THE NOHRSC SNODAS SNOW WATER EQUIVALENT DETERMINATION ON MOUNT ST. HELENS, WASHINGTON

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ABSTRACT

Mount St. Helens in Washington State erupted in 1980 with devastating results due to pyroclastic debris flows entraining large amounts of the existing snowpack on the mountain. With the renewed volcanic activity that began in October 2004, close monitoring of the snowpack is required. The total snowpack snow water equivalent (SWE) volume determined by the Natural Resources Conservation Service (NRCS) is used by other federal agencies to determine the flood size that could be expected from a rapid snowmelt flooding event from possible eruptive activity on the mountain. In the 2006 and 2007 water year, the National Weather Service (NWS) National Operational Hydrologic Remote Sensing Center (NOHRSC) Snow Data Assimilation System (SNODAS) model was used to determine the total amount of SWE on the mountain. In early May 2006, a series of intensive snow surveys undertaken by 7 teams around the mountain. This additional data was then ingested into the SNODAS model and slight changes in the gridded data and SWE total resulted. The snow survey improved the modeled snowpack, especially in the high elevation environment. Further surveys with additional data would improve the modeled snowpack for areas above existing SNOTEL measurement stations. The overall investigation provided significant validation that the SNODAS model provides a fairly accurate and a much-improved comprehensive picture of the snowpack on Mount St. Helens. These techniques could be applied to other volcanoes in the Cascade Mountain Range, and across the U.S.

INTRODUCTION

Mount St. Helens became active 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. 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 to reactivate the weekly Mount St. Helens snow report that had been stopped in the late 1980s. 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 using data from the existing SNOTEL network to determine the snowpack SWE on the mountain. In 2003, 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 (Figure 1.). 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 of maps, gridded fields and data tables. The GIS layers are available from NOHRSC, and also distributed through the National Snow and Ice Data Center and NOAA National Climatic Data Center. 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 also be easily included to update the model as required. Mount St. Helens was delineated using ArcGIS to create the 3 elevation zones and 4 quadrants around the mountain. The SNODAS SWE layer was then combined with the Mount St. Helens layers to create SWE maps and products for distribution. The weekly products produced by the NRCS are shown in Figure 2. 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

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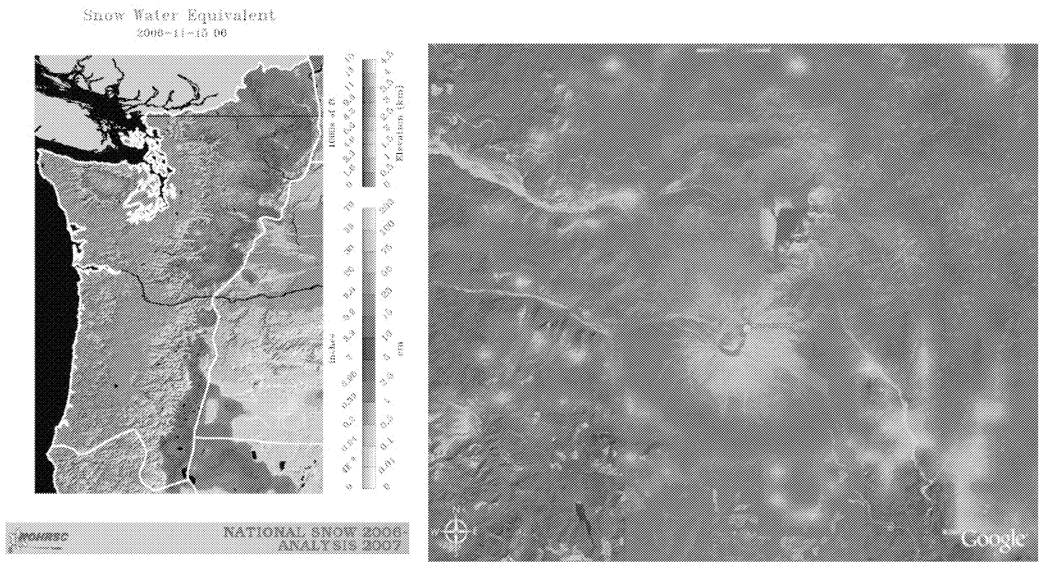

Figure 1. NWS NOHRSC SNODAS model products from their national snow analysis on the left, and three-dimensional visualization overlay on the right

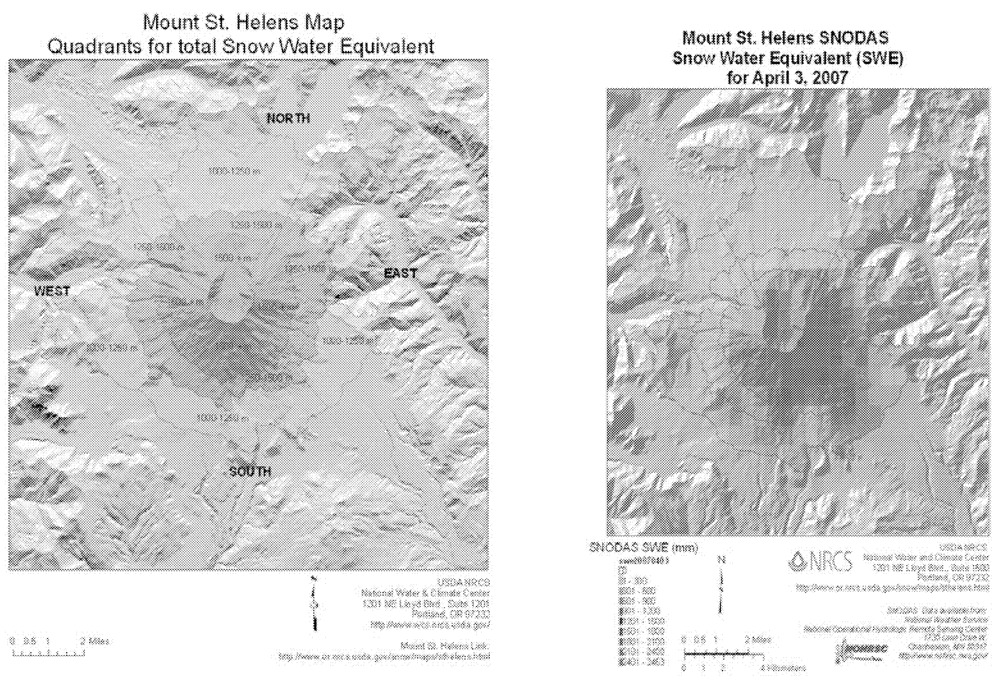

Figure 2. Mount St. Helens area GIS division map, and weekly SWE snow cover map product

THE 2006 AND 2007 SNOW SEASON AND RESULTS

SNODAS modeled SWE has been applied to Mount St. Helens throughout the 2005-2006 and 2006-2007 winter seasons. SNOTEL data is an input into the SNODAS model, though SNOTEL point data is not representative of the entire area it is located in, especially around the open volcanic terrain of Mount St. Helens. In this area, the SNOTEL stations are located in small openings in treed areas, where the site is protected from wind and can best collect snow data. 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.

To better analyze the SNODAS performance, and to improve the model on Mount St. Helens with additional data, seven teams did an intensive snow survey on April 25, 2006 around Mount St. Helens. The teams collected data from 61 additional snow survey points on and around the mountain over predetermined transects at different elevations, aspects and quadrants around the mountain. The data included snow depth and SWE and several snow pits were dug to collect additional data on snowpack temperature and density. The resulting data was then incorporated into SNODAS by the NOHRSC staff. The changes that were made in the SNODAS model are shown in Figure 3. The majority of the snow-covered area changed little from the additional data. Low elevation areas (1000-1250 m) surrounding the mountain changed the least, from 1 to 15 mm, with the average change an increase of 4 mm overall. The mid elevation zones in all quadrants had snow decreased in these areas, due to the additional snowpack measurements having lower SWE than the SNOTEL stations located near that elevation. The decreases in SWE ranged from 9 to 28 mm, with the 1250-1500m average change of 14 mm. The high elevation SNODAS modeled SWE was increased moderately due to the snow survey data from high on the mountain. The area above 1500 m increased the SWE by 27 to 48 mm, with an average increase of 38 mm for the top of the mountain. These high elevation data points were taken in areas next to ridgelines, due to the extreme depth of the snowpack that contained extensive, deep ice layers. The mid and high elevation zones had overall changes less than 20 percent from the SNODAS model before the snow survey. There are no SNOTEL stations near Mount St. Helens at the mid or high elevation zones, so the snow survey was able to provide important data for these areas. Overall, the changes at all elevations and quadrants on Mount St. Helens amounted to a 7 mm increase in modeled SWE.

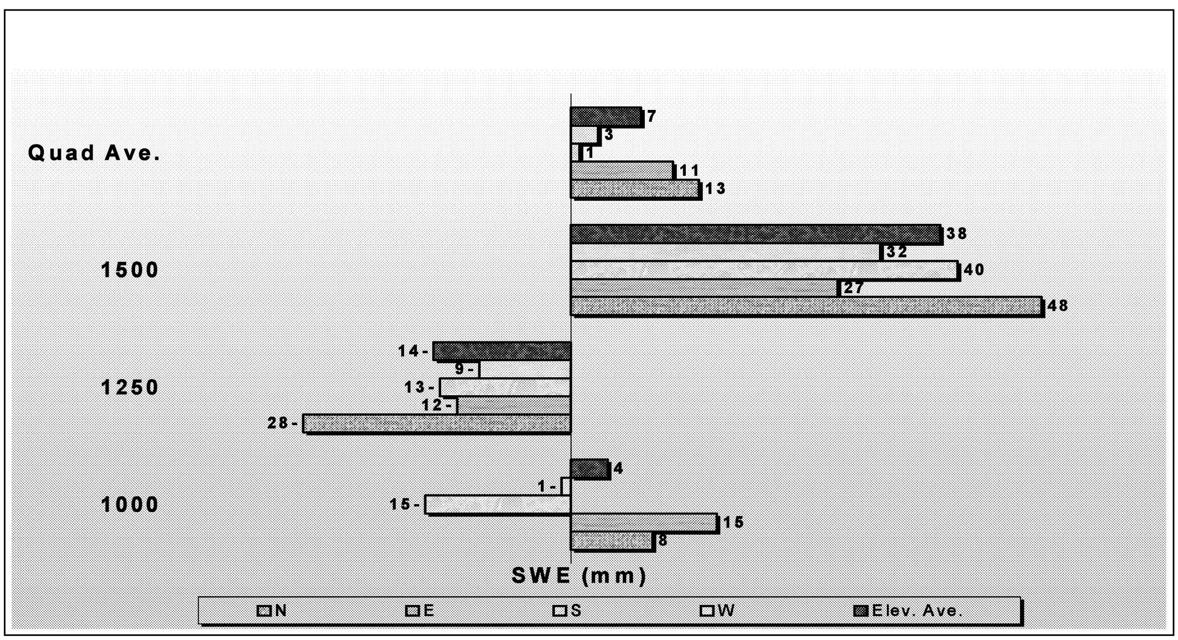

Figure 3. SNODAS model SWE changes from the extensive snow survey around Mount St. Helens

CONCLUSIONS

The NOHRSC SNODAS modeled SWE has been shown to be a reliable and consistent model for determining the snowpack water content around Mount St. Helens over several seasons. The limited SNOTEL 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. The additional SWE data provided by the intensive snow survey was easily incorporated into the SNODAS model by NOHRSC. These additional data points from the snow survey improved accuracy of the modeled SWE for the four quadrants and three elevation zones. While the low elevation zone change was slight, the mid elevation and high elevation zone changes were moderate, though the modeled snowpack for the entire mountain was changed by less than 20 percent. The most benefit to the SNODAS modeled SWE was in the mid and high elevation zones from the intensive snow survey which provided ground data to the model in this sparsely measured elevation in the area. These zones are above the SNOTEL sites in the area, so this area had no ground truth measurements before the snow survey. Mount St. Helen's unique physical environment also contributes to the complexity of snowpack modeling on the mountain. Annual snow surveys, especially in mid and high elevation zones, would improve snowpack modeling on the mountain. Continuing volcanic activity will require continued monitoring of the snowpack to assist in the best estimate SWE water available for flood risk assessment from potential eruptive events. Additional data collection in the Cascade Mountain volcanoes would also assist in snowpack modeling.

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