In [ ]:

```
**Project data information
https://archive.ics.uci.edu/ml/datasets/Beijing+Multi-Site+Air-Quality+Data#
Abstract: This hourly data set considersing.
Source:
Song Xi Chen, csx '@' gsm.pku.edu.cn, Guanghua School of Management, Center for Statistical Science, Peking University.
Data Set Information:
This data set includes hourly air pollutants data from 12 nationally-controlled air-quality monitoring sites.
The air-quality data are from the Beijing Municipal Environmental Monitoring Center.
The meteorological data in each air-quality site are matched with the nearest weather station from the China Meteorological Administration.
The time period is from March 1st, 2013 to February 28th, 2017. Missing data are denoted as NA.

Attribute Information:
No: row number
year: year of data in this row
month: month of data in this row
day: day of data in this row
hour: hour of data in this row
PM2.5: PM2.5 concentration (ug/m^3)
PM10: PM10 concentration (ug/m^3)
SO2: SO2 concentration (ug/m^3)
NO2: NO2 concentration (ug/m^3)
CO: CO concentration (ug/m^3)
O3: O3 concentration (ug/m^3)
TEMP: temperature (degree Celsius)
PRES: pressure (hPa)
DEWP: dew point temperature (degree Celsius)
RAIN: precipitation (mm)
wd: wind direction
WSPM: wind speed (m/s)
station: name of the air-quality monitoring site

Relevant Papers:
Zhang, S., Guo, B., Dong, A., He, J., Xu, Z. and Chen, S.X. (2017) Cautionary Tales on Air-Quality Improvement in Beijing.
Proceedings of the Royal Society A, Volume 473, No. 2205, Pages 20170457.
```

In [15]:

```
# NumPy deals with:
#1.mathematical and logical operations
#2.calulate mean,std,and describe statistics functions
#Pandas deals with:
#1.import database to dataframe
#2.reshape,clean and pivot of data sets
import numpy as np
import pandas as pd
```

In [28]:

```
# load data from csv file in folder AIR_DATA as dataframe
df_CP=pd.read_csv('AIR_DATA/Changping.csv')

# show detail data information: total 35064 rows, 18 columns, and data type
df_CP.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 35064 entries, 0 to 35063
Data columns (total 18 columns):
No          35064 non-null int64
year        35064 non-null int64
month       35064 non-null int64
day         35064 non-null int64
hour        35064 non-null int64
PM2.5       34290 non-null float64
PM10        34482 non-null float64
SO2         34436 non-null float64
NO2         34397 non-null float64
CO          33543 non-null float64
O3          34460 non-null float64
TEMP        35011 non-null float64
PRES        35014 non-null float64
DEWP        35011 non-null float64
RAIN        35013 non-null float64
wd          34924 non-null object
WSPM        35021 non-null float64
station     35064 non-null object
dtypes: float64(11), int64(5), object(2)
memory usage: 4.8+ MB
```

In [29]:

```
# using describe function show mean, standard deviation, max, min and percenti
les
df_CP['PM2.5'].describe().round(2)
```

Out[29]:

```
count    34290.00
mean        71.10
std         72.33
min          2.00
25%         18.00
50%         46.00
75%        100.00
max        882.00
Name: PM2.5, dtype: float64
```

In [30]:

```
# show record NO. 1814 to 1816, there are missing value at PM2.5 columns
df_CP.iloc[1813:1816]
```

Out[30]:

	No	year	month	day	hour	PM2.5	PM10	SO2	NO2	CO	O3	TEMP	PRES	D
1813	1814	2013	5	15	13	53.0	100.0	52.0	29.0	1200.0	131.0	27.5	1006.3	
1814	1815	2013	5	15	14	NaN	70.0	46.0	22.0	1100.0	157.0	27.7	1005.8	
1815	1816	2013	5	15	15	NaN	71.0	39.0	19.0	1100.0	188.0	27.9	1005.2	

In [31]:

```
# fill NaN value with forward value.
df_CP.fillna( method ='ffill', inplace = True)
df_CP.iloc[1813:1816]
```

Out[31]:

	No	year	month	day	hour	PM2.5	PM10	SO2	NO2	CO	O3	TEMP	PRES	D
1813	1814	2013	5	15	13	53.0	100.0	52.0	29.0	1200.0	131.0	27.5	1006.3	
1814	1815	2013	5	15	14	53.0	70.0	46.0	22.0	1100.0	157.0	27.7	1005.8	
1815	1816	2013	5	15	15	53.0	71.0	39.0	19.0	1100.0	188.0	27.9	1005.2	

In [32]:

```
#Group by data for aggregation and transformations.
# show records by monthly from 2013 to 2017
df_CP_year=df_CP.groupby(['year','month']).mean()

# Create a drop list, so that it can use it in next dateframe
drop_list=['No','day','hour','SO2','NO2','CO','O3','PRES','DEWP','RAIN']

# Drop columns from dataframe
df_CP_year.drop(drop_list,axis=1,inplace=True)
df_CP_year.round(2)
```

Out[32]:

		PM2.5	PM10	TEMP	WSPM
year	**month**				
2013	**3**	98.92	123.43	5.90	1.72
	4	59.69	90.05	12.41	2.23
	5	82.99	118.17	21.99	1.86
	6	81.04	102.32	23.71	1.25
	7	61.98	64.94	27.27	1.35
	8	55.35	67.43	26.97	1.45
	9	73.30	82.98	20.38	1.12
	10	82.51	99.91	13.43	1.33
	11	60.78	81.32	6.70	2.11
	12	67.15	80.84	0.84	2.06
2014	**1**	88.30	109.95	-0.01	1.89
	2	143.49	150.54	-0.42	1.73
	3	86.00	127.85	10.08	1.95
	4	105.65	140.63	17.33	1.83
	5	53.96	100.34	22.03	2.31
	6	45.04	59.51	25.14	1.66
	7	78.22	101.25	28.36	1.80
	8	56.56	75.98	26.36	1.72
	9	60.42	78.71	20.80	1.53
	10	118.53	138.47	13.62	1.45
	11	76.89	118.62	6.36	1.85
	12	52.99	90.15	-0.57	2.68
2015	**1**	97.05	115.28	-0.63	1.86
	2	86.95	116.48	1.59	2.22
	3	78.47	144.38	8.76	2.11
	4	61.99	99.59	15.67	2.18
	5	54.63	87.29	21.39	2.19
	6	57.68	74.95	24.59	1.88
	7	56.10	66.56	26.25	1.62
	8	38.59	56.85	26.23	1.46
	9	42.96	50.74	20.40	1.43
	10	46.56	66.15	14.44	1.97
	11	90.55	99.19	3.22	1.33
	12	120.23	146.50	0.03	1.87

		PM2.5	PM10	TEMP	WSPM
year	**month**				
2016	**1**	54.82	80.98	-4.15	2.67
	2	37.37	58.09	1.44	2.74
	3	73.02	125.01	8.85	2.10
	4	56.92	106.52	16.33	2.43
	5	50.80	80.30	21.06	2.16
	6	52.99	67.38	25.39	1.86
	7	54.93	67.84	27.11	1.65
	8	36.76	52.68	27.19	1.64
	9	44.16	56.34	21.40	1.55
	10	79.84	96.27	12.82	1.52
	11	85.79	119.69	4.12	1.78
	12	109.84	125.64	0.10	1.73
2017	**1**	98.30	113.93	-1.39	2.03
	2	59.23	72.21	2.38	2.22

In [33]:
```
#new dataframe include: PM2.5   PM10    TEMP    WSPM four columns, 48 rows
df_CP_year.info()
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 48 entries, (2013, 3) to (2017, 2)
Data columns (total 4 columns):
PM2.5    48 non-null float64
PM10     48 non-null float64
TEMP     48 non-null float64
WSPM     48 non-null float64
dtypes: float64(4)
memory usage: 1.8 KB
```

In [34]:

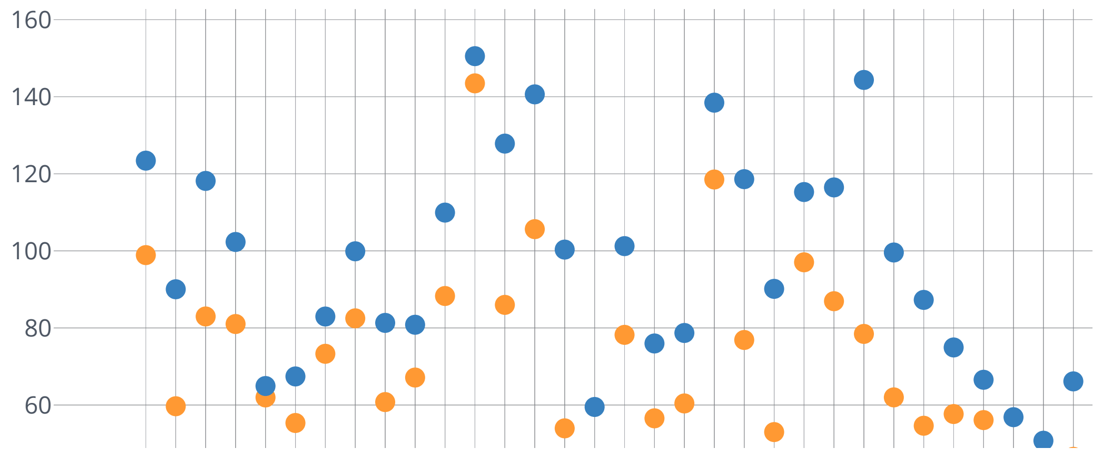
```
# groupby month, show average data from Jan. to Dec.
df_CP_month=df_CP.groupby(['month']).mean()
df_CP_month.drop(drop_list,axis=1,inplace=True)
df_CP_month.drop(['year'],axis=1,inplace=True)
df_CP_month.round(2)
```

Out[34]:

```
       PM2.5   PM10   TEMP  WSPM
month
    1  84.62  105.04  -1.55  2.11
    2  81.37   98.97   1.25  2.23
    3  84.10  130.17   8.40  1.97
    4  71.06  109.20  15.44  2.17
    5  60.59   96.53  21.62  2.13
    6  59.19   76.04  24.71  1.66
    7  62.81   75.15  27.25  1.60
    8  46.82   63.24  26.69  1.57
    9  55.21   67.19  20.75  1.41
   10  81.86  100.20  13.58  1.57
   11  78.50  104.71   5.10  1.77
   12  87.55  110.78   0.10  2.08
```

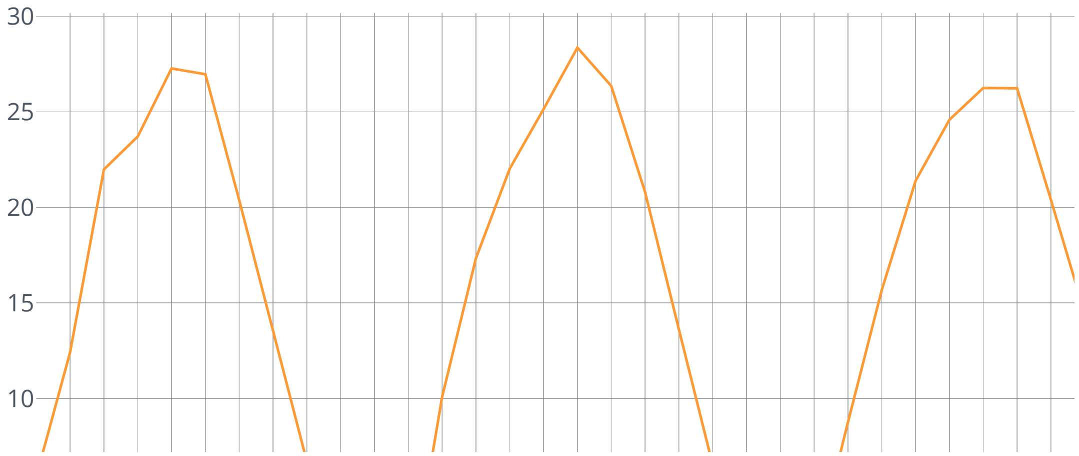
In [35]:

```
# Plotly is an interactive visualization library.
# Cufflinks connects plotly with pandas
import cufflinks as cf

# it also has open source that you can use offline
# to use the open source offline you need to type the following line
from plotly.offline import download_plotlyjs, init_notebook_mode, plot, iplot

# For Notebooks
# the following will connect the javascript to your notebook
# plotly connects python pandas to interactive javascript library
# the following line allows you to connect to those interactive visualization
init_notebook_mode(connected=True)
cf.go_offline()

# seaborn is used to create more attractive and informative statistical graphics.
# it is built on top of MatPlotLib
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline

#  four columns is shown by plotly interactive image,
df_CP_year.iplot(kind='scatter',mode='markers',size=10)
```


160
140
120
100
80
60

In [36]:

```
# show default plot which is the line graphs.
df_CP_year.iplot(y=['TEMP','WSPM'])
```



In [37]:

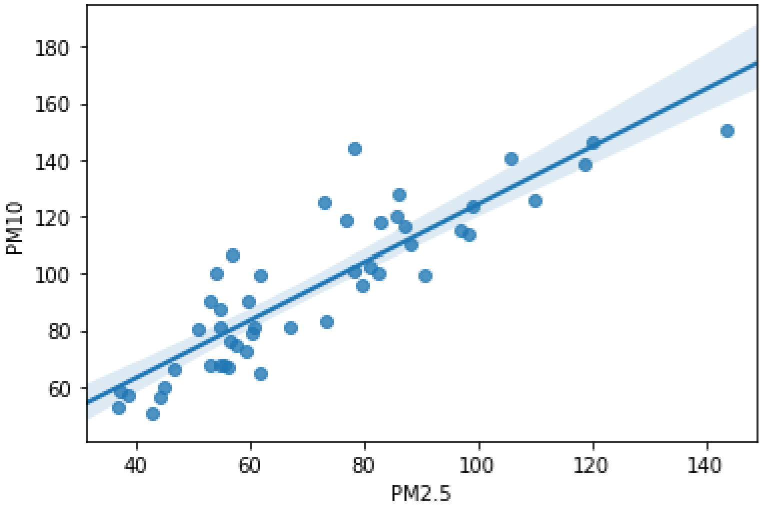
```
# Matrix form for correlation data
df_CP_year[['PM2.5','PM10','TEMP','WSPM']].corr().round(3)
```

Out[37]:

	PM2.5	PM10	TEMP	WSPM
PM2.5	1.000	0.879	-0.503	-0.204
PM10	0.879	1.000	-0.510	0.085
TEMP	-0.503	-0.510	1.000	-0.453
WSPM	-0.204	0.085	-0.453	1.000

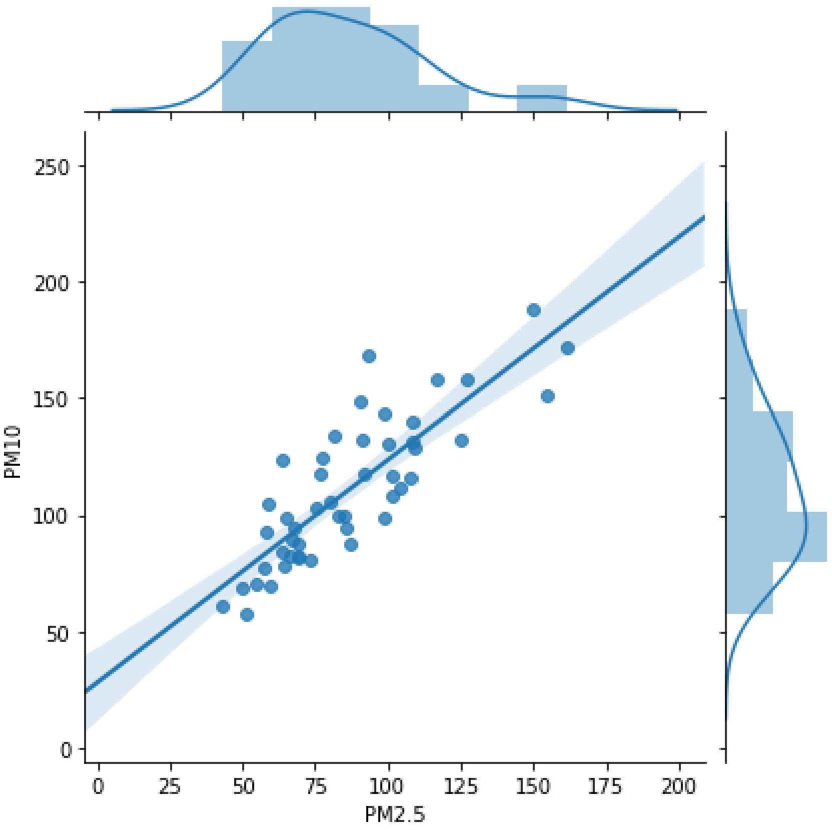
```
In [38]: # using regression line show correlation between PM2.5 & PM10
         sns.regplot(x='PM2.5',y='PM10',data=df_CP_year)
```

```
Out[38]: <matplotlib.axes._subplots.AxesSubplot at 0x22689706400>
```

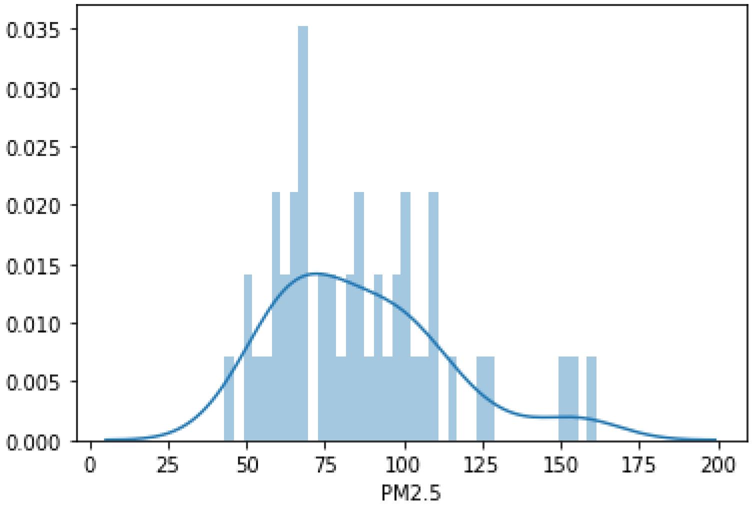


```
In [39]: # same as: read csv file for Dongsi, fillna, groupby,drop extra columns
         df_DS=pd.read_csv('AIR_DATA/Dongsi.csv')
         df_DS.fillna( method ='ffill', inplace = True)
         df_DS_year=df_DS.groupby(['year','month']).mean()
         df_DS_year.drop(drop_list,axis=1,inplace=True)
```

```
In [40]: # it show a regression line on the scattered point data,they are strong relati
         onship
         sns.jointplot(x='PM2.5', y='PM10', data=df_DS_year,kind='reg')

Out[40]: <seaborn.axisgrid.JointGrid at 0x22689b7e198>
```



```
In [41]: # show how the PM10 distributed, it is not nomal distribute
         sns.distplot(df_DS_year['PM2.5'],bins=40)

Out[41]: <matplotlib.axes._subplots.AxesSubplot at 0x22689457ef0>
```

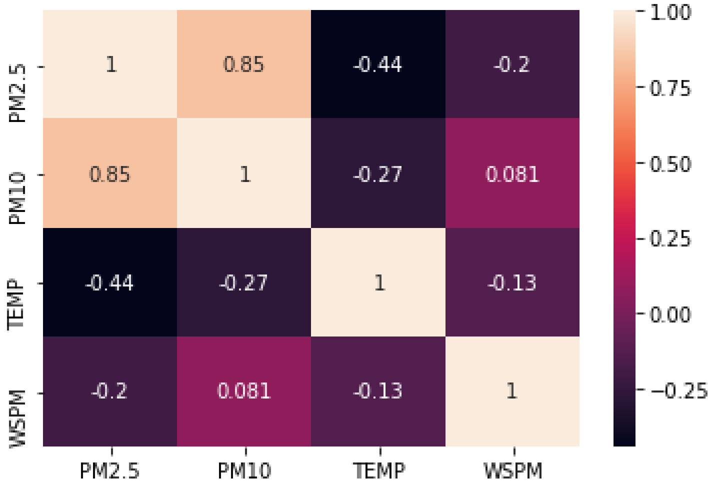


In [42]:

```
# same as before: read csv file for Huairou, fillna, groupby,drop extra column
s
df_HR=pd.read_csv('AIR_DATA/Huairou.csv')
df_HR.fillna( method ='ffill', inplace = True)
df_HR_year=df_HR.groupby(['year','month']).mean()
df_HR_year.drop(drop_list,axis=1,inplace=True)
df_HR_year.round(2)

# using heatmap show matrix form for correlation data
sns.heatmap(df_HR_year.corr(),annot=True)
```

Out[42]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x226896abe80>
```



In [43]:

```
# same as before: read csv file for SHUNYI, fillna, groupby,drop extra columns
df_SY=pd.read_csv('AIR_DATA/SHUNYI.csv')
df_SY.fillna( method ='ffill', inplace = True)
df_SY_year=df_SY.groupby(['year','month']).mean()
df_SY_year.drop(drop_list,axis=1,inplace=True)
df_SY_year.round(2)

# pivoting table by month and year
df_SY_year.pivot_table(index='month',columns='year',values='PM2.5').round(2)
```

Out[43]:

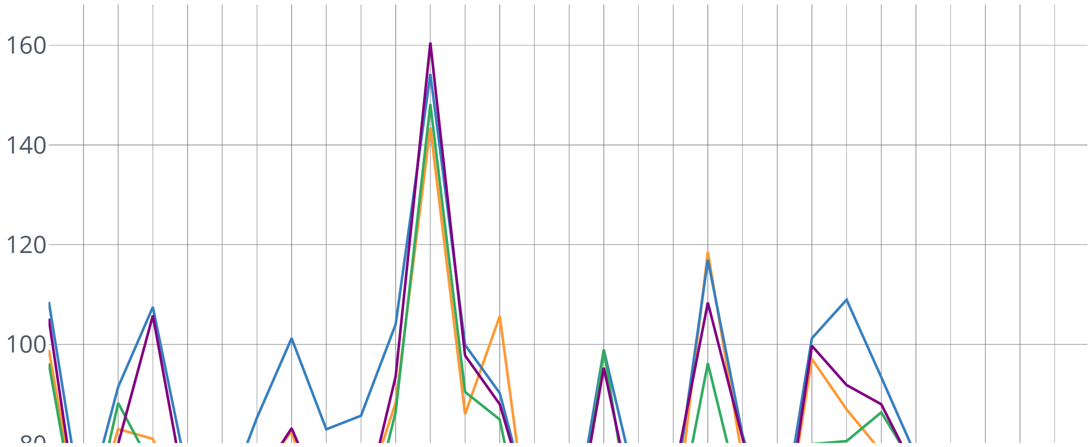
year	2013	2014	2015	2016	2017
month					
1	NaN	93.56	99.70	70.45	117.86
2	NaN	160.51	91.83	49.31	70.22
3	105.16	97.76	87.97	97.76	NaN
4	57.91	87.98	74.28	76.96	NaN
5	80.04	64.43	58.23	66.05	NaN
6	105.80	55.88	64.66	56.30	NaN
7	67.67	95.30	62.20	64.14	NaN
8	60.40	62.87	43.83	46.68	NaN
9	72.48	72.70	48.66	56.04	NaN
10	83.16	108.37	75.30	81.02	NaN
11	66.97	81.19	118.10	94.01	NaN
12	64.46	52.71	156.87	118.38	NaN

In [44]:

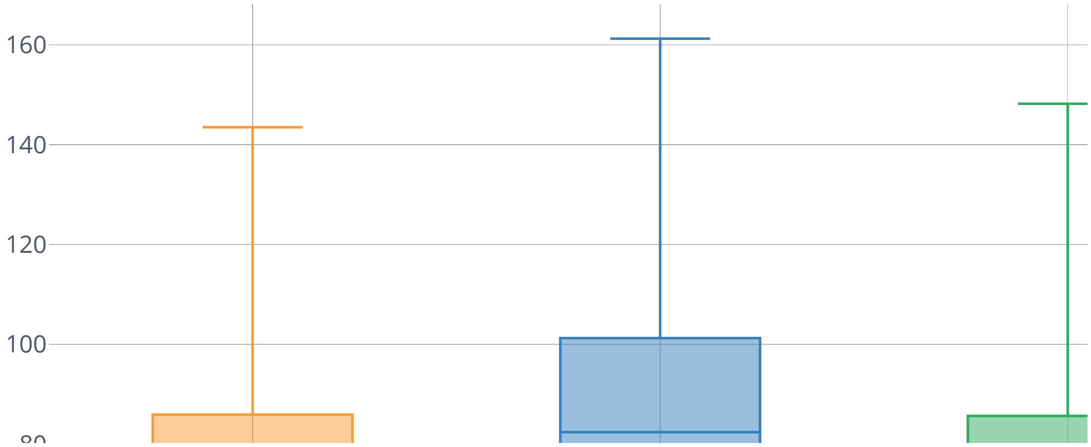
```
# only sign column PM10 to a new dataframe, so that it can concatenate.
df_CP_CON=df_CP_year[['PM2.5']].round(2)
df_DS_CON=df_DS_year[['PM2.5']].round(2)
df_HR_CON=df_HR_year[['PM2.5']].round(2)
df_SY_CON=df_SY_year[['PM2.5']].round(2)
```

In [45]:

```
# use .concat() function concat a dataframe and returns a new dataframe.
#  set axes join = inner for intersection of dataframe
df_BJ_year=pd.concat([df_CP_CON,df_DS_CON,df_HR_CON,df_SY_CON,], axis=1, join=
'inner')

# change columns name using a list
df_BJ_year.columns=['CP','DS','HR','SY']
df_BJ_year.iplot()
```



In [46]:
```
# using boxplot to show percentile
df_BJ_year.iplot(kind='box')
```



In [47]:
```
# the self define function changes the numeric to Categorial value
def BJ_Air(num):

    if num>=110:
        text='Hazardous'
    elif num>=90:
        text='Unhealthy'
    elif num>=70:
        text='healthy'
    elif num<70:
        text='Good'
    return text

#df_BJ_year['BJ_Air']=list_BJ
#df_BJ_year.loc[(df_BJ_year['CP']>=120),'BJ_Air']='Hazardous'
#df_BJ_year.loc[(df_BJ_year['CP']>=100) & (df_BJ_year['CP']<120),'BJ_Air']='Un
healthy'
#df_BJ_year.loc[(df_BJ_year['CP']>=80) & (df_BJ_year['CP']<100),'BJ_Air']='hea
lthy'
#df_BJ_year.loc[(df_BJ_year['CP']<=80),'BJ_Air']='Good'
```

In [48]:

```
# Using BJ_Air function to add new columns in the data set
df_BJ_year['CP_Air'] = df_BJ_year['CP'].apply(BJ_Air)
df_BJ_year['DS_Air'] = df_BJ_year['DS'].apply(BJ_Air)
df_BJ_year['HR_Air'] = df_BJ_year['HR'].apply(BJ_Air)
df_BJ_year['SY_Air'] = df_BJ_year['SY'].apply(BJ_Air)
df_BJ_year.head(15)
```

Out[48]:

		CP	DS	HR	SY	CP_Air	DS_Air	HR_Air	SY_Air
year	**month**								
2013	**3**	98.92	108.54	96.19	105.16	Unhealthy	Unhealthy	Unhealthy	Unhealthy
	4	59.69	65.29	57.35	57.91	Good	Good	Good	Good
	5	82.99	91.45	88.22	80.04	healthy	Unhealthy	healthy	healthy
	6	81.04	107.48	74.96	105.80	healthy	Unhealthy	healthy	Unhealthy
	7	61.98	73.60	62.10	67.67	Good	healthy	Good	Good
	8	55.35	66.95	56.20	60.40	Good	Good	Good	Good
	9	73.30	85.27	69.00	72.48	healthy	healthy	Good	healthy
	10	82.51	101.23	77.41	83.16	healthy	Unhealthy	healthy	healthy
	11	60.78	82.95	58.51	66.97	Good	healthy	Good	Good
	12	67.15	85.68	58.28	64.46	Good	healthy	Good	Good
2014	**1**	88.30	104.02	86.46	93.56	healthy	Unhealthy	healthy	Unhealthy
	2	143.49	154.26	148.20	160.51	Hazardous	Hazardous	Hazardous	Hazardous
	3	86.00	99.88	90.46	97.76	healthy	Unhealthy	Unhealthy	Unhealthy
	4	105.65	90.22	84.91	87.98	Unhealthy	Unhealthy	healthy	healthy
	5	53.96	63.79	51.49	64.43	Good	Good	Good	Good

In [49]:

```
import warnings
warnings.filterwarnings("ignore")
```

In [50]:

```
#import required libraries
from scipy.stats import normaltest
import scipy.stats as stats
```

In [51]:

```
# p-value is less than 0.05, PM2.5 is not normal distribution
stats.normaltest(df_CP_year['PM2.5'])
```

Out[51]:

```
NormaltestResult(statistic=6.896295706386154, pvalue=0.03180448844162603)
```

In [52]:

```
# Because the p-value is 0.0039, which is smaller than the significance level
 of 0.05,
# the decision is to support alternative hypothesis.
from statsmodels.stats.weightstats import ztest
(test_statistic, p_value) = ztest(df_CP_year['PM2.5'], value=62, alternative=
'larger', ddof=1.0)
print("The test statistic is: ", round(test_statistic,5))
print("The p-value is: ", round(p_value,5))
```

```
The test statistic is:  2.66078
The p-value is:  0.0039
```

In [53]:

```
#Because the p-value is 0.9961, which is greater than the significance level o
f 0.05,
#the decision is  to reject the alternative hypothesis.
(test_statistic, p_value) = ztest(df_CP_year['PM2.5'], value=62, alternative=
'smaller', ddof=1.0)
print("The test statistic is: ", round(test_statistic,5))
print("The p-value is: ", round(p_value,5))
```

```
The test statistic is:  2.66078
The p-value is:  0.9961
```

In [54]:

```
# show the mean of PM2.5 in the column
print("The mean of PM2.5 is: ", round(df_CP_year['PM2.5'].mean(),5))
```

```
The mean of PM2.5 is:  71.17278
```

In [ ]:

```
```