```
import pandas as pd
import numpy as np
from datetime import datetime, timedelta
import statsmodels.api as sm
from statsmodels.graphics.api import qqplot
import matplotlib.pyplot as plt
from statsmodels.tsa.holtwinters import ExponentialSmoothing
from statsmodels.nonparametric.smoothers_lowess import lowess
from sklearn.metrics import mean_squared_error, mean_absolute_error

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.animation import FuncAnimation
from IPython.display import HTML

cols = ["year", "month", "frac_date", "mean_spots", "mean_std",
"observations", "definitive"]
data = pd.read_csv("SN_m_tot_V2.0.csv", delimiter=';', names = cols,)
#data.to_csv("sunspot_data", index = False)
samp = data.copy()
data.head(10)
```

	year	month	frac_date	mean_spots	mean_std	observations	definitive
0	1749	1	1749.042	96.7	-1.0	-1	1
1	1749	2	1749.123	104.3	-1.0	-1	1
2	1749	3	1749.204	116.7	-1.0	-1	1
3	1749	4	1749.288	92.8	-1.0	-1	1
4	1749	5	1749.371	141.7	-1.0	-1	1
5	1749	6	1749.455	139.2	-1.0	-1	1
6	1749	7	1749.538	158.0	-1.0	-1	1
7	1749	8	1749.623	110.5	-1.0	-1	1
8	1749	9	1749.707	126.5	-1.0	-1	1
9	1749	10	1749.790	125.8	-1.0	-1	1

```
#function to convert astronomical dates to daily date format
def fraction_year_to_date(fractional_year):
    # Extracting the year
    year = int(fractional_year)
```

```
    # Calculating the remaining fractional part as days
    remaining_fraction = fractional_year - year
    days_in_year = 365 + int(year % 4 == 0 and (year % 100 != 0 or
year % 400 == 0))  # Account for leap year

    # Converting the fractional part to equivalent date
    total_days = int(remaining_fraction * days_in_year)

    # Creating a base date for the year
    base_date = datetime(year, 1, 1)

    # Calculating the target date
    target_date = base_date + timedelta(days=total_days)

    return target_date.strftime("%d-%m-%Y")

#an example
fractional_year = 1749.042
result_date = fraction_year_to_date(fractional_year)
print(f'The date for {fractional_year} is: {result_date}')
```

```
The date for 1749.042 is: 16-01-1749
```

```
dates = list(map(fraction_year_to_date, samp["frac_date"]))
#samp.insert(3,"dates",dates)
samp.head()
```

```
   year  month  frac_date       dates  mean_spots  mean_std
observations  \
0  1749      1   1749.042  16-01-1749        96.7      -1.0
-1
1  1749      2   1749.123  14-02-1749       104.3      -1.0
-1
2  1749      3   1749.204  16-03-1749       116.7      -1.0
-1
3  1749      4   1749.288  16-04-1749        92.8      -1.0
-1
4  1749      5   1749.371  16-05-1749       141.7      -1.0
-1

   definitive
0           1
1           1
2           1
3           1
4           1
```

```
samp.drop(columns=['mean_std','observations', 'definitive'],
inplace=True)
```

```
              year        month    frac_date   mean_spots
count  3300.000000  3300.000000  3300.000000  3300.000000
mean   1886.000000     6.500000  1886.497992    81.773333
std      79.397168     3.452576    79.397664    67.666304
min    1749.000000     1.000000  1749.042000     0.000000
25%    1817.000000     3.750000  1817.769250    24.100000
50%    1886.000000     6.500000  1886.496500    67.550000
75%    1955.000000     9.250000  1955.225000   122.400000
max    2023.000000    12.000000  2023.958000   398.200000
```

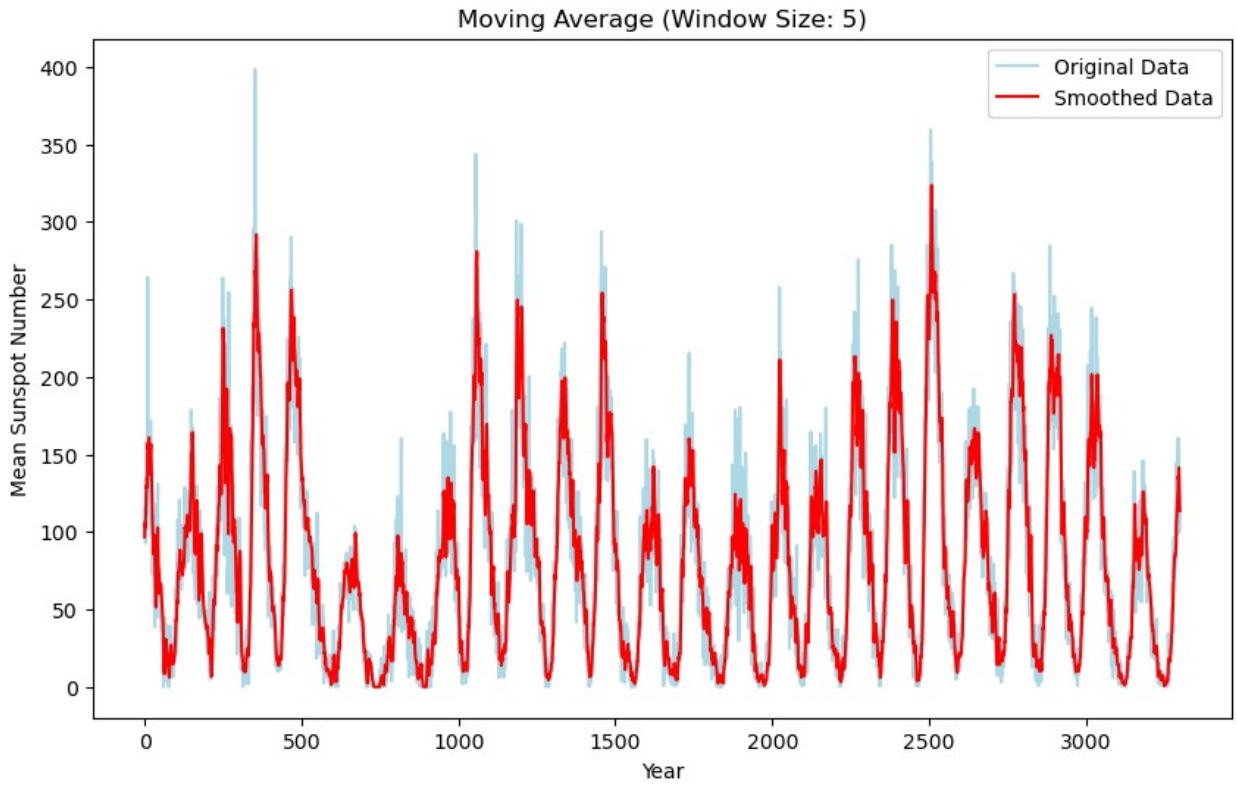
```
samp.head()
```

```
   year  month  frac_date       dates  mean_spots
0  1749      1   1749.042  16-01-1749        96.7
1  1749      2   1749.123  14-02-1749       104.3
2  1749      3   1749.204  16-03-1749       116.7
3  1749      4   1749.288  16-04-1749        92.8
4  1749      5   1749.371  16-05-1749       141.7
```

```
fig, ax = plt.subplots(figsize=(10, 6))

original_line = ax.plot(samp['mean_spots'], label='Original Data',
color='lightblue')

ax.set_title('Moving Average Animation for Sunspot Data')
ax.set_xlabel('Year')
ax.set_ylabel('Mean Sunspot Number')
ax.legend()

# Function to update the plot for each window size
def update_plot(window_size):
    smoothed_data = samp['mean_spots'].rolling(window=window_size,
min_periods=1).mean()
    smoothed_line.set_ydata(smoothed_data)
    ax.set_title(f'Moving Average (Window Size: {window_size})')

# Initialize the smoothed line with the first window size
smoothed_data_init = samp['mean_spots'].rolling(window=5,
min_periods=1).mean()
smoothed_line, = ax.plot(smoothed_data_init, label='Smoothed Data',
color='red')
ax.legend()

# Creating an animation
window_sizes = [5, 10, 12, 15, 20]  # Specify different window sizes
animation = FuncAnimation(fig, update_plot, frames=window_sizes,
interval=1000)

HTML(animation.to_jshtml())
```

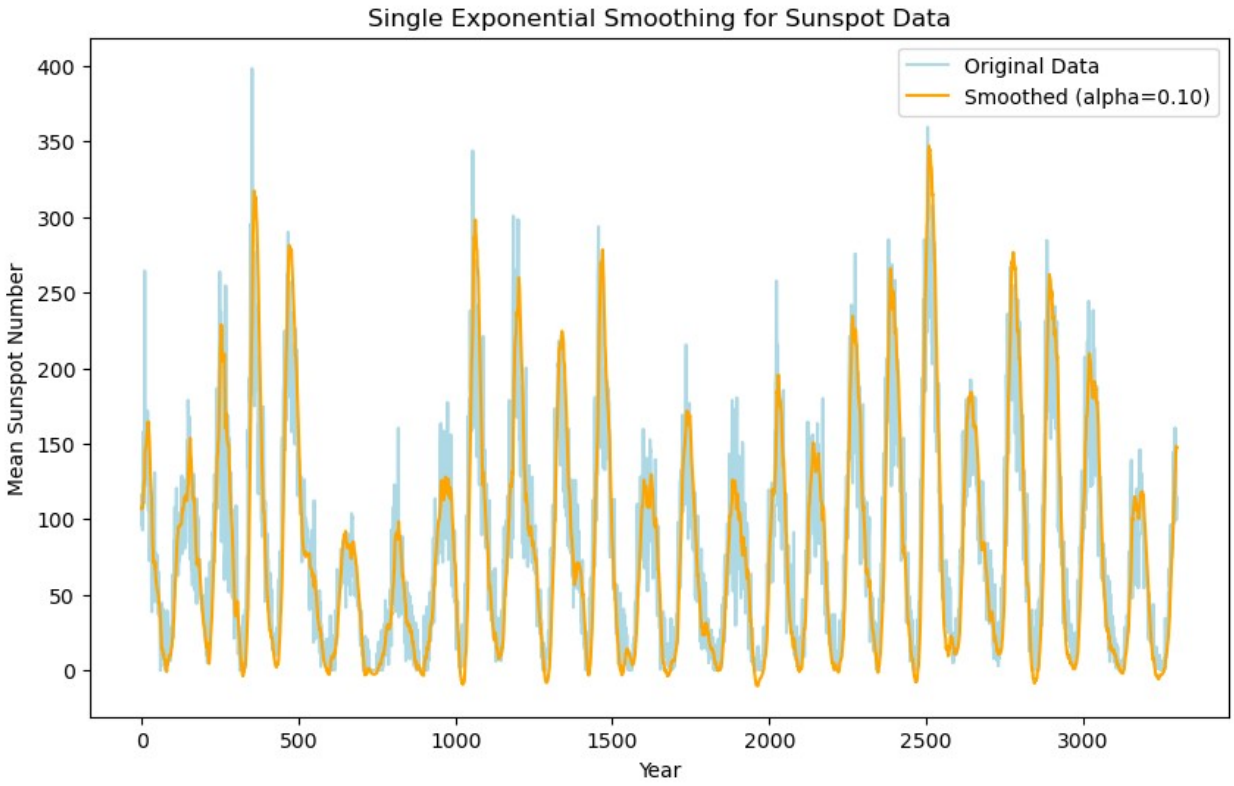
```
#animation.save('moving_average_animation.gif', writer='pillow',
fps=1)
```

```
<IPython.core.display.HTML object>
```




```
fig, ax = plt.subplots(figsize=(10, 6))

def update_plot(constant):
    plt.cla()  # Clear the previous plot
    model = ExponentialSmoothing(samp['mean_spots'], trend='add',
seasonal=None, initialization_method="estimated")
    result = model.fit(smoothing_level=constant)
    samp['Smoothed'] = result.fittedvalues

    plt.plot(samp.index, samp['mean_spots'], label='Original Data',
color='lightblue')
    plt.plot(samp.index, samp['Smoothed'], label=f'Smoothed
(alpha={constant:.2f})', color='orange')

    plt.title('Single Exponential Smoothing for Sunspot Data')
    plt.xlabel('Year')
    plt.ylabel('Mean Sunspot Number')
    plt.legend()

constants = np.arange(0.1, 1.1, 0.1)
```

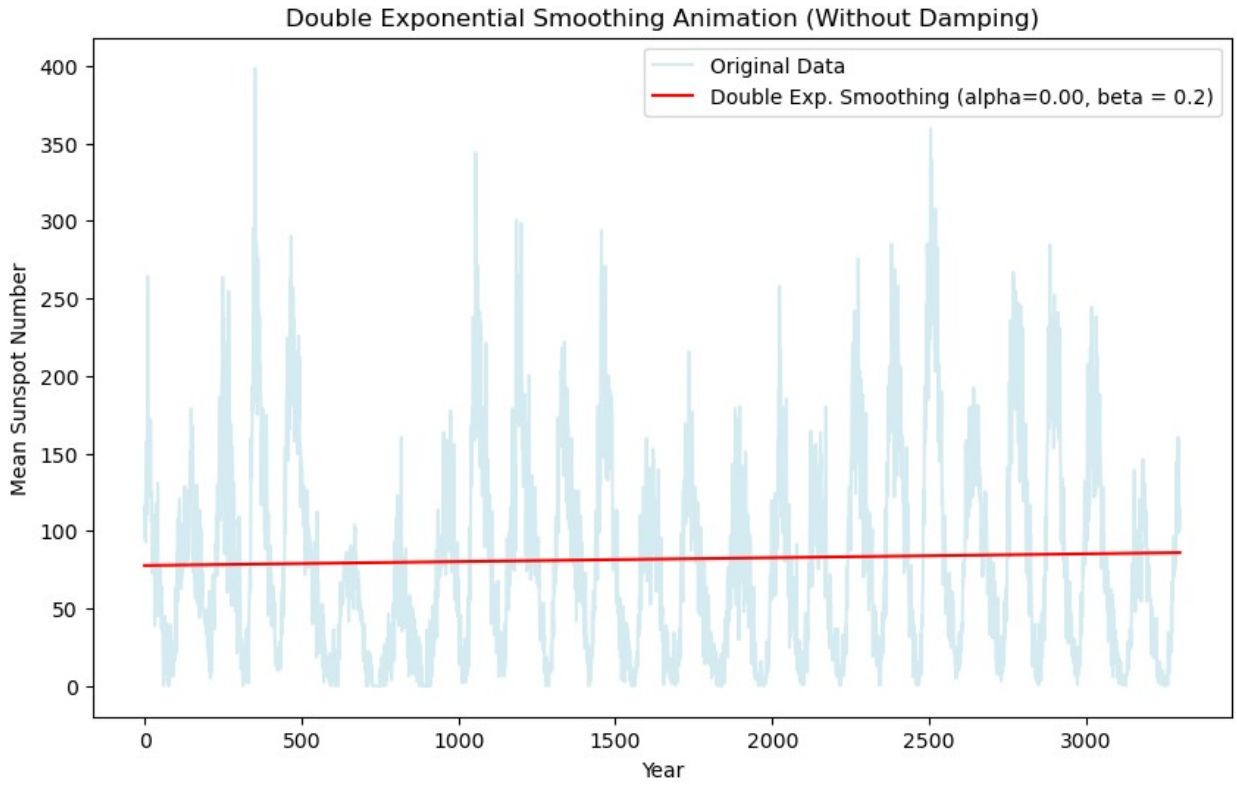
```
animation = FuncAnimation(plt.gcf(), update_plot, frames=constants,
interval=1000)

HTML(animation.to_jshtml())

animation.save('single_exp_smoothing_animation.gif', writer='pillow',
fps=1)
```




```
fig, ax = plt.subplots(figsize=(10, 6))
ax.plot(samp['mean_spots'], label='Original Data')
ax.set_title('Double Exponential Smoothing Animation (Without
Damping)')
ax.set_xlabel('Year')
ax.set_ylabel('Mean Sunspot Number')
ax.legend()

def update(frame):
    ax.clear()
    alpha = frame / 100.0  # Adjust the range of alpha as needed
    beta = 0.2  # You can adjust beta as needed

    model_double_exp = ExponentialSmoothing(samp['mean_spots'],
trend='add', seasonal=None)
    result_double_exp = model_double_exp.fit(smoothing_level=alpha,
smoothing_trend=beta)
```

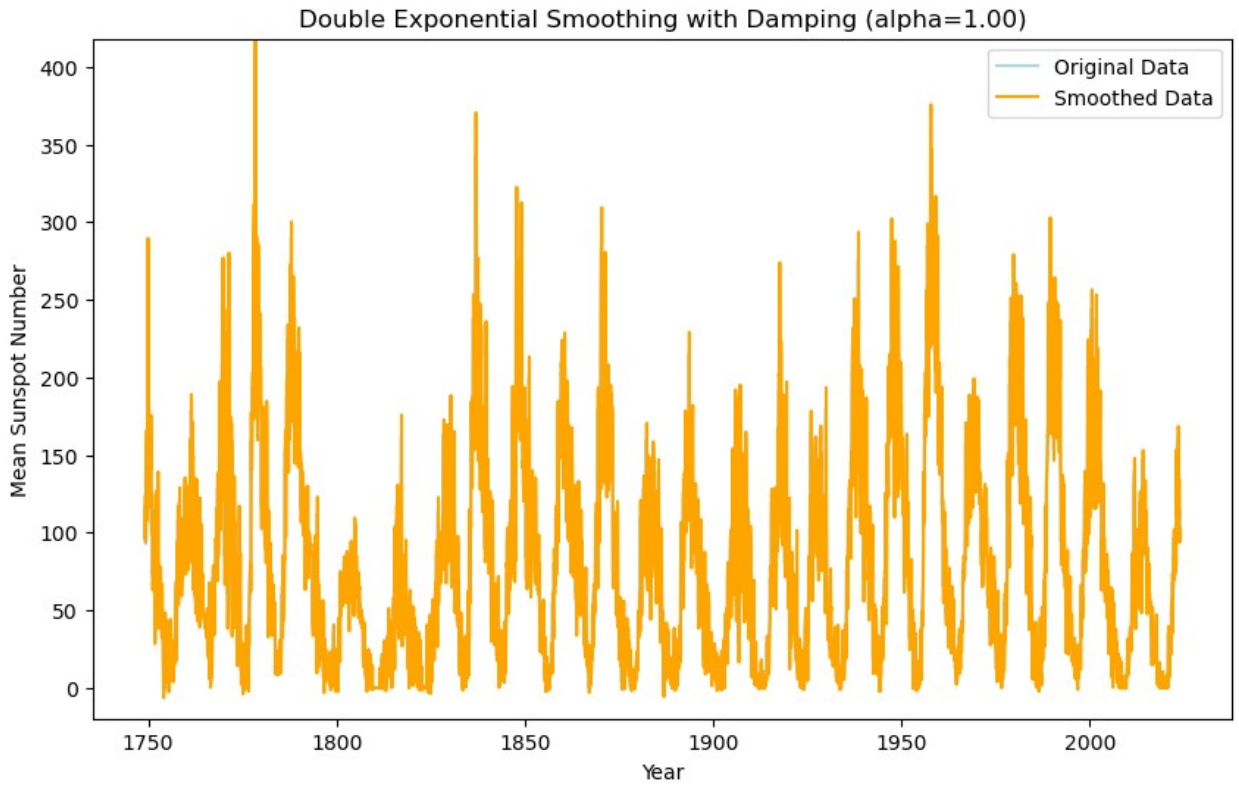
```
    samp['Double_Exp_Smooth'] = result_double_exp.fittedvalues

    ax.plot(samp['mean_spots'], label='Original Data',
color='lightblue', alpha=0.5)
    ax.plot(samp['Double_Exp_Smooth'], label=f'Double Exp. Smoothing
(alpha={alpha:.2f}, beta = 0.2)', color='red')
    ax.set_title('Double Exponential Smoothing Animation (Without
Damping)')
    ax.set_xlabel('Year')
    ax.set_ylabel('Mean Sunspot Number')
    ax.legend()


animation = FuncAnimation(fig, update, frames=np.arange(0, 101, 5),
interval=500)

animation.save('double_exp_smooth_no_damping_animation.gif',
writer='pillow')


HTML(animation.to_jshtml())
```

```
<IPython.core.display.HTML object>
```



```
fig, ax = plt.subplots(figsize=(10, 6))
line_original, = ax.plot(samp['frac_date'], samp['mean_spots'],
label='Original Data', color='lightblue')
line_smoothed, = ax.plot([], [], label='Smoothed Data',
color='orange')
ax.set_title('Double Exponential Smoothing with Damping')
ax.set_xlabel('Year')
ax.set_ylabel('Mean Sunspot Number')
ax.legend()

def update(frame):
    alpha = frame/ 100.0  # Adjust the step size for different values
of alpha
    beta = 0.2  # Smoothing parameter for trend
    phi = 0.9  # Damping factor

    model_double_exp = ExponentialSmoothing(samp['mean_spots'],
trend='add', seasonal=None, damped_trend=True)
    result_double_exp = model_double_exp.fit(smoothing_level=alpha,
smoothing_trend=beta, damping_trend=phi)

    samp['Double_Exp_Smooth'] = result_double_exp.fittedvalues

    line_smoothed.set_data(samp['frac_date'],
samp['Double_Exp_Smooth'])
    ax.set_title(f'Double Exponential Smoothing with Damping
(alpha={alpha:.2f})')

    return line_smoothed,

num_frames =np.arange(0, 101, 5)

animation = FuncAnimation(fig, update, frames=num_frames,
interval=500, blit=True)

animation.save('double_exp_smoothing_damping_animation.gif',
writer='pillow')

HTML(animation.to_jshtml())
```

```
<IPython.core.display.HTML object>
```




```
alpha = 0.2  # Smoothing parameter for level
beta = 0.2   # Smoothing parameter for trend
gamma = 0.2  # Smoothing parameter for seasonality

def update_plot(frame):
    alpha = frame / 100.0
    model = ExponentialSmoothing(samp['mean_spots'], trend='add',
seasonal='add', seasonal_periods=12)
    result = model.fit(smoothing_level=alpha, smoothing_trend=alpha,
smoothing_seasonal=gamma)
    samp['Triple_Exp_Smooth'] = result.fittedvalues

    ax.clear()
    ax.plot(samp.index, samp['mean_spots'], label='Original
Data',color='lightblue')
    ax.plot(samp.index, samp['Triple_Exp_Smooth'], label=f'Triple
Exponential Smoothing (alpha={alpha:.2f}, beta = {alpha:.2f}, gamma =
0.2)')
    ax.set_title('Triple Exponential Smoothing Animation')
    ax.set_xlabel('Year')
    ax.set_ylabel('Mean Sunspot Number')
    ax.legend()

fig, ax = plt.subplots(figsize=(10, 6))
animation = FuncAnimation(fig, update_plot, frames=np.arange(0, 101,
```

```
10), interval=500)


animation.save('triple_exponential_smoothing_animation.gif',
writer='pillow')
```

```
C:\Users\Lakshya Singh\anaconda3\Lib\site-packages\statsmodels\tsa\
holtwinters\model.py:915: ConvergenceWarning: Optimization failed to
converge. Check mle_retvals.
  warnings.warn(
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  warnings.warn(
```

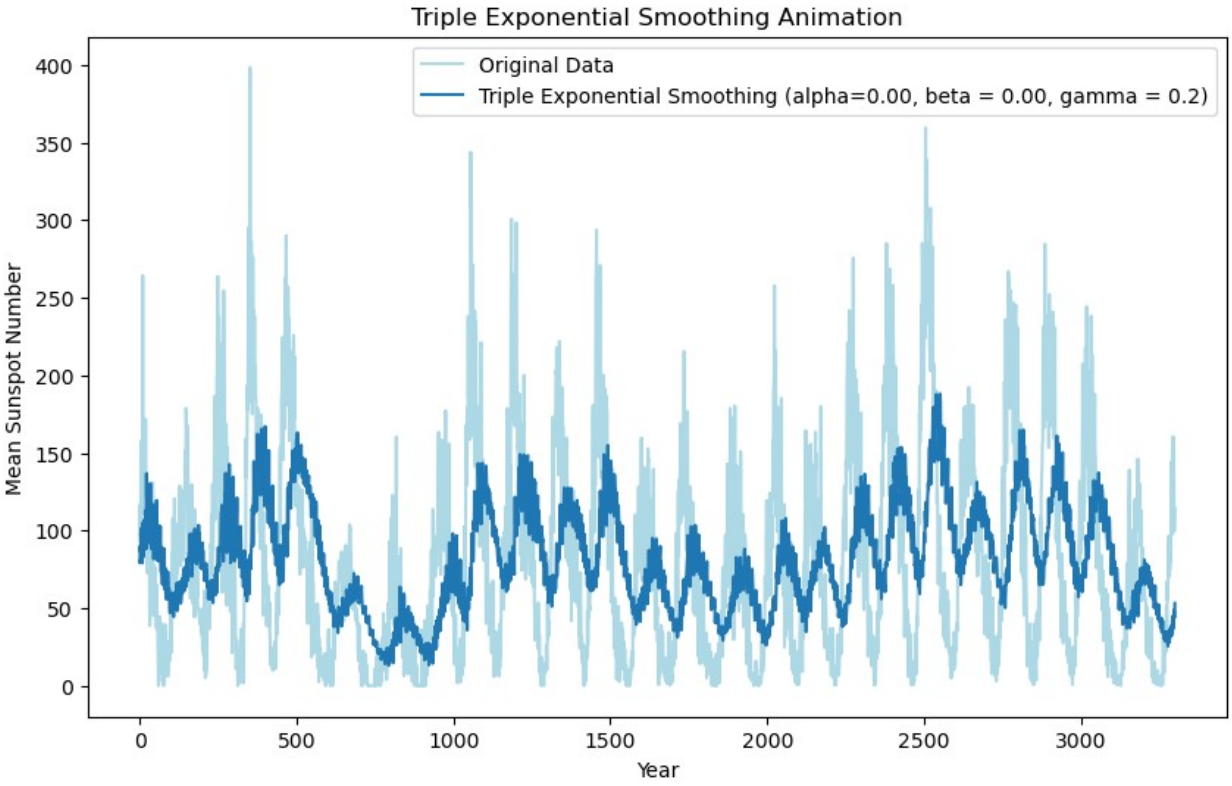
Triple Exponential Smoothing Animation
Original Data
Triple Exponential Smoothing (alpha=0.00, beta = 0.00, gamma = 0.2)
Mean Sunspot Number
Year
0
50
100
150
200
250
300
350
400
0
500
1000
1500
2000
2500
3000