exercice

September 6, 2023

1 Evolution of the atmospheric CO_2 concentration since 1958

Data obtained here

1.1 1. Import Data

Check if the DATA has already been downloaded to avoid downloading the data at every execution . If not, it download it and import it.

[1]:
```
%matplotlib inline
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
from os.path import exists
```

[2]:
```
data_url = "https://scrippsco2.ucsd.edu/assets/data/atmospheric/stations/
 ↪in_situ_co2/monthly/monthly_in_situ_co2_mlo.csv"

#boo Check if file has already been downloaded to not download the data at␣
 ↪every execution
boo=exists("DATA.csv")

if boo:
    raw_data=raw_data = pd.read_csv("DATA.csv")
else:
    raw_data = pd.read_csv(data_url,skiprows=57)
    raw_data.to_csv("DATA.csv")

raw_data
```

[2]:
```
      Unnamed: 0    Yr    Mn      Date         Date        CO2  seasonally  \
0              0                                                  adjusted
1              1                   Excel                    [ppm]      [ppm]
2              2  1958    01      21200     1958.0411    -99.99      -99.99
3              3  1958    02      21231     1958.1260    -99.99      -99.99
4              4  1958    03      21259     1958.2027    315.71      314.44
5              5  1958    04      21290     1958.2877    317.45      315.16
```

6	6	1958	05	21320	1958.3699	317.51	314.69
7	7	1958	06	21351	1958.4548	-99.99	-99.99
8	8	1958	07	21381	1958.5370	315.87	315.20
9	9	1958	08	21412	1958.6219	314.93	316.21
10	10	1958	09	21443	1958.7068	313.21	316.11
11	11	1958	10	21473	1958.7890	-99.99	-99.99
12	12	1958	11	21504	1958.8740	313.33	315.21
13	13	1958	12	21534	1958.9562	314.67	315.43
14	14	1959	01	21565	1959.0411	315.58	315.52
15	15	1959	02	21596	1959.1260	316.49	315.84
16	16	1959	03	21624	1959.2027	316.65	315.38
17	17	1959	04	21655	1959.2877	317.72	315.42
18	18	1959	05	21685	1959.3699	318.29	315.46
19	19	1959	06	21716	1959.4548	318.15	316.00
20	20	1959	07	21746	1959.5370	316.54	315.87
21	21	1959	08	21777	1959.6219	314.80	316.09
22	22	1959	09	21808	1959.7068	313.84	316.75
23	23	1959	10	21838	1959.7890	313.33	316.34
24	24	1959	11	21869	1959.8740	314.81	316.69
25	25	1959	12	21899	1959.9562	315.58	316.35
26	26	1960	01	21930	1960.0410	316.43	316.37
27	27	1960	02	21961	1960.1257	316.98	316.33
28	28	1960	03	21990	1960.2049	317.58	316.28
29	29	1960	04	22021	1960.2896	319.03	316.70
..	…	… …	…	…	…	…	
764	764	2021	07	44392	2021.5370	416.65	415.85
765	765	2021	08	44423	2021.6219	414.34	415.89
766	766	2021	09	44454	2021.7068	412.90	416.40
767	767	2021	10	44484	2021.7890	413.55	417.16
768	768	2021	11	44515	2021.8740	414.82	417.08
769	769	2021	12	44545	2021.9562	416.43	417.36
770	770	2022	01	44576	2022.0411	418.01	417.94
771	771	2022	02	44607	2022.1260	418.99	418.21
772	772	2022	03	44635	2022.2027	418.45	416.92
773	773	2022	04	44666	2022.2877	420.02	417.25
774	774	2022	05	44696	2022.3699	420.77	417.36
775	775	2022	06	44727	2022.4548	420.68	418.09
776	776	2022	07	44757	2022.5370	418.68	417.87
777	777	2022	08	44788	2022.6219	416.76	418.31
778	778	2022	09	44819	2022.7068	415.41	418.91
779	779	2022	10	44849	2022.7890	415.31	418.93
780	780	2022	11	44880	2022.8740	417.04	419.31
781	781	2022	12	44910	2022.9562	418.57	419.49
782	782	2023	01	44941	2023.0411	419.24	419.17
783	783	2023	02	44972	2023.1260	420.33	419.55
784	784	2023	03	45000	2023.2027	420.51	418.97
785	785	2023	04	45031	2023.2877	422.73	419.95

786	786	2023	05	45061	2023.3699	423.78	420.36
787	787	2023	06	45092	2023.4548	423.39	420.80
788	788	2023	07	45122	2023.5370	-99.99	-99.99
789	789	2023	08	45153	2023.6219	-99.99	-99.99
790	790	2023	09	45184	2023.7068	-99.99	-99.99
791	791	2023	10	45214	2023.7890	-99.99	-99.99
792	792	2023	11	45245	2023.8740	-99.99	-99.99
793	793	2023	12	45275	2023.9562	-99.99	-99.99

	fit	seasonally	CO2	seasonally	Sta
0		adjusted fit	filled	adjusted filled	NaN
1	[ppm]	[ppm]	[ppm]	[ppm]	NaN
2	-99.99	-99.99	-99.99	-99.99	MLO
3	-99.99	-99.99	-99.99	-99.99	MLO
4	316.19	314.91	315.71	314.44	MLO
5	317.30	314.99	317.45	315.16	MLO
6	317.89	315.07	317.51	314.69	MLO
7	317.27	315.15	317.27	315.15	MLO
8	315.86	315.22	315.87	315.20	MLO
9	313.97	315.29	314.93	316.21	MLO
10	312.44	315.35	313.21	316.11	MLO
11	312.42	315.41	312.42	315.41	MLO
12	313.61	315.46	313.33	315.21	MLO
13	314.77	315.52	314.67	315.43	MLO
14	315.64	315.57	315.58	315.52	MLO
15	316.29	315.63	316.49	315.84	MLO
16	316.98	315.70	316.65	315.38	MLO
17	318.09	315.77	317.72	315.42	MLO
18	318.68	315.85	318.29	315.46	MLO
19	318.07	315.94	318.15	316.00	MLO
20	316.67	316.03	316.54	315.87	MLO
21	314.80	316.13	314.80	316.09	MLO
22	313.30	316.22	313.84	316.75	MLO
23	313.31	316.31	313.33	316.34	MLO
24	314.53	316.40	314.81	316.69	MLO
25	315.72	316.48	315.58	316.35	MLO
26	316.63	316.56	316.43	316.37	MLO
27	317.29	316.64	316.98	316.33	MLO
28	318.03	316.72	317.58	316.28	MLO
29	319.14	316.79	319.03	316.70	MLO
..	…	…	…	… …	
764	416.95	416.18	416.65	415.85	MLO
765	414.78	416.36	414.34	415.89	MLO
766	413.04	416.55	412.90	416.40	MLO
767	413.14	416.74	413.55	417.16	MLO
768	414.69	416.92	414.82	417.08	MLO
769	416.19	417.10	416.43	417.36	MLO

```
770       417.34      417.26      418.01          417.94  MLO
771       418.21      417.42      418.99          418.21  MLO
772       419.11      417.56      418.45          416.92  MLO
773       420.50      417.71      420.02          417.25  MLO
774       421.27      417.86      420.77          417.36  MLO
775       420.60      418.03      420.68          418.09  MLO
776       418.98      418.21      418.68          417.87  MLO
777       416.80      418.40      416.76          418.31  MLO
778       415.07      418.59      415.41          418.91  MLO
779       415.18      418.78      415.31          418.93  MLO
780       416.74      418.98      417.04          419.31  MLO
781       418.27      419.18      418.57          419.49  MKO
782       419.46      419.38      419.24          419.17  MKO
783       420.38      419.59      420.33          419.55  MKO
784       421.34      419.79      420.51          418.97  MLO
785       422.81      420.01      422.73          419.95  MLO
786       423.65      420.23      423.78          420.36  MLO
787       423.03      420.46      423.39          420.80  MLO
788       -99.99      -99.99      -99.99          -99.99  MLO
789       -99.99      -99.99      -99.99          -99.99  MLO
790       -99.99      -99.99      -99.99          -99.99  MLO
791       -99.99      -99.99      -99.99          -99.99  MLO
792       -99.99      -99.99      -99.99          -99.99  MLO
793       -99.99      -99.99      -99.99          -99.99  MLO

[794 rows x 12 columns]
```

1.2 2. Data formatting

The raw data is not ready for analysis. The two first lines are used to comment the rows: - **Line 0:** used to comment the nature of the row - **Line 1:** used to comment the unit of the row

We start by deleting the two lines:

[3]:
```python
raw_data[raw_data.isnull().any(axis=1)]
```

[3]:
```
   Unnamed: 0    Yr   Mn      Date         Date       CO2  seasonally  \
0            0                                                adjusted
1            1                   Excel                   [ppm]      [ppm]

          fit    seasonally          CO2       seasonally  Sta
0              adjusted fit       filled  adjusted filled  NaN
1        [ppm]         [ppm]        [ppm]            [ppm]  NaN
```

[4]:
```python
data = raw_data.dropna().copy()
data
```

```
[4]:       Unnamed: 0    Yr   Mn     Date       Date      CO2 seasonally  \
    2              2  1958   01    21200  1958.0411   -99.99     -99.99
    3              3  1958   02    21231  1958.1260   -99.99     -99.99
    4              4  1958   03    21259  1958.2027   315.71     314.44
    5              5  1958   04    21290  1958.2877   317.45     315.16
    6              6  1958   05    21320  1958.3699   317.51     314.69
    7              7  1958   06    21351  1958.4548   -99.99     -99.99
    8              8  1958   07    21381  1958.5370   315.87     315.20
    9              9  1958   08    21412  1958.6219   314.93     316.21
    10            10  1958   09    21443  1958.7068   313.21     316.11
    11            11  1958   10    21473  1958.7890   -99.99     -99.99
    12            12  1958   11    21504  1958.8740   313.33     315.21
    13            13  1958   12    21534  1958.9562   314.67     315.43
    14            14  1959   01    21565  1959.0411   315.58     315.52
    15            15  1959   02    21596  1959.1260   316.49     315.84
    16            16  1959   03    21624  1959.2027   316.65     315.38
    17            17  1959   04    21655  1959.2877   317.72     315.42
    18            18  1959   05    21685  1959.3699   318.29     315.46
    19            19  1959   06    21716  1959.4548   318.15     316.00
    20            20  1959   07    21746  1959.5370   316.54     315.87
    21            21  1959   08    21777  1959.6219   314.80     316.09
    22            22  1959   09    21808  1959.7068   313.84     316.75
    23            23  1959   10    21838  1959.7890   313.33     316.34
    24            24  1959   11    21869  1959.8740   314.81     316.69
    25            25  1959   12    21899  1959.9562   315.58     316.35
    26            26  1960   01    21930  1960.0410   316.43     316.37
    27            27  1960   02    21961  1960.1257   316.98     316.33
    28            28  1960   03    21990  1960.2049   317.58     316.28
    29            29  1960   04    22021  1960.2896   319.03     316.70
    30            30  1960   05    22051  1960.3716   320.03     317.20
    31            31  1960   06    22082  1960.4563   319.58     317.45
    ..           …   …  …      …         …        …       …
    764          764  2021   07    44392  2021.5370   416.65     415.85
    765          765  2021   08    44423  2021.6219   414.34     415.89
    766          766  2021   09    44454  2021.7068   412.90     416.40
    767          767  2021   10    44484  2021.7890   413.55     417.16
    768          768  2021   11    44515  2021.8740   414.82     417.08
    769          769  2021   12    44545  2021.9562   416.43     417.36
    770          770  2022   01    44576  2022.0411   418.01     417.94
    771          771  2022   02    44607  2022.1260   418.99     418.21
    772          772  2022   03    44635  2022.2027   418.45     416.92
    773          773  2022   04    44666  2022.2877   420.02     417.25
    774          774  2022   05    44696  2022.3699   420.77     417.36
    775          775  2022   06    44727  2022.4548   420.68     418.09
    776          776  2022   07    44757  2022.5370   418.68     417.87
    777          777  2022   08    44788  2022.6219   416.76     418.31
    778          778  2022   09    44819  2022.7068   415.41     418.91
```

779	779	2022	10	44849	2022.7890	415.31	418.93
780	780	2022	11	44880	2022.8740	417.04	419.31
781	781	2022	12	44910	2022.9562	418.57	419.49
782	782	2023	01	44941	2023.0411	419.24	419.17
783	783	2023	02	44972	2023.1260	420.33	419.55
784	784	2023	03	45000	2023.2027	420.51	418.97
785	785	2023	04	45031	2023.2877	422.73	419.95
786	786	2023	05	45061	2023.3699	423.78	420.36
787	787	2023	06	45092	2023.4548	423.39	420.80
788	788	2023	07	45122	2023.5370	-99.99	-99.99
789	789	2023	08	45153	2023.6219	-99.99	-99.99
790	790	2023	09	45184	2023.7068	-99.99	-99.99
791	791	2023	10	45214	2023.7890	-99.99	-99.99
792	792	2023	11	45245	2023.8740	-99.99	-99.99
793	793	2023	12	45275	2023.9562	-99.99	-99.99

	fit	seasonally	CO2	seasonally	Sta
2	-99.99	-99.99	-99.99	-99.99	MLO
3	-99.99	-99.99	-99.99	-99.99	MLO
4	316.19	314.91	315.71	314.44	MLO
5	317.30	314.99	317.45	315.16	MLO
6	317.89	315.07	317.51	314.69	MLO
7	317.27	315.15	317.27	315.15	MLO
8	315.86	315.22	315.87	315.20	MLO
9	313.97	315.29	314.93	316.21	MLO
10	312.44	315.35	313.21	316.11	MLO
11	312.42	315.41	312.42	315.41	MLO
12	313.61	315.46	313.33	315.21	MLO
13	314.77	315.52	314.67	315.43	MLO
14	315.64	315.57	315.58	315.52	MLO
15	316.29	315.63	316.49	315.84	MLO
16	316.98	315.70	316.65	315.38	MLO
17	318.09	315.77	317.72	315.42	MLO
18	318.68	315.85	318.29	315.46	MLO
19	318.07	315.94	318.15	316.00	MLO
20	316.67	316.03	316.54	315.87	MLO
21	314.80	316.13	314.80	316.09	MLO
22	313.30	316.22	313.84	316.75	MLO
23	313.31	316.31	313.33	316.34	MLO
24	314.53	316.40	314.81	316.69	MLO
25	315.72	316.48	315.58	316.35	MLO
26	316.63	316.56	316.43	316.37	MLO
27	317.29	316.64	316.98	316.33	MLO
28	318.03	316.72	317.58	316.28	MLO
29	319.14	316.79	319.03	316.70	MLO
30	319.70	316.87	320.03	317.20	MLO
31	319.04	316.93	319.58	317.45	MLO

```
..          …          …          …        …    …
764        416.95      416.18      416.65      415.85   MLO
765        414.78      416.36      414.34      415.89   MLO
766        413.04      416.55      412.90      416.40   MLO
767        413.14      416.74      413.55      417.16   MLO
768        414.69      416.92      414.82      417.08   MLO
769        416.19      417.10      416.43      417.36   MLO
770        417.34      417.26      418.01      417.94   MLO
771        418.21      417.42      418.99      418.21   MLO
772        419.11      417.56      418.45      416.92   MLO
773        420.50      417.71      420.02      417.25   MLO
774        421.27      417.86      420.77      417.36   MLO
775        420.60      418.03      420.68      418.09   MLO
776        418.98      418.21      418.68      417.87   MLO
777        416.80      418.40      416.76      418.31   MLO
778        415.07      418.59      415.41      418.91   MLO
779        415.18      418.78      415.31      418.93   MLO
780        416.74      418.98      417.04      419.31   MLO
781        418.27      419.18      418.57      419.49   MKO
782        419.46      419.38      419.24      419.17   MKO
783        420.38      419.59      420.33      419.55   MKO
784        421.34      419.79      420.51      418.97   MLO
785        422.81      420.01      422.73      419.95   MLO
786        423.65      420.23      423.78      420.36   MLO
787        423.03      420.46      423.39      420.80   MLO
788        -99.99      -99.99      -99.99      -99.99   MLO
789        -99.99      -99.99      -99.99      -99.99   MLO
790        -99.99      -99.99      -99.99      -99.99   MLO
791        -99.99      -99.99      -99.99      -99.99   MLO
792        -99.99      -99.99      -99.99      -99.99   MLO
793        -99.99      -99.99      -99.99      -99.99   MLO

[792 rows x 12 columns]
```

We now need to convert the data from string to float in order to plot it.

data.keys() gives us the name of each row which allow us to treat the data row by row.

[5]:
```
data.keys()
```

[5]:
```
Index(['Unnamed: 0', '  Yr', ' Mn', '    Date', '      Date', '     CO2',
       'seasonally', '        fit', ' seasonally', '     CO2', ' seasonally',
       ' Sta'],
      dtype='object')
```

[6]:
```
data["      Date"]=[float(element) for element in data['      Date']]
x=data["      Date"]
```

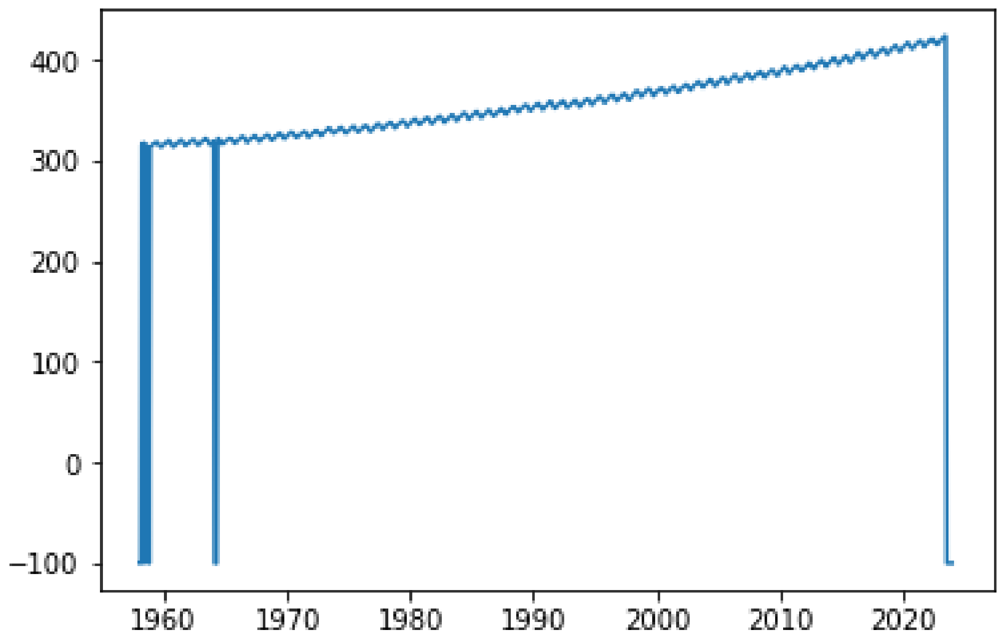
```
data["     CO2"]=[float(element) for element in data['     CO2']]
y=data["     CO2"]
```

1.3 3. Plotting the data

We are now able to plot the CO_2 concentration for every years.

[7]:
```
plt.plot(x,y)
plt.show
```

[7]: <function matplotlib.pyplot.show(*args, **kw)>



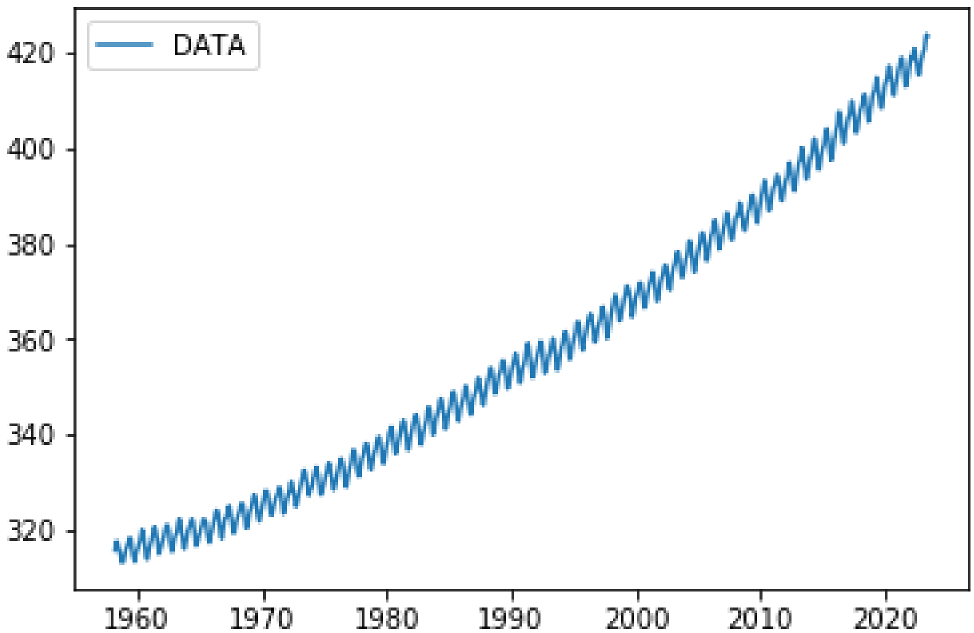
We can see that some missing values are represented by the -99.99 value.

Before we can continue, we need to delete this values:

[8]:
```
def cleandata(element):
    newvalue=element
    if(element==-99.99):
        newvalue=np.nan
    return newvalue

data["     CO2"]=[cleandata(element) for element in data['     CO2']]
datacleaned = data.dropna().copy()
data
```

```
x2=datacleaned["      Date"]
y2=datacleaned["     CO2"]
plt.plot(x2,y2,label="DATA")
plt.legend()
plt.show;
```



1.4 4. Analysis

As shown in the previous plot, we can see a *high* frequency oscillation coupled to a slow increase.

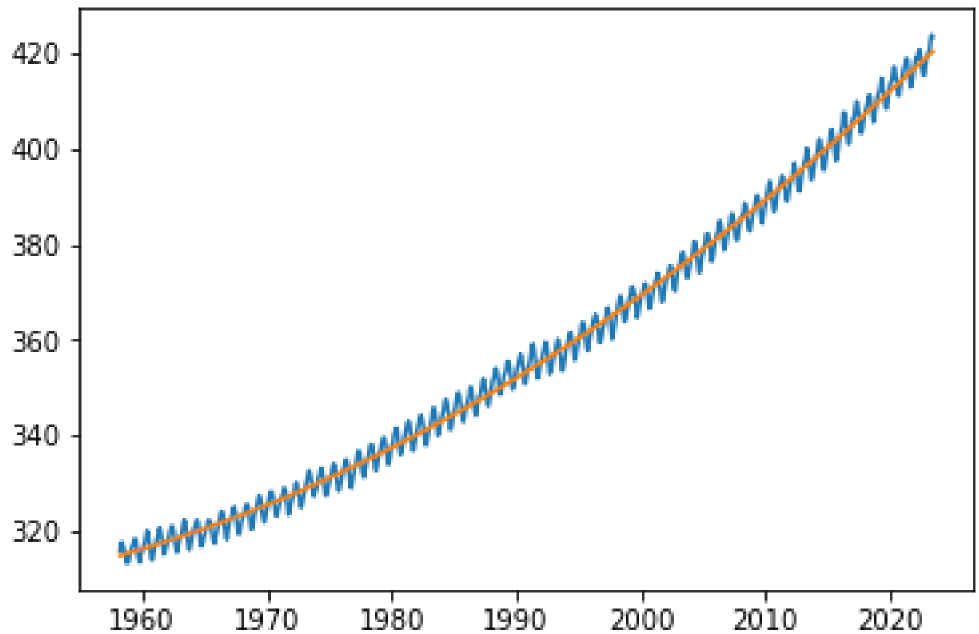
For the analysis, we want to isolate the oscilating contributionn from the continuous curve. For that we **assume** that this slow curve can be described by a square function with three parameters: $f(x) = a.x^2 + b.x + c$

[9]:
```
from scipy.optimize import curve_fit

def fitfunc(x, a, b, c):
    return a*x*x+b*x + c

popt,pcov=curve_fit(fitfunc,x2,y2)
plt.figure()
plt.plot(x2,y2,label="DATA")
plt.plot(x2,fitfunc(x2,*popt),label="Fit")
```

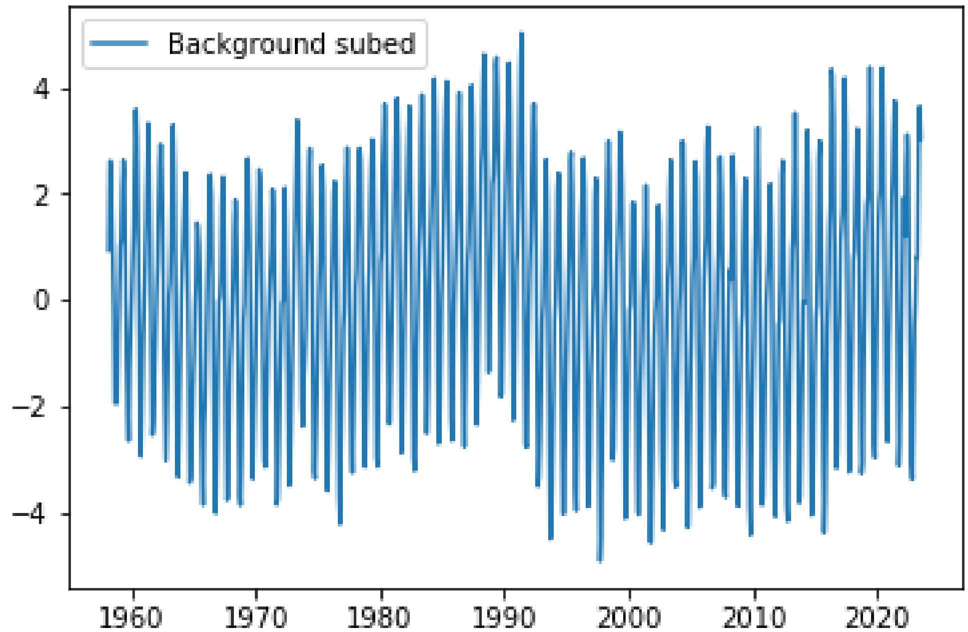
[9]: [<matplotlib.lines.Line2D at 0x7fcf57fe38d0>]



In **first approximation** we can say that this square fit is matching well the experimental data.

We can ensure this claim by isolating the oscilating contribution which should oscilate around 0.

[10]:
```
plt.figure()
plt.plot(x2,y2-fitfunc(x2,*popt),label="Background subed")
plt.legend()
plt.show()
```

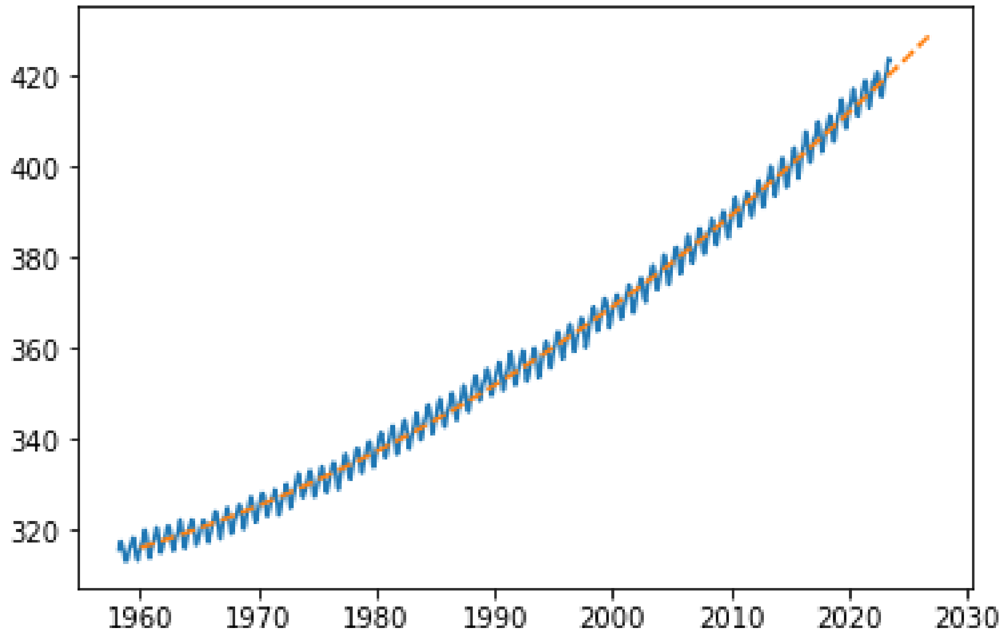


1.5 4. Result of the extrapolation

Now that we are conviced by the x^2 fit, we can extrapolate the data for the year 2025.

[11]:
```
plt.figure()
plt.plot(x2,y2,label="DATA")
plt.plot(np.linspace(1960,2027,200),fitfunc(np.
↪linspace(1960,2027,200),*popt),label="Fit Extrapolation",ls="--")
```

[11]:
```
[<matplotlib.lines.Line2D at 0x7fcf5d6dd518>]
```



The extrapolation would indicate a concentration around 424.246 [**ppm**] in 2025

[ ]:

```

```