An Analysis of School Cancellation Policies in Virginia

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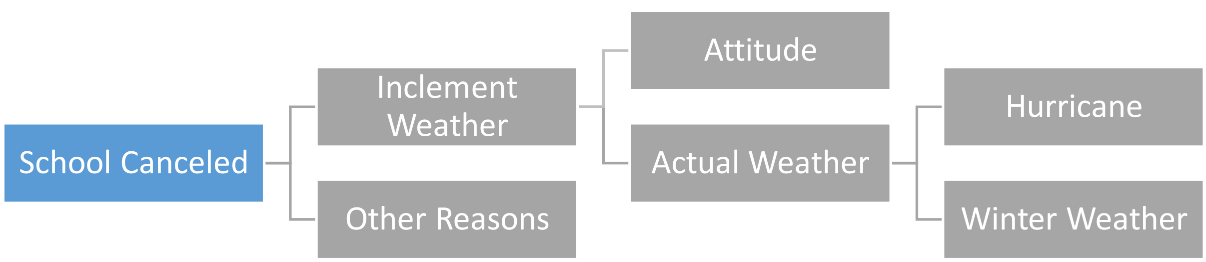
I. Introduction

Each year, when winter arrives, parents grumble about the supposed excessive willingness of school administrators to cancel school in bad weather and how that was rarer when they were kids. Data from the Virginia Department of Education (VDOE) and individual school districts show an increase in the number of days cancelled over time, but is it really a result of increased sensitivity toward winter weather and its consequences?

The number of school days cancelled each year in Virginia has, indeed, increased slightly at an estimated rate of .081 days per year between 1963 and 2015. Possible causes for this change include increased weather severity, increased sensitivity to severe weather, and increased school cancellations due to non-weather events. Reasons for school cancellations are summarized in Figure 1.

Figure 1: Factors Contributing to School Cancellations



The stakes are high when the superintendent or director of transportation for a district considers cancelling school. Her primary consideration is student and teacher safety, yet she also must balance parent opinions. Some students may actually be worse off when school is cancelled if they are left home alone, spend the day in a less safe environment, must be transported elsewhere, or are a recipient of free and reduced-price school lunches. Furthermore, canceling a day of school poses the administrative challenges of informing parents of changes to the school schedule on the day of cancellation and on possible future make-up days, since Virginia law requires that school be held for 180 days or 990 hours each year (West). A year with too many school cancellations will force a district to apply for a waiver from the state, although the Virginia Department of Education does not maintain a record of such waivers, and staff do not recall examples of waivers in recent years (Hieatt and communications with the VDOE). Finally, missing a day of school could negatively affect student achievement. This research aims to identify changes in school cancellation policies and to provide evidence for making more efficient decisions regarding school schedules, given the complex consequences of cancelling due to inclement weather.

We begin by reviewing the relevant literature on the causes and effects of school cancellations. We will introduce our Virginia school cancellations data by year and by day. Then, we will explain the weather variables we used to model school cancellations: number of days with at least half an inch of snowfall, total snowfall, number of days with a maximum temperature of up to 32˚F, and a hurricane severity variable. Our results identify a slight increase in the number of school days cancelled and, contrary to our hypothesis, no change in reactions to weather. In our discussion of these results, we will acknowledge limitations of an incomplete data set and suggest paths for further research, including normative analysis of school cancellations and school calendars.

II. Related Literature

Related studies have focused on understanding the costs and benefits of cancelling school for severe weather. Some show that missed class time impacts a student's learning from the beginning of their primary education, affecting their reading scores on the NAEP standardized test for every age, racial or ethnic group, and location (Ginsburg 2). Three percent fewer third graders perform satisfactorily on standardized tests in years with heavy snowfall that leads to the loss of five days of instructional time (Marcotte 9). In contrast, Goodman (2015) suggests that days with marginally bad weather that might cause some students to choose to stay home should be cancelled because the cost of helping those students to catch up with the rest of the class is greater than the cost of rescheduling or consolidating lesson plans for the entire class.

Related literature on how changing attitudes towards weather affect school cancellations seems scarce. Call and Coleman (2012) examine the decision-making process for school cancellations, finding that for districts in the state of Maryland, most cancellations in the past ten years occurred almost exclusively due to weather, especially in the winter. Furthermore, the process for cancellation decisions appeared to be similar across school districts, an assumption that we adopt for Virginia. Trubetskoy (2016) maps observations taken from a popular online discourse about school cancelations to help visualize regional tendencies to close school based on the amount of snowfall in 2014. Unsurprisingly, the map, and many people's personal experiences, show that many southern states, including Virginia, have been known to cancel school for "any snow" or even the likelihood of snow. The map shows that schools in the southern United States cancel school for less severe weather than do the northern schools, but it does not compare modern tendencies in school cancelation to past tendencies. Noting the aptitude of Virginians to cancel school during the snowy winter of 2014, Barkhorn (2016) pointed out in *The Atlantic* that there may be generational differences in attitudes towards canceling school for inclement weather. We attempt to confirm the observation that attitudes towards weather-related school cancellations have changed over time by looking at data for school cancelations and the weather that caused them over a longer period, as far back as 40 years for some districts.

III. Data

a. School Cancelations

We requested school cancelations data from 93 of Virginia's 137 public school districts that encompassed the largest populations. Forty-five of the districts provided data on their cancelations for ten or more years. Figure 2 displays the counties/cities and periods included in our school cancelations data. Missed days were counted if classes were cancelled for students for the entire day and district. Student-free days, such as teacher work days or parent-teacher conferences are not included in the 180 school days required in a school year by Virginia law, so they are not included as missed days. This method of counting missed days coincides with the manner in which snow days are counted in requests to the Virginia Department of Education (VDOE) to waive the requirement that Virginia public schools begin after Labor Day, and it is consistent with the reality that weather patterns affect large areas and usually cause the cancellations of entire districts, rather than individual schools. Our data on school closures consist of only the records that schools kept, so it is sparser in the beginning of the period. However, it should have equal accuracy in the beginning and end of the period because administrators a few decades ago probably had no disadvantage in recording school days that were cancelled. Figure 3 shows the number of districts by year for which data existed.

Some of the districts provided additional data, including the specific dates when school had been cancelled. Using this data, we examined frequencies of days missed between the beginning of September and the end of March, the period containing the strong majority of

Figure 2: School Cancellations Data Supplied by Virginia Districts

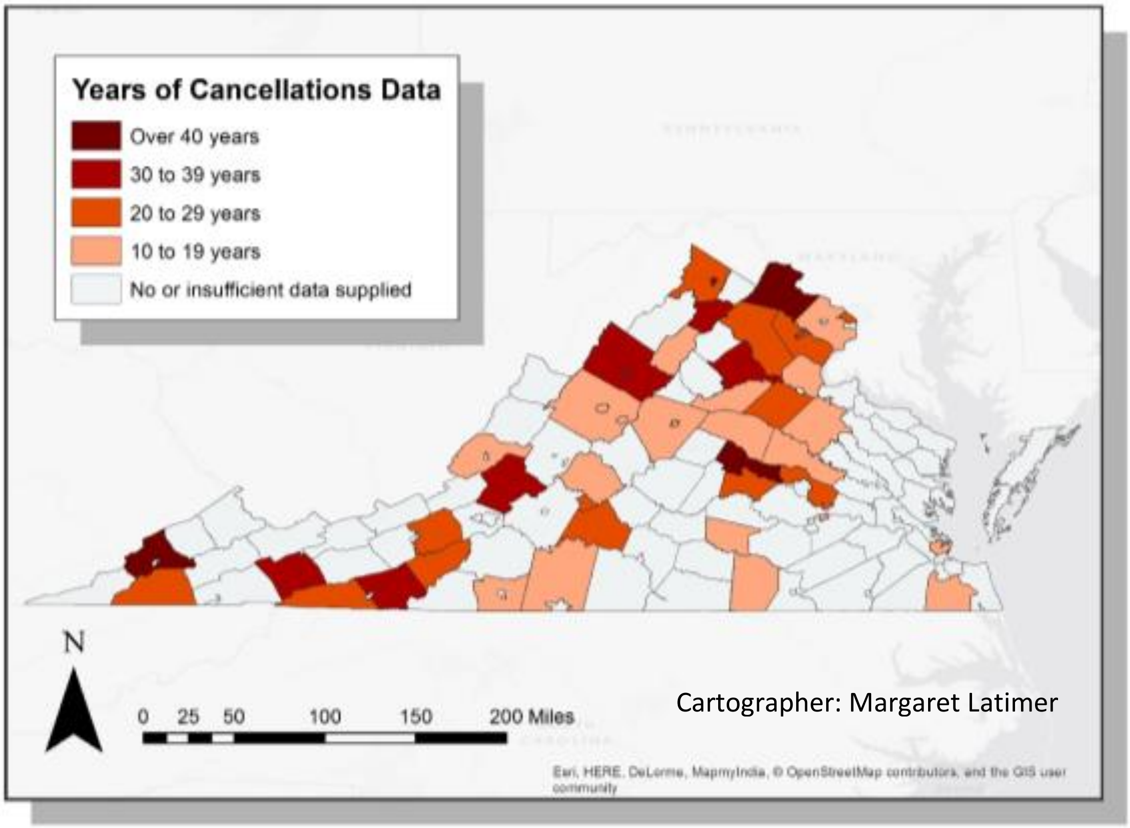
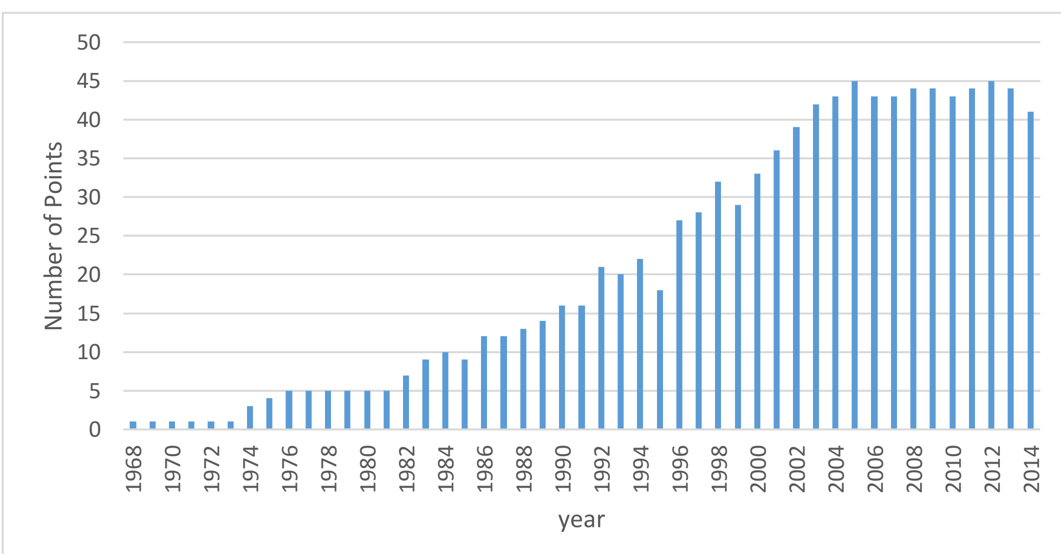
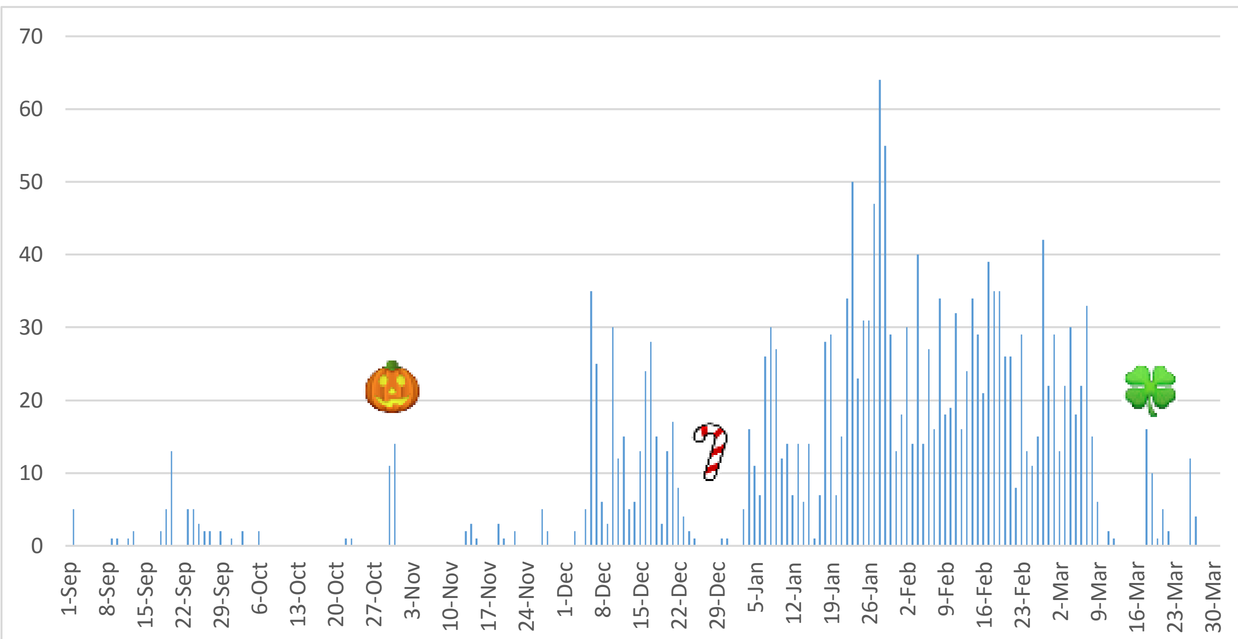


Figure 3: Number of School District Data Points by Year



cancelled days. Figure 4 shows the total number of school cancellations on each date for a balanced panel of 19 counties from school years beginning in 2000 to 2015. The data in September and early October can be interpreted as mostly days that were cancelled due to hurricanes. Cancellations from early December to late March were mostly due to winter weather, with the peak period for winter weather cancellation occurring in late January. Winter break is observed as a gap in the graph including 23 December through 1 January, since no days of school can be missed when school is not in session.

Figure 4: School Cancelations by Date from 2000-2015



A more surprising observation from the bar chart are the number of cancellations on Halloween (October 31) and St. Patrick 's Day (March 17). These holidays are similar because they have a stronger cultural than religious significance. Unlike national holidays, like President's day or Martin Luther King Day, which have no set date and are often scheduled as student holidays, spikes of cancellations on these cultural holidays are observable because they take place on the same day each year and are not usually scheduled as student-free days. It seems unlikely that the observable spikes in school cancellations on cultural holidays are merely due to coincidentally poor weather. Perhaps school is cancelled more on these days because students are already more likely to miss class on cultural holidays or because those who attend school are excited and more difficult for teachers to instruct and manage. Expecting students to learn less on these days lowers the stakes for cancelling school, thereby increasing the willingness to cancel school due to severe weather. The cancellations near the end of November may capture the beginning of hunting season, for which Appalachian districts have been known to cancel school (Sharp).

Information on when school is most likely to be missed already influences school calendars: school districts sometimes make their calendars flexible in scheduling teacher planning days or national holidays that can be used for makeup. Based on our tally of periods that tend to have many days cancelled due to poor weather, schools that want to reduce rescheduling school for make-up days could schedule teacher planning days in late January.

School districts sometimes provided additional data on reasons for school cancellations. Most of the reasons for closing were related to weather: hurricanes or winter storms. Other reasons include cancellation of various districts on the day after the September 11, 2001 attacks, the cancelation of several Northern Virginia districts in 2008 due to traffic from the presidential inauguration, cancellation of various districts for the presidential primaries in 2016, and cancellations for regional scenarios with live gunmen.

b. Time Periods

Virginia school academic calendars begin in August, and schools are usually in session from early September to mid-June, unless receiving a waiver to begin before Labor Day. This contrasts with the calendar years that are used for most other measurements, including weather. All data in this paper correspond to the calendar year in which the school year began, even if the weather took place in the beginning of the next calendar year. To measure winter weather, which is the primary reason for school cancellations, we aggregated data from monthly or daily measurements for the winter months, December through March. When using daily measurements, we excluded days on which inclement weather cannot have an effect on the number of school days cancelled, Saturdays and winter break, December 23 through January 1. We included November 30 in the winter months when they were aggregated by day because it was the beginning of the upward trend in cancellations through the beginning of December that signified worsening weather.

c. Weather

The Global Historical Climatology Network (GHCN) of the National Oceanic and Atmospheric Administration (NOAA) provides monthly and daily summaries of many weather variables. A combination of a weather station's proximity to the geographical center of a school district and the completeness of the weather data recorded at that location over the period of school closures data determined its choice.

Using measurements of the number of days when weather conditions reached a given threshold, rather than maximum, minimum, or average values, suits this project due to the assumed binary nature of the decision to cancel school: the superintendent chooses to cancel or not to cancel school for a day. On the day of a snowfall, additional weather severity does not matter once the weather conditions reach the (unknown) threshold. We investigated three levels (half an inch, one inch, and three inches) at which the variable was defined as the number of days above the threshold and identified the half inch of snowfall level as providing the most explanatory power. Cultural expectations of the American South are consistent with the half inch threshold for snow, especially in Southern Virginia (Barkhorn). An additional variable, annual total snowfall, accounts for storms that are so severe that school is cancelled for multiple days.

Differences in expectations, road-clearing infrastructure, and attitudes across Virginia may cause variance in the actual regional thresholds. The Barkhorn map, which drew on social media for data about the amount of snow that typically leads to cancellation of school in a region, provided an indication of these attitudes, and we originally used it to break our data set into three parts, corresponding to the different threshold levels. The half inch threshold was mostly used in the southeastern part of the state; the three-inch threshold was used in northern Virginia and the most mountainous western counties; and the one inch threshold was used for much of the state's center. However, the best threshold for explaining school cancellations throughout the state proved to be the most sensitive threshold, half an inch.

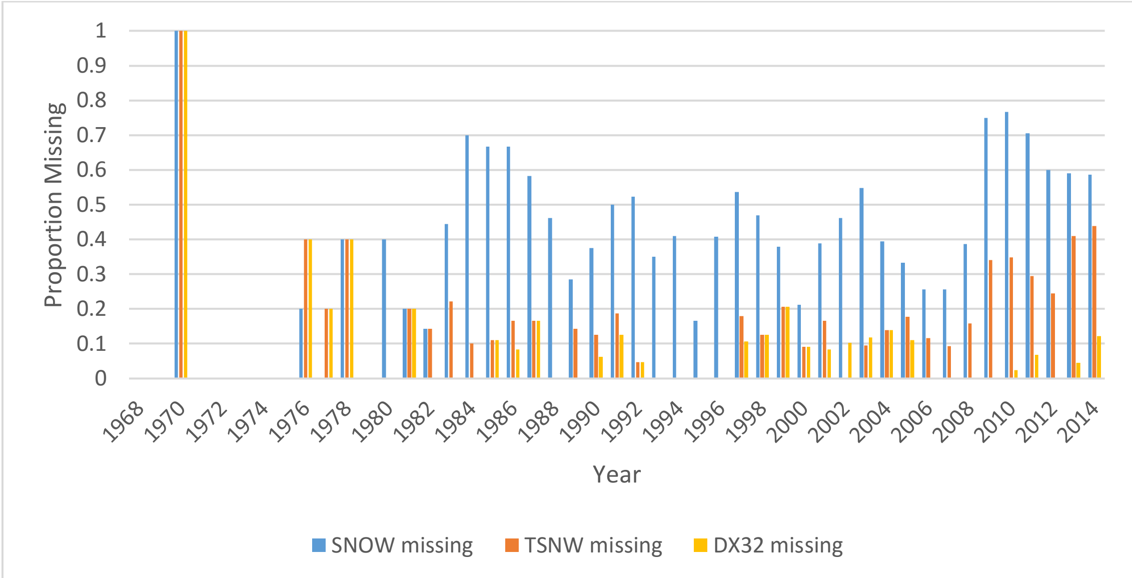
To repeat, SNOW variables for our regressions were calculated by counting the number of days in each winter for which snowfall was above half an inch. Missing data on any number of the days in a year's winter at a given weather station would bias that point downwards. Our original method of correction for this was to assume that the rate of days with at least a given snow threshold, on days with snow records and days without snow records, was the same. Thus, we could estimate the total number of days with greater than or equal to a given snow threshold by adding the percentage of snow days above the threshold level for the data that we had and the data that we were missing. This method was especially problematic when we were missing a large quantity of data, especially if that data were grouped in a specific month, because typical amounts of snowfall are not consistent throughout winter. We eventually ceased using estimated data because of this problem, even though it reduced our SNOW weather data sample by over 50%.

Low temperatures also can be a reason to cancel school, as they contribute to and exacerbate the problems caused by snow and ice for schools. The number of days with a maximum temperature of 32 ˚F or below (DX32) was our variable for low temperatures, taken from GHCN's monthly climate summaries. Even when time coverage of weather data was taken into account in choosing weather stations, it was common for up to a quarter of the data for a given year, taken from monthly summaries, to be missing.

A year's total snowfall (TSNW) in inches supplemented information from SNOW variables by helping to account for particularly large snowfalls that cancelled multiple days of school. Missing observations were also a problem in this variable. Figure 5 shows the incidence of missing data by weather variable. We had to drop between 10 and 50 percent of our data due to missing total snowfall data values, but many of the points dropped overlapped with those already dropped for insufficient daily SNOW data. Estimation of DX 32 and TSNW increased the number of points in our data set, but a data set with no estimated data produced remarkably similar results. Therefore, in our reported results, we use our most accurate data set, that without any estimated weather variables.

Another weather factor that affects the number of school days a district cancels in a given year is the incidence of tropical storms that affect the district. A hurricane variable takes into account the severity and location of storm paths for the academic years of our school cancellations data. Hurricanes tend to be worse for the Virginia districts located under or to the east of the hurricane's path, due to typically higher wind speeds and the lower elevation of the

Figure 5: Missing Data



tidewater geographical region on Virginia's eastern coast. Hurricanes span from 50 to 300 miles across, but given the lower intensity of Virginia storms during our time period, when none reached more than a category 1 out of 5, we chose 100 miles as a threshold for the effects of a hurricane to the west of its path (Hurricane Structure). Therefore, a district's location, relative to a hurricane's path, was taken into account by assigning 0 if a county was more than 100 miles to the west of a hurricane's path, 1 if the county was less than one hundred miles west of a hurricane's path, and 2 if the county was under or to the east of the hurricane's path. These location indicators were multiplied by a storm severity indicator, assigned according to the storm's category on the hurricane severity index for the majority of its path within Virginia, ranging from tropical depressions (1) to category one hurricanes (3). The hurricane variable for each academic year included all of the hurricanes between 1 September and 15 June. Academic years with no hurricanes between 1 September and 15 June were assigned 0 for the hurricane variable.

d. Location Fixed effects

Location fixed effects helped us to separate time trends from the effects of differences between school districts for school cancellations. For example, one district's administration might have been more likely to cancel school than another for a similar storm due to increased regularity of severe winter weather. Conveniently, school districts in Virginia are determined by county and city lines (cities are separate from counties in Virginia), so location fixed effects also take into account differences in transportation and road-clearing infrastructure between cities and counties. While the Virginia Department of Transportation controls the budget for most counties, Arlington, and Henrico counties control their own snow clearing budgets, as do all of Virginia's independent cities.

e. Descriptive Statistics

Descriptive statistics for the variables that we used in our analysis are located in Table 1. No estimated data are included. There were a few particularly bad winters, which skew the data right for number of days with a maximum temperature up to 32˚F and total snowfall. There were also a few particularly bad years for hurricanes, with the same effect. Likewise, the data for school cancellations is skewed right. In 1977, Wise County canceled 33 days of school. Smyth County, also in the southwestern corner of Virginia cancelled a comparable 27 days of school that year. The highest total snowfall observation of over nine feet, from Scott County in 1995, results from high levels of snowfall over four months, each with nearly two feet of snow. These levels of snowfall are high, but consistent with winter snowfall in Scott County, in the Southwest of Virginia. The highest hurricane observation, 8, is the result of the severe hurricane season of 1999, which included tropical storms Floyd and Dennis. Chesapeake city, in tidewater Virginia was the most severely affected by these storms due to its location, to the east of the storms.

f. Weather Trends

Table 2 shows our estimates of changes in variable over time by running a regression of the time trend with fixed location effects. Standard errors are in parentheses. While the number of days with more than half an inch of snowfall did not change, the total amount of snowfall increased over time at a rate of 0.159 inches per year. That is an economically significant level and implies an increase in six and a half inches over forty years. To achieve this outcome, there must have been some combination of more days with snowfall below the half inch threshold and greater amounts of snow on days above that threshold.

Table 1: Descriptive Statistics

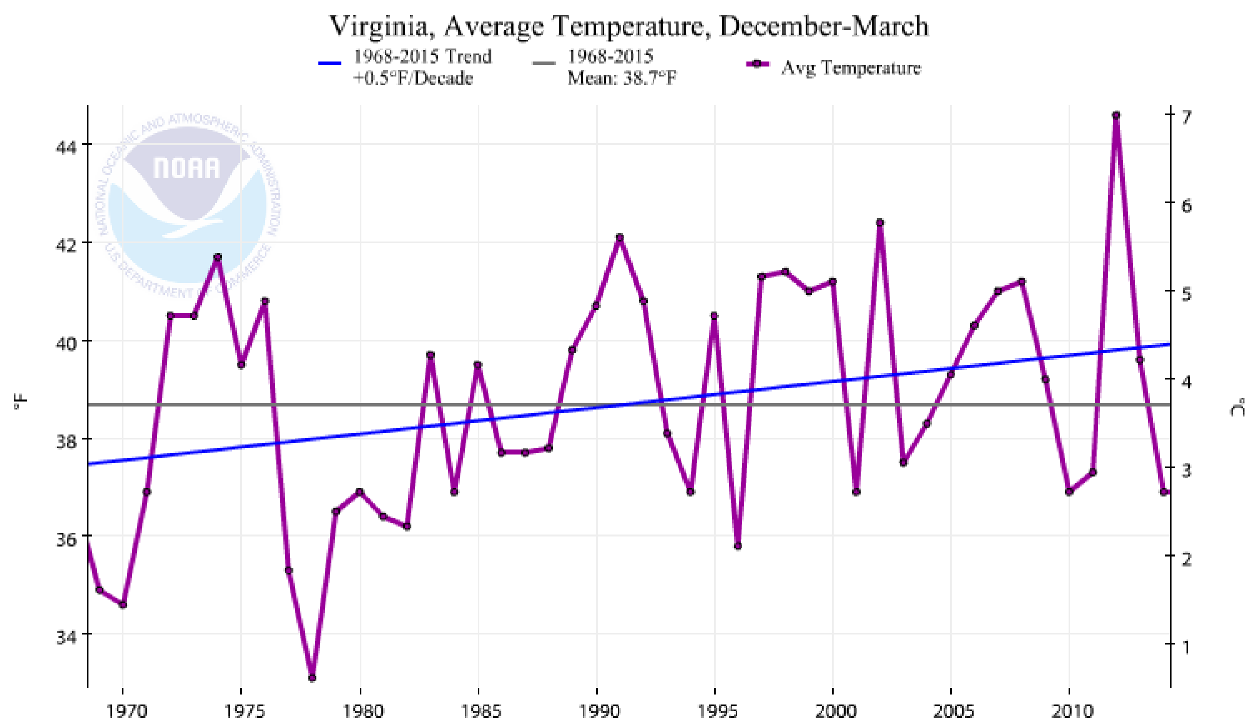
	N	Minimum	Maximum	Mean	Standard Deviation
Closings	994	0	33	6.87	5.144
DX32	929	0	47.00	10.6351	7.82316
TSNW	822	0	112.10	18.0594	17.12192
SNOW	578	0	24.00	4.5251	4.47579
Hurricanes	994	0	8	0.43	0.40

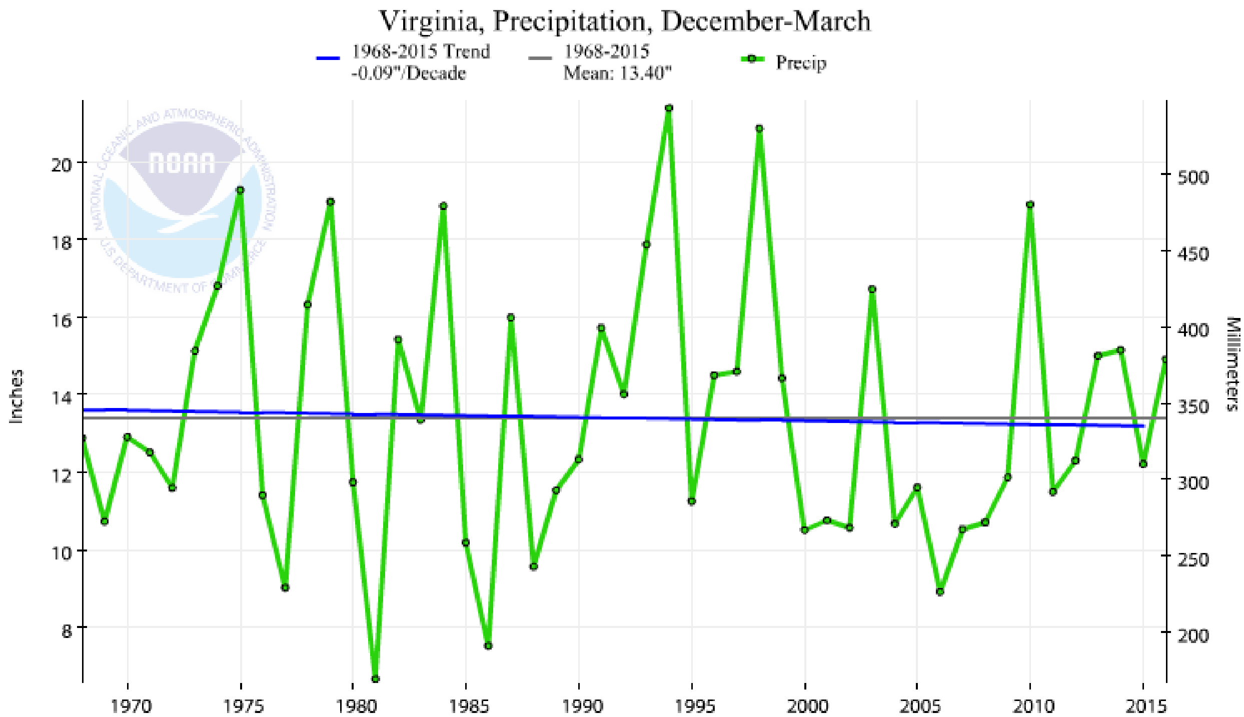
Table 2: Time Effects on Weather Variables

Weather Variables	Time Trend	Fixed Location Effects	Adjusted R^2	Observations
SNOW	0.008 (0.0155)	yes	0.579	537
DX32	- 0.0395 (.0319)	yes	0.335	537
Hurricane	-0.009 (.0072)	yes	0.022	537
TSNW	0.159** (.0777)	yes	0.3336	537
Standard errors are in parentheses. ** Significant at the 5% level				

NOAA provides data on monthly climate parameters, including maximum temperature, average temperature, and precipitation for the state of Virginia. In the winter months for the period 1968 to 2015 (the same period that this research covers, excluding one outlier) the average temperature and maximum temperature variables increase by approximately .05 ˚F per year. The total winter precipitation does not change. Figure 6 summarizes this information, showing the trend, average, and yearly values for average temperature and precipitation between December and March, for the years 1968 to 2015. While these Virginia climate parameters are an indicator of Virginia's climate in general, it is hard to compare these measurements, in degrees and inches, to some of the measurements used in this paper, such as the number of days

Figure 6: Virginia Climate Parameters, December-March, 1968-2015





reaching a certain threshold. Even if overall winter minimum temperatures are increasing slightly, there has been a consistent number of very cold days with maximum temperatures below 32 ˚F. Winter precipitation may have been constant, but over time, more of that precipitation could be snow. It is probably safe to say that any climate change occurring before 2016 has not had a large impact on weather that leads to school cancelations.

IV. Methods

Our analysis begins with a simple time trend and fixed location effects to confirm that the number of school cancellations increased over time. We then control for the most important factors in school cancellations, snowfall and hurricanes. Next we add TSNW to account for particularly severe storms (cumulative levels of snow) and DX32 to account for extreme cold. Finally, we interact time effects and SNOW variable to determine whether administrative reactions to snowfall changed over time. Our first test for changing administrative reactions interacts a dummy variable for the latter half of the observations, those in 2005 or later, with SNOW. We also interact SNOW with dummy variables that divide the data into three periods, before 2000, between 2000 and 2008, and after 2008. These variables would capture a structural change in attitudes. In order to capture a more gradual change, we interact the time trend variable beginning in 1963, our earliest observation, with the snowfall threshold term. A positive coefficient on these variables would indicate that the reactions to snowfall are increasing over time.

$$
\begin{aligned}
School\ Cancellations = \beta_1 + \beta_2 Time\ Trend \\
+\beta_3 SNOW + \beta_4 Hurricane \\
+\beta_5 DX32 + \beta_6 TSNW \\
+\beta_7 Admin.Reaction
\end{aligned}
$$

It is likely that the effects of some variables on school cancellations are not linear. For example, the effects of snowfall and extreme cold were probably step functions. As noted above, we take this into account by using variables that counted the days above a threshold level of weather, rather than the weather, itself. It is also reasonable to expect weather trends to have an exponential pattern, with more change closer to the present, due to the compounding nature of factors that influence climate change. Identifying these exponential effects could be dampened by our use of number of days above a threshold. Our period is short enough that linear regressions still seem reasonable. We also use the linear specification for our time trend. Tests for other time trend specifications are included in our robustness section.

A region's climate is indicative of what weather in a given year will be. It also shapes regional expectations of inclement weather, which influences inhabitants' reaction to it. Since climate determines both actual weather and regional reactions to that weather, the assumption that the error terms from the regressions were uncorrelated with the explanatory weather variables across counties is violated. For example, Rockingham County is in the Central Mountain Virginia Climate division, where the average winter temperature has been 35.5 ˚F during the 1901 to present time period (Time Series). This expectation causes them to schedule school with the expectation that they will have to miss more days in the winter than other districts and to cancel fewer school days at low levels of snow. Some years their tolerance for snow makes it unnecessary to cancel school, but some years the weather is so bad that they have to cancel many days. In contrast, Hampton County, in Tidewater Virginia, tends to get less snow. The average winter temperature there between 1901 and 2000 is 41.3 ˚F (Time Series). Its administrators cancel school for lower levels of snow, but the occurrence of weather that causes them to cancel school is rarer than in Rockingham County. To correct for locational heteroscedasticity, we used White-corrected standard errors.

V. Results and Interpretation

The regressions in Table 3 seek to explain school cancellations without incorporating changing reactions to severe weather. Regression 1 confirms the intuition that school is cancelled more often now than in the past. Although the coefficient on the time trend is statistically significant, it only indicates a total increase in annual school day closures of four days since the mid 1960's. Although the time trend itself does not indicate much change in the number of school days cancelled, the effect of any single factor may be larger and be cancelled out by another, opposite effect. In order to determine if the effect of attitude, weather, or non-weather factors, further analysis is required.

Table 3: Regressions of Weather Variables on School Cancellations

Regression No.	**Time Trend**	**SNOW**	**Hurricane**	**TSNW**	**DX32**	**Fixed Location Effects**	**Observations**	**Adjusted R^2**
1	0.081*** (0.0184)					yes	994	0.241
2	0.076*** (0.0175)	0.863*** (0.0567)	0.254*** (0.0933)			yes	578	0.513
3	0.069*** (0.0181)	0.597*** (0.0742)	0.333*** (0.0885)	0.084*** (0.0133)		yes	547	0.560
4	0.092*** (0.0170)	0.468*** (0.0765)	0.150 (0.1703)	0.042*** (0.0128)	0.263*** (0.0335)	yes	537	0.629
Significance level and standard errors (in parentheses) refer to White-corrected values.								
	***** Significant at the 10% level		** Significant at the 5% level			*** Significant at the 1% level		

Table 4: Correlations

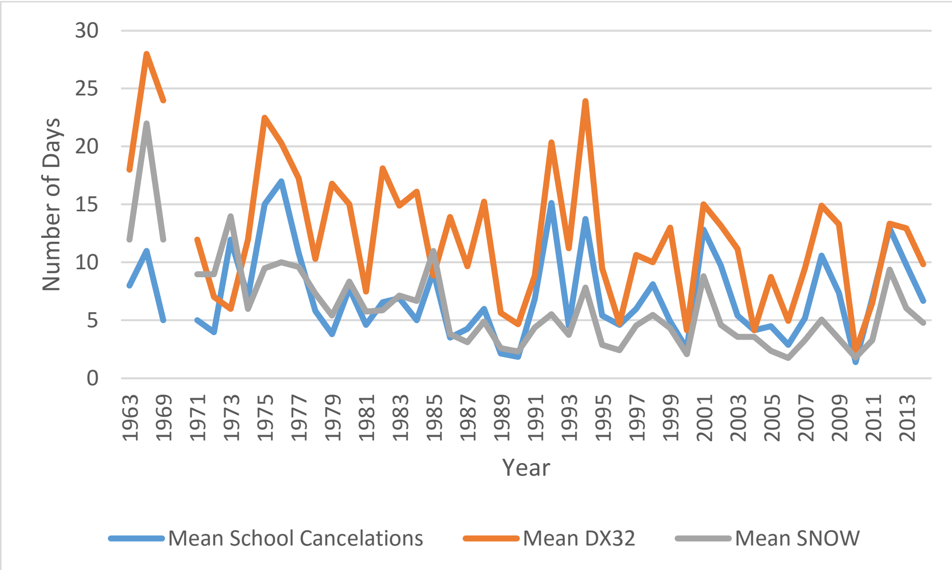
	SNOW	DX32	TSNW
SNOW	1	.497***	.805***
DX32	.497***	1	.544***
TSNW	.805***	.544***	1
*** Significant at the 1% level			

Adding weather variables in Regressions 2, 3, and 4 accounts for variation in the actual weather of any given year. The most important weather variable in this regression is SNOW. Interpretation of the coefficient for this variable is the clearest for Regression 2: for each additional day with at least one half inch of snow, the coefficient implies that on average, .87 days of school are cancelled. While different thresholds were investigated and even thresholds by region were modeled, the best-fitting model included the number of days with at least half an inch of snow for all counties. Having a low threshold is especially helpful if we are trying to detect change. It could be the case that school would always be cancelled when snowfall reached 1 inch, but has been cancelled more at the lower, one half inch level recently than in the past. Supposing that half an inch of snow is the true threshold for school cancellation, the importance of this variable is indicated by its coefficient's proximity to one.

The SNOW coefficient remains economically significant, but decreases in size, when other winter variables, DX32 (days with the maximum temperature of 32 or below) and TSNW (total snowfall) are added because DX32 and TSNW are highly correlated with SNOW, as seen in Table 4. One expects SNOW and TSNW to be correlated, since both terms rely on the daily amount of snowfall. Likewise, we expect correlation between SNOW and DX32 because a cold temperature is a factor required for snowfall to occur. Table 4 confirms that the correlations between DX32, SNOW, and TSNW are at least 0.497. Nevertheless, the addition of these variables improves the school cancellations model. Figure 7 shows the relationship between DX32, SNOW, and number of school days cancelled. All three variables tend to move together, as expected, because extreme cold (DX32), is a factor in high levels of snowfall (TSNW), which is a factor in the number of school cancellations in a year. The hurricane variable is theoretically required in the regression, but loses its explanatory power for school cancellations once DX32 is added, likely due to a failure of the variable to capture accurately the hurricane conditions that lead to school cancellation.

Table 5 adds interactions between time effects and SNOW to examine changes in responses to inclement weather. The Closebi_SNOW variable in Regression 5 reports the coefficient on the interaction between SNOW and a time binary, where the binary equals one for 2005 or later. The coefficient for this variable is not significantly different from zero, so we cannot identify any increasing responsiveness to snowfall in the latter period. We also divided the time period into three periods (before 2000, 2000-2008, and 2008 to the present), using

Figure 7: Averages of Winter Variables 1963-2015



dummy variables, and interacted with SNOW in Regression 6 to make CloseT1_SNOW for the second period and CloseT2_SNOW for the third period. The negative and statistically significant coefficient for the CloseT1_SNOW variable shows that between 2000 and 2008, the reaction to snowfall may have actually decreased in comparison to the periods before 2000 and after 2008. Although this result is statistically significant, the maximum impact of a coefficient this small is about one additional day of school that would have been cancelled before 2000 but was not cancelled between 2000 and 2008. The coefficient for CloseT2_SNOW, that indicates the sensitivity to weather of the period 2009 and later, are not statistically different from 0.

So far, we have discussed specifications that would indicate an abrupt shift in attitudes between periods. We have no reason to expect such an abrupt shift, so the Time_SNOW variable in Regression 7 interacts the SNOW variable with a time trend. The coefficient estimate is statistically insignificant, even with 537 observations, so there is no evidence of any change in school closure responsiveness toward half inch snowfalls, our best indicator of winter weather.

Table 5: Regressions with Interacted Time and Snow Effects

Regres-sion No.	**Time Trend**	**SNOW**	**Hurri-cane**	**DX32**	**TSNW**	**Closebi _SNOW**	**CloseT1 _SNOW**	**CloseT2 _SNOW**	**Time _SNOW**	**FLE**	**Obser-vations**	**Adjust-ed R^2**
5	0.092*** (0.0199)	0.467*** (0.3120)	0.150 (0.1097)	0.263*** (0.0335)	0.042*** (0.0131)	.001 (.0582)				yes	537	0.631
6	0.119*** (0.0241)	0.554*** (0.0920)	0.156 (0.1092)	0.268*** (0.0339)	0.035*** (0.0136)		-0.136** (0.0567)	-0.098 (0.0828)		yes	537	0.628
7	0.133*** (0.0284)	0.668*** (0.1801)	0.157 (0.1065)	0.265*** (0.0337)	0.043*** (0.0132)				-0.006 (0.0042)	yes	537	0.631
	Significance level and standard errors (in parentheses) refer to White-corrected values.											
	* Significant at the 10% level			** Significant at the 5% level			*** Significant at the 1% level					

Our data identify no evidence that attitudes towards inclement weather have changed over time, yet there may be changes in attitudes that are masked by problems of model interpretation or by missing data. We had expected that our interacted time and snowfall terms would distinguish the effects of changing attitudes from weather-related causes for cancellations and from all causes. Actual positive effects from a changing attitude towards snow might be hidden in the still positive coefficient on the time trend variable.

VI. Robustness

Virginia's laws regarding school calendars have changed several times since 1963. Prior to 1986, school calendars were guided by the labor needs of the agricultural industry, however in 1986, Virginia's tourism industry successfully lobbied to pass a law prohibiting schools from beginning before Labor Day (Schmidt). The next year, section 22.1-28 of the Code of Virginia passed, specifying a 180 day or 990-hour school year for funding purposes and with exceptions in the case of severe weather cancellations. Since then, these laws have been amended almost yearly, mostly to grant flexibility to districts that have trouble complying with them (Va. Code Ann. § 22.1-98). Any of these changes could have caused a structural shift in the attitudes of administrators towards winter weather, however legislative shifts are so frequent that it difficult to determine which change caused a shift or whether legislation or some other factor caused the shift. Even so, our results are not contingent on any state law, since any factor, including legislative changes, could have caused the shift in reaction to winter weather that our interaction terms seek to quantify.

We experimented with various functional forms for the time trend, including ln(year), $(\text{year})^2$, and $(\text{year})^3$ in order to understand the effects of actual weather on school cancellations. The time trend remained positive and significant, regardless of the functional form it took. The coefficients of both the cubic and squared time trends suggest that school cancellations have increased at a greater rate in the more recent years. Possible explanations for this include the intensifying effects of climate change in the 21st century, greater sensitivity to weather or non-weather events, or the concentration of our data in the later time periods. The adjusted R^2 values do not support any particular functional form strongly, so we have reported the linear time trend for simplicity. However, the cubic form for the true time trend provides an alternative explanation for the negative coefficient of the middle period in Regression 6.

Our evidence suggests that the number of days in a school year with more than .5 inches of snowfall mostly explains the number of cancellations in a school year. Thus, we focused on SNOW as the weather variable for interaction. However, other weather factors, such as amount of snowfall also affect administrators' decisions to cancel school. Perhaps reactions to a given level of total snow in a year, which increases faster than days with more than .5 inches of snow when snowfall is heavy, has increased over time, driving the positive time trend for number of cancellations. Thus, we also ran regressions for TSNW, to examine changes in reactions to large amounts of snowfall that could remain on the ground for several days over time. Negative coefficients for the continuous time trend and the three-period division interacted with TSNW suggest that if reactions to large snowfalls changed, they decreased. Even though these negative coefficients are statistically significant, they are not economically significant: the negative coefficient for the continuous time trend indicates only an additional .03 of a day lost over a 10-year period. Furthermore, the interaction of the two-period division with TSNW was not significant.

VII. Conclusion

While school cancellations are increasing slightly, it is challenging to identify the effects of weather, attitudes towards weather, and other factors, given the data that are available in Virginia. It seems more certain that weather accounts for the majority of school cancellations, but non-weather cancellations might be increasing. While we have yet to see significant increases in school cancellations due to more severe weather, it is likely that we will if climate change increases the number of days on which it snows more than half an inch, since climate change may increase weather severity. If the long-run effect of climate change in Virginia is less snow, then the number of school cancellation per year might decrease.

One complication in drawing conclusive results was the scarcity of complete weather and school cancellations data. Many school districts only had data on cancellations going back to 1999, and only a handful had collected more than 30 years of data. Meanwhile, much of the school cancellations data we had could not be used because the county it was from did not have complete weather data that year. More complete data could have helped to better sort the various causes of increasing school cancellations. Weather predictions are also relevant for school cancellation decisions, since administrators do not want unsafe travel conditions to strand students at school, but historical data on weather predictions were unavailable. In other words, this study is not able to identify increased school closings if occurring due to increased precaution towards inclement weather that may not occur. Our school cancellations variable is best suited to detect a change in weather and reactions to actual weather over time. Had we been able to identify data that allowed us to control for years and locations with known non-weather school cancellations, such as 2008 for the inauguration of President Obama and 2002 for the Northern Virginia sniper, these irregularities would be further controlled or the corresponding school cancellations dropped from our regressions. This research also might be improved by creating a hurricane variable that better reflects the damage done by hurricanes in the fall and late spring that causes school cancellations.

Further study could also focus on the creation of school calendars at the beginning of the school year, how they change as snow days are taken, and how make-up days are added. If standardized test scores or AP exam scores are a concern, perhaps there are better ways to plan school calendars so that students attend more of a school year before the tests. Further, there is still normative analysis to be done on when cancelling school is beneficial. In the future, we may see a more significant shift in attitude as teaching possibilities move out of the classroom and onto the internet. This development could increase the number of inclement weather days taken while avoiding decisions about what marginal weather poses a real threat to the safety of students and teachers. In the present, when contemplating marginal cancellation decisions, individual school districts should consider that their students are ultimately competing not with one another but with students outside their district and even region for future higher education admissions and employment.

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IX. Appendix

a. Abbreviations

DX32	Number of days in a winter with a maximum temperature less than or equal to 32
TSNW	Total amount of snowfall in a winter
SNOW	Number of days in a winter with at least .5 inches of snow
Closebi_SNOW	Interacted dummy variable for the period after 2004 (2 period time effect) and SNOW variable
CloseT1_SNOW	Interacted dummy variable for the period between 2000 and 2008 (3 period time effect) and SNOW variable
CloseT2_SNOW	Interacted dummy variable for the period after 2008 (3 period time effect) and SNOW variable
Time_SNOW	Interacted number of year since 1963 (yearly time effect) and SNOW variable
FLE	Fixed Location Effects

b. Counties/Cities and Weather Stations

County	**Station Name**
Augusta	STAUNTON WATER TREATMENT PLANT, VA US
Albemarle	FREE UNION, VA US
Alleghany	COVINGTON FILTER PLANT, VA US
Amherst	TYE RIVER 1 SE, VA US
Arlington	WASHINGTON REAGAN NATIONAL AIRPORT, VA US
Botetourt	COVINGTON FILTER PLANT, VA US
Brunswick	CAMP PICKETT, VA US
Campbell County	LYNCHBURG REGIONAL AIRPORT, VA US
Carroll	PULASKI, VA US
Caroline	CORBIN, VA US
City of Charlottesville	FREE UNION, VA US
City of Chesapeake	WALLACETON LK DRUMND VA US
Culpeper	WARRENTON 3 SE, VA US
Fairfax	WASHINGTON DC DULLES INTERNATIONAL AIRPORT, VA US
Fauquier	WARRENTON 3 SE, VA US
Floyd	ROCKY MOUNT, VA US

Frederick	WINCHESTER 7 SE, VA US
Goochland	CROZIER VA US
Grayson	TRANSOU, NC US
Hampton City	NEWPORT NEWS INTERNATIONAL AIRPORT VA US
Hanover	RICHMOND INTERNATIONAL AIRPORT, VA US
City of Harrisonberg	DALE ENTERPRISE, VA US
Henrico	RICHMOND INTERNATIONAL AIRPORT, VA US
Henry county	PHILPOTT DAM 2, VA US
City of Hopewell	HOPEWELL VA US
Loudoun	WASHINGTON DC DULLES INTERNATIONAL AIRPORT, VA US
Louisa	LOUISA, VA US
City of Lynchburg	LYNCHBURG REGIONAL AIRPORT, VA US
Manassas City	QUANTICO MCAS, VA US
Montgomery	PULASKI, VA US
Nottoway	CAMP PICKETT, VA US
Orange	PIEDMONT RESEARCH STATION, VA US
Page	CAMP PICKETT, VA US
Pittsylvania	CHATHAM, VA US
Powhatan	CROZIER VA US
Prince William	QUANTICO MCAS, VA US
Rockingham	DALE ENTERPRISE, VA US
Scott	WISE 3 E, VA US
Smyth	ABINGDON 3 S VA US
Spotsylvania	PIEDMONT RESEARCH STATION, VA US
Stafford	QUANTICO MCAS, VA US
City of Staunton	STAUNTON WATER TREATMENT PLANT, VA US
Warren	MOUNT WEATHER VA US
Waynesboro	STAUNTON WATER TREATMENT PLANT, VA US
City of Winchester	WINCHESTER 7 SE, VA US
Wise	WISE 3 E, VA US