paper04_imputations_sinaica

October 10, 2021

1 SINAICA Imputations

2 SINAICA Data.

```
/home/jaa6766/.conda/envs/cuda/lib/python3.7/importlib/_bootstrap.py:219:
RuntimeWarning: numpy.ufunc size changed, may indicate binary incompatibility.
Expected 192 from C header, got 216 from PyObject
/home/jaa6766/.conda/envs/cuda/lib/python3.7/importlib/_bootstrap.py:219:
RuntimeWarning: numpy.ufunc size changed, may indicate binary incompatibility.
Expected 192 from C header, got 216 from PyObject
/home/jaa6766/.conda/envs/cuda/lib/python3.7/importlib/_bootstrap.py:219:
RuntimeWarning: numpy.ufunc size changed, may indicate binary incompatibility.
Expected 192 from C header, got 216 from PyObject
/home/jaa6766/.conda/envs/cuda/lib/python3.7/importlib/_bootstrap.py:219:
RuntimeWarning: numpy.ufunc size changed, may indicate binary incompatibility.
Expected 192 from C header, got 216 from PyObject
```

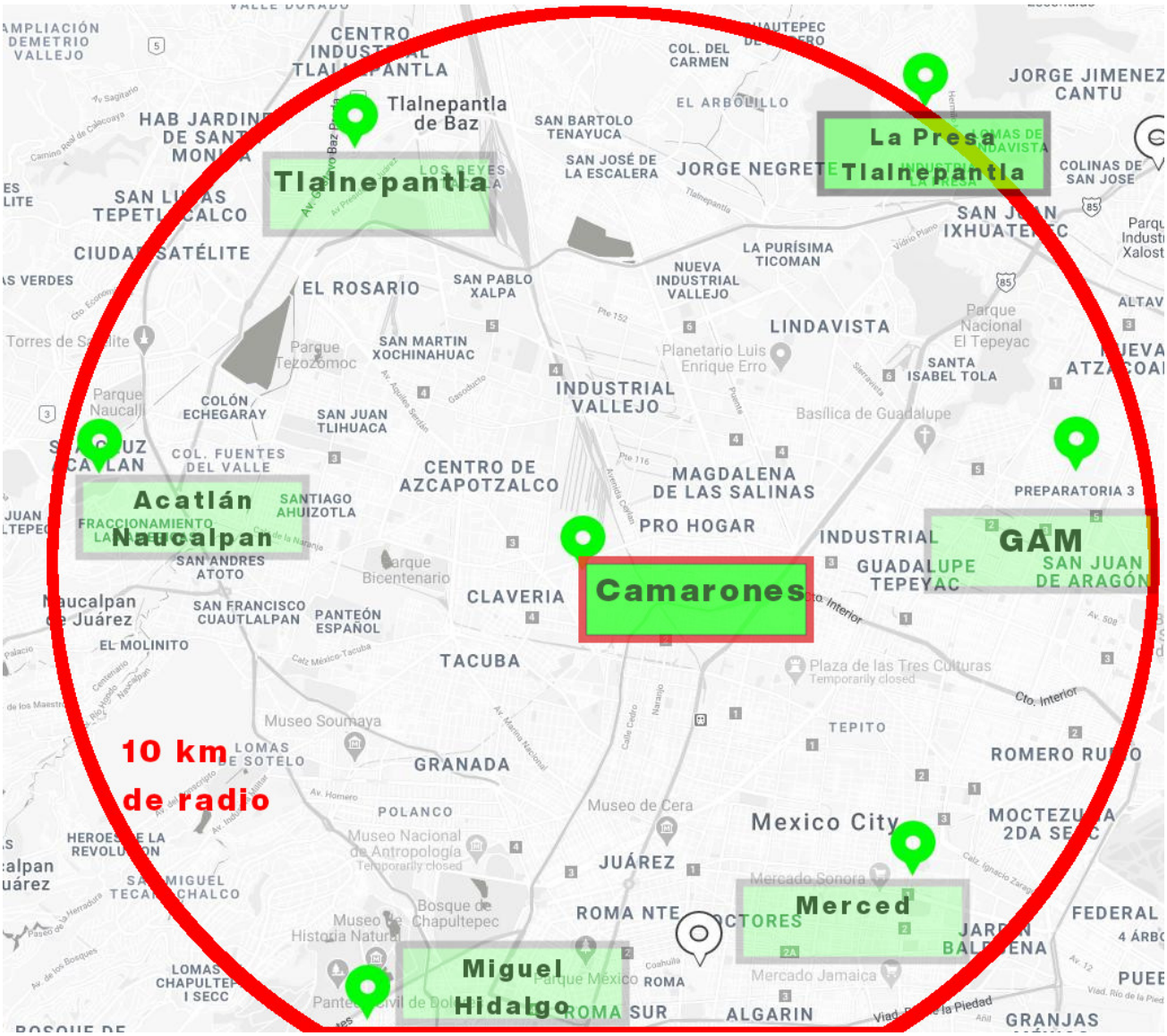
Listing data files from: /home/jaa6766/Documents/jorge3a/itam/deeplearning/dlfinal/data/sinaica2/…

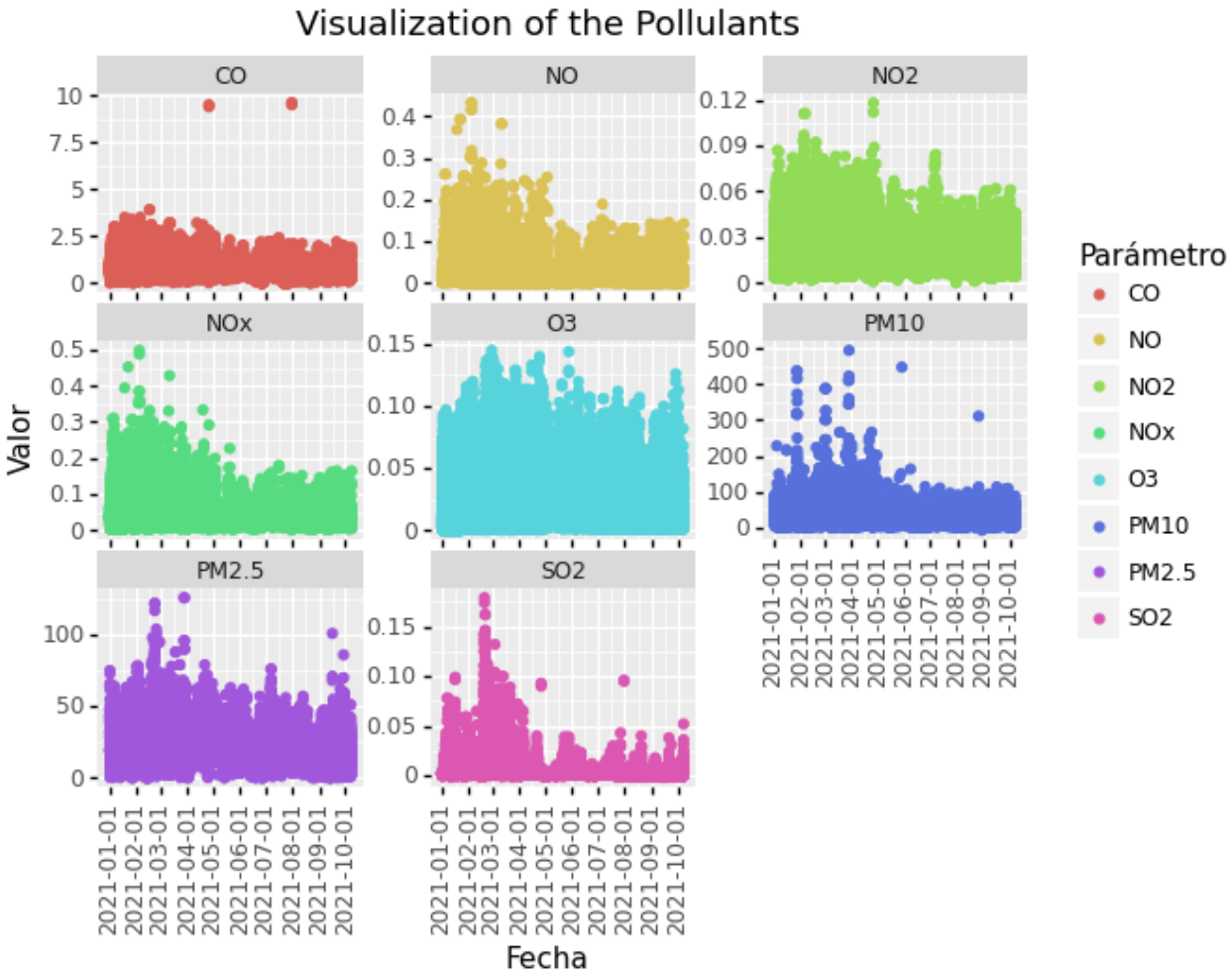
Done!

```
   Parámetro      Fecha  Valor Unidad   Estacion
 1        CO 2021-01-01  0.600    ppm  Camarones
 1        NO 2021-01-01  0.006    ppm  Camarones
 1       NO2 2021-01-01  0.029    ppm  Camarones
 1       NOx 2021-01-01  0.034    ppm  Camarones
 1        O3 2021-01-01  0.011    ppm  Camarones
..         …          …    …      …          …
 34      SO2 2021-10-08  0.002    ppm     Merced
 35      SO2 2021-10-08  0.001    ppm     Merced
 36      SO2 2021-10-08  0.001    ppm     Merced
 37      SO2 2021-10-08  0.000    ppm     Merced
 38      SO2 2021-10-08  0.001    ppm     Merced

 [196289 rows x 5 columns]
```

2.0.1 Nearby Air Quality Monitoring Stations

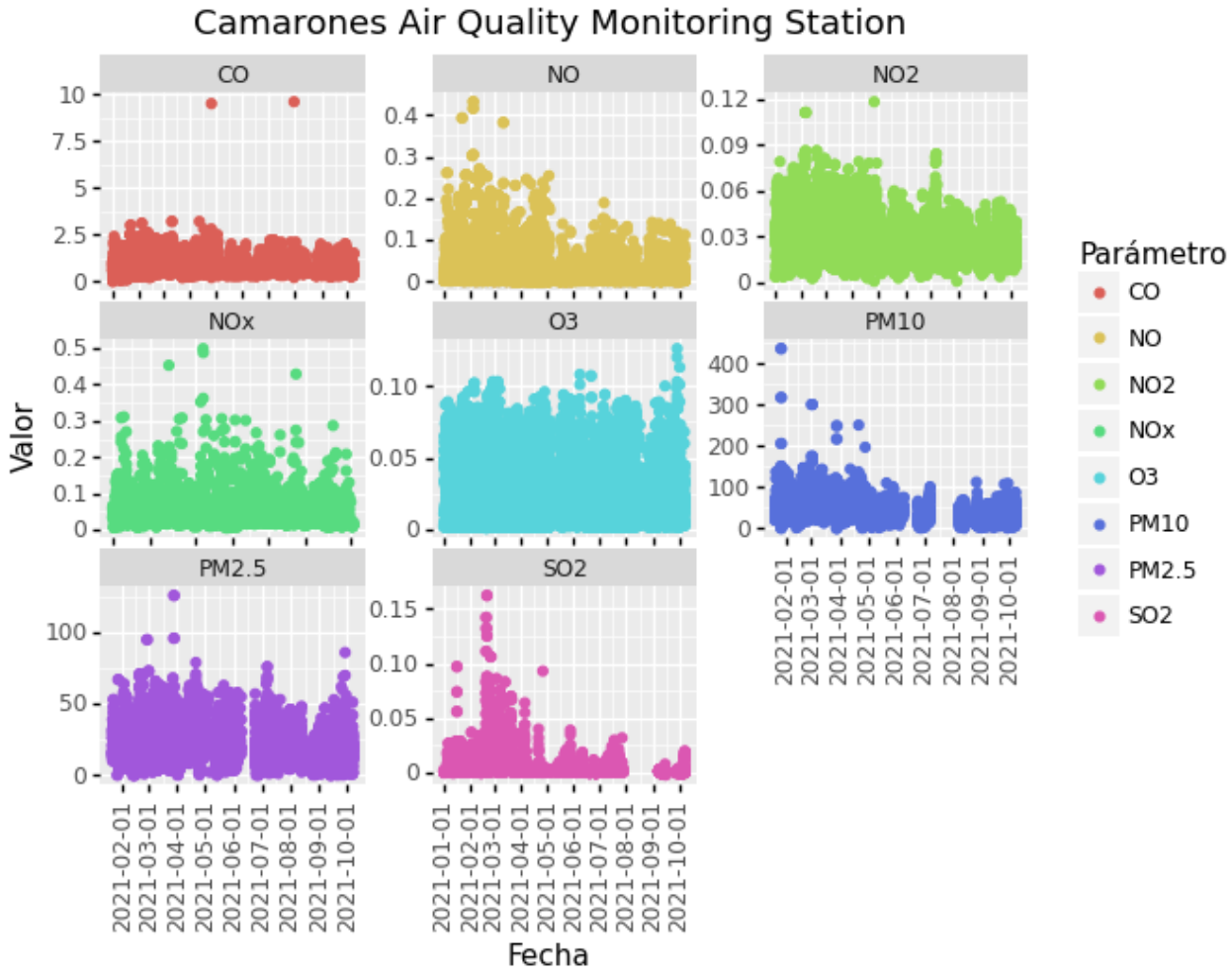
Here you may find the most proximate stations to “Camarones” which is the closest one to our sensor.


Tlalnepantla de Baz
Tlalnepantla
La Presa Tlalnepantla
Acatlán Naucalpan
Camarones
GAM
Miguel Hidalgo
Merced
10 km de radio
CENTRO INDUSTRIAL TLALNEPANTLA
COL. DEL CARMEN
JORGE JIMENEZ CANTU
EL ARBOLILLO
SAN BARTOLO TENAYUCA
SAN JOSÉ DE LA ESCALERA
JORGE NEGRETE
COLINAS DE SAN JOSE
SAN JUAN IXHUATEPEC
LA PURÍSIMA TICOMAN
NUEVA INDUSTRIAL VALLEJO
EL ROSARIO
SAN PABLO XALPA
LINDAVISTA
Parque Nacional El Tepeyac
SANTA ISABEL TOLA
SAN MARTIN XOCHINAHUAC
INDUSTRIAL VALLEJO
Basílica de Guadalupe
COLÓN ECHEGARAY
SAN JUAN TLIHUACA
COL. FUENTES DEL VALLE
CENTRO DE AZCAPOTZALCO
MAGDALENA DE LAS SALINAS
PREPARATORIA 3
PRO HOGAR
INDUSTRIAL
GUADALUPE TEPEYAC
SAN JUAN DE ARAGÓN
SANTIAGO AHUIZOTLA
SAN ANDRES ATOTO
CLAVERIA
SAN FRANCISCO CUAUTLALPAN
PANTEÓN ESPAÑOL
EL MOLINITO
TACUBA
Plaza de las Tres Culturas
Museo Soumaya
LOMAS DE SOTELO
GRANADA
TEPITO
ROMERO RUBIO
POLANCO
Museo de Cera
Mexico City
Museo Nacional de Antropología
JUÁREZ
Mercado Sonora
ROMA NTE
Bosque de Chapultepec
Museo de Historia Natural
Parque México
ROMA
Mercado Jamaica
ROMA SUR
ALGARIN
GRANJAS
FEDERAL
Cto. Interior



<ggplot: (8748608559861)>

2.0.2 Camarones Air Quality Monitoring Station




```
<ggplot: (8748605756781)>
```

2.1 Imputation: Missing Data from the Air Quality Monitoring Stations.

Some of the missisng observatinos are caused by maintenance on the monitoring systems. So we could try to fill out the missing data with nearby government sesnsors. Then we propose to evaluate how the imputations work.

```
                  Fecha  Camarones_CO  Camarones_NO  Camarones_NO2  \
0    2021-01-01 00:00:00      0.600000      0.006000       0.029000
1    2021-01-01 01:00:00      1.000000      0.021000       0.038000
2    2021-01-01 02:00:00      0.800000      0.013000       0.035000
3    2021-01-01 03:00:00      1.000000      0.031000       0.034000
4    2021-01-01 04:00:00      0.600000      0.005000       0.029000
…                    …             …             …              …
2347 2021-10-04 00:00:00      0.441667      0.008292       0.015833
2348 2021-10-05 00:00:00      0.490000      0.010000       0.017000
2349 2021-10-06 00:00:00      0.542857      0.007571       0.022571
2350 2021-10-07 00:00:00      0.582609      0.011565       0.023130
2351 2021-10-08 00:00:00      0.738889      0.023778       0.026778

      Camarones_NOx  Camarones_O3  Camarones_PM10  Camarones_PM2.5  \
0             0.034      0.011000             NaN              NaN
1             0.059      0.002000             NaN              NaN
```

```
2            0.049      0.003000            NaN             NaN
3            0.065      0.002000            NaN             NaN
4            0.034      0.005000            NaN             NaN
…              …          …                 …               …
2347           NaN      0.017167       22.173913       10.952381
2348           NaN      0.013947       22.142857        8.736842
2349           NaN      0.014333       25.150000       10.150000
2350           NaN      0.021304       33.500000       15.428571
2351           NaN      0.019667       41.266667       18.800000

      Camarones_SO2  FES Acatlán_CO  …  Miguel Hidalgo_O3  \
0          0.002000        0.400000  …              0.009
1          0.002000        0.600000  …              0.006
2          0.001000        0.900000  …              0.003
3          0.001000        0.800000  …              0.004
4          0.001000        1.000000  …              0.006
…             …              …  …                …
2347       0.000125        0.315000  …                NaN
2348       0.000000        0.466667  …                NaN
2349       0.000000        0.347619  …                NaN
2350       0.001783        0.447826  …                NaN
2351       0.010500        0.566667  …                NaN

      Miguel Hidalgo_SO2  Tlalnepantla_CO  Tlalnepantla_NO  Tlalnepantla_NO2  \
0                  0.003              0.6              NaN             0.030
1                  0.003              0.6              NaN             0.026
2                  0.002              0.7              NaN             0.032
3                  0.002              0.7              NaN             0.033
4                  0.002              0.7              NaN             0.032
…                    …                …                …                 …
2347                 NaN              NaN              NaN               NaN
2348                 NaN              NaN              NaN               NaN
2349                 NaN              NaN              NaN               NaN
2350                 NaN              NaN              NaN               NaN
2351                 NaN              NaN              NaN               NaN

      Tlalnepantla_NOx  Tlalnepantla_O3  Tlalnepantla_PM10  \
0                0.034            0.012               37.0
1                0.029            0.013               42.0
2                0.036            0.006               58.0
3                0.039            0.004               59.0
4                0.038            0.004               64.0
…                  …                …                  …
2347               NaN              NaN                NaN
2348               NaN              NaN                NaN
2349               NaN              NaN                NaN
2350               NaN              NaN                NaN
2351               NaN              NaN                NaN

      Tlalnepantla_PM2.5  Tlalnepantla_SO2
0                   19.0             0.002
1                   29.0             0.003
2                   43.0             0.002
3                   41.0             0.002
4                   46.0             0.002
…                    …                 …
2347                NaN               NaN
2348                NaN               NaN
2349                NaN               NaN
```

```
2350                NaN               NaN
2351                NaN               NaN

[2352 rows x 45 columns]

                   Fecha  Camarones_CO  Camarones_NO  Camarones_NO2  \
0    2021-01-01 00:00:00      0.600000      0.006000       0.029000
1    2021-01-01 01:00:00      1.000000      0.021000       0.038000
2    2021-01-01 02:00:00      0.800000      0.013000       0.035000
3    2021-01-01 03:00:00      1.000000      0.031000       0.034000
4    2021-01-01 04:00:00      0.600000      0.005000       0.029000
…                    …           …           …            …
2347 2021-10-04 00:00:00      0.441667      0.008292       0.015833
2348 2021-10-05 00:00:00      0.490000      0.010000       0.017000
2349 2021-10-06 00:00:00      0.542857      0.007571       0.022571
2350 2021-10-07 00:00:00      0.582609      0.011565       0.023130
2351 2021-10-08 00:00:00      0.738889      0.023778       0.026778

      Camarones_NOx  Camarones_O3  Camarones_PM10  Camarones_PM2.5  \
0             0.034      0.011000             NaN              NaN
1             0.059      0.002000             NaN              NaN
2             0.049      0.003000             NaN              NaN
3             0.065      0.002000             NaN              NaN
4             0.034      0.005000             NaN              NaN
…               …           …               …                …
2347            NaN      0.017167       22.173913        10.952381
2348            NaN      0.013947       22.142857         8.736842
2349            NaN      0.014333       25.150000        10.150000
2350            NaN      0.021304       33.500000        15.428571
2351            NaN      0.019667       41.266667        18.800000

      Camarones_SO2  FES Acatlán_CO  …  Miguel Hidalgo_O3  \
0          0.002000        0.400000  …              0.009
1          0.002000        0.600000  …              0.006
2          0.001000        0.900000  …              0.003
3          0.001000        0.800000  …              0.004
4          0.001000        1.000000  …              0.006
…               …             …  …  …                …
2347       0.000125        0.315000  …                NaN
2348       0.000000        0.466667  …                NaN
2349       0.000000        0.347619  …                NaN
2350       0.001783        0.447826  …                NaN
2351       0.010500        0.566667  …                NaN

      Miguel Hidalgo_SO2  Tlalnepantla_CO  Tlalnepantla_NO  Tlalnepantla_NO2  \
0                  0.003              0.6              NaN             0.030
1                  0.003              0.6              NaN             0.026
2                  0.002              0.7              NaN             0.032
3                  0.002              0.7              NaN             0.033
4                  0.002              0.7              NaN             0.032
…                    …                …                …                 …
2347                 NaN              NaN              NaN               NaN
2348                 NaN              NaN              NaN               NaN
2349                 NaN              NaN              NaN               NaN
2350                 NaN              NaN              NaN               NaN
2351                 NaN              NaN              NaN               NaN

      Tlalnepantla_NOx  Tlalnepantla_O3  Tlalnepantla_PM10  \
0                0.034            0.012               37.0
```

```
1               0.029            0.013               42.0
2               0.036            0.006               58.0
3               0.039            0.004               59.0
4               0.038            0.004               64.0
…               …                …                   …
2347              NaN              NaN                 NaN
2348              NaN              NaN                 NaN
2349              NaN              NaN                 NaN
2350              NaN              NaN                 NaN
2351              NaN              NaN                 NaN

      Tlalnepantla_PM2.5  Tlalnepantla_SO2
0                   19.0             0.002
1                   29.0             0.003
2                   43.0             0.002
3                   41.0             0.002
4                   46.0             0.002
…                   …                …
2347                 NaN              NaN
2348                 NaN              NaN
2349                 NaN              NaN
2350                 NaN              NaN
2351                 NaN              NaN

[1694 rows x 45 columns]
```

2.1.1 Missing Data in Camarones

We can tell that "Camarones", the closest one, has missing data on all variables.

```
      Camarones_CO  Camarones_NO  Camarones_NO2  Camarones_NOx  Camarones_O3  \
0         0.600000      0.006000       0.029000          0.034      0.011000
1         1.000000      0.021000       0.038000          0.059      0.002000
2         0.800000      0.013000       0.035000          0.049      0.003000
3         1.000000      0.031000       0.034000          0.065      0.002000
4         0.600000      0.005000       0.029000          0.034      0.005000
…              …             …              …              …            …
2347      0.441667      0.008292       0.015833            NaN      0.017167
2348      0.490000      0.010000       0.017000            NaN      0.013947
2349      0.542857      0.007571       0.022571            NaN      0.014333
2350      0.582609      0.011565       0.023130            NaN      0.021304
2351      0.738889      0.023778       0.026778            NaN      0.019667

      Camarones_PM10  Camarones_PM2.5  Camarones_SO2
0                NaN              NaN       0.002000
1                NaN              NaN       0.002000
2                NaN              NaN       0.001000
3                NaN              NaN       0.001000
4                NaN              NaN       0.001000
…                …                …              …
2347       22.173913        10.952381       0.000125
2348       22.142857         8.736842       0.000000
2349       25.150000        10.150000       0.000000
2350       33.500000        15.428571       0.001783
2351       41.266667        18.800000       0.010500

[791 rows x 8 columns]
```

Then we can look forward to avoid loosing a big portion of data: 33.63% by using imputation. Our goal is to evaluate the different imputation methods in order to have data to back our decision.

2.1.2 Complete Observations in Camarones.

```
      Camarones_CO  Camarones_NO  Camarones_NO2  Camarones_NOx  Camarones_O3  \
478       0.933333      0.035333        0.03275          0.028        0.0195
480       0.500000      0.021000        0.02400          0.046        0.0020
481       0.600000      0.017000        0.02300          0.039        0.0020
482       0.500000      0.023000        0.02200          0.046        0.0020
483       0.600000      0.030000        0.02100          0.051        0.0020
…              …             …              …              …             …
2167      0.400000      0.003000        0.01100          0.013        0.0160
2168      0.400000      0.002000        0.01100          0.012        0.0180
2169      0.400000      0.002000        0.01300          0.015        0.0160
2170      0.400000      0.002000        0.01900          0.021        0.0120
2171      0.400000      0.001000        0.01400          0.015        0.0210

      Camarones_PM10  Camarones_PM2.5  Camarones_SO2
478        43.047619        21.333333       0.004708
480        30.000000        14.000000       0.008000
481        28.000000        16.000000       0.006000
482        38.000000        26.000000       0.005000
483        35.000000        21.000000       0.003000
…                …                …              …
2167       69.000000         7.000000       0.001000
2168       71.000000         9.000000       0.001000
2169       37.000000         9.000000       0.001000
2170       19.000000         0.000000       0.001000
2171       61.000000        21.000000       0.001000

[1561 rows x 8 columns]
```

2.1.3 Train and Test Split

- Complete observations: 1561 (100%).
  - Complete observations on Training Set: 1092 (~70%).
  - Complete observations on Test Set: 469 (~30%).
- Incomplete Observations: 791.

2.1.4 Data Distribution

PM10 These are the Air Quality Monitoring Stations that measure PM10 pollutant.

```
      Camarones_PM10  FES Acatlán_PM10  Gustavo A. Madero_PM10  Merced_PM10  \
478        43.047619              34.0                    32.0    39.727273
480        30.000000              15.0                    33.0    34.000000
481        28.000000              11.0                    32.0    29.000000
482        38.000000              15.0                    28.0    33.000000
483        35.000000              15.0                    25.0    32.000000
…                …                 …                       …           …
2166       71.000000             178.0                    69.0    49.000000
2167       69.000000             162.0                    33.0    36.000000
2168       71.000000              49.0                    32.0    24.000000
2170       19.000000              14.0                    19.0    21.000000
2171       61.000000              56.0                    44.0    44.000000

      Tlalnepantla_PM10
478                23.0
480                32.0
481                24.0
482                41.0
```

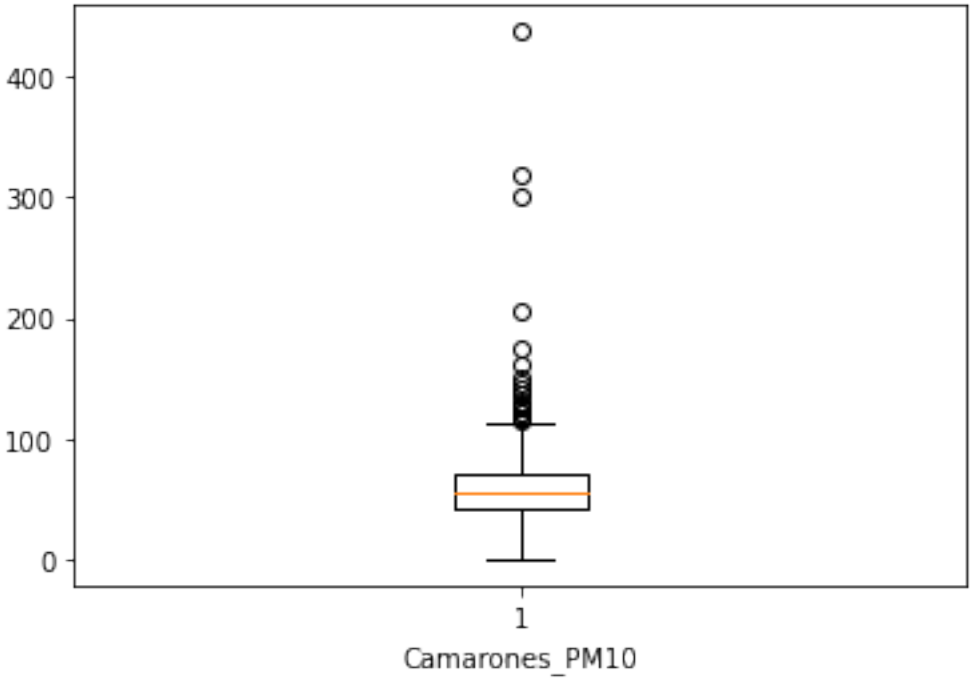
```
483                20.0
…                  …
2166               90.0
2167               52.0
2168               22.0
2170               11.0
2171               55.0

[1305 rows x 5 columns]
```

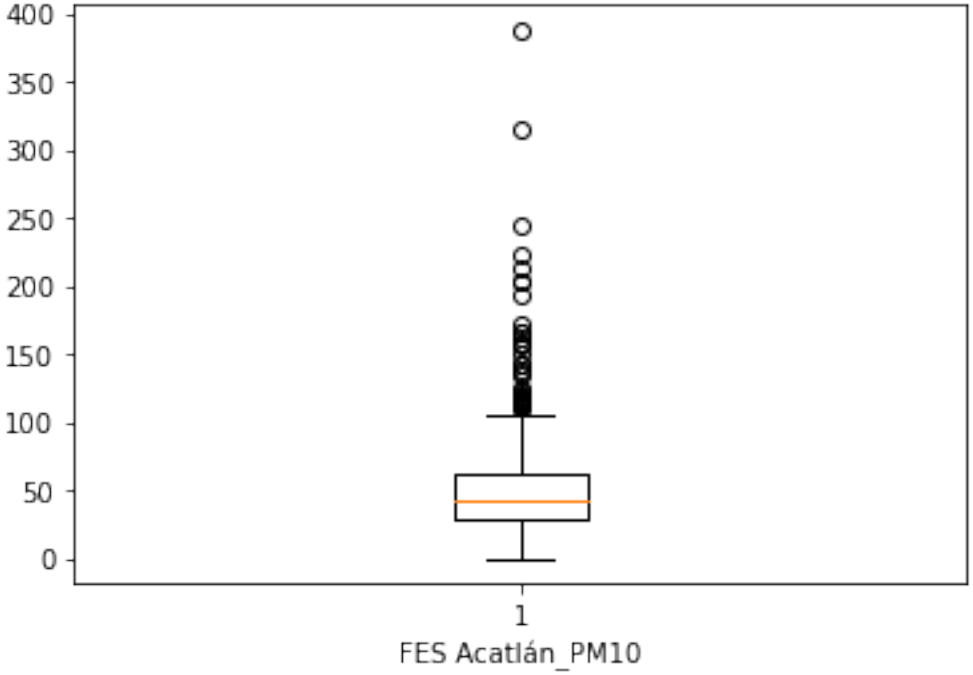
	Estacion	count	mean	std
Camarones_PM10	Camarones_PM10	1092.0	58.163765	27.817189
FES Acatlán_PM10	FES Acatlán_PM10	1011.0	48.669366	32.624587
Gustavo A. Madero_PM10	Gustavo A. Madero_PM10	1029.0	52.906706	26.733354
Merced_PM10	Merced_PM10	1084.0	56.798977	21.410434
Tlalnepantla_PM10	Tlalnepantla_PM10	1034.0	52.254352	29.446065

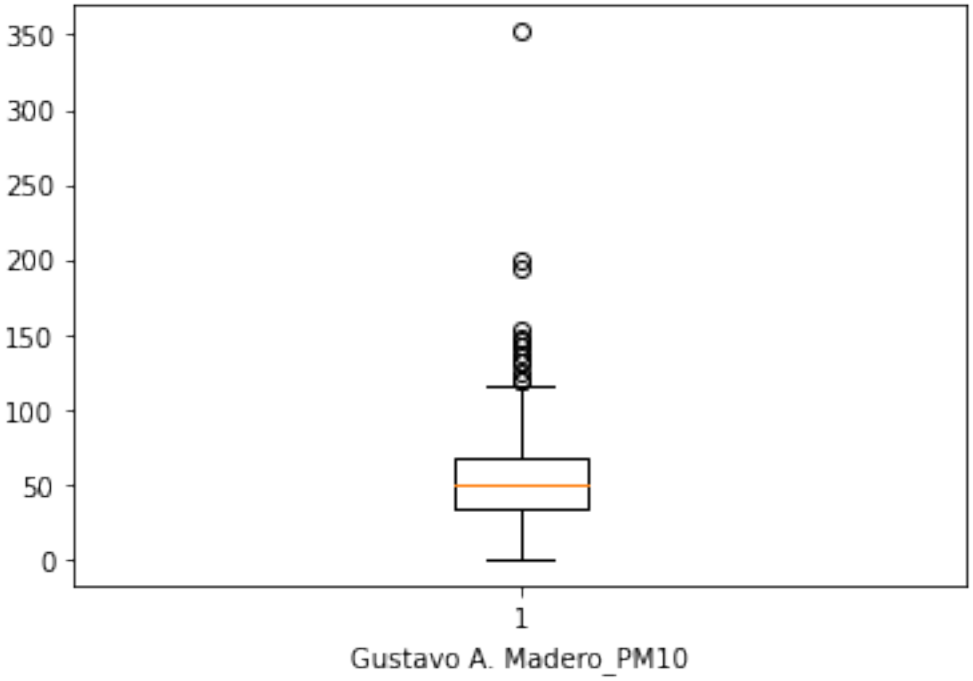
	min	25%	50%	75%	max	NAs
Camarones_PM10	0.0	42.0	55.0	71.0	437.0	0.0
FES Acatlán_PM10	0.0	29.0	43.0	61.0	388.0	81.0
Gustavo A. Madero_PM10	0.0	34.0	50.0	67.0	352.0	63.0
Merced_PM10	5.0	42.0	55.0	69.0	184.0	8.0
Tlalnepantla_PM10	0.0	36.0	48.0	63.0	416.0	58.0

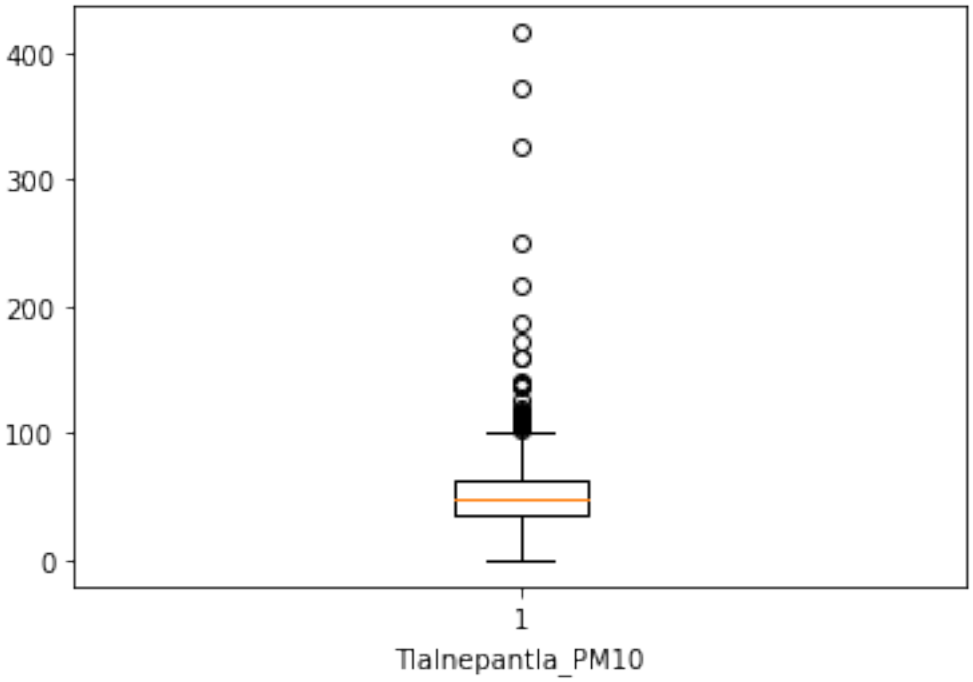
	Estacion	count	mean	std	min
Camarones_CO	Camarones_CO	2241.0	0.767037	0.412628	0.000000
Camarones_NO	Camarones_NO	2227.0	0.024599	0.043639	0.000000
Camarones_NO2	Camarones_NO2	2227.0	0.031139	0.015144	0.003000
Camarones_NOx	Camarones_NOx	2042.0	0.056961	0.054418	0.004000
Camarones_O3	Camarones_O3	2233.0	0.026094	0.022991	0.001000
Camarones_PM10	Camarones_PM10	1749.0	56.638261	26.729443	0.000000
Camarones_PM2.5	Camarones_PM2.5	1765.0	24.872841	12.620210	0.000000
Camarones_SO2	Camarones_SO2	2190.0	0.006284	0.012464	-0.000048

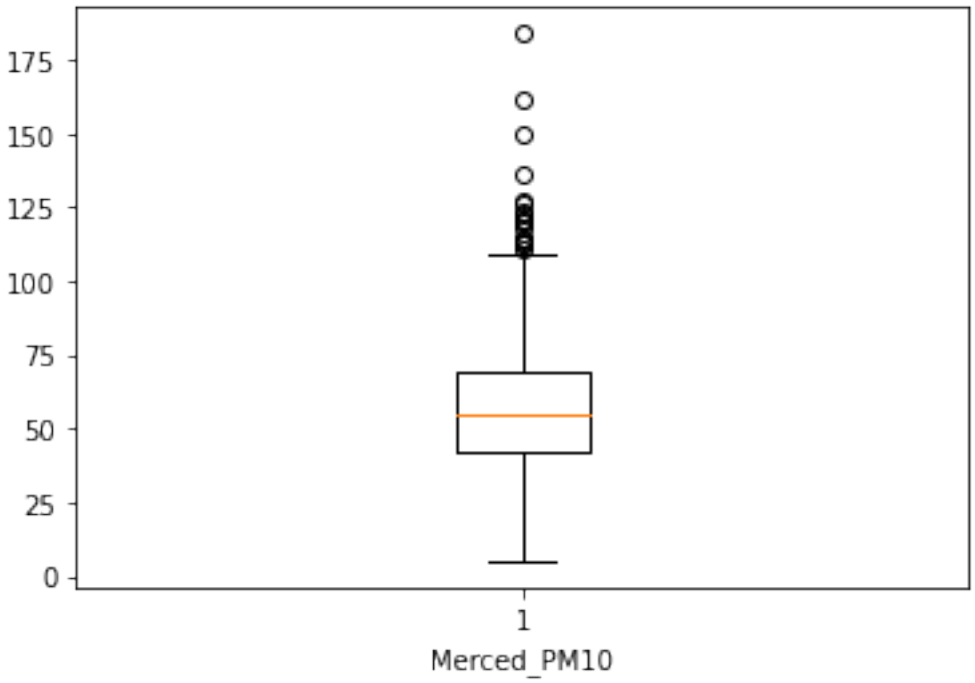
	25%	50%	75%	max	NAs
Camarones_CO	0.500000	0.700	0.900	3.200	111.0
Camarones_NO	0.003000	0.007	0.026	0.432	125.0
Camarones_NO2	0.020000	0.029	0.040	0.111	125.0
Camarones_NOx	0.022000	0.039	0.071	0.499	310.0
Camarones_O3	0.005000	0.021	0.039	0.103	119.0
Camarones_PM10	40.000000	54.000	70.000	437.000	603.0
Camarones_PM2.5	16.000000	24.000	32.000	126.000	587.0
Camarones_SO2	0.001217	0.003	0.005	0.162	162.0

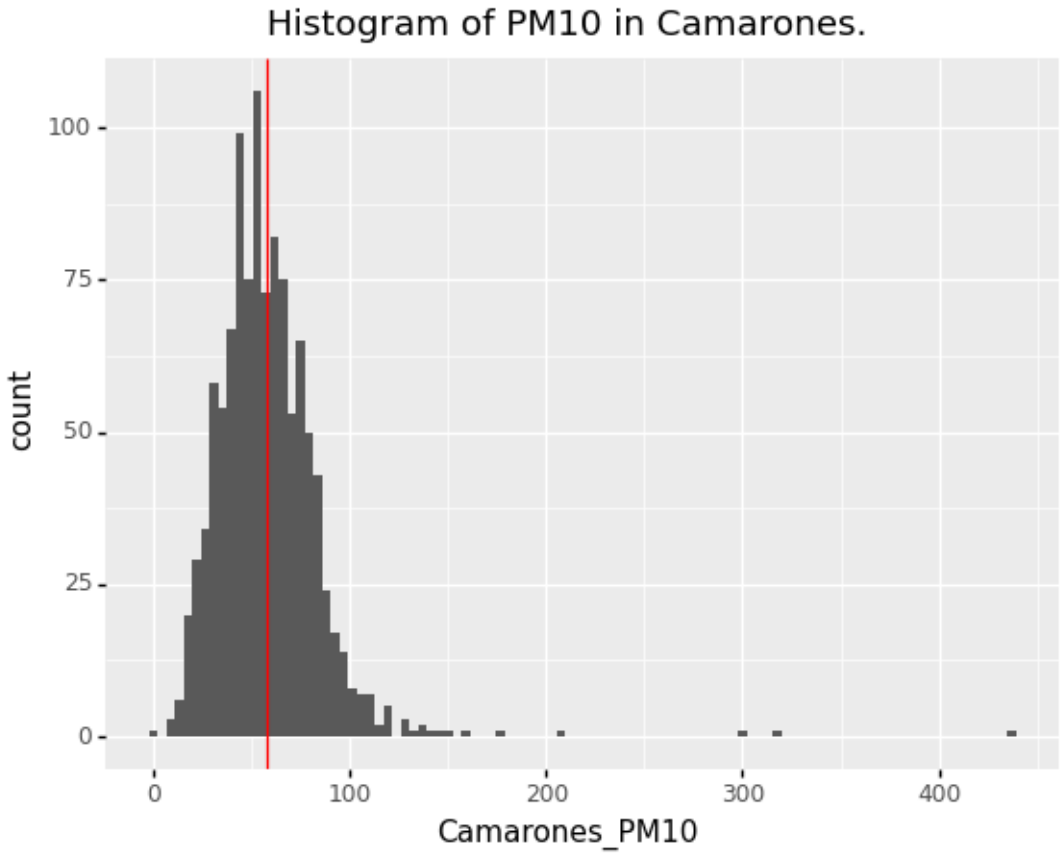

400
300
200
100
0
1
Camarones_PM10


400
350
300
250
200
150
100
50
0
1
FES Acatlán_PM10


350
300
250
200
150
100
50
0
1
Gustavo A. Madero_PM10


400
300
200
100
0
1
Tlalnepantla_PM10

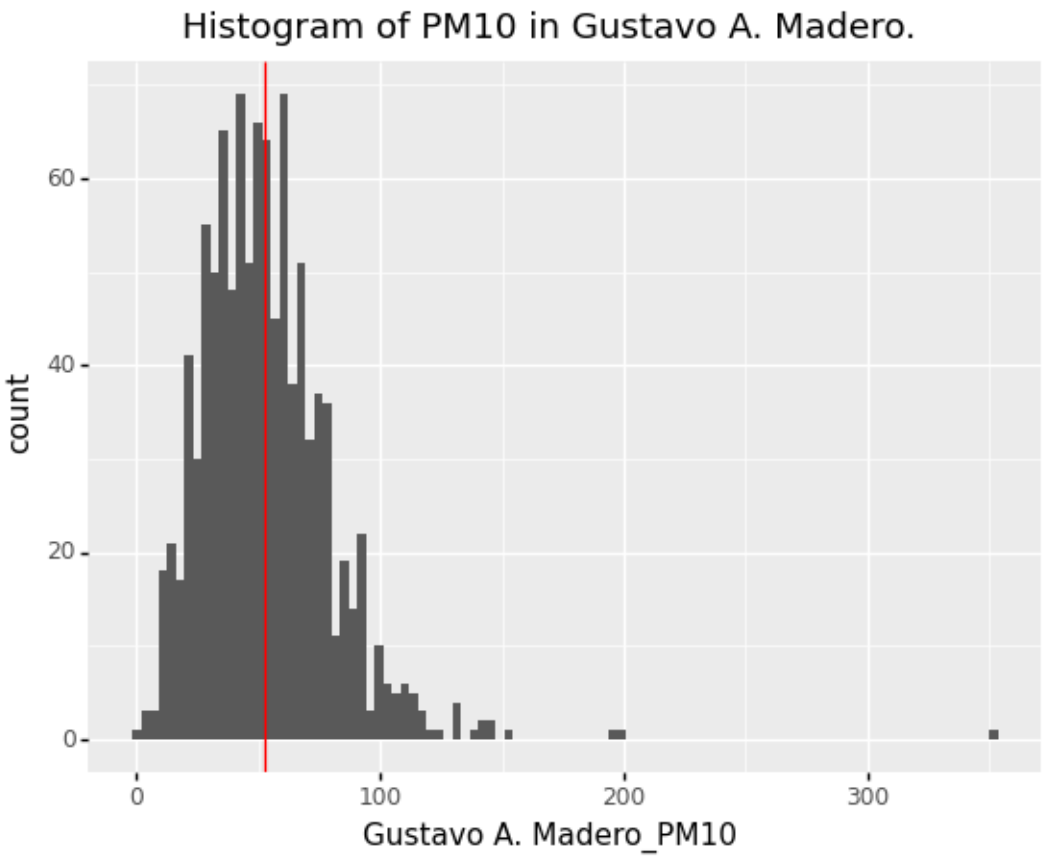





```
<ggplot: (8748605798857)>
```

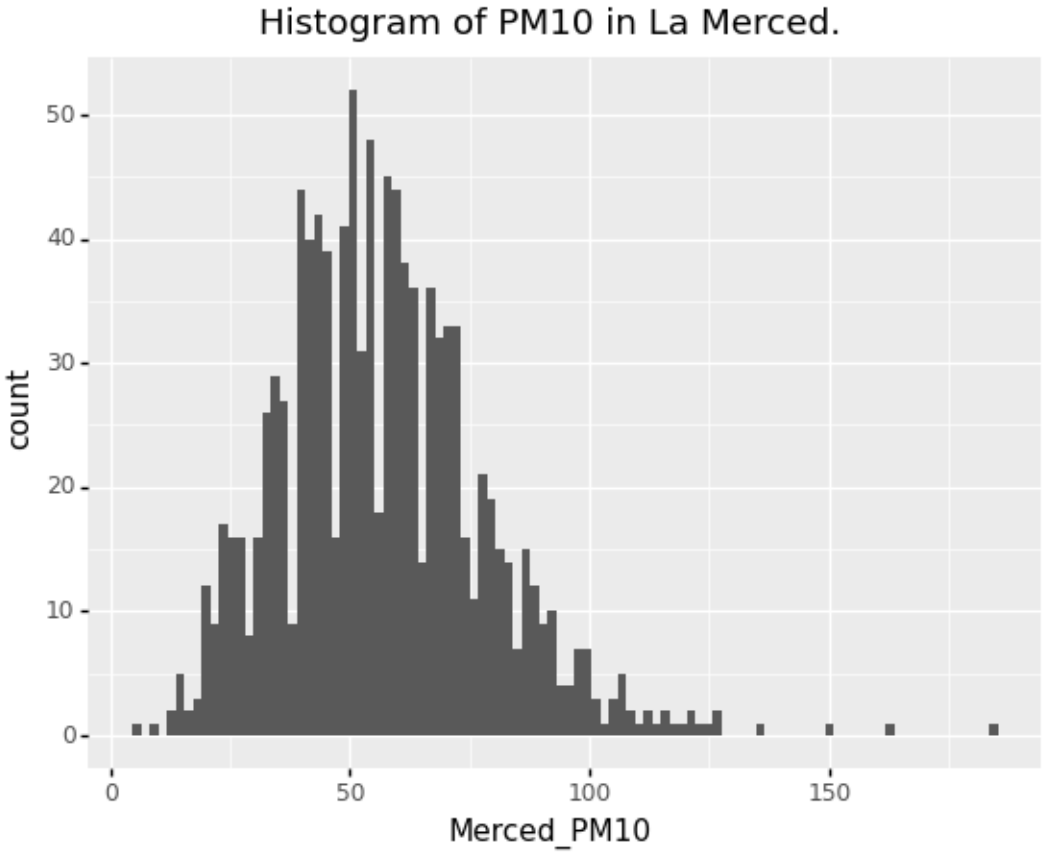
```
/home/jaa6766/.conda/envs/cuda/lib/python3.7/site-
packages/plotnine/layer.py:372: PlotnineWarning: stat_bin : Removed 63 rows
```

containing non-finite values.



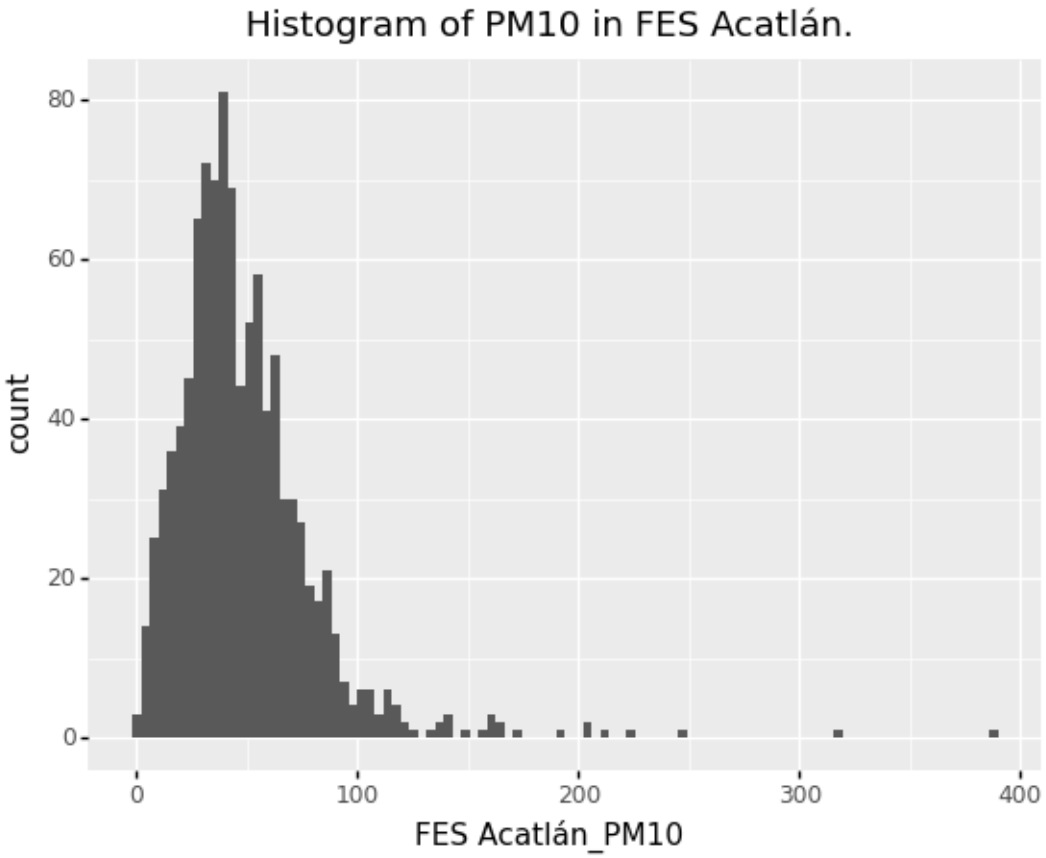
<ggplot: (8748605795749)>

/home/jaa6766/.conda/envs/cuda/lib/python3.7/site-packages/plotnine/layer.py:372: PlotnineWarning: stat_bin : Removed 8 rows containing non-finite values.



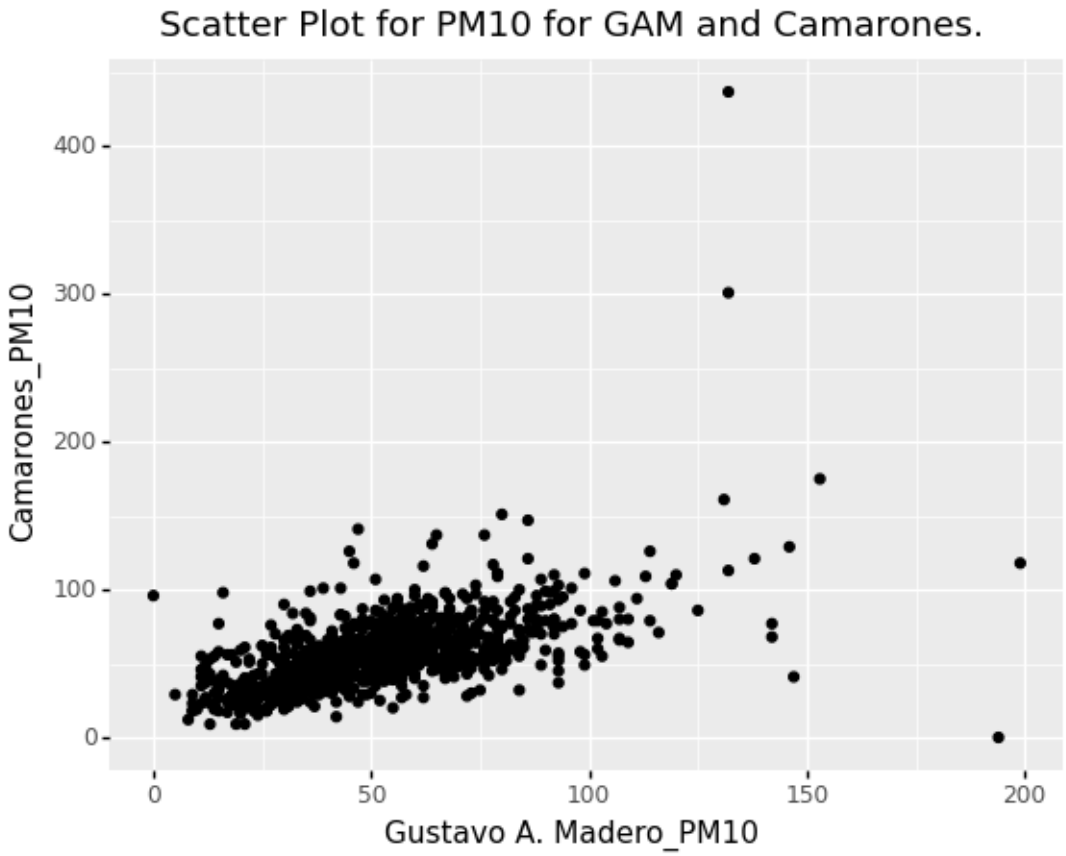

```
<ggplot: (8748605840569)>
```

```
/home/jaa6766/.conda/envs/cuda/lib/python3.7/site-
packages/plotnine/layer.py:372: PlotnineWarning: stat_bin : Removed 81 rows
containing non-finite values.
```

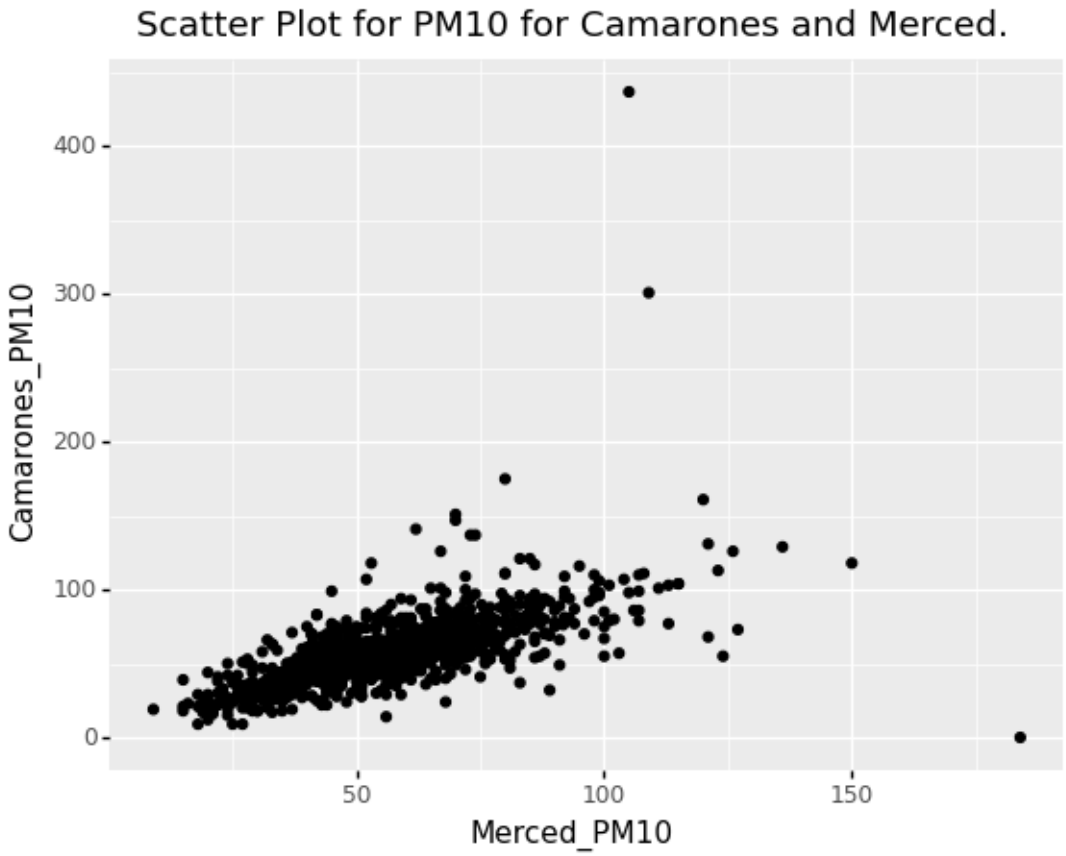



```
<ggplot: (8748598829781)>
```

Comparing Stations



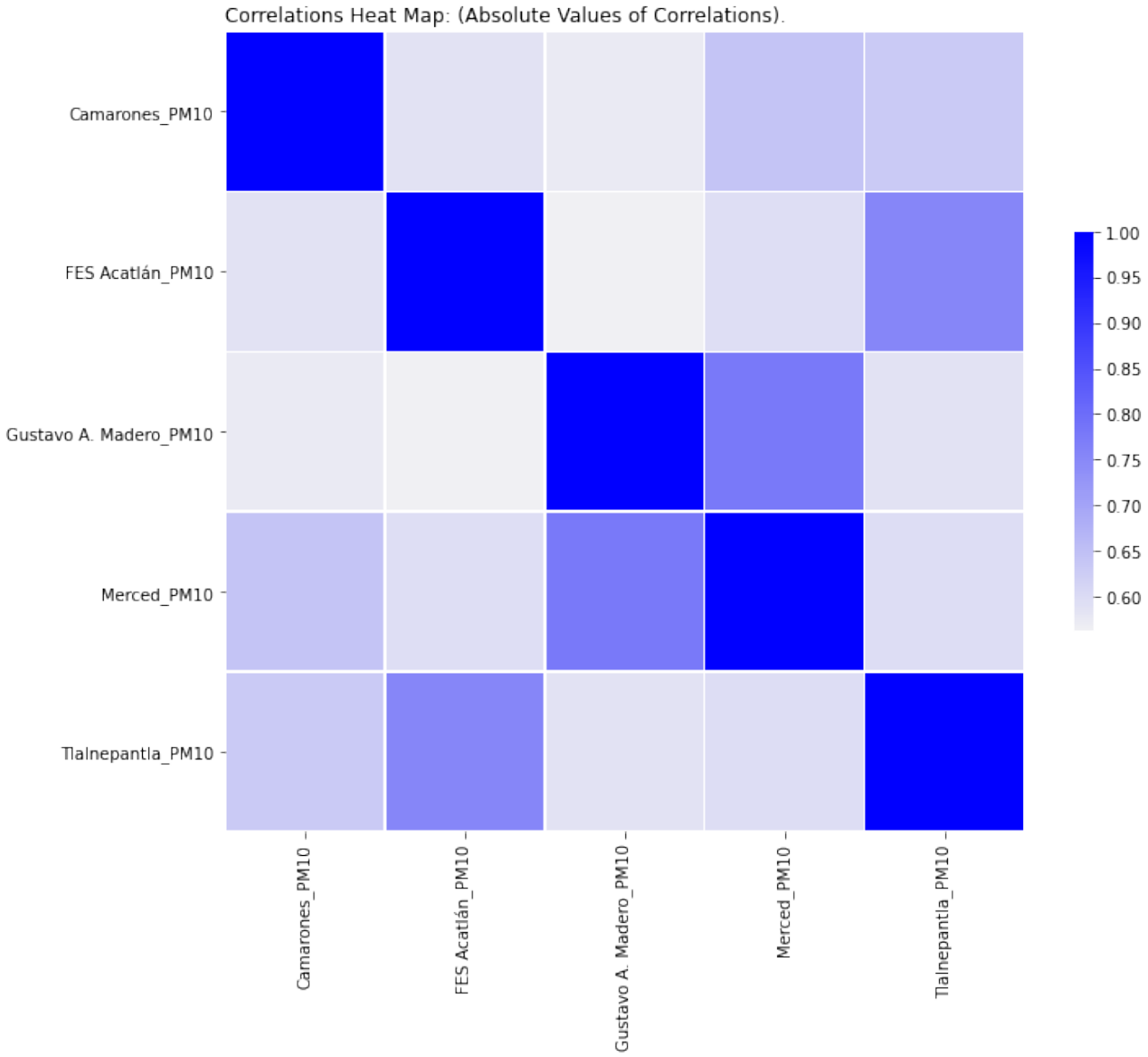

```
<ggplot: (8748598907869)>
```




```
<ggplot: (8748598840809)>
```

	Camarones_PM10	FES Acatlán_PM10	\
Camarones_PM10	1.000000	0.588032	
FES Acatlán_PM10	0.588032	1.000000	
Gustavo A. Madero_PM10	0.573777	0.561526	
Merced_PM10	0.642624	0.596102	
Tlalnepantla_PM10	0.633015	0.755112	

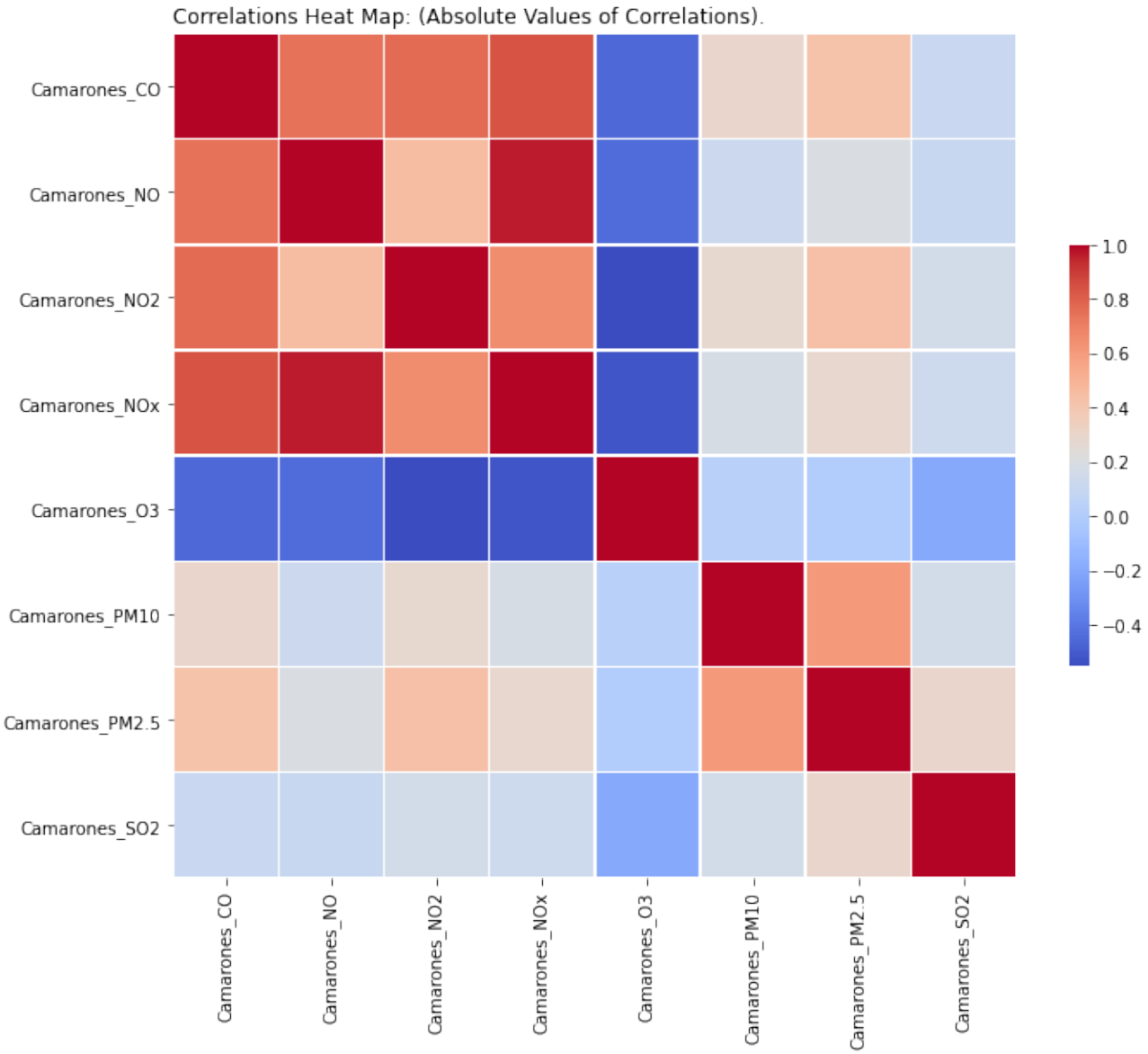
	Gustavo A. Madero_PM10	Merced_PM10	Tlalnepantla_PM10
Camarones_PM10	0.573777	0.642624	0.633015
FES Acatlán_PM10	0.561526	0.596102	0.755112
Gustavo A. Madero_PM10	1.000000	0.779445	0.588039
Merced_PM10	0.779445	1.000000	0.599155
Tlalnepantla_PM10	0.588039	0.599155	1.000000



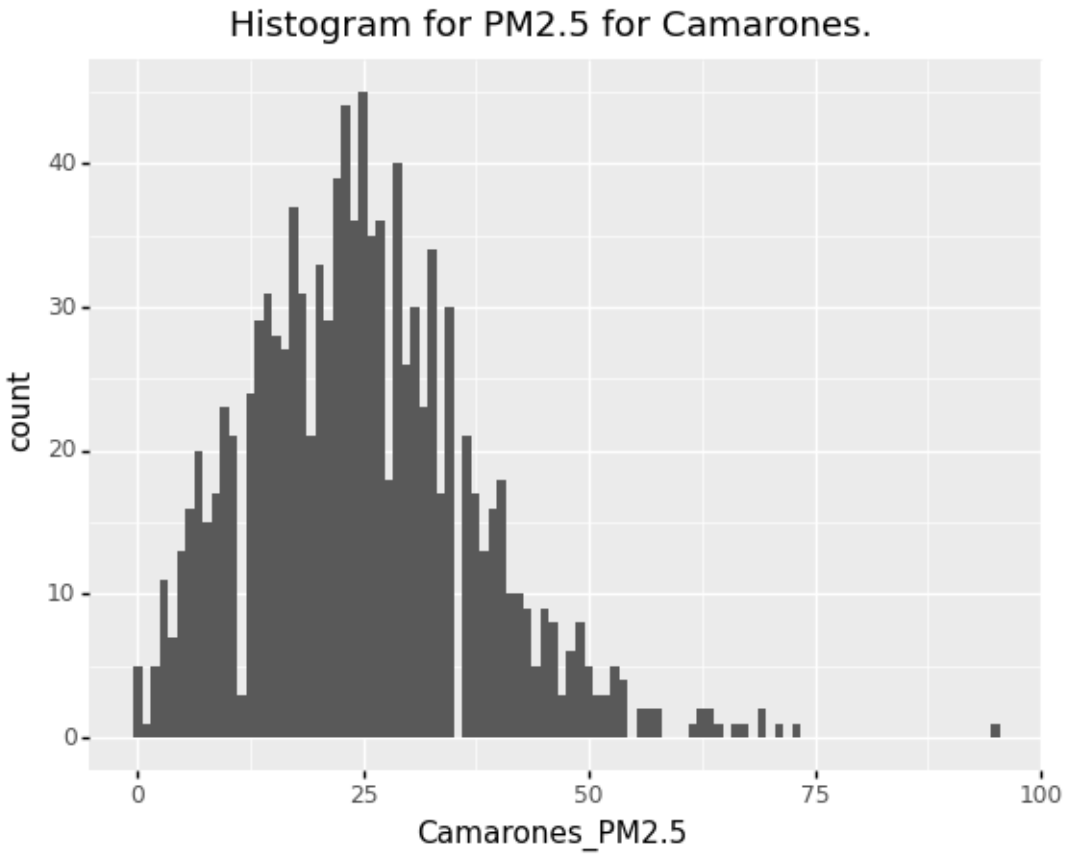
	Camarones_CO	Camarones_NO	Camarones_NO2	Camarones_NOx	\
Camarones_CO	1.000000	0.745593	0.771172	0.839178	
Camarones_NO	0.745593	1.000000	0.456594	0.965661	
Camarones_NO2	0.771172	0.456594	1.000000	0.656534	
Camarones_NOx	0.839178	0.965661	0.656534	1.000000	
Camarones_O3	-0.455741	-0.440542	-0.554310	-0.522438	
Camarones_PM10	0.297277	0.124081	0.279483	0.181161	
Camarones_PM2.5	0.425596	0.200851	0.435905	0.288952	
Camarones_SO2	0.109512	0.105557	0.160720	0.133070	

	Camarones_O3	Camarones_PM10	Camarones_PM2.5	Camarones_SO2
Camarones_CO	-0.455741	0.297277	0.425596	0.109512
Camarones_NO	-0.440542	0.124081	0.200851	0.105557
Camarones_NO2	-0.554310	0.279483	0.435905	0.160720
Camarones_NOx	-0.522438	0.181161	0.288952	0.133070
Camarones_O3	1.000000	0.030864	0.003132	-0.192407
Camarones_PM10	0.030864	1.000000	0.610515	0.157361
Camarones_PM2.5	0.003132	0.610515	1.000000	0.298078

Camarones_SO2	-0.192407	0.157361	0.298078	1.000000



PM2.5




```
<ggplot: (8748609230585)>
```

2.2 Regresión Lineal

Removemos observaciones incompletas para realizar la regresión.

```
Index(['Merced_PM10', 'Tlalnepantla_PM10'], dtype='object')
```

```
array([0.53026139, 0.36873538])
```

```
8.861413306258605
```

```
0.5089006183870153
```

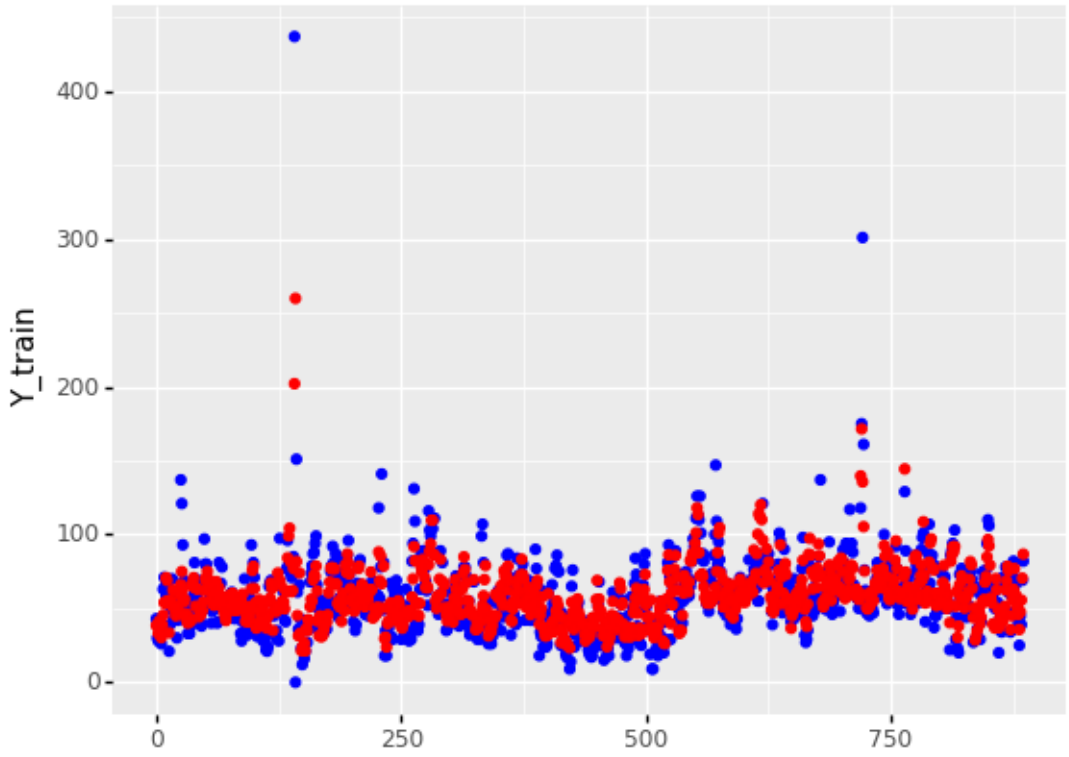
```
-0.4162199659052408
```

```
371.5820988359095
```

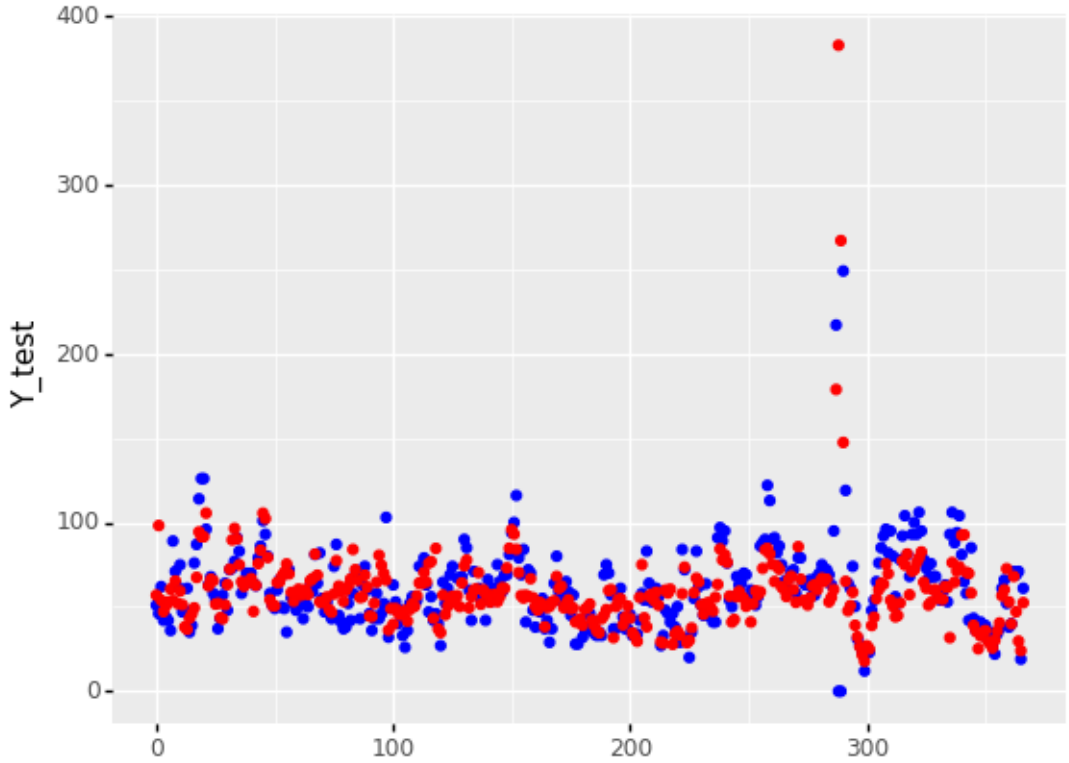
```
845.7794576326868
```

```
10.931473014049846
```

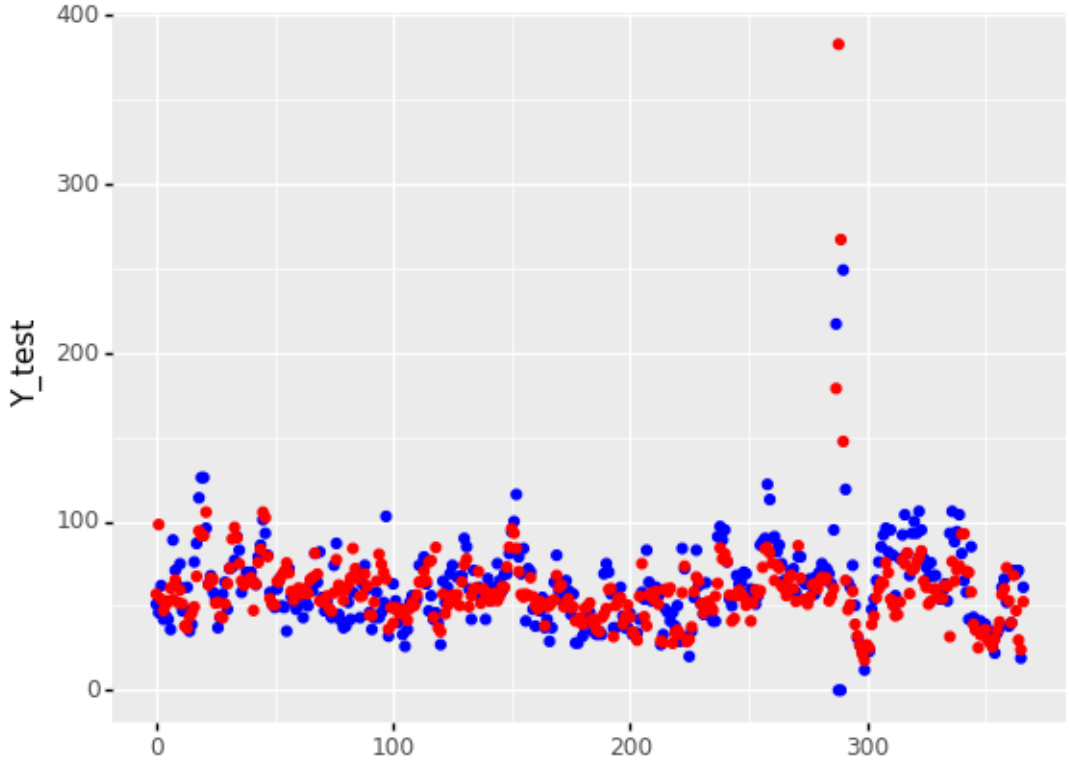
```
13.047752185462492
```



<ggplot: (8748609122933)>



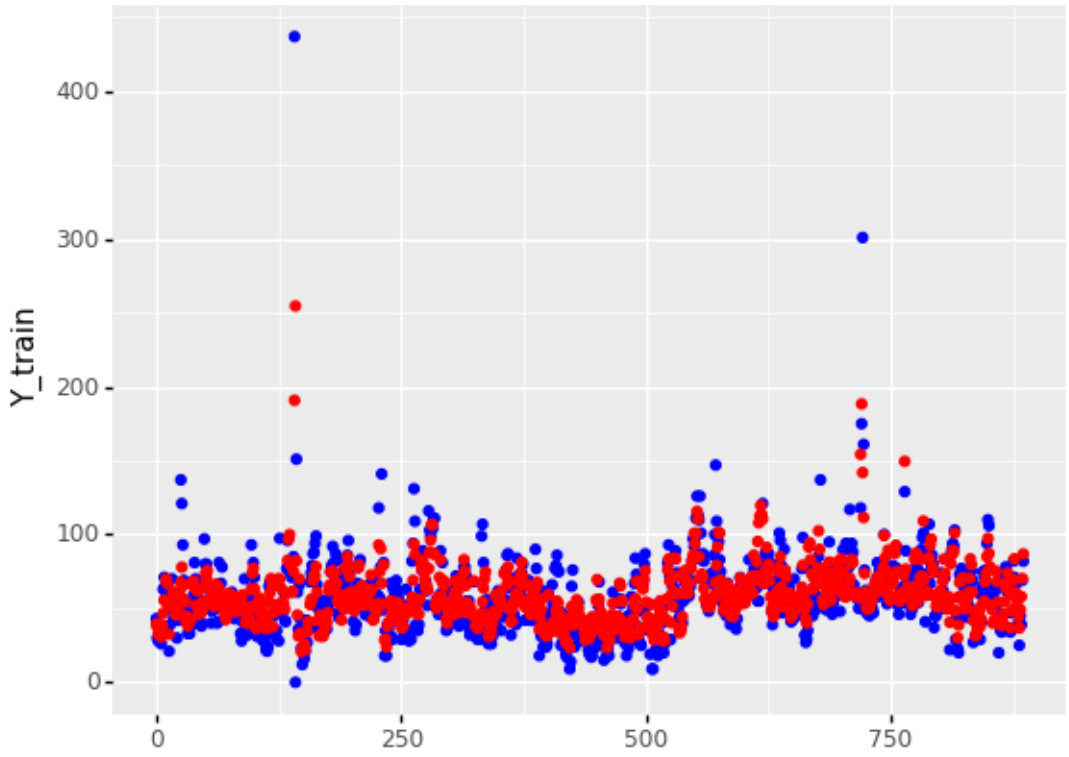
<ggplot: (8748608796597)>



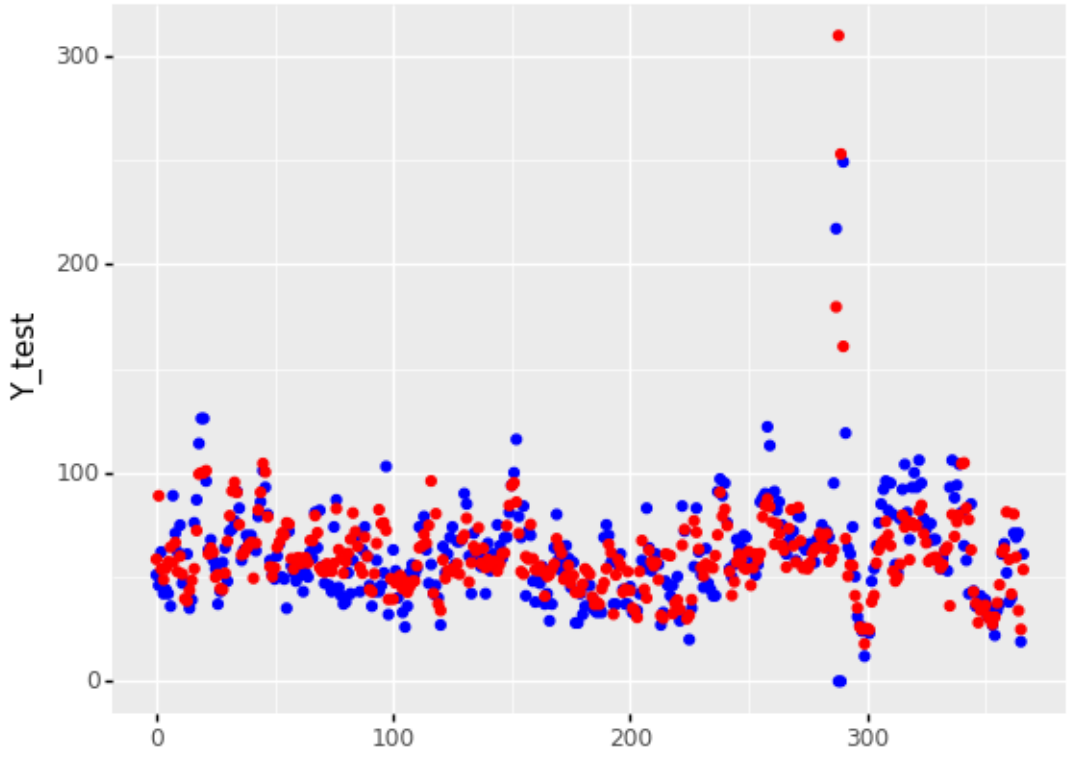

```
<ggplot: (8748608756745)>
```

2.3 Lasso

```
array([0.10494418, 0.0689564 , 0.43803925, 0.28309869])

9.793830115973797

0.5169119069776114

-0.11224862731990415

365.52049187746337

664.2450067183082

10.791035566246128

12.489847967051261
```



<ggplot: (8748608657061)>



<ggplot: (8748608729533)>

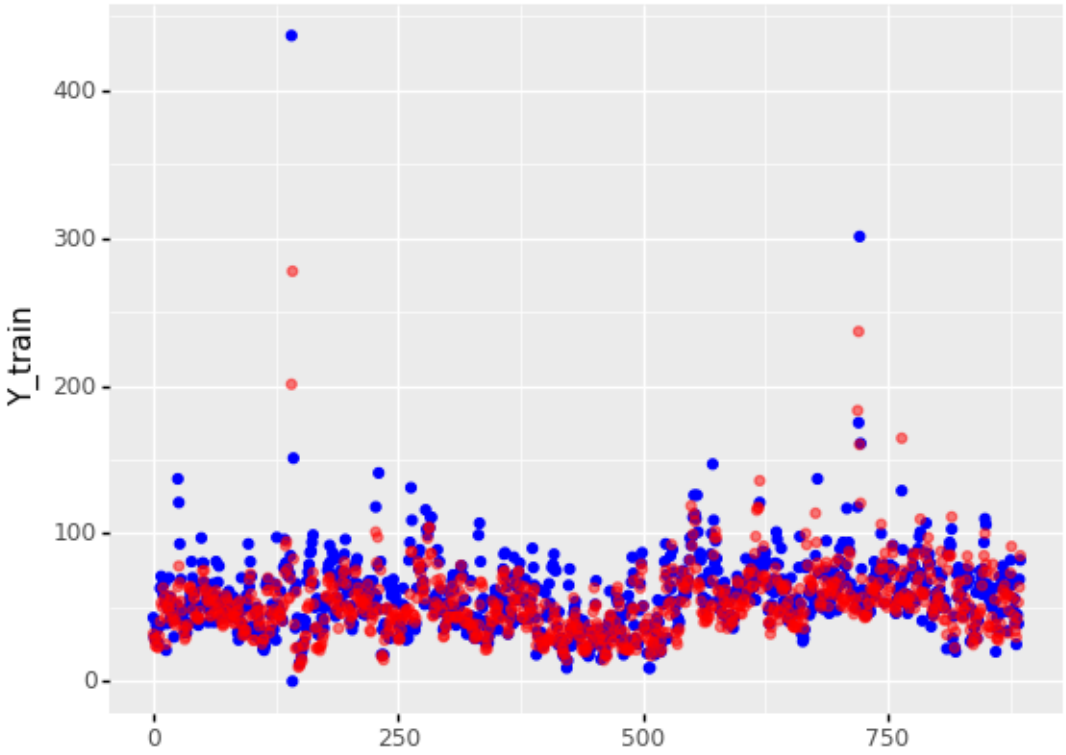
2.4 Mean

```
422.1441318590655
```

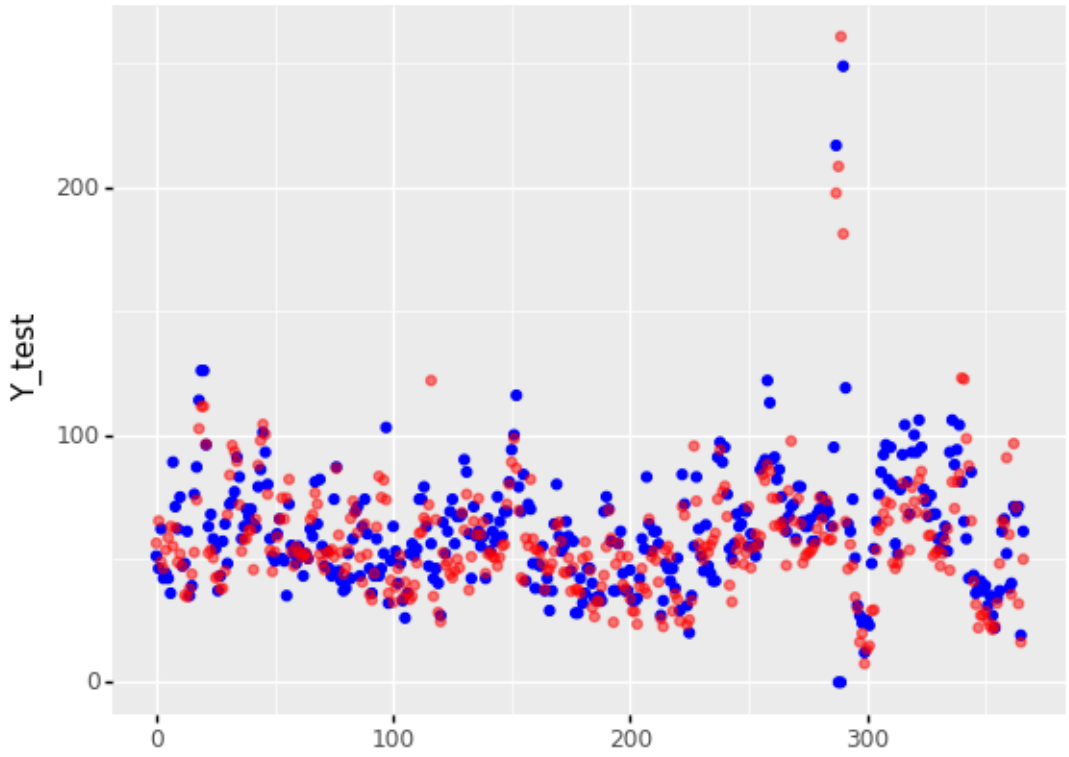
```
579.0378415931376
```

```
12.22969669074124
```

```
13.812958507896164
```




```
<ggplot: (8748608608917)>
```




```
<ggplot: (8748608547589)>
```

2.5 Generalized Linear Models: GLM

```
((886,), (886,))
```

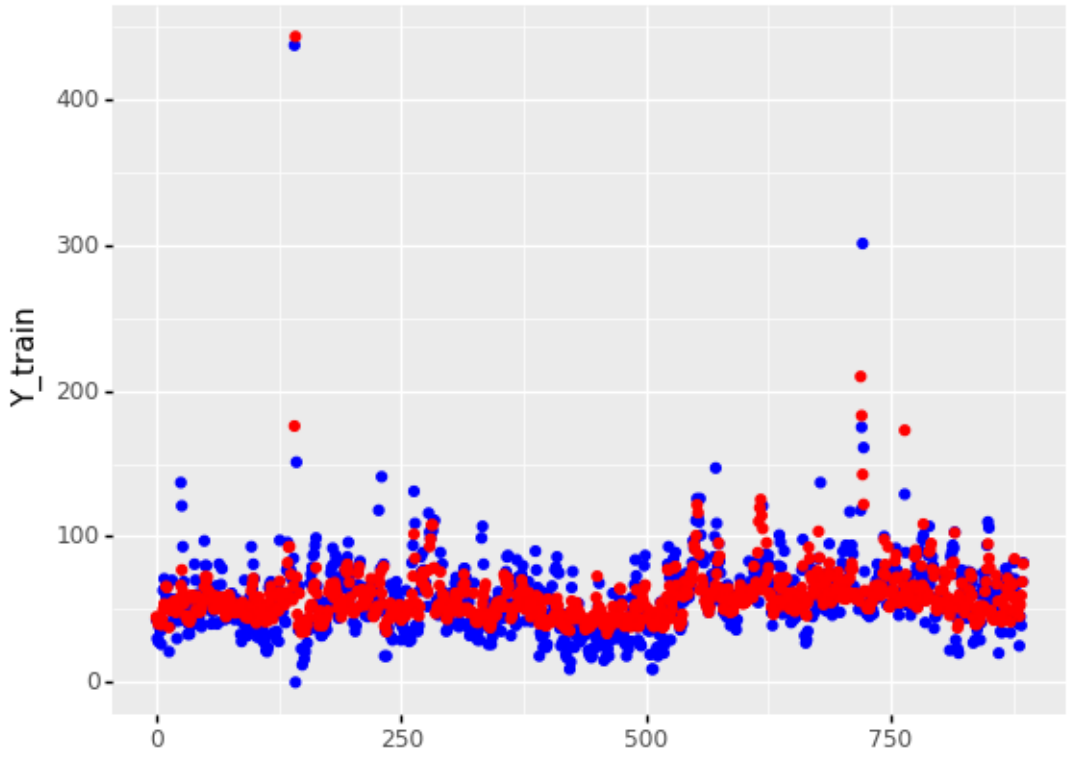
```
((367,), (367,))
```

```
562.8146939425658
```

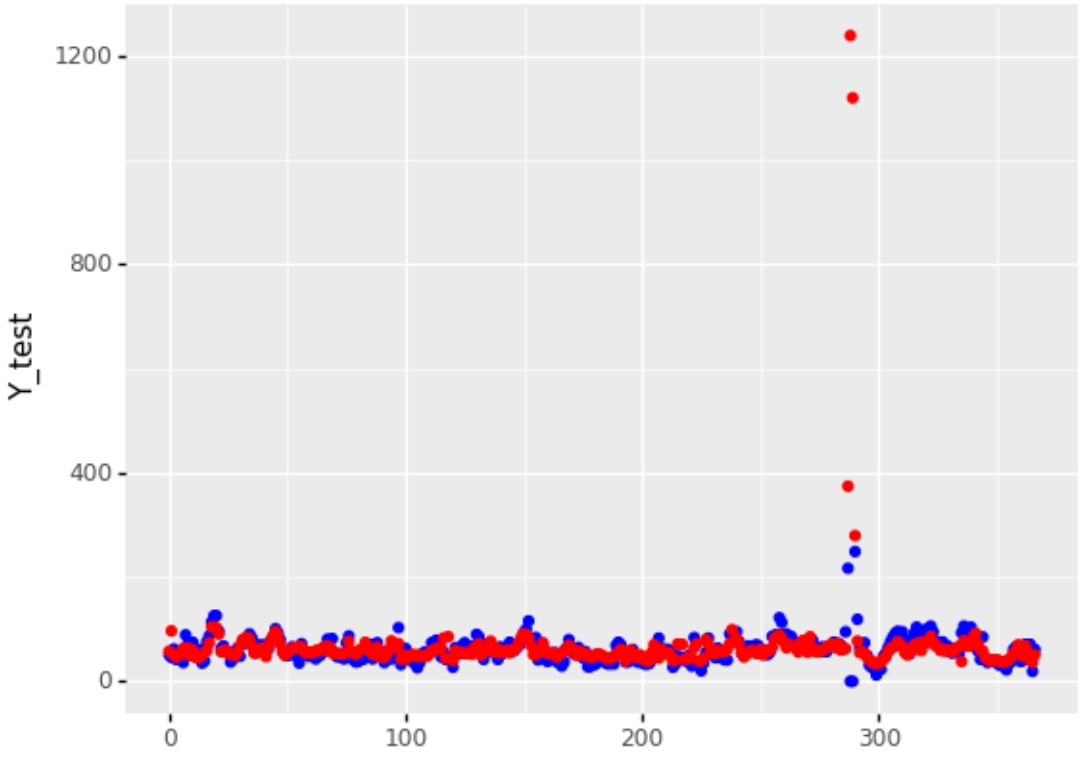
```
7875.849124574941
```

```
12.15806111211628
```

```
17.957714790509712
```



<ggplot: (8748609151741)>



<ggplot: (8748608529529)>

2.6 K-Nearest Neighbors

```
((886,), (886,))
```

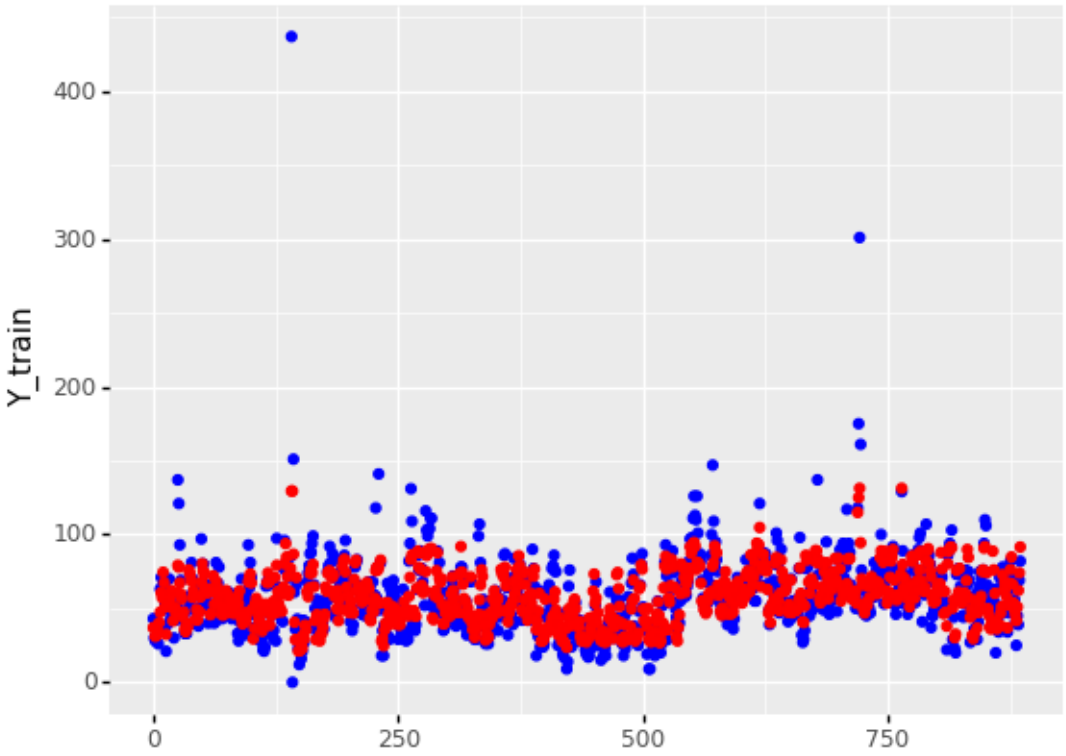
```
((367,), (367,))
```

```
347.29259904240126
```

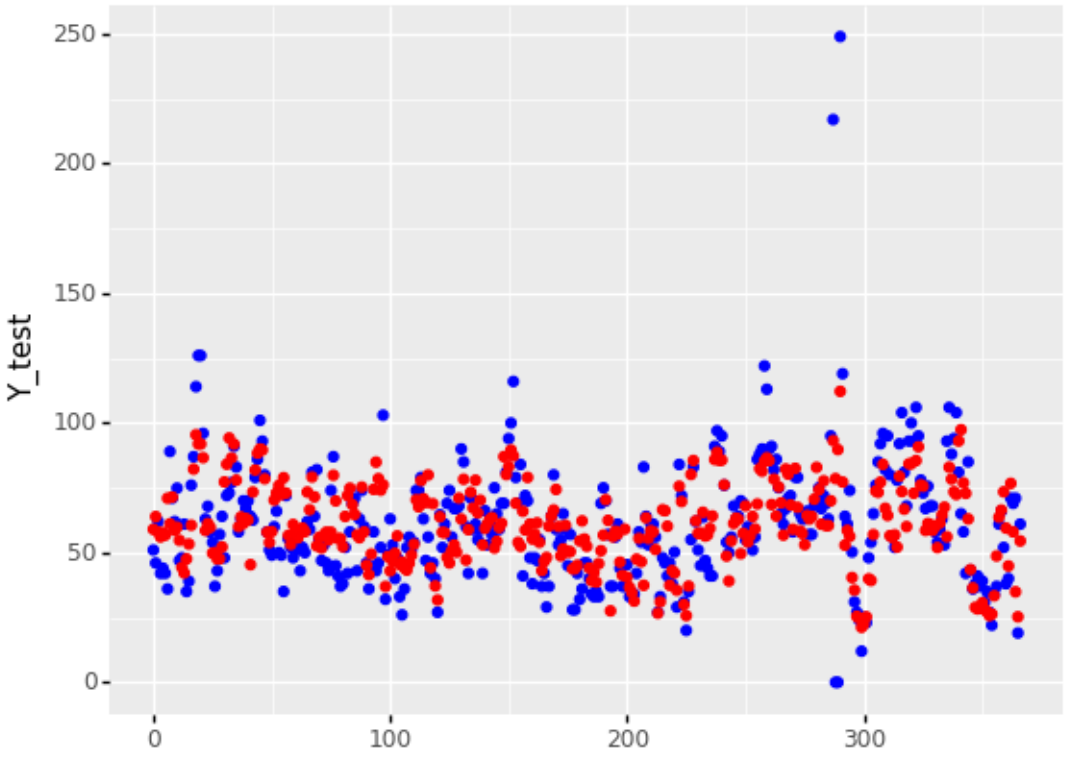
```
325.37804270928683
```

```
10.748652093480683
```

```
11.676590585214306
```




```
<ggplot: (8748608731669)>
```




```
<ggplot: (8748608731681)>
```

2.7 Evaluation

	Model	MSE (Train Set)	MAE (Train Set)	MSE (Test Set)	MAE (Test Set)
4	1.7 KNN	347.292599	10.748652	325.378043	11.676591
2	1.5 Media	422.144132	12.229697	579.037842	13.812959
1	1.3 Lasso	365.520492	10.791036	664.245007	12.489848
0	1.2 Regresión Lineal	371.582099	10.931473	845.779458	13.047752
3	1.6 GLM	562.814694	12.158061	7875.849125	17.957715

2.8 Early Conclusions

Given that we all further treatment to use the data should be in a sequential fashion, ie as timeseries: we found that linear interpolation is adequate.

Then in the next section we are detailing it.

2.9 Interpolation

We found in the EDA and in previous sections that Merced has similar data as Camarones, and it has fewer incomplete observations (missing data).

```
Merced_CO        70.0
Merced_NO       971.0
```

```
Merced_NO2       88.0
Merced_NOx       88.0
Merced_O3        82.0
Merced_PM10      31.0
Merced_PM2.5     36.0
Merced_SO2       64.0
Name: count, dtype: float64
```

Camarones has more incomplete observations:

```
Camarones_CO       111.0
Camarones_NO       125.0
Camarones_NO2      125.0
Camarones_NOx      310.0
Camarones_O3       119.0
Camarones_PM10     603.0
Camarones_PM2.5    587.0
Camarones_SO2      162.0
Name: count, dtype: float64
```

Using those results we create a new dataframe with those imputations.

The data in the dataframe have the following columns (vars) in the following manner:

- CO: Merced
- NO: Camarones
- NO2: Merced
- NOx: Merced
- O3: Merced
- PM10: Merced
- PM2.5: Merced

We used a lag to use the missing hours and found these gaps in the time line:

```
                  Fecha        CO        NO       NO2       NOx        O3  \
0    2021-01-01 02:00:00  1.100000  0.013000  0.032000  0.039000  0.004000
1    2021-01-01 03:00:00  1.200000  0.031000  0.033000  0.043000  0.001000
2    2021-01-01 04:00:00  1.200000  0.005000  0.031000  0.039000  0.002000
3    2021-01-01 05:00:00  1.200000  0.016000  0.028000  0.036000  0.002000
4    2021-01-01 06:00:00  1.400000  0.024000  0.029000  0.060000  0.001000
…                    …       …         …         …         …         …
2129 2021-10-04 00:00:00  0.545833  0.008292  0.019083  0.026875  0.015833
2130 2021-10-05 00:00:00  0.563158  0.010000  0.019722  0.030500  0.012278
2131 2021-10-06 00:00:00  0.672222  0.007571  0.026111  0.035611  0.011000
2132 2021-10-07 00:00:00  0.713636  0.011565  0.028636  0.040318  0.017909
2133 2021-10-08 00:00:00  0.758824  0.023778  0.029412  0.050588  0.017941

           PM10      PM2.5       SO2            datetime  year  month  day  \
0     37.000000  24.000000  0.003000 2021-01-01 02:00:00  2021      1    1
1     49.000000  39.000000  0.003000 2021-01-01 03:00:00  2021      1    1
2     80.000000  65.000000  0.003000 2021-01-01 04:00:00  2021      1    1
3     89.000000  75.000000  0.003000 2021-01-01 05:00:00  2021      1    1
4     75.000000  64.000000  0.003000 2021-01-01 06:00:00  2021      1    1
…           …          …         …                   …   …    …  …
2129  11.826087   7.913043  0.000750 2021-10-04 00:00:00  2021     10    4
2130  11.090909   6.772727  0.000556 2021-10-05 00:00:00  2021     10    5
2131  18.722222  11.833333  0.000111 2021-10-06 00:00:00  2021     10    6
2132  26.772727  17.000000  0.001045 2021-10-07 00:00:00  2021     10    7
2133  29.000000  17.705882  0.008176 2021-10-08 00:00:00  2021     10    8
```

```
      hour          datetime-1  delta  imputated
0        2 2021-01-01 00:00:00    2.0      False
1        3 2021-01-01 02:00:00    1.0      False
2        4 2021-01-01 03:00:00    1.0      False
3        5 2021-01-01 04:00:00    1.0      False
4        6 2021-01-01 05:00:00    1.0      False
…    …                   …    …        …
2129     0 2021-10-03 00:00:00    0.0      False
2130     0 2021-10-04 00:00:00    0.0      False
2131     0 2021-10-05 00:00:00    0.0      False
2132     0 2021-10-06 00:00:00    0.0      False
2133     0 2021-10-07 00:00:00    0.0      False

[2134 rows x 17 columns]
```

These are the missing gaps:

```
                 Date  Missing observations
0 2021-01-09 13:00:00                  13.0
1 2021-03-11 23:00:00                  12.0
2 2021-03-17 09:00:00                   9.0
3 2021-03-17 00:00:00                   8.0
4 2021-01-21 23:00:00                   8.0
5 2021-02-26 08:00:00                   8.0
6 2021-02-26 00:00:00                   7.0
7 2021-02-22 15:00:00                   6.0
8 2021-02-26 14:00:00                   6.0
9 2021-01-01 18:00:00                   5.0
```

Realizamos una interpolación quedando los datos así:

```
Skipping 0
CPU times: user 759 ms, sys: 2.96 ms, total: 762 ms
Wall time: 762 ms

               CO        NO       NO2       NOx        O3       PM10  \
987      2.200000  0.205000  0.031000  0.207000  0.002000  45.000000
988      2.200000  0.205000  0.031000  0.207000  0.002000  45.000000
989      2.200000  0.205000  0.031000  0.207000  0.002000  45.000000
990      2.200000  0.205000  0.031000  0.207000  0.002000  45.000000
991      2.200000  0.205000  0.031000  0.207000  0.002000  45.000000
…             …         …         …         …         …         …
1582081  0.765217  0.009174  0.027826  0.039043  0.015304  20.304348
1582082  0.765217  0.009174  0.027826  0.039043  0.015304  20.304348
1582083  0.765217  0.009174  0.027826  0.039043  0.015304  20.304348
1582084  0.765217  0.009174  0.027826  0.039043  0.015304  20.304348
1582085  0.765217  0.009174  0.027826  0.039043  0.015304  20.304348

             PM2.5       SO2  month  day  hour                     datetime  \
987      22.000000  0.004000      2   12     6 2021-02-12 06:05:35.846304417
988      22.000000  0.004000      2   12     6 2021-02-12 06:05:38.837326527
989      22.000000  0.004000      2   12     6 2021-02-12 06:05:47.812360048
990      22.000000  0.004000      2   12     6 2021-02-12 06:05:50.803695202
991      22.000000  0.004000      2   12     6 2021-02-12 06:05:53.795462847
…              …         …    …   …  …   …                              …
1582081  16.391304  0.001304      9   18     0 2021-09-18 00:59:47.142104626
1582082  16.391304  0.001304      9   18     0 2021-09-18 00:59:50.136709690
1582083  16.391304  0.001304      9   18     0 2021-09-18 00:59:53.131285429
1582084  16.391304  0.001304      9   18     0 2021-09-18 00:59:56.125959396
1582085  16.391304  0.001304      9   18     0 2021-09-18 00:59:59.120573282
```

```
         minute  temperature  pressure  humidity  gasResistance    IAQ
987        35.0        21.51    777.41     44.04       152149.0   34.7
988        34.0        21.51    777.41     43.98       152841.0   33.6
989        32.0        21.54    777.41     43.73       153259.0   31.5
990        32.0        21.53    777.41     43.70       152841.0   31.5
991        30.0        21.52    777.41     43.70       153399.0   30.2
…           …           …         …         …            …     …
1582081   138.0        26.00    782.92     56.34       916837.0  138.2
1582082   138.0        26.00    782.92     56.33       917462.0  137.7
1582083   138.0        26.00    782.90     56.34       916837.0  137.6
1582084   136.0        26.00    782.92     56.35       921233.0  136.0
1582085   134.0        25.99    782.92     56.35       922497.0  134.5

[1581099 rows x 18 columns]
```

We have imputated successfully all our data frame.

```
Empty DataFrame
Columns: [Date, Missing DAta]
Index: []
```

We recognize this might not be the best method, but we can explore more imputation methods on timeseries modeling.

2.10 References

- https://scikit-learn.org/stable/modules/linear_model.html#generalized-linear-regression
- https://pythonhealthcare.org/2018/05/03/81-distribution-fitting-to-data/
- https://medium.com/@amirarsalan.rajabi/distribution-fitting-with-python-scipy-bb70a42c0aed
- https://scikit-learn.org/stable/modules/generated/sklearn.neighbors.KernelDensity.html?highlight=kernel%20density#sklearn.neighbors.KernelDensity