In [9]:

```
import pandas as pd
import numpy as np

from statsmodels.tsa.statespace.sarimax import SARIMAX
from statsmodels.tsa.seasonal import seasonal_decompose
from pmdarima import auto_arima

import warnings
from statsmodels.tools.sm_exceptions import ConvergenceWarning, ModelWarning
warnings.simplefilter('ignore', ConvergenceWarning)
warnings.simplefilter('ignore', ModelWarning)
warnings.simplefilter('ignore')

from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error
```

In [3]:

```
df = pd.read_csv('airline_passengers.csv', sep=',', index_col='Month', parse_dates=True)
df
```

Out[3]:

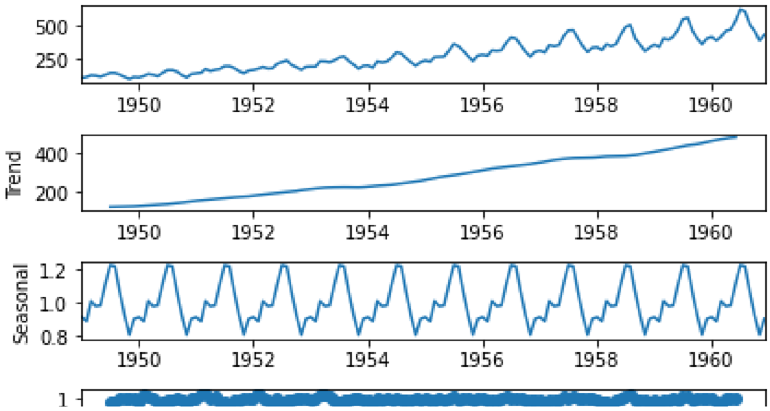
	Thousands of Passengers
Month	
1949-01-01	112
1949-02-01	118
1949-03-01	132
1949-04-01	129
1949-05-01	121
...	...
1960-08-01	606
1960-09-01	508
1960-10-01	461
1960-11-01	390
1960-12-01	432

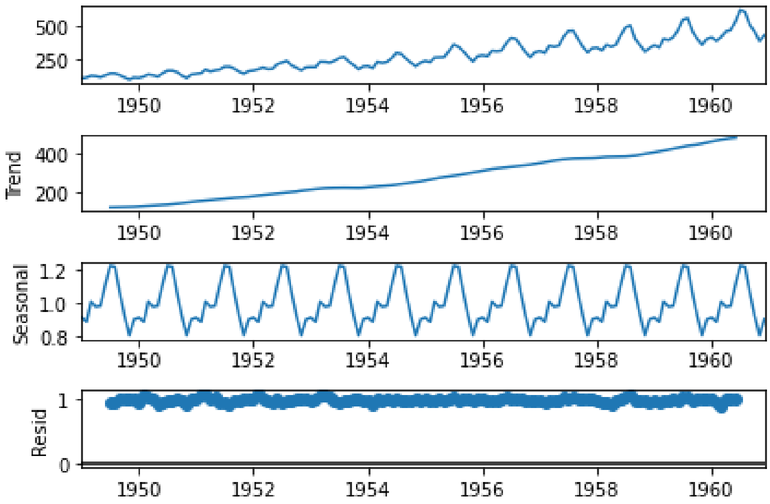
144 rows × 1 columns

In [4]:

```
sDecomp = seasonal_decompose(df, model='mul')
sDecomp.plot()
```

Out[4]:





In [5]:

```
auto_arima(df, seasonal = True, m = 12, trace = True).summary()
```

```
Performing stepwise search to minimize aic
 ARIMA(2,1,2)(1,1,1)[12]             : AIC=1020.048, Time=0.86 sec
 ARIMA(0,1,0)(0,1,0)[12]             : AIC=1031.508, Time=0.01 sec
 ARIMA(1,1,0)(1,1,0)[12]             : AIC=1020.393, Time=0.06 sec
 ARIMA(0,1,1)(0,1,1)[12]             : AIC=1021.003, Time=0.12 sec
 ARIMA(2,1,2)(0,1,1)[12]             : AIC=1019.935, Time=0.48 sec
 ARIMA(2,1,2)(0,1,0)[12]             : AIC=1019.290, Time=0.15 sec
 ARIMA(2,1,2)(1,1,0)[12]             : AIC=1019.546, Time=0.50 sec
 ARIMA(1,1,2)(0,1,0)[12]             : AIC=1024.160, Time=0.07 sec
 ARIMA(2,1,1)(0,1,0)[12]             : AIC=1017.847, Time=0.17 sec
 ARIMA(2,1,1)(1,1,0)[12]             : AIC=1017.914, Time=0.39 sec
 ARIMA(2,1,1)(0,1,1)[12]             : AIC=1018.359, Time=0.40 sec
 ARIMA(2,1,1)(1,1,1)[12]             : AIC=1018.248, Time=0.91 sec
 ARIMA(1,1,1)(0,1,0)[12]             : AIC=1022.393, Time=0.04 sec
 ARIMA(2,1,0)(0,1,0)[12]             : AIC=1022.393, Time=0.04 sec
 ARIMA(3,1,1)(0,1,0)[12]             : AIC=1019.084, Time=0.16 sec
 ARIMA(1,1,0)(0,1,0)[12]             : AIC=1020.393, Time=0.03 sec
 ARIMA(3,1,0)(0,1,0)[12]             : AIC=1023.666, Time=0.05 sec
 ARIMA(3,1,2)(0,1,0)[12]             : AIC=1021.083, Time=0.26 sec
 ARIMA(2,1,1)(0,1,0)[12] intercept   : AIC=inf, Time=0.36 sec

Best model:  ARIMA(2,1,1)(0,1,0)[12]
Total fit time: 5.072 seconds
```

Out[5]:

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	144
Model:	SARIMAX(2, 1, 1)x(0, 1, [], 12)	**Log Likelihood**	-504.923
Date:	Tue, 12 Apr 2022	**AIC**	1017.847
Time:	07:53:04	**BIC**	1029.348
Sample:	0	**HQIC**	1022.520
	- 144		
Covariance Type:	opg		

	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
ar.L1	0.5960	0.085	6.987	0.000	0.429	0.763
ar.L2	0.2143	0.091	2.343	0.019	0.035	0.394
ma.L1	-0.9819	0.038	-25.601	0.000	-1.057	-0.907

sigma2	129.3114	14.556	8.884	0.000	100.782	157.841

Ljung-Box (L1) (Q):	0.00	**Jarque-Bera (JB):**	7.68
Prob(Q):	0.98	**Prob(JB):**	0.02
Heteroskedasticity (H):	2.33	**Skew:**	-0.01
Prob(H) (two-sided):	0.01	**Kurtosis:**	4.19

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).

In [6]:

```
train = df.iloc[:-12]
test = df.iloc[-12:]
len(test)
```

Out[6]:

```
12
```

construct the model

In [7]:

```
model = SARIMAX(train, order = (2, 1, 1), seasonal_order=(0,1,0,12))
results = model.fit()
results
```

Out[7]:

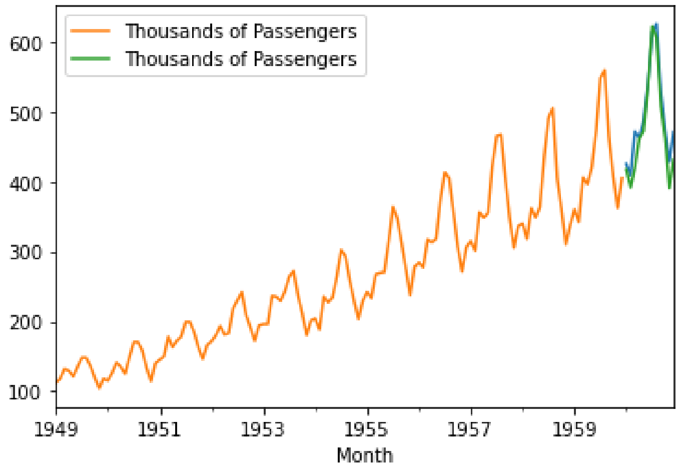
```
<statsmodels.tsa.statespace.sarimax.SARIMAXResultsWrapper at 0x1561a66bca0>
```

In [12]:

```
start = len(train)
end = start + len(test) - 1
predictions = results.predict(start = start, end = end, dynamic=False, typ='levels').rename('SARIMA(2,1,1)(0,1,0,12)')
ax = predictions.plot()
train.plot(ax=ax)
test.plot(ax=ax)
mean_absolute_percentage_error(test, predictions)
```

Out[12]:

```
0.04431755007749067
```



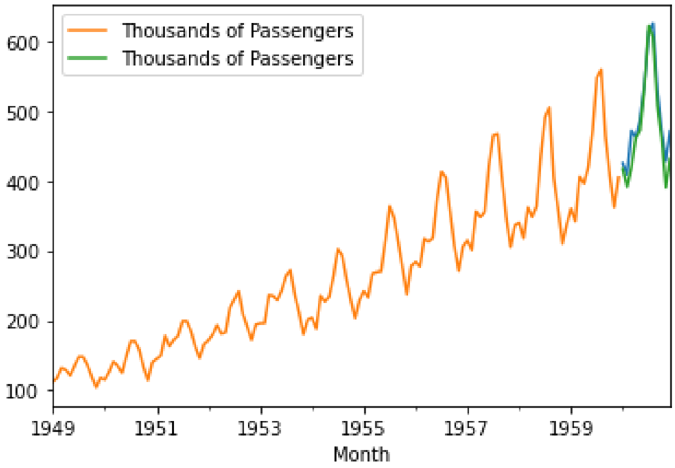
skipping typ

In [14]:

```
start = len(train)
end = start + len(test) - 1
predictions = results.predict(start = start, end = end, dynamic=False).rename('SARIMA(2,
1,1)(0,1,0,12)')
ax = predictions.plot()
train.plot(ax=ax)
test.plot(ax=ax)
mean_absolute_percentage_error(test, predictions)
```

Out[14]:

```
0.04431755007749067
```



CO_2 data

In [46]:

```
df = pd.read_csv('co2_mm_mlo.csv', sep=',', parse_dates=True)
df['date'] = df.apply(lambda x : pd.to_datetime(str(int(x['year'])) + '-' + str(int(x['m
onth']))), axis = 1)
df.drop(['year','month'], inplace=True, axis = 1)
df.set_index('date', inplace = True)
dfN = df['interpolated']
dfN
```

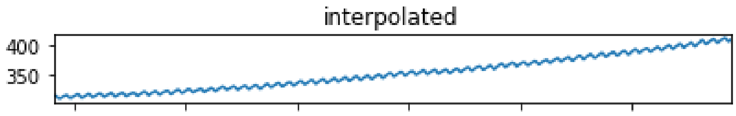
Out[46]:

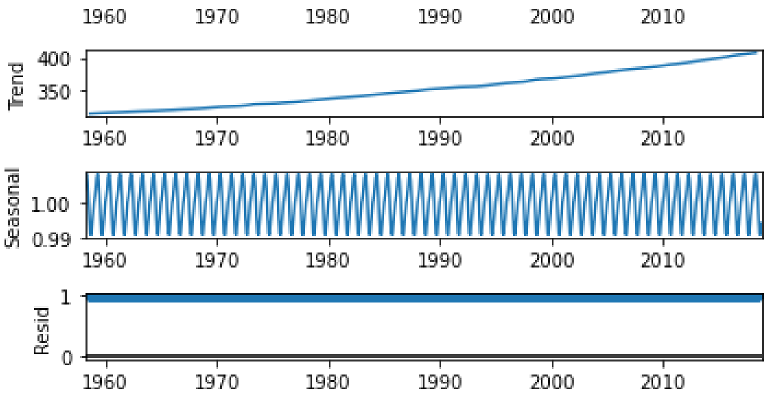
```
date
1958-03-01    315.71
1958-04-01    317.45
1958-05-01    317.50
1958-06-01    317.10
1958-07-01    315.86
               ...
2018-07-01    408.71
2018-08-01    406.99
2018-09-01    405.51
2018-10-01    406.00
2018-11-01    408.02
Name: interpolated, Length: 729, dtype: float64
```

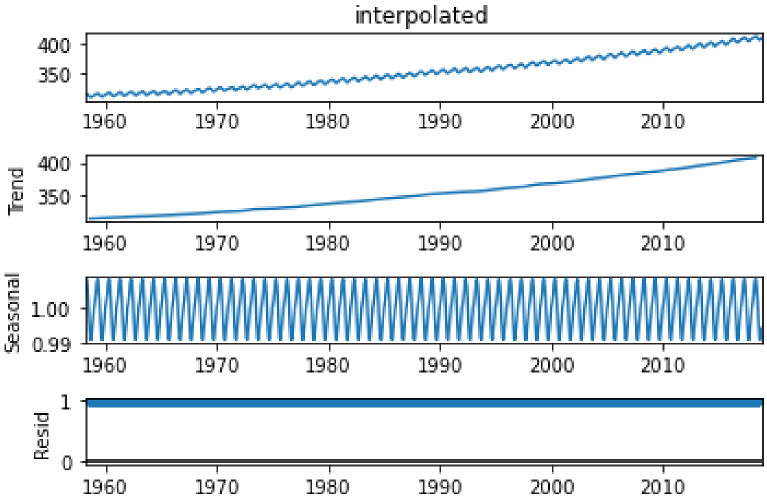
In [47]:

```
sDecomp = seasonal_decompose(dfN, model='mul')
sDecomp.plot()
```

Out[47]:







In [50]:

```
auto_arima(dfN, seasonal = True, m = 1, trace = True).summary()
```

```
Performing stepwise search to minimize aic
 ARIMA(2,1,2)(0,0,0)[0] intercept   : AIC=1440.918, Time=0.39 sec
 ARIMA(0,1,0)(0,0,0)[0] intercept   : AIC=2369.532, Time=0.02 sec
 ARIMA(1,1,0)(0,0,0)[0] intercept   : AIC=1880.794, Time=0.07 sec
 ARIMA(0,1,1)(0,0,0)[0] intercept   : AIC=1935.623, Time=0.09 sec
 ARIMA(0,1,0)(0,0,0)[0]             : AIC=2375.248, Time=0.01 sec
 ARIMA(1,1,2)(0,0,0)[0] intercept   : AIC=1715.503, Time=0.14 sec
 ARIMA(2,1,1)(0,0,0)[0] intercept   : AIC=1440.128, Time=0.26 sec
 ARIMA(1,1,1)(0,0,0)[0] intercept   : AIC=1785.006, Time=0.11 sec
 ARIMA(2,1,0)(0,0,0)[0] intercept   : AIC=1684.115, Time=0.10 sec
 ARIMA(3,1,1)(0,0,0)[0] intercept   : AIC=1441.136, Time=0.53 sec
 ARIMA(3,1,0)(0,0,0)[0] intercept   : AIC=1608.681, Time=0.11 sec
 ARIMA(3,1,2)(0,0,0)[0] intercept   : AIC=1442.505, Time=0.75 sec
 ARIMA(2,1,1)(0,0,0)[0]             : AIC=1532.865, Time=0.08 sec

Best model:  ARIMA(2,1,1)(0,0,0)[0] intercept
Total fit time: 2.660 seconds
```

Out[50]:

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	729
Model:	SARIMAX(2, 1, 1)	**Log Likelihood**	-715.064
Date:	Tue, 12 Apr 2022	**AIC**	1440.128
Time:	08:15:40	**BIC**	1463.079
Sample:	0	**HQIC**	1448.984
	- 729		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
intercept	0.0395	0.003	11.810	0.000	0.033	0.046

ar.L1	1.5468	0.022	70.815	0.000	1.504	1.590
ar.L2	-0.8502	0.023	-36.917	0.000	-0.895	-0.805
ma.L1	-0.9012	0.018	-49.926	0.000	-0.937	-0.866
sigma2	0.4158	0.021	19.426	0.000	0.374	0.458

Ljung-Box (L1) (Q):	0.82	**Jarque-Bera (JB):**	34.52
Prob(Q):	0.36	**Prob(JB):**	0.00
Heteroskedasticity (H):	1.23	**Skew:**	0.48
Prob(H) (two-sided):	0.11	**Kurtosis:**	3.44

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).

In [52]:

```
train = dfN.iloc[:-12]
test = dfN.iloc[-12:]
len(test)
```

Out[52]:

```
12
```

In [55]:

```
model = SARIMAX(train, order = (2, 1, 1), seasonal_order=(0,0,0,12))
results = model.fit()
results
```

Out[55]:

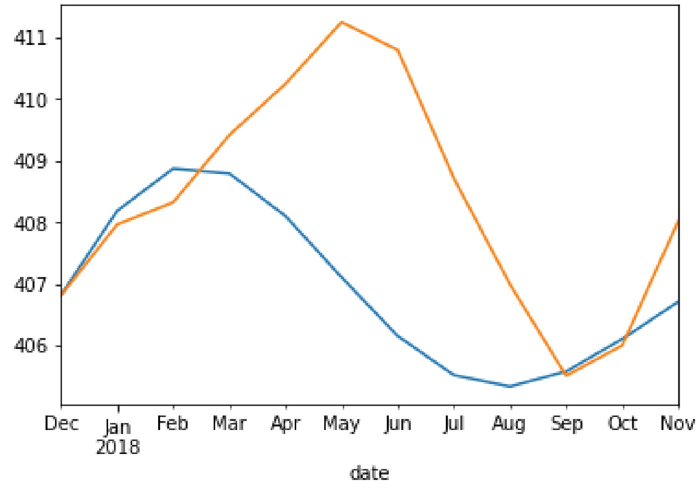
```
<statsmodels.tsa.statespace.sarimax.SARIMAXResultsWrapper at 0x15673ebe6d0>
```

In [58]:

```
start = len(train)
end = start + len(test) - 1
predictions = results.predict(start = start, end = end, dynamic=False, typ='levels').ren
ame('SARIMA(2,1,1)(0,0,0,12)')
ax = predictions.plot()
#train.plot(ax=ax)
test.plot(ax=ax, name)
mean_absolute_percentage_error(test, predictions)
```

Out[58]:

```
0.003790623958247233
```



predict into the future

predict into the future

In [ ]:

```
start = len(train)
end = start + len(test) - 1
predictions = results.predict(start = start, end = end, dynamic=False, typ='levels').rename('SARIMA(2,1,1)(0,1,0,12)')
ax = predictions.plot()
train.plot(ax=ax)
test.plot(ax=ax)
mean_absolute_percentage_error(test, predictions)
```