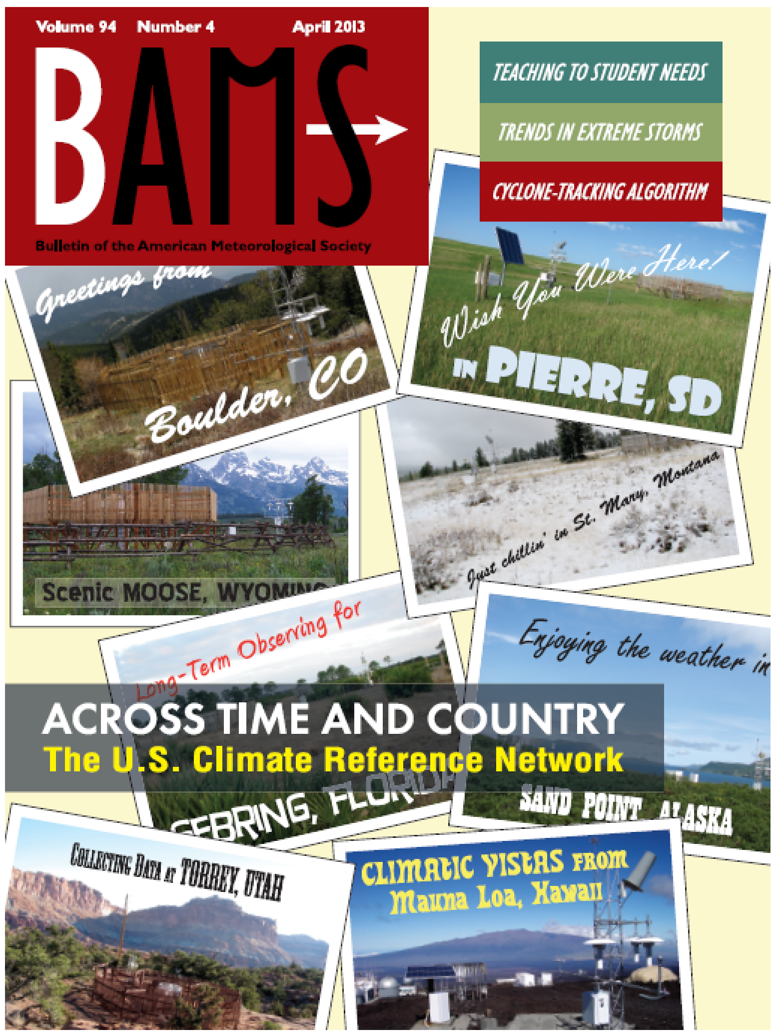
US Climate Reference Network

Annual Report for Fiscal Year 2013



Compiled by
the National Oceanic and Atmospheric Administration
October 2013

Cover Photo:
Reproduction of the cover from the April 2013 issue of the Bulletin of the American Meteorological Society containing an overview of the first decade achievements of the U.S. Climate Reference Network.

Compiled on behalf of NOAA Jointly by:

NESDIS/National Climatic Data Center (NCDC)
151 Patton Avenue
Asheville, NC 28801-5001

OAR/Air Resources Laboratory (ARL)/Atmospheric Turbulence and Diffusion Division (ATDD)
456 S. Illinois Avenue
Oak Ridge, TN 37830

Howard J. Diamond, USCRN Program Manager at NCDC
e-mail: howard.diamond@noaa.gov

C. Bruce Baker, Director, ARL/ATDD
e-mail: bruce.baker@noaa.gov

Michael A. Palecki, USCRN Science Project Manager at NCDC
e-mail: michael.palecki@noaa.gov

Report will be posted on the USCRN Website at

http://www.ncdc.noaa.gov/oa/climate/uscrn/

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 FY13:

Jesse Bell, Rocky Bilotta, Bill Collins, Scott Embler, Andrea Fey, Grant Goodge, Mark Hall, Diana Kantor, John Kochendorfer, Jay Lawrimore, Ronnie Leeper, Tilden Meyers, and Tim Wilson

Preface and Introduction

During 2013, the U.S. Climate Reference Network (USCRN) continued to progress under the auspices of NOAA's National Climatic Data Center (NCDC) and Atmospheric Turbulence and Diffusion Division (ATDD). The network consists of 114 sites across the conterminous 48 states, with 2 additional sites in Hawaii, and 2 at international test sites. Stations are installed in open (where possible), rural locations very likely to have stable land cover/use conditions for several decades to come. A major paper about the network was published in the Bulletin of the American Meteorological Society, and the availability and quality of its new soil moisture observation suite was recognized through two further refereed publications.

At each site a suite of meteorological parameters are monitored, including triple redundancy for the primary temperature and precipitation variables, and for soil moisture/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 13 operational USCRN stations (12 commissioned) in Alaska, with an eventual goal of having 29 commissioned stations by 2021. Operating an automated climate quality observing network in a harsh and remote environment that exist 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 NCDC 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 FY2013

(1) Celebrating the First Decade of USCRN with a Cover Article in BAMS

In FY13, a cornerstone article about the USCRN was published in a leading journal of the meteorology/climatology field, the Bulletin of the American Meteorological Society. The article reviewed the achievements of the network program in the first decade of its existence, and outlined a strong argument for continuing to be the gold standard for measuring climate change in the U.S. during the 21st Century, in addition to also being useful as a reference network for comparisons to other observation platforms, and providing fundamental observations for many important applications.

Diamond, H. J., T. R. Karl, M. A. Palecki, C. B. Baker, J. E. Bell, R. D. Leeper, D. R. Easterling, J. H. Lawrimore, T. P. Meyers, M. R. Helfert, G. Goodge, and P. W. Thorne, 2013: U.S. Climate Reference Network after one decade of operations: status and assessment. *Bull. Amer. Meteor. Soc.*, **94**, 489-498. doi: 10.1175/BAMS-D-12-00170.1

(2) Expanding the User Base for the USCRN Soil Moisture/Temperature Observations

The USCRN Program published two papers and submitted a third describing the recently completed soil moisture/temperature addition to the network and showing some of the unique applications that are possible with triple redundancy of measurements in the soil. The three papers were executed for the express purpose of introducing USCRN soil climate observation capabilities to three important sectors: hydrology, soil science, and biogeosciences. The USCRN soil moisture/temperature data are now also part of the International Soil Moisture Network, and have been acquired by the NASA Soil Moisture Active Passive Mission for use in validation of satellite products. Work is continuing toward the goal of using USCRN data for drought monitoring and other applications.

Bell, J. E., M. A. Palecki, C. B. Baker, W. G. Collins, J. H. Lawrimore, R. D. Leeper, M. E. Hall, J. Kochendorfer, T. P. Meyers, T. Wilson, and H. J. Diamond. 2013: U.S. Climate Reference Network soil moisture and temperature observations. *J. Hydrometeorol.*, **14**, 977-988. doi: 10.1175/JHM-D-12-0146.1

Palecki, M. A., and J. E. Bell, 2013: U.S. Climate Reference Network soil moisture observations with triple redundancy: measurement variability. Valdose Zone Journal, 12, p. vzj2012.0158. doi: 10.2136/vzj2012.0158

Bell, J.E., and J.L. Matthews. Evaluation of air and soil temperatures for determining the onset of the growing season. Under revision for *Journal of Geophysical Research - Biogeosciences*.

(3) **Completing a New Precipitation Calculation Algorithm**

In a project stretching over two years, an improved precipitation calculation algorithm has been developed and rigorously tested. While having three independent measurements of precipitation depth accumulating in each gauge may seem like a great advantage, it also has led in the past to some potential issues due to the need for these changing depths to agree in order to generate an official precipitation total. The new algorithm relaxes some of these expectations and utilizes the existing information more fully to generate both a more accurate precipitation total for an event, and a more realistic distribution of that precipitation with an event at 5-minute intervals. A paper written in FY13 is in final revisions and will be submitted in FY14.

Leeper, R.D., M.A. Palecki, and J. Davis. USCRN quality assurance methods for weighing bucket precipitation gauges with triplicate depth measurements. For *Journal of Atmospheric and Oceanic Technology*.

(4) **Comparing USCRN and COOP Network Observations of Temperature and Precipitation**

A small subset of 13 USCRN stations each are located within 0.5 km of a Cooperative Observer Program (COOP) Network station managed by the National Weather Service. While previous work has shown that anomalies from carefully constructed normals are comparable, many applications of climate data require whole values of temperature or precipitation. Also, each network has its own operational approach (automated versus manual) and instrumentation. A project to compare temperature and precipitation between the two networks was completed, demonstrating the utility of USCRN as a reference network and illustrating important differences in observations between the two networks.

Leeper, R.D., J. Rennie, and M.A. Palecki. Observational perspectives from U.S. Climate Reference Network (USCRN) and Cooperative Observer Program (COOP) Network: temperature and precipitation comparison. For *Journal of Applied Meteorology and Climatology*.

(5) National Temperature Index

Air temperature anomalies for the conterminous U.S. derived from the USCRN observations and the U.S. Historical Climatology Network (USHCN) observations can now be compared on a new page on the NCDC Web site. The National Temperature Index page shows the close agreement of air temperature anomalies for the U.S. derived from two independent networks, confirming that current air temperature values from the long standing historical network are valid. The current location for the new Web page is: http://www.ncdc.noaa.gov/national-temperature-index/.

(6) USCRN Data and Products Archived

The USCRN Program completed a transition to a new archive agreement with the Archive Branch of NCDC. Both the USCRN database and USCRN products are now regularly deposited by the USCRN program to the Archive Branch. The raw data from the database are now formatted into standard netCDF file formats for future use by internal and outside user groups, along with all documentation required to understand the data. Governing documents of USCRN Program have also been placed in archive for permanent retention.

The remainder of the report will cover 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 Activities
- Monitoring Activity Highlights
- Plans for FY 2014

FY 2013 Operational Activities in Alaska

Site Surveys – One site survey trip was completed during August 2013 visiting 19 potential site locations and completing 12 detailed site surveys at four grid locations in Alaska (Figure 1).

Site Licenses Signed – Site license agreements were completed for one additional Alaska site (Cordova) during FY 2013, with several others in progress.

Stations Installed – One new station (Glennallen) was installed in Alaska in FY 2013.

Stations Commissioned – Seven stations (Barrow, Fairbanks, St. Paul, Sitka, Gustavus, Metlakatla, and King Salmon) were commissioned in FY 2013. Four of these stations were previously deemed experimental and were originally provided by the conterminous USCRN Program (Barrow and Fairbanks) and the Global Climate Observation System (GCOS) Program (St. Paul and Sitka). However, since they now meet all the criteria for commissioned USCRN stations, they have been formally joined to the Alaska USCRN.

In addition to the station installed in FY 2013 at Paxon Airstrip (Glennallen), four more sites have been selected for future installations, with three sites already licensed (Selawik NWR, Nowitna NWR, & Cordova Eyak Native Corporation). Licenses are pending from the State of Alaska Department of Natural Resources in Deadhorse, Arctic Slope Regional Corporation at Ivotuk Airstrip, and Kodiak National Wildlife Refuge at Red Lake. Four more grid target areas were explored in FY 2013, with site surveys completed in central Alaska within Denali National Park, southeast Alaska in the Yakutat area, southwest Alaska in the Yukon Delta National Wildlife Refuge, and northeast of Fairbanks near Fort Yukon.

Surveys have now been completed in 23 grids of the 29 grid network in Alaska (Figure 1). The project expects that the final 6 remaining grids, located in western and southwestern Alaska, will be completed by FY 2015. Issues with site surveying, site licensing, and site engineering and installation have all proven to be more complex in Alaska, and some delays have been encountered, especially when funding levels are not known until very late in the fiscal year, as happened in FY 2013. Lessons learned each year increase the speed of the processing of site approvals and site licenses. This improvement, along with engineering and logistics experiences gained, will allow for station installation to continue on pace in FY 2014, assuming funding arrives in a timely manner.

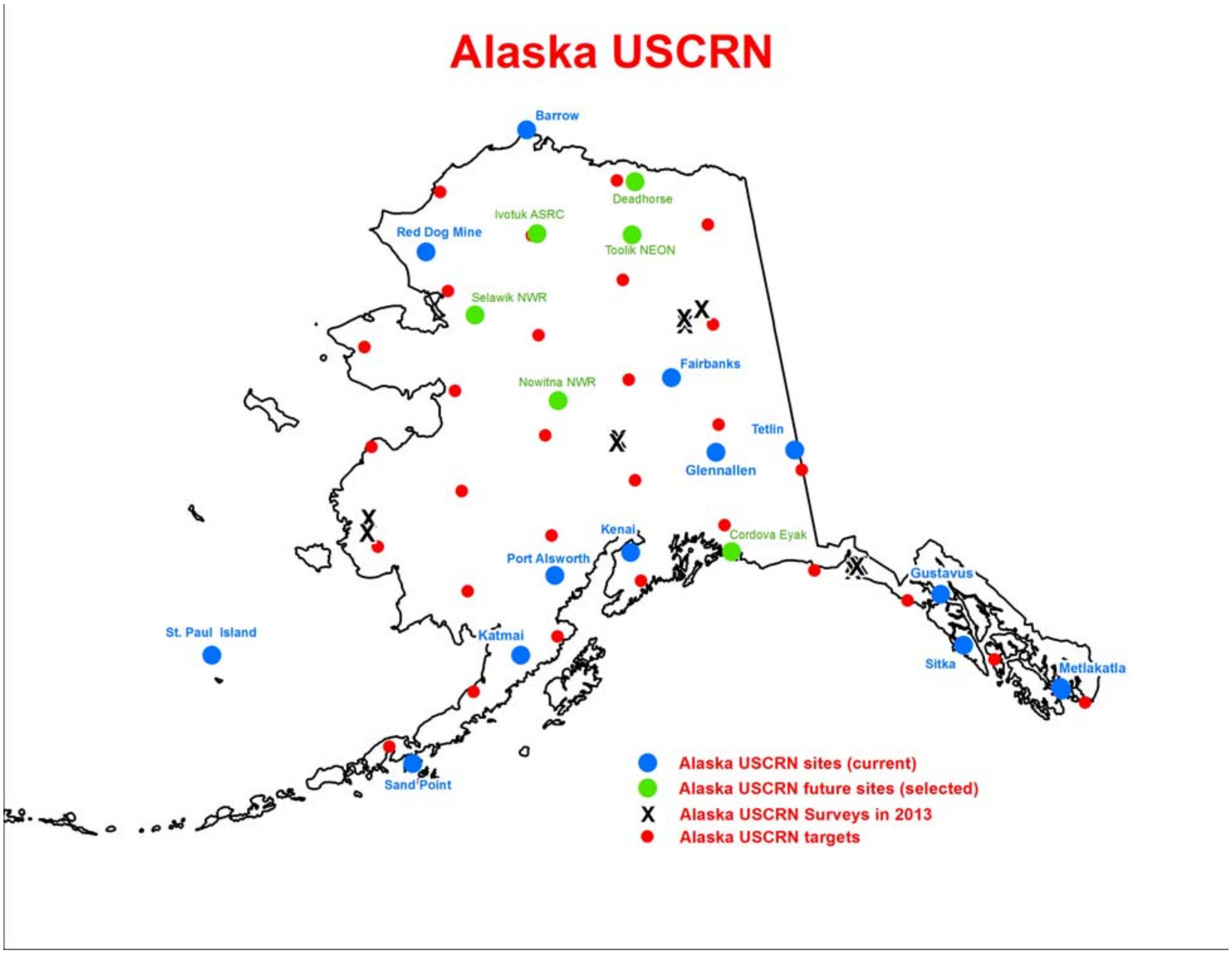


Figure 1. The map of USCRN in Alaska grids (centered on the red dots), along with existing and planned USCRN sites.

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%

Table 2. USCRN in Alaska Data Receipt Rates (%)

		Within 30 days	As of Oct 1, 2013
2013	Q1*	91.6	91.6
	Q2*	80.0	80.0
	Q3	99.6	99.6
	Q4	100.0	100.0

*The Tok fuel cell failed in early winter, and data transmissions resumed with increased solar energy and recharged batteries in April 2013. The other four commissioned Alaskan stations transmitted 100% of expected data records.

Table 3. FY 2013 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	FY 2014
Selawik (Selawik NWR)	05/29/2012	TBD	TBD
Nowitna (Nowitna NWR)	05/29/2012	TBD	TBD
Cordova (Eyak Corporation)	01/23/2013	TBD	TBD
Deadhorse (Dept. of Natural Resources)	Pending	TBD	TBD
Ivotuk (Arctic Slope Regional Corp.)	Pending	TBD	TBD
Denali (Denali NP)	Pending	TBD	TBD
Yakutat (Tongass USFS)	Pending	TBD	TBD
Bethel (Yukon Delta NWR)	Pending	TBD	TBD
Fort Yukon (US Air Force)	Pending	TBD	TBD
Kodiak (Kodiak NWR)	Pending	TBD	TBD

FY 2013 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). The new station (Figure 2) installed near Goodwell, OK, has completed a two year overlap course of measurements in order for it to eventually take the place of the original Goodwell site that will be discontinued in FY14 due to a gray water center pivot installation nearby. It is an example of an excellent result due to good site-host communication that allowed for the overlap period to take place.

Table 4. USCRN Data Receipt Rates (%)

		Within 30 days	As of Oct 1, 2013
2013	Q1	99.9	100.0
	Q2	99.9	100.0
	Q3	99.9	100.0
	Q4	100.0	100.0
	Total	99.9	100.0

Figure 2. Station OK Goodwell 2 SE, installed on June 18, 2011.

Site license revisions are continuing as needed due to the change in ownership of several locations and other issues raised by a review of the existing site licenses. This work should be completed in FY 14.

Data Ingest and Processing

Improvements to Data Processing, Monitoring, Data Access, and Product Quality

The USCRN programmer analysts developed enhancements to USCRN systems which improved data processing, data access and archive, and product quality in FY13. These included implementing Exception List software for correcting and documenting erroneous values in the USCRN database and establishing an archive process that meets 21st century standards for data stewardship. A number of configuration change requests were implemented, and full processing and access to data from the Siberian station of Tiksi, Russia, was added. Software design enhancements helped meet NCDC's emerging quality management goals by improving the maintainability of software through smarter design, including reducing the amount of redundant code and cutting rebuild error rates while reducing the time required for future software development efforts. A number of improvements also were made to data access and website functionality to provide the user community with the highest possible quality and ease of access.

Data Stewardship and Quality Assurance

New archive process and documentation: A revised and greatly expanded Archive Submission Agreement for USCRN was completed and approved. This agreement now covers raw files, datalogger files, processed data, FTP products, and relevant documentation. A new software application was written to create netCDF files representing the processed USCRN data. A detailed functional specification document describing the USCRN data ingest process is included in the archive and on the website. This accomplishment sustains observations that provide the capacity to assess climate variability and change and demonstrates a commitment to data stewardship by ensuring that all data and derived products are archived with complete provenance. It incorporates best practices to ensure scientific quality, integrity, and the long-term utility of climate data while ensuring all USCRN data meet standards for traceability, lineage, and provenance.

Enhanced climate observations: USCRN Exception List software was implemented to allow measurements which are known or suspected of being faulty to be flagged in the database so they will not be used in calculations. Sometimes exceptional circumstances occur that causes some recorded data values at a station to be unrepresentative of actual weather and climate conditions. Examples include brush fires or controlled burns near a station increasing air temperatures, and instruments failing yet still reporting values within the range of outer limits for error detection. The Exception List Process was designed and implemented to allow such values to be flagged with a special "EXCEPTION" indicator, telling users of our data that a value is untrusted and preventing it from being used in analyses.

The new process adds to the transparency of the USCRN quality assurance process. Any value that is flagged as an EXCEPTION, and any value that is corrected, is linked to a descriptive Exception List ticket which provides details on the issue and how it was resolved. Future web development will be able to take advantage of this new information stored in our database to provide added visibility and transparency into these changes.

International station in Tiksi, Russia: The CRN station in Tiksi (Russia) was added to the Integrated Station Information System (ISIS), with assistance from ATDD, NOAA Earth System Research Laboratory, and the ISIS team at NCDC. Data for Tiksi are processed on a daily basis through the USCRN Ingest software. A modified stream format and special handling in the ingest software was added to allow for the processing of Tiksi records. The installation and operation of the USCRN station in Tiksi was achieved in 2011 through a partnership between NOAA and the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). Located on the Arctic Ocean coast on the Buor-Khaya Gulf of the Laptev Sea, Tiksi is one of the most northerly settlements in the world and in an area particularly susceptible to the effects of climate change. Tiksi observations can be viewed on the CRN website under the name SA Tiksi 4 SSE (http://www.ncdc.noaa.gov/crn/station.htm?stationId=1789).

Dataset maintenance: Two change requests approved by the USCRN Configuration Control Board in 2013 required actions to upgrade data processing software.

- Change Request #44 addressed an issue with the Geonor precipitation gauge, which can at times suffer from a shifted calibration, where the gauge has a depth reading of less than -5 mm when empty. The lower range for flagging precipitation depth was changed to -15 mm, which will still detect broken wires without excluding precipitation from the calculation algorithm. In addition an issue with the wetness sensor was identified in 2013; a wetness sensor signal of zero was found to indicate that electricity is not flowing properly to the detection grid. To ensure measurements of exactly zero are properly flagged, the wetness sensor channel 1 lower range flag limit was raised to 0.5. In addition, if either channel 1 or channel 2 is flagged, then both channels will now be flagged. This is done to provide an indication of a lack of reliability in the total instrument if one channel is not working.

- Following CR#44, the wetness channel 2 flag limit was lowered from 500 to 1 in Change Request #45. This was done to account for the occasional heavy precipitation event that depresses the signal below 500, but is still associated with valid precipitation and a valid wetness channel 1 value. Since CR#44, both wetness channels are flagged if one is out of range, so this change was made to prevent inadvertent loss of genuine calculated precipitation.

- Change Request #45 also addressed an issue with the new aspiration fan model placed in Met One shields. The fan tends to slow on occasion below the current lower flag limit of 90, yet continues to operate well in aspirating the temperature instruments. Given that aspiration is adequate between 80 and 90, the flag threshold was lowered to 80, so that aspiration rates between 80 and 90 inclusive will no longer be flagged. This ensures the thermometer associated with the fan will be included in temperature calculations.

Software Design (Shared Java Application Programming Interface; API): Three major improvements were made to the shared Java API in 2013.

- Programmer analysts greatly enhanced their ability to manage and upgrade USCRN software systems through the integration of the Ivy dependency management tool. Project dependencies were defined along with the resources necessary for building a software project. With this accomplished the Ivy tool was configured so that it can be used to resolve and automatically download required resources from the USCRN version control software repository each time the software build process is initiated. Code committed to the repository is now distributed automatically and can be integrated and tested in USCRN projects which use the API. The distribution is promoted to release status with the click of a button. These features allow more frequent and simplified upgrades of software dependencies and reduces rebuild error rates while reducing the overhead (programmer time) required when software upgrades or new systems are necessary.

- A substantial software development effort was required to accommodate the upgrade of a software package (iBatis to MyBatis) which provides methods for querying and updating data in the USCRN Oracle database. MyBatis is the world's most popular structured query language-based data mapping solution for Java software development. The iBATIS project was retired by the Apache Software Foundation, and developers used the opportunity to take advantage of MyBatis' context switching capabilities for ease of moving between database environments (development, testing, and operations) for testing and integration purposes. The upgrade also benefits from improved development practices and automation, and simplifies coding compared to its predecessor.

- Another major improvement to the API was the integration of Google Guava to accomplish tasks like Object filtering and mathematical aggregation. Google Guava is an open-source set of common libraries for Java. It provides basic utilities to reduce menial labors to implement common methods and behaviors. It also provides an extension to the Java collections framework, and it includes other utilities which provide productive features such as functional programming, caching, range objects, and hashing. This makes USCRN code easier to read and diminishes the amount of redundant code, reducing the future maintenance load which helps meet NCDC's emerging quality management goals.

Database Improvements: USCRN developers collaborated on adopting tools to manage database schema migration. This eases the burden of managing multiple database tiers and ensures documentation of schema changes over time. Additionally, the internal application which enables developers to view schema documentation received an authentication upgrade, allowing developers to use OpenID-based authentication instead of maintaining separate passwords for this system.

Hardware Upgrades: NCDC's acquisition of a new blade server has allowed USCRN web programmers to spin up virtual servers for the testing and integration phases of web development without competing for resources with other developers. This has greatly enhanced the ability of programmers to conduct testing and integration of new and upgraded software.

Data Access and Analysis

FTP Products: The USCRN program provides data via ftp protocols to facilitate access for scientists and others in the user community who require quick access to large volumes of data including period of record for the entire network. Summary of the month and day as well as hourly and sub-hourly observations are provided at http://www.ncdc.noaa.gov/crn/qcdatasets.html. In 2013 the sub-hourly quality-controlled data product was upgraded to be more easily retrieved by users. Large, multi-megabyte files were partitioned by year so that each file was smaller and faster to download. With this partitioning, users can also navigate more quickly to the data which is of interest to them. This product is now updated regularly every week with new 5-minute data.

Website Design: Several enhancements were made to the USCRN website in FY13.

- A major shift with USCRN processing is the storage of extra degrees of precision in intermediate calculations to prevent bias during aggregation. In FY13 changes were made to the USCRN website code to ensure consistency with changes previously made to the USCRN database; ensuring data are displayed to appropriate precision, which can be less than the precision stored in the database. The software system was re-architected to associate the required database storage precisions and the web presentation precisions with the observed element such as temperature or precipitation. It was previously associated with each data stream. Now that it is associated with each data element it is easier to maintain.
- After most stations had transitioned to report new corrected IR, programmers provided graphing support for these new values (Figure 3).

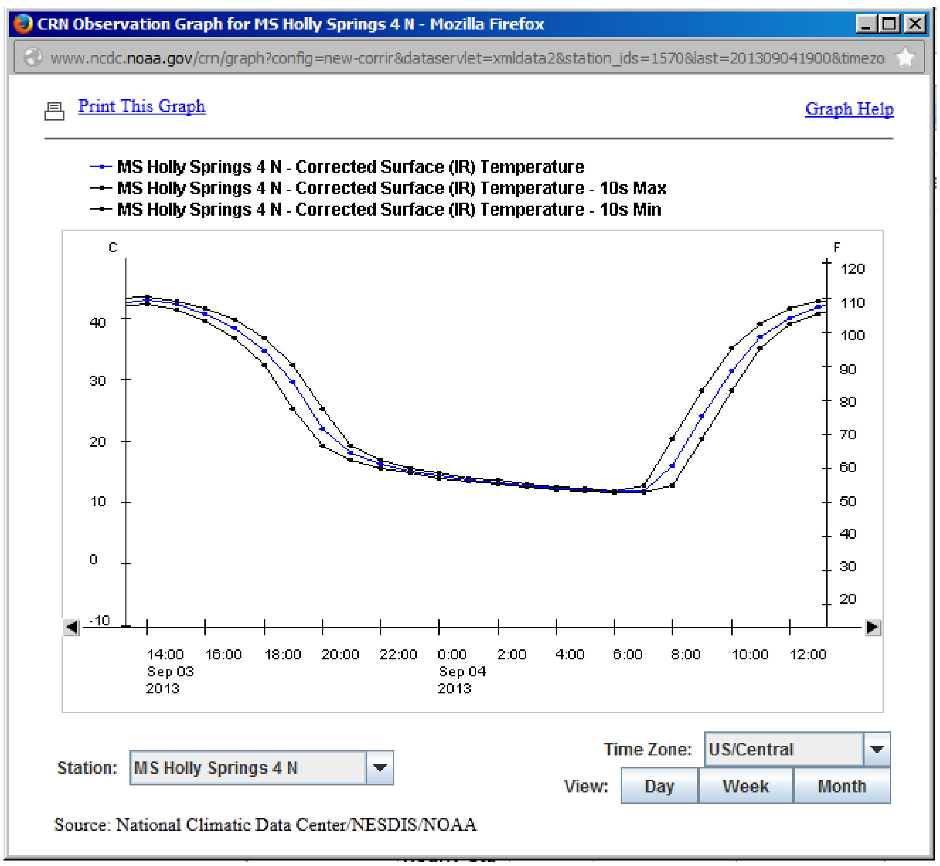


Figure 3. Sample graph with corrected IR surface temperature.

- The Ivy dependency management tool (described above) was also integrated into the web application to facilitate a faster upgrade process and increased the longevity of the software.

- To help the USCRN program gain a better understanding of its customers' needs, developers integrated Google Analytics into the USCRN website to gain a more complete understanding of data usage.

SMART: The Station Monitoring and Reporting Tool (SMART) continued to provide ATDD engineers and quality control technicians with hourly reports on the status of USCRN and USRCRN stations. Following new development that took place in the prior year, attention in FY13 turned to ensuring optimum functionality of the system. Maintenance activities included making updates to standard libraries to remain consistent with most recent software versions and changes to e-mail configurations to add and remove users.

Support to the User Community

Climate monitoring and assessment. The USCRN network was envisioned to measure U.S. climate with a high degree of observational rigor and serve both as a reference for other current networks and as a long term program to measure climate change in the U.S. over the next 50 years or more. In recent years these observations have been shown to produce very similar national temperature anomalies to those of the existing U.S. Historical Climatology Network (USHCN), validating the recent history of the most commonly used record of U.S. temperature since 1895. To enable an ongoing comparison of USCRN with the legacy USHCN network and a new homogenized and gridded GHCN dataset that will take over for the USHCN in March 2014, a National Temperature Index web page was designed in 2013 (Figure 4). With the cooperation of three branches in two NCDC divisions, a complex, multistep process was developed to produce comparable data streams from USCRN and USHCN in an automated fashion monthly. USCRN and USHCN national temperature anomalies are computed in relation to a 1981-2010 reference period, creating a uniform and comparable National Temperature Index (NTI) for each data source. CSMD produced a Web site that contained explanatory pages from GCAD and graphs of USCRN and USHCN data from GCAD and CSMD displaying 1-month, 3-month, 6-month, 12-month, and calendar annual NTI values at the NCDC Web site link: http://www.ncdc.noaa.gov/national-temperature-index/.

Earth Science Research and Education: The USCRN program assisted Dr. David Brooks of the Institute for Earth Science Research and Education (http://www.instesre.org/) by providing solar radiation, soil temperature, and soil moisture data for researchers and students. Dr. Brooks has written a document for students that explain what USCRN is and how our data can be used for research (http://www.instesre.org/NOAACRN.pdf). He has also developed web applications that allow users to query and visualize USCRN data see http://www.instesre.org/PHPCRN/CRNDisplayData.htm.

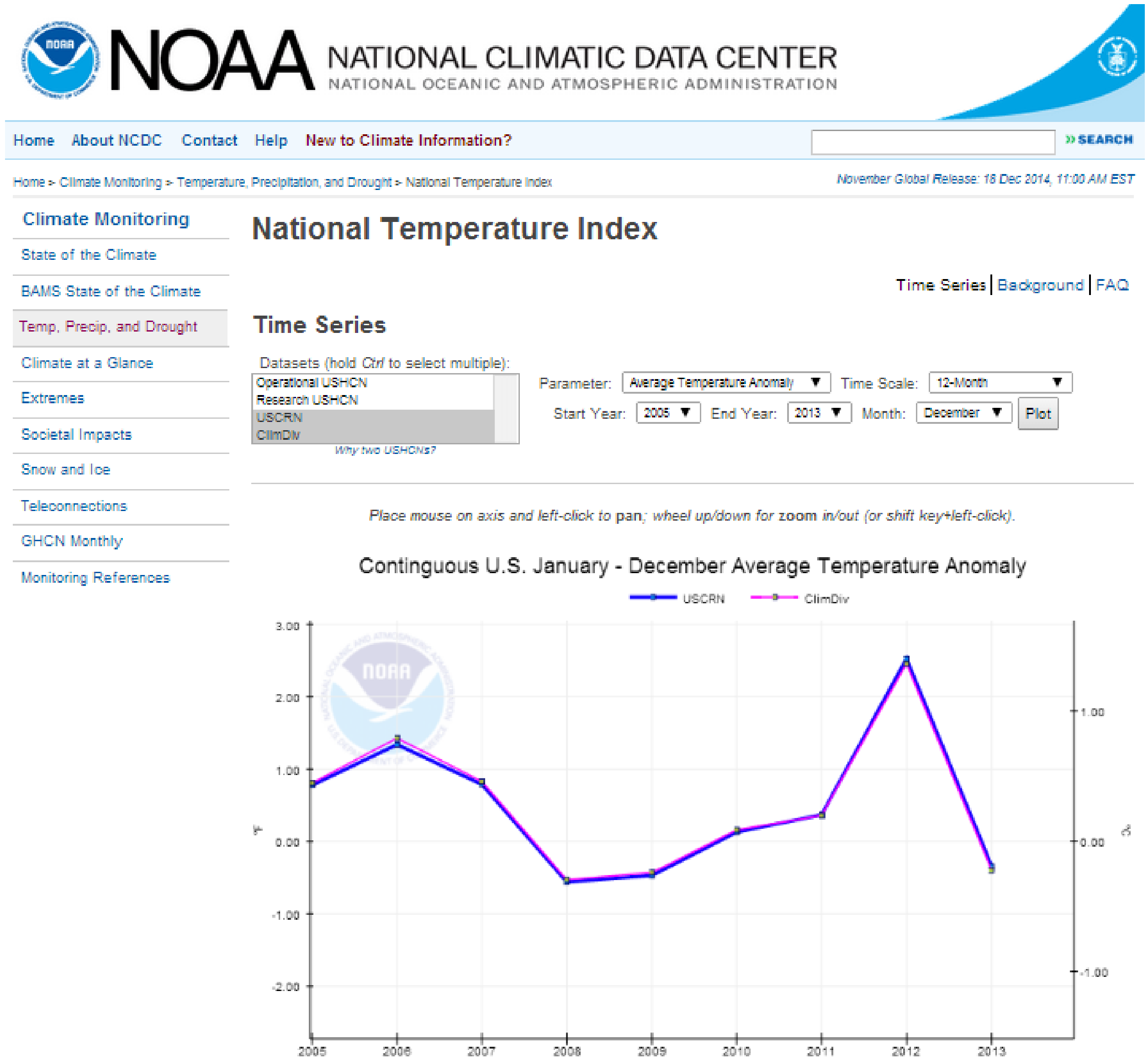


Figure 4. National temperature index Web page on the NCDC Web site, showing very strong agreement between USCRN and homogenized and gridded COOP station annual anomalies.

USCRN Science and Development Activities

<u>Soil Moisture and Soil Temperature Research</u>

The USCRN Program published two papers and submitted a third describing the recently completed soil moisture/temperature addition to the network and showing some of the unique applications that are possible with triple redundancy of measurements in the soil. The three papers were executed for the express purpose of introducing USCRN soil climate observation capabilities to three important sectors: hydrology, soil science, and biogeosciences.

The first two years of the full network deployment provided a great opportunity to examine the soil moisture variance of the triplicate measurements during moist conditions in most of the U.S. in 2011 and dry conditions in most of the U.S. in 2012. The coefficient of variation, which is standard deviation divided by mean, is an efficient statistic to use to compare variance from many stations and times of year. For April through July, the distribution of the coefficient of variation versus mean soil moisture is substantially raised at low means and diminished at high means during 2012 (Figure 5). In other words, the dry year has more measurement variance at low mean moisture levels and less variance at those locations that are still moist at the edges of the national-scale drought.

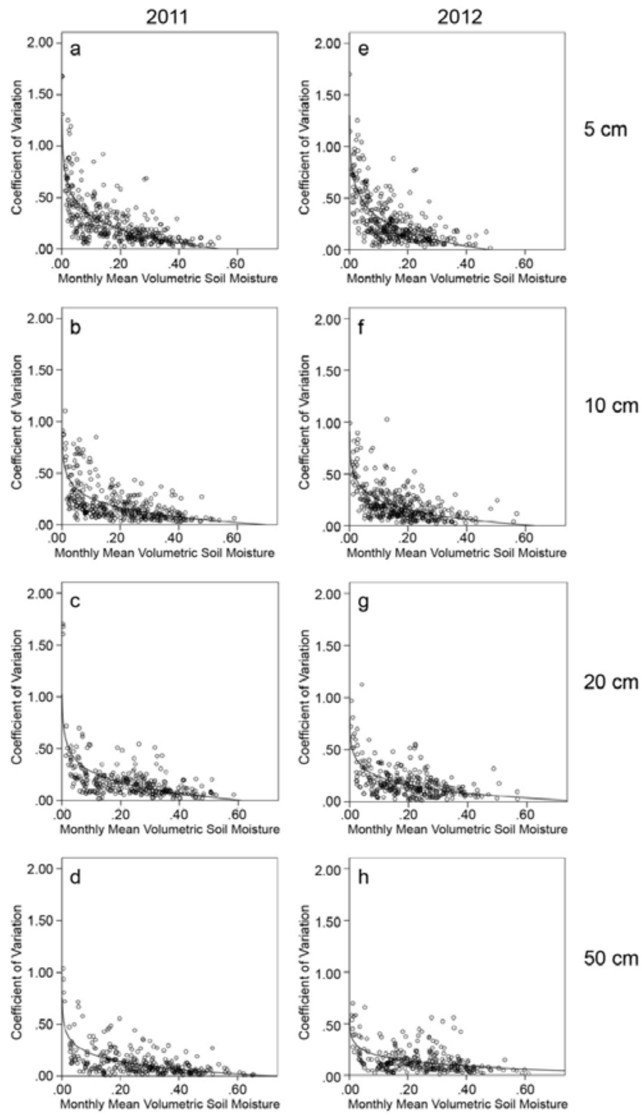


Figure 5. Coefficient of variation for soil moisture for each station and month, for April through July, graphed against mean soil moisture for 2011 and 2012 (from Palecki and Bell, 2013).

Soil temperature is also a key variables now being measured by USCRN. Bell and Matthews (submitted) have been examining the roles of air temperature, surface IR temperature, and soil temperature at various depths in spring vegetation green-up at selected stations. They have found that the timing of spring green-up is most closely related to the date when soil temperatures at 10 cm reach 5°C (Figure 6). At that point, the green-up commences in an exponential fashion which can be predicted.

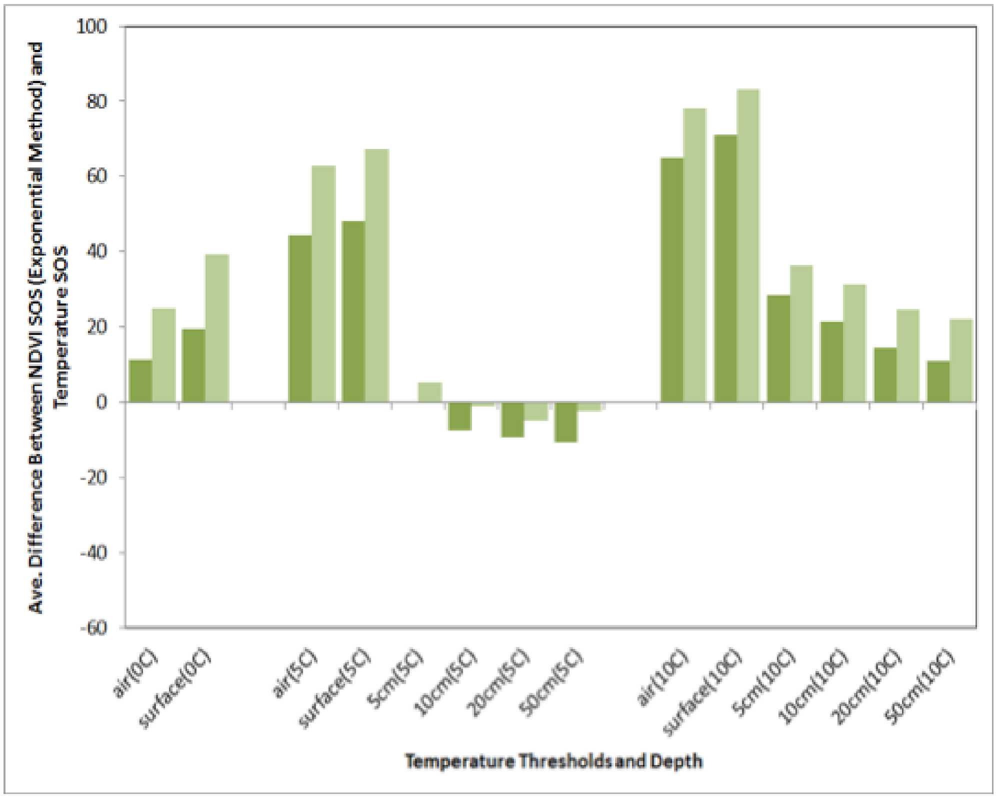


Figure 6. The average difference in days between the vegetation start of spring as indicated by the normalized difference vegetation index and the climate start of spring as indicated by temperature exceeding 0°C or 5°C thresholds.

Finally, progress is being made on soil moisture characterization over larger areas around our stations. The first collection of gravimetric soil moisture samples has begun, with the goal of scaling our electronic soil moisture measurements at 5 cm with true measurements of soil moisture at that level. This work will continue into FY14 and beyond as a priority activity. In addition, at Millbrook, NY, and Crossville, TN, sites, satellite networks have been put in place to measure soil moisture in the 9 km and 3 km areas around the USCRN stations, respectively, for an entire growing season. These data will show how representative the USCRN station soil moisture measurements are for the area around the station at the 5 cm level. A preliminary examination of Crossville area soil moisture measurements (Figure 7) indicates that the mean of the 15 satellite sight and most of the individual satellite sites are drier than the USCRN site (Figure 8), which would imply the need to adjust the USCRN data so as to correctly relate it to remotely sensed soil moisture values for the larger area.

Figure 7. Satellite soil moisture stations (numbered 1-15) near the USCRN station (red dot) at Crossville, TN.

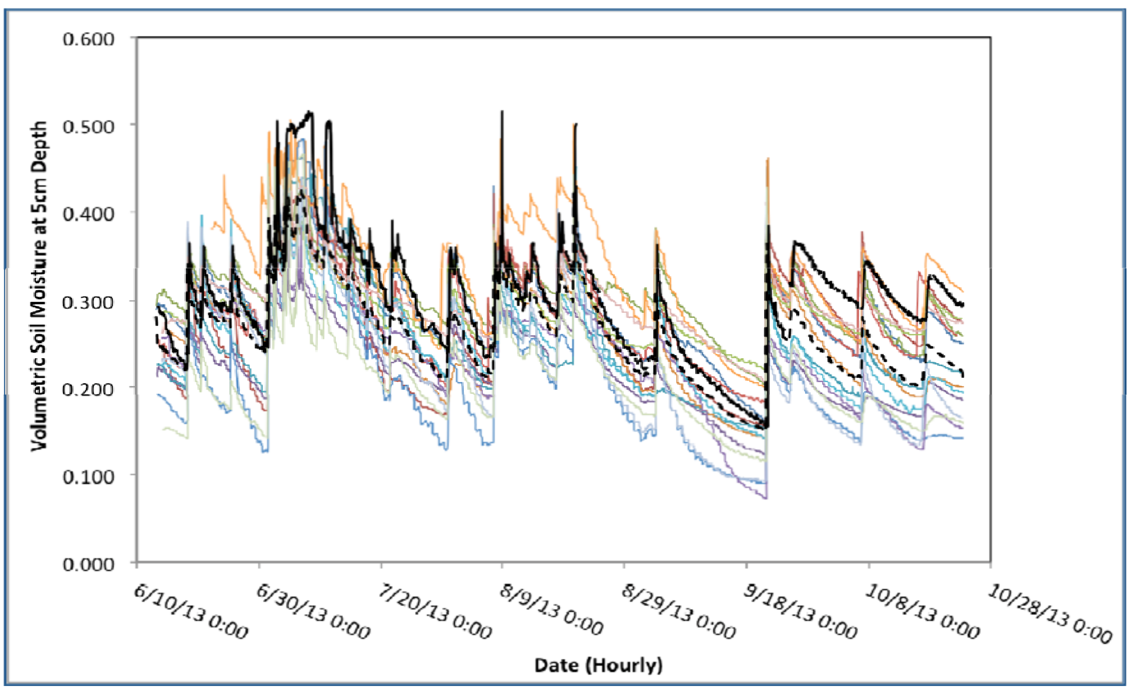


Figure 8. Soil moisture during 2013 at Crossville, TN. The solid black line is the USCRN average value by hour, and the dashed black line is the mean value of all 15 satellite stations at 5 cm depth. The color lines are the individual soil moisture plots for the 15 satellite stations. The results to date indicate USCRN is somewhat wetter than the surrounding area.

Precipitation Research
An improved precipitation calculation algorithm has been developed and rigorously tested. The new algorithm relaxes some expectations of simultaneous depth changes in the bucket and utilizes the existing information more fully to generate both a more accurate precipitation total for an event, and a more realistic distribution of that precipitation with an event at 5-minute intervals. A large subset of the stations was entered into a comparison between the current precipitation calculation algorithm and the new algorithm, and a 1.6% increase in precipitation has resulted from this change overall. About 87% of the stations show an increase in total precipitation greater than 0.5%, about 7.9% of stations stayed about the same and only 4.9% of stations indicated reduced precipitation totals (Figure 9). The latter category is related to stations with significant quality events that were handled better by the new algorithm than the old algorithm.

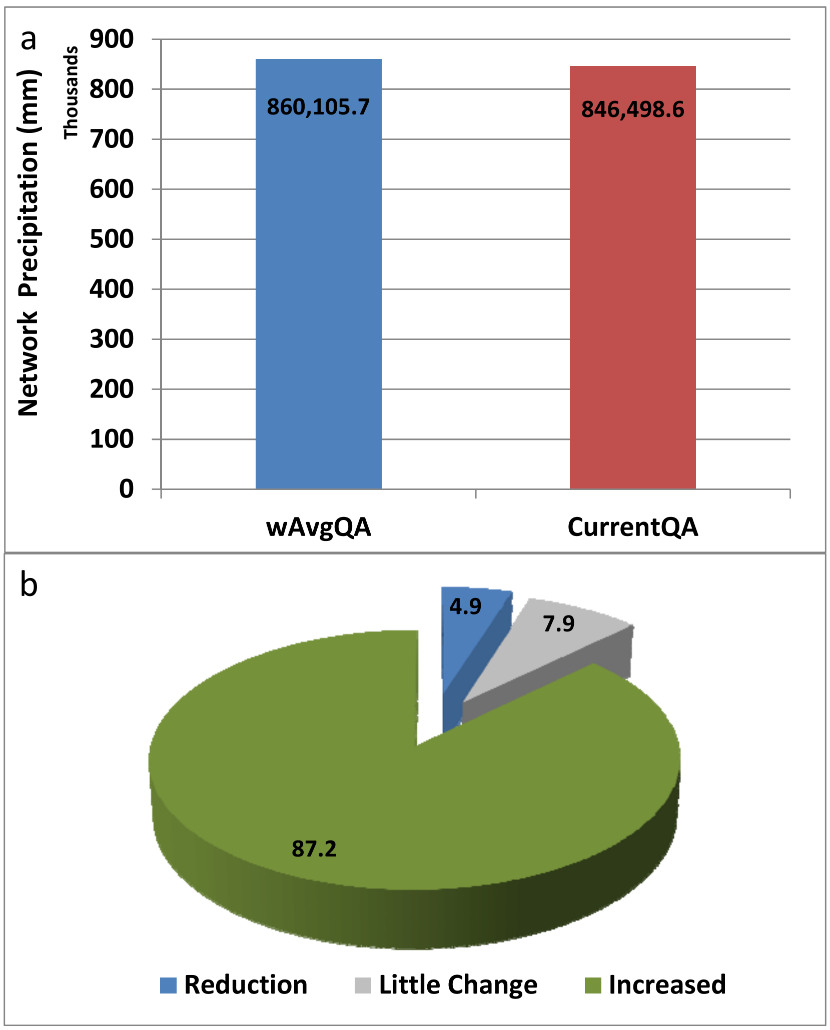


Figure 9. a) Overall calculated precipitation for the new wAvgQA algorithm (blue) versus the old CurrentQA algorithm (red); b) Percentage of stations with calculated precipitation increased by more than 0.5% (green), remaining nearly the same (gray), or decreased by more than 0.5% (blue).

Comparison of USCRN and COOP Stations

A small subset of 13 USCRN stations each are located within 0.5 km of a Cooperative Observer Program (COOP) Network station managed by the National Weather Service (Figure 10). A project to compare temperature and precipitation between the two networks was completed, demonstrating the utility of USCRN as a reference network and illustrating important differences in observations between the two networks. The station pairs included provide a variety of background climates under which to perform the comparisons of temperature and precipitation.

Figure 10. Map of USCRN and COOP stations located within 500 meters.

Maximum temperatures are consistently less at USCRN stations than at nearby cooperative observer stations, while minimum temperatures are generally greater at USCRN stations, although not at consistently (Figure 11). Both outcomes are expected given that the USCRN platinum resistance thermometers are fan aspirated, while the COOP thermistors are naturally aspirated. Perhaps an unexpected outcome was the variation in the relationships from site-to-site, indicating the importance of local topographic and vegetation influences.

Precipitation differences are even more unexpected. While the USCRN gauge surrounded by a small double fence intercomparison reference shield clearly captured more frozen precipitation and more precipitation during strong winds, the cooperative observer gauge is slightly different with liquid precipitation capture (Figure 12). This is especially true in light precipitation events under low winds. These differences are likely due to USCRN gauge wetting effects compounded by a precipitation algorithm that is too rigorous in demanding agreement in gauge depth among three sensors. While the overall difference in the 13 paired sites averages to USCRN observing 1.21% less than COOP, much of this will be corrected by the new precipitation algorithm discussed above.

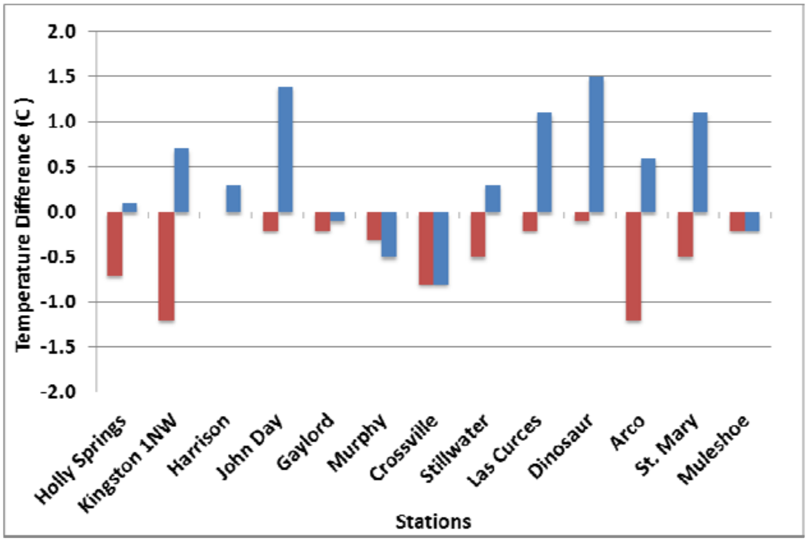


Figure 11. USCRN minus COOP average minimum (blue) and maximum (red) temperature differences at collocated station pairs.

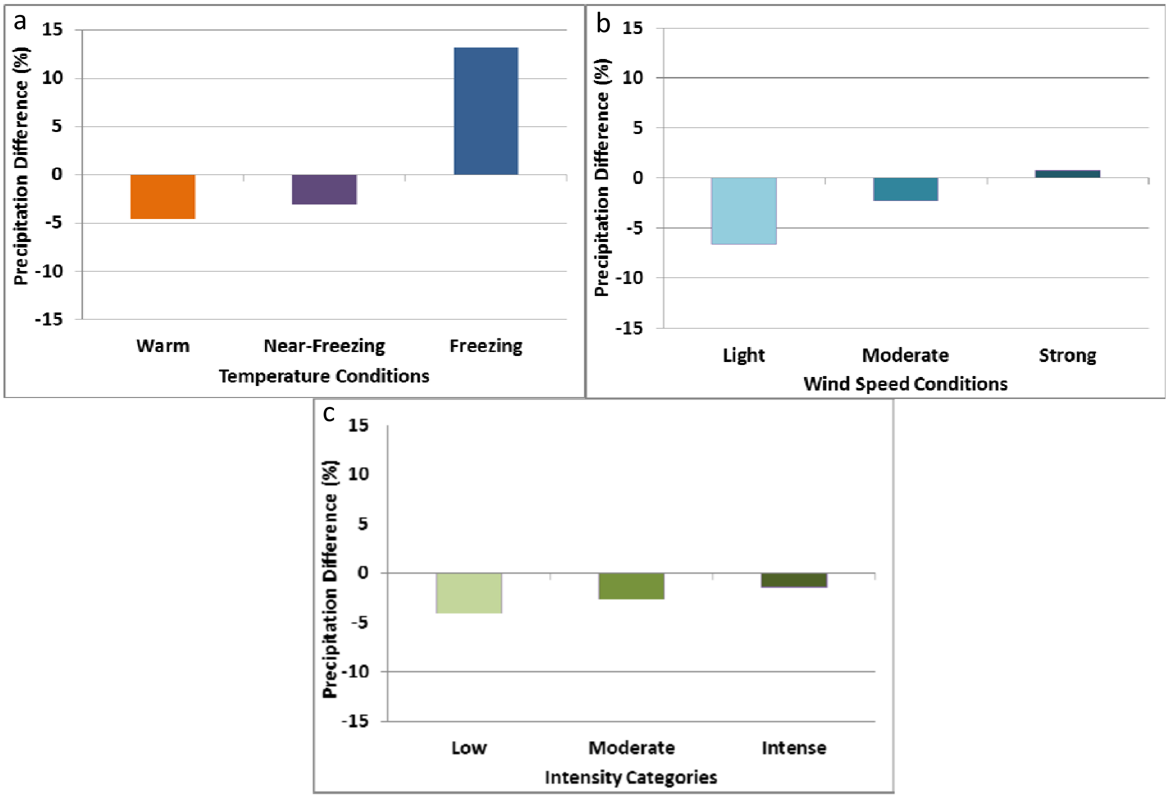


Figure 12. USCRN precipitation minus COOP by: a) warm (min. temperature > 5°C), near-freezing (max. temperature > 0 and < 5°C),and freezing conditions(max. temperature < 0°C) temperature conditions; b) light (<= 2 m s^{-1}), moderate (>2 and <4 m s^{-1}), and strong (>=4 m s^{-1}) surface wind speeds and c) low (<1.5 mm hr^{-1}), moderate (>=1.5 and <=2.8 mm hr^{-1}), and intense (>2.8 mm hr^{-1}) rain rate events.

Field and Testbed Activities

<u>Continued Intecomparison and Sensor Testing</u>

Air Temperature Bias Experiment: Homogenization of temperature records is required to account for the effects of urbanization and changes in sensor technology. Homogenization is largely based on statistical techniques, however, and contributes to uncertainty in the measured U.S. surface-temperature record. To provide some physical basis for the ongoing controversy focused on the U.S. surface temperature record, an experiment was performed to evaluate the effects of artificial heat sources such as buildings and parking lots on air temperature. Air temperature measurements within a grassy field, located at varying distances from artificial heat sources at the edge of the field, were recorded throughout 2013 using both the NOAA US Climate Reference Network methodology and the National Weather Service Maximum Minimum Temperature Sensor system. The effects of the roadways and buildings was quantified by comparing the air temperature measured close to the artificial heat sources to the air temperature measured well-within the grassy field, over 200 m downwind of the artificial heat sources.

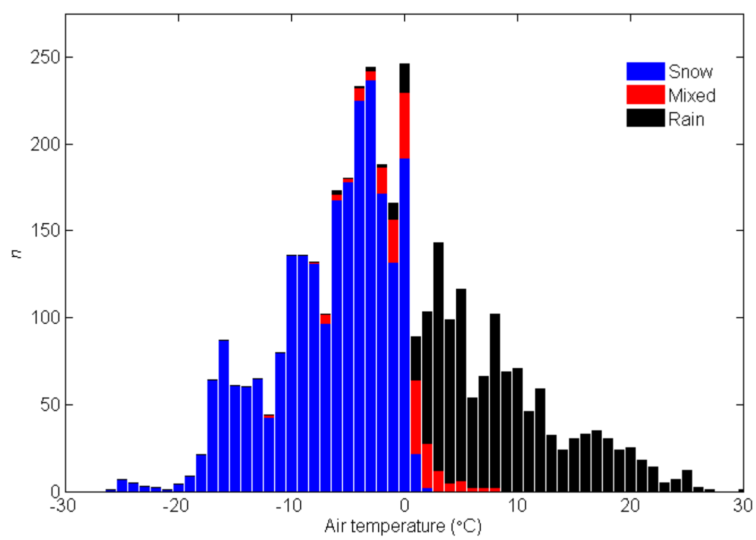


Figure 13. A histogram of precipitation type demonstrates the distribution of precipitation type with air temperature. Precipitation type was measured with a present weather detector (Vaisala PWD22). Over four years of data from the Marshall, CO testbed are included.

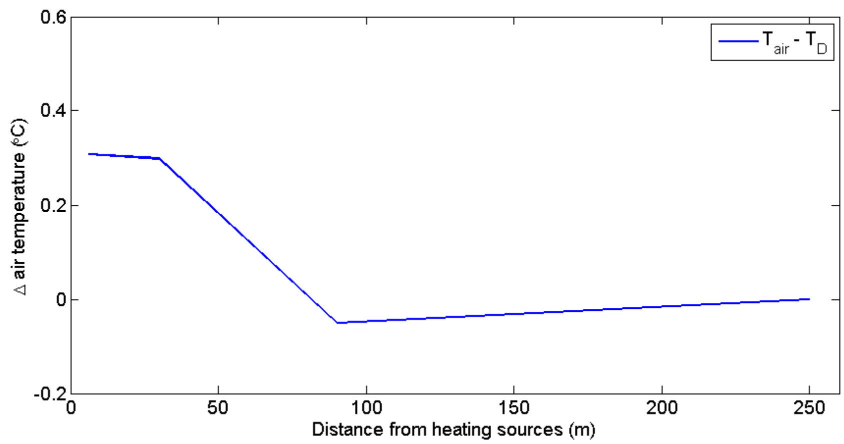


Figure 14. The average change in air temperature relative to a near-ideal temperature measurement site situated 250 meters from all artificial heat sources is shown as a function of distance from heat sources. This is from a study performed in Oak Ridge, TN in a mowed field adjacent to buildings and roads in the prevailing upwind direction. Over one year of 5-min data is included in the figure.

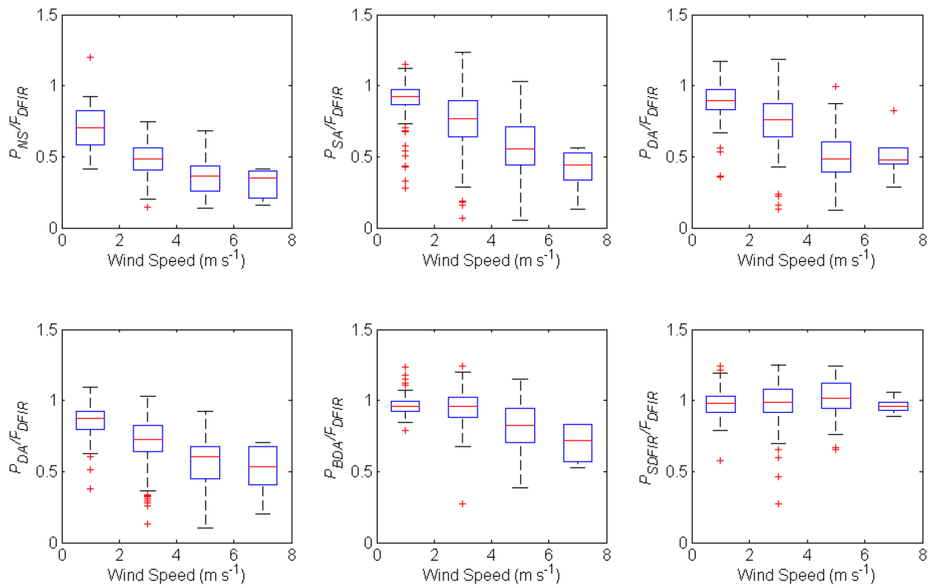


Figure 15. The catch efficiency of precipitation gauges shielded by no shield (NS), a single Alter (SA), Double Alters (DA - there are two of these), a Belfort double Alter (BDA), and a small double fence intercomparison reference fence (SDFIR) is estimated by evaluating 30-min precipitation (P) with respect to precipitation from within a double fence intercopmarison reference (DFIR) as a function of wind speed. The figure includes only events classified as snow.

WMO Solid Precipitation Intercomparison Experiment: In collaboration with other countries participating in the WMO Solid Precipitation Intercomparison Experiment (WMO-SPICE) NOAA/ATDD has contributed significantly to experiment planning, project management, and data analysis methods used in this international comparison of precipitation measurement methods. The goal of the experiment is to create a new standard for the automated measurement of solid precipitation, and to develop methods to relate the prevailing precipitation measurement techniques back to this standard. Wind shielding plays an important role in the amount of precipitation measured, especially when the precipitation is in the form of snow. NOAA/ATDD helped quantify the uncertainty in these types of measurements and determine the minimum amount of precipitation that can be measured accurately enough to produce reliable relationships between catch efficiency and wind speed. In addition NOAA/ATDD is leading the effort to accurately determine precipitation type for WMO-SPICE.

Monitoring Activity Highlights

<u>Another new USCRN Record</u>

Given that an earlier USCRN record 5 minute record (0.73”) had been recorded at the Lander, WY CRN site in the central part of the state, it was no real surprise that the new USCRN record of 0.88” in 5 minutes was recorded at another Wyoming site this time at the Sundance 8 NNW CRN site. It is located in the far northeast part of Wyoming. The event occurred during the late night hours of September 4, 2013. Late season “monsoon” moisture had been transported into the area and one of the resulting thunderstorm cells moved over the station. The 5 minute rainfall data from the site showed that the most intense (0.88”) rainfall of the storm occurred in the first 5 minutes and was followed by a lesser but still impressive 5 minute intensity of 0.62” (See precipitation graph). Resulting outflow from the storm produced a peak 10 second wind speed of 37mph (18.3m/s) and a temperature drop of 8ºF in 5 minutes that occurred coincident with the first 5 minute period of precipitation. National Weather Service radar confirmed the magnitude of the event. (See yellow pixel at point of red arrow in Figure 16 below).

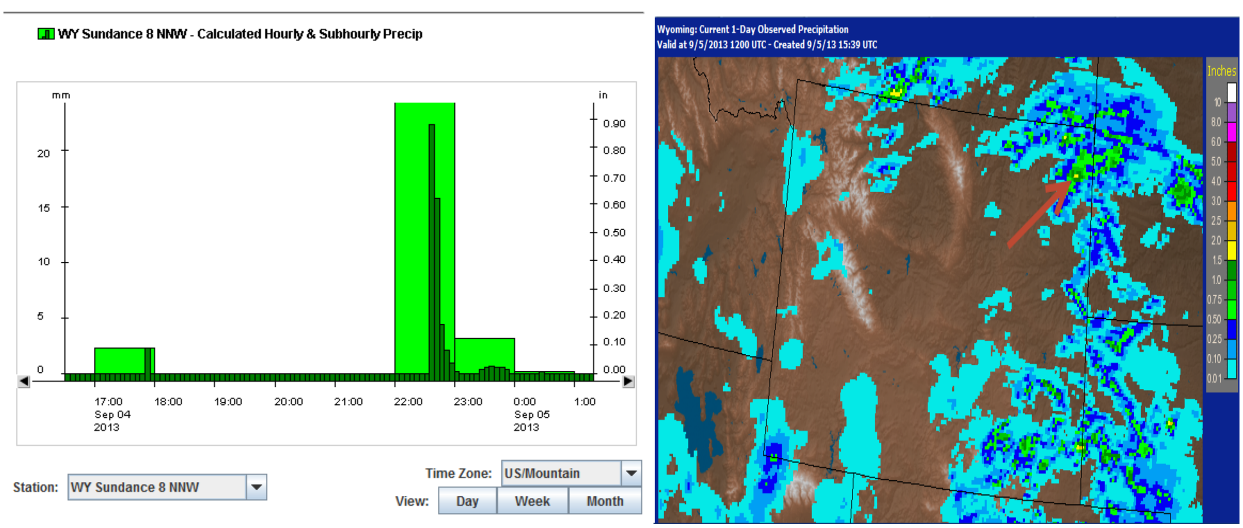
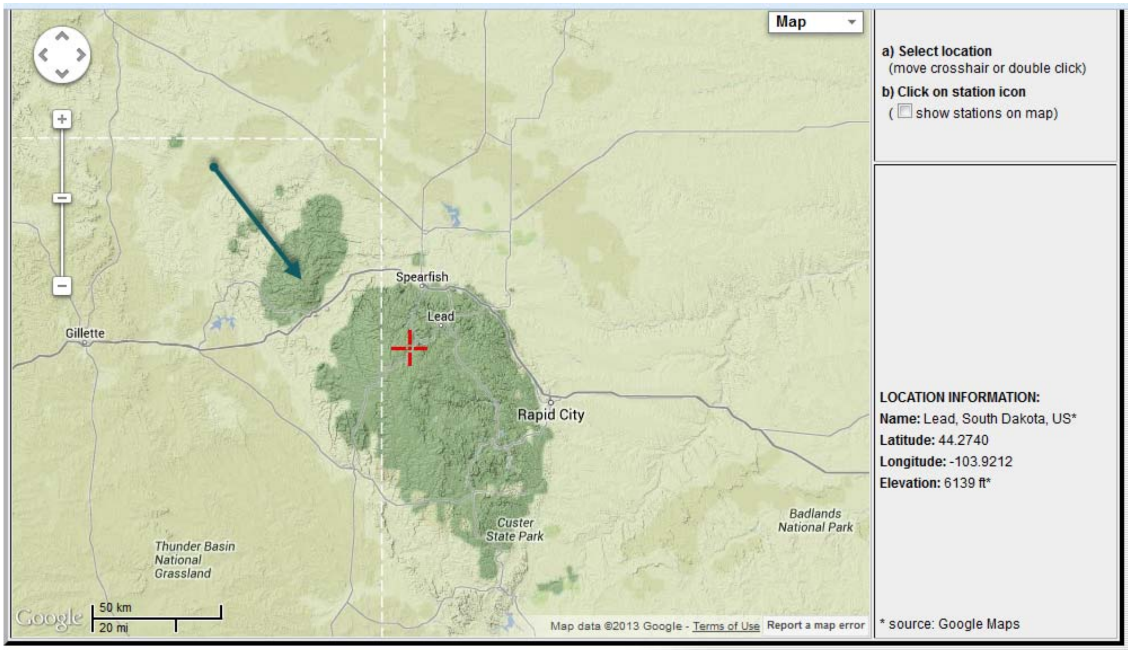


Figure 16. Synoptic Weather Case at Lander, Wyoming on September 4, 2013

In an effort to give some perspective to this event the NOAA Atlas 14 for South Dakota was consulted for a nearest geographically similar location since the NOAA Atlas 14 has not been completed for the State of Wyoming. The results of the point frequency estimates indicated that the 5 minute rainfall of 0.88" was about a one in one hundred year return period and the 10 minute value of 1.50" was about a one in two hundred year return period (Figure 17). The Sundance 8 NNW CRN site is located at the point of the green arrow, while the red cross-hairs indicate the site near Lead, SD for which the Point Precipitation Frequency (PF) Estimates were generated.



POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION

NOAA Atlas 14, Volume 8, Version 2

PF tabular | PF graphical | Supplementary information | Print Page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.266 (0.206-0.343)	0.329 (0.255-0.426)	0.437 (0.338-0.567)	0.530 (0.407-0.691)	0.662 (0.494-0.905)	0.768 (0.559-1.07)	0.877 (0.617-1.25)	0.991 (0.669-1.47)	1.15 (0.746-1.75)	1.27 (0.803-1.97)
10-min	0.389 (0.302-0.502)	0.482 (0.374-0.624)	0.640 (0.495-0.831)	0.776 (0.596-1.01)	0.970 (0.723-1.32)	1.13 (0.818-1.56)	1.28 (0.904-1.84)	1.45 (0.980-2.15)	1.68 (1.09-2.57)	1.86 (1.18-2.88)

Figure 17. Map and Point Precipitation Frequency (PF) Data Table for Lead, SD

Satellite Imagery Confirms Validity of an Apparent Anomaly

On Jan 7, 2013 the spatial display of the maximum surface (IR) temperatures indicated an anomalous reading at the USCRN site La Junta 17 WSW, CO. All of the nearest surrounding stations reported readings that were at least 10ºC/18ºF colder (Figure 18). A check of the visible polar satellite data for the same day (right panel Figure 18) clearly indicated that the immediate area around the station had no snow cover which allowed the ground surface to warm well above freezing and thus validating the apparent warm reading.

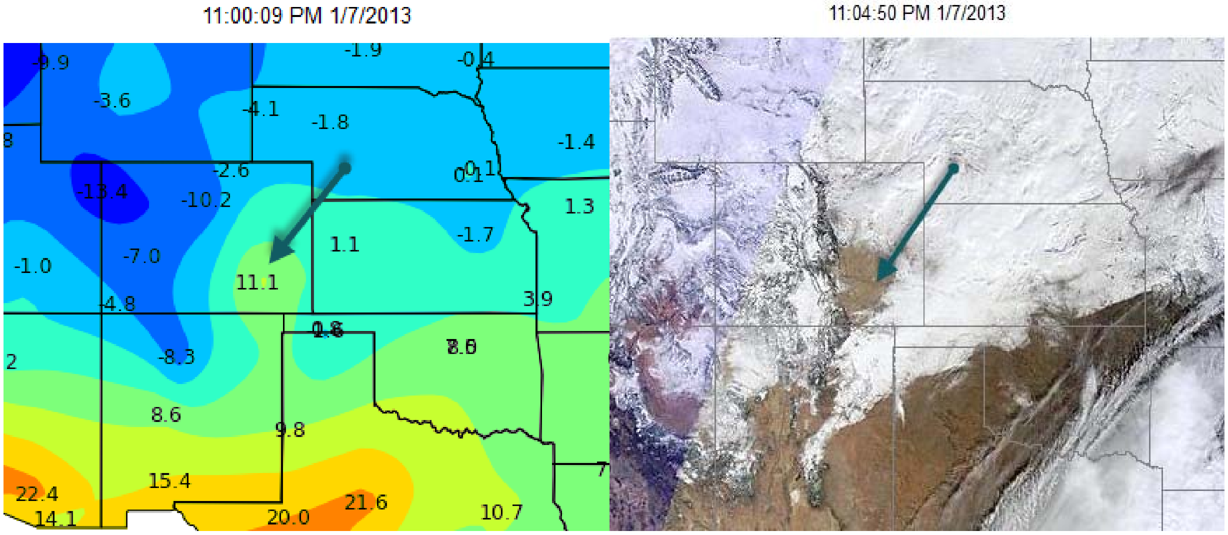


Figure 18. Synoptic Weather Case at La Junta, CO on January 7, 2013

Forest Fire Causes Loss of AC Power

On June 4, 2013 the USCRN site at Los Alamos 13 W, NM (Valles Caldera National Preserve) was adversely affected by a large forest fire that brought about a loss of AC power to the USCRN climate station. With on-site battery backup and the combined efforts of the ATDD engineers and a knowledgeable local site host, only 21 hours of data were not transmitted during the 312 hour outage (Figure 19).

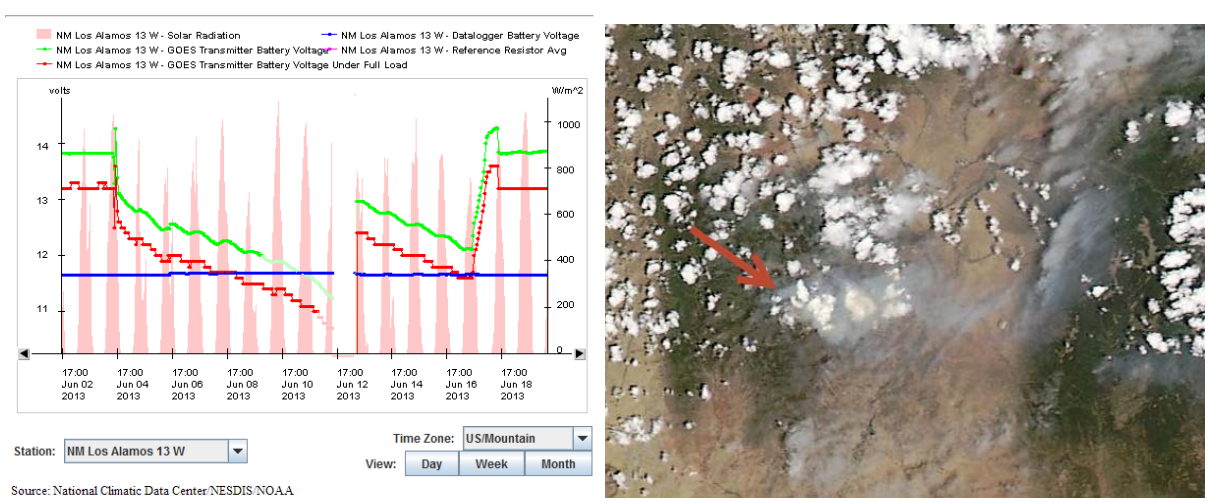


Figure 19. Los Alamos, NM battery graph (left) and Satellite Image of Fire at Los Alamos (right) on June 4, 2013

“Heat Bursts” at Williams 35 NNW Arizona

On July 1, 2013 the CRN site at Williams 35 NNW, AZ recorded a “heat burst” event during the early morning hours. Ambient temperatures rose from 67ºF to 87ºF in about 50 minutes between 0240 and 0350 hours MDT. Such an event is not rare in the southwest US, however, it was more unusual to have a second “heat burst” at the same station only about 26 hours later. The magnitude of the rise of the temperatures in the second event was similar to the previous day’s event (about 20ºF). The maximum 5-minute rise in temperature was also similar for both events at 10ºF (See graphs below). As can be seen in the left panel of Figure 20, both “heat burst” events (red arrows) were accompanied with a sudden rise in wind speeds to about 23mph/10.4m/s (green arrows). The right panel of Figure 20 is an expanded view of the temperatures during the second “burst” event on July 2.

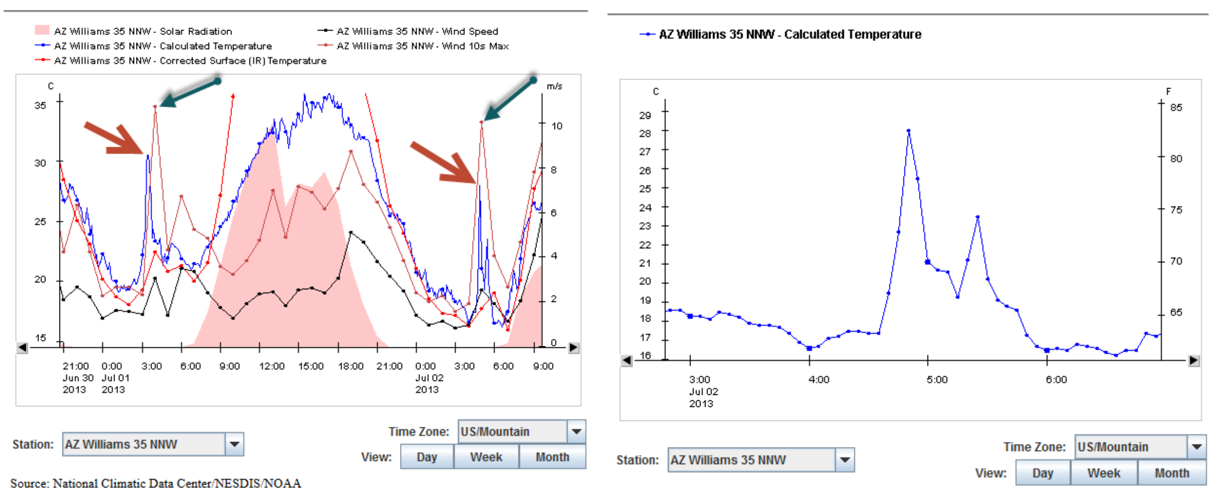


Figure 20. Heat Burst Events at Williams, AZ from July 1-2, 2013

Plans for FY14

A number of long-term science projects described above will reach completion in FY 2014:

- Precipitation algorithm approval is anticipated in FY14, and this will allow for a project to repair precipitation exceptions (poor quality data that passed automated QC), apply the new precipitation calculations, generate new estimated normal, and then create a new precipitation monthly anomaly data set for comparison with GHCN gridded data.
- USCRN-COOP comparison paper will be submitted to a journal.
- USCRN soil temperature and plant green-up paper will be submitted to a journal.
- Air freezing index paper will be submitted to a journal.

Several new science projects will build upon the progress made over the past year:

- Development of new USCRN air temperature products for energy and agriculture.
- Submission of a paper using USCRN soil moisture data to examine the 2012 drought in the central U.S.
- Further research on soil moisture lead-lag relationships with precipitation, temperature, and SPI/SPEI values.
- Collaborative work on soil moisture calibration, scaling, and representativeness with ATDD.
- Continued efforts to create climate end-products taking advantage of data from the USCRN.

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

- Modernize Monthly reports on the USCRN website, making changes necessary to ensure data are consistent with other USCRN products.
- Upon approval by the USCRN Configuration Control Board complete final integration and deployment of the new precipitation algorithm into the USCRN Ingest software.
- Collaborate with Data Access and Analysis Branch to identify and implement methodologies for improving the speed and efficiency of USCRN database entry and updates.

Hardware testing and deployments will continue:

- A site survey trip to Alaska will take place during Summer 2014
- Three new stations will be deployed in Alaska during the Summer 2014 timeframe
- 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 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 2014 will see a milestone where over half (16) of our planned 29 station configuration of sites for the state of Alaska will be installed and operating.