3.1 USING K-16 WEATHER STATION DATA IN CLIMATE RESEARCH AND AS AN OUTREACH OPPORTUNITY

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1. INTRODUCTION

The increased coverage and reliability of climate monitoring stations such as National Weather Service cooperative sites (COOP) has provided climate researchers opportunities to study climate problems at much finer resolutions than was previously available. However, COOP sites only provide one observation per day of the diurnal maximum (Tmax) and minimum (Tmin) temperatures as well as total precipitation (PRECIP) in the form snowfall during winter months and liquid equivalent or rainfall during the warm season months. Although this information is useful, it does not provide the same temporal resolution as that of first-order NWS sites, which are hourly or greater, nor does it provide many of the other types of elements that climate researchers and forecasters find useful (i.e.. wind speed, wind direction, present weather).

The School Weather Network (SWN) provides a possible solution to the poor temporal resolution and limited number of elements recording by the COOP sites. The SWN represent high quality weather stations installed at schools and universities (K-16) throughout the U.S. to be used primarily as educational tools for students at the respective schools and the public through local TV media. Their coverage has increased rapidly during the past decade and now total over 8000 stations scattered across the U.S. (AWS, Inc. 2008-maps.weatherbug.com). Many are located nearby other NWS and/or COOP sites while others are more isolated, providing an opportunity to fill in "gaps" that may exist in the current climate record.

Concerns about the quality of data from the SWN have existed since they were first installed. This is primarily related to assumptions of poor instrument quality, improper siting (e.g. on roofs or too close to buildings) and lack of regular calibration. Thus, the data coming from these sites have been deemed to not be of sufficient "research quality" and have been generally ignored by researchers. However, there have also been similar concerns about COOP data (Daly et al, 2007; NOAA, 2008) yet these data are used.

In recent years the National Weather Service has begun to use weather stations at schools for verification of severe weather events (primarily wind gusts and heavy rain) and also informal verification of maximum/minimum temperature forecasts (NWS, 2008). This combined with improved instrument quality and siting decisions has brought more attention to the potential of using weather stations at K-16 schools as supplemental weather data to that provided through NWS and COOP sites. Moreover, use of these data by climate researchers provides an opportunity to involve K-16 students in climate research projects by demonstrating the application of these data towards better understanding real climate problems.

The objective of this study is to investigate the potential for using weather stations from K-16 schools as a supplement to the current climate observing network in the U.S. Although the data from these stations cannot be considered to be of equal quality to that of regular NWS or COOP sites, they can potentially be used to assist climate researchers in situations where increased temporal and spatial resolution is needed beyond that currently available. Some examples of such projects and potential outreach opportunities are discussed at the end of this paper.

2. DATA COLLECTION AND ANALYSIS

The study region for this project is Southeastern (SE) Wisconsin. This region was selected because it surrounds the primary K-16 SWN station of interest, located on the campus of the University of Wisconsin-Whitewater (UW-W). This weather station has been in place at UW-W for over ten years and provides the only high resolution archive of climate variations at WW. One of the primary driving forces behind this project is to determine if this data archive can be used for comparative purposes and potentially for long term trend analysis of climate change as the record continues to grow. The surrounding region of SE Wisconsin contains a dense network of NWS and COOP sites as well as numerous other SWN stations (Figure 1).

To test the potential of using the SWN to supplement NWS and COOP sites, statistical comparisons were done to determine the level of association between each group of stations, stratified by station type, as well as to test the consistency of station recordings within each sub-group. Pearson correlation coefficients (R-values)

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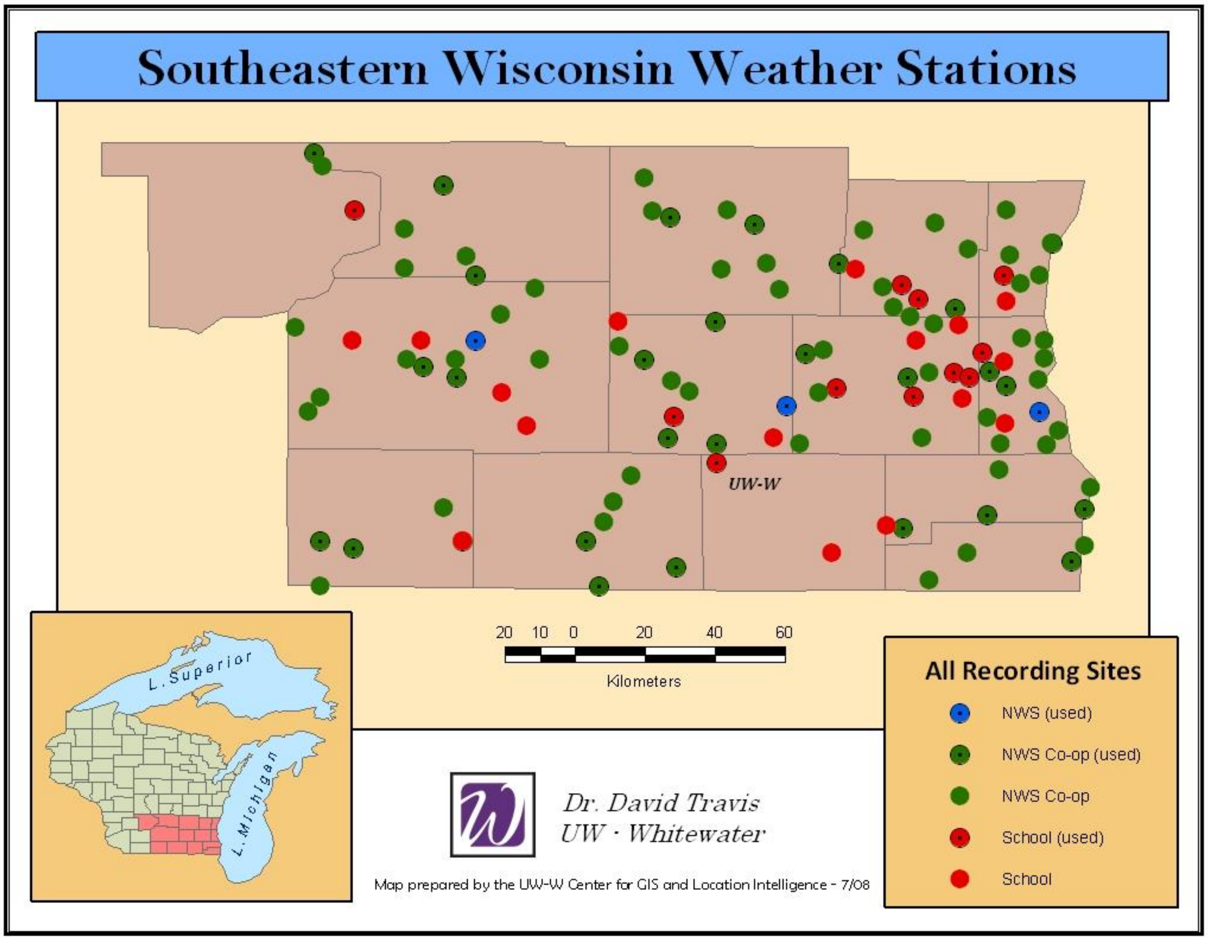

Figure 1: Locations and types of weather stations in SE Wisconsin (used and not used in this study).

were calculated to determine the level of association between each station within groups and between mean daily values for each station types. To capture a wide range of meteorological conditions, the late winter/early spring period of April 1- May 31st, 2008 was used for the statistical analyses. This period typically includes a wide range of temperatures and high frequency of precipitation events in SE Wisconsin. Although many COOP and SWN sites are available, only those stations that had 90% or more of observations available during the study period were included in the analysis. A total of 28 COOP sites, 3 NWS sites, and 11 SWN sites were included in the analysis (Figure 1). Because COOP sites only record Tmax, Tmin, and PRECIP, the comparisons between these sites and the other two groups were limited to these three variables. However, because the NWS and SWN sites record wind information and have similar temporal resolutions (hourly), it was possible to compare wind consistency between these two types of stations. Maximum daily wind (WINDMAX) (1 minute average) was selected.

3. RESULTS

Pearson R correlation coefficients showing the level of association between mean values of each group of weather station types by variable are shown for each climate element in Table 1. It can be see that R-values are consistently high (0.8 - 0.9) for each group of weather stations for Tmax and Tmin and only slightly lower for Precip and Maxwind comparisons (0.7 – 0.8). It is noteworthy that the R-values between the mean values recording by SWN stations and those of the other two groups are not significantly different, and even slightly higher, than the R-values between the other two groups (COOP and NWS). This implies that there is no obvious drop-off in data quality for the SWN stations compared to the other two groups, at least for mean values and the variables studied here. In fact, the PRECIP correlations were strongest between SWN sites and NWS/COOP sites rather than between the assumed higher quality COOP and NWS stations.

Pearson R Correlation	SWN * COOP & NWS	SWN* NWS	SWN * COOP	NWS * COOP
Max Temp	.99	.94	.99	.94
Min Temp	.89	.95	.88	.95
Rainfall	.86	.88	.86	.72*
Max Wind	-	.83	-	-

Table 1: Pearson R-values for correlation tests between types of weather stations and mean values for selected meteorological variables. All relationships significant at the <0.01 level except where noted. (<0.05 level)*

The slightly lower R-values for Rainfall and Max Wind are not surprising. This most likely reflects the more convective nature of rainfall events that occurred, particular later in the period. The wind variations are heavily dependent upon local environmental conditions (e.g., land cover, proximity to large water bodies, etc.) and subtle changes in elevation as well as proximity to thunderstorms which can cause localized increases.

To further investigate the consistency of stations for each group, Pearson correlation R-values were calculated between each station within each sub-group of stations for the same variables as in Table 1. The mean R-value was then determined for each sub-group, which can be viewed as a measure of "consistency" through level of agreement between stations. Table 2 demonstrates the mean R-values by station type.

Pearson R Correlation	SWN STATIONS	COOP STATIONS	NWS STATIONS
Max Temp	.91	.87	.70
Min Temp	.92	.83	.80
Rainfall	.86	.74*	.36**
Max Wind	.83	n/a	.74*

Table 2: Mean Pearson R-values calculated between individual stations within each group. All relationships significant at the <0.01 level except where noted. (<0.05 level) (** not significant).*

Inspection of Table 2 indicates that the intergroup station correlations are again greatest for Tmax and Tmin. The only exception is for the NWS stations where correlation values are lowest but this is likely a result of the wider spacing of these stations and the fact that one of the three sites (Milwaukee) is located immediately adjacent to Lake Michigan, which can heavily influence Tmax and Tmin during relatively weak flow synoptic conditions. Mean Pearson R-values are quite high for Rainfall and Max Wind as well but noticeably higher for the SWN sites compared to the COOP and NWS sites. The low and insignificant R-value (0.36) for Rainfall is particularly noteworthy as it represents the only non-significant correlation between groups of stations or individual stations in the entire study. This is difficult to explain other than the possibility that during this particular study period there was substantial influence on precipitation occurrence and/or intensity from Lake Michigan (either seen as enhancement or lessening) compared to the other two NWS sites (Madison; Watertown), which are located well away from the lake. However, the SWN and COOP sites also have numerous stations located in the Milwaukee area which seem to be less influenced by the lake. It is also noteworthy that the SWN stations had significantly high Pearson R-values for Max Wind measurements, which were again higher than the NWS stations (no wind available at the COOP stations). These results suggest that the SWN sites are potentially as consistent and reliable in their temperature, precipitation, and wind readings as their counterparts at nearby COOP and NWS stations.

4. DISCUSSION

The availability of SWN data and their apparent greater reliability than previously assumed, at least for temperature, precipitation, and maximum wind speed, creates a number of opportunities for climate researchers to utilize the improved spatial and temporal resolution made available by their existence. Mesoscale climate projects which rely on a high density of stations well above synoptic scales can use SWN stations to increase station density by as much as 10 times what is currently available using just NWS and COOP sites in certain regions. It is still advisable, however, to ensure that the stations are deemed reliable by doing a comparison to nearby COOP or NWS sites in a similar or more extensive way than demonstrated here. Most likely, it would be best to treat the SWN sites as supplemental sites used in combination with the NWS and COOP sites rather than on their own with no comparative data to ensure reliability. In and near most urban areas there is already sufficient station coverage through COOP and/or NWS sites so the usefulness of SWN sites will most likely be seen in rural areas or smaller towns that have schools of sufficient size to invest in a weather station.

One of the greatest advantages of the SWN sites are that they display, update, and record data at a temporal resolution equal to or greater than that of NWS sites. Most have data archived hourly but it is possible to increase this resolution to much finer increments as small as justa few minutes. Thus, for studies where very fine temporal resolution is needed, the SWN provides an ideal data source than can still be compared to nearby NWS sites for ensuring reliability and accuracy. Another distinct advantage of SWN sites are that they vast majority are connected to an active web site thus providing access in real-time to these data for "on the fly" information (e.g. UW-W weathersite). This could be deemed useful for storm chasers or tracking the progression of severe weather. Finally, many sites now have "weathercam" cameras mounted onto the tower housing the weather instruments which provides an opportunity for "present weather" to be seen in association with the real-time observations being displayed or for archived use later when using the data for climate research (e.g. UW-W weathercam).

The SWN was originally created as an opportunity for students to learn and get excited about weather and climate through observations of data collected at their own schools and through data comparisons with nearby schools. If climate researchers are willing to use these data in their own projects, even in limited form, it will provide an opportunity to establish relationships with K-16 teachers and their students by getting them involved in climate projects. This could represent simple activities such as having students monitor the number of heavy rain events or maximum wind gusts beyond a certain threshold, or compare Tmax and Tmin recorded at their schools to nearby schools and/or NWS and COOP sites to better understand why the values are difference (such as Urban Heat Island influences). Students and their teachers could also supplement the data automatically collected at their schools by collecting additional observations co-occurring with the station recordings such as cloud cover, snow depth, or unique weather phenomena (e.g. hail, lightning strikes). Moreover, students can better understand human impacts on climate by studying their surroundings and comparing the landscape influencing station measurements near their school to other nearby areas which may have more/less influence from human activity.

5. CONCLUSIONS

The results presented in this study suggest that climate researchers should look at the potential of using select SWN sites to supplement the data sets already established to improve both spatial and temporal resolution of observations. Through strategic planning with K-16 instructors, this also provides an opportunity for outreach to local schools to increase student education and potential interest in climate research and applications of climate data to better understanding climate problems.

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