SNOTEL NETWORK - ANALYSIS OF AND FUTURE PLANS FOR THE COLLECTION OF ADDITIONAL CLIMATIC PARAMETERS AT SNOTEL STATIONS

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ABSTRACT

Advancements in technology and sensor development have allowed additional climatic data to be collected in harsh winter environments associated with remote SNOTEL sites. The new generation of climatic data collected includes snow depth, wind speed and direction, solar radiation, humidity, soil moisture and soil temperature. Currently, several of these sensors are being evaluated in remote mountainous areas. The snow depth sensor is proving to be a reliable and dependable sensor and will produce a wealth of additional information such as daily snowfall amounts, depth of snow on ground, and when combined with snow pillow data, snowpack density. This paper summarizes 1) the new generation of climatic data being collected and requested, 2) problems encountered 3) products and studies utilizing the data, 4) quality control of data, and 5) future plans for installing these climatic sensors at SNOTEL sites.

INTRODUCTION

The USDA-Natural Resources Conservation Service (NRCS) has successfully operated the SNOTEL (SNOw TELemetry) Data Collection Network in the western United States since the late 1970s. This network automated and supplemented the traditional manual snow courses that originated in the early 1900s. The primary purpose of this network is to collect remote high elevation snowpack data to aid in accurately forecasting spring and summer streamflows. Originally, snow water equivalent (SWE) and precipitation were the standard parameters monitored on a daily basis. Daily air temperature data (maximum, minimum, and average) was soon added as a standard parameter. Today, the SNOTEL Network collects multiple readings per day from over 600 sites in the western US.

In addition to providing information to aid in streamflow forecasting, the SNOTEL Data Collection Network has provided a better climatological understanding of the mountainous regions in the western US. The availability of near-real time data has resulted in: 1) more precise and accurate streamflow forecasts, 2) improved flood and drought mitigation, and 3) a need for more climatic parameters for specific studies or purposes.

Advancements in technology and sensor development have allowed additional climatic parameters to be collected in remote, harsh, winter environments. Improved technology has simplified the interfacing of additional climatic sensors with radios used to transmit SNOTEL data. Recent advancements include the compatibility of programming data loggers with the new generation of SNOTEL radios. Snow depth was once collected as a standard data parameter when manual snow courses were measured, but with the advent of the SNOTEL system, this parameter was not available. New sensors now provide accurate snow depth measurements. This paper discusses: 1) a new generation of climatic sensors for SNOTEL sites, 2) problems encountered, 3) products and studies utilizing this type of data, 4) quality control of data, and 5) future plans for installing additional climatic sensors at SNOTEL sites.

1) A NEW GENERATION OF CLIMATIC SENSORS FOR SNOTEL SITES

Table 1. The new generation of climatic data being collected at SNOTEL sites includes snow depth, wind speed and direction, solar radiation, humidity, soil moisture, soil temperature, and barometric pressure.

Sensor	*Type of Data Parameters Collected / Available*
Snow Depth	1. Depth of snow on ground and snowpack density 2. Snowfall intensity and density of new snowfall
Soil Moisture	1. Monitored at 5, 10, 20, 51, and 102 cm (2, 4, 8, 20 and 40 in) depths 2. Soil salinity is also collected
Soil Temperature	1. Monitored at same depths as above 2. Daily maximum, minimum and average

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Wind	1. Speed, bearing, maximum wind speed 2. Averages for selected periods
Barometric Pressure	1. Current, maximum and average
Humidity	1. Daily maximum, minimum and average
Solar Radiation	1. Net daily radiation

A recently completed NRCS Snow Survey Research & Development project investigated the installation and applicability of depth sensors at SNOTEL stations. The recommended design as the standard methodology for installing snow depth sensors, pending approval, includes mounting the sensor on a three-legged antenna tower 1-2 m (3-6 ft) from the snow pillow's edge. The depth sensor is mounted on a 2 m (6 ft) boom extending over the snow pillow. Recommended installation technique is based primarily on safety, sensor stability / reliability, maintenance accessibility, and versatility in adding additional climatic sensors on tower. Standards have not been established for other sensor installations.

2) PROBLEMS ENCOUNTERED

This section summarizes some of the problems, hurdles and obstacles to consider when installing and collecting data of this type at remote locations.

Snow Depth
Problems that induced inconsistent snow depth data were typically not a result of the sensor. These problems resulted from vegetation growth, loose mounting of the boom, improper target area affected by snow sliding off shelter roof, etc. These types of problems were solved by using the recommended installation technique. Target area for depth sensor is over the snow pillow to ensure the measurement can be reliably used with SWE data for density calculations. False readings occasionally occur during windy storm events. Multiple comparative readings are taken to eliminate bad data. Data analysis indicates a diurnal effect of several millimeters (tenths of an inch). This may be a result of temperature-related expansion or contraction of guy cables, tower or boom. The snowpack may also exhibit slight thermal expansion and contraction tendencies or the thermistor may be slow to adjust. This diurnal affect may be a result of other reasons or a combination of these. This is a minor problem within the 12 mm (0.5 in) measurement standard.

Wind
Not all SNOTEL sites are the best locations for collecting wind data. SNOTEL sites are typically located in small-forested openings or near the edge of a forested environment. The forested canopy helps to create an area free of scour and deposition of blowing snow, which is ideal for monitoring snowfall and precipitation unaffected by wind. Solutions to overcome this problem include: 1) If canopy is not unreasonably high, install a taller tower. However, such data would be collected at much greater height above ground than desired. 2) Install tower for mounting sensors up to 300 m (1,000 ft) away and bury cable. 3) Install a data logger with radio frequency transmitter to collect and transmit data to a line-of-sight SNOTEL station for transmission to the central SNOTEL computer.

Other considerations when locating the best spot for collecting wind data include: 1) Potential vandalism - sensors located on a tower in an open meadow may be a more ideal location, however, this may also induce vandalism. 2) Microclimate at SNOTEL sites - monitoring wind at SNOTEL stations may be better at defining the microclimate in the area of the site. Recently, wind sensors for avalanche forecasting were installed about 225 m (750 ft) from Galena Summit SNOTEL in central Idaho. However, analysis with a near by station, indicates that this area was in a microclimate less affected by wind and not ideal for collecting wind data specifically for avalanche forecasting.

Soil Moisture / Soil Temperature
In the early 1990s, soil moisture and soil temperature sensors were installed at several SNOTEL stations in the Boise basin. The sensors evaluated provided a wetness / dryness indication rather than actual soil moisture. Problems encountered with these earlier sensors included: sensor failure and poor soil / sensor contact. Recently, a new type of soil moisture / temperature sensor was installed at two SNOTEL sites in central Idaho. Sensor output includes soil moisture (fraction water by volume), salinity and temperature. No soil calibration is required, and the probe can be used in all soil types. These sensors are being installed at NRCS Soil Climate Analysis Network (SCAN) sites, which is an initiative to install SNOTEL type-sites with additional climatic sensors nation-wide.

Depending upon the need and type of study, monitoring soil moisture may be better suited at low and mid-elevation SNOTEL sites. Some higher elevation SNOTEL sites may have a seasonal snow cover for six months of the year or more. Site selection is also very important when installing these soil moisture sensors. One station in the Boise basin was located in a wet forested environment near a small creek where the soils remain fairly wet well into the fall each year. Thus, soil moisture data did not change very much during the non-snow cover period.

Solar Radiation

Radiation sensors were first installed at a few lower elevation SNOTEL sites in the late 1980s. In 1996, radiation sensors were installed at three higher elevation SNOTEL sites in the Boise River basin. The goal of this research project was to enhance the instrumentation at SNOTEL sites and to provide additional input data to support a spatially distributed "energy budget snowmelt simulation model". Since then, additional radiation sensors have been installed at several more SNOTEL sites for specific studies.

Humidity

Relative humidity sensors have been installed at several SNOTEL stations in conjunction with specific projects. Overall, the sensors work well; occasionally data values exceed 100 percent by a few percentage points. Data quality may be affected during winter storms by snow coating the side of the sensor. Affected data is difficult to distinguish from valid data due to higher humidity during and after storm events.

Other Problems

Problems encountered, and expected at times, include snow occasionally covering these climatic sensors. Snow cover on the radiation sensor causes a temporary loss of valid data, but is not expected to be a problem during the ablation period. However, it is difficult to decipher valid radiation data from data affected by snow on the sensor as a result of the sensor still reporting data but at a lesser value. Wind and humidity sensors also experience snow capping. The sensors eventually shed the snow when warmer temperatures occur. When snow capping ceases to affect wind speed or direction, valid data are more obvious due to noticeable changes in sensor data.

3) PRODUCTS AND STUDIES UTILIZING THE DATA

Table 2. Thus far, many of the additional climatic sensors installed at SNOTEL sites are for Research & Development projects or for specific projects. The following table illustrates actual and potential uses of data.

Sensor	*Uses of Product / Information*
Snow Depth	1. Winter recreation information - ski / snowmobile, 2. Density calculations of new snowfall and total snowpack, 3. Snowfall intensities / total snowfall for selected periods (storm event), 4. Early flood warning information - monitor onset of melting snow, especially during rain-on-snow events, 5. Wildlife habitat management, 6. Avalanche forecasting, 7. Highway transportation department - snow removal, 8. Near-real time data for snow / roof load information.
Soil Moisture / Soil Temperature	1. Range readiness - livestock management, 2. Global climate changes, 3. Long-term productivity of soil, 4. Correlation to plant physiology, 5. Time period soils are saturated / drainage pumps may be needed.
Wind	1. Avalanche forecasting, 2. Modeling.
Humidity	1. Fire weather monitoring, 2. Calculations of sensible and latent heat flux.
Solar Radiation	1. Spatially distributed energy budget snowmelt models, 2. Glacier recession.

Additional Uses and Examples

Snow depth data are used in many ways including density estimates, which are critical in determining various physical characteristics of the snowpack as well as the potential onset of melt. Many organizations and individuals are interested in depth readings and having near-real time snow depth data available provides and allows users another tool to make informed decisions. The popular Utah "Snow Recreation Report" is an example of the type of information that can now be provided utilizing snow depth data.

NRCS in Montana is coordinating the installation of Fire Weather Monitoring sensors at 10 SNOTEL sites to supplement the US Forest Service Remote Automatic Weather Stations (RAWS) data collection network. With the SNOTEL Network already established, additional sensors can easily be installed to improve coverage of the RAWS

Fire Weather Monitoring Network. Climatic data are being collected and processed for use as input to the spatially distributed energy-budget snowmelt model of Garen and Marks (1996) to simulate the snowpack and, ultimately, the streamflow in the Boise River basin. Similarly, the City of Seattle is using solar radiation and wind data in the development of their water supply model.

4) QUALITY CONTROL OF DATA

NRCS has built a reputation of providing consistent, reliable, quality and easily accessible current and historic data. Users have come to expect high quality, timely, and unbiased interpretive products from the NRCS. If the high quality control data standard of validating and archiving data for historic purposes is to be applied to this new data being requested and collected, additional personnel and software are needed. Quality control standards and specifications are needed to ensure consistency.

Currently, the requesting cooperator is responsible for reviewing, verifying and editing the data for their own use. NRCS in Washington State has implemented a ***"Non Standard Sensor Agreement"*** for cooperators requesting additional sensors at SNOTEL sites. The agreement states that the user is responsible for the quality control of the data, and if these secondary sensors fail, it is agreed that scheduling the time and personnel to resolve the problem may not occur as timely as if the primary sensors were to fail.

5) FUTURE PLANS FOR INSTALLING ADDITIONAL CLIMATIC SENSORS AT SNOTEL SITES

Presently, there is not a program wide budget initiative to install depth sensors at all SNOTEL sites. Cooperators provide funding for additional sensors at their sites of interest. NRCS offices are installing depth sensors as funds and schedules allow. New SNOTEL sites installed are being equipped with a snow depth sensor.

NRCS is currently leading in the sponsorship for several new budget initiative proposals for expansion of this SNOTEL type technology nationwide (Werner, Schaefer & Woodward, 1998). One initiative is for a Soil Climate Analysis Network (SCAN), a national network of new SNOTEL type-sites with integration of various existing soil moisture and soil temperature sites and systems.

SUMMARY

Recent advancements in sensor development and technology have provided an opportunity to collect additional climatic data at remote SNOTEL sites. The new snow depth products and information available are beneficial to the water user community in making informed decisions. In the near future, snow depth will most likely become a standard parameter collected at most if not all SNOTEL sites. There is a need for the monitoring and collection of additional climatic parameters in the mountainous regions where the SNOTEL Network is located. However, to ensure high quality current and historic data of these new parameters, additional personnel are needed. Otherwise, the data may be collected for real-time analysis and not maintained for historic purposes.

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