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# Winter Storm Orlena: An Analysis of the Impacts of Changing Precipitation with Atmospheric Conditions

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**Abstract**

*Winter Storm Orlena, a large Nor'easter containing strong winds and heavy snow, caused disastrous impacts across the Tri-State area, as well as the northeast United States from January 31, 2020 to February 3, 2021. The storm contained different precipitation conditions, with many areas receiving changes between snow and a wintry mix (i.e., freezing rain and sleet) a few times a day. The atmospheric conditions throughout the storm were a factor in changing the precipitation type and creating the dangerous hazards left by Orlena. Using photo-imagery of the changing ice aggregates, weather station data was compared to the different types of precipitation that occurred and analyzed to gain a better understanding of the impacts of rapid changing winter weather conditions.*

Winter Storm Orlena was a snowstorm for the record books across the majority of the United States, with some communities recording their largest snowfall numbers in over twenty years. Many were left without power and a large amount of snow and ice to dig out of. However, the deadly hazards left by Orlena could have been better mitigated if warnings were coordinated with the changing conditions of the storm, specifically between January 31, 2020 and February 1, 2021. Through a comparison of weather station data taken in southeastern Pennsylvania and photo-imagery of the different ice aggregates, an analysis determined how a community can better prepare for a high-impact winter storm.

## Background

Snow is considered one of the most beautiful weather phenomena that occurs in nature, with many associating it with good times and holiday joys. However, snow formation is particularly complex and can result in many different types other than just the stereotypical powder people enjoy. Snowflake formation first begins when extremely cold water droplets freeze onto airborne particulate matter, such as dust. These new ice crystals then begin to aggregate, forming different shapes of snowflakes. The shapes that the ice crystals grow into depend on the conditions going on around them, more specifically, the temperature and humidity of the air surrounding each aggregate (National Oceanic and Atmospheric Administration,

2016). Based on the Nakaya Diagram (Refer to Appendix, Figure 1), a graph depicting snowflake formations based on changing air temperatures and humidity, Orlena was able to produce two types of formed snowflakes. The beginning of the storm yielded plate-like snowflakes, changing later into column-like snow crystals, finishing with another change back to the plate-like snowflakes. Plate-like snowflakes are the "typical" snowflake, or a flat crystal with six legs to it (also known as a dendrite). Column-like snow crystals can range from needles to solid prisms, as well as hollow columns (Libbrecht, 1999). These types of snow crystals tend to look more like ice crystals than snowflakes.

**Data Collection**

To begin data collection, observations were made using an AcuRite home weather station located in Barto, Pennsylvania. Observations and photography were coordinated at the same times based on the visual changes occurring during the duration of Orlena. The atmospheric conditions changing in Orlena produced the aggregation of different snow crystals (Refer to Appendix, Figure 2). As the low-pressure system moved into southeastern Pennsylvania, pressure steadily dropped as humidity increased. As temperature decreased, the snow crystal changes from a powdery dendrite, to a stiff and formed dendrite, to finally solid prism-like ice crystals. Then, as the temperature increases, the precipitation turns back into a powdery dendrite.

**Discussion**

What are the implications associated with these changes in precipitation, and what can be done to help avoid their disastrous effects? When Orlena went through southeastern Pennsylvania, it added various layers of snow to the ground. The initial layer was more wet due to the temperature of the air, making it heavy. The next layer was very icy since the temperature had decreased, which then started to freeze the initial layer. Lastly, another wet and heavy layer fell on top of the now hardened previous layers. Since the temperature did not reach above freezing until after Orlena was well into the northeast United States, the three layers continued to slowly freeze together. This left many people struggling with slick, heavy, and thick amounts of snow and ice to dig out of.

Two types of hazards were prominent during this storm: dangerous driving conditions and difficult snow to clear away. On February 1, 2021, the Pennsylvania Department of Transportation, and the Turnpike Authority restricted travel at 9:00am, with many roads under a Tier 1, Tier 3, or Tier 4 restriction. Each tier places a different degree of restriction on vehicles, with Tier 4 restricting all commercial vehicles from driving (WGAL News, 2021). However, while speed limits are decreased in these tiers, many were already on the road by this time. The slippery road conditions mixed with the strong winds and blowing snowfall led to hundreds of vehicle crashes in the Tri-State area (Childs, 2021). This can be avoided in the future by enforcing a larger restriction on all motor vehicles as the storm progresses through its phases. People tend to misjudge the severity of road conditions either because they need to be somewhere, or do not believe the impacts that meteorologists are warning about. By working closer with forecast meteorologists, transportation officials can improve accuracy on when all-vehicle restrictions should be put in place even before the most severe part of the storm makes it into the area.

On average, roughly 11,500 people are injured, and 100 people are fatally injured, just from shoveling during the winter. This is due to the strenuous activity shoveling places on the body in a cold environment. Most normal injuries are soft tissue related (i.e.,

pulled muscles), while all fatalities are related to cardiovascular injuries, such as heart attacks (Searing, 2019). Winter Storm Orlena is a good example of strenuous snow shoveling conditions. If someone had waited until Orlena had completely passed to begin digging out, they could have been trying to move upwards of three feet of snow that had compacted and froze, making it extremely difficult to move by hand. To prevent future injuries and fatalities occurring from large winter storms, meteorologists with the help of emergency managers should issue helpful shoveling alerts and warnings based on the radar movement of the storm. For example, the National Weather Service Weather Forecast Office in Mount Holly, NJ could have issued an alert around 7:00pm on January 31, 2020, suggesting that homeowners should take a moment to clear off cars and make a clear pathway to doors. This would show people the importance of keeping on top of the snowfall amounts during the storm as opposed to clearing everything at once when it is finished, potentially eliminating dangerous injuries.

Winter Storm Orlena was a large snowstorm that highly impacted regions across the United States, especially on the East Coast. However, through the struggles of individuals, we can use this case study as an advantage to improve future winter storm preparations.

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## Appendix

***Figure 1***
*Nakaya Diagram (Libbrecht, 1999)*

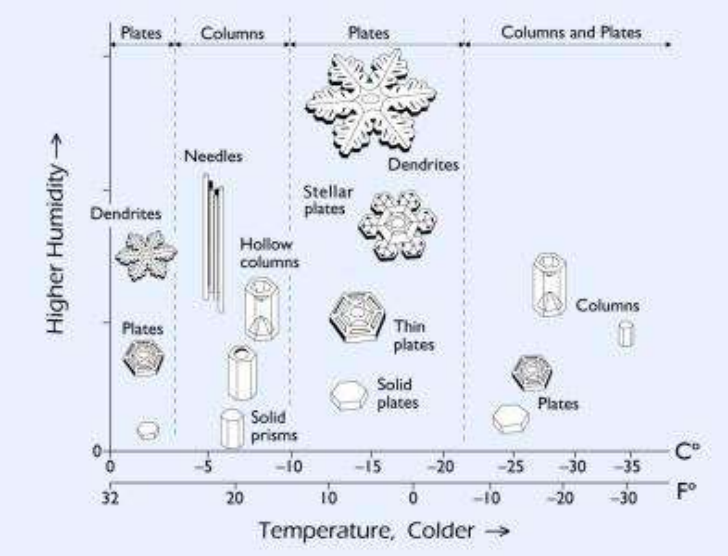


***Figure 2*** *depicts the recorded snow crystal imagery compared to the atmospheric conditions present during that time.*

| Image | Date/Time | Temperature | Humidity | Pressure |
|---|---|---|---|---|
|  | 01/31/2020 12:30PM | -2.78 °C | 73% | 1021 hPa |
|  | 01/31/2020 4:00PM | -3.89 °C | 82% | 1018 hPa |
|  | 02/01/2021 11:00AM | -4.44 °C | 89% | 1006 hPa |
|  | 02/01/2021 5:00PM | -2.22 °C | 96% | 1002 hPa |

**Recommended Citation**
Gonteski, C. D. (2021). Winter Storm Orlena: An analysis of the impacts of changing precipitation with atmospheric conditions. *Made in Millersville Journal*, 2021. Retrieved from https://www.mimjournal.com/paper-58