HAWC Rates and Pressure Analysis for the years 2015 - 2023

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Background

HAWC is an observatory which collects secondary cosmic ray shower particles.
The primary cosmic ray particle interacts with the atmosphere, producing these secondary shower particles which are then detected by HAWC.
The pressure of the atmosphere right above HAWC affects the rate of detecting these shower particles.
What we have seen is as the pressure increases, there is a decrease in the rate of detection, showing a negative correlation.

- Weather data released through 2022 (Thank you Alberto Carramiñana, Esperanza Carrasco, Jorge Reyes, and Xavier Alcantara)

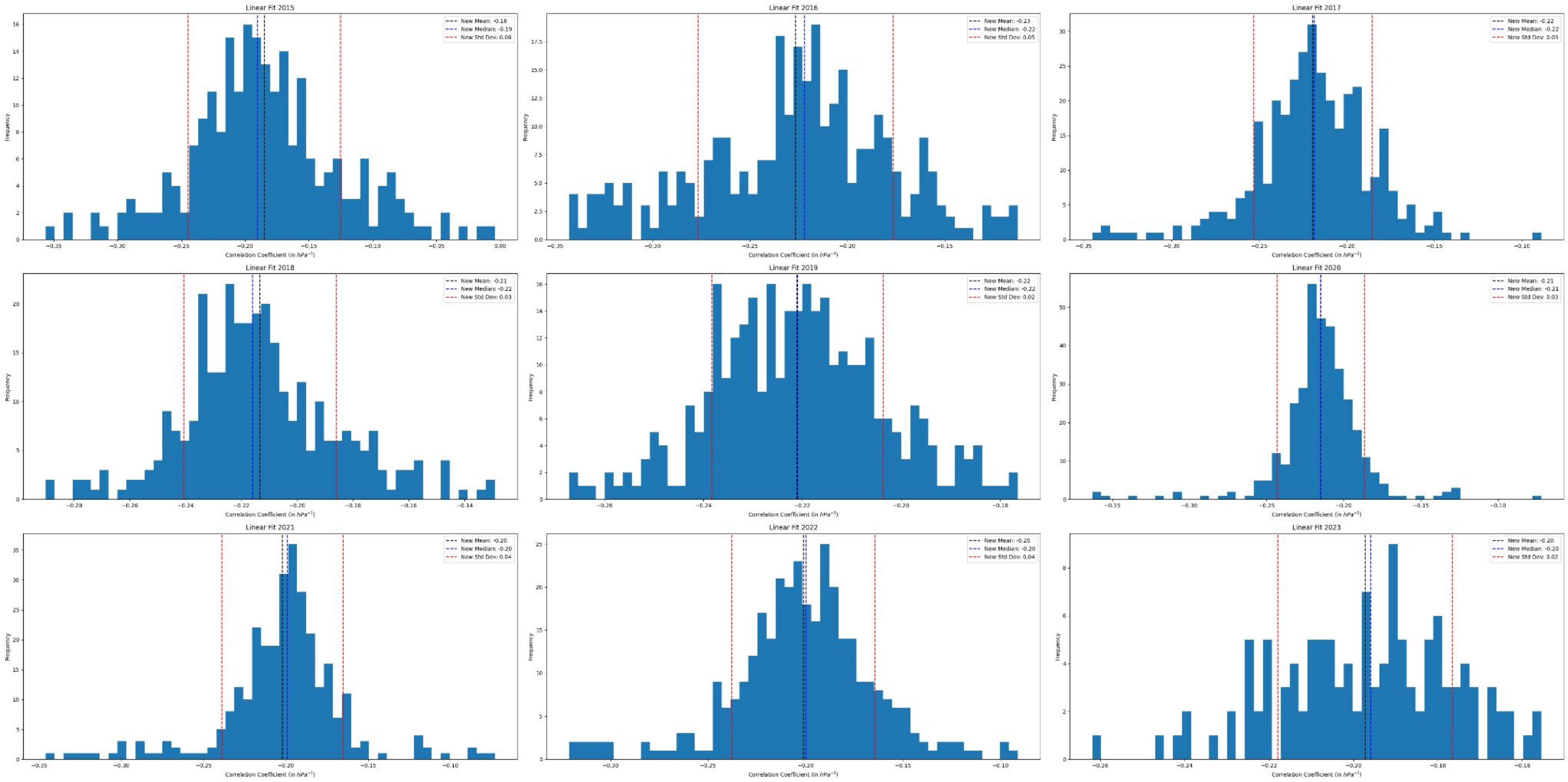
What I have been working on

- I started with binning the Rates and Pressure data for each year with each bin having the values in 8 mins range. (I chose 8 mins because the Rates data is taken every 4 mins while the Pressure data is taken every 1 min)
- I performed a linear regression to calculate the linear and exponential correlation coefficient.
    - The linear correlation coefficient is the slope calculated when I perform a linear regression on the average rates per time interval vs. the average pressure per time interval (Here, the time interval is 8 mins).
    - Similarly, the exponential correlation coefficient is the slope when I perform a linear regression on the log on average rates per time interval vs the average pressure per time interval.
- After this process, I cleaned the data by only taking into account the correlation coefficients in a year that are one standard deviation away from the mean.

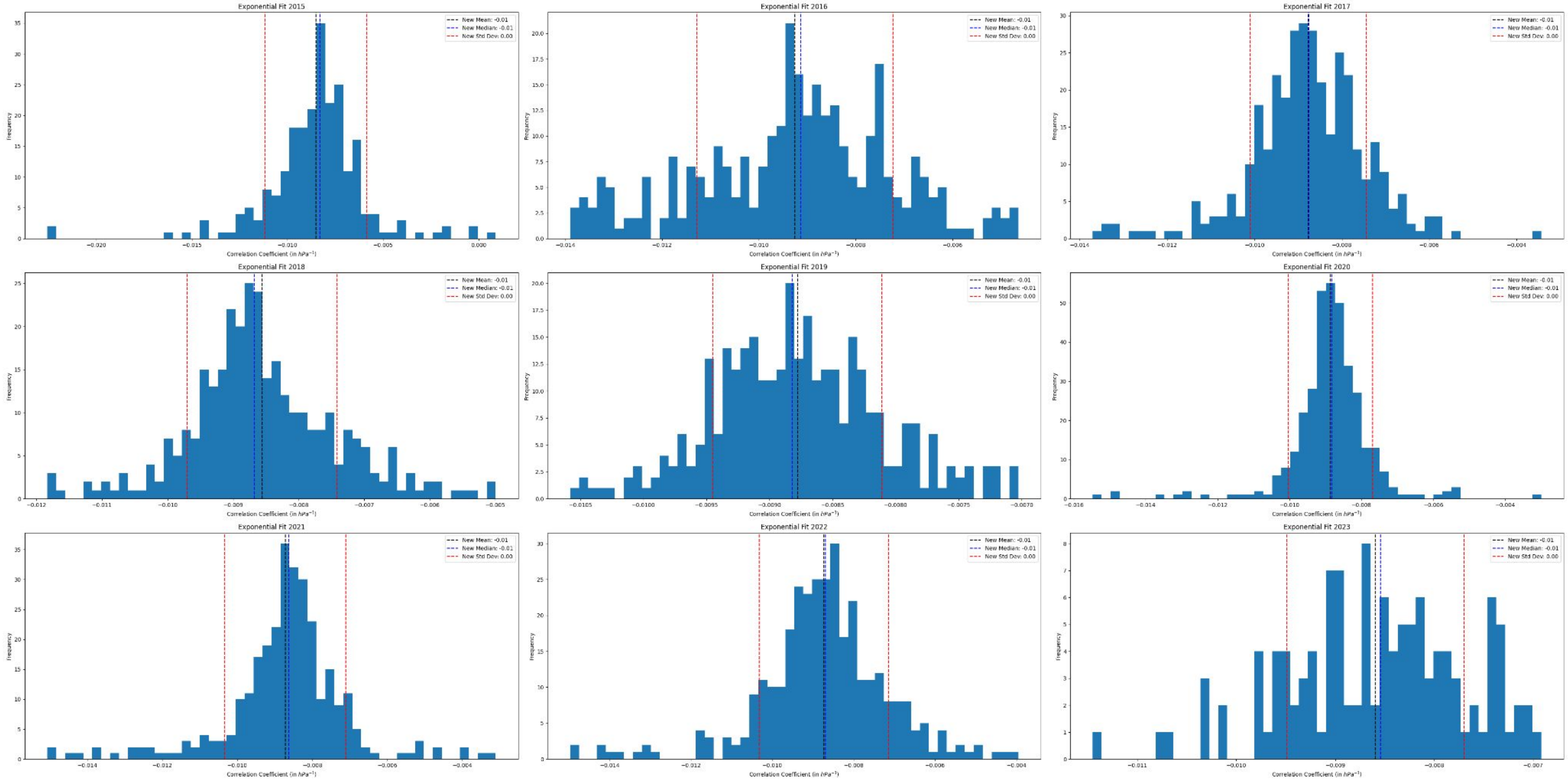
- For the linear fit, I used $f(x) = -bx + c$, here "f(x)" is rate, "x" is pressure, and "b" is the required linear correlation coefficient.
- For the exponential fit, I used $f(x) = ae^{-bx}$, here "f(x)" is the rate, "x" is the pressure, and "b" is the required exponential correlation coefficient.

Here are the plots I got after the cleaning…

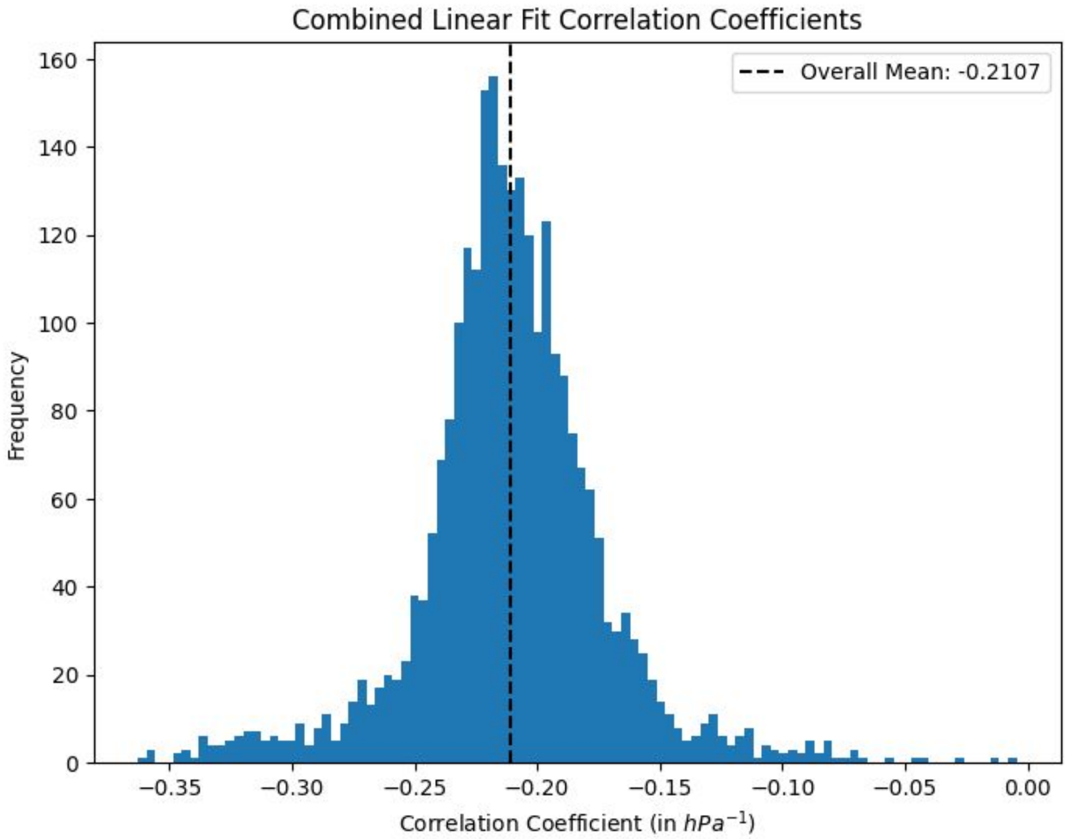
Linear Correlation Coefficient Distribution:



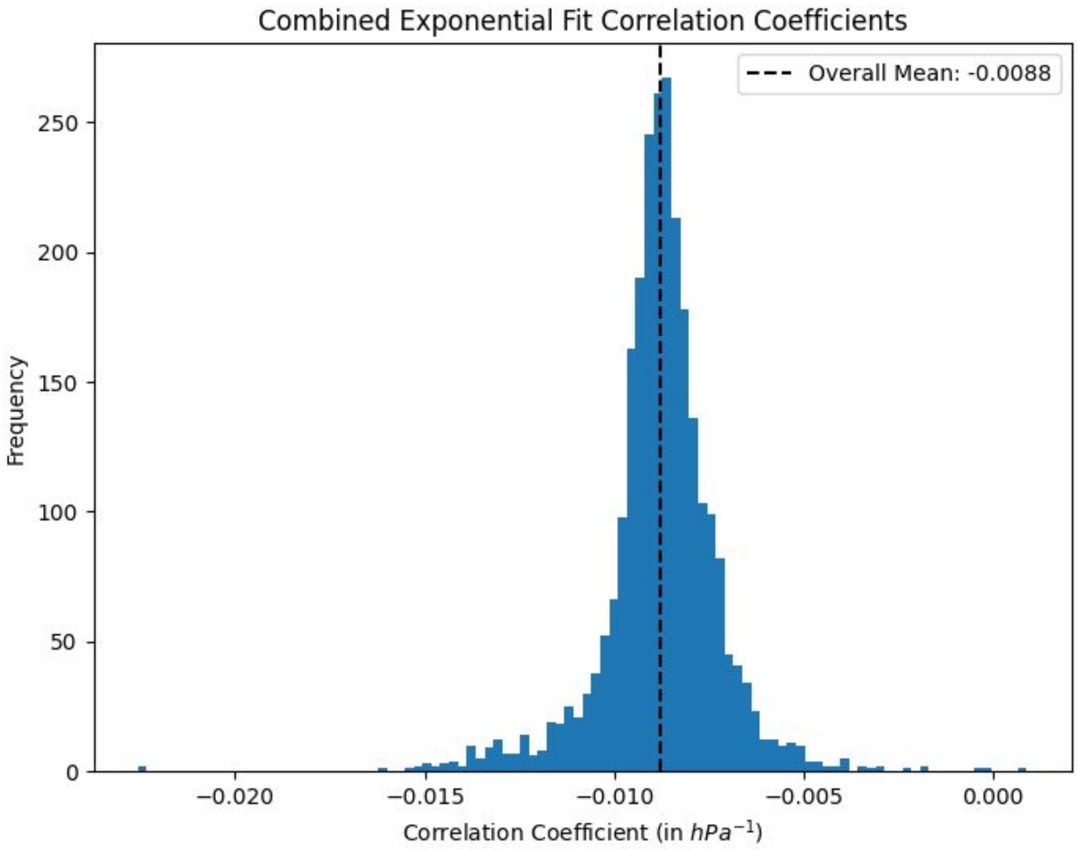
Exponential Correlation Coefficient Distribution:



I combined all the data from all the years for the linear correlation coefficient and plotted the values one standard deviation away from the mean



I did the same thing for the exponential correlation coefficient and this is the plot I got with the mean value being -0.0088 hPa^{-1}

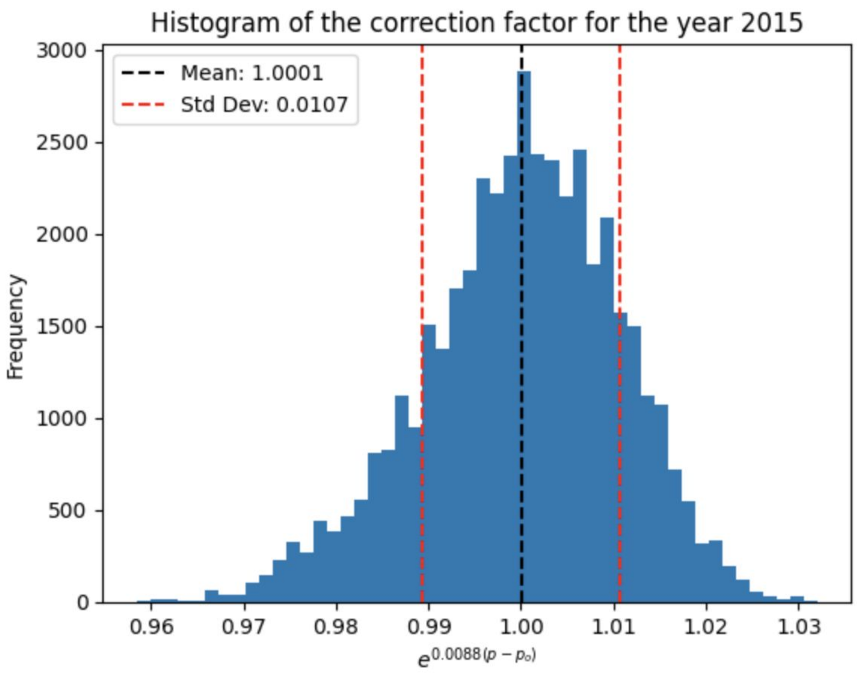


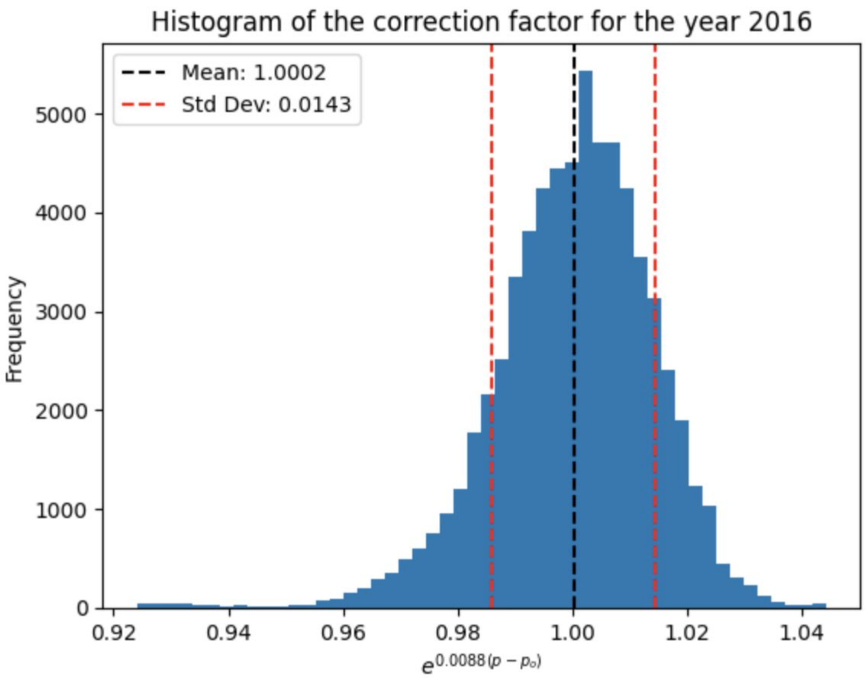
Then, I applied a correction to the rates to scale them with a factor that involves the exponential correlation coefficient and the pressure. Here is the equation is used:

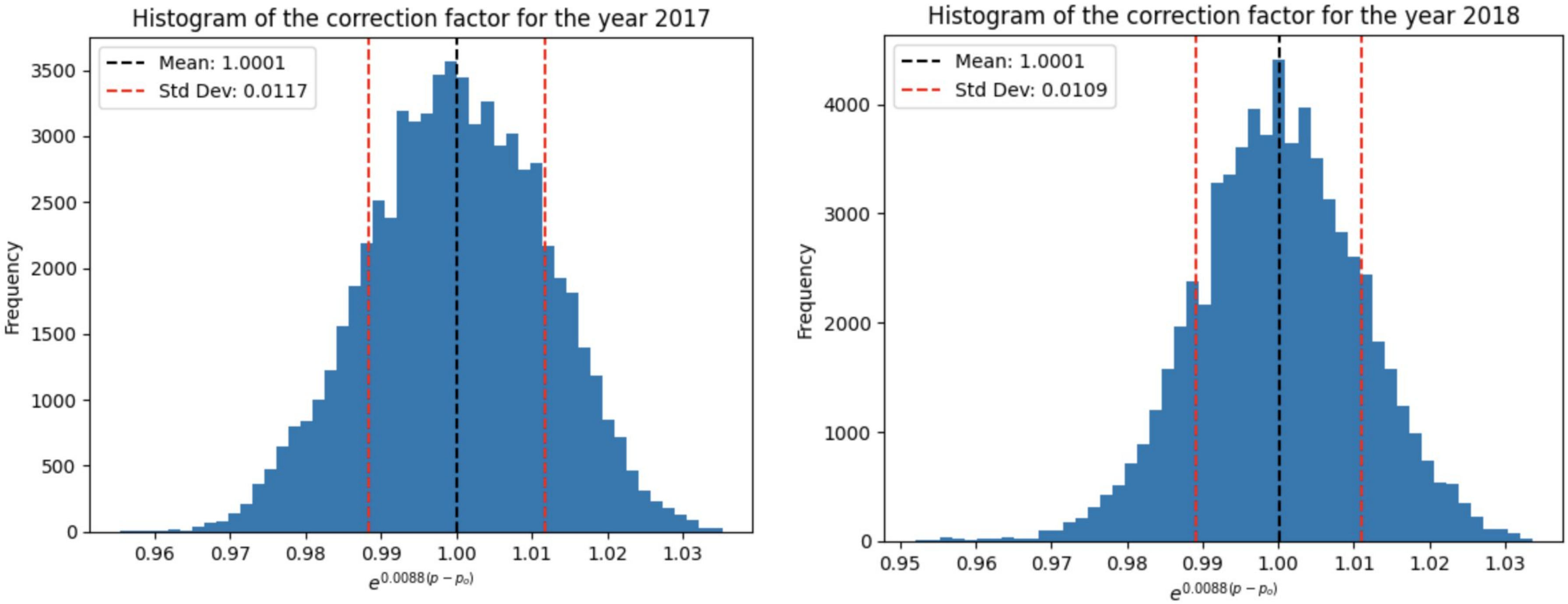
$$rcorr = r * e^{-\beta(p - p_o)}$$

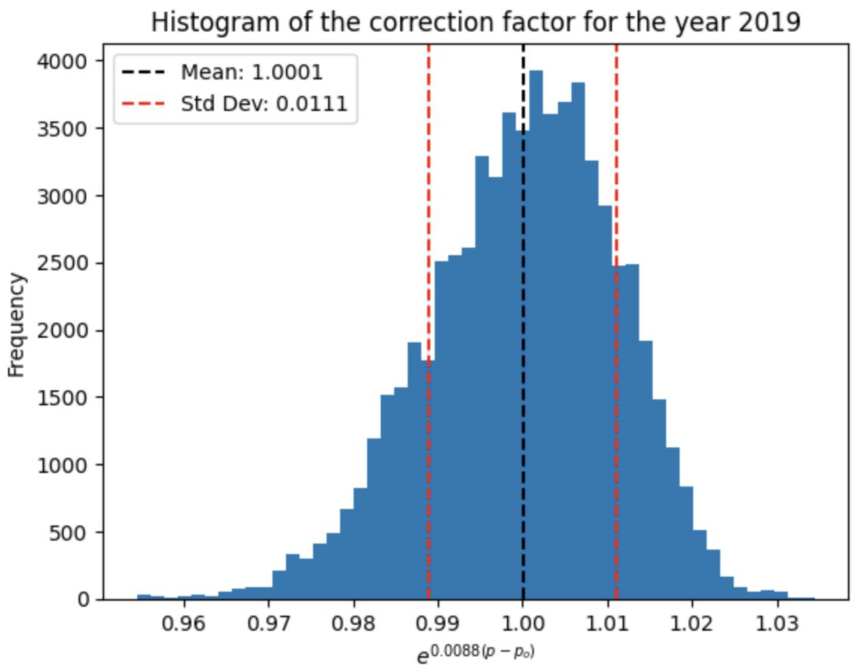
$$w_i = e^{-\beta(p(t_i) - p_o)}$$

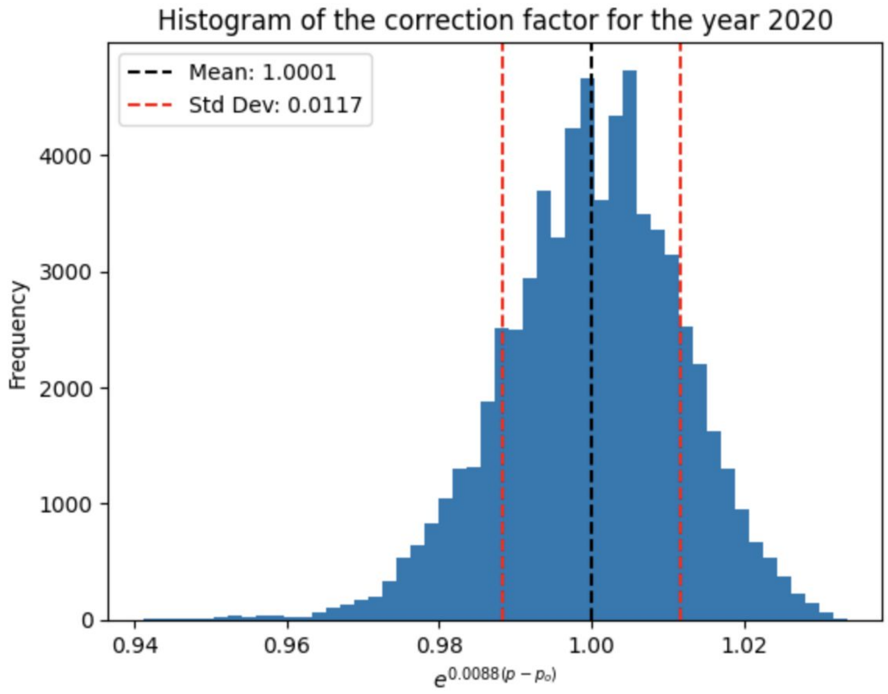
This correction factor adds a weight to each value of the rates. Here is how this correction factor looks like for the years from 2015 to 2023:

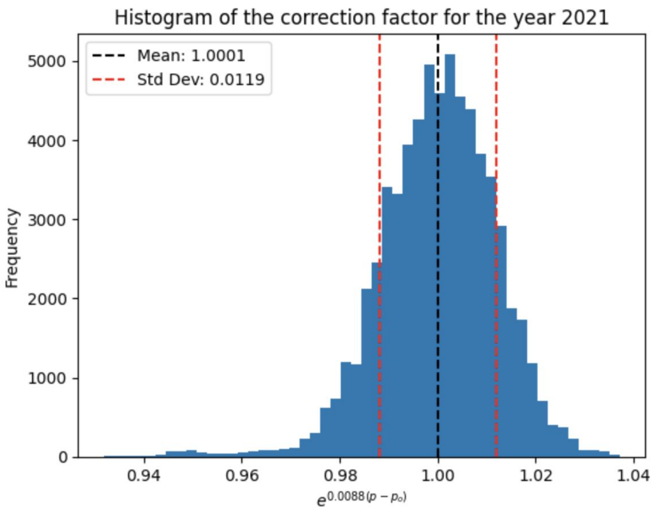

Histogram of the correction factor for the year 2015
Mean: 1.0001
Std Dev: 0.0107
Frequency
0
500
1000
1500
2000
2500
3000
0.96
0.97
0.98
0.99
1.00
1.01
1.02
1.03
$e^{0.0088(p-p_o)}$

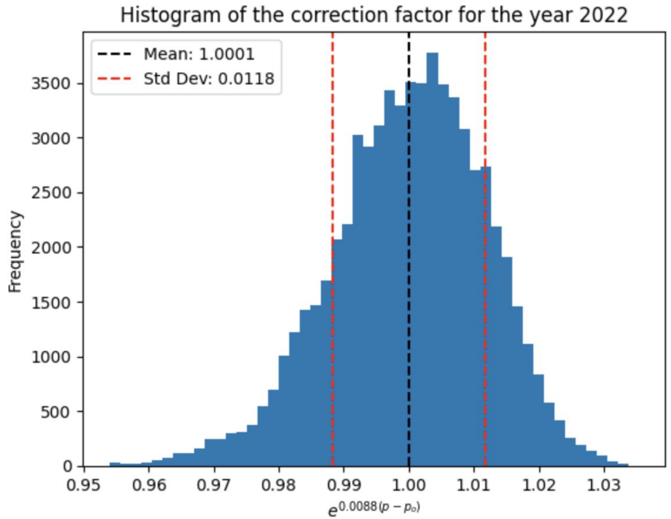

Histogram of the correction factor for the year 2016
Mean: 1.0002
Std Dev: 0.0143
Frequency
0
1000
2000
3000
4000
5000
0.92
0.94
0.96
0.98
1.00
1.02
1.04
$e^{0.0088(p-p_o)}$

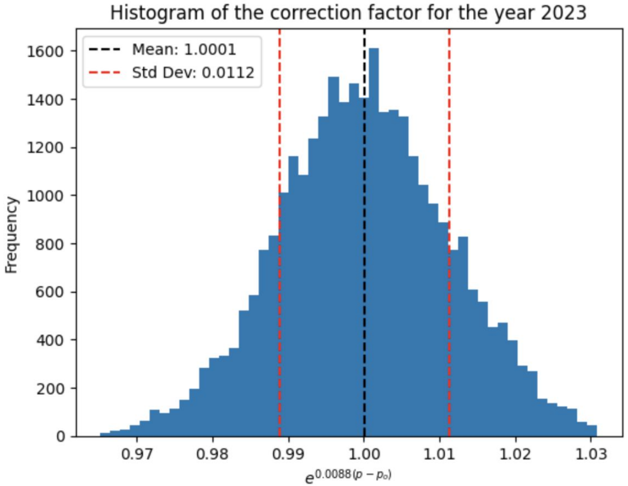

Histogram of the correction factor for the year 2017
Mean: 1.0001
Std Dev: 0.0117
Frequency
$e^{0.0088(p-p_o)}$
Histogram of the correction factor for the year 2018
Mean: 1.0001
Std Dev: 0.0109
Frequency
$e^{0.0088(p-p_o)}$


Histogram of the correction factor for the year 2019
Mean: 1.0001
Std Dev: 0.0111
Frequency
$e^{0.0088(p-p_o)}$

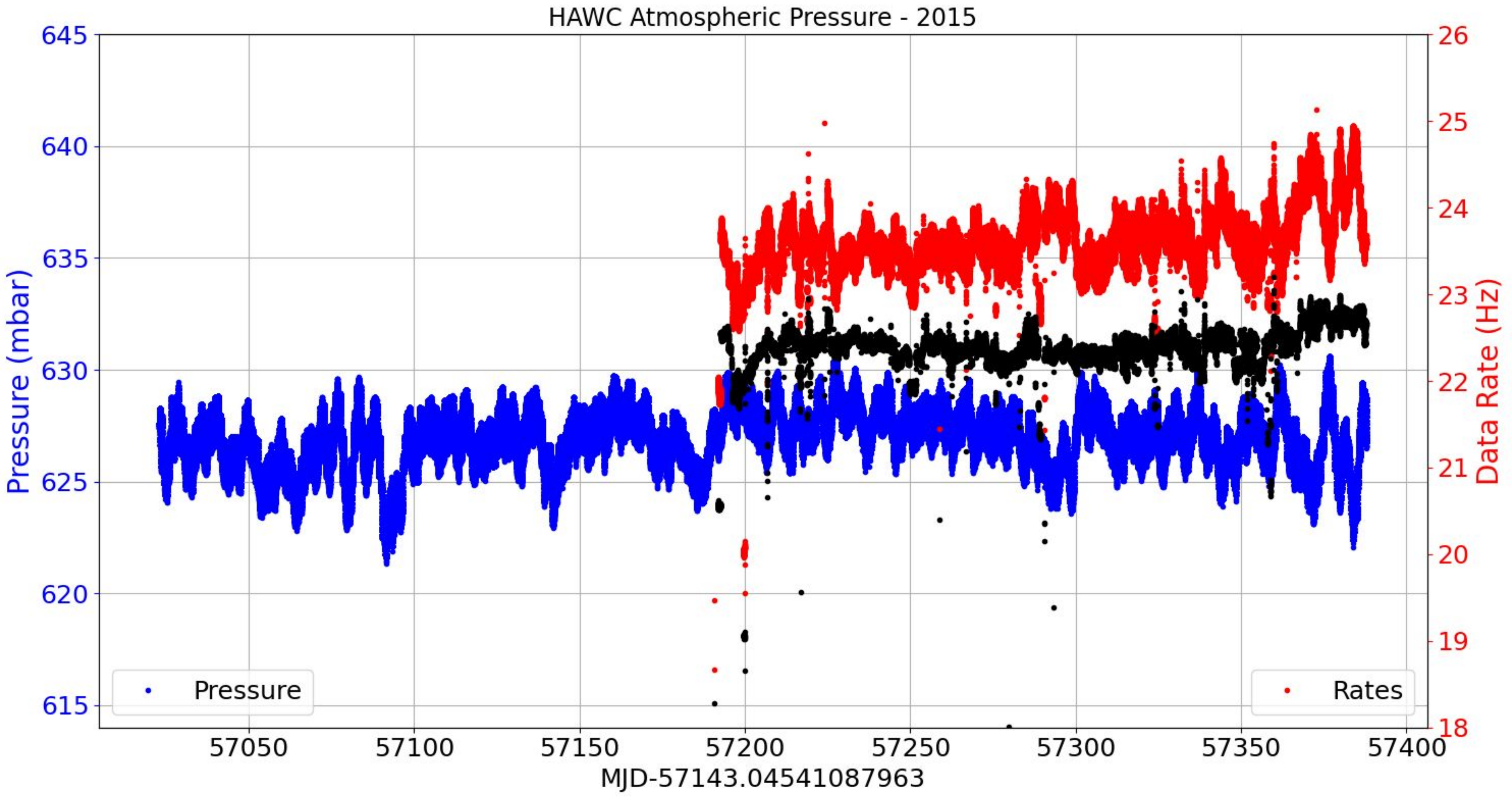

Histogram of the correction factor for the year 2020
Mean: 1.0001
Std Dev: 0.0117
Frequency
$e^{0.0088(p-p_o)}$

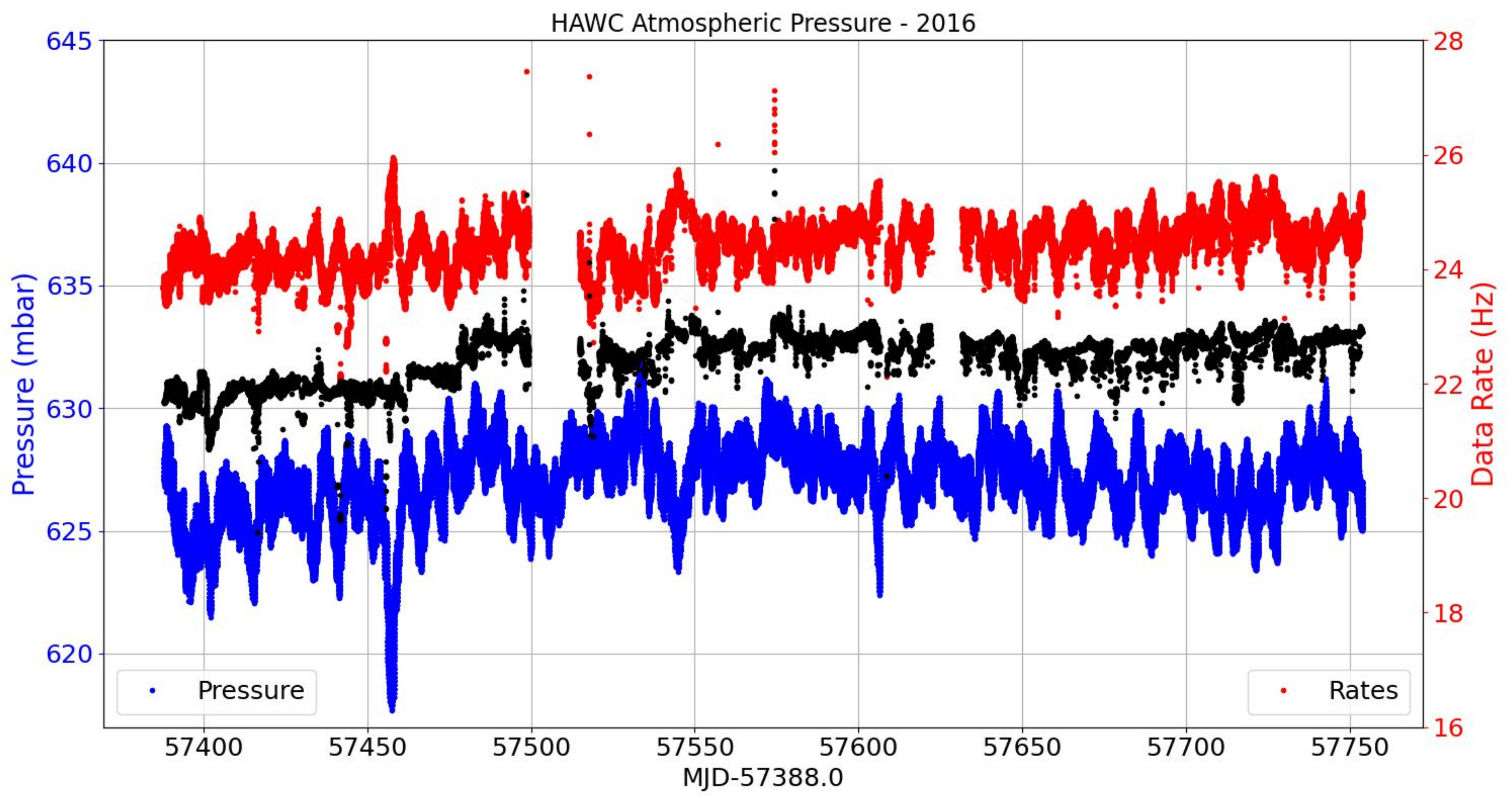

Histogram of the correction factor for the year 2021
Mean: 1.0001
Std Dev: 0.0119
Frequency
0
1000
2000
3000
4000
5000
0.94
0.96
0.98
1.00
1.02
1.04
$e^{0.0088(p-p_o)}$


Histogram of the correction factor for the year 2022
Mean: 1.0001
Std Dev: 0.0118
Frequency
0
500
1000
1500
2000
2500
3000
3500
0.95
0.96
0.97
0.98
0.99
1.00
1.01
1.02
1.03
$e^{0.0088(p-p_o)}$

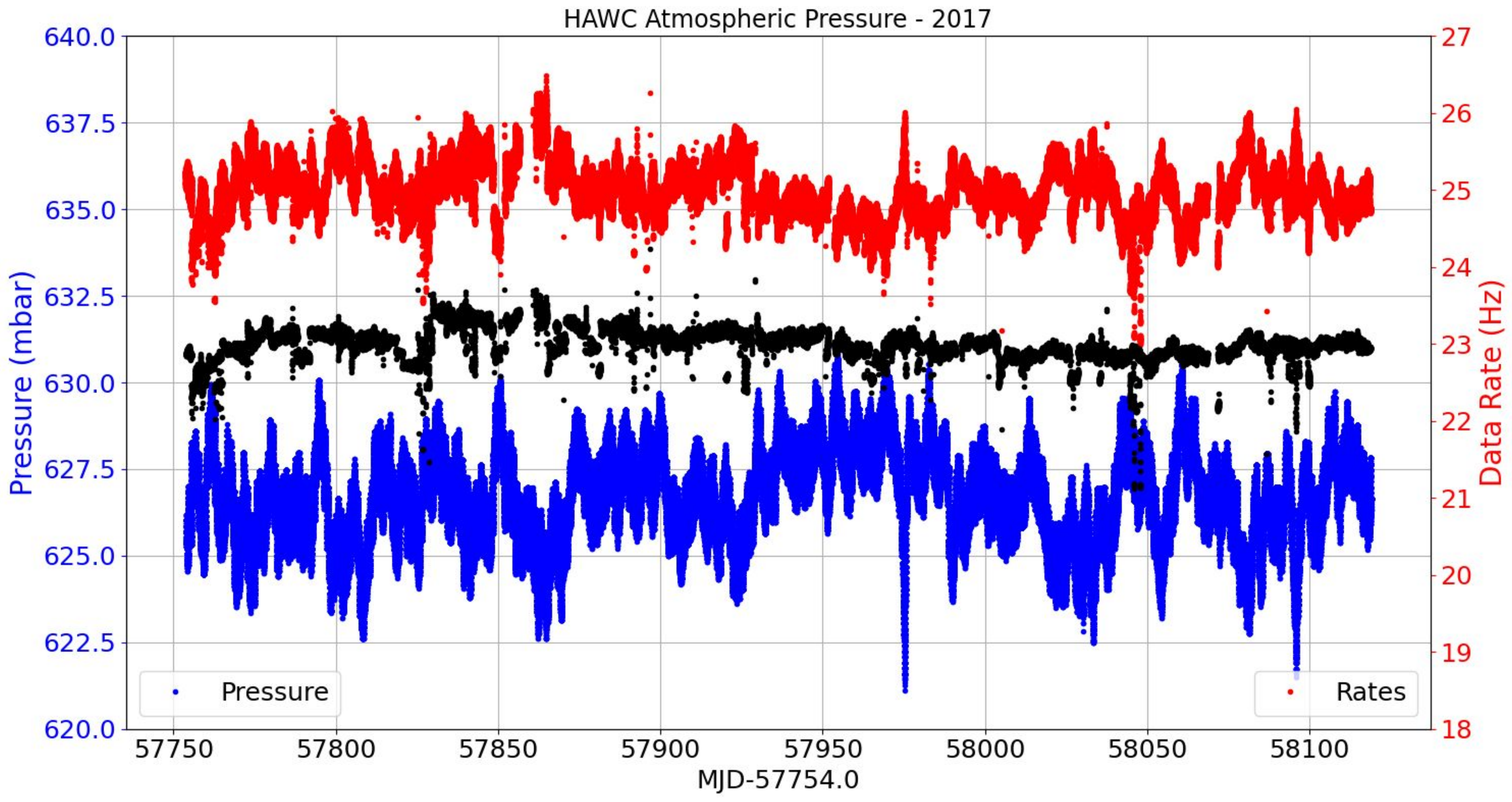

Histogram of the correction factor for the year 2023
Mean: 1.0001
Std Dev: 0.0112
Frequency
0
200
400
600
800
1000
1200
1400
1600
0.97
0.98
0.99
1.00
1.01
1.02
1.03
$e^{0.0088(p-p_o)}$

I calculated the corrected rates by binning the Rates and Pressure data in the same way as when I was calculating the correlation coefficient. Then, I plotted the Pressure, Rates and Corrected Rates for each year with time being on the x axis. Here are the plots:

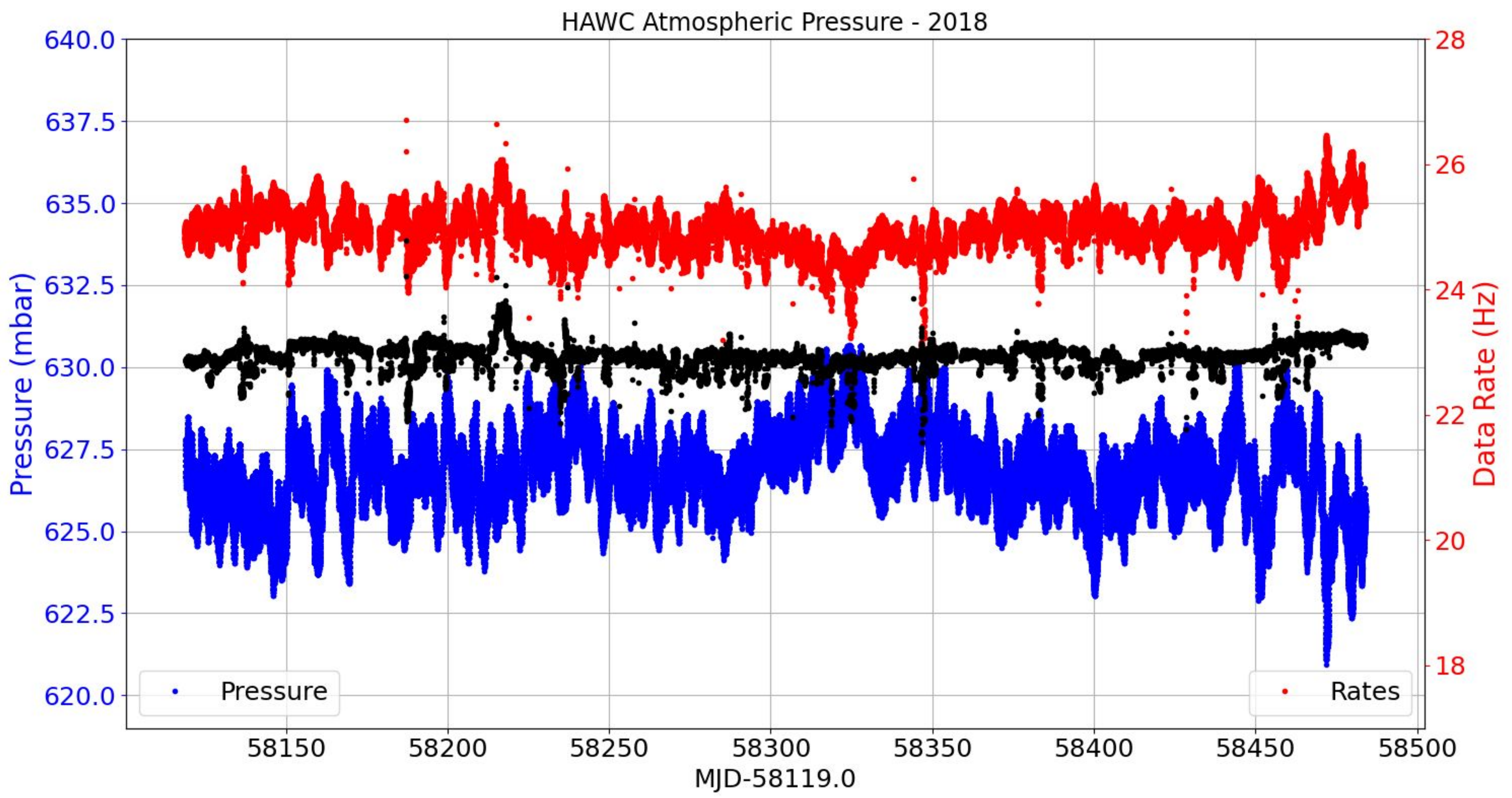

HAWC Atmospheric Pressure - 2015
Pressure (mbar)
Data Rate (Hz)
MJD-57143.04541087963
645
640
635
630
625
620
615
26
25
24
23
22
21
20
19
18
57050
57100
57150
57200
57250
57300
57350
57400
Pressure
Rates

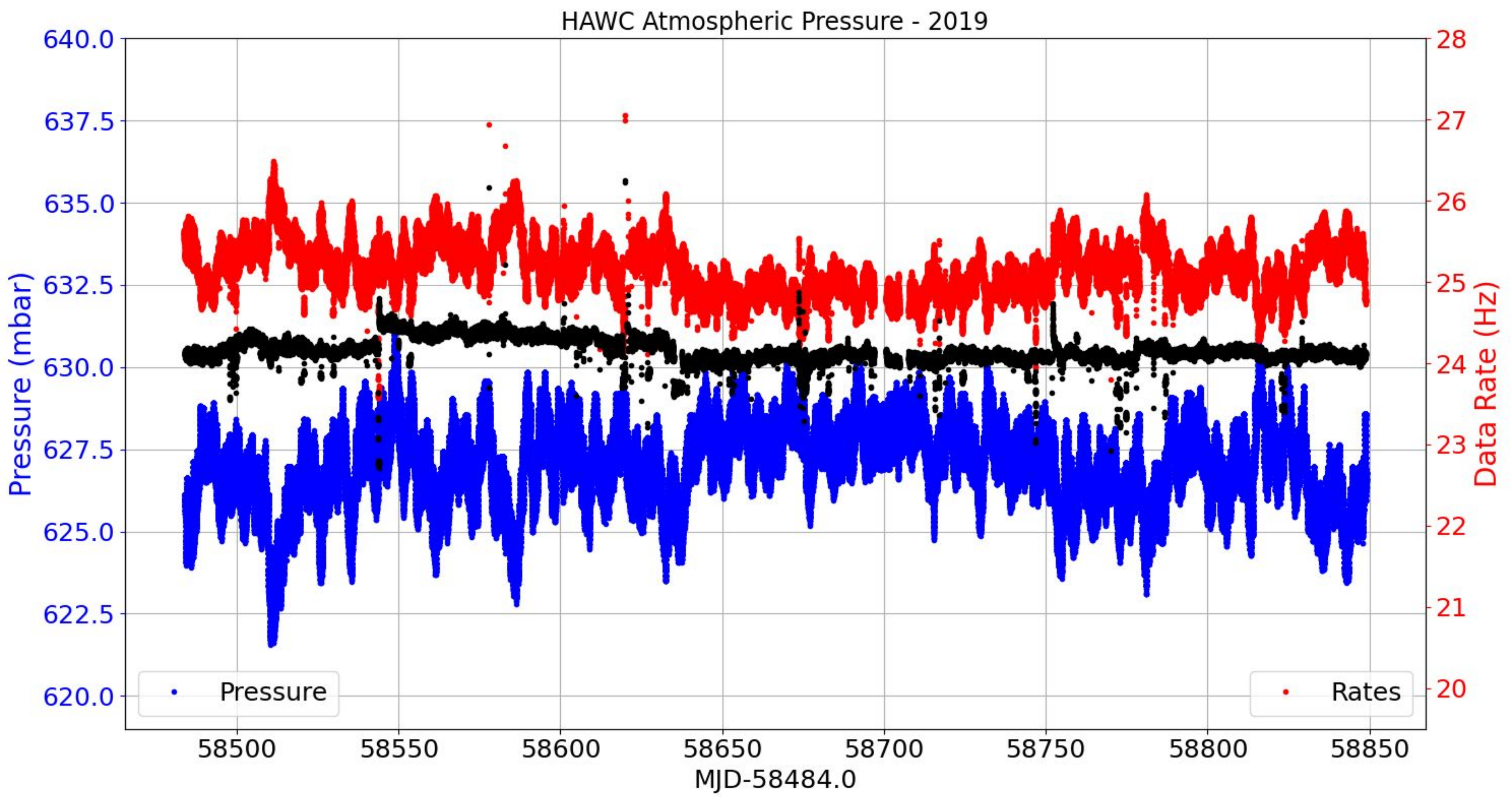


HAWC Atmospheric Pressure - 2016
Pressure (mbar)
645
640
635
630
625
620
Data Rate (Hz)
28
26
24
22
20
18
16
57400
57450
57500
57550
57600
57650
57700
57750
MJD-57388.0
Pressure
Rates

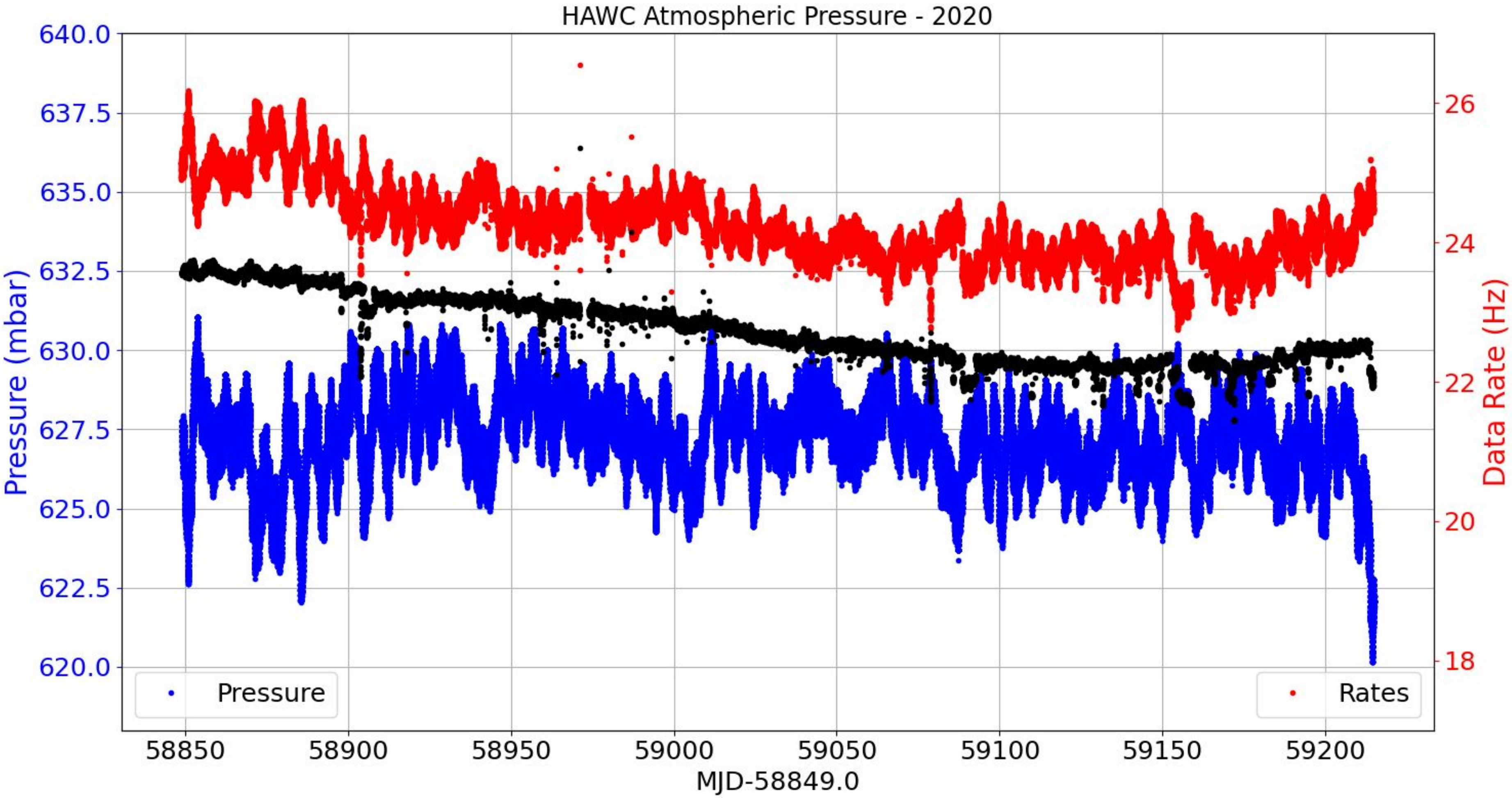


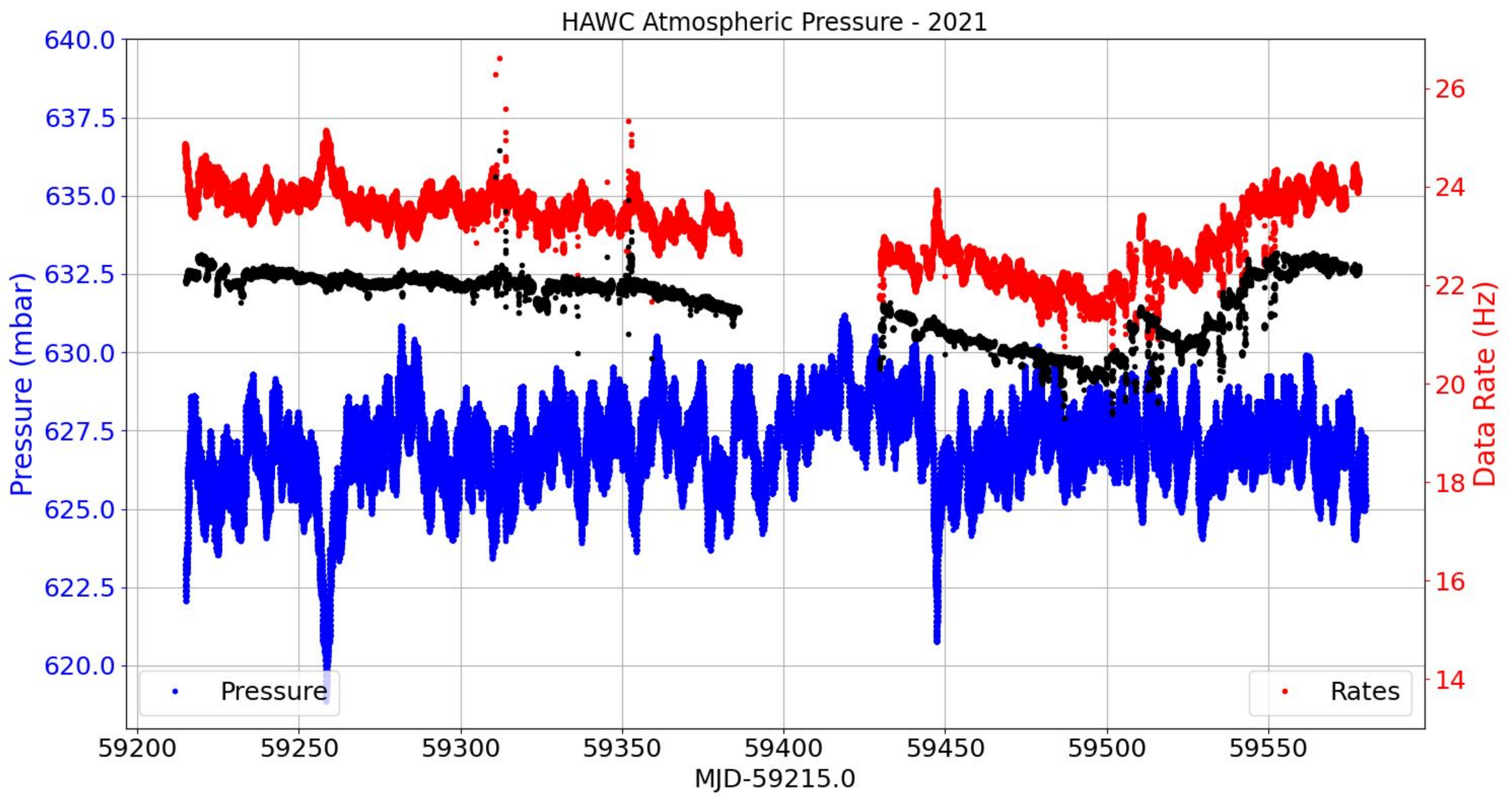
HAWC Atmospheric Pressure - 2017
Pressure (mbar)
Data Rate (Hz)
MJD-57754.0
Pressure
Rates
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
27
26
25
24
23
22
21
20
19
18
57750
57800
57850
57900
57950
58000
58050
58100


HAWC Atmospheric Pressure - 2018
Pressure (mbar)
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
Data Rate (Hz)
28
26
24
22
20
18
58150
58200
58250
58300
58350
58400
58450
58500
MJD-58119.0
Pressure
Rates

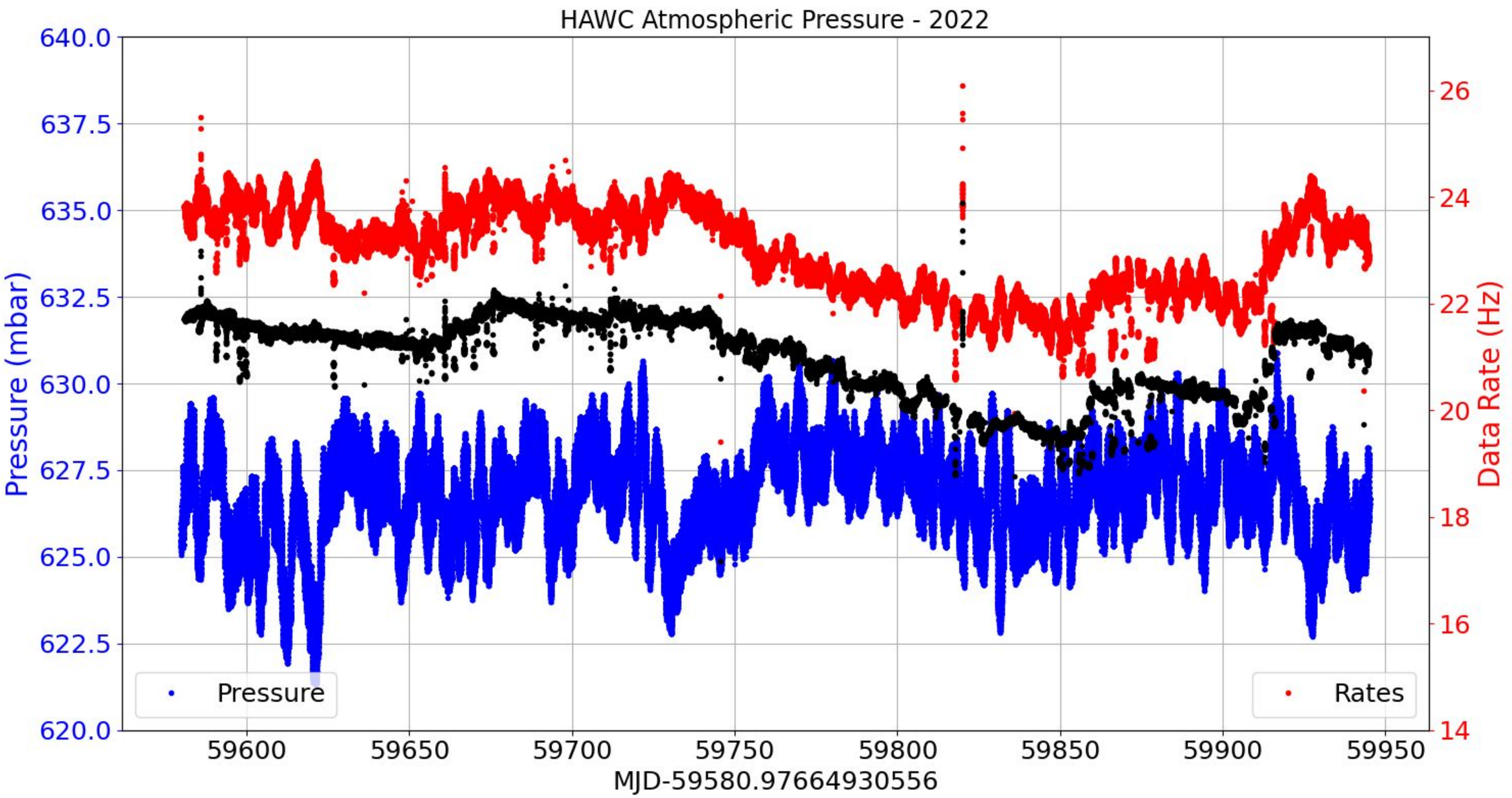


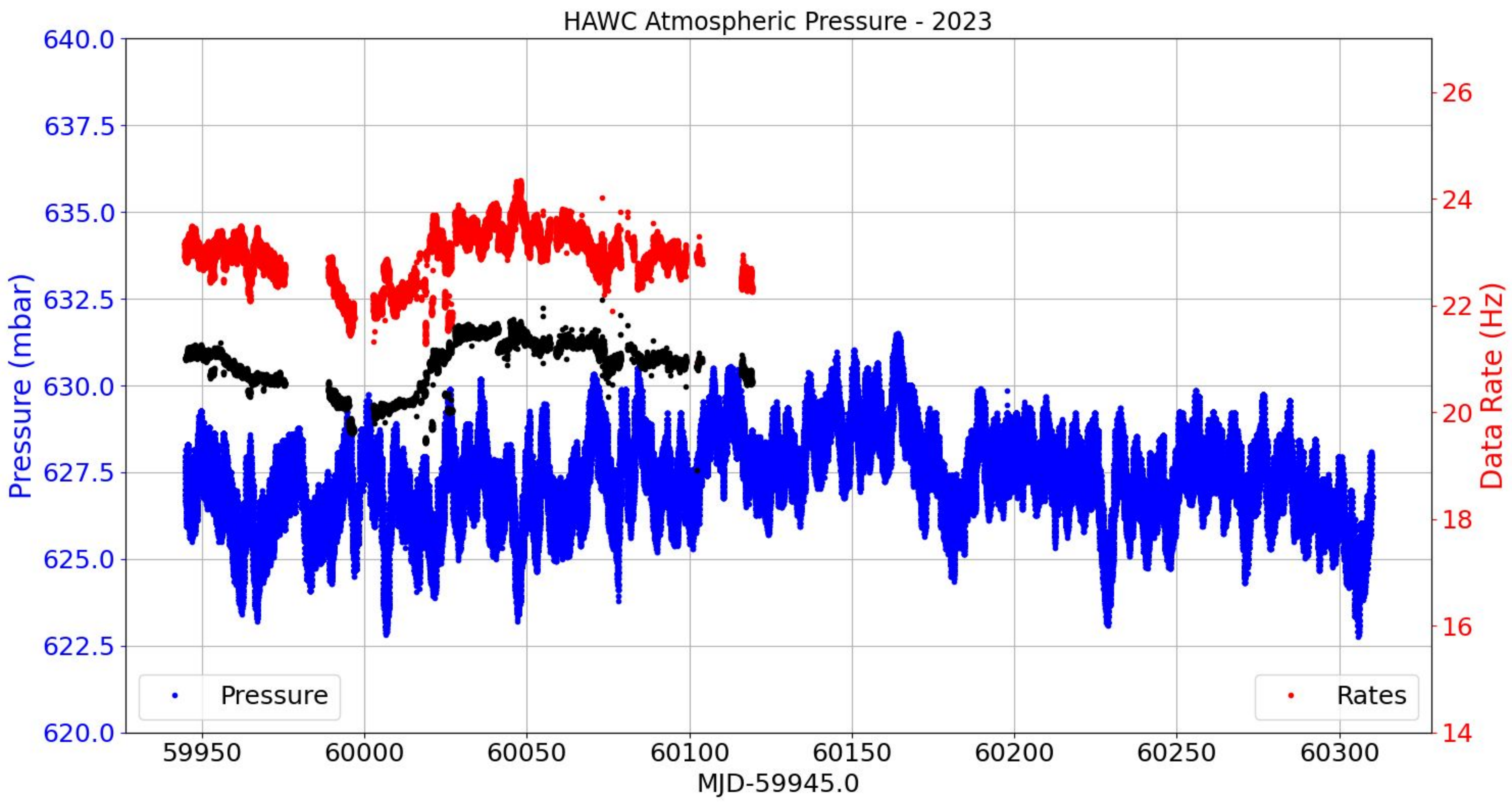
HAWC Atmospheric Pressure - 2019
Pressure (mbar)
Data Rate (Hz)
MJD-58484.0
Pressure
Rates
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
28
27
26
25
24
23
22
21
20
58500
58550
58600
58650
58700
58750
58800
58850


HAWC Atmospheric Pressure - 2020
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
Pressure (mbar)
26
24
22
20
18
Data Rate (Hz)
Pressure
Rates
58850
58900
58950
59000
59050
59100
59150
59200
MJD-58849.0



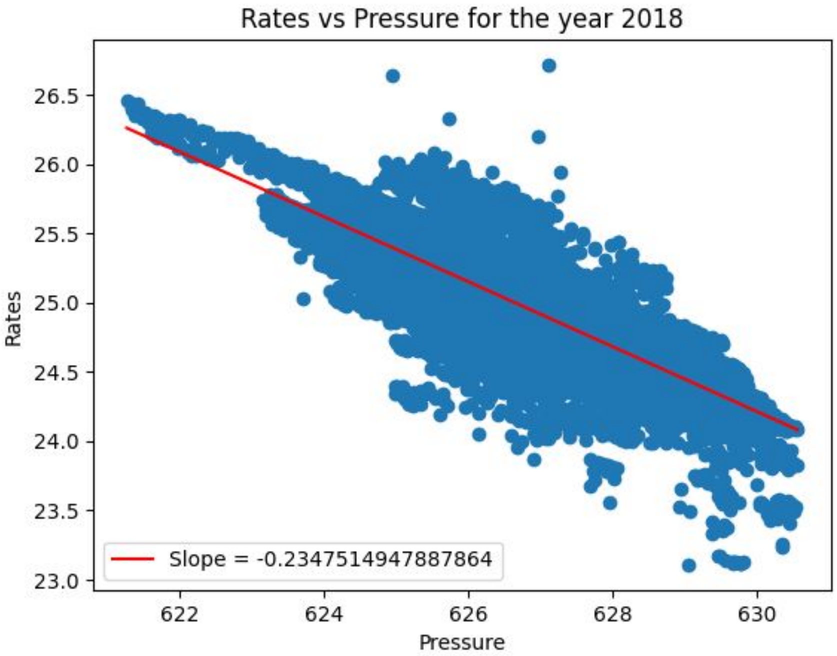
HAWC Atmospheric Pressure - 2021
Pressure (mbar)
Data Rate (Hz)
MJD-59215.0
Pressure
Rates
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
26
24
22
20
18
16
14
59200
59250
59300
59350
59400
59450
59500
59550

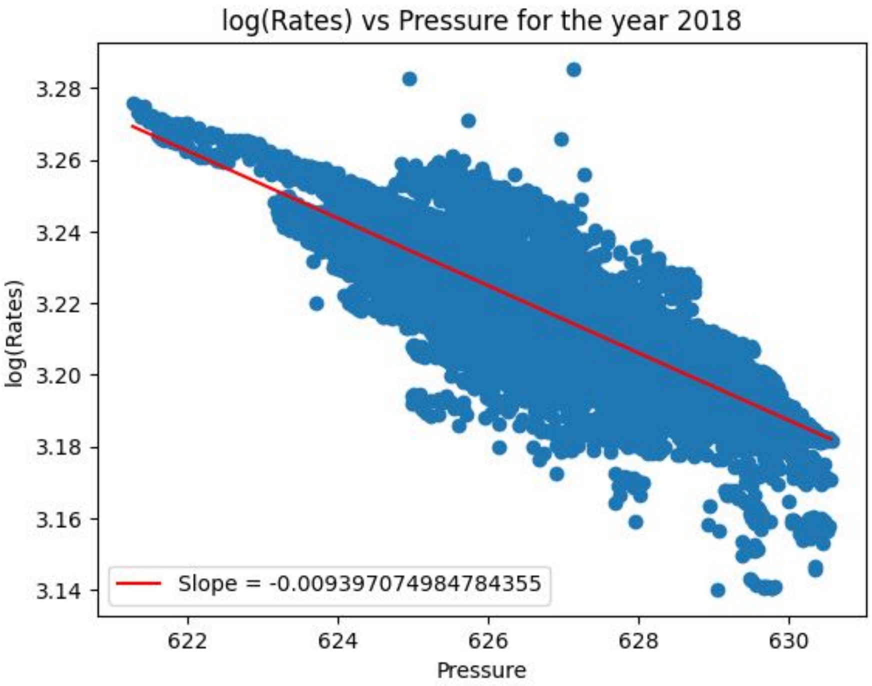

HAWC Atmospheric Pressure - 2022
Pressure (mbar)
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
Data Rate (Hz)
26
24
22
20
18
16
14
59600
59650
59700
59750
59800
59850
59900
59950
MJD-59580.97664930556
Pressure
Rates


HAWC Atmospheric Pressure - 2023
Pressure (mbar)
640.0
637.5
635.0
632.5
630.0
627.5
625.0
622.5
620.0
Data Rate (Hz)
26
24
22
20
18
16
14
59950
60000
60050
60100
60150
60200
60250
60300
MJD-59945.0
Pressure
Rates

Backup Slides

What exactly is the correlation coefficient? It is the slope of the line of best fit which passes through the points of the rates vs pressure plot.





If we plot the rates vs pressure along with the line of best fit for one day of the year, this is what it looks like: