AN AUTOMATED METEOROLOGICAL DATA VALIDATION SYSTEM FOR THE SOIL CONSERVATION SERVICE SNOTEL NETWORK

by

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INTRODUCTION

The USDA Soil Conservation Service (SCS) operates a network of over 550 remote data collection stations in the mountainous areas of the western United States. The system is called SNOTEL (for SNOw TELemetry), and collects snowpack and other climatic information in support of water supply forecasting and other resource management activities. Standard parameters collected at all SNOTEL sites include snow water equivalent (SWE), cumulative precipitation, and four air temperature parameters: current, maximum, minimum, and average. These data are transmitted from the remote sites to a master receiving station using meteor burst telemetry, where ionized meteorite trails provide the reflective medium for radio transmission.

Five SCS Data Collection Offices (DCO's) in the western U.S. have the responsibility for quality control of telemetered SNOTEL information. With each SNOTEL site reporting six or more parameters daily, each DCO must review and quality control at least 600 individual values a day. This volume of data, coupled with an increased reliance on SNOTEL data for streamflow forecasting and other activities, warranted development of improved data screening capabilities. While previous investigators have developed quality control programs for climatic data, each effort has been designed for a particular purpose and a specific data set (Bissell and Zimmerman, 1992; Reek, et. al., 1992; Redmond, 1990). Therefore, SCS and the USDA Agricultural Research Service (ARS) have collaborated on the design and development of an automated validation procedure for hydrometeorological data collected by the SNOTEL system.

THE VALIDATION SYSTEM

The validation system developed for the SNOTEL network relies on a set of daily limits, or "windows", established by analyzing historical daily data collected by the system. Unscreened data is then evaluated against these windows, and is also subjected to other logical tests (such as maximum temperature greater than minimum, etc.). These windows and logical relationships are stored in a site "profile". A user defined matrix table determines which tests are to be applied to the real-time data.

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The Elk Butte SNOTEL site, located in the Clearwater Mountains of central Idaho, was selected for profile development and evaluation due to its relatively long period of record (1984-1993). Validation windows were established for each of the standard SNOTEL parameters by analyzing historical data from the Elk Butte site. Test criteria in the profile include: 1) upper and lower bounds for the current day's SWE; 2) upper and lower bounds for year-to-date cumulative precipitation; 3) maximum daily SWE increase; 4) maximum daily SWE decrease (melt); 5) maximum daily precipitation increase; 6) upper and lower bounds for daily maximum air temperature; 7) upper and lower bounds for daily minimum air temperature; 8) upper and lower bounds for daily average air temperature.

AIR TEMPERATURE VALIDATION WINDOWS

The highest and lowest observed daily values of maximum, minimum, and average air temperature were extracted from the data set at Elk Butte for the ten year period 1984-93. Since all values fall between the highest maximum and the lowest minimum, these two limits define the range of values that have been observed at the site. Because these limits demonstrate high variability, a procedure was developed to smooth the values. A number of procedures were investigated, but a thirty-one day running average (fifteen days on either side of a given day) produced the best fit of the seasonal trend of the data. A second smoothing using a fifteen day moving average performed five times removed the remaining short term variability. A "wrap around" procedure was employed to handle smoothing at the beginning and the end of the water years.

Figure 1 illustrates the results of the smoothing procedure applied to the highest and lowest observed values of average air temperature at Elk Butte SNOTEL. While the smoothed lines shown in Figure 1 represent the general trend of the observed data, they do not represent the outer limits that have been observed and in fact only include about 86 percent of the historical data. Another method was developed to adjust the smoothed curves to include more or less of the expected values depending on the needs of the user. This procedure simply adds or subtracts a specified number of degrees to the smoothed curve values. For example, if the upper and lower smooth curves are spread by three degrees each, the curves in Figure 2 are obtained. In this case 97 percent of the observed values fall within the two smoothed curves. By specifying the amount of offset, the user can select the degree of screening applied to the data. As the period of record increases, these curves should smooth out more and better describe the range of expected values.

SNOWPACK AND PRECIPITATION VALIDATION WINDOWS

Maximum and minimum daily limits were developed for snowpack snow water equivalent and cumulative precipitation using the techniques described for air temperatures. In addition, daily increases of snowpack and precipitation and daily decreases of snowpack (snowmelt) were analyzed. For these three parameters, the best fit smoothed line was adjusted by multiplying by the ratio of the maximum daily increase (or decrease) divided by the maximum daily smoothed increase (or decrease) value for the period of record. This procedure is graphically demonstrated in Figures 3 and 4 for the maximum daily SWE increases and decreases at the Elk Butte site.

For example, the maximum daily SWE increase observed at Elk Butte for the 1984-93 period is 3.5 inches. The maximum daily smoothed value for that site and period is 1.25 inches. The factor used for multiplying all of the smoothed daily values is 3.5 divided by 1.25 or 2.8. The adjusted line at any point is thus the smoothed value times a factor of 2.8. This method produces a maximum curve value equal in magnitude to the maximum observed daily increase, but the two points do not necessarily coincide in time. The shape of the adjusted curve, however, fits the observed data well for all the cases tested to this point. In order to account for the effect of a fixed boundary condition on snowmelt (snow can't melt past a value of zero SWE), the maximum adjusted melt value is extended to the latest date of observed or expected snowpack.

SUMMARY

The SCS and ARS have collaborated on a project to develop an automated validation system for hydrometeorological data collected by the SCS SNOTEL system. The analysis portion of the software analyzes historical data collected at individual SNOTEL sites, defining the expected ranges and daily changes of snowpack, precipitation, and air temperature data. The validation portion of the software screens real time data against these limits as well as performing other quality control tests. The implementation of this software into the SCS SNOTEL system will yield improved data quality for water supply forecasting and other resource management activities. Future planned developments include the incorporation of tests comparing data from nearby sites, and development of an algorithm for estimating missing or erroneous data.

REFERENCES

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Reek, T., S.R. Doty, and T.W. Owen, 1992. A deterministic approach to the validation of historical daily temperature and precipitation data from the cooperative network. Bull. American Meteorology Society, 73:753-772.

Redmond, K.T., 1990. Quality control of western U.S. climate data. Proceedings, Annual Meeting of American Society of Agricultural Engineers., Columbus, Ohio, June 24-27, 6pp.

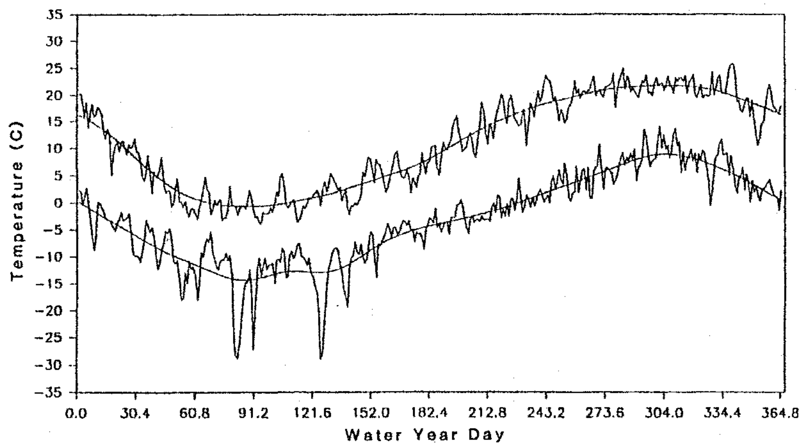

Figure 1. Highest and lowest daily average air temperature and corresponding smoothed daily values for the 1984-1993 period at the Elk Butte, Idaho SNOTEL site.

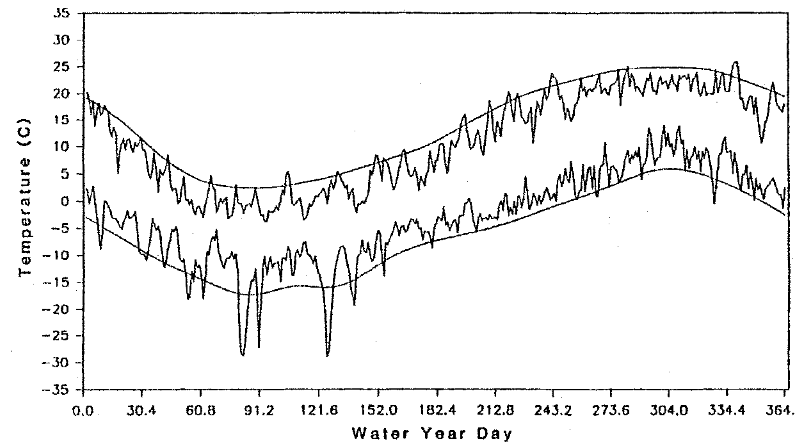

Figure 2. Highest and lowest daily average air temperature and corresponding smoothed daily values (± 3°C) for the 1984-1993 period at the Elk Butte, Idaho SNOTEL site.

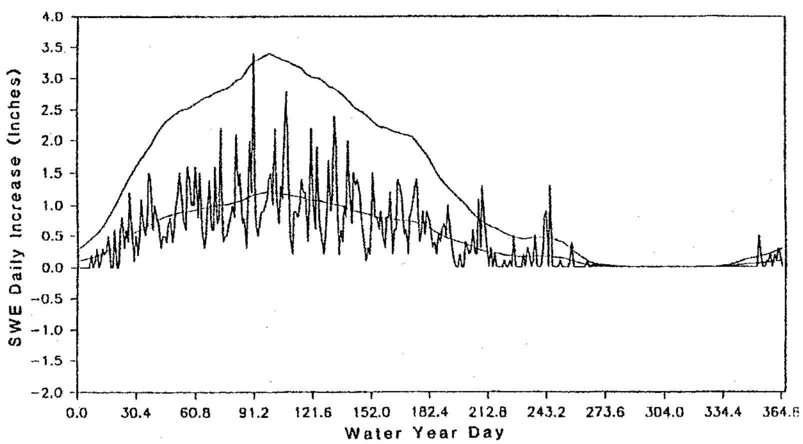

Figure 3. Highest daily snow water equivalent increases, corresponding smoothed daily snow water equivalent increases, and adjusted daily snow water equivalent increases for the 1984-1993 period at the Elk Butte, Idaho SNOTEL site.

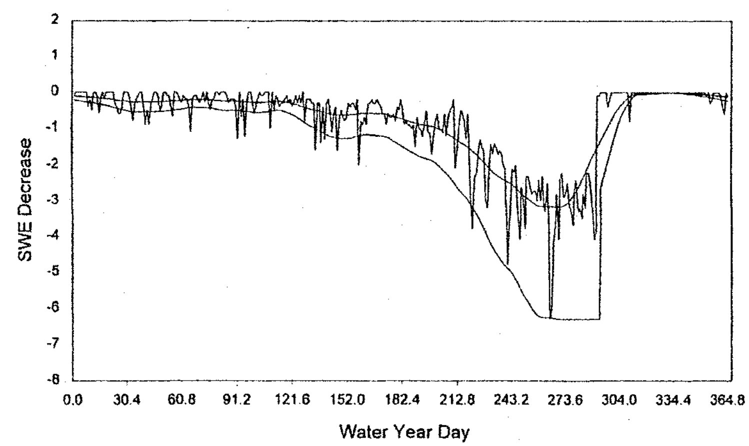

Figure 4. Highest daily snow water equivalent decreases, corresponding smoothed daily snow water equivalent decreases, and adjusted daily snow water equivalent decreases for the 1984-1993 period at the Elk Butte, Idaho SNOTEL site.