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ReadME file for New York State Mesonet Winter Weather Products

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1. Introduction

The New York State Mesonet (NYSM) is an advanced, statewide weather network that provides unprecedented weather information across the state. This network is the first of its kind in New York and consists of 127 standard surface weather stations across the state with an average spacing of 17 miles. Each of the Mesonet's weather stations collects observations of surface temperature, relative humidity, wind speed and direction, precipitation, solar radiation, atmospheric pressure, snow depth, and soil moisture and temperature at three depths (5, 25, and 50 cm). Each site is also outfitted with a camera that collects still images. Several additional networks are also operated by the NYSM; these include a 17 station Profiler Network, an 18-station Flux Network, a 20-station Snow Network, a 18-station urban network, and a 12-station roadside network. Collectively, the NYSM operates and maintains 212 weather stations.

Many of the NYSM sensors either directly or indirectly provide critical winter weather information. These data are useful for a variety of applications, including emergency management, winter road operations, and aviation. In 2021, NOAA awarded the NYSM a two-year grant to evaluate and make available value-added winter weather observations and products for use by the National Weather Service. One result of that outcome is creation of separate files containing specific NYSM winter weather products. This ReadMe file is a detailed description of those variables, how those products are created, and the limitations associated with those measurements. For any additional information or questions, please contact NYSM staff.

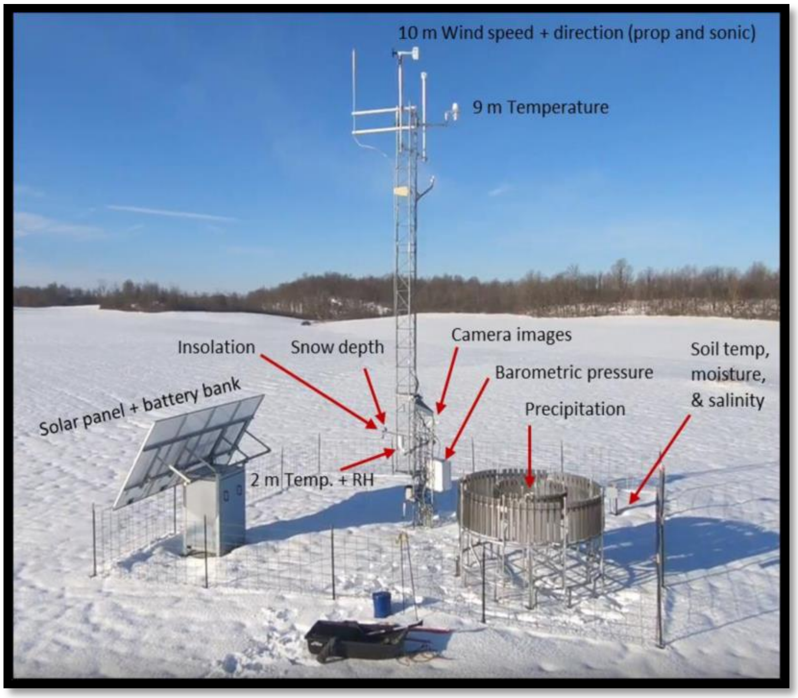


Figure 1: A NYSM Standard station measures air temperature, relative humidity, wind speed and direction, precipitation, snow depth, solar radiation, and soil temperature and moisture. A camera collects photos. Data are collected every 5 minutes.

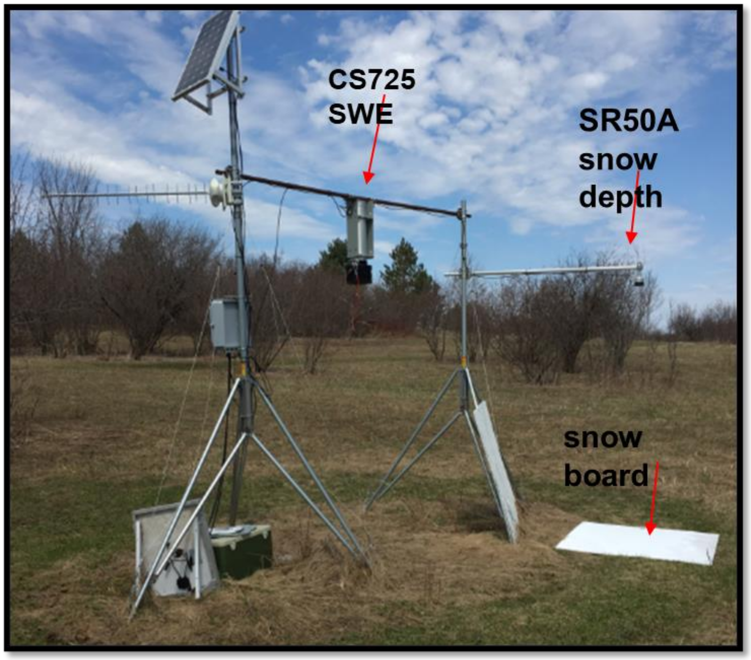


Figure 2: A NYSM Snow station measures Snow Water Equivalent (SWE) and snow depth. SWE is an integrated 24-hr average updated every 6 hours.

2. Snow depth (running 30-min average)

The NYSM measures snow depth directly using a sonic-based sensor known as the SR50A available from Campbell Scientific (https://www.campbellsci.com/sr50a). The downward facing sensor transmits an ultrasonic wave; the top of the snow surface (or ground) reflects the wave back to the sensor. The distance from SR50A to the top of the snow top is calculated as a function of the time interval between the sensor transmittance and its return signal. Snow depth is the difference of the distances without and with snow on the ground. The sensor is mounted at a height of 2 m AGL and samples over an area approximately 0.9 m^2 (9.7 ft^2). Sensor accuracy is about ±1 cm with a resolution of 0.25 mm. A rigid snowboard is placed on the ground under the sensor to minimize interference from vegetation and smooth out uneven ground. Snow depth sensors are deployed at every Standard, Thruway, and external Snow site and select NYC Micronet stations. Data are averaged and collected every five minutes.

Snow depth is one of the most difficult parameters to measure accurately. Measurement issues include:

- Drifting of snow under the SR50A.
- Representativeness of a point measurement.
- Precipitates blocking the sonic signal during moderate to heavy events.
- Ground heaving during the spring and fall.
- Sensor error.

In windy conditions, it's common for "waves" of snow to blow through the site under the gauge. Waves can be seen in time series plots of snow depth, with a rather significant amplitude of 6+ inches observed at times. The stronger the winds and/or lighter ("fluffier") the snow, the greater the problem. These can be 'averaged out' by using a longer time interval to estimate the "true" snow depth. Also note that some sites are much more prone to drifting than others. More open (WMO-rated 1, 2) sites are more prone to drifting issues.

Of special note, the Ellenburg site and New York City (NYC) sites have the snow depth flagged out. The Ellenburg station is situated atop a small rise that is especially susceptible to large drifts under the snow sensor. The NYC sites are located on rooftops, susceptible to strong winds and drifting.

For this winter weather data stream, a 30-minute running mean is applied to the snow depth data as a filter to smooth out large oscillations caused by wind drifting. For example, a snow depth estimate calculated at 1:15 pm is a 30-minute average which includes the 3 observations before (1:00, 1:05, 1:10 pm), the observation at 1:15 pm, and the 3 observations following (1:20, 1:25, and 1:30 pm). Snow depth estimates are reported 15-minutes late (after real-time) to accommodate the 30-minute averaging period.

There is also the issue of representativeness. Snow cover depth may vary widely over short distances due to variations in storm intensity, vegetation height and density, tree cover, and topography. A single point observation may or may not be representative of the larger region around the site.

Several additional issues include signal blockage, ground heaving, and sensor error. During moderate to heavy precipitation, falling precipitate may block the sonic signal entirely, reducing the data quality enough that the reading is unable to calculate a depth estimate. During transitional periods, significant ground heaving may occur due to the freezing/thawing cycle. When this occurs, the sensor-to-ground distance varies accordingly, yielding "snow depth" at these sites. Finally, sensor errors may occur. The most common failure is the sensor transducer which slowly degrades with time and is replaced every two years.

3. Snow depth change

Snow depth change refers to the change in snow depth observed over a given period of time. Snow depth change over time can be positive or negative and is due to additional snow, drifting, melting, settling/compaction, and sublimation. Snow depth change is computed over 1-hr, 3-hr, 6-hr, 12-hr, and 24-hr time intervals. These values are summed to calculate snow depth change over periods of up to 7 days. To minimize potential problems with snow drifting, the 30-minute running averages of snow depth are used to compute the snow depth change.

4. Snow accumulation

Snow accumulation refers to the total (positive) snow amount that accumulates over a given period of time. This measurement sums the positive snow amounts that have fallen before it's had time to melt, settle, or sublimate. Specifically, this automated estimate is meant to mimic the manual NWS measurement process as closely as possible. As with other variables, the smoothed 30-minute averages are used. In this case, 30-minute averages are summed every 5 minutes over the given intervals whenever the 5-min precipitation $\geq$ 0.05 mm (rain gauge detection threshold). The latter can significantly remove the snow drifting. Snow accumulation is computed over 1-hr, 3-hr, 6-hr, 12-hr, and 24-hr time intervals. These values are summed to calculate snow accumulation over periods of up to 7 days.

5. Liquid-equivalent Precipitation

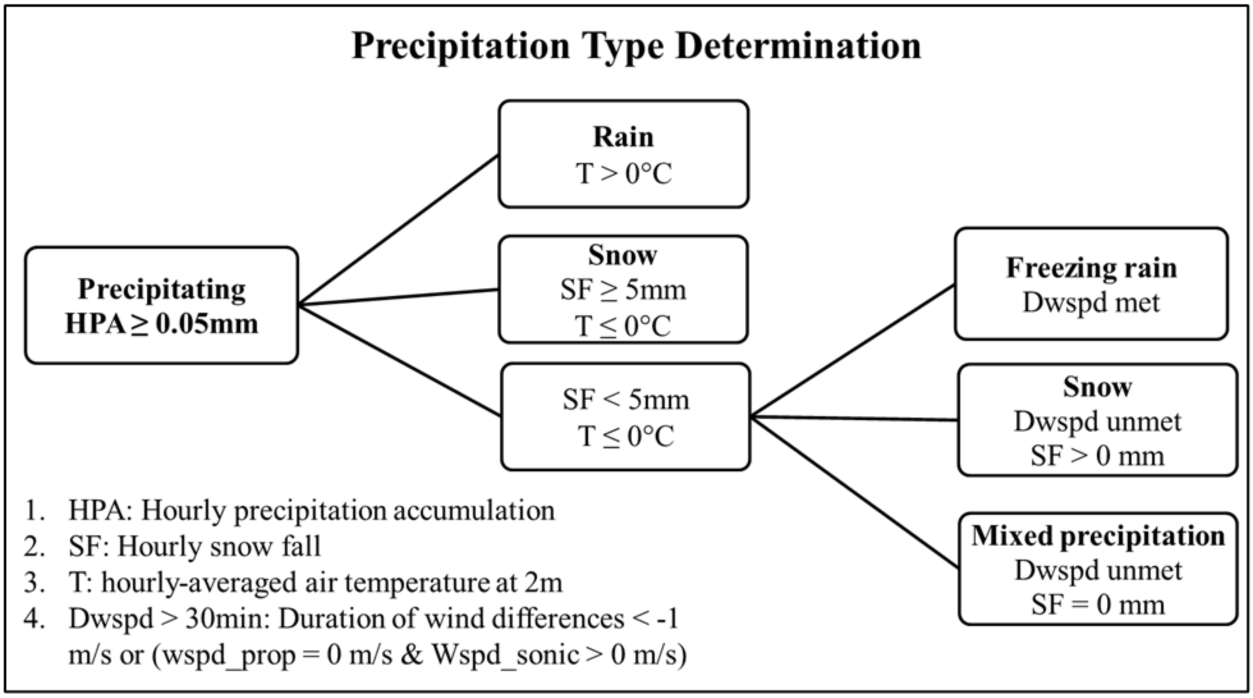
Liquid-equivalent precipitation is measured directly using a weighing gauge manufactured by Ott (the Pluvio2 and Pluvio2L; https://www.otthydromet.com/en/p-ott-pluvio-weighing-rain-gauge/70.040.021.9.0). The weighing gauge uses a very sensitive weighing scale and which converts the weight of precipitation to a liquid amount. This is especially helpful in areas like New York where a significant portion of precipitation is frozen. The gauge has a heated rim to minimize ice or wet snow buildup at the orifice of the gauge. A double Alter shield is installed around each gauge to minimize under catchment and turbulent effects.

Strong winds vibrating the gauge and/or differential solar radiative heating of the gauge can cause some false precipitation to be reported. An embedded fan and software help correct for these issues, but some false precipitation is still reported on occasion. Manual quality control removes the false precipitation from the data archive once identified.

The liquid-equivalent precipitation is reported every 5 minutes from every Standard site and 16 NYC Micronet stations.

6. Precipitation type flag (Standard Network)

Precipitation type is a critical measurement, but difficult to ascertain from automated measurements. In this case, we utilize liquid-equivalent precipitation, snow depth, air temperature and wind measurements from propeller and sonic anemometers to determine precipitation type. Hourly estimates are calculated every five minutes to yield more accurate, consistent results. While still largely experimental, initial evaluations are encouraging. These flag values are meant as a first guess, and the use of additional supporting information (e.g., camera data) is encouraged. The precipitation type determination algorithm is summarized in the schematic diagram below and explained in detail below.



The precipitation flag is defined as follows:

0 - no precipitation
1 - rain
2 - snow
4 – freezing rain

Rain is selected if:

(i) hourly accumulation of precipitation is ≥ 0.05 mm,
(ii) average air temperature > 0° C.

Snow is selected if:

(i) hourly accumulation of precipitation is ≥ 0.05 mm,
(ii) average air temperature ≤ 0° C, and
(iii) hourly snowfall ≥ 5 mm OR (no freezing rain detected and hourly snowfall > 0 mm).

Freezing rain is determined if:

(i) hourly accumulation of precipitation is ≥ 0.05 mm,

(ii) average air temperature ≤ 0° C,
(iii) hourly snowfall < 5 mm,
(iv) the difference in wind speed between the NYSM propeller anemometer and sonic anemometer < -1 ms^{-1} OR the propeller anemometer wind speed equals 0 ms^{-1}, for a period of > 30 minutes (see Wang et al. 2021).

Mixed precipitation is determined if:
(i) hourly accumulation of precipitation is < 0.05 mm,
(ii) average air temperature ≤ 0° C,
(iii) no freezing rain detected and hourly snowfall = 0 mm..

The propeller anemometer begins to stall during freezing rain or occasionally wet snow, eventually slowing to a stop as ice buildup accretes on the propeller. In contrast, little to no ice buildup accrues on the interior of the sonic anemometer with little to no impact on the sonic wind measurements. The difference in wind speed between the anemometers acts as a proxy for identifying periods of freezing rain.

See the following publication for more information:
Wang, J., Brotzge, J., Shultis, J., & Bain, N. (2021). Enhancing Icing Detection and Characterization Using the New York State Mesonet, *Journal of Atmospheric and Oceanic Technology*, *38*(9), 1499-1514.
DOI: https://doi.org/10.1175/JTECH-D-20-0215.1
https://journals.ametsoc.org/view/journals/atot/38/9/JTECH-D-20-0215.1.xml?tab_body=pdf

7. Snow-to-Liquid Ratio (SLR)

The Snow-to-Liquid Ratio (SLR) is the ratio of snow depth to the amount of liquid equivalent precipitation. For example, if 10” of snowfall fell, which when melted down equaled 1” of liquid precipitation, the SLR is 10/1 = 10. The SLR is a useful tool for tracking how dry or wet a particular snowfall may be. SLR is typically around 10, with wetter snows < 10 and much fluffier, drier snows > 10.

Hourly estimates of snow accumulation and liquid-equivalent precipitation totals are used to compute the hourly SLR. Hourly estimates of SLR are then averaged over the selected time interval (e.g., 1-, 3-, 6-, 12- or 24-hr). These values are used to calculate average SLR over periods of up to 7 days.

8. Frozen soils flag

Within the NSYM, soil temperature and moisture are measured directly at 5-, 25- and 50 cm depths using the Stevens’ Hydra Probes (https://stevenswater.com/products/hydraprobe/). Often times, it’s useful to know where and when these soil temperatures dip below freezing. Frozen ground can have important hydrological implications on whether or not precipitation is absorbed into the soil or becomes runoff.

Frozen soil is determined based on thresholds for soil temperature and real dielectric permittivity. Soil moisture data for frozen soil are flagged out.

The frozen soils flag is defined as follows:
- 0 – Non-frozen soil
- 1 – Frozen soil

For hourly or daily statistics, a count of the number of 5-minute observations the soil was frozen will be shown. On the Winter Weather map display, sites with frozen soil are marked with the letter “F”.

9. Snow Water Equivalent

Snow Water Equivalent (SWE) is a measure of how much water is within the snow pack and is computed directly at the 20 Snow Network sites across the state. SWE is competed every 6 hours and is an integrated 24-hr measurement. Please see the NYSM Snow Network ReadMe file for more information regarding the SWE data.

10. Precipitation Type (Profiler Network)

The NYSM Profiler Network collects vertical profiles of temperature, moisture, and wind at 17 stations across the state (Shrestha et al. 2021). Profiles are plotted every 10 minutes, and skew-T images are created for use by the NWS. From these data, precipitation type also can be approximated. A “partial thickness” technique is applied as adapted from Cantin et al. (1993) and as described by G. Schmocker (2004 NOAA Winter Weather Workshop). This method computes the 1000-850 mb and 850-700 mb thickness layers, and then computes precipitation type based on the depth of those respective thickness layers. This original technique was developed for southeastern Canada, and its values appear to work well for New York state.

Please see the NYSM Profiler Network ReadMe file for more information regarding the Profiler Network sensors and variables.

11. Photo images

NSYM photos are especially helpful during the winter for monitoring precipitation type and snow depth. The NYSM first deployed the DS-2CD2032-I security network camera manufactured by Hikvision. Due to federal security concerns, these cameras are now being replaced with the Vigilance DCS-4701E-VB1 Mini Bullet IP camera sold by D-Link. An infrared capability allows for image collection at night.

Each camera is oriented such that the horizon is centered in the photo, with the ground encompassing the lower half of the image and the sky the upper half. This allows for regular monitoring of snow and vegetation heights as well as sky conditions. Each camera is mounted level on the station tower at a height of 3 m. Small roofs have been built over each camera to protect them from snow and ice falling from the tower above.

Most cameras face north towards the station gate. This provides some level of security for the site, but facing the cameras north also minimizes direct solar glare on to the camera lens. Cameras at 25 sites (20% of the network) face a direction other than 0º north. In some cases, site hosts requested that the camera be pointed in a different direction for privacy concerns (e.g., away from the family pond). In other cases, other angle directions provided a much longer-range vista, yielding greater applications of the camera when the view to the north was blocked by nearby trees or other obstructions. At a few sites, a particularly picturesque view in some other direction was more desirable. Once in place, we try and minimize adjustments to preserve continuity in the long-term record.

Camera still images are collected every five minutes from each site during daylight hours.. To further reduce bandwidth use and storage, images are collected only once per hour during the night. This switch to night data collection is made 30 minutes prior to sunrise and 30 minutes after sunset; a download script is used to instruct this switch and to download the images to the central archive. A 2 MP (1920 x 1080 resolution) image is taken, but the photo is downgraded such that a 0.9 MP (1280 x 720) image is downloaded from the site; this reduces the bandwidth needs by over half. Infrared capability allows for nighttime images; these photos appear in black and white. Cameras automatically switch to infrared mode once light levels drop below a given threshold.

12. References

Cantin, A., and D. Bachand, 1993: Synoptic pattern recognition and partial thickness techniques as a tool for precipitation types forecasting associated with a winter storm. Centre Meteorologique du Quebec Tech. Note 93N-002, 9 pp. [Available from Environmental Weather Services Office, 100, boul. Alexis-Nihon, Suite 300, Saint-Laurent, PQ H4M 2N8, Canada.].

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