ANALYSIS OF AIR TEMPERATURE DATA IN SOUTH-EASTERN NIGERIA

The data is from two states in the south-east of Nigeria,Enugu and Port-Harcourt. It covers the average monthly temperatures over the course of 120 months. The 120 months spans January of 2009 to December 2018.

OBJECTIVES

1. To analyse the data for trends using statistical tools
2. To test for inhomogeneities in the data
3. To visualize the data

In [131…
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import pymannkendall as mk
import pyhomogeneity as hg
import seaborn as sns

%matplotlib inline
```

In [132…
```
df = pd.read_excel('dbs data.xlsx')
df.head()
```

Out[132]:

	STATE	MONTH	2009	2010	2011	2012	2013	2014	2015	2016	
0	ENUGU	JAN	27.874194	26.900000	27.200000	27.212903	27.209677	27.835484	26.714516	27.043548	27.4
1	ENUGU	FEB	28.957143	30.160714	28.031034	29.264286	28.826786	29.052155	29.030727	28.991071	29.0
2	ENUGU	MAR	29.974194	30.722581	30.145161	29.116129	29.529032	29.967742	29.625806	29.037097	29.2
3	ENUGU	APR	28.240000	29.836667	28.790000	27.983333	28.521667	28.871667	29.191667	29.298333	28.7
4	ENUGU	MAY	27.300000	28.051613	27.103226	27.487097	28.000000	27.582258	27.285484	26.995161	26.9

In [133…
```
df.tail()
```

Out[133]:

	STATE	MONTH	2009	2010	2011	2012	2013	2014	2015	2016
19	PORT HARCOURT	AUG	26.158065	25.367742	26.290323	25.816129	25.853226	25.932258	25.793548	26.038710
20	PORT HARCOURT	SEP	26.396667	26.393333	26.523333	26.360000	25.863333	26.016667	26.486667	26.444167
21	PORT HARCOURT	OCT	27.161290	27.167742	27.000000	26.629032	26.927419	27.227419	27.270968	27.063710
22	PORT HARCOURT	NOV	28.440000	27.976667	27.650000	28.036667	27.970000	27.903333	28.313333	28.345833
23	PORT HARCOURT	DEC	27.251613	28.819355	27.938710	27.425806	27.459677	27.493548	27.864516	27.587903

In [134…
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 24 entries, 0 to 23
Data columns (total 12 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   STATE   24 non-null     object
 1   MONTH   24 non-null     object
 2   2009    24 non-null     float64
 3   2010    24 non-null     float64
 4   2011    24 non-null     float64
 5   2012    24 non-null     float64
 6   2013    24 non-null     float64
 7   2014    24 non-null     float64
 8   2015    24 non-null     float64
 9   2016    24 non-null     float64
 10  2017    24 non-null     float64
 11  2018    24 non-null     float64
dtypes: float64(10), object(2)
memory usage: 2.4+ KB
```

As seen from the above, the data has 24 rows and 12 columns. The year columns (2009-2018) have integer temperature values in celsius. The month and state columns have object (string) values (January - December, and Enugu and Port-Harcourt respectively).

The first 12 rows of the data are for Enugu while the last 12 rows are Port-Harcourt. The 'STATE' column is not needed so it will be dropped. The data will be split in two accordingly .

In [135…
```
df = df.drop(['STATE'], axis=1)
df_Enugu = df[:12].copy()
df_PH = df[12:].copy()
```

In [136…
```
df_Enugu.describe()
```

Out[136]:

	2009	2010	2011	2012	2013	2014	2015	2016	2017	20
count	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.0000
mean	27.552217	27.926726	27.427683	27.063395	27.413648	27.494301	27.339931	27.271832	27.212187	27.1286
std	1.255520	1.582390	1.265504	1.449627	1.247956	1.353277	1.343973	1.291731	1.314578	1.1974
min	25.960000	26.113333	25.911290	24.093333	25.874194	25.771667	25.680645	25.758065	25.563333	25.5548
25%	26.495161	26.736290	26.371492	25.982742	26.077110	26.206747	26.411895	26.380672	26.086694	26.1798
50%	27.587097	27.515806	27.151613	27.183118	27.387097	27.443548	27.052419	27.019355	27.120161	26.9693
75%	28.305806	28.856667	28.093437	27.734543	28.404167	28.335417	28.133932	28.305268	28.148750	27.8585
max	29.974194	30.722581	30.145161	29.264286	29.529032	29.967742	29.625806	29.298333	29.288710	29.4129

From the above:

1. The average yearly temperature in Enugu is about 27 degrees Celsius
2. The record maximum temperature is 30.72 degrees Celsius (in 2010)
3. The record minimum temperature is 24.09 degrees Celsius (in 2012)
4. Average standard deviation is less than 1.6

In [137…
```
df_PH.describe()
```

Out[137]:

	2009	2010	2011	2012	2013	2014	2015	2016	2017	20

count	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.000000	12.0000
mean	27.173153	27.384136	27.697715	27.139704	27.207570	27.287828	27.365389	27.508726	27.519037	27.6985
std	0.968667	1.055810	1.040976	0.949458	0.979065	1.025650	1.086892	1.054198	1.027681	1.2270
min	25.964516	25.367742	26.290323	25.816129	25.853226	25.932258	25.793548	26.038710	26.185833	26.2612
25%	26.337016	26.901559	26.834194	26.426290	26.414919	26.217702	26.535417	26.885266	26.741331	26.6693
50%	27.206452	27.525000	27.794355	26.980588	27.193548	27.360484	27.562903	27.325806	27.556048	27.5648
75%	27.717500	27.985726	28.294758	28.030941	28.122696	28.012500	28.370468	28.434980	28.140524	28.8484
max	28.709677	28.819355	29.422581	28.596774	28.430645	28.759677	28.727419	29.070833	29.095833	29.7903

From the above:

1. The average yearly temperature in Port-Harcourt is about 27 degrees Celsius
2. The record maximum temperature is 29.79 degrees Celsius (in 2018)
3. The record minimum temperature is 25.37 degrees Celsius (in 2010)
4. Average standard deviation is less than 1.3

DATA VISUALIZATION

A

1. Plot of year-wise air temperature variation in Enugu State

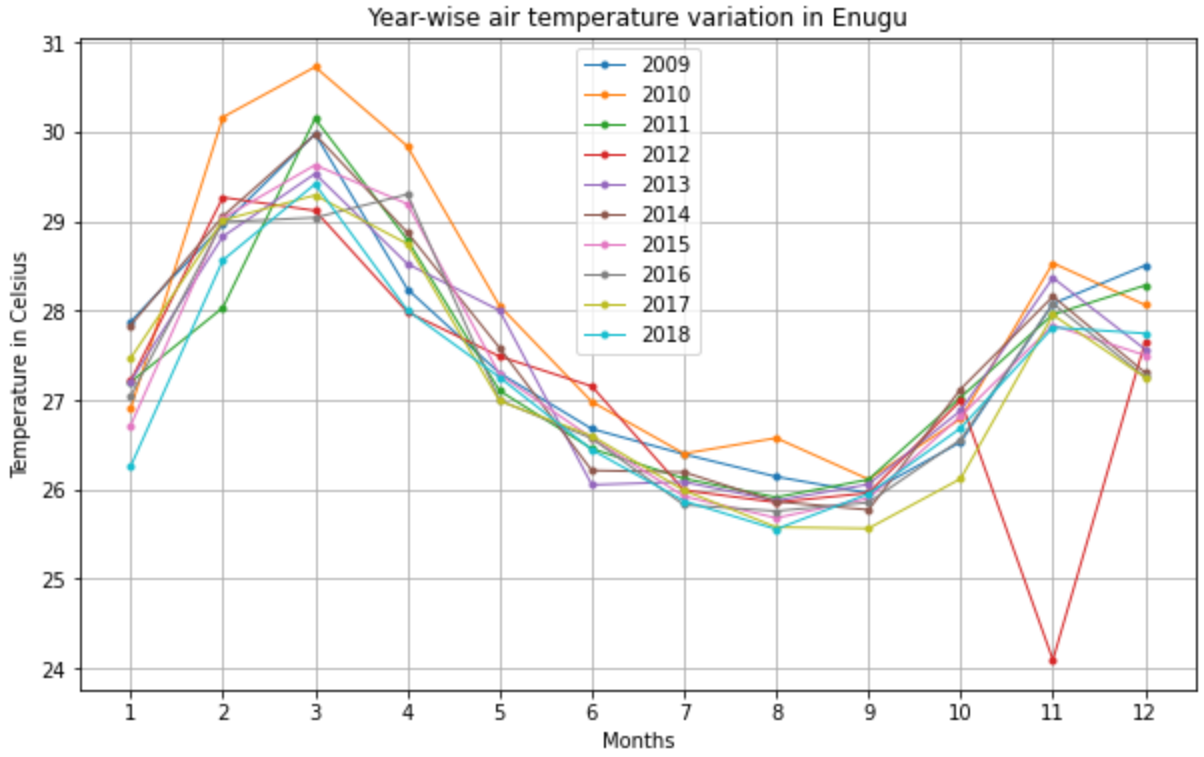
In [138…

```
df_Enugu.index = range(1,13,1)

plt.figure(dpi = 200)
df_Enugu.plot(
    figsize = (10,6), grid = True,title = 'Year-wise air temperature variation in Enugu'
    xlabel= 'Months', ylabel = 'Temperature in Celsius',legend = True, linestyle = 'soli
    marker = 'o',linewidth = 1, markersize = 3, xticks = range(1,13,1)
    )
```

Out[138]:

```
<AxesSubplot:title={'center':'Year-wise air temperature variation in Enugu'}, xlabel='Mo
nths', ylabel='Temperature in Celsius'>
<Figure size 1200x800 with 0 Axes>
```



From the above:

1. The plot shows a saddle-shaped yearly temperature with distinct peaks
2. There is a major temperature peak in March and a minor peak in November
3. The coldest period is between July and September
4. 2010 was a particularly hot year with record temperatures in 5 different months
5. The record lowest temperature in November 2012 appears to be an outlier

2. Plot of average yearly temperature and slope in Enugu State

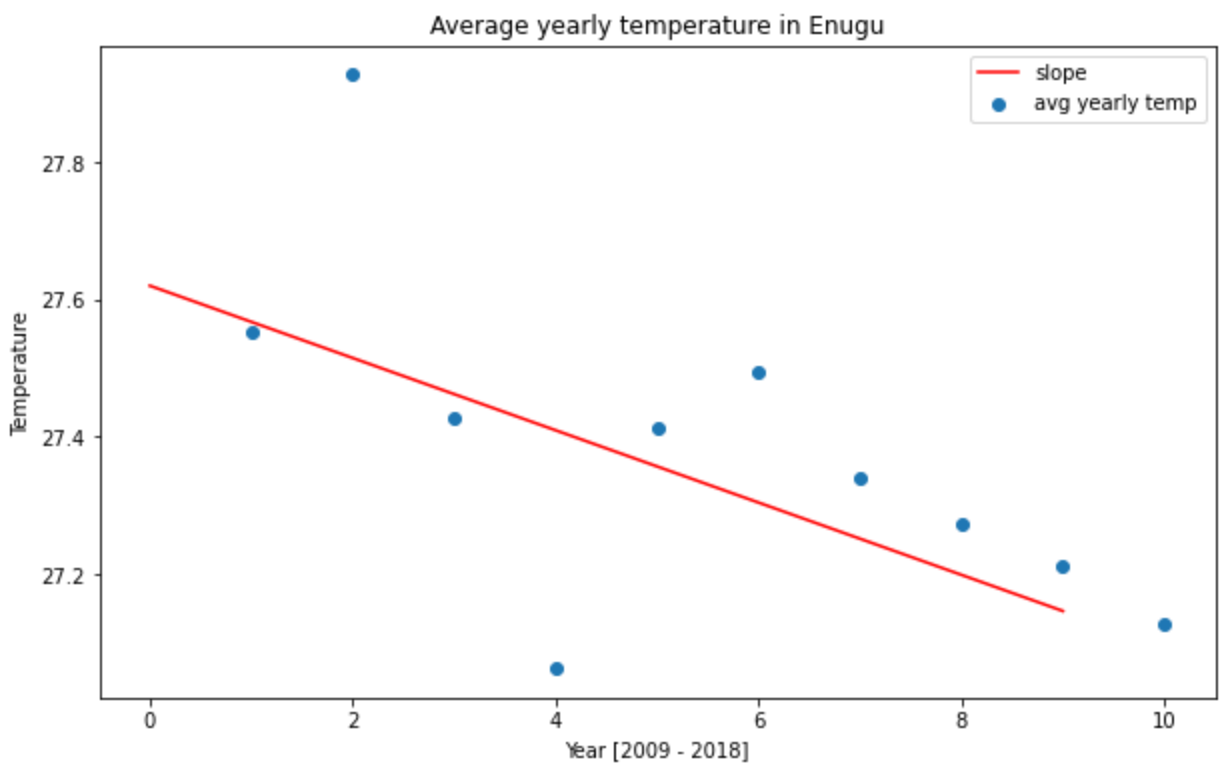
The line values for the slope are generated thus:

1. Calculate the arithmetic mean of each year in the data
2. Fit a straight line to the values of that mean

In [139…
```
mean_En = df_Enugu.iloc[:,1:].mean()
slope, intercept = np.polyfit(np.array(range(1,11,1)),np.array(mean_En), 1)
abline_values = pd.DataFrame(data = [slope * i + intercept for i in range(1,11,1)])
```

In [140…
```
fig, axes = plt.subplots(nrows =1, ncols = 1,figsize=(10, 6))
axes.plot(abline_values, color = 'r', label = 'slope')
axes.scatter(np.array(range(1,11,1)), np.array(mean_En), label = 'avg yearly temp')
axes.set_xlabel('Year [2009 - 2018]')
axes.set_ylabel('Temperature')
axes.set_title('Average yearly temperature in Enugu')
axes.legend()
```

Out[140]:
```
<matplotlib.legend.Legend at 0x25bdeeebd60>
```



From the above:

1. There appears to be a downward trend in the average yearly temperature in Enugu

3. Plot of month-wise air temperature in Enugu State

Convert the data from wide to long format

In [141…
```
df_Enugu = df_Enugu.melt('MONTH', var_name = 'Year', value_name = 'Temperature')
```

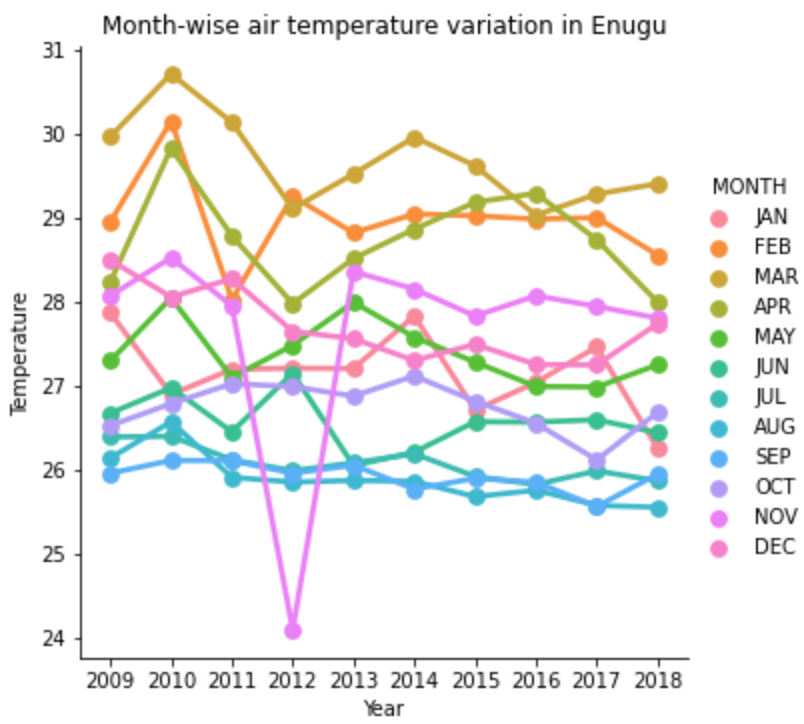
Convert the data type of the 'Year' column from string to integer

In [142…
```
df_Enugu = df_Enugu.astype({'Year':int})
```

In [143…
```
plt.figure(figsize = (10,6), dpi = 400)
sns.catplot(x = 'Year', y = 'Temperature', hue = 'MONTH', data = df_Enugu, kind = 'point
    title = 'Month-wise air temperature variation in Enugu'
)
```

Out[143]:
```
<seaborn.axisgrid.FacetGrid at 0x25bdf1b7520>

<Figure size 4000x2400 with 0 Axes>
```

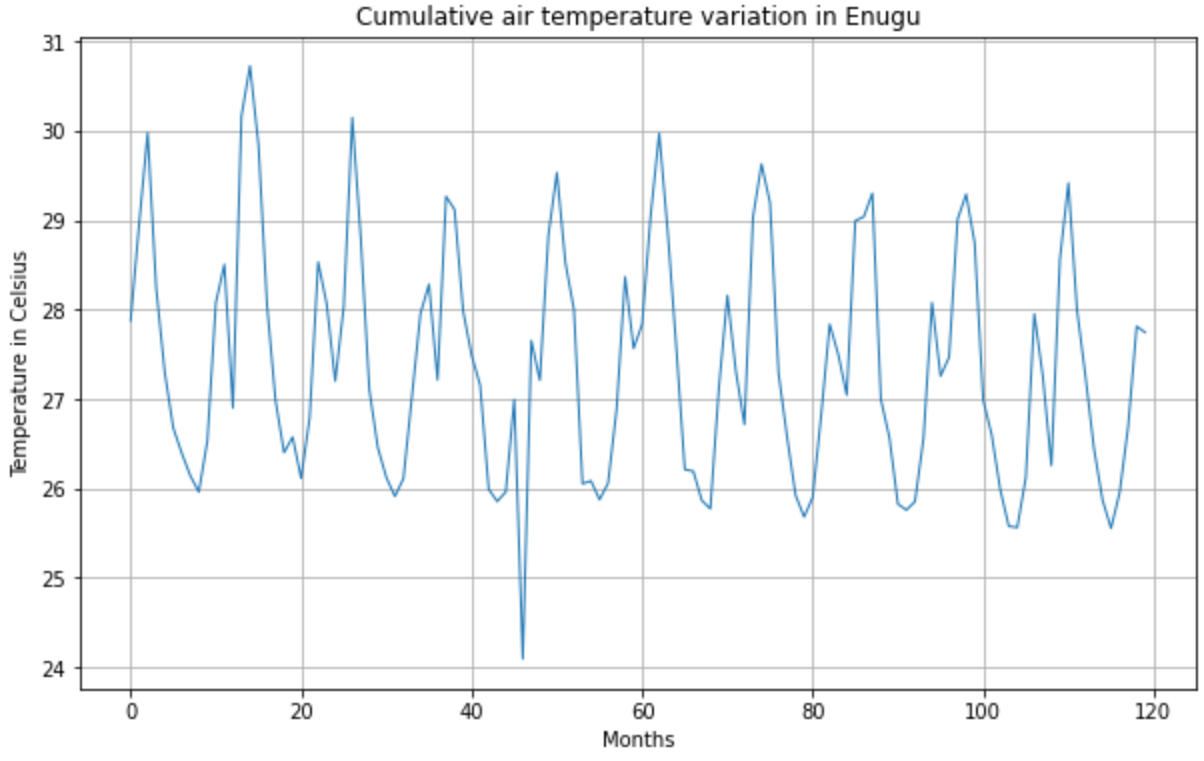


From the above:

1. On average, March is the hottest month of the year with a peak temperature of ~31 degrees Celsius (2010)
2. On average, August-September is the coolest period of the year
3. It is confirmed that the lowest temperature (24 degrees Celsius in November 2012)is an outlier

In [158…
```
df_Enugu.iloc[:,2].plot(
    figsize = (10,6), grid = True,title = 'Cumulative air temperature variation in Enugu
    xlabel= 'Months', ylabel = 'Temperature in Celsius', linestyle = 'solid', linewidth
)
```

Out[158]:
```
<AxesSubplot:title={'center':'Cumulative air temperature variation in Enugu'}, xlabel='M
onths', ylabel='Temperature in Celsius'>
```

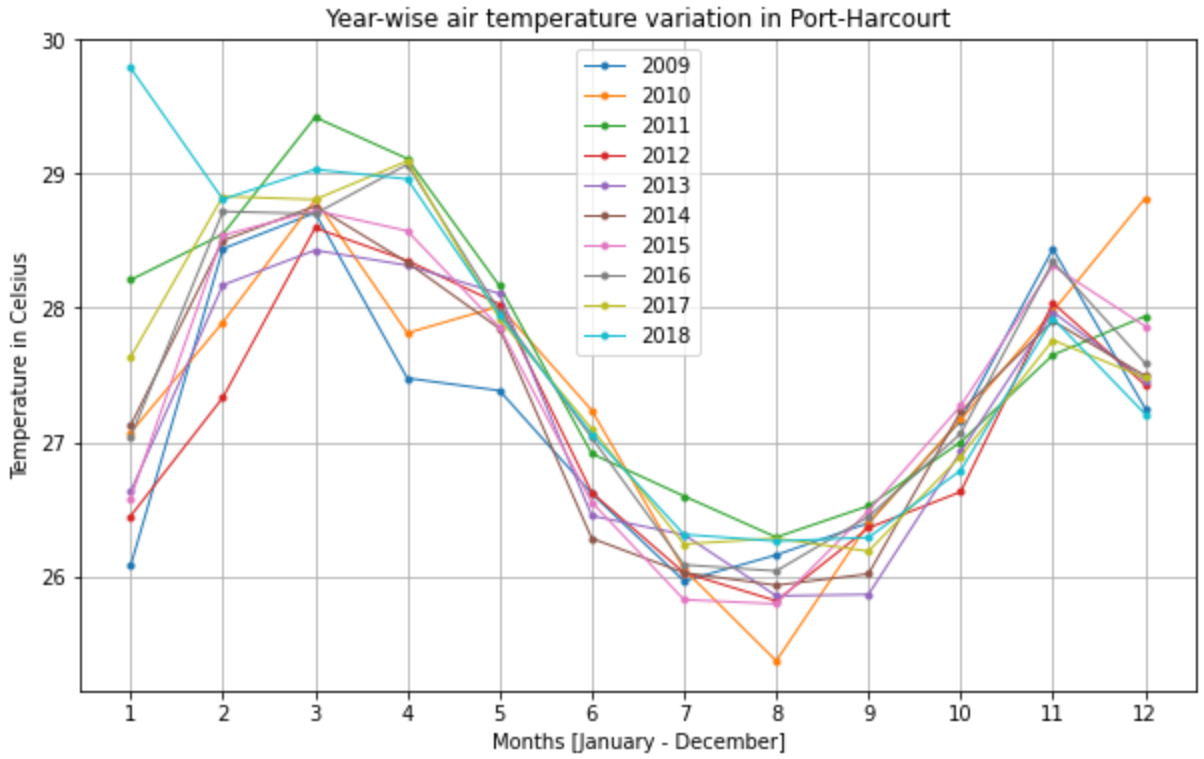


B

1. Plot of year-wise air temperature variation in Port-Harcourt

In [145…
```
df_PH.index = range(1,13,1)
df_PH.plot(
    figsize = (10,6), grid = True,title = 'Year-wise air temperature variation in Port-H
    xlabel= 'Months [January - December]',ylabel = 'Temperature in Celsius',legend = Tru
    marker = 'o',linewidth = 1, markersize = 3, xticks = range(1,13,1)
)
```

Out[145]:
```
<AxesSubplot:title={'center':'Year-wise air temperature variation in Port-Harcourt'}, xl
abel='Months [January - December]', ylabel='Temperature in Celsius'>
```



From the above:

1. The plot shows a saddle-shaped yearly temperature with distinct peaks
2. There is a major temperature peak in March and a minor peak in November
3. August is the coldest month, on average
4. Temperature values of January 2018 and December 2010 appear to be outliers

2. Plot of average yearly temperature and slope in Port-Harcourt

The line values for the slope are generated thus:

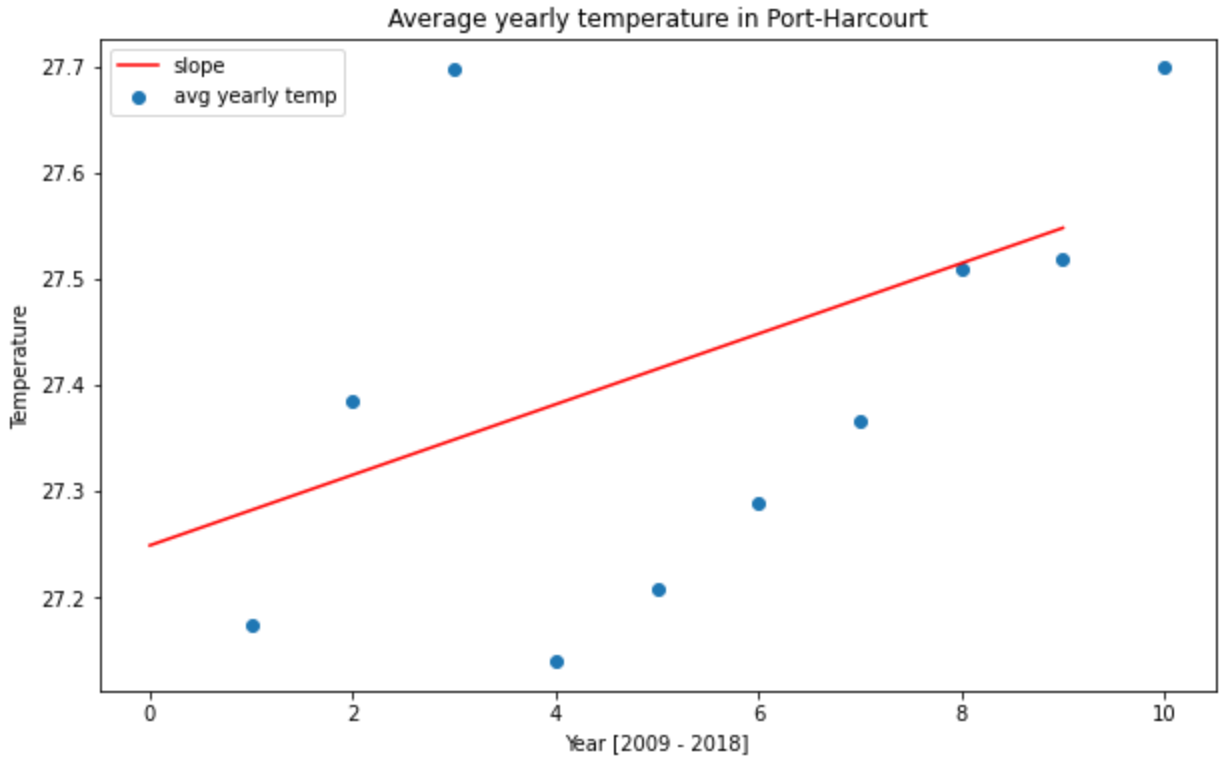
1. Calculate the arithmetic mean of each year in the data
2. Fit a straight line to the values of that mean

In [146…
```
mean_PH = df_PH.iloc[:,1:].mean()
slope, intercept = np.polyfit(np.array(range(1,11,1)),np.array(mean_PH), 1)
abline_values = pd.DataFrame(data = [slope * i + intercept for i in range(1,11,1)])
```

In [147…
```
fig, axes = plt.subplots(nrows =1, ncols = 1,figsize=(10, 6))
axes.plot(abline_values, color = 'r', label = 'slope')
axes.scatter(np.array(range(1,11,1)), np.array(mean_PH), label = 'avg yearly temp')
axes.set_xlabel('Year [2009 - 2018]')
```

```
axes.set_ylabel('Temperature')
axes.set_title('Average yearly temperature in Port-Harcourt')
axes.legend()
```

Out[147]:
```
<matplotlib.legend.Legend at 0x25bdf1930d0>
```



From the above:

1. There appears to be an upward trend in the average yearly temperature in Port-Harcourt

3. Plot of month-wise air temperature in Enugu State

Convert the data from wide to long format

In [148…
```
df_PH = df_PH.melt('MONTH', var_name = 'Year', value_name = 'Temperature')
```

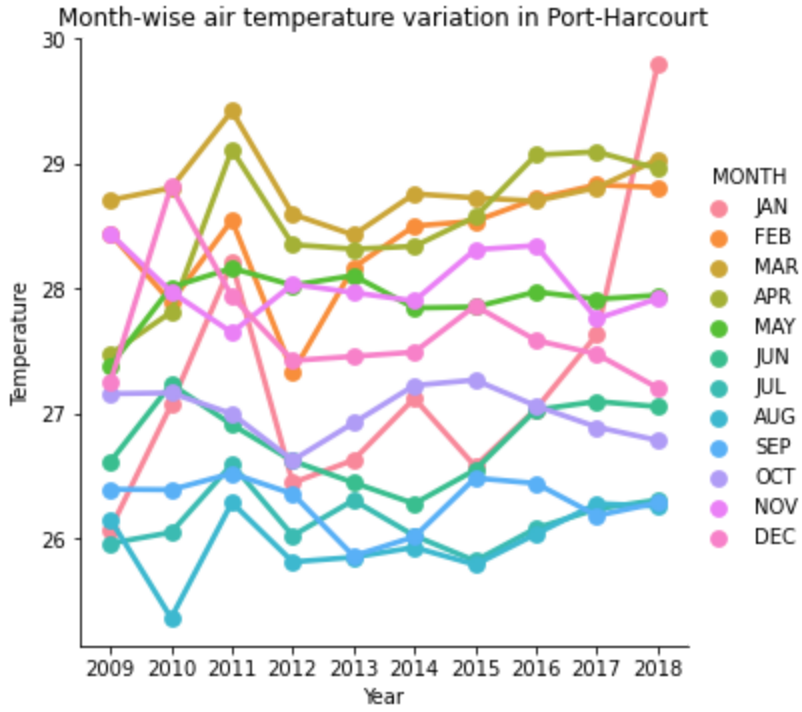
Convert the data type of the 'Year' column from string to integer

In [149…
```
df_PH = df_PH.astype({'Year':int})
```

In [150…
```
plt.figure(figsize = (10,6), dpi = 400)
sns.catplot(x = 'Year', y = 'Temperature', hue = 'MONTH', data = df_PH, kind = 'point',
    title = 'Month-wise air temperature variation in Port-Harcourt'
)
```

Out[150]:
```
<seaborn.axisgrid.FacetGrid at 0x25bdf2f7310>

<Figure size 4000x2400 with 0 Axes>
```

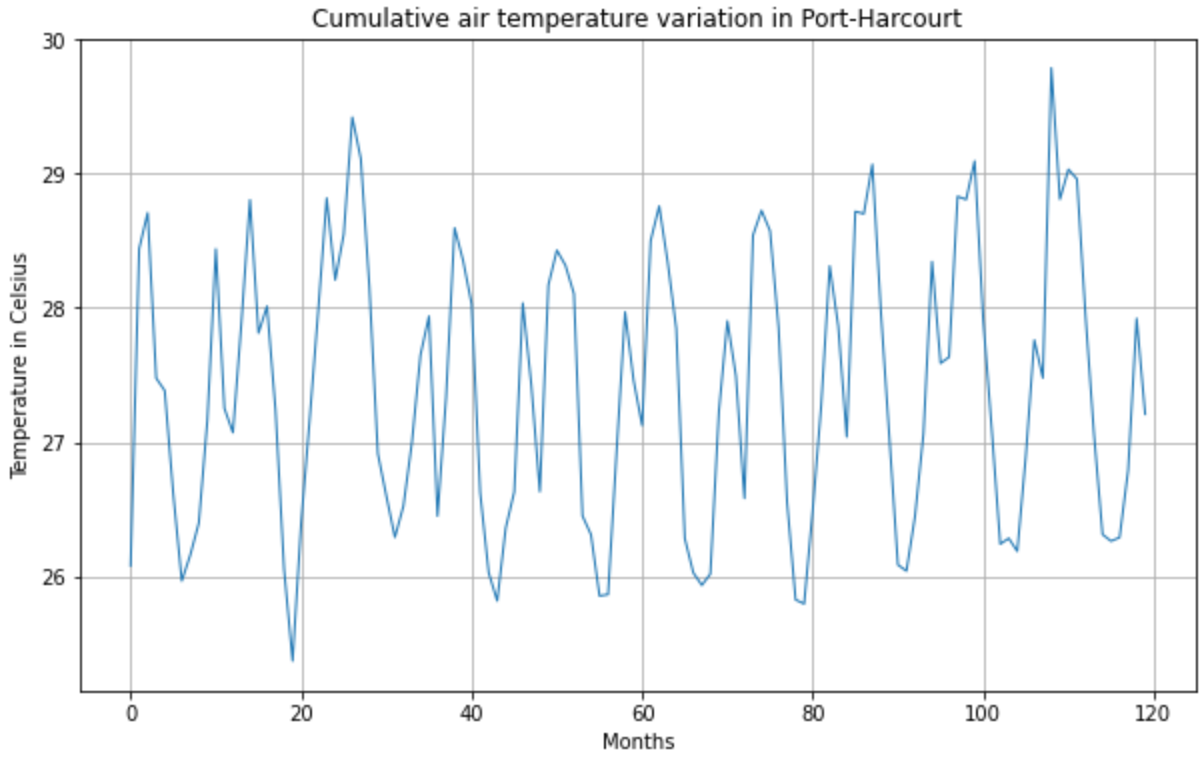


From the above:

1. On average, March is the hottest month of the year with a peak temperature of ~30 degrees Celsius (2010)
2. On average, August is the coolest month of the year

In [159…
```
df_PH.iloc[:,2].plot(
    figsize = (10,6), grid = True,title = 'Cumulative air temperature variation in Port-
    xlabel= 'Months', ylabel = 'Temperature in Celsius', linestyle = 'solid', linewidth
)
```

Out[159]:
```
<AxesSubplot:title={'center':'Cumulative air temperature variation in Port-Harcourt'}, x
label='Months', ylabel='Temperature in Celsius'>
```



STATISTICAL ANALYSIS

1. Multi-variate Mann-Kendall Test: The Mann-Kendall Trend Test (sometimes called the MK test) is used to analyze time series data for consistently increasing or decreasing trends (monotonic trends). All Mann-Kendall tests return a named tuple which contain:

   trend: tells the trend (increasing, decreasing or no trend)

   h: True (if trend is present) or False (if the trend is absence)

   p: p-value of the significance test

   z: normalized test statistics

   Tau: Kendall Tau

   s: Mann-Kendal's score

   var_s: Variance S

   slope: Theil-Sen estimator/slope

   intercept: intercept of Kendall-Theil Robust Line

2. Pettitt Test: The Pettitt test is a common tool for detection of a single unknown abrupt change point (inhomogeneity), in the sense of abrupt changes in the mean of the time series of environmental data. All Homogeneity tests return a named tuple which contain:

   h: True (if data is nonhomogeneous) or False (if data is homogeneous)

   cp: probable change point location

   p: p value of the significance test

   U/T/Q/R/V: test statistics which depends on the test method

   avg: mean values at before and after the change point

1. Enugu State:

In [152…
```
trend, h, p, z, Tau, s, var_s, slope, intercept = mk.multivariate_test(
    df.iloc[:12,1:].values, alpha = 0.05)
print('trend =', trend,'\n','h =', h,'\n', 'slope =', slope)
```

```
trend = decreasing
 h = True
 slope = -0.17356720430107425
```

In [153…
```
h, cp, p, U, mu = hg.pettitt_test(df_Enugu.iloc[:,2].values)
print('h =', h,'\n', 'probable change-point =', cp)
```

```
h = False
 probable change-point = 41
```

From the above tests:

1. It is confirmed that average yearly temperature decreased between 2009 - 2018 (downward trend)
2. The data is homogenous
3. Probable change point corresponds to may 2012

2. Port-Harcourt:

In [154…
```
trend, h, p, z, Tau, s, var_s, slope, intercept = mk.multivariate_test(
    df.iloc[12:,1:].unstack().values)
print('trend =', trend,'\n','h =', h,'\n', 'slope =', slope)
```

```
trend = no trend
 h = False
 slope = 0.0015377250810719107
```

In [155…
```
h, cp, p, U, mu = hg.pettitt_test(df.iloc[12:,1:].unstack().values)
print('h =', h,'\n', 'probable change-point =', cp)
```

```
h = False
 probable change-point = 82
```

From the above tests:

1. There is no trend in the data
2. The data is homogenous
3. Probable change point corresponds to October 2015

CONCLUSION

1. The air temperature data for Enugu and Port-Harcourt was visualized and analysed systematically
2. It is shown that the data in the two states is homogenous
3. The trends and probable change points in the data were highlighted
4. The average temperature in both states is 27 degrees Celsius
5. March is the hottest month in both states for the period 2009 - 2018
6. July - September is the coldest period for the given time period
7. On average, Enugu has a cooler (downward trend) temperature than Port-Harcourt (no trend)