWIPS-II.

As satellite observations are updated more frequently, and at higher resolutions, displaying gigabytes upon gigabytes of data in a manageable, user-friendly framework becomes increasingly important, explained Sieglaff.

"The way that science is going, it is impossible for one person to look at this deluge of data, so with ProbSevere we strived to distill a lot of that information into one probability," he said, adding that the team even modeled the aesthetics of ProbSevere after the radar displays that forecasters look at during severe weather, making the user experience more familiar to them.

While this was Cintineo's first time at the HWT, Sieglaff has made the journey the past five years, previously to present the Cloud Top Cooling (CTC) storm prediction algorithm developed at CIMSS and now for ProbSevere. Approaching deep convection somewhat differently, CTC uses frequent infrared GOES satellite observations to monitor cooling, and to determine the vertical growth rate of developing convective clouds, which, rife with water droplets and ice, are optimal for producing storms large and small. The product remains in use at CIMSS, and, in February, Sieglaff and fellow CIMSS scientists Lee Cronce and Wayne Feltz reported seeing significant improvement by incorporating GOES visible optical depth retrievals into the algorithm.

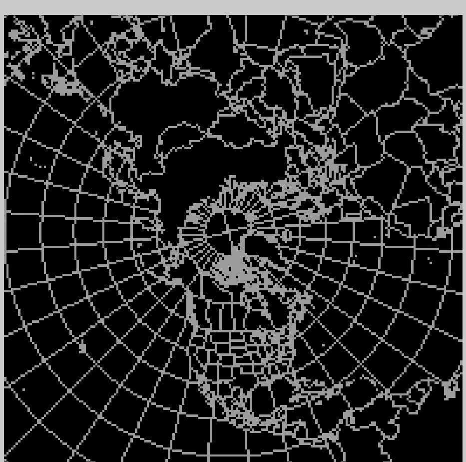
Sieglaff says years of validating the CTC algorithm, learning and getting feedback on object tracking, played a major role in preparing him for ProbSevere's first run. Both technologies benefit from the high temporal resolution offered by geostationary satellites, which, Sieglaff says, has so far been largely underutilized for weather forecasting purposes.

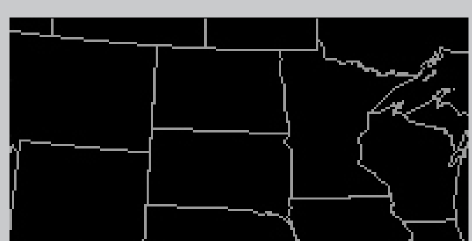
"Thunderstorms develop quickly, so you need something that observes on that time-scale, which satellites do, and future satellites, like GOES-R, will do even better," Sieglaff said.

"The ability of ProbSevere to rapidly update as new satellite and radar data come in is a huge advantage," Pavolonis added.

Of any product Sieglaff has demonstrated at the HWT, he said ProbSevere has easily garnered the most traction. But there is still plenty of work to do. The team hopes to log more hours researching the model, to make it even better.

"Currently, ProbSevere is only able to predict severe weather in a general sense," said Pavolonis. "We hope to develop methods to make more specific predictions such as hail versus tornado versus wind." ■





▶ The ProbSevere display is able to show varying fields of view. Credit: NOAA, CIMSS.

Quantifying flash floods

Graduate student's water vapor research has important societal implications

by Sarah Witman

It was June 2008 when unusually heavy rains resulted in a flash flood that broke through a dam, washing out a subdivision in the small tourist community of Lake Delton, Wisconsin.

According to the Midwestern Regional Climate Center, the average precipitation during the two weeks bookending the flood was more than five times the normal amount for the area, allowing widespread flooding to develop.

And, flood probabilities estimated from various local U.S. Geological Survey streamgages across southern Wisconsin ranged from .2 to .002, corresponding to 5-year to 500-year flooding events.

It's been more than six years, but in some ways the area is still recovering. As recently as April 2014, the Milwaukee Journal Sentinel reported, courts overturned a homeowner's lawsuit against the Village of Lake Delton for damages sustained in the flood.

Enter Jacola Roman, who has been interested in studying severe flash floods since she began working with Space Science and Engineering Center (SSEC) scientist Bob Knuteson as an undergraduate student, and is now continuing her work at SSEC with Knuteson as an atmospheric and oceanic sciences graduate student. Roman is well on her way to developing a highly accurate model that could be used for predicting large flooding events like the one that struck southern Wisconsin, allowing cities to better prepare for damages, injuries, and the socioeconomic costs they bring.

Anticipating these events becomes ever more important as changes in climate are expected to bring more frequent flooding, especially in the tropics, some areas of which are already economically vulnerable. Roman recognizes the need for quantitative, satellite data-based modeling of these events looking decades into the future, and, under the mentorship of Knuteson, she has investigated methods to do just that: Earlier this year, Roman was lead author on a paper published in the *Journal of Climate* called "Time-To-Detect Trends in Precipitable Water Vapor with Varying Measurement Error."

Precipitable water vapor, the total depth of water in a column of the atmosphere, is the primary ingredient for heavy rains and flooding, and can be detected by satellite instrumentation on an hourly basis. Roman deals primarily with this metric, since most of the events she examines are uniquely characterized by extreme amounts of atmospheric water vapor.

"If there is enough precipitable water vapor, there is potential for convection to come in and trigger an event," she said. "With an extreme amount, it can get pretty nasty."

▲ June 2008 flooding in Lake Delton, WI. Credit: Ready Wisconsin, Wisconsin Emergency Management.

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Roman's paper incorporated data from climate models, from the CMIP3 and CMIP5 archive, to calculate the time it takes to detect a trend in precipitable water vapor. Unlike weather observing systems, which would only allow them to monitor current conditions, climate modeling systems are designed to detect trends in water vapor, temperature and other long-term factors.

In a global climate model, time-to-detect refers to the difference of two dates: the onset of a climate trend, and its actual detection by scientists. When scientists detect a trend, they will work backward to find when the trend started, at which point they are able to calculate a theoretical time value.

The study aimed to calculate the time-to-detect for 100-year trends of precipitable water vapor. Taking realistic measurement errors into consideration, Roman found that global trends ranged from 0.055 to 0.072 millimeters of precipitable water vapor per year, and varied minimally from season to season. With no measurement error, global time-to-detect was between 3 and 4.8 years.

But, a measurement error of just 5% increased the time-to-detect by nearly six times — from 17.6 years to 22 years — illustrating the importance of accurate measurements.

This finding also made Roman look more closely: If measurement error was affecting the time-to-detect more negatively on a global scale, maybe she should be focusing on what the zonal trends were telling her (defining zones as areas of 15 degrees latitude by 360 degrees longitude, and regions as 15 degrees latitude by 30 degrees longitude). She saw that zonal trends were highest near the equator, and that latitude had little impact on zonal time-to-detect when 5% measurement error was included. Zonal time-to-detect results were also significantly reduced, or better, when the trends were analyzed by season.

"With time-to-detect, you see bigger differences when you look very locally," she said.

This close-up view is familiar to Roman: Zeroing in on specific regions and cities affected by flooding has become a hallmark of her work. Ever since a flood struck her home state of Minnesota in 2012, in Duluth, she has closely followed extreme flash flooding events in the news and on social media.

Roman is also a prime example of how, by bringing together bright individuals from different disciplines, universities and university-based research centers such as SSEC often spark interdisciplinary innovation. Said Knuteson, a roommate studying infectious disease in India at UW-Madison inspired Roman to research water-borne illness from flooding events extensively, one of many threads running through her body of work.

"I feel that Jacola is giving an important 'heads up' to the science community that the implications of climate change are even worse than was previously thought..."

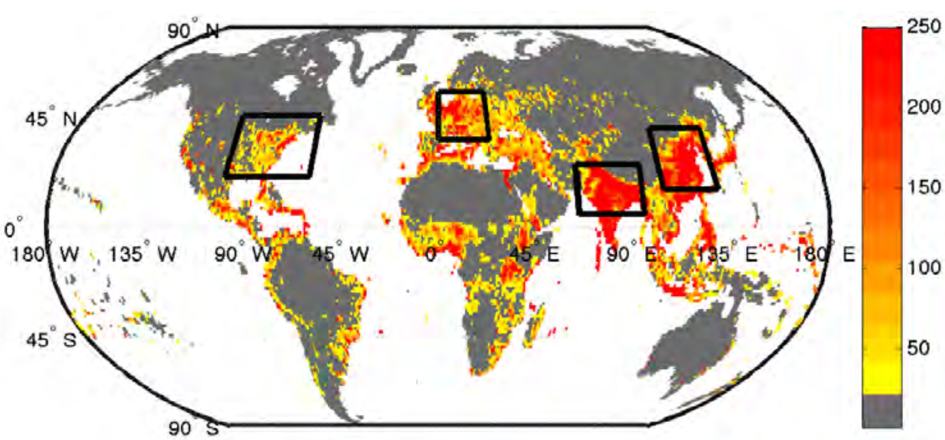
-Bob Knuteson, SSEC scientist

"When you have a lot of rain falling very quickly, that can affect agriculture, infrastructure, and lead to a variety of public health problems," she said.

Knuteson described their approach to the research as an arc — building a bridge, block by block, that starts with water vapor and ends with its impact on people. Other than getting the data, developing that multi-step relationship was the most time-consuming aspect of the study, Roman added.

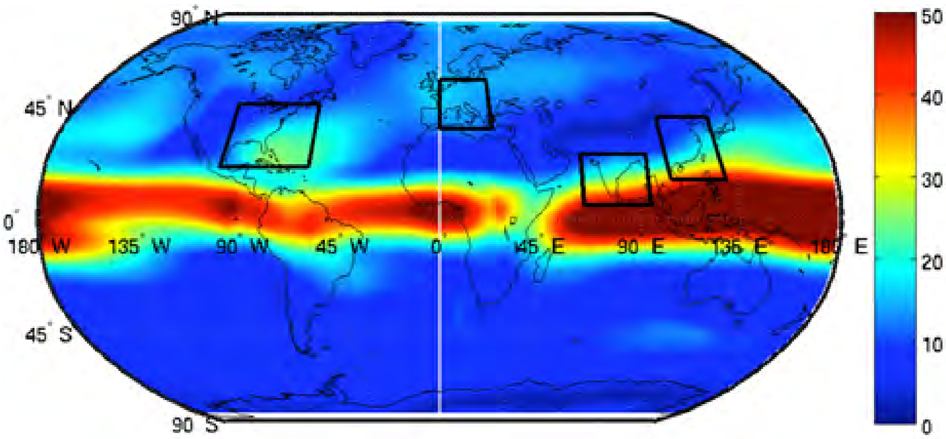
"There needs to be a series of connections," Knuteson said. "Jacola looked into past studies, and those connections had not really been made yet. But, there is a community that's studying each little piece."

For her paper, Roman chose four regions with high population densities to use as case studies — China, India, central Europe, and the eastern U.S. — focusing on areas where large populations would be affected in the event of a flash flood. These case study regions showed that analyzing trends on a regional, spatial scale, rather than global or zonal, might be the key to providing timely environmental information on highly populated regions.



▲ This figure, from Roman's 2014 Journal of Climate paper, shows the population density (population per square kilometers) for 2015, with regional boundaries. She chose to focus on regions with dense populations because of their potential for severe societal impacts. Credit: Jacola Roman.

▼ A figure from Roman's companion paper, showing changes in frequency of flooding events over a number of years. Credit: Jacola Roman.



Roman gave a presentation on these findings, as well as the results of a companion paper currently under review in the *Journal of Climate*, "Predicted Changes in the Frequency of Extreme Precipitable Water Vapor Events," in Berlin, Germany, in mid-October at the World Climate Research Program Global Vapor Experiment (GVAP). She addressed climate researchers from around the world, recommending measurements and sampling that, in the experience of she and her co-authors, have provided the best results for satellite remote sensing of precipitable water vapor.

Rather than mean trends, the companion paper covers trends in the frequency of extreme water vapor events. Specifically, this paper predicts that extreme water vapor events around the globe will increase in frequency in the next 100 years, likely between 2013 and 2087. On a regional, seasonal scale, the increase is shown to be even more drastic, becoming about 48 times as frequent.

Hearkening back to the Lake Delton incident in Wisconsin, Knuteson explained that while a "truly destructive storm" like that may currently happen only once every 100 years, years from now, according to their model, that breed of storm could happen every decade.

"I feel that Jacola is giving an important 'heads up' to the science community that the implications of climate change are even worse than was previously thought, and that our society needs to prepare for the worst," Knuteson said. "In every part of the world, infrastructure has always been based on climatology of the past. But, with this change, there needs to be some warning time so we can prepare."

Going forward, Roman will continue to investigate particular types of floods individually, such as how often the top 1% of events occurs. She is interested in one day creating a computer model that she could run for any region of the world, inputting known factors such as precipitation and watersheds, which would then predict the economic and environmental effects of flooding.

"We need to know, very specifically, how climate change will affect places," Knuteson said.

"If we can relate the frequency of these water vapor events back to flooding events," Roman added, "people can start preparing for future economic costs of flooding. We have had a number of events this year, even just in the U.S."

Roman's time-to-detect paper was co-authored with Knuteson and Steve Ackerman, director for the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at SSEC. Knuteson, Ackerman, and SSEC director Hank Revercomb also contributed to the companion paper. ■

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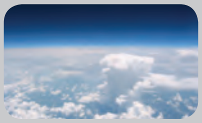
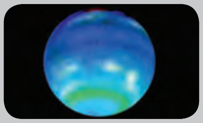

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