# The Creation of a Denser Basin Averaged SWE Grid by Incorporating Daily Observations with Biweekly Basin Averaged SWE

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## ABSTRACT

Snow measurements physically taken from the northeastern United States are used to produce a Snow Water Equivalent (SWE) map at the National Weather Service (NWS) Northeast River Forecast Center (NERFC). From this map, Basin Average SWE values are then derived and compared to the NWS Snow-17 model. Basin Average SWE values in Snow-17 are adjusted by the hydrologic forecasters to calibrate the snow model based on the information of a snow survey. The existing method to derive the SWE map is limited because snow surveys are taken every two weeks and there are many sparse areas where surveys are not taken. The goal of this project is to explore a method on how to produce denser grid cells in the SWE map in hopes to refine the values going into the Snow-17 model. This project is to create a procedure in which the NERFC can incorporate Daily Cooperative Observations and Daily Mesonet data into the generation of biweekly Basin Average SWE values. This project calculates SWE from measurements of snow depth and estimates of snow density. Research will be done to find the best way to estimate snow density values to use in the calculation of SWE.

## INTRODUCTION

The Northeast River Forecast Center (NERFC) of the National Weather Service (NWS) creates a basin averaged snow water equivalent (SWE) map every two weeks during the snow season to calibrate their Snow 17 model (Fig 1). The values that come in during a biweekly snow survey are composed of SWE values and snow depth (SD) values. These values are measured at survey points set up by organizations such as the U.S. Army Corps of Engineers, Maine Geological Survey, and many other organizations throughout the Northeast United States. Along with these values sent in by snow survey locations, cooperators under the National Co-operative Observer Program (co-op) measure snow depth on a daily basis and may not be equipped to measure SWE. This project develops a technique in which the co-op data are integrated into the NERFC SWE analysis by creating an interpolated SWE value based on the integration of the co-op SD values into a snow density (SS) grid, a product from NERFC snow surveys of SWE and SD data.

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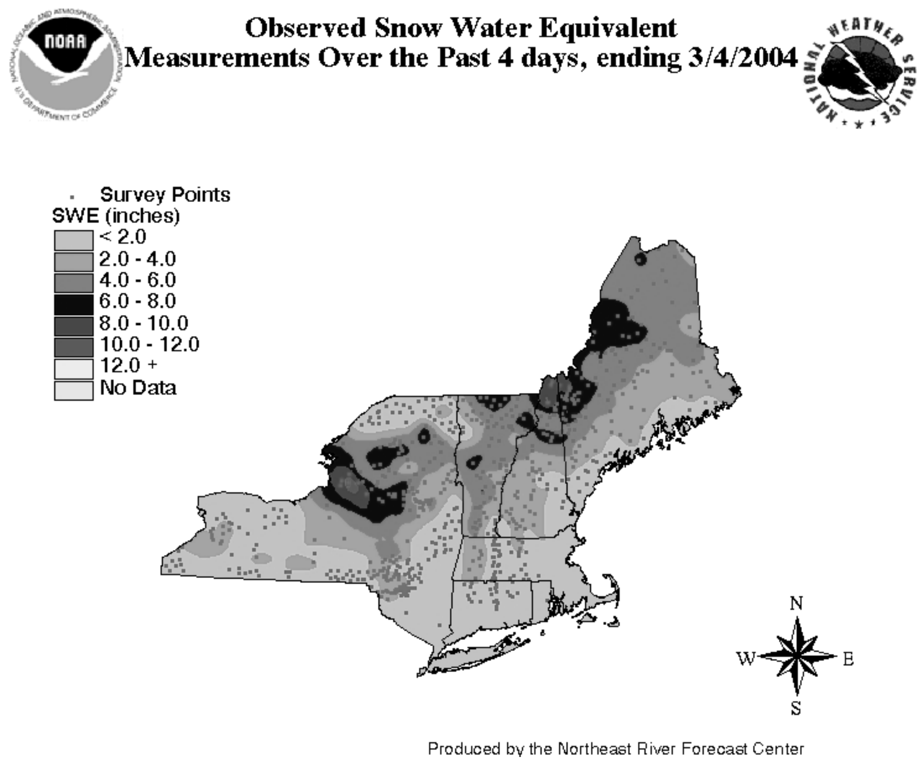


Figure 1. Current Basin Averaged SWE map layout

Samelson and Wilks (1993) performed a similar study by trying to create a simple method for specifying snowpack water equivalent. As mentioned in their report, the co-op stations do not report SWE routinely, but they do participate in periodic snow surveys during which SWE is also directly measured. Samelson and Wilks developed a way to model estimated SWE based on equations using the SD and 24-hour daily maximum and minimum temperatures.

## PROCESS

This project incorporates co-op data by use of a point-to-grid ESRI™ Avenue™ script, which has the potential to add multiple survey points to the NERFC biweekly basin averaged SWE map (Fig 2). Incorporating daily SD points into the basin averaged SWE map (Fig 1) causes a problem because a SWE value is calculated using both SD and SS. Without an SS value, the equation

$$SWE = SD * SS \qquad (1)$$

is not useable, therefore making the daily data of no use to the biweekly basin averaged SWE. Retrieving SS data from the snow survey to produce an SS grid is a viable solution to this problem.

Snow density is calculated by using the data provided by the snow survey locations:

$$SS = SWE / SD. \qquad (2)$$

Equation 2 can be applied to the snow survey data to create SS data (Fig 2: Step 2). A gridded SS map can be produced using ESRI™ ArcView™ Geographic Information Systems (GIS). This SS grid is used with the daily SD values to create an interpolated SWE value for every SD point.

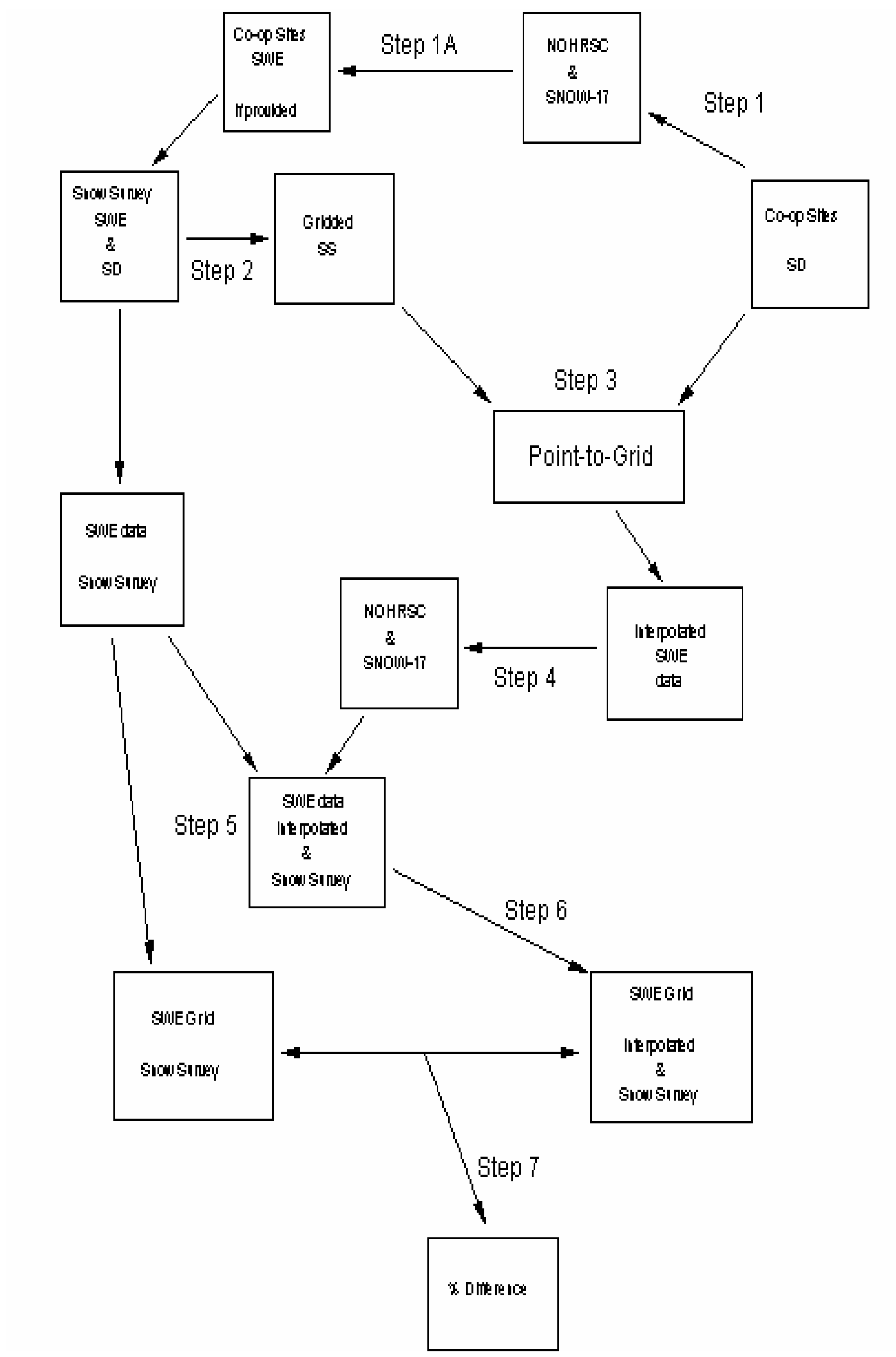


Figure 2. Steps to Complete Incorporation

Interpolated SWE values are obtained by using the gridded SS from the snow survey and the SD from the co-op sites (Fig 2: Step 3). Since snow density is a gridded map of the whole northeast United States and the snow depth value is at irregular points, an Avenue™ must be run in ESRI™ ArcView™ GIS to extract the grid value at a certain point. Grids are based on a latitude and longitudinal coordinate system and each point that comes in through the daily observations has an exact latitude and longitude location.

With the use of an ESRI™ ArcView™ GIS point-to-grid Avenue™ script, each SD point can be integrated into the SS grid to create interpolated SWE points for that latitude–longitude location.

As Schmidlin (1990) found in his critique of the record of "Water Equivalent on the Ground," some problems arise with daily summary datasets ranging from typographical errors to physically impossible values. When values such as these came into the study done by Samelson and Wilks (1993) they were either corrected or omitted entirely from the study. Possible reasons for these problems with the data could be the time at which the measurements were made and the instruments used to gain each measurement if different co-op sites used different instruments.

This project applied the technique of Schmidlin (1990) by checking data that come in through co-op sites by using the NERFC's Snow-17 model and the NOHRSC model. These two models will be used at multiple times throughout the calculation of SWE from the co-op data (Figure 3). These models will first be used to check the accuracy of the SD data that come in through co-op sites by comparing the snow model's average basin snow depth, which is tracked closely on a daily basis by the NERFC (Fig 2: Step 1).

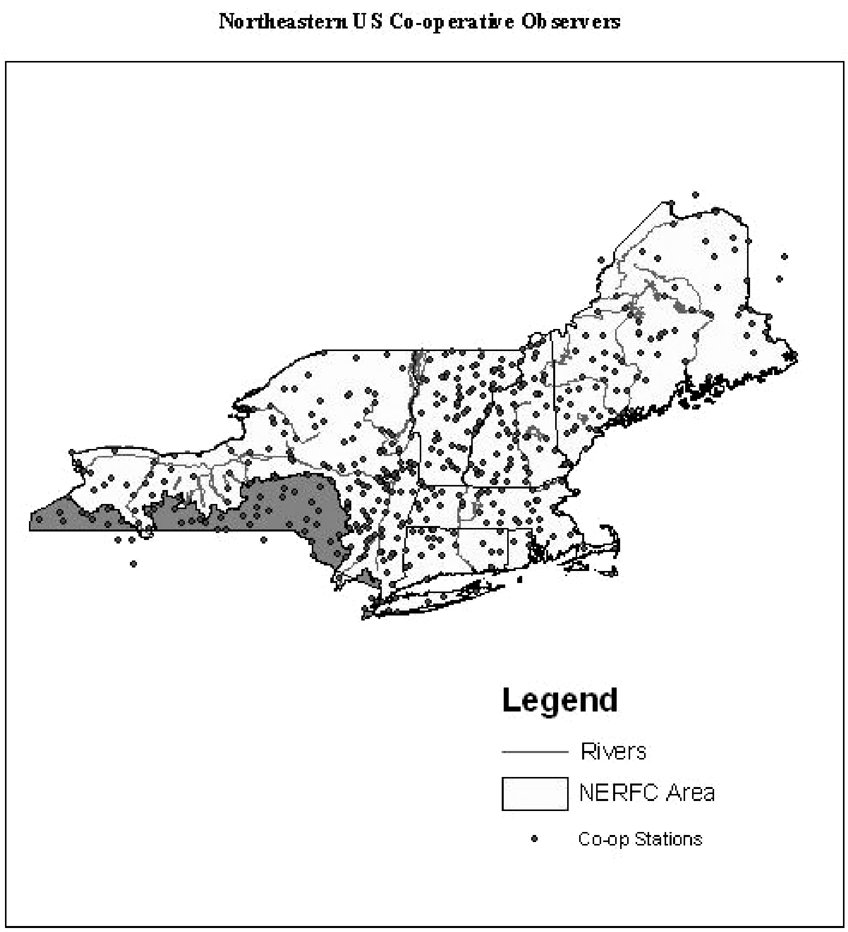


Figure 3. 2004 Co-op site locations

If a co-op site sends in inaccurate data or data with errors, these models will be used to correct the data or aid in the decision to omit the value. When co-op sites do by chance send in a SWE value, these models will serve as a quality control check of that SWE value (Fig 2: Step 1). Schmidlin et al. (1995) uses a similar technique for quality control check. If the two models accept the co-op SD data that come in, it will be integrated into the SS grid to create the interpolated SWE value. At this point the two models would be used again to do a quality control check of the interpolated SWE (Fig 2: Step 4).

The last check by the snow models is critical due to SS variability. In a study done on the Ross Ice Shelf in Antarctica, Braaton (1996) observed variability of SS in three snow pits. He found that as SD varies by several centimeters, SS would vary. This poses a possible problem because the SD of the snow survey used to create the gridded SS may be completely different from the SD of the co-op sites. This could cause an error in the calculation of the interpolated SWE and therefore the models must be used to create a quality control check. Lapen and Martz (1996) found similar problems in SD data in his study of snow depth variability in an agricultural site of the Canadian Prairies.

SWE values are directly calculated for the SD point and they are interpolated to match the SS grid from the biweekly snow surveys. The interpolated SWE is joined with the SWE data created by the snow survey (Fig 2: Step 5). The snow survey has more precision because it is based on data taken from the same location. The daily SWE values are interpolated, therefore have less precision, and the interpolated SWE values will create a bias towards the snow survey values.

This bias towards the snow survey is smoothed out using universal Kriging to create a data set composed of interpolated and snow survey SWE data. Kriging is used in ESRI™ ArcView™ GIS to smooth out the data because the snow survey and co-op data may be influenced by different environmental variables. Each snow survey point is set in a basin by the organization that controls that site. A co-op site is set by the NWS, but the observers are not supplied with the instruments to measure snow. Since locations are set by different organizations, different environmental variables will be affecting each site. "Kriging is also used as a specialized interpolation method that assumes the distance and direction between sample points to show spatial correlation and help to describe the surface" (Johnston and McCoy 2001). Kriging helps to determine the SWE values between each point where there are no data present or no observation was taken.

The SWE data, composed of both the interpolated and snow survey, are put into a gridded format to create a SWE map using the two observation types. This grid is a relatively dense grid because of the joining of the two data sets (Figure 4). The co-op data can fill gaps between survey observation points, and at the same time may create new but smaller gaps away from survey observation points.

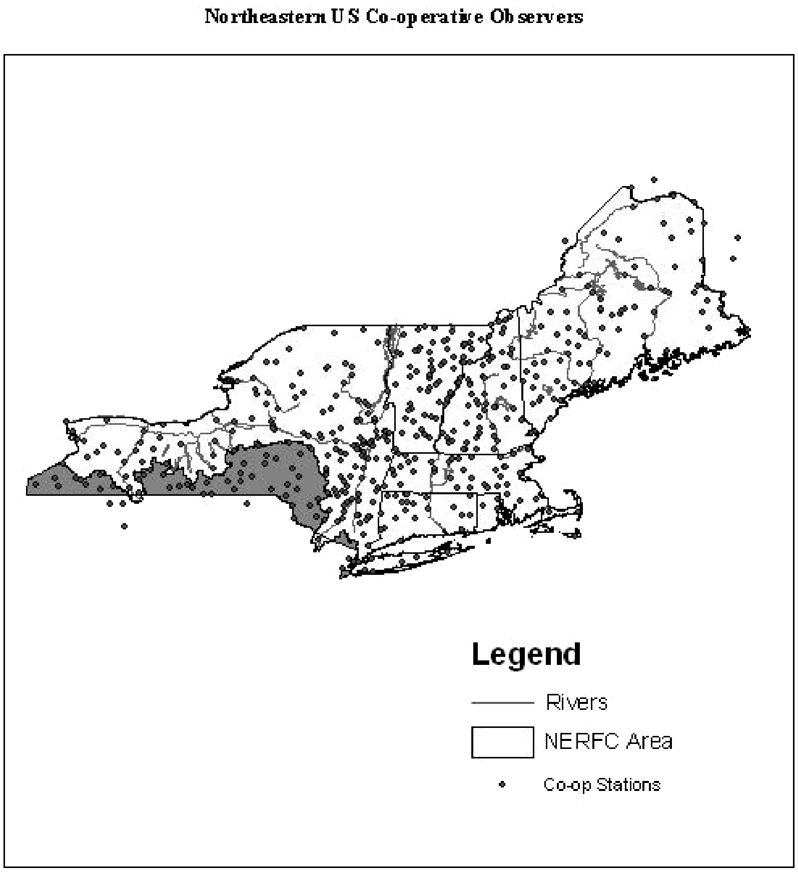


Figure 4. 2004 Map of Co-op and Snow Survey locations over 1000 sites

The gridded SWE map, composed of interpolated and snow survey data, is compared to the original gridded SWE map composed of only the snow survey data (Fig 2: Step 7). This comparison of the two grid maps will present a percent difference between the two maps. The percent difference will be highly affected by how well the bias of the snow survey data are decreased by the kriging of the co-op and snow survey points when creating the grid map. Kriging is used to create the snow survey grid maps as well, but the environmental variables and distances between points will be affected when the co-op data are added to the snow survey data.

**CONCLUSION**

This procedure used to create the technique to incorporate co-op data will produce a physical, near-real-time map, whereas previous studies have been made to create an empirical way to forecast SWE. The technique discussed in this project incorporates co-op data into a snow survey; it is a way to enhance the current SWE forecast. The percent difference of the two maps that are the outcome of this technique can be used as a stepping stone to finding possible refinements to the technique. This technique should be applied to snow surveys throughout an entire snow season and then evaluated.

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Anderson, Eric A., 1976. A Point Energy and Mass Balance Model of a Snow Cover. NOAA Technical Report 19, U.S. Dept of Commerce, Silver Spring, MD, 150 p.

Carrol, Thomas. Airborne Gamma Radiation Snow Survey Program: User's Guide. National Operational Hydrologic Remote Sensing Center. 2001.

Econopouly, Thomas, and Victor Hom. Overseeing and advising on operations during an internship at the NERFC.

Grundstein, Andrew J., and Daniel J. Leathers. *Factors Influencing the Variability of Midwinter Snow-Depth Decrease in the Northern Great Plains of the United States*. Grundstein and Leathers. 1997, pp. 408–423.

Hayhoe, H.N., et al. Estimating Snowmelt Runoff Erosion Indices for Canada. J. Soil and Water Sons. 1995, pp. 174–179.

Hellström, Robert. Bridgewater State College. Advising and for internship and overseeing progresses made at the NERFC.

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Schmidt, R.A. Properties of Blowing Snow. *Reviews of Geophysics and Space Physics*, 20: 39–44, 1982.

Slocum, Terry A. *Thematic Cartography and Visualization*. Prentice-Hall, Inc. New Jersey, 1999.

U.S. Army Corps of Engineers. Runoff From Snowmelt. Engineer Model. Manual No. 1110-2-1406. 31 March 1998.

**REFERENCES**

Braaton, D.A. 1996. Characterization of snow accumulation variability on the Ross Ice Shelf, Antarctica. Department of Physics and Astronomy, University of Kansas.

Johnston, K., and J. McCoy. Using ArcGis Spatial Analyst: GIS by ESRI™. ESRI, Redlands, CA.

Lapen, D. R., and L.W. Martz. 1996. An investigation of the spatial association between snow depth and topography in a Prairie agricultural landscape using digital terrain analysis. *Journal of Hydrology*. **184**(3–4): 277–298.

Samelson, D., and D.S. Wilks. 1993. A Simple Method for Specifying Snowpack Water Equivalent in the Northeastern United States. *Journal of Applied Meteorology*. **32**: 956–974.

Schmidlin, T.W. 1990. A Critique of the Climatic Record of "Water Equivalent of Snow on the Ground" in the United States. *Journal of Applied Meteorology*. **29**: 1136–1141.

Schmidlin, T.W., D.S. Wilks, M. McKay, and R.P. Cember. 1995. Automated Quality Control Procedure for the "Water Equivalent of Snow of the Ground" Measurement. *Journal of Applied Meteorology***. 34**: 143–152.