

Research Paper

Identification of In-Situ Observational Sites for Snow Monitoring in Kentucky, USA

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Keywords: Kentucky Mesonet, snow cover, SWE, climate services, climatology

Journal of Applied and Service Climatology

Snow plays an important role in a variety of social and environmental sectors for which real-time monitoring can be used to inform managerial and logistical decisions. In more southerly regions of the United States, such as Kentucky, snow is classified as ephemeral or transient. In those locations, there exists limited infrastructure to monitor snow conditions at frequencies shorter than daily temporal scales. In this study, a climatologically-informed approach to identify regions within the Commonwealth of Kentucky that could be targeted for a deployment of snow monitoring instrumentation is conducted. The study aims to identify locations that are representative of their larger climate division characteristics. Results indicate there are many 4km grid cells within each of Kentucky's four climate divisions for which over 80% of variance in climate-division-averaged snow season snow depth, snow water equivalent, and snow cover frequency are explained. Results are then aligned with the geographic locations of existing Kentucky Mesonet observation stations. The five stations per climate division with the most variance in snow characteristics explained are documented and prioritized for further consideration for snow monitoring instrumentation. This approach can be used to efficiently identify suitable locations across relatively large domains and could be scaled to account for available budget and operational needs.

1. INTRODUCTION

Seasonally, approximately 45% of the North American land mass is snow covered, greatly increasing hemispheric albedo and influencing the surface energy balance (Estilow et al. 2015; Fassnacht et al. 2016). At localized levels, snow cover provides insulation to the topsoil, allowing for greater retention of moisture and heat during cold air outbreaks that can benefit agricultural and native species (Liang et al. 2020; Zhu et al. 2022; Liu et al. 2023). Snow further plays a critical role within regional hydroclimatology, providing water resources for over 15% of the global population and contributes to over 50% of the annual runoff in the northern and mountainous U.S. (Barnett et al. 2005). As such, regions with snow cover are historically well instrumented to observe variations and even long-term changes in snow for a variety of applications.

Throughout the U.S., there is various infrastructure in place to observe snow conditions in-situ, most typically at

daily temporal scales. Networks such as the Cooperative Observer Program (COOP; NOAA-NWS 1989) and the Community Collaborative Rain, Hail, and Snow (CoCoRaHS; Cifelli et al. 2005) both rely on volunteers to provide observations of snowfall, snow depth, and/or snow water equivalent (SWE), among other meteorological variables, once per day. These networks have stations with varying spatial and temporal coverages often based on the density of population and the ebb and flow of volunteers with time. But, historically the networks have provided robust data for climatological applications despite some well documented limitations (Robinson 1988; Doesken and Robinson 2009). In regions with more persistent snow, regional networks have been developed such as the Snow Telemetry network (SNOTEL) and the NYS Mesonet (Brotzge et al. 2020), among others, that often provide more comprehensive snow-related observations potentially including snowfall, snow depth, SWE, snow temperature, and others at high temporal resolutions. Spatial coverage is often similar to

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the COOP and CoCoRaHS networks, and stations often do not yet have as long of historical records. However, the automation, short latency, and frequent sampling periods of snow observations from SNOTEL and mesonets provides added benefit of real-time monitoring capabilities during snow events and can be a valuable layer of information for decision makers (Wang et al. 2021; Minder et al. 2025).

In more southerly U.S. regions, such as the Mid-South, snow cover is highly ephemeral. While evidence exists that runoff and flood risk can be meaningfully enhanced in this region by snow ablation (e.g., Suriano et al. 2024), snow has relatively limited impacts on annual water budgets and long-term energy balances. As such, there has historically been limited investment in snow monitoring despite the challenges snow presents for these communities in transition zones between regularly snow covered and snow free cold season locations. The high variability of snow conditions within and between seasons poses difficulties in adequately preparing for snow with respect to snow removal infrastructure and road treatments. While snow cover and snowfall are two distinct measurements, snow depth monitoring can be used to estimate snowfall rates and inform decisions based on snowfall accumulations. For example, across south-central Kentucky, the median annual snowfall during the last climatic normal (1991-2020) was approximately 4 inches compared to an average of approximately 8 inches (Suriano and Guercio 2024). Thus, these communities need to prepare for successive winter seasons with minimal snowfall followed by the occasional winter with two or three times the average amount. Such variations can place strain on local governments in managing de-icing supplies, snowplow maintenance, and winter weather-related messaging on roadways (Matthews et al. 2017; Tobin et al. 2022; Keshari et al. 2024). Finally, due to the relative infrequency of snow in the mid-south U.S., there can be substantial impacts from only modest snow amounts to the transportation and economic sectors (Sullivan et al. 2019; Rainey and Sheridan 2025; Najar et al. 2025). Often, businesses, schools, and even entire cities will shut down during relatively small snowfall events (< 4 inches) due to the limited snow removal infrastructure and residents' limited experience driving on snow covered roads in general (e.g., Usman et al. 2010). While less frequent and more ephemeral compared to more northerly regions, snow in the Mid-South U.S. is impactful to the community. There is a need to identify regions of interest that can appropriately represent the snow conditions for a relatively larger domain (e.g., climate division) for targeted and cost-effective deployment of snow monitoring infrastructure in the to benefit real-time monitoring.

Using a daily resolution 4 km gridded product of snow depth and SWE from 1981-2023, this study quantifies the statistical correlation of individual grid cells within Kentucky to climate-division-averaged conditions as a means of identifying locations most suitable for targeted snow monitoring deployment. Located within the snow transition zone of more consistent snow to the north and more transient snow to the south, and largely lacking automated snow monitoring infrastructure, Kentucky is well suited for

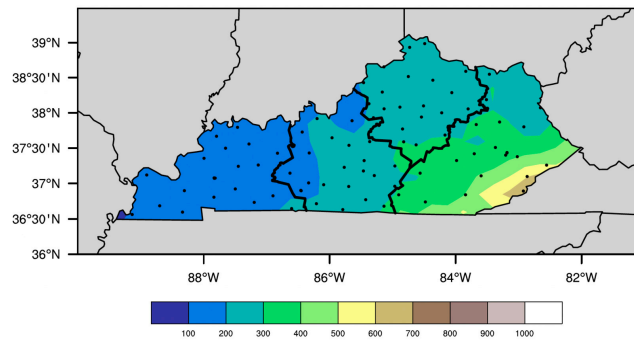


Figure 1. Locations of Kentucky Mesonet stations (dots) within Climate Divisions 1-4 (from left to right). Elevation, in meters, shown in shading.

this analysis. Assessments of snow monitoring potential are made with respect to snow depth, SWE, and frequency of snow days (defined as any day with snow cover) and align with existing monitoring infrastructure from the Kentucky Mesonet.

2. MATERIALS AND METHODS

2.1. STUDY REGION

The Commonwealth of Kentucky is located in the Mid-South region of the U.S., bounded by the region of approximately 36.6-39.1°N latitude, 82.0-89.6°W longitude (Figure 1). Topography is spatially variable, ranging from approximately 75 m in the southwest at the confluence of the Ohio and Mississippi Rivers to over 1200 m within the Appalachian Mountain range in the east. Kentucky's geographic location in the U.S. results in a highly variable climate, with hot summers and cold to mild winters; The majority of Kentucky's Köppen Climate Classification is humid subtropical (Cfa), with a very small region of temperate oceanic or subtropical highland climate (Cfb) classification in the Appalachian Highlands (Tekoe and Suriano 2025; Beck et al. 2018). There are four climate divisions in Kentucky designated by NCEI, with climate division 1 representing the western region, climate division 2 representing the central region, climate division 3 representing the bluegrass region, and climate division 4 representing the eastern region (Figure 1). Precipitation is plentiful and consistent throughout the year, with each month experiencing 9-13 cm on average, with annual totals ranging from over 130 cm in the south to less than 110 cm in the north (Tekoe and Suriano 2025). Snowfall typically represents less than 10% of the annual total precipitation, where most of the central and western portions of the state receive less than 30 cm of snowfall on average and portions of northern and extreme eastern Kentucky receive over 45 cm (Suriano and Guercio 2024). To-date, there have not been assessments of snow depth and SWE conditions within Kentucky.

As the state with the longest distance of navigable inland waterways in the contiguous U.S., Kentucky is landlocked with abundant surface and sub-surface water that supports a variety of agricultural, forest, recreational, and

manufacturing sectors (Poudel et al. 2022; Kentucky Cabinet for Economic Development 2025). Approximately 4.5 million people live in Kentucky, with nearly 40% of the population living within its two largest population centers: Louisville (~1.3 million) and Lexington (~500,000; United States Census Bureau 2020). Kentucky is also home to the Kentucky Mesonet (Mahmood et al. 2019; <https://www.kymesonet.org/>), a statewide weather network of 83 research-grade stations designed to support real-time environmental monitoring. First deployed in 2007, the Kentucky Mesonet collects a variety of atmospheric and near-surface observations, including air temperature, relative humidity, wind speed and direction, atmospheric pressure, precipitation, solar radiation, and soil moisture and temperature. Each station is also equipped with a camera to collect photographic images coincident with the observations. All data are collected in real-time every 5 minutes; data are transmitted to a central repository where the data are integrated, quality-controlled, archived, and disseminated to users within several minutes of data collection. A variety of derived products are generated for specific user groups such as farmers, emergency managers, and media. Nevertheless, despite the relatively common but significant disruption of winter weather across Kentucky, neither snow depth nor SWE are currently measured by the Kentucky Mesonet.

2.2. DATA AND ANALYSIS

Snow data for this study were obtained from the Daily 4-km Gridded SWE and Snow Depth from Assimilated in-Situ and Modeled Data Over the Conterminous US, Version 1 (Zeng et al. 2018). Henceforth, this dataset will be referred to as the gridded snow dataset. The gridded snow dataset generates estimates of SWE and snow depth based on observations from COOP and SNOTEL stations, assimilating them with estimates of temperature and precipitation from PRISM, across the contiguous U.S. (Broxton, Dawson, et al. 2016; Zeng et al. 2018). Validation against various snow datasets, including CoCoRaHS, indicates the gridded snow dataset provides robust estimates of SWE and snow depth across the U.S., and the dataset has been used for a variety of snow-based research applications (e.g., Dawson et al. 2018; Welty and Zeng 2021; Suriano et al. 2024; 2025). For complete details on the methodological approach and validation, consult Broxton, Dawson, et al. (2016), Broxton, Zeng, et al. (2016), Dawson et al. (2018), and Zeng et al. (2018).

Daily SWE and snow depth were extracted from the gridded snow dataset over the period of record, 1981-2023, for all grid cells within the geographic boundary of Kentucky. Frequency of snow days, defined as any day with greater than zero snow depth, were derived. Based on a centroid method, each grid cell was then associated with its respective climate division. A snow-season average, consisting of October-September, for each Kentucky grid cell and variable was calculated. Further, areal-weighted snow-season averages were calculated for each climate division and an initial climatology of snow characteristics over the 42-year period of record presented. To determine how representa-

tive each grid cell was to its corresponding climate division, with respect to the snow variables, Pearson correlation analysis ($\alpha = 0.05$) was performed for SWE, snow depth, and frequency of snow days. Further, the correlation coefficients of the grid cells containing Kentucky Mesonet stations were extracted and analyzed. The grid cells with Mesonet stations that explained the most variance in the snow variables were ranked and assigned relative priority for consideration to deploy snow observational equipment.

2.3. LIMITATIONS

The gridded snow dataset provides estimates, not direct observations, of snow depth and SWE, and thus may have biases due to the model's algorithm, particularly in locations where only COOP stations are available, compared to COOP and SNOTEL, and/or where model is more heavily reliant on interpolation. There is some evidence that suggests the gridded snow dataset persists snow cover too long following an ablation event (e.g., Suriano et al. 2025). This may result in additional days of snow cover within the presented climatology, however this bias should be relatively systematic across all grid cells in the domain. Further, there are well-known snow measurement biases that are likely embedded within the gridded snow dataset based on their incorporation of COOP observations. Within COOP snow observations, there are biases related to time of day reporting, underreporting of small snow measurements, and tendencies to report snow depth as the total of snow depth and new snowfall (i.e., not fully capturing role of compression of pack), as previously documented (Robinson 1988; Kunkel et al. 2007; Doesken and Robinson 2009). Despite these limitations, validation metrics suggest the gridded snow dataset provides satisfactory levels of accuracy relative to in-situ observations for the described objectives (Dawson et al. 2018; Zeng et al. 2018).

The output from this analysis is at the gridded snow dataset's native 4 km spatial resolution. While some degree of homogeneity could be expected within the domain, it is possible that there may be specific locations within individual grid cells which would offer better or worse representation of the overall climate division domain. Given the design and availability of the data, this cannot be overcome. As such, there will still arise the need for human subjectivity for determining station siting.

3. RESULTS

3.1. A BRIEF SNOW CLIMATOLOGY

To more fully understand snow cover variability across Kentucky, a brief climatology of snow depth, SWE, and snow cover frequency is presented. Relative to more northerly regions, snow cover in Kentucky can be reasonably classified as transient, with snow cover existing for approximately 33.1 days per snow season somewhere within the state, on average, with a mean depth of 35.3 mm on snow cover days and mean SWE of 7.7 mm (Figure 2). Spatially, there was variability in average snow depth and SWE across the state,

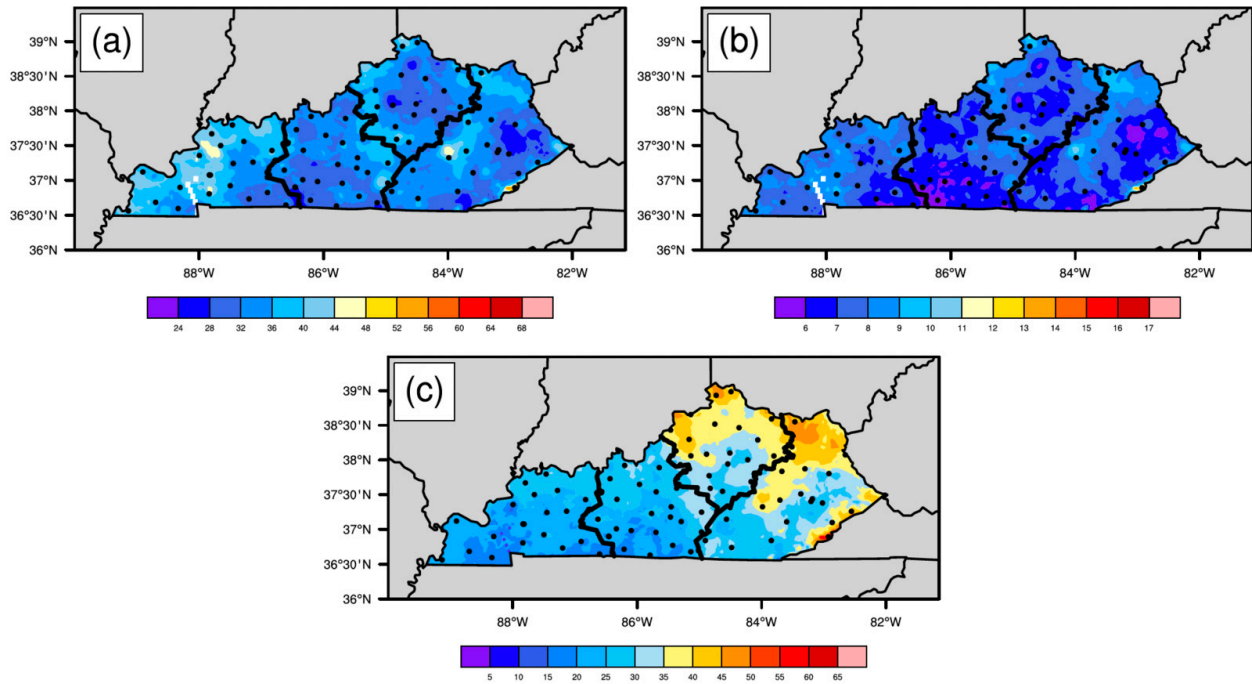


Figure 2. October-September 1981-2023 seasonal mean (a) snow depth and (b) SWE in mm, and (c) snow cover frequency in days. Climate divisions and Kentucky Mesonet stations shown for reference.

and an isolated region in the extreme southeast for which snow depth and SWE were approximately double the statewide average due to topographic enhancement (Figure 2a, 2b). There was greater variation, however, for the frequency of snow cover across the state. Across the southern tier of Kentucky, snow cover was present for approximately 15-17 days per snow season, compared to over 45 days per year in the northeast (Figure 2c).

Climate division 1 had the largest average seasonal snow depth from 1981-2023 at 37.0 mm (SD: 32.3 mm) of Kentucky's four climate divisions, followed by climate divisions 3, 4, and 2. Variations in snow depth were large within the climate divisions, where divisions 1, 2, and 4 exhibited coefficients of variation over 100% (Table 1). There was relatively little variation between the four climate divisions with respect to SWE with all four divisions ranging between a seasonal mean of 6.7-7.5 mm of SWE (Table 1). Despite exhibiting the largest mean seasonal snow depth of the four divisions, climate division 1 exhibited the smallest average seasonal snow cover frequency at just 22.8 days (SD: 12.9 d). In comparison, climate division 3 had the largest seasonal frequency of snow cover at 35.4 days (SD: 17.0 d; Table 1).

3.2. SPATIAL CORRELATIONS OF SNOW VARIABLES

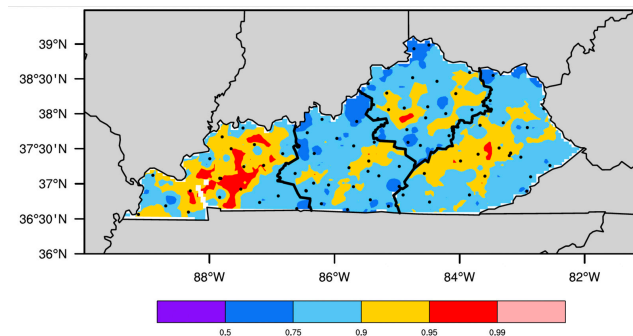
Statewide, the average correlation coefficient between climate division-averaged snow depth and that of their spatially-corresponding individual grid cells was 0.86, indicating a relatively large amount of variance explained. Of the climate divisions, correlations were highest within climate division 1 (Figure 3); 79.9% of the variance in climate di-

vision 1's average snow depth was explained by the snow depth of the average grid cell. Within climate division 1, the maximum correlation between the climate division average and an individual grid cell was 0.98 compared to a minimum of 0.57; some 20% of climate division 1 had grid cells with a correlation coefficient greater than 0.95. With climate division 2, there was a corridor of relatively higher correlation coefficients above 0.90 in the southcentral to east central portions of the division. However, relatively larger regions to the north, west, and southeast exhibited correlation coefficients below 0.75. Collectively, the average grid cell explained 68.2% of the variance in climate division two's average snow depth, ranging from a maximum of 91.1% to a minimum of 29.1% (Figure 3). Climate division 3 was the most spatially consistent of the divisions with respect to the snow depth variable. The average correlation coefficient was 0.84, ranging from 0.96-0.56 and the maximum variance explained occurring in the central portion of the division (Figure 3). Within climate division 4, the most variance explained in average snow depth was observed in the central and western portions of the division (Figure 3). The average correlation coefficient was 0.86, the second highest of the four divisions.

Statewide correlation between grid cells and their corresponding climate division averaged SWE was 0.83, with the maximum value of 0.98 and minimum value of 0.37 occurring with climate division 1 (Figure 4). Similar to snow depth, climate division 1 had the highest average correlation coefficient of the four divisions at 0.86, followed by climate divisions 4, 3, and 2 at 0.84, 0.82, and 0.79, respectively. For divisions 1, 3, and 4, the maximum correlation coefficients were generally located in the center of the cli-

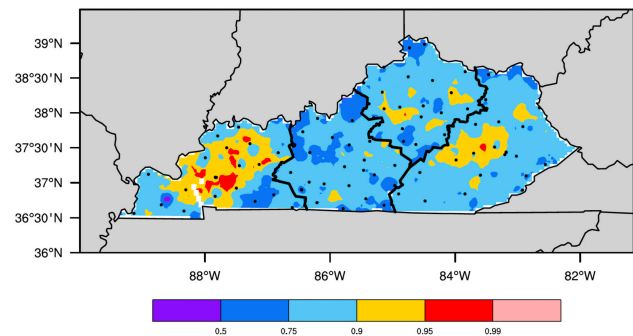
Table 1. Areal-weighted October-September seasonal descriptive statistics for snow depth (mm), SWE (mm) and snow cover frequency (days) from 1981-2023 for Kentucky's four climate divisions.

	CD 1	CD 2	CD 3	CD 4
Snow Depth				
Mean (mm)	37.0	32.7	33.6	33.3
STDDEV (mm)	32.3	22.1	19.3	23.0
Coef. Var. (%)	87.3	67.7	57.4	68.9
Max (mm)	145.9	118.5	91.7	105.5
Min (mm)	4.2	4.7	6.5	5.6
SWE				
Mean	7.3	6.7	7.5	7.3
STDDEV	6.2	4.4	4.5	5.1
Coef. Var.	85.3	65.7	59.7	69.8
Max	26.3	22.5	19.0	24.6
Min	1.1	1.3	1.5	1.5
Snow Cover Frequency				
Mean (d)	22.8	25.3	35.4	33.9
STDDEV (d)	12.9	13.6	17.0	14.9
Coef. Var. (%)	56.6	53.9	47.9	43.9
Max (d)	54.9	53.4	75.1	65.6
Min (d)	3.6	5.1	7.5	8.3


Figure 3. Correlation coefficient between individual grid cells' mean 1981-2023 seasonal snow depth and the geographically-corresponding mean seasonal climate division snow depth. Kentucky Mesonet station locations displayed as dots.

mate divisions, however for climate division 2, the maximum value was located in the southcentral region of the division (Figure 4).

Of the three analyzed variables, the correlations between the frequency of snow cover for climate divisions and their corresponding grid cells were the highest, with over 90% of Kentucky exhibiting a correlation coefficient of 0.9 or higher (Figure 5). The average station-wide correlation coefficient was 0.93, indicating the average grid cell explained approximately 86.9% of the variance in its respective climate division's seasonal frequency of snow cover. There was a zone of relatively higher correlation coefficients, in excess of 0.95, stretching southwest to northeast across climate divisions 1, 2, and 3 parallel to the Ohio River (Fig-


Figure 4. As in Figure 3, but for seasonal SWE.

ure 5). Within climate division 1, an average of 88.0% of the variance in seasonal snow cover frequency was explained by the average grid cell, compared to 86.2%, 90.1%, and 84.3% variance explained for climate divisions 2, 3, and 4, respectively (Figure 5).

3.3. ALIGNMENT WITH KENTUCKY MESONET STATIONS

The majority of the grid cells containing Kentucky Mesonet stations report correlation coefficients in excess of 0.9 for at least one of the three snow variables, however differences exist by variable. The average grid cell with a Kentucky Mesonet station explained 71.7% of the variance in climate division snow depth, 66.3% in SWE, and 85.7% in snow cover frequency. Within climate division 1, the top five ranking stations with the highest correlation coefficients across all three variables were PGHL, CCTY, PRCC, DRFN and PVRT which exhibited coefficients for average climate

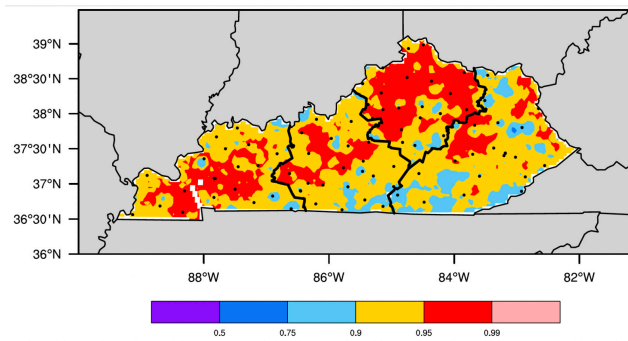


Figure 5. As in [Figure 3](#), but for seasonal snow cover frequency.

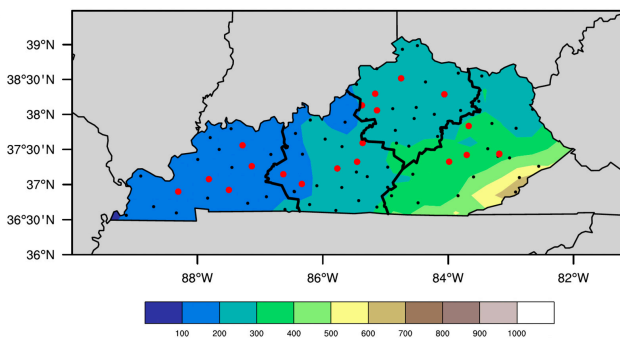


Figure 6. Kentucky Mesonet stations, in red, identified as being among the top five stations for explaining the variability in climate division specific snow variability, 1981-2023. Stations not in the top five per division are retained as black dots.

division 1 snow depth, SWE, and snow cover frequency of 0.95, 0.94, and 0.96, respectively ([Table 2](#)). Within climate division 2, the top five stations, WDBY, BNGL, HDYV, LRTO, and EWPK, exhibited average correlation coefficients of 0.89, 0.86, and 0.95 for snow depth, SWE, and snow cover frequency, respectively ([Table 3](#)). Within climate division 3, the top five stations for explained variance in the snow variables were CARL, CROP, WADD, SWON, and FCHV. Average correlation coefficients across those stations were 0.90 for snow depth, 0.89 for SWE, and 0.96 for snow cover frequency ([Table 4](#)). Finally, within climate division 4, the top five stations were OLIN, RFRT, RFVC, BNVL, and DCRD. The average correlation coefficients across the top five climate division 4 stations were 0.92 for snow depth, 0.90 for SWE, and 0.94 for snow cover frequency ([Table 5](#)).

Spatially, the grid cells with Kentucky Mesonet stations identified as those with the highest correlations with their respective climate division snow conditions are generally located within the central portion of the divisions with respect to latitude, however are not necessarily central with respect to longitude ([Figure 6](#)). With the exception of the RFRT and RFVC stations in Breathitt County of climate division 4 that are in very close geographic proximity (< 2 km), the isolated stations cover a relatively large portion of their respective climate divisions ([Figure 6](#)). The decision to retain both RFRT and RFVC as separate stations in cli-

mate division 4, despite their close geographic proximity, was due to their relative elevation and siting. RFRT sits at approximately 220 m higher elevation than RFVC and is at the top of a mountain ridge. In comparison, RFVC is located in the valley between mountain ridges. Retaining both stations not only best represents the results based on the experimental design but also could allow for future research into the exploration of topographic enhancement of snow characteristics.

4. DISCUSSION

The spatial variations of snow depth, SWE, and frequency of snow cover days across Kentucky exhibit many similarities to previous analyses of snowfall, but some key differences are observed. First, the frequency of snow days, here, were largest along the northern-most tier of Kentucky, and in the regions of highest elevation to the east (see [Figure 2c](#)). This pattern resembles that of the seasonal snowfall frequency climatology, where approximately 12-16 daily snowfall events were observed per year in northern Kentucky from 1948-2021 and seasonal snowfall totals peaked in the east along the Appalachian Mountains (Suriano and Guercio 2024). This is a logical association as more frequent snowfall would likely equate to more frequent snow cover. Secondly, the magnitude of average snow depth ranged from approximately 25-45 mm across the state, with some of the highest values occurring in the western portions of the state, where elevation and snow cover frequency was the least, on average. Based on the study design, only days with snow cover are included in the descriptive statistics of seasonal averages (i.e., days with no snow cover are removed). As such, this suggests the snowpack in the western region (climate division 1) likely ablates quickly following snowfall accumulation as to have fewer days with shallow snow depths relative to the eastern regions. Prior research into the climatology of snow ablation across the Ohio River Valley supports this conclusion; A region of relatively enhanced snow ablation frequency and magnitude (~25% greater than Kentucky average) was reported in western Kentucky, aligning with the western climate division, here (Suriano et al. 2024). This further adds to the importance of snow monitoring in this region where it is feasible for there to be a relatively enhanced flood risk associated with rapid snow ablation, potentially in association with rain-on-snow (Levia and Leathers 2011; Freudiger et al. 2014; Cohen et al. 2015).

Within each climate division, locations generally within a more central latitudinal position appear to have relatively higher correlations to their respective climate division averages than locations at more northerly or southerly locations. We suggest this can be reasonably attributed to the patterns that generate, and ultimately ablate, snow from specific weather systems that impact the state. For much of Kentucky, the majority of snowfall occurs from the wrap-around sector of mid-latitude cyclones that traverse the region, with secondary snowfall occurring from snow bands in the northeast quadrant of the low (Guercio and Suriano 2025). The patterns of snowfall from these weather systems

are largely zonal in nature and vary primarily as a function of temperature profiles associated with the specific storm track (Guercio and Suriano 2025), similar to that of the larger mid-south and Ohio valley regions (e.g., Kluver and Leathers 2015). Additionally, it is anticipated that snow ablation would similarly occur over more uniform spatial patterns given the mechanisms linked to rapid ablation in the eastern United States (e.g., Suriano et al. 2023). As such, more central locations latitudinally, not necessarily longitudinally, logically better capture the variation in snow conditions within individual climate divisions. Further variability in regions with enhanced correlations to climate division averages may be due to more localized land surface conditions and other geographic features and could be explored in future research in application to snow hazards or resources. Elevation did not appear to be a meaningful factor in the magnitude of variance explained in the gridded products of snow depth, SWE, or snow cover frequency correlations for Kentucky Mesonet stations within the climate divisions. While higher elevation stations are anticipated to have deeper and more persistent snow due to heavier snowfalls (e.g., Guercio and Suriano 2025), having a higher elevation doesn't necessarily mean it is a better representation of the snow characteristics of the climate division, as shown here with station elevation not being a significant predictor of climate division scale correlations of snow characteristics.

This effort identified five Kentucky Mesonet stations within each of the state's four climate divisions for prioritized consideration in adding snow monitoring instrumen-

tation, for a state-wide total of 20 stations. Ultimately this threshold of five stations per climate division was subjective and used as a benchmark based on a target of limiting deployment to less than 25% of current Kentucky Mesonet stations. This value could be reasonably adjusted based on available funding and need. However here, the five-station threshold aligns closely to a correlation coefficient of 0.90, meaning nearly all of the stations identified are explaining a very large amount of variance in their respective climate division's snow conditions. It is possible for changes over time in snow characteristics to influence these results, where increases or decreases over time could render the representation of a climate division by a station less effective. However, evidence largely suggests insignificant changes in related variables such as snow ablation frequency and magnitude, snowfall frequency, and to a lesser extent, snowfall magnitude per event (Suriano and Guercio 2024; Suriano et al. 2024).

State weather networks, such as the Kentucky Mesonet, provide a unique opportunity for monitoring local winter weather, as already demonstrated by other networks. For instance, the New York State Mesonet includes snow depth sensors at all 126 sites in addition to 17 SWE sensors deployed across the Adirondacks region (e.g., Brotzge et al. 2020; <http://nysmesonet.org/networks/snow#stid=snow>). Similarly, the state of Delaware maintains a robust 26-station snow monitoring network that provides real-time snow depth measurements in support of the Delaware Department of Transportation snow removal reimbursement program and other applications (Mahmood et al. 2017;

Table 2. Correlation coefficients between individual grid cells aligned with Kentucky Mesonet stations and areal-weighted averages in Kentucky Climate Division 1 for snow cover frequency, SWE, and snow depth. A station's rank relative to the others within the Climate Division is quantified. The Rank Total is the rank of the rankings.

STID	Lat	Lon	Correlation Frequency	Correlation SWE	Correlation Depth	Rank Freq	Rank SWE	Rank Depth	Rank Total
PGHL	36.95	-87.52	0.97	0.94	0.96	1	1	1	1
CCTY	37.29	-87.16	0.96	0.94	0.95	3	2	3	2
PRCC	37.10	-87.85	0.95	0.93	0.95	5	5	2	3
DRFN	36.92	-88.34	0.95	0.93	0.95	6	4	4	4
PVRT	37.59	-87.32	0.96	0.93	0.93	4	6	7	5
DIXO	37.52	-87.69	0.93	0.93	0.95	11	3	5	6
PNCC	37.10	-87.87	0.95	0.92	0.93	7	8	8	7
PRNC	37.10	-87.86	0.95	0.92	0.93	7	8	8	7
ERLN	37.27	-87.48	0.92	0.93	0.95	17	7	6	9
MRRY	36.61	-88.36	0.96	0.80	0.92	2	17	11	9
CADZ	36.83	-87.86	0.94	0.87	0.87	9	11	16	11
FRNY	37.69	-87.84	0.92	0.90	0.92	16	10	10	11
HCKM	36.57	-89.16	0.93	0.87	0.91	15	12	12	13
GRHM	37.82	-87.51	0.94	0.87	0.86	10	14	17	14
HTFD	37.46	-86.86	0.93	0.86	0.88	12	15	14	14
BAND	37.13	-88.95	0.93	0.85	0.87	14	16	15	16
RPTN	37.38	-88.04	0.89	0.87	0.89	19	13	13	16
ZION	36.76	-87.21	0.93	0.65	0.80	13	21	21	18
PRYB	36.70	-88.72	0.92	0.77	0.84	18	19	19	19
SWZR	36.67	-86.61	0.88	0.79	0.81	20	18	20	20
RSVL	36.85	-86.92	0.87	0.74	0.84	21	20	18	21

Table 3. As in [Table 2](#), but for Climate Division 2.

STID	Lat	Lon	Correlation Frequency	Correlation SWE	Correlation Depth	Rank Freq	Rank SWE	Rank Depth	Rank Total
WDBY	37.18	-86.65	0.96	0.88	0.90	1	2	2	1
BNGL	37.36	-85.46	0.95	0.89	0.93	7	1	1	2
HDYV	37.26	-85.78	0.96	0.85	0.89	3	4	3	3
LRTO	37.63	-85.37	0.95	0.86	0.86	4	3	7	4
EWPK	37.04	-86.35	0.95	0.84	0.87	5	7	5	5
MROK	37.01	-86.11	0.96	0.83	0.82	2	8	13	6
PCWN	37.28	-84.96	0.92	0.85	0.85	14	5	8	7
HARD	37.76	-86.46	0.95	0.81	0.80	6	9	14	8
HDGV	37.57	-85.70	0.93	0.77	0.85	11	10	9	9
RNDH	36.99	-85.70	0.87	0.84	0.87	23	6	4	10
BRND	37.95	-86.22	0.94	0.76	0.78	9	11	15	11
BLRK	37.46	-86.34	0.94	0.73	0.75	8	14	18	12
GRBG	37.21	-85.47	0.84	0.76	0.86	24	12	6	13
GRDR	36.80	-85.43	0.92	0.75	0.76	12	13	17	13
CMBA	37.14	-85.29	0.90	0.73	0.77	19	15	16	15
CCLA	37.68	-85.98	0.94	0.68	0.71	10	20	21	16
FARM	36.93	-86.47	0.88	0.66	0.83	20	21	10	16
CRMT	36.93	-86.47	0.88	0.66	0.83	13	16	24	20
ALBN	36.93	-86.47	0.88	0.66	0.83	17	18	19	21
SCTV	37.92	-85.66	0.92	0.71	0.65	15	17	23	22
WOOD	36.71	-85.14	0.90	0.68	0.74	18	19	22	23
GAMA	36.74	-86.22	0.92	0.71	0.70	16	24	20	24

Table 4. As in [Table 2](#), but for Climate Division 3.

STID	Lat	Lon	Correlation Frequency	Correlation SWE	Correlation Depth	Rank Freq	Rank SWE	Rank Depth	Rank Total
CARL	38.32	-84.04	0.97	0.93	0.93	2	1	1	1
CROP	38.33	-85.17	0.96	0.91	0.92	8	2	2	2
WADD	38.09	-85.14	0.96	0.91	0.91	6	3	3	2
SWON	38.55	-84.74	0.97	0.86	0.86	1	6	9	4
FCHV	38.16	-85.38	0.95	0.84	0.89	9	8	4	5
WSHT	38.62	-83.81	0.95	0.88	0.88	13	4	5	6
RBSN	38.50	-84.35	0.97	0.82	0.86	3	11	10	7
LSML	38.12	-84.88	0.96	0.83	0.83	4	9	13	8
PRST	38.09	-83.78	0.95	0.83	0.88	10	10	8	9
ELST	37.72	-84.15	0.91	0.86	0.88	20	5	7	10
LXGN	37.97	-84.53	0.94	0.84	0.86	15	7	11	11
SPIN	38.13	-84.50	0.94	0.80	0.88	14	13	6	11
HRDB	37.81	-84.84	0.96	0.77	0.83	7	16	14	13
BLOM	37.96	-85.31	0.96	0.73	0.81	5	19	15	14
CRRL	38.69	-85.14	0.95	0.82	0.81	11	12	16	14
WNCH	38.03	-84.21	0.94	0.79	0.85	16	15	12	16
HHTS	39.02	-84.47	0.95	0.74	0.72	12	18	19	17
LGNT	37.58	-84.62	0.88	0.79	0.79	21	14	17	18
LGRN	38.46	-85.47	0.93	0.77	0.76	19	17	18	19
DANV	37.62	-84.82	0.94	0.66	0.70	17	21	20	20
HUEY	38.97	-84.72	0.93	0.69	0.68	18	20	21	21

Table 5. As in [Table 2](#), but for Climate Division 4.

STID	Lat	Lon	Correlation Frequency	Correlation SWE	Correlation Depth	Rank Freq	Rank SWE	Rank Depth	Rank Total
OLIN	37.36	-83.97	0.95	0.92	0.93	2	1	1	1
RFRT	37.47	-83.16	0.94	0.91	0.93	4	2	3	2
RFVC	37.46	-83.16	0.94	0.91	0.93	4	2	3	2
BNVL	37.45	-83.69	0.93	0.90	0.93	9	4	2	4
DCRD	37.87	-83.65	0.96	0.88	0.90	1	6	8	4
QKSD	37.54	-83.34	0.92	0.88	0.91	12	5	7	6
DABN	37.18	-84.56	0.92	0.86	0.92	11	9	5	7
RFSM	37.43	-83.18	0.92	0.88	0.90	10	7	9	8
LUSA	38.10	-82.60	0.93	0.86	0.86	7	8	12	9
FLRK	36.77	-84.48	0.94	0.82	0.83	3	13	16	10
PBDY	37.14	-83.58	0.90	0.86	0.91	16	10	6	10
VEST	37.41	-82.99	0.90	0.83	0.89	15	12	10	12
WLBT	37.90	-83.27	0.89	0.82	0.87	17	14	11	13
DORT	37.28	-82.52	0.93	0.75	0.77	6	19	19	14
BTCK	37.83	-82.88	0.85	0.85	0.85	19	11	14	14
WTBG	37.13	-82.84	0.93	0.72	0.79	8	20	17	16
BMBL	36.87	-83.83	0.91	0.76	0.84	14	17	15	17
MONT	36.87	-84.90	0.88	0.81	0.85	18	15	13	17
CHTR	38.58	-83.42	0.91	0.76	0.75	13	18	20	19
MRHD	38.22	-83.48	0.80	0.76	0.78	20	16	18	20
BMTN	36.92	-82.91	0.78	0.68	0.69	21	21	21	21

<https://deos.udel.edu/applications/snow-conditions/#/>).

For southern states such as Kentucky that operate similar networks, a few, relatively inexpensive operational changes could allow for routine monitoring of winter weather. Snow depth sensors could be added at a subset of stations, as discussed herein. Cameras at sites provide still images that can be used to verify automated snow depth sensors; a snow stick can be placed in the camera field of view to aid with image interpretation (Brotzge et al. 2022). The use of weighing gauges, as already operated by Kentucky Mesonet, can aid with estimating snow water equivalent.

The results from this work are encouraging in that relatively few sites must be outfitted with snow sensors to capture mean regional snow estimates. If knowing the range and/or variance of snow totals across an area were of more importance, then far more sites, labor and resources would be needed; for example, far more mountainous sites across eastern Kentucky would need to be equipped with snow depth sensors than estimated herein. For some applications (e.g., emergency management, transportation), more sites may be needed to capture those localized snow totals in troublesome areas. Nevertheless, this work shows that a relatively few stations across each climate division is more than sufficient for long-term climate monitoring, and this can be achieved at relatively low cost.

5. CONCLUSIONS

Snow within Kentucky, and the mid-south U.S. broadly, is classified as a transient, where only a small number of

snowfall events occur per year and snow cover, depth, and water equivalent are relatively low compared to more northerly regions. As such, there historically has been limited interest for the substantial investment needed for a large-scale deployment of snow monitoring infrastructure. However, the transient nature of snow here has a counter-intuitive effect where despite relatively lower frequencies and totals, there is a relatively higher than anticipated impact to the community. We posit that a small and targeted deployment of snow monitoring infrastructure can provide value-added benefits to the community by strategically positioning instrumentation based on its representativeness of a larger domain without substantial cost. This research assessed the statistical association between snow variables at individual locations across the Commonwealth of Kentucky to that of the average snow conditions by climate division from 1981-2023. A number of sub-regions within each climate division were identified as having significant correlations to their respective climate division averages, in excess of a coefficient of 0.90, and further aligned with existing observational stations from the Kentucky Mesonet. A total of five stations were identified within each climate division as candidates for prioritization based on having among the highest significant correlations with respect to snow depth, SWE, and frequency of snow cover over the 42-year period. With these priorities in hand, initial piloting of snow monitoring can begin with greater confidence in the representativeness of individual stations to the larger domain. For other states or regions considering a partial roll out of snow monitoring infrastructure, this approach may be considered.

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ACKNOWLEDGEMENTS

This research is based upon work supported by the NOAA / Desert Research Institute (DRI) sub-award National Centers for Environmental Information under award GR21039 and the U.S. National Science Foundation under award 2344533. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NOAA/DRI or NSF. Mr. Samuel Davidson is acknowledged for his efforts in

developing an algorithm to extract the gridded datapoints corresponding to U.S. Climate Division boundaries.

DATA AVAILABILITY STATEMENT

Snow data used in this study are publicly available at the National Snow and Ice Data Center.

Submitted: July 23, 2025 EDT. Accepted: March 22, 2026 EDT.



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