Time Series Project-CO2 prediction

July 30, 2024

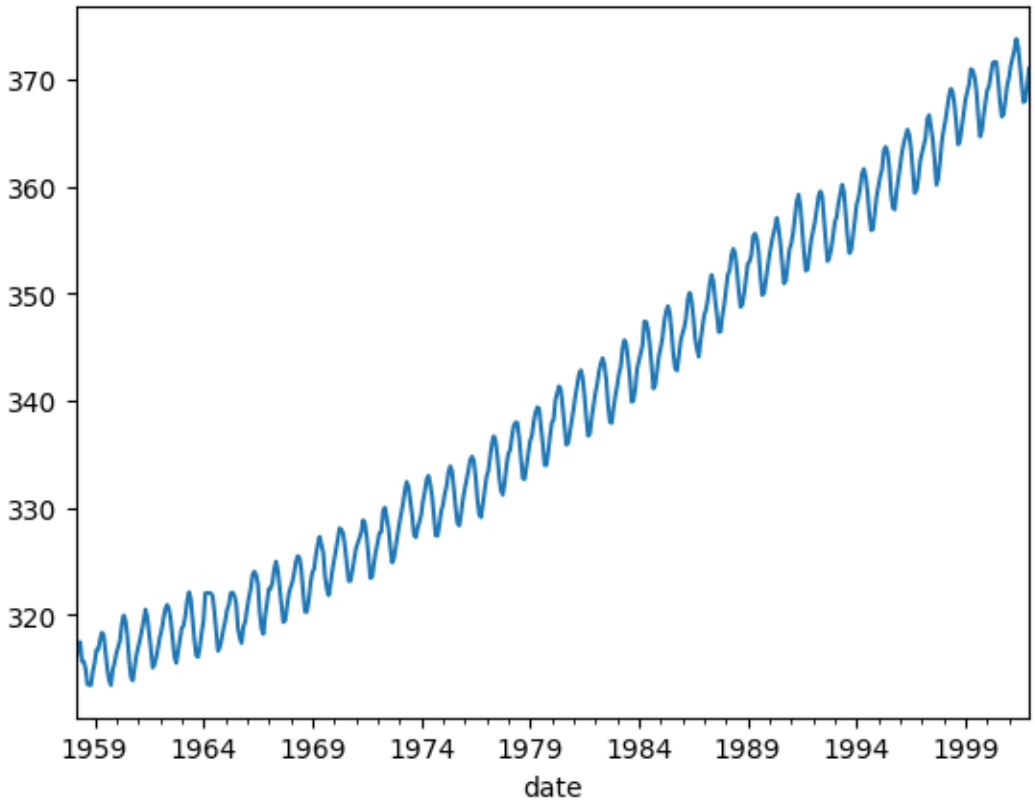
[24]:
```
import pandas as pd
import numpy as np
import statsmodels.api as sm
import matplotlib.pyplot as plt
import warnings
from statsmodels.tsa.stattools import adfuller
warnings.filterwarnings('ignore')
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf

data  = pd.read_csv('co2.csv', parse_dates=['date'], index_col='date')
data.isnull().sum()
```

[24]:
```
co2    59
dtype: int64
```

0.1 Resample

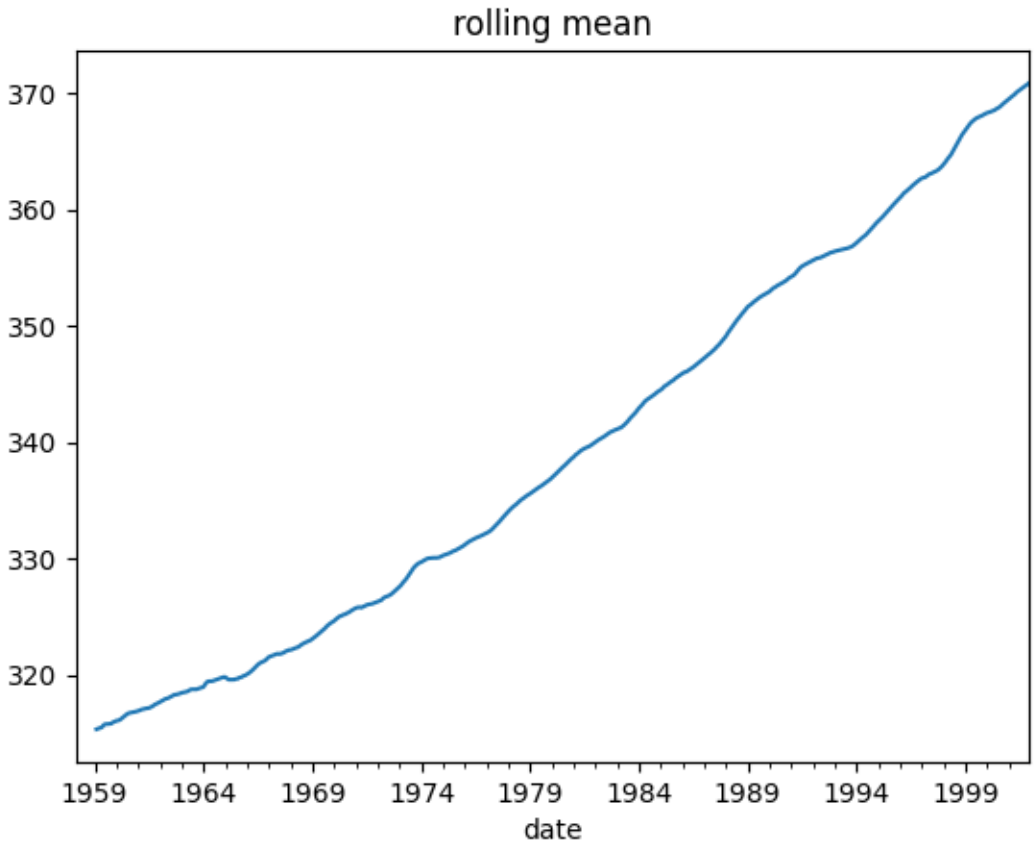
[8]:
```
df = data['co2'].resample('MS').mean()
df = df.fillna(df.bfill())
df.plot()
```

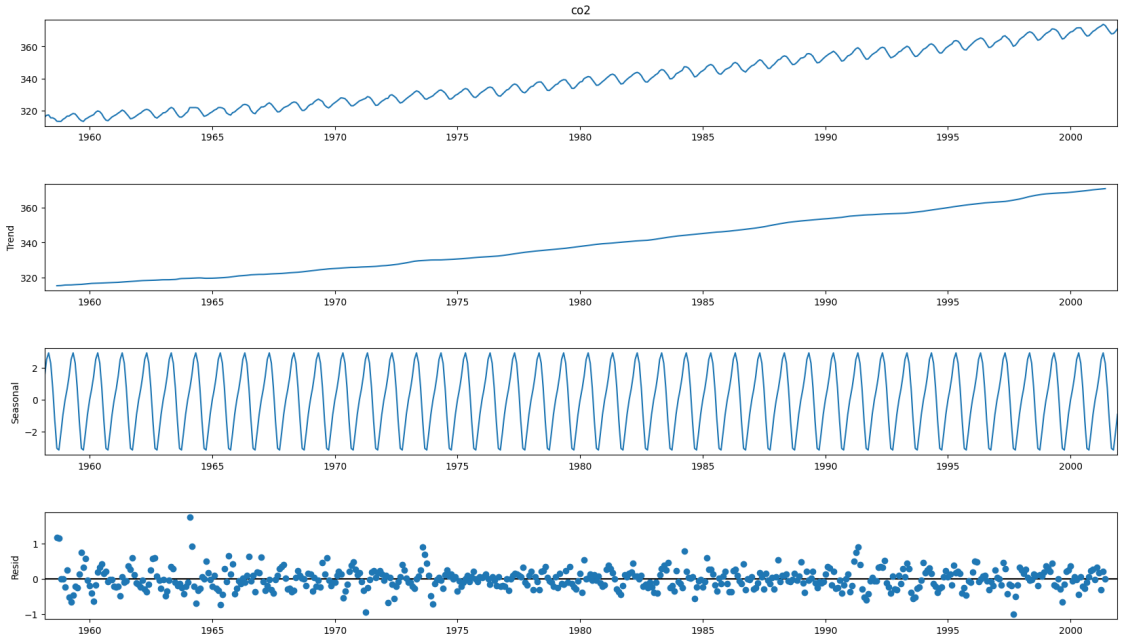
[8]:
```
<Axes: xlabel='date'>
```



0.2 Detrending

[25]:
```
y = df.rolling(window=12).mean()
y.plot(title = 'rolling mean')
decomposed = sm.tsa.seasonal_decompose(df, model='additive')
fig = decomposed.plot()
fig.set_size_inches(18.5, 10.5)
plt.show()
```

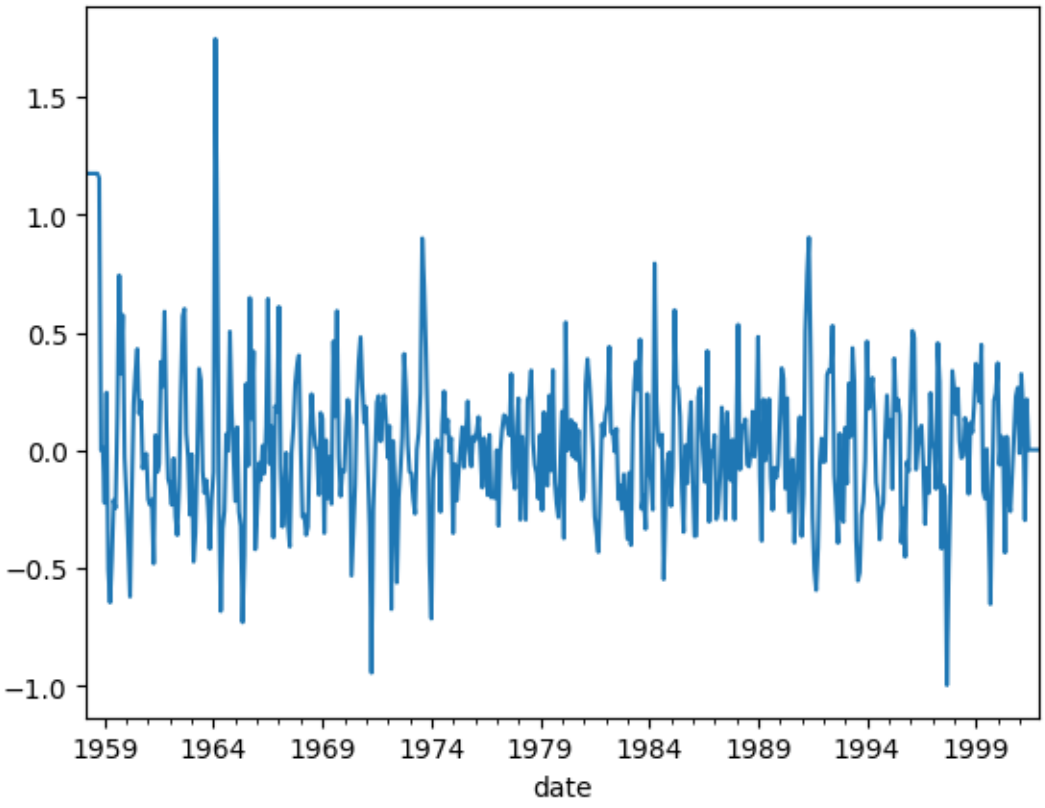

rolling mean
370
360
350
340
330
320
1959
1964
1969
1974
1979
1984
1989
1994
1999
date


co2
Trend
Seasonal
Resid
1960
1965
1970
1975
1980
1985
1990
1995
2000

[20]:
```
# Test the stationarity of residual
res = decomposed.resid.fillna(decomposed.resid.bfill())
res = res.fillna(res.ffill())
adf = adfuller(res)
print('ADF Statistic: %f' % adf[0])
print('p-value: %f' % adf[1])
print('Critical Values:')
for key, value in adf[4].items():
        print('\t%s: %.3f' % (key, value))
res.plot()
```

```
ADF Statistic: -12.181866
p-value: 0.000000
Critical Values:
        1%: -3.443
        5%: -2.867
        10%: -2.570
```

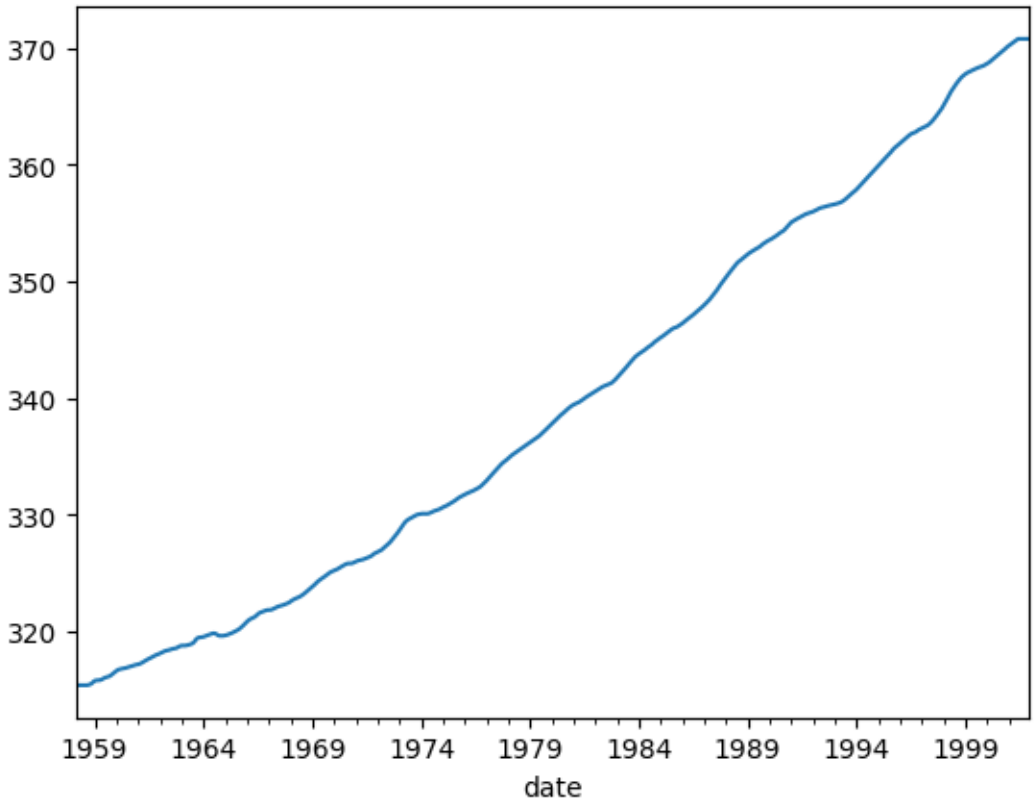
[20]: <Axes: xlabel='date'>



[22]:
```
#Test the trend
trend = decomposed.trend.fillna(decomposed.trend.bfill())
trend = trend.fillna(trend.ffill())
adf_T = adfuller(trend)
print('ADF Statistic for trend: %f' % adf_T[0])
print('p-value for trend: %f' % adf_T[1])
print('Critical Values:')
for key, value in adf_T[4].items():
        print('\t%s: %.3f' % (key, value))
trend.plot()
```

```
ADF Statistic for trend: 1.761347
p-value for trend: 0.998269
Critical Values:
        1%: -3.443
        5%: -2.867
        10%: -2.570
```

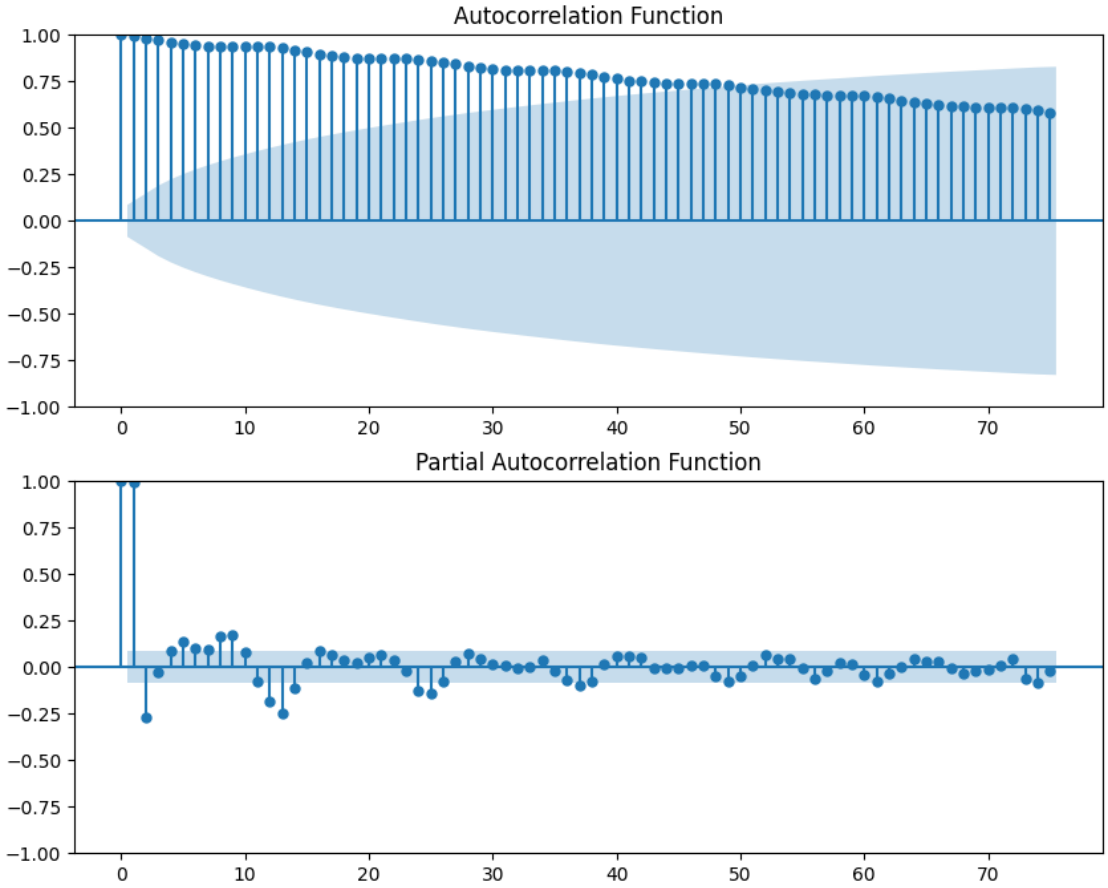
[22]: <Axes: xlabel='date'>



0.3 Plot ACF and PACF

[27]:
```
fig, (ax1, ax2) = plt.subplots(2, 1, figsize=(10, 8))
plot_acf(df,ax=ax1,lags=75)
ax1.set_title('Autocorrelation Function')
plot_pacf(df, ax=ax2, lags=75)
ax2.set_title('Partial Autocorrelation Function')
```

[27]:
```
Text(0.5, 1.0, 'Partial Autocorrelation Function')
```

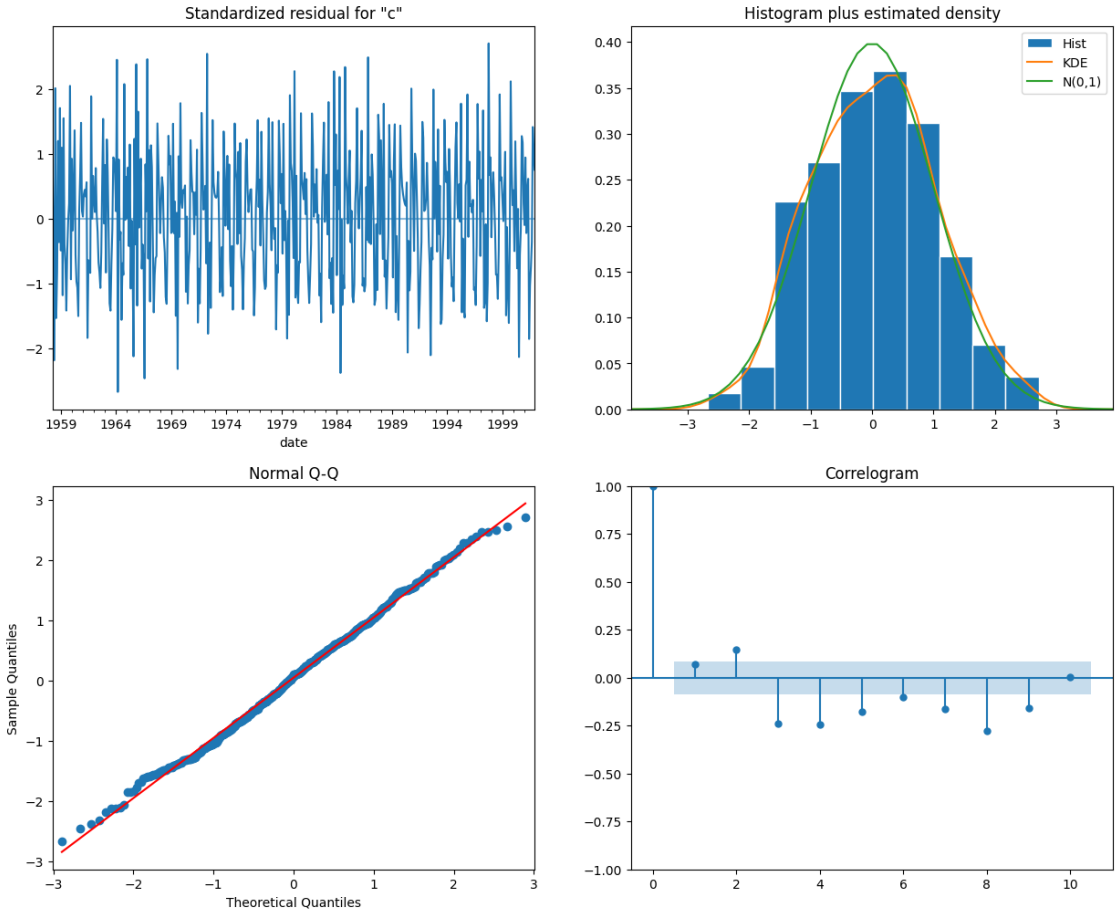


0.4 Train Model

[31]:
```
mod = sm.tsa.statespace.SARIMAX(df, order=(1, 1, 1))
model = mod.fit()
model.plot_diagnostics(figsize=(15, 12))
plt.show()
```

```
 This problem is unconstrained.

RUNNING THE L-BFGS-B CODE
```

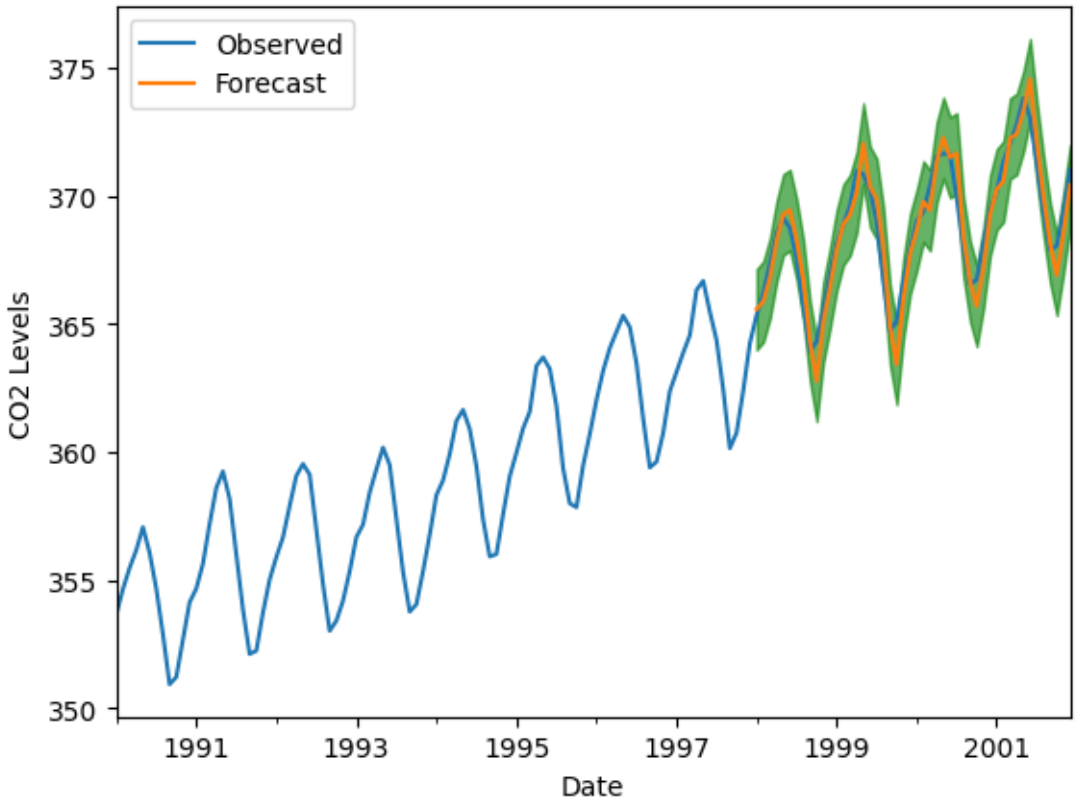
```
           * * *

Machine precision = 2.220D-16
 N =            3     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  1.20140D+00    |proj g|=  7.33263D-02

At iterate    5    f=  1.19886D+00    |proj g|=  7.53011D-04

           * * *

Tit   = total number of iterations
Tnf   = total number of function evaluations
Tnint = total number of segments explored during Cauchy searches
Skip  = number of BFGS updates skipped
Nact  = number of active bounds at final generalized Cauchy point
Projg = norm of the final projected gradient
F     = final function value

           * * *

   N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
    3      7     10      1     0     0   1.903D-06   1.199D+00
  F =   1.1988612234696618

CONVERGENCE: NORM_OF_PROJECTED_GRADIENT_<=_PGTOL
```



0.5 Predict

[36]:
```
pred = model.get_prediction(start=pd.to_datetime('1998-01-01'), dynamic=False)␣
  ↪# Use real number to predict
pred_ci = pred.conf_int()

ax = df['1990':].plot(label='Observed')
pred.predicted_mean.plot(ax=ax, label='Forecast')
ax.fill_between(pred_ci.index, pred_ci.iloc[:, 0], pred_ci.iloc[:, 1],␣
  ↪color='g', alpha=.6)
ax.set_xlabel('Date')
ax.set_ylabel('CO2 Levels')
plt.legend()
plt.show()

#MSE
forecasted = pred.predicted_mean
truth = df['1998-01-01':]
```

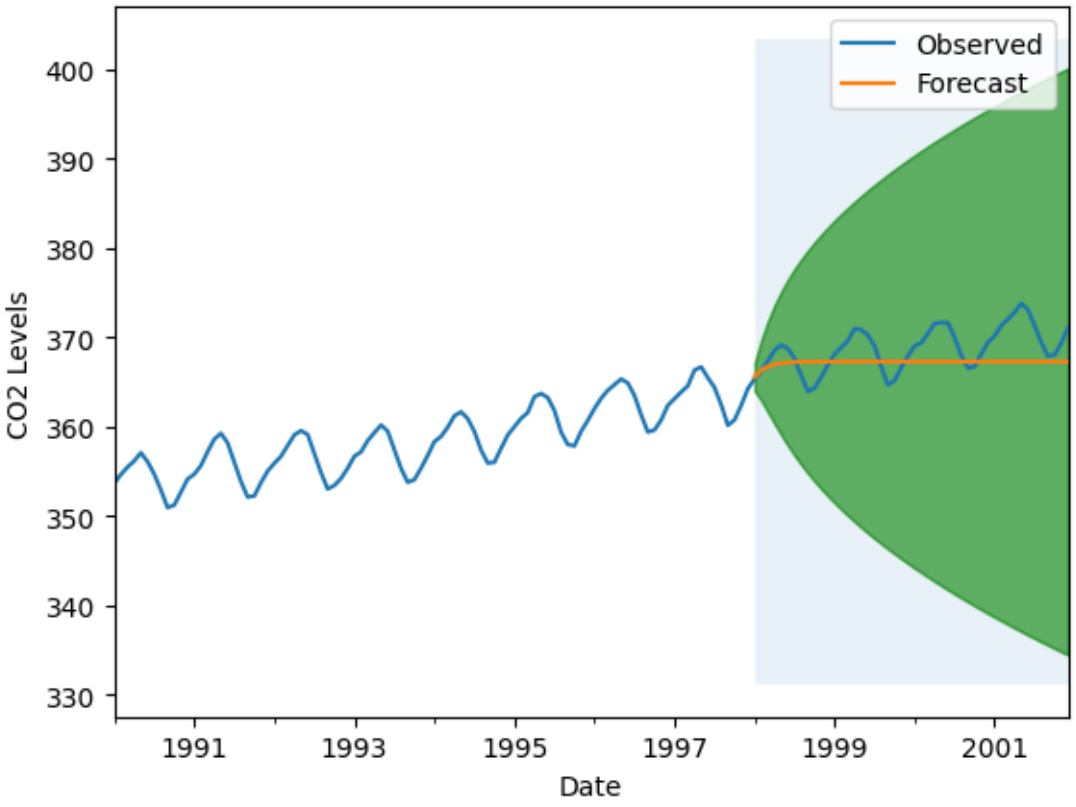
```
mse = ((forecasted - truth) ** 2).mean()
print('The Mean Squared Error of our forecasts is {}'.format(round(mse, 2)))
```




```
The Mean Squared Error of our forecasts is 0.57
```

[38]:
```
pred = model.get_prediction(start=pd.to_datetime('1998-01-01'), dynamic=True,␣
 ↪full_results=True) # Use predicted number to predict
pred_ci = pred.conf_int()

ax = df['1990':].plot(label='Observed')
pred.predicted_mean.plot(ax=ax, label='Forecast')
ax.fill_between(pred_ci.index, pred_ci.iloc[:, 0], pred_ci.iloc[:, 1],␣
 ↪color='g', alpha=.6)
ax.fill_betweenx(ax.get_ylim(), pd.to_datetime('1998-01-01'), y.index[-1],␣
 ↪alpha=.1, zorder=-1)
ax.set_xlabel('Date')
ax.set_ylabel('CO2 Levels')
plt.legend()
plt.show()
#MSE
forecasted = pred.predicted_mean
```

```
truth = df['1998-01-01':]
mse = ((forecasted - truth) ** 2).mean()
print('The Mean Squared Error of this forecasts is {}'.format(round(mse, 2)))
```




```
The Mean Squared Error of this forecasts is 7.81
```

[ ]: