NCICS Highlights

North Carolina Institute for Climate Studies Inspire. Advance. Engage.

# 2018–2019 Institute Highlights

Formally approved as an inter-institutional research institute by the University of North Carolina General Administration in January 2011, 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's primary activity continues to be the operation of the North Carolina location of a NOAA Cooperative Institute. From 2009 through June 2019, NCICS hosted the North Carolina location of the Cooperative Institute for Climate and Satellites (CICS). In July 2019, CICS was superseded by the Cooperative Institute for Satellite Earth System Studies, with NCICS again acting as the North Carolina host organization (CISESS; see page 2). NCICS's mission is facilitated by its co-location with our primary NOAA sponsor, the National Centers for Environmental Information (NCEI), in the Veach-Baley Federal Complex in Asheville, North Carolina.

Other current extramural support includes federal projects supported by NSF, DoD, DOE, and NASA as well as several smaller private-industry project awards.

Our main objectives are to:

- promote discovery of new knowledge about global, regional, and local climate variability and its impacts, and
- provide information that is critical for determining trends and validating climate forecasts at all of these spatial scales.

Underpinning all of these activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth System.

# **Institute Vision**

- Inspire cutting-edge research and collaboration
- Advance understanding of the current and future state of the climate
- Engage with business, academia, government, and the public to enhance decision-making

# **A New NOAA Cooperative Institute**

NOAA Cooperative Institutes (CIs) provide long-term institutional relationships between NOAA and external academic partners; however, they are subject to a full competitive solicitation process every 10 years. NOAA released a Federal Funding Opportunity in November 2018 seeking proposals for a new Cooperative Institute that would build on the work done over the past 10 years by CICS.

Throughout December and January, NCICS staff worked closely with our partners at the University of Maryland (UMD) and an expanded consortium of other institutions and partners to develop and submit a comprehensive proposal for a new CI (Figure 1).

In May 2019, NOAA announced that the consortium led by UMD and NCSU had been selected to host the new Cooperative Institute for Satellite Earth System Studies (CISESS). CISESS began operations in July 2019, and we look forward to continuing our affiliation with NOAA NCEI as we expand on the success of CICS-NC. The science activities of CISESS are organized around three broad research themes: satellite services, Earth system observations and services, and Earth system research (Figure 2).

The CISESS Consortium includes the entire University of North Carolina System (17 campuses, including

NCSU); the University of Maryland, Baltimore County; the University of Alabama; the University of Alabama in Huntsville; the City University of New York; George Mason University; Oregon State University; Howard University; the University of Michigan; the University of South Carolina; the University of Georgia; the University of California, Irvine; South Dakota State University; Florida International University; and the University of Nebraska Medical Center. It also includes four nonacademic partners: The Pacific Northwest National Laboratory, the University Corporation for Atmospheric Research,

The Nature Conservancy, and the Research Triangle Institute.

The consortium also includes a significant participation of Minority Serving Institutions and NOAA Cooperative Science Centers to facilitate and accelerate the reach of CISESS activities to underrepresented groups and to promote the development of an increasingly diverse future workforce.

The Consortium institutions offer a broad array of graduate-level programs as well as the mechanisms to facilitate collaborative research, education, and outreach with NOAA (e.g., post-doctoral appointments, graduate research assistantships, and research appointments).



Figure 1: Cover of the CISESS proposal.



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# **Task Streams**

NCICS efforts are organized in eight task/activity streams:

### Administration

Administrative and information technology support for Institute activities

### **Access and Services Development**

Supporting improvements to access mechanisms for NCEI's data and product holdings

### **Assessment Activities**

Supporting interagency activities for global, national, and regional assessments of climate change

### **Climate Data Records and Science Data Stewardship**

Providing quality satellite and in situ climate observing datasets to document the Earth's climate

### **Climate Literacy, Outreach, Engagement, and Communications**

Improving public knowledge and understanding of climate change, its impacts, and options for adaptation and mitigation

### **Surface Observing Networks**

Sustaining and improving the quality of in situ observations and observing networks

### Workforce Development

Preparing the next generation of climate scientists, engineers, and technicians

### **Other Institute Projects**

Augmenting Institute capabilities through NCICS consortium member partnerships and collaborative endeavors supported by various other sponsors

# **Selected Highlights By Task Stream**

# **Administration**

### **Computing and Network Infrastructure**

- Server replacement. The compute cluster head node hardware was replaced to better support user needs. The new hardware has four times as many CPUs and twice the memory of the old hardware.
- **Network upgrades**. The end-of-life firewall was replaced with a current model that fully supports our newly upgraded symmetrical 10 Gigabit internet connection, additional hosts were connected to 100 Gigabit interfaces, and all critical hosts now have redundant network paths.
- File systems and tape library replacement. The Quantum Stornext file systems and tape library were replaced with Gluster file systems, six new Red Hat configured servers with internal disk storage were purchased to host the output data file system, four Promise SANs and two Stornext Metadata Controllers were repurposed to host the input data file system, and all data was moved to Amazon Glacier to decommission the iScalar 6000 tape library.



Diagram showing the newly upgraded NCICS network and computing infrastructure

# **Access and Services Development**

### **NOAA Big Data Project**

CICS-NC is a partner in the NOAA Big Data Project (BDP), acting as a broker between NOAA and the public cloud providers. Our data and information technology experts help transfer multiple NOAA data sets to several Cloud platforms and certify the cloud copies of the data.

Cloud partners include Amazon Web Services, Google Cloud Services, IBM NOAA Earth Systems Data Portal, Microsoft Azure, and the Open Commons Consortium.

The second year of BDP efforts focused on broadening the availability of NOAA datasets, maintaining performance, and using cloud-based agents to mediate transfers.

- New datasets made available to the BDP collaborators include the National Water Model, Climate Forecast System, Global Forecast System, Global Ensemble Forecast System, Operational Forecast System, Global Historical Climate Network Daily, Integrated Surface Database, Global Hourly, and various products from GOES-17 and NOAA-20.
- We began using Apache NiFi, a workflow management tool that supports writing the data directly into cloud-native object stores.
- The daily transfer volume to the collaborators increased from about 500GB per day in 2017 to about 7.75TB per day in 2018.
- We've expanded procedures for reconciling cloud copies of the data with official versions in the NOAA archive.

### **NOAA's Climate Services Portal Program**



#### Overview and NCICS/CICS-NC Contributions

NOAA's Big Data Project (BDP) is designed to facilitate public use of key environmental datasets by providing copies of NOAA's information in the Cloud, allowing users to do analyses of data and extract information without having to transfer and store these massive datasets themselves. NCICS/CICS-NC is a partner in the BDP and acts as a broker between NOAA and the



public cloud providers. Our data and information technology experts play key roles in the transfer and certification of data sets, and our high-performance computing cluster serves as a critical gateway for delivering data to the Cloud. We are currently facilitating the nearreal-time transfer of more than a dozen datasets, including NEXRAD Level 2 and 3 radar data, GOES-16-17 satellite data, National Water Model, Global Ensemble Forecast System (GEFS), Global Forecast System (GFS) and other data sets to several Cloud platforms, including Amazon Web Services (AWS), Google Cloud Platform (GCP), IBM NOAA Earth Systems Data Portal, Microsoft Azure and the Open Commons Consortium (OCC).

See the links below for more information on the Big Data Project and selected examples of the growing collection of datasets available to you in the Cloud. The "Listing of holdings" link under each Cloud platform provides a table of currently available NOAA datasets from that Cloud provider.

For an overview of NOAA's Big Data Project, please see NOAA Big Data Project

For more on NCICS/CICS-NC's contributions to the project, see: CICS-NC Portfolios: The NOAA Big Data Project and CICS-NC News: GOES-16 Data in the Cloud



The BDP section of our website provides an overview of the project and lists the NOAA data holdings available through each BDP partner.

UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) provides continuing technical support for NOAA's suite of climate services tools. Accomplishments this year included maintenance and development support for the climate.gov team and input on strategic planning for a global climate dashboard. NEMAC also developed and deployed version 2.5 of the Climate Explorer; version 3 is under development, including user testing at the 2019 National Adaptation Forum. NEMAC also provides support to the National Integrated Drought Information System (NIDIS) as it prepares to redesign the https://www.drought.gov site and migrate it from Drupal 7 to Drupal 8.

### Architecture Development and User Interface Design for NCEI and OneStop

Mediacurrent analyzed user interactions with the new NOAA OneStop website and provided a full competitive analysis on the existing NOAA Data Catalog and NCEI Geoportal. The resulting strategic approach plan for OneStop included a set of key performance indicators, an assessment of current web analytics, target audience research, and a recommended sitemap and information architecture.

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### **Embracing the Cloud**

Recognizing the opportunities provided by cloud computing environments, NCICS welcomed Dr. Brad Rubin, Director of the Center of Excellence for Big Data, from the University of St. Thomas in St Paul, Minnesota, for a sabbatical visit during the Spring of 2018. During his time in Asheville, he worked with NCICS researchers on two "proof of concept" projects using the Amazon Web Service platform. The first involved processing hundreds of terabytes of geostationary satellite albedo data, while the second involved running a computationally intensive pairwise homogeneity algorithm hundreds of times in parallel on a global land surface temperature dataset.

- Extrapolating from a small pilot study indicated that the satellite albedo processing could be completed in about 20 hours, compared to about 1,000 hours on the Institute's own compute cluster, and at a fraction of the cost.
- For the temperature dataset, individual jobs completed in an average of about 18 hours versus about 30 hours on NCEI's system, and an entire 100-ensemble set of runs took less than 7 days—the same process generally takes a month or more on the NCEI system.

The team wrote a blog about their experiences and lessons learned that was published by Amazon as part of its Sustainability Data Initiative. The story is available at https://aws.amazon.com/blogs/public-sector/embracing-the-cloud-for-climate-research/.

### **NCEI Infrastructure Architecture Planning and Implementation**

NCICS researchers are supporting a new, cross-function collaborative team at NCEI exploring IT infrastructure and architecture solutions that will support a modern, flexible, distributed approach to data science, archive, and access capabilities. Preliminary outcomes included equipment purchasing, security review, and initial deployment of object storage, data, and metadata workflow systems and development of a "Common Systems Notional Architecture" for NCEI.



This diagram represents the NCEI Common Systems Notional Architecture developed in Mission Science Network meetings. Each component performs a major NCEI function: Inventory Manager at the center collecting event information from all services and processing it through center-defined workflows to generate comprehensive metadata and events for end-user oriented views; Common Ingest taking files into the center, preparing and storing them via Storage Services; Collection Manager allowing users to interact with existing stored collection metadata; Access Services providing a front-end for users external to the system to obtain data and related information; OneStop offering a flexible query-based view for locating data throughout known storage.

# **Assessment Activities**

### The Fourth National Climate Assessment, Volume II (NCA4)

On November 23, 2018, the U.S. Global Change Research Program released *Volume II of the Fourth National Climate Assessment: Impacts, Risks, and Adaptation in the United States.* The report explores the sectoral and regional impacts and risks of climate change, as well as the state of adaptation and mitigation efforts across the country.

On the day of release, Volume II 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.

The report will continue to inform planning, decision-making, and discussions of climate change risks, impacts, and responses for years to come.

The NOAA Technical Support Unit, staffed primarily by NCICS personnel, provided extensive scientific and technical support for the design, development, production, and delivery of the report in print, digital, and web formats.

### **Key Technical Support Unit Contributions**



Volume II Impacts, Risks, and Adaptation in the United States Report-in-Brief

- provided project management support throughout the development and production process
- served as lead or contributing authors for four chapters (Southeast, Midwest, Appendix 3: DataTools and Scenario Products, and Appendix 5: Frequently Asked Questions)
- developed 18 specialized scientific figures for the report, including projected changes in vapor pressure deficit for the Midwest, hydrologic changes for the Northern Great Plains, and regional analysis of Localized Constructed Analogs (LOCA) temperature and precipitation extremes for several cities
- managed collection and quality control of metadata for all figures
- produced 47 derived temperature- and precipitation-based climate variables from the LOCA dataset
- provided access to the data for all figures created by the TSU via the report's interactive metadata viewer and posted the full suite of derived LOCA datasets on https://scenarios.globalchange.gov/
- completed multiple editorial reviews of the entire report as the content evolved in response to comments from the public, the National Academies, and federal agencies
- designed, developed, and delivered the interactive report website as well as a new viewer for accessing figure metadata
- contributed extensive graphic design support, including coordinating with graphic designers in NCEI's Communications and Outreach Branch, developing many new figures and infographics, refining more than two hundred other figures, designing templates for the PDF versions of the report, and producing the final PDF products



This figure created by the TSU for NCA4 shows projected changes in plant hardiness zones due to increases in winter temperatures. Source: USGCRP 2018.

### **State Climate Summaries**

TSU science team staff completed and published the NOAA State Climate Summary for Puerto Rico and the U.S. Virgin Islands (NOAA Technical Report NES-DIS 149-PR). The report summarizes historical climate trends as well as Coupled Model Intercomparison Project Phase 5 (CMIP5) projections of temperature and precipitation for the islands.

The team is currently rolling out updates to the summaries for all 50 states, which were originally released in 2017. The project involves updating approximately 📕 ABOUT - CHAPTERS - DOWNLOADS -CH 19: SOUTHEAST CHAPTER 19 Southeast Background Throughout the southeastern United States, the impacts of sea level rise + Authors increasing temperatures, extreme heat events, heavy precipitation, and decreased water availability continue to have numerous consequences + Contributors for human health, the built environment, and the natural world. This + Recommended Citation assessment builds on the above concerns described in the Third National Climate Assessment (NCA3) and includes impacts to urban and rural + Related Links landscapes as well as natural systems. The impacts from these changes are becoming visible as 1) flooding increases stress on infrastructure, ecosystems, and populations; 2) warming temperatures affect human health and bring about temporal and geographic shifts in the natural environment and landscapes; and 3) wildfires and growing wildfire risk create challenges for natural resource managers and impacted communities The Southeast includes vast expanses of coastal and inland low-lying areas, the southern (and highest) portion of the Appalachian Mountains numerous high-growth metropolitan areas, and large rural expanses. Embedded in these land- and seascapes is a rich cultural history developed over generations by the many communities that call this

areas, the southern (and highest) portion of the Appalachian Mountains, mumcrous high-growth metropolitan areas, and large truat expanses. Embedded in these land- and seascapes is a rich cultural history developed over generations by the many communities that call this region home. However, these beaches and abyous, fields and forsets, and cities and small towns are all at risk from a changing climate. These risks vary in type and magnitude from place to place, and while some climate change impacts, such as sea level rise and extreme downpours, are being acutely felt now, others, like increasing exposure to dangerously high temperatures—often accompanied by high humidity—and new local diseases, are expected to become more significant in the coming decades. While all regional residents and communities are potentially at risk for some impacts, some communities or populations are at greater risk due to the locations, services available, and economic situtions. In fact, a recent economic study using a higher scenario (RCP8.5)<sup>II</sup> suggests that the southern and midwestern populations are likely to suffer the largest losses from projected Climate change in the United States. According to the article, "[b]ceause losses are largest to increase presexing inequality in the United States." Understanding the demographic and



The NCA4 website allows viewers to quickly access topics within each chapter via a navigation menu, share sections and figures via social media, and expand and shrink figures. Icons above each figure facilitate viewing larger versions of the image and accessing figure metadata.

1,500 figures, revising text to include recent climate-related events, updating figure metadata, coordinating with regional climate experts, and producing new PDF and web versions of each summary.

### **Other Assessment Reports**

### Second State of the Carbon Cycle and Ozone Assessments

In addition to its work on NCA4, the TSU web team produced the website for another USGCRP report the *Second State of the Carbon Cycle Report*, which was released in PDF form in November 2018. Work began on the full HTML web version shortly after the release of NCA4, and the new site was released in April 2019 at https://carbon2018.globalchange.gov.



Meanwhile, the TSU editorial team provided science editing and copyediting support for 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.

The PDF version of the report is available at https://www.esrl.noaa.gov/csd/assessments/ozone/2018.

The TSU web team also developed a website for the report, which was released in June 2018 and is available at https://www.esrl.noaa.gov/csd/assessments/ozone/2018/

### **Climate Change Indicators**

TSU staff continue to support the USGCRP Indicators project in conjunction with colleagues from NCEI's Monitoring branch.

Outcomes this year included process improvements that significantly reduced the time required to identify, develop, approve, and release new indicators and the resulting successful rollout of several new indicators.

The TSU web and data teams are currently working on incorporating the metadata viewer designed for NCA4 into the USGCRP Indicator Platform. When rolled out later this year, users of the indicators will have easy access to key details and underlying datasets.

### **India Partnership for Climate Resilience**

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 ca workshops held in 2017 and early 2018, recent acc



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.

and advance the state of local climate services capacity. Following successful and groundbreaking workshops held in 2017 and early 2018, recent accomplishments included:

- partnering with The Energy Resource Institute (TERI, India) to organize the October 2018 "Workshop on Climate and Health" in New Delhi, which included topics on future climate health impacts, the relationship of vector-borne diseases to temperature changes, health impacts and adaptation plans for urban heat, tools for citizen science, climate-smart health systems, and methods for climate projections and modeling.
- supporting the World Resources Institute (WRI) and the Partnership for Resilience and Preparedness (PREP) in the development of tailored "climate preparedness dashboards" for two Indian states, Madhya Pradesh and Uttarakhand. www.prepdata.org/dashboards
- organizing a session, "Climate Services in India Moving the Needle," at the TERI World Sustainable Development Summit, featuring a presentation on the U.S.–India Partnership for Climate Resilience activities and the facilitation of panelists on the topic of "Capacity Building and Climate Services: Perspectives from Public and Private Sectors."



The World Sustainable Development Summit 2019 panel discussion, Climate Services in India – Moving the Needle, highlighted current government climate services initiatives, climate extremes in India, climate products and services for regional modeling, climate tools under development, and current challenges for mountainous regions.

# **Climate Data Records and Science Data Stewardship**

## Scientific Subject Matter Expertise Support and Climate Data Record Product Teams

This year, NCICS scientists participated in integrated product teams for six CDRs: Total Solar and Solar Spectral Irradiance, Land Surface Bundle, Global Surface Albedo, Sea Ice Concentration – Annual, Ocean Surface Bundle, Precipitation – CMORPH. NCICS staff are also serving as Product Leads for 21 of NCEI's 208 products and as Product Area Leads for 3 of 15 product areas.

## **NCEI Common Ingest Agile Development Team**

A major effort this year involved supporting the NCEI Operations team in migrating the remaining datasets from the legacy ingest system to the new Common Ingest system. The team designed and developed solutions in ways that could be generically applied for the ingest of current and future datasets. Key accomplishments included enhancements required to ingest the Nexrad3 data stream and efforts to streamline the migration process. The result was more than 30 releases over the past year, whereas previous releases sometimes took as long as a month each.

# Spatial-Temporal Reconstruction of Land Surface Temperature (LST) from Daily Max/Min

This year, the project team refined the approach for reconstructing LST by subdividing the available in situ and model data into training, test, and validation subgroups and applying a non-linear Levenberg-Marquardt least square fit technique. The validation was extended further by including U.S. Climate Reference Network data for 2018, with surface incident insolation data used in lieu of surface absorbed solar radiation.

## Transitioning of the International Satellite Cloud Climatology Project Process (ISCCP) to NCEI

The ISCCP-H series product for the extended period 2010 to mid-2015 was completed and archived. Production for the period mid-2015 to mid-2017 was also completed and archived as an interim CDR, pending availability of the nnHIRS profile. The drifting NOAA-18 polar orbiter was replaced with NOAA-19 as the afternoon anchor satellite, starting with data for 2013.

# Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES Data

The GSA algorithm is being implemented as the U.S. contribution to an international collaboration between Europe, Japan, and the United States to produce a joint climate data record of land surface albedo.

Looking forward to next-generation reprocessing efforts, a pilot study is underway to explore satellite data reprocessing in the cloud. Careful cost comparisons, in terms of both dollars and time, are being calculated to understand the scale of future reprocessing of next-generation remote sensing data. Initial results suggest that the cloud environment will provide significant cost- and time-sav-



Left: In situ measurements of LST at Bowling Green (KY) (+ symbols) for the days marked at the top title and reconstructed LST (shown in magenta diamond symbols). Right: Observed LST vs incident solar insolation for ascending and descending (magenta) solar legs. The inset numbers represent the mean error and standard deviation in K.

ings. The results of the pilot study are included in the blog post published by Amazon (see "Embracing the Cloud" on page 6).

# **HIRS Temperature and Humidity Profiles**

The project team is developing a global temperature and humidity profile dataset for the time period of 1978–present by applying a neural network analysis approach to the NOAA High-resolution Infrared Radiation Sounder (HIRS) observations. A new v2018 dataset was released this year. Key updates include simplifying from three neural networks to two, addressing stability and reliability issues with certain satellite datasets, applying bias corrections and outlier identification/removal, and generating additional quality control flags.

To validate this long-term dataset, evaluation of the intersatellite time series stability is coupled with intercomparisons with independent observation platforms.

Correlation coefficients were calculated for each atmospheric pressure level and each satellite pair, which may be interpreted as a measure of the agreement



Histogram of surface temperature for Infrared Atmospheric Sounding Interferometer (IASI) versus HIRS in January 2014.

between the two sets of observations. When evaluating all cases for both temperature and humidity, correlation coefficients greater than 0.7 are achieved more than 90% of the time.

## Scientific Data Stewardship for Digital Environmental Data Products

NCICS's Ge Peng lead-authored a paper reviewing maturity assessment models and led the development of the World Meteorological Organization (WMO) Stewardship Maturity Matrix for Climate Data (SMM-CD) and a guidance booklet to facilitate the SMM-CD assessment of individual WMO datasets. This work was part of the WMO CCI High Quality Global Data Management Framework for Climate (HQ-GDMFC). She also organized/co-chaired several conference sessions and lead- or co-authored several conference presentations on systematically curating and presenting data quality information to users.

# **Regional Variability of Sea Ice Coverage**

The focus this year was on evaluating and transitioning to NOAA the climate normals (averages over the last three decades) of sea ice concentration, area, and extent for the Arctic and sub-Arctic regions. A unique aspect of these products is representing data uncertainty estimates by using the spread (represented by the difference between the maximum and minimum), standard deviation, 10th and 90th percentiles, and the first, second, and third quartile distribution of all monthly values. This additional uncertainty information should help improve climate projections for better climate adaptation and risk mitigation planning.

# Toward the Development of Climate Data Records (CDRs) for Precipitation: Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs)

Evaluation of CDRs at the daily scale was completed this year, with a focus on extreme events. Among the three satellite products considered, CMORPH presents the highest values for the 99th percentile of daily rainfall when compared to PERSIANN and GPCP. Maximum daily precipitation derived from the three CDRs was compared against radar and in situ data.

There was a wide range of maximum values due to the varying periods of records as well as differences in observation platforms and retrieval algorithms. A large part of this work was used for a book chapter currently under review. Also, an evaluation of the AMSU/MHS Hydro-Bundle was completed and an article was published in *Remote Sensing*.



Value of the 99th percentile daily rainfall retrieved from in situ data (USCRN), and satellite products (PERSI-ANN-CDR, CMORPH, GPCP) for the period 2007–2015.

## Toward Earlier Drought Detection Using Remotely Sensed Precipitation Data from the Reference Environmental Data Record (REDR) CMORPH

Results from sensitivity runs accounting for a variety of parameters suggest that a daily standardized precipitation index (SPI) could provide better detection of drier conditions leading toward the onset of a drought, improve characterization of drought severity, and offer faster indication of relief from drought conditions than a monthly SPI. Preliminary comparisons indicated that both monthly and daily SPIs present the same timing and area for major drought episodes over the continental United States as well as for selected drought events around the globe. While those results are encouraging, further validation is needed as results may differ in terms of magnitude and severity when compared to drought indices derived from in situ data.

# Identifying Tropical Variability with CDRs

Two manuscripts were published this year comparing the interactions of teleconnections with various CDRs. In addition, new diagnostics using NCEI's OISST climate data record were added to https://ncics.org/mjo to monitor how the Madden-Julian Oscillation (MJO) and equatorial waves interact with ocean temperatures.

This project also supported work that contributed to the rollout of two new NCEI datasets: version 4 of the International Best Track Archive for Climate Stewardship (IBTrACS) and nClimGrid-Daily.

IBTrACS v4 is a major upgrade that streamlines the number of formats provided and gives users easier access to the high-impact tracks from the National Hurricane Center and the U.S. Department of Defense (DoD) Joint Typhoon Warning Center (JTWC). It also builds on code from https://ncics.org/mjo to provide these data in near real time.

nClimGrid-Daily provides daily temperature and precipitation data for the contiguous United States from 1951 to the present. It has a nominal 5-km grid that can be aggregated to a variety of levels, including census tracts, climate divisions, and states.

# El Niño–Southern Oscillation (ENSO) Normals

The project team completed development of a methodology for calculating alternative climate normals that account for the influences of the El Niño–Southern Oscillation (ENSO).

This is a three-step process. First, the optimal climate normal (OCN) is subtracted as a running mean from all the data (using an 11-year mean for temperature and a 15-year mean for precipitation).

Second, years are parsed based on the ENSO phase and statistics are calculated for each phase.

Finally, these anomaly statistics are added to the current OCN to produce the final normals.

A peer-reviewed paper describing the ENSO normals is currently in press in the *Journal of Applied Meteorology and Climatology*.



ENSO composites of DJF mean monthly maximum temperature for (a) Strong La Niña, (b) Strong El Niño, (c) Weak La Niña, and (d) Weak El Niño. Hatching indicates values outside of the near-zero interval (white) that are not significantly different from zero at 90% confidence.

## Relationship Between Occurrence of Precipitation and Incidence of Traffic Fatalities Using NEXRAD Reanalysis

NCICS researchers and colleagues from the Centers for Disease Control and Prevention and the University of Nebraska Medical Center found that the overall risk of a fatal car crash increases by about 34% during precipitation events in the contiguous United States. These risks were significantly higher for heavier precipitation events, with a relative risk of 2.46 for heavy precipitation events, but even light precipitation produced an average relative risk of 1.27.

The authors' innovative use of high-resolution radar precipitation reanalysis, rather than data from in situ weather stations or police reports, resulted in much more precise information on precipitation conditions at the time and location of each crash. The paper, which was published in the *Bulletin of the American Meteorological Society*, generated significant media interest (including the Associated Press, Washington Post, and The Weather Channel—see https://ncics.org/in-the-media).



# **Climate Literacy, Outreach, Engagement, and Communications**

### **Engagement Activities**

NCICS conducts numerous engagement activities to reach various types of stakeholders in the areas of environmental data and information, climate change and variability, adaptation and mitigation, and interdisciplinary uses and applications of information for decision-making.

### **Operational Support to NOAA NCEI Center for Weather and Climate**

Key highlights this year included the development of an NCEI Executive Sheet, new Success Stories, and Sector Information Sheets, which were shared on the NCEI website at https://www.ncdc.noaa.gov/success. NCICS also helped facilitate the NCEI's Users' Workshop held atThe Collider in Asheville in May 2019. The workshop focused on data uses and needs in the following topic areas: agriculture, retail, finance, service providers, logistics and transportation, 1991–2020 climate normals, and blue economy.

### **Targeted Engagement Discussions**

NCICS and/or NCEI scientists were speakers or participants at a variety of events sharing research and data applications; these interactions also identified needs that can be cataloged for the NCEI requirements repository:

- Climate Adaptive Design Symposium, November 2018, led by CASE Consultants International
- American Bar Association Webinar, June 2018, with NCEI scientists to discuss applications of NOAA NCEI data information for the legal community
- Carolinas Climate Resilience Conference, October 2018, Columbia, SC, with presentations and discussions on communicating science and driving innovation with engagement and data
- NCICS staff and colleagues from NCEI subcontractor GST led several activities at the 2019 Annual American Meteorological Society, including a Town Hall entitled "Upcoming NCEI Data Users Conference: An Agriculture Example," three presentations, and two posters that shared the progress of customer engagement at NCEI.

### **Educational and Public Outreach**

NCICS staff engage in a robust interdisciplinary program of outreach involving K–12, undergraduate, and graduate students as well as the general public. In this role, we advance NOAA mission goals by promoting STEM education and disseminating environmental information for capacity building and education.

This year, our staff participated in more than 25 outreach activities, including presentations to a wide range of audiences at a variety of events. Large events included the North Carolina Mountain Science Expo, attended by approximately 2,000 students, parents, and educators, and the Isothermal Community College Annual Science and Technology Expo, involving about 300 sixth-grade students.



(top) Using basic statistics to explain shifting temperature distributions to students at the 2019 Region 8 Western Regional Science Fair held on the campus of Western Carolina University in Cullowhee, NC. (bottom) Our new climate pachinko board in action at the 2019 Mountain Science Expo at the North Carolina Arboretum.

Smaller outreach events included two talks at an Asheville-area retirement community and multiple presentations to individual classes at various K–12 schools in Western North Carolina.

The NCICS Outreach Team is developing a climate "pachinko" game board and accompanying software designed to help explain the differences between weather and climate and how climate change alters the probabilities of events like very hot days. In early testing, these tools have proven to be popular and effective for a broad range of audiences.

Institute staff from the Technical Support Unit helped organize and lead three events at The Collider in Asheville that highlighted various aspects of the Fourth National Climate Assessment (NCA4). These events were all open to the public and featured lively question-and-answer discussions.

### **Communications**

Communication activities this year centered around the publication of the largest-ever edition of the Institute's *Trends* newsletter, which also featured a new magazine-style visual design. The newsletter highlighted significant accomplishments from the past year. NCICS staff and research outcomes were also featured prominently in various print, online, and broadcast outlets this year, with much of the activity arising from recent extreme precipitation and hurricane events. More than a dozen of these media items are linked from our website at https://ncics.org/in-the-media.



(above) The cover of the March 2019 issue of Trends. (top right) Sarah Champion explains the importance of traceability and reproducibility in the National Climate Assessment (NCA). (bottom right) Tom Maycock discusses climate adaptation topics in the NCA.



## NC STATE UNIVERSITY

# **Surface Observing Networks**

### **Drought-Related Health Impacts: Advancing the Science for Public Health Applications**

Two studies were initiated to help identify linkages between drought and public health impacts.

The first is aimed at determining the impact of soil moisture on the 2017 outbreak of Valley Fever (coccidioidomycosis) in the southwestern United States. Unlike previous outbreaks, the 2017 event showed unique differences between California and Arizona in how the outbreak manifested. Recent drought in California, and subsequent changes in the environment, likely caused these differences. NOAA soil moisture data and Centers for Disease Control and Prevention (CDC) coccidioidomycosis incidence records were compiled for analysis, which is currently underway.

The second study utilizes annual counts from the CDC of all-cause mortality on a county level from 1980–2014 for all age groups in the 48 U.S. contiguous states and several drought indices to investigate drought event impact on regional and national mortality rates. Recent work applied the Evaporative Demand Drought Index (EDDI) to the health data for Nebraska. EDDI is a measure of drying potential of the atmosphere that can serve as an indicator of both flash and sustained droughts. Results confirm the relevance of studying different drought time scales, as the 12-month drought Incidence Rate Ratios show an increase in mortality with prolonged hydrological droughts compared to the short-scale meteorological droughts.

### **U.S. Climate Reference Network (USCRN) Applications and Quality Assurance**

The high quality and temporal resolution of USCRN precipitation data were leveraged to verify the Hourly Precipitation Dataset (HPD) network's new quality control (QC) algorithm. HPD gauges were recently modernized from analog tape to digital, with QC applied to the digital era. Comparisons against USCRN measurements revealed fewer instances of trace/false precipitation events in addition to more similar counts of higher total events in the digital era compared to legacy. These results were used to validate HPD's new QC process. In an additional analysis, the frequency of exceedance was applied to USCRN precipitation data for various NOAA Atlas-14 durations and thresholds. These counts were evaluated to compare against similar Global Historical Climatology Network–Daily frequency analysis used in the SERDP project (see Other Institute Projects).

Cloudy conditions can obscure satellite-based measurements of land surface temperature (LST), challenging efforts to estimate/model the diurnal cycle of LST. A novel approach that combines in situ air temperature measurements with remotely sensed data from multiple satellite platforms to estimate LST under all sky conditions was applied to select USCRN and SURFRAD stations. Estimates of LST using this approach are currently being evaluated against USCRN-observed surface infrared observations.

Finally, USCRN temperature data were utilized to support measurements from a field campaign investigating the impact of urban encroachment on air temperature. The impacts were largest (0.84°C warmer) on evenings following sunny days with a light breeze from the urban area. This signal diminished with distance and was undetectable from the site located 124 meters from the urban area. Slight differences were



This figure shows the magnitude of the effect of smallscale urban development on USCRN temperature at varying distances from the built-up area for all conditions (purple line), nocturnal observations (blue), nocturnal observations on days receiving more than 20 MJ solar radiation (yellow), and nocturnal observations on high solar receipt days with wind from the urban area compass directions 225-315° (red).

detected between sensors with differing types of aspiration (fan versus natural ventilation of sensor shielding). The results were published in the *Journal of Applied Meteorology and Climatology*.

### The Utility of In Situ Observations for the 2017 Great American Solar Eclipse

Sub-hourly observations from USCRN were analyzed during the 2017 Great American Solar Eclipse, revealing important changes to the diurnal cycle of air and surface temperature measurements. Stations under clear-sky conditions in the path of totality had the largest change in both air and surface temperatures (up to 5° and 15°C, respectively); the magnitude of these changes gradually diminished with distance from the path of totality.

### Standardization of USCRN Soil Moisture Observations

Various methods to standardize hourly soil moisture data from short-term USCRN records were evaluated. Percentile differences among these approaches were negligible when aggregated at national and regional scales; however, there were times at individual stations where differences exceeded 10%. Comparisons with U.S. Drought Monitor and other drought metrics revealed important nuances between various types of drought (agricultural versus hydrological), which suggests that standardized soil moisture can provide context about trends from worsening to improving drought conditions. The same sampling methodology has also been extended to remotely sensed AMSR-E soil moisture data. While results from this pilot project revealed some major limitations in the satellite product, the methodology was successfully applied to remotely sensed data and could be easily extended to other satellite platforms, including Soil Moisture Active Passive or Soil Moisture and Ocean Salinity.

### **Development of the USCRN National Precipitation Index**

An algorithm to build a national precipitation index (NPI) using 100+ stations from USCRN and an accompanying technical report are close to completion, and the NPI will soon become operational. Because USCRN data begin in the early 21st century, providing a robust 30-year climatology from USCRN is not feasible. The team implemented a new approach to estimating precipitation normals based on 1981–2010 averages of precipitation derived from the nClimGrid dataset. Monthly departures from these normals were calculated as depth and percentage anomalies for both adjusted and unadjusted normals. For seasonal and annual values, monthly data were summed before calculating a departure.

# Maintenance and Streamlining of the Global Historical Climatology Network–Monthly (GHCNm) Dataset

A major milestone was achieved with the operational release of Version 4 of NOAA's global temperature product: GHCN-Monthly. A corresponding manuscript published in Journal of Climate describes the workflow and the uncertainty methods applied to the data. These uncertainty estimates were produced by running a 100-member ensemble of the pairwise homogeneity algorithm (PHA). NCICS assisted in this task using Amazon Web Services to reduce runtime from weeks to days (see "Embracing the Cloud" page 6). From these ensembles, error estimates are provided based upon uncertainties in homogenization, normal estimation, instrument exposure, sampling error, and spatial coverage. These estimates are combined into one global time series. Updates are ongoing and provided as necessary. See https://www.ncei.noaa.gov/news/noaa-updates-global-temperature-dataset.



A comparison of both global land surface temperatures from versions 3 and 4 of GHCNm for adjusted and unadjusted values, where the adjusted data are the result of a suite of calculations performed to account for non-climatic shifts in the raw station data due to changes in instrumentation, station locations, and observing practices. Source: Menne et al. 2018.

## **Development of a Homogenized Sub-Monthly Temperature Monitoring Tool**

The sub-monthly temperature monitoring tool developed by NCICS is being used to assess extreme heat events in the United States from 1895–2018. The dataset has been updated through 2018, and location-specific, multi-day heat events are identified using the resulting quasi-homogenized data.

A manuscript is under development to report on the results from statistical and trend analyses of these events.

Once the article is accepted, this dataset will be used as the baseline to match heat event data with available health data provided by the University of Nebraska Medical Center, the University of Pittsburgh, and the North Carolina Detect (NC DETECT) organizations.

Future work will also include comparison with available data from the United States Climate Reference Network, including soil moisture.

## Night Marine Air Temperature (NMAT) Near-Real-Time Dataset Development

A distance weighted gridding scheme was implemented and a preliminary global ocean monthly NMAT was generated on a 5° x 5° grid from January 2002 to August 2017. This year, differences between NCEI NMAT and HadN-



Number of TMIN Heat Events: 1991-2018 | 98th percentile

MAT2 were investigated, with the largest differences reflected in the Arctic and the Southern Ocean as well as the east coasts of both North America and Asia.

## International Comprehensive Ocean–Atmosphere Data Set (ICOADS)

The International Comprehensive Ocean–Atmosphere Data Set (ICOADS) offers surface marine data spanning the past three centuries. As it contains observations from many different observing systems encompassing the evolution of measurement technology over hundreds of years, ICOADS is the most complete and heterogeneous collection of surface marine data in existence. The most recent version, ICOADS Release 3.0, released in June 2016, contains over 455 million individual marine reports for 1662–2014, with Near-Real-Time extensions from 2015–present.

The migration of the ICOADS data management process to a new, more robust computing environment at NCEI is progressing as planned. Scripts to retrieve and process incoming data have been streamlined and made less dependent on software that requires frequent updates. All processing is now being done with native Linux applications.

## **Investigation of Trends in Airport Weather Conditions**

A study of 45 years of hourly weather observations for the 30 busiest airports in the United States revealed a marked decrease in the frequency of instrument flight rule (IFR) conditions at 29 of 30 airports, driven primarily by a decreasing frequency of hours in which visibility is low. The results were published in the *Journal of Applied Meteorology and Climatology* and highlighted in the Smithsonian's *Air & Space* magazine: http://bit.ly/ncics\_ifrsas. Two likely reasons for the reduction in IFR conditions are that rising temperatures, especially in urban areas, are reducing the frequency of the moisture saturation conditions required for clouds and fog, and that improved air quality as a result of pollution regulations are resulting in fewer particles for clouds and fog to form around.

Number of heat events in the United States from 1991-2018. Results are organized by divisions defined by NCEI.

# Workforce Development

NCICS actively works to identify and train the next generation of scientifically and technically skilled climate scientists. Junior and/or aspiring scientists, including post-doctoral researchers and students, play an important role in the conduct of research at NCICS. High school, undergraduate, and graduate students as well as recent post-docs support projects across our task streams. Activities over the past year included the following:

- Andrew Ballinger, post-doctoral Research Scholar, completed his second year working with Kenneth Kunkel and collaborating on the multi-institutional, NSF-sponsored Urban Resilience to Extremes— Sustainability Research Network (UREx SRN) project—he also assisted with project onboarding of graduate student Geneva Gray. In Fall 2018, Andrew began work with Kunkel and Jenny Dissen supporting the U.S. –India Partnership for Climate Resilience efforts.
- Sarah Champion and Brooke Stewart-Garrod are engaged in NCSU doctoral studies in Atmospheric Sciences, with Champion focusing on extreme precipitation and Stewart-Garrod investigating atmospheric blocking highs.
- During the past year, NCICS scientists mentored six PhD students, two NASA DEVELOP teams involving a total of seven students and recent graduates, three NOAA Hollings Scholars, three graduate student interns, three undergraduate and recent graduate interns, and one high school intern. Projects include graduate-level work on changes in extreme rainfall and flooding, interactions between Kelvin waves and easterly waves, contributions to the UREx SRN project, and the diurnal cycle of convection over the Maritime Continent and related impacts on subseasonal-to-seasonal forecasts. NASA DEVELOP projects included monitoring the spread of invasive grasses and the impacts on grassland management practices (https://develop.larc.nasa.gov/2018/summer/SouthDakotaEco.html) and an analysis of the historic 2011 drought on urban forest conditions in Houston and Austin (https://arcg.is/0i8en8).

# **Other Institute Projects**

Funding organizations for each project are indicated in brackets.

- Changes in the Frequency of Freezing Precipitation: International environmental change studies focused on the northern extratropics were conducted to better inform vulnerable societies and better prepare them for potential future developments. A study devoted to Eurasian drylands is near completion (peer-reviewed papers were published and a book is in press). Two more international studies devoted to the Arctic water cycle and extreme events over Europe are proposed. [Multiple]
- The Urban Resilience to Extremes Sustainability Research Network (UREx SRN) is an NSF-funded multi-institutional project led by Arizona State University. This year, the team analyzed locally constructed analog (LOCA) downscaled climate model data for multiple cities in the United States and Mexico and performed high-resolution modeling of an extreme precipitation and flooding event in Ellicot City, MD. [NSF]
- Incorporation of the Effects of Future Anthropogenically Forced Climate Change in Intensity–Duration–Frequency Design Values: An algorithm to automatically identify weather fronts in climate model and reanalysis data was refined and applied to historical and future climate model simulations. Analysis of weather system changes indicates future decreases in summer fronts, but the number of summer fronts may not correlate with extreme precipitation. Also, increases in slow-moving cyclones and high moisture convergence in the North American Monsoon are projected. The team delivered multiple presentations based on work from this project, including several at the annual American Meteorological Society and American Geophysical Union meetings. [DoD/SERDP]
- IPCC Special Report on 1.5°C of Global Warming: NCICS provided editorial and technical support for the Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C of Global Warming, one of the most significant and policy-relevant international climate assessments produced to date. Support efforts included leading the copyediting team for the full report, editorial and science communication input on the report's "Summary for Policymakers," the provision of a figure and metadata management web portal, and on-site technical support at the report approval session in Incheon, Korea. [IPCC Working Group I]
- Climate Indicators to Track the Seasonal Evolution of the Arctic Sea Ice Cover: NCICS's Ge Peng lead-authored/co-authored two peer-reviewed papers and lead-authored/co-authored two posters presented at the AGU 2018 Fall Meeting. A dataset has been released by National Snow and Ice Data Center. See: https://ncics.org/cics-news/seasonal-and-regional-changes-in-arctic-sea-ice/. [NASA]
- Synthesis of Observed and Simulated Rain Microphysics to Inform a New Bayesian Statistical Framework for Microphysical Parameterization in Climate Models: In order to quantify uncertainties in how microphysical processes of rainfall are represented in weather and climate models, the team developed an innovative Bayesian statistical framework that combines the extensive radar and groundbased data from the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) field campaigns, bin microphysical modeling, and a new bulk parameterization. [DOE]
- Climate Change Impacts on Human Health: The goal of this exploratory work is to examine the impact of climate change—a known environmental determinant—on maternal and mental health risks. Results will address a significant research gap in understanding climate and health interactions and inform the development of a scalable population-based indicator to be used in climate-health surveillance efforts. This year resulted in a number of publications, as well as the ascertainment of three large public health datasets to be used in indicator surveillance work to examine the impacts of climate change and vulnerability on mental health and maternal health in 2019–2020. [MAHEC; in-kind partnerships]

- Continuous Monitoring of Individual Exposure to Cold Work Environment—A Participatory Sensing: This pilot study utilized new wearable sensor technology to test and implement more sensitive means of evaluating cold temperatures as an occupational hazard and developed effective report-back strategies as a means to communicate with participants about harmful occupational exposures and their associated health risks. The principal investigators recruited grounds-management workers at the same two geographic locations as a previous pilot high-temperature study: North Carolina State University in Raleigh, NC, and Appalachian State University in Boone, NC. Three data collection periods were completed during the months of January and February, and results were published in *Environmental Research*. [University of South Florida, NIOSH]
- Multiscale Convection and the Maritime Continent: The project investigates the diurnal cycle of convection over the Maritime Continent (MC) using a variety of TRMM and ISCCP datasets and explores the skill of a novel Fourier filtering of combined observations and CFSv2 hindcasts in the region. Results from the first area showed that rainfall over the MC islands peaks around 1800 local standard time, in association with organized deep convection, while rainfall over the coastal and oceanic regions peaks in the early morning hours and does not have as clear of a connection to the convective variations. These results have been resubmitted to *International Journal of Climatology* following major revisions. The second stream of work verified some of the forecast diagnostics from https://ncics. org/mjo/, which uses 1+ years of observed TRMM TMPA rainfall and appends it with CFSv2 hindcasts for 45 days and then climatology thereafter. These combined data are filtered for the MJO and key equatorial waves. These results will be submitted for publication during the next year. [NASA]
- Investigations Between Kelvin Waves and Easterly Waves Using CYGNSS Data: This team is using NASA's new Cyclone Global Navigation Satellite System (CYGNSS) retrievals to investigate the surface interactions between Kelvin waves and easterly waves. Progress continues across three separate phases of work. [NASA]
- Developing New Forecast Tools for the USAF 14th Weather Squadron's Tropical Pacific Convective Outlook: The tools at https://ncics.org/mjo are currently based on NCAR's Command Language (NCL). However, the 14WS requested the processing software code be delivered in Python version 3. The primary functions were refactored in Python 3 and delivered to the 14WS. A technical report highlighting the skill of these products was produced and provided to the 14WS. The project team continues to support the 14WS as they work to implement the code. [DoD/USAF]
- Operational Transition of Novel Statistical–Dynamical Forecasts for Tropical Subseasonal to Seasonal Drivers: Subseasonal-to-seasonal (S2S) forecasting has emerged as one of the great frontiers for atmospheric predictability. These time scales of weeks-to-months are at the heart of the mission for NOAA's Climate Prediction Center (CPC), which has been particularly focused on expanding and improving their 3–4-week forecasts. This team is transitioning key tropical subseasonal metrics from NCICS's Madden–Julian Oscillation monitoring page (https://ncics.org/mjo) into operations in the Climate Prediction Center. [NOAA/CPC]
- Collaborative Support for the Development of the Quantitative Urban-Scale Microclimatic Modeling Tool (QUEST): The availability of high-resolution geospatial data; monitoring of land, coastal, and water resources; and high-resolution environmental modeling at local scales can support timely and reliable climate-sensitive urban planning. The project team provided the Urban Redevelopment Authority (URA) of Singapore with three 6-hour datasets, an interface to convert the data into spectral space as inputs for the NCEP Mesoscale Model (MSM), and NCEP MSM simulations with a resolution of 1 km x 1 km over Singapore to evaluate the model performance and generate baseline climate scenarios. [URA]

- Extension of the Great Smoky Mountain Rain Gauge Mesonet and Exploration of the Origins of Extreme Precipitation Events in the Southern Appalachian Mountains and their Signatures as Observed by GOES-R: The team completed Spring, Summer, and Fall 2018 maintenance and data collection gauge visits as part of this collaborative research effort to extend the period of observations of the Duke University Great Smoky Mountains National Park Rain Gauge Network. [NESDIS/GOESPO]
- Simplified and Optimal Analysis of NOAA Global Temperature Data: Data Validation, New Insights, Climate Dynamics, and Uncertainty Quantification: Improvements were made in the software technology—4DVD (4-Dimensional Visual Delivery of big climate data)—and Amazon entered a big data partnership with 4DVD in December 2018 to host the 4DVD database. The system has the capability to rapidly deliver NOAA environmental data to classrooms, the scientific community, and the general public. [NCEI]

# 2019 By the Numbers

2019 was in many ways the busiest and most productive year in the Institute's 10-year history. While numbers don't capture the full scope and importance of the work we do, they do give a sense of what we accomplished over the past twelve months:

- 50 peer-reviewed journal articles, reports, and book chapters
- More than 120 invited presentations and posters
- 22 outreach and engagement presentations and panel discussions
- 7 other community outreach events, ranging from science fairs to NOAA's Hurricane Awareness Tour
- Approximately 1,500 people attended our outreach and engagement activities



NCICS staff at our May 2019 quarterly offsite meeting. Not pictured: Qing Dong, Pasha Groisman, Jared Rennie, Carl Schreck, Brooke Stewart, and Lou Vasquez.





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