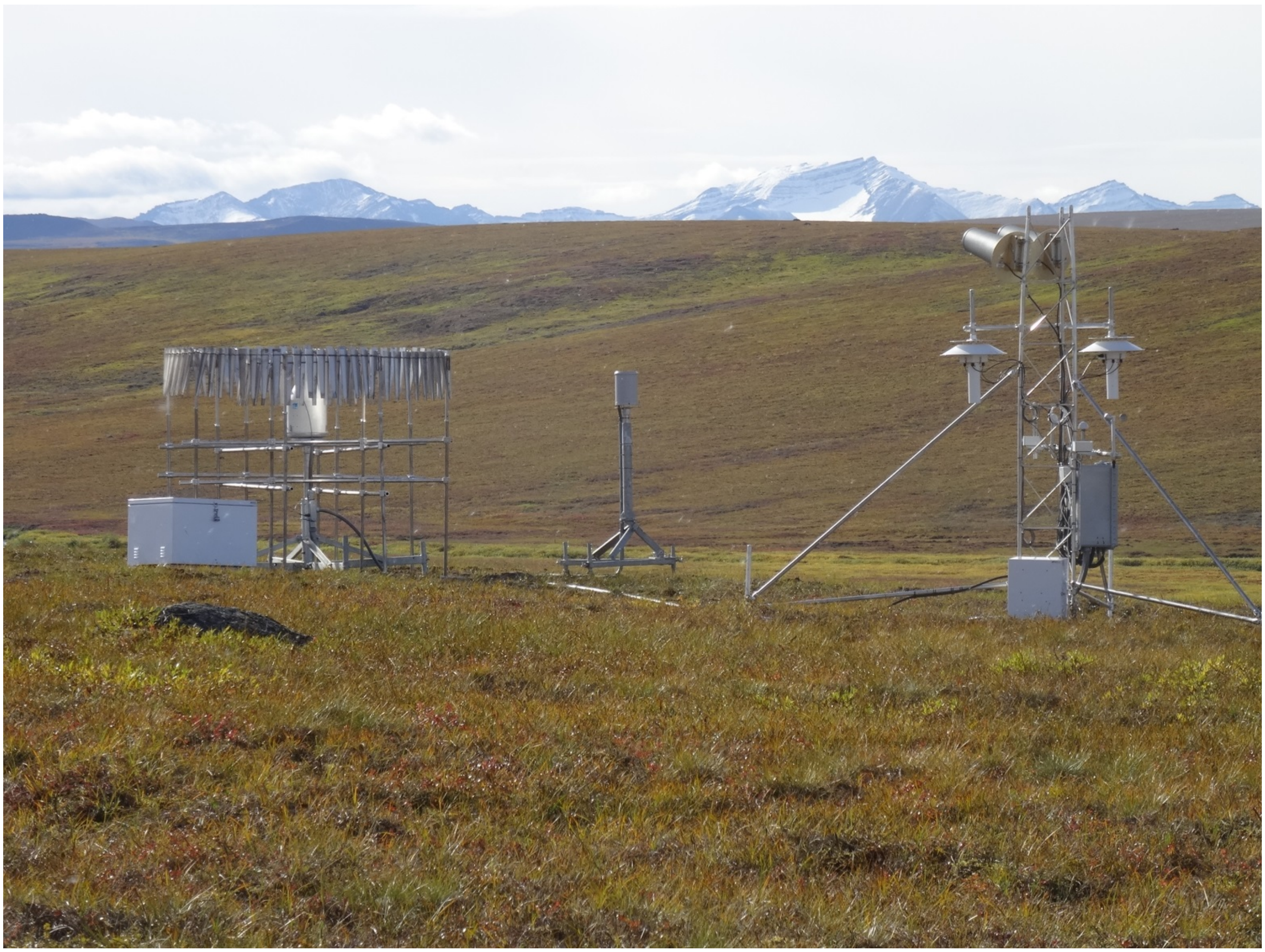
US Climate Reference Network

Annual Report for Fiscal Year 2017



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Cover Photo:
Photo of the new USCRN station in Toolik Lake, Alaska; installed in August 2017. (Credit – Mark Hall)

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Report will be posted on the USCRN Website at

http://www.ncdc.noaa.gov/crn/annual-reports.html

Many thanks to the USCRN Team members for their invaluable assistance in aiding in the preparation of this report and for their many contributions during FY17:

Jesse Bell, Michael Black, Michael Buban, Nancy Casey, Scott Embler, Brent French, Grant Goodge, Mark Hall, John Kochendorfer, Ronnie Leeper, Tilden Meyers, Michael Potter, Lynne Satterfield, Barbara Shifflett, Devin Thomas, Kristy Thomas, and Tim Wilson

Preface and Introduction

During Fiscal Year 2017, the U.S. Climate Reference Network (USCRN) continued to make significant progress under the auspices of NOAA's Atmospheric Turbulence and Diffusion Division (ATDD) with cooperation and collaboration from NOAA's National Centers for Environmental Information (NCEI). The network consists of 114 stations across the conterminous 48 states, 21 stations in Alaska, 2 additional stations in Hawaii, and 2 at international test sites in Canada and Russia. Stations are installed in open (where possible), rural locations very likely to have stable land cover/use conditions for several decades to come.

At each site a suite of meteorological parameters are monitored, including triple redundancy for the primary temperature and precipitation variables, and for soil moisture and soil temperature. Instrumentation is regularly calibrated to National Institute for Standards and Technology (NIST) standards and maintained by a staff of expert engineers. This attention to detail in USCRN is intended to ensure the creation of an unimpeachable record of changes in surface climate over the United States for decades to come. Data are made available without restriction for all public, private, and government use. This section describes the rationale for the USCRN, its implementation, and some of the highlights of the first decade of operations.

Long-term, high-accuracy, stable environmental observations are essential to define the state of the global integrated Earth system, its history, and its future variability and change. Scientifically acceptable observations for climate analyses include: (1) operational weather observations when appropriate care in collection and archival methodologies has been exercised to establish sufficiently high accuracy for climate purposes; (2) limited-duration observations collected as part of research investigations to elucidate chemical, dynamical, biological, or radiative processes that contribute to maintaining climate patterns or to their variability; (3) high-accuracy, high-precision observations to document decadal-to-centennial changes; and (4) observations of well-recognized and scientifically acceptable climate proxies which are non-instrumental but nevertheless sufficiently controlled as to ensure numerical high-precision values that are scientifically valid.

The USCRN continues to fulfill this need for obtaining long-term sustainable and robust climate observations that are necessary to document long-term climate change trends for the United States. Beginning in 2009, the USCRN effort in the U.S. began expanding into the State of Alaska, and operating this climate observing network in an Arctic environment presents some unique challenges. There are currently a total of 21 operational USCRN stations (19 commissioned) in Alaska, with an eventual goal of having 29 commissioned stations by 2022. Operating an automated climate quality observing network in the harsh and remote environment that exists at many sites in Alaska presents some unique problems related to station power, access to the station, and continued transmission of data. One critical use of these observations is as an independent data source to verify the existing U.S. temperature record derived from networks corrected for non-homogenous histories. These records can now be compared on the web site, and are found to agree well. Constructive feedback from end-users will allow for continued improvement of USCRN in the future and ensure that it continues to meet stakeholder requirements for precise climate measurements.

Highlights for FY2017

1. **Program Management Change**
   In line with a budget realignment in NOAA, the USCRN Program Manager was transferred from NCEI to ATDD and therefore, the focus of the program will now be managed from ATDD, with NCEI continuing to perform the data management, stewardship, and related science activities that they have been involved in from the beginning of the program. The primary USCRN website will continue to be hosted by NCEI at http://www.ncdc.noaa.gov/crn

2. **Continuing to Push past the Halfway point in Alaska**
   In FY17, two new stations were installed in Alaska (a) on Eyak Native Corporation property in Cordova, AK, in the southeast portion of the state; and (b) on Bureau of Land Management property (and co-located with the National Science Foundation's National Ecological Observatory Network site) in Toolik Lake, AK, in the northeast central portion of the state. This brings the network configuration in the state up to 21 out of a planned total of 29 stations by FY2022.

3. **Monitoring Power Systems at USCRN Stations in Alaska**
   Operating automated climate observing systems in Alaska presents some unique challenges both due to the typically harsh winter weather, as well as limited solar energy availability from December to February. Therefore, special emphasis was begun in 2016 to upgrade the power systems at the sites in Deadhorse, King Salmon, Selawik, Sitka, and Tok. The upgrades involved reconfigured methane generators, the addition of wind generators, enhanced battery configurations, and changes to the power draw of selected instrumentation. We continue to learn how to operate in this harsh winter environment, and our continued improvements will result in greater up-time and availability of stations not on A/C power across Alaska.

4. **Software and Data System Improvements**
   Dramatic improvements in the performance of the USCRN database, and their associated web-based data and information access tools were made during the past year. The software development team worked closely with NCEI's database administrators to test and evaluate new database schemas and methods for improving performance.

5. **Science and Development Activities**
   Five journal articles completed in previous fiscal years were published in FY2017 using USCRN data to address a variety of issues, from model verification to human health issues. Three new journal article submissions were made during FY2017. Work was completed on further improvements of USCRN precipitation calculations (OAP 2.1.1), and improved quality control flagging methods developed last year for precipitation observations were implemented to address issues with other variables. Presentations were made at numerous conferences and workshops, and efforts were made to enhance social media outreach supporting the USCRN, especially at the time of the 2017 Solar Eclipse. However, most of the science efforts were oriented toward two main projects: 1) the continuing development of a standardized soil moisture product and the further synthesis of these data into drought indices in support of the National Integrated Drought Information System (NIDIS) effort; and 2) validating a potential replacement for the current USCRN soil moisture sensor.

6. **New Gridded Data for USCRN**
   To address a need for an enhanced utilization of the USCRN dataset, a gridded product was produced. Daily means of more than 20 variables were computed, going back to at least 2006.

The remainder of the report will cover progress and activities in the following areas:
- Operational Activities in Alaska
- Operational Activities in the Conterminous U.S.
- Projects to Improve Data Processing, Monitoring, Data Access, and Product Quality
- USCRN Science and Development Activities
- Field and Testbed, and Monitoring Activities
- Development of Gridded USCRN Data
- Soil Sensor Testing and Evaluation
- Plans for FY2018

FY2017 Operational Activities in Alaska

Site Surveys: With the completion of the USCRN site survey program in FY2016, the work from that last survey was evaluated and the final three candidate station locations were selected in Aniak, Aleknagik, and St. Michael, in the western portion of the state (Figure 1). This will give the program a way forward to complete the installation of the final 8 stations by the end of FY2022.

Site Licenses Signed: Site license agreements were completed for five additional Alaska sites (Bethel, Kodiak, Galena, Huslia and Toolik Lake) in FY2017, with several others in progress.

Stations Installed: Two new stations (Cordova and Toolik Lake) were installed in Alaska in FY2017.

Stations Commissioned: One station (Yakutat) was commissioned in Alaska in FY2017.
In addition to the stations installed in FY2017 in Cordova and Toolik Lake, four additional sites are licensed and pending installation (Bethel, Kodiak, Galena, and Huslia). Licenses are pending from the Alaska Department of Natural Resources at Salmon Lake, Alaska Department of Natural Resources at Pumice Creek, Alaska North Slope Borough at Kaktovik, US Air Force site at Fort Yukon, Alaska Department of Transportation at St. Michael, Federal Aviation Administration at Aniak and Aleknagik Airport.

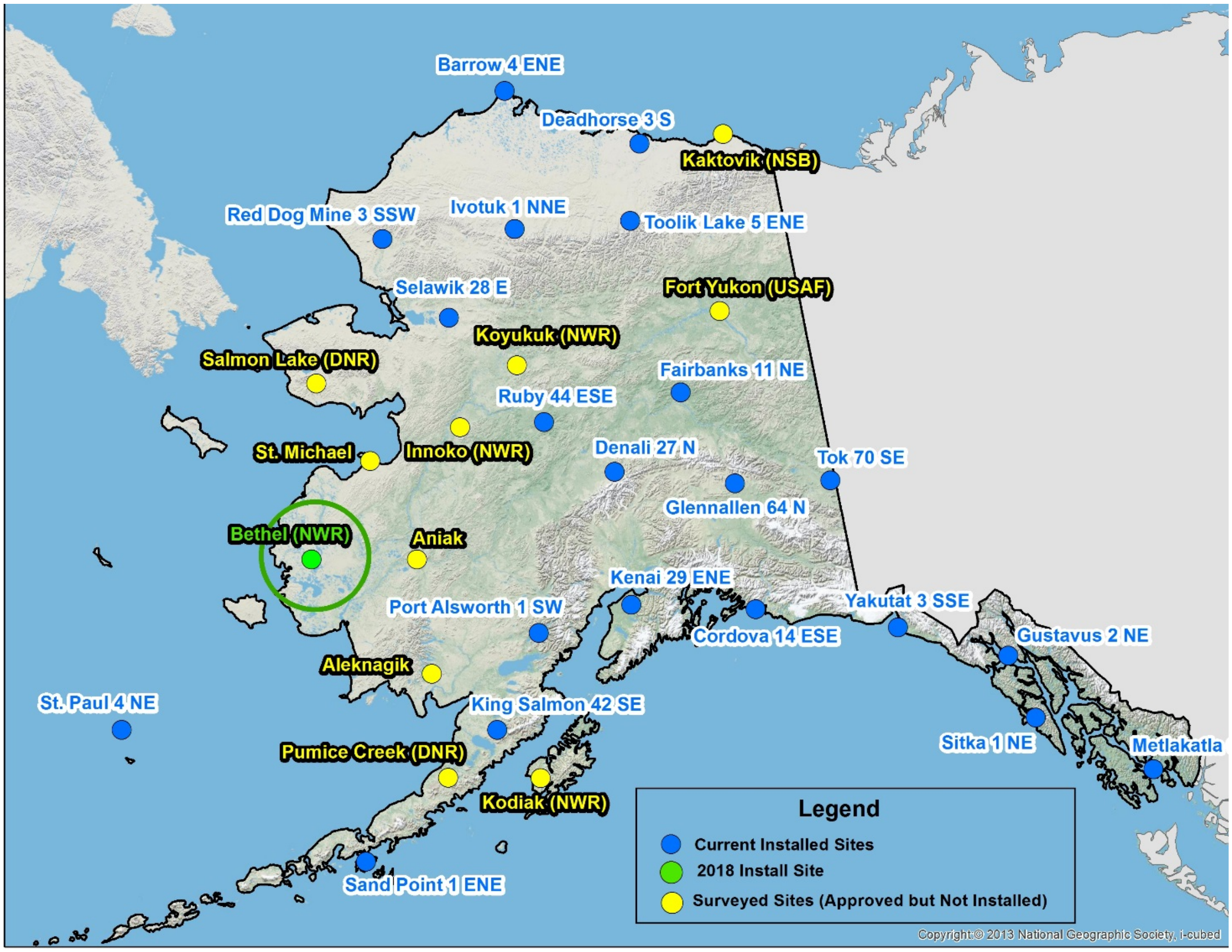

Figure 1. The map of USCRN stations in Alaska – existing and planned sites.

Table 1. USCRN in Alaska Reduction in Climate Uncertainty

FY	Sites Commissioned	Temperature Confidence	Precipitation Confidence
2010	2	59.0%	58.9%
2011	4	62.9%	62.7%
2012	5	64.4%	64.2%
2013	12	72.6%	72.4%
2014	13	73.4%	73.1%
2015	16	76.7%	76.0%
2016	18	79.1%	78.6%
2017	19	79.9%	79.3%

Table 2. USCRN in Alaska Data Receipt Rates (%) for FY2017 by Quarter[1]

	Within 30 days	As of 9/30/17
Q1	91.3	91.3
Q2	88.3	88.4
Q3	99.7	99.7
Q4	97.7	99.6
Total	**94.3**	**94.7**

Table 3. FY2017 USCRN in Alaska Station Status

Station	Licensed	Installed	Commissioned
Barrow (NOAA Earth Systems Res. Lab.)	4/27/2001	08/2002	07/2013
Fairbanks (NOAA/NESDIS(FCDAS))	7/23/2002	08/2002	07/2013
St. Paul (NOAA NWS)	6/10/2005	08/2005	07/2013
Sitka (USGS)	6/15/2005	08/2005	07/2013
Sand Point (USGS)	02/12/2009	08/2009	09/2010
Port Alsworth (Lake Clark NPS)	09/09/2009	09/2009	09/2010
Red Dog Mine (NANA Regional Corp.)	07/13/2010	08/2010	09/2011
Kenai (Kenai NWR)	07/13/2010	08/2010	09/2011
Tok (Tetlin NWR)	07/13/2010	09/2011	09/2012
Gustavus (near Glacier Bay NP)	06/27/2011	09/2011	07/2013
King Salmon (Katmai NP)	06/20/2011	08/2012	07/2013
Metlakatla (Annette Island WSO)	03/27/2012	07/2012	07/2013
Glennallen (BLM)	06/11/2012	08/2013	07/2014
Deadhorse (Dept. of Natural Resources)	05/07/2014	06/2014	09/2015
Ivotuk (Arctic Slope Regional Corp.)	05/07/2014	06/2014	09/2015
Ruby (Nowitna NWR)	05/29/2012	08/2014	09/2015
Selawik (Selawik NWR)	05/29/2012	08/2015	09/2016
Denali (Denali NP)	01/07/2015	08/2015	09/2016
Yakutat (Tongass USFS)	06/28/2016	08/2016	09/2017
Cordova (Eyak Corporation)	01/23/2013	07/2017	TBD
Toolik Lake (BLM)	06/07/2017	08/2017	TBD
Bethel (Yukon Delta NWR)	03/14/2017	TBD	TBD
Huslia (Koyukuk NWR)	03/14/2017	TBD	TBD
Kodiak (Kodiak NWR)	03/14/2017	TBD	TBD
Galena (Innoko NWR)	03/14/2017	TBD	TBD
Fort Yukon (US Air Force)	Pending	TBD	TBD
Nome (Salmon Lake AKDNR)	Pending	TBD	TBD
Port Heiden (Pumice Creek AKDNR)	Pending	TBD	TBD
Kaktovik (North Slope Borough)	Pending	TBD	TBD
St. Michael (AKDOT)	Pending	TBD	TBD

[1] **The overall data receipt rate for the entire USCRN (including the stations in Alaska) was 99.8% (see Table 4) which is above the performance measurement standard of 98% across the entire network.**

Aniak (FAA)	Pending	TBD	TBD
Aleknagik (Native)	Pending	TBD	TBD

FY2017 Operational Activities in the Conterminous U.S.
The USCRN Program continues to successfully meet the requirements of data delivery in the conterminous U.S. (Table 4).

Table 4. Overall USCRN Data Receipt Rates (%) for FY2017 by Quarter (including Alaska)

	Within 30 days	As of 9/30/17
Q1	99.7	99.8
Q2	99.7	99.8
Q3	99.9	99.9
Q4	99.7	100.0
Total	**99.8**	**99.9**

USCRN Data Processing, Monitoring, Access, and Product Systems
NOAA/NCEI continued to provide operation and maintenance of USCRN data ingest, quality assurance, monitoring, access, and product systems in FY17. As in past years, the program's two software developers did an outstanding job keeping systems up and running while also addressing new requirements such as reprocessing of the official precipitation algorithm, development of new archive submission agreements and processes, and migration to new operating environments. They did these while providing systems monitoring on a continual basis and providing quick response to outages that periodically occurred due to various factors.

Database Performance Improvements and Other Changes
Dramatic improvements in the performance of the USCRN database and associated web-based data and information access tools were made during the past year. The software development team worked closely with NCEI's database administrators to test and evaluate new database schemas and methods for improving performance. This included the transition to a new Oracle Database Appliance that was deployed across all three IT tiers of (a) development; (b) testing; and (c) production over a four-month period. Numerous changes were required to adapt to the new environments and continual communication between the software developers and personnel in the IT and Data Access Branch was a necessity. The close working relationship that the software developers had established with the IT and Data Access Branch personnel over the past several years made a smooth transition possible. An example of the success of this upgrade is the popular Monthly Summary Product (Fig. 2), which can be generated by interrogating a full month of 5-minute observation data in less than 20 seconds.

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Monthly Summary

Change the Site / Month:
AK Barrow 4 ENE [Aug 09 2002 – Nov 28 2017]
2017-10 | Go

AK Barrow 4 ENE — Oct 2017

Display Units: Metric US Customary

DAY	TEMPERATURE						PRECIPITATION			WIND		SOLAR RADIATION		
	AVG	MAX		MIN		MEAN	TOTAL	MAX HOURLY	MAX 5M	MAX HOURLY	MAX 10S	TOTAL	MAX HOURLY	
	°C	°C	TIME	°C	TIME	°C	MM	MM	MM	M/S	M/S	(MJ/M^2)	W/M^2	TIME
1	0.7	3.6	15:20	-1.5	03:40	1.1	3.0	1.1	0.3	4.5	8.3	0.7	103	15:00
2	1.6	2.4	09:25	0.8	21:55	1.6	0.0	0.0	0.0	9.4	13.2	0.6	75	14:00
3	0.4	1.3	01:25	-0.7	11:05	0.3	0.0	0.0	0.0	8.6	11.5	1.7	308	13:00
4	0.1	1.4	14:45	-0.5	00:20	0.5	0.0	0.0	0.0	6.8	9.1	1.3	203	15:00
5	1.2	2.2	13:50	0.1	00:15	1.2	2.6	0.8	0.3	5.7	7.7	1.4	182	14:00
6	1.3	2.2	14:15	-0.1	23:50	1.1	0.7	0.4	0.3	8.0	11.0	0.8	94	15:00
7	-0.4	0.7	11:15	-2.0	22:05	-0.6	1.1	0.5	0.3	6.4	9.5	1.9	272	15:00
8	-0.7	0.4	19:30	-1.9	05:15	-0.8	0.8	0.3	0.3	3.9	6.5	1.1	195	12:00
9	-0.5	0.4	01:40	-2.1	22:45	-0.8	0.0	0.0	0.0	4.4	6.1	0.6	46	14:00
10	-0.4	0.2	23:45	-1.8	00:10	-0.8	0.9	0.4	0.3	6.2	7.8	0.8	80	15:00
11	-0.6	0.3	02:30	-2.7	22:00	-1.2	0.0	0.0	0.0	4.0	5.6	1.0	70	15:00
12	-1.1	0.1	21:50	-2.4	00:55	-1.1	0.0	0.0	0.0	12.4	15.9	1.2	172	13:00
13	-0.2	0.0	18:15	-0.7	23:05	-0.3	0.0	0.0	0.0	11.4	14.5	0.4	31	13:00
14	-2.6	-0.1	01:05	-3.7	23:40	-1.9	0.4	0.4	0.4	10.0	12.9	0.1	36	11:00
15	-4.3	-3.0	00:00	-6.3	19:25	-4.6	0.7	0.5	0.3	5.1	7.4	0.9	171	15:00
16	-2.3	-1.2	09:40	-3.9	23:15	-2.6	3.4	1.4	0.4	6.4	9.2	0.4	78	14:00
17	-3.4	-1.4	13:35	-6.6	00:00	-4.0	1.7	0.4	0.4	13.2	16.7	0.4	70	14:00
18	-7.9	-6.5	00:25	-9.6	13:20	-8.1	1.5	0.4	0.4	9.8	13.4	1.1	249	13:00

Figure 2. Example of a Monthly Summary report providing summary of the day observations for temperature, precipitation, wind, and solar radiation. With the database improvements made in FY17, such reports are now provided more consistently and rapidly in response to user queries.

Other database changes included the addition of new streams and elements to the USCRN database schema to make possible the testing of new Acclima soil sensors. The USCRN schema also was modified to hold additional metadata from ISIS, the metadata repository for the Network. This additional metadata allows USCRN to assign multiple stations to the same GOES identifier over time, improving ID reuse. It also provides a more complete history of station hardware, improving quality control and dataset reprocessing. Further schema and program modifications were performed to improve the availability of data from dual-transmitter stations in Alaska. In cases where the primary sensors for a station are unable to report, the secondary station's observations are automatically substituted. This feature is used by the USCRN website to populate element fields in tables and products. Doing this provides a more seamless dataset to the public, who would without this feature, only see an empty web page or rows of missing values in the products.

On two occasions updates to the USCRN DOMSAT receiver had to be made when the broadcast frequency from the satellite was changed by federal GOES Data Collection System operations. The DOMSAT receiver serves as a backup system for acquisition of data from the USCRN network. It involves retransmission of data from Wallops to the DOMSAT satellite and subsequent receipt via a small satellite dish on the roof of NCEI. This serves as a critical last source of data in the event of loss of connectivity from primary sources via the internet. The updates involved coordination with NCEI IT personnel and direct physical changes at the server on the IT operations floor. The changes were made without any issues and no interruption of service occurred.

Updates to the Official Precipitation Algorithm

Improvements to the Official Precipitation Algorithm were made in FY16 and were followed by additional improvements in FY17; from version 2.1 to v2.1.1 (see section on USCRN Science and Development for more in this improvement). In order to apply the V2.1.1 changes, the USCRN database had to be reprocessed. This involved recalculating precipitation for all stations for their periods of record (for 5-minute measurements). The re-design of the USCRN ingest software system that was accomplished in FY16, made for a relatively fast reprocessing of v2.1.1 (approximately 10 days).

After the reprocessing and as part of the configuration change process, the software developers performed comparisons with the previous version, alongside USCRN scientists, to ensure the differences found with the previous version were as expected. Following this process of verification, the official FTP product files were recreated and made publically available. The README files for each product also were updated and a "Dataset Status" document was created and posted on the USCRN website.

Archive Submission Agreement Revision and Implementation

The second phase of an initiative to develop new Submission Agreements (SA) and process flows that began in FY16 was completed in FY17. One SA covering USCRN's *products and processed data* had been completed in FY16. With the assistance of NCEI's Archive Branch (AB), this SA was updated in FY17 to incorporate changes that were made in association with the updated Official Precipitation Algorithm; v2.1.1. As part of the SA update, software also was updated in order to archive the new data version properly and to include updated documentation in the archive package.

A second Submission Agreement and archive process was completed in FY17. This SA and the associated data transfer processes ensure all USCRN *raw and experimental data* are fully documented and archived. This includes ingested data from LRGS (Local Readout Ground Station) and NOAAPort (aka "raw-transmitted" sources), data downloaded during annual maintenance visits via the station's dataloggers (PDAs), and also experimental data from the sites at Sterling, VA, Johnstown, PA, the Marshall test bed in Boulder, CO, and Tiski, Russia. Documentation was written, and several scripts were created to reorganize and package data into the monthly file formats necessary for meeting NCEI's Archive requirements. By the end of FY17, all data, documentation, and software code from all data sources had been developed, collected, packaged, tested, and transmitted to Archive (in accordance with the new SA). This effort ensures the long-term security and stewardship of all USCRN raw and experimental observations for future generations.

Station Monitoring and Reporting Tool (SMART) Improvements
Significant improvements to the USCRN Station Monitoring and Reporting Tool (SMART) software were made in FY16. The benefits of the efforts during the previous year were borne out in FY17. This software tool that provides engineers, scientists, and maintenance personnel with information on the status of each instrument on all USCRN stations worked flawlessly during the past year, requiring little maintenance or updates. Only one change was required in FY17 in response to an ATDD request. The thresholds for Geonor-Overflow reports were changed for the 1000mm buckets; they now report when 400mm or less remains, instead of the previous 250 mm threshold.

The re-design of the system in FY16 resulted in no longer needing to depend directly on the USCRN Ingest software. The system can now operate from any environment that offers access to the USCRN database, and maintenance was drastically simplified and its reliability greatly improved. Its performance in FY17 highlights the benefit of well-designed software infrastructure.

Operational quality control processes for soil moisture/temperature data
At most USCRN stations, measurements of soil temperature and soil moisture are made at five depths from 5 to 100 cm in three equally spaced locations surrounding the tower. The large number of sensors combined with the environment in which the sensors operate requires continued attention by software developers and scientists to identify potential instrument problems. Developers continued to support USCRN scientists in the monthly assessment through on-the-fly production of soil measurements plots including plotting sensors individually, and producing 3-panel graphs with statistics on soil sensor values (dielectric constants, precipitation, and volumetric soil moisture). Each month approximately five to 35 soil sensors were found to be providing erroneous soil moisture or temperature values either due to short-duration issues or long-term problems possibly requiring repair or replacement. So that inaccurate data are not provided to the user community, the identified sensors are added to a “bad sensor” list each month. After sensor problems are resolved by ATDD engineers in the field, the sensors are removed from the list of bad sensors. These activities require close collaboration with ATDD engineers.

Other Quality Control and Processing improvements
Occasionally, equipment malfunctions or other issues cause data to be erroneous, even though the values fall within the range of acceptable values set within the preset quality control threshold limits. In such cases, the inaccurate measurements are not flagged by the automated quality control algorithms in the ingest software system. However, there is a process of steps, based on manual intervention, to flag these faulty data values. The proper flagging of the erroneous observations are deployed via the ingest software “bad sensor list”, and once deployed in real-time, are then implemented retroactively, and verified. Numerous “exceptions” involving faulty precipitation data from past years were processed and resolved via manual flagging and recalculation. In addition and with the assistance of NCEI’s IT personnel, the mechanisms to store and deploy changes involving manual flagging were improved. This was done to ensure that quality control modifications are not made inadvertently and that they are fully tested prior to going into production.

Other manual corrections also were required in FY17, associated with incoming data from four Alaskan stations in order address two issues involving faulty transmissions. One problem occurred when a new system update was applied to the datalogger's operating system. This resulted in the recording/broadcasting of the wrong datalogger version for almost two months. With the incorrect version, the ingest software could not read the stream information and properly ingest the data. The other issue involved removing data broadcasted with incorrect GOES IDs. Software developers wrote scripts to decode and alter the raw pseudo-binary data streams that were transmitted via satellite in order to correct the data transmission problems so all problematic data could be properly ingested into the database each day it arrived.

Multigraph and Website Updates

To improve the user experience many parts of the USCRN website were updated. Content was updated to reflect new station installations, navigation on the sensor page was improved by adding a "Last Hour" link that would adjust to a station's last reported hour, and graphs of USCRN data were updated to use the latest version of Multigraph while remaining backwards compatible for Java Applets. Special news content was also deployed for the 2017 eclipse. Additionally, several bug fixes were made to website reports.

Data and Analysis Support for Scientists/Engineers

Software developers fulfilled data pull requests in support of internal and external USCRN scientific and engineering inquiries, and provided analysis and research support on several occasions. In addition, using tools developed in previous years for improving quality control, soil moisture and temperature plots were made for every USCRN soil sensor and evaluated in order to assist with site selection for testing the new Acclima soil sensor probes. Once the test stations were agreed upon by USCRN personnel, ATDD engineers removed Hydra soil sensors at all depths in one of the three holes and replaced them with Acclima probes for testing. Following each installation, the software developers manually flagged the Acclima test data so that the data would not be used in the official layer averages for soil moisture and temperature. Additionally, they updated plotting code to display the test sensors and provided data, plots, statistics, and analysis comparing the soil moisture and soil temperature behavior of the two sensor types. Results were presented to the USCRN team and will feed into an eventual NOAA Technical Memorandum in FY18 to look at what it will take for possibly transitioning from the Hydra to Acclima soil sensors.

USCRN Science and Development Activities

Five journal articles completed in previous fiscal years were published by researchers in the USCRN program in FY2017 using USCRN data to address a variety of issues, from model verification to human health issues. Three new journal article submissions were made during FY2017. Work was completed on further improvements of USCRN precipitation calculations (OAP 2.1.1) and improved quality control flagging methods developed last year to quality control precipitation-related observations were implemented to address issues with other variables. Presentations were made at numerous conferences and workshops, and efforts were made to enhance social media outreach supporting the USCRN, especially at the time of the 2017 Solar Eclipse. However, most of the science efforts were oriented toward two main projects: 1) the continuing development of a standardized soil moisture product and the further synthesis of these data into drought indices in support of the National Integrated Drought Information System (NIDIS) effort; and 2) validating a potential replacement for the current USCRN soil moisture instrument.

Papers Published in FY2017

Findings described in the following three papers were discussed in the FY2016 Annual Report, although the work to complete the publications is recognized as occurring during this FY2017:

Coopersmith, E. J., M. H., Cosh, J. E. Bell, and R. Boyles, 2016. Using machine learning to produce near surface soil moisture estimates from deeper in situ records at US Climate Reference Network (USCRN) locations: Analysis and applications to AMSR-E satellite validation. Advances in Water Resources, 98, 122-131. doi: 10.1016/j.advwatres.2016.10.007.

Coopersmith, E. J., M. H. Cosh, J. E. Bell, V. Kelly, M. Hall, M. A. Palecki, and M. Temimi, 2016: Deploying temporary networks for upscaling of sparse network stations. International Journal of Applied Earth Observation and Geoinformation, 52, 433-444. doi: 10.1016/j.jag.2016.07.013.

Leeper, R. D., J. E. Bell, C. Vines, and M. A. Palecki, 2017. An Evaluation of the North American Regional Reanalysis Simulated Soil Moisture Conditions during the 2011 to 2013 Drought Period. Journal of Hydrometeorology, 18. doi: 10.1175/JHM-D-16-0132.1.

USCRN Soil Moisture and Health in the U.S. Southwest

An article was submitted and published during FY2017 by USCRN Science Team members in the first issue of the AGU Journal GeoHealth exploring the relationship of soil moisture to coccidioidomycosis (valley fever) in Arizona and southern California:

Coopersmith, E. J., J. E. Bell, K. Benedict, J. Shriber, O. McCotter, and M. H. Cosh, 2017. Relating coccidioidomycosis (valley fever) incidence to soil moisture conditions, *GeoHealth*,**1**, doi:10.1002/2016GH000033.

The article was chosen to provide the cover figure, which is a picture of the USCRN station in Tucson. A thorough analysis showed that the occurrence of valley fever was inversely correlated to soil moisture the previous year in both California and Arizona (i.e., following a drought), but the relationship becomes more complex in Arizona with the conditions two years earlier. If soil conditions are wetter than normal two winters before the current year, this actually promotes the occurrence of valley fever two years later, essentially generating the fungal spores that are then dispersed in succeeding drought periods (Fig. 3).

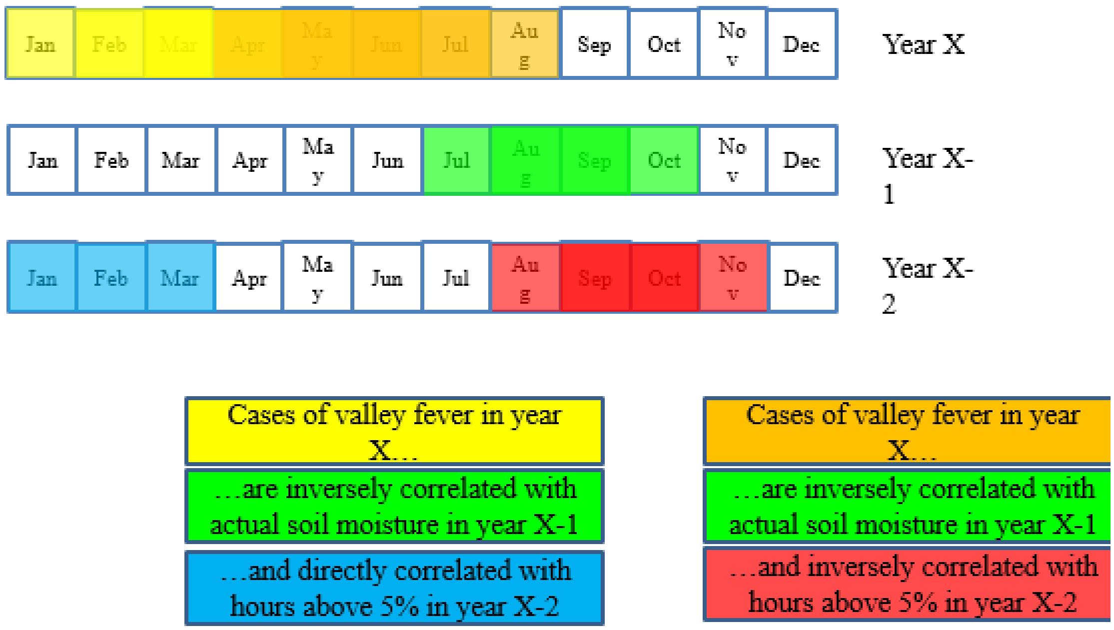

Figure 3. Time relationship of soil moisture state to cases of Valley Fever in Arizona.

USCRN Site-Specific Soil Properties and Soil Moisture

The national scope of the USCRN and its placement in a variety of natural settings allowed for the relationships between soil properties and soil moisture characteristics to be examined in the paper:

Wilson, T. B., C. B. Baker, T. P. Meyers, J. Kochendorfer, M. Hall, J. E. Bell, H. J. Diamond, and M. A. Palecki, 2016. Site-Specific Soil Properties of the US Climate Reference Network Soil Moisture. *Vadose Zone Journal*, **15**(11). doi: 10.2136/vzj2016.05.0047.

During soil probe installation, samples of soil were extracted at each depth of the three independent plots at each station. The laboratory samples for 70 sites were processed to reveal texture, bulk density, wilting point, field capacity, and assays of several bases. A strong non-linear relationship between wilting point and field capacity was found. This non-linearity was due to the wilting point changing more slowly with clay content or sand content than the field capacity (Fig. 4). The paper also served to demonstrate how soil properties vary with depth and with site, causing soil moisture to vary between USCRN sites and even between nearby plots at the same site exposed to similar precipitation regimes.

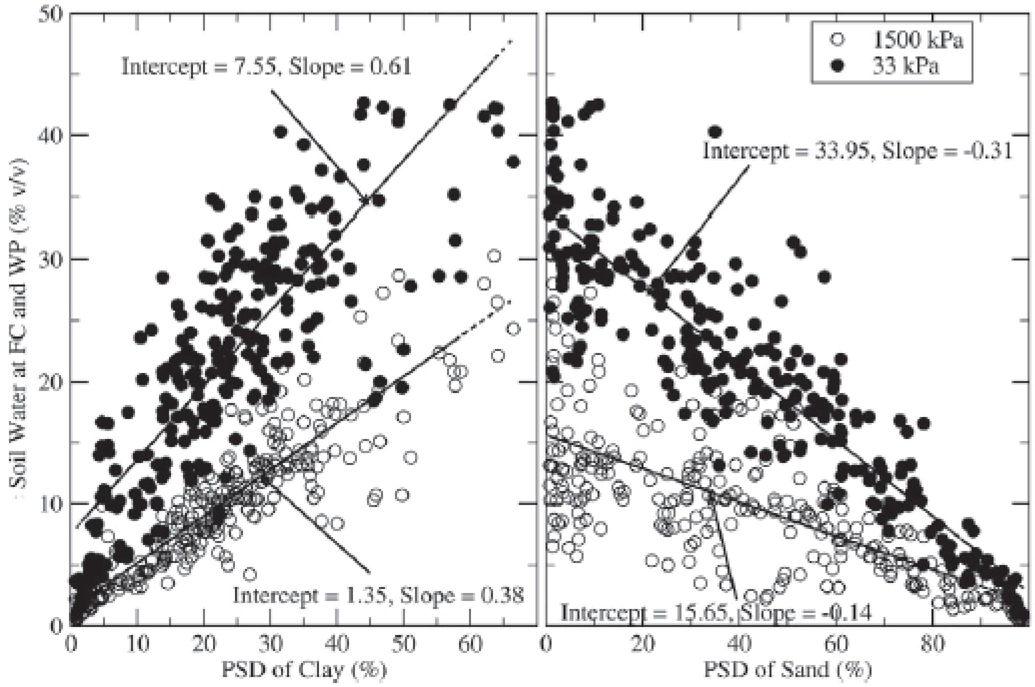

Figure 4. Soil volumetric water content at wilting point (1500 kPa) and field capacity (33 kPa) as a function of clay and sand contents.

Papers Submitted in FY2017

Three additional journal articles were submitted during FY2017 that have since been accepted and/or published. Two of the articles were written by large groups of contributors that included USCRN Science Team members:

Chan, S. K., R. Bindlish, P. O'Neill, T. Jackson, E. Njoku, S. Dunbar, J. Chaubell, J. Piepmeier, S. Yueh, D. Entekhabi, A. Colliander, F. Chen, M.H. Cosh, T. Caldwell, J. Walker, A. Berg, H. McNairn, M. Thibeault, J. Martínez-Fernández, F. Uldall, M. Seyfried, D. Bosch, P. Starks, C. Holifield Collins, J. Prueger, R. van der Velde, J. Asanuma, M. Palecki, E.E. Small, M. Zreda, J. Calvet, W. T. Crow, and Y. Kerr, 2018. Development and assessment of the SMAP enhanced passive soil moisture product. *Remote Sensing of the Environment*, **204**, 931-941. doi: 10.1016/j.rse.2017.08.025.

Thorne, P. W., H. J. Diamond, B. Goodison, S. Harrigan, Z. Hausfather, N. B. Ingleby, P. D. Jones, J. H. Lawrimore, D. H. Lister , A. Merlone, T. Oakley, M. Palecki, T. C. Peterson, M. de Podesta, C. Tassone, V. Venema, K. M. Willett, 2018. Towards a global land surface climate fiducial reference measurements network. *International Journal of Climatology,* in print, doi: 10.1002/joc.5458.

The first article evaluates the performance of the new set of enhanced Soil Moisture Active Passive (SMAP) mission soil moisture product suite that combines passive microwave data from overlapping swaths to take the original SMAP instrument resolution of 36 km and produce a resampled 9 km resolution product. USCRN has long provided soil moisture data for what is considered to be "sparse network" assessments that are conducted by comparing SMAP product surface soil moisture estimates with in situ 5 cm depth soil moisture measurements from USCRN

and other networks.
The second article enjoys participation from three USCRN scientists and provides the background, rationale, metrological principles, and practical considerations for developing a global network of stations that make quality measurements of essential climate variables. Improved information from such a network would allow climate change and variation information of the highest quality to be available for global, national, and regional decision makers. The USCRN is one example of this approach that was highlighted in the paper.

Great American Eclipse
A project of opportunity was mounted in response to the 21 August 2017 total solar eclipse that crossed the United States from Oregon to South Carolina and impacted 9 USCRN stations with lengths of totality varying from 0.52 to 2.55 minutes (Fig. 5a). Activities took place across the USCRN team, analyzing station climate data during the eclipse day and deploying a team into the path of totality in Tennessee to take supplemental measurements of surface fluxes and boundary layer profiles. Highlights of the findings of these observations have been accepted for publication in EOS, the news and perspectives magazine of the American Geophysical Union:

Lee, T., M. Buban, M. A. Palecki, R. D. Leeper, H. J. Diamond, E. Dumas, T. P. Meyers, and C. B. Baker, 2018. NOAA scientists get a rare opportunity to study the effects of the Great American Eclipse. *EOS* (in press).

The USCRN view of the eclipse was unique, consisting of a standard set of high quality instruments spread across the coterminous United States. In addition to the 9 stations that reached complete obscuration, 54 stations had at least 75% obscuration, and all but one station had at least 50% obscuration. Therefore, the climate impacts spread nationwide, and were not confined simply to the path of totality, as is seen in the decrease in solar radiation during the 5-minute interval closest to totality for each location (Fig. 5b).

The eclipse caused a decrease in air temperature (Fig. 6a) and corresponding increase in relative humidity (Fig. 6c). Maximum cooling ranged from 2°C to 5°C near the centerline. Surface temperature decreased at 109 sites; surface temperature decreases were much larger than air temperature decreases and ranged from 5°C to 15°C (Fig. 6b).

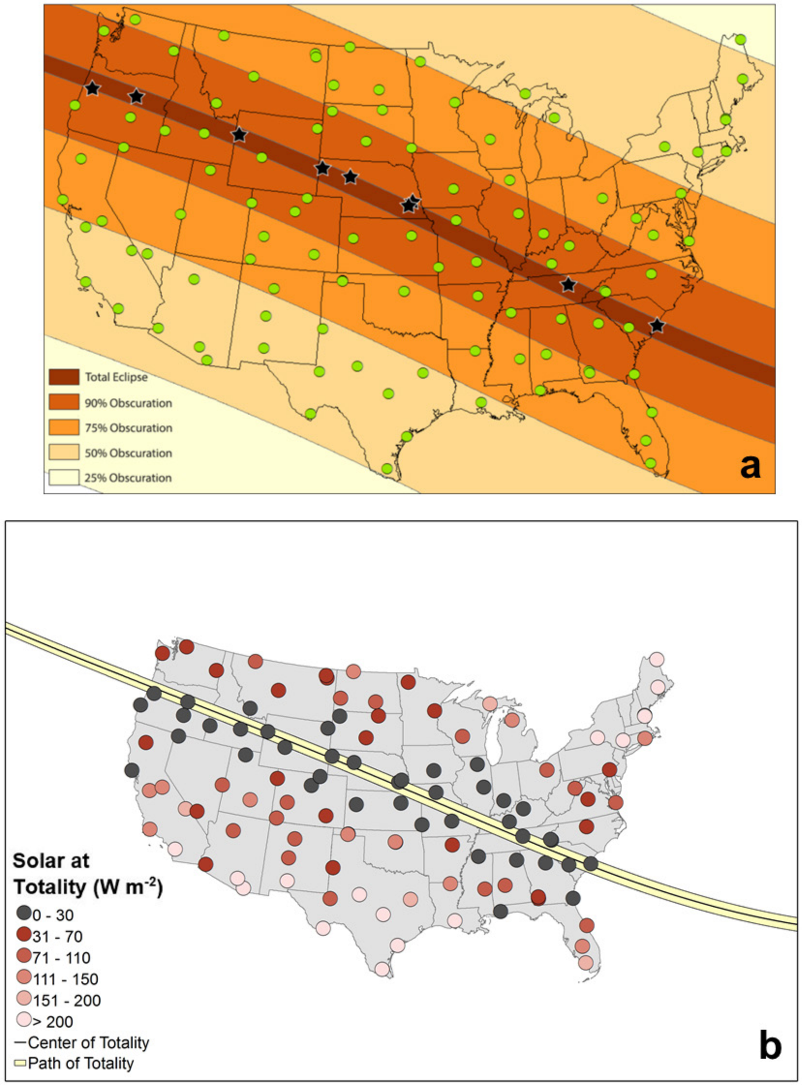

Figure 5: (a) USCRN stations in the path of the 21 August 2017 total solar eclipse (black stars); and (b) global solar radiation (W m^{-2}) during the 5-minute interval when each USCRN station was closest to totality.

Eclipse data from the USCRN stations and additional data animations are available from ftp://ftp.atdd.noaa.gov/pub/crn/solar_eclipse_data/ and http://www.atdd.noaa.gov/crn-eclipse, respectively. A document reporting on the climate impacts of the eclipse is available at: https://www1.ncdc.noaa.gov/pub/data/uscrn/publications/events/Total Eclipse 2017.pdf.

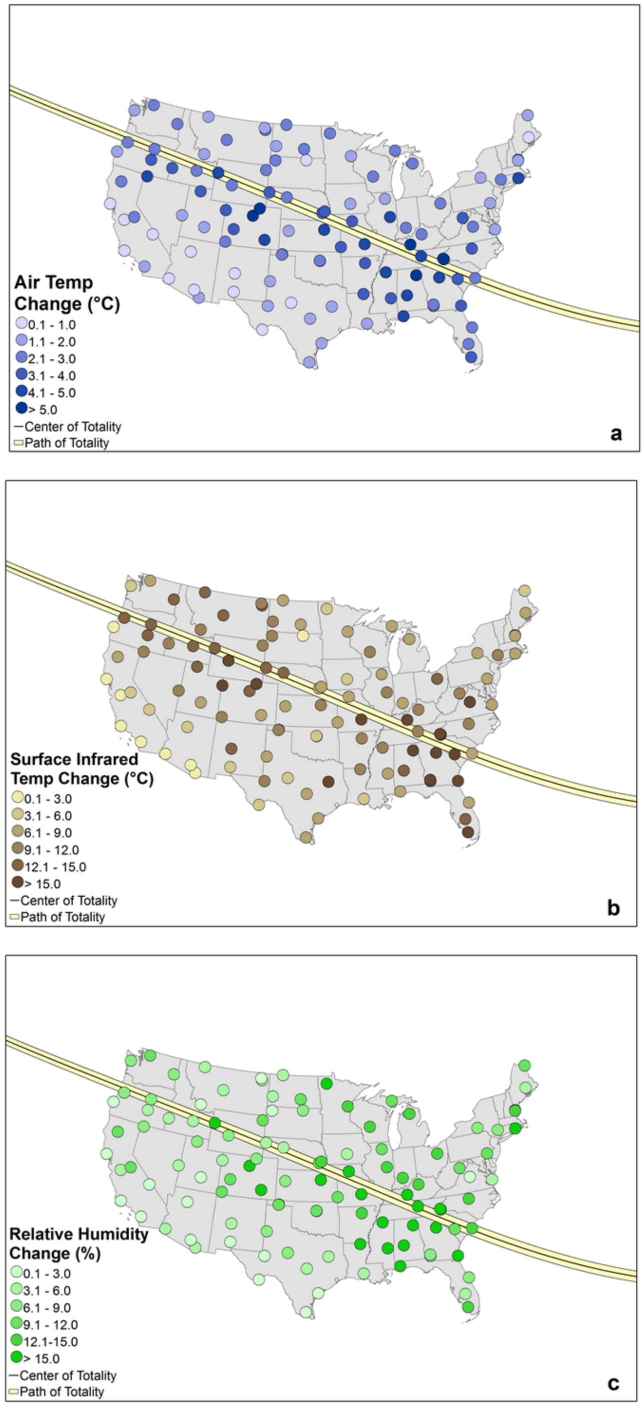

Figure. 6: (a) Air temperature (°C), (b) surface infrared temperature (°C), and (c) relative humidity (%) change between the maximum temperature (minimum relative humidity) within the two hours prior to closest approach to totality and the minimum temperature (maximum relative humidity) near totality at the USCRN stations in the coterminous United States.

Standardized Soil Moisture Product Development

While soil moisture is an important component of the hydrological cycle, the utility of these data for monitoring and decision support can be limited if not placed in proper context. It is well understood that local soil characteristics, land cover, slope (i.e. drainage), and seasonal precipitation patterns impact soil moisture measurements. As a result, typical soil moisture conditions can vary substantially over short distances and with season, making it difficult for users to distinguish between dry and wet observations without a well-defined climatology. For instance, a soil moisture observation of 0.17 m^3m^{-3} may be dry for a location in the eastern half of the U.S. during spring, but may indicate wetter than normal conditions at the same time in the desert Southwest. The combination of soil moisture sensitivity and a lack of measurement standards make it difficult to monitor soil moisture conditions across regional and national scales and provide consistent understanding of conditions across time and geography.

Standardization of raw soil moisture measurements is the key to their successful application in a monitoring context. One potential approach is the use of simple anomalies, removing the mean for the time of year and working with the residuals. These anomalies can then be converted to Z-scores by dividing through by the appropriate standard deviation. However, this approach depends on the soil moisture measurements being normally distributed, which is not generally the case (Fig. 7). The time series length also impacts the distribution of soil moisture measurements, with shorter time series not fully representing the natural range of possibilities for a given day of the year.

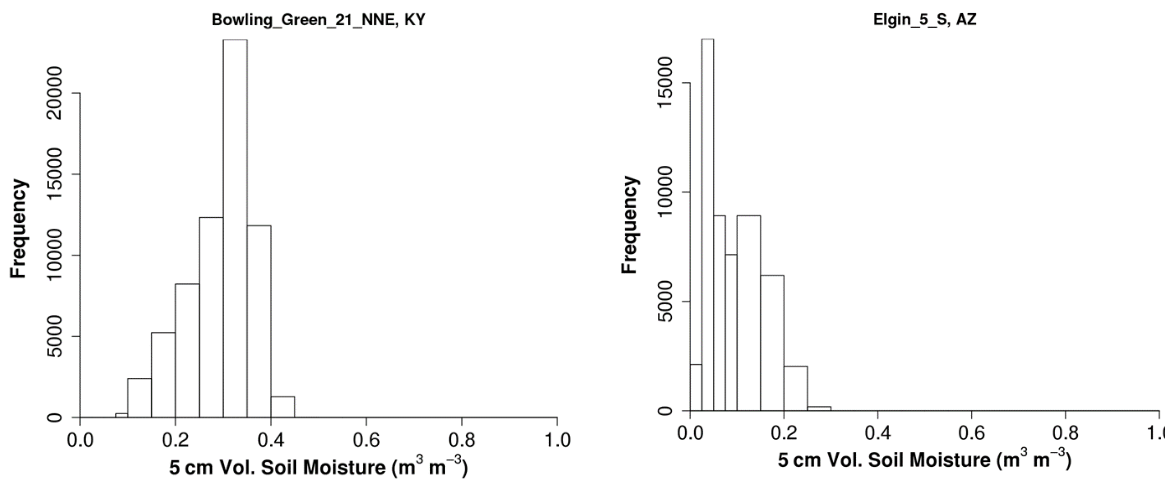

Figure 7. The period-of-record distribution of hourly soil moisture (m^3m^{-3}) at Bowling Green KY and Elgin AZ.

To overcome this issue, an approach based on the empirical distribution of seasonal soil moisture anomalies was developed during FY2017. Since most USCRN stations have only 5-8 years of soil moisture measurements, it was critical to sample not only interannually but also some number of days surrounding the target date and time in each year. Since day-to-day soil moisture is reflective of the imbalance of precipitation and evapotranspiration, this sampling strategy adds some degrees of freedom to the total sample with which to construct the empirical cumulative distribution function for a given hour of the annual cycle. This work resulted in the preparation of an alpha version standardized soil moisture dataset for the USCRN. Sampling strategy testing continues into

FY2018 in order to optimize the results for users. The example case here was generated in the manner of the alpha standardized soil moisture product.

First, a smoothed representation of the seasonal cycle was generated (Fig. 8). This was used to calculate anomalies for each hour of the records at a station.

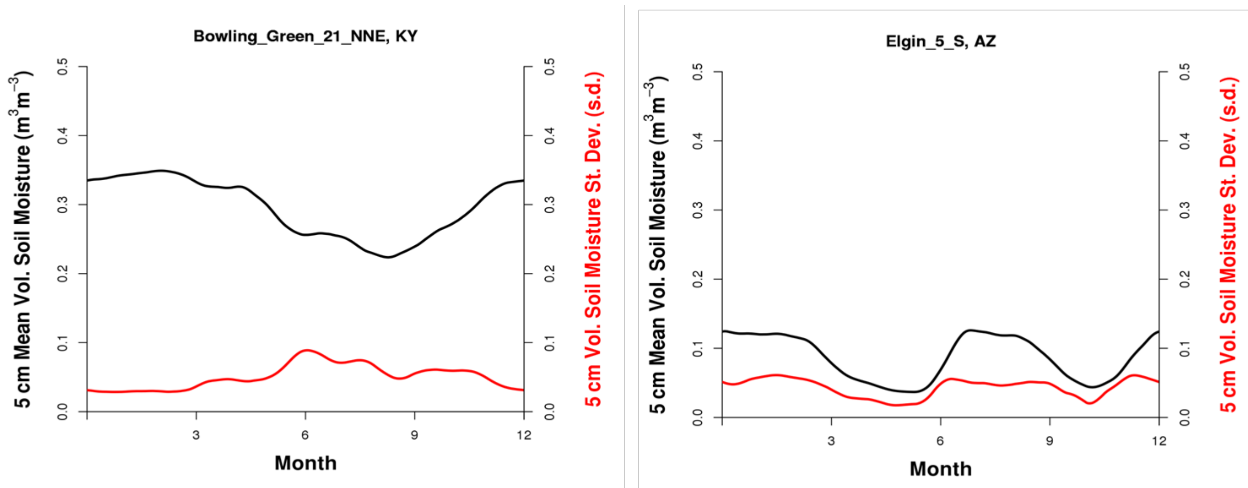

Figure 8. The black lines and left axes represent the mean soil moisture conditions for each hour of the seasonal cycle (m^3m^{-3}), using 15-day sampling and a similar length smoothing after the hourly means were calculated.

The anomalies were used to generate the empirical cumulative distribution. Sampling only the hour of interest for the number of years available results in an ill-defined, blocky distribution. Using a 15-day sample, on the other hand, produced a much smoother distribution for the soil moisture with important extensions into very high and very low percentile ranges (Fig. 9).

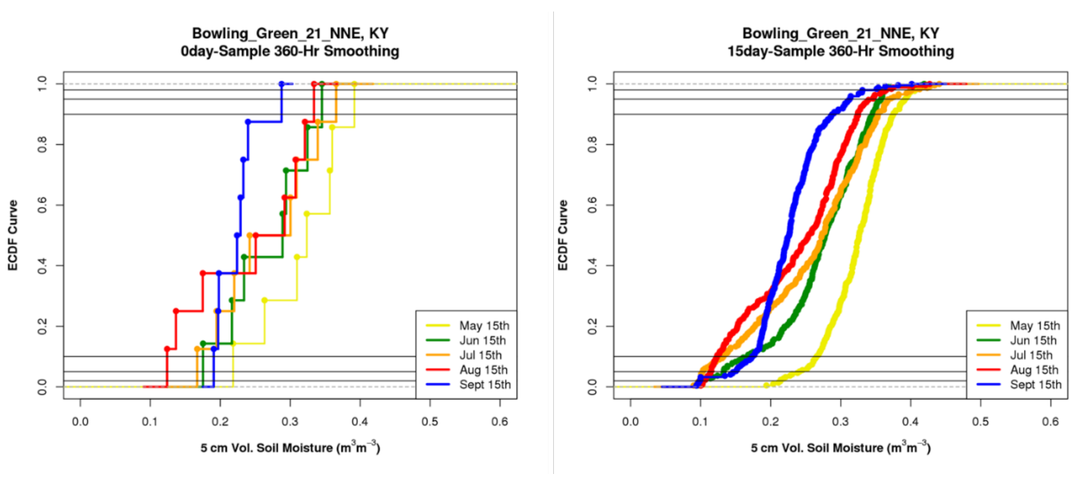

Figure 9. Empirical cumulative distribution functions for Bowling Green, KY for all years and specific dates: (left) no sampling; (right) 15-day sample to either side of the date in question.

The effects at the desert location of Elgin, AZ were even more pronounced, with sampling capturing many more cases of wet soil extremes due to the wider sampling period (Fig. 10).

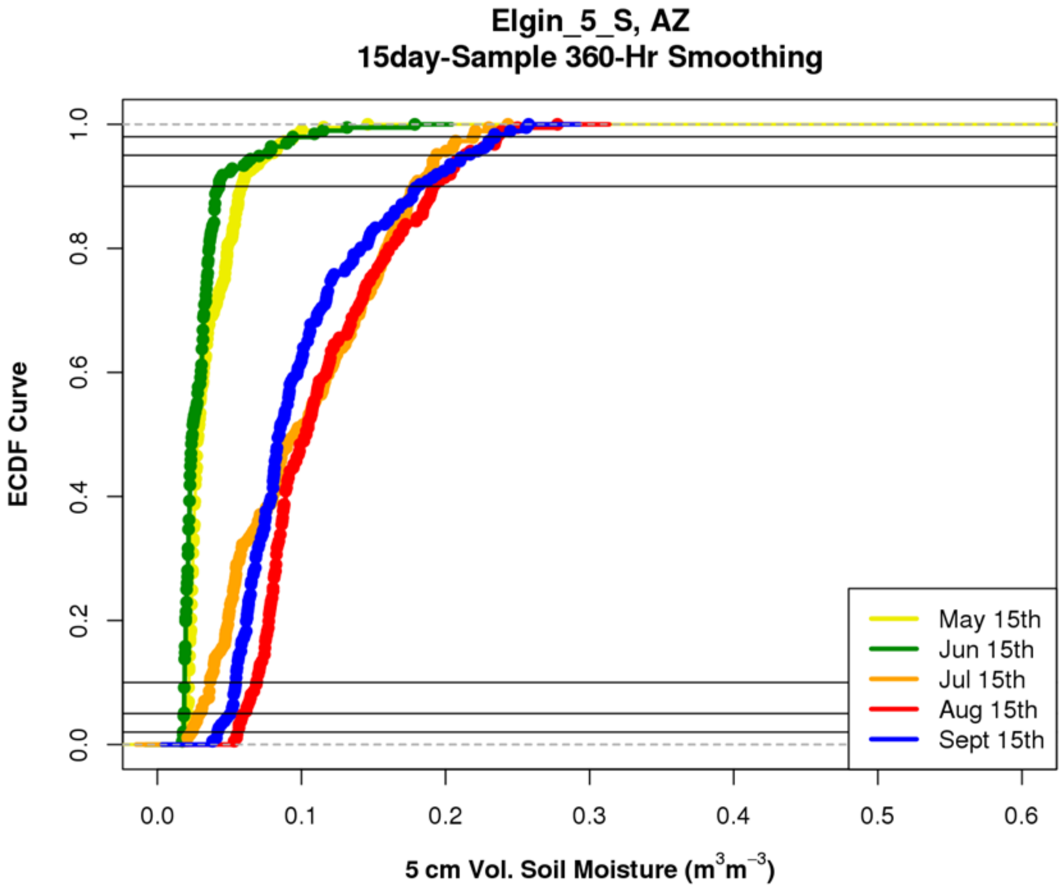

Figure 10. Empirical cumulative distribution functions for Elgin, AZ for all years and specific dates with a 15-day sample to either side of the date in question.

The standardized soil moisture anomalies are represented by their associated percentile in the empirical cumulative distribution function. These values are comparable from station-to-station, and are the basis for further development of useful drought indices. Various approaches to combining these percentiles over time are being studied, including averages and medians for weeks to seasons prior to current time, or counts of hours when the percentile is above or below certain thresholds associated with significantly wet or dry conditions. Initial testing relating these indices to U.S. Drought Monitor (USDM) levels indicates that standardized soil moisture is useful for both determining current drought status and for tracking changes in drought status. On a national basis, the percentage of hours for the seven days prior to a change in USDM status tends to skew toward wetter percentiles when improvement occurs, and skews strongly toward drier percentiles when deterioration occurs (Fig. 11).

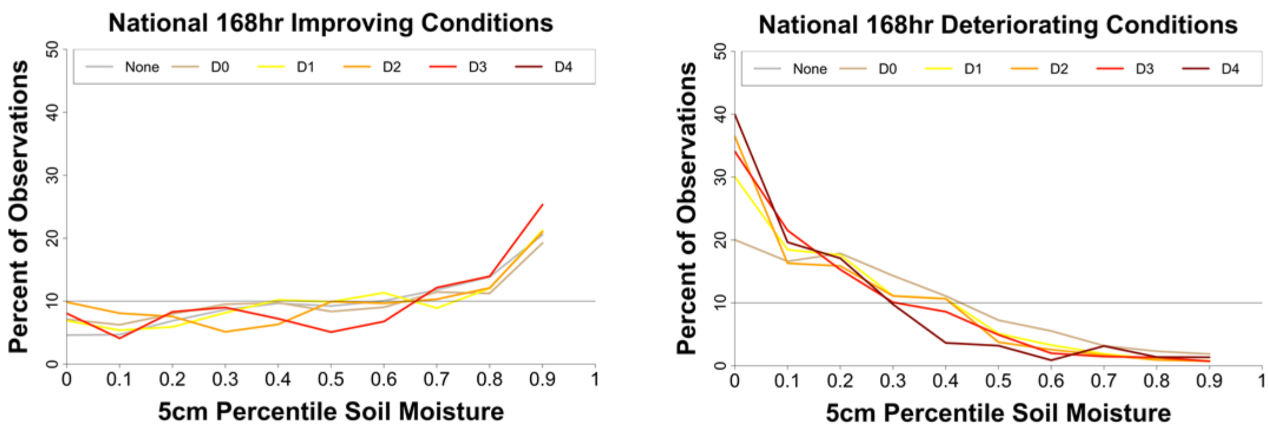

Figure 11. On a national basis, more moderate to very wet percentile hours occur at 5 cm depth when drought status is improving (left), and more strongly dry percentile hours occur when drought status is deteriorating, especially when reaching D2 to D4 levels (right).

The work on the standardized soil moisture and drought indices project will continue through FY2018. Expected outcomes include a final version of the standardized soil moisture data, cumulative drought indices, and analyses relating these drought indices to USDM evolution and other drought indices.

USCRN Marshall Testbed

At the USCRN testbed at Marshall, CO, the World Meteorological Organization Solid Precipitation Intercomparison Experiment (WMO-SPICE) measurement period has officially ended, but many of the manufacturer-provided sensors and other measurement systems installed for WMO-SPICE remain under evaluation at the site. In addition to routine maintenance of all of the sensors at the site, the primary activities related to the testbed in FY17 were analysis and synthesis of the testbed results for inclusion in the WMO-SPICE final report and other publications.

The majority of the preparation of the WMO-SPICE final report was completed in FY17, and was submitted for copy-editing in January 2018. In addition, measurements from the USCRN testbed were used in several publications that were either submitted (Kochendorfer et al., 2017a) or published (Kochendorfer et al., 2017b and 2017c) in FY17. These publications were focused on the derivation of transfer functions for different types of weighing precipitation gauges and windshields. Transfer functions for automated weighing gauges were developed using multiple testbeds for the first time, resulting in estimates of site-specific variability and transfer functions that are more widely applicable. In addition, it was determined that the same transfer function could be used on different types of weighing precipitation gauges, because wind shielding (or a lack thereof) was the primary determinant of the appropriate transfer function, as opposed to gauge type.

The following papers have been an outgrowth of the Marshall testbed activities in FY17.

Kochendorfer, J., Nitu, R., Wolff, M., Mekis, E., Rasmussen, R., Baker, B., Earle, M. E., Reverdin, A., Wong, K., Smith, C. D., Yang, D., Roulet, Y.-A., Meyers, T., Buisan, S., Isaksen, K., Brækkan, R., Landolt, S., and Jachcik, A.: Testing and Development of Transfer Functions for Weighing Precipitation Gauges in WMO-SPICE, *Hydrol. Earth Syst. Sci. Discuss*., https://doi.org/10.5194/hess-2017- 228, in review, 2017a.

Kochendorfer, J., Nitu, R., Wolff, M., Mekis, E., Rasmussen, R., Baker, B., Earle, M. E., Reverdin, A., Wong, K., Smith, C. D., Yang, D., Roulet, Y.-A., Buisan, S., Laine, T., Lee, G., Aceituno, J. L. C., Alastrué, J., Isaksen, K., Meyers, T., Brækkan, R., Landolt, S., Jachcik, A., and Poikonen, A. (2017): Analysis of single-Alter-shielded and unshielded measurements of mixed and solid precipitation from WMO-SPICE, *Hydrol. Earth Syst. Sci*., **21**, 3525-3542, https://doi.org/10.5194/hess-21-3525-2017b.

Kochendorfer, J., Rasmussen, R., Wolff, M., Baker, B., Hall, M. E., Meyers, T., Landolt, S., Jachcik, A., Isaksen, K., Brækkan, R., and Leeper, R. (2017): The quantification and correction of wind-induced precipitation measurement errors, *Hydrol. Earth Syst. Sci*., **21**, 1973-1989, doi:10.5194/hess-21-1973-2017c.

A Continuing Evaluation of New Soil Moisture/Temperature Sensor Technology

In 2009, Hydra Probes were deployed to automatically measure soil moisture across the 113 USCRN stations[2] in the conterminous US. The Hydra Probes, which conduct point measurements of soil water content, soil temperature, and bulk soil electrical conductivity, offer the ability to make automatic and continuous measurements under a wide range of soil type, water and temperature conditions. The principle behind the Hydra Probe is the very high dielectric constant of pure water (80) compare to that of mineral soils (4-16) and air (1) at 20 degree C. Hydra Probes compute the soil dielectric constant which is then converted to water content. The Hydra Probes generate a 50 MHz signal from which the dielectric is computed, although this calculation is subject to some errors for soils with high conductivities. Soil specific calibration equations are required to convert the dielectric constant to water content. For USCRN, since site-specific calibrations were not performed before deploying the Hydra Probes, soil water content measurements are based on calibration equations developed for loamy soil types by Seyfried et al. (Vadose Zone Journal 4:1070–1079 (2005), doi:10.2136/vzj2004.0148).

Despite the general success of the USCRN soil moisture measurements, investigations of the Hydra Probe performance over several years have revealed the need for further evaluation. Hydra Probes have performed poorly in soils with relatively high clay content. This poor performance is attributed to both the clay content and the clay mineralogy interaction with water content and temperature. Hydra Probe dielectric constant measurements are strongly influenced by clay properties such as surface area and CEC. This is an issue that cannot be addressed by using factory-supplied calibration equations for clay, because they are generalized equations based on soil texture types, not on the mineralogy of a particular soil type. The Hydra Probe may be unsuitable for certain clay soils. An alternative for USCRN has been to replace the Hydra Probe with the Acclima Probe, which offers an affordable alternative by using time domain reflectometry (TDR), which is considered to be one of the best methods for measuring soil moisture.

[2] The USCRN network in the conterminous US has 114 stations, but one (Torrey, UT) has rocky soil precluding the installation of any soil sensors.

In light of this effort, since June 2016, the Hydra Probe and the Acclima Probe have been evaluated in a homogeneously packed coarse loamy soil testbed in the immediate vicinity of a USCRN test site in Oak Ridge, TN. The testbed covers a rectangular area about 130 cm x 245 cm and about 20 cm high above the natural ground. Uniform grass cover is maintained over both testbed and the surrounding ground. The average bulk density of the soil in the testbed is about 1.17 gm cm^{-3}. Four Hydra probes buried at 10 cm were used to measure volumetric soil water content and soil temperature. Both variables were also measured with four Acclima probes, also buried at 10 cm. The probes were about 25 cm apart. To validate the soil water measurement, gravimetric soil water measurements have been used, as well as soil water measurements from multiple Decagon sensors and an EnviroPro sensor.

In addition to the evaluation in the testbed further comparisons are also underway at 8 USCRN sites beginning in 2017. For this study, the Acclima probes were used to replace malfunctioned Hydra Probes at all depths in one of the three replicate probe sets. These data are being pulled, processed and provided to ATDD from NCEI.

Volumetric soil water content measured during 2016 and 2017 using Hydra and Acclima probes in the uniform soil testbed were compared. Differences in the water content measured with the two probes were less than a couple percent and in spite of the different events, excellent regression fits were obtained during 2016 (slope = 0.98, R^2 = 0.99, RMSD = 0.44%) and 2017 (slope = 1.03, R^2 = 0.98, RMSD = 0.49%). Differences in the line intercepts between the 2 years may have resulted because there were only 2 working Acclima Probes versus 4 Hydra Probes during 2016, while there 4 working Acclima Probes versus 4 Hydra Probes during 2017. Clearly this result shows that there is no difference between the Hydra and Acclima probes when they are used simultaneously in a spatially uniform soil layer. Despite considerable variation between individual probe pairs, the mean Acclima probe soil moisture values agree well with the mean Hydra probe soil moisture values in the uniform soil layer of the test bed

The Production of Gridded USCRN Data

To address a need for an enhanced utilization of the US Climate Reference Network (USCRN) dataset, a gridded product was produced. Daily means of more than 20 variables were computed, going back to at least 2006. In addition to the 114 conterminous USCRN stations analyzed, an additional 70 former Regional USCRN stations (RUSCRN) in the southwest US and Alabama (some of which are now run by the state climatologists in those states) were included to increase data coverage. These data were then analyzed to a grid and resulting analyses were output into a common netCDF format for use by the larger meteorological community. A brief description of this process follows.

After daily means of variables (e.g., air temperature, relative humidity, soil moisture and temperature, etc.) were computed, the freely available National Center for Atmospheric Research (NCAR) NCAR Command Language (NCL) was used to objectively analyze the data on to a 0.2° by 0.2° grid spanning from 20°N to 50°N and from 125°W to 60°W, covering the continental US. This was accomplished using a two-pass Barnes Objective analysis scheme. In this process, a first pass is completed using a relatively large region of influence, where data within a 6.0° radius were included in the analyses. Then a second pass was used to improve the analysis using a 1.0° radius of influence and a small convergence parameter to reduce the spectral response.

Once the analyses were produced, individual yearly animated .gifs were produced to visualize the data. These were output to netCDF files, with each file containing one variable for all days that the variable was available. For the files with the entire 11-year record, this corresponds to 4018 days. The files contain standard netCDF conventions as attributes, such as standard names, units, etc. They also contain "long names" for a more descriptive means for identifying the data included in each file. The time units are "days since 2006-01-01 00:00:00" as this was the first time period of the analyses. The analyses have been uploaded to the ATDD ftp server and can be found at ftp://ftp.atdd.noaa.gov/CI/crn/gridded/netCDF/archive/alldays/.

Monitoring Activity Highlights

Damaging Wind Storm in Death Valley Observed by USCRN Site at Stovepipe Wells, CA

On the afternoon of September 11, 2017, a "downburst" from a thunderstorm produced wind gusts estimated by National Park Service personnel to have been near 100 mph. The roofs of six structures were damaged including the one pictured below in Fig 12. Four cars also had smashed windows, while heavy metal trash "dumpsters" were tumbled down the street at the maintenance yard. It is located just below Park Village which lies about 4 miles north of Park Headquartes in Furnace Creek (see Fig. 13 below, an aerial photo of the maintenance yard). The red arrow indicates the approximate westerly direction from which the wind was blowing. The photograph in Fig. 12 is looking to the west. Note the debris in the parking lot on the east side of the building.

Figure 12. Severe wind damage to the roof of a Park Service building. Photo Credit Alexandria Boyer (NPS)

Figure 13: Aerial view of maintenance facility.

About 10 miles to the west-northwest at Stovepipe Wells, the USCRN station measured a 10-second gust of 48 mph at 5 feet above ground. If adjusted to the standard used for measuring wind speeds at most airport weather stations (a 3-second gust measured at 33 feet above ground) the (USCRN) station 10 second speed of 48 mph would represent a standard gust measurement of 60 to 65 mph. Such speeds were sufficiently strong to do minor damge in the Stovepipe Wells area. The peak winds at the Stovepipe Wells station occurred between 6:00 and 6:10 pm PST (see accompanying graphs below for further meteorological and geographical details).

Fig. 14 below is a wider satellite view of the north half of Death Valley. The three principal sites are marked by colored arrows. The yellow arrow marks the Stovepipe Wells site, red the wind damaged maintenance site just below Park Village, and the green arrow for Furnace Creek where Park Headquarters are located.

Figure 14: Satellite view of North half of Death Valley National Park

Fig. 15 on the next page shows the time of the peak wind 6:00-6:10 pm PST (green arrow) which was coincident in time with the rapid temperature fall of 20ºF (11ºC) in 20 minutes (red arrow). Temperatures fell from 106ºF (41ºC) to 86ºF (30ºC) during the storm. Fig. 16 on the next page shows the same temperature trace (blue line and red arrow) as in Fig. 15, but the additional data in red at the bottom of the graph is relative humidity expressed in percent (%). Note that the relative humidity (green arrow) rises about 30% from 17% to 47% during the same time that the temperature dropped about 20ºF.

That rise in the relative humidity is in response to the evaporation of the rain drops that fell from the base of the storm and in turn cooled the air. The cooled air being heavier than its surroundings sank towards the ground and spread rapidly outward producing the damaging winds of the downburst. Given that very little rain reached the ground at the USCRN weather station, this downburst would be classified as a "dry' downburst which is the most frequent type in desert regions. Fig. 17 shows that only 0.04 inches (1.0 mm) of rain was recorded from the thunderstorm. We know that it was a thunderstorm based on eyewitness reports that lightning struck one of the palm trees at Furnace Creek and set it on fire. Data in Figs. 15-17 also show that there was another rain and wind event that occurred between 9:15 and 9:25 am PST, however, the peak winds were only 26 mph (11.7 m/s) with no damage reported.

Fig. 18 is a polar satellite view of the desert regions of Southern California and Nevada. For perspective Las Vegas and Lake Mead are highlighted with red arrows to the right in the image, while the sites of Stovepipe Wells (green arrow) and Furnace Creek (yellow arrow) are indicated about 85 miles to the WNW of Las Vegas. The polar orbiting satellite view of the area was made between 1:23 and 1:25 pm PST on September 11, 2017. Even though the image was made about 5 hours before the time of the storm, it is clear that convective clouds still persisted over the higher terrain.

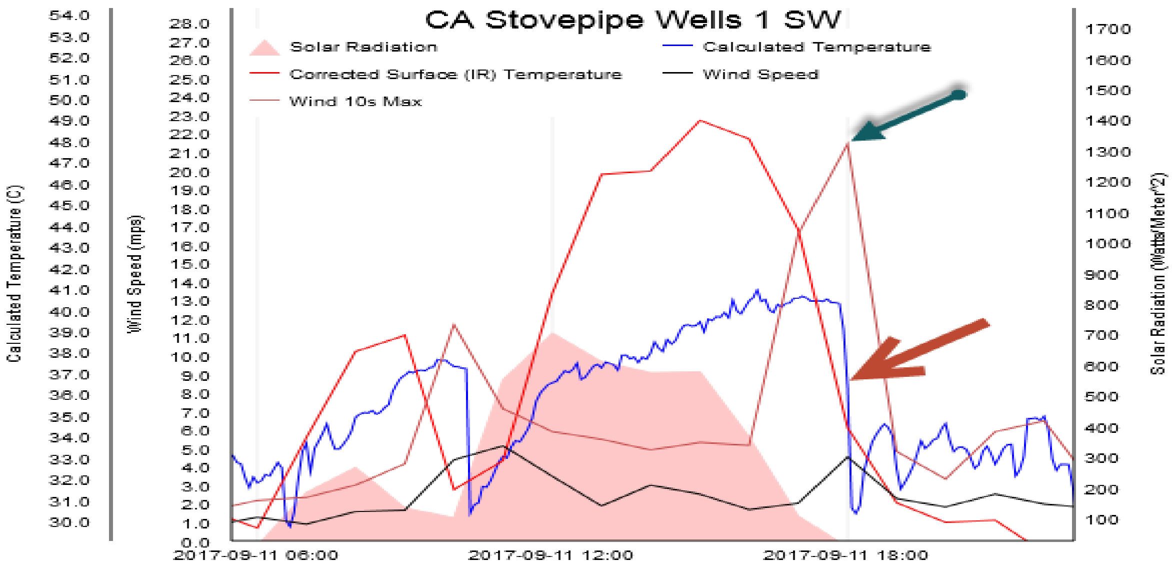

Figure 15: Temperatures (°C), solar radiation (W/m^{-2}), and wind (m/s)

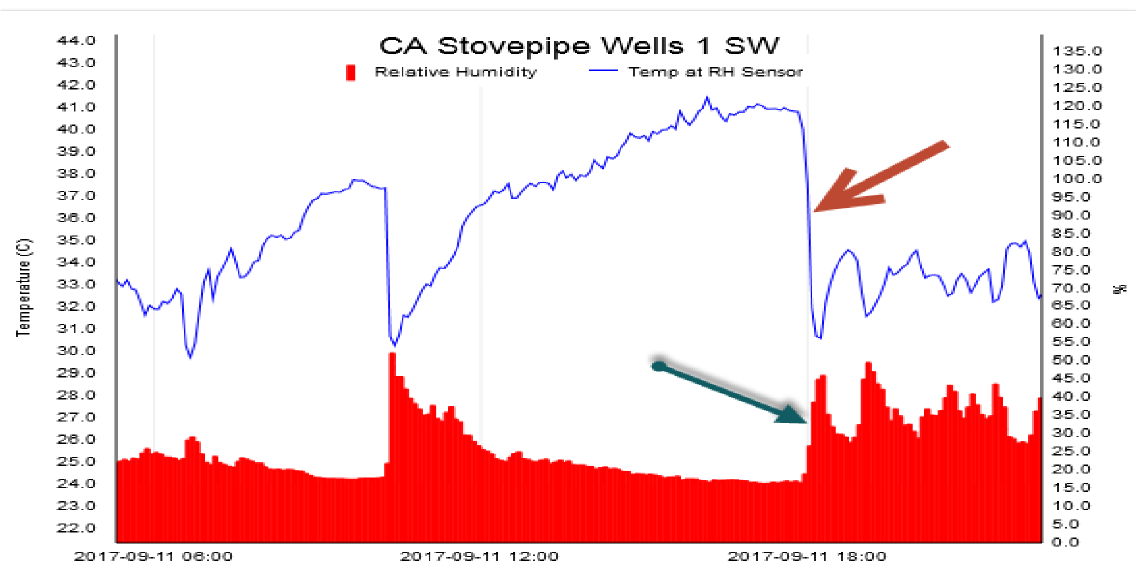

Figure 16: Temperature (°C) and Relative Humidity (%)

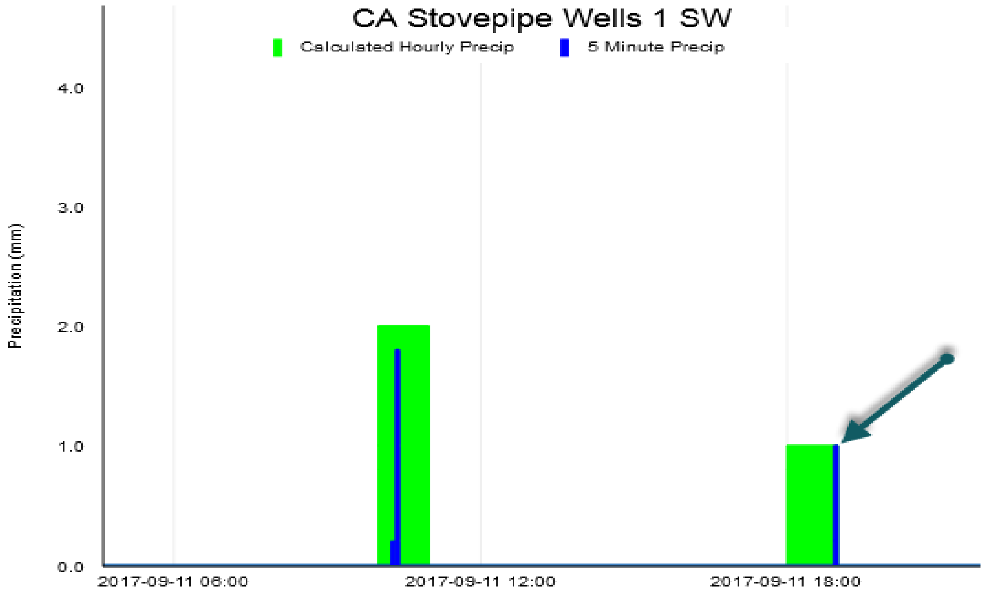

Figure 17: Precipitation (mm)

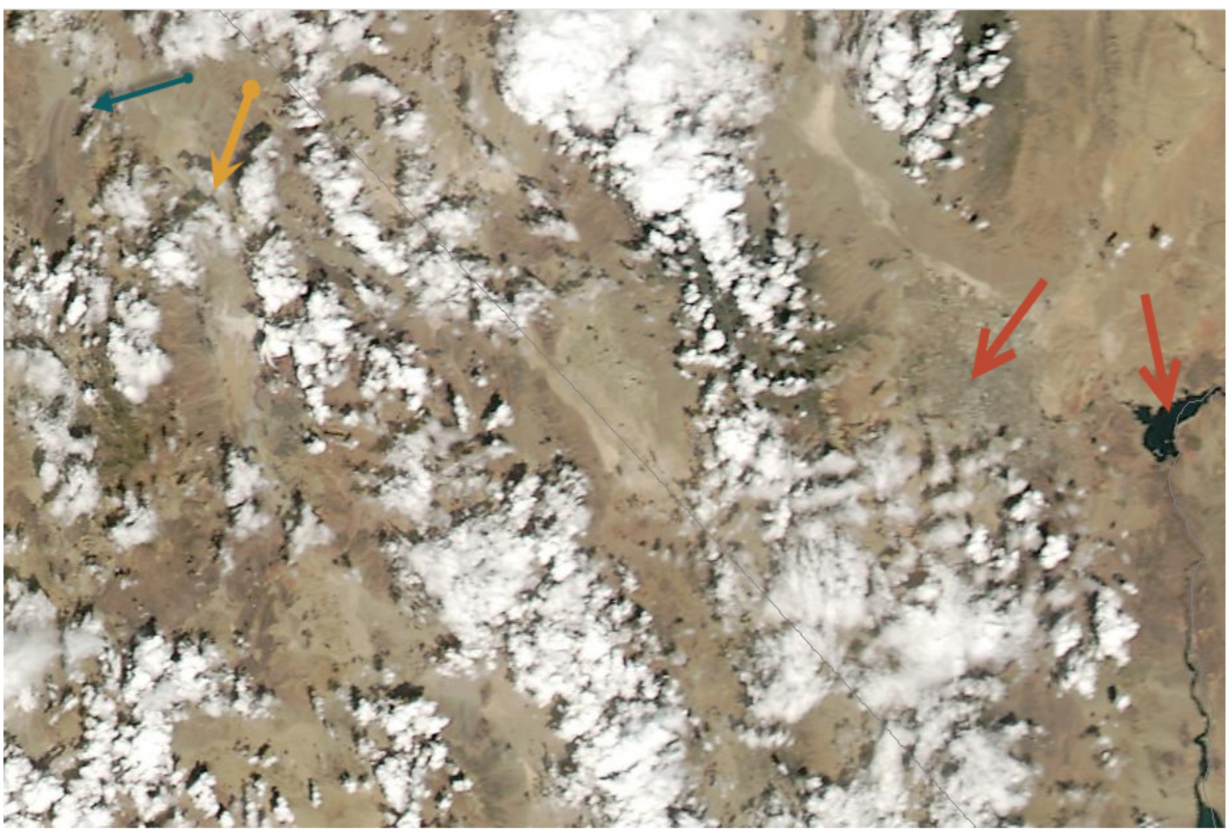

Figure 18: Polar satellite image (1:23-1:25 PM PST)

USCRN Station at Port Aransas, Texas, Survives Hurricane "Harvey"

On August 25, 2017, the center of the eye of Hurricane Harvey made landfall on the SE Texas Coast just south of the USCRN site (green arrow on radar image (Fig. 19). This placed the station near the north side of the eye wall as Harvey slowly moved inland. The station measured a maximum 10-second wind speed of 60 mph (26.9 m/s) (See Fig. 20). For climate purposes the wind speed sensors on the USCRN stations are located at 5 feet (1.5m) above the ground, while wind sensors at airports are located at about 33 feet (10m) above ground. The gust duration of the aviation sites are also for a shorter period of 3 seconds. Applying an adjustment to the USCRN value to account for the increased height and decreased time of the aviation measurements, the 60 mph value would have been measured at standard height in the 75-80 mph (33.5-35.7 m/s) range. Fortunately there was no wind damage to the site, and it continued to operate throughout the storm. The 60 mph peak 10-second wind value was a new station record, the previous record being 31 mph (14.0 m/s) set in December 2009.

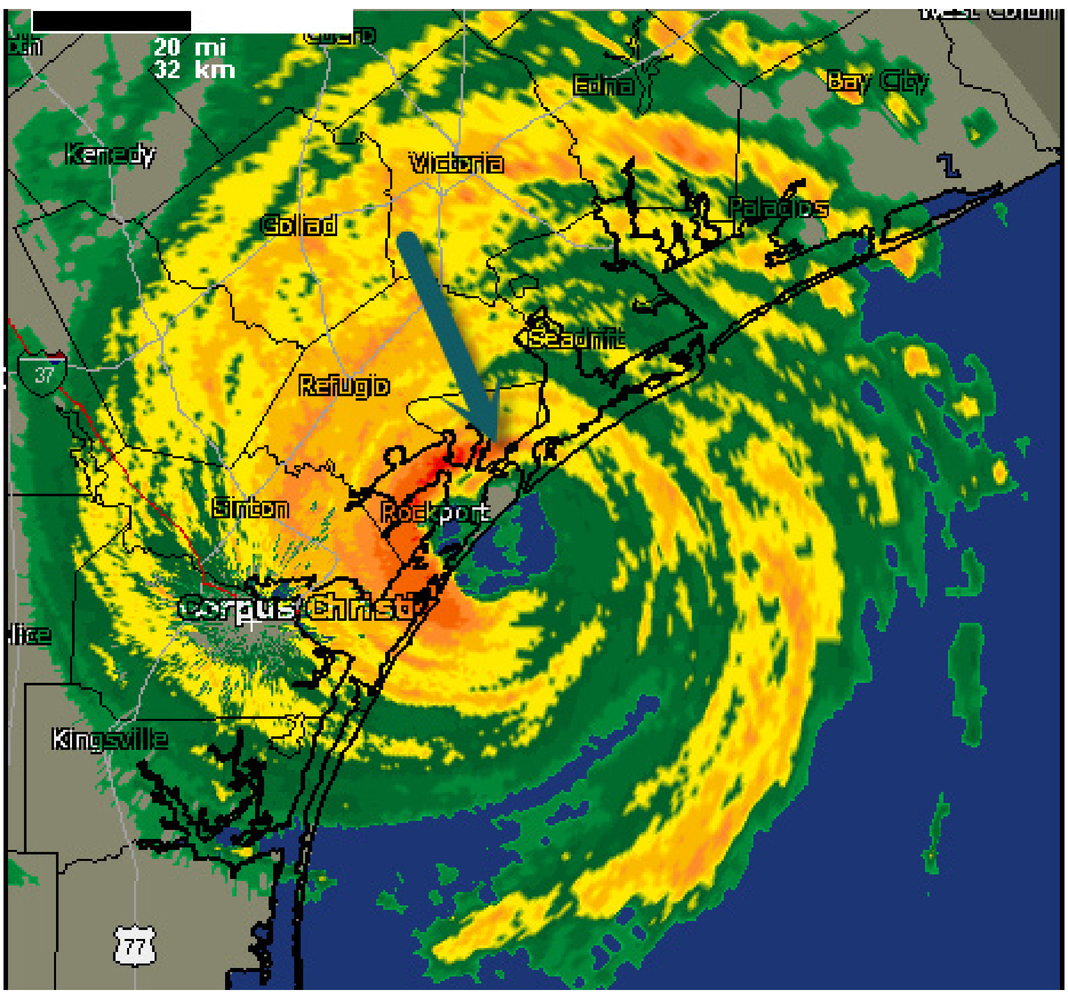

Figure 19. Radar image of Hurricane Harvey making landfall.

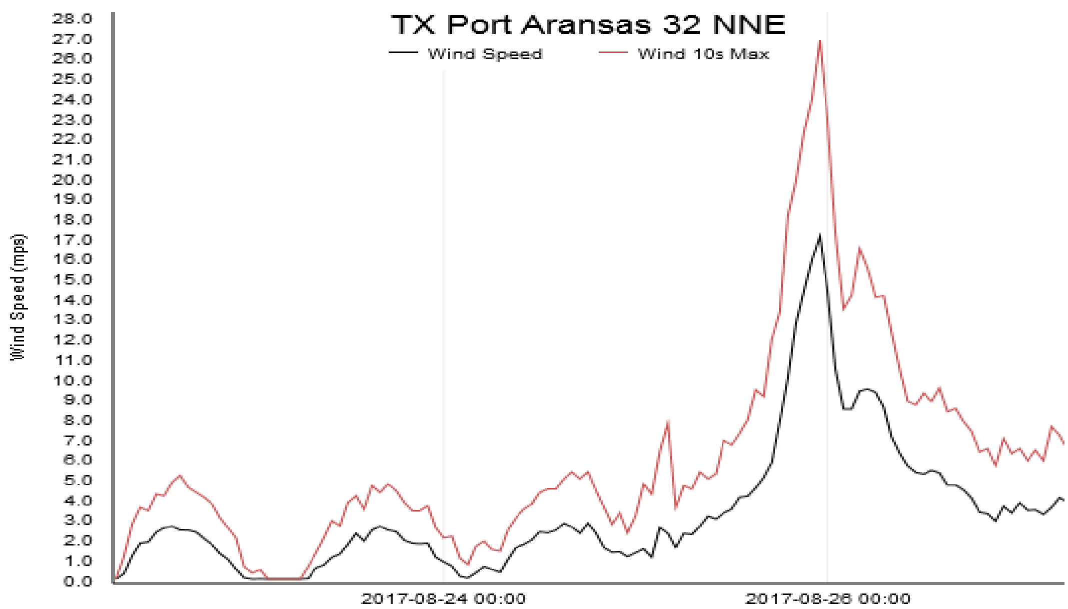

Figure 20. Wind speeds (m/s), black line indicates the maximum hourly values)

The storm also brought new station record rainfall amounts for various periods. The maximum 24 hour total was 11.69" (296.0 mm) easily eclipsing the previous record of 6.04" (153.4 mm) on September 18-19, 2010. The storm total of 15.05" (382.3mm) brought the August monthly total to 19.10" (485.1 mm) which was not only a new record for August, but also for any month. The previous station record for any month was 17.44" (443.0mm) set September 2010.

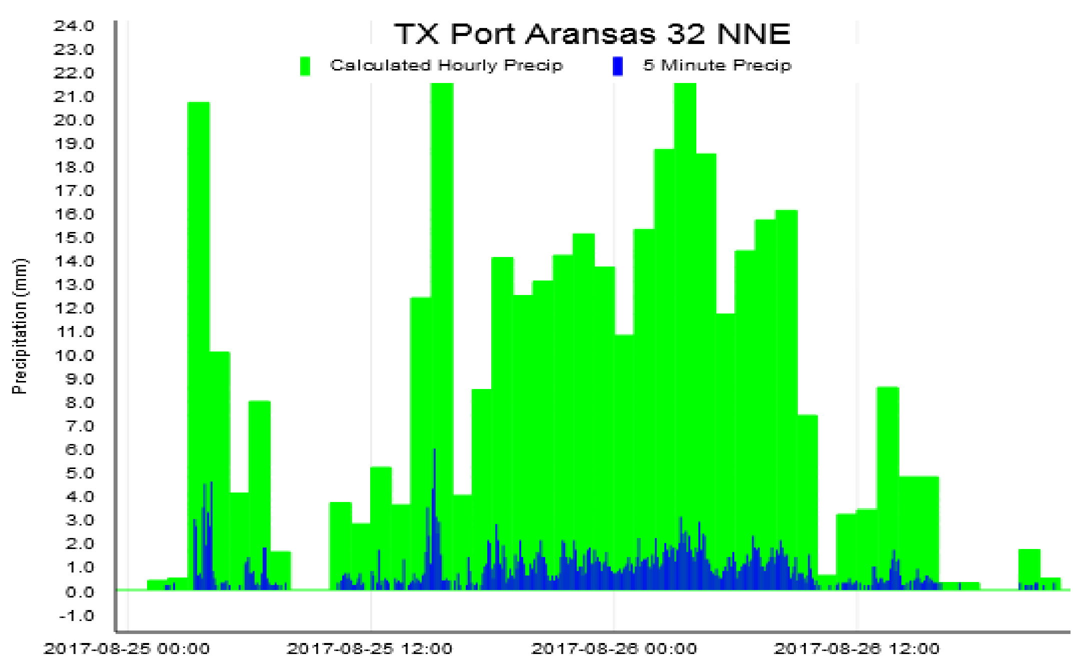

Figure 21. Distribution of the 5-minute and hourly rainfall amounts during Harvey.

Rapid Temperature Changes at Katmai National Park, AK

The USCRN station at Katmai National Park southeast of King Salmon, AK, experienced a rapid fluctuation in the ambient temperatures between 19:20 and 20:20 AKST on January 22, 2017 (Fig. 22). The first rise was 19.0ºF (10.6ºC) in 5 minutes, then 15 minutes later the temperatures fell 20.0ºF (11.1ºC) in 10 minutes. Just as quickly, the temperatures began to rise again from a temperature of -9F (-23.0ºC) to +14.0ºF (-10.0ºC) in 30 minutes. These rapid changes were brought on by an increase in the wind speed (Fig. 23) that mixed the relatively warmer layer of air above the station with the cold air near the ground. The cold air near the ground had been reinforced by the drainage of colder air from the nearby higher terrain to the North (see map in Fig. 24, and station photo in Fig. 25 below).

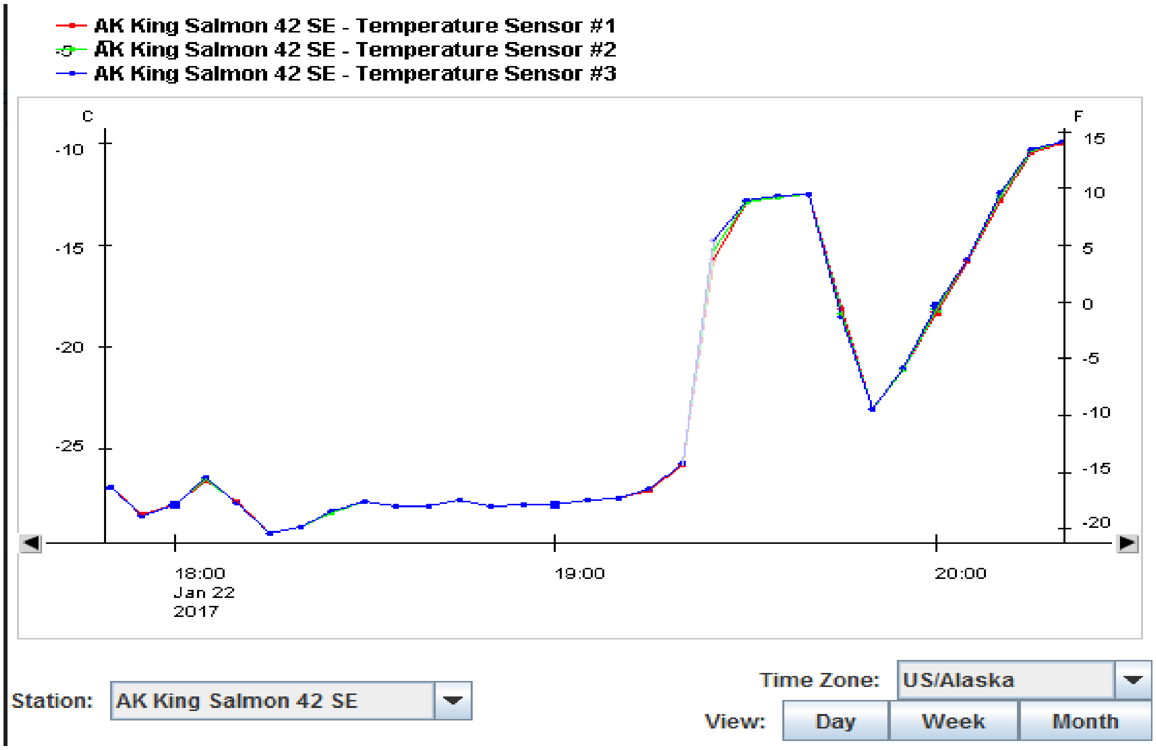

Figure 22. Temperature Changes at King Salmon on 22-Jan-2017

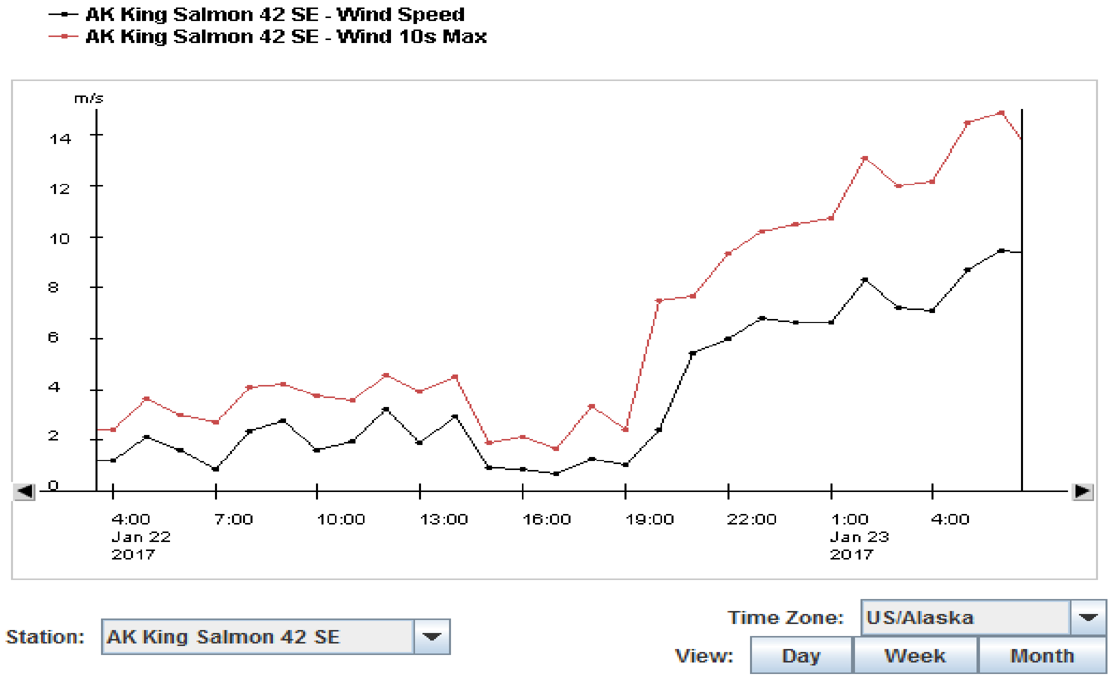

Figure 23. Wind Changes at King Salmon on 22-Jan-2017

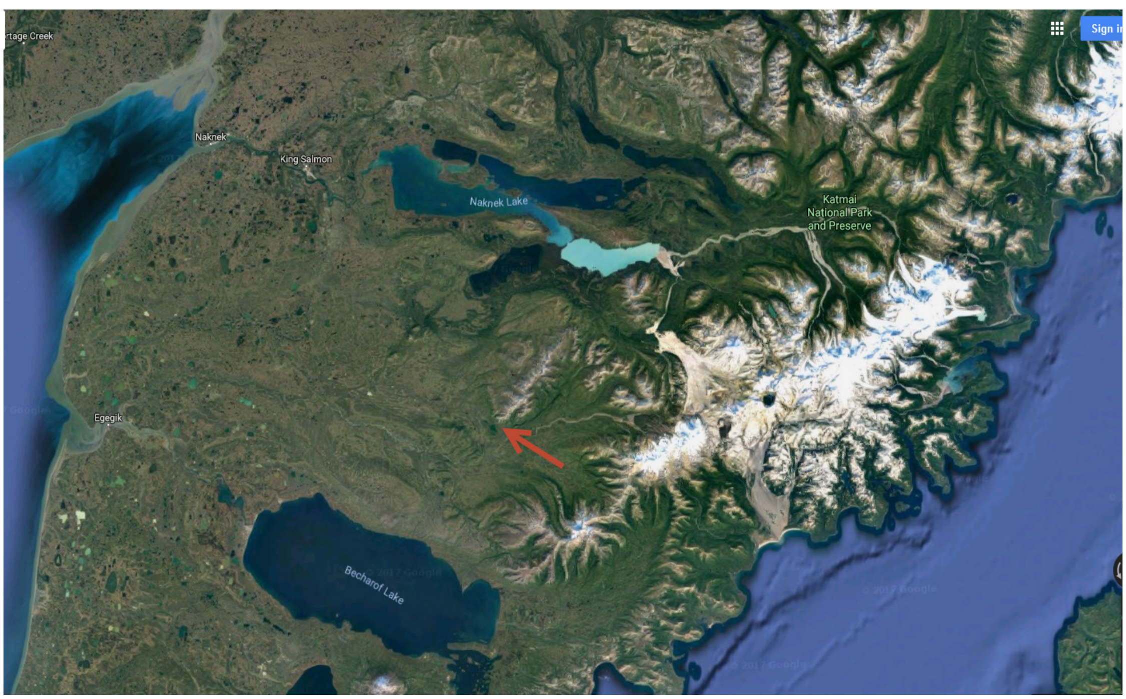

Figure 24. Topography of King Salmon; station location depicted by red arrow.

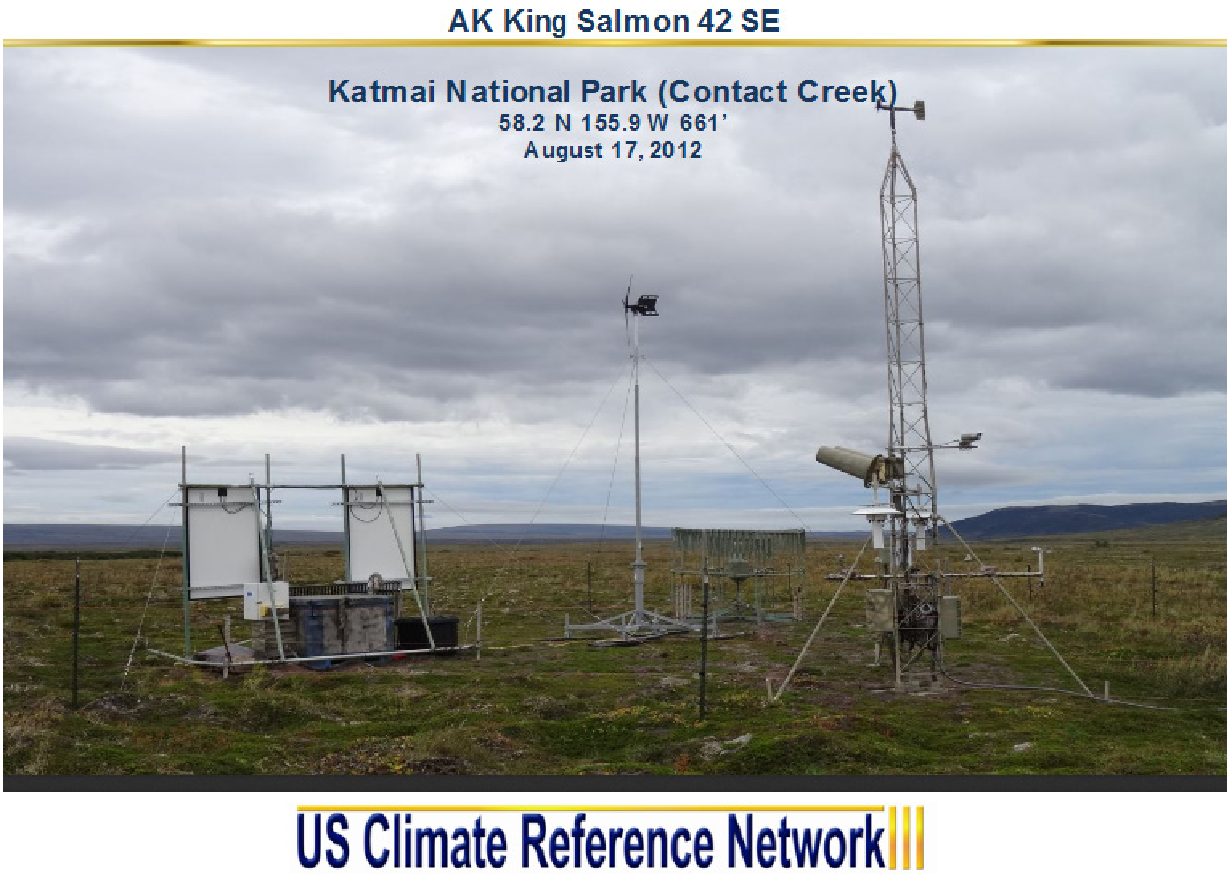

Figure 25. Photo of King Salmon Station; note the mountains toward the lower right.

Large Rise in Temperatures East of the Southern Rocky Mountains

On February 10, 2017, strong westerly winds descending off the Southern Rocky Mountains quickly raised temperatures east of the mountains more than 42.0ºF (23.0ºC) in 6 hours. (Fig. 26). The USCRN station that saw the greatest increase was in Goodwell, OK. The morning minimum temperature was 48.0 ºF (8.7ºC) (thin green arrow on Fig. 27), and by mid-afternoon LST the temperature was up to nearly 90.0ºF (32.3ºC) (red arrow on Fig. 27). Since the warm-up was a two-day event, the previous day's warm-up was equally amazing, rising from a midnight minimum of 23.0ºF (-5.0ºC) (wide green arrow on Fig. 27) to a late afternoon maximum of 75.0ºF (24.0ºC) (yellow arrow), a total rise of 52.0ºF (29.0ºC) in 16 hours.

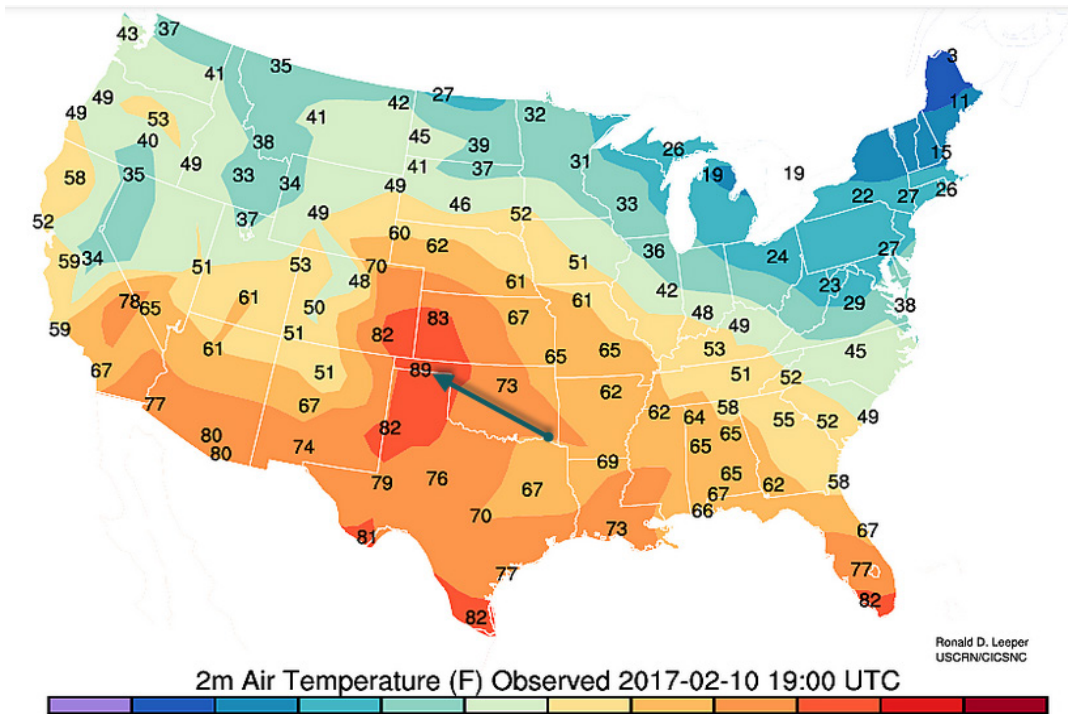

Figure 26. USCRN Temperatures; the temperature value of 89.0ºF for Goodwell, OK (blue arrow) is at 1:00 pm CST.

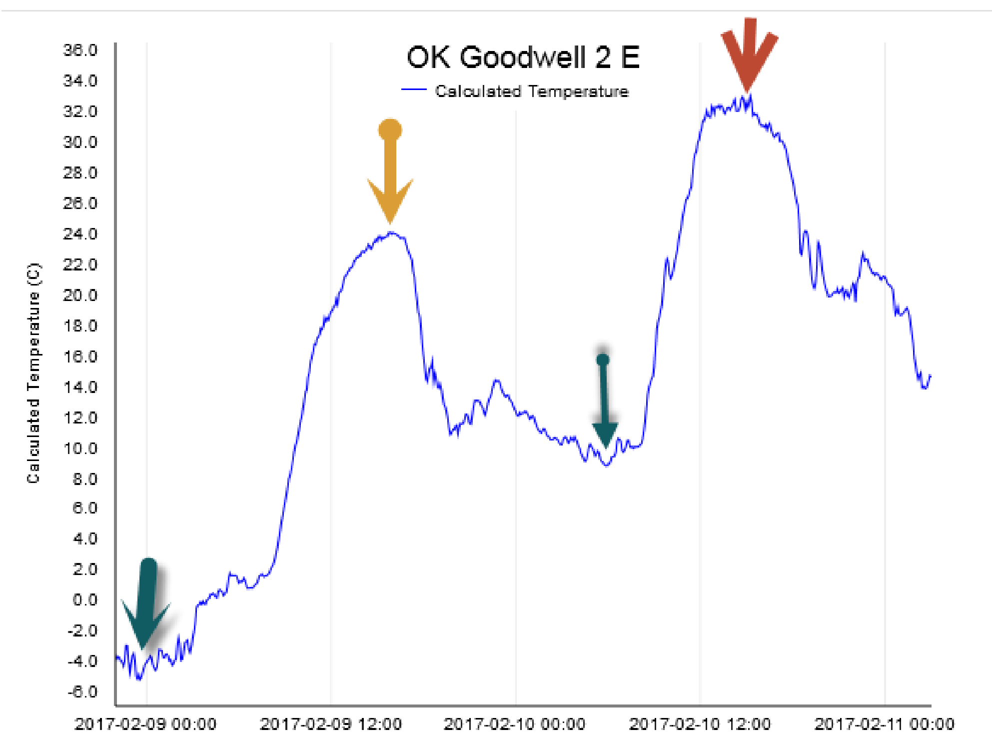

Figure 27. Hourly Temperature Graph at Goodwell, OK (times in hours CST).

Record Station Rainfall at the USCRN Station in Everglades City, FL

Despite an early start to the 2017 Atlantic hurricane season, the USCRN site near Everglades City, FL (green arrow in Fig. 28) recorded new station record 10- and 24-hour rainfall totals from an unnamed tropical weather system (Fig. 28). The station also set a new record total for the month of June or any month. The record values were 10.17” (258.3 mm) in 10 hours on 6-June, 14.93” (379.2 mm) in 24 hours on the 6th and 7th of June, and an overall June total of 27.17” (690.1 mm). The previous June record was 12.62” (320.5 mm) set in 2014, and the previous station’s maximum monthly total was 14.71” (373.6 mm) set in August 2008. The 2017 annual total has set a new record annual total for the site of 89.90” (2283.5 mm). The previous record maximum annual total of 70.62” (1,793.7mm) occurred in 2008. Figure 29 shows the hourly and 5-minute distribution of the rainfall during the event. The total duration of time for June 6 is highlighted by the red bar in Fig. 29. It is also interesting to note that while Hurricane Irma made a second landfall near Marco Island, FL, on September 10, 2017, and only about 30 miles away from the Everglades City station, and rainfall records there were not set by Irma.

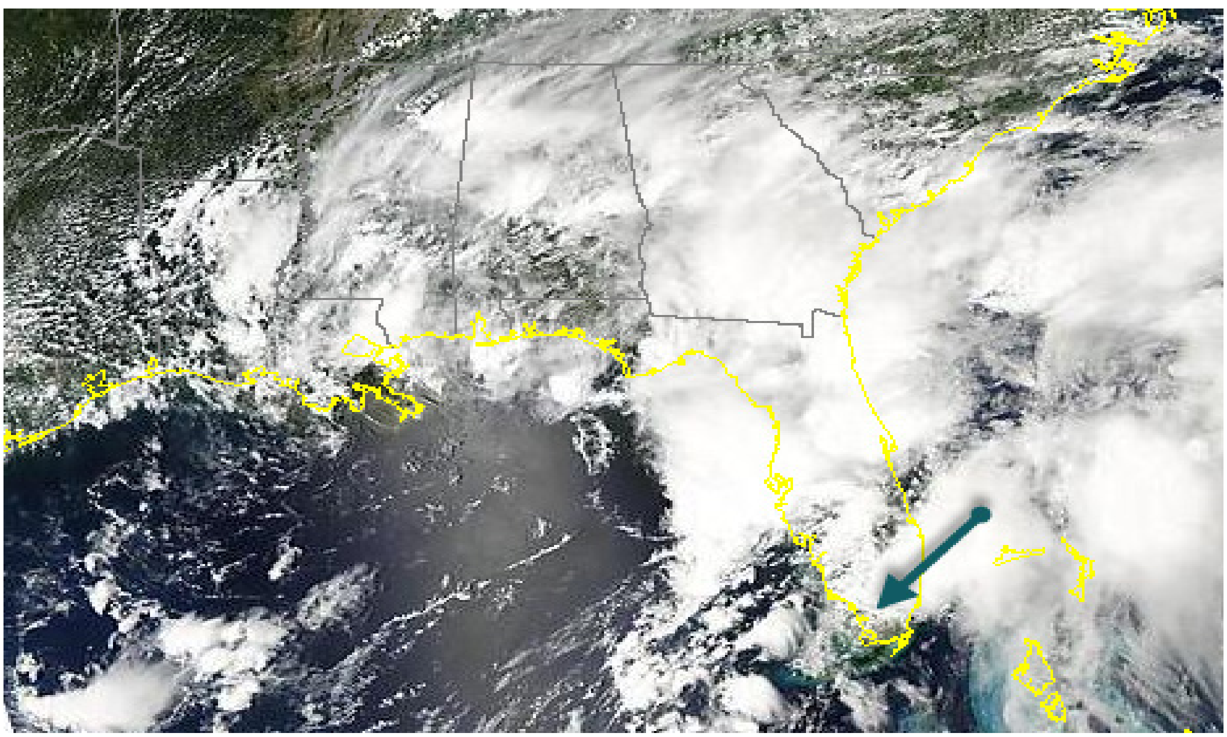

Figure 28. Visible NOAA-17 polar satellite image of the southeast US on June 6, 2017

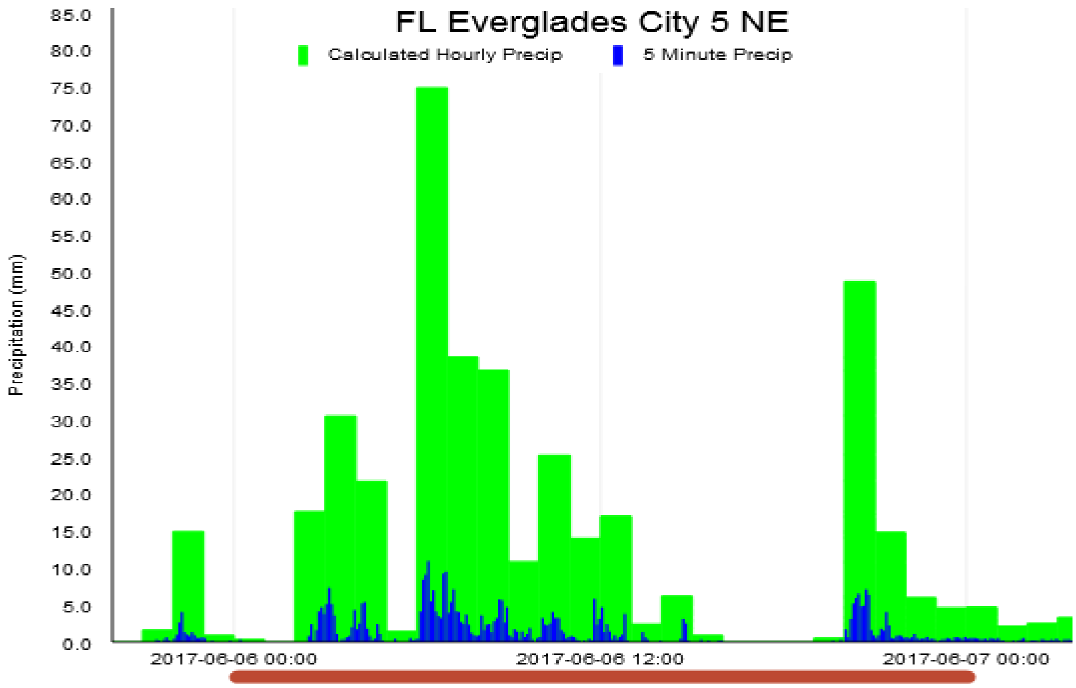

Figure 29. Hourly precipitation totals from Everglades City, FL, USCRN station.

Plans for FY18

A number of long-term science projects will continue or commence during FY18:

FY2018 Plans for USCRN Science at NCEI

- Release of beta version of Standardize Soil Moisture Product to the public and the National Soil Moisture Network.
- Drought indices development for U.S. Drought Monitor, including current drought status estimation and weekly drought status change.
- Heat health product advancement based on the accumulation of 5-min periods exceeding dangerous thresholds of air temperature and heat index.
- Create a USCRN-based National Precipitation Index.
- Contribute to Acclima soil probe evaluation.
- Continue improving the quality assurance of observations.
- Promote USCRN utilization through presentations, publications, and collaborations.

Data and software infrastructure are continuing to evolve and improve according to long-term plans:

- With the retirement of the backup DOMSAT system slated for May 2019, which is used as an alternate route for getting USCRN data when the primary dissemination system is down, will work to implement a High Rate Information Transmission (HRIT) backup system at NCEI.
- Improvements continue to help facilitate the access to USCRN data and products for users.
- Work continues in incorporating changes to GOES ID numbers as part of the CS1 to CS2 GOES transmitter transition that began in 2016 and that must be completed network-wide by 2025.
- Continued implementation of changes to the database and ingest systems to incorporate new soil elements as part of the soil sensor upgrade effort.

Hardware testing and deployments will continue:

- One new station will be deployed in Alaska during the summer 2018 building season, which will bring us closer to the eventual final total of 29 stations across Alaska. The site to be installed is in Bethel, AK, which begins the program's effort to populate the more sparse western areas of the state with USCRN stations.
- As many stations enter their second decade of service, the routine implementation of a refresh of critical equipment at stations around the network include the need for new back-up batteries, improved solar panels, replacement of soil sensors, and repairs to precipitation shield fencing.

USCRN continues to play a larger role in monitoring U.S. climate change as it has entered its second decade of service; and the challenge is to continue the high level of performance and data receipt rate that are being taken advantage of by more and more users.