Final assignment on visualisation and analysis tools for climate change trends

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Contents

1 Global temperature, Carbon dioxide and Glaciers mass correlations

Do CO_2 emissions correlate with the rise of Global Temperature? Is there a correlation between Global Temperature and Glaciers mass? Using data series on atmospheric carbon dioxide, global temperatures and Glaciers mass, we investigate the relation between these for the period 1900-2017.

2 Methodology

The visualisation and analysis tools used throughout this exercise are in python run in the form of jupyter notebooks. The data sets are loaded as python pandas and dataframes are used to operate on the content. Occasionally, data are dumped in the format of binary npy files. The plots are based on the seaborn module.

In our analysis we use three well-known data sets:

1. Global Land and Ocean-and-Land Temperatures,
2. CO_2 PPM - Trends in Atmospheric Carbon Dioxide,
3. Average cumulative mass balance of reference Glaciers worldwide.

2.1 Global Land and Ocean-and-Land Temperatures

"Early data was collected by technicians using mercury thermometers, where any variation in the visit time impacted measurements. In the 1940s, the construction of airports caused many weather stations to be moved. In the 1980s, there was a move to electronic thermometers that are said to have a cooling bias.

Given this complexity, there are a range of organizations that collate climate trends data. The three most cited land and ocean temperature data sets are NOAA's MLOST, NASA's GISTEMP and the UK's HadCrut.

Kaggle have repackaged the data from a newer compilation put together by the Berkeley Earth, which is affiliated with Lawrence Berkeley National Laboratory. The Berkeley Earth Surface Temperature Study combines 1.6 billion temperature reports from 16 pre-existing archives. It is nicely packaged and allows for slicing into interesting subsets (for example by country). They publish the source data and the code for the transformations they applied. They also use methods that allow weather observations from shorter time series to be included, meaning fewer observations need to be thrown away.".

Source: Global Land and Ocean-and-Land Temperatures (GlobalTemperatures.csv) from [1].

2.2 CO_2 PPM - Trends in Atmospheric Carbon Dioxide

"CO_2 PPM - Trends in Atmospheric Carbon Dioxide. Data are sourced from the US Government's Earth System Research Laboratory, Global Monitoring Division. Two main series are provided: the Mauna Loa series (which has the longest continuous series since 1958) and a Global Average series (a global average over marine surface sites)."

Description Data are reported as a dry air mole fraction defined as the number of molecules of carbon dioxide divided by the number of all molecules in air, including CO_2 itself, after water vapor has been removed. The mole fraction is expressed as parts per million (ppm). Example: 0.000400 is expressed as 400 ppm."

Source: co2-mm-mlo.csv from [2].

2.3 Average cumulative mass balance of reference Glaciers worldwide

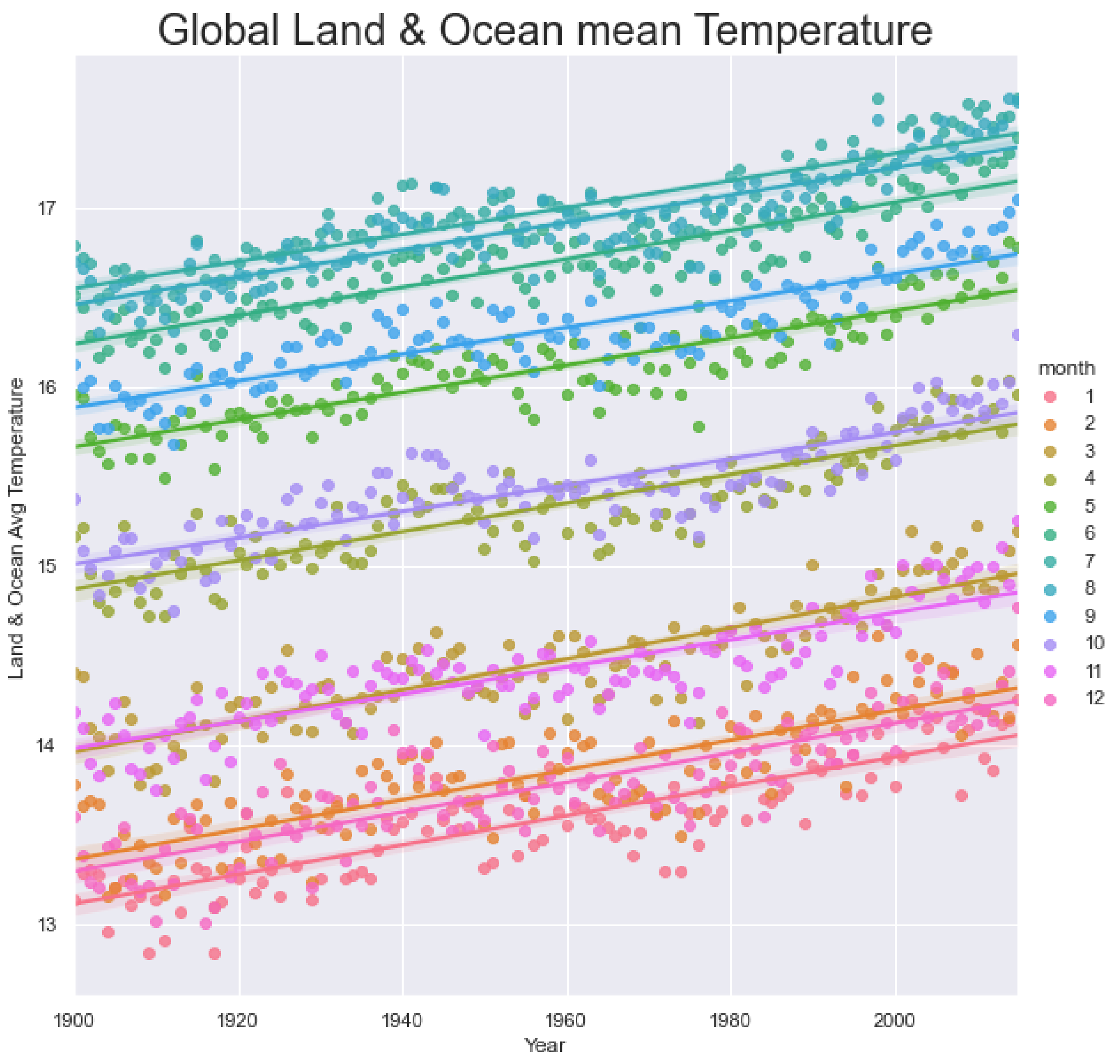
"Average cumulative mass balance of "reference" Glaciers worldwide from 1945-2014 sourced from US EPA and the World Glacier Monitoring Service (WGMS). This is cumulative change in mass balance of a set of "reference" glaciers worldwide beginning in 1945. The values represent the average of all the glaciers that were measured. Negative values indicate a net loss of ice and snow compared with the base year of 1945. For consistency, measurements are in meters of water equivalent, which represent changes in the average thickness of a glacier."

Source: glaciers.csv from [3].

3 Code and Results

[1]:
```python
import numpy as np # linear algebra
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import seaborn as sns
import datetime as dt
```

[2]:
```python
df = pd.read_csv(r"C:\Users\amanta\Documents\ClimateChange\GlobalTemperatures.
 ↪csv")
#data convert
df['dt'] = pd.to_datetime(df['dt'])
df['dt'].dt.year
df['dt'].dt.month
df['year'] = df['dt'].dt.year
df['month'] = df['dt'].dt.month
df1 = df[['dt','year','month','LandAndOceanAverageTemperature']]
dfGlobal = df1[(df1['year'] >= 1900) & (df1['year'] <= 2020)]

sns.set_theme()

x = dfGlobal['year']
y = dfGlobal['LandAndOceanAverageTemperature']
hue = dfGlobal['month']
dfGlobalgroup = sns.lmplot(
    data=dfGlobal,
    x="year", y="LandAndOceanAverageTemperature", hue="month",
    height=8)

plt.title( "Global Land & Ocean mean Temperature" , size = 24 )

# Use more informative axis labels than are provided by default
dfGlobalgroup.set_axis_labels("Year", "Land & Ocean Avg Temperature")
plt.show()
```

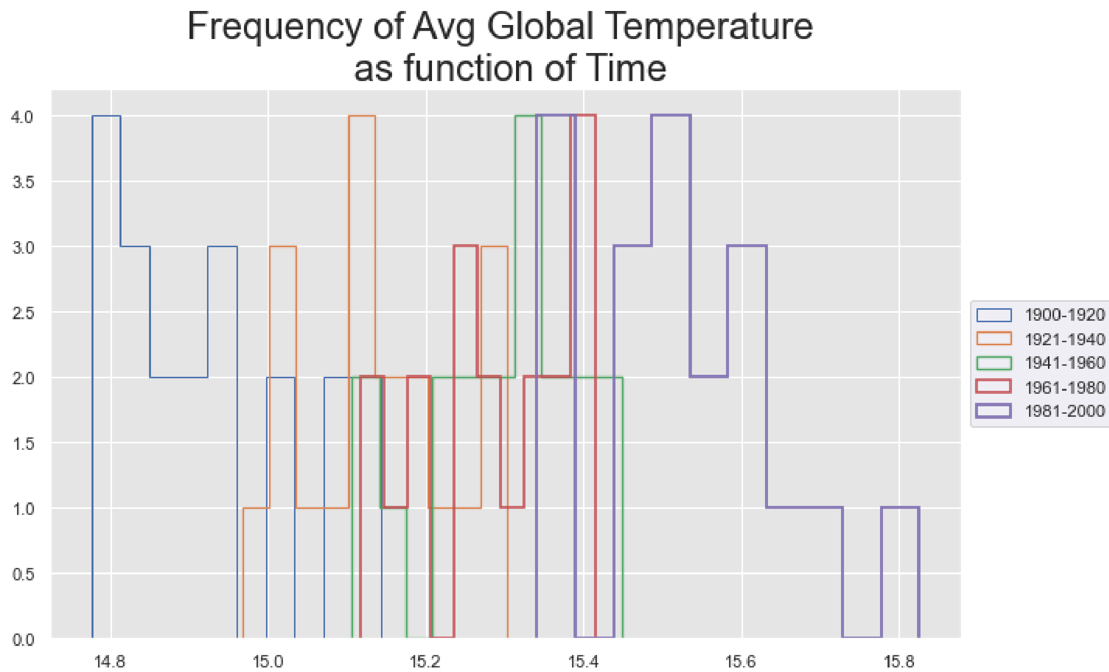


There is a consistent increase in Temperature during the years from 1900 for every month.

[3]:

```
df = pd.read_csv(r"C:\Users\amanta\Documents\ClimateChange\GlobalTemperatures.
↪csv")
#data convert
df['dt'] = pd.to_datetime(df['dt'])
df['dt'].dt.year
df['dt'].dt.month

df['year'] = df['dt'].dt.year
df['month'] = df['dt'].dt.month

df1 = df[['year','month','LandAndOceanAverageTemperature']]

dfGlobal = df1[(df1['year'] >= 1900) ]
```

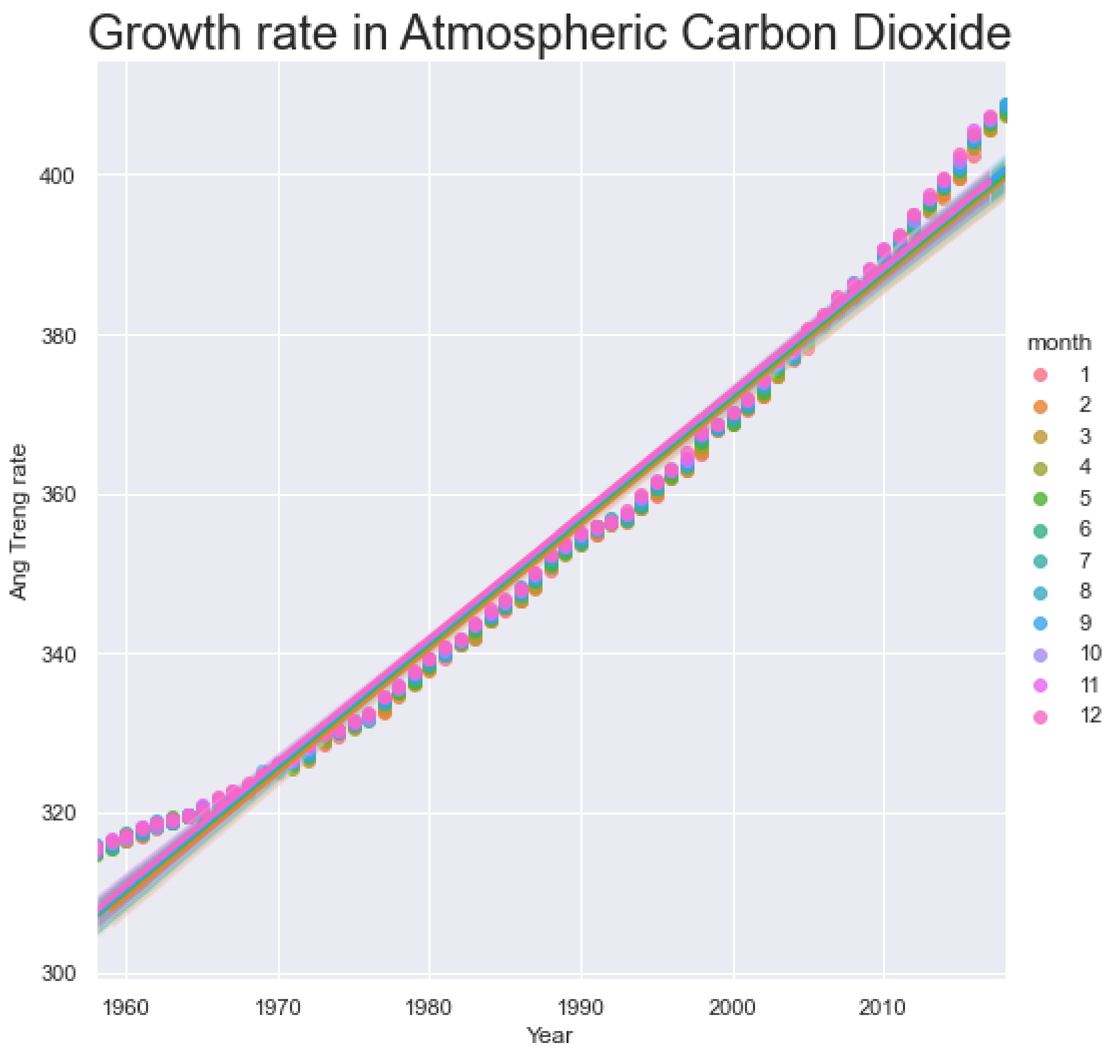
```
dfGroup = dfGlobal.groupby('year').agg(
    {'month':['count'],
        'LandAndOceanAverageTemperature':['mean', 'std']})

dfGroup.columns = dfGroup.columns.droplevel(0)
dfGroup.reset_index(inplace=True)

x = dfGroup['year']
y = dfGroup["mean"]
err = dfGroup["std"]

DeltaT = []
for Ti in y:
    #print (Ti)
    dT = Ti - y[0]
    DeltaT.append(dT)

fig2, ax2 = plt.subplots()
fig2.set_size_inches(10.5, 6.5)
ax2.set(facecolor = "grey")
ax2.patch.set_alpha(0.20)


ax2.hist(y[0:20],bins = 10, label = '{:d}-{:d}'.format(x[0], x[20]),␣
 ↪histtype='step', stacked=True, fill=False, linewidth=1)
ax2.hist(y[21:40],bins = 10, label = '{:d}-{:d}'.format(x[21], x[40]),␣
 ↪histtype='step', stacked=True, fill=False,linewidth=1.2)
ax2.hist(y[41:60],bins = 10, label = '{:d}-{:d}'.format(x[41], x[60]),␣
 ↪histtype='step', stacked=True, fill=False,linewidth=1.4)
ax2.hist(y[61:80],bins = 10, label = '{:d}-{:d}'.format(x[61], x[80]),␣
 ↪histtype='step', stacked=True, fill=False,linewidth=1.6)
ax2.hist(y[81:100],bins = 10, label = '{:d}-{:d}'.format(x[81], x[100]),␣
 ↪histtype='step', stacked=True, fill=False,linewidth=1.8)

ax2.legend(loc='center left', bbox_to_anchor=(1, 0.5))
ax2.set_title('Frequency of Avg Global Temperature \n as function of Time',size␣
 ↪= 24)

plt.show()
```



The temperature distribution per 20-year periods is shifting to the right. As a conclusion to this the frequency of higher temperatures is getting higher.

[4]:
```
df = pd.read_csv(r"C:\Users\amanta\Documents\ClimateChange\co2_mm_mlo.csv")

#data convert
df['Date'] = pd.to_datetime(df['Date'])
df['Date'].dt.year
df['Date'].dt.month

df['year'] = df['Date'].dt.year
df['month'] = df['Date'].dt.month

df1 = df[['year','month','Trend']]
#keep the beging year and exclude errors = -99.99
dfCo2 = df1[(df1['year'] >= 1900) & (df1['Trend'] >0)]
#groupby selected and mean all the rest
dfCo2group = dfCo2.groupby(['year','month']).mean()
dfCo2group.reset_index(inplace=True)
sns.set_theme()
x = dfCo2group['year']
y = dfCo2group["Trend"]
hue = dfCo2group['month']
# Plot sepal width as a function of sepal_length across days
dfCo2group = sns.lmplot(
```

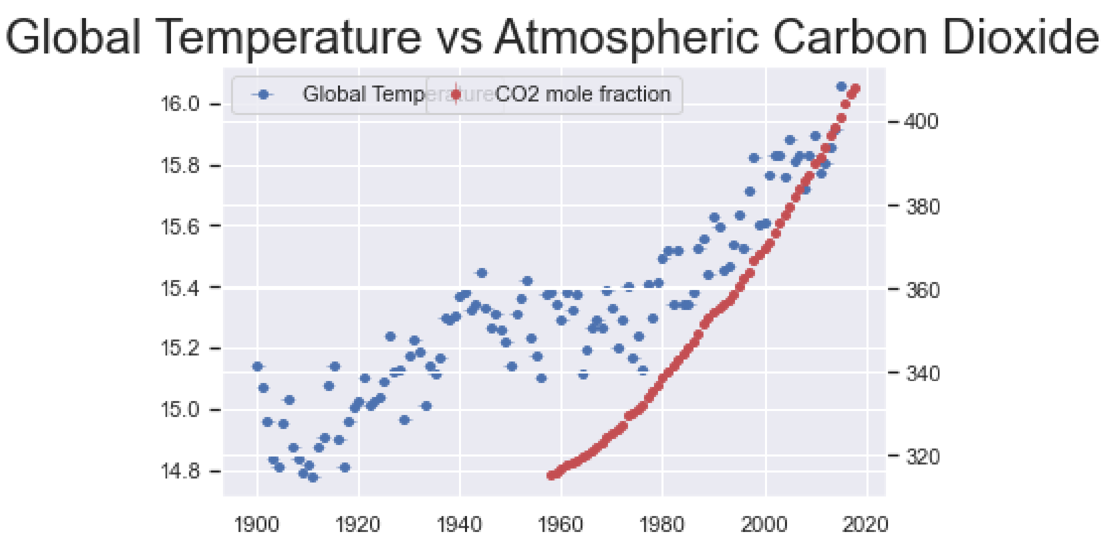
```
    data=dfCo2group,
    x="year", y="Trend", hue="month",
    height=7)
#Use more informative axis labels than are provided by default
dfCo2group.set_axis_labels("Year", "Ang Treng rate")
plt.title( "Growth rate in Atmospheric Carbon Dioxide" , size = 24 )
plt.show()
```



There is a positive rise in CO_2 Average mlo franction the period from 1900 for every month.

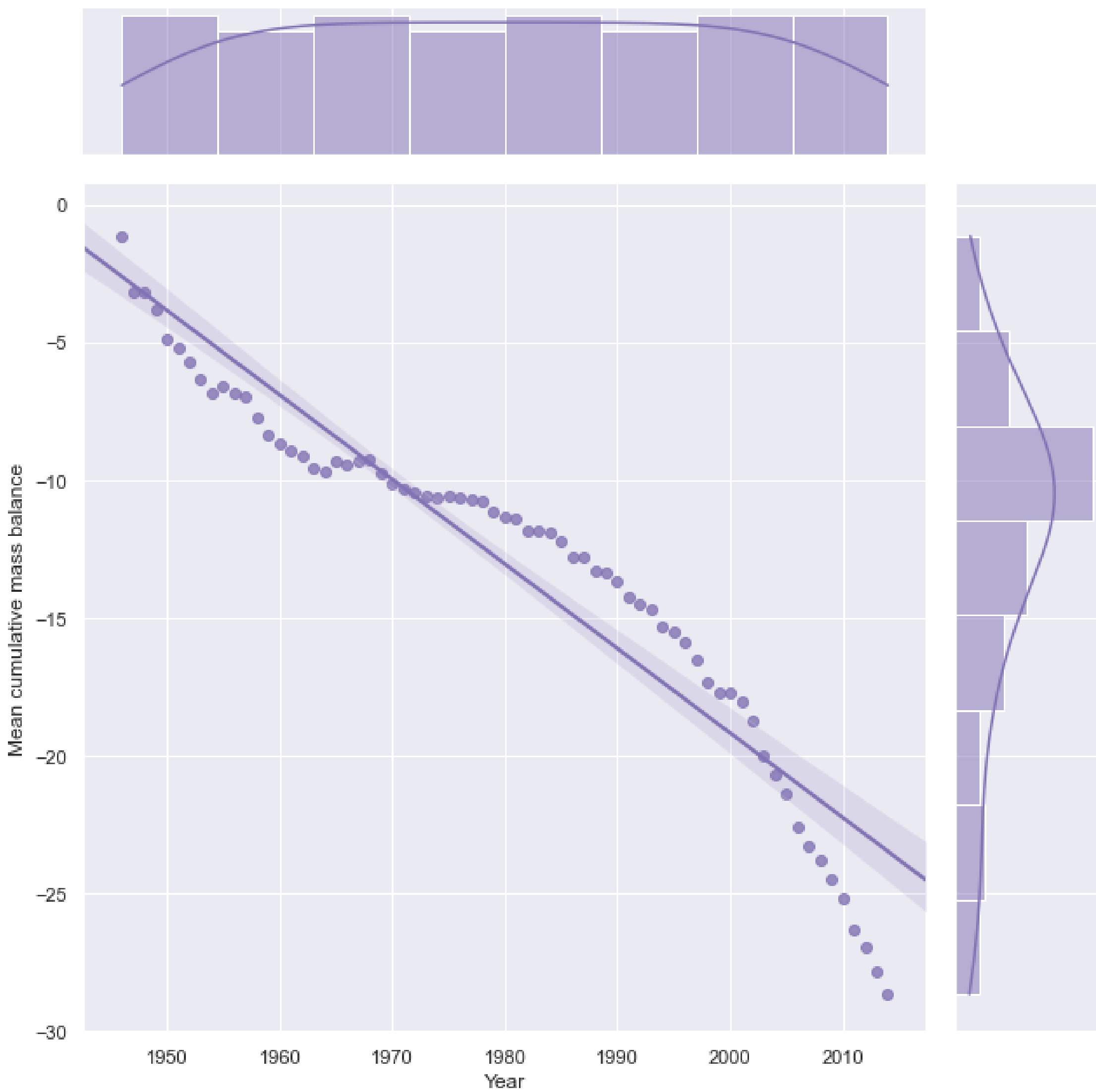
[5]:
```
GlobalTemperatures = np.load(r"C:
↪\Users\amanta\Documents\ClimateChange\GlobalTemperatures.npy")
Co2mloFraction = np.load(r"C:
↪\Users\amanta\Documents\ClimateChange\Co2mloFraction.npy")
```

```python
x = GlobalTemperatures[0]
y = GlobalTemperatures[1]
ygerr = GlobalTemperatures[2]
xco = Co2mloFraction[0]
yco = Co2mloFraction[1]
ycoerr = Co2mloFraction[2]

#https://matplotlib.org/3.1.1/gallery/statistics/errorbar_features.
 ↪html#sphx-glr-gallery-statistics-errorbar-features-py
lower_error = ygerr
upper_error = ygerr
asymmetric_error = [lower_error, upper_error]

fig, ax1 = plt.subplots()
ax2 = ax1.twinx()
plt.rcParams['figure.figsize'] = [14,10]
ax1.errorbar(x, y, xerr=asymmetric_error, fmt='o', markersize=4, elinewidth=0.
 ↪5, capsize=0, label='Global Temperature')
ax2.errorbar(xco, y=yco, yerr=ycoerr, fmt='ro', markersize=4, elinewidth=0.5,␣
 ↪capsize=0, label='CO2 mole fraction')
ax1.legend(loc ='upper left')
ax2.legend(loc ='upper center')
plt.title( "Global Temperature vs Atmospheric Carbon Dioxide" , size = 24 )
plt.show()
```



The first CO_2 measurement is from 1958. There is a positive rise to both Global Temperature and CO_2 mlo fraction.

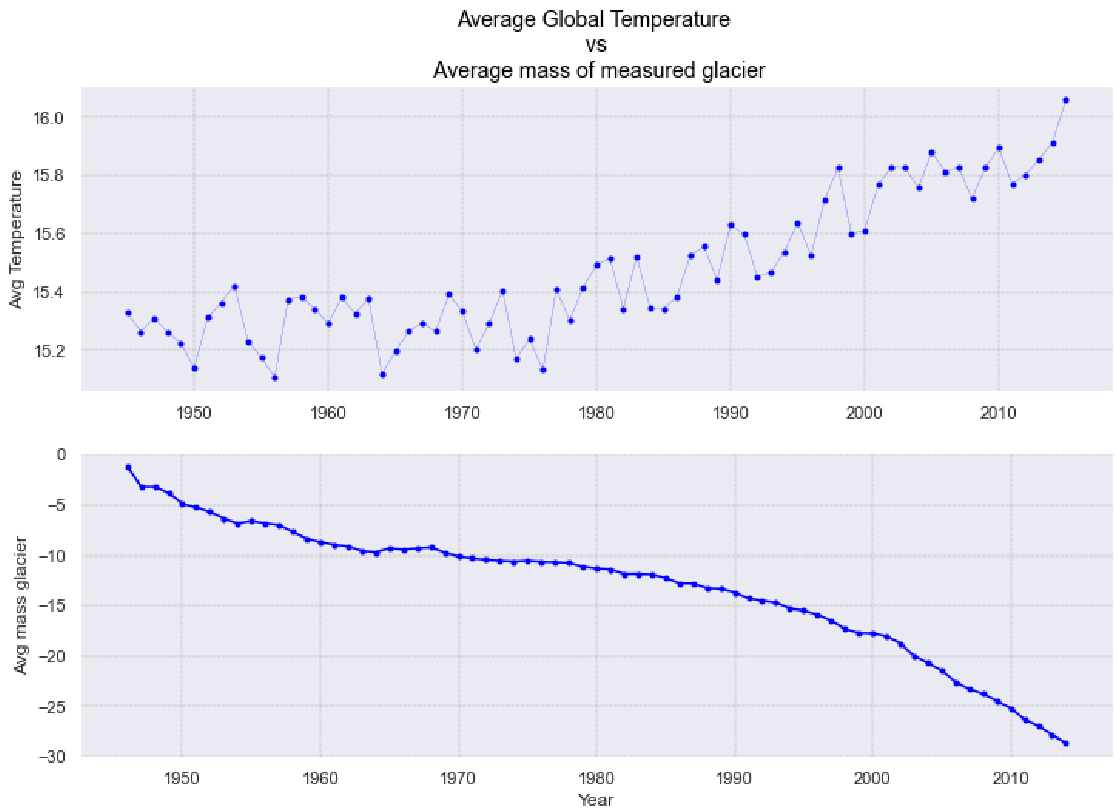
[6]:
```
df = pd.read_csv(r"C:\Users\amanta\Documents\ClimateChange\glaciers.csv")
dfGl = df[(df['Year'] > 1945) ]
x = dfGl['Year']
y = dfGl["Mean cumulative mass balance"]

sns.set_theme(style="darkgrid")

g = sns.jointplot(x="Year", y="Mean cumulative mass balance", data=dfGl,
                  kind="reg", truncate=False,
                  #xlim=(0, 60), ylim=(0, 12),
                  color="m", height=9)
plt.show()
```



The measured Glacier mass is decreasing every year.

[7]:
```
df = pd.read_csv(r"C:\Users\amanta\Documents\ClimateChange\glaciers.csv")
dfGl = df[(df['Year'] > 1945) ]
#Global
df = pd.read_csv(r"C:\Users\amanta\Documents\ClimateChange\GlobalTemperatures.
↪csv")

#data convert
df['dt'] = pd.to_datetime(df['dt'])
df['dt'].dt.year
df['dt'].dt.month
df['year'] = df['dt'].dt.year
df['month'] = df['dt'].dt.month
df1 = df[['year','month','LandAndOceanAverageTemperature']]
dfGlobal = df1[(df1['year'] >= 1945) ]
#getting discription
dfDescr = dfGlobal.describe()
dfDescr.reset_index(inplace=True)
#getting the std from average temperature
dfGroup = dfGlobal.groupby('year').agg(
    {'month':['count'],
        'LandAndOceanAverageTemperature':['mean', 'std']})

dfGroup.columns = dfGroup.columns.droplevel(0)
dfGroup.reset_index(inplace=True)
#Creating the plot

x = dfGl['Year']
y = dfGl['Mean cumulative mass balance']
#ygerr = npyData[2]
xgl = dfGroup['year']
ygl = dfGroup['mean']

#-------------------

plt.rcParams['figure.figsize'] = [12,8]
plt.subplot(2, 1, 1)
plt.plot(xgl, ygl, 'o-', markersize=3, linewidth=0.2,color="blue" )
plt.title('Average Global Temperature \n vs \n Average mass of measured␣
↪glacier',
          fontsize=14,
          color="black")

plt.ylabel('Avg Temperature')
plt.grid(b=True, which='major', color='grey', linestyle='-.', linewidth=0.3)
```

```python
plt.subplot(2, 1, 2)
plt.plot(x, y, '.-',color="blue")
plt.xlabel('Year')
plt.ylabel('Avg mass glacier')
plt.grid(b=True, which='major',color='grey', linestyle='-.', linewidth=0.3)

plt.show()
```



Global mean Temperature increases while Glaciers mass decreases.

4 Discussion

As a conclusion there seems to be a cause-and-effect relationship between these three parameters: Global Temperature, Atmospheric Carbon Dioxide and Glaciers mass. Further analysis needs to be made.

5 Conclusions

Based on these conclusions, more focused studies will be carried out in order to find ways to control this phenomenon, as well as new ways of approaching industrial development.

6 References

1. https://www.kaggle.com/berkeleyearth/climate-change-earth-surface-temperature-data
2. https://datahub.io/core/co2-ppm
3. https://datahub.io/core/glacier-mass-balance#readme

7 Acknowledgements

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