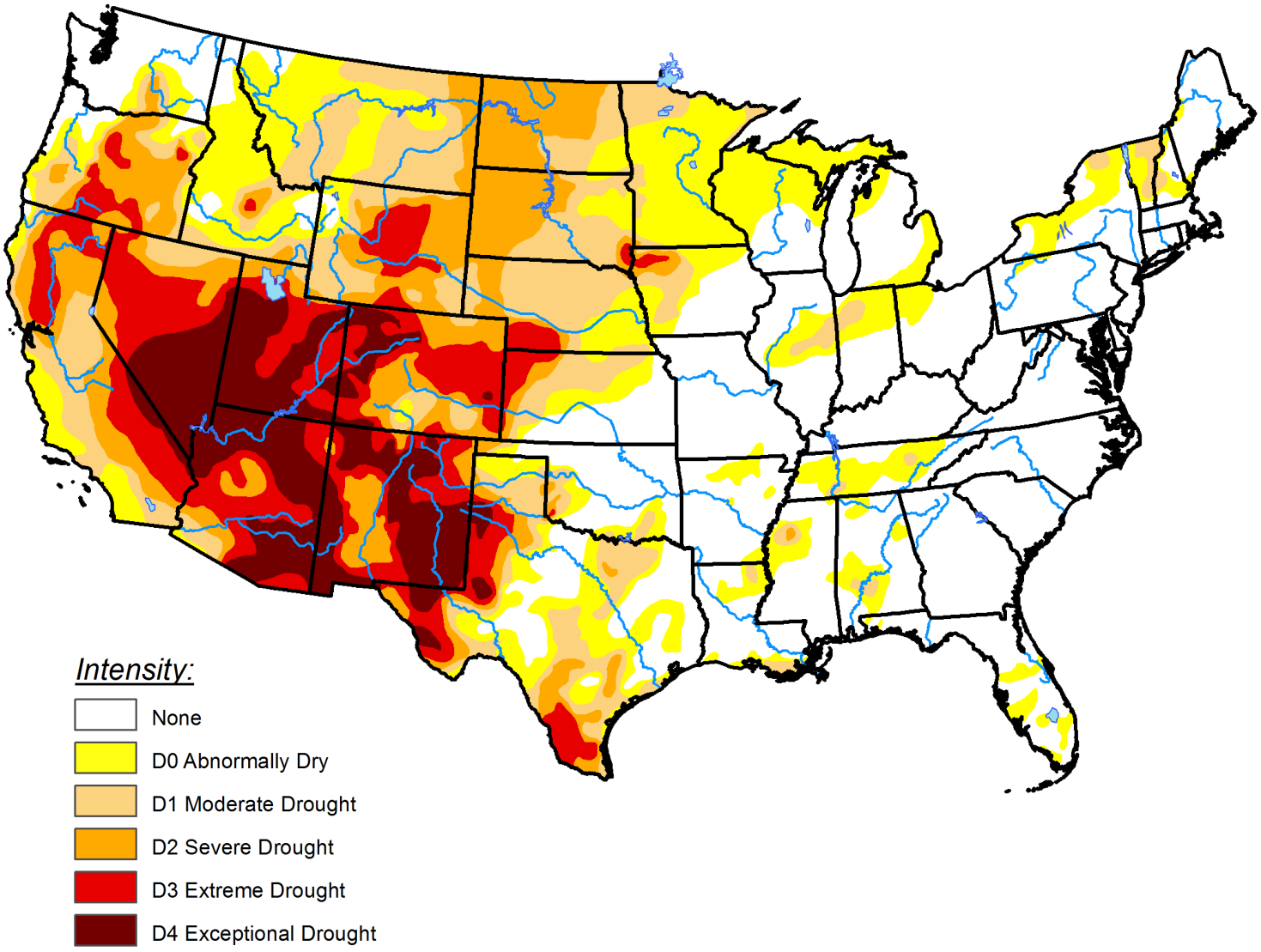
TRENDS

April 2021

Inspire. Advance. Engage.



Advancing Global-Scale Drought Monitoring

The North Carolina Climate Science Report

Responding to COVID-19

Climate Change Webinar Series

North Carolina Institute for Climate Studies

NC STATE UNIVERSITY

TRENDS

April 2021

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Contents

ON THE COVER

The U.S. Drought Monitor map for February 16, 2021. The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center (NDMC) at the University of Nebraska–Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC.

PRODUCTION TEAM

Tom Maycock – lead writer/editor
Andrea McCarrick – writer/editor
Jessicca Allen – graphic design

Who We Are

Hosted by North Carolina State University, the North Carolina Institute for Climate Studies (NCICS) is a unique center of excellence showcasing a partnership between universities, the private sector, nonprofit organizations, community groups, and the federal government.

NCICS's primary activity is the operation of the North Carolina location of the Cooperative Institute for Satellite Earth System Studies (CISESS).

CISESS is a multidisciplinary team of experts who collaborate in climate and satellite research to support the research-to-operations strategy of NOAA's National Centers for Environmental Information.

Our Vision

- NCICS **inspires** cutting-edge research and collaboration.
- NCICS **advances** understanding of the current and future state of the climate.
- NCICS **engages** with business, academia, government, and the public to enhance decision-making.

Research Themes

Satellite Services

Earth System Observations and Services

Earth System Research

Task Streams

Access and Services Development

Assessments

Information Technology Services

Science and Services

Workforce Development

Consortium Projects

Note from the Director

– Otis Brown, NCICS Director
info@ncics.org

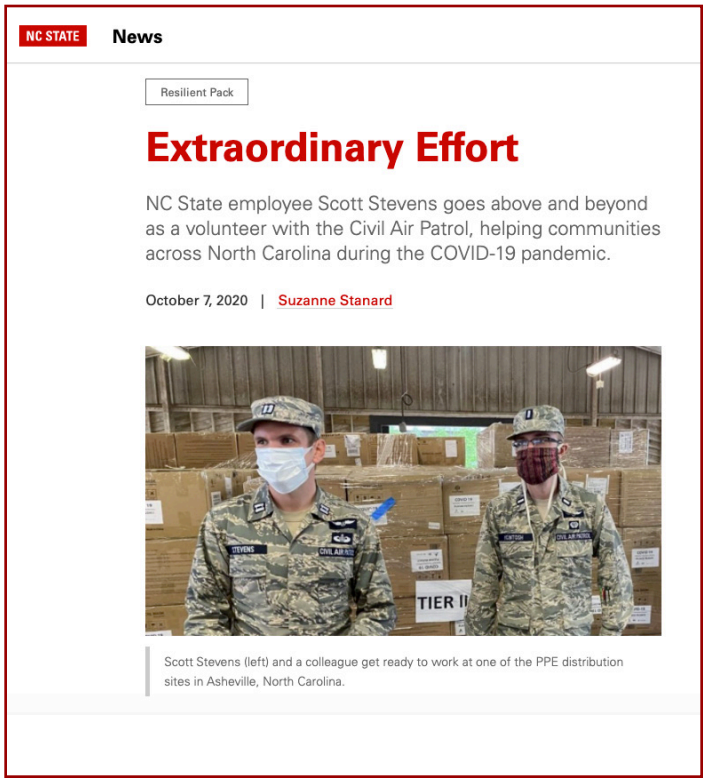
Hello from NC State in Asheville!

It's been a very busy year but not exactly how we expected it to be! The COVID-19 pandemic impacted us all, including forcing all of us into a virtual workplace with concomitant technological and work–life balance challenges. NCICS was fortunate to have systems in place prior to the pandemic to maximize productivity, including robust information technology infrastructure, flexible work schedules, and telework policies. Our most significant challenges have been in the social arena. We have instituted weekly virtual meetings of all staff, more frequent one-on-one meetings, and a variety of other opportunities to address social needs. These have helped, but the reality is that we are ready to return to the workplace and look forward to doing so.

NCICS staff have been very productive since our last newsletter. Notable outcomes are the North Carolina Climate Science Report, led by Dr. Kenneth Kunkel; more than 50 peer-reviewed publications, including one on arctic sea ice projections, which resulted in the most-visited NCEI web story of last year and an early publication on environmental influences on COVID-19 transmissibility led by Dr. Jennifer Runkle; drought monitoring and early warning research led by Dr. Olivier Prat and Ronald Leeper; new efforts in machine learning led by Drs. Douglas Rao, Bjorn Brooks, and Garrett Graham; enhancement of tropical monitoring activities led by Dr. Carl Schreck; many presentations at the American Geophysical Union and American Meteorological Society annual meetings; and support for new outreach and engagement collaborations. It has been a very productive year for NCICS.

Our congratulations to Ronald Leeper, who was given the NESDIS Outstanding Information Technology and Engineering Employee(s) of the Year award as a team member for work on the U.S. Climate Reference Network (see page 6), and to Douglas Rao on his selection as an Impact Scholar under a new program organized by NC State University's Office of Outreach and Engagement (see page 15).

Scott Stevens was also recognized by NC State's Resilient Pack program for his efforts with the Civil Air Patrol to deliver much-needed personal protective equipment across North Carolina in response to the COVID-19 pandemic. You can learn more about Scott's efforts in this NC State web story.



NC STATE News

Resilient Pack

Extraordinary Effort

NC State employee Scott Stevens goes above and beyond as a volunteer with the Civil Air Patrol, helping communities across North Carolina during the COVID-19 pandemic.

October 7, 2020 | Suzanne Stanard

Scott Stevens (left) and a colleague get ready to work at one of the PPE distribution sites in Asheville, North Carolina.

Our goal for this newsletter was to capture the highlights of this diverse portfolio of outcomes at a high level. While this newsletter provides a summary of highlights, you are encouraged to explore more deeply the cited publications, media releases, and web links.

If you have difficulty accessing content due to technological or other challenges, please let us know. This is the first issue where our goal is to deliver a publication that is fully accessible, including to those with visual impairments or other limitations. Please let us know if we succeeded.

Please provide us with your feedback on this issue. We are always interested in ways to improve our communications, and your insights can be very helpful.

Thank you.

Otis

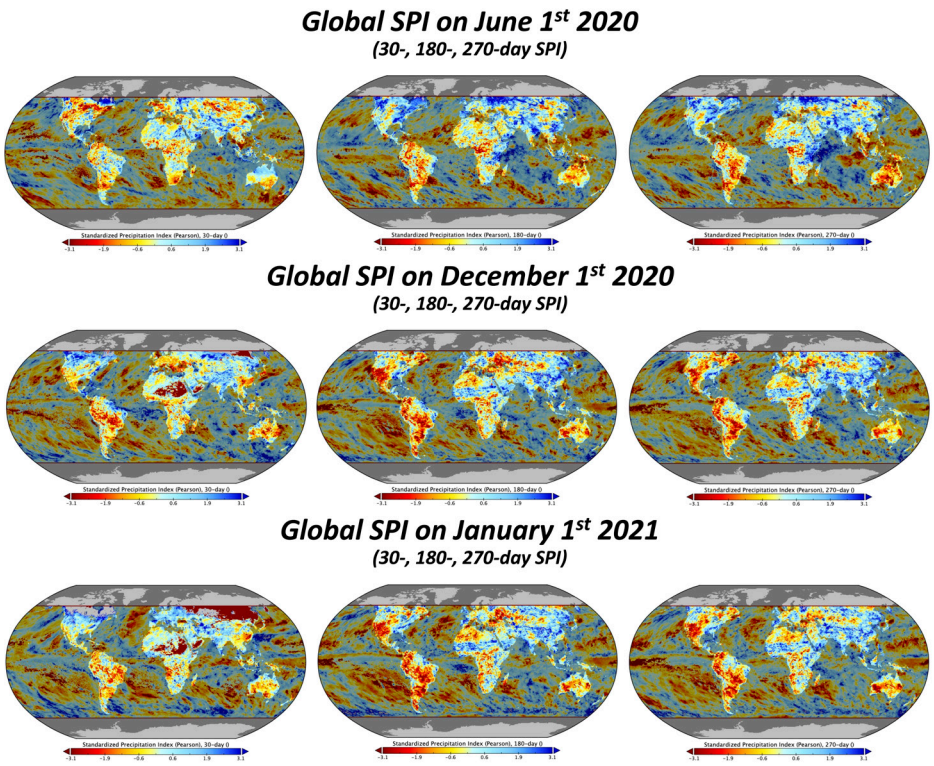
Feature: Drought Monitoring and Early Warming

Drought Monitoring

In 17 of the last 21 years, the United States has experienced droughts resulting in at least $1 billion in damages. The 2012 drought across much of the southern United States generated more than $30 billion in damages.

These events, which often evolve over weeks and months, tend to receive less attention than hurricanes, and wildfires, which happen over shorter time frames and often produce more spectacular images. However, droughts can be similarly devastating, with significant, widespread, and long-lasting impacts on human health, infrastructure, and food and water supplies.

Droughts are also difficult to predict and monitor. Different types of drought conditions can be produced by combinations of multiple factors, including the timing and amounts of precipitation, evaporation rates, and runoff. Conditions can also vary significantly over relatively small areas, even in the midst of a widespread drought.



These maps show operational global drought conditions for June 1, 2020; December 1, 2020; and January 1, 2021. The daily standardized precipitation index (SPI) is derived from CMORPH-CDR and CMORPH-ICDR and computed for 30-, 90-, 180-, 270-, 365-, and 730-day time scales. Presented here are the 30-, 180-, and 270-day global SPIs.

As a result, it is a challenge to provide early warning of emerging drought conditions, accurate information about local conditions, and indicators of improving drought conditions. Drought monitoring is particularly problematic in areas of the world that lack sufficient ground-based observations, sources of data, or the visualization tools that are needed to derive actionable information from the data that are available.

NCICS scientists are engaged in a variety of research activities aimed at addressing these problems. One recent effort applied statistical techniques to soil moisture observations from the U.S. Climate Reference Network. The goal is to develop standardized soil moisture datasets that can provide earlier information on emerging and improving drought conditions. That work earned NCICS's Ronald Leeper an award from NOAA's National Environmental Satellite, Data, and Information Service (NESDIS; see page 6, and the story in our October 2019 issue).

Leeper and NCICS's Dr. Olivier Prat are now working with colleagues from the National Centers for Environmental Information (NCEI), the U.S. Drought Monitor (USDM), and other institutions to develop a detailed climatology of drought in the United States over the past 20 years. Using the USDM drought index, they identified significant regional and seasonal differences in the frequency, severity, and length of droughts. The results should be valuable not only for decision-makers charged with planning for and responding to drought but also for the drought research community. The team expects the results to be published in a peer-reviewed journal later this year.

A hallmark of NCICS's research is developing innovative datasets and applications by leveraging expertise in both satellite-based observing systems and ground-based systems. Prat, Leeper, and NCICS's Dr. Jessica Matthews are engaged in just such a project: they are using two satellite-based climate data records, CMORPH and PERSIANN, to generate monthly and daily standardized precipitation indices (SPIs) and then comparing the results with ground-based data to evaluate the suitability of the SPIs for drought monitoring across the globe.

The CMORPH dataset is the most suitable for monitoring efforts, as it is produced daily. The PERSIANN dataset is used for longer-term analysis, since it is updated only every few months but has data back to 1983 (compared to 1998 for CMORPH). These operational SPI products will be made available to the public through an interactive dashboard, along with interactive visualization tools providing near-real-time information on drought conditions.

NCICS also supports drought work through several of its consortium partners at CISESS. For example, as part of its ongoing support for NOAA's National Integrated Drought Information System efforts, the National Environmental Modeling and Analysis Center at the University of North Carolina Asheville provided user research, user testing, and content development for the recent redesign of the drought.gov portal, which was released in January 2021.

Meanwhile, Leeper, NCICS colleague Jared Rennie, and scientists at the University of Nebraska Medical Center (UNMC) were recently awarded a NOAA grant to study ways to reduce the burden of drought on health. This work will build on an earlier CISESS project at UNMC that showed a net reduction in overall mortality during drought events but with significant racial disparities. The UNMC team also convened two state-level workshops on drought and public health.

Other projects focusing on the nexus of drought and human health are also underway: NCICS's Dr. Jennifer Runkle is facilitating access to NCEI drought data for scientists from the Centers for Disease Control and Prevention, and Runkle and Leeper recently collaborated with Dr. Maggie Sugg of Appalachian State University on a literature survey of drought impacts on society.

All of these projects reflect the importance of turning data on drought into actionable information, providing more sophisticated drought monitoring and early warning systems, and connecting users with those tools to improve drought resilience.

Drought is an international problem, so NCICS is developing new, global-scale drought-monitoring tools using a combination of satellite- and ground-based data. This photo shows arid soils in Mauritania on February 17, 2012, during a major drought event affecting the Sahel region. Photo by Oxfam International, used under a Creative Commons CC BY-NC-ND 2.0 license.

Ronnie Leeper Receives NOAA Employee Award

Ronnie Leeper

In June 2020, NCICS's Ronnie Leeper was selected as the year's NESDIS Outstanding Information Technology and Engineering Employee. The award recognized Ronnie's multiple contributions to the U.S. Climate Reference Network (USCRN), including the development of a new standardized soil moisture dataset and new quality-control software.

We asked Ronnie to tell us more about these projects, the collaborative efforts involved, and next steps:

Q: The award recognized a mix of scientific and technical/engineering work on a couple of related tasks. Can you tell us more about the projects and what challenges or gaps these projects were aimed at addressing?

The development of the standardized soil moisture dataset is part of a broader goal of mine to improve assessments of drought impacts on society. Essentially, the primary goal of this project was to improve the interoperability of soil moisture measurements by placing them into historical context. These standardized measurements (i.e., anomalies and percentiles) allow folks monitoring hydrological conditions (droughts or floods) the ability to determine how wet or dry soil moisture conditions are, in a similar way to using temperature anomalies to assess how much warmer or cooler a location is compared to normal.

Soil moisture and temperature are the only USCRN measurements where quality control currently has to be done manually. This is a very time-consuming process that involves the review of hourly observations from over 1,500 soil sensors deployed across the U.S., which is repeated monthly. From the moment a graphic is visualized to the implementation of a manual flag in the dataset could take upwards of 5 minutes. This was further complicated by the introduction of a new soil sensor the network is currently deploying. The team's effort here was to identify ways in which this process could be expedited with fewer errors while also handling the introduction of newer sensing technologies.

Q: Who else was involved with these projects?

Neither of these projects would have been possible without support from USCRN's developers Scott Embler, Nancy Casey, and, more recently, Bryan Iddings. Contributors to the standardization of USCRN's soil moisture dataset include former NCICS colleague Dr. Jesse Bell and Michael Palecki of NCEI. For improved efficiency of USCRN manual QC efforts, I should also recognize the important contribution from Devin Thomas of Riverside.

Q: What's the current status of these projects? Are they now part of production NCEI datasets?

The standardized soil moisture dataset is now available alongside other USCRN FTP (File Transfer Protocol) products in beta form, with software in place to produce and update the dataset in real time. In addition, the standardized dataset has been used to develop and evaluate a soil-moisture-based drought index, which has been captured in a scholarly journal article submitted for publication. An Alpha version of this dataset is currently available now to the public via the Cooperative Institute:

Standardized dataset URL: https://www.ncdc.noaa.gov/crn/qcdatasets.html
Alpha Drought Index Product: https://ncics.org/pub/crnDrtIndex/Alpha/

Q: What's next for you?

I continue to look for ways to improve the efficiency of network quality control of soil moisture and temperature observations, and I successfully submitted an NCEI Innovates proposal to apply machine learning techniques with the hope of automating much of this process.

COVID-19

Responding to a Global Pandemic

As a result of the COVID-19 pandemic, NCICS staff have been working remotely almost exclusively since mid-March 2020, as have most of our colleagues at NCEI. A strong team culture and robust IT and communications infrastructure were essential for making a relatively seamless transition to full-time teleworking.

The intervening months have posed various challenges, ranging from relatively minor issues, like establishing reasonably comfortable, ergonomic home offices, to more impactful issues, such as supporting children's virtual learning and maintaining physical and emotional health in the face of a deadly pandemic and social and political upheaval.

The Buncombe County COVID-19 self-checker, designed by Dr. Runkle, provided county residents with guidance and follow-up contacts and gave the county high-quality data on the prevalence of the disease in the county. The tool is available online at: https://www.buncombecounty.org/covid-19

Despite these challenges, the Institute has continued to make significant progress in all of its varied missions, including basic and applied research, support of research-to-operations efforts at NCEI, and a variety of virtual engagement and outreach activities.

We have also continued, and even expanded, our internship opportunities. Mentoring interns via Zoom is sometimes difficult, and interns are unable to benefit from the immersive experience of working on-site at NCEI. But the remote environment has allowed us to bring on interns who might not have been able to relocate to Asheville for an in-person position. NCICS scientists are also continuing to mentor NOAA Hollings Scholars and participants in NASA's DEVELOP program.

NCICS staff have also put expertise to use in direct response to the COVID-19 pandemic:

NCICS researchers Dr. Jennifer Runkle, Ronald Leeper, Dr. Douglas Rao, Dr. Jessica Mathews, and Jared Rennie teamed up with Dr. Maggie Sugg of Appalachian State to explore the potential influence of environmental factors—temperature, humidity, and solar radiation—on the spread of COVID-19 cases in eight U.S. cities. Their results, published in June 2020, suggested a significant relationship between COVID-19 transmission and humidity in three of the cities studied. See https://bit.ly/3dh0n2L for more on this research.

Runkle and NCICS's Dr. Garrett Graham are both serving on the scientific advisory committee for the Buncombe County (NC) Department of Health and Human Services' Epidemiology Team. Graham led efforts to set up a regional public health COVID-19 testing lab to monitor municipal wastewater for population-wide viral loads. Runkle worked with Buncombe County to develop a symptom "self-checker" for county residents, which is designed to help residents assess potential symptoms and make decisions about seeking medical care and to provide county public health experts with better information about the spread of the virus. See https://bit.ly/ncicscovidsc and a recent paper published in *Public Health Reports* for more on the development of the Buncombe County self-checker.

Runkle also led a NOAA-wide effort to assemble a new web-based directory of environmental datasets relevant to studying the influences of climate and weather factors on COVID-19 and other infectious diseases. https://www.climate.gov/covid

COVID-Related Publications

Andersen, L., S. Harden, M. Sugg, **J. Runkle**, and T. Lundquist, 2021: Analyzing the spatial determinants of local Covid-19 transmission in the United States. *Science of The Total Environment*, **754**, 142396. https://doi.org/10.1016/j.scitotenv.2020.142396

Runkle, J. D., M. M. Sugg, **G. Graham**, B. Hodge, T. March, J. Mullendore, F. Tove, M. Salyers, S. Valeika, and E. Vaughan, 2021: Participatory COVID-19 surveillance tool in rural Appalachia: Real-time disease monitoring and regional response. *Public Health Reports*, **In press**. http://dx.doi.org/10.1177/0033354921990372

Runkle, J. D., M. M. Sugg, **R. D. Leeper**, **Y. Rao**, **J. L. Mathews**, and **J. J. Rennie**, 2020: Short-term effects of weather parameters on COVID-19 morbidity in select US cities. *Science of The Total Environment*, **740**, 140093. http://dx.doi.org/10.1016/j.scitotenv.2020.140093

NCEI's Top Web Story

Arctic Sea Ice Research Results in Most Popular NCEI Web Story of 2020

Our colleagues at NCEI post multiple news stories each week at https://www.ncei.noaa.gov/news. Some of these stories highlight collaborations between NCEI and NCICS, with a notable example being the 2017 web story on a tool for viewing projected cloud clover conditions for the August 21, 2017, solar eclipse. That story was the most-viewed page on the NCEI website in 2017.

In 2020, another NCICS and NCEI collaboration resulted in NCEI's most-viewed news story of the year. This time, the topic was the future of sea ice cover in the Arctic. The story described an analysis of climate model projections of ice cover published by Drs. Ge Peng, Jessica Matthews, and Liqiang Sun of NCICS, Dr. Muyin Wang of NOAA's Pacific Marine Environmental Laboratory and the University of Washington, and Dr. Russell Vose of NCEI. The team determined that, on average, models project that the first ice-free arctic summer (defined as less than one million square kilometers of sea ice) could occur in 2054 under a moderate emissions scenario or in 2042 under a high emissions scenario. Statistical projections extrapolating from the first thirty years of climate model simulations (for 2006–2035) suggest a more rapid transition to ice-free summers—as early as 2034. The researchers also concluded that there is room for improvement in how models represent arctic sea ice.

You can read the full NCEI story at https://www.ncei.noaa.gov/news/arctic-ice-study, and see page 10 for more on arctic sea ice research. It's also worth noting that the four top NCEI news stories of the year were all related to climate change, including the link between global warming and hurricane strength, continuing increases in ocean heat content, and the rapid intensification of tropical cyclones.

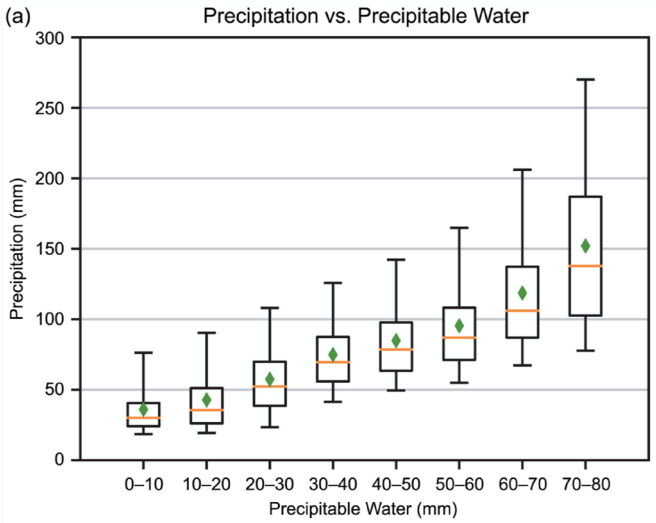
Research Highlights

Water Vapor Is the Critical Factor for Precipitation Amounts in Heavy Events

New research published in *Geophysical Research Letters* shows that for the continental United States, extreme precipitation amounts generally scale linearly (vary in proportion) with precipitable water—the amount of water vapor in a column of air. But particularly high levels of precipitable water can produce disproportionately large extreme precipitation totals. The team also found that precipitable water, rather than velocity of upward airflow in the atmosphere, sets the upper limit on precipitation totals during the most intense events. These findings suggest that future increases in the amounts falling in the heaviest events may outpace the rate of increase in water vapor as the climate warms.

This research was a key component of a five-year Strategic Environmental Research and Development Program (SERDP) project to update statistics on the intensity, duration, and frequency (IDF) of heavy precipitation events for Department of Defense facilities around the country. These IDF statistics, or design values, are used by planners to develop infrastructure that will be sufficiently resilient to flooding and other impacts of extreme precipitation. As climate change brings more frequent and more intense heavy precipitation events, IDF design values need to be updated to accurately reflect future risks. Updating the IDF values required a multifaceted research effort to understand the many factors that influence extreme precipitation and to understand how those various factors are expected to change in a warming climate.

Read more at: https://ncics.org/cics-news/quantifying-the-relationship-between-extreme-precipitation-and-atmospheric-water-vapor/



Precipitation totals in extreme precipitation events (y-axis) generally scale linearly with precipitable water (x-axis), but the relationship becomes non-linear for the highest values of precipitable water, which are associated with disproportionately large amounts of precipitation. Source: Kunkel et al. 2020.

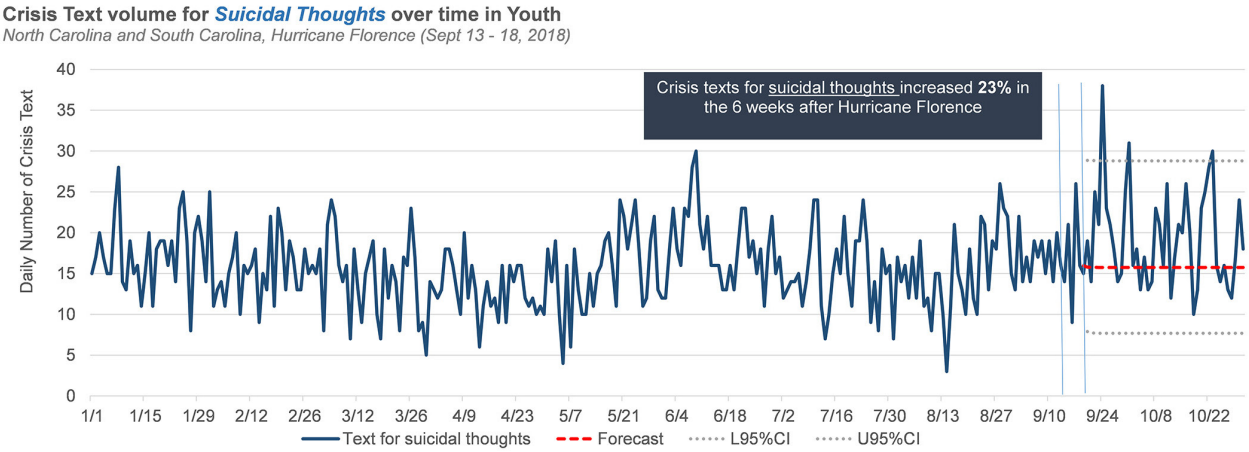
Kunkel, K. E., **S. E. Stevens**, **L. E. Stevens**, and T. R. Karl, 2020: Observed climatological relationships of extreme daily precipitation events with precipitable water and vertical velocity in the contiguous United States. *Geophysical Research Letters*, 47, e2019GL086721. http://dx.doi.org/10.1029/2019gl086721

Hidden Damage: The Mental Health Impacts of Hurricane Florence

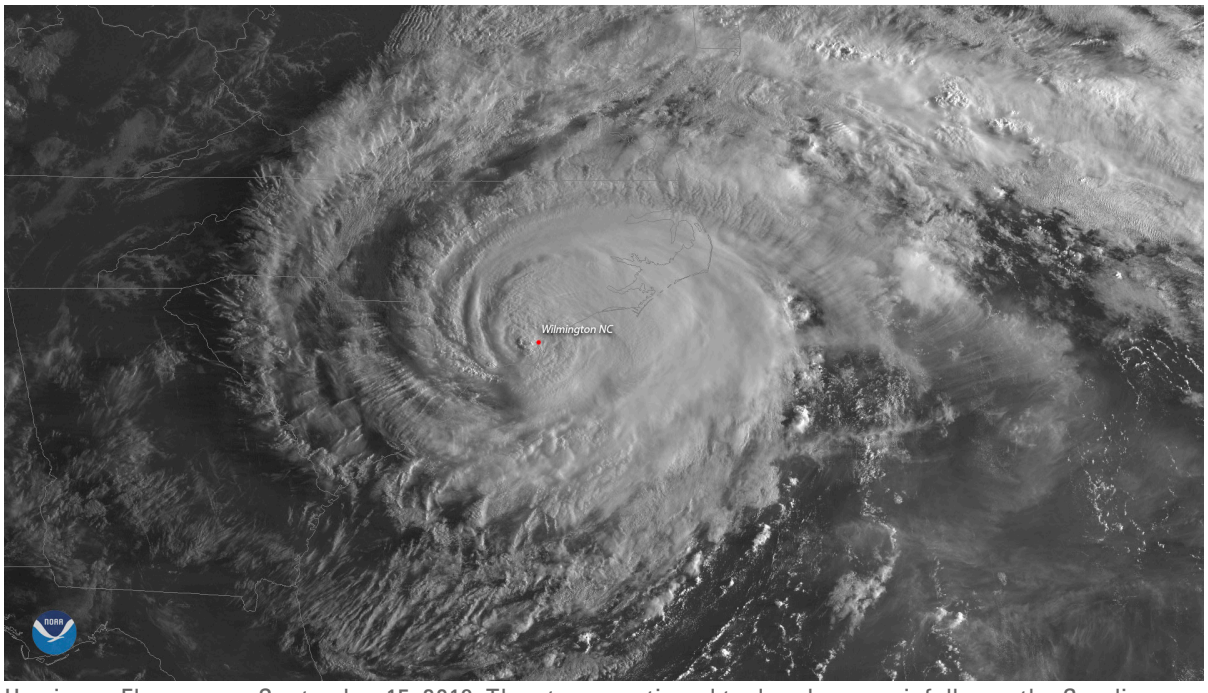
Innovative research using data from the Crisis Text Line shows that Hurricane Florence had significant mental health impacts on young people in the Carolinas and points the way to better monitoring of mental health issues when disasters strike. Researchers from NCICS and Appalachian State University found statistically significant increases in text volume for seven combinations of responses and impact periods associated with the storm. For example, crisis texts were significantly higher for anxiety and stress and for suicidal thoughts in the two weeks after Florence. Text volume was also significantly higher for anxiety and stress, depression, and suicidal thoughts for the six weeks following the storm. Depression texts were significantly higher for the delayed but continuing impact phase.

Read more at:
https://ncics.org/cics-news/hidden-damage-the-mental-health-impacts-of-hurricane-florence/

Runkle, J. D., K. D. Michael, **S. E. Stevens**, and M. M. Sugg, 2021: Quasi-experimental evaluation of text-based crisis patterns in youth following Hurricane Florence in the Carolinas, 2018. *Science of The Total Environment*, 750, 141702. http://dx.doi.org/10.1016/j.scitotenv.2020.141702



Crisis texts for suicidal thoughts in the Carolinas (blue line) increased by 23% in the six weeks following Hurricane Florence, with text volume exceeding the upper 95% confidence interval limit (dotted lines) on three days during that period. Source: Runkle et al. 2021.



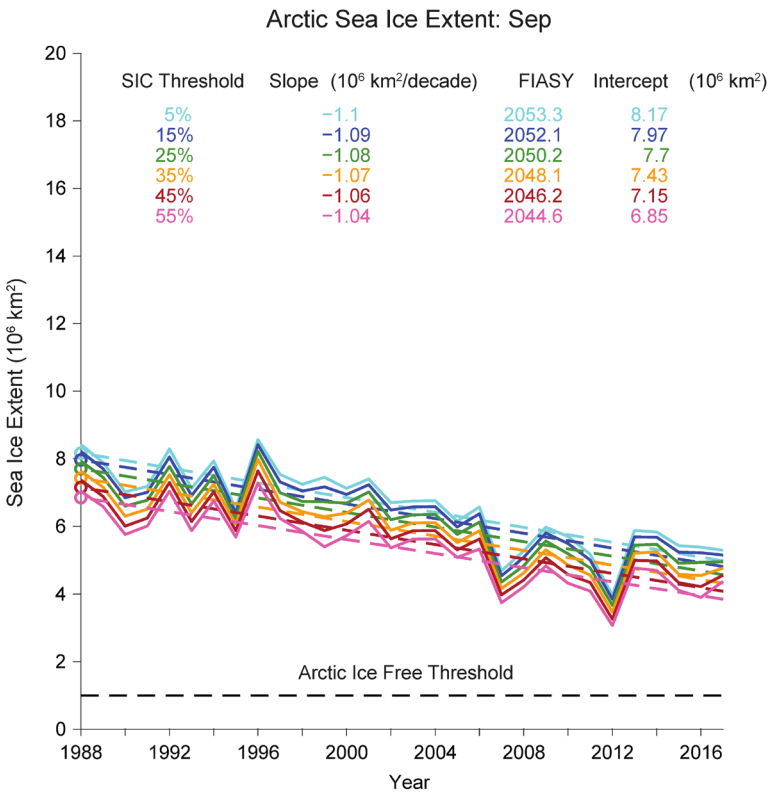
Hurricane Florence on September 15, 2018. The storm continued to drop heavy rainfall over the Carolinas following initial landfall. Photo: NOAA.

Arctic Sea Ice Observations

Satellite observations are a critical tool for measuring and understanding the rapid decline in arctic sea ice, but turning satellite data into ice cover estimates requires some choices. To calculate sea ice extent (SIE), satellite observations are divided into multiple grid boxes—typically squares of 25 kilometers on each side. If a sufficient percentage of the area in a given grid box contains sea ice, that grid box is deemed to be sea-ice-covered and is included in the count toward the total estimated SIE. The most common threshold for ice cover is 15%—that is, 15% or more of the grid box must contain sea ice for it to count toward the SIE estimate.

Researchers at NCICS and the National Snow and Ice Data Center recently wondered how the choice of threshold value might affect estimates of the downward trend in arctic SIE and projections of future sea ice coverage based on those trends.

They found that different choices of thresholds can indeed affect both the timing and estimated value of the annual minimum SIE. Threshold choices also affect statistical projections of the first occurrence of an ice-free arctic summer (the first year when SIE would fall below 1 million square kilometers), with higher threshold values producing earlier and more consistent estimates of the first ice-free summer. The authors call for further investigation as the rapid melting of arctic sea ice extent appears to be changing ice cover characteristics, particularly in the summer.



Higher threshold values yield lower estimates of annual minimum SIE (solid lines) from 1988 to 2017, so trends based on linear regressions (dashed lines) suggest that higher threshold values produce slightly slower rates of decline but earlier first ice-free years, since they are associated with lower SIE estimates.

Matthews, J. L., **G. Peng**, W. N. Meier, and **O. Brown**, 2020: Sensitivity of arctic sea ice extent to sea ice concentration threshold choice and its implication to ice coverage decadal trends and statistical projections. *Remote Sensing*, **12**, 807. https://doi.org/10.3390/rs12050807

Book Contributions

Building on years of research, Dr. Olivier Prat co-authored a chapter on satellite precipitation measurement and extreme rainfall for a book entitled *Satellite Precipitation Measurement, Volume 2*. https://doi.org/10.1007/978-3-030-35798-6_16

Dr. Pavel Groisman co-authored two chapters in a new book entitled *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*. This international effort explores the interconnections and interactions between changes in land cover, land use, and climate with the people, societies, and ecosystems of the drylands of Greater Central Asia. https://www.springer.com/gp/book/9783030307417

Engagement and Outreach

NOAA Engagement Efforts

Engagement efforts at NCICS include identifying strategic sector-based engagement opportunities and collaborative research activities, developing engagement methodologies and roadmaps, and forming partnerships and collaborations. Much of this work focuses on engagement with current and potential new users of NOAA datasets to better characterize how they use and apply data and to assess the value of the data. Two major areas of focus this year involved supporting NOAA's Big Data Program and the development of NCEI's new Information Services Roadmap, along with continuing community and educational outreach efforts.

NOAA Big Data Program Engagement

Making environmental information accessible to the public and enhancing capabilities to interpret that information are complex challenges that can be addressed in part by improving and democratizing access to NOAA data. NOAA's Big Data Program continues to strengthen its partnership with cloud service providers Microsoft, Google, and Amazon through strategic engagement activities, including 1) developing user case studies and blog stories, 2) investing in partnerships that enhance the expertise of NOAA scientists in cloud-based analytics, and 3) strengthening the ability of NESDIS and other NOAA line offices to provide data and guides to using that data via the cloud partners.

NCEI Information Services Roadmap

NCICS is supporting the development of NCEI's Information Services Roadmap, which identifies and integrates center-wide best practices and makes recommendations for engagement activities over a 5-year horizon. Building on NCEI's Five-Year Roadmap, it identifies the distinct ways NCEI engages with customers and suggests ways to modernize processes and use new technologies to enhance the delivery of services to its customers.

Educational and Community Outreach

Due to the COVID-19 pandemic, NCICS staff were able to participate in only a handful of in-person outreach events over the past year, concluding with an open-house event at The Collider in downtown Asheville in early 2020. However, as with many other aspects of life, we were able to continue community outreach efforts via online platforms.

Our in-person and virtual activities involved a wide range of audiences and included a STEAM (science, technology, engineering, art, and mathematics) event for elementary school students, a Buncombe County Schools professional development day, multiple "Skype a Scientist" sessions, and presentations to high school students and a local garden club.

The Institute also continued its focus on workforce development by mentoring (in person and remotely) six undergraduate and eight graduate interns, eighteen NASA DEVELOP interns, and two NOAA Hollings Scholars.

The CISESS Science Seminar Series

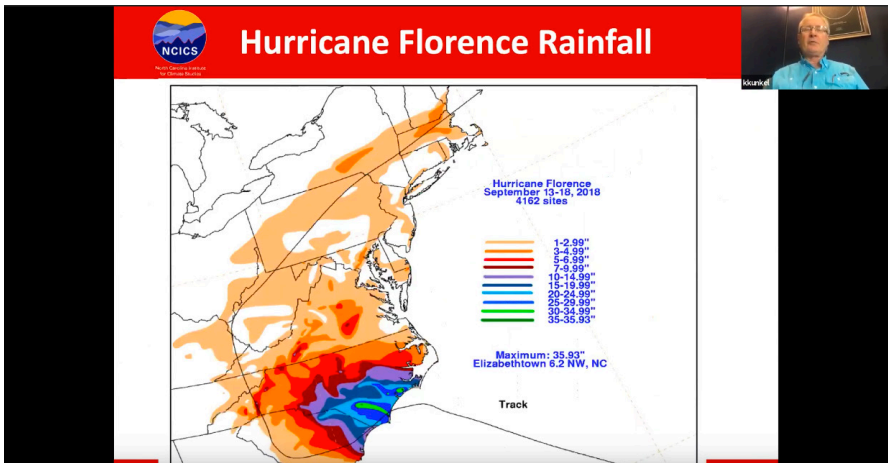
The North Carolina and Maryland locations of CISESS are collaborating on a new series of science presentations for staff at CISESS, NOAA NCEI, and NOAA's Center for Satellite Applications and Research.

We have two primary goals in organizing this series. The first is to create a venue for science talks that will not only be interesting and accessible to the broad target audience but also relevant to CISESS and NOAA missions. The second is to inspire new research ideas, identify new opportunities for collaboration, and better understand how NOAA and CISESS products and research are used by our many stakeholders.

The series began in March, and the initial sessions feature talks on the interactions between climate, weather, and forests in the southern United States and on the use of remote sensing to understand the impacts of climate change on human health.

North Carolina Climate Change Webinar Series

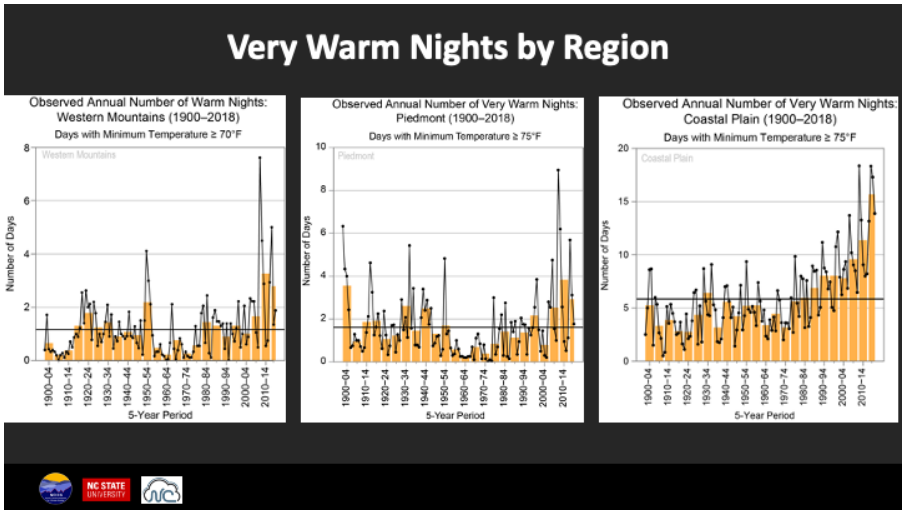
In the fall and winter of 2020, NCICS partnered with the State Climate Office of North Carolina for a series of six webinars on climate change. The primary audiences for the series were the state's Cooperative Extension network and their partners, including master gardeners and others working directly with individuals and groups for whom climate and weather are vital concerns, such as farmers, agribusiness, and community planners.



Screenshot of Dr. Kunkel's slide presentation on Hurricane Florence from the third webinar.

The webinars were designed to explore the findings of the North Carolina Climate Science Report (NCCSR) and put that information in context for these important stakeholders, as well as to highlight ongoing research and explore best practices and solutions. Each session included opportunities for presenters to respond to questions from attendees. Several NCICS staff participated in the series, along with authors of the NCCSR and other researchers and experts from around the state.

The first webinar offered an overview of climate change in North Carolina from Dr. Kenneth Kunkel, including the major findings from NCCSR, and an update on state-level resilience activities. The next session was on temperatures, including extreme heat and nighttime warming, with a focus on the human health impacts. NCICS's Jared Rennie and Dr. Jennifer Runkle were among the presenters.



Jared Rennie's presentation on heat in North Carolina included these figures from the North Carolina Climate Science Report that document increasing trends in warm nights in all three regions of the state.

Kunkel returned for the third webinar, where he explored Hurricane Florence in detail and the extent to which it was a harbinger of future storm impacts. He was followed by two presentations on resilience-building activities related to extreme precipitation and flooding. The fourth webinar in the series explored the history and future of drought and wildfire in North Carolina and how human activities have influenced these events, including a look at how climate change will affect the ability to use prescribed fire as a defense against uncontrolled wildfire and a discussion of educational and outreach resources. The fifth webinar focused on sea level rise. It included a detailed look at Chapter 4 of the NCCSR and the many factors influencing water levels along the North Carolina coast, including the dominant role played by accelerating rates of global sea level rise. Projections for the future were also discussed. A second presentation covered the often-overlooked threat that sea level rise poses for coastal on-site wastewater systems, including home septic systems.

The final session featured a panel discussion on challenges, opportunities, and best practices for talking about climate change. Panelists shared personal experiences and lessons learned from their outreach to diverse individuals and communities, particularly those without a background in climate science.

Links to the video recordings of the webinars are available on the State Climate Office website, along with copies of the presentations, answers to questions, and additional resources. All of the content was designed to be accessible to non-specialists.

We invite anyone interested in how climate change is affecting North Carolina and the efforts underway to meet the challenges it poses to check out these webinars.

We also extend our thanks to our partners at the State Climate Office for leading this important effort.

Science and Services

Going Global with Tropical Cyclone Reports

NCEI's Monthly Reports Now Include All Tropical Cyclone Basins

In our March 2019 issue, we reported on pioneering work by Dr. Carl Schreck that led to the addition of near-real-time updates to International Best Track Archive for Climate Stewardship (IBTrACS). That advance paved the way for another recent innovation.

In the past, NCEI's monthly National State of the Climate reports only included tables of hurricane and tropical cyclone statistics for two basins—the North Atlantic and East Pacific—and these tables had to be compiled manually each month, using data from NOAA's National Hurricane Center. But thanks to access to the near-real-time data for these basins as well as global data from the U.S. Military's Joint Typhoon Warning Center, Schreck and his NCEI colleague Jesse Enloe were able to automate the process and generate tables for all of the tropical cyclone basins. These statistics are now presented in NCEI's monthly Global State of the Climate reports. For example, the table below is from the October 2020 report:

Significant Events | North Atlantic | East Pacific | West Pacific | North Indian | South Indian | Australia | South Pacific | Global

West Pacific

October 2020 West Pacific Tropical Cyclones

NAME	MAXIMUM CATEGORY	DATES ≥39 MPH	MAXIMUM SUSTAINED WINDS	MINIMUM CENTRAL PRESSURE
Chan-Hom	1	October 5-11	90 mph	962 mb
Linfa	TS	October 10-11	45 mph	999 mb
Nangka	TS	October 12-14	60 mph	989 mb
Saudel	2	October 20-25	95 mph	968 mb
Molave	3	October 24-28	125 mph	950 mb
Goni	5	October 28-November 5	195 mph	884 mb

Tropical cyclone statistics for the West Pacific basin from the NCEI October 2020 Global State of the Climate report (https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202010).

Assessments

The North Carolina Climate Science Report

In March 2020, NCICS released the North Carolina Climate Science Report (NCCSR), an independent scientific assessment of observed and projected climate change in North Carolina. The report was led by Dr. Kenneth Kunkel and supported by the NOAA Assessments Technical Support Unit (TSU), which is staffed largely by NCICS scientific and technical experts.

The report is intended to inform the citizens of North Carolina about important climate trends and potential future changes. It was developed in response to Governor Roy Cooper's Executive Order 80, which calls for a range of state-level efforts to address the challenges of climate change and transition the state to a clean energy economy.

You can access the full report, a shorter document with the Executive Summary and Report Findings, and an even shorter plain-language summary on our website at: https://ncics.org/programs/nccsr/.

More information about the development process is available in the October 2019 issue of Trends.

Building on NCCSR: The State Risk Assessment and Resilience Plan

In parallel with work on the NCCSR, several NCICS staff, including Kunkel, Sarah Champion, Jenny Dissen, and Dr. Jennifer Runkle, served as technical experts and advisors for the 2020 North Carolina Climate Risk Assessment and Resilience Plan (RARP), which was released on June 2, 2020, by the North Carolina Department of Environmental Quality.

The RARP serves as a guiding framework for state agencies in their efforts to engage with stakeholders and build climate resilience. The Report Findings and Executive Summary from NCCSR are presented in Chapter 3 of the resilience plan, and the full NCCSR is included as an appendix. The resilience plan is available at: NC Climate Risk Assessment and Resilience Plan.

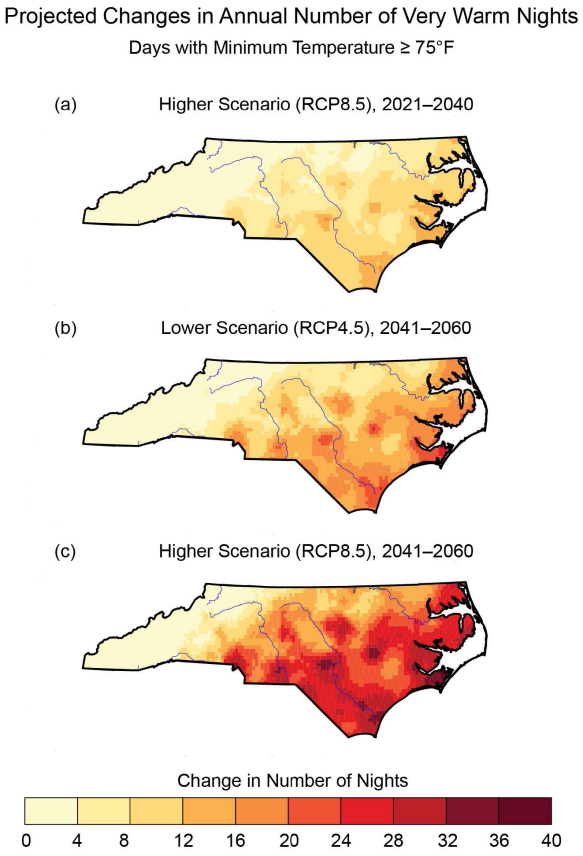


Figure 2.7 from NCCSR shows the projected changes in the number of warm nights per year for North Carolina for two time periods (2021–2040 and 2041–2060) and two scenarios: one where greenhouse gas emissions continue to increase through the end of the century (RCP8.5) and one where emissions increase at a slower rate, peak around the middle of this century, and then decline (RCP4.5).

Enhancing the Accessibility of NCCSR

In September 2020, NCICS released an update to the NCCSR to make the report more accessible for users with visual, physical, and other limitations. The report, presented in PDF format, comprises more than 60,000 words, 125 figures, and several tables, all requiring a range of accessibility considerations. Some of those were addressed in the initial release of the report, such as using appropriate font sizes and contrast ratios to enhance text readability and ensuring that figures used color schemes appropriate for those with color vision deficiency. However, the rapid development schedule for the report meant that there were some accessibility gaps in the initial version released in March.

Improvements in the September 2020 version focused on users of screen readers, primarily blind and low-vision people. One effort involved improving the structure of the tags in the PDF file that define each text element (e.g., headings, captions, body text) so that screen readers process the text in the proper reading order. The team also wrote alternative text descriptions for each figure and table in the report. These alternative text scripts can be read out loud by screen readers to give visually impaired readers concise yet comprehensive descriptions of figures and other images.

These efforts built on accessibility work done by the TSU on recent National Climate Assessment reports, which must meet the accessibility standards outlined in Sections 504 and 508 of the Rehabilitation Act (1973 and 1998, respectively) and the Americans with Disabilities Act (1990). Lessons learned from the NCCSR will, in turn, help the TSU maximize the accessibility of the Fifth National Climate Assessment, which is currently in the early stages of development.

AGU and AMS Participation

As a result of COVID-19, both the 2020 Fall Meeting of the American Geophysical Union (AGU) and the 2021 Annual Meeting of the American Meteorological Society (AMS) were held as online-only events. Although the online environment didn't really allow for the kind of networking and hallway conversations that are often at the heart of new research ideas and new collaborations, the lack of travel requirements did make it possible for more people to attend both events. Both meetings also featured some innovative approaches to online presentations and discussions, and some of those experiments may serve to reshape science conferences in the future.

Despite the changes, Institute staff were again able to engage with fellow scientists and experts by participating in a wide range of presentations, poster sessions, and discussions. Activities this year included participation in 23 sessions at the AGU meeting and 27 sessions at the AMS meeting. See AGU sessions and AMS sessions on our website for a full list of activities.

Workforce Development

Douglas Rao Selected as Spring 2021 Impact Scholar Cohort

Douglas Rao

NCICS postdoc Dr. Douglas Rao was recently selected as one of 12 members of the inaugural Spring 2021 Impact Scholars cohort as part of the Strengthening the Impact of Research (STIR) program organized by NC State University's Office of Outreach and Engagement.

The STIR program was developed to enhance capabilities for designing and conducting research that has broad beneficial impacts on society. The Impact Scholars will receive training aimed at building their impact identities, increasing their capacity to do innovative research with beneficial impacts on society, and expanding their abilities to write competitive grant proposals.

Rao has already made a significant impact here at NCICS. Since joining the Institute in 2019, he has contributed to a major effort to develop a new near-surface air temperature data product that uses statistical methods to blend ground-based data with satellite observations. He also co-leads an ongoing training program on the use of machine learning techniques for staff at NCICS and NCEI, regularly engages in a variety of community and educational outreach efforts, and contributes to various social and organizational health initiatives here at the Institute.

NCICS Publications

NCICS staff (indicated in bold below) have authored or co-authored more than 50 publications in 2020 and the first quarter of 2021:

Andersen, L. M., S. R. Harden, M. M. Sugg, **J. D. Runkle**, and T. E. Lundquist, 2021: Analyzing the spatial determinants of local Covid-19 transmission in the United States. *Science of The Total Environment*, **754,** 142396. http://dx.doi.org/10.1016/j.scitotenv.2020.142396

Arguez, A., S. Hurley, **A. Inamdar**, L. Mahoney, A. Sanchez-Lugo, and L. Yang, 2020: Should we expect each year in the next decade (2019–2028) to be ranked among the top 10 warmest years globally? *Bulletin of the American Meteorological Society*, **101,** E655–E663. http://dx.doi.org/10.1175/bams-d-19-0215.1

Bailey, E., M. M. Sugg, C. Fuhrmann, **J. Runkle**, **S. E. Stevens**, and M. Brown, 2020: Wearable sensors for personal temperature exposure assessments: A comparative study. *Environmental Research*, **180,** 108858. http://dx.doi.org/10.1016/j.envres.2019.108858

Brooks, B.-G. J., D. C. Lee, L. Y. Pomara, and W. W. Hargrove, 2020: Monitoring broadscale vegetational diversity and change across North American landscapes using land surface phenology. *Forests*, **11,** 606. http://dx.doi.org/10.3390/f11060606

Byrd, B., S. L. Richards, **J. D. Runkle**, and M. M. Sugg, 2020: Vector-borne diseases and climate change: North Carolina's policy should promote regional resilience. *North Carolina Medical Journal*, **81,** 324. http://dx.doi.org/10.18043/ncm.81.5.324

Chen, J., Z. Ouyang, R. John, G. M. Henebry, **P. Y. Groisman**, A. Karnieli, M. Kussainova, A. Amartuvshin, A. Tulobaev, E. T. Isabaevich, C. Crank, K. Kadhim, J. Qi, and G. Gutman, 2020: Chapter 10: Social-ecological systems across the Asian Drylands Belt (ADB). *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*, G. Gutman, J. Chen, G. M. Henebry, and M. Kappas, Eds., Springer, 191–225. http://dx.doi.org/10.1007/978-3-030-30742-4

Dello, K., W. Robinson, **K. Kunkel**, **J. Dissen**, and **T. Maycock**, 2020: A hotter, wetter, and more humid North Carolina. *North Carolina Medical Journal*, **81,** 307. http://dx.doi.org/10.18043/ncm.81.5.307

Diamond, H. J., and **C. J. Schreck**, 2020: The tropics [in "State of the Climate in 2019"]. *Bulletin of the American Meteorological Society*, **101,** S185–S238. http://dx.doi.org/10.1175/bams-d-20-0077.1

Dong, Q., W. Wang, **K. E. Kunkel**, Q. Shao, W. Xing, and J. Wei, 2020: Heterogeneous response of global precipitation concentration to global warming. *International Journal of Climatology*. http://dx.doi.org/10.1002/joc.6851

Dunn, R., C. Lief, **G. Peng**, W. Wright, O. Baddour, M. Donat, B. Dubuisson, J.-F. Legeais, P. Siegmund, R. Silveira, X. L. Wang, and M. Ziese, 2021: Stewardship maturity assessment tools for modernization of climate data management. *Data Science Journal*, **20(1)**, 7. http://dx.doi.org/10.5334/dsj-2021-007

Gardiner, N., **J. Runkle**, J. Fox, and A. Patel, Eds., 2020: Ch. 5: Vulnerability, risk, and resilience strategies for addressing climate related hazards. *North Carolina Climate Risk Assessment and Resilience Plan: Impacts, Vulnerability, Risks, and Preliminary Actions. A Comprehensive Strategy for Reducing North Carolina's Vulnerability to Climate Change*, State of North Carolina, 5A-1—5N-3. https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf

Graham, G., N. Csicsery, E. Stasiowski, G. Thouvenin, W. H. Mather, M. Ferry, S. Cookson, and J. Hasty, 2020: Genome-scale transcriptional dynamics and environmental biosensing. *Proceedings of the National Academy of Sciences of the United States of America*, **117,** 3301–3306. http://dx.doi.org/10.1073/pnas.1913003117

Groisman, P. Y., O. N. Bulygina, G. M. Henebry, N. A. Speranskaya, A. I. Shiklomanov, Y. Chen, N. M. Tchebakova, E. I. Parfenova, N. D. Tilinina, O. G. Zolina, A. Dufour, J. Chen, R. John, and P. Fan, 2020: Chapter 2: Dry Land Belt of Northern Eurasia: Contemporary environmental changes. *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*, G. Gutman, J. Chen, G. M. Henebry, and M. Kappas, Eds., Springer, 11–23. http://dx.doi.org/10.1007/978-3-030-30742-4

Huang, B., M. J. Menne, T. Boyer, E. Freeman, B. E. Gleason, J. H. Lawrimore, C. Liu, **J. J. Rennie**, **C. J. Schreck, III**, F. Sun, R. Vose, C. N. Williams, X. Yin, and H.-M. Zhang, 2020: Uncertainty estimates for sea surface temperature and land surface air temperature in NOAAGlobalTemp version 5. *Journal of Climate*, **33,** 1351–1379. http://dx.doi.org/10.1175/JCLI-D-19-0395.1

Johnson, K. M., and W. B. Ouimet, 2021: Reconstructing historical forest cover and land use dynamics in the northeastern United States using geospatial analysis and airborne LiDAR. *Annals of the American Association of Geographers*, **In Press**. http://dx.doi.org/10.1080/24694452.2020.1856640

Klotzbach, P. J., M. M. Bell, S. G. Bowen, E. J. Gibney, K. R. Knapp, and **C. J. Schreck**, 2020: Surface pressure a more skillful predictor of normalized hurricane damage than maximum sustained wind. *Bulletin of the American Meteorological Society*, **101,** E830–E846. http://dx.doi.org/10.1175/BAMS-D-19-0062.1

Klotzbach, P. J., **C. J. Schreck, III**, G. P. Compo, S. G. Bowen, E. J. Gibney, E. C. J. Oliver, and M. M. Bell, 2020: The record-breaking 1933 Atlantic hurricane season. *Bulletin of the American Meteorological Society***,** 1–54. http://dx.doi.org/10.1175/BAMS-D-19-0330.1

Knapp, K. R., A. H. Young, H. Semunegus, **A. K. Inamdar**, and W. Hankins, 2021: Adjusting ISCCP cloud detection to increase consistency of cloud amount and reduce artifacts. *Journal of Atmospheric and Oceanic Technology*, **38**, 155-165. http://dx.doi.org/10.1175/jtech-d-20-0045.1

Kunkel, K. E., 2020: Extreme precipitation and climate change: Observations and projections. *ASDSO Journal of Dam Safety*, **17,** 22–28.

Kunkel, K. E., D. R. Easterling, A. Ballinger, S. Bililign, **S. M. Champion**, D. R. Corbett, K. D. Dello, **J. Dissen**, G. M. Lackmann, R. A. Luettich, Jr., L. B. Perry, W. A. Robinson, **L. E. Stevens**, **B. C. Stewart**, and A. J. Terando, 2020: North Carolina Climate Science Report, 233 pp., https://ncics.org/programs/nccsr/

Kunkel, K. E., D. R. Easterling, T. R. Karl, **J. C. Biard**, **S. M. Champion**, B. E. Gleason, **K. M. Johnson**, **A. Li**, S. Stegall, **L. E. Stevens**, **S. E. Stevens**, M. Squires, **L. Sun**, and X. Yin, 2020: Incorporation of the Effects of Future Anthropogenically Forced Climate Change in Intensity-Duration-Frequency Design Values. Final Report., 104 pp., North Carolina Institute for Climate Studies, North Carolina State University.

Kunkel, K. E., T. R. Karl, M. F. Squires, X. Yin, **S. T. Stegall**, and D. R. Easterling, 2020: Precipitation extremes: Trends and relationships with average precipitation and precipitable water in the contiguous United States. *Journal of Applied Meteorology and Climatology*, **59,** 125–142. http://dx.doi.org/10.1175/JAMC-D-19-0185.1

Kunkel, K. E., **S. E. Stevens**, **L. E. Stevens**, and T. R. Karl, 2020: Observed climatological relationships of extreme daily precipitation events with precipitable water and vertical velocity in the contiguous United States. *Geophysical Research Letters*, **47,** e2019GL086721. http://dx.doi.org/10.1029/2019gl086721

Lawrimore, J. H., D. Wuertz, A. Wilson, **S. Stevens**, M. Menne, B. Korzeniewski, M. A. Palecki, **R. D. Leeper**, and T. Trunk, 2020: Quality control and processing of Cooperative Observer Program hourly precipitation data. *Journal of Hydrometeorology*, **21**, 1811-1825. http://dx.doi.org/10.1175/jhm-d-19-0300.1

Matthews, J. L., **G. Peng**, W. N. Meier, and **O. Brown**, 2020: Sensitivity of arctic sea ice extent to sea ice concentration threshold choice and its implication to ice coverage decadal trends and statistical projections. *Remote Sensing*, **12,** 807. http://dx.doi.org/10.3390/rs12050807

Mekonnen, A., **C. J. Schreck**, and B. D. Enyew, 2020: The Impact of Kelvin wave activity during dry and wet African summer rainfall years. *Atmosphere*, **11,** 568. http://dx.doi.org/10.3390/atmos11060568

Morrison, H., M. van Lier-Walqui, A. M. Fridlind, W. W. Grabowski, J. Y. Harrington, C. Hoose, A. Korolev, M. R. Kumjian, J. A. Milbrandt, H. Pawlowska, D. J. Posselt, **O. P. Prat**, K. J. Reimel, S.-I. Shima, B. van Diedenhoven, and L. Xue, 2020: Confronting the challenge of modeling cloud and precipitation microphysics. *Journal of Advances in Modeling Earth Systems*, **12,** e2019MS001689. http://dx.doi.org/10.1029/2019ms001689

Morrison, H., M. van Lier-Walqui, M. R. Kumjian, and **O. P. Prat**, 2020: A Bayesian approach for statistical-physical bulk parameterization of rain microphysics, Part I: Scheme description. *Journal of the Atmospheric Sciences*, **77,** 1019–1041. http://dx.doi.org/10.1175/JAS-D-19-0070.1

Nelson, K. B., **J. D. Runkle**, and M. M. Sugg, 2020: Reporting back environmental health data among outdoor occupational workers in the cold season in North Carolina, USA. *Southeastern Geographer*, **60,** 159–182. http://dx.doi.org/10.1353/sgo.2020.0013

Peng, G., C. Lacagnina, R. R. Downs, I. Ivanova, D. F. Moroni, H. Ramapriyan, Y. Wei, and G. Larnicol, 2020: Laying the Groundwork for Developing International Community Guidelines to Effectively Share and Reuse Digital Data Quality Information—Case Statement, Workshop Summary Report, and Path Forward., *Ocean Science Framework*, Version: v03r04-20200828. http://dx.doi.org/10.31219/osf.io/75b92

Peng, G., **L. J. Matthews**, M. Wang, R. Vose, and **L. Sun**, 2020: What do global climate models tell us about future arctic sea ice coverage changes? *Climate*, **8,** 15. http://dx.doi.org/10.3390/cli8010015

Prat, O. P., and B. R. Nelson, 2020: Satellite precipitation measurement and extreme rainfall. *Satellite Precipitation Measurement, Volume 2*, V. Levizzani, C. Kidd, D. B. Kirshbaum, C. D. Kummerow, K. Nakamura, and F. J. Turk, Eds., Springer, 761–790. http://dx.doi.org/10.1007/978-3-030-35798-6_16

Rennie, J. J., M. A. Palecki, S. P. Heuser, and H. J. Diamond, 2021: Developing and validating heat exposure products using the US Climate Reference Network. *Journal of Applied Meteorology and Climatology*, **In press**. http://dx.doi.org/10.1175/jamc-d-20-0282.1

Runkle, J. D., K. D. Michael, **S. E. Stevens**, and M. M. Sugg, 2021: Quasi-experimental evaluation of text-based crisis patterns in youth following Hurricane Florence in the Carolinas, 2018. *Science of The Total Environment*, **750,** 141702. http://dx.doi.org/10.1016/j.scitotenv.2020.141702

Runkle, J. D., M. M. Sugg, **G. Graham**, B. Hodge, T. March, J. Mullendore, F. Tove, M. Salyers, S. Valeika, and E. Vaughan, 2021: Participatory COVID-19 surveillance tool in rural Appalachia: real-time disease monitoring and regional response. *Public Health Reports*, **In press**. http://dx.doi.org/10.1177/0033354921990372

Runkle, J. D., M. M. Sugg, **R. D. Leeper**, **Y. Rao**, **J. L. Mathews**, and **J. J. Rennie**, 2020: Short-term effects of weather parameters on COVID-19 morbidity in select US cities. *Science of The Total Environment*, **740,** 140093. http://dx.doi.org/10.1016/j.scitotenv.2020.140093

Runkle, J. D., M. M. Sugg, S. McCrory, and C. C. Coulson, 2021: Examining the feasibility of blood pressure self-monitoring: Advancing remote prenatal care for rural Appalachia. *Telemedicine Reports*, In Press. http://dx.doi.org/10.1089/tmr.2020.0021

Saunders, M. A., P. J. Klotzbach, A. S. R. Lea, **C. J. Schreck**, and M. M. Bell, 2020: Quantifying the probability and causes of the surprisingly active 2018 North Atlantic hurricane season. *Earth and Space Science*, **7**. http://dx.doi.org/10.1029/2019EA000852

Schreck, C. J., M. A. Janiga, and S. Baxter, 2020: Sources of tropical subseasonal skill in the CFSv2. *Monthly Weather Review*, **148,** 1553–1565. http://dx.doi.org/10.1175/mwr-d-19-0289.1

Shen, M., N. Jiang, D. Peng, **Y. Rao**, Y. Huang, Y. H. Fu, W. Yang, X. Zhu, R. Cao, X. Chen, J. Chen, C. Miao, C. Wu, T. Wang, E. Liang, and Y. Tang, 2020: Can changes in autumn phenology facilitate earlier green-up date of northern vegetation? *Agricultural and Forest Meteorology*, **291,** 108077. http://dx.doi.org/10.1016/j.agrformet.2020.108077

Sugg, M., **J. Runkle**, **R. Leeper**, H. Bagli, A. Golden, L. H. Handwerger, T. Magee, C. Moreno, R. Reed-Kelly, M. Taylor, and S. Woolard, 2020: A scoping review of drought impacts on health and society in North America. *Climatic Change*, **162,** 1177–1195. http://dx.doi.org/10.1007/s10584-020-02848-6

Sugg, M. M., C. M. Fuhrmann, and **J. D. Runkle**, 2020: Geospatial approaches to measuring personal heat exposure and related health effects in urban settings. *Geospatial Technologies for Urban Health*, L. Yongmei, and E. Delmelle, Eds., Springer International Publishing, 13–30. http://dx.doi.org/10.1007/978-3-030-19573-1

Sugg, M. M., T. J. Spaulding, S. J. Lane, **J. D. Runkle**, S. R. Harden, A. Hege, and L. S. Iyer, 2021: Mapping community-level determinants of COVID-19 transmission in nursing homes: A multi-scale approach. *Science of The Total Environment*, **752,** 141946. http://dx.doi.org/10.1016/j.scitotenv.2020.141946

Sugg, M. M., S. Woolard, M. Lawrimore, K. D. Michael, and **J. D. Runkle**, 2020: Spatial clustering of suicides and neighborhood determinants in North Carolina, 2000 to 2017. *Applied Spatial Analysis and Policy*. http://dx.doi.org/10.1007/s12061-020-09364-1

van Lier-Walqui, M., H. Morrison, M. R. Kumjian, K. J. Reimel, **O. P. Prat**, S. Lunderman, and M. Morzfeld, 2020: A Bayesian approach for statistical-physical bulk parameterization of rain microphysics, Part II: Idealized Markov chain Monte Carlo experiments. *Journal of the Atmospheric Sciences*, **77**. http://dx.doi.org/10.1175/JAS-D-19-0071.1

Waliser, D., P. J. Gleckler, R. Ferraro, K. E. Taylor, S. Ames, **J. Biard**, M. G. Bosilovich, **O. Brown**, H. Chepfer, L. Cinquini, P. J. Durack, V. Eyring, P. P. Mathieu, T. Lee, S. Pinnock, G. L. Potter, M. Rixen, R. Saunders, J. Schulz, J. N. Thépaut, and M. Tuma, 2020: Observations for Model Intercomparison Project (Obs4MIPs): Status for CMIP6. *Geoscientific Model Development*, **13,** 2945–2958. http://dx.doi.org/10.5194/gmd-13-2945-2020

Wang, S., J. Chen, **Y. Rao**, L. Liu, W. Wang, and Q. Dong, 2020: Response of winter wheat to spring frost from a remote sensing perspective: Damage estimation and influential factors. *ISPRS Journal of Photogrammetry and Remote Sensing*, **168,** 221–235. http://dx.doi.org/10.1016/j.isprsjprs.2020.08.014

Wang, S., **Y. Rao**, J. Chen, L. Liu, and W. Wang, 2021: Adopting "difference-in-differences" method to monitor crop response to agrometeorological hazards with satellite data: A case study of dry-hot wind. *Remote Sensing*, **13**. http://dx.doi.org/10.3390/rs13030482

Wilson, T. B., H. J. Diamond, J. Kochendorfer, T. P. Meyers, M. Hall, N. W. Casey, C. B. Baker, **R. Leeper**, and M. A. Palecki, 2020: Evaluating time domain reflectometry and coaxial impedance sensors for soil observations by the U.S. Climate Reference Network. *Vadose Zone Journal*, **19**. http://dx.doi.org/10.1002/vzj2.20013

Wood, K. M., P. J. Klotzbach, J. M. Collins, L.-P. Caron, R. E. Truchelut, and **C. J. Schreck**, 2020: Factors affecting the 2019 Atlantic hurricane season and the role of the Indian Ocean Dipole. *Geophysical Research Letters*, **47,** e2020GL087781. http://dx.doi.org/10.1029/2020gl087781

Worku, L. Y., A. Mekonnen, and **C. J. Schreck**, 2020: The impact of MJO, Kelvin, and equatorial Rossby waves on the diurnal cycle over the Maritime Continent. *Atmosphere*, **11,** 711. http://dx.doi.org/10.3390/atmos11070711

Zhou, J., J. Chen, X. Chen, X. Zhu, Y. Qiu, H. Song, **Y. Rao**, C. Zhang, X. Cao, and X. Cui, 2021: Sensitivity of six typical spatiotemporal fusion methods to different influential factors: A comparative study for a normalized difference vegetation index time series reconstruction. *Remote Sensing of Environment*, **252,** 112130. http://dx.doi.org/10.1016/j.rse.2020.112130

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North Carolina Institute for Climate Studies
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