Climate Data Part 3: snow, climate, and streamflow networks

By Zack Guido

This article accompanies two others written in March and April 2009. Together they summarize many of the important monitoring networks that provide climate and weather data for the Southwest. The March 2009 article featured National Weather Service's Cooperative Observer Program and the related Historical Climate Network. The April 2009 article described data from Remote Automated Weather Stations (RAWS) and the Arizona Meteorological Network (AZMET) and data generated by the Parameter-elevation Regressions on Independent Slopes Model (PRISM) statistical technique.

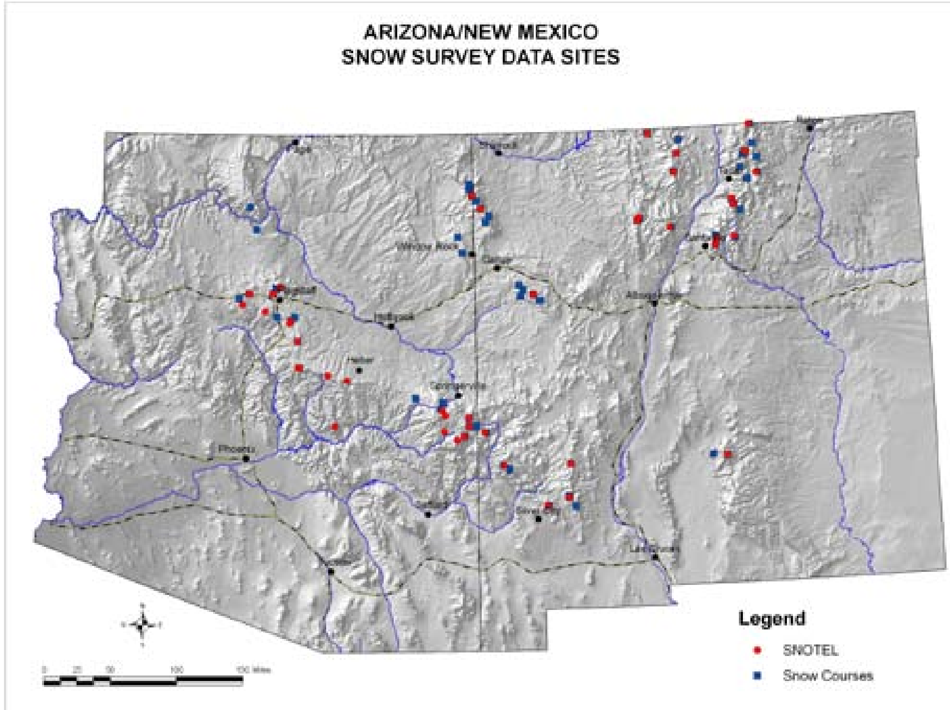

Figure 1. There are 21 SNOTEL stations and 23 snow courses in Arizona, and 23 and 39, respectively, in New Mexico. Map courtesy of Dino DeSimon, NRCS.

Climate and weather data support many important functions, including streamflow forecasting, determining dates to plant and harvest crops, and lending historical perspective to current warming trends. Despite clamors for a one-stop information clearinghouse, information is scattered around the Internet, making accessibility challenging, even for those in the know.

Knowing what data is available is only half the battle. Understanding where stations are located, the quality control standards for the data, and other details about the limitations and utility of the data often requires substantial detective efforts, and sometimes even those cannot uncover the desired information.

A closer look at four networks clarifies some of the finer points about site locations, quality control standards, and limitations. These networks include the automated snow telemetry stations (SNOTEL), which record conditions at frosty elevations in the West; the Climate Reference Network and Modernized Historical Climate Network, which are new efforts established to record national and regional climate changes; and real-time streamflow gauges, which are the nation's window into river conditions.

Automated Snow Telemetry Network

The Natural Resources Conservation Service (NRCS) monitors nearly 2,000 high-elevation stations and focal points around the West using SNOTEL and manual measurements called snow courses. The network is the nation's principal source of climate and weather information at high elevations.

The primary use for SNOTEL is to monitor snowpack conditions that provide valuable information for streamflow forecasters. The information is also vital to fire managers because high or low snowpacks either suppress fire potential in the spring or hasten drying, priming the landscape for elevated fire risks. Climate researchers also rely on this network to characterize long-term changes at high elevations.

SNOTEL sites automatically record measurements every 15 minutes and transmit the data to NRCS; these increments are then averaged in hourly and daily format and are posted on the NRCS website.

In Arizona and New Mexico, about 44SNOTEL stations are situated in remote places near watershed divides, mostly at elevations between 8,000 and 9,000 feet (Map 1); no station is below 6,900 feet.

"Most stations are located in meadows or open areas and near the crests of ridges separating watersheds," said Dino DeSimone, water supply specialist for the NRCS. Sites are often on north aspects; if they were placed on the southern slopes that receive the brunt of the winter sun

continued on page 4

Climate Data Part 3, continued

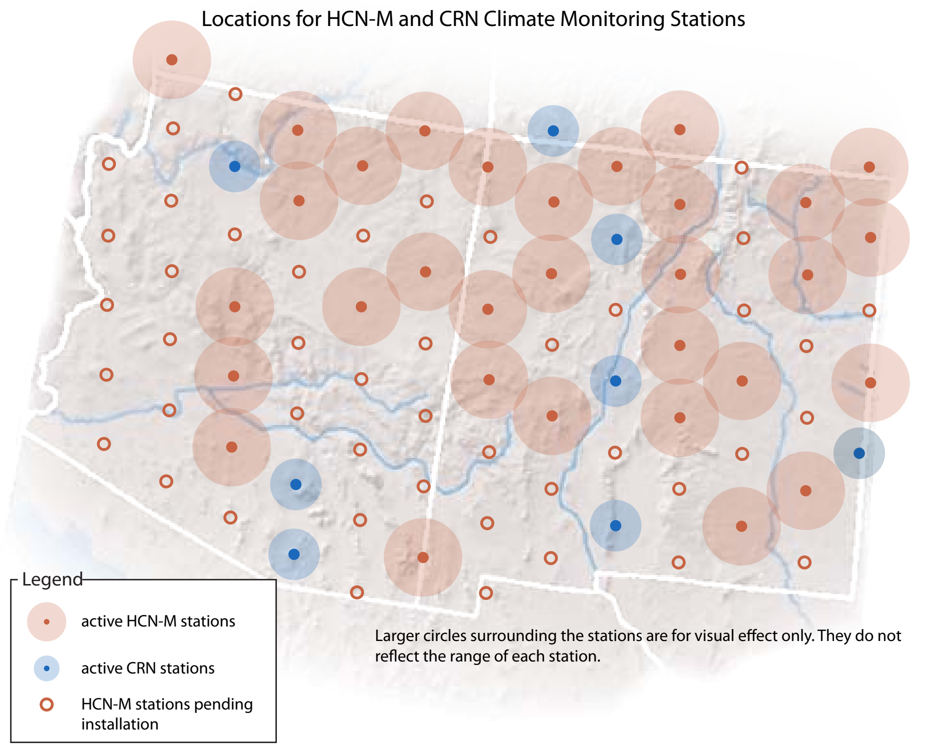

Figure 2. The CRN and HCN-M were recently developed to record climate changes at U.S. and regional scales. The larger HCN-M network is still being deployed and has 14 and 18 active stations in Arizona and New Mexico, respectively.

they wouldn't be measuring much snow in the Southwest.

The NRCS began installing the Arizona stations in the late 1970s. The basic SNOTEL station provides daily maximum, minimum, and average snowpack, snow water content (SWC), snow depth, precipitation, and air temperature data. The more sophisticated SNOTEL stations also are equipped to measure soil moisture and temperature at various depths (Table 1).

Snow course sites have the same characteristics as SNOTEL—they sit near basin divides, at high elevation, and away from the tree canopy—and the SWC and snow depth measurements at snow courses are made at six locations in a 50-foot transect. However, they have one major drawback: measurements are periodic, made only when someone visits the site, so weeks can pass without insight into snowpack conditions. In that time, intense storms can dump copious snow or rain, or a warm spell can cause rapid melting that elevates flood risk.

Available data from snow course sites dates to the mid-1930s. Historically, snow course surveyors skied or snowshoed into the remote sites about twice a month. Many of these snow courses are still operational today and account for about 60 percent of the 1,950 automated and manual monitoring sites in the West, including Alaska.

Climate Reference Network and Modernized Historical Climate Network
Most data networks were established to monitor weather, not climate. The distinction is subtle, yet important. Weather monitoring is concerned with changes in temperature and precipitation, among other variables, over days to a few weeks, not over long periods lasting decades.

In most networks, many stations have been moved, had thermometers replaced, or been influenced by the construction of nearby heat-absorbing buildings. These changes often cause artificial jumps in the measurements that become problematic for climate analysis. Although scientists have gone to great lengths to homogenize the data before and after the shift so that actual—as opposed to artificial—changes in the climate are recorded, many networks remain susceptible to these changes, and thus inaccuracies.

To create a stable network immune to this problem, two new National Oceanic and Atmospheric Administration (NOAA) efforts recently began. The sole intentions of the Climate Reference Network (CRN) and Modernized Historical Climate Network (HCN-M) are to accurately characterize changes over many years (Figure 2).

"We want to be able to go to this data and answer how climate has changed without any doubts," said Howard Diamond, program manager for the CRN. The networks, he said, "are the gold standard of climate observations."

The CRN and HCN-M will monitor changes in regional and U.S. climate and will become the go-to data once these young networks mature.

"We've set-up these networks to give us as absolute of a measurement of climate as possible," Diamond said.

A unique aspect of both networks is that they measure each climate variable, including temperature and precipitation, every five minutes with three different sensors. Each station has three thermometers and rain gauges, for example. This redundancy prevents faulty measurements if a sensor fails and ensures accuracy by preventing subtle measurement drifts, which are difficult to identify without multiple measurements.

continued on page 5

Climate Data Part 3, continued

The sites in both networks are also selected to ensure that the environments will not change over time. Many of the HCN-M stations are placed on protected lands like wildlife refuges and national parks, where heat absorbing buildings and roads likely won't alter the climate for another 100 years.

The CRN began in 2000 and consists of 122 sites around the U.S. There are three stations in Arizona and four in New Mexico (Map 2). The first station in Arizona began recording in 2002; the inaugural station in New Mexico began in 2003.

The CRN characterizes climate change at the national scale, whereas the HCN-M is focused on smaller, regional climate signals and therefore requires a more closely spaced network.

The HCN-M network, on the other hand, will have 538 stations across the U.S. when all are installed. The difference in the number of sites reflects the intention of the networks. The HCN-M began in 2008 as a pilot project in the Arizona, New Mexico, Utah, and Colorado. The network is still under development in the region and has yet to be extended to the rest of the U.S. Currently, 14 stations in Arizona and 18 in New Mexico are operational. As many as 26 more sites will be installed in Arizona and 19 more in New Mexico.

Stations were initially spaced in a grid about 65 miles apart, and future stations will be separated by about 85 miles. Researchers determined that an 85-mile grid spacing would be sufficient to detect a 10 percent change in precipitation, per century, which is significant change in the West, and at least a 0.5-degree Celsius temperature change per century, Diamond said in an email.

The CRN stations principally record temperature, precipitation, soil moisture and temperature, and relative humidity. Some experimental stations also measure wind speed and solar radiation. The HCN-M sites only monitor temperature and precipitation.

The data for both networks are available in hourly and daily format. Statistical algorithms check to make sure the data are within expected ranges and free of anomalous readings. The triple redundancy also helps ensure high quality and accurate data.

A limitation of these networks is that measurements began only recently. The longest record is only 10 years, rendering

continued on page 5

Table 1.

Network	Data Source	Principal Climate Variables	Available Data Intervals	Record Length	Primary Application	Web Host
CRN	122 active stations in U.S., 3 in AZ and 4 in NM	1. Temperature 2. Precipitation 3. Soil moisture 4. Soil temp. 5. Relative humidity	Measurement made every 5 minutes; easily accessible data are in hourly and daily format	Network began in 2000; first station in AZ and NM began in 2002 and 2003, respectively	Monitor U.S. climate changes	National Climatic Data Center (NCDC)
HCN-M	Pilot project in the Southwest; 14 stations in AZ and 18 in NM	1. Temperature 2. Precipitation	Measurement made every 5 minutes; easily accessible data are in hourly and daily format	Network began in January 2008	Monitor regional climate changes in U.S.	National Climatic Data Center (NCDC)
USGS Real Time	More than 9,200 real-time sites in U.S.; 232 in AZ and 141 in NM	1. Stream discharge 2. Stream velocity 3. Water height (stage)	Measurements made every 15-60 minutes; sub-hour data available for 120 days, daily or monthly data available for entire record	Network began in 1889	Water management issues	U.S. Geological Survey (USGS)
SNOTEL*	~1,200 stations in the West, including 21 in AZ and 23 in NM	1. Snowpack water content 2. Snow depth 3. Precipitation 4. Air temperature	Measurements made every 15 minutes and averaged in daily or monthly format	Record began in AZ and NM in October 1978	Monitor high elevation snow conditions, principally for streamflow forecasting	Natural Resources Conservation Service (NRCS)

*This information pertains only to automated SNOTEL sites and not snow courses.

CRN: U.S. Climate Reference Network
HCN-M: Modernized U.S. Historical Climate Network
USGS-Real Time: U.S. Geological Survey Real-Time Data
SNOTEL: Snow Telemetry

Climate Data Part 3, continued

trend analysis inadequate for climate studies. Another limitation is that most stations in both networks only measure a few climate parameters, forgoing other important variables such as wind.

Also, data only can be downloaded one station and year at a time, making retrieval cumbersome for queries of multiple stations and years. Finally, there are large distances between stations, making it difficult to understand changes in rain and snow patterns in areas where precipitation is spotty, such as in the Southwest during the monsoon season.

These networks eventually will be best suited for detecting longer-term changes in temperature and winter precipitation in the Southwest and less effective at characterizing trends in summer precipitation in the Southwest.

Data for Rivers and Streams

Climate data pertain to more than temperature and precipitation. The information also includes streamflow measurements, which incorporate many climate-related phenomena such as temperature, precipitation, and soil moisture.

The U.S. Geological Survey (USGS) began streamflow monitoring in 1889 and has increased the streamflow network to include more than 25,000 active stations in the U.S. About 9,200 of those are called real-time stations that automatically measure stream conditions every 15 to 60 minutes. The data usually are available on the USGS website within an hour. Arizona and New Mexico have 232 and 141 real-time stations, respectively.

The data generated by these stations are available for only 120 days and are "provisional," meaning they have not been quality controlled. The data, however, are eventually converted into daily format and are quality controlled and labeled as "approved."

The daily data are archived and users can obtain them for the entire period of record for each station. The daily data can include average, median, maximum, and minimum streamflows and other stream-related variables, depending on the station. Real-time data does not have statistical summaries like averages or maximums.

Because the real-time data, as opposed to the daily format, lack quality control, users should be weary of potential inaccuracies, particularly after large events that can alter the stream channel and cause errors in the measurements. After an extreme event such as a flood, the USGS visits the site to recalibrate the station, but the data are corrected and become available in "approved" daily format.

The daily values include "provisional" during the last few months and "approved" data. While provisional data has not been vetted for accuracy, approved data undergoes several layers of quality control that include visual inspections by scientists and cross-checking with other variables.

For example, measured discharged is compared to the discharge calculated from a relationship between river height and flow volume. Approved data require no additional quality control but users of provisional data should be on the lookout for anomalous readings and avoid using the information at sites that experienced extreme events.

The USGS also measures groundwater, water quality, and limited meteorological data, including precipitation. The agency, however, does not quality control the precipitation data, which can only be downloaded for the previous 120 days; there are no long-term records of precipitation.

Data come in many flavors that can present challenges for selecting the appropriate network. It would be inapt, for example, to use precipitation data from the USGS network or data from the CRN and HCN-M to characterize changes in summer precipitation in the Southwest. Fortunately, there are many networks that produce information suitable for diverse purposes. Knowing what is available is an important first step to accessing and properly using data.

Where to find the data

SNOTEL and Snow Course

1. Access SNOTEL sites for Arizona and New Mexico:
   http://www.wcc.nrcs.usda.gov/snow

2. Access Snow Course sites for Arizona and New Mexico:
   http://www.wcc.nrcs.usda.gov/snowcourse

Climate Reference Network and Modernized Historical Climate Network

1. Information about CRN and HCN-M:
   http://www.ncdc.noaa.gov/crn/observations.htm
2. FTP access to a stations entire record in daily and monthly format:
   http://www.ncdc.noaa.gov/crn/products.html
3. Data covering the last month:
   http://www.ncdc.noaa.gov/crn/observations.htm

U.S. Geological Survey streamflow data

1. Real-time data for Arizona:
   http://waterdata.usgs.gov/az/nwis/rt

2. Real-time data for New Mexico:
   http://waterdata.usgs.gov/nm/nwis/rt