SNOTEL - DESIGN, PERFORMANCE AND USE

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Introduction

Since 1935, the Soil Conservation Service (SCS) has coordinated a snow survey and water supply forecast program in the western United States. An extensive data collection network has been established to serve western water user needs. This network includes 1600 manually measured snow courses, 200 aerial snow depth markers, and 300 mountain precipitation gages. More than 900 individuals from SCS and other federal, state and private agencies assist in making measurements at the field sites during the winter and spring months. The aggregated time amounts to over 300-staff years.

Data collected at these sites are used to prepare volume water supply forecasts, usually by the regression method, at 400 streamgage locations. Typically forecasts are issued once a month, January through June, about two weeks after the data are collected.

In the early 1970's, SCS recognized that water users needed more real-time data and more sophisticated and frequent forecasts. Since fuel and labor costs were rising rapidly, the agency began searching for a more efficient way to gather snow data for water supply forecasting.

Consultants were hired in 1974 to evaluate and recommend systems for automatically collecting snow pack and related data. An automated system was needed which would: (1) provide real-time information for use in the control and management of water resources in the western United States; (2) eliminate the slow, expensive, manual procedures; and, (3) provide more accurate, timely, and standardized data to improve forecasting and expand applications for additional user requirements.

The study recognized the importance of identifying user requirements and then of assessing the extent to which candidate system designs could meet these needs.

Three types of telemetry systems were considered: (1) VHF line-of-sight, (2) satellite, and, (3) meteor burst:

Each of the systems had five basic elements, except VHF line-of-sight which had six. The basic elements were: (1) the remote site (500 sites westwide), (2) the telemetry ground station or master station, (3) the snow survey supervisor station or data collection office station, (4) the technical control center or data processing facility, and, (5) the data base management facility. The extra element in the VHF line-of-sight system was the repeater system.

Each system was evaluated on cost, administration, performance, flexibility and risk.

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VHF Line-of-Sight System

The biggest problem with a VHF line-of-sight system is the number of repeaters required to maintain the line-of-sight from remote sites to the master station(s). In a 500 remote site system, approximately 100 repeater stations would be required. Repeaters in VHF line-of-sight communications must be installed on or near exposed peaks, making their installation and maintenance difficult and costly.

Satellite System

Satellite systems were designed around the use of the Geostationary Operational Environmental Satellite (GOES) and its ground support system for data acquisition from remote sites. Satellite communication systems have proved an outstanding method of communication. (The negative aspects of the GOES system were not associated with telemetry but rather with the control of the system.) The GOES satellite is under the jurisdiction of the National Oceanic and Atmospheric Administration (NOAA) and is intended for the use of "all governmental agencies having responsibility for environmental service, conservation of natural resources, and natural disaster warnings". As this satellite system grows, NOAA may have to impose priority restrictions on channel capacity and data access. Unless the user installs a private downlink dish, all remote site data are acquired through Wallop's Island, Virginia. Data are transmitted to the NOAA facility in Suitland, Maryland, where they are available typically every 4-6 hours. This method of retrieving data, although technically sound, introduces many elements over which SCS has little control, including a data access limitation which could slow timeliness of data.

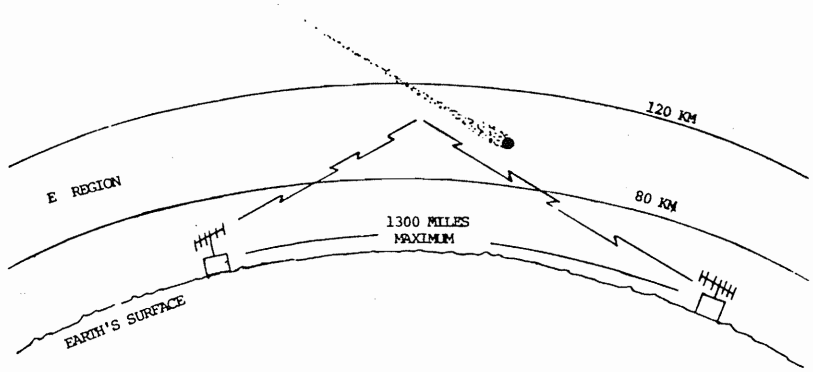
Although satellites are very reliable, problems can and do occur. An inoperable GOES satellite would be unacceptable to SCS unless backup satellites were programmed to handle the data load.

Meteor Burst Phenomenon

Each day billions of meteors burn as they enter the earth's atmosphere. Each burn forms a long column of ionized particles which diffuse rapidly and usually disappear within a few seconds. During their brief existence, however, the ionized columns can reflect radio signals.

This phenomenon is called meteor burst, meteor scatter or, meteor propagation. Figure 1 gives a graphic representation of the meteor-burst phenomenon.

FIG. 1 METEOR BURST COMMUNICATIONS



The number of meteor trials vary by time of day, season and latitude. The earth's forward orbital velocity combines with rotational velocity to make the predawn hours the most favorable time for meteor activity. The greatest meteor activity in the northern hemisphere occurs at the autumnal equinox, when the earth is tilted toward the apex position of earth's orbital velocity vector. Daily rate variation decreases with increase in latitude, while seasonal variation decreases nearer the equator.

Meteor-burst technology is relatively new. It was 1946 before any clear correlation between radio signals and individual meteor trails was reported. Most of the work between 1946 and 1975 was basically experimental in nature, although some small systems in Europe were operational.

System Comparison

The question is frequently asked, "Why aren't there more meteor-burst systems in operation?" The main reason is the availability of communications satellites. Satellites are very efficient in applications requiring continuous point-to-point communications, or prescheduled polling, or both.

However, in examining the communication needs of a snow survey remote data collection system, meteor-burst becomes a prime candidate for data transmission. Most remote data collection systems require only periodic transmission of short messages from remote locations, often on an unscheduled basis, which is an application tailor-made for meteor-burst communication systems and snow survey data collection.

Four basic conclusions can be reached concerning the use of meteor-burst communications in a snow survey data collection system.

1. Meteor-burst communications provide a highly reliable means of communication between any two points on the earth's surface up to 1200 miles apart, using only two low band VHF frequencies.

2. Meteor-burst systems have an advantage where power conservation is important.

3. Meteor-burst communications are relatively immune to interference.

4. Meteor-burst communications are ideally suited to those applications where message lengths are less than a second.

The meteor-burst system has an advantage over the VHF line-of-sight system because it requires no repeater towers. It has an operational advantage over the satellite system because it gives complete control of the system to SCS in collecting data.

Growth potential within a meteor-burst system is excellent. Additional sites can be added without affecting performance, and if properly designed, master and central stations can grow via additional hardware and software with no loss of the initial investment.

The initial cost estimates for the candidate systems indicated that the meteor-burst system was the least costly at $3.0 million (1974 prices). The subsequent award confirmed this finding. The total cost of the system when completed in 1980 was about $7.5 million.

System Selected

The total SCS system was given the acronym SNOTEL from Snow Telemetry. A meteor-burst system with 478 remote data collection sites, 2 master stations (Telemetry Ground Station), 9 Snow Survey Supervisor Stations and a Technical Control Center has been installed. The data base management facility is at the USDA computer center at Ft. Collins, Colorado.

The remote sites have VHF transceivers and logic to respond to remote polling requests.

The master stations each have a VHF transceiver with logic and mechanics to selectively poll the remote sites. They also have the capability of checking message errors, on-line storage of one week of data, operator interface, and land line communications with the Technical Control Center in Portland, Oregon.

Each snow survey supervisor station has an interactive terminal to communicate via leased lines with the Technical Control Center (Portland, Oregon) and the data base management facility (Ft. Collins Computer Center). They have local operator interface and a hard copy device.

The Technical Control Center in Portland, Oregon, is a data processing facility capable of interactive communications with the Snow Survey Supervisor stations and the master stations (Telemetry Control Stations). The facility communicates with the Ft. Collins Computer Center, controls the sequence and frequency of polling of all remote sites in 10 western states, performs computations, stores data on-line up to one year for all sites, provides off-line storage back up, and provides operator interface.

System Performance

In 1978, the first data were received through the new SNOTEL system. Since then, telemetered data have been compared to ground measurements at each of the remote sites. During this period, there were several extreme years of record, providing a wide range of conditions under which to examine performance.

The telemetering of precipitation data from precipitation gages over the 5-year period showed minimal systematic error and had accuracy sufficient to forecast streamflow.

Observed snow pillow manometer readings and corresponding telemetered values were analyzed as in the precipitation gage study. The influence of random errors caused by expansion and contraction of air trapped inside the snow pillows and plumbing lines, transducer malfunction, misreading of pillow manometer, and lack of synchronization between transmission and observation times is greater than in the precipitation gage study. Although the telemetry of pillow manometer values appears to be reliable, caution must be exercised in accepting the reported reading as a true representation and physical reality. Sometimes ice layers in the snowpack create a condition known as "bridging," which prevents the full weight of the snow pack from registering on the snow pillows. This causes the telemetered snow pillow reading to increase slower than precipitation gage readings. This condition reinforces the desirability of having both snow and precipitation sensors at each remote site. Many of the error causing factors can be eliminated by improved installation techniques and equipment. This, coupled with careful editing, produces timely and suitably accurate snow data.

The 478 remote SNOTEL sites are polled each day at 5.00 a.m. PST. The variation in response can be predicted by the meteor-burst communication theory that was discussed earlier. As shown in Fig. 2, the overall system performance has been steadily improving since installation. In May 1982, for the first time, 90 percent of the remote sites responded to the daily system-wide poll. SCS considers the 90 percent response level as acceptable overall.

System Use - Present and Possible Future

The SNOTEL system covers ten western states and Alaska. Its primary purpose is to gather information on the western snowpack and related parameters for water supply forecasting. The system has sixteen data channels; however, at most sites only four are presently being used. Each site gathers data on total precipitation (precipitation gage), the amount of water in the snowpack (snow pillow), temperature, and battery voltage. The battery voltage indicates whether solar panels are working and warns of telemetry problems that might result in faulty data.

The potential for expanding the system nationwide is excellent. The addition of one master station (Telemetry Control Station) somewhere in the Midwest would provide system coverage for virtually the entire United States. A study made in 1979 showed that it would be economically feasible to expand the SNOTEL system into the upper Midwest and Northeast to gather snow data.

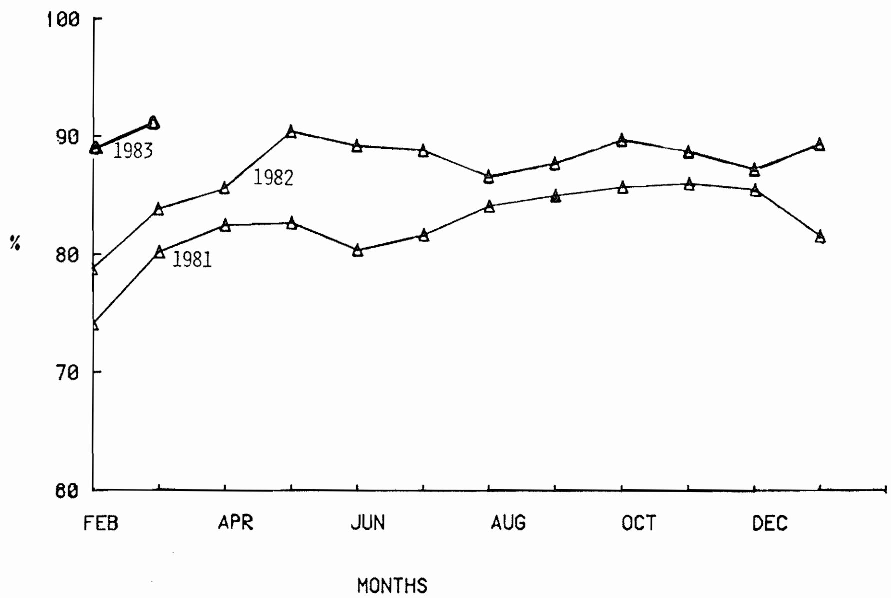
Snow surveys are extensive in the Northeast. Twenty-five different agencies, groups or individuals read nearly 800 snow courses. Inter-agency coordination is limited except for the Eastern Snow Conference. Data gathered usually are not published in any unified manner except for a summer release by the Eastern Snow Conference. Data are used mainly for specific missions such as flood forecasting, river regulation, or hydro-power potential in local areas.

The Northeast could benefit from a consolidated, standardized data collection network.

An extensive precipitation data collection network also exists in the upper Midwest. The National Weather Service (NWS) operates this system with cooperative observers. Except for some NWS observers who read snow depth data and measure snow water content, no other snow data readings are taken in this area. Flood forecasting in the upper Midwest probably could be improved if a more dependable and accurate measure of snow water content were available.

FIG. 2

SNOTEL SYSTEM PERFORMANCE



Data Collection (other than Snow)

Other data parameters, such as soil moisture, soil temperature, wind velocity, relative humidity, streamflow, and air pollution, can be gathered by remote sensing and transmitted by the meteor-burst system.

Soil moisture and soil temperature information would help soil scientists to delineate soil temperature and moisture regimes more accurately. The indication of a approaching drought problems would be more readily apparent if a network of soil moisture sensors were in place in strategic locations. Following the 1977 drought, the governors of the Great Plains states unanimously agreed that data on real-time soil moisture content on a continuing basis is something they "desperately needed."

Firefighters, among others, have expressed a need for data on wind velocity, wind direction, and humidity.

Public safety officials need early warning data on potential flash floods.

Environmental protection officials require a variety of real time air quality measurements.

Data for all these parameters could be collected using a SNOTEL-type data collection system. This merits careful consideration.

REFERENCES

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