Universidade Federal do Paraná
Setor de Ciências Exatas
Departamento de Estatística
Programa de Especialização em *Data Science* e *Big Data*

Ramsay Malange

Investigating the Relationship Between Meteorological Factors and Suicide in Clallam County, Washington

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Orientador: Paulo Justiniano Ribeiro Junior

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Investigating the Relationship Between Meteorological Factors and Suicide in Clallam County, Washington

Ramsay Malange[1]
Paulo Justiniano Ribeiro Junior[2]

Resumo

O suicídio é uma preocupação de saúde global urgente. A literatura anterior identificou regularmente fatores ambientais, como o clima, como afetando o risco de comportamento suicida em várias regiões do mundo; este estudo procurou ver se as variáveis meteorológicas estavam relacionadas a chamadas para o serviço de emergência local 911 por suicídio ou crise de saúde mental no Condado de Clallam, Washington. As variáveis meteorológicas examinadas aqui incluíram temperatura do ar, pressão, umidade e velocidade do vento. As variáveis de comportamento suicida incluíram 911 chamadas para suicídios, tentativas de suicídio e onde as ações foram tomadas sob a Lei de Tratamento Involuntário dos EUA (ITA). Foram utilizados modelos de regressão binomial negativa. A temperatura e a umidade do ar foram significativamente relacionadas negativamente às chamadas de ITA e todas as chamadas juntas. As árvores de regressão forneceram mais evidências de que a variação na temperatura e umidade do ar predisse algumas das variações nas chamadas de ITA e em todas as chamadas. O modelo não se ajusta a nenhuma relação entre variáveis meteorológicas e ligações de suicídio ou tentativas de suicídio. Implicações e limitações são discutidas.

Palavras-chave: Suicídio, Clima, Negative Binomial Regression

Abstract

Suicide is a pressing global health concern. Previous literature has regularly identified environmental factors, like weather, as affecting the risk of suicidal behavior in a number of regions around the globe; this study looked to see if weather variables were related to calls to the local 911 emergency service for suicide or mental health crisis in Clallam County, Washington. The weather variables examined here included air temperature, pressure, humidity, and wind speed. The suicide behavior variables included 911 calls for suicides, for suicide attempts, and where actions were taken under the US Involuntary Treatment Act (ITA). Negative binomial regression models were used. Air temperature and humidity were both found to be significantly negatively related to ITA calls and all calls together. Regression trees provided further evidence that variation in air temperature and humidity predicted some of the variation in ITA calls and all calls. The model fits shoed no relationships between weather variables and suicide calls or suicide attempt calls. Implications and limitations are discussed.

***Keywrods**: Suicide, Weather, Negative Binomial Regression*

[1]Aluno do programa de Especialização em Data Science & Big Data, malange.ramsay@gmail.com
[2]Professor do Departamento de Estatística - DEST/UFPR.

I Introduction

Suicide is a pressing global health concern. More than 700,000 people die by suicide each year—about 10.5 per 100,000 individuals (World Health Organization [WHO], 2021). It is an especially large concern for young people—it is the fourth leading cause of death among 15- to 19-year-olds (WHO, 2021). While global suicide rates have decreased somewhat since 2000, the rates have continued to rise in the Americas over the same period (WHO, 2019). It is now the 10th leading cause of death in the United States, and second among 10- to 34-year-olds (Hedegaard et al., 2020).

Suicide occurs as a result of a complex interaction of a number of factors, including psychological, biological, and demographic. Increasingly, there is evidence that environmental factors may also influence risk for suicide. For example, suicide risk appears to vary by season (Dixon & Kalkstein, 2018). Several studies have found that suicide rates peak in late spring and early summer, and then fall during winter (Barker et al., 1994; Bridges et al., 2005; Dixon & Kalkstein, 2018; Jensen et al, 1998). Other studies have found relationships between temperature (Dixon & Kalkstein, 2018), humidity (Linkowski et al. 1992), and pressure (Yan, 2000) among other variables.

While there is considerable evidence that environmental variables are related to suicide risk, the relationships that studies find are inconsistent. For example, Barker et al., 1994 found that season was related to admissions for suicide at the general hospital of Oxford for women, but not men. Another exploratory study conducted on data from Scotland found weak seasonality patterns, and also that these patterns were stronger for men than women (Moore et al., 2018). Some also suggest that the seasonal patterns

of suicide are weakening over time (Dixon & Kalkstein, 2018).

Temperature. There is similarly complicated evidence for an effect of weather parameters on suicide (Deisenhammer, 2003; Dixon et al., 2007). When researchers have found an effect of temperature on suicide rates, most studies have found that warmer weather is associated with increased suicide rates (Dixon & Kalkstein, 2018; Dixon et al., 2014; Hiltunen et al., 2014; Kim et al., 2016; Yang et al., 2011). However, a few studies have found that colder weather is linked to elevated suicide risk (Geltzer et al., 2000; Tsai, 2010; Wu et al., 2014).

Pressure. Some studies find relationships between suicide risk and atmospheric pressure, but again, the results appear to be somewhat inconsistent. Wang et al. (1997) found a relationship between extremely high and low atmospheric pressure and suicide while Yan (2000) found a negative relationship between pressure and suicide. Wu et al. (2014) also found a negative relationship between pressure and suicide, but only for men.

Humidity. Linkowski et al. (1992) found a positive relationship between humidity and suicide, while Maes et al. (1994) found a negative relationship between the same variables. Wu et al. (2014) found that rainy days were negatively correlated with suicide for men, but not women.

To further obscure clear conclusions about the effect of environmental variables on suicide, one study from Iran found that while air temperature, humidity, and air pressure are related with psychiatric hospital admissions, they were not significantly related to suicide (Talaei et al., 2014). Other studies have not found associations between suicide and weather variables (Barker et al., 1994).

These studies seem to suggest that there is a relationship between environmental factors and suicide risk. However, the relationship remains unclear. The purpose of the present study was to explore a set of data from a county in the Pacific Northwest of the United States and investigate whether there were similar relationships between weather and suicide risk. The main research question that this study attempted to answer was: *Is suicide behavior related to weather (as operationalized by 911 emergency calls) in the Pacific Northwest region of the United States?*

2 Materials and Methods

To answer this question, the author engaged in an exploratory study using archival data on local weather variables and *911* calls related to suicide behaviour and mental health crisis.

2.1 Data Collection

The study used archival weather and *911* call data for Clallam County, Washington. Clallam County is located in the Northeast of Washington state on the Olympic Peninsula. About 77,750 people live in the county (United States Census Bureau, 2022).

Emergency call data. Calls to the *911* emergency line between January 1, 2019 and June 30, 2020 were obtained from emergency services in Clallam county. *911* call data was provided as a table in pdf format. The primary author used an online software application (Nanonets, n.d.) to extract the data into an excel file.

The *911* call data provided the date and time of each call incident, as well as the type of call. We were given a subset of all *911* calls that included 3 call types: suicides, suicide attempt threat, and mental person–Involuntary Treatment Act (ITA). A *911* operator codes the call type as a suicide when a caller reports that a person has died by suicide; they report a call as a suicide attempt threat when a caller reports that a person has threatened suicide; and they report a call as an ITA when emergency services have had to make an action under the Involuntary Treatment Act, including holding a person against their will because they are at risk of self-harm. For the remainder of this report, we will call these “Suicide calls”, “Attempt calls”, and “ITA calls” respectively.

Weather data. Readings of weather data were taken from the weather station located at the Port Angeles airport. The five weather variables retrieved were air temperature, measured in degrees Celsius; altimeter, measured in Pascals; air pressure, measured in Pascals; relative humidity, measured as a percentage out of 100; and wind speed, measured in meters per second. Weather variable readings were retrieved via API requests from Mesonet (Mesonet, n.d.). Since altimeter was perfectly correlated with air pressure ($r = 1.00$), it was removed from all analyses and only pressure was considered.

2.2 Data Analysis Strategy

Descriptive statistics were performed on both the *911* calls and the weather variables. Next, Pearson product moment correlation coefficients were calculated between each of the variables to explore intercorrelations. Then, to examine the primary research question, Poisson regressions were used to investigate the relationship between weather variables and *911* calls. Poisson regressions were deemed an appropriate model because the dependent variable—the *911* calls—are count data. Following the Poisson regressions, negative binomial regressions were performed on the same variables. The Poisson regressions were then compared to the negative binomial regressions and each was assessed using a number of diagnostic tests to determine how well they fit the data. Finally, regression trees were applied to the data and assessed. This analysis provided an opportunity to examine the data using another strategy and see whether it resulted in similar conclusions as the regressions. Because this investigation is primarily exploratory, the significance threshold was set at 0.10 for all analyses.

3 Results

Between January 1, 2019 and June 30, 2020 there were 21 suicide calls, 656 attempt calls, and 1045 ITA calls

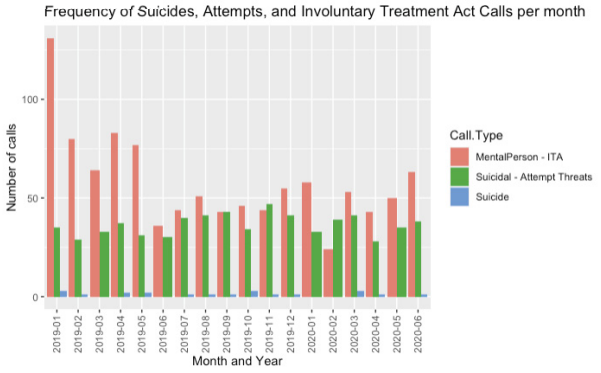

Figure 1: The frequency of suicides, suicide attempts, and Involuntary Treatment Act calls each month from January 1, 2019 to June 6, 2020.

Throughout the time period, air temperature ranged from -12 to 29 degrees Celsius (M = 8.72, SD = 5.49); air pressure ranged from 97,548 Pascals to 102,747 (M = 100,801, SD = 694.43); relative humidity ranged from 13.96% to 100% (M = 80.81%, SD = 15.15); and wind speed ranged from 0 m/s to 13.89 m/s (M = 2.47, SD = 1.82). Figure 2 displays the air temperature and relative humidity over the study period.

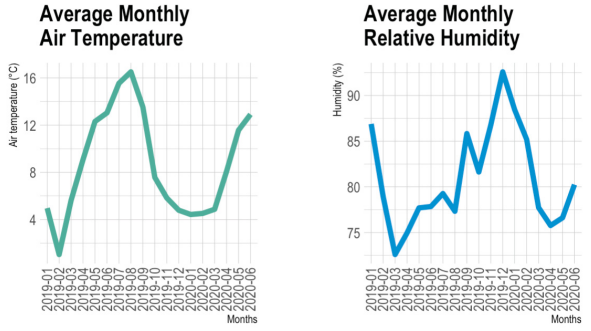

Figure 2: The average air temperature and relative humidity each month from January 1, 2019 to June 6, 2020.

3.1 Correlation Analyses

Pearson's product-moment correlations were calculated between the daily average of each weather variable (air temperature, air pressure, relative humidity, and wind speed) and the number of calls for each *911* call variable (see Figure 3). *911* call variables included suicide calls, attempt calls, and ITA calls. Two additional dependent variables were also created for this analysis. The first, "suicide and attempt calls" was created by summing daily suicide calls and attempt calls. This variable represents all calls for suicide behaviour—both attempts and calls. The second variable added, named "all calls", was created by adding together suicide calls, attempt calls, and ITA calls. This variable represents all calls from individuals related to mental health crisis—both suicide and other calls where police had to make an action under the *Involuntary Treatment Act*.

There were significant intercorrelations between several of the weather variables. Temperature was significantly correlated with humidity (r = -0.12) and wind speed (r = 0.20). Humidity was also significantly related to pressure (r = -0.18) and wind speed (r = -0.46).

Some correlations between weather variables and call variables were found to be significant. Air temperature was found to be significantly correlated with ITA calls (r = -0.12). Relative humidity was found to be significantly correlated with all calls (r = -0.08). Suicide calls, attempt calls, and ITA calls were all unrelated to each other.

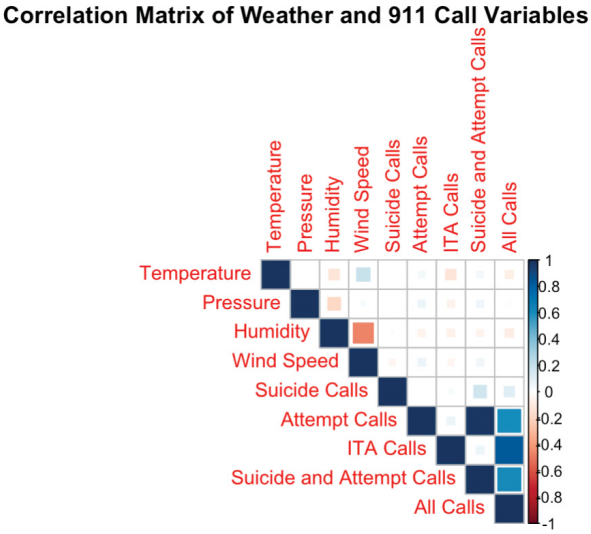

Figure 3: A correlation matrix showing the strength of the relationships between all the study variables

3.2 Regression Analyses

Poisson regression analyses were performed to examine the relation of each of the four weather variables to each of the five *911* call variables. However, model diagnostics suggested that negative binomial models provided some improvements for model fit over the Poisson regressions. Further, tests of overdispersion (Cameron & Trivedi, 1990) were significant, suggesting that the data were overdispersed and justifying the use of the negative binomial model over Poisson models. For those reasons, negative binomial regressions were ultimately chosen for this analysis and are reported here.

There were no significant relationships between any of the weather variables and suicide calls, attempt calls, or suicide and attempt calls. However, there were some significant relationships with ITA calls and all calls.

Model 1: Air temperature and relative humidity on all calls. Daily average air temperature and daily average relative humidity accounted for a significant amount of the variance in daily "all calls" counts. Together, the predictors accounted for a significant

amount of variance in the outcome, likelihood ratio χ^2 (3) = 12.58, p < 0.01. Daily average air temperature and daily average relative humidity significantly predicted all calls, B = -0.01, SD_B = 0.006, p = 0.05, and B = -0.01, SD_B = 0.003, p = 0.03, respectively. This suggests that for each unit increase in air temperature, there is a decrease in all calls by 0.989. Similarly, for each unit increase in relative humidity, there is a decrease in all calls by 0.994.

Model 2: Air temperature and relative humidity on ITA calls. Daily average air temperature and daily average relative humidity also accounted for a significant amount in the variance in daily ITA call counts. Together, the predictors accounted for a significant amount of variance in the outcome, likelihood ratio χ^2 (3) = 14.48, p < 0.01. Daily average air temperature and daily average relative humidity significantly predicted all calls, B = -0.02, SD_B = 0.01, p < 0.01, and B = -0.01, SD_B = 0.003, p = 0.06, respectively. This suggests that for each unit increase in air temperature, there is a decrease in ITA calls by 0.976. Similarly, for each unit increase in relative humidity, there is a decrease in all calls by 0.994.

3.3 Regression Diagnostics

Several diagnostic analyses were performed to evaluate the fit of both negative binomial models. First, rootgrams ("rootgram" function from package "vcd"; RDocumentation, n.d.a.) were produced to visualize the fit of the two negative binomial models. The graphs show some overfitting (where the bars hang below the X-axis) and some underfitting (where the bars hang above the X-axis) for both the all calls data (Figure 4) and the ITA calls data (Figure 5), but nothing pathological.

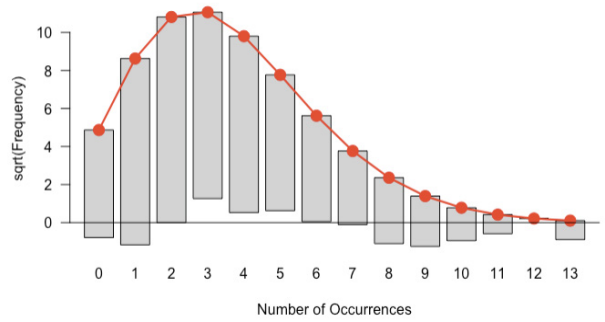

Figure 4: Rootgram showing the fit of the negative binomial model on the "all calls" count variable (Model 1).

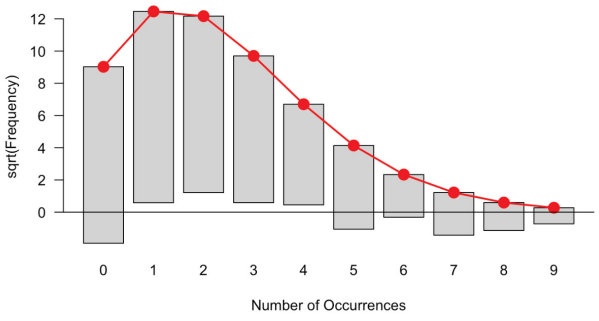

Figure 5: Rootgram showing the fit of the negative binomial model on the "ITA calls" count variable (Model 2).

A "negative binomialness plot" ("distplot" function from package "vcd"; RDocumentation, n.d.b) also suggest that the negative binomial model fits the count all calls and ITA calls data quite well (Figures 6 and 7, respectively).

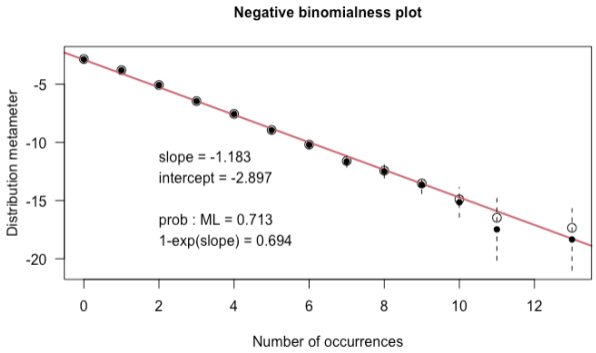

Figure 6: Plot showing the frequency of "all calls" against the distribution metameter of the negative binomial distribution (Model 1).

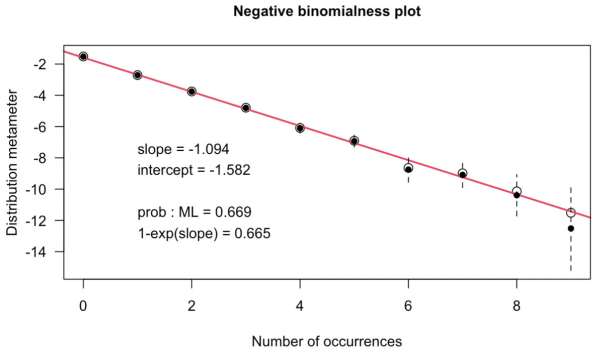

Figure 7: Plot showing the frequency of "ITA calls" against the distribution metameter of the negative binomial distribution (Model 2).

Next, the linearity of the predictor variables was assessed using term plots ("ggpredict" function from package "ggeffects"; Lüdecke, n.d). The plots show the predicted dependent variable value given a single independent variable, not considering the second.

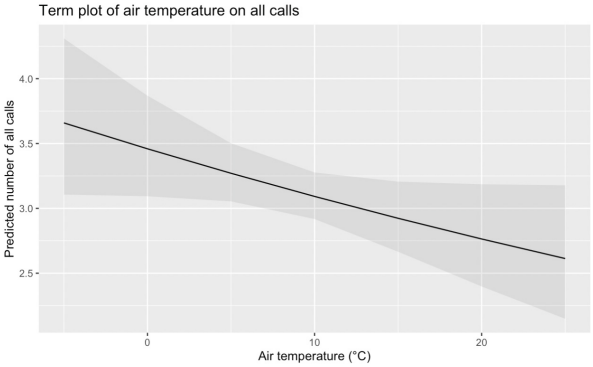

Figure 8: Plot of the predicted all calls variable given different levels of air temperature.

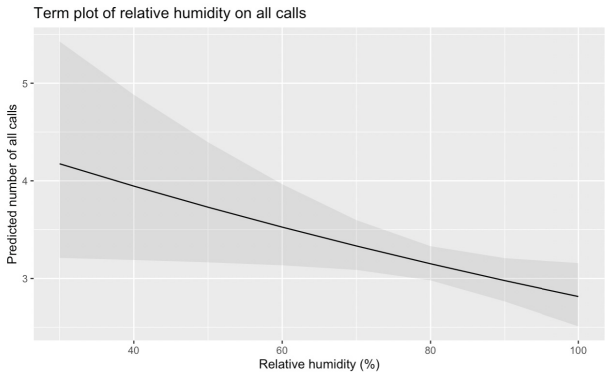

Figure 9: Plot of the predicted all calls variable given different levels of relative humidity.

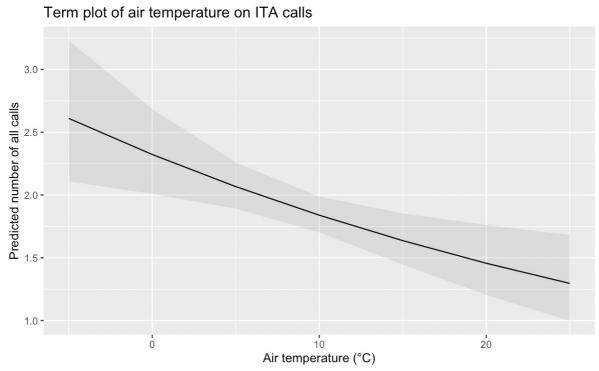

Figure 10: Plot of the predicted ITA calls given different levels of air temperature.

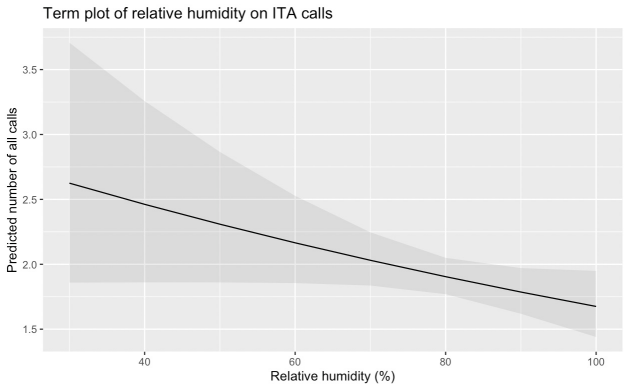

Figure 11: Plot of the predicted ITA calls given different levels of relative humidity.

Finally, Q-Q plots were created by plotting the deviance residuals ("residuals" function from package "stats"; The R Stats Package, n.d.) on the y-axis vs. the log of the predicted values on the x-axis. The plots were examined to determine whether the residuals are normally distributed for model 1 (Figure 12) and model 2 (Figure 13). The residuals appear to generally follow a normal distribution, although not perfectly. However, normality of deviance residuals is not necessarily expected for negative binomial distribution (Hartig, 2022), so the residuals here differing from a straight line is not necessarily a concern for model fit.

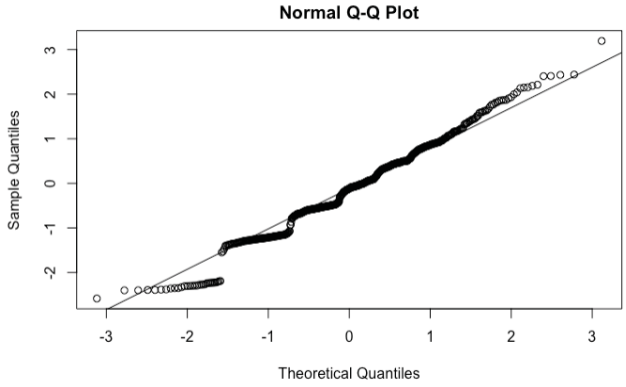

Figure 12: Q-Q plot for Model 1.

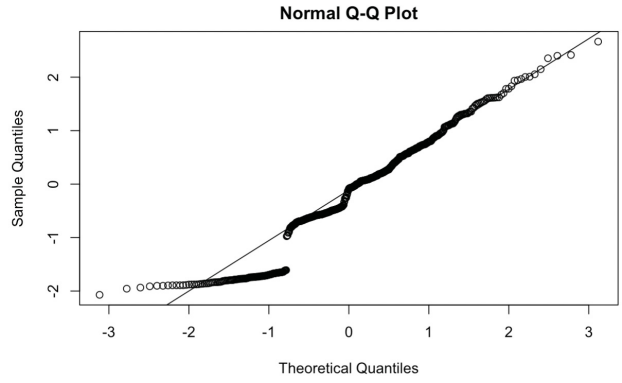

Figure 13: Q-Q plot for Model 2.

Together, the diagnostic tests suggested that the two models were appropriate and had good fit. No evidence of pathological poorness of fit was found.

3.4 Regression Tree Analysis

A regression tree analysis ("tree" function from package "tree"; Ripley, 2022) was used to confirm the main variables included in the model. Regression tree analysis is a type of supervised learning algorithm that can be used for regression problems. It can be used to predict an output value given a set of inputs. In this analysis, regression trees are simply used as an alternative way to confirm the weather variables that belong in the model.

All four weather variables were included in the tree for two models: one with "all calls" as the dependent variable, and one with "ITA calls" as the dependent variable. For all calls, only air temperature and humidity were found to be important features in the tree; wind speed and pressure were not (see Figure 14). For ITA calls, all four weather variables were found to be important features and included in the tree (see Figure 15). These two trees support the conclusions of the previous negative binomial regression models that humidity and air temperature have an influence on the variability of *911* call volumes for mental health crises—both all calls and ITA calls.

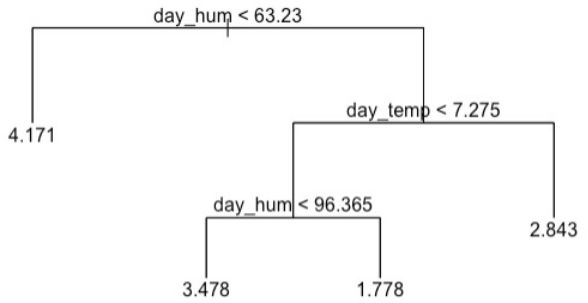

Figure 14: Regression tree for "all calls".

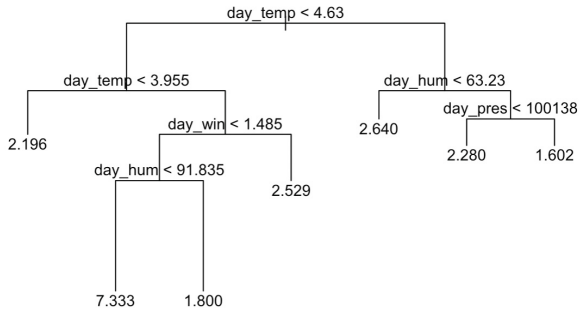

Figure 15: Regression tree for "ITA calls".

4 Discussion

This study sought to determine whether the relationships between weather and mental health crises including suicide that had been found in previous research would be replicated in data from the Pacific Northwest of the United States. In the current dataset, suicide behavior—either calls or attempts—was not found to be associated with any weather variable. It's not clear whether this is because there is truly no association or because there were so few of these calls that a true association could not be detected.

There were some significant relationships between air temperature and humidity with ITA calls and "all calls". The models suggest that as air temperature and humidity decrease, ITA calls and all calls related to mental health crises increase. Note that ITA calls make up the majority of calls in the "all calls" variable, so it may not be surprising that the same weather variables seem to affect both. A regression tree model provided further evidence that air temperature and humidity are important features for predicting *911* calls. These findings are consistent with previous studies that found humidity to be related to mental health crises (Maes et al., 1994; Wu et al., 2014). It's also consistent with findings that lower temperatures are related to more calls (Geltzer et al., 2000; Tsai, 2010; Wu et al., 2014).

4.1 Limitations and Future Research

There are some significant limitations to this study. The goal was to determine whether weather variables are associated with suicide behaviour, but the current data set had too few data to truly answer the question. Further, even if there were more data available, 911 calls is not a perfect measure for suicide behavior or other mental health crises. It only accounts for suicide behavior or mental health crises that are reported to the emergency services. Future research would benefit from using a larger dataset, perhaps with different measures of suicidal behavior.

Another limitation is that the weather variables were calculated by taking a daily average of all of the weather readings for the day and using that daily average to predict 911 calls. However, the daily average may not be the best predictor—perhaps the daily median is a better choice, or the daily maximum, or minimum. Or perhaps an average over the previous few days or week could be a better predictor. Perhaps looking at the relationship between extreme weather events—very high temperatures or pressures—that predict suicidal behavior. Similarly, there are many ways the response variable can be examined. In this study, it was analyzed as count data, but it could have been examined as a binomial variable with suicide behavior either present or absent in a specified time period, like a day or week. It could also be conceived as a variable on an ordinal scale. Each of these would have allowed different analyses and may have provided different insights. Future research may profit from investigating several different ways of defining the variables produces a clearer picture of the relationship between weather and suicidal behavior.

A third limitation is that this dataset was unable to provide insight into differences in relationships between different groups. For example, some previous research found gender differences in the relationship between weather variables and suicidality (Wu et al., 2014). Since gender was not a variable that was included in the current dataset, we were unable to include it in our models and determine whether there were gender differences.

5 Concusion

The limitations of this study prevent us from making conclusions about the true nature of the effect of weather variables on suicide behavior. However, the study did find evidence that the structure of variation of some weather variables (air temperature and humidity) can help explain variability in some indicators of mental health crises—the number of 911 calls that required action under the Involuntary Treatment Act and the number of all calls related to mental health crises. This study corroborates previous research that found that weather has an effect on mental health crises and suicidal behavior.

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