

# Low code time series and geospatial data handling, analysis and visualization

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## Download data from Kaggle: <https://www.kaggle.com/datasets/decide-soluciones/air-quality-madrid>

- madrid\_2018.csv
- stations.csv

## Use the Import Data App to

import "madrid\_2018.csv", then preview the File

## Import data from text file

Script for importing data from the following text file:

```
filename: C:\Users\kleptoka\OneDrive -  
MathWorks\Desktop\EMEA_Webinar\Demo1_Madrid_Air_Geodata\madrid_2018.csv
```

Auto-generated by MATLAB on 16-Jul-2025 14:20:46

## Set up the Import Options and import the data

```

opts = delimitedTextImportOptions("NumVariables", 16);

% Specify range and delimiter
opts.DataLines = [2, Inf];
opts.Delimiter = ",";

% Specify column names and types
opts.VariableNames = ["date", "BEN", "CH4", "CO", "EBE", "NMHC", "NO", "NO_2",
"NOx", "O_3", "PM10", "PM25", "SO_2", "TCH", "TOL", "station"];
opts.SelectedVariableNames = ["date", "CH4", "CO", "NO", "NO_2", "station"];
opts.VariableTypes = ["datetime", "string", "double", "double", "string", "string",
"double", "double", "string", "string", "string", "string", "string", "string",
"string", "double"];

% Specify file level properties
opts.ExtraColumnsRule = "ignore";
opts.EmptyLineRule = "read";

% Specify variable properties
opts = setvaropts(opts, ["BEN", "EBE", "NMHC", "NOx", "O_3", "PM10", "PM25",
"SO_2", "TCH", "TOL"], "WhitespaceRule", "preserve");
opts = setvaropts(opts, ["BEN", "EBE", "NMHC", "NOx", "O_3", "PM10", "PM25",
"SO_2", "TCH", "TOL"], "EmptyFieldRule", "auto");
opts = setvaropts(opts, "date", "InputFormat", "yyyy-MM-dd HH:mm:ss",
"DatetimeFormat", "preserveinput");

% Import the data
%madrid_2018 = readtimetable("C:\Users\kleptoka\OneDrive -
MathWorks\Desktop\EMEA_Webinar\Demo1_Madrid_Air_Geodata\madrid_2018.csv", opts,
"RowTimes", "date");
madrid_2018 = readtimetable("C:\Users\lsammon\MATLAB
Drive\1_Seminars\Enhancing Geoscience with MATLAB\Madrid_Air_Quality-
main\madrid_2018.csv",opts,"RowTimes","date");

madrid_2018.station = categorical(madrid_2018.station);
madrid_2018 = sortrows(madrid_2018, "date")

```

```
madrid_2018 = 69096x5 timetable
```

	date	CH4	CO	NO	NO_2	station
1	2018-01-01 01:00:00	NaN	0.3000	2	15	28079004
2	2018-01-01 01:00:00	1.3800	0.2000	6	33	28079008
3	2018-01-01 01:00:00	NaN	NaN	3	11	28079011
4	2018-01-01 01:00:00	NaN	0.2000	1	12	28079016
5	2018-01-01 01:00:00	NaN	NaN	6	23	28079017
6	2018-01-01 01:00:00	NaN	0.6000	63	32	28079018
7	2018-01-01 01:00:00	1.1100	0.2000	1	1	28079024

	date	CH4	CO	NO	NO_2	station
8	2018-01-01 01:00:00	NaN	NaN	1	9	28079027
9	2018-01-01 01:00:00	NaN	0.2000	2	19	28079035
10	2018-01-01 01:00:00	NaN	0.2000	4	16	28079036
11	2018-01-01 01:00:00	NaN	NaN	7	13	28079038
12	2018-01-01 01:00:00	NaN	0.3000	2	12	28079039
13	2018-01-01 01:00:00	NaN	NaN	2	12	28079040
14	2018-01-01 01:00:00	NaN	NaN	1	9	28079047
15	2018-01-01 01:00:00	NaN	NaN	1	11	28079048
16	2018-01-01 01:00:00	NaN	NaN	1	8	28079049
17	2018-01-01 01:00:00	NaN	NaN	7	12	28079050
18	2018-01-01 01:00:00	NaN	NaN	1	8	28079054
19	2018-01-01 01:00:00	1.1400	NaN	1	9	28079055
20	2018-01-01 01:00:00	NaN	0.3000	18	37	28079056
21	2018-01-01 01:00:00	NaN	0.2000	1	5	28079057
22	2018-01-01 01:00:00	NaN	NaN	1	1	28079058
23	2018-01-01 01:00:00	NaN	NaN	1	5	28079059
24	2018-01-01 01:00:00	NaN	NaN	1	8	28079060
25	2018-01-01 02:00:00	NaN	0.4000	1	35	28079004
26	2018-01-01 02:00:00	1.3800	0.3000	14	64	28079008
27	2018-01-01 02:00:00	NaN	NaN	9	33	28079011
28	2018-01-01 02:00:00	NaN	0.3000	2	26	28079016
29	2018-01-01 02:00:00	NaN	NaN	8	43	28079017
30	2018-01-01 02:00:00	NaN	0.4000	8	41	28079018
31	2018-01-01 02:00:00	1.1100	0.2000	1	6	28079024
32	2018-01-01 02:00:00	NaN	NaN	1	13	28079027
33	2018-01-01 02:00:00	NaN	0.3000	3	29	28079035
34	2018-01-01 02:00:00	NaN	0.3000	11	43	28079036
35	2018-01-01 02:00:00	NaN	NaN	16	40	28079038
36	2018-01-01 02:00:00	NaN	0.3000	6	25	28079039
37	2018-01-01 02:00:00	NaN	NaN	6	37	28079040
38	2018-01-01 02:00:00	NaN	NaN	1	35	28079047
39	2018-01-01 02:00:00	NaN	NaN	3	38	28079048
40	2018-01-01 02:00:00	NaN	NaN	1	23	28079049

	date	CH4	CO	NO	NO_2	station
41	2018-01-01 02:00:00	NaN	NaN	23	36	28079050
42	2018-01-01 02:00:00	NaN	NaN	3	31	28079054
43	2018-01-01 02:00:00	1.1400	NaN	2	15	28079055
44	2018-01-01 02:00:00	NaN	0.4000	25	62	28079056
45	2018-01-01 02:00:00	NaN	0.3000	1	16	28079057
46	2018-01-01 02:00:00	NaN	NaN	1	1	28079058
47	2018-01-01 02:00:00	NaN	NaN	1	12	28079059
48	2018-01-01 02:00:00	NaN	NaN	2	17	28079060
49	2018-01-01 03:00:00	NaN	0.3000	1	29	28079004
50	2018-01-01 03:00:00	1.3700	0.3000	15	63	28079008
51	2018-01-01 03:00:00	NaN	NaN	4	27	28079011
52	2018-01-01 03:00:00	NaN	0.3000	4	39	28079016
53	2018-01-01 03:00:00	NaN	NaN	4	34	28079017
54	2018-01-01 03:00:00	NaN	0.3000	2	26	28079018
55	2018-01-01 03:00:00	1.1100	0.2000	1	8	28079024
56	2018-01-01 03:00:00	NaN	NaN	1	21	28079027
57	2018-01-01 03:00:00	NaN	0.2000	7	35	28079035
58	2018-01-01 03:00:00	NaN	0.3000	6	49	28079036
59	2018-01-01 03:00:00	NaN	NaN	6	23	28079038
60	2018-01-01 03:00:00	NaN	0.3000	4	32	28079039
61	2018-01-01 03:00:00	NaN	NaN	8	43	28079040
62	2018-01-01 03:00:00	NaN	NaN	1	34	28079047
63	2018-01-01 03:00:00	NaN	NaN	2	35	28079048
64	2018-01-01 03:00:00	NaN	NaN	1	22	28079049
65	2018-01-01 03:00:00	NaN	NaN	16	35	28079050
66	2018-01-01 03:00:00	NaN	NaN	2	33	28079054
67	2018-01-01 03:00:00	1.1400	NaN	1	29	28079055
68	2018-01-01 03:00:00	NaN	0.2000	12	33	28079056
69	2018-01-01 03:00:00	NaN	0.3000	1	30	28079057
70	2018-01-01 03:00:00	NaN	NaN	1	18	28079058
71	2018-01-01 03:00:00	NaN	NaN	1	19	28079059
72	2018-01-01 03:00:00	NaN	NaN	1	19	28079060
73	2018-01-01 04:00:00	NaN	0.3000	1	16	28079004

	date	CH4	CO	NO	NO_2	station
74	2018-01-01 04:00:00	1.3700	0.3000	10	51	28079008
75	2018-01-01 04:00:00	NaN	NaN	2	16	28079011
76	2018-01-01 04:00:00	NaN	0.2000	1	17	28079016
77	2018-01-01 04:00:00	NaN	NaN	2	29	28079017
78	2018-01-01 04:00:00	NaN	0.2000	1	22	28079018
79	2018-01-01 04:00:00	1.1100	0.2000	1	3	28079024
80	2018-01-01 04:00:00	NaN	NaN	1	11	28079027
81	2018-01-01 04:00:00	NaN	0.2000	13	38	28079035
82	2018-01-01 04:00:00	NaN	0.2000	2	29	28079036
83	2018-01-01 04:00:00	NaN	NaN	2	14	28079038
84	2018-01-01 04:00:00	NaN	0.3000	2	27	28079039
85	2018-01-01 04:00:00	NaN	NaN	5	29	28079040
86	2018-01-01 04:00:00	NaN	NaN	1	18	28079047
87	2018-01-01 04:00:00	NaN	NaN	1	22	28079048
88	2018-01-01 04:00:00	NaN	NaN	1	16	28079049
89	2018-01-01 04:00:00	NaN	NaN	8	22	28079050
90	2018-01-01 04:00:00	NaN	NaN	1	22	28079054
91	2018-01-01 04:00:00	1.1400	NaN	1	15	28079055
92	2018-01-01 04:00:00	NaN	0.2000	10	23	28079056
93	2018-01-01 04:00:00	NaN	0.3000	1	18	28079057
94	2018-01-01 04:00:00	NaN	NaN	1	6	28079058
95	2018-01-01 04:00:00	NaN	NaN	1	9	28079059
96	2018-01-01 04:00:00	NaN	NaN	1	17	28079060
97	2018-01-01 05:00:00	NaN	0.3000	1	12	28079004
98	2018-01-01 05:00:00	1.3800	0.3000	13	57	28079008
99	2018-01-01 05:00:00	NaN	NaN	1	11	28079011
100	2018-01-01 05:00:00	NaN	0.3000	1	14	28079016

:

### Clear temporary variables

```
clear opts
```

## Unstack Table Variable

```
% Unstack variables
NO = unstack(madrid_2018,"NO","station",AggregationFunction=@mean, ...
    VariableNamingRule="preserve")
```

## Clean Missing Data

```
% Fill missing data
[NO_new,missingIndices] = fillmissing(NO,"linear");

% Display results
figure

% Plot cleaned data
plot(NO.date,NO_new.("28079011"),SeriesIndex=1,LineWidth=1.5, ...
    DisplayName="Cleaned data")
hold on

% Plot filled missing entries
plot(NO.date(missingIndices(:,3)),NO_new.("28079011")(missingIndices(:,3)),".", ...
    MarkerSize=12,SeriesIndex=2,DisplayName="Filled missing entries")
title("Number of filled missing entries: " + nnz(missingIndices(:,3)))

hold off
legend
ylabel("28079011")
xlabel("date")
clear missingIndices
```

## Check out the stations location

### import "stations.csv", then preview the File

Transform the "id" variable from *Double* to *String*

```
% Import data from text file
stations = readtable("C:\Users\kleptoka\OneDrive -
MathWorks\Desktop\EMEA_Webinar\Demo1_Madrid_Air_Geodata\stations.csv", "TextType",
"string");

% Display results
stations

stations.id = string(stations.id)
```

## Create a Plot - to plot the Stations on a map

```
% Create geoscatter of stations.lat and stations.lon
```

```
S = geoscatteer(stations.lat,stations.lon,[],stations.elevation,"filled");
colorbar
colormap("hot")
% Add title
title("stations.lat vs. stations.lon")
```

## Change the geobasemap and fill the circles

Ask [MATLAB GPT](#) or [MATLAB AI Chat Playground](#) to "change the format of degrees in the geographic plot" (check the documentation!)

```
geobasemap("satellite")
geotickformat("-dd")
```

## Ask Copilot how to add station labels

"Can you add in the figure the text label (id) for the stations? Don't use a for loop"  
(Make sure "lat" is the first argument and "lon" the second one!!)

```
% Add text labels for the stations
text(stations.lat, stations.lon, stations.id, 'VerticalAlignment', 'bottom',
'HorizontalAlignment', 'right', 'FontSize', 8);
```

Add a Colorbar (you can import a colormap from the IPCC [Standard-Climate-Colormaps-for-MATLAB - File Exchange - MATLAB Central](#))

```
cmap = uint8(readmatrix("misc_seq_2.txt"));
colorbar
colormap(cmap)
```

## BONUS! Launch and Explore the "signalAnalyzer" App

```
NO_values = NO_new("28079008");      % input data for signal analyzer
signalAnalyzer
```

## You can now Try:

### Smooth Data

```
% Smooth input data
[newTable,winSize] = smoothdata(NO_new,"gaussian",days(1));

% Display results
figure
plot(NO_new.date,NO_new("28079004"),SeriesIndex=6,DisplayName="Input data")
hold on
plot(NO_new.date,newTable("28079004"),SeriesIndex=1,LineWidth=1.5, ...
    DisplayName="Smoothed data")
```

```
hold off
title("Moving window size: " + string(winSize));
legend
ylabel("28079004")
xlabel("date")
clear winSize
```

## Remove Trends, Outliers, etc

```
% Fill outliers
[newTable2,outlierIndices,lo,hi] = filloutliers(NO_new,"linear","mean", ...
    ThresholdFactor=6);

% Display results
figure
plot(NO_new.date,NO_new("28079011"),SeriesIndex=6,DisplayName="Input data")
hold on
plot(NO_new.date,newTable2("28079011"),SeriesIndex=1,LineWidth=1.5, ...
    DisplayName="Cleaned data")

% Plot outliers
plot(NO_new.date(outlierIndices(:,3)),NO_new("28079011")(outlierIndices(:,3)), ...
    "x",Color=[145 145 145]/255,DisplayName="Outliers")

% Plot filled outliers
plot(NO_new.date(outlierIndices(:,3)),newTable2("28079011")
(outlierIndices(:,3)),".", ...
    MarkerSize=12,SeriesIndex=2,DisplayName="Filled outliers")

% Plot outlier thresholds
plot([xlim missing xlim], ...
    [lo("28079011") lo("28079011") missing hi("28079011") hi("28079011")], ...
    Color=[145 145 145]/255,DisplayName="Outlier thresholds")

hold off
title("Number of outliers cleaned: " + nnz(outlierIndices(:,3)))
legend
ylabel("28079011")
xlabel("date")
clear lo hi
```

## Plot NO data at all stations in a single figure

asking copilot: "NO\_new variable has data from many stations (different columns). How can I plot all of them as tiles in a compiled figure?"

Then open figure in window for better view

```
NO_new
```



## Compare pollutant values

e.g., NO with NO2 - unstack and clean missing values for NO2 and the plot NO vs NO2 and check out basic fitting

```
% Unstack variables
NO2 = unstack(madrid_2018,"NO_2","station", ...
    VariableNamingRule="preserve")
% Fill missing data
[NO2_new,missingIndices2] = fillmissing(NO2,"linear");

% Display results
figure

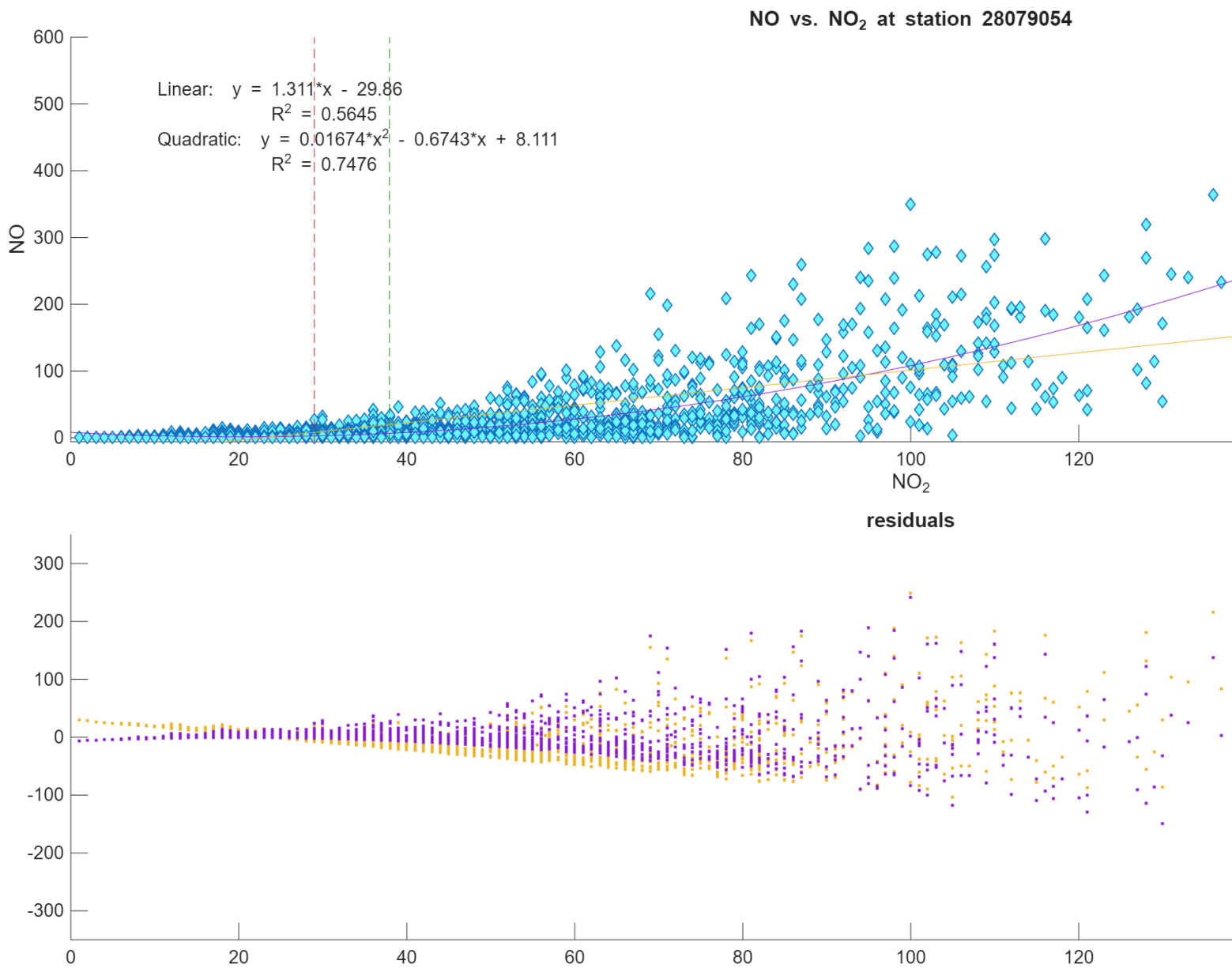
% Plot cleaned data
plot(NO2.date,NO2_new.("28079004"),SeriesIndex=1,LineWidth=1.5, ...
    DisplayName="Cleaned data")
hold on

% Plot filled missing entries
plot(NO2.date(missingIndices2(:,1)),NO2_new.("28079004")(missingIndices2(:,1)),".",
    ...
    MarkerSize=12,SeriesIndex=2,DisplayName="Filled missing entries")
title("Number of filled missing entries: " + nnz(missingIndices2(:,1)))

hold off
legend
ylabel("28079004")
xlabel("date")
clear missingIndices2

% Create scatter of selected data
s = scatter(NO2_new.("28079054"),NO_new.("28079054"),"DisplayName","28079054");

% Add xlabel, ylabel, title, and legend
xlabel("28079054")
ylabel("28079054")
title("28079054 vs. 28079054")
legend
[rho,p] = corr(NO2.("28079054"),NO.("28079054"),"Type","Spearman")
```



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