NYSM Icing Detector Data [UAlbany, NYSM]

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1. Data Set Description

1.1. Introduction: This dataset contains data from Rosemont 0871LH1 Ice Detector (a.k.a., Freezing Rain Sensor; Campbell Scientific, 2015). These deployed at New York State Mesonet (NYSM) stations in northeastern New York, USA in support of the WINTRE-MIX field campaign (https://www.eol.ucar.edu/field_projects/wintre-mix). The instrument is used to detect the presence/absence of icing conditions and. When icing is present, two different post-processing approaches are used to derive a quantitative estimate of the cumulative thickness of ice accreted. The ice detector measurements are collocated with (or adjacent to) NYSM "standard" stations, which measure a host of other meteorological variables (Brotzge et al. 2020; http://nysmesonet.org/). Two-meter temperature data from these NYSM stations is used when post-processing the icing detector data. NYSM data can be accessed from http://nysmesonet.org/weather/requestdata.

1.2. Data version: v1.0, 18 October 2022

1.3. Time period covered: 22 December 2021 – 1 May 2022**.** The specific date range of data provided at each site is given in Table 1. Substantial periods of missing data are given in Table 4.

Table 1: Location and time range of data collection for each icing detector in the dataset. Station names and IDs correspond to the associated NYSM stations.

Station (ID)	Latitude [°]	Longitude [°]	Elevation [m]	Start date [UTC]	End date [UTC]
Chazy profiler (PROF_CHAZ)	44.889	-73.46634	74.3	9 Jan 2022	1 Apr 2022
*Chazy (CHAZ)**	*44.89565*	*-73.46461*	*56.6*		
Whiteface Mt. Base (WFMB)	44.39324	-73.85883	614.6	22 Dec 2021	1 Apr 2022
Essex (ESSX)	44.31360	-73.37190	55.5	18 Jan 2022	1 Apr 2022
Ellenburg (ELLE)	44.8955	-73.84502	297.9	20 Jan 2022	1 Apr 2022
Saranac (SARA)	44.70759	-73.67115	313.7	20 Jan 2022	1 Apr 2022

* *The Chazy ice detector was deployed at the NYSM Chazy profiler station (PROF_CHAZ). Location information from the adjacent NYSM Chazy standard station (CHAZ) is also given here because surface meteorological conditions (e.g., 2-m temperature) from that station was used in icing detector data post-processing.*

1.4. Location: The icing detectors were deployed at NYSM stations in northeastern New York (Figure 1). The location and elevation of the stations are given in Table 1. Four of the instruments were deployed at NYSM “standard” stations (ESSX, ELLE, SARA, WFMB). The fifth instrument was deployed at a NYSM rooftop “profiler” station (PROF_CHAZ). Meteorological data from the standard sites is used in icing detector data post-processing. For the PROF_CHAZ station, data from the adjacent CHAZ standard station is used (Table 1). Additional site information about each NYSM station can be found at: http://nysmesonet.org/about/sites.

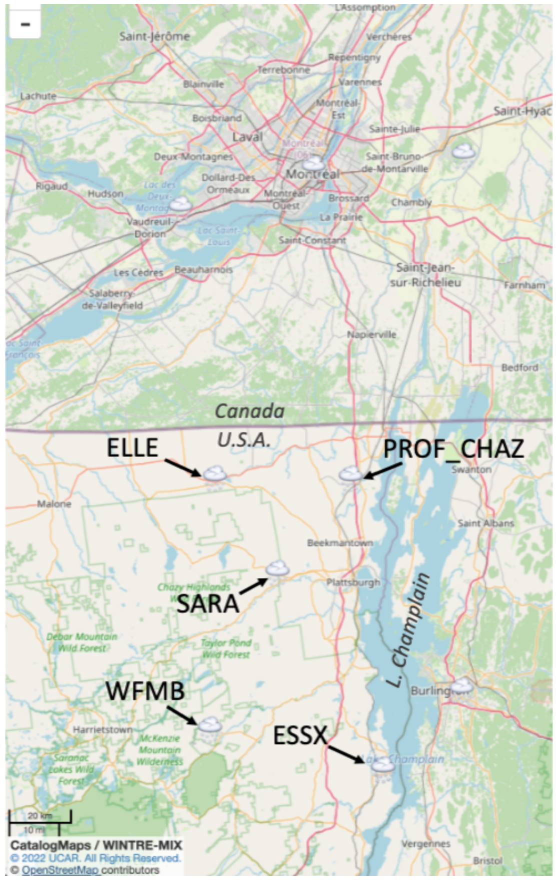

Figure 1: Map of approximate locations of NYSM sites where icing detectors were deployed.

1.5. Data frequency: Raw data was collected from the sensors every 3 seconds. The data was resampled to coarser time resolution during post-processing. Two datasets are provided, at 1 minute and 5 minute intervals. Details about resampling and post-processing are given in section 3.

1.6. **Dataset restrictions:** Please refer to the WINTRE-MIX data policy (https://www.eol.ucar.edu/content/wintre-mix-data-policy) as well as the WINTRE-MIX data management plan (https://www.eol.ucar.edu/system/files/Data_Management_Plan-1Dec2021.pdf) for more information regarding dataset restrictions and dissemination.

2. Instrument Description

This dataset is based on measurements from a Rosemount Aerospace 0871LH1 Ice Detector sold by Campbell Scientific (Campbell Scientific, 2015). The sensor uses an ultrasonically axially vibrating tube-shaped nickel alloy probe, driven by a manetostrictive oscillator (MSO) circuit to detect and quantify ice accretion. A 1-inch long segment of the tube is exposed to the environment. In the absence of accreted ice, the probe oscillates at a natural resonant frequency that is tuned to be approximately 40 kHz. When ice accretes onto the probe, the added mass decreases the resonant frequency. Accretion of 0.5 mm of equivalent flat ice "causes the operating frequency of the probe to decrease by approximately 130 Hz" (Campbell Scientific, 2015). When this threshold amount of ice accretion is detected by the sensor, an icing "event" is recorded and a probe heater is activated for 60 seconds to de-ice the instrument.

Output from the sensor includes a time series of the probe oscillation frequency (LH1_MSO_Freq_Hz), a running count of icing events (LH1_ICE_count), flags to indicated icing events and probe heater activation (LH1_Ice, LH1_heat), and various other instrument status flags. More technical details about the instrument can be found in Campbell Scientific (2015).

3. Data Collection and Processing

3.1. Instrument mounting: At ESSX, ELLE, SARA, and WFMB, the sensor was mounted on the NYSM standard station tower on a cross-arm at 2 m above ground level, adjacent to the stations snow depth sensor, using the Campbell Scientific 0871LH1 Mounting Kit. At PROF_CHAZ, the sensor was mounted onto a rooftop structure using the same mounting kit at 2 m above the rooftop.

Because of inconsistencies in the manual, the sensor was initially deployed at CHAZ (on 17 December 2021) and WFMB (on 21 December 2021) in a manner that acted to collect snow on the metal mounting bracket. Following some experimentation, the orientation was then changed at WFMB (on 11 January 2022) to a deployment that acts to shed snow, and became the final iteration of how the sensors were deployed the rest of the winter at the 5 sites (changed at CHAZ on 29 January 2022). Figure 2 shows photos of the sensor mounted at each site.

3.2. Raw data collection: Data was collected using the sensor's RS-422 output every 3 seconds and recorded in .csv format.

3.3. Post-processing: The raw data was post-processed, using a python script, to: (a) resample the data to 1-min and 5-min intervals, (b) implement quality control procedures to mask out suspect data, (c) produce time series of ice occurrence and cumulative flat ice accretion (T_i), and (d) convert to netCDF format with detailed metadata. For (a)–(c), the post-processing procedure used generally follows the approaches detailed in NOAA (1998) and Ryerson and Ramsay (2007). The specific post-processing procedure is detailed below.

- **Initial masking:** After loading in the 3-second data, the raw frequency data (*LH1_MSO_Freq_Hz*) and ice count data (*LH1_ICE_count*) are masked where either the frequency is lower than an expected minimum valid value (*LH1_MSO_Freq_Hz* < 39 kHz) or the instrument's status output variable indicates a failure (*LH1_Status_Fail*>0). New masked versions of these variables are created (*LH1_MSO_Freq_Hz_masked*, *ICE_count_masked*).
- **1-minute resampling:** Next, selected variables are resampled from the raw 3-second output with 1-minute frequency. Resampling is done for the *LH1_MSO_Freq_Hz* and *LH1_ICE_count* variables (both original and masked) and the icing event and probe heater flags (*LH1_Ice*, *LH1_heat*). The resampling is done using a nearest neighbor approach with the time index corresponding to the end of the 1-minute interval.
- **Flat ice accretion (T_i) from net frequency change (method 1):** The cumulative daily (since 0000 UTC) flat ice accretion is calculated broadly following the approach of Ryerson and Ramsay (2007) using the 1-minute masked MSO frequency data *(LH1_MSO_Freq_Hz_masked*). First, a 15-minute running minimum is applied to the data (index based on the end time of the 15-minute period, values masked if at least 2 valid measurements are not available within the window). Then, this running minimum value is subtracted from the masked 1-minute MSO frequency data to calculate a frequency change (*FC*). To avoid artifacts associated with fluctuations in MSO frequency unrelated to icing, small values of *FC* (<2.5 Hz) are set to zero. To avoid identification of icing at unrealistically warm atmospheric temperatures, if the 2-meter air temperature measured by the co-located (for WFMB, ESSX, ELLE, SARA) or adjacent (for PROF_CHAZ, CHAZ) NYSM standard site exceeds 3°C then *FC* is set to zero.

  Values of *FC* associated with 15-min windows where the heater was activated (according to *LH1_heat flag*) are presumed to be affected by the applied heating and are set as missing (masked). After the above quality checks are applied, missing values of *FC* (including those that are masked due to operation of the sensor heater) are filled using linear interpolation wherever the gap between missing values is less than 15 minutes.

The daily net frequency change (*NFC*) is calculated as a cumulative sum of *FC*, starting at 0000 UTC. Finally, the cumulative daily flat ice accretion is calculated as $T_i = - c_1 \times NFC$, where the constant c_1= 0.0035 mm Hz^{-1} is a calibration constant relating NFC to ice accretion (Ryerson and Ramsay 2007; Campbell Scientific 2015).

- **Ice accretion from icing events (method 2):** The cumulative daily (since 0000 UTC) flat ice accretion is also calculated by counting icing “events” detected by the sensor. For each minute, the 1-min icing event counter (*LH1_ICE_count*) is differenced with its 0000 UTC value (or first non-missing value of the day) to determine the number of icing events since the start of the day. To estimate T_i, this count is multiplied by a factor of 0.5 mm/event, corresponding to the amount of ice accretion needed to trigger an event (and a de-icing heating cycle). The 1-min T_i from this method is also resampled to 5-min frequency (using a nearest neighbor approach and right-labeled index) and included in the 5-min version of the dataset.
- **Icing detection flag:** A flag indicating the presence/absence of icing conditions is calculated from the MSO frequency output, broadly following NOAA (1998). When the 1-min frequency change variable (*FC,* described in sec. 3.3.3) is <-2.5 Hz (the same value used for masking FC in section 3.3.3) the icing flag is set to 1 (icing detected). At all other times with valid *FC* data, the icing flag is set to 0 (no icing detected). This provides a continuous 1-min time series of icing detection.

 A distinct 5-min version of the icing detection flag is calculated by first resampling *FC* to 5-min frequency, using a 5-min mean, then comparing the resulting 5-min *FC* values to the -2.5Hz threshold, as above. This version of the icing detection flag is affected by spurious detection of icing conditions associated with noise in the MSO frequency data.

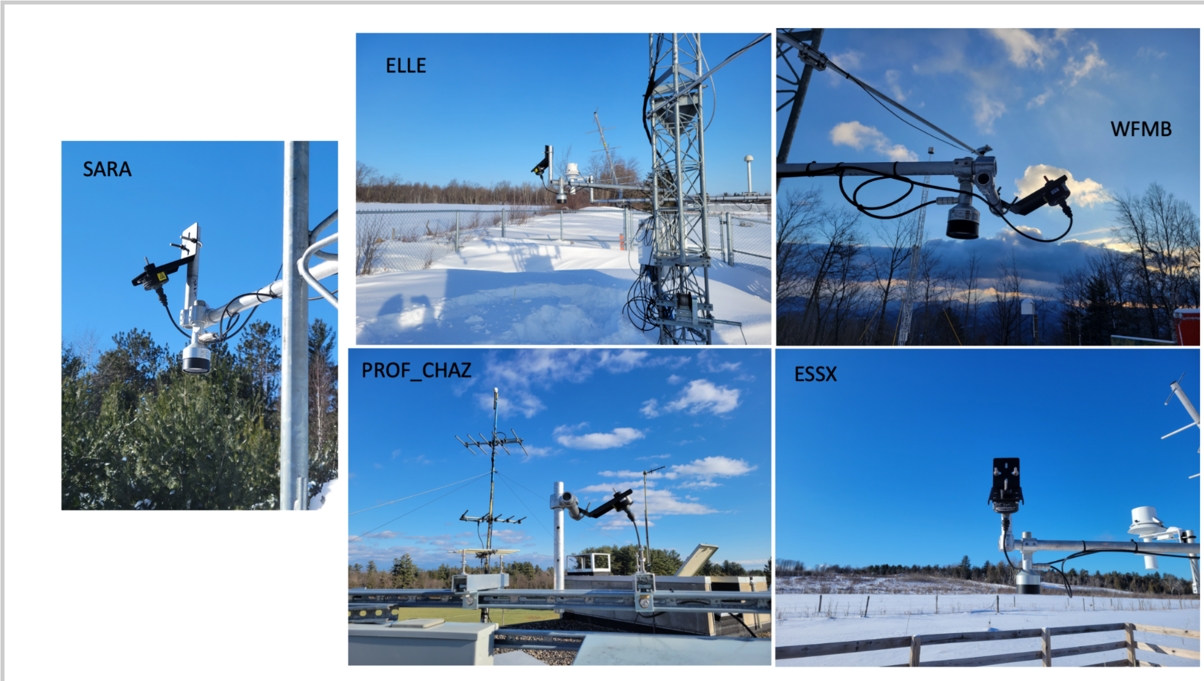

Figure 2: Photos showing the ice detectors mounted at each of the five stations. Photos are labeled with the station IDs given in Table 1.

4. **Data format**

   Post-processed data is saved in netCDF files. Files are daily, containing 24 hours of data for all operational stations, and are named with the following naming conventions:

   WINTRE-MIX_icing_detector_YYYYMMDD_1min.nc

   WINTRE-MIX_icing_detector_YYYYMMDD_5min.nc

   where *YYYYMMDD* is the date of data collection in UTC. The “1min” or “5min” at the end of the file name denotes the 1-min and 5-min post processed datasets.

The variables provided in each file are summarized in Tables 2 and 3. Additional metadata is provided in the netCDF file.

Table 2: Variables recorded in 1-min icing detector data files

Field Name	**Description**	**Unit**
time	time	UTC
station	station ID of NYSM station where sensor was deployed	

LH1_MSO_Freq_Hz	Sensor oscillation frequency, resampled from raw 3-sec data with 1-min averaging. *No quality checks applied*	Hz
LH1_MSO_Freq_Hz_masked	Sensor oscillation frequency, resampled from raw 3-sec with 1-min averaging. Masked where MSO freq <39000.0 Hz and where LH1_Status_Fail >0.	Hz
LH1_Ice	Current icing status (1=ice, 0=no ice). Resampled from raw 3-sec with 1-min max.	Binary flag
LH1_Heat	Current heater status (1=probe heater on, 0=probe heater off). Resampled from raw 3-sec with 1-min max.	Binary flag
LH1_ICE_count	Running cumulative total of number of icing "events" since sensor initialized. Resampled from raw 3-sec with 1-min max.	counts
LH1_ICE_count_masked	Running cumulative total of number of icing "events"since sensor initialization. Resampled from raw 3-sec with 1-min max. Masked where MSO freq <39000.0 Hz and where LH1_Status_Fail >0.	counts
Icing_flag	Indicates the detection of icing during the previous minute (1=icing detected, 0= no icing detected). Diagnosed when the 15-min running minimum frequency change is < -2.5 Hz. *NOTE: This method is subject to spurious FZRA detections due to noise in the MSO_freq data. FZRA_flag from 5-min version of the data is likely more reliable.*	Binary flag

T_i_method_1	Estimate of daily cumulative flat ice ice accretion from 0000 UTC. Calculated from 1-min LH1_MSO_Freq_Hz_masked using Ryerson & Ramsey (2007) approach with a 15-minute running minimum MSO_Freq. Assumes net frequency change (NFC) of 1Hz corresponds to0.0035mm of ice. NFC set to zero (no ice accretion diagnoses) when interpotated NYSM station measured 2-m temperature (temp_2m) is >3 deg. C. *NOTE: This method is sometimes subject to small spurious ice accretions due to noise in the MSO_freq data.*	mm
T_i_method_2	Estimate of daily cumulative flat ice ice accretion from 0000 UTC. Calculated from 1-min LH1_ICE_count assuming that each icing event corresponds to 0.5mm of ice. *NOTE: This method does not detect icing insufficient to trigger icing "event".*	mm
CS_0871LH1_software_ver	CS_0871LH1_SN FZRA sensor software number	
CS_0871LH1_SN	Serial number of CS_0871LH1_SN FZRA sensor	
station_name	Name of NYSM station where sensor was deployed	
latitude	Latitude of NYSM station where sensor was deployed	degrees_north

longitude	Longitude of NYSM station where sensor was deployed	degrees_east
elevation	Elevation of NYSM station where sensor was deployed	meters above sea level

Table 3: Variables recorded in 5-min icing detector data files

Field Name	**Description**	**Unit**
time	time	UTC
station	station ID of NYSM station where sensor was deployed	
Icing_flag	Indicates the detection of FZRA during the previous 5 minutes (1=icing detected, 0= no icing detected). Diagnosed from the 15-min running minimum frequency change (FC) calculated on 1-min data and resampled with 5-min mean.FZRA is diagnosed when FC < -2.5 Hz. *NOTE: This method may occasionally include spurious FZRA detections due to noise in the MSO_freq data.*	Binary flag
T_i_method_2	Estimate of daily cumulative flat ice ice accretion from 0000 UTC. Calculated from 1-min LH1_ICE_count assuming that each icing event corresponds to 0.5mm of ice, then resampled to 5-min using max value. *NOTE: This method does not detect icing insufficient to trigger icing "event".*	mm
CS_0871LH1_software_ver	CS_0871LH1_SN FZRA sensor software number	

CS_0871LH1_SN	Serial number of CS_0871LH1_SN FZRA sensor	
station_name	Name of NYSM station where sensor was deployed	
latitude	Latitude of NYSM station where sensor was deployed	degrees
longitude	Longitude of NYSM station where sensor was deployed	degrees
elevation	Elevation of NYSM station where sensor was deployed	meters above sea level

5. Data Remarks

The icing detector used for this dataset generally performed well during the WINTRE-MIX deployment period. Significant periods of missing and suspect data are summarized in Table 4. There are some periods of missing data, especially at the PROF_CHAZ site, largely associated with outages in communications between the sensor and the data logging computer.

As mentioned above in section 3.1, the first two deployments (CHAZ and WFMB) were mounted in a way that acted to collect snow in the "elbow" of the metal mounting bracket. Following some experimentation, the mount was changed to actively shed accumulating snow. As such, any data between 21 December 2021 and 11 January 2022 for WFMB, and 17 December 2022 and 29 January 2022 could be susceptible to snow affecting the sensor, perhaps initiating the heating mode, and false ice detection, during non-icing times.

Occasionally, the sensor heater appeared to be stuck in the "on" position, leading to bad and/or missing data. This happened most frequently at WFMB.

The MSO frequency data often exhibits small departures from its nominal 40 kHz baseline value, even when no icing is occurring. The post-processing procedure described in section 3 attempts to minimize the impacts of these departures on the estimates of icing occurrence and accretion. However, the procedures are imperfect and artifacts associated with these non-icing MSO frequency departures remain in the data. In particular, the 1-min T_i estimated by method 1 (sec. 3.3.3) often displays small accumulations of ice during periods where other meteorological measurements (e.g., NEXRAD radar, NYSM station observations) indicate that icing is unlikely to be occurring. Similarly, apparent false-positive detections of icing are sometimes apparent in the 1-min icing flag data. The T_i estimated by method 2 and the 5-min icing flag data appear to be minimally affected by these artifacts.

While the estimates of T_i from method 2 are less affected by false icing artifacts, they are susceptible to underestimating icing. In particular, when using this method T_i only increases when an icing "event" sufficient to trigger a sensor heating cycle occurs (~0.5 mm flat ice accretion). As such, periods of light ice accretion may be missed by this method. Additionally, ice accretion that occurs while the sensor heater is activated may be systematically underestimated. Also, T_i from method 2 occasionally shows false ice accretion when the sensor is turned on after installation or data outage and shows an increase in *LH1_ICE_Count* that is not associated with icing.

Given the uncertainties in ice detection and ice accretion estimation, data users are encouraged to consider the raw MSO frequency data, the estimates generated with different methods and time frequencies, and the meteorological context (e.g., from NYSM station observations) to determine how to best use the data for their application of interest.

Table 4: Summary of known periods of substantial missing or suspect data. Time ranges are approximate.

date [UTC]	**Station ID**	**start time [UTC]**	**end time [UTC]**	**notes**
1/4/22	WFMB	0:00	23:59	detection and accumulation of icing starting around 1500 UTC is suspect. No precipitation was recorded at

				WFMB or nearby stations and measured RH at site was <80%.
1/7/22	PROF_CHAZ	0:00	23:59	sensor not yet operational. Bad/missing data
1/7/22	WFMB	17:00	19:00	Detection and accumulation of icing by method 1 is suspect. Icing estimated by method 1 is in excess of measured precipitation. RH<80%
1/9/22	PROF_CHAZ	0:00	17:30	sensor not yet operational. Bad/missing data
1/10/22	WFMB	0:00	5:00	Bad/missing data. Sensor heater appears to be stuck on.
1/12/22	PROF_CHAZ	6:30	23:59	Sensor down. Missing data.
1/13/22	PROF_CHAZ	0:00	20:00	Sensor down. Missing data. When data collection resumes, LH1_ICE_Count produces a false count, leading to incorrect accumulation of $T\_i\_method\_2$.
1/14/22	PROF_CHAZ	7:00	9:30	Sensor down. Missing data.
1/18/22	ESSX	0:00	20:00	sensor not yet operational. Bad/missing data. When data collection begins, LH1_ICE_Count produces a false count, leading to incorrect accumulation of $T\_i\_method\_2$.
1/20/22	ELLE	0:00	15:00	sensor not yet operational. Bad/missing data. When data collection begins, LH1_ICE_Count produces a false count, leading to incorrect accumulation of $T\_i\_method\_2$.
1/20/22	SARA	0:00	16:30	sensor not yet operational. Bad/missing data. When data collection begins, LH1_ICE_Count produces a false count, leading to incorrect accumulation of $T\_i\_method\_2$.
1/25/22	SARA	17:00	18:30	Detection and accumulation of icing

				by method 1 is suspect. Icing estimated by method 1 when no precip was measured.
1/27/22	PROF_CHAZ	7:00	23:59	Sensor down. Missing data.
1/28/22	PROF_CHAZ	0:00	23:59	Sensor down. Missing data.
1/29/22	PROF_CHAZ	0:00	23:59	Sensor down. Missing data.
1/30/22	PROF_CHAZ	0:00	2:30	Sensor down. Missing data.
2/1/22	PROF_CHAZ	3:30	19:30	Sensor down. Missing data.
2/12/22	ELLE	18:00	19:30	Bad/missing data. Sensor heater appears to be stuck on.
2/18/22	WFMB	15:30	19:00	Detection and accumulation of icing by method 1 is suspect. Icing estimated with no measured precipitation. RH<80%
3/12/22	WFMB	9:30	23:59	Bad/missing data. Sensor heater appears to be stuck on.
3/13/22	WFMB	0:00	15:30	Bad/missing data. Sensor heater appears to be stuck on.
3/14/22	SARA	0:00	1:00	Missing data
3/15/22	SARA	23:30	23:59	Bad/missing data. Sensor heater appears to be stuck on.

6. Related datasets

6.1. NYSM standard site station data: The NYSM standard site data provides a host of complimentary meteorological measurements at (or adjacent to) each of the icing detector deployment locations. In addition, NYSM generates a host of winter weather products from these station data, including an indirect estimation of the occurrence of icing (Wang et al. 2021).

- http://nysmesonet.org/weather/requestdata

6.2. PROF_CHAZ NYSM profiler data: The NYSM PROF_CHAZ site also hosts a profiling lidar (providing wind profiles) and a profiling radiometer (providing thermodynamic profiles).

- http://nysmesonet.org/weather/requestdata

6.3. PROF_CHAZ MRR-2 and Parsivel data: At the PROF_CHAZ site, a MRR-2 profiling radar and Parsivel[2] disdrometer were also deployed for WINTRE-MIX. These sensors provide additional information on vertical variations in precipitation, precipitation size and fall speed, and precipitation type.

- https://data.eol.ucar.edu/dataset/612.018
- https://data.eol.ucar.edu/dataset/612.017
- https://data.eol.ucar.edu/dataset/612.020

6.4. CFI Climate Sentinel icing detector data: A similar icing detector dataset is available for the Canadian CFI Climate Sentinel sites.

- https://data.eol.ucar.edu/dataset/612.030

7. Acknowledgements

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**This document is provided as an attachment to the dataset*

9. Appendix

Suggested GCMD keywords to accompany this dataset are provided below in no particular order:

- Freezing rain
- Freezing drizzle
- Ice storms
- Extratropical cyclones
- Total freezing rain accumulation
- Rosemount icing detector