Hydrology and Hydrochemistry of Alpine Basins

Jeff Dozier and Mark Williams

This year has seen the first strides toward a global understanding of the hydrology and hydrochemistry of alpine areas. Seasonally snow-covered areas of the Earth's mountain ranges are important components of the global hydrologic cycle, even though they cover a small portion of the Earth's surface area. For example, snow melt in the Sierra Nevada is the major source of the water supply for runoff and groundwater recharge for large agricultural communities in the Central Valley of California. Furthermore, many alpine basins will be sensitive to changes in precipitation, and low buffering ability.

Our knowledge of the hydrologic cycle in these topographically rugged basins has been limited by our understanding of the processes that determine the hydrologic cycle and the inability to collect enough data to characterize and model these processes. For example, the simple measurement of the total volume of water held in a snow pack is made difficult by the large variations in areas of rugged terrain. Recently Elder et al. [1991] have shown that snow accumulation and distribution in alpine basins can be classified into similar zones of snow accumulation, based on radiation, slope, and elevation. Direct measurement of snow properties through remote sensing with synthetic aperture radar of both snow-covered areas and the wetness of that snow, at a resolution of about 10 m, has been tested in the Oetztal Alps of western Austria [Shi et al., 1991]. The next challenge facing alpine hydrologists is to combine this information into a distributed snow-melt model that predicts the timing and magnitude of snow-melt runoff from energy balance parameters. Such a model will provide a useful management tool for hydrologists concerned with maximizing water yield and minimizing the impact of floods.

An important new understanding of the alpine hydrologic cycle derived from both models and field measurements is that snow packs in alpine basins store wet and dry deposited chemical species throughout the snow accumulation season. Solutes are released in meltwater from the snow pack differentially; the first meltwater has a chemical concentration 4-10 times higher than the mean concentration in the snow pack. Typically the first 20% of meltwater contains about 80% of the solutes stored in the seasonal snow pack [Williams and Melack, 1991]. Numerous studies have shown that this "ionic pulse" can cause a rapid change in the chemical composition of lakes and streams, with lethal effects on the local biota in some cases. Recent advances in snow physics have shown that the magnitude of the ionic pulse is a function of both the number of melt-freeze cycles the snow pack undergoes and the rate of melt [Davis, 1991]. By modeling energy inputs into the snow pack and sampling the chemical content at the time of maximum accumulation, it may be possible to predict the magnitude and length of the ionic pulse over large areas.

Patterns of air flow over mountainous regions have been investigated by the California Air Resources Board in the Sierra Nevada and the ALPTRAC project in the Alps of Italy, Austria, Switzerland, and France. Tracer studies of air masses allow for identification of source regions of precipitation chemistry. A global perspective on the hydrology and hydrochemistry of alpine basins has been initiated through research efforts on several continents. Investigators associated with NASA's Earth Observing System have begun cooperative work with institutions throughout the world to combine process-level research and modeling with remotely sensed data in each of the regions identified below. These investigations provide models and data over a range of hydrologic scales from small headwater basins to large watersheds.

Cooperative International Investigations

Tien Shan Mountain Range, China: Lanzhou University of Innsbruck

Parsonn Alps, Switzerland: Swiss Institute for Snow and Avalanche Research

Oetztal Alps, Austria: University of Innsbruck

Rocky Mountains, Colo.: National Park Service

Sierra Nevada, Calif.: California Air Resources Board

References


Time Variations in the Earth's Gravity Field

C. K. Shum and R. J. Eanes

At the present time, the causes and consequences of changes in the Earth's gravity field due to geophysical and meteorological phenomena are not well understood. The Earth's gravity field represents the complicated distribution of all of the matter that makes up our planet. Its variations are caused by the motions of the solid Earth interacting with the gravitational attraction of the Sun and the Moon (tides) and with the Earth's atmosphere, oceans, polar ice caps and groundwater due to changing weather patterns. These variations influence the rotation of the Earth, alter the orbits of Earth satellites, cause sea level fluctuations, and indirectly affect the global climate pattern.

Measurements from laser tracking stations on the Earth to orbiting geodetic satellites and from space-borne radar altimetry satellites to the oceans and ice caps are providing a unique opportunity to enhance our understanding of the phenomena associated with temporal variations of the gravity field. In the last decade, research has demonstrated that the temporal variations in Earth's gravity field due to lunar and solar tides, meteorological mass redistribution, and post-glacial rebound of the solid Earth can be observed from the analysis of satellite laser ranging to geodetic satellites such as Lageos and Starlette.

The rise and fall of tides has long been a fascinating research topic for ancient philosophers and modern day geodesists and oceanographers. The motions that are driven by tides have well-known frequencies determined by the rotation of the Earth and the