Trend Analysis of Climate in Norway

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0.1 Introduction

Climate is an important element of most people's daily lives since it affects every sector of society. Precise weather forecast can increase productivity of people and businesses. The science of weather prediction has progressed a lot, with new satellites being sent into space every day. However, it is not as accurate and precise as we want it to be. So, there is room for further research into the subject.

Weather in Norway is unpredictable due to varying topography – it has long coastlines and wide mountain ranges. So that, over the centuries, Norwegians have considered weather conditions and have adapted to weather variability. Like the rest of the world, the Norwegian climate has become warmer. Global warming has affected all continents and oceans.

There are many factors that describe the weather conditions. Among them, temperature and precipitation are considered in most of the climate studies. Temperature affects humidity which in turn, affects the potential for rain falls. The interaction of these factors also directly affects the health of humans. Hence, we chose temperature and precipitation datasets to analyze climate trends.

All in all, further research is important to find patterns to make a precise prediction. Here, we look at historical data of temperature and precipitation which is important to predict future trends. We also look at the differences between the major cities, as well as comparing with global CO2 emissions. In addition, we investigated the number of reported disasters worldwide.

0.2 Methods

We decided to analyze four Norwegian cities in the trend analysis. We chose Oslo, Bergen, Trondheim and Tromsø. They all had consistent temperature and precipitation measurements from 1960-2018. They are also spread out in different parts of the country, allowing us to look at regional differences.

All temperature and precipitation data was downloaded from the Norwegian Meteorological agency website: http://eklima.met.no
Data for global CO2 emissions was downloaded from the world bank: https://data.worldbank.org/indicator/EN.ATM.CO2E.KT
Data for natural disasters was downloaded from The International Disaster Database: http://www.emdat.be

Inital data cleaning was done directly in excel. We then loaded data into python and used the python libraries numpy and pandas for data transformation. We performed regression with scikit learn, and visualized the data with matplotlib.

We also made maps to illustrate regional weather differences in Norway. These maps were made with the Geographical Information System (GIS) software ArcGIS Pro.

0.3 Data import, cleaning and transformation

We read the excel files, append the files into a single table. Then, we average 3 months data to come to a seasonal average.

[2]:
```
%%javascript
IPython.OutputArea.prototype._should_scroll = function(lines){return false;}
```

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

[3]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.linear_model import LinearRegression
from scipy.interpolate import make_interp_spline

# Import data
temp_oslo = pd.read_excel('Monthly_values_1960_2018_Temperature_Oslo_Blindern.
 ↪xlsx');temp_oslo['City']="Oslo";temp_oslo['Parameter']="Tmp"
temp_bergen = pd.read_excel('Monthly_values_1960_2018_Temperature_Bergen_Florida.
 ↪xlsx');temp_bergen['City']="Bergen";temp_bergen['Parameter']="Tmp"
temp_trondheim = pd.
 ↪read_excel('Monthly_values_1960_2018_Temperature_Trondheim_Vaernes.xlsx');
 ↪temp_trondheim['City']="Trondheim";temp_trondheim['Parameter']="Tmp"
temp_tromso = pd.read_excel('Monthly_values_1960_2018_Temperature_Tromso.xlsx');
 ↪temp_tromso['City']="Tromso";temp_tromso['Parameter']="Tmp"
```

[4]:
```
precip_oslo = pd.
 ↪read_excel('Monthly_values_1960_2018_Precipitation_Oslo_Blindern.xlsx');
 ↪precip_oslo['City']="Oslo";precip_oslo['Parameter']="Pptn"
precip_bergen = pd.read_excel('Monthly_values_1960_2018_Precipitation_Bergen.
 ↪xlsx');precip_bergen['City']="Bergen";precip_bergen['Parameter']="Pptn"
precip_trondheim = pd.
 ↪read_excel('Monthly_values_1960_2018_Precipitation_Trondheim_Vaernes.xlsx');
 ↪precip_trondheim['City']="Trondheim";precip_trondheim['Parameter']="Pptn"
precip_tromso = pd.read_excel('Monthly_values_1960_2018_Precipitation_Tromso.
 ↪xlsx');precip_tromso['City']="Tromso";precip_tromso['Parameter']="Pptn"

emissions_global = pd.read_excel('global_co2_total_emissions.xlsx')
natDis=pd.read_csv("natural-disasters-by-type.csv", index_col='Year')

dataset=pd.
 ↪concat([temp_oslo,temp_bergen,temp_trondheim,temp_tromso,precip_oslo,precip_bergen,precip_tro

dataset['Winter'] = (dataset['Dec'] + dataset['Jan'] + dataset['Feb'])/3
```

```
dataset['Spring'] = (dataset['Mar'] + dataset['Apr'] + dataset['May'])/3
dataset['Summer'] = (dataset['Jun'] + dataset['Jul'] + dataset['Aug'])/3
dataset['Autumn'] = (dataset['Sep'] + dataset['Oct'] + dataset['Nov'])/3
```

A look at snippet of the final table:

[5]:
```
dataset.head()
```

[5]:
```
   St.no  Year  Jan  Feb  Mar  Apr   May   Jun   Jul   Aug   Sep  Oct  Nov  \
0  18700  1960 -4.0 -6.5  1.1  5.3  12.3  16.1  15.0  14.9  11.3  4.2  0.8
1  18700  1961 -4.8 -1.5  3.2  5.9  10.6  15.6  16.3  14.1  12.5  9.7  2.0
2  18700  1962 -2.5 -1.0 -4.0  4.8   8.3  13.3  14.7  13.1  10.4  7.1 -0.1
3  18700  1963 -8.6 -8.4 -3.3  4.0  10.7  16.1  16.2  15.0  11.0  7.0  1.3
4  18700  1964 -2.6 -3.3 -0.3  5.8  11.3  13.2  14.3  14.7  10.7  5.6  1.2

   Dec  City Parameter    Winter    Spring     Summer    Autumn
0 -1.4  Oslo       Tmp -3.966667  6.233333  15.333333  5.433333
1 -5.5  Oslo       Tmp -3.933333  6.566667  15.333333  8.066667
2 -6.3  Oslo       Tmp -3.266667  3.033333  13.700000  5.800000
3 -3.9  Oslo       Tmp -6.966667  3.800000  15.766667  6.433333
4 -3.0  Oslo       Tmp -2.966667  5.600000  14.066667  5.833333
```

0.4 Function for plotting trend graphs

[6]:
```
def plot_spline_line( Season, Weather):
    list_city={'Oslo':'r','Bergen':'orange','Trondheim':'dodgerblue','Tromso':
 ↪'limegreen'}
    plt.figure(figsize=(12,6))
    for City, Color in list_city.items():
        filter=  (dataset['City']==City) &   (dataset['Parameter']==Weather)
        rValues=dataset[['Year',Season]][filter]
        rValues.columns=['Year','Measure']
        regLine = LinearRegression().fit( np.asarray(rValues['Year']).
 ↪reshape(-1,1), np.asarray(rValues['Measure']) )

        Years_new = np.linspace(rValues['Year'].min(), rValues['Year'].max(),␣
 ↪400)

        Values_smooth = make_interp_spline(rValues['Year'], rValues['Measure'],␣
 ↪k=3)(Years_new)
        plt.plot(Years_new, Values_smooth, Color)
        plt.plot(rValues['Year'], regLine.predict(np.asarray(rValues['Year']).
 ↪reshape(-1,1)), Color, linestyle='--',label='_nolegend_')

    plt.xlabel("Year",fontsize=16); plt.ylabel("Degrees celcius" if␣
 ↪Weather=="Tmp" else "mm",fontsize=16)
```

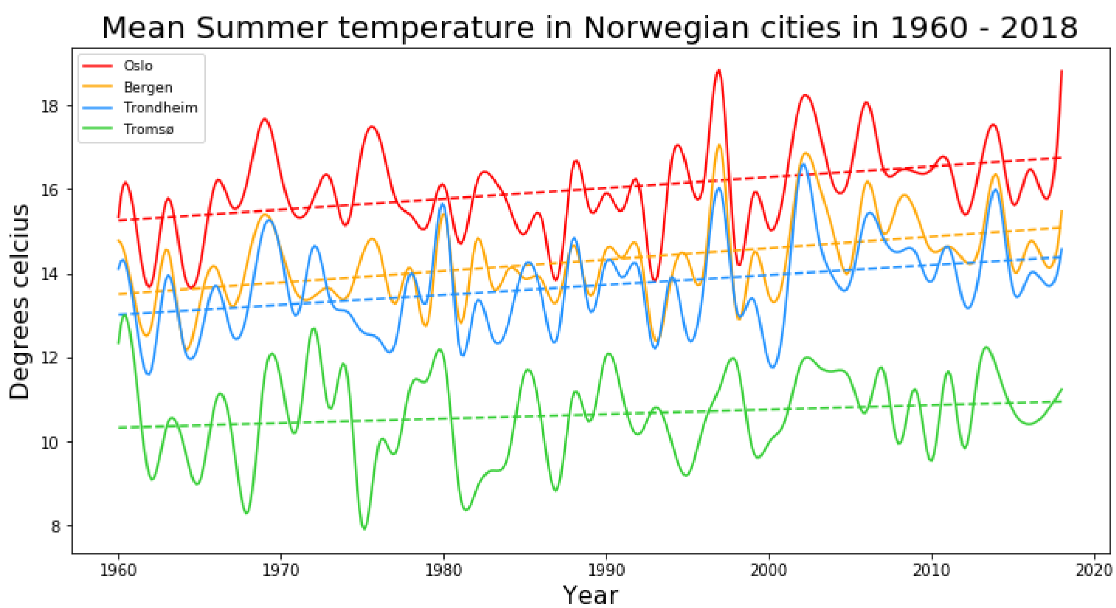
```
    plt.title("Mean "+Season+" temperature in Norwegian cities in 1960 - 2018"␣
↪if Weather=="Tmp" else Season+" precipitation in Norwegian cities in 1960 -␣
↪2018", fontsize=20)
    plt.legend(['Oslo', 'Bergen', 'Trondheim', 'Tromsø'], prop={'size': 9},␣
↪loc=2)
```

0.5 Results

We plot the trend graphs one season at a time. All 4 cities are plotted in the same graph.

0.5.1 Summer temperature:

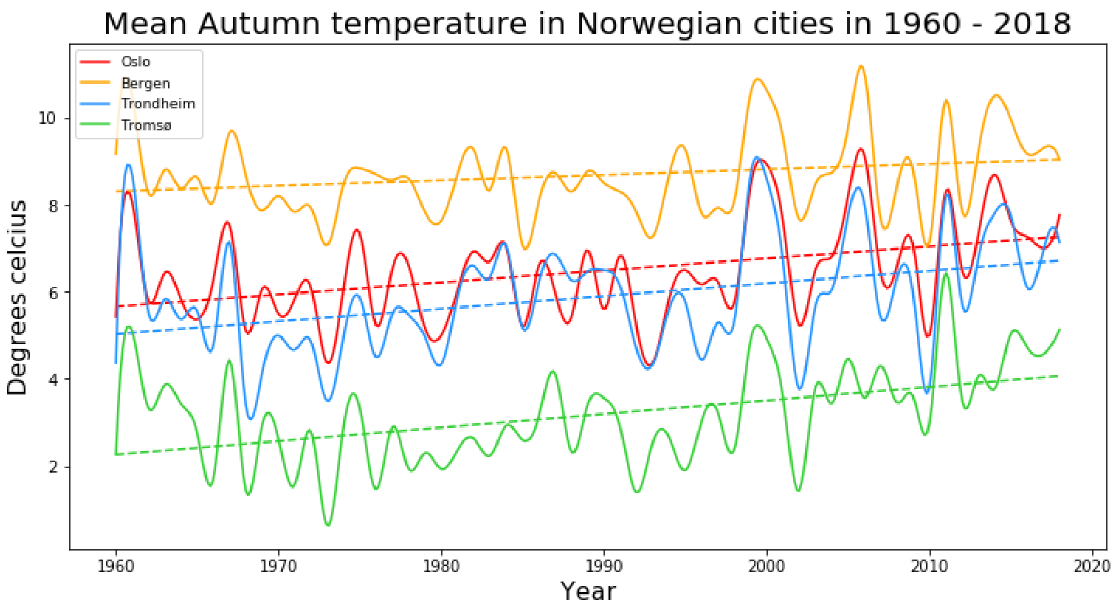
[7]:
```
plot_spline_line("Summer","Tmp")
```



Here we see a rise in temperature in all four cities in summer, as shown by the dotted lines, which are the estimated regression lines based on the data of the same color. Tromsø had less increase in temperature than the other cities. Tromsø is also clealy the coldest of these cities in summer.

0.5.2 Autumn temperature:

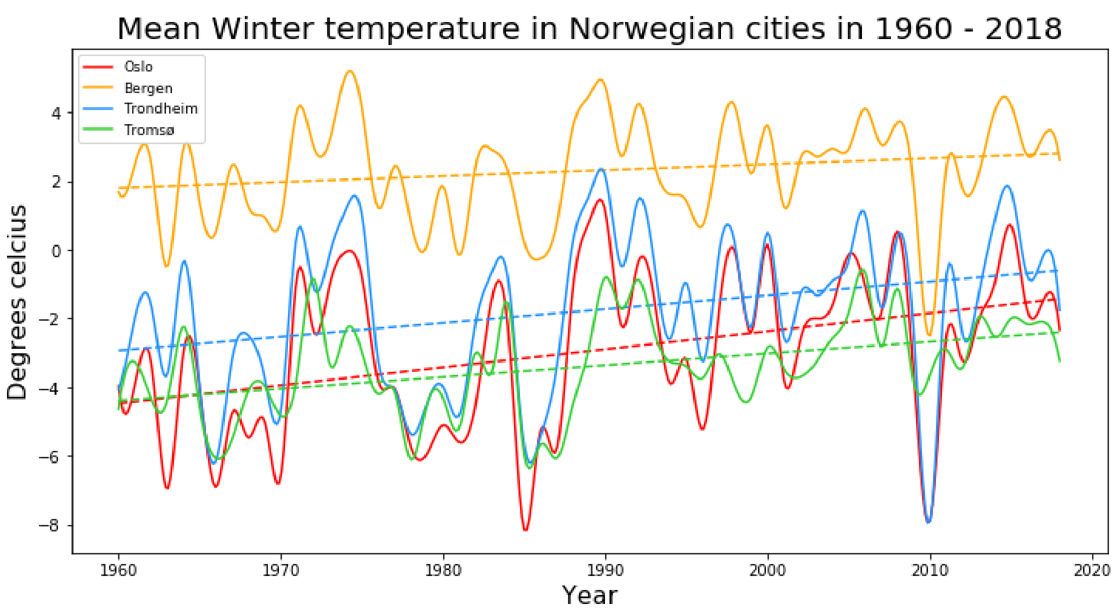
[8]:
```
plot_spline_line("Autumn","Tmp")
```



In autumn we also see an increase in temperature in all four cities. Bergen is the warmest city of these four in autumn, as opposed to Oslo which was the warmest in summer. Tromsø is the coldest city in autumn.

0.5.3 Winter temperature:

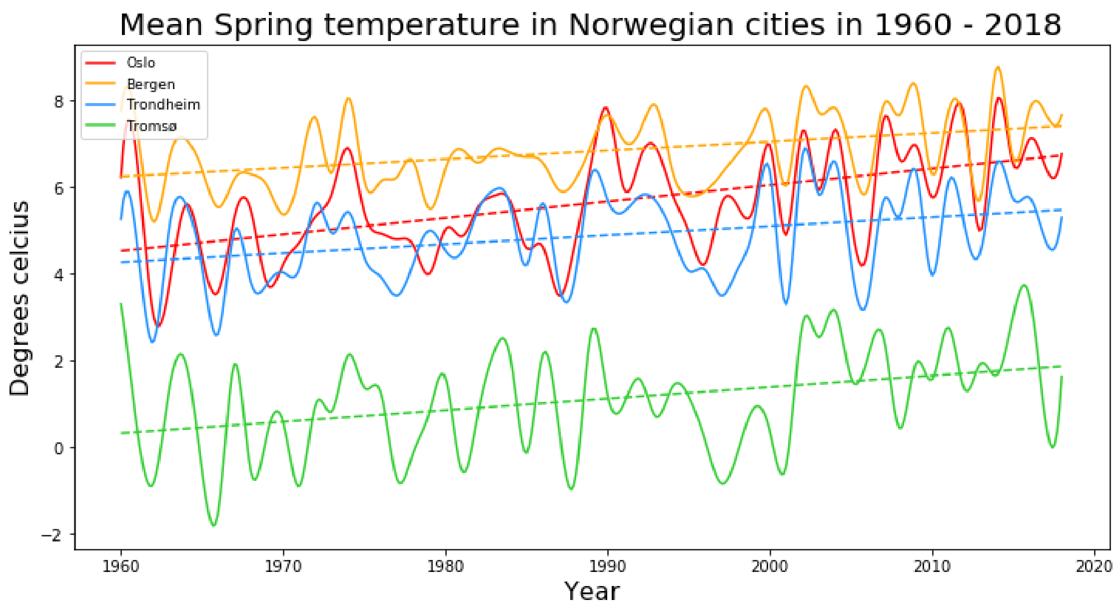
[9]:
```
plot_spline_line("Winter","Tmp")
```



In winter we also see an increase in temperature in all four cities. Bergen is the mildest city in winter, rarely any years with mean temperature below 0 degrees. Although Bergen seems to be the city with the least temperature rise in winter. Oslo has increased more than Tromsø in this period, around 1960 they started at roughly the same temperature, while now Oslo is significantly warmer.

0.5.4 Spring temperature:

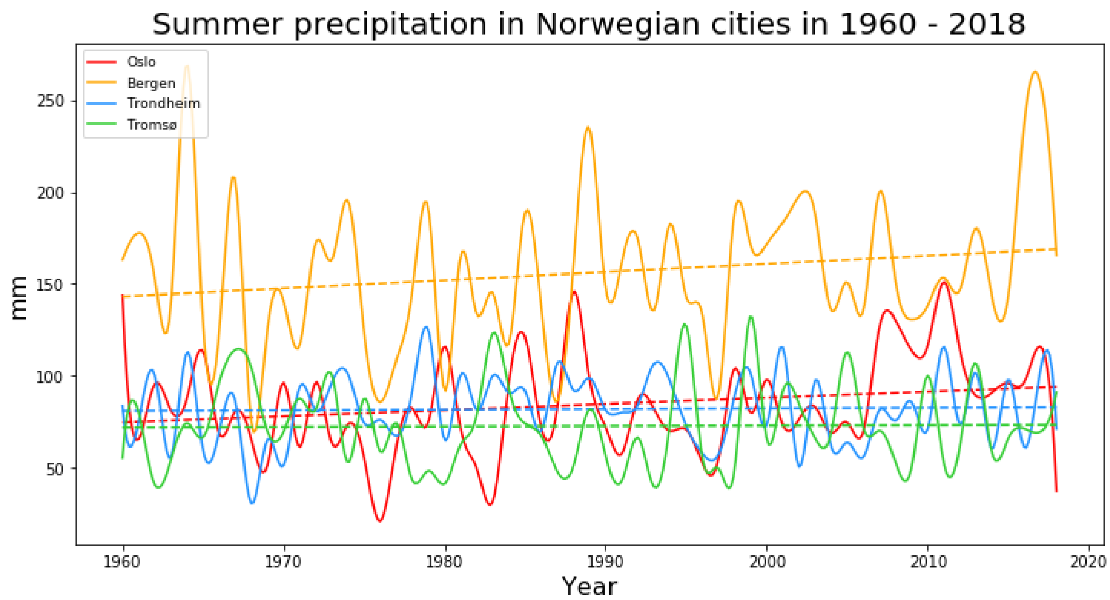
[10]:
```
plot_spline_line("Spring","Tmp")
```



In spring we also see an increase in temperature. Bergen is the warmest in spring, and Tromsø is the coldest.

0.5.5 Summer precipitation:

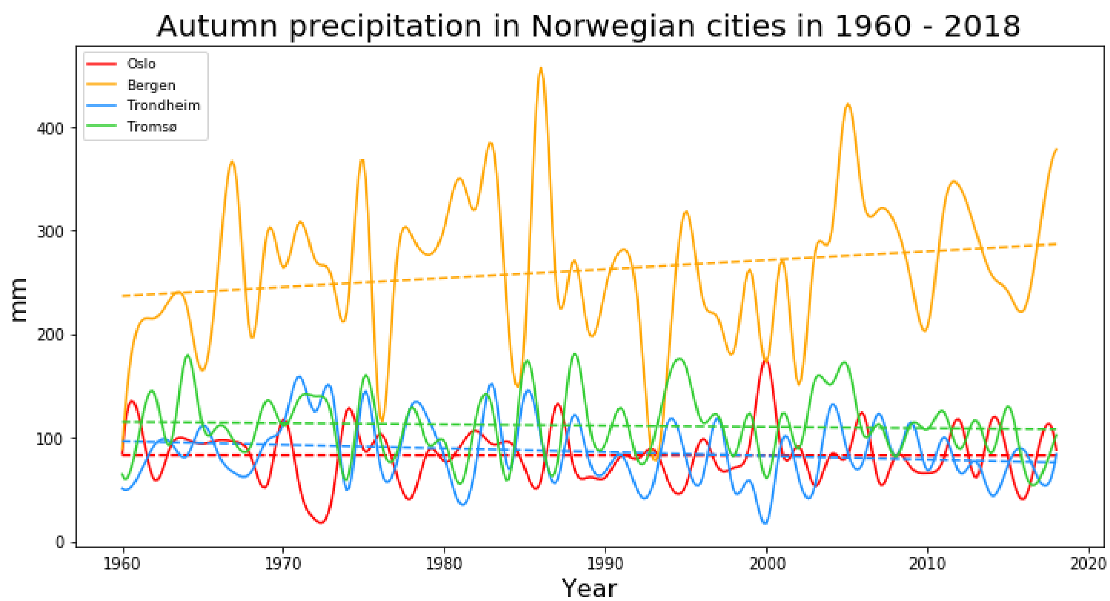
[11]:
```
plot_spline_line("Summer","Pptn")
```



We can see here that Bergen clearly has more precipitation than the other cities in summer. Precipitation is also increasing in all four cities, Bergen with the biggest increase.

0.5.6 Autumn precipitation:

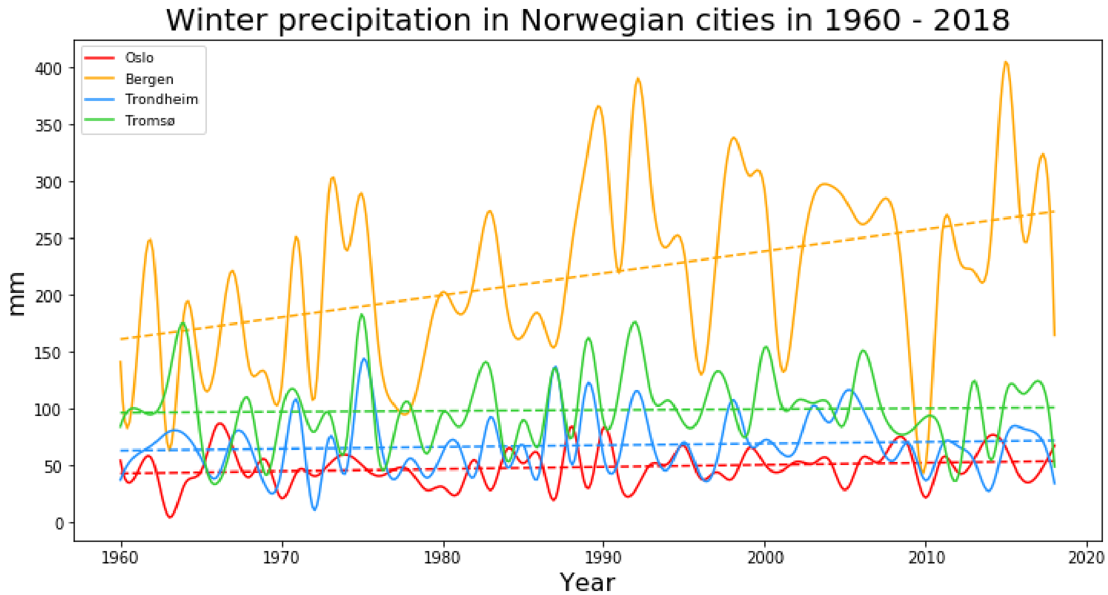
[12]:
```
plot_spline_line("Autumn","Pptn")
```



In autumn, we see much of the same as in summer, except that precipitation is slowly decreasing in Oslo, Trondheim and Tromsø.

0.5.7 Winter precipitation:

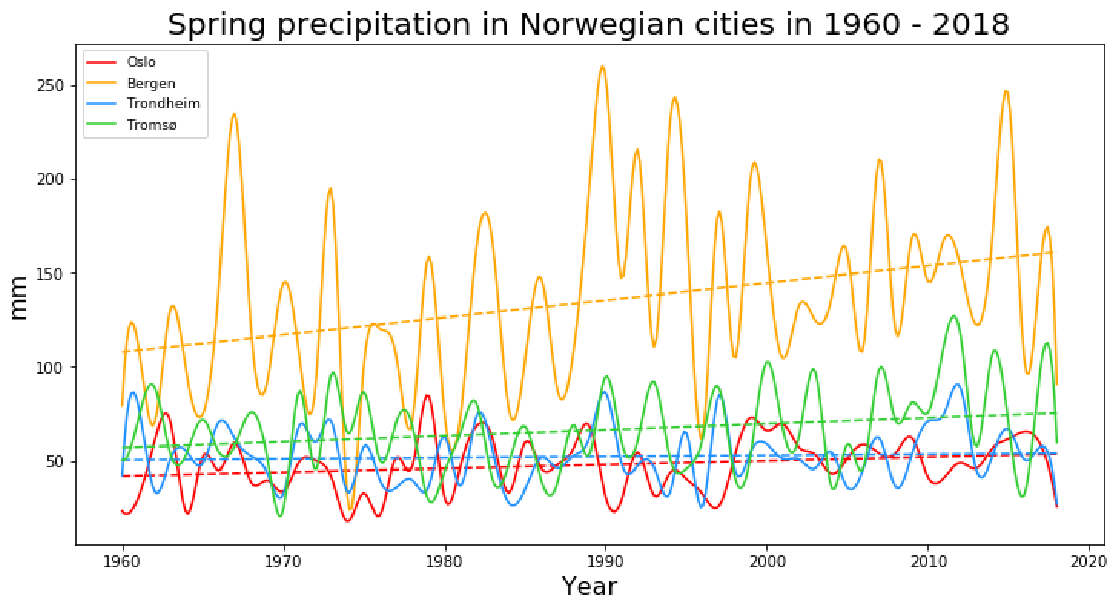
[13]:
```
plot_spline_line("Winter","Pptn")
```



In winter, Bergen has had an extreme increase in precipitation compared to the other cities. We are not able to explain why Bergen has had such a big increase compared to the other cities here. It's special geographic posistion on the western coast of Norway may cause this increase. BUt this needs to be investigated further by climate scientists.

0.5.8 Spring precipitation:

[14]:
```
plot_spline_line("Spring","Pptn")
```



In spring we also see that Bergen has the most precipitation, and is increasing much faster than the other cities.

0.5.9 Global Carbon Emissions

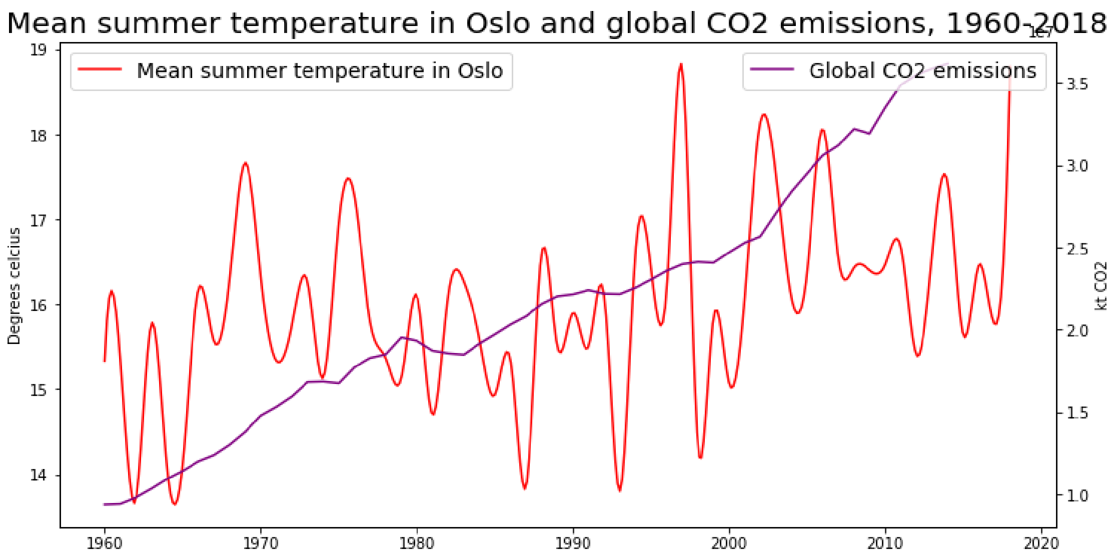
Here we compare mean summer temperature in Oslo to global CO2 emissions. We used a dual axis plot to see the correlation.

[74]:
```
Years=pd.unique( dataset['Year'].values)
TempValues_oslo = dataset['Summer'] [( dataset['City']=="Oslo") &␣
↪(dataset['Parameter']=="Tmp" ) ].values
Years_new = np.linspace(Years.min(), Years.max(), 400)
fig, ax1 = plt.subplots(figsize=(12,6))
ax2 = ax1.twinx()

TempValues_oslo_smooth = make_interp_spline(Years, TempValues_oslo,␣
↪k=3)(Years_new)

ax1.plot(Years_new, TempValues_oslo_smooth, 'r')
ax2.plot(emissions_global['Year'], emissions_global['CO2'], 'Purple')

ax1.set_ylabel('Degrees celcius')
ax2.set_ylabel('kt CO2')
plt.title('Mean summer temperature in Oslo and global CO2 emissions, 1960-2018',␣
↪fontsize=20)
ax1.legend(['Mean summer temperature in Oslo'], prop={'size': 14}, loc=2)
ax2.legend(['Global CO2 emissions'], prop={'size': 14}, loc=1)
plt.show()
```



The plot shows some correlation between the mean summer temperature in Oslo and global CO2 emissions. The correlation is not perfect. Climate and temperature is an extremely complicated process afftected by many different processes which leads to large yearly variation. Another explanation could be that it takes some time to see the effects of climate gases in temperature rise.

0.5.10 Trend of natural disasters globally

We investigated the number of reported natural disasters since the last century.

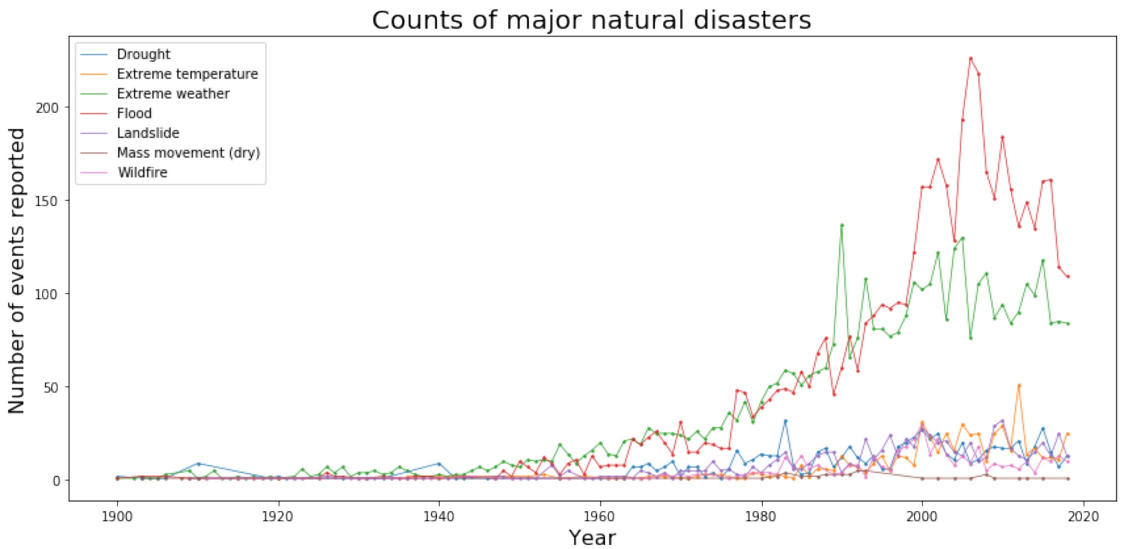
[75]:
```
natDis=pd.read_csv("natural-disasters-by-type.csv", index_col='Year')

natDis.columns=['Entity', 'Code','Reported_Disasters']
natDis.head()

names=np.unique(natDis['Entity']).tolist()

natDis['Entity'].value_counts()
Ignore=['All natural disasters', 'Earthquake', 'Impact', 'Volcanic activity']

list = [x for x in names if x not in Ignore]
plt.figure(figsize=(12,6))
for i in list:
    data=natDis[ natDis['Entity']==i ]
    plt.tight_layout()
    plt.plot( data['Reported_Disasters'],lw=0.7)
    plt.scatter(data.index,data['Reported_Disasters'],s=2)
    plt.legend(list)
    plt.xlabel("Year",fontsize=16); plt.ylabel("Number of events␣
 ↪reported",fontsize=16)
    plt.title("Counts of major natural disasters", fontsize=20)
```



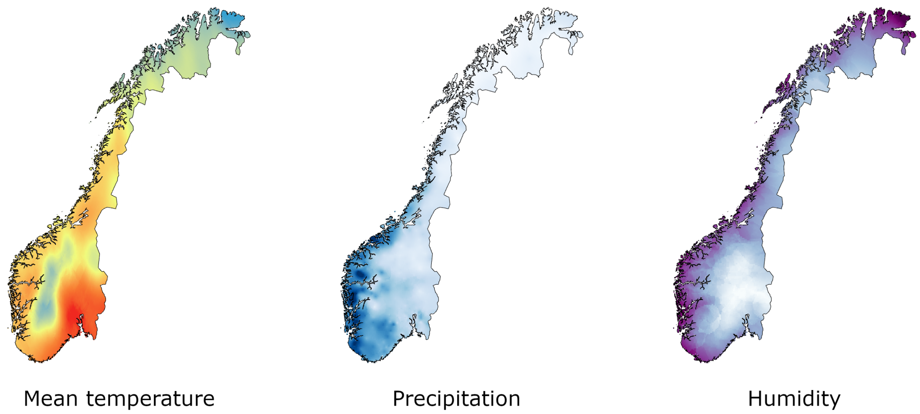
Increase in natural disasters can be a consequence of climate change. We see from the plot that the number of reported natural disasters has increased sharply in the same period that we saw temperature increase.

It is important however to note that the method of reporting these disasters also affects how many are reported. The criteria is that one of the following is true for each disaster: 10 or more people dead; 100 or more people affected; The declaration of a state of emergency, or a call for international assistance.

Since 1900, the population of the world has increased from 1.6 billion to 7.7 billion. The increased population of course raises the probability of a disaster qualifying for either 10 or more people dead, or 100 or more people affected. It is also likely that countries more often now than in the past ask for international assistance.

0.5.11 Regional differences in Norway

In order to look at regional differences, we wanted to create some maps. We used the GIS software ArcGIS for this purpose. We looked at july 2019 for all the maps. The maps were created by interpolating between measurements at weather stations. This was done using the Kriging inerpolation method.



0.6 Conclusion

The results generally confirmed our expectations. We observed an increase in both temperature and precipitation across Norway. The temperature increase was correlated with increased CO2 emissions, but not as much as we might have expected. This may be because climate is a very complicated process, and the variation in temperature is a result of many different processes.

Oslo was shown to be the warmest city of the four analyzed, and Bergen was the wettest. The maps showed that Southeastern Norway was warmest, and that Western Norway was wettest and most humid.

We can expect higher temperatures and more precipitation in Norway in the future. This will affect nearly every aspect of society and will increase the frequency of natural disasters. We will therefore need to take actions in order to be prepared for the consequences of these changes.