NOAA-OHDL Progress Report for Project:

'Scaling Snow Observations From the Point to the Grid Element: Supporting NOHRSC's National Snow Analysis System'

PI: Noah P. Molotch; Co-PI's Steven Fassnacht, Tim Link, and William Yeh

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Project Objective

By merging detailed field observations and advanced remote sensing snow products into a spatially distributed snowmelt model, this project is focused on characterizing the subgrid variability in SWE surrounding select SNOTEL sites in 4 regions of the Western US. These analyses aim to improve understanding of the relationship between measured SWE at SNOTEL sites and the SWE of the surrounding grid elements, providing NOHRSC with an improved ability to evaluate residuals in the NSA system, ultimately improving snowpack information for end-users. As part of this research we have made considerable progress in three related aspects of the work plan: 1) Field data collection; 2) Modeling activities; 3) Dissemination of results and inter-agency collaboration.

Field Data Collection

Phase one of this research involves and ambitious set of field campaigns focused on evaluating *'the distribution of SWE within grid elements encompassing SNOTEL sites and determining how representative SNOTEL sites are relative to the mean of the surrounding distribution'*. In this regard, intensive field surveys of the distribution of snowpack properties (snow depth, grain size, SWE, and snow temperature) have been conducted in the 1-km^2 area surrounding 4 SNOTEL sites in each of our Sierra Nevada and Colorado regions. Due to the difficulty of sampling in the dense canopies of our Idaho and Oregon regions, we have sampled three sites in each of these regions. Each campaign has been conducted in early April of 2008. At each of the 14 sites we have made snow depth observations at over 230 locations, with triplicate samples this equals over 690 snow depth measurements within each 1 km^2 area. Across all of our regions and associated 14 study sites this is equivalent to nearly 10,000 snow depth measurements. This information will provide unprecedented understanding of the relationships between topography, snow distribution, and scaling properties of the snow measurements used in NOAA/NOHRSCS National Snow Analysis system. This sampling protocol is being repeated during the first two weeks of May and subsequent analyses of binary regression-tree interpolation models will be used to interpolate field data over the 16-km^2 areas surrounding each SNOTEL site.

Modeling Activities

Phases two and three of this project are focused on modeling the temporal evolution of SNOTEL representativeness through the snowmelt season. These efforts are less time sensitive, relative to the field data acquisition of phase one described above, and thus these efforts will fully develop during summer and fall of 2008 after students can be recruited; note the start date of this project began after the beginning of the 2007-08 academic year and thus student recruitment has not been completed. In preparation for these modeling activities, meteorological forcings from the North American Land Data Assimilation System have been archived for our study regions and down-scaling algorithms are currently under development. Baseline meteorological data, needed to evaluate these forcings, have been archived as have historical snow water equivalent data, and distributed snow depth data from hydrologic instrument clusters deployed around 3 of our focus sites (one in each of the Northern Rockies, Sierra Nevada, and Central Rockies regions). Remotely sensed snow cover data for the Sierra Nevada region from the Moderate Resolution Imaging Spectrometer have been archived and prepared for merging into the distributed snowpack mass and energy balance model.

Dissemination of Results and Inter-Agency Collaboration

During the reporting period the PI's have actively engaged the water resources communities regarding the project objectives and forthcoming deliverables. As this project directly serves NOHRSC daily activities, the project objectives and site selection criteria have been developed in collaboration with Don Cline (NOHRSC Director) and Carrie Olheiser (NOHRSC Staff). Based on this interaction and logistical considerations, sites were selected to maximize impact and to dovetail with broader activities in the scientific community (e.g. NSF-CUAHSI; NASA-Cold Lands Processes Experiment). Involvement from Natural Resource Conservation Service regional offices (Mike Gillespie (Colorado) and Ronald Abramovich (Idaho)) has been notable as have discussions with California Department of Water Resources Snow Survey Section Chief Frank Gherke. These collaborators are in charge of maintaining these observation networks and thus, this project needs to develop in collaboration with these groups as the results may influence future observation network design.

The PI's have engaged the scientific community to leverage future ground-based and airborne measurement campaigns to meet objectives of this project. Measurements of snow covered area and snow grain size surrounding our southern Sierra Nevada sites will be made in spring 2009 using the NASA Jet Propulsion Laboratory's Airborne Visible and Infrared Imaging Spectrometer (AVIRIS). This opportunity has been leveraged through the PI's involvement in the UCLA-JPL Joint Institute for Regional Earth System Science and Engineering (JIFRESSE) – with flight hours supported by NASA's terrestrial hydrology program.

Engagement of the scientific community has been ongoing since the inception of this project. The PI's have presented 8 papers at scientific meetings (see attached) related to previous analyses of data that will be used in this project. In this regard, this project has supported further development of these previous analyses leading to new understanding of the relationships between vegetation micro-structure and snow distribution which have been submitted to a leading scientific journal (*Molotch et al., in review*). Such understanding is critical for scaling operational snow observations to the NSA grid element scale and will guide the modeling analyses throughout the duration of this project.

Presentations at Scientific Meetings:

Molotch, N.P., J.R. McConnell, M. Litvak, and P.D. Brooks, Ecohydrological controls on snowmelt partitioning in a mixed-conifer sub-alpine forest, Valles Caldera, New Mexico, *2007 Fall AGU Meeting, San Francisco, CA.*

Rice, R., **N.P. Molotch**, and R.C. Bales, Embedded sensor network design for spatial snowcover, *2007 Fall AGU Meeting, San Francisco, CA.*

Veatch, W.C., P.D. Brooks, **N.P. Molotch**, J.R. Gustafson, and P.D. Broxton, Quantifying the Effects of Forest Canopy Cover on Snow Accumulation and Ablation at a Continental, Mid-latitude Site, Valles Caldera National Preserve, NM, *2007 Fall AGU Meeting, San Francisco, CA.*

Durand, M, **N.P. Molotch**, and S.A. Margulis, Estimating snowfall patterns using timeseries of remote sensing images within a Bayesian framework, *2007 Fall AGU Meeting, San Francisco, CA.*

Fassnacht,S.R., D Hultstrand, R Bales, Physiographic Variables to Describe Basin Scale Snow Water Equivalent, *2007 Fall AGU Meeting, San Francisco, CA.*

Peer-Review Publications

Molotch, N.P., *K. Musselman, J.R. McConnell, M. Litvak, S.P. Burns, R.K. Monson, and P.D. Brooks, Ecohydrological controls on snowmelt partitioning in mixed-conifer sub-alpine forests, *Ecohydrology*, in review.