News from the CLIMAS El Niño-Drought Initiative

END InSight

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THE UNIVERSITY OF ARIZONA®

Snowpack in the Southwest

When one considers the climate of the Southwest, snow may not come to mind as readily as rainless months and scorching temperatures. Despite the fact that large areas of our region never, or only very rarely, see the white stuff, snow plays a vital role in the hydrology, ecology, and water supplies of the Southwest. While the most important variable in annual water demand in some areas may be the timing and strength of summer monsoon storms, winter snowpack is the single most important determinant of annual water supply. Snowfall, primarily upon high mountain ranges, is estimated to provide 50 to 80 percent of the West's annual water supply (1) and corresponds directly with spring-to-early summer streamflow in the Southwest. In Arizona, 54 percent of the state's water supply comes from surface water (2), while in New Mexico, the corresponding figure is 57 percent (3). Most streamflow in both states is replenished annually by snowmelt.

Snowfall accumulates during winter and spring, several months before the snow melts and appears as streamflow; thus climatic conditions between autumn and late spring will set the stage for relief from, or a continuation of, drought conditions next summer. This lag time between snowfall and snowmelt allows forecasters to estimate runoff amounts, and hence streamflow, well in advance.

But there is more to predicting streamflow based on snowpack in the Southwest than simply measuring inches of snowfall. The composition of snow, both when it falls and as it progresses toward melting, determines how much water it contains (known as snow water equivalent, or SWE). One foot of freshly fallen heavy, wet snow may produce up to 1.5 inches of water, while light, powdery snow may contain only half an inch of water. Precipitation patterns, fluctuations in air temperature, use of water by plants, wind, atmospheric moisture, and the frequency of storm events also determine the accumulation of snowpacks and influence runoff amounts (1). Fall soil moisture conditions affect how much snowmelt is absorbed into the ground and how much becomes runoff.

The current situation in some areas of New Mexico provides an example of how these factors combine to determine runoff amounts. The extremely dry conditions that plagued the state during 2002 will have a significant effect on the 2003 runoff season. In many areas, less than 40 percent of average winter precipitation fell during the winter and spring of 2001-2002. Snowpacks melted up to two months ahead of average in New Mexico and Colorado, according to water supply forecaster Tom Pagano of the National Water and Climate Center. In New Mexico, the season broke low runoff records set back in 1977, with streamflows that were lower than those of historically dry years such as 1950, 1956, 1967, and 1996 (4).

Just how bad were things on the Rio Grande in particular last spring? Streamflow forecasts ranged from 33 percent of average in the headwaters, to only 2 percent downstream, just above Elephant Butte Reservoir. On May 1, 2002, the forecast was for a record-breaking low flow of 135,000 acre-feet; but only 96,000 acre-feet were actually recorded. Until 2002, the record low-flow from April to September was 155,770 acre-feet in 1977 based on data collected since 1990. The average flow is 533,240 acre-feet (5).

The soil in many areas of New Mexico is so dry that even if the snowpack this winter is average, roughly 25 percent of the snowmelt water could be absorbed directly into the parched soils, rather than contributing to runoff. Under these conditions, about 120 percent of average winter precipitation would be necessary to produce average runoff. Pagano notes that the current El Niño conditions do bring increased hope that above-average snowfall will relieve drought conditions. While over 120 percent of average precipitation occurs in about 20 percent of years all together, the presence of El Niño ups the chances of this happening to 45 percent (5).

New Mexico isn't the only area of the West where last summer's severe to extreme drought conditions actually

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Snow, continued

had their start the previous winter and have been intensifying over the past several years. Extremely low seasonal snowpacks last winter also resulted in record minimum streamflows in parts of Arizona, southern Utah, and southern Colorado. In Arizona, three out of four key watersheds were reporting snowpacks in the single digit percentages of average by April 1, 2002, while the statewide snowpack was at 11 percent of average (6). This led to continued declines in already-low reservoir levels, including the large reservoirs along the Colorado River. The Salt and Verde rivers, which are an important source of water supplies for some areas of Phoenix via the Salt River Project (SRP), have experienced record low streamflows due to minimal snowpacks over the past four years. This has drained SRP's storage reservoirs to 25 percent of capacity and forced the utility to slash its deliveries by one-third (the first full-year allocation cuts since 1951). Officials say that the coming winter would have to generate twice the average runoff to bring the reservoirs back to a "comfortable" level (7).

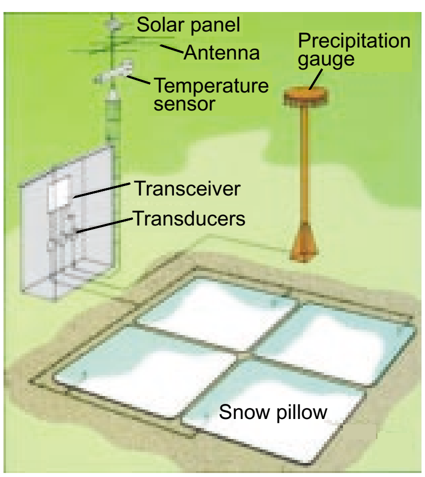

Figure 1. SNOTEL (SNOpack TELemetry) station. Pressure pillows are used for measuring snowfall, a storage precipitation gauge and temperature sensor provide current information about conditions at the site. The sites are designed to operate unattended for 1 year in severe climates. The reliability of each SNOTEL site is verified by ground truth measurements taken during regularly scheduled manual snow surveys. (Information courtesy of NRCS).

El Niño is not the only climatic factor that influences snowfall amounts on a year-to-year basis; some researchers believe that the Pacific Decadal Oscillation (PDO; see the October END InSight newsletter) is actually the primary driving force in snowpack variability across the West (8). Snowpack variability at 323 sites in the Western United States on April 1 (normally considered to be the date of the highest annual snow accumulation) over the fifty-year period between 1941-90 was compared with indices of sea surface temperatures in the Pacific Ocean that indicate ENSO and PDO conditions. Researchers found that PDO accounts for 45 percent of the total variability in April 1 snowpack, while ENSO explains only 16 percent of the variability. Linkages between PDO and snowpack in the Western United States reflect overall year-to-year variations in precipitation. PDO is currently believed to be in its cool phase, which normally brings drier conditions to the Southwest; this might argue for continued lower snowpack accumulations. These correlations, combined with the slow evolution and relatively long persistence of ENSO and PDO, may eventually enable forecasters to forecast streamflow up to a year in advance.

Because of the critical importance of snowpack to water supplies in the West, considerable effort has gone into developing sophisticated means of tracking snow water levels and predicting runoff amounts. The Natural Resources Conservation Service (NRCS) has directed the Snow Survey and Water Supply Forecasting Program in the Western states since the mid-1930s. The SNOTEL (short for SNOpack TELemetry) system is a key element of this program. SNOTEL is a near real-time hydrometeorological data collection network in the Western United States. Each day data from nearly 600 remote sites in the high mountains of 11 Western states, including snow water equivalent, precipitation, and temperature data, are received by a central computer facility at the National Water and Climate Center (NWCC) in Portland, Oregon. There, data reports are created and are sent out to many recipients, including the National Weather Service, the Western Regional Climate Center, and others. Water supply forecasters at the NWCC analyze the data and produce streamflow forecasts, which then are coordinated with forecasts produced by the National Weather Service river forecast centers. These forecasts are distributed by the state NCRS weather offices monthly from January through June. The SNOTEL system also provides data useful for climate studies, air and water quality investigations, and resource management (9).

SNOTEL data provide a great deal of information about conditions at individual locations, and they have been used for many years to reliably forecast streamflow using traditional statistical techniques. However, there are several 'blind spots' in the network where snow is not measured. Furthermore, the next generation of computer models require high spatial resolution maps of snowpack to accurately forecast streamflow.

CLIMAS researcher Roger Bales is helping to fill these gaps by developing methods to integrate information from satellites with traditional snow mapping techniques. Bales' new system combines digital elevation models, snowcover maps, and landcover information with hydrological models in order to achieve improved streamflow forecasts. This system also uses energy-balance modeling that includes information on snow-water equivalent, precipitation, solar radiation, air temperature, relative humidity, wind speed, vegetation, topography, and soils to produce a more accurate picture of snow conditions. Bales is developing better ways of using satellite data to map snow conditions under areas covered by clouds and under trees. More information about state-of-the-art snow mapping techniques is available at http://hydis.hwr.arizona.edu/snow/index.html.

Snow References

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About END InSight

END InSight is a year-long project to provide stakeholders in the Southwest with information about current droughkt and El Niño conditions. As part of the Climate Assessment for the Southwest (CLIMAS) project at the University of Arizona, END InSight is gathering feedback from stakeholders to improve the creation and use of climate information.

The *END InSight Newsletter* is published monthly and includes background and topical climate information. All material in the newsletter may be reproduced, provided CLIMAS is acknowledged as the source. The newsletter is produced with support from the National Oceanic and Atmospheric Administration (NOAA).

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