# Developing a Socioeconomic-Aware Winter Storm Scale for Erie County, New York

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## Background

- The Winter Storm Severity Index (WSSI) provides a graphical view of winter weather-related impacts based on current NWS snow, ice, wind, and temperature forecasts.
- The WSSI incorporates a few select non-weather factors, such as snow climatology, land use, and urban-area designation.
- However, several non-weather datasets aren't considered.
  - Socioeconomic factors, such as population & housing characteristics and the CDC Social Vulnerability Index
  - Road networks
  - Critical infrastructure

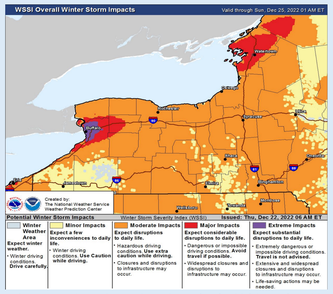
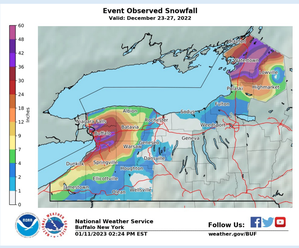



***Figure 1:*** *Winter Storm Severity Index (WSSI) issued on 22 December 2022 ahead of the Buffalo Blizzard.*

## Motivation: Buffalo Blizzard of December 2022

- Occurred from 23-27 December 2022
- 51.9" of snow and a peak wind gust of 72 mph at KBUF
- Impacts included:
  - Impossible travel on the Friday before a holiday weekend
  - Thruway closure from the NY/PA border to Rochester
  - School, government, and Buffalo Airport closures
  - **Loss of 47 lives** (Fig. 3)
- The event exposed the ever-increasing need for adequate preparation, communication of hazards, and response to high-end winter storms.
- Erie County leaders expressed a desire for a forecast tool that highlights impacts to vulnerable populations and infrastructure.
- The WSSI provides a great starting point for such a tool!



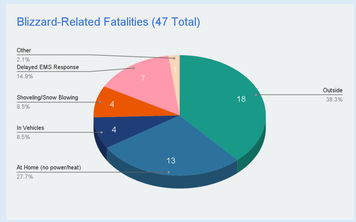




***Figure 2 (left):*** *Total snowfall during the event (map courtesy of NWS Buffalo).*
***Figure 3 (right):*** *Blizzard-related fatalities by cause of death (map courtesy of NWS Eastern HQ).*

## The Product

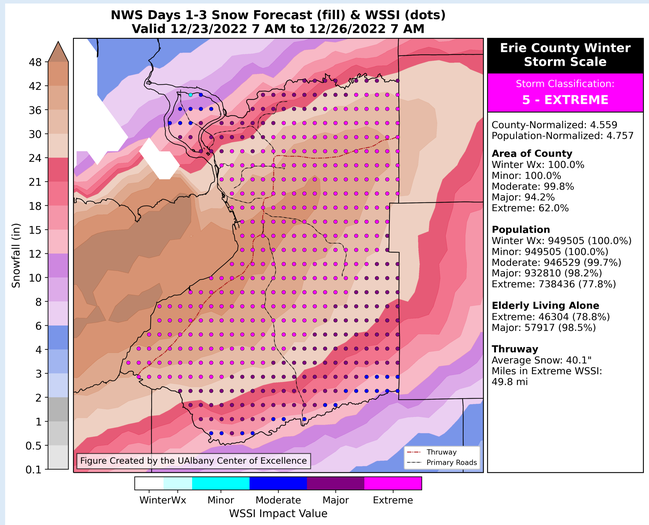



***Figure 7:*** *ECWSS for the December 2022 Buffalo Blizzard. 72-hour NWS forecast snowfall is shown as color fill, while the WSSI impact value at each point is shown as color-filled dots. The panel at right displays metrics including the Storm Classification, county- and population-normalized ECWSS values, area of the county and populations within each WSSI classification, and NYS Thruway impacts.*

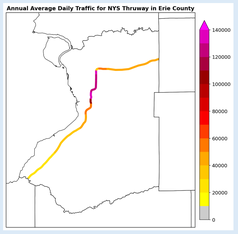
- The Erie County Winter Storm Scale (ECWSS) is based upon the Winter Storm Severity Index (WSSI), incorporating additional socioeconomic & geographical characteristics to enhance county & emergency leaders' understanding of a forecasted winter event.
- The scale directly ingests population data, weighting each location proportional to the population it represents.
- Other, more specific demographic & infrastructural datasets are indirectly ingested.
- The final product is an easy-to-read figure with impact levels by location and as a whole county, as well as information regarding affected populations and infrastructure.
- The Storm Classification is based upon a blend of forecast snow coverage and the percentile of the ECWSS population-normalized value relative to the subset of non-zero snowfall days used in testing (Table 1).

| Storm Classification | Minimal | Minor | Moderate | Major | Extreme |
|---|---|---|---|---|---|
| >25% Snow Coverage | 0.1" | 4" | 9" | 18" | 36" |
| Pop. Norm. Percentile | N/A | 75$^{th}$ | 90$^{th}$ | 96$^{th}$ | 99.2$^{nd}$ |
| Pop. Norm. ECWSS | > 0 | 1.28 | 2.03 | 3.36 | 4.27 |
| Total Unique Occurrences | 346 | 69 | 28 | 15 | 4 |
| Occurrences per Year | 86 | 17 | 7 | 4 | 1 |

***Table 1:*** *Forecast snow coverage, percentile thresholds, and unique occurrences in the testing dataset associated with each Storm Classification category. ">25% Snow Coverage" indicates that this snow amount is forecast for at least 25% of the area of Erie County. Note that all 4 "Extreme" days were from the major lake-effect snow events of November and December 2022.*

### NYS Thruway Impacts

- Winter weather can be highly consequential on the Thruway in Erie County, as up to 140,000 vehicles travel it on an average day (Fig. 8).
- Fig. 9 provides a quick view of the snow forecast and associated WSSI along the Thruway. The reader can easily see where along the Thruway the heaviest snow will fall, as well as potential conditions on nearby roads in the event the Thruway is closed.



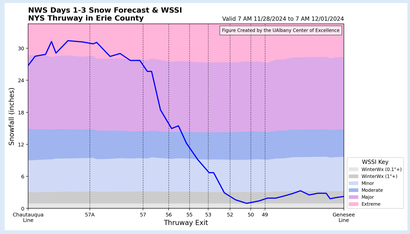
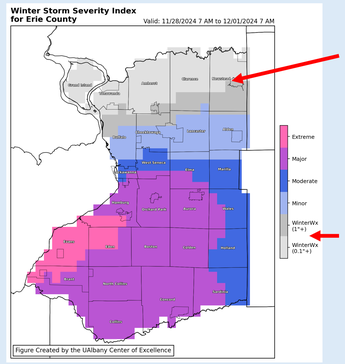




***Figure 8 (left):*** *Annual average daily traffic (cars/day) for the NYS Thruway in Erie County.*

***Figure 9 (right):*** *NWS 72-hour snow forecast issued the morning of 28 November 2024 along the NYS Thruway in Erie County. Background color indicates the WSSI category.*



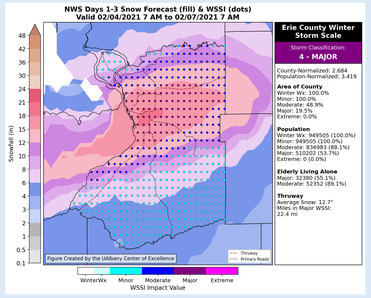

Municipality boundaries are shown on some maps for easy orientation.

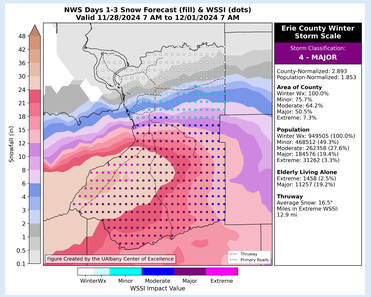
For the ECWSS, the "Winter Weather" WSSI category is split into 0.1"+ and 1"+ designations given the often-significant difference in typical driving conditions across this range of snowfall. For calculation purposes on the 0-5 scale, the 0.1"+ threshold is treated as '0.5' (out of 5), and 1"+ as '1'. (See Methodology)

***Figure 10:*** *Days 1-3 WSSI for Erie County on 28 November 2024 with municipality boundaries.*

## Some more examples…

- When the snow maximum is over heavier-populated areas, the population-normalized ECWSS is higher than the county-normalized ECWSS (Fig. 11). Vice versa is true when the snow max is over the lesser-populated region (Fig. 12).



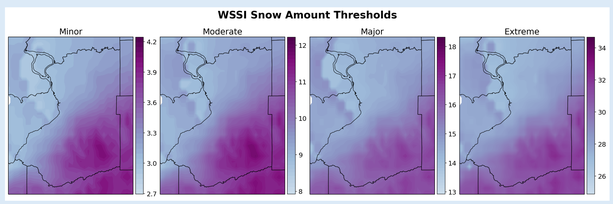

***Figures 11-12:*** *As in Figure 7, but for the forecasts issued the morning of 4 February 2021 (top) and 28 November 2024 (bottom).*

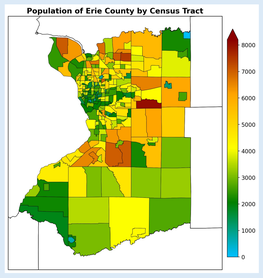
### Limitations

- The importance of each individual socioeconomic factor is vague. Thus, the numerical ECWSS won't directly incorporate every factor.
- Other weather-related factors, such as freezing rain or a storm's duration, aren't considered (yet).
- The current format of the product requires the development of several images. The eventual goal is to have a single image that portrays all necessary information regarding snow & wind impacts, along with a potential user-customizable web tool.

## Data & Methodology

- WSSI snow amount thresholds (Fig. 4)
- NWS 72-hour snow forecasts: 1 Nov. to 31 March, 2020-21 to 2023-24
  - n=603 days (462 with non-zero snow)
  - Reprojected to match WSSI grid
- Socioeconomic, geographical, and infrastructural datasets
  - Population & housing characteristics (2020 Census)
  - CDC Social Vulnerability Index
  - Hospitals & nursing homes
  - Road networks & classifications
  - Elevation
- Transform census-tract datasets onto the 2.5-km WSSI grid (Figs. 5-6)
- Normalize population data
  - Divide values in Fig. 6 by total population of Erie County
- For each 72-hour snow forecast, a WSSI impact value (Minor, Moderate, Major, Extreme) is assigned to each point within the county, based on the WSSI threshold the snow forecast reached.
- Then, a county- and population-normalized ECWSS value is calculated for each day.
  - Based on impact level at each point (translated to 0-5 scale)
  - County-normalized weights each box equally
  - Population-normalized weights according to the fraction of Erie County's population in each box
  - Multiply each box's 0-5 impact level by its weight, then sum the results of all boxes to get the final ECWSS value



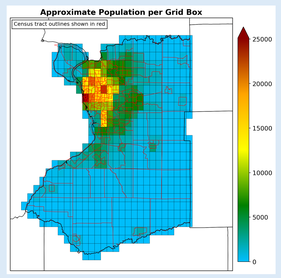




***Figure 4 (above):*** *WSSI snow thresholds for each impact level.*
***Figure 5 (right):*** *Population within each census tract in Erie County.*
***Figure 6 (far right):*** *Approximate population per 2.5-km grid box within Erie County.*

## Blowing Snow

- The ECWSS as shown above does not incorporate wind or visibility data. Given the significant hazards associated with blowing snow, a supplementary scale is tested.
- Scale is based on 6-hour NWS forecasts of snow, maximum wind gust, and minimum visibility *(note: NWS visibility forecasts are an experimental product)*
- Limitations
  - The NWS experimental visibility forecast only extends to 30-36 hours, so the scale isn't calculated beyond that period.
  - Fast-moving snow squalls aren't adequately captured
  - Scale is only valid for falling snow
  - Terrain and land-use effects aren't considered

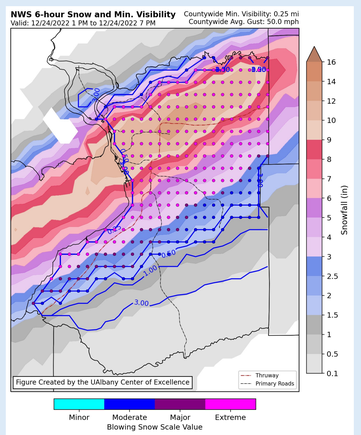



***Figure 13:*** *ECWSS blowing snow scale, valid from 18 UTC 24 Dec. 2022 to 00 UTC 25 Dec. 2022, based on forecast at 12 UTC 24 Dec. 2022. 6-hour snow is shown as color fill, blowing snow scale values as color-filled dots, and 6-hour minimum visibility as blue contours.*

## Summary

- The ECWSS aims to elevate the current WSSI with additional socioeconomic info and efficiently inform county leaders and emergency planners ahead of winter weather events.
  - Will directly incorporate a few broader factors (i.e., population)
  - Will indirectly output info regarding more specific factors (i.e., elderly population that lives alone, nursing homes, road impacts)
- The reader will easily understand:
  - Location of heaviest snow and expected impacts to population / infrastructure
  - Demographics within each tier of impacts
  - A forecasted storm in the context of past storms
- The products are running in real-time this winter (6x daily) and being correlated with observed impacts in Erie County.
- References available upon request

### Ongoing & Future Work

- Incorporate wind and roadway impacts more directly into the ECWSS and Storm Classification
- Comparison of current forecasts to past events (analogs)
- Snow forecast along the Thruway for adjacent counties
- Extend the forecast using NBM data
- Refinements to the figures, delivery format, and the language / word choice used to communicate hazards (particularly that in the Storm Classification)