

The SNOTEL Temperature Dataset

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Real-time weather data and its archived “climate” dataset must be used with an appreciation of its original purpose and inherent limitations. By knowing a station's history/metadata (e.g., location, equipment, maintenance schedule, sensor changes, etc.), operators and researchers can then expect the highest degree of data quality and use. The SNOTEL system was initially installed in the late 1970's primarily as a water supply forecasting hydro-climatic data collection network. To that end, sites were located specifically to forecast water supply in the western United States and in most cases, replaced existing manual snow courses that historically had good correlations between snow water-equivalent (SWE) and streamflow. There were limitations in the amount and type of data that the early system could process and transmit. Thus early on, only the SWE, precipitation and *current* air temperature data were initially collected. The observation times of these early data occurred without any uniformity. This situation was adequate for SWE and precipitation measurements but gave a much less than desired result for temperature. The data poll for individual sites typically started at midnight, 6:00 am, noon, 6:00 pm and could last for up to five or more hours. Thus air temperature data would be reported at the time an individual station was contacted and might vary from as early as shortly after midnight to as late as 5:00 am. Polls were conducted four times daily but in that early period, a station might report between zero and four times per day and the time stamp on those data would be dependent on when the station reported. Temperature data were to be used in a relational context to calculate or predict snow melt rates, predict the onset of melt and generally be used in a water supply context. As the data collection, processing and transmitting electronic components were improved, additional sensors were added to the system.

In the mid 1980's, with the advent of better electronics, daily minimum, maximum and average temperature data were added as standard data collection to SNOTEL. Unfortunately, temperature sensors were not uniformly installed across the entire network and in fact, a rather poor job was done particularly in the mounting of these sensors. The first temperature sensors were generally Climatronics or Climet thermistors and were in small ~3X3 inch aluminum box shaped shields or in aspirated housings. Most of these sensors were mounted on or very close to the brown SNOTEL shelters. Others were mounted to the antenna tower. Various mounting configurations were used, mostly dictated by the ease of installation and not to any technical standards. In some cases, they were mounted horizontally across the face of the shelter about six to 12 inches below the shelter roof and about 24 inches from the side and in all cardinal directions. In other cases, an "S" shaped aluminum tube was used to mount the sensor vertically to the side of the shelter which put the thermistor about six inches from the shelter side and up to 12 inches above the roof line. In yet another configuration, the sensor was mounted vertically above the shelter at a distance of between three and six feet. Clearly any mounting configuration that put the sensor near the brown radiating shelter would have a net warming bias on the early dataset. Some of these early sensors were mounted to

remote antenna towers then moved to a shelter mount to be moved again to the antenna tower and finally moved to the meteorological tower. Much of the early data from these sites are compromised by inappropriate mounting, sensor moves and various changes in sensors and aspirators. Another more isolated and easily identifiable problem with this mounting scheme is that occasionally, a shelter and its temperature sensor was completely buried in snow or the roof snow load encased the sensor in which case, the air temperature sensor became a snow temperature sensor. Later, some sensors were moved to the antenna towers, which in most cases is a better location. However, some towers were directly adjacent or attached to the shelter and the temperature data at these sites could be compromised to some degree, other towers, remote from the shelter should have reasonably consistent data.

In Photo 1, the SNOTEL site at Beaver Divide, Utah is shown with a standard YSI thermistor, a three gill aluminum aspirator and the "S" mount attached to the side of the shelter and extending above the roof line. This configuration is perhaps the worst of all mounting scenarios.



Photo 1.

Photo 2 shows the Rock Creek SNOTEL site and the impact on snow the brown shelter can have via long wave radiation. Notice the snowpack has melted to a distance of about 2 feet from the edge of the shelter and that the temperature sensor mounted horizontally

across the top of the shelter in a northeastern direction is in a direct line above that obvious impact.



Photo 2.

In photo 3, (Buck Flat, Utah) there is a standard YSI thermistor mounted on a remote tower. This sensor has subsequently been moved from this location to the meteorological tower some 20 feet distant, but the overall impact of this move would be small. Data from these sites would be the most consistent in relation to current standard location and mounting practices.



Photo 3.

Temperature sensors gradually migrated to YSI thermistors with a range of aspirators including the most commonly used, a silver three vent aluminum model. There were tower mounted sensors and aspirators that were white, wind directed models and a variety of other configurations. In the mid 1990's, snow depth was added to many sites as a standard sensor and this began the installation of standardized meteorological data collection towers. At that time, there was still a mix of temperature sensors mounted on shelters and on antenna towers with a wide variety of aspirators. Since snow accumulation is variable across the West, tower height is also variable with most meteorological towers being in the 10, 20 and 30 foot ranges, depending on snow depth. Sensor mountings are therefore also variable in height being at about seven, 17 and 27 feet respectively. The majority of all sensors are at the 17 foot height. That stated, during a significant portion of the year, the ground surface level is constantly changing due to the accumulation and ablation of the snowpack and the respective height of any individual sensor may range from 17 feet to as low as five feet or less.



Photo 4.

In photo 4, (Cascade Mountain, Utah) the current standard temperature mounting configuration is shown with the sensor at 17 feet, mounted three to six feet from the tower and in a white, six gill aspirator.

In the mid 1990's as the installation of meteorological towers progressed, another sensor change was made from the standard YSI sensor to the extended range YSI sensor in order to capture temperature readings to minus 40 degrees F. The coldest sites were the first to get the extended range sensor. Personnel in the Idaho region had the foresight to run both the standard YSI and the extended range YSI side by side for several years with identical mounting and aspirator configurations and noticed a plus one degree C difference in a very large portion of the observed temperature range of the extended sensor compared to the standard sensor.

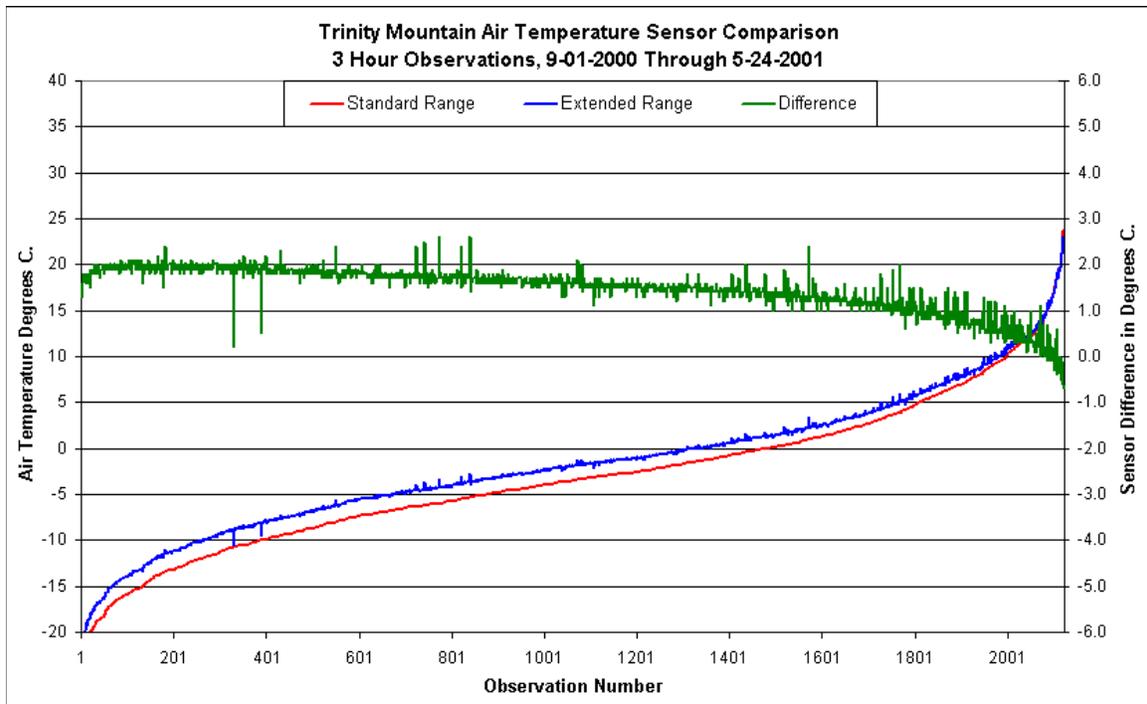


Chart 1.

Chart 1 displays a comparison of side by side mounted standard and extended range YSI temperature sensors, the results which show a one to two degree C difference between the two sensors, with the current extended range sensor warmer than the standard sensor. This difference is most noted at the lower end of the temperature scale whereas at the upper end, the difference becomes much less. This is consistent at all of the Idaho sites tested.

Physical site changes will continue to pose some problems in overall data consistency. Vegetation grows, and at times, dies yielding an ever changing solar view and site characteristics. At some sites, this could be dramatic and at others, not likely to be much of a source of an inhomogeneous dataset. The removal of one or several trees at a site can impact the canopy, solar window and evapotranspiration characteristics which could change the temperature regime over some or all of a daytime pattern including nighttime pattern. The same could be true of growing vegetation altering the periods of full sun or shade at any given site.



Photo 5.

In photo 5, (Camp Jackson, Utah) one can clearly see the proximity of the vegetation to the tower and the temperature sensor as opposed to the vegetation in photo 4. Vegetation height and proximity is constantly changing at some sites, while at others it tends to be relatively stable. At this site, the dominant species is Aspen (*Populus Tremuloides*) and has the added feature of being deciduous which changes the overall solar input as leaves are generated in the spring and subsequently lost in the fall. At other sites such as Big Flat, Utah, (photo 6) which is in a mature Spruce and Fir (*Picea* and *Abies*) forest, the vegetation is and has been very stable. However, should the current beetle and bud worm infestation spread with subsequent high spruce mortality, currently experienced in southern Utah, the vegetation at this site could change dramatically and hence, the solar window.



Photo 6.

Another source of potential inconsistency in the dataset is that of data editing and quality control. For the most part and with the exception of Idaho, the SNOTEL temperature dataset has undergone little in the way of systematic data quality control and verification. The data editing that is done is primarily the removal of howlers and screamers and focused on the daily maximum, minimum and average. Some areas such as Idaho have done more and have concentrated on a serially complete dataset complete with estimated data points but the techniques of data estimation and editing have been far from standardized system wide at this point. The NRCS is attempting to use spatial climate station comparison methodology to resolve suspected data and fill-in missing data by assigning quality control flags that are quantified by confidence probabilities.

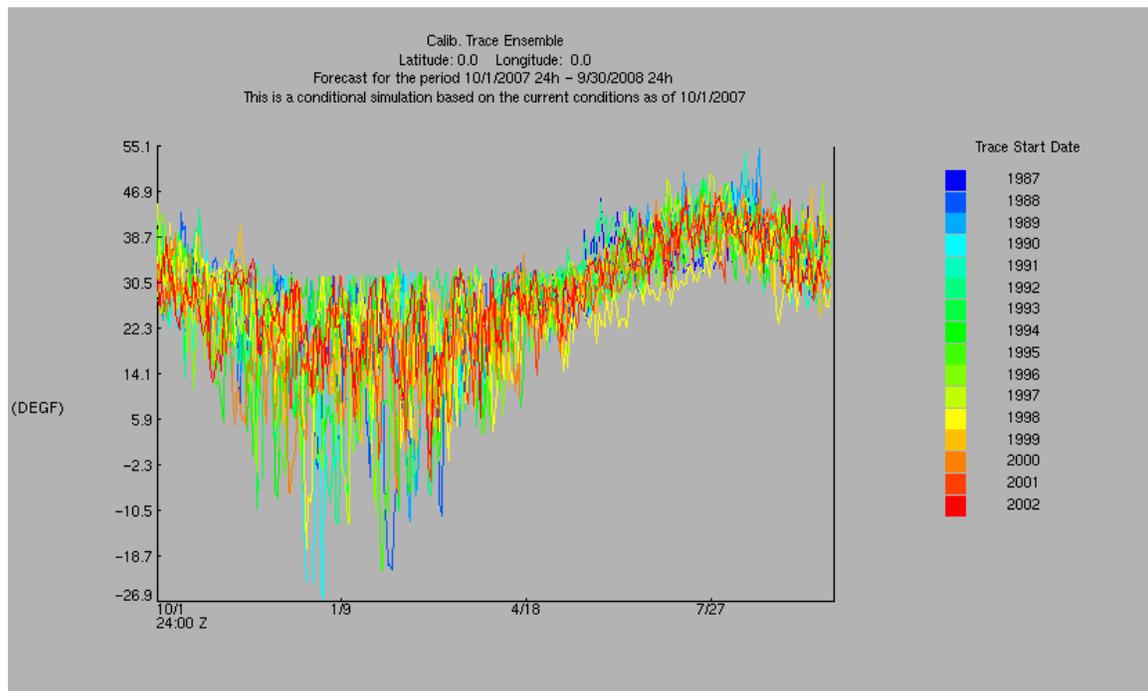
An un-quantified source of data error is in the electronics of the system and could be either random, systematic or a combination of both. There have been a series of joint transceiver/receiver/data processors in combination with the series of different temperature sensors. These include the Secode, MCC 550A, MCC 550B and the current version, the MCC 545 coupled to a Cambell CR10X data logger. Each of these systems measure voltages from each sensor which are then equationally converted to meaningful engineering units. Errors may occur due to: error in the thermistor, resistive errors such as line loss, ground potentials, excitation voltages, and errors associated with the data logger reading the voltages. These errors may occur from something as mundane as the type of cable used or in the connections from the cable to an interface. Drift in the voltage reading device could be the source of some un-quantified error.

In summary, the historic temperature data from the SNOTEL network have some significant systematic and random bias. This bias includes poor mounting techniques, sensor changes, location changes, aspirator changes, vegetation changes and electronic errors. Vegetation changes can be in the form of 20 to 30 years of growth or instantaneous change due to fires, disease, or insects. Documentation of these changes has been inconsistent system wide and currently resides mostly on paper records difficult to access and digitize. Much of the very early record, from mid 1980's to the early 1990's will be difficult to salvage and much of those data are compromised by poor sensor mounting techniques and are suspected to record much warmer temperatures than actually occurred. General use of these early records as comparisons to current conditions is discouraged. Some records, particularly those sensors that were mounted to remote towers early on will have reasonable quality, subject only to observation time, aspirator and sensor changes and possibly some vegetation change. Useful metadata on dates of sensor, aspirator and location changes would facilitate the potential construction of a reasonable, corrected dataset for these specific sensors.

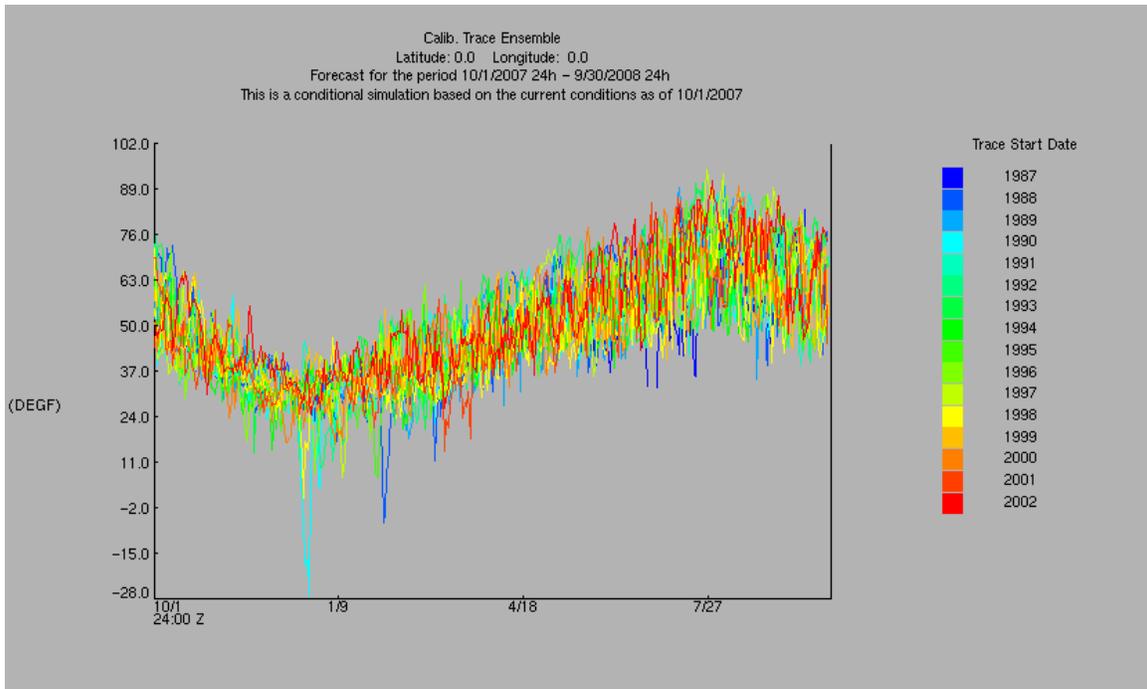
Currently, NRCS is moving to standardized temperature sensor mountings that are on a meteorological tower in a specified data collection area at a height of 7, 17 or 27 feet and a distance of four to six feet horizontally from the tower.

Addendum: November 9, 2007

The following was identified by Kevin Berghoff of the National Weather Service, NOAA and illustrates a serious potential systematic error in the SNOTEL temperature data set.



This graph shows the minimum daily temperatures from the Thunder Basin SNOTEL site in Washington for the years 1987 through 2003. The issue is a flat line of temperature data at 32 degrees starting in late November and continuing into April. The "minimum minimums" look good with a large range of data from -27 degrees up to near freezing conditions, however, the "maximum minimums" hit a ceiling at 32 degrees.



This chart shows the maximum data for the same site and time period. Notice that there is no ceiling in these data, both the "maximum maximums" and the "minimum maximums" show a very jagged edge on top and bottom with a large amplitude and defined sinusoidal pattern through the year. Obviously the sensor itself is sensing exactly what it sees - in other words, the sensor is operating correctly and the ceiling in the minimum temperature trace must be an artifact of the environment of the sensor.



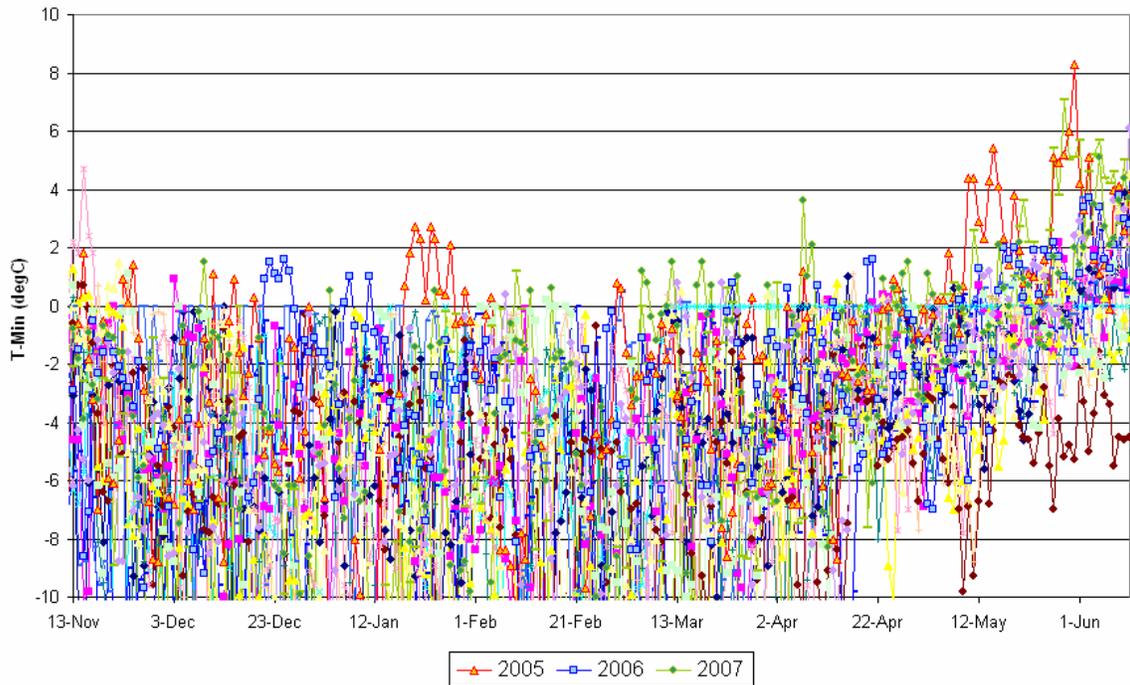
The sensor environment.

This sensor is mounted at about 10 feet, on the shelter to the lee side of prevailing winds and just below the top of the shelter itself. When there is significant snow accumulation, this sensor is about 12 inches from an open ice box. Snow on top of this shelter could be several feet to potentially 4+ feet deep which means that the air temperature is actually measuring temperature near the snow surface. In the daytime, solar radiation from the shelter would allow increased maximum temperatures but at night, absent solar heating and given some protection from warm wind impacts, this sensor would not register values much above the snow surface values. The minimum minimums are free to fall, but the maximum minimums are constrained to near 32 degrees.

This sensor was moved to a location on the antenna tower at a height of 19 feet. This means that it is about 7 feet higher than the shelter roof at this point and given a snow depth on top of the roof of say, 5 feet, may still be compromised to some degree.

An analysis of the data post 2003 by Melissa Webb of the Oregon NRCS Snow Survey Office shows that the current mounting configuration is much better than the old.

Thunder SNOTEL
Minimum Temperature for POR



This chart clearly shows that the 32 degree ceiling of the previous charts no longer exists. Given the current sensor location this site may still have some ceiling, the question becomes what that ceiling may be and what time duration it may exist.

This sensor mounting technique was very common throughout the SNOTEL system for many years. This specific problem of a minimum temperature "ceiling" has just been identified. There is a significant potential for this systematic bias to be misinterpreted. In the observed data, there can be this minimum temperature ceiling and when removed, as it has been by moving these sensors to a meteorological tower remote from the shelter, there will be a net increase in minimum temperatures system-wide.

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