Big Data Analysis using MATLAB: Connections Between Atmospheric Muon Count and Local Weather Patterns in Atlanta, GA

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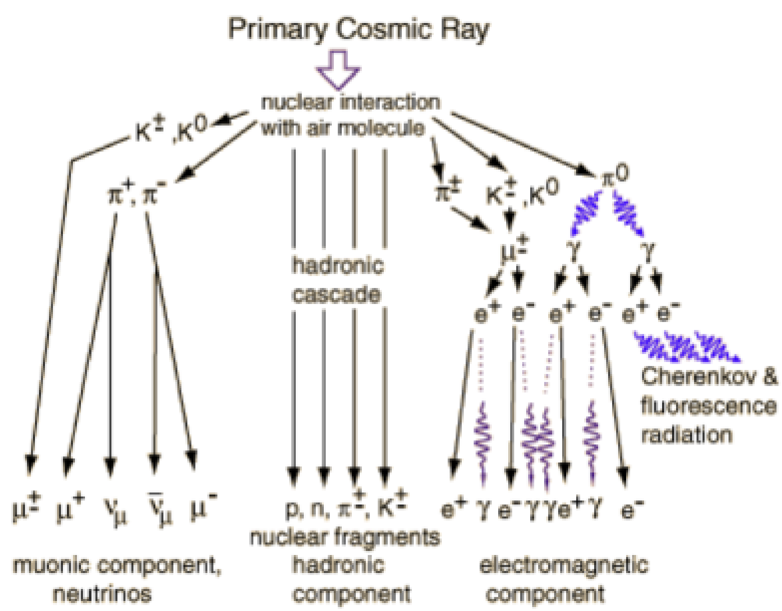
Sections:

Introduction

Every day in Earth's atmosphere is bombarded by thousands of Cosmic Rays. With these interactions, subatomic particles of all types are given off, many with different properties. The area of focus for our project is the muon sub atomic particle. The muon is especially important because of its qualities. It is vastly like the electron with it being a negatively charged but unlike the electron the muon has a mass that is 207 times heavier than the electron. Because of this the muon is a very fascinating particle to study but what exactly affects muon count? After much thought our group decided that a study of local weather factors would be great to see thse local weather conditions affect muon count, and if they do how so.



(Figure 1: Depicts Cosmic Ray Activity and breakdown of subatomic particles released after nuclear interaction with air molecules)

Data Accumulation

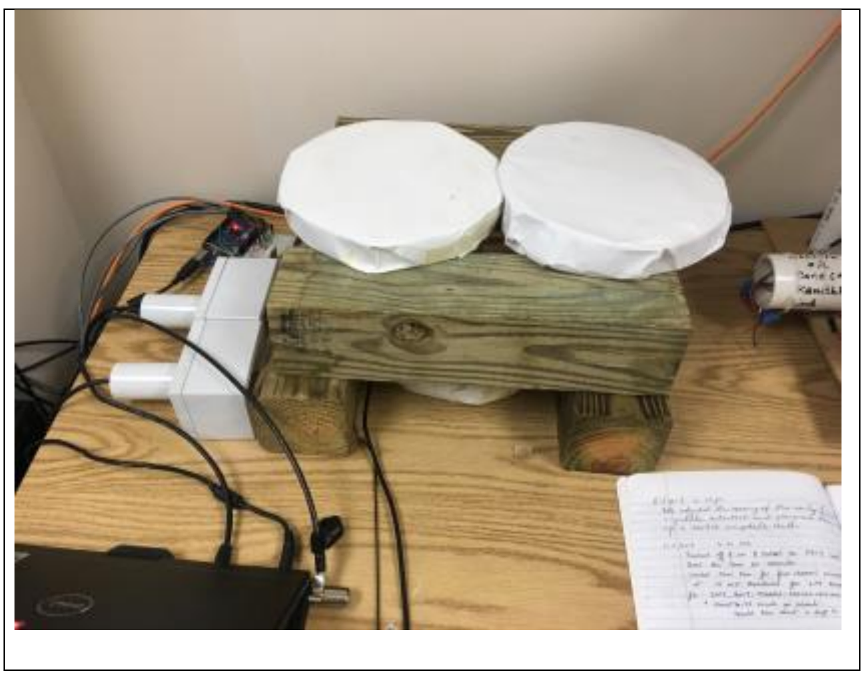
After preliminary research and introducing of the physics facilities by Dr. He, the time came to accumulate data for the project for processing, and analysis. Data accumulation was not initially difficult because of the sheer amount of different data sets that were widely available, but after looking through many sites some data sets were a lot more tedious to deal with than others. Problems such as unorthodox file types, sets with no labels, and some data set files were just too large. However, we did find a suitable website where we could find data sets to analyze: **MesoWest.** Thus, project data comes two viable locations: Dr. He directly for the Muon Particle count and MesoWest database for local weather factor data accumulation.

MesoWest is an ongoing cooperative project, started in 1996, to provide access to current and archive weather observations across the United States. Data are collected from a variety of organizations. Some stations participate in voluntary weather observing networks such as the Citizen Weather Observer Program. Others are part of mesonets that are managed by private firms or federal/state/local agencies. These data are available for a multitude of uses. Over 20,000 weather stations actively report to the MesoWest database.

Once the locations of extracting the data were finalized, the factor analysis was then narrowed six factors: cloud layer of 1, temperature, wind speed, dew point, humidity and atmospheric pressure. A set period of sixty-nine was also established because at the time Dr. He's muon data set started January 01, 2017 and ended March 17, 2017; a total of sixty-nine days.

Dr. He's data sets are accumulated by a total of four devices: A Pot Detector, Four-Paddle Detector, Double-Paddle Detector, and Weather Station. All devices except the Weather Station detector are located on the 9th floor of Langdale hall. The Weather Station device is installed on the roof of the Natural Science Center at Georgia State University, which is also beneficial for Dr. He's research because of elevation difference.

(Figure 2: Double-Paddle Detector captured from my cellular device)



(Figure 3: Another angle of the Double-Paddle Detector captured from my cellular device)

Data Processing

With the data sets compiled it became time to process the data and figure out how we would average results for analysis. Many factors went it to how this process would work; time, degree of error, and function creation. Initially we did try to process data points in Matlab using defined Matlab functions and even user created functions, however because of the way the data is structured, generation of averaging functions would require either different programming languages or averaging in Microsoft excel. In the end, we decided to average and process values for direct importation in Matlab using Microsoft Excel. Although this was not intended from the beginning, it worked out because of Andira's knowledge with using Microsoft excel, however from Andira's perspective, averaging values provided quite time consuming.

Tables

CSV files proved to be the easiest for Matlab to handle so after processing and averaging data files a direct table was created that is used directly in our project. Even after data was compiled and arranged into one main CSV file, a creation of tables using the averaged data was still created into Matlab. Because of how linear modeling is created in Matlab a creation of data tables using Matlab functions were also created. Below are example of the process of data processing is shown using Microsoft Excel and Matlab table creation for our project.

1	# STATION: KATL		
2	# STATION N	Hartsfield - Jackson Atlanta International Airport	
3	# LATITUDE: 33.64028		
4	# LONGITUDE: -84.42694		
5	# ELEVATION [ft]: 1027		
6	# STATE: GA		
7	Station_ID	Date_Time	air_temp_set_1
8			Fahrenheit
9	KATL	12/31/2016	42.8
10	KATL	12/31/2016	42.8
11	KATL	12/31/2016	42.8
12	KATL	12/31/2016	42.8
13	KATL	12/31/2016	42.8
14	KATL	12/31/2016	42.8
15	KATL	12/31/2016	42.8
16	KATL	12/31/2016	42.8
17	KATL	12/31/2016	42.8
18	KATL	12/31/2016	42.8
19	KATL	12/31/2016	42.8
20	KATL	12/31/2016	42.08
21	KATL	12/31/2016	42.8
22	KATL	12/31/2016	42.8
23	KATL	12/31/2016	42.8
24	KATL	12/31/2016	42.8
25	KATL	12/31/2016	42.8
26	KATL	12/31/2016	42.8
27	KATL	12/31/2016	42.8
28	KATL	12/31/2016	42.8
29	KATL	12/31/2016	42.8
30	KATL	12/31/2016	42.8
31	KATL	12/31/2016	42.8
32	KATL	12/31/2016	42.8
33	KATL	12/31/2016	42.98
34	KATL	12/31/2016	42.8
35	KATL	12/31/2016	42.8

(Figure 4: an example of Temperature data obtained from MesoWest. Each file had an excess of 25,000+ data points and each day was averaged.)

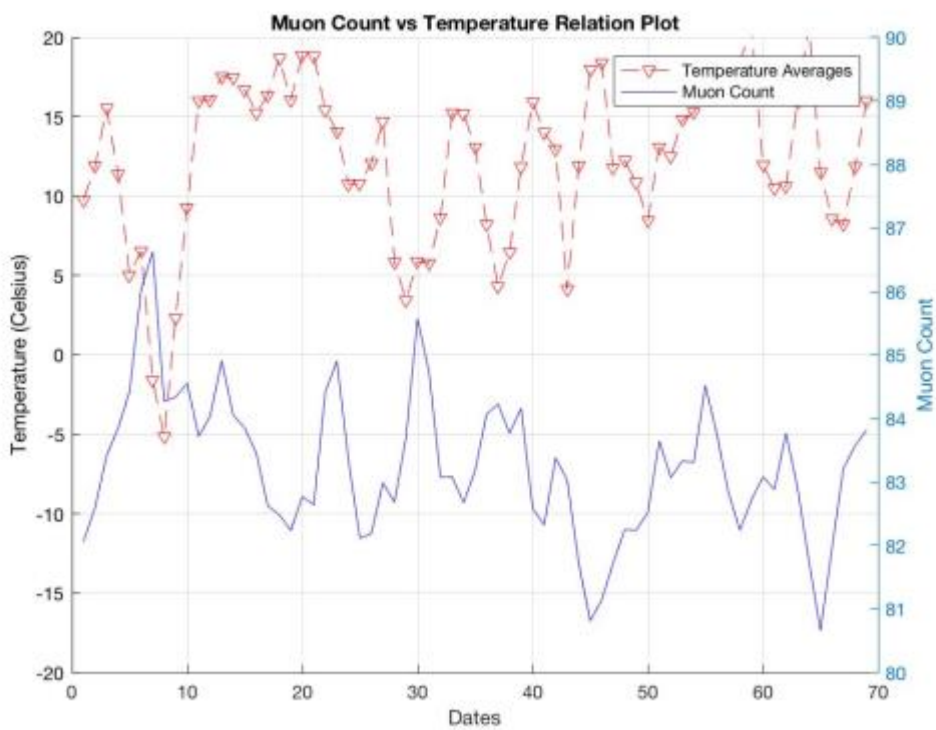
Muon Count		Temperature		Pressure		Wind Speed		Relative Humidity		Cloud Thickness		Dew Point	
Averages		Averages		Averages		Averages		Averages		Averages		Averages	
Day	Count	Day	Celsius	Day	Pascals	Day	Wind Speed	Day	Humidity	Day	Thickness	Day	Dew Point
1	82.06662	1	9.776923	1	98320.5	1	3.5925	1	94.90145	1	184.9057	1	7.465898
2	82.59931	2	11.89135	2	98264.63	2	3.334844	2	99.66756	2	155.0926	2	12.03723
3	83.41389	3	15.53197	3	97474.84	3	3.917175	3	87.32997	3	97.86885	3	12.07754
4	83.84861	4	11.41493	4	97444.45	4	5.387396	4	70.98463	4	33.33333	4	3.777623
5	84.42708	5	5.037544	5	97709.15	5	3.409649	5	57.06864	5	86.14865	5	-1.38367
6	86.02986	6	6.538811	6	97654.07	6	4.259336	6	81.32104	6	148.1073	6	-1.7373
7	86.62292	7	-1.54757	7	98097.64	7	6.891007	7	73.37801	7	65.09434	7	-8.50175
8	84.26944	8	-5.1316	8	99375.92	8	6.640833	8	53.18737	8	7.457627	8	-12.12
9	84.34097	9	2.344964	9	99726.43	9	2.986751	9	38.05528	9	27.73723	9	-11.6959
10	84.55556	10	9.271731	10	99055.76	10	4.266714	10	61.75489	10	78.61842	10	2.836791
11	83.71597	11	16.00903	11	98786.06	11	3.915729	11	65.61043	11	96.60194	11	8.720613
12	84.04236	12	16.04097	12	98972.07	12	2.872535	12	76.7485	12	50.96463	12	11.73448
13	84.91042	13	17.54653	13	99338.54	13	1.823611	13	80.7923	13	88.94231	13	13.62745
14	84.05278	14	17.44236	14	99314.75	14	1.171667	14	70.70709	14	31.43322	14	11.45991
15	83.85278	15	16.69688	15	98923.58	15	1.429826	15	61.40369	15	22.59136	15	4.79962
16	83.45347	16	15.24479	16	98735.76	16	1.30934	16	78.58571	16	85.01629	16	12.53218
17	82.62569	17	16.37222	17	98602.88	17	3.220868	17	75.68129	17	75.16234	17	14.19126
18	82.48506	18	18.68715	18	98126.81	18	4.189271	18	72.12018	18	66.28289	18	11.49337
19	82.23958	19	16.05035	19	98125.51	19	2.462882	19	76.39009	19	79.56811	19	14.10807
20	82.77222	20	18.8816	20	97508.34	20	3.796551	20	89.43638	20	85.24845	20	15.08534
21	82.64028	21	18.82639	21	97406.16	21	3.554444	21	95.39273	21	128.3333	21	13.85613
22	84.41875	22	15.40486	22	96876.45	22	3.327674	22	90.92724	22	158.597	22	9.940153
23	84.90764	23	14.08438	23	95947.87	23	5.030104	23	71.23308	23	133.3333	23	5.404431
24	83.35694	24	10.76181	24	95794.37	24	6.588958	24	54.95149	24	78.26797	24	2.520097
25	82.11736	25	10.80804	25	97181.94	25	6.648175	25	62.57505	25	6.560784	25	6.477208
26	82.19306	26	12.11029	26	97513.09	26	2.573382	26	58.29683	26	45.58824	26	-3.03676
27	82.99167	27	14.71277	27	97342.25	27	5.675693	27	49.58356	27	12.54545	27	-5.86388
28	82.68264	28	5.858712	28	97990.23	28	5.129242	28	50.67756	28	6.092437	28	-3.97116
29	83.69792	29	3.448014	29	98046.48	29	4.824188	29	52.61587	29	60.78767	29	-2.87777
30	85.57083	30	5.894585	30	97777.94	30	4.765343	30	48.35053	30	5.123675	30	0.985
31	84.73333	31	5.753676	31	97794.6	31	5.596434	31	62.2169	31	5.731225	31	7.228809
32	83.07778	32	8.659191	32	98167.63	32	4.304632	32	76.88663	32	36.45833	32	8.493524
33	83.08611	33	15.22434	33	98056.03	33	4.384045	33	48.73935	33	53.69718	33	-3.98906
34	82.67569	34	15.20786	34	98258.35	34	3.806043	34	32.23432	34	84.61538	34	-11.1571
35	83.17569	35	13.08029	35	98428.93	35	3.695448	35	88.63065	35	20.35088	35	6.00296
36	84.06667	36	8.231673	36	98591.49	36	5.272918	36	78.72781	36	144.918	36	11.32872
37	84.22986	37	4.312411	37	99007.3	37	4.105142	37	90.1454	37	87.2549	37	13.12527
38	83.76736	38	6.466906	38	98561.77	38	2.524209	38	87.75606	38	92.40506	38	12.33403
39	84.1625	39	11.8581	39	98427.13	39	2.153768	39	49.86555	39	129.7428	39	-5.47626
40	82.58681	40	15.92562	40	97905.45	40	3.539004	40	41.90678	40	56.73401	40	-2.7738
41	82.32361	41	14.03548	41	97267.39	41	2.480251	41	79.12696	41	5.06993	41	14.73316
42	83.38194	42	12.98175	42	97406.25	42	6.70786	42	64.84715	42	129.2388	42	8.343834
43	83.03264	43	4.124653	43	98863.09	43	5.275104	43	31.25534	43	139.5639	43	-5.67049
44	81.72292	44	11.91285	44	98768.05	44	3.482535	44	55.13699	44	3.636364	44	3.069632
45	80.81597	45	17.99688	45	98366.35	45	3.905694	45	41.81773	45	37.96296	45	-5.02092
46	81.14167	46	18.38576	46	98167.19	46	5.515903	46	34.29825	46	60.28037	46	-3.78979
47	81.73125	47	11.8	47	98277.87	47	4.156562	47	59.93022	47	1.724138	47	4.491852
48	82.25208	48	12.24755	48	97504.63	48	1.470944	48	75.40342	48	5.485232	48	10.16334
49	82.24306	49	10.83646	49	97032.56	49	6.645208	49	58.34672	49	90.64626	49	7.435982
50	82.51806	50	8.472222	50	97874.7	50	4.731319	50	77.93929	50	69.62025	50	11.88347
51	83.64653	51	13.10139	51	97949.24	51	3.324306	51	88.67387	51	9.927798	51	15.21613
52	83.07222	52	12.51014	52	97789.36	52	1.660175	52	71.99598	52	78.52564	52	12.18206
53	83.33333	53	14.80347	53	98002.25	53	3.150625	53	65.85736	53	121.3846	53	12.32724
54	83.3125	54	15.27083	54	98360	54	2.520903	54	41.92567	54	40.13841	54	-1.74196
55	84.52014	55	16.63368	55	98234.82	55	3.363785	55	33.06451	55	39.7651	55	-6.54899
56	83.75347	56	16.63785	56	97651.99	56	3.692535	56	71.93347	56	31.67203	56	5.287945
57	82.84028	57	16.34549	57	97477.3	57	4.524931	57	84.77482	57	2.173913	57	14.67089
58	82.24236	58	18.45417	58	97441.05	58	2.183519	58	63.08156	58	47.99331	58	10.30951
59	82.71667	59	20.63299	59	97262.74	59	3.846528	59	40.89982	59	77.33119	59	-4.82298
60	83.08333	60	11.97222	60	97735.81	60	6.898958	60	31.3234	60	99.37888	60	-7.99193
61	82.88264	61	10.5309	61	98525.4	61	2.496399	61	35.61583	61	12.81588	61	-4.13663
62	83.76944	62	10.61076	62	98753.89	62	3.628507	62	47.43991	62	1.896552	62	4.023528
63	82.91806	63	15.96528	63	98592.8	63	3.124097	63	60.60877	63	3.846154	63	8.872546
64	81.75	64	20.72188	64	97882.85	64	5.887361	64	69.77825	64	42.75618	64	7.863006
65	80.66135	65	11.525	65	98349.01	65	7.243507	65	33.39518	65	119.3811	65	-2.22288
66	81.96042	66	8.575694	66	99255.62	66	4.583542	66	57.29858	66	88.62179	66	7.337454
67	83.22153	67	8.210764	67	99659.24	67	2.665575	67	40.55511	67	45.68966	67	-3.39064
68	83.56944	68	11.86632	68	99444.46	68	1.494792	68	87.2265	68	3.696498	68	2.693067
69	83.81981	69	16.00035	69	99182.89	69	4.142847	69	88.90748	69	40.26403	69	1.888374

(Figure 5: Finished Table after Data Processing and Averaging)

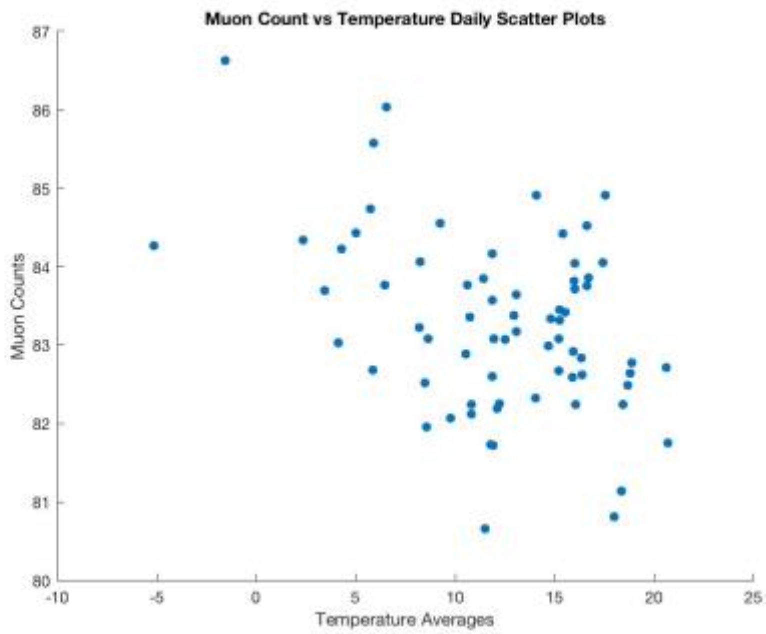
Factor Studies/Analysis/Plots

Muon Count vs Temperature

Although Dr. He's initial studies had already determined that the relationship between Muon count and Temperature was anti-correlative, we still decided that analyzing local temperature in relation to muon count would be a great area of focus. After processing the data different collections of plots were created using Matlab technology and a linear regression model was also created. However due to low R-Squared values in the model, we could only low confidence conclusions between muon count and temperature. Even though the statistical model may not be within desirable confidence bounds, correlations are still shown in the plots below.



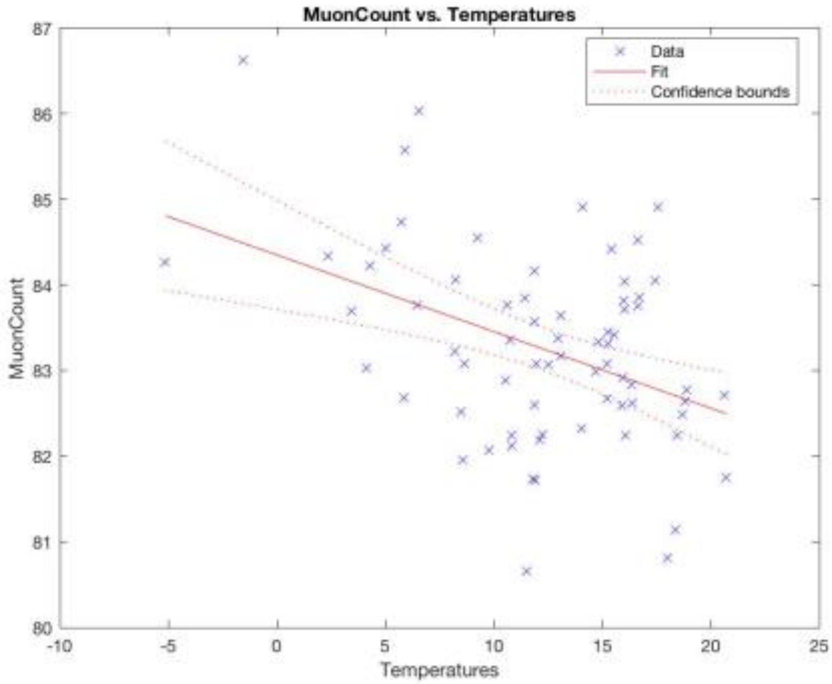
(Figure 6: Muon Count versus Temperature Plot Over Time total of 69 Days)



(Figure 7: Scatter Plot that shows relationship between Muon Count and Temperature in Atlanta Georgia)

```
MuonCount_vs_TemperatureReadingLinearModel =


Linear regression model:
    MuonCount ~ 1 + Temperatures

Estimated Coefficients:
                     Estimate       SE        tStat       pValue
                    _________    ________    _______    __________

    (Intercept)        84.351     0.31956     263.96    8.0148e-103
    Temperatures    -0.089484    0.024081    -3.7159     0.00041512


Number of observations: 69, Error degrees of freedom: 67
Root Mean Squared Error: 1.03
R-squared: 0.171,  Adjusted R-Squared 0.159
F-statistic vs. constant model: 13.8, p-value = 0.000415
```

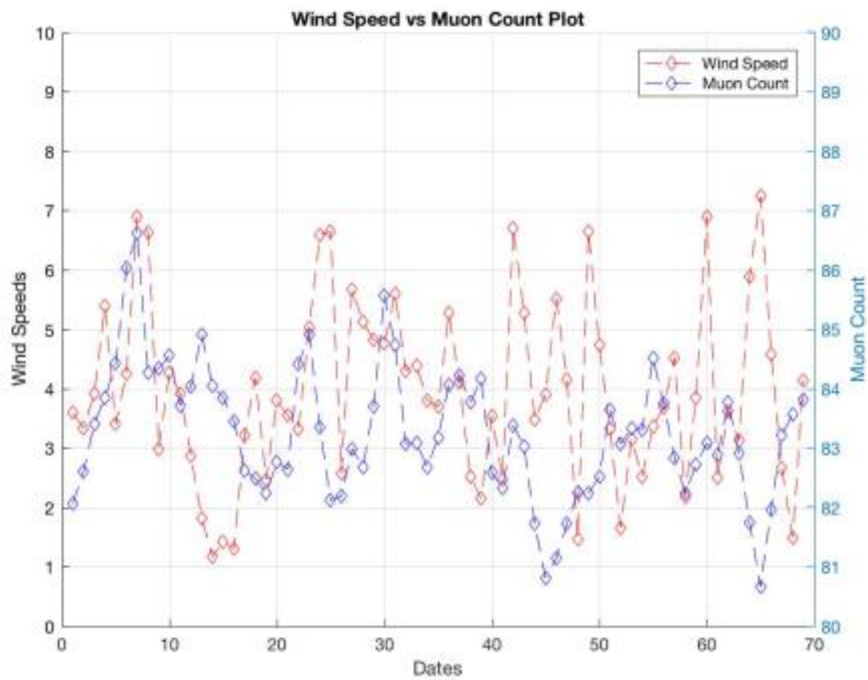
(Figure 8: Linear Regression Model of Muon Count in Response to Temperature)



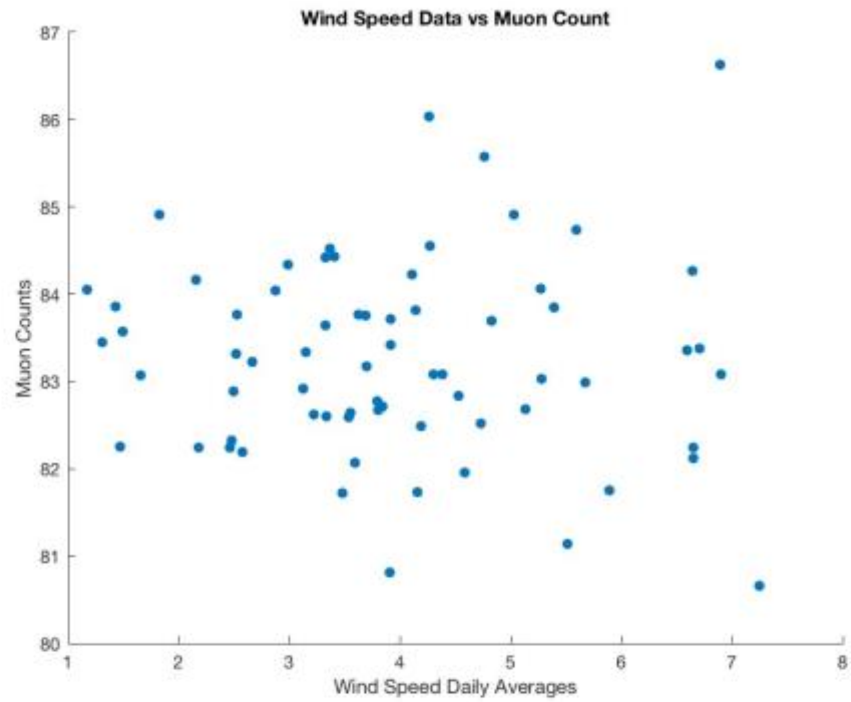
(Figure 9: Linear Regression Model of Muon Count and Temperature, with 95% Confidence bounds generated by Matlab, which supports anti-correlative relationship)

Muon Count vs Wind Speed

Wind Speed was a factor mentioned by Dr. He to analyze and after further analysis of it, wind speed proved to be a non-correlative factor. Because of low confidence bounds again on the statistical model we cannot be highly confident of our conclusion, but I still feel intuitively that wind speed does not have much effect on muon count in the atmosphere.



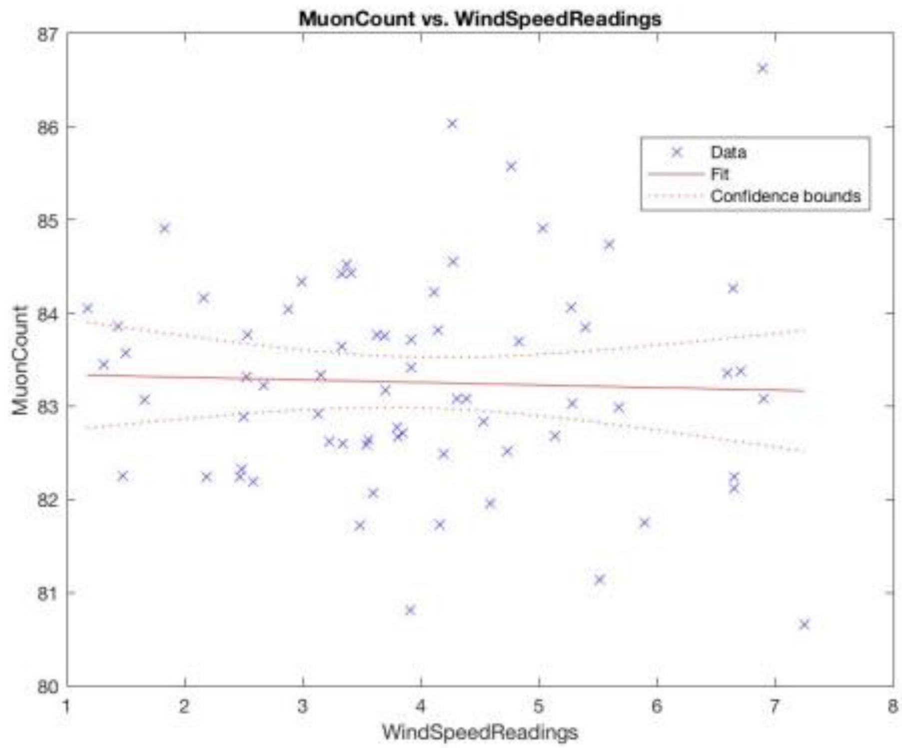
(Figure 10: Muon Count vs Wind Speed Values plotted over a period of 69 Days)



(Figure 11: Muon Count versus Wind Speed Scatter Plot)

```
MuonCount_vs_WindSpeedLinearModel =


Linear regression model:
    MuonCount ~ 1 + WindSpeedReadings

Estimated Coefficients:
                         Estimate       SE         tStat       pValue
                         _________    ________    ________    __________

    (Intercept)             83.367     0.38101       218.8    2.2749e-97
    WindSpeedReadings    -0.027808    0.089888    -0.30937         0.758


Number of observations: 69, Error degrees of freedom: 67
Root Mean Squared Error: 1.13
R-squared: 0.00143,  Adjusted R-Squared -0.0135
F-statistic vs. constant model: 0.0957, p-value = 0.758
```

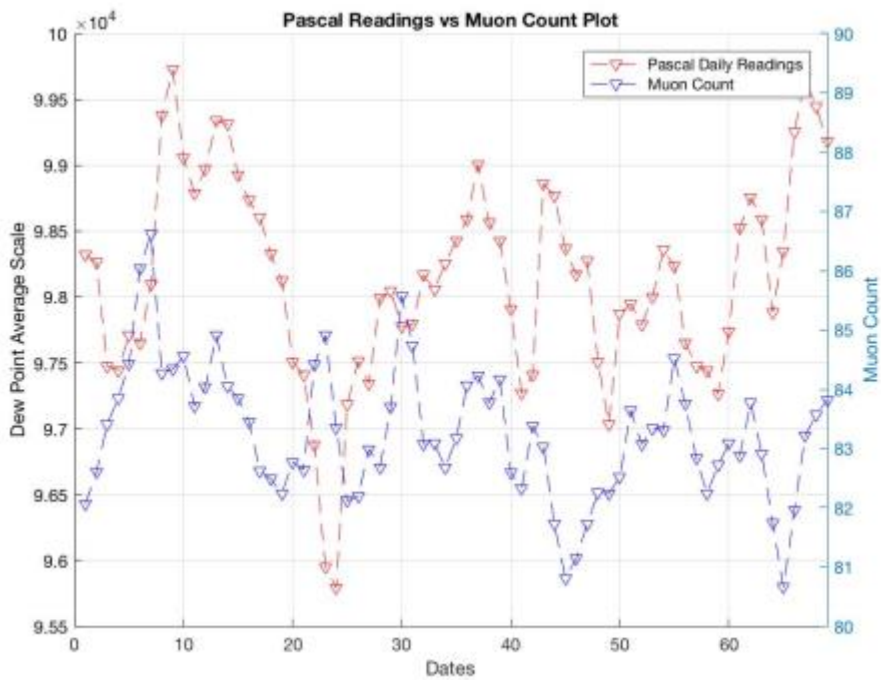
(Figure 12: Linear Regression Model of Muon Count and Wind Speed)



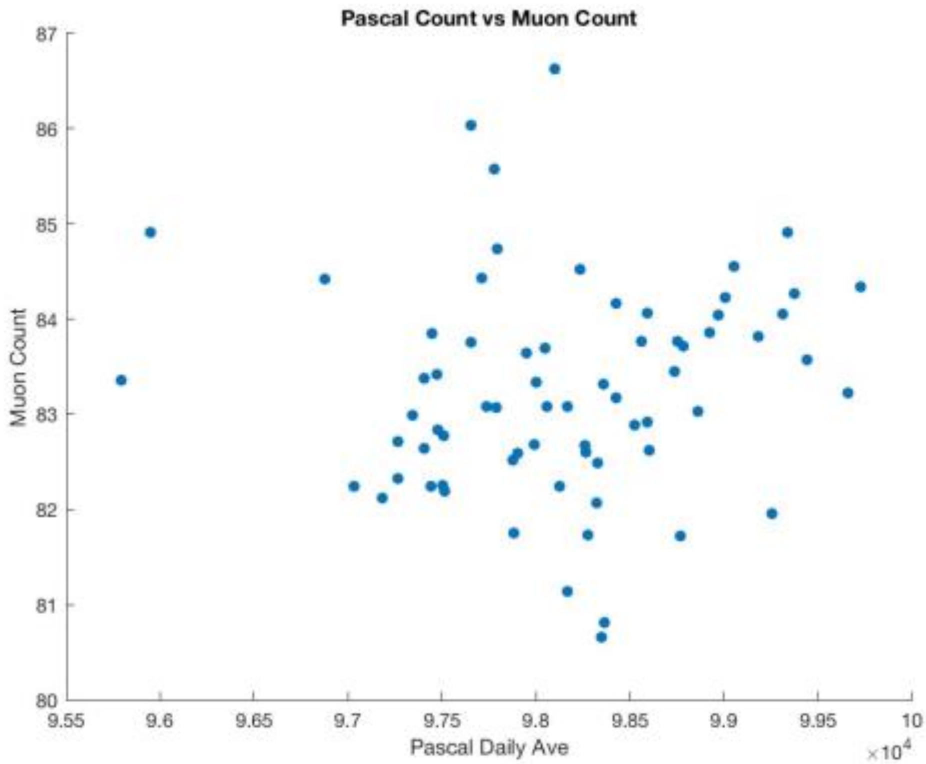
(Figure 13: Muon Count vs Wind Speed with 95% Confidence bounds generated by Matlab)

Muon Count vs Pressure

While in the preliminary stages of the project I initially thought that pressure would have a major impact on muon count just because of the fragile nature of subatomic particles. After processing and analysis my intuition proved to be wrong. Analysis shows that local atmospheric pressure has little to no effect on muon count. Pressure is relatively consistent in Atlanta so deviations in data are not high. Below are figures over this data.



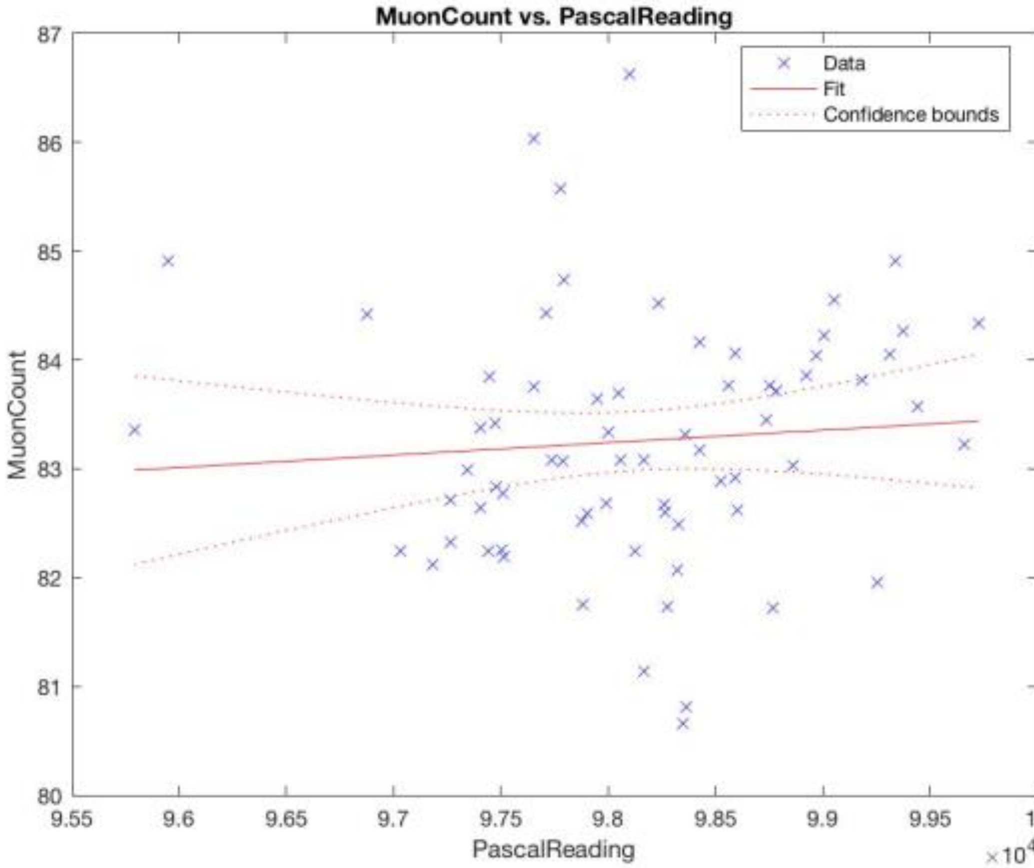
(Figure 14: Muon Count vs Pressure Readings over a period of 69 Days)



(Figure 15: Muon Count vs Pressure Reading Scatter Plot)

```
MuonCount_vs_PascalLinearModel =


Linear regression model:
    MuonCount ~ 1 + PascalReading

Estimated Coefficients:
                      Estimate        SE         tStat       pValue
                     __________    _________    _______    __________

    (Intercept)          72.023       17.205     4.1862    8.4558e-05
    PascalReading    0.00011446    0.0001753    0.65294       0.51603


Number of observations: 69, Error degrees of freedom: 67
Root Mean Squared Error: 1.13
R-squared: 0.00632,  Adjusted R-Squared -0.00851
F-statistic vs. constant model: 0.426, p-value = 0.516
```

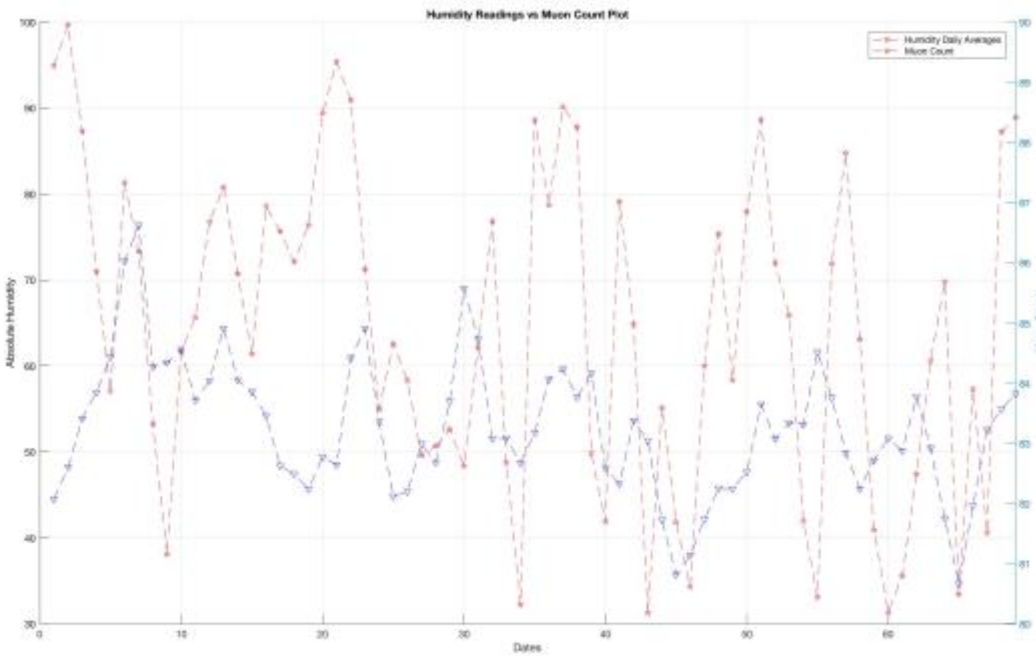
(Figure 16: Linear Model of Muon Count to Pressure, of all models this model has the worst R-squared values)



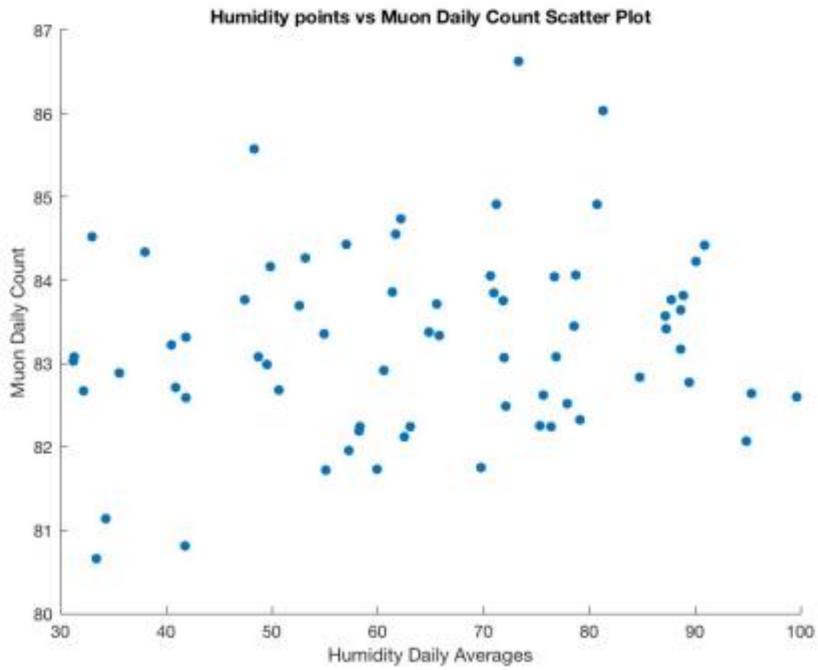
(Figure 17: Linear Model between Muon Count and Pressure Values, this figure shows a slight correlation but because of poor confidence values we cannot confirm this. With 95% Confidence intervals)

Muon Count vs Humidity

Humidity was chosen as a factor for analysis because it is an integral part of our environment. Especially living in the southeastern coast of the United States humidity places a vital role into our lives as citizens of Atlanta. Humidity proved to also be a non-correlative factor in response of muon count. R squared values also proved to be low for this model as well so confidence is not high for conclusion.

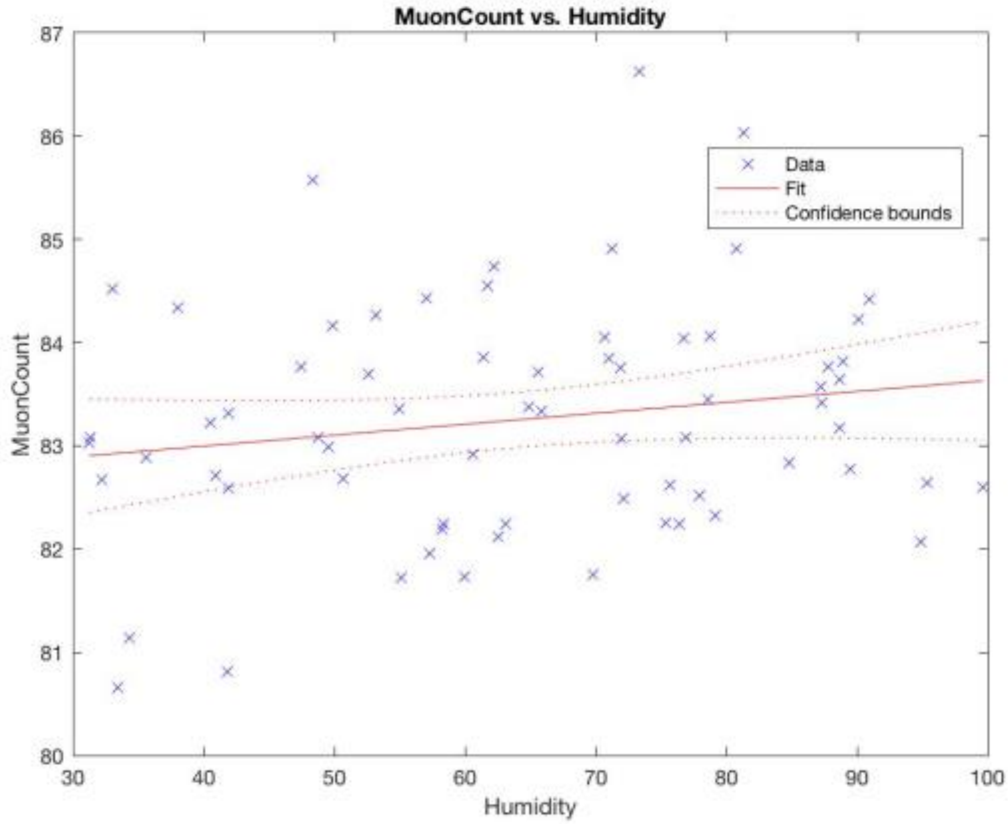


(Figure 18: Humidity vs Muon Count Plot over 69 days)



(Figure 19: Scatter Plot of Muon Count and Humidity values)

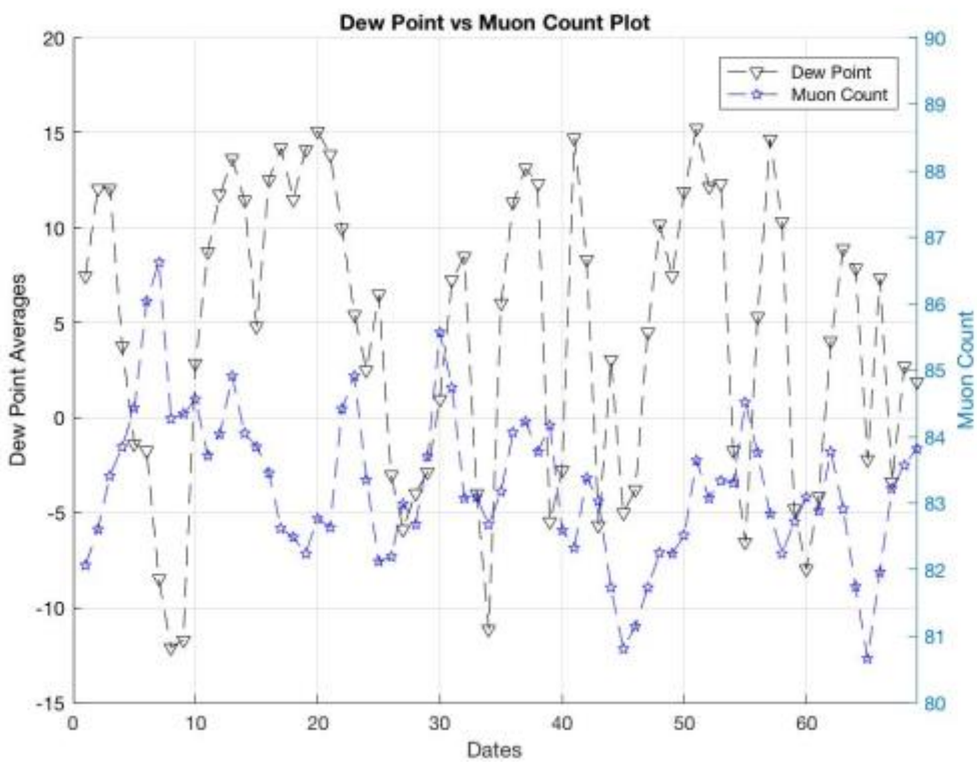
```
MuonCount_vs_HumidityLinearModel =


Linear regression model:
    MuonCount ~ 1 + Humidity

Estimated Coefficients:
                   Estimate        SE        tStat       pValue
                   ________    _________    ______    __________

    (Intercept)      82.573      0.48507    170.23    4.4528e-90
    Humidity       0.010601    0.0072297    1.4663       0.14725


Number of observations: 69, Error degrees of freedom: 67
Root Mean Squared Error: 1.11
R-squared: 0.0311,  Adjusted R-Squared 0.0166
F-statistic vs. constant model: 2.15, p-value = 0.147
```
(Figure 20: Linear Model generated using Matlab function. Muon Count in Response to Humidity)



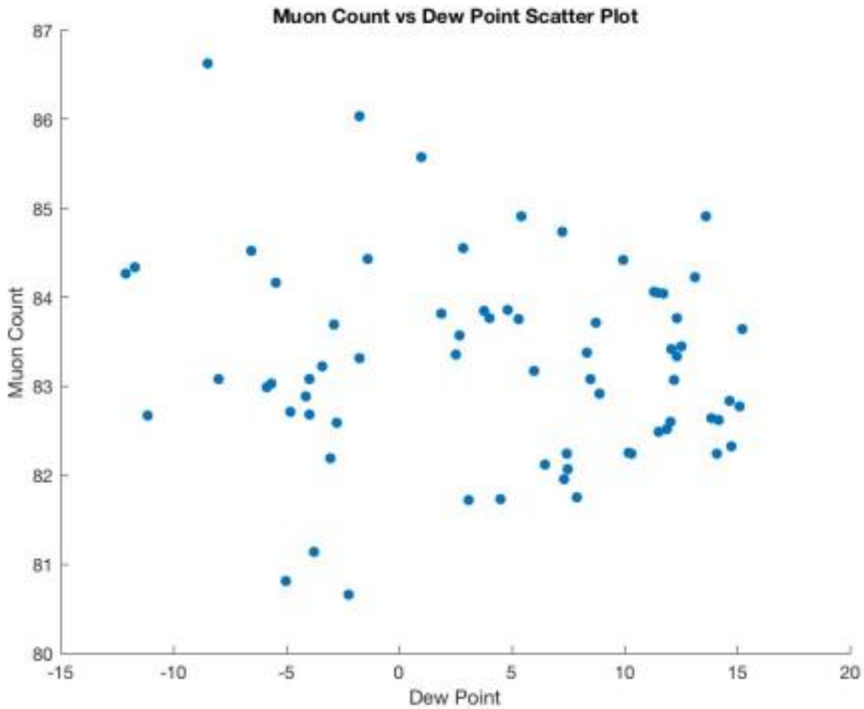
(Figure 21: Linear Regression Model Plotted Muon Count vs Humidity with 95% Confidence variables)

Muon Count vs Dew Point

Relative humidity and dew point both give us an idea of the amount of moisture in the atmosphere; however only dew point is a true measurement of the atmospheric moisture. Dew point is the term that most meteorologists use to describe the amount of moisture in the air. Because of this analysis of muon count in response to dew point seemed to be a valid point for research.



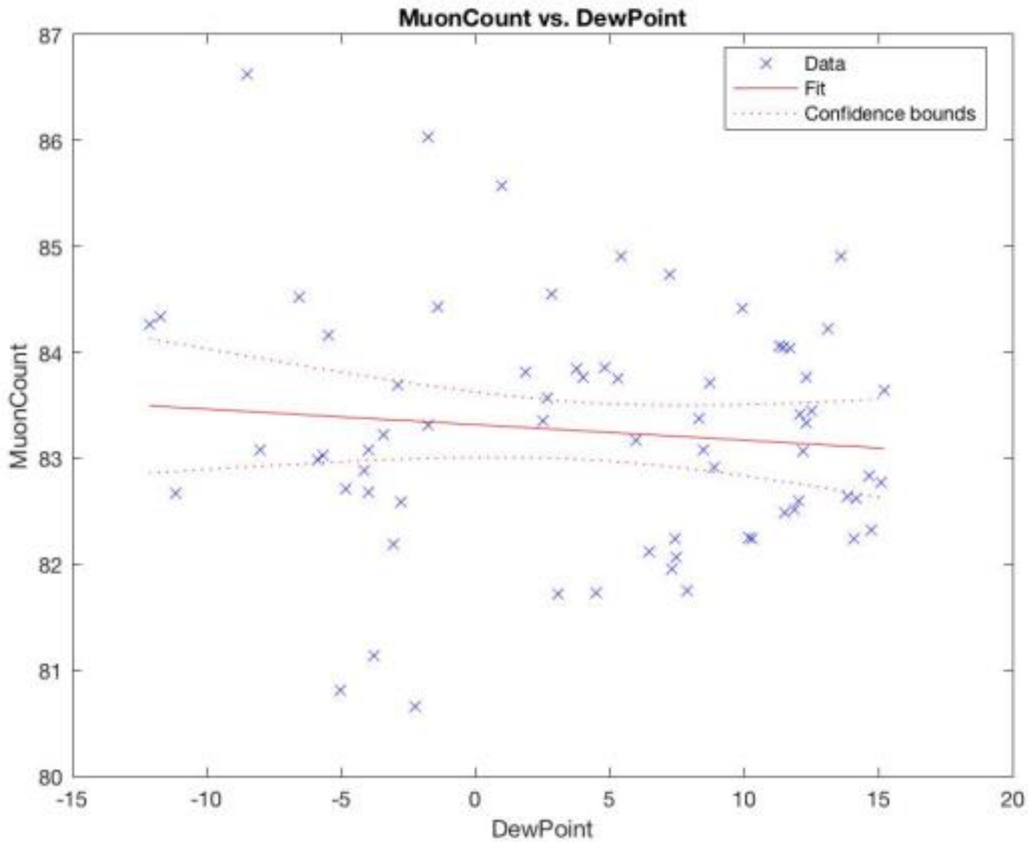
(Figure 22: Muon Count vs Dew Point Plot over a period of 69 days)



(Figure 23: Scatter Plot of Muon Count vs Dew Point, shows no correlation between two data sets)

```
MuonCount_vs_DewPointLinearModel =


Linear regression model:
    MuonCount ~ 1 + DewPoint

Estimated Coefficients:
                   Estimate       SE        tStat        pValue
                   _________    _______    ________    ___________

    (Intercept)        83.32    0.15505      537.37    1.6957e-123
    DewPoint       -0.014656    0.01755    -0.83511        0.40662


Number of observations: 69, Error degrees of freedom: 67
Root Mean Squared Error: 1.13
R-squared: 0.0103,  Adjusted R-Squared -0.00447
F-statistic vs. constant model: 0.697, p-value = 0.407
```

(Figure 24: Linear Model for Muon Count in Response to Dew Point data)



(Figure 25: Linear Regression Model Plotted of Muon Count in response to Dew Point with 95% confidence intervals)

Cloud Layer Coverage Data

Cloud Layer data was supposed to be a pivotal factor in our project because subatomic particles are highly affected by cloud coverage. Because of this we made a huge effort to take this into account and analyze cloud coverage data. While we could accumulate the data for cloud layer coverage, the data was more qualitative than quantitative. Our data set obtained from MesoWest provided Cloud Layer coverage based on three factors: layer type, height, and cloud type. We decided to use “Cloud Layer Coverage 1” meaning that only one cloud layer was present for that day the data was taken.

The data is broken down as follows:

- Thousandth and hundreds place of the value represents height, in hundreds of feet
- The tens place digit represents the cloud type following this model
    - 0 = missing
      1 = clear
      2 = scattered
      3 = broken
      4 = overcast
      5 = obscured
      6 = thin scattered
      7 = thin broken
      8 = thin overcast
      9 = thin obscured
- Example: 567 means a cloud is at a height of 56 = 5600 feet
- The last digit 7 identifies the cloud type as “think broken.”

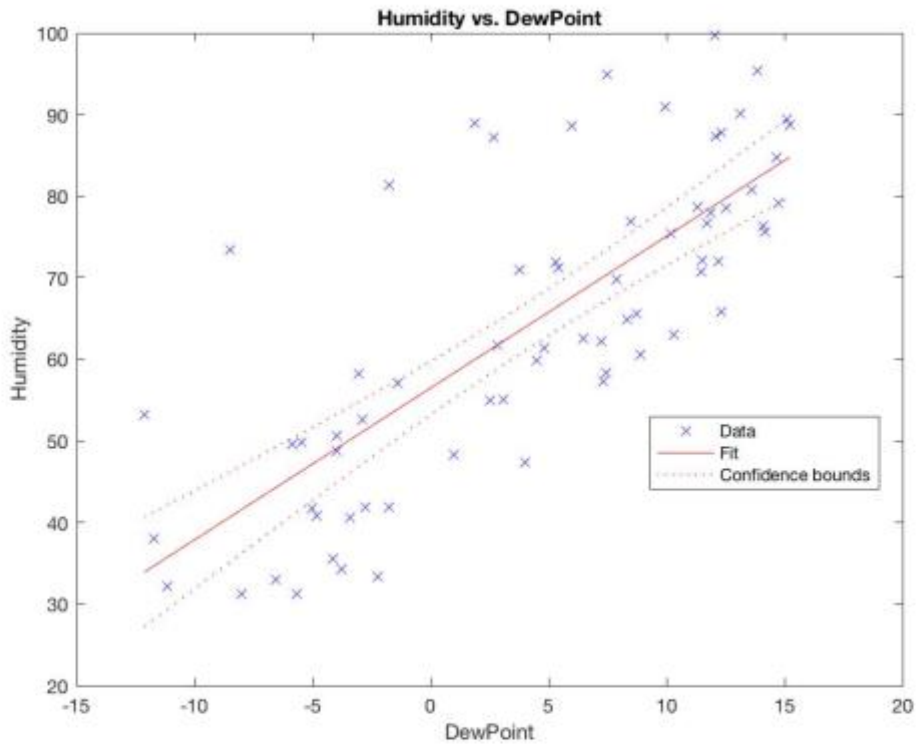
  Because of this qualitative data type few conclusions could be made that would be of high relevance to the project and research. Andira did create a linear regression model between muon count and cloud layer coverage, but in my report I am choosing not to show it because it not having high relevant research value.

Humidity vs Dew Point

Because of such low confidence values on the statistical models generated in our research. A decision was made to test relations between dew point and humidity. After research, online we found out that dew point and humidity did have a positive correlation between one another, and so we tested our data and looked to see if we could come to the same conclusion. This would prove whether data processing was done correctly by our group. And after testing the two factors we received a positively correlated model between the two values and a very good R-Squared value, meaning that we could conclude that data processing for our project was done correctly.

```
DewPoint_vsHumidityLinearModel =


Linear regression model:
    Humidity ~ 1 + DewPoint

Estimated Coefficients:
                   Estimate      SE       tStat       pValue
                   ________    _______    ______    __________

    (Intercept)     56.49       1.6403    34.439    2.4581e-44
    DewPoint         1.86      0.18566    10.018      5.96e-15


Number of observations: 69, Error degrees of freedom: 67
Root Mean Squared Error: 11.9
R-squared: 0.6,  Adjusted R-Squared 0.594
F-statistic vs. constant model: 100, p-value = 5.96e-15
```

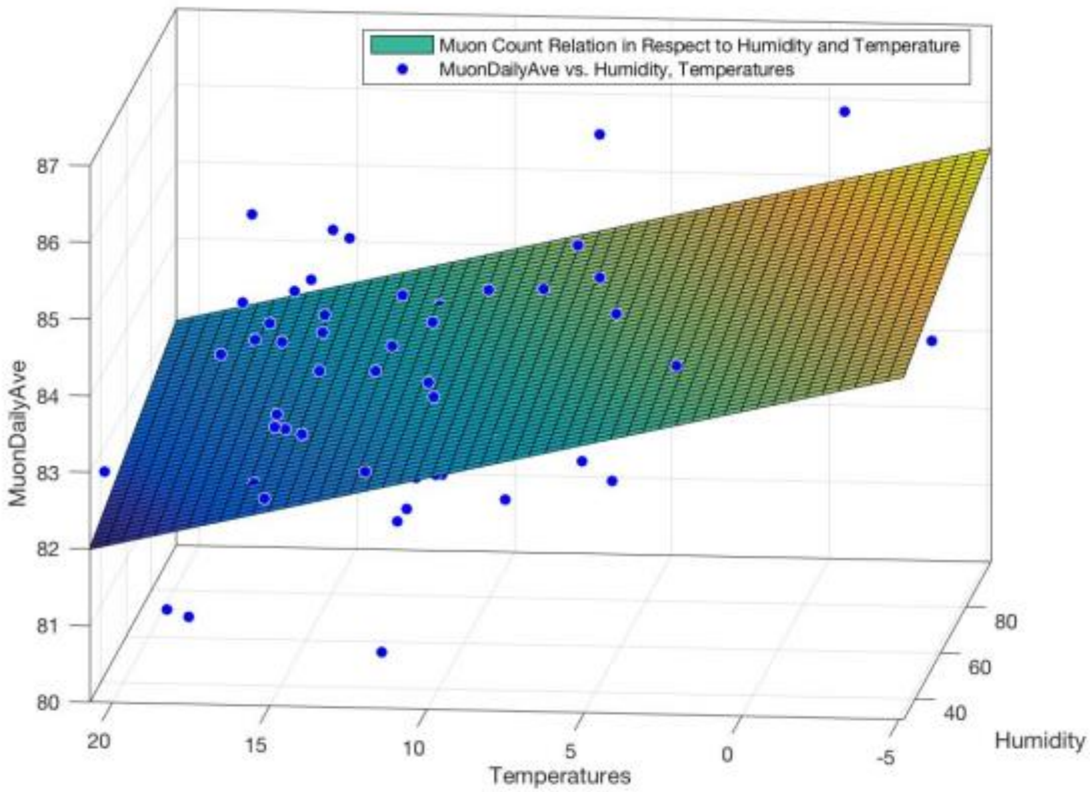
(Figure 27: Linear Model Generated through Matlab for Humidity in Response to Dew Point Data)



(Figure 28: Humidity vs Dew Point Linear Regression Model plotted using Matlab with 95% confidence bounds)

Multivariable Analysis

Also as a test of muon count in response to more than one variable at a time, we decided to plot a 3D plot of Muon Count versus Temperature and Humidity. The plot did look good, and contrary to our other factor analysis, did have a higher R squared values than other variables singularly modeled against muon count.



(Figure 29: 3D Plot of Muon Count in Response to Humidity and Temperature, most points are not however in the plane)

Conclusion

In conclusion, it would be easy to say that most factors analyzed in our project have no correlation on muon count, however due to such low confidence values we cannot conclude this thoroughly. Many plots and models such as the scatter plots and linear regression models show none correlative evidence, but very low R squared values go against this claim. It is easy to say the plot or models show no correlation but low confidence values don't provide a claim backed in good standing. Intrinsically however, I personally feel that out of all of the factors analyzed in our project, temperature and cloud layer are probably the only local weather factors that have most likely have an impact on muon count. But in the scientific community personal claims are rarely supported without scientific evidence (as it should be). For better analysis, next time I think that obtaining larger sets of data would be better, maybe obtaining data sets from conglomerate databanks such as NASA or the CDC. Averaging maybe could be done maybe in other computer programs such as python for better data processing and averaging. I believe that more research should happen for muon count in response to local weather analysis because it could be huge in areas such as cancer and medical research. Overall I enjoyed our project and I would consider further research.

Accreditation/ Acknowledgment

I would like to give many thanks to Dr. He for his research, data and enthusiasm to help us in our project, Dr. Jiang for help with the project, help with coding, and teaching the class because Matlab is an incredible tool that I am glad I learned to use. And of course my partner Andira Putri, because without her help, knowledge, and precious time our project would not be near as good as it is, and data processing and averaging would've killed me lol. Thank you

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Citations!

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