

Feb. 22, 2007

On Feb. 20, a small group of University of Washington climate and weather scientists met to discuss observed trends in snow water equivalent in the Cascade Mountains and to provide an up-to-date assessment of data on trends in snow water equivalent.

Mark Albright and Philip Mote presented snow course data analysis, and Alan Hamlet presented an analysis of a computer model of snow water equivalent that uses observations of temperature and precipitation as input. Some of the data analysis is new and not peer-reviewed, but we feel it is important to assess the implications of the more recent data analysis since it is directly relevant for planning and policy development purposes by local and state agencies. UW scientists present to observe and ask questions were Qiang Fu, Dennis Hartmann, Nathan Mantua, Cliff Mass, Ed Miles, Stephen Warren and Robert Wood.

The basic data considered were April 1 snow water equivalent measurements from snow courses in Washington and Oregon. The data are affected by temperature and precipitation during the previous winter and they indicate the available water supply from snow melting and runoff during the coming summer. The data show large year-to-year and decade-to-decade variability associated with natural variations in weather. That means that records covering rather long time periods are needed to make meaningful estimates of long-term trends. Also, year-to-year variability at one snow course may be quite different from that at another location. Trend estimates seem to depend systematically on altitude, with higher-altitude snow courses tending to show less evidence of trends than lower elevation snow courses.

Following the meeting, Dennis Hartmann, chairman of atmospheric sciences, prepared the following statements in consultation with other UW faculty who were observers.

1. While some stations show a 50 percent downward trend in April 1 snow water equivalent between 1950 and the present, we believe the overall observed trend for the Cascade Mountains of Washington and Oregon is smaller.
2. Snow water equivalent is affected by both temperature and precipitation, each of which shows large year-to-year and decadal variations associated with natural variability.
3. Because of the large distances between snow courses and differing time frames for snow water equivalent observations, estimates of long-term trends from snow course data are sensitive to the particular set of stations chosen and to the beginning and ending years of the analysis period. One set of observations using all of the Cascade mountain stations in Washington State with less than 20 percent missing data from 1945<sup>1</sup> until the present shows a snow water equivalent decrease of about 30 percent. If an earlier starting date is chosen, the trend is smaller but the number of stations available before 1945 is relatively small and their average altitude is high. If a shorter record is chosen, starting in about 1975 for example, there is a small increase in snow water equivalent. However, the statistical significance of 30-year records is smaller than 60-year records because of the shorter time frame and the high level of natural variability in the data. The record shows three periods of relatively high snow water

equivalent, each of about a decade in length, centered on about 1950, 1970 and 2000. The period from 1950 to 1995 used for some previous published reports ends at a relative minimum in snow water equivalent, while the period from 1997-2006 included a number of wet years with relatively high snow water equivalent.

4. Modeling snow water equivalent using observed precipitation and temperature as inputs to separate the influences of precipitation and temperature suggests that a significant fraction of the observed trend since 1950 can be associated with temperature increases, approximately two-thirds of the 30 percent estimated trend over this period. The absence of a trend in the last 30 years seems to be associated with increased precipitation rather than with a lack of warming.

5. We expect that temperatures in the Washington and Oregon Cascades will increase in the future as a result of global warming associated with human modification of the atmosphere, and it is expected that this, by itself, should result in further decreases of snow water equivalent, particularly at lower elevations. It is less certain how precipitation will change in response to future temperature increases associated with global warming and how precipitation changes might affect snow water equivalent in the future.

6. Snow water equivalent will continue to be affected by large year-to-year and decadal changes in weather and associated temperature and precipitation amounts. These year-to-year variations will continue to be larger than the year-to-year changes associated with global warming for several decades, but we expect that the effect of global warming will be more systematic and persistent and will increase over time.

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<sup>i</sup> Snow course records beginning before 1940 and continuing with little missing data are rare, and the earliest continuous records tend to be from high-altitude stations. High-altitude stations have higher snow water equivalent values and colder mean temperatures and thus are less likely to show significant negative trends in snow water equivalent associated with warming. Snow water equivalent at lower-altitude stations is more sensitive to temperature and tends to show more significant negative trends. About half of the volume of snow water equivalent is below the elevation of 4,200 feet. A substantial collection of snow course data records with a reasonably representative and stable distribution with altitude exists since about 1945.

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