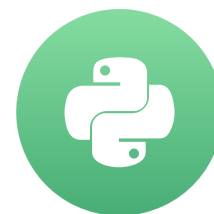


Seasonal time series

ARIMA MODELS IN PYTHON



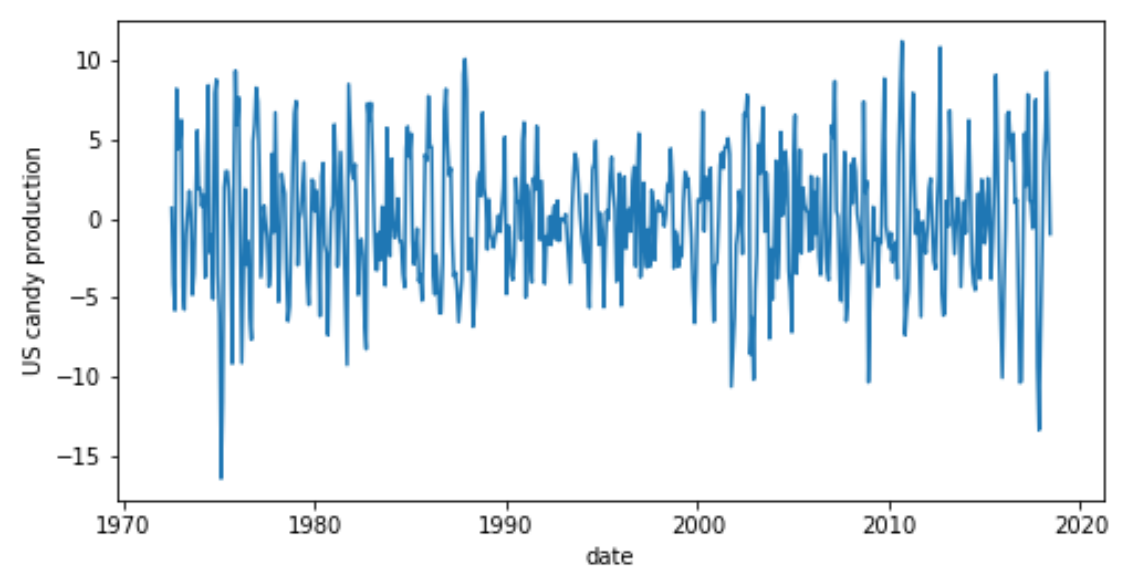
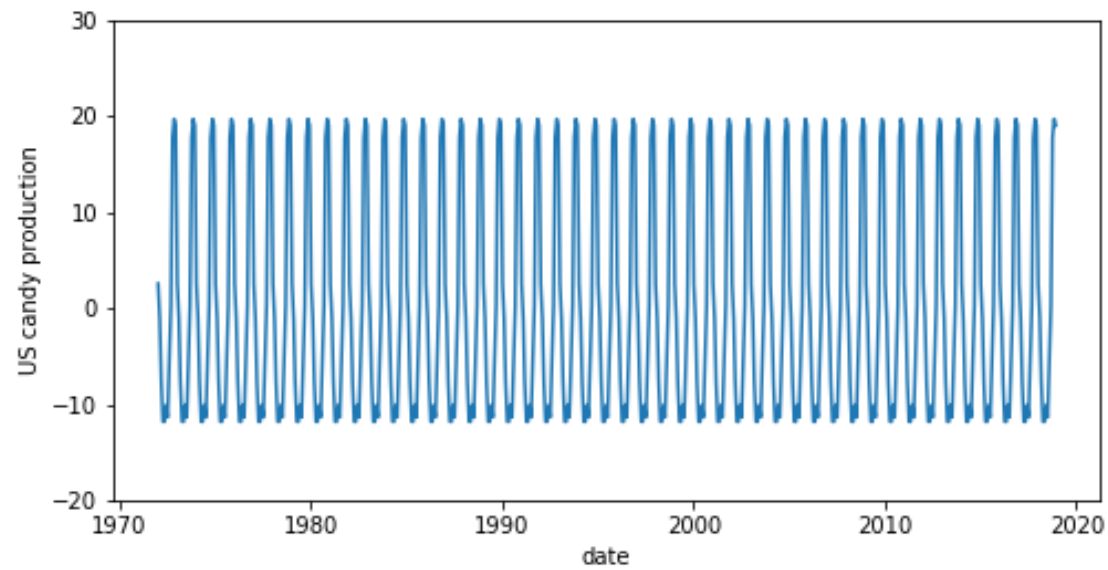
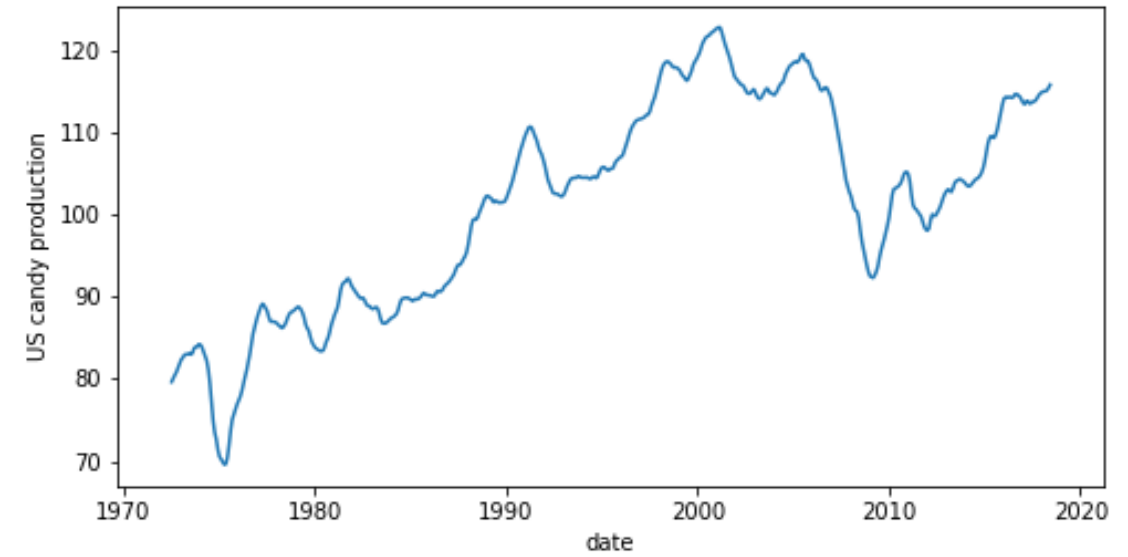
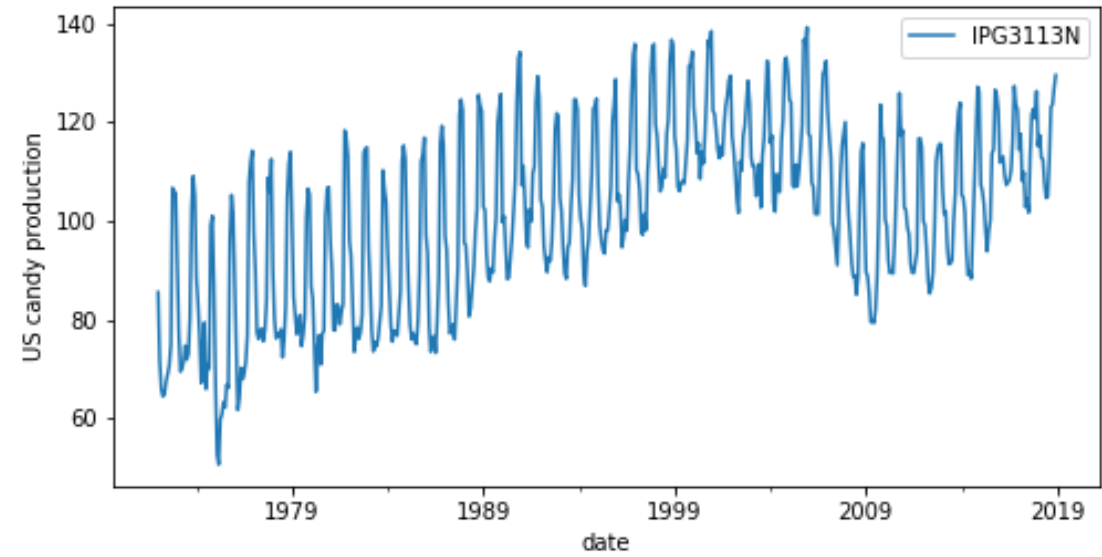
James Fulton

Climate informatics researcher

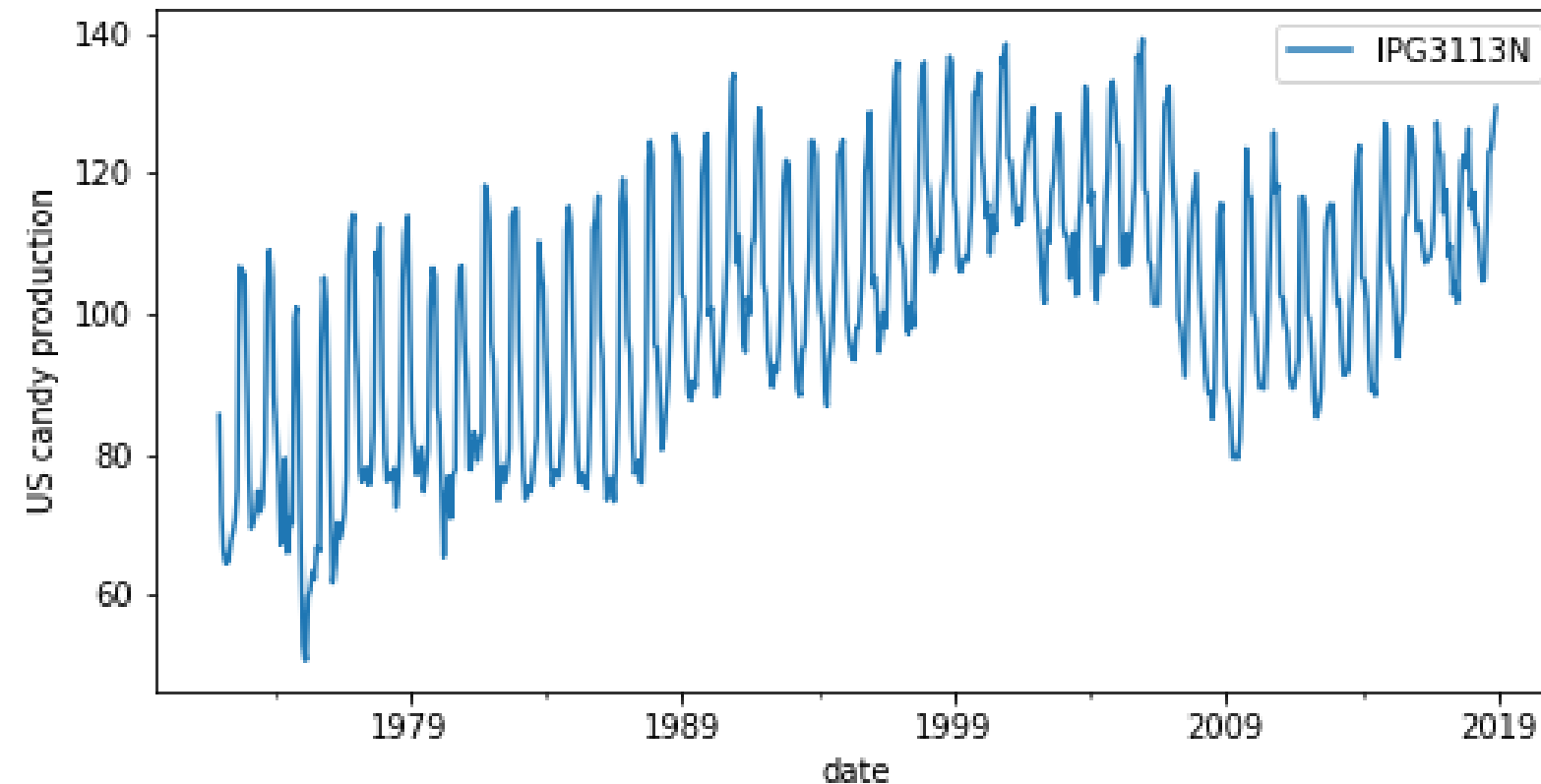
Seasonal data

- Has predictable and repeated patterns
- Repeats after any amount of time

Seasonal decomposition



Seasonal decomposition



time series = trend + seasonal + residual

Seasonal decomposition using statsmodels

```
# Import
from statsmodels.tsa.seasonal import seasonal_decompose
```

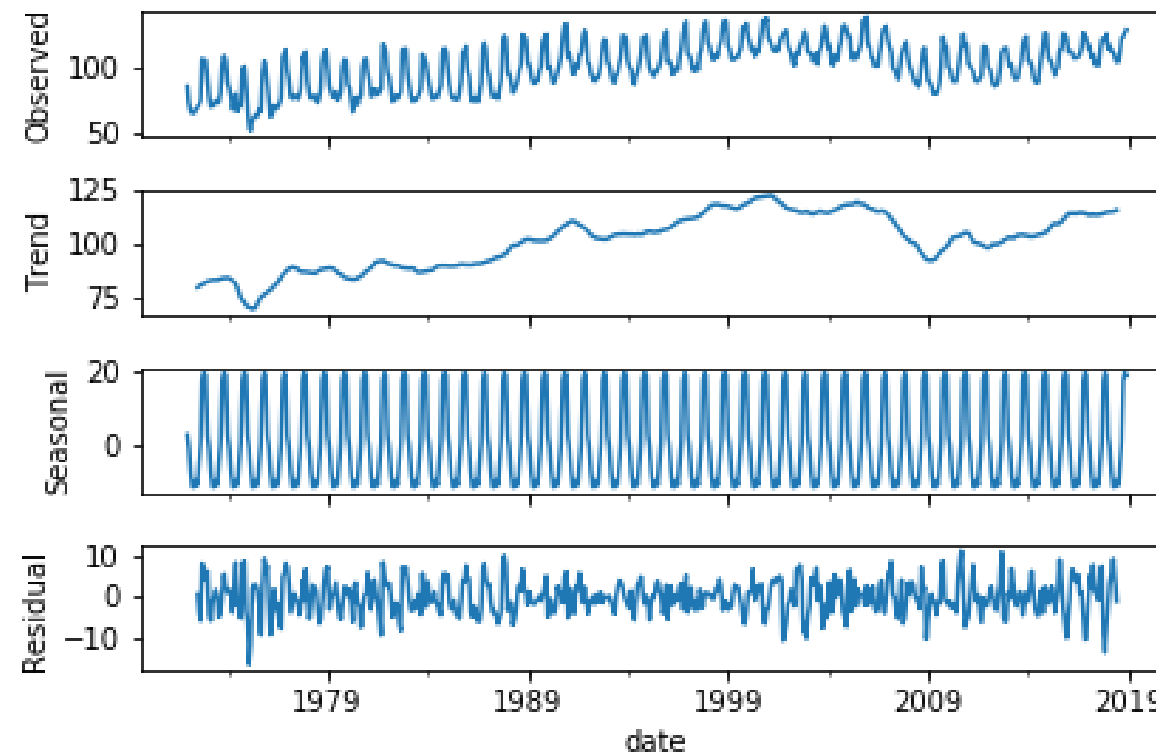
```
# Decompose data
decomp_results = seasonal_decompose(df[ 'IPG3113N' ], freq=12)
                                the number of data points in each repeated cycle
```

```
type(decomp_results)
```

```
statsmodels.tsa.seasonal.DecomposeResult
```

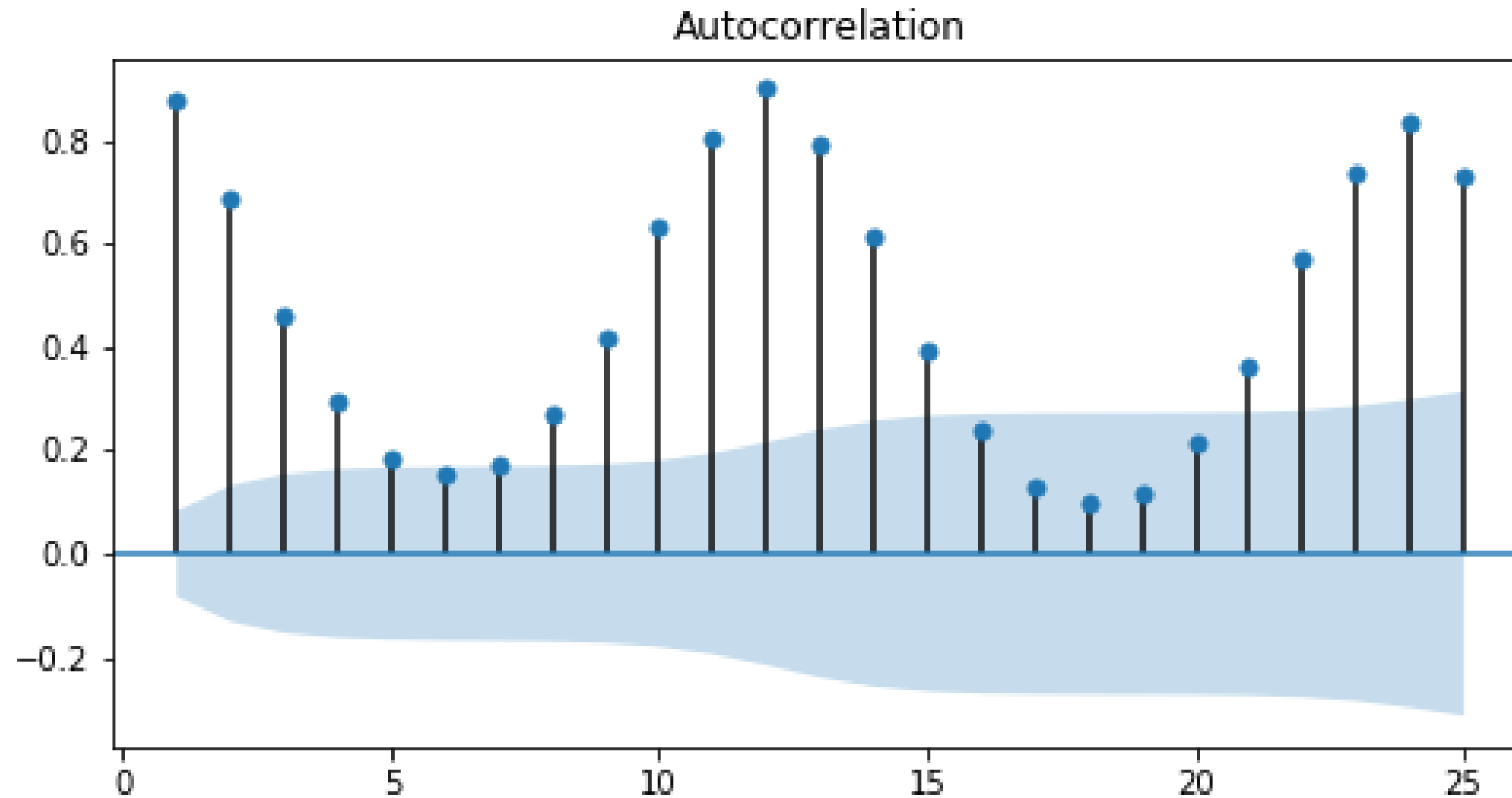
Seasonal decomposition using statsmodels

```
# Plot decomposed data  
decomp_results.plot()  
plt.show()
```

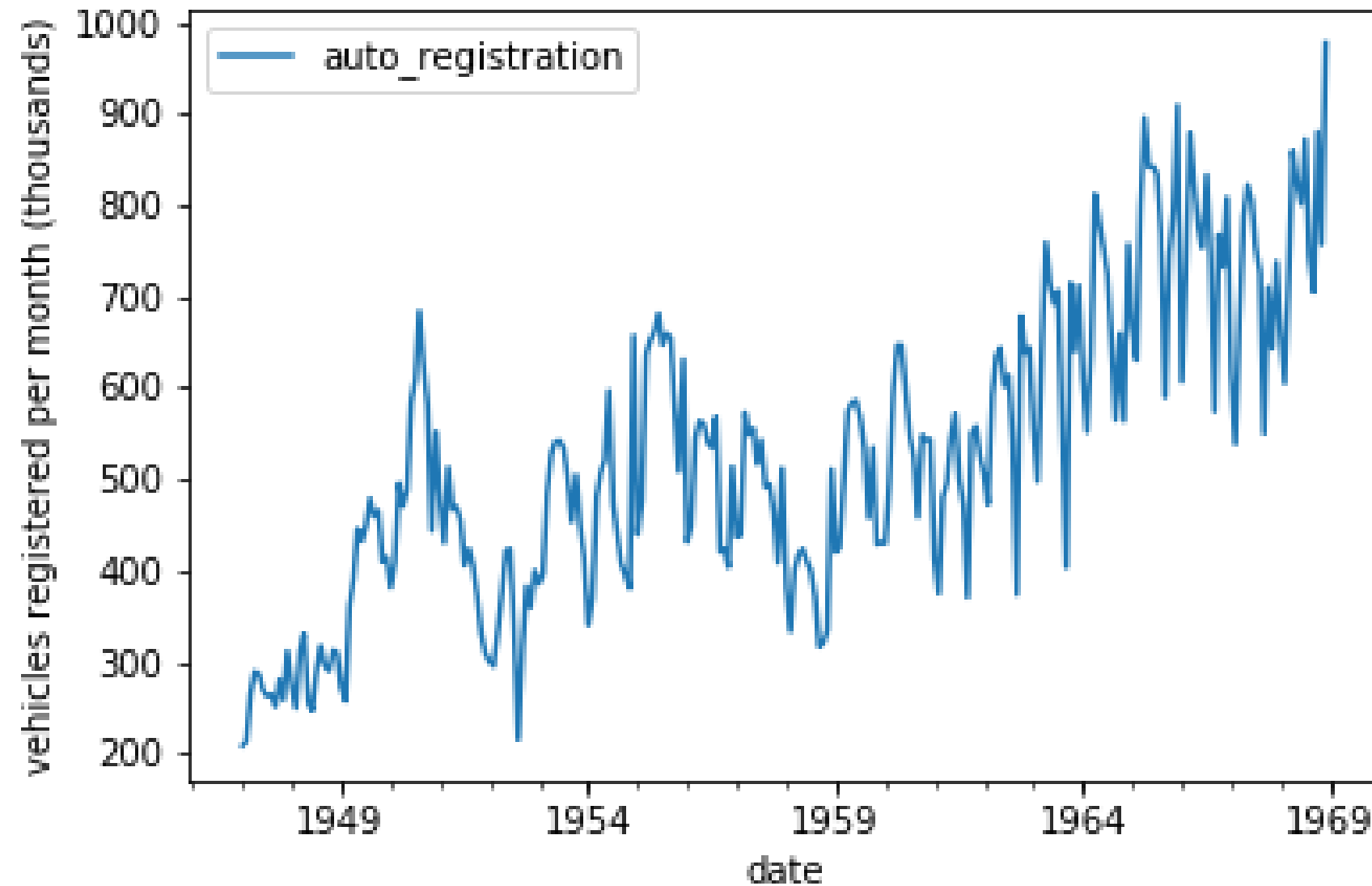


Finding seasonal period using ACF

There is a peak at 12 lags, so this means the seasonal components repeat every 12 time steps.

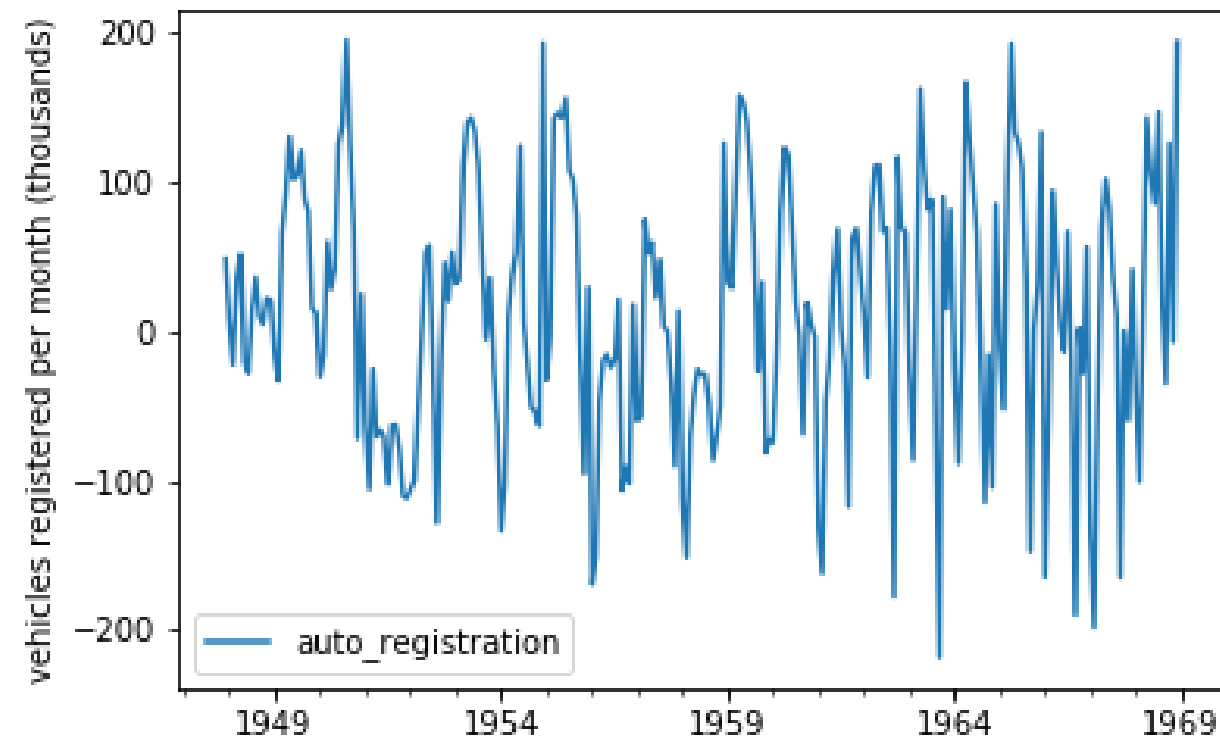


Identifying seasonal data using ACF



Detrending time series

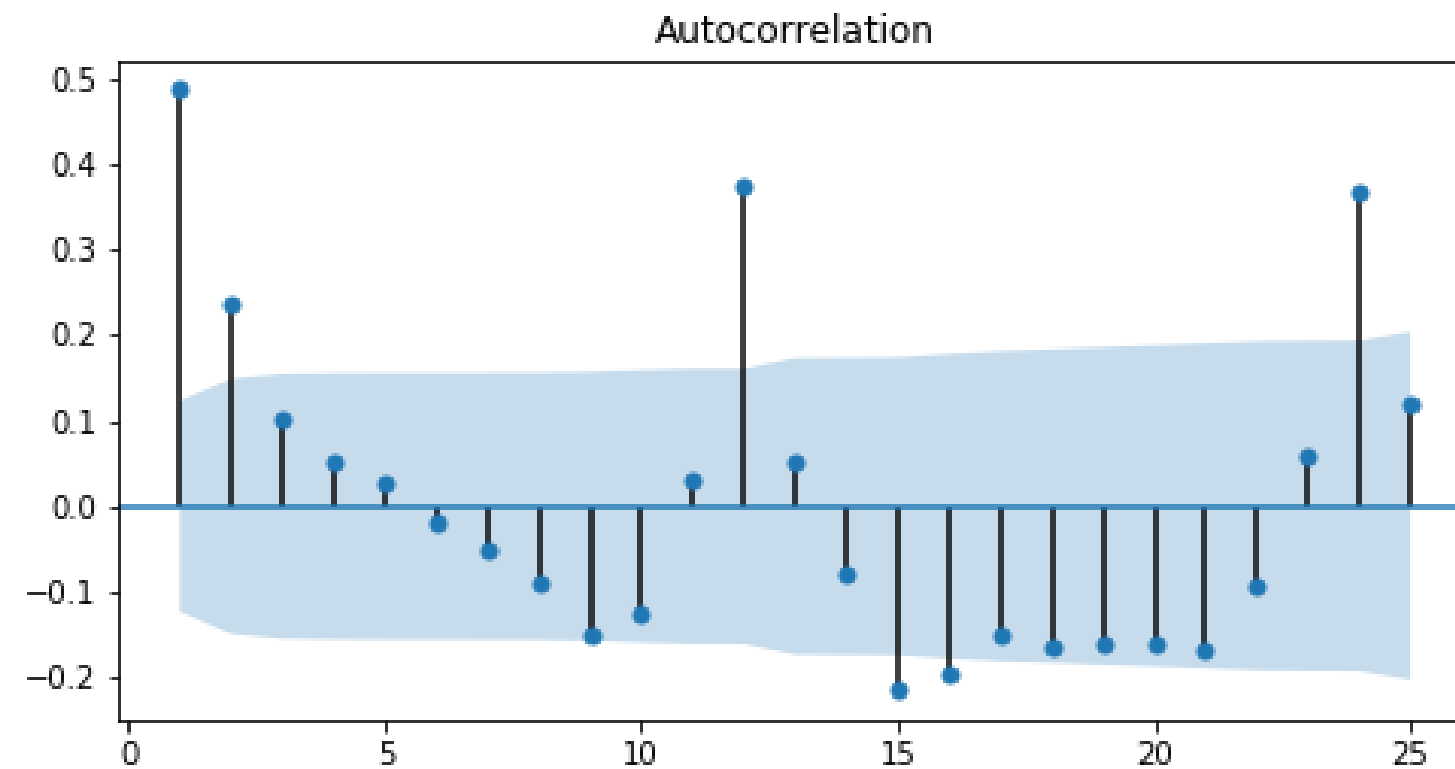
```
# Subtract long rolling average over N steps  
df = df - df.rolling(N).mean()  
  
# Drop NaN values  
df = df.dropna()
```



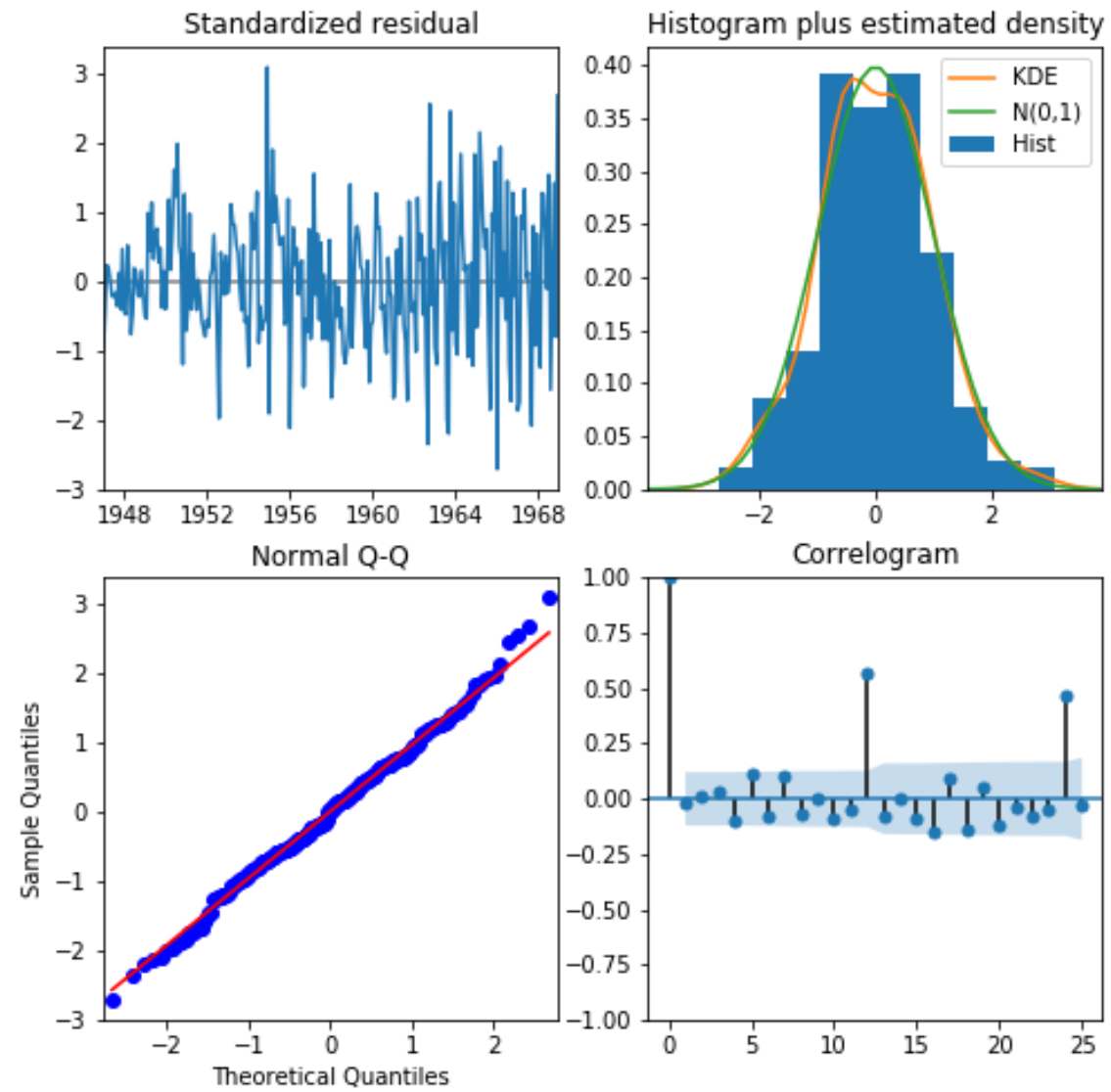
Identifying seasonal data using ACF

```
# Create figure
fig, ax = plt.subplots(1,1, figsize=(8,4))

# Plot ACF
plot_acf(df.dropna(), ax=ax, lags=25, zero=False)
plt.show()
```



ARIMA models and seasonal data



Let's practice!

ARIMA MODELS IN PYTHON

SARIMA models

ARIMA MODELS IN PYTHON



James Fulton

Climate informatics researcher

The SARIMA model

Seasonal ARIMA = SARIMA

- Non-seasonal orders
 - p : autoregressive order
 - d : differencing order
 - q : moving average order

$\text{SARIMA}(p,d,q)(P,D,Q)_S$

- Seasonal Orders
 - P : seasonal autoregressive order
 - D : seasonal differencing order
 - Q : seasonal moving average order
 - S : number of time steps per cycle

The SARIMA model

ARIMA(2,0,1) model:

$$y_t = a_1 y_{t-1} + a_2 y_{t-2} + m_1 \epsilon_{t-1} + \epsilon_t$$

SARIMA(0,0,0)(2,0,1)₇ model:

$$y_t = a_7 y_{t-7} + a_{14} y_{t-14} + m_7 \epsilon_{t-7} + \epsilon_t$$

Fitting a SARIMA model

```
# Imports
from statsmodels.tsa.statespace.sarimax import SARIMAX

# Instantiate model
model = SARIMAX(df, order=(p,d,q), seasonal_order=(P,D,Q,S))

# Fit model
results = model.fit()
```

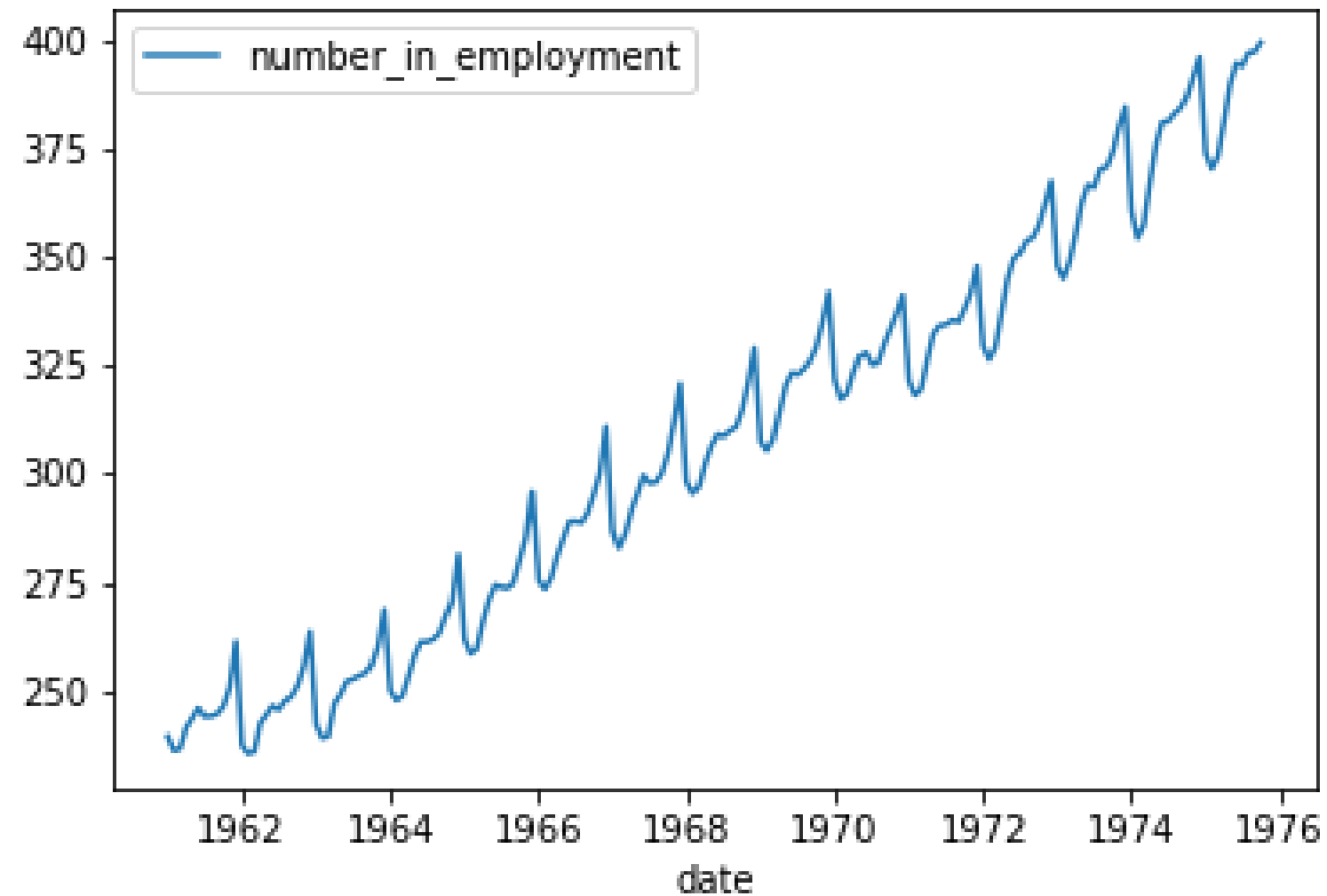

Seasonal differencing

Subtract the time series value of one season ago

$$\Delta y_t = y_t - y_{t-S}$$

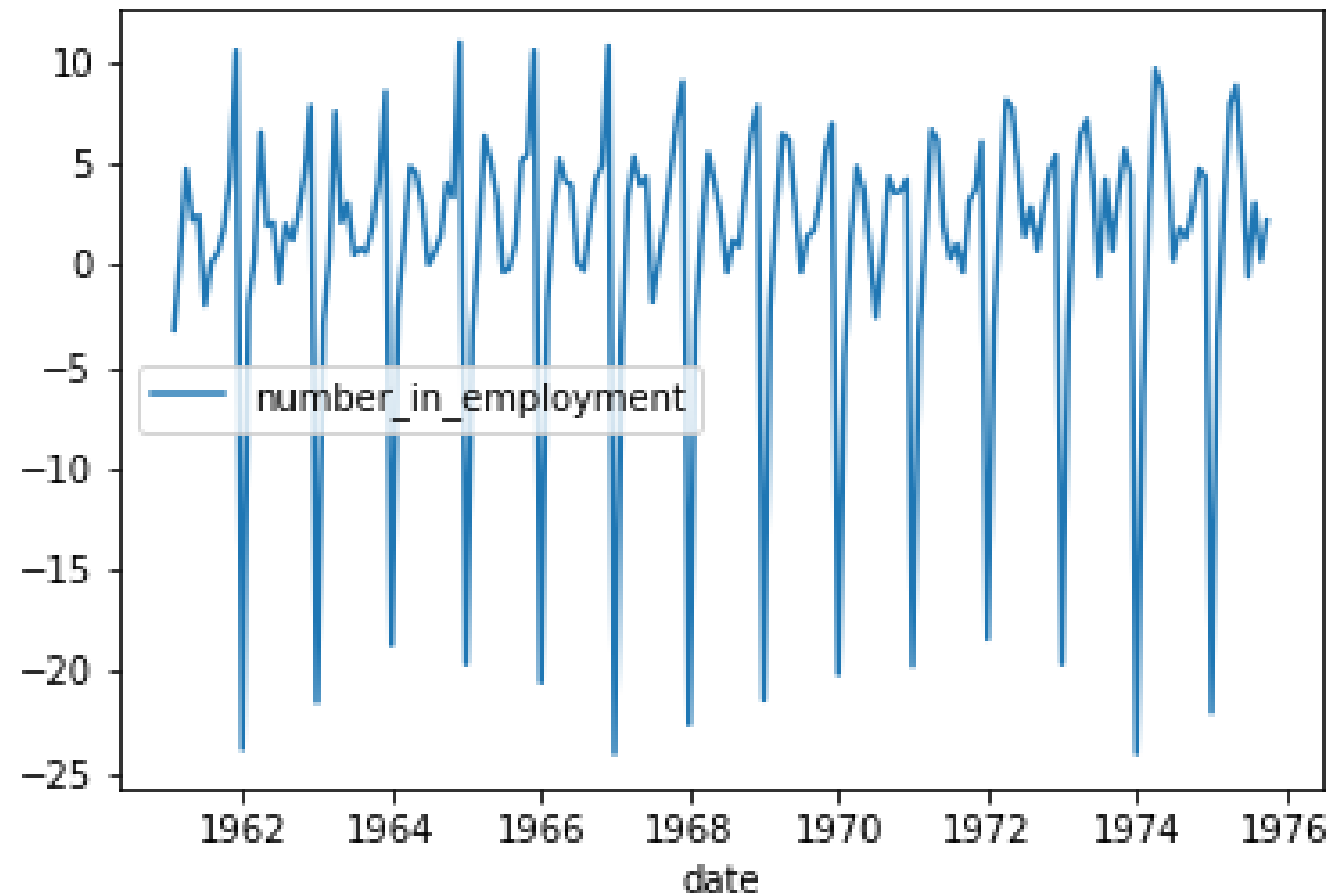
```
# Take the seasonal difference  
df_diff = df.diff(S)
```

Differencing for SARIMA models



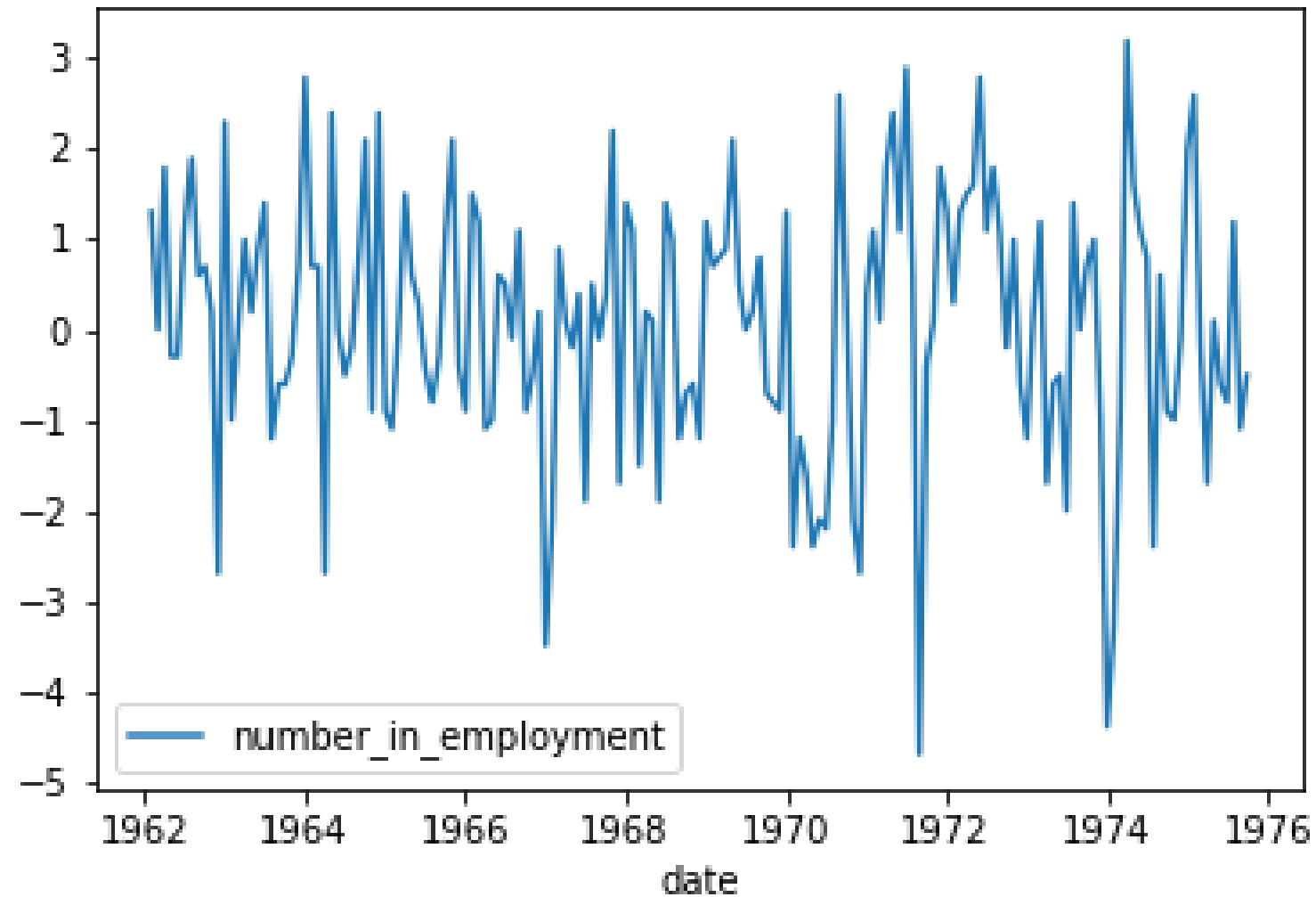
Time series

Differencing for SARIMA models



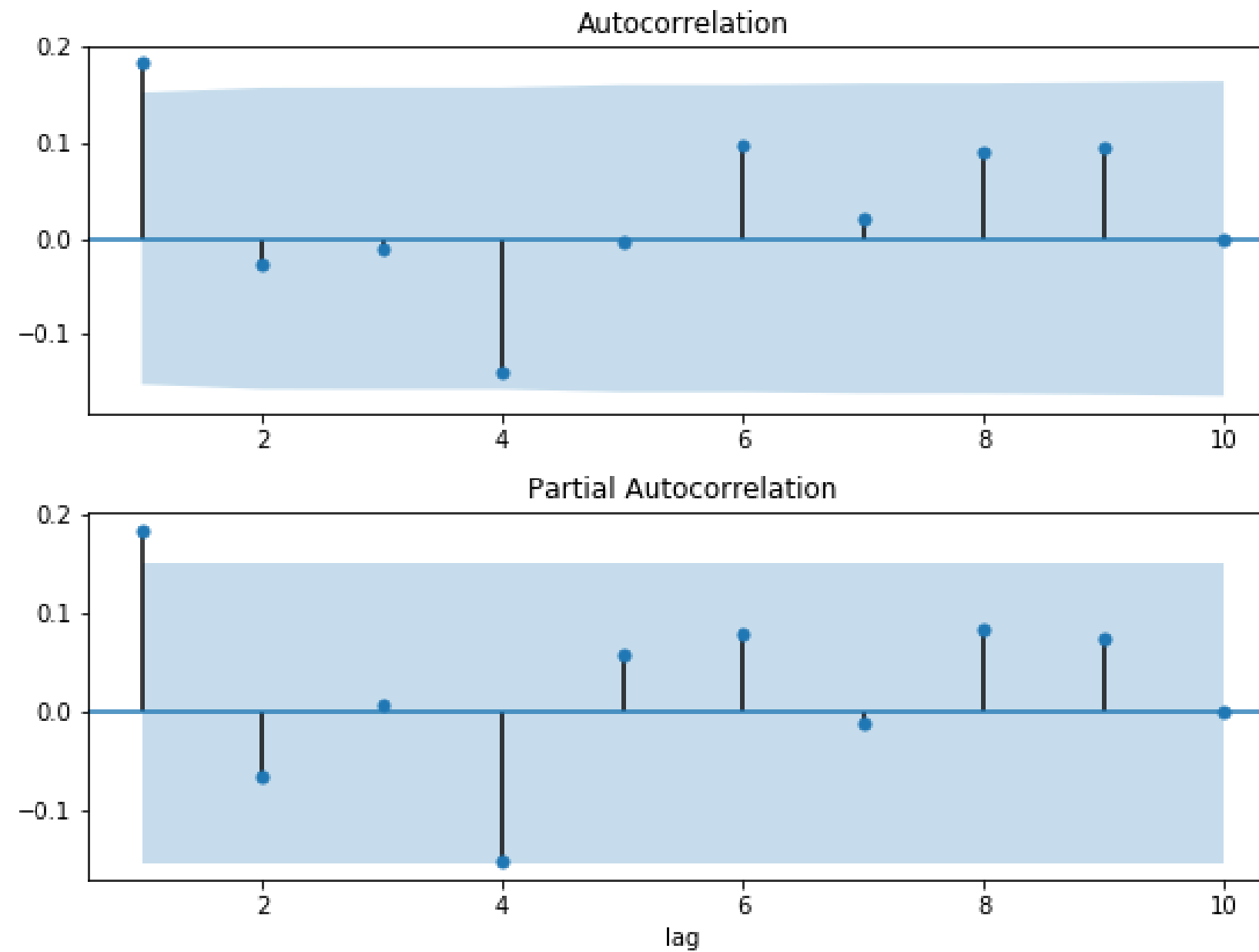
First difference of time series

Differencing for SARIMA models

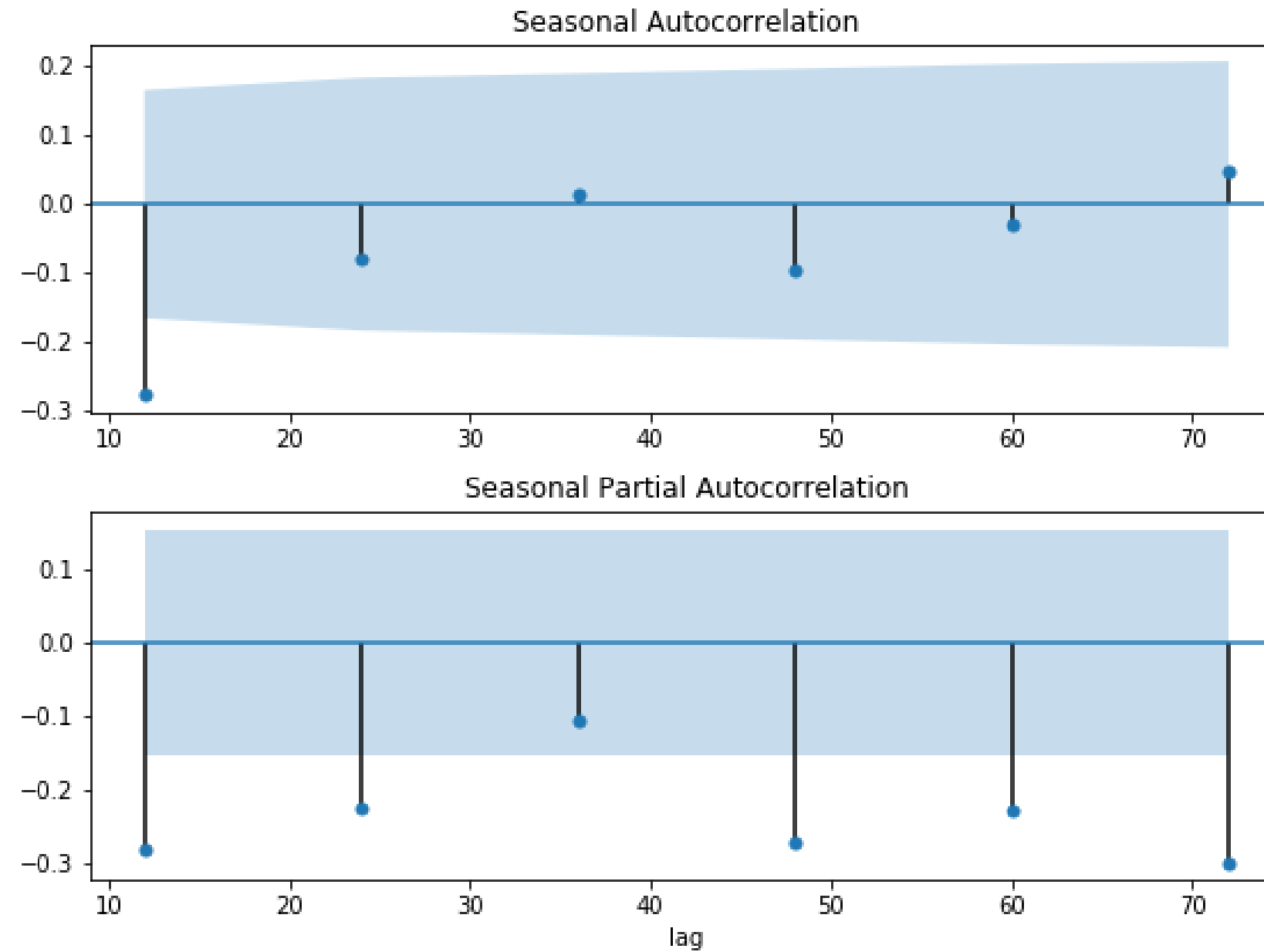


First difference and first seasonal difference of ime series

Finding p and q



Finding P and Q



Plotting seasonal ACF and PACF

```
# Create figure
fig, (ax1, ax2) = plt.subplots(2, 1)

# Plot seasonal ACF
plot_acf(df_diff, lags=[12, 24, 36, 48, 60, 72], ax=ax1)

# Plot seasonal PACF
plot_pacf(df_diff, lags=[12, 24, 36, 48, 60, 72], ax=ax2)

plt.show()
```

Let's practice!

ARIMA MODELS IN PYTHON

Automation and saving

ARIMA MODELS IN PYTHON



James Fulton

Climate informatics researcher

Searching over model orders

```
import pmdarima as pm
```

```
results = pm.auto_arima(df)
```

```
Fit ARIMA: order=(2, 0, 2) seasonal_order=(1, 1, 1, 12); AIC=nan, BIC=nan, Fit time=nan seconds
Fit ARIMA: order=(0, 0, 0) seasonal_order=(0, 1, 0, 12); AIC=2648.467, BIC=2656.490, Fit time=0.062 s
Fit ARIMA: order=(1, 0, 0) seasonal_order=(1, 1, 0, 12); AIC=2279.986, BIC=2296.031, Fit time=1.171 s
...
Fit ARIMA: order=(3, 0, 3) seasonal_order=(1, 1, 1, 12); AIC=2173.508, BIC=2213.621, Fit time=12.487 s
Fit ARIMA: order=(3, 0, 3) seasonal_order=(0, 1, 0, 12); AIC=2297.305, BIC=2329.395, Fit time=2.087 s
Total fit time: 245.812 seconds
```

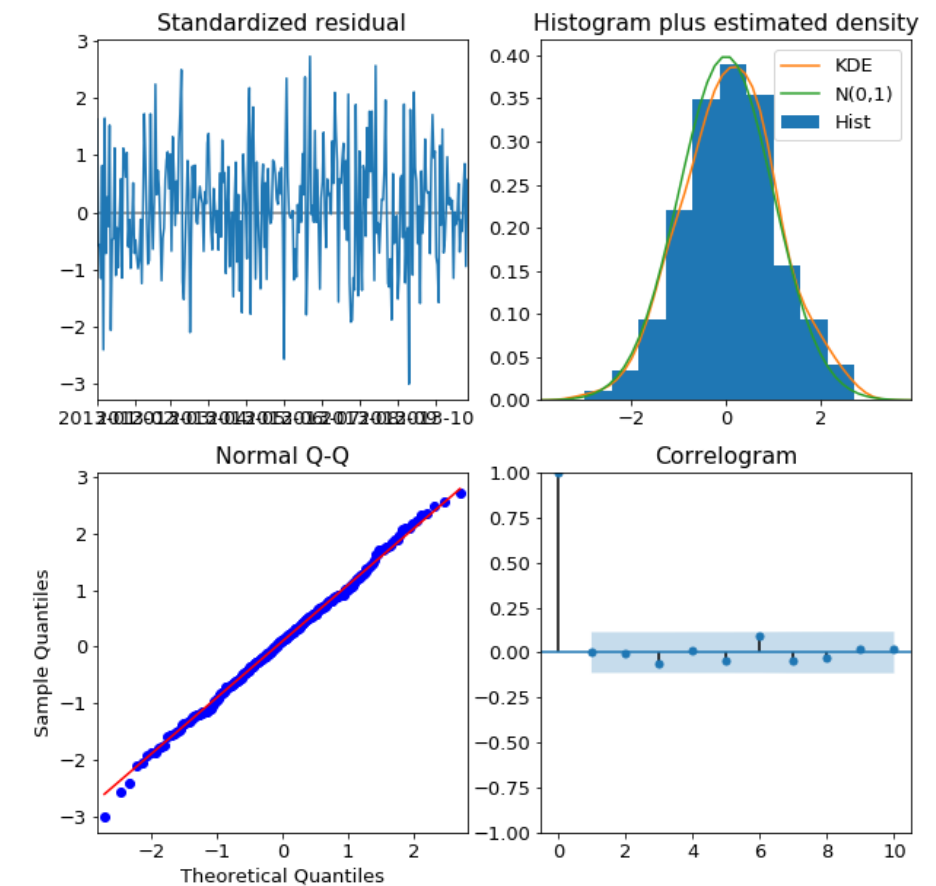
pymarima results

```
print(results.summary())
```

```
=====
                        Statespace Model Results
=====
Dep. Variable:          real values      No. Observations:          300
Model:                  SARIMAX(2, 0, 0)  Log Likelihood             -408.078
Date:                   Tue, 28 May 2019  AIC                        822.156
Time:                   15:53:07          BIC                        833.267
Sample:                 01-01-2013       HQIC                       826.603
                        - 10-27-2013
Covariance Type:        opg
=====
              coef    std err          z      P>|z|      [0.025    0.975]
-----
ar.L1         0.2189     0.054      4.072     0.000     0.114     0.324
ar.L2         0.1960     0.054      3.626     0.000     0.090     0.302
sigma2        0.8888     0.073     12.160     0.000     0.746     1.032
=====
Ljung-Box (Q):                32.10    Jarque-Bera (JB):                0.02
Prob(Q):                      0.81    Prob(JB):                      0.99
Heteroskedasticity (H):        1.28    Skew:                          -0.02
Prob(H) (two-sided):           0.21    Kurtosis:                       2.98
=====

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

```
results.plot_diagnostics()
```



Non-seasonal search parameters

Non-seasonal search parameters

```
results = pm.auto_arima( df,          # data
                        d=0,          # non-seasonal difference order
                        start_p=1,     # initial guess for p
                        start_q=1,     # initial guess for q
                        max_p=3,       # max value of p to test
                        max_q=3,       # max value of q to test
                        )
```

¹ [https://www.alkaline²ml.com/pmdarima/modules/generated/pmdarima.arima.auto_arima.html](https://www.alkaline2ml.com/pmdarima/modules/generated/pmdarima.arima.auto_arima.html)

Seasonal search parameters

```
results = pm.auto_arima( df,          # data
                        ... ,         # non-seasonal arguments
                        seasonal=True, # is the time series seasonal
                        m=7,          # the seasonal period
                        D=1,          # seasonal difference order
                        start_P=1,    # initial guess for P
                        start_Q=1,    # initial guess for Q
                        max_P=2,      # max value of P to test
                        max_Q=2,      # max value of Q to test
                        )
```

Other parameters

```
results = pm.auto_arima( df,                # data
                        ...,                # model order parameters
                        information_criterion='aic', # used to select best model
                        trace=True,          # print results whilst training
                        error_action='ignore', # ignore orders that don't work
                        stepwise=True,       # apply intelligent order search
                        )
```

Saving model objects

```
# Import
```

```
import joblib
```

```
# Select a filepath
```

```
filepath = 'localpath/great_model.pkl'
```

```
# Save model to filepath
```

```
joblib.dump(model_results_object, filepath)
```


Saving model objects

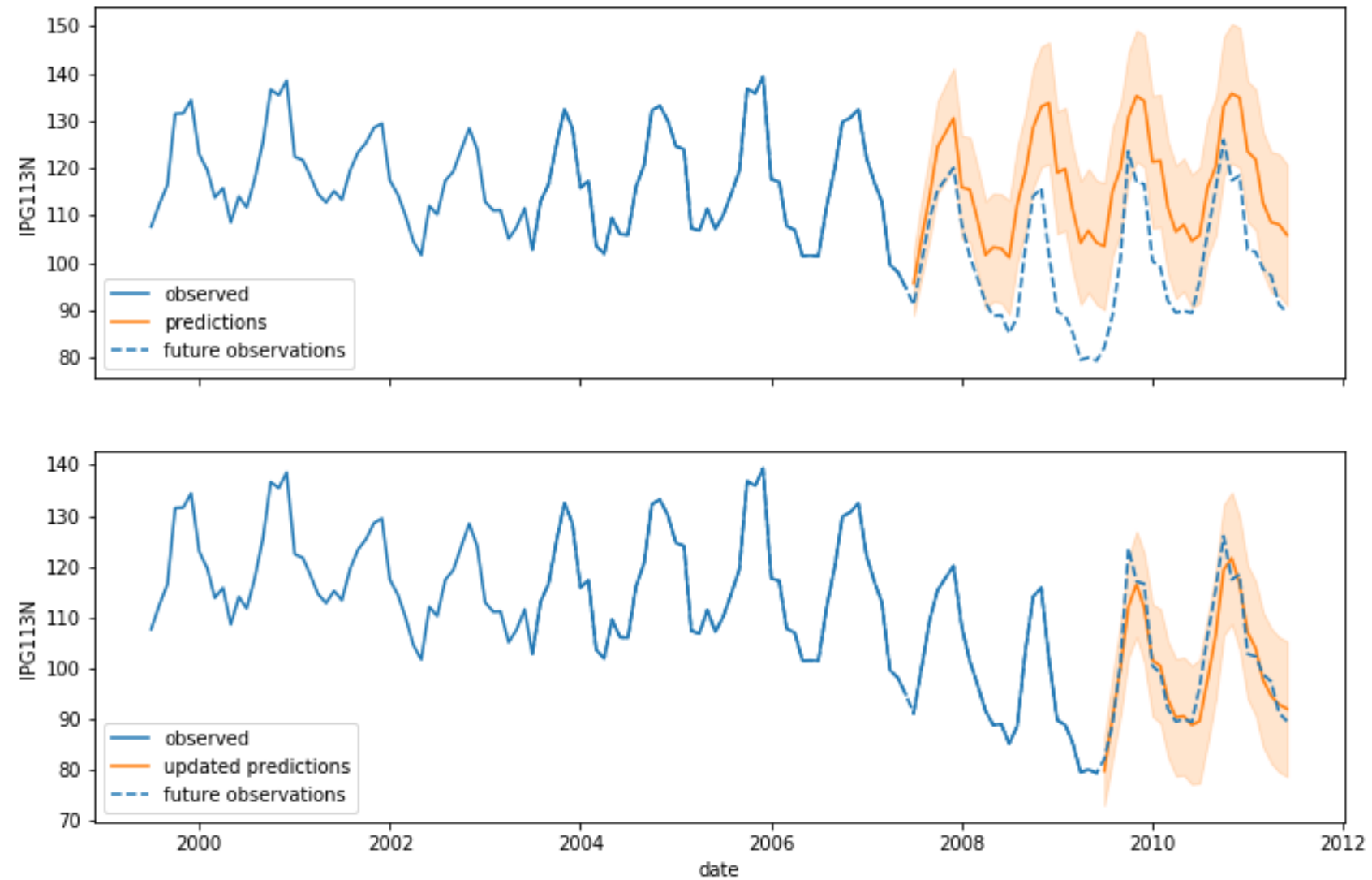
```
# Select a filepath
filepath = 'localpath/great_model.pkl'

# Load model object from filepath
model_results_object = joblib.load(filepath)
```

Updating model

```
# Add new observations and update parameters  
model_results_object.update(df_new)
```

Update comparison



Let's practice!

ARIMA MODELS IN PYTHON

SARIMA and Box-Jenkins

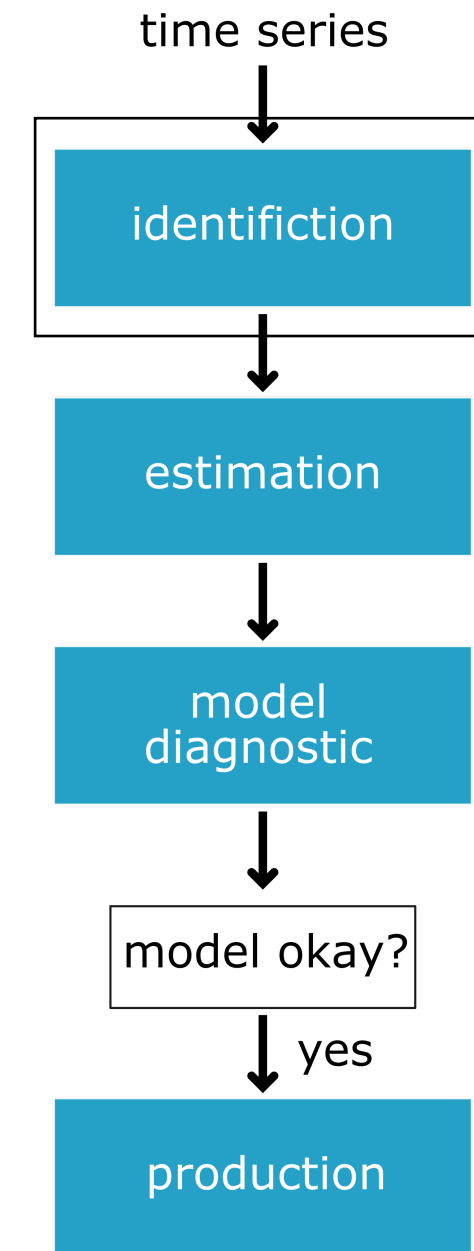
ARIMA MODELS IN PYTHON



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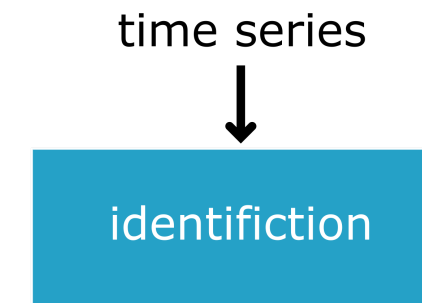
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Box-Jenkins



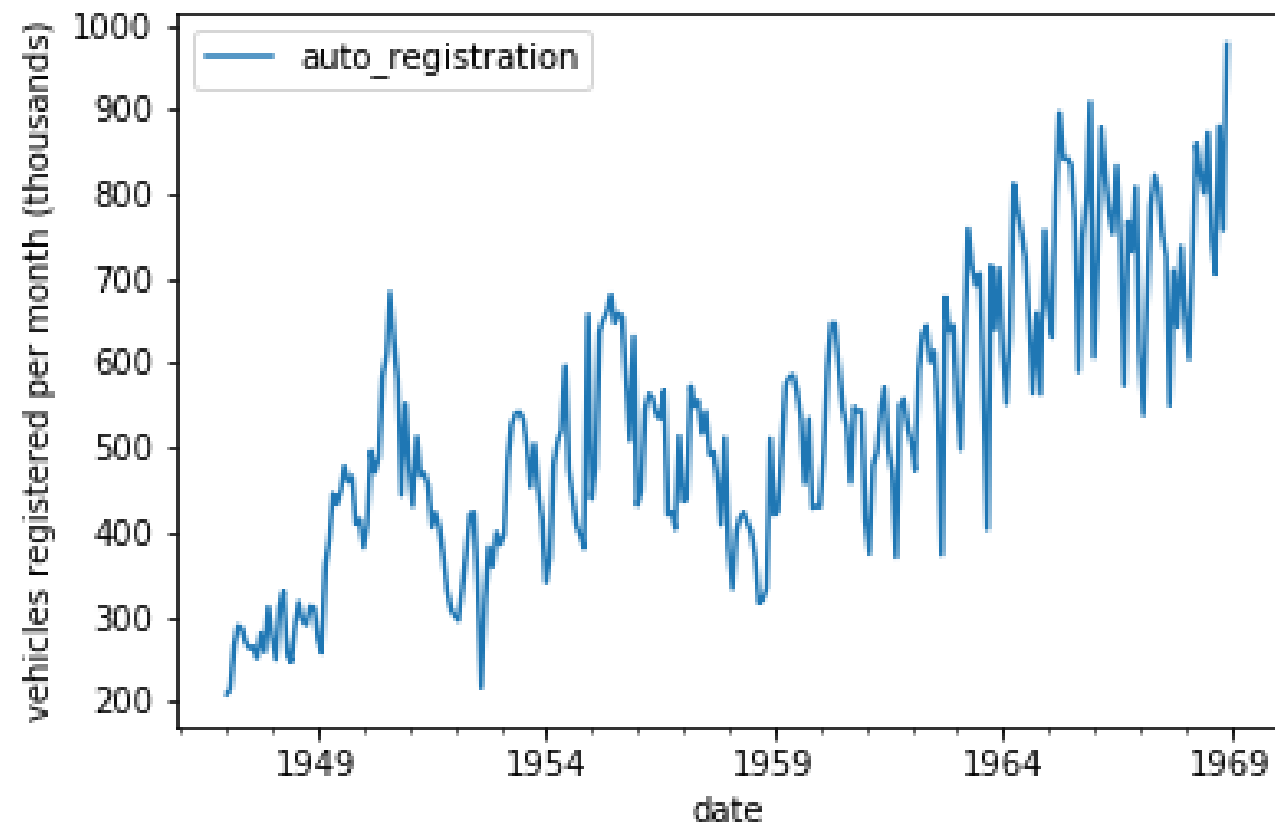
Box-Jenkins with seasonal data

- Determine if time series is seasonal
- Find seasonal period
- Find transforms to make data stationary
 - Seasonal and non-seasonal differencing
 - Other transforms

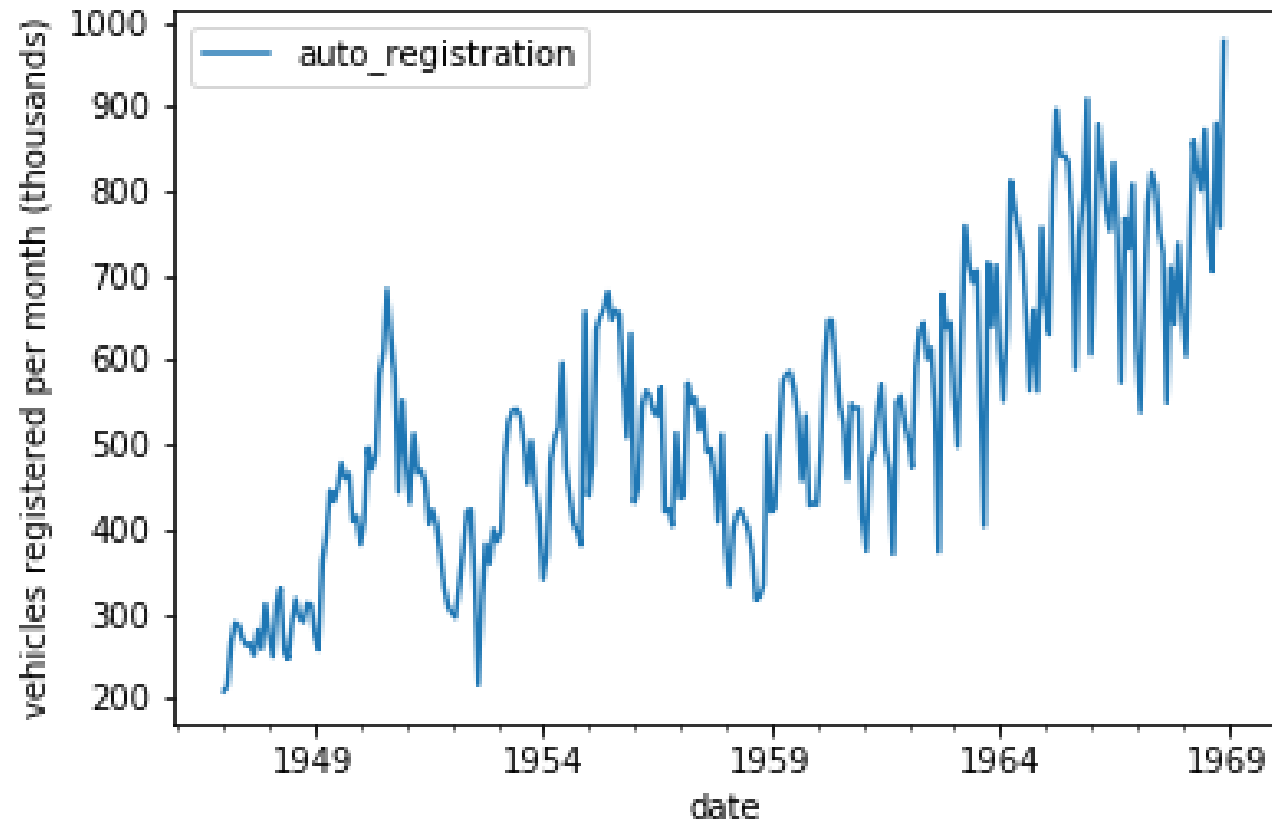


Mixed differencing

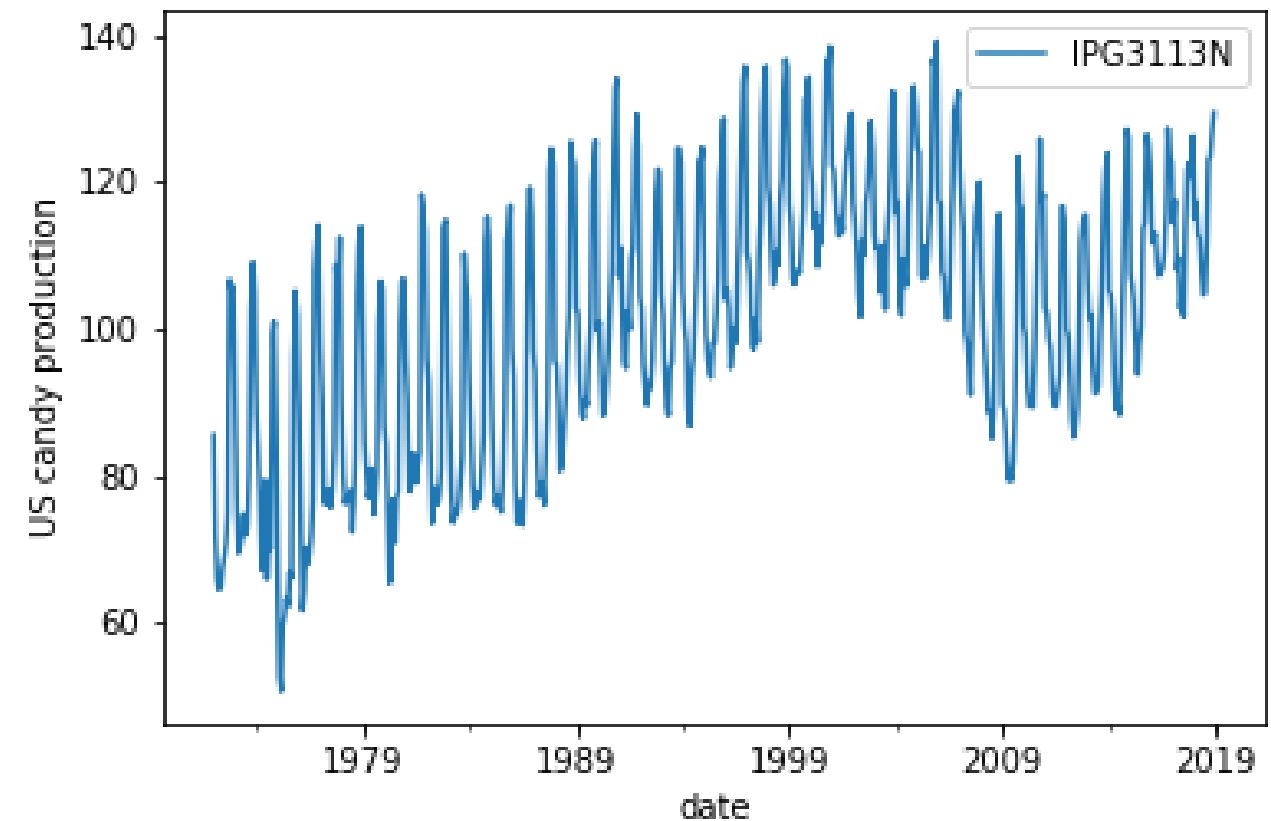
- D should be 0 or 1
- $d + D$ should be 0-2



Weak vs strong seasonality

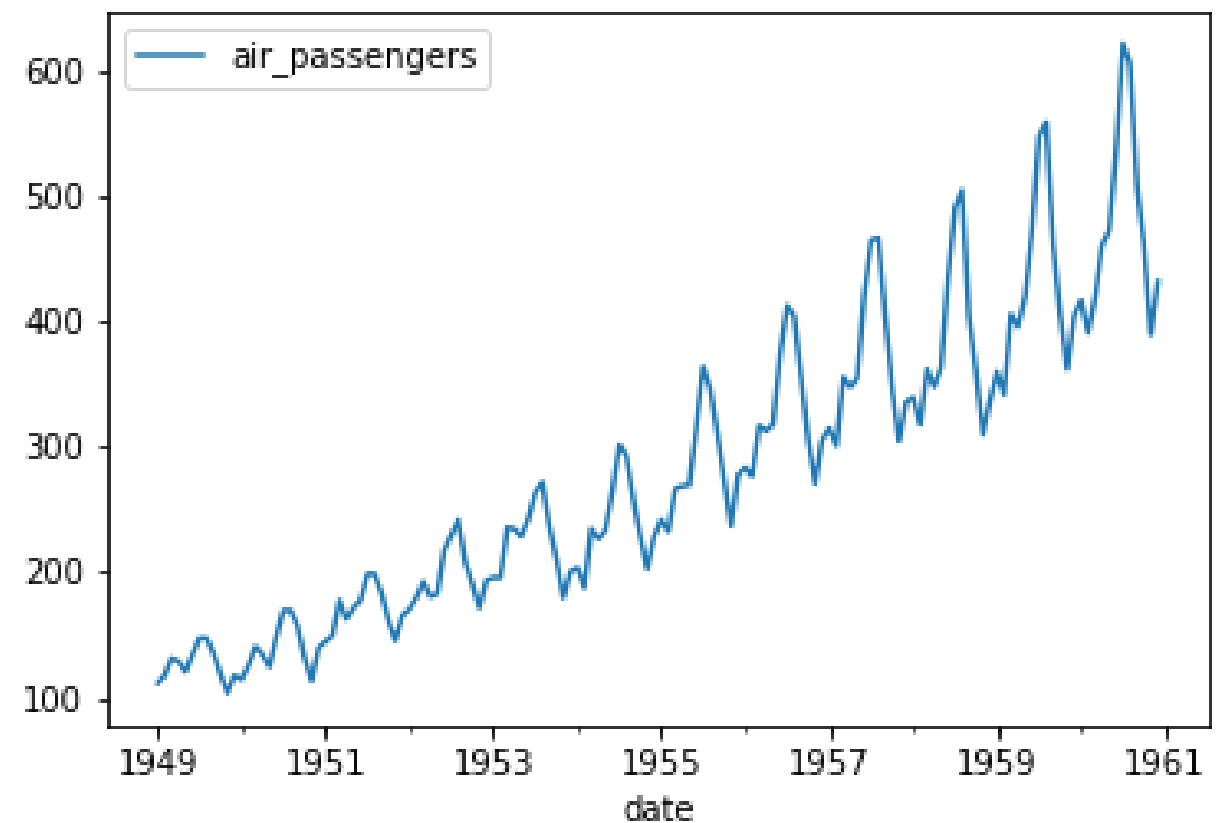
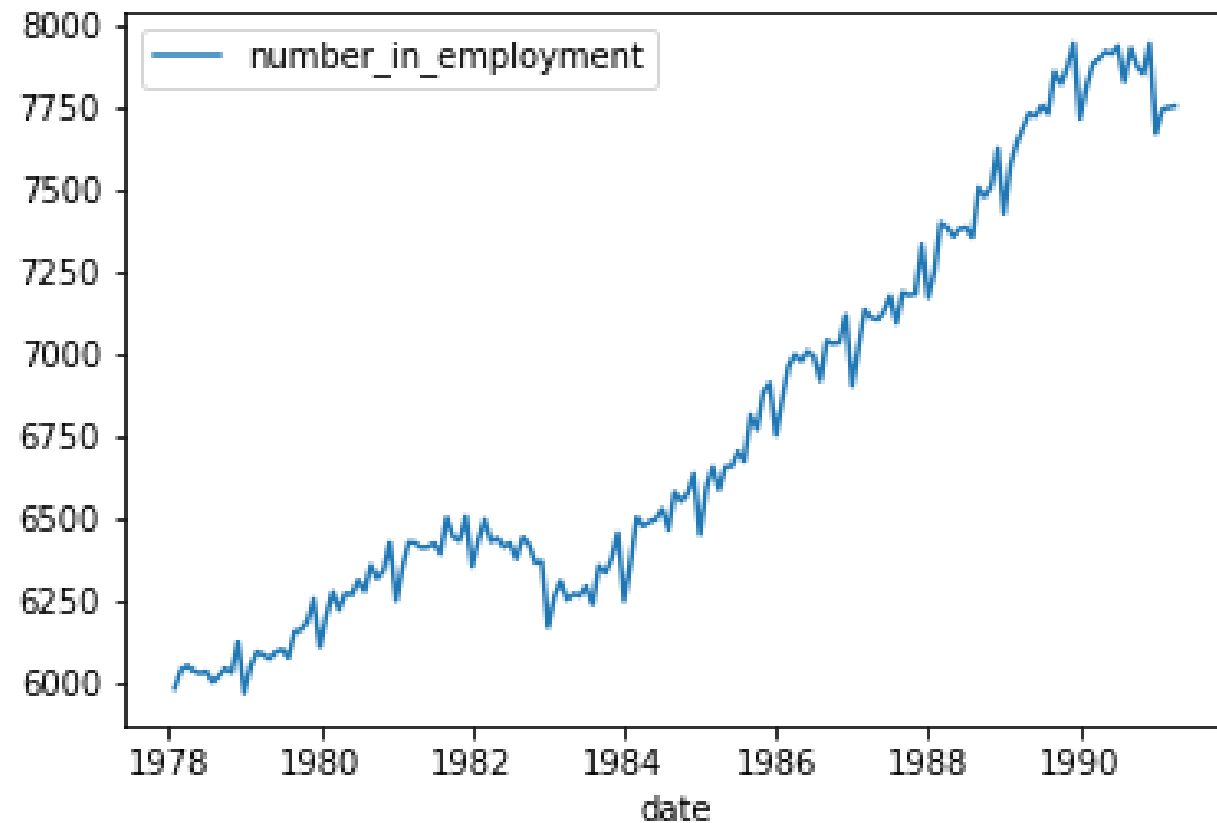


- Weak seasonal pattern
- Use seasonal differencing if necessary



- Strong seasonal pattern
- Always use seasonal differencing

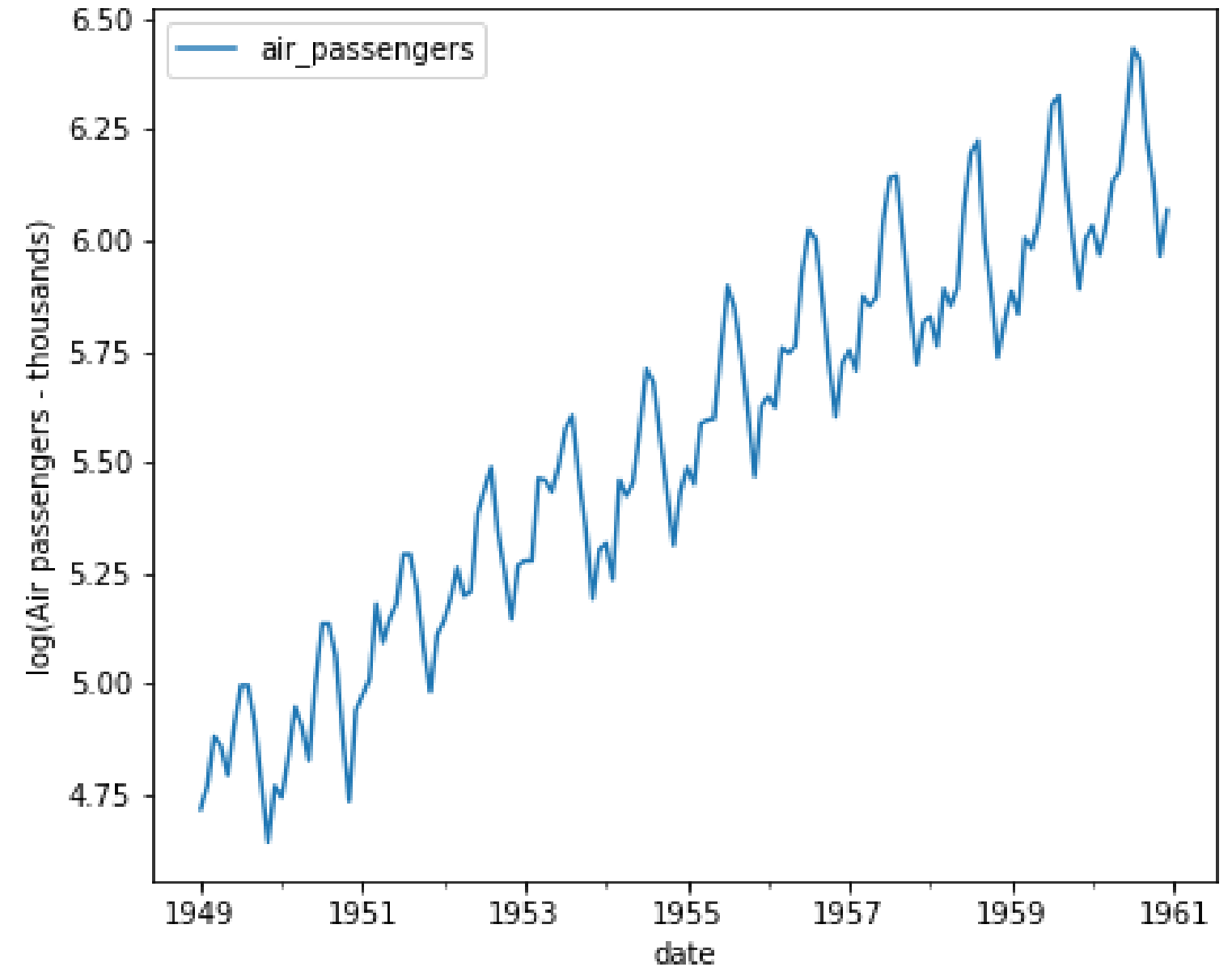
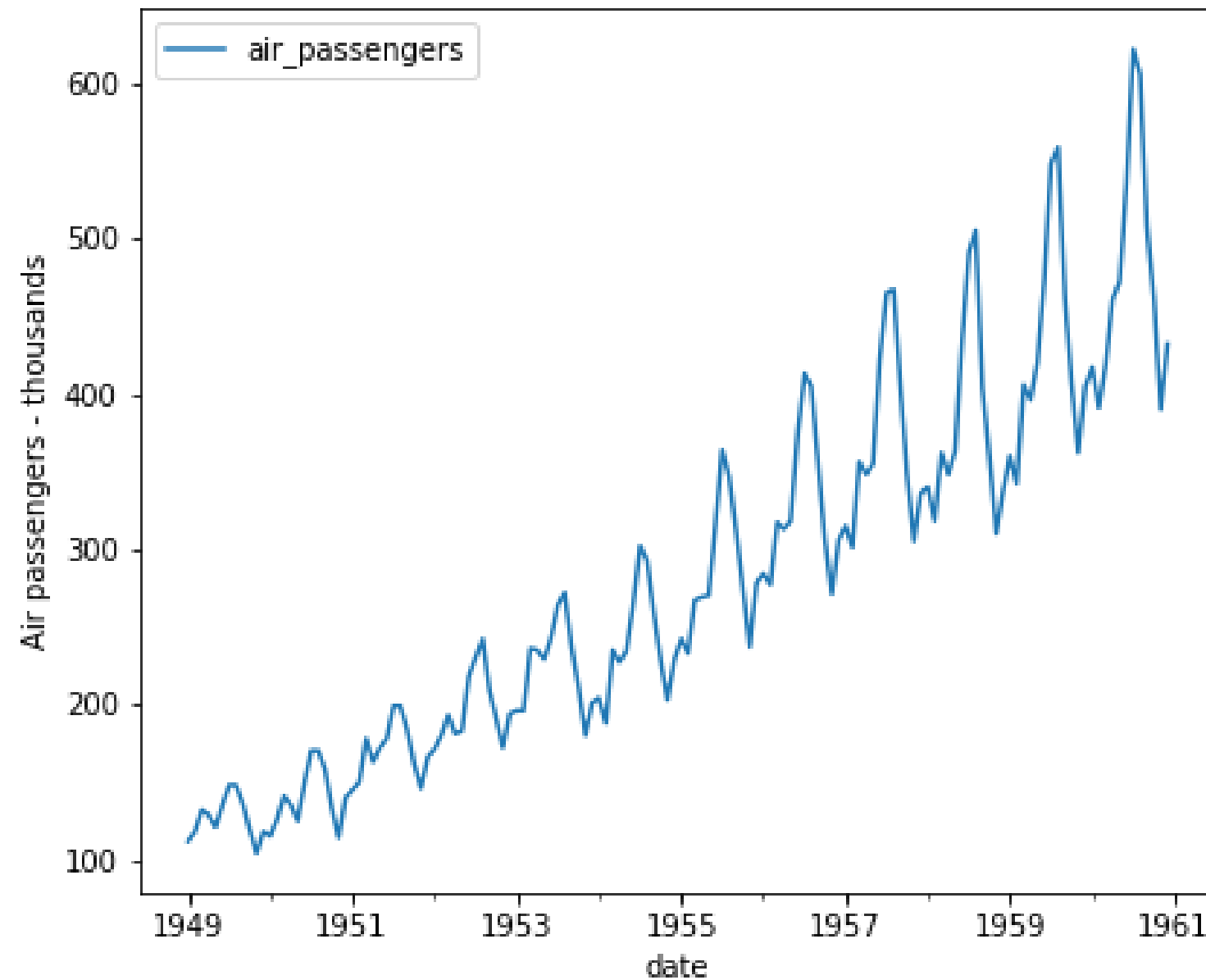
Additive vs multiplicative seasonality



- Additive series = trend + season
- Proceed as usual with differencing

- multiplicative series = trend x season
- Apply log transform first - `np.log`

Multiplicative to additive seasonality



Let's practice!

ARIMA MODELS IN PYTHON

Congratulations!

ARIMA MODELS IN PYTHON



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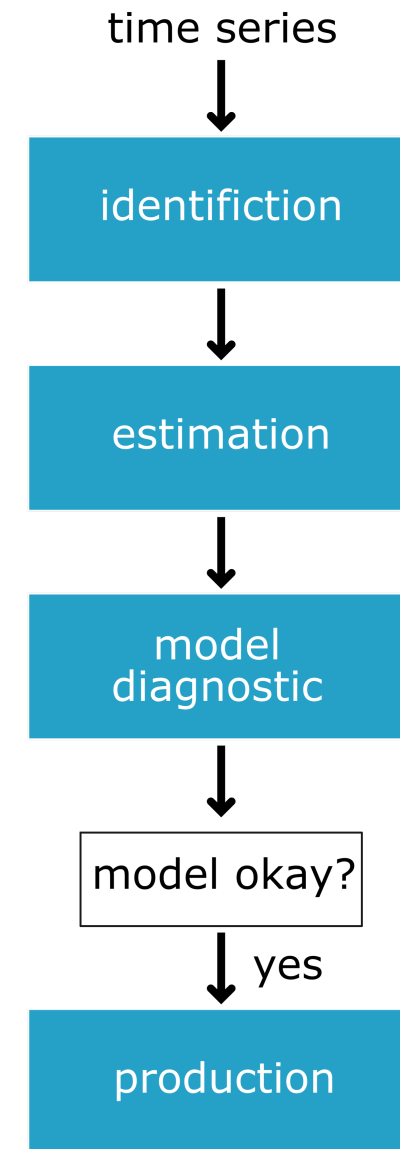
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The SARIMAX model

S - seasonal
A
R - autoregressive
I - integrated
M
A - moving average
X - exogenous

Time series modeling framework

- Test for stationarity and seasonality
- Find promising model orders
- Fit models and narrow selection with AIC/BIC
- Perform model diagnostics tests
- Make forecasts
- Save and update models



Further steps

- Fit data created using `arma_generate_sample()`
- Tackle real world data! Either your own or [examples from statsmodels](#)

Further steps

- Fit data created using `arma_generate_sample()`
- Tackle real world data! Either your own or [examples from statsmodels](#)
- More time series courses here

¹ <https://www.statsmodels.org/stable/datasets/index.html>

Good luck!

ARIMA MODELS IN PYTHON