Evaluating and Enhancing the New York State Mesonet (NYSM)
Snow Accumulation Estimation

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Abstract

This research project aims to examine and enhance the performance of the New York State Mesonet (NYSM) Snow Accumulation Estimation. The NYSM is a state-of-the-art network of 126 standard weather stations located across the state of New York, collecting high-quality meteorological data to improve forecast accuracy, reduce uncertainty, and mitigate harm. All NYSM standard stations measure snow depth with Campbell Scientific’s SR50A ultrasonic distance sensor. This acoustic sensor measures the distance from the sensor to a rigid snowboard if there is no snow on the ground or the top of snow layer. A reference distance and a temperature correction are applied to determine the snow depth. While snow depth measurements can be made relatively straightforward with the use of this sensor, recording total snow accumulation is more difficult. During heavy snowfall events, compaction acts to reduce total snow depth during the course of a long-duration event. Then after a snowfall event, drifting of snow may act to reduce or increase snow depth depending on the water content of the snow and the wind speed. Due to these factors, there is often a difference between estimated snowfalls and the actual snow accumulation. As such, snow accumulation is calculated using an algorithm developed by the NYSM using snow depth, rain gauge precipitation, temperature and other data. This project aims to examine the performance of this algorithm in providing accurate snow accumulation data, and to find possible enhancements to improve this algorithm.

To complete this evaluation, data has been synthesized from throughout the winter of 2022-2023, including NYSM daily snowfall data, as well as National Centers for Environmental Information (NCEI) daily snowfall data, to draw comparisons between the data sets. Data from winter 2022-2023 and previous winter seasons have shown NYSM snowfall data systematically lower than NCEI data for most locations across NYS. This project will examine the reasons for these differences, and examine individual cases during winter 2022-2023 to determine how the snow accumulation algorithm behaved on both a seasonal and daily basis. The findings of this project will contribute to a better understanding of the methods used to produce accurate snow accumulation measurements, and improve those measurements overall particularly for the New York State Mesonet.
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1) Introduction

1.1) Background

While being one of the most difficult meteorological phenomena to predict and measure, snow accumulation is one of the most important and impactful (Doesken 2009). Snowfall events can occur in many different varieties including synoptic scale low pressure systems, snow squalls, and lake effect snow bands. New York State, in its varying topography and geography, is unique in the United States as it is susceptible to all of these snowfall hazards which are impactful in their own ways. The effects of snowfall not only occur from a societal impacts standpoint but also a forecasting standpoint, as data from NYSM sites and similar snowfall measurements are used as input for NWP model initializations. This paper will focus on snowfall in New York State, how NYSM sites measure snowfall in comparison to other data sources, and how the data that the NYSM provides could be improved, if at all.

1.2) Types of Snow Events in NYS

New York state has some of the most varying geography of any state in the northeast, leaving it susceptible to a wide variety of winter weather hazards. The NYC Metropolitan area, one of the most populous urban centers in the world, is located on the coast and subject to coastal snowstorms such as nor’easters that can bring heavy snow and other impacts such as high winds and mixed precipitation. Upstate New York features complex topography, where valleys such as the Mohawk and Hudson, and mountains such as the Catskills and Adirondacks play a large role in where snow accumulates heaviest. In many cases, where temperatures are marginally cold
enough for snowfall, the difference in a few hundred feet of elevation will be the difference between a high-impact snowfall event and a cool rain. Additionally, the Great Lakes, specifically Erie and Ontario, allow for extreme lake effect snow events to take place where feet of snow can quickly bury cities such as Buffalo and Syracuse (Hartnett 2021). Snowfall generally occurs in New York State between November and April of each year, so with the variety of hazards posed by snowfall and the length of the snowy season in the state, it is crucial to both accurately measure and predict snowfall.

1.3) Snowfall Measurements

Snowfall measurements have been taken for decades along with other weather records via manual measurements. Since networks such as ASOS replaced manual observers, reliable snowfall measurements became less common and reliable (Ryan et al 2008). More recently however, automated meteorological measurements have taken over as the primary source of weather data. This works out very well for variables such as temperature which can easily be measured with a thermometer, but not as well with snowfall, which is most easily measured with a snow stick. Once automated measurements became more commonplace, snow accumulation measurements became less common as they were more difficult to take without an in-person observer. However, instrumentation such as the Campbell Scientific SR50 aims to solve this issue by sending out a sound pulse and determining the height (depth) of the snow via how long it takes to receive the pulse back at the sensor.
While instruments such as the SR50 can be very helpful in providing a measurement for snow on the ground, they are not a perfect solution. There are a number of factors that will alter the amount of snowfall on the ground during a storm such as blowing, drifting, and compaction. These factors can lead to uncertainty in the snow depth measured, especially whereas blowing and drifting can lead to uneven areas of snow depth (Fischer 2011). The bigger issue with these other factors comes when further calculating snow accumulation. Change in snow depth, along with other measurements, such as a liquid precipitation threshold are used to calculate total snow accumulation. The use of the liquid precipitation threshold should be investigated, as it has been found that many snowfall events occur without measurable liquid precipitation (Ryan 2013) Total snow accumulation will often be different than current snow depth because of compaction throughout a snowfall event decreasing snow depth or blowing/drifting snow artificially decreasing or increasing snow depth. By using SR50 sensors, the current snow depth can be measured, with snow accumulation being estimated from those values. Another issue that arises with these measurements comes up during particularly heavy snowfall. Because it is an acoustic sensor, a high number of large snowflakes falling between the sensor and the ground will cause interference, decreasing measurement quality. This is problematic because it is during these periods of heavy snow that it is important to have measurements, but when measurement quality with these sensors struggles the worst. These sensors are technically able to measure to 0.1”, though that may be too optimistic, with perhaps 0.5” being more realistic, especially when heavy snowfall compromises data quality (Ryan 2013).
1.4) Use in Forecasting and Model Evaluation

Accurate meteorological observations are crucial not only for operational applications but for research as well. Data collected from observations made at NYSM sites are fed into NWP models and used as input for initialization conditions. In addition to using this data as input for NWP models, it can be used after the storm has passed as well to evaluate the model’s performance. In this project, the NYSM snowfall estimation is analyzed to determine the accuracy of snow accumulation measurements that are being fed into these models. These more accurate measurements can then be used to evaluate the performance of NWP models.

Understanding the quality of data going into forecast models and verifying research models is crucial, but this data is also important for real time forecasting as well. During winter storm events, having live measurements of snow accumulation, even in remote locations, allows for more accurate real-time forecasting, and better messaging of impacts (Hurwitz 2020).

1.5) Science Questions

Considering this introductory information, answers to the following questions will guide this project. Firstly, what are the primary sources of differences in snow accumulation between the NYSM and NCEI data, and how do these discrepancies vary across geographic and meteorological conditions? Following that, how well does the current NYSM snowfall algorithm perform in capturing snowfall events compared to NCEI data, and in what ways, if any, can it be enhanced to reconcile observed differences in snow accumulations?
2) Data and Methods

This project utilizes snow accumulation data from the New York State Mesonet as well as from the National Center for Environmental Prediction (NCEI) so that the two datasets can be compared. Location data and daily snowfall data were acquired from both sources to allow comparisons to be drawn between the two sources. NYSM data was pulled from all 126 standard stations, including daily snowfall and liquid precipitation. NCEI data was pulled from all stations in New York and neighboring states including Pennsylvania, New Jersey, Connecticut, Massachusetts, and Vermont.

2.1) Data

2.1.1) New York State Mesonet (NYSM)

The main dataset used for this study will come from the NYSM. The NYSM provides high-quality meteorological observations with a high spatial and temporal density across the state of New York. This network of weather stations includes 126 standard stations where standard meteorological variables are measured such as temperature, humidity, wind speed/direction, pressure, solar radiation, soil temperature/moisture, and snow depth (Brotzge 2020). There are a variety of instruments at these sites to collect this data, however, the instrument of importance to this work is the SR50A snow depth sensor manufactured by Campbell Scientific. The SR50A is an acoustic sensor that measures the distance between the sensor and a rigid snowboard on the ground. It measures the distance as a function of how long it takes for a sound wave to return to
the sensor after bouncing off the rigid snowboard on the ground. A reference distance and temperature correction are applied to determine the snow depth from the readings provided by this sensor. Further, an algorithm is applied to derive the snow accumulation from snow depth.

Because of the effects of compaction, as well as blowing and drifting, snow depth measurements, even taken just at the end of a winter storm, are often not representative of the true snow accumulation that occurred in a given location. Since SR50A snow depth sensors can only directly measure snow depth, the NYSM utilizes a basic algorithm to determine the snow
accumulation. First, a 30-minute moving average of snow depth is recorded from the SR50A snow depth sensor. Then, if the difference in snow depth over the given time span is positive, and the change in liquid precipitation during the same time span is above 0.05mm, the change in snow depth is added to snow accumulation. The first criterion of having positive snow depth change ensures that accumulation will only change if snow depth increases, as there cannot be a negative accumulation. The second criterion of liquid precipitation ensures that all changes in snow depth are a result of actual new snowfall as opposed to blowing or drifting snow that may land under the sensor, even when snow is not actively falling. The 0.05mm threshold is selected to avoid any potential false precipitation that may be recorded by the Pluvio rain gauge, which may occur at values less than 0.05mm. One concern with this 0.05mm threshold has been that it may be too selective, and unintentionally filtering out actual snowfall. This potential issue is examined in this project. 5-minute liquid precipitation data is analyzed along with snow accumulation to determine if there are any circumstances where it did in fact snow, but the liquid precipitation fell below the threshold, filtering out that snowfall.

2.1.2) National Center for Environmental Information (NCEI)

The dataset being used to compare against the NYSM snowfall data in this project is sourced from NCEI. NCEI keeps records of daily snowfall in every state in the United States, including New York and the surrounding states. These sites, GHCN stations, are similar to the NYSM in that they feature a relatively high spatial density across the state, making it possible to effectively compare the snowfall between them. GHCN stations however are less consistent than NYSM stations, as the NCEI dataset is comprised of a variety of different networks, with
CoCoRaHS, COOP, and WBAN stations all being counted as GHCN stations. While there may be some inconsistency due to the inclusion of multiple networks, all snowfall measurements are recorded by hand with in-person observers. This means that it will be possible to observe the potential differences that may arise due to differences in measurement techniques, manual vs automatic.

Figure 2 Map of NCEI stations measuring snowfall across New York State. Measurements shown include snow accumulation measured on 26 December 2022.
2.2) Methods

In order to begin drawing comparisons between NYSM and NCEI snowfall data, the difference in site locations must first be addressed. Considering that both networks feature a relatively high spatial density, it is possible to find stations that are close enough to where their snowfall measurements can be accurately compared. The first step in this process is to find the distances between NYSM sites and their closest NCEI stations. Given the latitude and longitude of both networks’ stations, the haversine distance was calculated between all the stations between both networks. A data frame was then created which paired each NYSM station with its closest NCEI station. This data was then filtered, where any NYSM station whose closest NCEI counterpart was over 16km (~10 miles) apart would not be counted. This threshold was determined to match an earlier study that compared the previous season’s snowfall using this distance threshold between sites. By using the same threshold here, an accurate comparison between the results of this project and the previous project can be drawn.

While distance between sites is a very important factor in determining how similar two stations are, it is not the only factor that can cause differences in data. With varying topography across many parts of New York State, it is also important to consider elevation. In the case where there may be stations that are only 10km apart, but an elevation difference of around 1000ft, these stations should not be considered similar enough to compare snowfall data. In many cases, elevation may actually be a much more important factor than distance in determining how similar two nearby stations are, as elevation-dependent snowfall events are very common in New York State, where valley locations often receive little to no snow while the higher terrain may receive a major snowfall event. Considering this, a threshold of 500ft in elevation difference
between sites is used in addition to the distance threshold to filter neighboring stations. After filtering out stations that do not meet the distance and or elevation thresholds, the number of NYSM stations (and corresponding NCEI sites) is reduced from 126 to 102. This reduction, while significant, still provides enough sites to complete a thorough analysis of snow accumulation data across the state.

With an idea now of which sites are closest to each other and can be compared effectively, snowfall data can be processed and compared. A variety of plotting methods will be used to effectively compare this data on a daily and seasonal time scale. Time series plots will be crucial to examine the evolution of snow accumulation measurements at NYSM sites on a daily time scale. These snow accumulation time series plots can be overlayed with liquid precipitation to show how the snow accumulation increases along with liquid precipitation. This will be able to help in determining if the snow accumulation estimation is filtering out actual snowfall. Cumulative snowfall comparisons can also be done to examine the data over the entirety of the 2022-2023 winter season. By examining a comparison of cumulative snowfall between the NYSM sites and their nearest NCEI sites, we can get an idea of trends showing if automatic NYSM snowfall measurements are systematically different than standard, in-person measurements. These cumulative measurements can also be displayed on a map of New York State to examine any spatial pattern to differences in measurements between NYSM and NCEI. Finally, NYSM camera images can be used to verify the snowfall measurements, as 5-minute camera images will confirm or deny any change in snow depth.
3) Results

3.1) Cumulative Snowfall Comparison (NYSM vs NCEI)

Before discussing the cumulative snowfall comparisons between NYSM and NCEI measurements for the 2022-2023 winter season, it would first be useful to discuss a similar analysis completed for the previous season, 2021-2022. The premise for this project came about after an analysis for the previous season suggested a possible trend between NYSM and NCEI snowfall whereas the NYSM was potentially under-estimating snow accumulation (Figure 3). As shown in Figure 3 there is a clear trend where with higher or increasing snowfall amounts, it seems that NCEI snowfall measurements were higher than corresponding NYSM measurements. This issue raises some concerns from a number of standpoints, starting with the accuracy of the snow accumulation estimation used by the NYSM, as well as the accuracy of the snow depth sensors themselves. What is also considered is the accuracy and reliability of the NCEI snowfall data. Given that these are manual measurements that come from multiple different networks, this is another important factor to consider within the comparison.

![Figure 3 Comparison of NYSM vs NCEI snowfall during the 2021-2022 Winter Season. Regression line shows a positive trend where with increasing snow accumulation, the NYSM tends to underestimate snow accumulation. Plot made by Erik Creighton, 2023](image-url)
Having seen the trend in snow accumulation discrepancy between NYSM and NCEI for the 2021-2022 season, a similar comparison can be drawn for the following 2022-2023 season to see how they compare. If the following season were to show a similar trend, this could support the suggestion that NYSM sites are systematically underestimating total snow accumulation and that the algorithm used to derive snow accumulation from the snow depth sensor and other data may be filtering out actual snowfall. Having successfully mapped each NYSM station to its closest NCEI station, the comparison of cumulative snowfall for the 2022-2023 can be drawn. Figure 4 shows a similar scatterplot to Figure 3 where NYSM cumulative snowfall is on the x-axis and NCEI cumulative snowfall is on the y-axis. Immediately it can be noticed that there is a

Figure 4 Scatterplot of snow accumulation measurements between NYSM and corresponding NCEI stations for winter 2022-2023. NYSM snowfall on x-axis, corresponding NCEI snowfall on y-axis.
much less discernable trend over the entire season, with a somewhat even distribution of sites where cumulative snowfall is higher or lower at either the NYSM station or corresponding NCEI stations. There are however some parts of this plot that should be looked into more deeply. Firstly, is the group of scatter points located in the red circle, above the perfect alignment line. The pattern of these sites seems to somewhat closely represent a similar trend to what was seen in the previous years’ comparison, where the higher the snowfall amounts become, the more the NYSM measurements seem to be lower than the corresponding NCEI sites snow accumulation measurements. The other grouping of scatter points however, in the blue circle, show a different trend than what was seen in the previous season. These points are below the perfect alignment line suggesting NYSM snow accumulation measurements are higher than the corresponding NCEI measurements. There is seemingly less of a “trend” with these points, whereas when snow accumulation increases, it does not seem that NYSM measurements become increasingly better or worse. While a season-long overview such as this is useful to get an idea of how these measurements perform and compare over the long term, it is also important to look at shorter time scales in order to understand the reasoning behind these discrepancies.

3.2) Daily Snowfall Comparisons

To gain a better understanding of the reasoning behind the discrepancies between the NYSM and NCEI cumulative snow accumulation measurements, the first method here is making time series plots, plotting cumulative daily snowfall at particular sites. This will show the patterns of snow accumulation increases throughout the season, allowing a determination to be made on the exact causes of discrepancies at different NYSM and corresponding NCEI stations.
Figure 5 shows one example of a time series plot for the Harrisburg NYSM station and its corresponding NCEI station. This is one of the sites where the NYSM cumulative snow accumulation for the entire season was lower than its corresponding NCEI site. For situations like this, there could be a number of factors to look at. In the case of the Harrisburg site, we can see based on the time series that there was actually good agreement between the sites for the entire winter season. However, there was one snowfall event with a major disagreement between NYSM and NCEI measurements, which was quite a high-impact winter weather event, the Dec. 2022 lake effect snow event. This event brought blizzard conditions and record-breaking snowfall to the areas east of Lake Erie and Lake Ontario in New York State. Considering that Harrisburg is a site that lies in a lake-effect snow-prone area, it is possible that this played a role in the discrepancy between the measurements. This brings up an important issue when looking at this data, in that the measurements for NYSM and NCEI sites are in different locations. While a distance threshold was used to determine if sites were compatible enough to be effectively compared, there are some situations where issues may still arise due to site location differences, especially due to the varied geography, topography, and snow hazards across New York State. For example, where localized snowfall events set up, such as lake effect snow, snow squalls, or
even mesoscale snow bands, there can be occasionally major differences between sites that are only 10 miles or less apart from each other.

In the case of the Harrisburg site being in a lake effect area, the discrepancy noted for the 24 Dec through 26 Dec lake effect event could certainly be due to the difference in location between the NYSM and NCEI stations. One way to verify this is by including the liquid precipitation measured at the NYSM site during the same time. If there was only a minimal amount of liquid precipitation, it is likely that it simply did not precipitate or snow at the NYSM site, while just a few kilometers away at the NCEI site, it did in fact snow. This is verified in Figure 6, where it can be seen that on the days where the snow accumulation discrepancy occurred, there was only around one inch of liquid precipitation, which would be in support of the approximately 10 inches of snow that was reported at the NYSM site. While there are clearly examples of cases like Harrisburg that exist throughout the network, there are similar cases that do not have the same explanation, even though they still result in NYSM snowfall being reported lower than NCEI measurements, further contributing to possible reasoning for NYSM measurements appearing lower than NCEI.

Figure 6 Cumulative snowfall time series for Harrisburg (HARR) NYSM station (blue) and corresponding NCEI station (orange). Liquid precipitation time series (green) on second y-axis.
Another explanation for why NYSM snow accumulation measurements may appear lower is not because of the distance between NYSM and corresponding NCEI sites, but because of the conditions going on while the measurements are being taken. While automatic snow depth sensors such as the SR50A used at all NYSM standard stations are incredibly valuable in providing accurate snow depth readings with minimal maintenance, it is important to understand the limitations of this equipment. Since the SR50A is an acoustic sensor measuring the distance between the sensor and the ground by sending out sonic pulses and waiting for their return, it can be sensitive to objects interrupting the path between the sensor and the ground. In some cases, very heavy snowfall or even blowing snow could cause interference, reducing the quality of the data. If the quality of the data is reduced enough due to this heavy or blowing snow, the snow depth data may be automatically flagged out and not used, therefore making it impossible to calculate snow accumulation via the algorithm used by the NYSM.

One interesting case of data quality from the SR50A sensor affecting NYSM snow accumulation measurements is again during the 24-26 Dec 2022 lake effect event, but this time at the Brant NYSM site, located east of Lake Erie, south of Buffalo. Figure 7 shows an analysis of snowfall over the region by NOHRSC during the multi-day period of the storm. In this case, examining the time series plot for seasonal, cumulative snowfall (Figure 8) reveals that besides this one high-impact event, the NYSM station and its NCEI counterpart were in good agreement. It is during this case then, that the vast majority of the discrepancy arises. At first glance, this case may seem similar to the aforementioned Harrisburg case, as Brant fell just on the tight gradient of heavy snowfall to the south of Buffalo. However, unlike the Harrisburg case which
reported still a moderate to high amount of snowfall, the Brant site reported next to no snow

![Figure 7 National Gridded Snowfall Analysis during 72h period of the December 2022 Buffalo Blizzard event. Orange arrow indicates approximate location of BRAN NYSM station.](image)

![Figure 8 Cumulative Snowfall and Liquid Precip. Time Series Comparison for BRAN NYSM station. Red circles show major lake effect snow events (Nov 2022 and Dec 2022). Large discrepancy occurred for December event which did not occur for previous November event.](image)
Figure 9 Quality Control plot of SR50A raw data from the BRAN NYSM station on 25-26 Dec 2022. SR50A snow depth data included on both plots. Green line on top plot shows quality number. Quality # rapidly changes due to heavy snowfall occurring over many hours.

accumulation. Based on camera images taken at the site during the time of this discrepancy, it is confirmed that near a foot of new snow depth was present at the site during this time. This raises questions then about the quality of the data that the SR50A was recording during the periods of heavy snowfall. By examining plots of data quality and raw snow depth values recorded by the sensor (Figure 9) it can be seen that just as the distance between the sensor and the ground began to decrease, the quality number of the data quickly began to change, and flags began to appear in the data. With very windy conditions throughout this event and very heavy snowfall occurring, the sensor was forced to flag out its readings of snow depth during the times of heaviest snowfall because it simply could not take accurate readings with interference caused by high amounts of snow falling and blowing between the sensor and the ground. As a result of this, just about the
entire snowfall event was not added as snow accumulation at the Brant NYSM site. Considering how much of the seasonal snowfall here came from this one event, this had major impacts on the seasonal differences between measurements from the Brant NYSM site and its corresponding NCEI site.

While the cases explained so far describe situations where NYSM snowfall was lower than NCEI sites, there were also a number of sites where NYSM snow accumulation measurements were higher than their NCEI counterparts. One interesting case to look at within this subset is the Red Hook NYSM site during two light snowfall events in mid-December, 2022. Like most every other case discussed so far, the time series plots (Figure 10) for snow accumulation between both sites match up quite well, however there is a discrepancy for two small snowfall events in December that result in the NYSM measurements being higher over the course of the whole season. In this case, the NYSM station measured an increase in snow depth and subsequent increase in snow accumulation, as well as liquid precipitation. This information is corroborated by camera images (Figure 11) which confirm that two light snowfall events did occur in the area of Red Hook on 11 Dec 2022 and 16 Dec 2022. NCEI measurements for these days however show no snow accumulation whatsoever on these days. This raises the question of the completeness of the NCEI dataset. While snow accumulation is fully and correctly reported for almost the entire season, the fact that one to two snow events are missing in the NCEI dataset means that there is a discrepancy, making it seem as though the NYSM is overreporting snow accumulation. Data completeness seems to be the biggest issue when it comes to locations where the NYSM sites are recording higher snow accumulation than the NCEI site.
Figure 10: Cumulative snow accumulation and liquid precip. time series plot for REDH NYSM station for 2022-2023 season. Red circle denotes two small snowfall events where season-total discrepancy was caused.

Figure 11: Camera images from REDH NYSM site during snowfall events on 11 & 16 December 2022 snowfall events. These images confirm that snowfall did occur on these days.

3.3) Spatial Analysis of Snow Accumulation Differences

Another intriguing way to examine the discrepancies between NYSM and NCEI sites is looking at a spatial analysis. Plotted in Figure 12 are the locations of all the NYSM sites included
in this study. It is important to note here that only 102 of the 126 total NYSM stations are included here, as the other sites did not have an NCEI site close by enough to be accurately compared to. That said, there are certain patterns to look out for with a map like this. One interesting feature is that it seems for the vast majority of sites around Lakes Erie and Ontario, NYSM snow accumulation measurements are significantly lower than NCEI measurements. This is likely due to a combination of issues discussed previously, where slight differences in sight location and limitations of the SR50A sensor mean that during heavy snowfall periods, much of the heaviest snowfall is actually not recorded, or the NYSM site was missed by the lake effect.

Figure 12 Snow accumulation spatial analysis for winter 2022-2023. Each dot represents a NYSM site. The color of the dot represents the percentage difference between the NYSM snowfall and its corresponding NCEI site.
snow band. Considering that the two lake effect events in November and December 2022 were the major contributors to the seasonal snowfall totals in lake effect regions, it is not surprising that the SR50A having flagged out data due to heavy snowfall during periods of these events has led to discrepancies where NYSM measurements are lower than NCEI.

Beyond the lake effect regions, there tends to be decent agreement among NYSM and NCEI across much of the extreme southern portions of New York State, with a handful of sites where NYSM measurements were higher. Considering the extremely low snowfall amounts in this part of the state during the 2022-2023 season, which were largely less than 10 inches total for the season, it is expected that the NYSM measurements would be in line with manual measurements by NCEI. In some of the cases where NYSM sites recorded more snowfall, it is the case for most NCEI sites that often the little snowfall that did occur, if any occurred at all was simply not reported, or the data was incomplete. Over the rest of New York State, there seems to be a variety of discrepancies, moderately favoring NYSM measurements being lower than NCEI, mostly due to previously discussed limitations of the SR50A sensor during periods of very heavy snowfall.

4) Conclusions

The measurement of snowfall has always been an involved and difficult process in the meteorology community. With automatic weather stations becoming increasingly common across the United States and the world, it was crucial for technology to be developed that would allow for snow accumulation measurements, even in remote locations. Even though this technology is beginning to be used in the form of the SR50A snow sensors that the NYSM is
using, for example, some actions need to be taken to ensure the accuracy of measurements and data that come from these instruments. This project analyzes discrepancies between automatic measurements taken at NYSM stations and manual measurements taken at NCEI sites. Considering a past analysis done for a previous year, this study is able to examine the reasons for these discrepancies.

Considering that the discrepancies from the 2021-2022 winter season showed that NYSM snow accumulation measurements were lower than the NCEI measurements, it was important in this project to see if there was a similar trend observed in the following season. Upon plotting seasonal snowfall for that following season, there were sites that in fact followed a similar trend where with increasing snowfall amounts, NYSM stations seemed to be under-measuring snowfall when compared to manual NCEI stations. However, there were a number of sites that did not fit this trend, where NYSM measurements were higher than NCEI.

For the sites where NYSM measurements were lower than NCEI, there are a number of reasons that could cause this, explaining why there are a significant amount more sites where this is the case. First of all, location differences between the sites, even though they are all below 10 miles, could still cause some differences between measurements due to very localized snowfall events. These events include lake effect, snow squalls, and mesoscale snow bands. In these cases, one site may be missed while the other was more severely impacted. Another possibility stems from the limitations of the automatic SR50A snow depth sensors used at NYSM sites. When there is extremely heavy or blowing snow, interference may reduce the data quality of the sensor, causing data to be flagged and not included. Finally, there are the sites where NYSM measurements are higher than NCEI measurements. In many of these cases as earlier described, NCEI data will match NYSM data very well for the majority of the snow season, except for
during one or only a handful of events where the data was not reported or was incomplete. In these cases, because most of the data is present for the season, they were used for analysis, but just missing one snowfall event showed a seasonal bias where the NYSM measurements were higher.

Considering the factors discussed that are causing these differences, it is unlikely that changing the algorithm that the NYSM uses to estimate snow accumulation would affect the discrepancies between measurements in a positive way. Since that algorithm uses a 0.05mm liquid precipitation threshold to allow changes in snow depth to count as accumulation, one idea was that this may lead to actual snowfall not being counted if the threshold was too high. In reality, most discrepancies on a seasonal time scale are caused by just one storm, where missing data is a large culprit. Though a change to the algorithm is not recommended as a result of this study, it is still notable that there are significantly more sites where NYSM snowfall was lower than NCEI measurements, so it would be useful to continue to look into this issue further, perhaps including future seasons in this analysis, to try to identify any other patterns causing these discrepancies.
References


Ryan, W. A., & Doesken, N. J. (2013). *AN ALGORITHM TO ESTIMATE TRADITIONAL SNOWFALL MEASUREMENTS FROM ULTRASONIC SNOW DEPTH SENSORS AT U.S. OBSERVING SITES.*


