ASSESSMENT OF NWS SURFACE-MEASURED SNOW WATER EQUIVALENT DATA BASED ON REMOTELY-SENSED DATA IN THE NORTHERN PLAINS

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INTRODUCTION

The snow water equivalent (SWEQ) is important to climatologists and hydrologists. This is the depth of water resulting from a melt of the snow pack. The potential melt water in snow provides a late winter and spring recharge to groundwater and stream flow. However, an excessive amount of snow melt water, especially when accompanied by heavy rain and frozen soil, can contribute to stream flooding. Stream flow forecasting in cold climates requires knowledge of the amount of water held in the snow pack. This parameter is highly variable in time and space so is difficult to measure accurately.

The National Weather Service (NWS) began measuring the SWEQ at first-order stations in 1952. This point measurement is taken daily, usually on sod at a large airport, whenever the snow depth is 5 cm or greater. The method of measurement may be melting, weighing, or estimation. Thirty-eight years of data now allow for the study of SWEQ climatology from these data (Edgell, 1988).

The National Weather Service began a program of measuring the areal mean SWEQ by low-flying aircraft in the early 1980's. This program, the Airborne Gamma Radiation Snow Survey, is part of the National Remote Sensing Hydrology Program (Carroll and Allen, 1988). The attenuation of gamma radiation emitted by the soil is an indication of the water content of snow packs. The gamma radiation is measured by low-flying aircraft over 1440 flight lines in the northern U.S. and southern Canada. Flight lines are 16 km long and 0.3 km wide so the resultant SWEQ measurement is an areal average over about 5 km^2. This measurement is taken at the request of a local NWS or River Forecast Office when excessive SWEQ might cause high streamflow problems. The sporadic nature of the measurement and the short record reduce its climatological value. However, it might be used to judge the 38 years of point surface measurements of SWEQ.

RESEARCH QUESTIONS

Does the snow water equivalent (SWEQ) measurement taken at National Weather Service offices since 1952 adequately represent the SWEQ of the region around the NWS office? If not, can remotely-sensed areal SWEQ measurements be used to find a relationship between the surface point measurement of SWEQ and the true regional SWEQ?

Problems with the surface measurement of SWEQ at NWS offices include:

1. The quality of the measurement may depend on the method used (Schmidlin and Edgell, 1989).
2. The method of measurement varies within stations and among stations, without a record of the method used each day.
3. Snow cover exhibits great spatial variability so a point measurement of SWEQ may not be representative.
4. The distance between NWS offices is typically 80-200 km.

5. The SWEQ at the airport site where the measurement is taken may not be typical of the surrounding terrain.
6. It is difficult to account for ice lenses in the snow or ice at the surface.

In contrast, the remotely-sensed gamma radiation areal SWEQ measurement methods are consistent in time and space, give a mean SWEQ over a 5 km "flight line", and measure all of the water in snow or ice above the soil. Problems with the remotely-sensed gamma radiation SWEQ measurement include:

1. Uncertainty about the water content of the upper 20 cm of soil can affect SWEQ estimates.
2. Quality of the measurement may decrease as the gamma radiation signal is reduced by increasing SWEQ.
3. Variability of SWEQ along a flight line causes the SWEQ to be underestimated (Carroll and Carroll, 1989).

RESEARCH METHODS

Airborne gamma radiation SWEQ data were provided for selected flight lines in the central United States by Dr. Tom Carroll, NWS, Minneapolis. The surface measured SWEQ at NWS offices was taken from the government publication, Climatological Data (by state).

The surface point measurement of SWEQ at NWS offices was compared to the remotely-sensed areal SWEQ data where there were several flight lines within an 80 km radius circle of a NWS office. For each date with sufficient remotely-sensed SWEQ data, the point measurement of SWEQ at the NWS office was expressed as a percentage of the average of the remotely-sensed SWEQ data.

RESULTS

The NWS office at Fargo, North Dakota, was the best site for this research, since there have been eight years of remotely-sensed SWEQ data near that office. Most results apply to that site, although other sites were examined for comparison.

Six dates were examined at Fargo. The number of flights lines available for comparison on these six dates ranged from 8 to 18. Results are shown in Table 1. Two items are important from this table. First, the point measurement of SWEQ at the Fargo NWS office was about half of the remotely-sensed areal SWEQ measurement. Secondly, there is considerable variability in that relationship, from 0.22 to 0.90. Examples of the SWEQ data for two dates are shown in Figures 1 and 2. Data from Sioux Falls, South Dakota, gave similar results.

If we assume that the remotely-sensed gamma radiation SWEQ measurement is near the '"true" SWEQ, then it is clear that the SWEQ at the Fargo NWS office is substantially underestimating the SWEQ of the region. The possibility of poor representation by the NWS point measurements of SWEQ was one reason that the gamma radiation snow survey was established.

The large variability in the relationship between the surface point measurement of SWEQ and the remotely-sensed areal measurement of SWEQ is discouraging. A smaller variability would have allowed a "correction factor" to be applied to the NWS surface measured SWEQ data to estimate the true SWEQ of the region. However, large variability means that the 38 years of SWEQ data from NWS offices is of little regional climatological value since it does not represent the SWEQ of the region around the NWS offices.

The variability in the relationship between the surface and remotely-sensed SWEQ measurements may be caused by daily differences in SWEQ methods at the NWS offices and by differences in snowfall episodes. A snowfall accompanied or followed by wind or melting, for example, may accent the differences between the surface and remotely-sensed SWEQ data.

TABLE 1.
Comparison of surface measured SWEQ at Fargo, North Dakota, and areal average SWEQ from remotely-sensed data within 80 km of Fargo

Date	SWEQ (cm) Point measurement at Fargo	SWEQ (cm) Average of remotely-sensed flight lines	SWEQ (cm) Number of flight lines	Ratio of point/areal average SWEQ	Standardized departure of point measurement (Z-score)
4 March 1980	1.9	5.4	18	0.35	-3.0
7 Feb 1982	6.6	7.3	13	0.90	-0.6
28 Feb 1982	5.8	7.9	15	0.73	-1.6
23 March 1982	3.0	9.1	13	0.33	-3.4
5 March 1984	3.5	6.4	13	0.55	-1.9
5 March 1985	0.8	3.6	8	0.22	-3.3
Average	**3.6**	**6.8**		**0.53**	

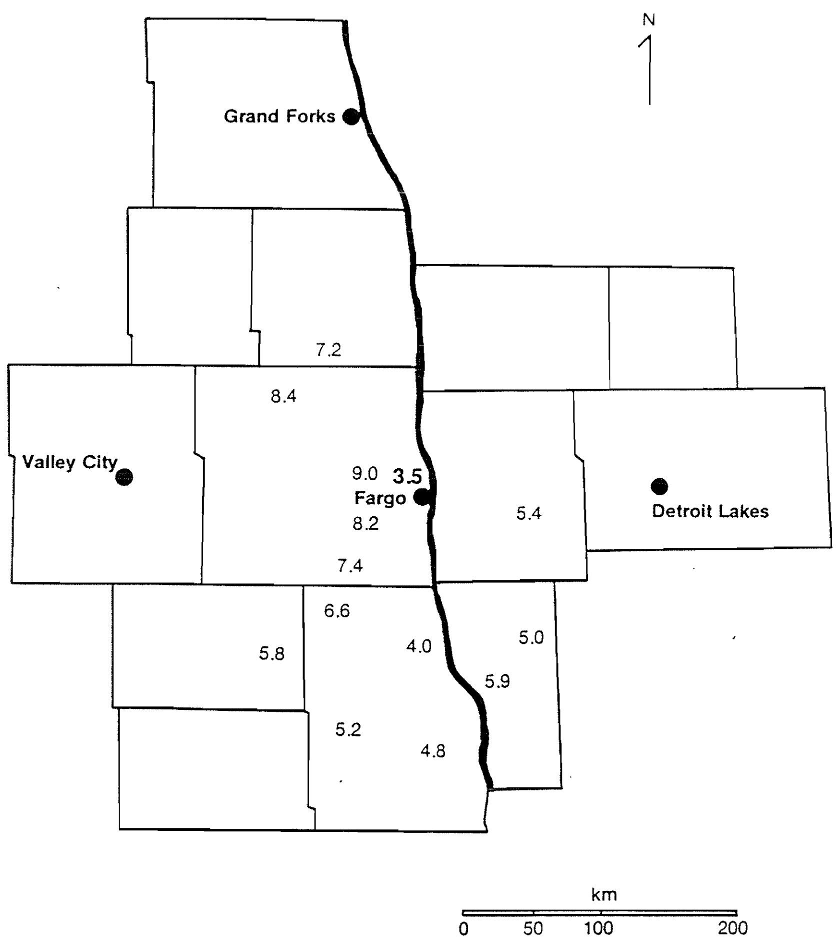

Figure 1. Example from 5 March 1984 of a typical relationship between the surface point measurement of SWEQ at the Fargo NWS office and remotely sensed SWEQ near Fargo (ratio = 0.55)

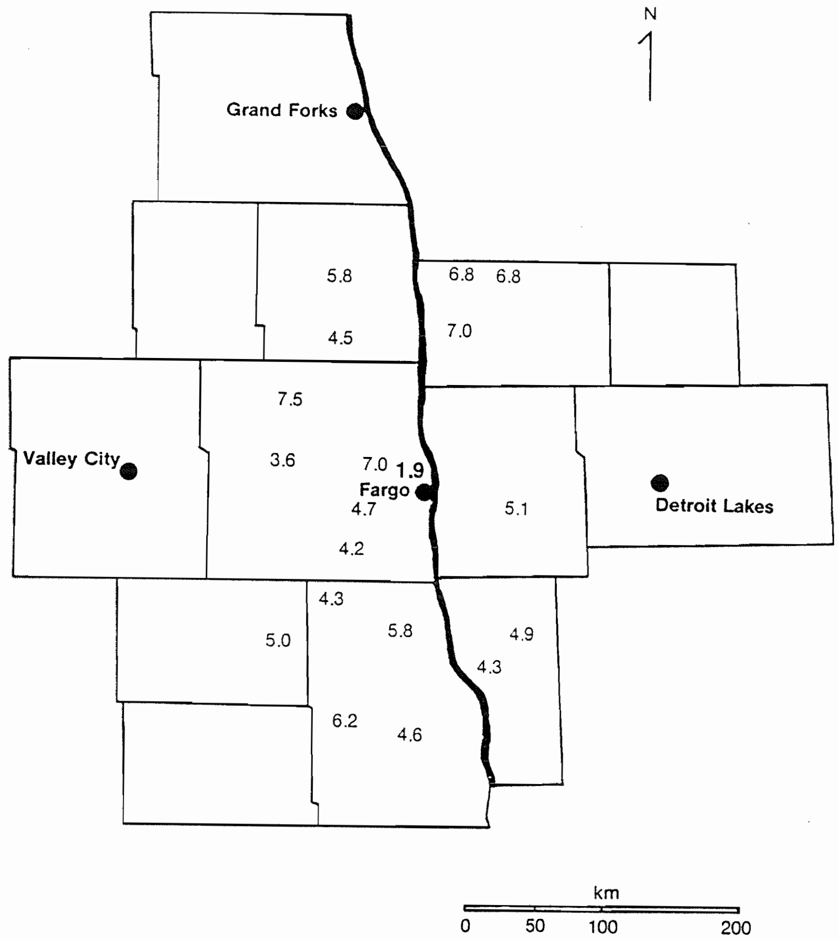

Figure 2. Example from 4 March 1980 of a case in which the NWS surface point measurement of SWEQ is much less than the regional remotely-sensed average SWEQ (ratio = 0.35).

CONCLUSIONS

The 38 years of SWEQ data measured at NWS offices is a poor source of information concerning SWEQ in the United States. A comparison with remotely-sensed areal SWEQ data showed the NWS surface point SWEQ measurement underestimates regional SWEQ by about 50% at Fargo, North Dakota. However, this cannot be used as a correction factor because it may vary from 20% to 90%.

The remotely-sensed areal SWEQ data provides little climatic information on SWEQ because the data collection program is less than 10 years old, data are collected sporadically, and only when the SWEQ is uncommonly large.

Changes should be made in SWEQ measurement programs to obtain a set of SWEQ data worthy of climatic analysis. If surface point measurements of SWEQ were expanded into the NWS Cooperative Observer network, then more sample points would be available and terrain features other than airports would be represented in the data.

A program of routine measurements in the Airborne Gamma Radiation Snow Survey would provide reliable areal averages of SWEQ. This could be instituted (at some cost) on a biweekly basis over a flight line density suitable for the terrain variability, perhaps one per 2000 km^2.

REFERENCES

Carroll, S.S. and T.R. Carroll. 1989. Effect of uneven snow cover on airborne snow water equivalent estimates obtained by measuring terrestrial gamma radiation. Water Resources Research 25:1505-1510.

Carroll, T. and M. Allen. 1988. Airborne gamma radiation snow water equivalent and soil water measurements and satellite aerial extent of snow cover measurements: A user's guide, version 3.0. National Remote Sensing Hydrology Program, Office of Hydrology, National Weather Service, Minneapolis, MN.

Edgell, D. 1988. An analysis of the snow water equivalent measurement in Ohio with applications for snowmelt climatology. M.A. Thesis, Geography Department, Kent State University, Kent, OH.

Schmidlin, T.W. and D. Edgell. 1989. Observations on the measurement of the water content of shallow snow covers. Proceedings of the Sixth Conference on Applied Climatology (p. 70-71), American Meteorological Society, Boston, MA.