SAN JUAN MOUNTAINS SNOW SYSTEM OBSERVATORY & RESEARCH VENUE

Christopher C. Landry*
Center for Snow and Avalanche Studies, Silverton, Colorado

ABSTRACT: Building on a legacy of San Juan Mountains snow research begun in the 1970's, the Center for Snow and Avalanche Studies is hosting and conducting interdisciplinary 'snow system' research, initiating a long-term mountain snow system observation program, and providing 'snow system' field education. The CSAS has developed the 290 ha. Senator Beck Basin Study Area at Red Mountain Pass, installing two weather, snowpack, and soil monitoring study plots in the Basin, an automated stream gauging station at the Basin pour-point, and a third micro-met site nearby. A comprehensive baseline inventory of the Basin's plant community was performed in 2004. Data from the Senator Beck Basin Study Area are periodically published on the CSAS website. Current and proposed research and monitoring activities at the SBBSA offer examples of a 'snow system' science agenda.

KEYWORDS: San Juan Mountains, snow system science, snow hydrology, snow ecology, mountain climate monitoring.

1. INTRODUCTION

The Senator Beck Basin Study Area (SBBSA) operated by the Center for Snow and Avalanche Studies, of Silverton, Colorado is a 'snow system' observatory and research venue, with an emphasis on the role of the seasonal snowcover in mountain system interactions. SBBSA is located at the headwaters of the Uncompahgre River and Red Mountain Creek in the western San Juan Mountains of Southwest Colorado, centered at 37° 54' 30" N x 107° 43' 30" W. The 290 ha (717 acre) SBBSA exhibits physical and climatological attributes reflecting its continental position, high altitudes, and comparatively southerly latitude. Elevations within the SBBSA range from 4118m (13,510') to 3353 m (11,000'). Given those characteristics, the San Juan Mountains were described by E. R. LaChapelle in 1973 as a "radiation snow climate" (Armstrong and Ives, 1976), where dynamic energy fluxes dominate snowpack processes.

Further, the San Juans exhibit a bi-modal precipitation regime, with winter snow and summer monsoonal rain peaks. The San Juan Mountains are also home to over 100 identified rock glaciers, and SBBSA contains a lobate rock glacier that appears to be active and may contain an ice core.

* *Corresponding author address:* Chris Landry, Exec. Dir., Center for Snow and Avalanche Studies, PO Box 190, Silverton, CO 81433-0190; tel: 970-387-5080; fax: 970-387-5082; email: clandry@snowstudies.org

SBBSA landcover is typical of alpine basins throughout the western San Juan Mountains but, unlike adjoining basins, no active roads are present and early 20th Century mining activity resulted in only minor disturbances. All mining claims within the SBBSA have been acquired and returned to US Forest Service ownership. The SBBSA's namesake derives from the historic Senator Beck mine, and the Swamp Angel Study Plot adjoins the abandoned Swamp Angel Lode, a minor mining operation apparently named for an American Civil War cannon that proved decisive in the Battle of Charleston. Two primary study sites have been developed within the Basin, and a stream gauging station has been installed at the Basin pour point. A third micro-met station has been developed at a nearby summit to the east to obtain 'free air' wind measurements. Data are acquired from these sites via RF link and published on the CSAS website.

The CSAS's SBBSA research and monitoring infrastructure also includes a plant community baseline study performed in 2004 that documents current plant community distributions and conditions. Repeat studies are planned on a five-year interval.

Current research activities in SBBSA revolving around the effects of desert dust depositions on the San Juan Mountains snowpack illustrate an interdisciplinary, multi-scale 'snow system science' approach to investigating desert and mountain systems interactions driven by climate, weather, and anthropogenic disturbances in arid landscapes.

2. SBBSA RESEARCH & MONITORING INFRASTRUCTURE

Four separate instrumented study sites comprise the Senator Beck Basin Study Area research and 'snow system' monitoring infrastructure. The SBBSA is operated under a Special Use Permit issued to the CSAS by the Uncompahgre National Forest, US Forest Service. Overview photographs and maps of SBBSA can be viewed at the following website: http://www.snowstudies.org/maps.html

2.1 Senator Beck Study Plot

Located at 3719 m (12,200') on a level bench, in an alpine tundra setting, the Senator Beck Study Plot (SBSP) captures weather and snowpack conditions in an exposed basin location subject to wind effects. SBSP consists of a single 10 m mast hosting an extensive array of instrumentation, and an adjoining 12 m x 36 m 'level' snow profile plot. The instrument array and snow profile plot are well marked and left entirely undisturbed by highly cooperative recreationists using the Basin side-by-side with the CSAS.

Wind monitors are installed at two heights on the mast. Air temperature and humidity sensors are also installed at two heights on the mast. Two up-looking 'broad-band' pyranometers (one shadowed at solar noon), one uplooking 'NIR' pyranometer, and one uplooking pyrgeometer are installed at the top of the mast. Two down-looking pyranometers, one 'broad-band' and one 'NIR', are installed on an arm extending south from the mast. An infrared snow surface temperature sensor is also located on that arm. An ultrasonic snow depth sensor is located on another arm extending west (generally upwind) from the mast. An array of five snow temperature sensors are configured in a horizontally-oriented 'fork', at 10 cm spacing, which is manually inserted in the snowpack at some distance from the mast and periodically relocated. An array of three soil temperature sensors at various depths, a temperature sensor at the snowpack/soil surface interface, a soil heat flux sensor, and a soil volumetric water content sensor are located 4 m southeast of the mast.

12 V DC power for the SBSP instrument system and radio telemetry gear is provided by a single 40 watt photovoltaic panel which maintains a bank of four 100 amp-hour gel batteries housed in a sealed enclosure some 10 m from the mast.

Photographs and additional descriptions of SBSP can be viewed at the following website: http://www.snowstudies.org/senbeck.html

2.2 Swamp Angel Study Plot

The Swamp Angel Study Plot (SASP) is located in a sub-alpine forest clearing at 3368 m (11,050'), very near the lowest point in the Senator Beck Basin. SASP is comprised of a 6 m primary instrument mast constructed of pipe, an adjoining automated precipitation gauge, and a 'level' snow profile plot surrounding the instrumentation.

SASP is well-sheltered and mean hourly wind speeds during and between storms in 2005/2006 were less than 1.5 m/s (scalar, and less than 1 m/s resultant), with hourly peak gusts averaging 5 m/s, and a season maximum gust of 14 m/s. The site is, therefore, well suited to measuring precipitation and also presents a comparatively uniform snowcover throughout the 30 m x 30 m snow profile plot surrounding the instrument array. The instrument array and snow profile plot are, again, well marked and left entirely undisturbed by others using the Basin.

Wind monitors are installed at two heights on the mast. Air temperature and humidity sensors are also installed at two heights on the mast. Two up-looking 'broad-band' pyranometers (one shadowed at solar noon), one uplooking 'NIR' pyranometer, and one uplooking pyrgeometer are installed at the top of the mast. Two down-looking pyranometers, one 'broad-band' and one 'NIR', are installed on an arm extending south from the mast. An infrared snow surface temperature sensor and an ultrasonic snow depth sensor are also located on that arm. A barometer is housed in the datalogger enclosure. An array of five snow temperature sensors are configured in a horizontally-oriented 'fork', at 10 cm spacing, which is manually inserted in the snowpack at some distance from the mast and periodically relocated. An array of three soil temperature sensors at various depths, a temperature sensor at the snowpack/soil surface interface, a soil heat flux sensor, and a soil volumetric water content sensor are located some 3 m southwest of the mast.

Precipitation is measured with an automated, self-charging gauge utilizing a tipping-bucket-emulating (transducer) collector atop a 14 foot standpipe. The gauge is equipped with a windscreen.

12 V DC power for the SASP instrument system and radio telemetry gear is provided by a single 40 watt photovoltaic panel which maintains a bank of four 100 amp-hour gel batteries housed in a sealed enclosure some 10 m from the primary mast.

Photographs and additional descriptions of SASP can be viewed at the following website: http://www.snowstudies.org/swamp.html

2.3 Senator Beck Stream Gauge

The Senator Beck (Basin) Stream Gauge (SBSG) is located at 3362 m (11,030') in a small gorge incised through bedrock and located only meters upstream from the so-called hydraulic 'pour-point' of the 290 ha Basin, where the unnamed stream draining SBBSA becomes Red Mountain Creek. SBSG consists of a notched, broad-crested weir constructed of concrete. The weir was designed and has been calibrated to monitor flows as high as 1 m^3/s (35 cfs) when flows fill the width and depth of the weir, as well as very low flows, captured in the weir's notch. Basin base flows appear to be a little less than 1 cfs.

SBSG is equipped with a staff gauge for visual observations of stream stage as well as an automated transducer constantly monitoring water depth. Water temperature and electrical conductivity are also monitored. In order to prevent freezing, the automated sensors are installed in the weir just prior to the onset of snowmelt in late winter and removed in late fall.

12 V DC power for the instrument system and radio telemetry gear is provided by a single 10 watt photovoltaic panel which maintains an 8 amp-hour battery housed in the datalogger enclosure. That enclosure is mounted on a 5 m mast positioned on the bank above the stream gauge.

Photographs and additional descriptions of SBSG can be viewed at the following website: http://www.snowstudies.org/flume.html

2.4. Putney Study Plot

The Putney Study Plot (PTSP) is located 2 km southeast of the Swamp Angel Study Plot and outside of the SBBSA on a ridgecrest sub-peak at 3757 m (12,325'). The 10 m mast located at the PTSP site was installed in the early 1970s by the INSTAAR San Juan project and named 'Putney' after a dog belonging to a member of the team. CSAS continues to use the PTSP site, a patented mine claim, with the generous permission of the landowner, Tronox Inc.

The ridgecrest location of PTSP and configuration of the surrounding terrain facilitate the collection of 'free air' wind speed and direction data, minimally disrupted by adjoining terrain. The site is generally stripped of any snowcover by winds. PTSP is equipped with a wind monitor at the top of the 10 m mast, and an air temperature and relative humidity sensor located at 3 m above the ground (to prevent damage from flying gravel). The highest peak wind gust measured at PTSP, by the CSAS, is 48.2 m/s (108 mph), April 5, 2006.

12 V DC power for the instrument system and radio telemetry gear is provided by a single 10 watt photovoltaic panel which maintains an 8 amp-hour battery housed in the datalogger enclosure.

Photographs and additional descriptions of PTSP can be viewed at the following website: http://www.snowstudies.org/putney.html

2.5 Senator Beck Basin Baseline Study

In the summer of 2004 CSAS contracted the Colorado Natural Heritage Program to perform a comprehensive 'baseline' survey of the plant community within the SBBSA. Vegetation and soil surface characteristics were documented in three elevation bands - alpine tundra, krumholz line, and sub-alpine forest - along twenty-three separate 30.5 m (100') transects. Each transect consisted of ten 0.10 m^2 Daubenmire frame micro-plots spaced at 3.05 m (10') intervals. The largest number of species were found in the mid-elevation krumholz transect, and the upper and lower transects exhibited statistically and ecologically significant differences in species composition and abundance. Survey monuments were placed at the end-points of each 30.5 m (100') transect to enable repeat studies on a five-year schedule.

Photographs and a map of the Baseline Study can be viewed at: http://www.snowstudies.org/beckbaselinestudy.html

3. SBBSA DATA

Data at all SBBSA instrumented sites are collected in 1-hour, 3-hour (except SBSG), and 24-hour (calendar day) arrays. Winter and Summer datasets for each study site, as well as metadata for each dataset, and the CSAS's Data Policy, can be found on the CSAS's Data website page: http://www.snowstudies.org/data.html

A species list from the 2004 SBBSA Baseline Study is available on the CSAS website: http://www.snowstudies.org/beckbaselinestudy.html

4. SCIENCE AGENDA

The CSAS has developed the SBBSA to monitor and facilitate investigations of the alpine 'snow system' as an Earth surface system, driven by complex interactions over space and time between the atmosphere, lithosphere, cryosphere, and 'anthroposphere'. Mountains, via their

seasonal snowpacks and other cryospheric reservoirs, are often referred to as the water towers of the world. In the western United States some 70-80% of the human water supply is initially stored in and later released from seasonal mountain snowpacks. Globally, more than a billion people depend on the alpine snow and ice system for water supplies. The seasonal delivery and distribution of mountain snowcover, snowpack storage and release of water, the biogeochemical role of the snow system, and the affects of climate on those processes, are clearly of increasing importance to the American West and to snowmelt-watered regions everywhere.

By way of example, the CSAS is currently collaborating with and hosting a number of University of Colorado scientists and graduate students, from a number of disciplines, on research that illustrates a 'snow system' approach to the research themes listed above, and others. Because of their geographic position downwind of the Colorado Plateau, the San Juan Mountains frequently receive measurable depositions of 'red' desert dust in winter and spring, both during and between snow (and rain) precipitation events. With support from the National Science Foundation (Grant #ATM-0431955), the CSAS is both conducting and supporting several inter-connected lines of investigation at SBBSA regarding this 'dust on snow' phenomenon including:

- monitoring and quantifying the effects of the dust on snowpack albedo;
- the remote sensing and interpretation of reduced snowpack albedo caused by dust deposition on alpine snow;
- monitoring and modeling the effects of dust on snow on snowmelt flux at the basin scale;
- assessing the role of dust in avalanche formation processes;
- the biogeochemical effects of the dust on San Juan Mountain soils, plant productivity and hydrology;
- the synoptic climatology of desert dust deposition in the San Juan Mountains;
- the climatic record of dust deposition in the San Juans, in lake sediment cores;
- and the detection of desert dust (and other particulates) in the atmosphere over the San Juan Mountains.

Several of the researchers pursuing these 'dust on snow' themes will be presenting their results at the 2006 International Snow Science Workshop.

Long-term monitoring of the SBBSA 'snow system', and of the role of snow in driving 'mountain system' processes in the San Juan Mountains (and, by proxy, in other mountain ranges), is integral to and synergistic with the CSAS's 'snow system' research agenda. Climate change researchers around the world have recognized mountains as a sensitive bellwether of global change, where system responses are perhaps more transparent and quicker to manifest than in lower elevation urbanized or rural settings. As the challenges and threats posed by global climate change become increasingly apparent, the need for and value of place-based, 'designed' monitoring of mountains has emerged. Protocol-based mountain system observation programs, and historic mountain (and snow) system observatory datasets, will improve the ability of climatologists to assess current conditions, discern trends and, eventually, validate their forecasts regarding mountain systems. Participating in and facilitating the development of a 'mountain snow system observation protocol' with an interdisciplinary team representing constituents of the mountain snow system, and testing and implementation of that protocol at the SBBSA (and other sites), is a top priority for the CSAS.

Leaders throughout the world, in both the public and private sectors, are asking, 'how will 21st Century cultures adapt to increased variability, and decreasing reliability, in natural systems?' The known interannual variability of the snow resource, and the possibility that climate change could cause substantial long-term changes in the distribution of seasonal snow and other cryospheric reserves of water, are a considerable source of uncertainty. Further, as settlement in mountain regions increases, the snow system increasingly poses hazards – such as snow avalanches and floods – to residents, travelers, recreationists, commerce, and infrastructure.

Ongoing investigations and monitoring of the complex interactions comprising the mountain snow system, and how those processes may change over space and time, are fundamental to understanding critical human/environment relationships, and to developing effective tools and policies for forecasting and apportioning snowmelt resources and coping with winter hazards.

5. REFERENCES

Armstrong, R. L. and J. D. Ives, 1976. Avalanche release and snow characteristics, San Juan Mountains, Colorado. *Institute of Arctic and Alpine Research Occasional Paper 19*, Univ. of Colorado, 256 pp.