Air Quality Index Analysis

[1]:
```
import numpy as np
import pandas as pd
import warnings
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
import statsmodels.api as sm
import itertools

from pylab import rcParams

warnings.filterwarnings('ignore')
rcParams['figure.figsize'] = 18, 15
sns.set_style('darkgrid')
```

[2]:
```
''' reading dataset '''
df_city_day = pd.read_csv('city_day.csv')
```

[3]:
```
''' displaying 5 rows '''
df_city_day.head()
```

[3]:

	City	Date	PM2.5	PM10	NO	NO2	NOx	NH3	CO	SO2	O3	Benzene	Toluene	Xylene	AQI	AQI_Bucket
0	Ahmedabad	2015-01-01	NaN	NaN	0.92	18.22	17.15	NaN	0.92	27.64	133.36	0.00	0.02	0.00	NaN	NaN
1	Ahmedabad	2015-01-02	NaN	NaN	0.97	15.69	16.46	NaN	0.97	24.55	34.06	3.68	5.50	3.77	NaN	NaN
2	Ahmedabad	2015-01-03	NaN	NaN	17.40	19.30	29.70	NaN	17.40	29.07	30.70	6.80	16.40	2.25	NaN	NaN
3	Ahmedabad	2015-01-04	NaN	NaN	1.70	18.48	17.97	NaN	1.70	18.59	36.08	4.43	10.14	1.00	NaN	NaN
4	Ahmedabad	2015-01-05	NaN	NaN	22.10	21.42	37.76	NaN	22.10	39.33	39.31	7.01	18.89	2.78	NaN	NaN

[4]:
```
''' checking null values '''
df_city_day.isnull().sum()
```

[4]:
```
City              0
Date              0
PM2.5          4598
PM10          11140
NO             3582
NO2            3585
NOx            4185
NH3           10328
CO             2059
SO2            3854
O3             4022
Benzene        5623
Toluene        8041
Xylene        18109
AQI            4681
AQI_Bucket     4681
dtype: int64
```

[5]:
```
''' shape of dataset '''
df_city_day.shape
```

[5]:
```
(29531, 16)
```

[6]:
```
''' percentage of missing values in each column '''
for c in df_city_day.columns:
    null_values = df_city_day[c].isna().sum()
    percentage = (null_values / len(df_city_day)) * 100
    print("In {}, mean of null value is: {}".format(c, percentage))
    print("-" * 60)
```

```
In City, mean of null value is: 0.0
------------------------------------------------------------
In Date, mean of null value is: 0.0
------------------------------------------------------------
In PM2.5, mean of null value is: 15.570078900138837
------------------------------------------------------------
In PM10, mean of null value is: 37.72307067149775
------------------------------------------------------------
In NO, mean of null value is: 12.129626494192543
------------------------------------------------------------
In NO2, mean of null value is: 12.139785310351833
------------------------------------------------------------
In NOx, mean of null value is: 14.17154854220988
------------------------------------------------------------
In NH3, mean of null value is: 34.97341776438319
------------------------------------------------------------
In CO, mean of null value is: 6.9723341573262
```

```
------------------------------------------------------------
In SO2, mean of null value is: 13.050692492634857
------------------------------------------------------------
In O3, mean of null value is: 13.619586197555112
------------------------------------------------------------
In Benzene, mean of null value is: 19.041007754563
------------------------------------------------------------
In Toluene, mean of null value is: 27.229013578950934
------------------------------------------------------------
In Xylene, mean of null value is: 61.32200060952897
------------------------------------------------------------
In AQI, mean of null value is: 15.851139480545868
------------------------------------------------------------
In AQI_Bucket, mean of null value is: 15.851139480545868
------------------------------------------------------------
```

[7]:
```
''' filling null values with mean of each column '''
for c in df_city_day.columns:
    if df_city_day[c].isna().sum() > 0:
        if df_city_day[c].dtype == 'float64':
            df_city_day[c] = df_city_day[c].fillna(df_city_day[c].mean())
        elif df_city_day[c].dtype == 'object':
            df_city_day[c] = df_city_day[c].fillna(
                df_city_day[c].value_counts().index[0])
```

[8]:
```
'''again checking null values'''
df_city_day.isna().sum()
```

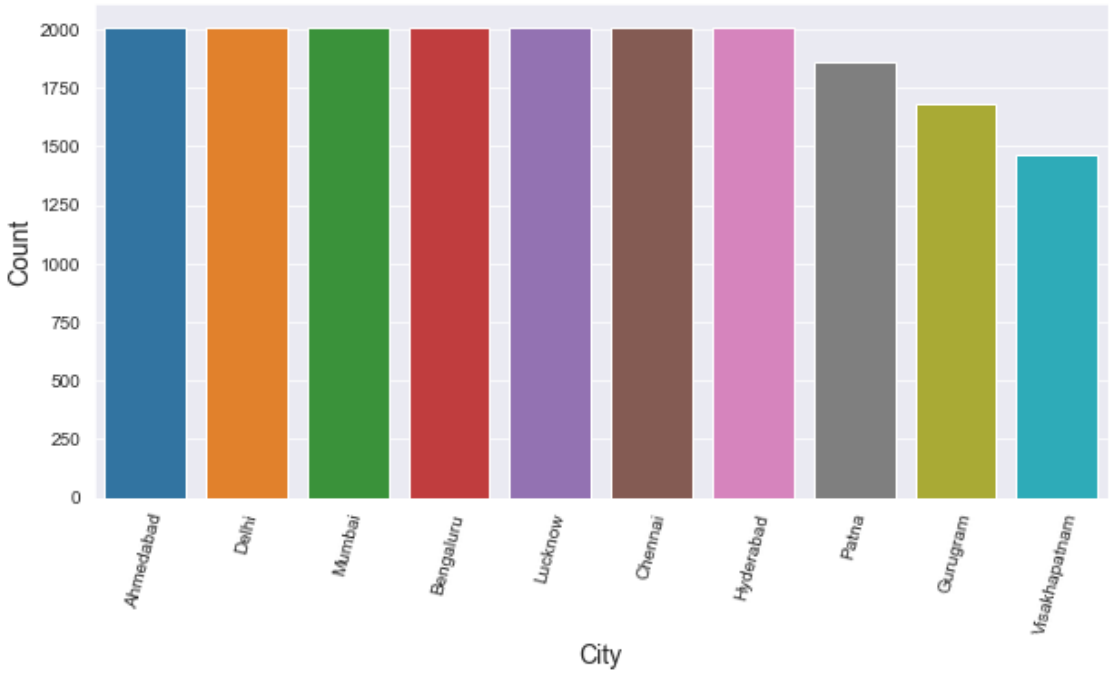
[8]:
```
City          0
Date          0
PM2.5         0
PM10          0
NO            0
NO2           0
NOx           0
NH3           0
CO            0
SO2           0
O3            0
Benzene       0
Toluene       0
Xylene        0
AQI           0
AQI_Bucket    0
dtype: int64
```

[9]:
```
''' info of dataset '''
df_city_day.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 29531 entries, 0 to 29530
Data columns (total 16 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   City        29531 non-null  object
 1   Date        29531 non-null  object
 2   PM2.5       29531 non-null  float64
 3   PM10        29531 non-null  float64
 4   NO          29531 non-null  float64
 5   NO2         29531 non-null  float64
 6   NOx         29531 non-null  float64
 7   NH3         29531 non-null  float64
 8   CO          29531 non-null  float64
 9   SO2         29531 non-null  float64
 10  O3          29531 non-null  float64
 11  Benzene     29531 non-null  float64
 12  Toluene     29531 non-null  float64
 13  Xylene      29531 non-null  float64
 14  AQI         29531 non-null  float64
 15  AQI_Bucket  29531 non-null  object
dtypes: float64(13), object(3)
memory usage: 3.6+ MB
```

[10]:
```
''' count of cities '''
city_label = df_city_day.City.value_counts().nlargest(10)
''' barplot '''
plt.figure(figsize=(10, 5))
plt.xticks(rotation=75)
sns.barplot(city_label.index, city_label)
plt.xlabel('City', fontsize=14)
plt.ylabel('Count', fontsize=14)
```

[10]:
```
Text(0, 0.5, 'Count')
```



[11]:
```
''' making date as index of data '''
df_city_day.index = pd.DatetimeIndex(df_city_day['Date'])
df_city_day.head()
```

[11]:

Date	City	Date	PM2.5	PM10	NO	NO2	NOx
2015-01-01	Ahmedabad	2015-01-01	67.450578	118.127103	0.92	18.22	17.15
2015-01-02	Ahmedabad	2015-01-02	67.450578	118.127103	0.97	15.69	16.46
2015-01-03	Ahmedabad	2015-01-03	67.450578	118.127103	17.40	19.30	29.70
2015-01-04	Ahmedabad	2015-01-04	67.450578	118.127103	1.70	18.48	17.97
2015-01-05	Ahmedabad	2015-01-05	67.450578	118.127103	22.10	21.42	37.76

Date	NH3	CO	SO2	O3	Benzene	Toluene	Xylene
2015-01-01	23.483476	0.92	27.64	133.36	0.00	0.02	0.00
2015-01-02	23.483476	0.97	24.55	34.06	3.68	5.50	3.77
2015-01-03	23.483476	17.40	29.07	30.70	6.80	16.40	2.25
2015-01-04	23.483476	1.70	18.59	36.08	4.43	10.14	1.00
2015-01-05	23.483476	22.10	39.33	39.31	7.01	18.89	2.78

Date	AQI	AQI_Bucket
2015-01-01	166.463581	Moderate
2015-01-02	166.463581	Moderate
2015-01-03	166.463581	Moderate

```
2015-01-04  166.463581   Moderate
2015-01-05  166.463581   Moderate
```

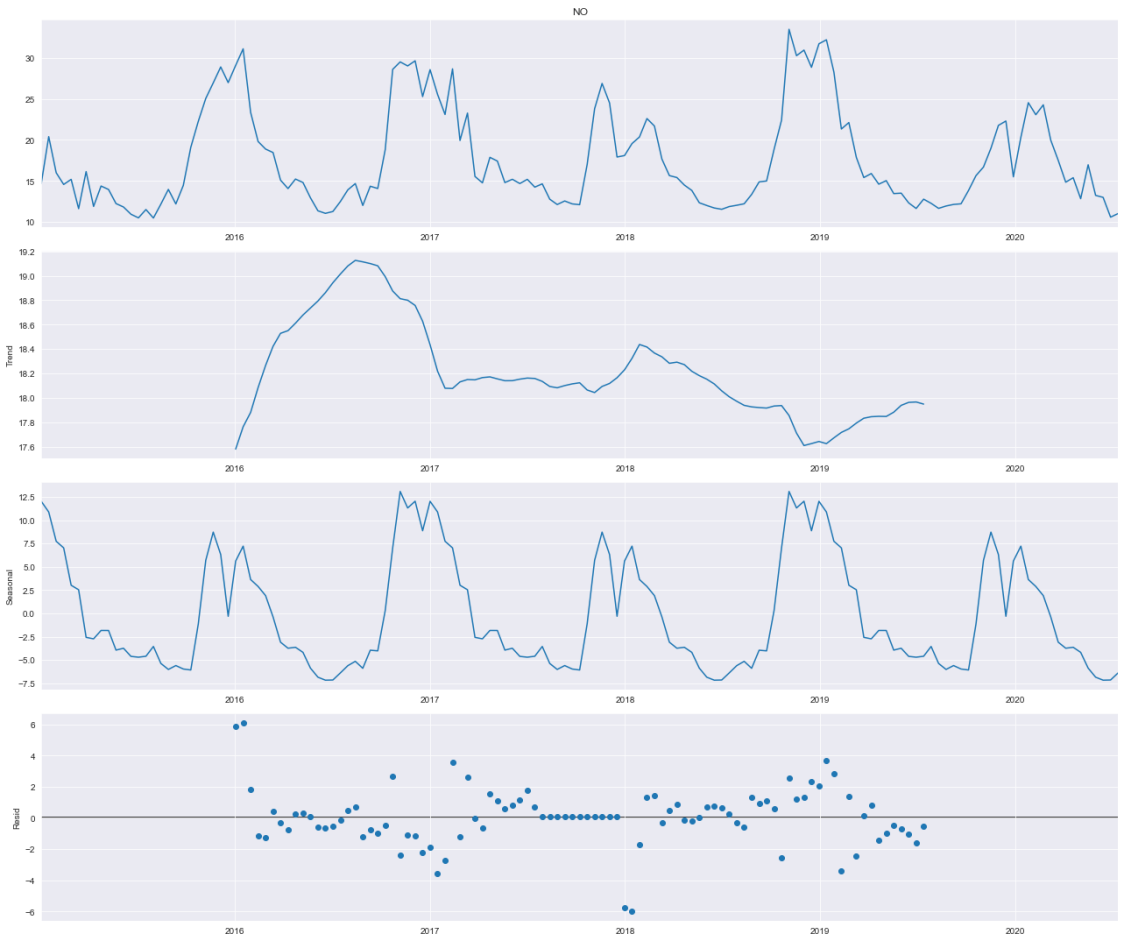
[12]:
```
''' dropping some columns '''
df_city_day.drop([
    'City', 'PM2.5', 'PM10', 'Benzene', 'Toluene', 'Xylene', 'AQI',
    'AQI_Bucket'
],
                 axis=1,
                 inplace=True)
```

[13]:
```
''' after dropping some columns, data looks like '''
df_city_day.head()
```

[13]:

	Date	NO	NO2	NOx	NH3	CO	SO2	O3
Date								
2015-01-01	2015-01-01	0.92	18.22	17.15	23.483476	0.92	27.64	133.36
2015-01-02	2015-01-02	0.97	15.69	16.46	23.483476	0.97	24.55	34.06
2015-01-03	2015-01-03	17.40	19.30	29.70	23.483476	17.40	29.07	30.70
2015-01-04	2015-01-04	1.70	18.48	17.97	23.483476	1.70	18.59	36.08
2015-01-05	2015-01-05	22.10	21.42	37.76	23.483476	22.10	39.33	39.31

[14]:
```
''' Considering the pollutant NO  '''
decomp_no = sm.tsa.seasonal_decompose(df_city_day['NO'].resample('2W').mean(),
                                      model='additive')
fig1 = decomp_no.plot()
plt.show()
```



[15]:
```
''' SARIMA Model for NO '''

a = b = c = range(0, 3)
p = list(itertools.product(a, b, c))
seas_pdq = [(x[0], x[1], x[2], 12) for x in list(itertools.product(a, b, c))]
print('SARIMAX: {} x {}'.format(p[1], seas_pdq[1]))
print('SARIMAX: {} x {}'.format(p[1], seas_pdq[2]))
print('SARIMAX: {} x {}'.format(p[2], seas_pdq[3]))
print('SARIMAX: {} x {}'.format(p[2], seas_pdq[4]))
```

```
SARIMAX: (0, 0, 1) x (0, 0, 1, 12)
SARIMAX: (0, 0, 1) x (0, 0, 2, 12)
SARIMAX: (0, 0, 2) x (0, 1, 0, 12)
SARIMAX: (0, 0, 2) x (0, 1, 1, 12)
```

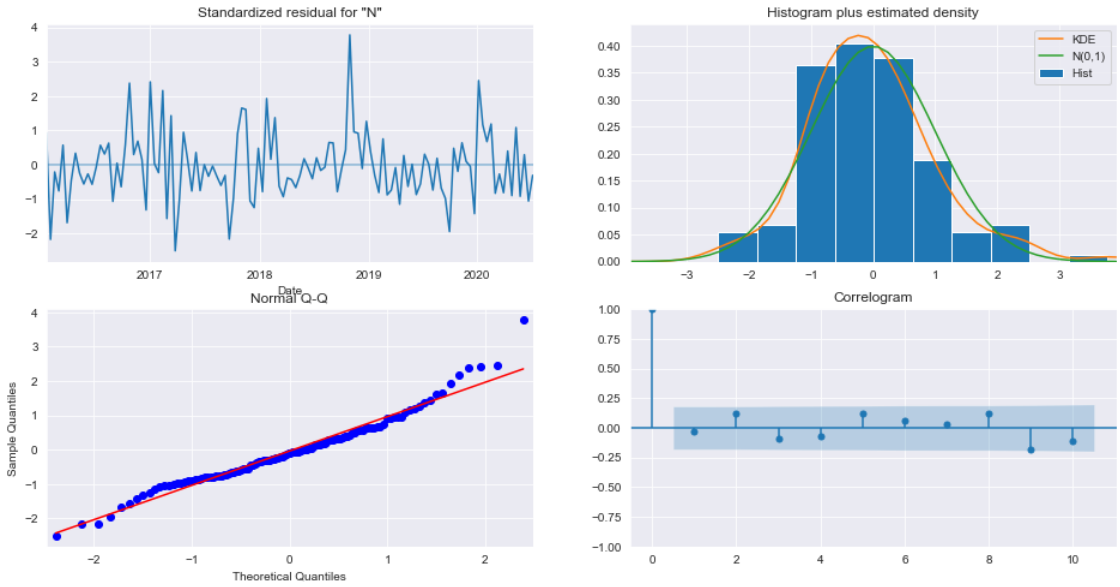
[16]:
```
for params in p:
    for p_seasonal in seas_pdq:
        try:
```

```
            m = sm.tsa.statespace.SARIMAX(
                df_city_day['NO'].resample('2W').mean(),
                order=param,
                seasonal_order=p_seasonal,
                enforce_stationarity=False,
                enforce_invertibility=False)
            results = m.fit()
        except:
            continue
```

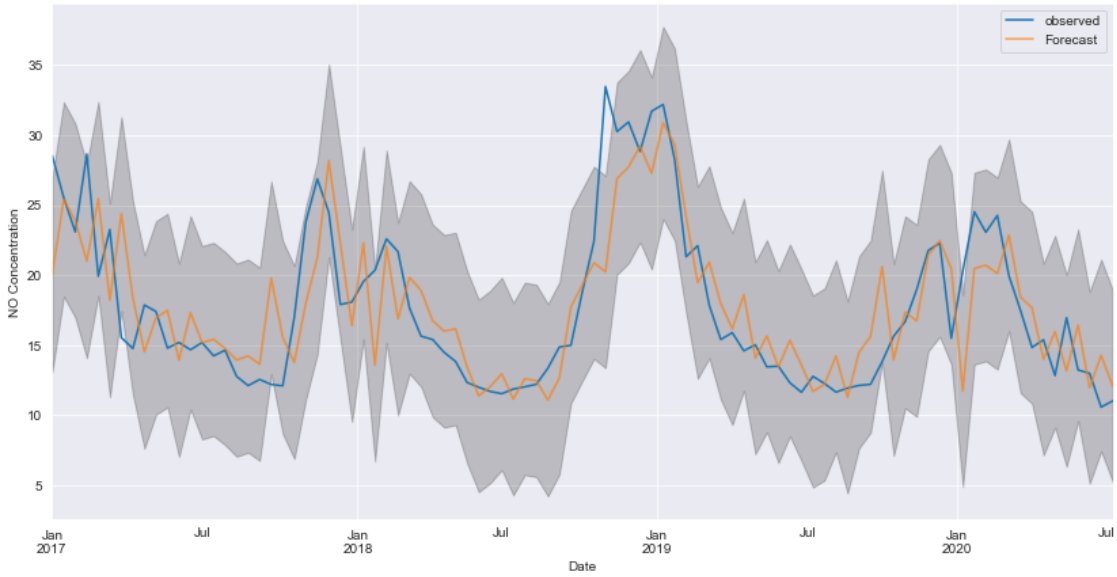
[17]:
```
''' model '''
model = sm.tsa.statespace.SARIMAX(df_city_day['NO'].resample('2W').mean(),
                                  order=(2, 1, 1),
                                  seasonal_order=(1, 1, 0, 12),
                                  enforce_stationarity=False,
                                  enforce_invertibility=False)

res = model.fit()
print(res.summary().tables[1])
```

```
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.8449      0.107      7.897      0.000       0.635       1.055
ar.L2         -0.0304      0.088     -0.347      0.728      -0.202       0.141
ma.L1         -1.0000    188.216     -0.005      0.996    -369.897     367.897
ar.S.L12      -0.6792      0.067    -10.078      0.000      -0.811      -0.547
sigma2        12.0933   2276.533      0.005      0.996   -4449.829    4474.015
==============================================================================
```

[18]:
```
''' plotting '''
res.plot_diagnostics(figsize=(16, 8))
plt.show()
```



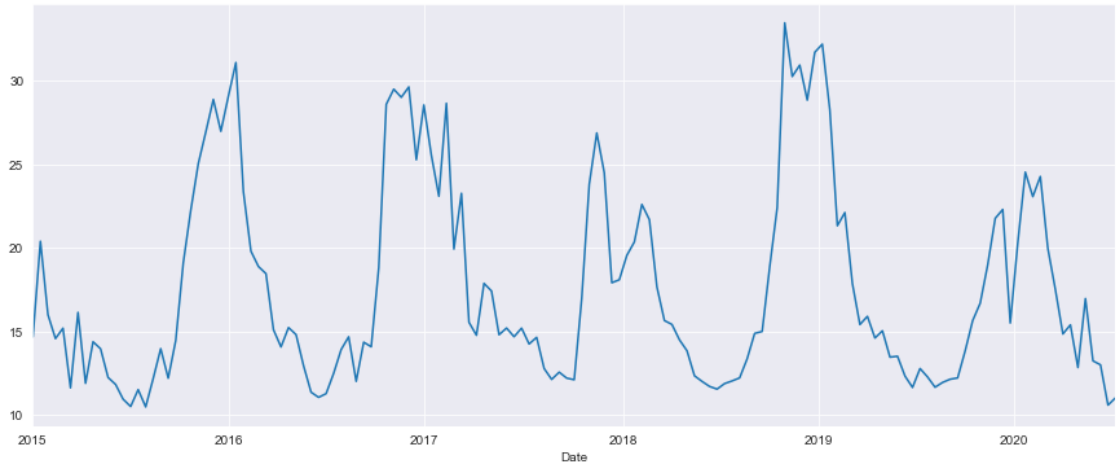
[19]:
```
y_pred = res.get_prediction(start=pd.to_datetime('2017-01-01'), dynamic=False)
y_pred_ci = y_pred.conf_int()

ax = df_city_day['NO'].resample('2W').mean()['2017':].plot(label='observed')
y_pred.predicted_mean.plot(ax=ax, label='Forecast', alpha=.7, figsize=(14, 7))

ax.fill_between(y_pred_ci.index,
                y_pred_ci.iloc[:, 0],
                y_pred_ci.iloc[:, 1],
                color='k',
                alpha=.2)
ax.set_xlabel('Date')
ax.set_ylabel('NO Concentration')

plt.legend(['observed', 'Forecast'])
plt.show()
```



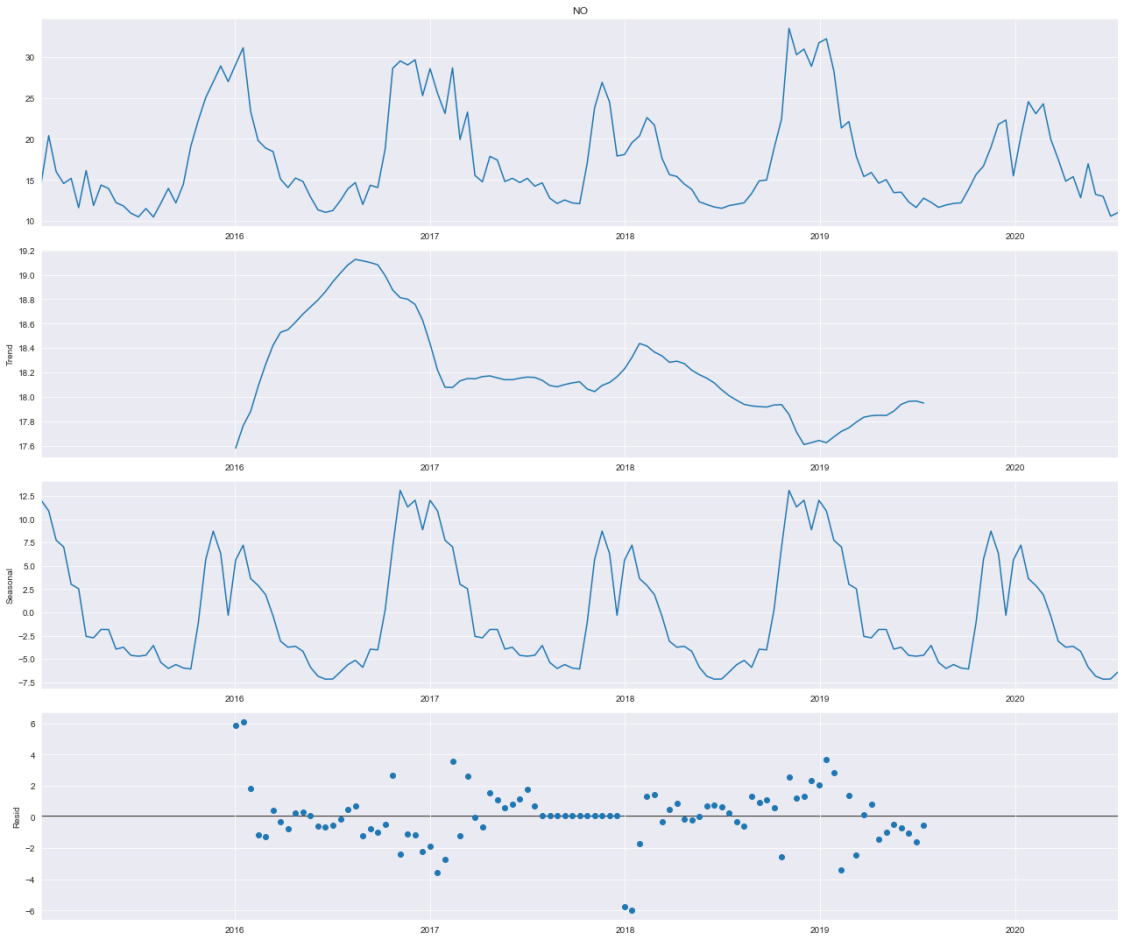
[20]:
```
''' calculating mse and rmse '''

y_f = y_pred.predicted_mean
actual = df_city_day['NO'].resample('2W').mean()['2017-01-01':]
mse = ((y_f - actual)**2).mean()

print('The Mean Squared Error of our forecasts is {}'.format(round(mse, 2)))
print('The Root Mean Squared Error of our forecasts is {}'.format(
    round(np.sqrt(mse), 2)))
```

```
The Mean Squared Error of our forecasts is 12.83
The Root Mean Squared Error of our forecasts is 3.58
```

[21]:
```
''' considering the pollutant SO2  '''

df_city_day['NO'].resample('2W').mean().plot(figsize=(15, 6))
plt.show()
```



[22]:
```
decomp_so2 = sm.tsa.seasonal_decompose(df_city_day['NO'].resample('2W').mean(),
                                       model='additive')
fig_so2 = decomp_so2.plot()
plt.show()
```



[23]:
```
''' SARIMA for SO2 '''

a = b = c = range(0, 3)
p = list(itertools.product(a, b, c))
seas_pdq = [(x[0], x[1], x[2], 12) for x in list(itertools.product(a, b, c))]
print('SARIMAX: {} x {}'.format(p[1], seas_pdq[1]))
print('SARIMAX: {} x {}'.format(p[1], seas_pdq[2]))
print('SARIMAX: {} x {}'.format(p[2], seas_pdq[3]))
print('SARIMAX: {} x {}'.format(p[2], seas_pdq[4]))
```

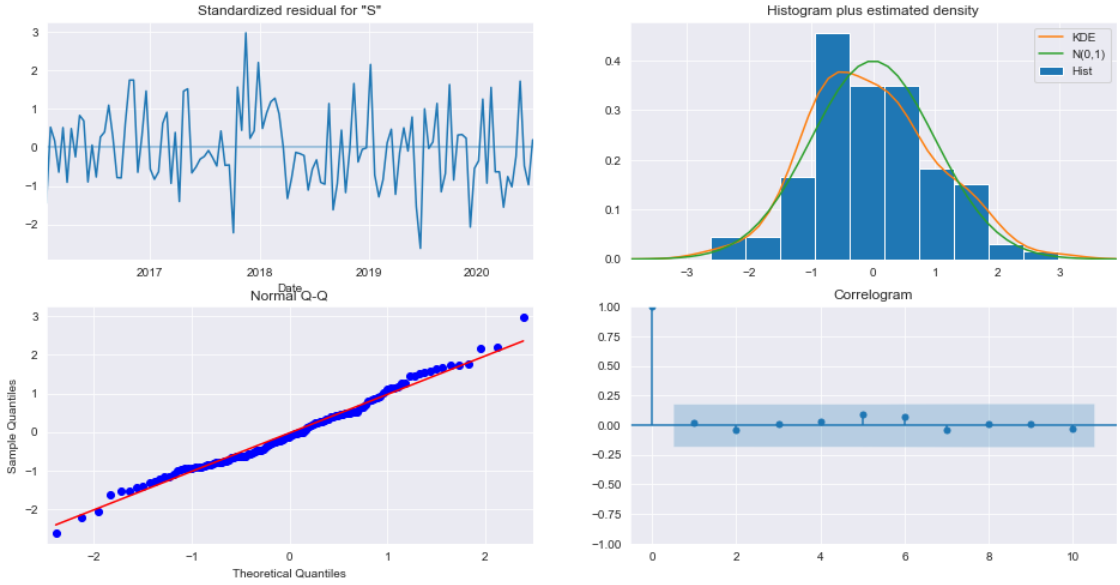
```
SARIMAX: (0, 0, 1) x (0, 0, 1, 12)
SARIMAX: (0, 0, 1) x (0, 0, 2, 12)
SARIMAX: (0, 0, 2) x (0, 1, 0, 12)
SARIMAX: (0, 0, 2) x (0, 1, 1, 12)
```

[24]:
```
for params in p:
    for p_seasonal in seas_pdq:
        try:
            m = sm.tsa.statespace.SARIMAX(
                df_city_day['SO2'].resample('2W').mean(),
                order=param,
                seasonal_order=p_seasonal,
                enforce_stationarity=False,
                enforce_invertibility=False)
            results = m.fit()
        except:
            continue
```

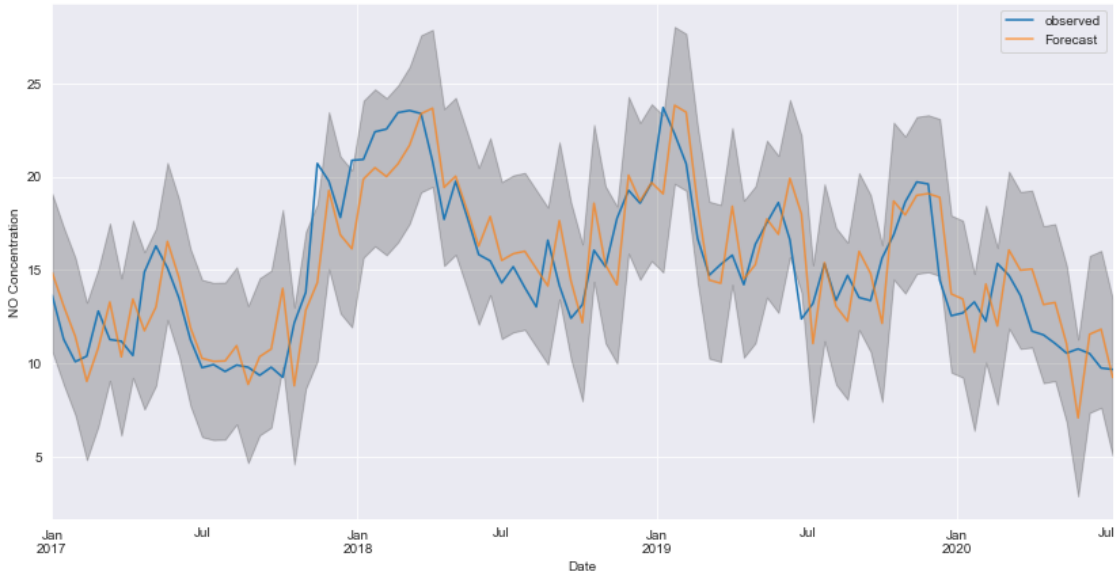
[25]:
```
mod = sm.tsa.statespace.SARIMAX(df_city_day['SO2'].resample('2W').mean(),
                                order=(2, 1, 1),
                                seasonal_order=(1, 1, 0, 12),
                                enforce_stationarity=False,
                                enforce_invertibility=False)
res = mod.fit()
print(res.summary().tables[1])
```

```
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          1.0314      0.123      8.410      0.000       0.791       1.272
ar.L2         -0.2354      0.094     -2.509      0.012      -0.419      -0.052
ma.L1         -0.9631      0.050    -19.293      0.000      -1.061      -0.865
ar.S.L12      -0.4423      0.076     -5.786      0.000      -0.592      -0.293
sigma2         4.6062      0.630      7.315      0.000       3.372       5.840
==============================================================================
```

[26]:
```
''' plotting '''
res.plot_diagnostics(figsize=(16, 8))
plt.show()
```



[27]:
```
y_pred = res.get_prediction(start=pd.to_datetime('2017-01-01'), dynamic=False)
y_pred_ci = y_pred.conf_int()

ax = df_city_day['SO2'].resample('2W').mean()['2017':].plot(label='observed')
y_pred.predicted_mean.plot(ax=ax, label='Forecast', alpha=.7, figsize=(14, 7))

ax.fill_between(y_pred_ci.index,
                y_pred_ci.iloc[:, 0],
                y_pred_ci.iloc[:, 1],
                color='k',
                alpha=.2)
ax.set_xlabel('Date')
ax.set_ylabel('NO Concentration')

plt.legend(['observed', 'Forecast'])
plt.show()
```



[28]:
```
''' calculating mse and rmse '''

y_f = y_pred.predicted_mean
actual = df_city_day['SO2'].resample('2W').mean()['2017-01-01':]
mse = ((y_f - actual)**2).mean()

print('The Mean Squared Error of our forecasts is {}'.format(round(mse, 2)))
print('The Root Mean Squared Error of our forecasts is {}'.format(
    round(np.sqrt(mse), 2)))
```

```
The Mean Squared Error of our forecasts is 4.92
The Root Mean Squared Error of our forecasts is 2.22
```