TRENDS

March 2019 Inspire. Advance. Engage.

Tropical Cyclones – Near-Real-Time Storm Track Data

Supporting National and International Assessments

Regional and Seasonal Changes in Arctic Sea Ice

NOAA NCEI's New Monthly Temperature Dataset

NCICS
North Carolina Institute
for Climate Studies
NC STATE UNIVERSITY

TRENDS

March 2019 **Inspire. Advance. Engage.**

Contents

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Thanks to the many members of the NCICS staff who provided content and reviewed material.

Cover photo: Photo: NASA/GSFC. https://www.flickr.com/photos/gsfc/7873353514/

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, non-profit organizations, community groups, and the federal government.

NCICS' primary activity is the operation of the Cooperative Institute for Climate and Satellites–North Carolina (CICS–NC).

CICS-NC is a multidisciplinary team of experts who collaborate in climate and satellite research to support NOAA NCEI's "research to operations" strategy.

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.

Main Research Activities

Access and Services Development

Climate Assessments

Climate Data Records and Scientific Data Stewardship

Climate Literacy, Outreach, Engagement, and Communications

Surface Observing Networks

Workforce Development

Consortium Projects

North Carolina Institute for Climate Studies
NC STATE UNIVERSITY

NOTE FROM THE DIRECTOR

– Otis Brown, NCICS Director
info@cicsnc.org

It's been longer than usual since we've updated you on NCICS. Please accept our apologies: we've been engaged in multiple activities which have not left time for a new edition of *Trends* until now, as we hope you will see from the contents of this issue.

NOAA announced the re-competition of the Cooperative Agreement covering operation of the Cooperative Institute for Climate and Satellites on November 1, 2018. Volume 2 of the Fourth National Climate Assessment was released on Black Friday in November 2018. Moreover, activities continued supporting NOAA NCEI's surface networks, Climate Data Records, Common Ingest, Common Access, NOAA's Big Data Project, and many engagement events. We have been very busy over the past year.

We worked diligently with our colleagues at the University of Maryland to develop a vision and implementation plan for our joint activities in a responsive framing for a "Cooperative Institute for Satellite Earth System Science" and submit a proposal in response to NOAA's announcement of the Cooperative Agreement re-competition. This proposal, approximately 150 pages in length, was submitted on January 31, 2019. We expect to hear the results of NOAA's review by mid-spring 2019.

The Assessments Technical Support Unit (TSU) delivered the *Climate Science Special Report*, Volume 1 of the Fourth National Climate Assessment, in November 2017. Work on Volume II, *Impacts, Risks, and Adaptation in the United States*, continued through 2018. In response to a federal request for an early release, the TSU was able to accelerate production and meet the new deadline. This volume, written by more than 300 authors and peer-reviewed by 13 federal agencies, was published online on November 23, 2018. Publication generated intense public interest, with more than 600,000 web hits and more than 2,000 articles in the national media. See page 7 for more details on this work.

Ken Kunkel, David Easterling (NOAA), and Jenny Dissen have continued their engagement with colleagues in India on developing and implementing an India national assessment. This has involved multiple trips and workshops, along with the development of a new web-based tool for downscaling model projections. See page 12 for details on this important partnership, in addition to an update on the Institute's ongoing participation in engagement efforts, including the American Geophysical Union and American Meteorological Society's annual meetings.

NCEI is integrating its data ingest activities with a new process, termed Common Ingest (CI). Linda Copley and Lou Vasquez led the creation of an Agile software development team in Asheville for NCEI to address CI software development. This team has taken a core set of CI technologies developed by colleagues at NCEI's Colorado location and enhanced them to operate across the breadth of NCEI data streams. Common Ingest was placed in operation in Fall 2018. See page 6 for more information.

We have specifically highlighted the recent hurricane season and implementation of a near-real-time version of IBTrACS to demonstrate how research and stewardship can improve national resilience by making archival information more accessible.

While all this was happening, our scholarly productivity has continued to improve, with more than 40 peer-reviewed publications and more than 100 presentations over the past year. The Institute staff has excelled during this past year and met or exceeded all their goals. I am proud of their accomplishments and encourage you to spend a few moments reading the high-level overviews in this issue of *Trends*. Should you desire more detailed information on these or other topics, please look at the Institute website, ncics.org, or email us at info@ncics.org.

We hope you enjoy reading this issue.

Best,

Otis

FOCUS: Tropical Cyclones

Tropical Cyclone Information in Near Real Time

For more than a decade, the International Best Track Archive for Climate Stewardship, or IBTrACS, has served as the standard global database of tropical cyclone data. IBTrACS combines data from multiple sources into a standard set of formats, providing the most complete set of historical tropical cyclone data available in a way that facilitates scientific analysis. Until recently, data for a given year wasn't available in the database until well into the following year. Thanks in part to work by NCICS' Carl Schreck, IBTrACS data is now available on a near-real-time basis.

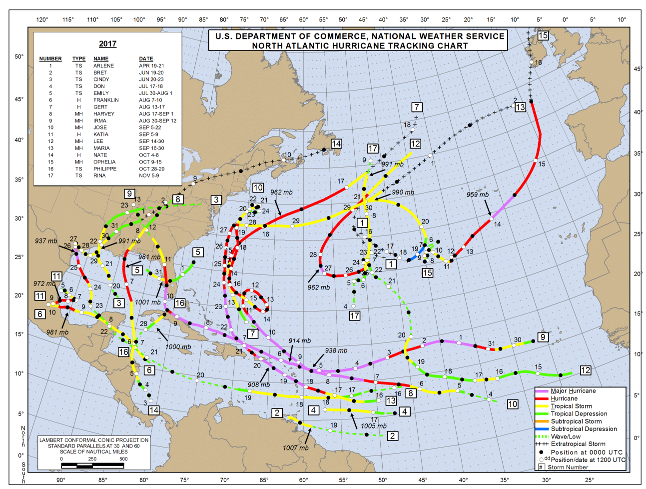
These near-real-time updates were first introduced as part of Carl's popular suite of tropical monitoring tools, available on our website at ncics.org/mjo. In order to plot tropical cyclone tracks in real time, the tools on ncics.org/mjo automatically download "tcvitals" data from NOAA's National Centers for Environmental Prediction. These are essentially the operational tropical cyclone tracks from the National Hurricane Center and the U.S. military's Joint Typhoon Warning Center.

Version 4 of IBTrACS, released by NOAA NCEI in March 2019, leverages that same code in order to provide best track data to users in near real time. Version 4 also streamlines the number of formats provided and includes more parameters for each storm.

2017: A Record-Breaking Hurricane Season

The 2017 North Atlantic hurricane season was one of the most active and destructive on record. In a paper published in the journal *Monthly Weather Review*, a team of researchers, co-led by CICS–NC's Carl Schreck, explored the small- and large-scale meteorological conditions that led to such an active season and revealed how changing conditions during the year resulted in a season that was more active than expected. By understanding the ingredients that led to this record-breaking hurricane season, the scientists hope to improve early-season projections of hurricane activity.

The 2017 North Atlantic season saw 17 named storms, compared to a median value of 12 over the last 30 years. Ten of those storms reached hurricane strength, compared to a 30-year median of 6.5. Six of those became major hurricanes, registering Category 3 or higher on the Saffir–Simpson scale, which is triple the 30-year median of two such storms per year.



Tracks of all North Atlantic named storms in 2017. Figure courtesy of NOAA's National Hurricane Center.

For the first time on record, two Category 4 hurricanes made landfall on the continental United States in the same year. Other metrics, including total hurricane days and accumulated cyclone energy (ACE), ranked in the top 10 compared to the long-term historical record. September 2017 saw a higher ACE value than any other calendar month on record for any global tropical cyclone basin.

In addition to an unusually large number of storms overall, the 2017 season saw more storms affect the United States than in recent years. Winds that had tended to turn hurricanes to the north and east over 2006–2016 were not in place in 2017, leading to more westerly tracks for many of the storms, bringing significant impacts to islands in the Caribbean and to the contiguous United States.

The result was more than $260 billion in total economic damages in the United States alone, approximately 200 direct fatalities, and likely hundreds or thousands of additional indirect fatalities in Puerto Rico as a result of Hurricane Maria.

Fortunately, despite warm sea surface temperatures (SSTs) and weak La Niña conditions, October was a relatively quiet month.

Evaluating and Improving Forecasts

Forecasts released in April through June of 2017 generally called for a below- or near-average hurricane season. Those forecasts generally did not anticipate changes that occurred in the El Niño–Southern Oscillation (ENSO) and in Atlantic SSTs during spring and summer. Those changes led to more favorable conditions for tropical cyclones.

To help improve seasonal forecasting, the team examined other particularly active seasons from 1982–2017 to look for similarities with 2017. The six most active seasons, including 2017, all featured a positive Atlantic meridional mode, which favors warmer tropical Atlantic SSTs to fuel stronger hurricanes. Five of those seasons also featured neutral-to-La Niña conditions. Both of these factors were present in 2017, but neither was exceptional enough to indicate the extreme activity observed.

La Niña and El Niño are traditionally observed based on SSTs in the Pacific, but the atmospheric component of ENSO can also be measured using the Pacific Walker Circulation Index—a measure of where tropical Pacific large-scale ascent is favored (supporting deep thunderstorm activity) and where large-scale ascent is inhibited (suppressing deep thunderstorm activity). The authors found that the Walker Index would have served as a better indicator of the impacts of La Niña in 2017 than using tropical Pacific SSTs. Future seasonal forecasts could be improved by using the Walker Circulation Index.

Despite the advances in seasonal forecasting from this and other studies, these forecasts remain a challenge. This past year, 2018, was no exception, as hurricane activity was again well above normal despite a developing El Niño event in the Pacific. As in 2017, the Walker Circulation Index remained more La Niña–like, which was indicative of conditions that may have contributed to the enhanced tropical cyclone activity. The authors are planning another study examining the 2018 season.

Klotzbach, P. J., C. J. Schreck III, J. M. Collins, M. M. Bell, E. S. Blake, and D. Roache, 2018: The extremely active 2017 North Atlantic hurricane season. *Monthly Weather Review*, **146**, 3425–3443. https://doi.org/10.1175/MWR-D-18-0078.1

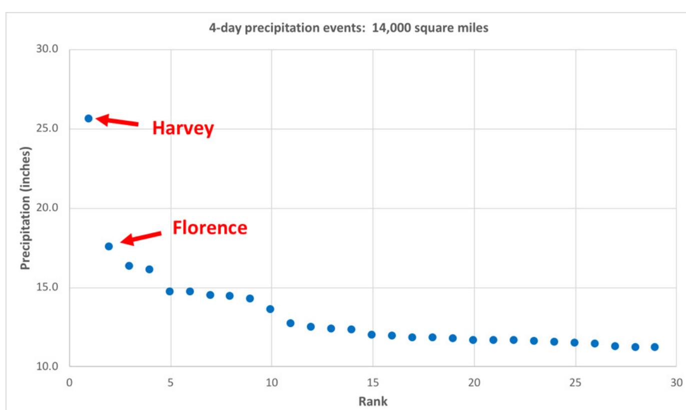
NCICS in the Media: Hurricane Florence

Unfortunately, the 2018 hurricane season brought devastating impacts to the United States much like those seen in 2017. The Carolinas were hit particularly hard by Hurricane Florence, and experts on tropical cyclones and extreme precipitation at NCICS provided the public with some context on this historic event through several media outlets.

In advance of Florence making landfall, Carl Schreck participated in a discussion on the "ACC Today" program on SiriusXM radio. Although the discussion was initially aimed at the impacts on scheduled ACC football games, the result was an insightful discussion about tropical storms, the risks they present, and the role of climate change in altering the behavior of storms. You can hear the interview on our web page. Carl was also featured in a segment on WLOS TV in Asheville, NC, where the discussion focused on how climate change is affecting the intensity and tracks of tropical storms.

Less than two weeks after Florence made landfall, Ken Kunkel produced a preliminary analysis comparing the four-day rainfall totals from Florence to other heavy rainfall events across the United States, averaging over areas ranging from 10,000 square miles to up to 90,000 square miles.

When averaging over 14,000 square miles, Florence ranked as the second-rainiest storm in U.S. history, behind only 2017's Hurricane Harvey. When averaging over 20,000 square miles, Florence ranked as the 7th rainiest storm.



Ken Kunkel analyzed heavy rainfall events across the continental United States over the last 70 years. When averaging rainfall totals over an area of 14,000 square miles, Hurricane Florence ranks second, behind only Hurricane Harvey.

The analysis was detailed in an Associated Press story by Seth Borenstein that was picked up in numerous publications around the country. Ken also presented his results at the 2019 AMS meeting—that presentation is available online. More details are also available on our website.

ACCESS AND SERVICES DEVELOPMENT

Common Ingest – Rebuilding NCEI's Ingest Pipeline

Before NCEI can store data and make it available to users, it first needs to bring those data into the archives. Information arrives at NCEI in a huge variety of formats from about 80 different providers from around the world. It all adds up to about 6.7 terabytes per day of weather and climate data information arriving in as many as 39,000 archive information packages.

Until recently, the data ingest infrastructure at NCEI in Asheville relied on a complex and aging suite of legacy software products that had been gradually pieced together over many years as new datasets and new types of information were added to the ever-growing archive. Replacing that software stack with a modern, robust, and efficient architecture was a major software engineering challenge.

The team tasked with building an all-new "Common Ingest" system included federal civil servants, contractors, and CICS–NC's Linda Copley and Lou Vasquez. Working in an agile development framework and building on efforts at NCEI in Boulder, Colorado, the team implemented a modern software architecture composed of an Ingest Manager and multiple Ingest Engines.

Ingest Manager is responsible for submitting granules through the system for processing and monitoring the result of these submissions. Ingest Engines are responsible for processing granules as they pass through the system. Some engines are designed to route processing to the next engine, removing the necessity to pass all processing through the manager.

The new Common Ingest system provides a browser-based interface for configuration and monitoring. It also stores all steps of processing files through the system, resulting in persistent system status and full file provenance throughout the ingest process. Common Ingest is built to handle multiple, complex data streams without the need for additional programming.

Over the course of the past year, the team deployed the new Common Ingest software, began migrating datasets from the legacy system to Common Ingest, and completed all the functionality required to implement all of the datasets archived at NCEI's Asheville location.

NOAA Big Data Project

NOAA's Big Data Project (BDP) facilitates public use of key NOAA environmental datasets by providing copies of the data in the cloud, making them more easily accessible to the general public and allowing users to perform analyses directly on the data.

CICS–NC provides technical expertise and IT infrastructure for the BDP project, serving as a broker between NOAA and the public cloud collaborators. The Institute is currently transferring and certifying multiple NOAA datasets to several cloud platforms, including Amazon Web Services, Google Cloud Platform, IBM NOAA Earth Systems Data Portal, and the Open Commons Consortium.

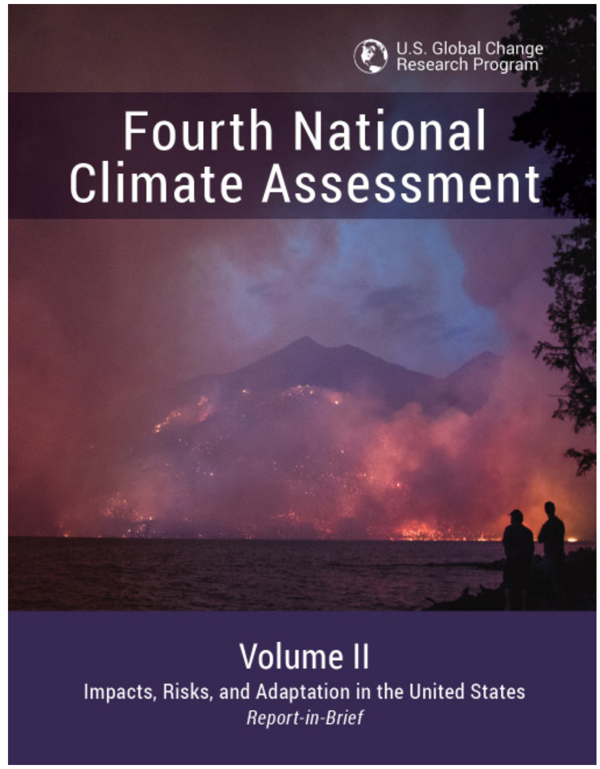
The datasets we transmit to our cloud collaborators span the range of NOAA's mission and observing systems. Key ongoing activities include transferring near-real-time data from NOAA's GOES-16 and GOES-17 satellites to three providers—which involves moving more than 700 gigabytes of information per day—and providing NOAA's National Water Model and High-Resolution Rapid Refresh (HRRR) atmospheric model data and NOAA NCEI's Global Historical Climatology Network Daily (GHCN-D) temperature dataset to multiple cloud providers.

CICS–NC is also involved in transferring NOAA's Global Ensemble Forecast System, Operational Forecast System, and Climate Forecast System data to the cloud.

For more information and links to details on the datasets available through each of these cloud providers, see https://ncics.org/data/noaa-big-data-project and https://ncics.org/cics-news/goes-16-data-in-the-cloud on our website.

ASSESSMENTS

Fourth National Climate Assessment Report



On November 23, 2018, the U.S. Global Change Research Program (USGCRP) released Volume II of the Fourth National Climate Assessment (NCA4), entitled *Impacts, Risks, and Adaptation in the United States* (https://nca2018.globalchange.gov).

The successful launch of this important report represents the culmination of more than two and a half years of very intense work by CICS–NC staff and their colleagues at NOAA's Assessments Technical Support Unit (TSU).

Since early 2016, the TSU has been working closely with the National Coordination Office at USGCRP and with several hundred authors around the country, providing an array of scientific and technical expertise to support the development and delivery of both Volume II and its predecessor, the *Climate Science Special Report: Volume I of the Fourth National Climate Assessment*.

The summer and fall of 2017 were particularly busy, as the TSU was racing to finalize production on Volume I and to prepare a draft version of Volume II. On November 3, 2017, Volume I was released and the draft version of Volume II was made available for public comment and for expert review by the National Academies of Science, Engineering, and Medicine.

As the feedback from the reviews of Volume II came in during early 2018, the most intensive phase of the TSU's work on the multi-year project began. Several members of the TSU attended an author meeting in late March, and from that point on, the TSU was heavily engaged in a wide range of tasks, including producing new scientific analyses and figures, conducting detailed editorial reviews of the text, and developing and refining infographics.

Concurrently, the TSU web team was working on the design and functionality of the website for Volume II and collaborating with colleagues from the National Environmental Modeling and Analysis Center (NEMAC) on the development of several interactive figures. Meanwhile, when not busy leading the TSU science team, Ken Kunkel was making contributions as a co-author on four chapters of the report.

Following additional rounds of government review, the TSU worked against tight deadlines to complete final copyediting and figure revisions, secure remaining copyright permissions for photos and figures, and convert more than 1,500 pages of Word documents into polished PDF and web versions of the report. The TSU and the NOAA NCEI visual communications team also supported the development of several supplemental products.

While Volume I focuses on the physical science of climate change, Volume II is a much larger report that explores the sectoral and regional impacts and risks of climate change, as well as the state of adaptation and mitigation efforts across the country. The release of Volume II generated significant attention from the public and the media. On the day of release, the report was featured in more than 2,000 news articles (potentially reaching more than 1.8 billion people) and was mentioned in more than 18,000 social media posts. On the following day, it was featured on the front page of more than 140 newspapers.

In the first two weeks following release of Volume II, the website received more than 650,000 visits, and the *Report-in-Brief*—a 196-page summary of the report findings and key messages from all of the chapters—was downloaded more than 38,000 times. The report will continue to inform planning, decision-making, and discussions of climate change risks, impacts, and responses for years to come.

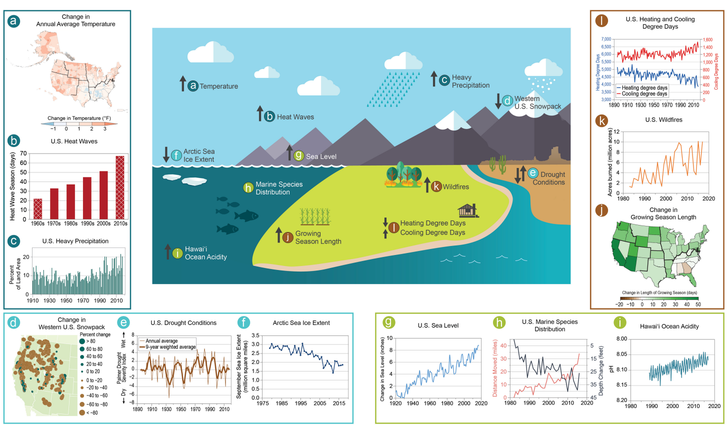
NCA4: Unprecedented Transparency and Data Access

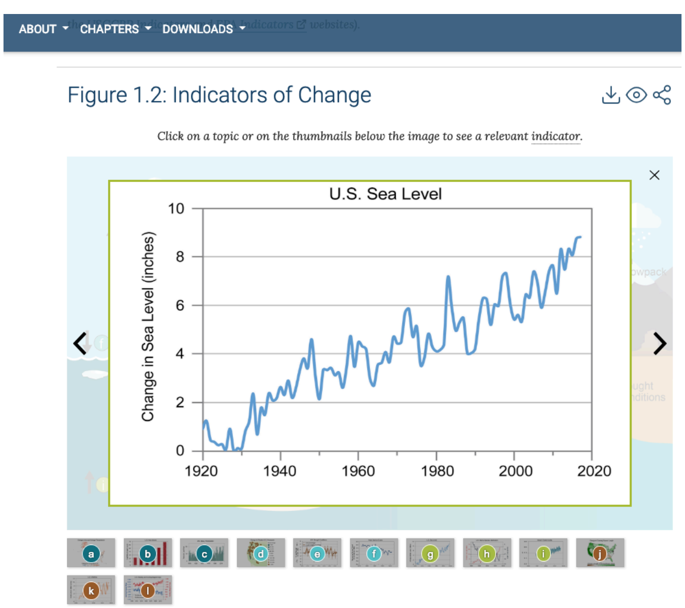
The National Climate Assessment is classified by the Federal Government as a "highly influential scientific assessment," which means that it must adhere to very high standards of peer review, data accessibility and transparency, and reproducibility. A significant portion of the work done at the TSU is aimed at ensuring those standards are met.

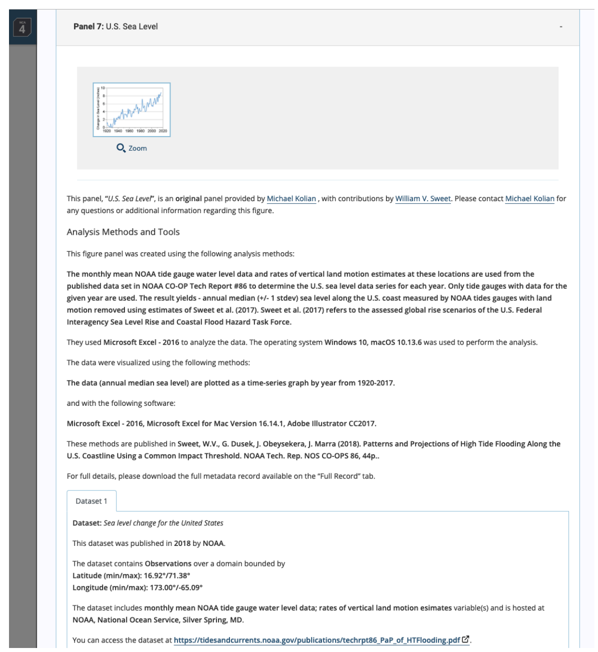
As one part of that ongoing effort, the data and web teams at the TSU built and continue to refine a web-based tool for collecting source information and detailed metadata for all of the scientific figures and infographics included in the NCA reports, as well as other reports produced directly by the TSU, such as the NOAA State Climate Summaries.

Data Architect Sarah Champion oversaw the collection and extensive quality control of the metadata for more than 370 figures comprising more than 900 individual panels in Volumes I and II of NCA4. All of this information was then transmitted to the U.S. Global Change Research Program's Global Change Information System (GCIS) using tools built by NCICS software engineers Jim Biard and Andrew Thrasher. Details on more than 5,500 unique papers, reports, and other sources of information cited in the report were also transmitted to GCIS.

The figure metadata is accessible to online readers at the click of a mouse via an interactive metadata viewer designed by Sarah Champion and Angel Li. In addition, 13 datasets derived by the TSU to generate more than a dozen original NCA4 figures are directly accessible via this same metadata viewer. These datasets are available in multiple file formats and are each accompanied by a tailored ReadMe file. This improvement takes NCA data accessibility to the next level. While some data for the Third National Climate Assessment (NCA3) were made available on the NCICS website in the months following release, this is the first time derived data for NCA have been made available immediately and directly via the report website. Like the NCA3 data files, these files are hosted on the NCICS website.



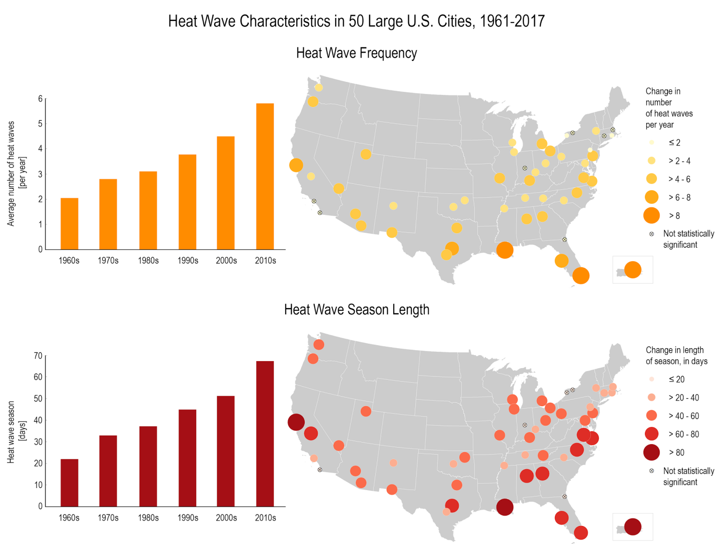




(top left) Figure 1.2 from NCA4 Volume II consists of an infographic and 12 charts showing trends in key climate indicators. (bottom left) The interactive online version (built by colleagues at NEMAC) allows users to scroll through zoomed-in versions of the 12 indicators charts. (top right) Clicking on the "eye" symbol above any figure brings up a viewer showing the metadata for that figure. For scientific figures created specifically for the report, as in this example, the metadata viewer provides complete details on the underlying datasets and the methodology used to generate the data visualization.

Global Change Indicators

In addition to her duties as a member of the TSU science team supporting the National Climate Assessment project, NCICS' Laura Stevens also serves as a coordinator for the USGCRP Indicators Interagency Working Group, managing the development and maintenance of the USGCRP's catalog of climate change indicators. Working with colleagues from NCEI, Laura led the production of several indicators that were recently added to the site and played a key role in drastically reducing the time required to identify, develop, approve, and release new indicators.

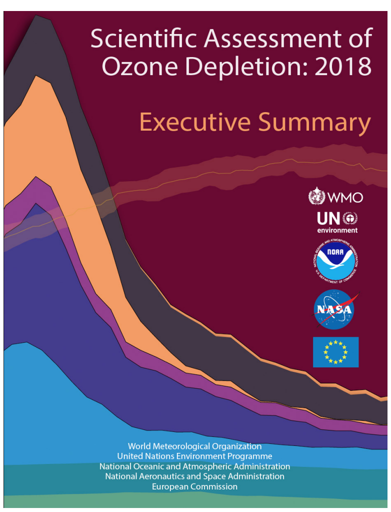


Laura also handled much of the data visualization work for a companion set of indicators that constituted one of the foundational figures in NCA4 (see figure on previous page). The TSU web and data teams are currently working on incorporating the metadata viewer designed for NCA4 into the USGCRP Indicators Platform. When rolled out later this year, users of the indicators will have easy access to key details and underlying datasets.

One of the newest USGCRP indicators tracks U.S. trends in both the number of heat waves per year (top chart and map) and the length of the season in which heat waves occur (bottom chart and map). Both metrics have been increasing steadily in recent decades. For more details, see https://www.globalchange.gov/browse/indicator-details/3983

International Assessments

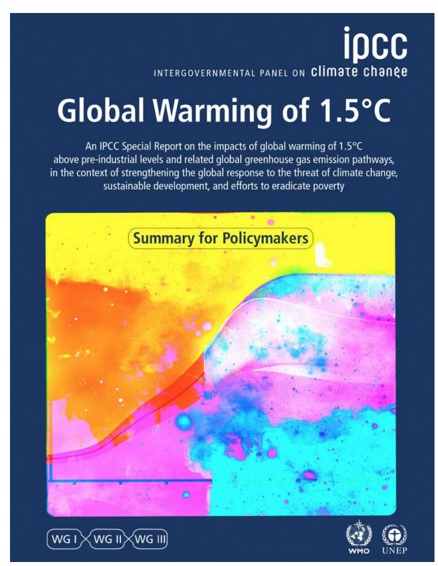
NCICS's assessments editorial team also made significant contributions to two major international assessment projects:



In addition to leading the NCA4 editorial team, Brooke Stewart provided a detailed scientific edit of the 2018 edition of the quadrennial Scientific Assessment of Ozone Depletion. This report, led by the World Meteorological Organization and the United Nations Environment Programme, evaluates the state of the science on the ozone layer in support of the Montreal Protocol agreement. Andrea McCarrick and Tiffany Means provided additional technical and copyediting support. The report, which is available at https://www.esrl.noaa.gov/csd/assessments/ozone/2018, provides crucial information for policymakers managing agreements on emissions of ozone-depleting substances.

Tom Maycock, who is also part of the NCA editorial team, provided editorial support for the Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C of Global Warming. He participated in the IPCC's 48th Plenary meeting and first joint session of the three IPCC Working Groups in October in Incheon, Korea, where the Special Report's "Summary for Policymakers" was finalized and approved by representatives from all participating governments.

This highly policy-relevant report received massive worldwide attention. In the first 48 hours after release, the "Summary for Policymakers" received more than 8 million website hits and was the subject of more than 15,000 online and print news articles.



CLIMATE DATA RECORDS AND DATA STEWARDSHIP: Arctic Sea Ice

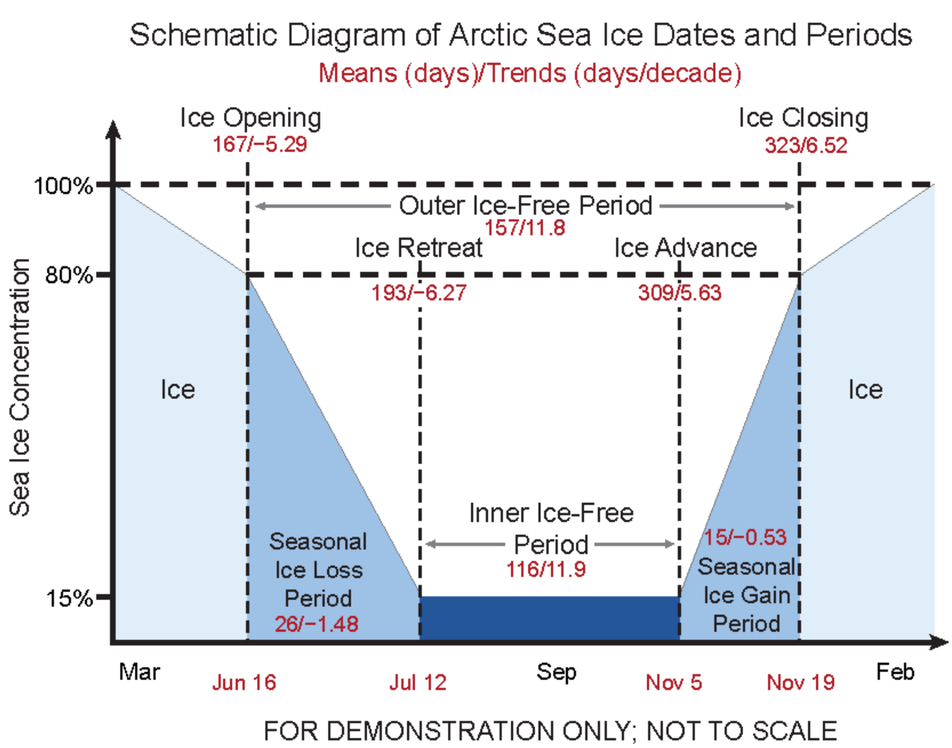
Two recent papers by a team of authors, including CICS–NC's Ge Peng, explore the changing seasonality and regional variability of Arctic sea ice cover. This research provides a more detailed understanding of changes in the timing of critical thresholds, such as the annual start of melting in the spring, and how changes in ice cover patterns vary spatially across the region.

The fact that Arctic sea ice cover is declining rapidly in a warming world is well known. However, changes in the annual maximum and minimum ice extent are not the whole story. The timing of seasonal milestones, such as the start of the melt season in the spring and the start of ice advance in the fall, is also changing. These changes have important implications for society and for efforts to forecast annual sea ice conditions.

Two recent papers from CICS–NC's Ge Peng and colleagues from the National Snow and Ice Data Center, the University of Washington, and Oregon State University quantify trends in key seasonal thresholds, both for the Arctic as a whole and for twelve subregions. Both papers use data for 1976–2016 derived from the daily passive microwave sea ice concentration Climate Data Record (CDR), which is the result of a collaboration between CICS–NC, NOAA, NASA, and the National Snow and Ice Data Center.

The first paper, published in *Remote Sensing*, concludes that key dates related to the retreat of the sea ice in spring and summer—including the onset of melt and the dates at which sea ice cover drops below thresholds of 80% and then 15%—are arriving earlier at a rate of about 5 days per decade. Similarly, the advance of sea ice cover is starting later in the fall, with the dates at which sea ice cover exceeds thresholds of 15% and then 80% getting later at the same rate of about 5 days per decade.

These threshold metrics serve as useful indicators of a changing climate, but they also provide information that is useful in the shorter term. For example, better data on the timing of melt onset and the seasonal ice loss period in a given year can improve efforts to forecast ice cover extent and the length of the open-water (nearly ice-free) season that summer. This information has implications for navigation, economic activity, and hunting and transportation for indigenous populations, as well as for wildlife and ecosystems.



This conceptual diagram shows the key thresholds and periods analyzed in the paper. The cycle depicted here starts at the beginning of March and ends on the last day of the following February. The numbers in red show the average date (as a number of days since March 1) of occurrence, followed by the estimated trend measured in days per decade.

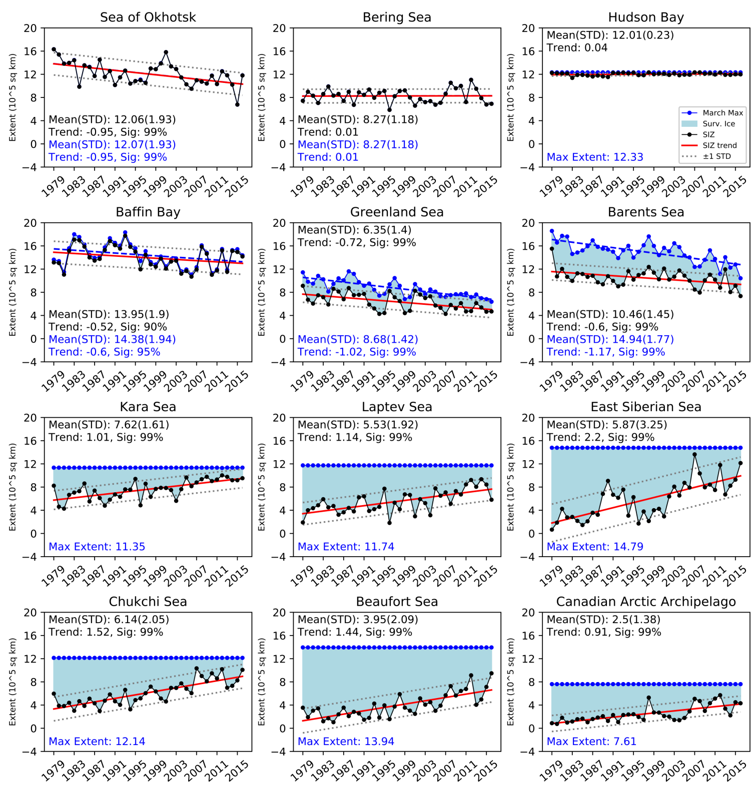
Corresponding average dates are shown in red along the x-axis. For example, the ice opening threshold occurs on average on the 167th day of the cycle, or June 16th, and is shifting earlier in the year at a rate of 5.29 days per decade.

Source: Peng et al. 2018, licensed under a Creative Commons Attribution 4.0 International License.

A second study by the same author group published in *Environmental Research Letters* focuses on the regional variability of the dates of these key seasonal thresholds and periods. The study divides the Arctic into twelve regions, with varying geography and weather patterns. For example, the Barents Sea is an open ocean with a southern peripheral boundary, while Hudson Bay is landlocked in the central Arctic. Both winter sea ice extent and summer retreat vary from year to year in the Barents Sea, while Hudson Bay sees more consistent conditions, being fully ice-covered each winter and almost entirely free of ice each summer.

A key conclusion of the paper is that the seasonal ice zone (SIZ)—the area in which sea ice advances and retreats each year—is generally expanding. This is consistent with the declining trend in overall sea ice extent. The inner ice-free period – when ice extent is below the 15% threshold – is also expanding. This increases the amount of solar radiation that is absorbed by the oceans rather than being reflected by ice cover during the melting season, which tends to further increase the long-term trend towards reduced ice volume. The authors report trends for nine different metrics for each of the twelve regions (some metrics do not apply for all regions).

Together, these papers advance our understanding of key seasonal and regional aspects of ongoing, rapid changes in Arctic sea ice cover. The data (Steele et al. 2019) will soon be available from NSIDC.



These charts show sea ice data for 12 Arctic regions. Data and statistics for March sea ice extent (SIE) are shown in dark blue, while data and statistics for seasonal ice zone (SIZ) are shown in black.

The light blue shading indicates the surviving SIE at the end of the melt season. In regions that are open to the south (such as the Baffin Bay and Greenland regions), there are statistically significant trends in March SIE ranging from –0.6 x 105 km^2 to –1.02 x 105 km^2, although there is no significant trend for the Bering region.

Landlocked and interior regions (such as the Kara, Chukchi, and Beaufort regions) are still entirely ice covered during March (except for a small ice-free area in the Kara Sea in 2008) but show increasing trends in the seasonal ice zones. Source: Bliss et al. 2019 licensed under a Creative Commons Attribution 3.0 International License.

Peng, G., M. Steele, A. Bliss, W. N. Meier, and S. Dickinson, 2018: Temporal means and variability of Arctic sea ice melt and freeze season climate indicators using a satellite climate data record. *Remote Sensing*, **10**, 1328. http://doi.org/10.3390/rs10091328

Bliss, A. C., M. Steele, G. Peng, W. N. Meier, and S. Dickinson, 2019: Regional variability of Arctic sea ice seasonal change climate indicators from a passive microwave climate data record. *Environmental Research Letters*, **In press**. http://dx.doi.org/10.1088/1748-9326/aafb84

Steele et al., 2019. Arctic sea ice seasonal change and melt/freeze climate indicators from satellite data. Boulder, Colorado, USA. National Snow and Ice Data Center Distributed Active Archive Center (forthcoming). https://dx.doi.org/10.5067/KINANQKEZI4T

CLIMATE LITERACY, OUTREACH, ENGAGEMENT, & COMMUNICATIONS

India: Supporting Climate Resilience and Climate Services

For more than two years, the Institute has been working closely with a variety of partners to help organizations in India build climate resilience and advance the state of local climate services capacity. Building on a successful and groundbreaking workshop held in 2017, we helped organize two more workshops in 2018 and contributed to discussions at a major sustainable development conference in February 2019.

World Sustainable Development Summit 2019

On February 11–13, 2019, Jenny Dissen and Andrew Ballinger joined over 2,000 delegates and speakers from more than 40 countries at the 2019 World Sustainable Development Summit in New Delhi. The three-day summit, hosted by The Energy and Resources Institute (TERI), brought together global leaders, policymakers, academicians, and corporate leaders, among others, to discuss the most urgent, universal climate issues.

Jenny Dissen and Andrew Ballinger at the World Sustainable Development Summit in New Delhi.

The theme of this year's summit was "Attaining the 2030 Agenda: Delivering on Our Promise." Topics of discussion included renewable and clean energy, climate data, data-based science policy solutions, adaptation, air quality, and innovations for a sustainable world.

Jenny and Andrew, along with TERI's Saurabh Bhardwaj and Shreya Trivedi, led a panel discussion on "Climate Services in India – Moving the Needle." Climate services are defined as "a mechanism to identify, produce, and deliver authoritative and timely information about climate variations and trends and their impacts on built, social–human, and natural systems on regional, national, and global scales to support decision making."

Changing climate patterns that affect health, food and freshwater availability, and air quality, among other concerns, have increased the demand for climate services. Global climate research organizations have undertaken initiatives to address limitations in information sharing, such as timing and accessibility, as well as the wide-ranging needs of users of such information, particularly countries facing the highest risks and impacts of climate change. An example of one such initiative is the World Meteorological Organization's Global Framework for Climate Services.

The panel discussion sought to define the current state of climate services in India and to generate ideas for expanding climate services capabilities across India through public and private partnerships.

The session also explored other global examples of user-engagement strategies, addressed the challenges of incorporating historical and projected climate information into decision-making, and examined an India-based case study on utilizing climate information to formulate action plans.

U.S.–India Partnership for Climate Resilience Workshops 2018

In early 2018, a U.S. delegation including Jenny Dissen and Ken Kunkel of CICS–NC, David Easterling of NOAA NCEI, and Katharine Hayhoe of Texas Tech University attended two workshops in India. The events, which built on the success of a similar set of workshops held in 2017, were part of the ongoing U.S.–India Partnership for Climate Resilience, one of the initiatives of the U.S.–India Joint Working Group on Combating Climate Change.

In New Delhi on February 9, 2018, CICS–NC and NOAA's National Centers for Environmental Information (NCEI) partnered with the Indian Institute of Tropical Meteorology–Pune (IITM-Pune), Understanding Climate and Health Associations in India, TERI, and the Indian Meteorological Society to convene the Workshop on High-Resolution Climate Projections and Analysis for India.

The aim of the collaborative workshop was to present and explain methodologies involved in downscaling international climate model data for the Indian subcontinent.

On February 12 and 13, the same members of the U.S. delegation attended a related workshop in Hyderabad, partnered by CICS–NC, NOAA NCEI, IITM-Pune, the Environmental Protection Training and Research Institute, and the National Bank for Agriculture and Rural Development.

The objectives of the workshop were to share expertise in climate modeling techniques, engage in hands-on exercises on climate downscaling methods, and discuss and collaborate on the application of downscaled climate information, particularly in the areas of agriculture, energy, and infrastructure planning.

See the links below for videos of several presentations and a newspaper article covering the Hyderabad workshop:

Welcome remarks: https://youtu.be/R9A55DVqppo

Dr. Kulkarini: https://youtu.be/X0gtyncd9zk

Ken Kunkel: https://youtu.be/uGGIV305o1c

Katharine Hayhoe: https://youtu.be/hbSXL8LDo6w

Newspaper article: https://telanganatoday.com/india-us-to-jointly-fight-climate-change

Telangana Today

[Scientific Intervention]

India, US to jointly fight climate change

Over 50 delegates from both countries attend EPTRI workshop, exchange ideas

MATTER OF CONCERN: *Climate change triggers floods, drought, extreme heat and sudden extreme rainfall.* — File Photo

SHARJEEL
HYDERABAD

In order to improve existing climate prediction models in the country, researchers from India are collaborating with their counterparts in the United States. As part of this initiative, Environmental Protection Training and Research Institute (EPTRI) held a workshop on 'High Resolution Climate Projections and Analysis for India' in Hyderabad on Monday.

The workshop features top environmental scientists from US who are sharing their knowledge of computing models to predict accurately temperatures, rainfall, pressure, pollution and all other aspects of climate change, said Director General of EPTRI, B Kalyan Chakravarthy.

"The stress is on collaborating and understanding from the US researchers, about what they are planning to do about climate change so that we can learn from them the best ways to tackle the challenge at a local level," he said. The scientific sessions will enable researchers to better understand the variations in climate change at the local level.

Govt schemes Mission Kakatiya and Haritha Haram are aimed at climate mitigation — DR RAJAT KUMAR, PRINCIPAL SECRETARY (ENVIRONMENT)

More than 50 delegates representing premier environment research institutes from the US and 16 Indian States are attending the climate change India-US workshop titled 'High Resolution Climate Projections and Analysis for India'.

Principal Secretary (Environment) Dr Rajat Kumar, who inaugurated the workshop, said the State government was implementing the schemes Mission Kakatiya and Haritha Haram for climate mitigation.

Dr David Easterling from US NOAA National Centre for Environmental Information said, "Working with India will help improve the overall advancement in down-scaling the impacts of climate change."

Dr Ken Kunkel from North Carolina State University, CSR Murthy from Nabard, Associate Consul General for US Geoffrey Chin, Dr Ashwini Kulkurni from IITM, Dr Sesha Srinivas and other delegates spoke on day one of the workshop. In addition to EPTRI, the climate change workshop was organised by Institute for Tropical Meteorology (IITM), the US Department of State, NOAA-NCEI, the Cooperative Institute for Climate and Satellites – North Carolina State University.

'Good environment as important as growth'

Director General of EPTRI, B Kalyan Chakravarthy is a firm believer in climate change. The top EPTRI official told Telangana Today that climate as a whole is undergoing a change which could potentially impact the entire animal species.

On climate change

Primarily, there is a need to understand climate change at various levels. There is a certain pattern of temperature, pressure, flow of air and water currents, making up a complete system. Over a period of time, the system remains constant and predictable. At present, however, the system is undergoing changes because of excessive emission of greenhouse gases and carbon dioxide. Due to this, environment as a whole is undergoing changes, which could impact several species of life.

Impact on human life

Floods, drought, extreme heat and sudden extreme rainfall are all caused by the change in the climate system. What does the farmer know about climate change? They plan according to conventional knowledge. Why is there 200mm of rainfall? How will the crop and the farmer survive? We need to know and inform the farmers about such extreme changes.

For Telangana, what is the vision of EPTRI?

We must provide clean air, clean water and a healthy environment to the people of the State. A good environment is as important as development. The State government has mooted a 'Clean Air Authority' to be set up soon. We are of the view that such a body needs to be set up at the earliest. We have also proposed for 192 forest blocks in and around Hyderabad to be developed as lung spaces and the Forest Department has responded positively.

Hyderabad Main
Page No. 2 Feb 13, 2018
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ANNUAL SCIENCE MEETINGS

Institute staff were once again very active at the recent annual meetings of the American Geophysical Union and the American Meteorological Society. Between the two events, our scientists and staff were involved with more than 50 presentations, posters, sessions, and town halls.

The workload at the 2019 AMS meeting was higher than expected for several Institute staff who were asked to take an active role in presentations and other sessions on behalf of federal co-authors who were unable to attend due to the partial government shutdown.

For a complete list of activities, see the AGU 2018 and AMS 2019 pages on our website.

SURFACE OBSERVING NETWORKS

Global Historical Climatology Network–Monthly Version 4

A major development at NCEI in 2018 was the rollout of version 4 of the monthly Global Historical Climatology Network temperature dataset, dubbed GHCNm v4. The update increases the number of observing stations included in the database from about 7,200 to about 26,000 and provides more robust uncertainty estimates.

NCICS's Jared Rennie was a key member of the NCEI team responsible for GHCNm v4. Jared is also a key contributor to the International Surface Temperature Initiative (ISTI), an international effort organized in 2010 to develop a more comprehensive, high-quality monthly record of global land surface temperature.

The ISTI databank, first released in 2014, now serves as the foundation for the revamped GHCNm dataset. ISTI in turn uses NCEI's daily temperature dataset (GHCN-Daily) as its primary input. These daily and monthly versions of GHCN have historically been completely distinct datasets, but now that GHCNm is built on the ISTI foundation, NCEI's monthly and daily datasets are, for the first time, directly linked.

For more information on Jared's work with ISTI, see our web story. NCEI also has a web story with more information on GHCNm v4. Technical details are available in Menne et al. 2018.

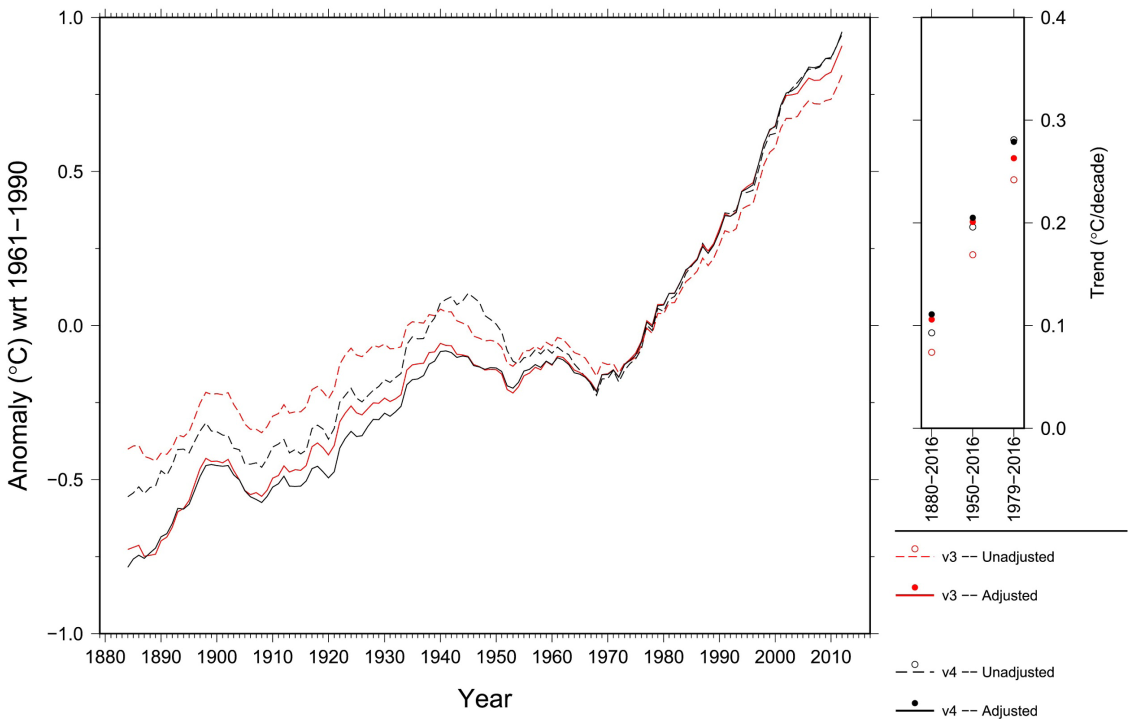

Figure 4a from Menne et al. 2018 compares global land surface temperatures from versions 3 and 4 of GHCNm. Values are shown for "adjusted" and "unadjusted" versions of both datasets, where the adjusted data are the result of a suite of calculations performed to account for non-climatic shifts, or biases, in the raw station data that arise from factors such as changes in instrumentation, changes in station locations, and changes in the time of day when observations were taken. The panel on the right shows the calculated trends in global land surface temperature for the various datasets for three different time periods. Source: Menne et al. 2018.

Menne, M. J., C. N. Williams, B. E. Gleason, J. J. Rennie, and J. H. Lawrimore, 2018: The Global Historical Climatology Network monthly temperature dataset, version 4. *Journal of Climate*, **31**, 9835-9854. http://doi.org/10.1175/JCLI-D-18-0094.1

NOAA NESDIS Award

Congratulations to Ronnie Leeper and his colleagues from NCEI on receiving the 2018 NOAA National Environmental Satellite, Data, and Information Service Outstanding Information Technology and Engineering Employees award. The honor was given in recognition of the team's efforts to develop and implement a new algorithm for measuring precipitation for NCEI's U.S. Climate Reference Network observing stations. The new algorithm outperformed the old approach by better characterizing light precipitation events and improved detection of the onset of precipitation. For more information on this work, see this NCEI web story: https://www.ncdc.noaa.gov/news/uscrn-implements-new-approach-precipitation. Ronnie was also the lead author on the peer-reviewed journal article that describes the new approach, which is available at https://journals.ametsoc.org/doi/10.1175/JTECH-D-14-00185.1.

RESEARCH HIGHLIGHT: Changing Instrument Flight Rules Conditions

In his spare time, NCICS' Scott Stevens is a private pilot who participates in local search-and-rescue efforts and teaches a weather course for pilots at a community college. Scott recently earned his Instrument Rating, which allows him to fly in poor weather conditions where the FAA's Instrument Flight Rules (IFR) apply. A question from his mother prompted Scott to wonder whether the frequency of IFR conditions, which are normally the result of either low cloud ceilings or ground-level visibility limitations (usually fog), have been changing over time.

Fortunately, Scott is an expert at accessing and analyzing weather data, so he set out to answer that question. Scott analyzed the frequency of IFR conditions at 30 of the busiest U.S. airports from 1973 through 2017. He found that IFR conditions are becoming notably less common at 28 of those 30 airports, with many locations seeing a decrease of 25% or more over that time period.

Scott Stevens, on the day he earned his Instrument Rating. Photo by Ray Davis.

IFR conditions require larger separations between planes, reducing the rate at which planes can take off and land. In some cases, they can even result in planes being diverted to different airports. So this decreasing trend in IFR conditions is good news both for airlines that want to operate as efficiently as possible and for passengers who are eager to reach their destinations on time.

Why the change? There are probably two factors at work. First, temperatures are rising, especially in urban areas where these busy airports are usually found. As a result, the moisture saturation conditions required for clouds and fog are probably happening less often. In fact, Scott found that low-visibility conditions almost never happen above 23°C (about 73°F)—a threshold that is being reached more often in a warming climate. Second, improved air quality as a result of pollution regulations means there are now fewer particles in the atmosphere for clouds and fog to form around.

Scott published his findings in the *Journal of Applied Meteorology and Climatology* and presented the results at the 2019 Annual Meeting of the American Meteorological Society in Phoenix. You can listen to Scott's presentation at https://ams.confex.com/ams/2019Annual/meetingapp.cgi/Paper/349041. The work was also highlighted in the Smithsonian's Air & Space magazine. You can read that article at https://www.airspacemag.com/daily-planet/good-news-pilots-weathers-getting-better-180971328/.

Stevens, S. E., 2019: Trends in Instrument Flight Rules (IFR) conditions at major airports in the United States. *Journal of Applied Meteorology and Climatology*, **58**, 615-620. http://dx.doi.org/10.1175/JAMC-D-18-0301.1

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