# AN EVALUATION OF SNODAS FOR DETERMINING SNOW WATER EQUIVALENT ON MOUNT ST. HELENS, WASHINGTON

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## ABSTRACT

When Mount St. Helens erupted on May 18, 1980 melting snow and ice on the mountain enhanced a large debris flood wave from all sides of the mountain, creating exceptional flooding along the Toutle River in southwest Washington. Mount St. Helens became active again in September 2004. During both of these episodes there was considerable concern that another eruption would entrain the existing snowpack resulting in a devastating flood. The US Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), National Water and Climate Center (NWCC) was requested to provide weekly snow water equivalent (SWE) on Mount St. Helens to the National Weather Service Northwest River Forecast Center (NWRFC) and North Pacific Division of the US Army Corps of Engineers for determining potential flood magnitude in the event of an eruption. In the 1980s the snowpack was determined from the NRCS SNOTEL station network located around the mountain. While many of these sites are in existence today, two sites have been discontinued. Recently, National Weather Service (NWS) National Operational Hydrologic Remote Sensing Center (NOHRSC) has developed the SNOw Data Assimilation System (SNODAS). SNODAS uses a physically based, spatially-distributed energy and mass-balance snow model in conjunction with assimilated satellite, airborne and ground-based observations of snow covered area and SWE to determine several snowpack parameters and modeled SWE at a 1 km grid scale national coverage. The SNODAS system is compared to the traditional SNOTEL method of determining the snowpack at three elevation bands and four quadrants on Mount St. Helens. SNODAS provides an improved model of the snowpack SWE around Mount St. Helens.

## INTRODUCTION

Mount St. Helens in southwest Washington gained world wide attention when it erupted on May 18, 1980 (Figure 1). Pyroclastic flows from the mountain caused severe flooding in the rivers flowing from the mountain. Exceptional flooding along the Toutle River caused sediment and debris to fill in shipping lanes in the Columbia River, blocking a major river and preventing access to important ports for ocean vessels. The flooding was exacerbated by the snow that was melted and entrained with debris and mud from the mountain. Soon after that time the US Army Corps of Engineers (COE) and National Weather Service Northwest River Forecast Center (NWRFC) requested that the Natural Resources Conservation Service (NRCS) Snow Survey and Water Supply Forecasting Program (SS-WSF) provide weekly guidance on the amount of snow water contained in and around Mount St. Helens. This weekly report was provided by an NRCS hydrologist from the early 1980s to 1988, when it was determined that an immediate eruption was no longer a threat. Mount St. Helens became active again in October of 2004 with a series of notable explosions that lofted ash plumes several miles into the air, and threw rock fragments across the crater. Seismic and dome building activity has continued since October 2004 with renewed concerns for possible debris flows and snowmelt flooding. Rock avalanches or small explosions that spew hot gases and ash can swiftly melt snow and ice and form floods or lahars that surge out of the crater. Such floods and lahars can endanger people especially along the upper North Fork Toutle River (Major et al., 2005).

The COE and NWRFC approached the NRCS SS-WSF again to reestablish the weekly Mount St. Helens snow report. During the 2004-2005 snow season, the amount of water in the snow or snow water equivalent (SWE) on Mount St. Helens was determined by the existing SNOTEL network. A Microsoft Excel spreadsheet model was used based on the existing eleven SNOTEL stations surrounding the mountain with elevational and quadrant relationships to determine the snowpack SWE amounts. This spreadsheet model requires expert hydrologic judgment to determine the snowpack SWE and landscape character and is difficult to duplicate.

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Paper presented Western Snow Conference 2006

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## SNODAS

The NWS NOHRSC developed a SNOw Data Assimilation System (SNODAS) model that incorporates the wide variety of snow data available from satellite, airborne and ground based stations, including SNOTEL. This model is a spatially distributed energy and mass balance snow model run hourly and with daily output at a 1 $km^2$ resolution. The snow model is driven by downscaled analysis and forecast fields from a mesoscale, Numerical Weather Prediction model, surface weather observations, satellite-derived solar radiation data, and radar-derived precipitation data and can be updated using satellite, airborne, and ground-based snow observations (Carroll et al., 2001). The products that are generated from the model include a wide variety maps, gridded fields and data tables. These include SWE, snow depth, average snowpack temperature, SWE change, snow precipitation, non-snow precipitation, snowmelt, blowing snow sublimation, and snow surface sublimation. Realtime observations can be easily included to update the model as required.

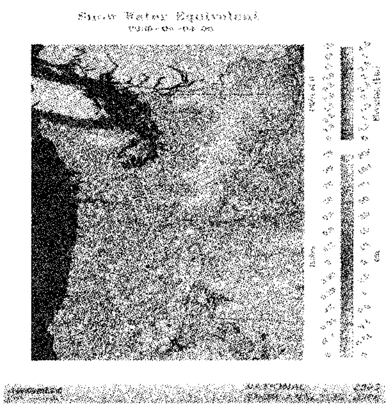

Figure 1. SNODAS SWE for the Pacific NW (NOHRSC NAS, 2006)

## GIS PROCESSES

The 1980s vintage maps of Mount St. Helens with the agreed-to elevation and quadrant divisions were reviewed and translated into ArcGIS-formatted quadrants and elevation bands. Separate polygon shapes were developed to determine the area for each quadrant and elevation band for a total of twelve subareas. This provides a baseline for intersecting the SNODAS gridded data products with the polygon shapes. The daily SNODAS gridded data have been downloaded from the National Snow and Ice Data Center (NSIDC) ftp site. http://nsidc.org/ weekly since November, 2005.

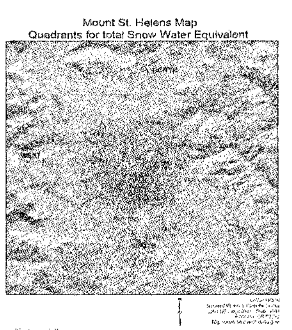


Figure 2. Mount St. Helens elevation bands and quadrants

ArcGIS 9.1, developed by the Environmental Systems Research Institute, Inc. is used to estimate volumetric snow water equivalent in the snow pack in the vicinity of Mount St. Helens. An overlay (intersection) analysis is employed to summarize the volume by aspect and elevation zone. To facilitate iteration of the calculation during the year, the procedure is automated using ArcObjects and Python 2.1 scripting.

The extracted SWE data are imported to an ESRI GRID format and converted to polygon shape file format. The shape file is intersected with a shape file of the Mount St. Helens vicinity which contains polygons with attributes representing 12 distinct combinations of elevation zone (1000m, 1250m, 1500m) and aspect quadrant (N, S, E, W). The resulting polygon attribute table contains, for each polygon, values for aspect, elevation zone, and SWE depth.

A new data element, swe_vol, is added to the polygon attribute table and calculated as the volume of snow water in each polygon:

$$Area_{polygon} * SWE_{depth} * k = swe\_vol,$$

where k is a constant used to express the volume in acre feet.

The resulting table is summarized using a pivot table in Microsoft Excel, to yield a table listing SWE volume by elevation zone and aspect. Weekly products include a document with the table of SWE in average millimeters of depth and a table of total acre feet of SWE per subarea and some written analysis, and the resulting SNODAS map of Mount St. Helens.. These products are emailed to the NWS NWRFC and USACE as well as being posted on the Oregon Snow Survey web site: http://www.or.nrcs.usda.gov/snow/maps/sthelens.html

## 2006 RESULTS

SNODAS modeled SWE has been tested throughout the 2005-2006 winter season. A direct comparison to the old method or to ground stations gives only a rough comparison. The old method of determining the SWE on Mount St. Helens uses point data to represent elevation and quadrant subareas relying on the local expertise of the hydrologist to give area estimates of SWE. SWE from SNODAS can be compared to SNOTEL station data in only a qualitative inference can be made. Point data such as SNOTEL is not representative of the majority of the area it is located in and around Mount St. Helens due to the way SNOTEL stations are located. SNOTEL stations are located in treed areas, where the site is protected from wind and can best collect snow data. The two SNOTEL stations on the South side of the mountain, June Lake and Swift Creek, are located on the lee side of a major ridge area and surrounded by trees, while the Spirit Lake SNOTEL station is located in the open terrain north of the crater in the 1980 blast area. Most of Mount St. Helens is bare of trees from the 1980 eruption, and covered in loose pumice and ash flows. The majority of the mountain area is on steep open slopes with ridges and shallow valleys, and is very heavily affected by wind. Only the low elevation site,

Spirit Lake, is located in similar open terrain, though the site is fairly level. Figure 3 shows the closest three SNOTEL station data compared to the SNODAS modeled area data. This Figure shows that the model generally does follow the increase in snowpack recorded by the SNOTEL stations. Early season SNOTEL SWE is, and should be, higher at these protected locations than the generally open windy terrain of Mount St. Helens. After a certain threshold, where the mountain seems to be fairly well snow covered, the SNODAS and SNOTEL station relationship becomes fairly consistent. The correlation holds true for both SNOTEL stations. Additional years of analysis will assist in determining the relationship between the SNOTEL and SNODAS.

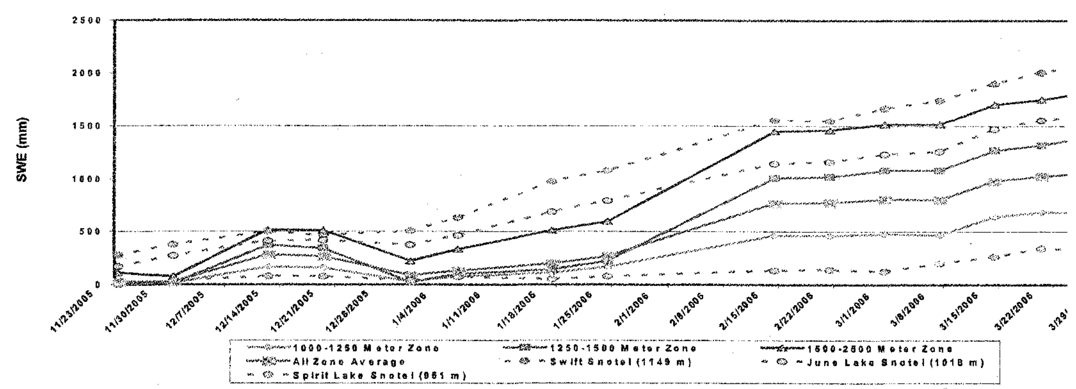


Figure 3. SNODAS modeled SWE by Elevation Zone.

In Figure 4 looking at the different quadrants of the mountain, the SNODAS modeled SWE on south side of the mountain seem to have more snow than any other area, and the North side has the least snow. This follows the SNOTEL trend, as the south side has more treed areas, and ridges, while the north area was heavily affected by the 1980 eruption and is very open and baren of vegetation. The East and West quadrants have very similar SWE values.

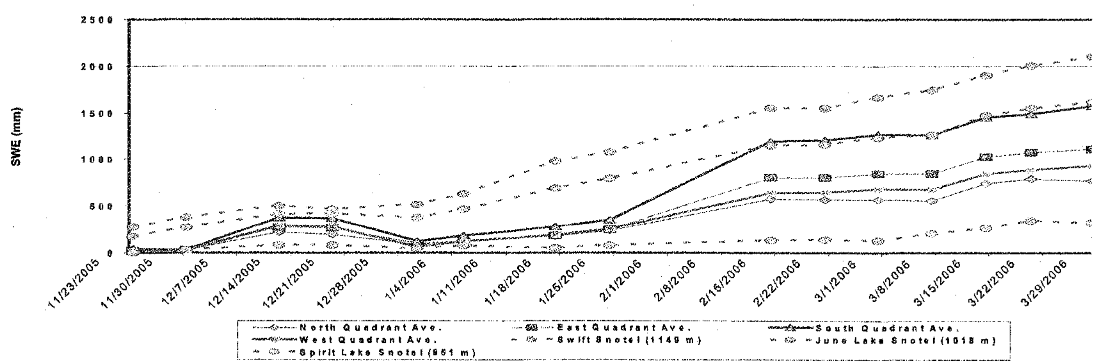


Figure 4. SNODAS Modeled SWE by Quadrant Averages.

The NOHRSC SNODAS modeled SWE has great promise to be a reliable consistent model for determining the snowpack water content around Mount St. Helens. The limited station data in the area will continue to provide only a point estimate of the snow water in the area on and around the mountain. Additional data would benefit the SNODAS model and be easily incorporated into the SWE estimate of the four quadrants and three elevation zones. Mount St. Helens continuing volcanic activity will require continued monitoring of the snowpack to assist in the best estimate of any flood risk from future potential eruptive events. An intensive manual snow survey on and around Mount St. Helens by the NRCS is scheduled for late April 2006, and the data will be incorporated into SNODAS model by NOHRSC staff. Pending the outcome of the snow survey, this should provide additional point data to improve the SNODAS model and compare to the model output. This will also give the best estimate of SWE on Mount St. Helens to date.

## ACKNOWLEDGEMENTS

We would like to thank the staff at NWS NOHRSC for assistance in developing the SNODAS application and their ongoing support for the Mount St. Helens snowpack SWE determinations.

## REFERENCES

Carroll, T., D. Cline, G. Fall, A. Nilsson, L. Li, and A. Rost. 2001. NOHRSC Operations and the Simulation of Snow Cover Properties for the Coterminous U.S. Proceedings of the 69th Annual Western Snow Conference; Sun Valley, Idaho; 2001 April 16-19. pp 1-10.

Major, J.J., W.E. Scott, C. Driedger, and D. Dzurisin. 2005, Mount St. Helens Erupts Again: Activity from September 2004 through March 2005, U.S. Geological Survey Fact Sheet FS2005-3036, p. 4.

National Operational Hydrologic Remote Sensing Center. 2004. Snow Data Assimilation System (SNODAS) data products at NSIDC. Boulder, CO. National Snow and Ice Data Center, Digital Media.