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Climatology of Cold Fronts in the Appalachian-Piedmont Region

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Abstract

MU-Piedmont-area Arctic Storm Tracking (MU-PAST) is a research project involving over 35 undergraduate meteorology majors designed to study the structure and evolution of winter season Arctic fronts as they progress across the Appalachian piedmont region. The project takes a 3-pronged approach: 1) a climatological study of cold fronts affecting the region; 2) a field campaign where three teams conducted balloon-borne upper-air profiles; and 3) a numerical simulation initialized with observational data. Using surface analysis data from 1985- 2021, this study developed climatology for the area of interest, including cold front frequency and approximate time of frontal passage. The relationship between front frequency and global teleconnections was investigated using statistical analysis.

The passage of fronts is a key factor influencing the weather conditions over the midlatitudes. A front can be defined as the interface between air masses of differing density and origin, featuring a strong horizontal temperature gradient (Markowski & Richardson, 2010). Consequently, frontal passage over a given area is marked by a change in temperature, humidity, pressure and wind direction. In some cases, these differences between adjacent air masses can induce disturbed weather conditions. The arctic front, or the semi-permanent and semi-continuous boundary between a deep mass of arctic air and a shallower mass of polar air, can often push south into the midlatitudes during the wintertime. This type of front often breeds winter weather events affecting the Appalachian piedmont region, a plateau region between the Appalachian Mountains Atlantic coastal plain depicted in Figure 2. Since frontal passage impacts atmospheric conditions and has the capacity to produce hazardous weather events, knowledge of how often fronts affect a specific area would prove helpful for local forecasters and researchers alike. Despite their strong meteorological significance, however, few studies examining front frequency exist. This has been attributed to some inherent difficulties associated with compiling a climatology for fronts; forecasting centers have historically analyzed surface charts manually, necessitating that climatology representing features obtained from surface analyses, in turn, must be generated manually making the construction of front climatology a lengthy process (Sinclair, 2013). While time-consuming, recording front frequency would benefit the local forecasting and weather prediction community, particularly when considering any possible effects from global teleconnections like the Atlantic Oscillation (AO) and the North Atlantic Oscillation (NAO). The AO is a large-scale mode of climate variability characterized by winds circulating counterclockwise around the Arctic, while the NAO is the dominant mode of winter climate variability in the North Atlantic and characterized by the surface sea-level pressure differences between the semi-permanent areas of high and low atmospheric pressure in the Azores and Icelandic regions respectively.

This component of the MU-Piedmont area Arctic Storm Tracking (MU-PAST) project serves to conduct a climatological investigation into cold front (CF) frequency and time of passage over Millersville, PA from the years 1985-2021. Furthermore, this project strives to test the newly compiled CF frequency data against the AO and NAO index, using a Pearson Correlation Coefficient test to determine the relationship between the variables.

Data and Methodology

The data employed in this study was obtained from the High-Resolution Surface Analysis provided by the Weather Prediction Center (WPC). This resource allows users to view interactive surface analyses from 1985 to the present. Each calendar day features eight surface analysis maps showcasing data from 0 UTC-21 UTC, with maps released every three hours (0 UTC, 3 UTC, etc.) While these archives represent most of the observed time period, some gaps in the data exist. These gaps were particularly severe and pervasive during the months of January; the years 2000, 2005 and 2006 all lacked January data entirely. This can likely be attributed to holidays around this time period. Through examining every map available from 1985-2021, the number of CF passages per day and the approximate time of frontal passage were recorded. Since the surface analyses are released in three-hour increments, a degree of estimation was involved in recording when a frontal passage occurred. To approximate the time of a frontal passage, the synoptic structure and patterns before and after frontal passage were closely observed and the development of the system of interest over time was considered. To maintain consistency and account for the human estimation involved, cold fronts were recorded to the closest approximate hour of arrival. To investigate the relationship between CF frequency and greater global atmospheric teleconnections, monthly mean AO and NAO indexes were employed. These values were obtained from the National Oceanic and Atmospheric Association's National Centers for Environmental Information (NCEI). To diagnose the relationship between the index and CF frequency for each event, the Pearson Correlation Coefficient was calculated with each of the indexes serving as the independent variable and CF frequency serving as the dependent variable.

Results

Utilizing the CF frequency and time of passage data, several histograms were generated. First, month-specific graphs were created, focusing on January and February. Figures 3a and 3b display the total number CF occurrences by hour, during January and February, respectively. The histograms in Figures 4a and 4b show the total number of recorded January and February CFs per year. A broader histogram is depicted in Figure 5, representing the total recorded CFs per each month over the observed period. While October featured the highest total at 202, January featured the second highest at 190, despite missing 3 years of data. Performing the Pearson Correlation Coefficient test on NAO yielded an R = 0.14, indicating a slightly positive correlation. Performing the Pearson Correlation Coefficient test on AO yielded an R = 0.20, indicating a stronger, but still only slightly positive correlation. Figures 6a and 6b depict the AO and NAO index respectively, plotted against CF frequency.

Discussion

The results of the Pearson Correlation Coefficient test did reflect a slightly positive correlation between CF frequency and the teleconnections of interest, with the stronger correlation associated with the AO Index. This is indicative of possible effects of the Artic Oscillation on CF occurrence, more so than possible impacts of the North Atlantic Oscillation on CF occurrence. However, it should be acknowledged that the significant gaps in surface analysis data impacted the results of this climatological study. Bearing that in mind, future climatological investigations in the cold fronts may necessitate collecting other forms of data to supplement the periods of times that lacked maps.

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WPC surface analysis zoom, pan, animation and archives. Retrieved Winter, 2021, from https://www.wpc.ncep.noaa.gov/html/sfc-zoom.php.

Appendix

Figure 3a: Total occurrences for January cold front arrival time

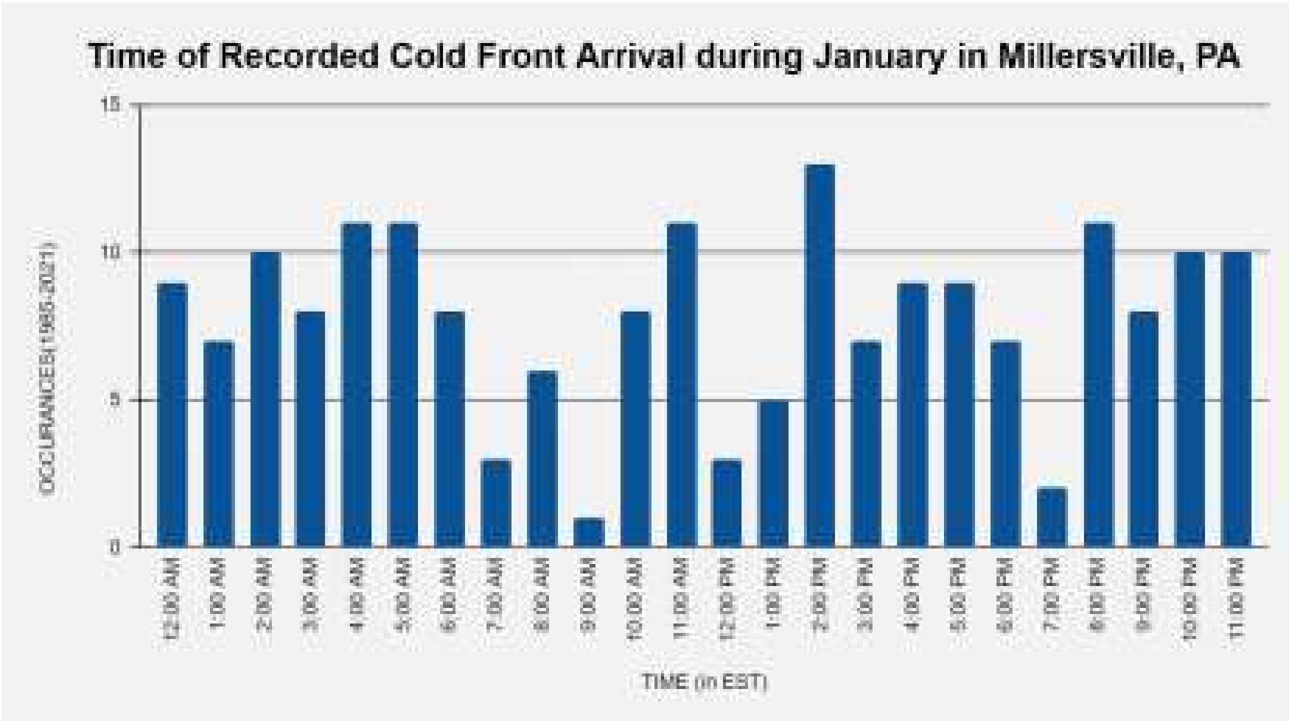


Figure 3b: Same as Fig 1a., except for February

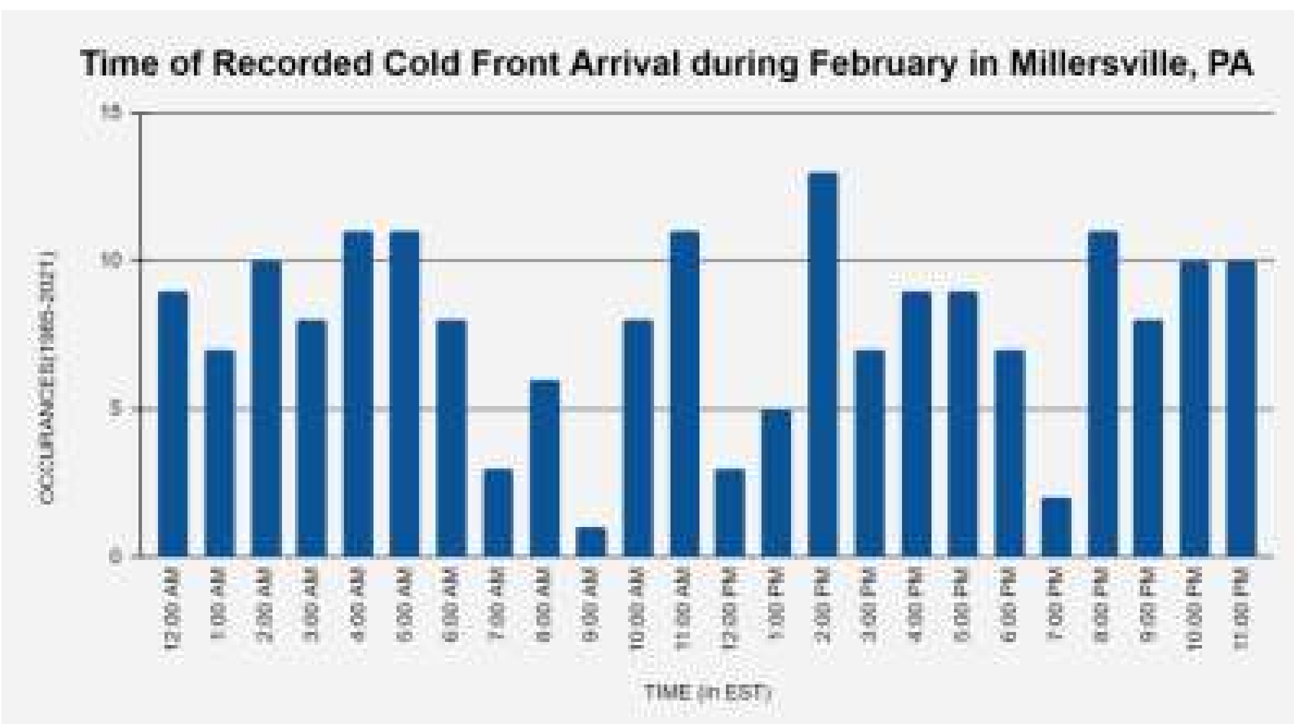


Figure 4a: Total number of January cold fronts recorded each year

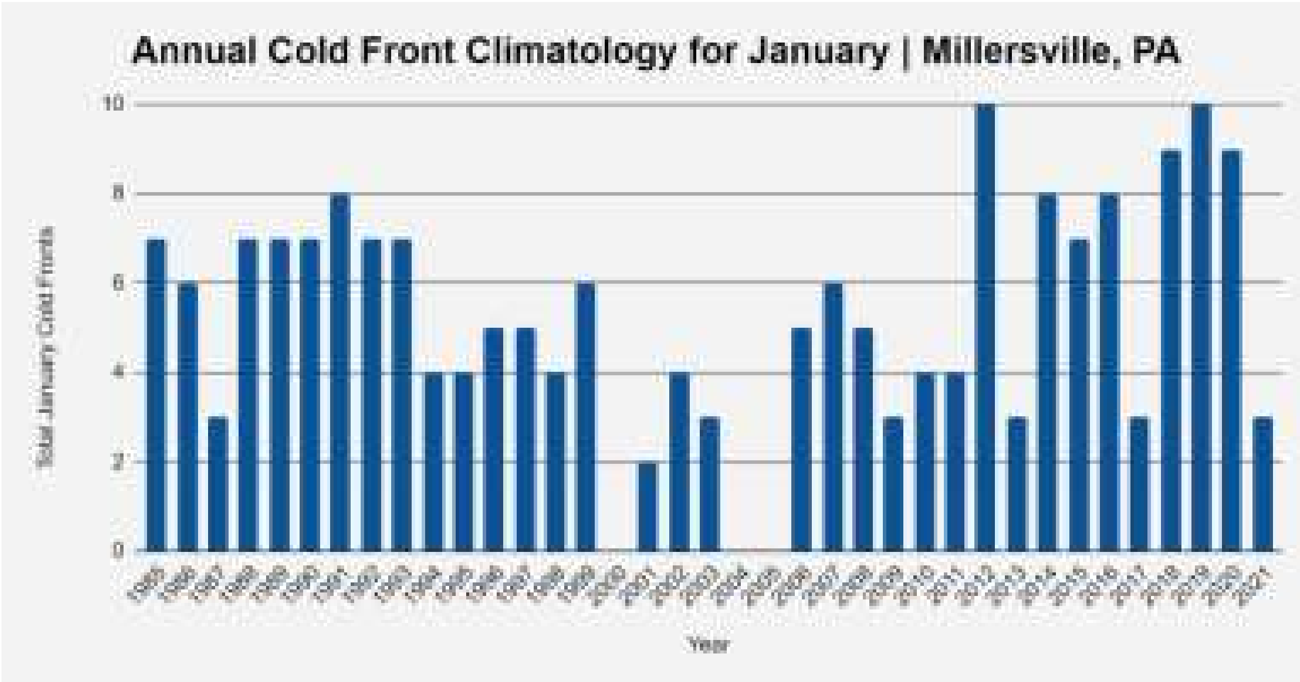


Figure 4b: Total number of February cold fronts recorded each year

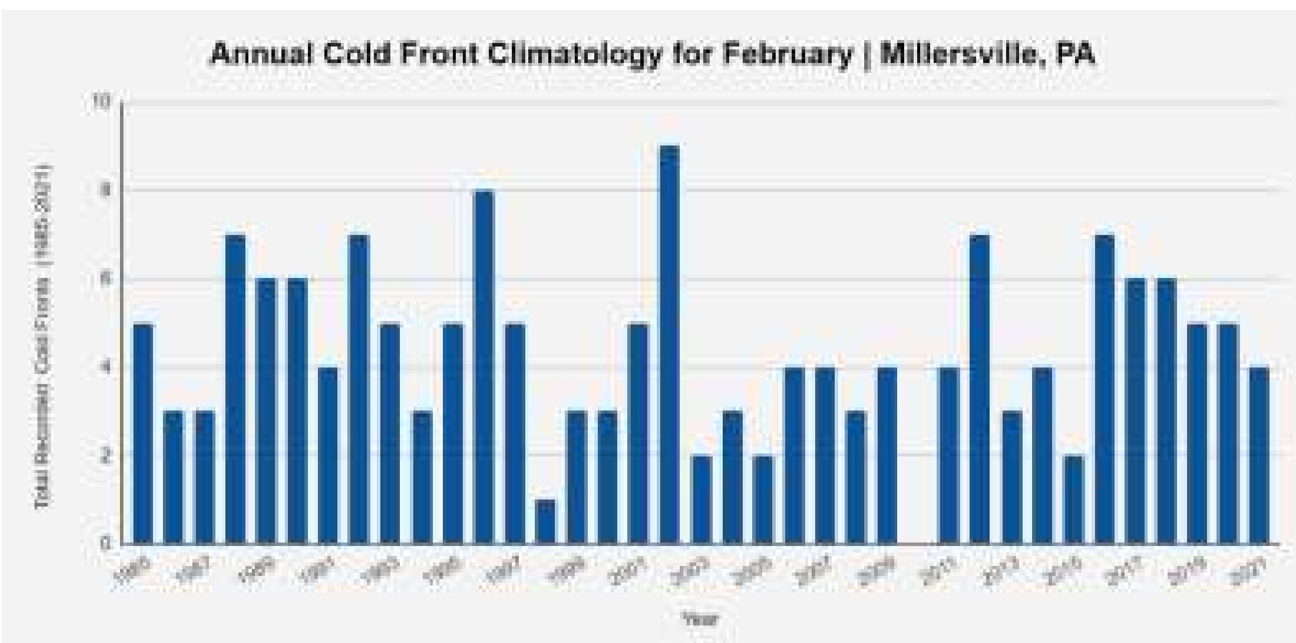


Figure 5: Monthly cold front totals

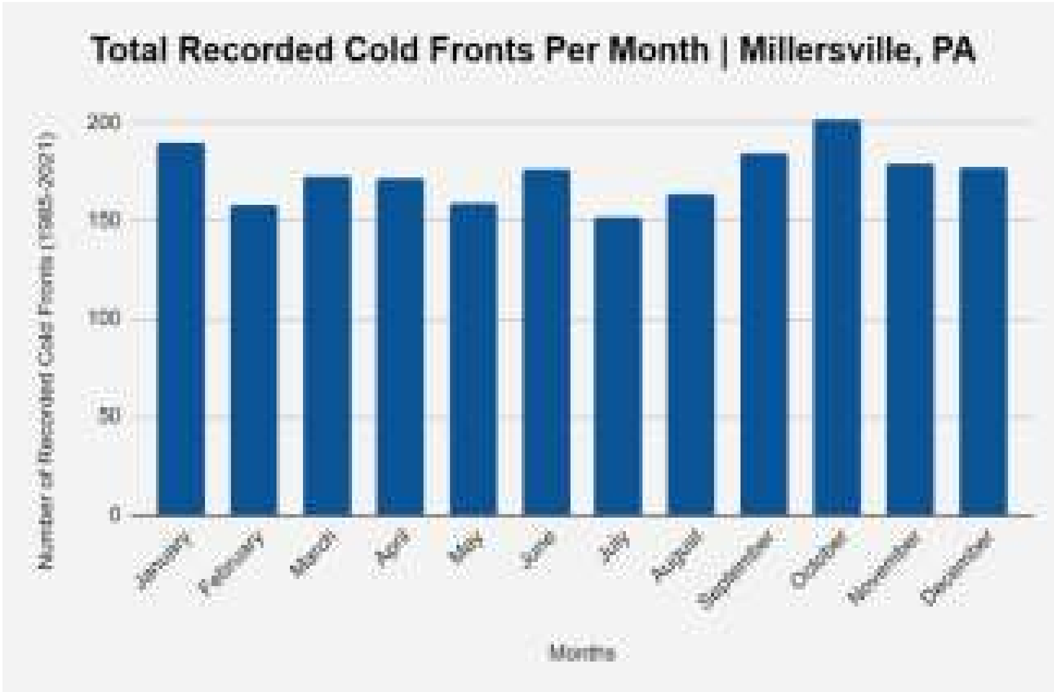


Figure 6a: Time series plot displaying AO Index (in Yellow) vs. Cold Front Frequency (in Blue)

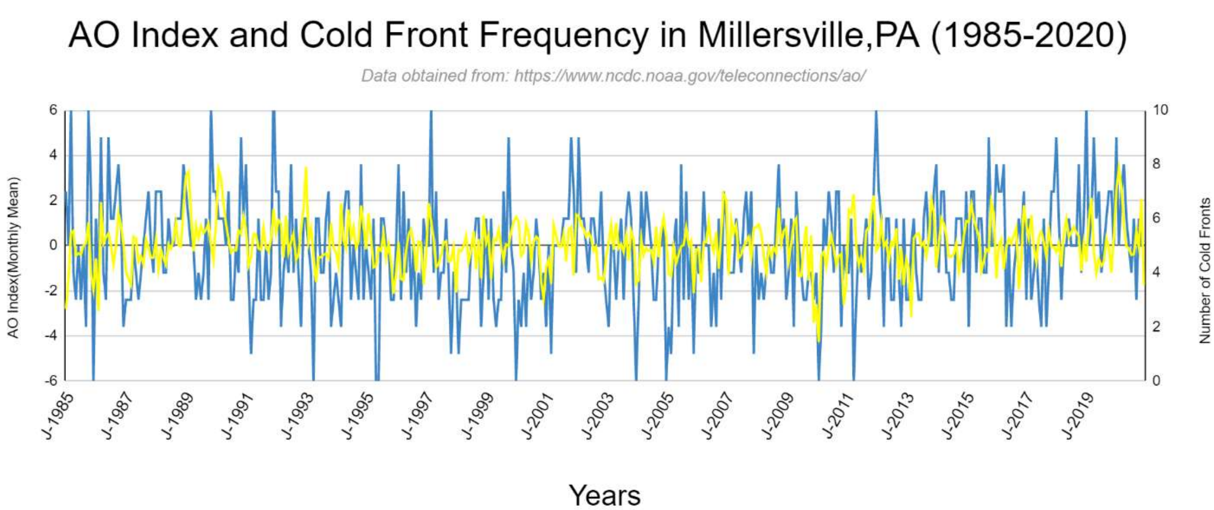
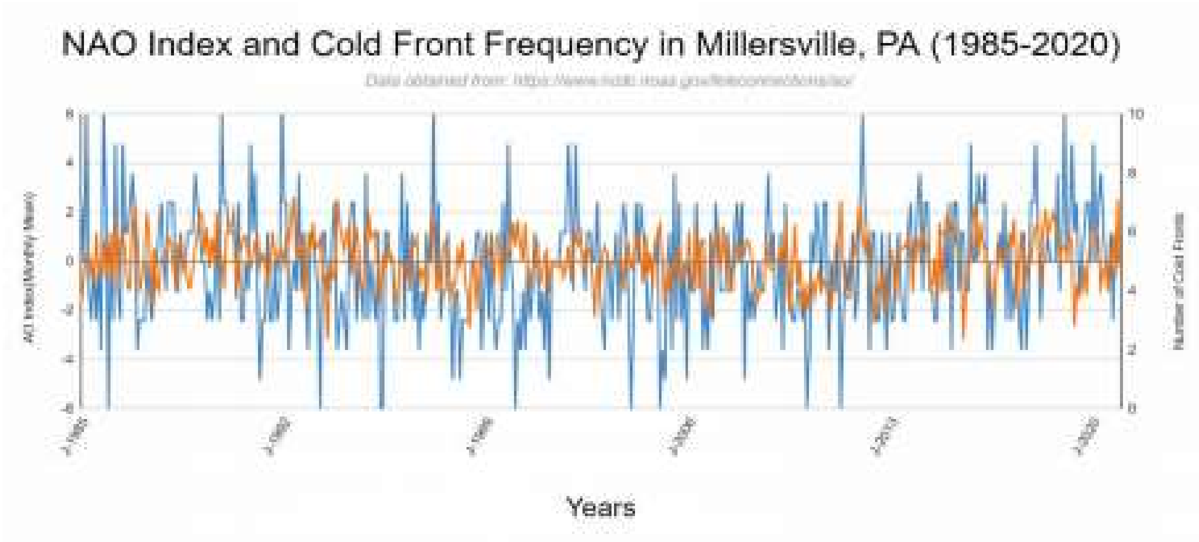


Figure 6b: Time-series plot displaying NAO Index (in Orange) vs. Cold Front Frequency (in Blue)



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AO	**Artic Oscillation**
NAO	**North Atlantic Oscillation**
CF	**Cold Front**

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