Copyright Notice

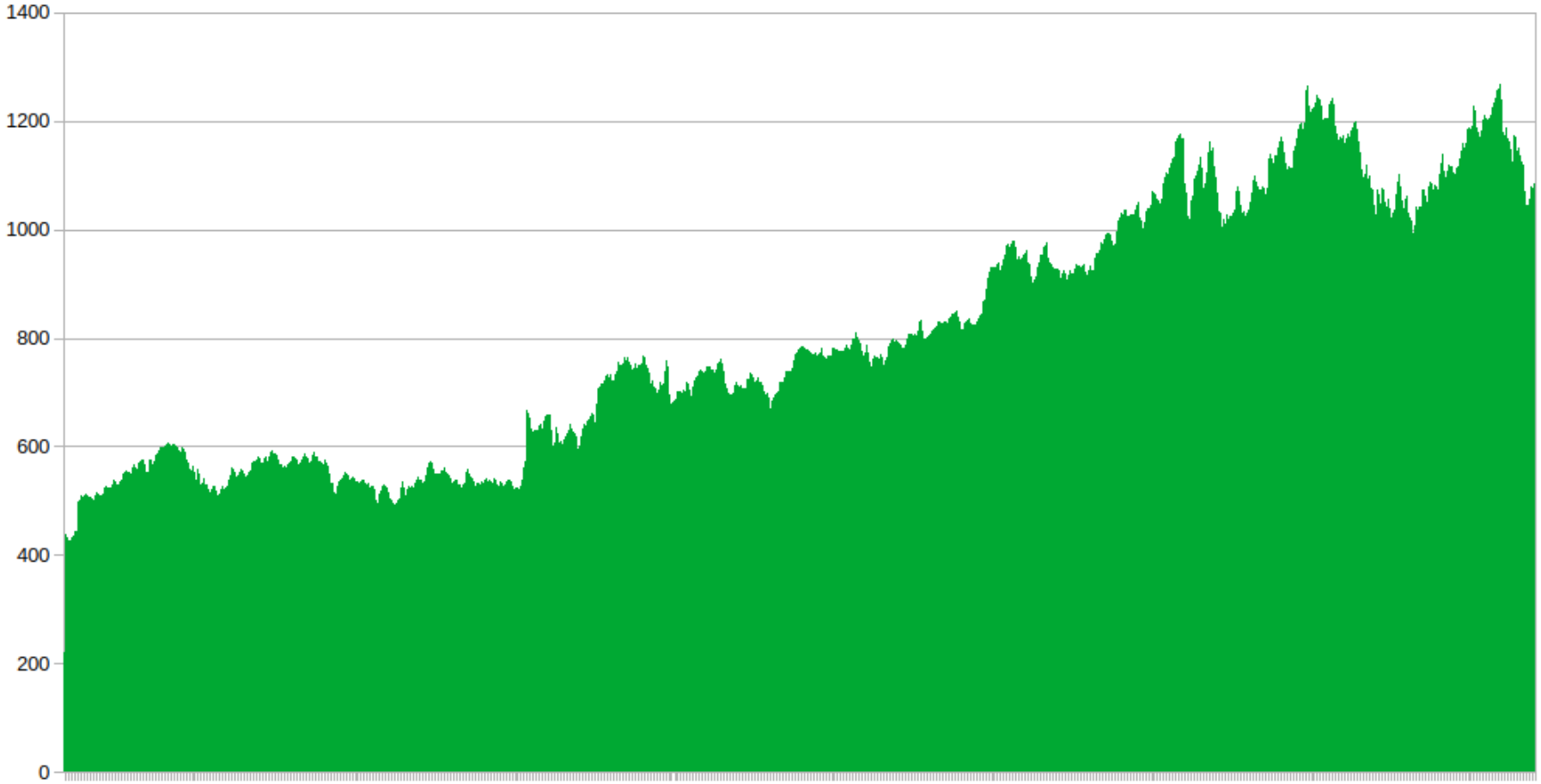


Chart Created by lmoroney@

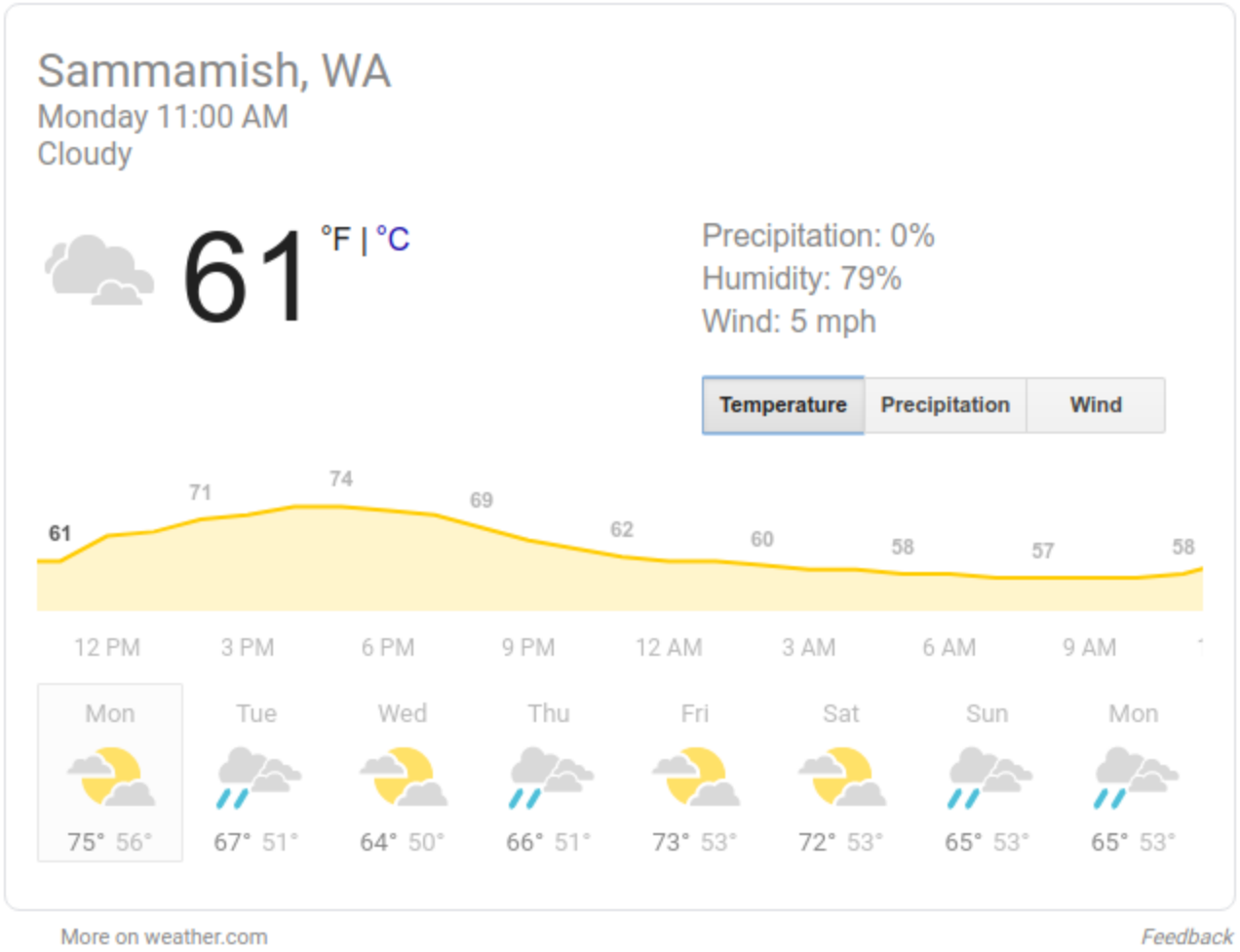


Chart From Google Search

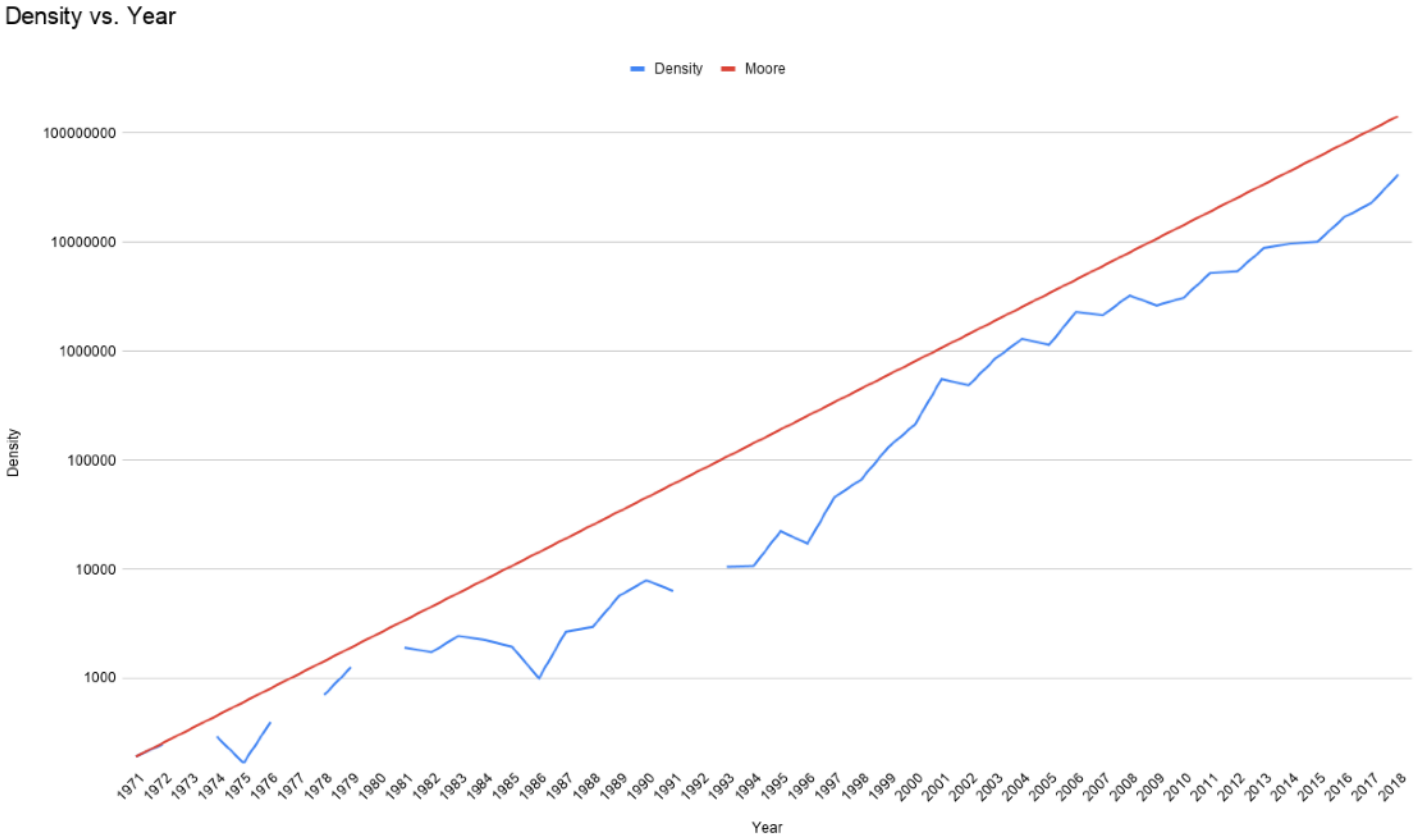
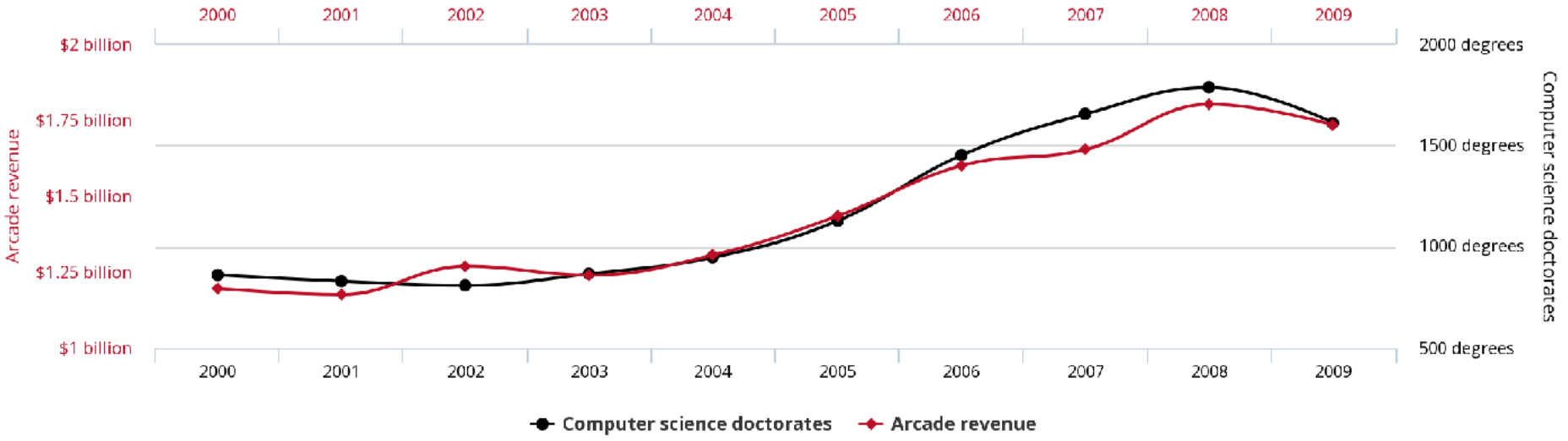


Chart Created by lmoroney@

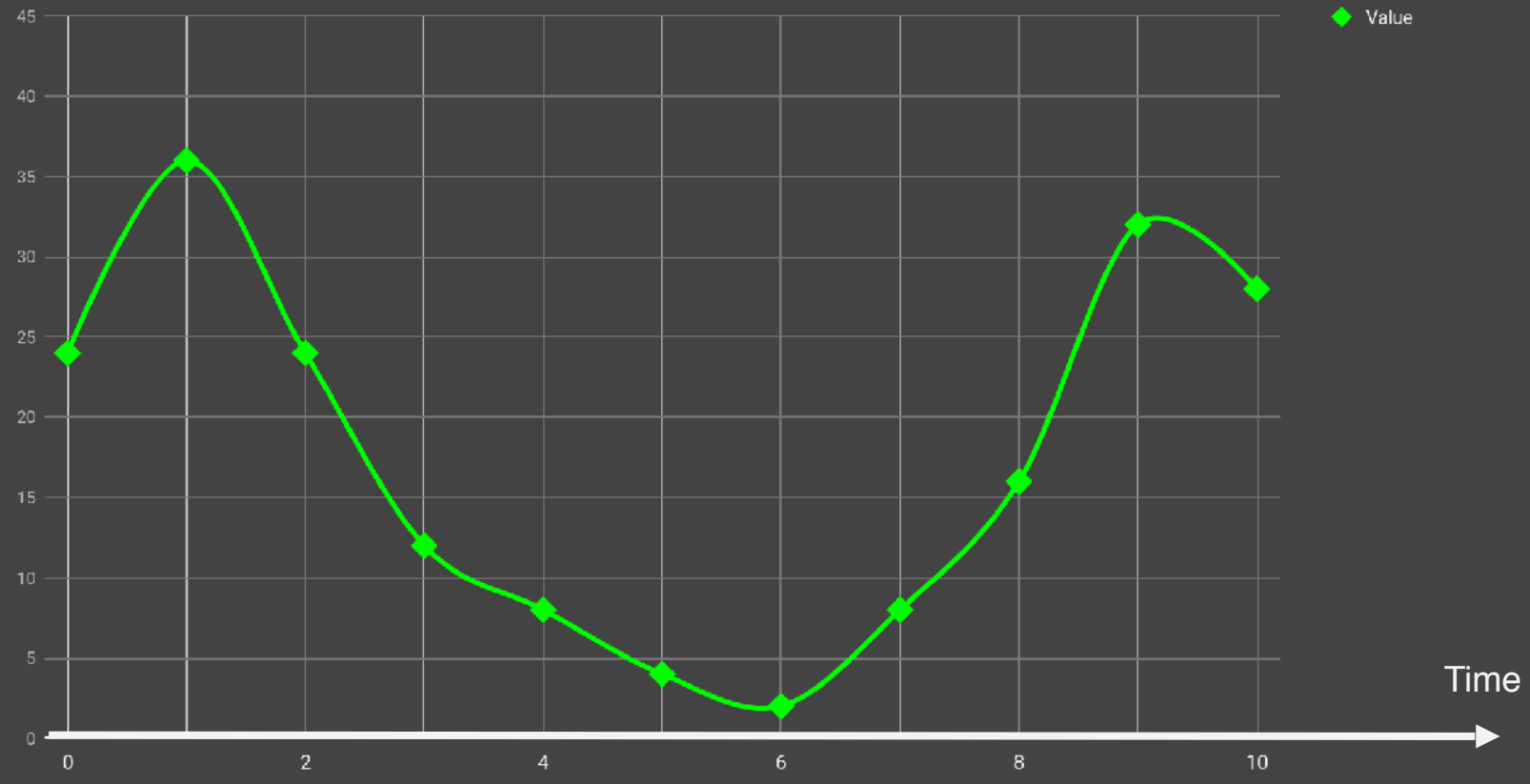
Total revenue generated by arcades

correlates with

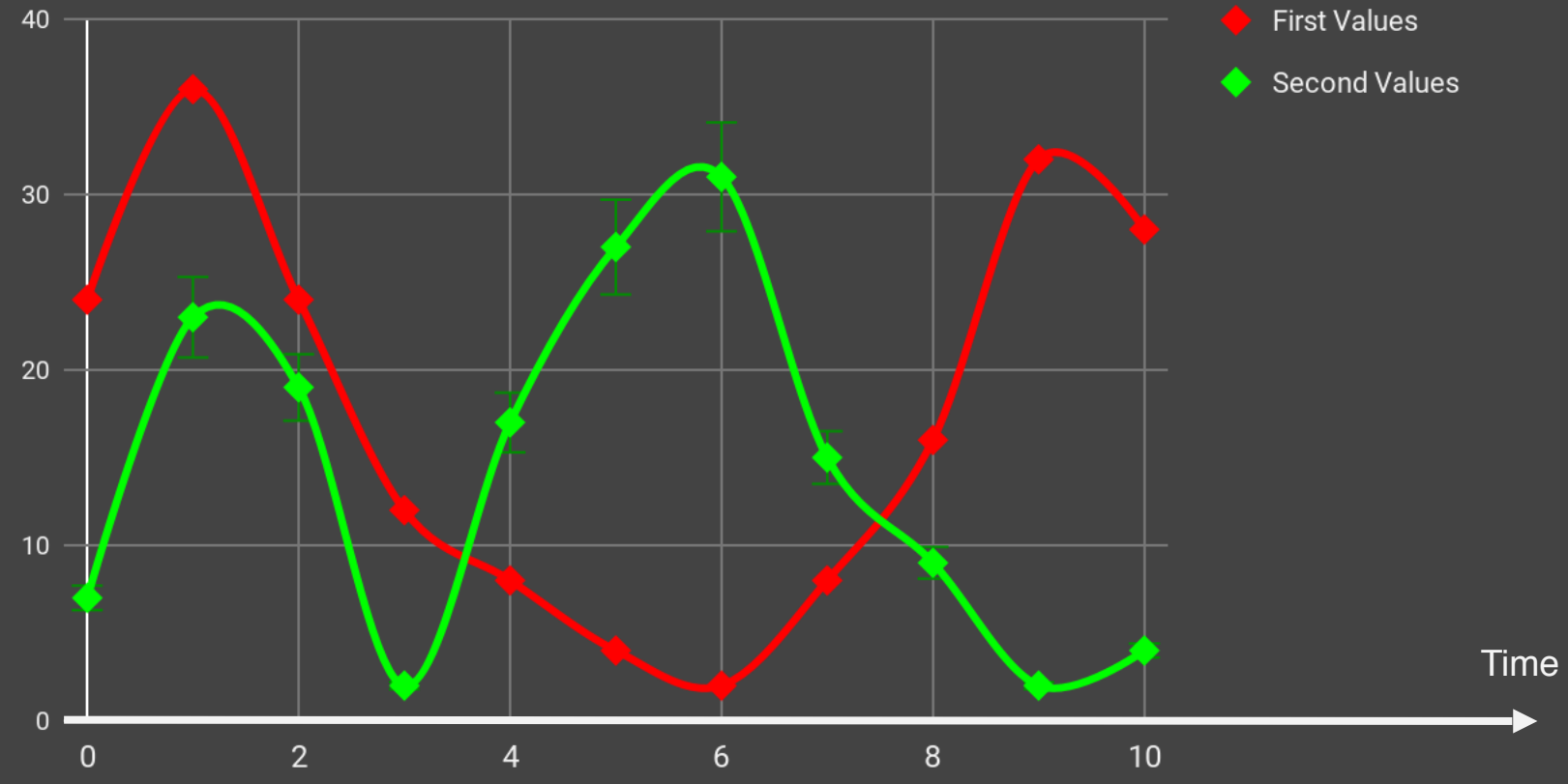
Computer science doctorates awarded in the US



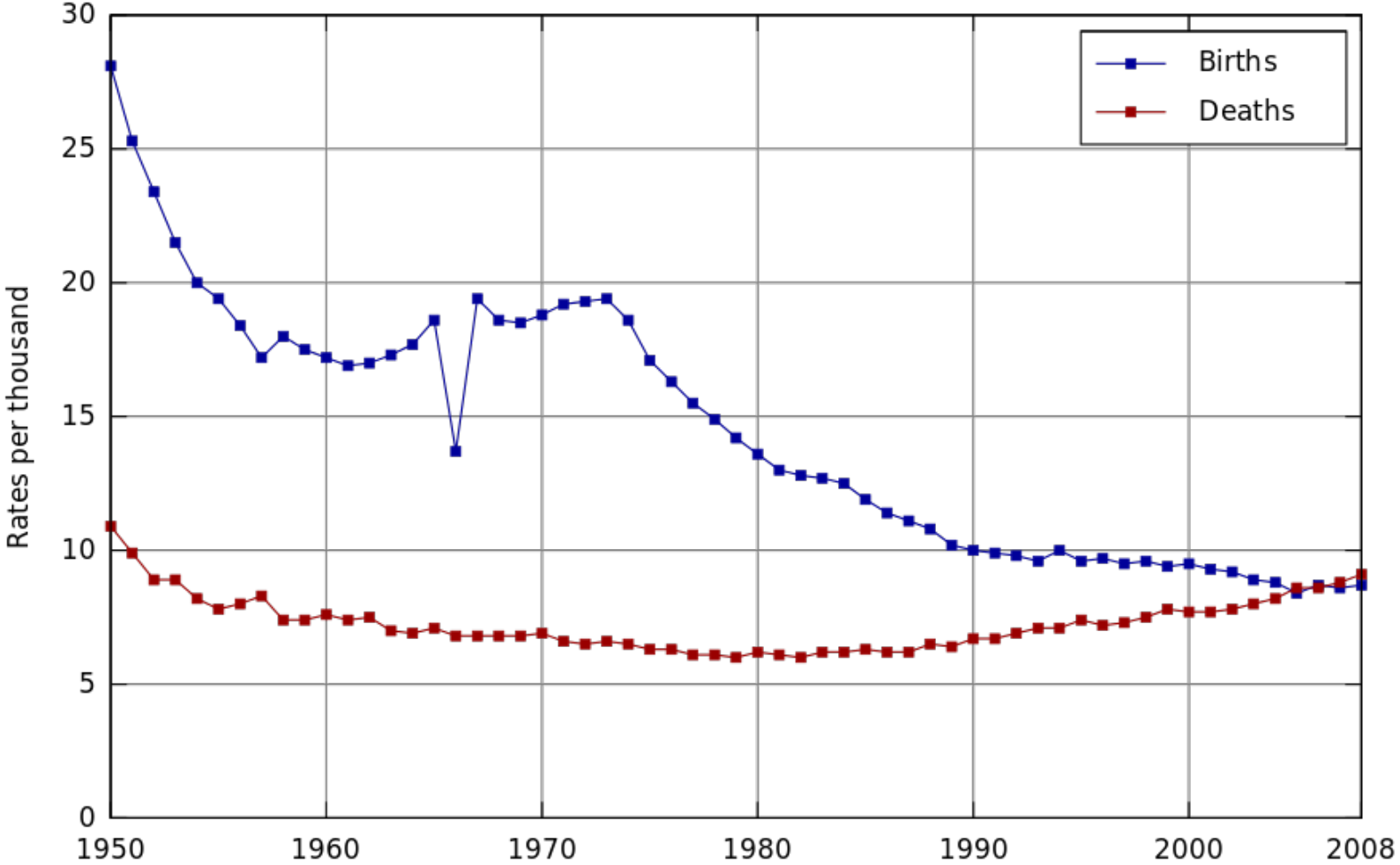
Univariate Time Series

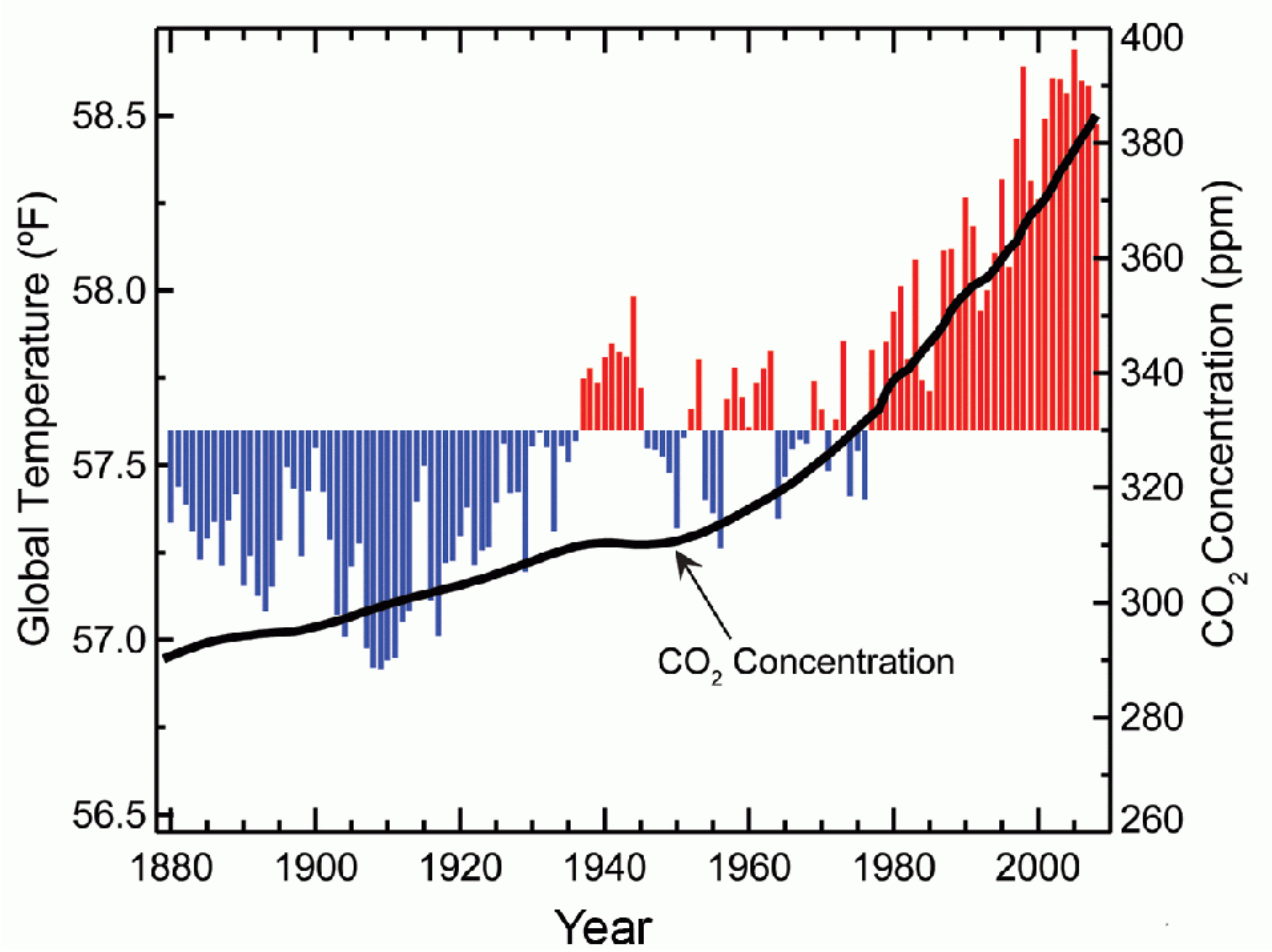


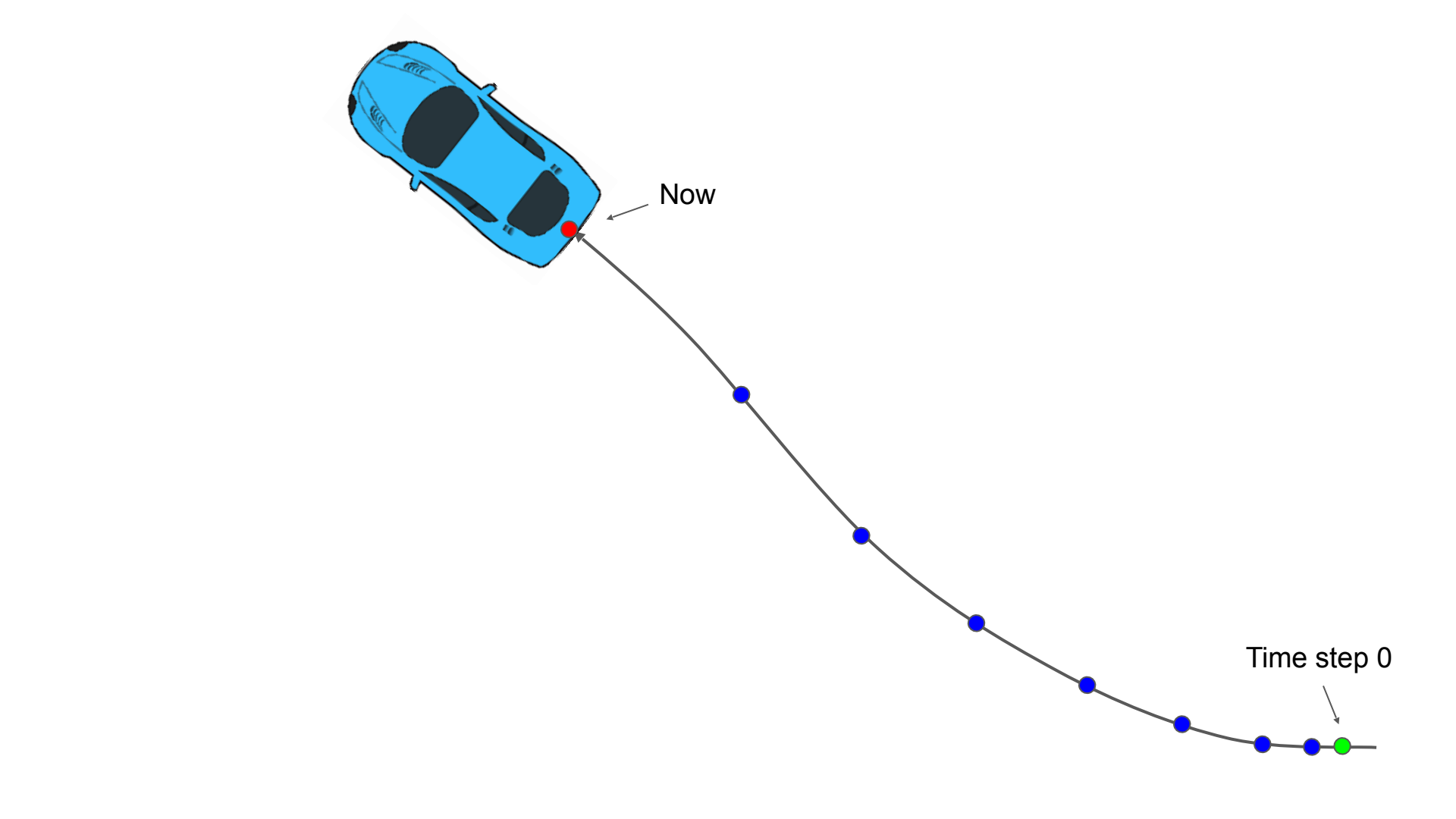
Multivariate Time Series

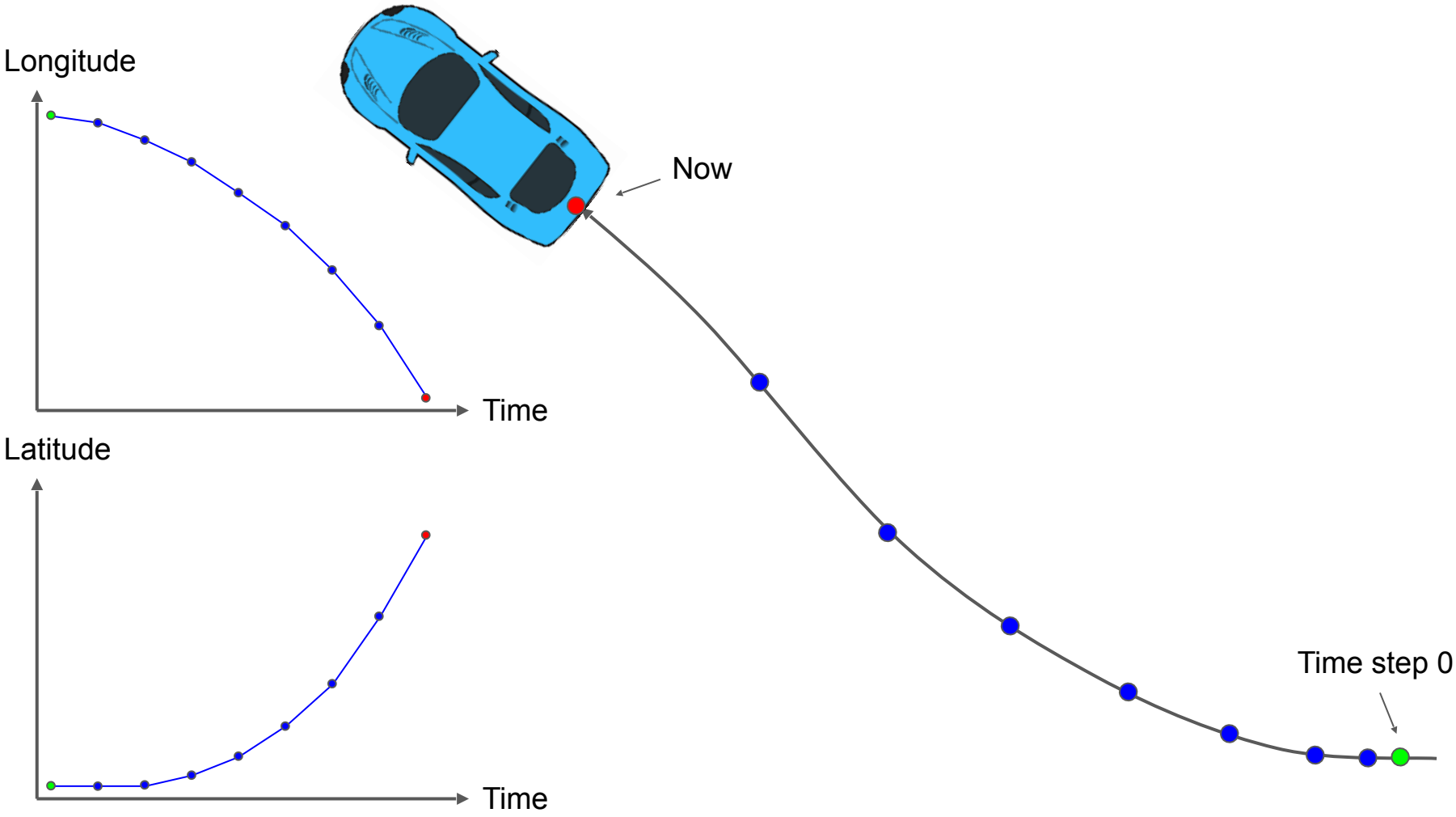


Birth and Death Rate in Japan

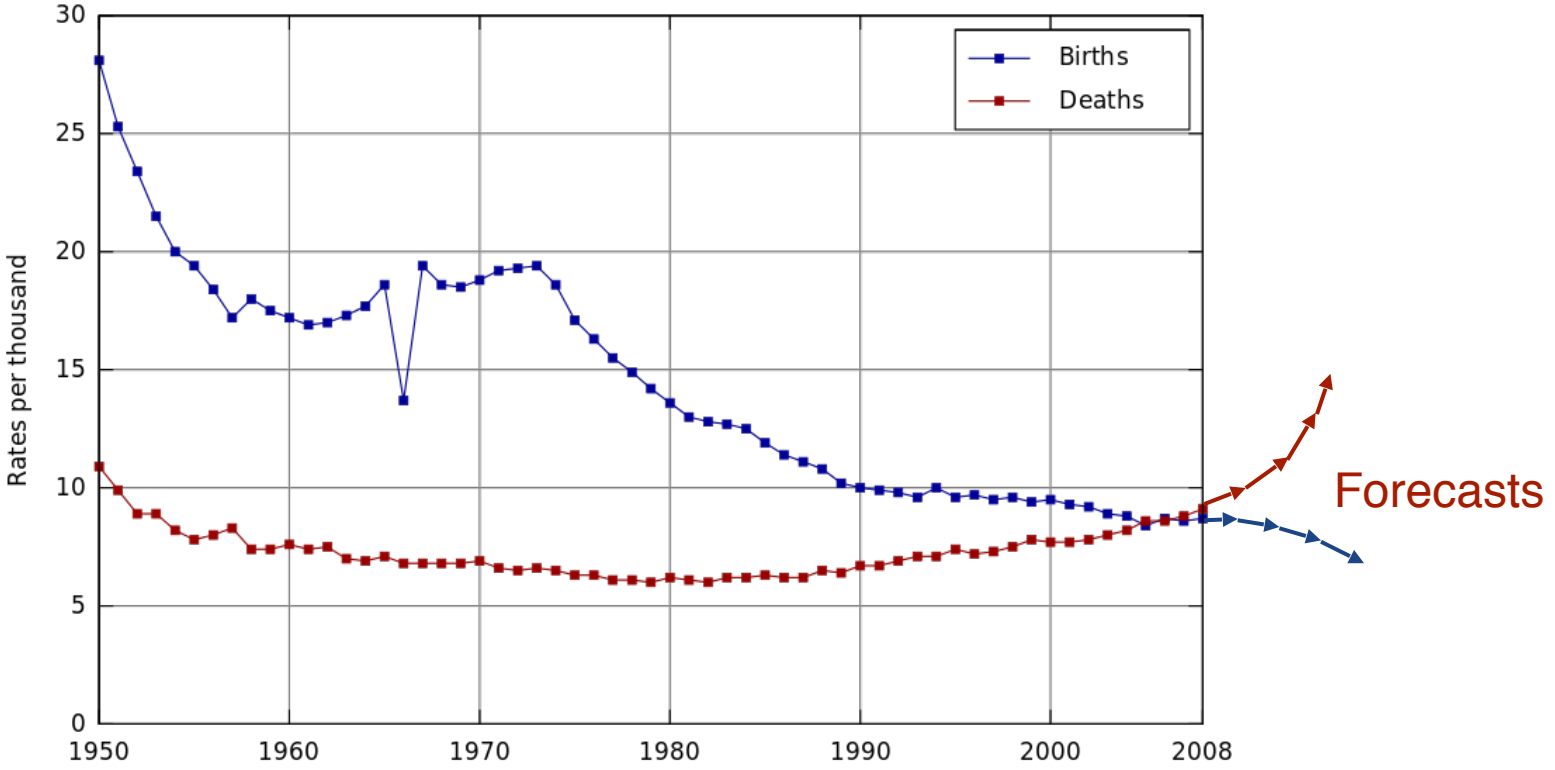



Global Temperature (ºF)
58.5
58.0
57.5
57.0
56.5
400
380
360
340
320
300
280
260
CO2 Concentration (ppm)
1880
1900
1920
1940
1960
1980
2000
Year
CO2 Concentration


Now
Time step 0


Longitude
Time
Latitude
Time
Now
Time step 0

Birth and Death Rate in Japan



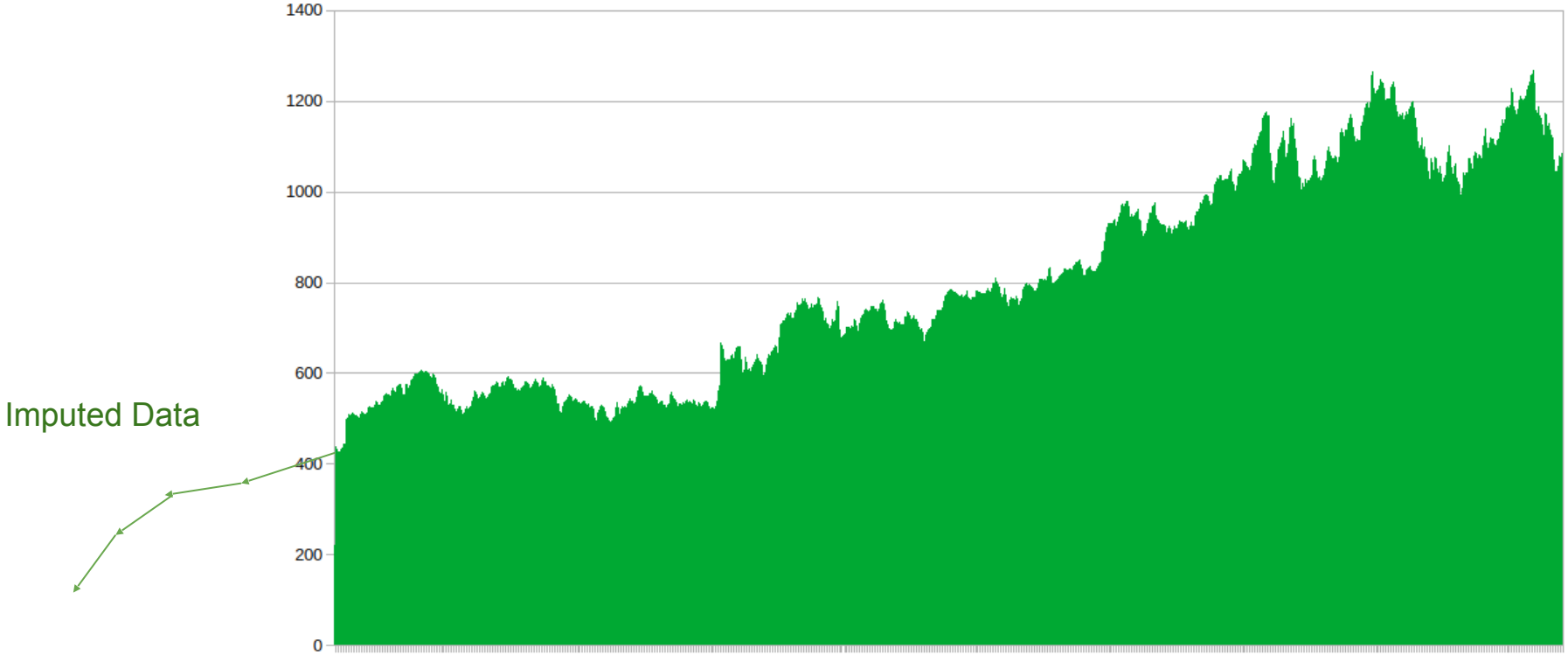


Chart Created by lmoroney@

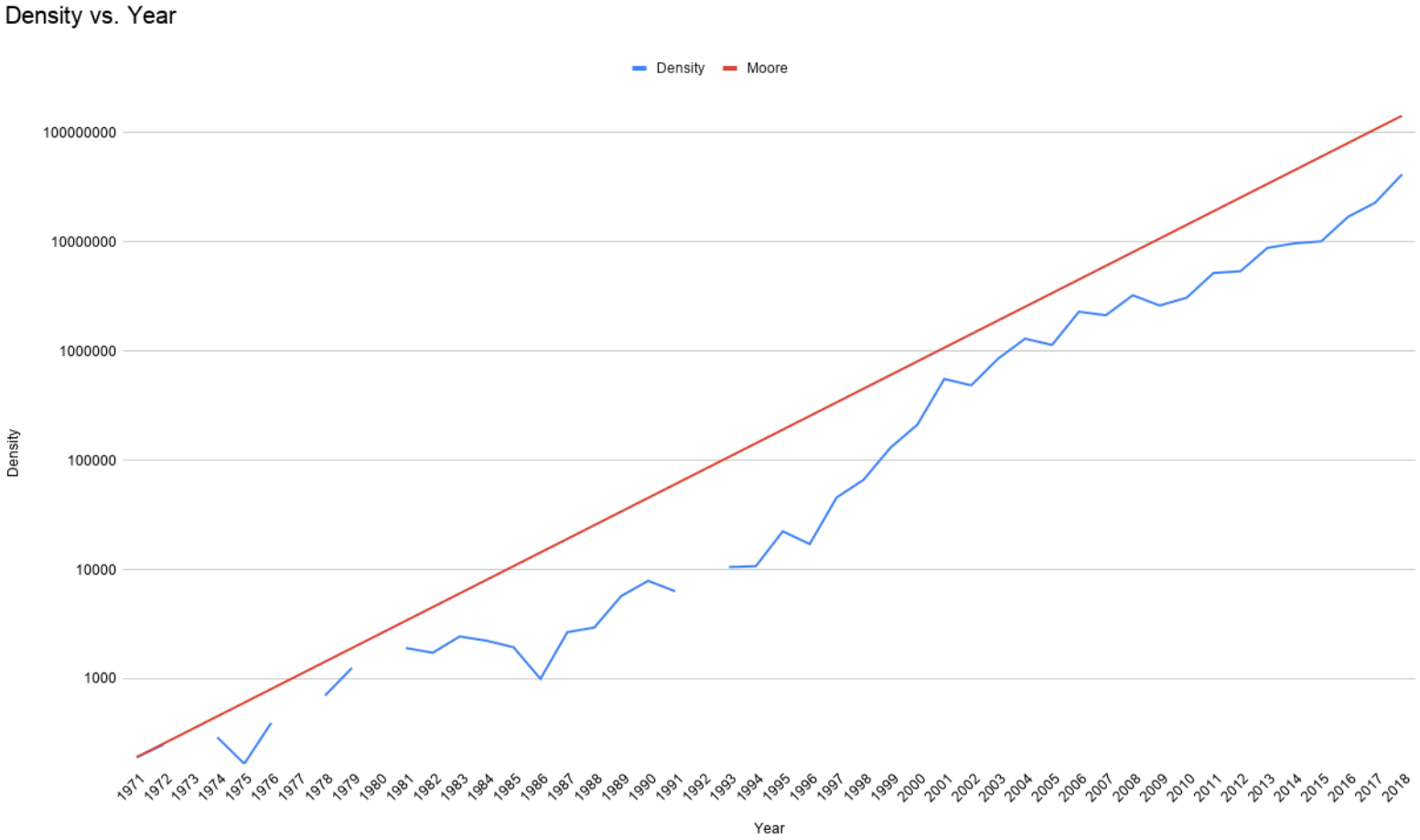


Chart Created by lmoroney@

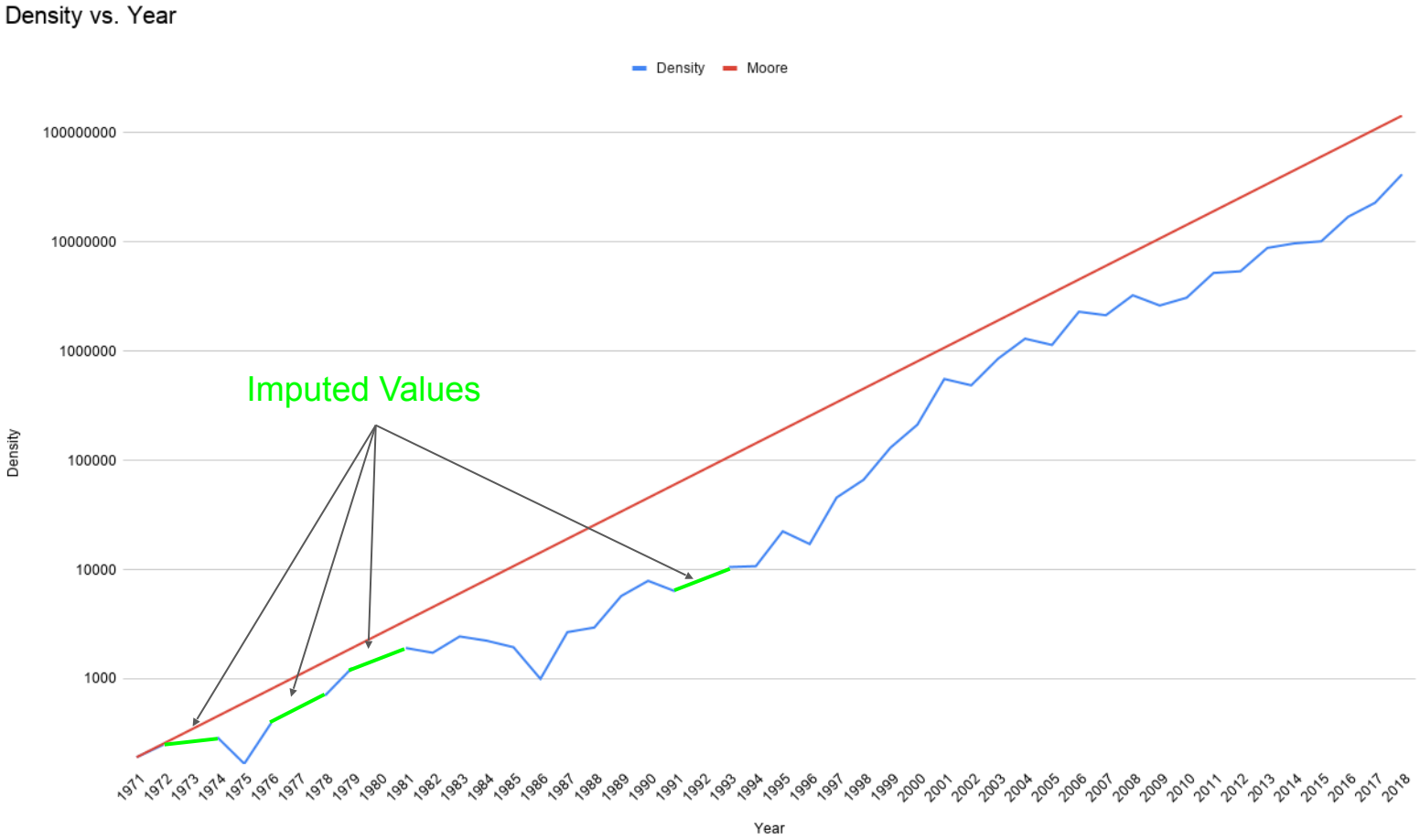
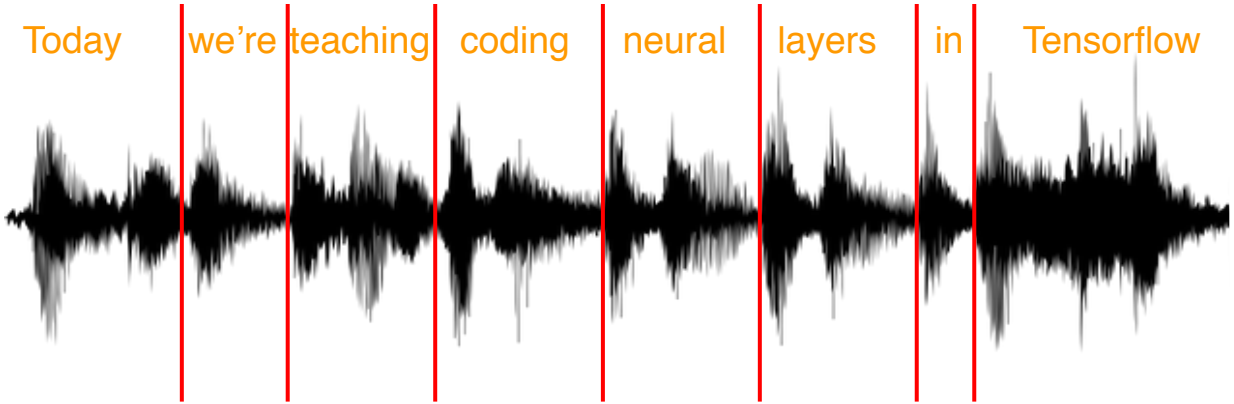


Chart Created by lmoroney@


150
140
130
120
110
100
90
0
50
100
150


Today
we're
teaching
coding
neural
layers
in
Tensorflow

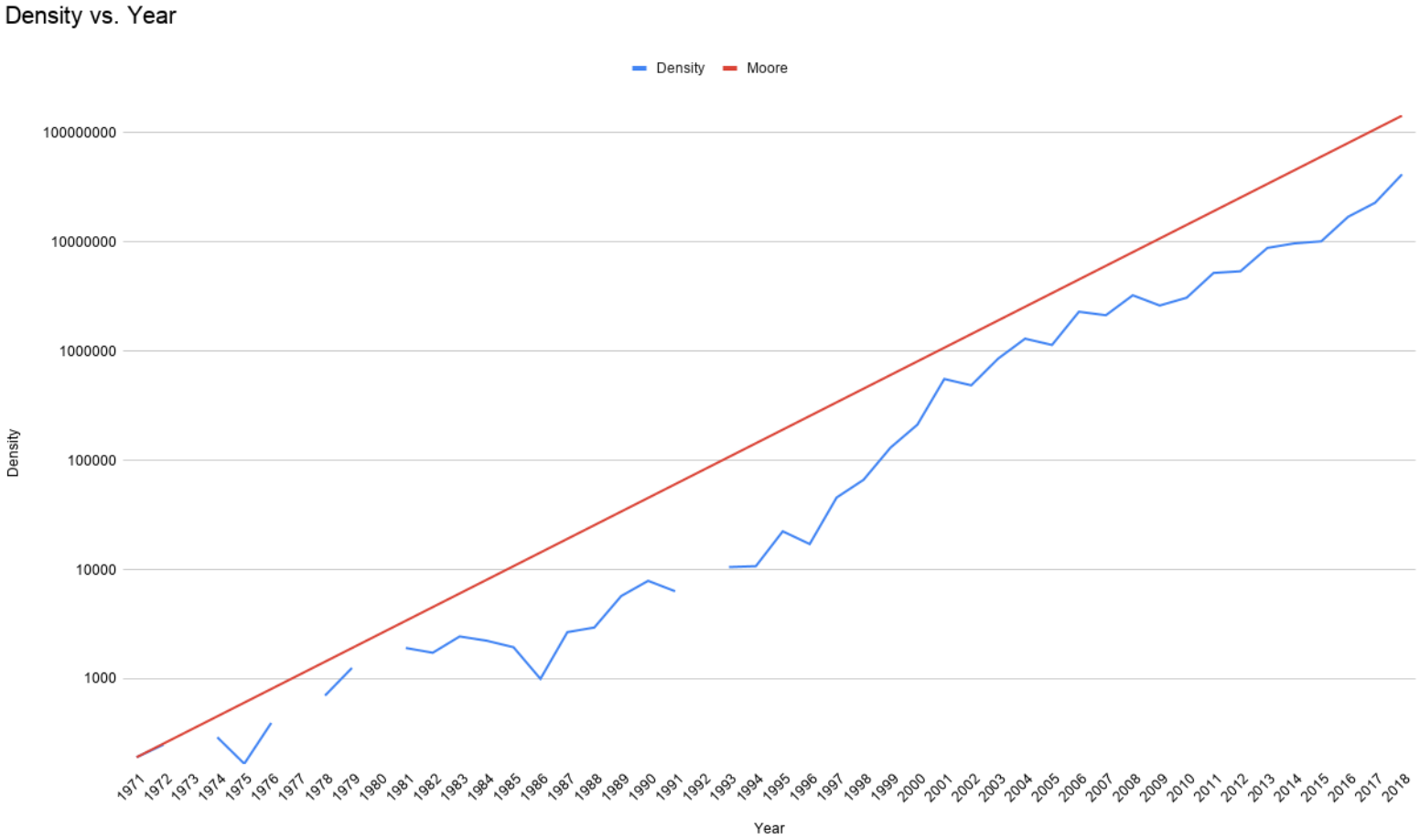
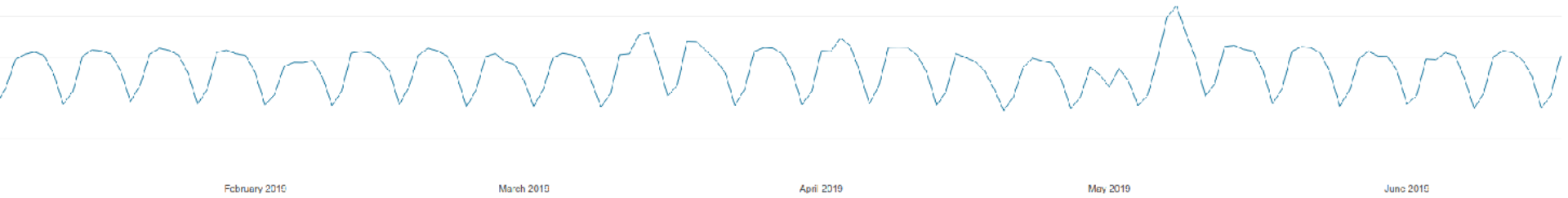
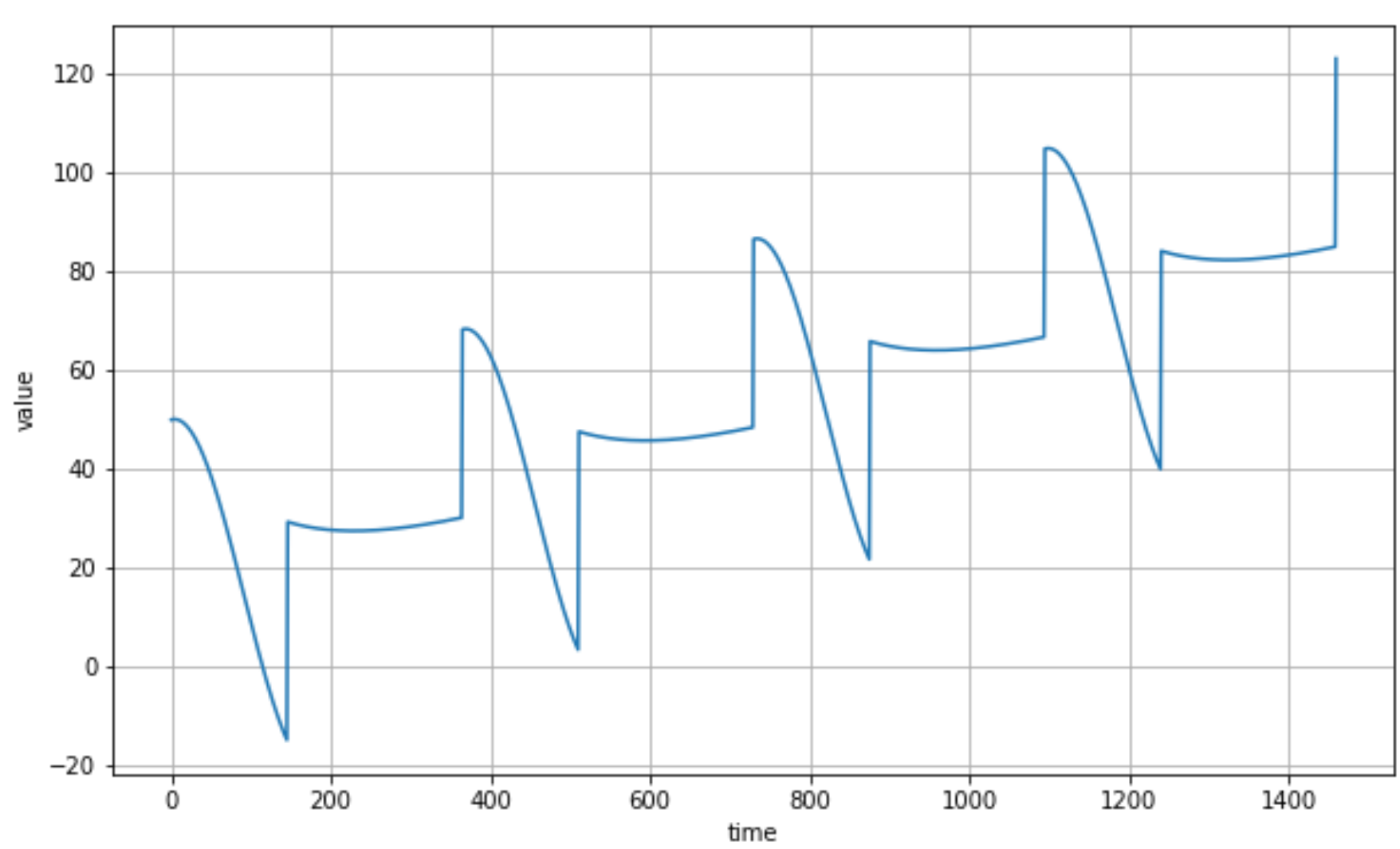
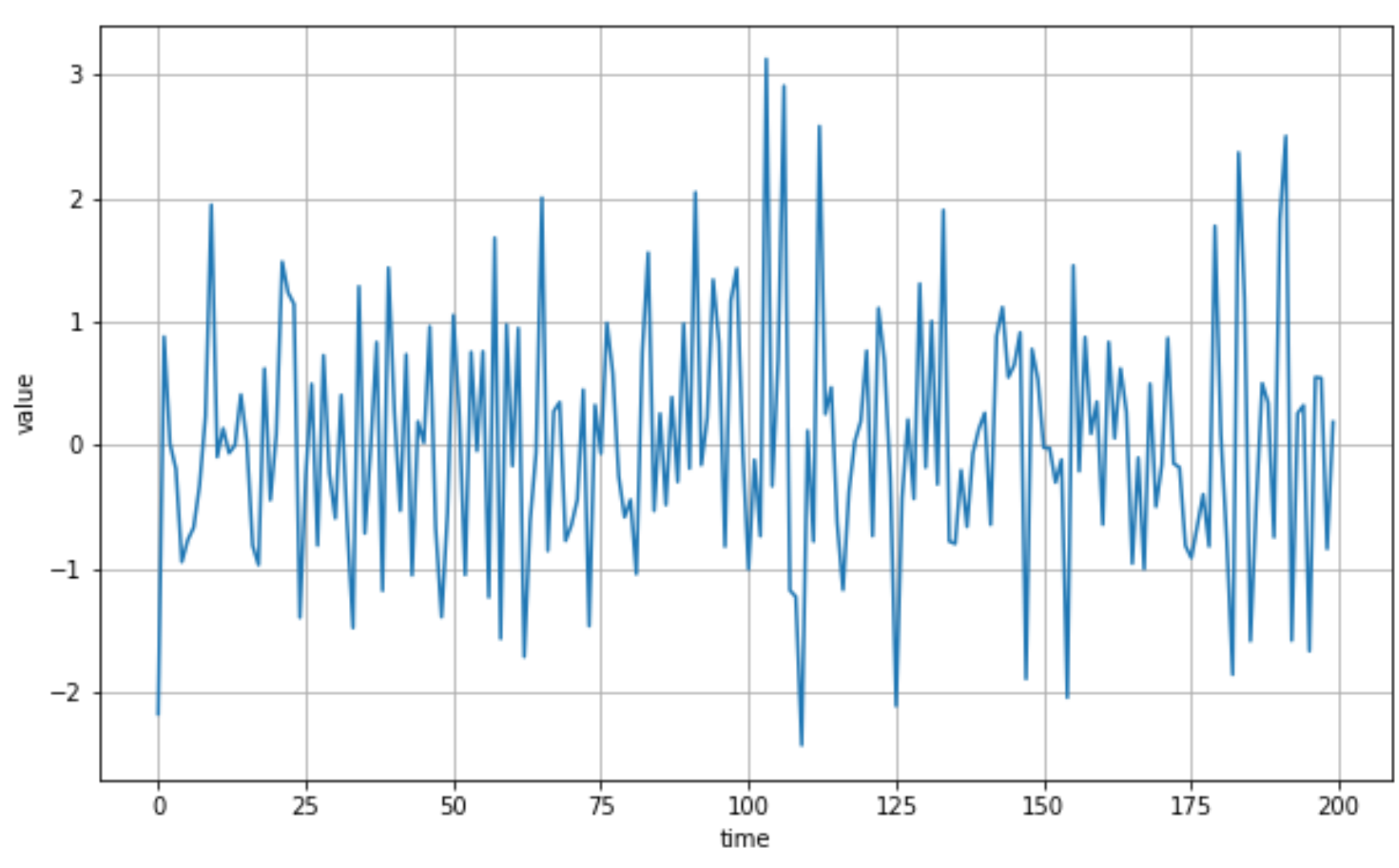


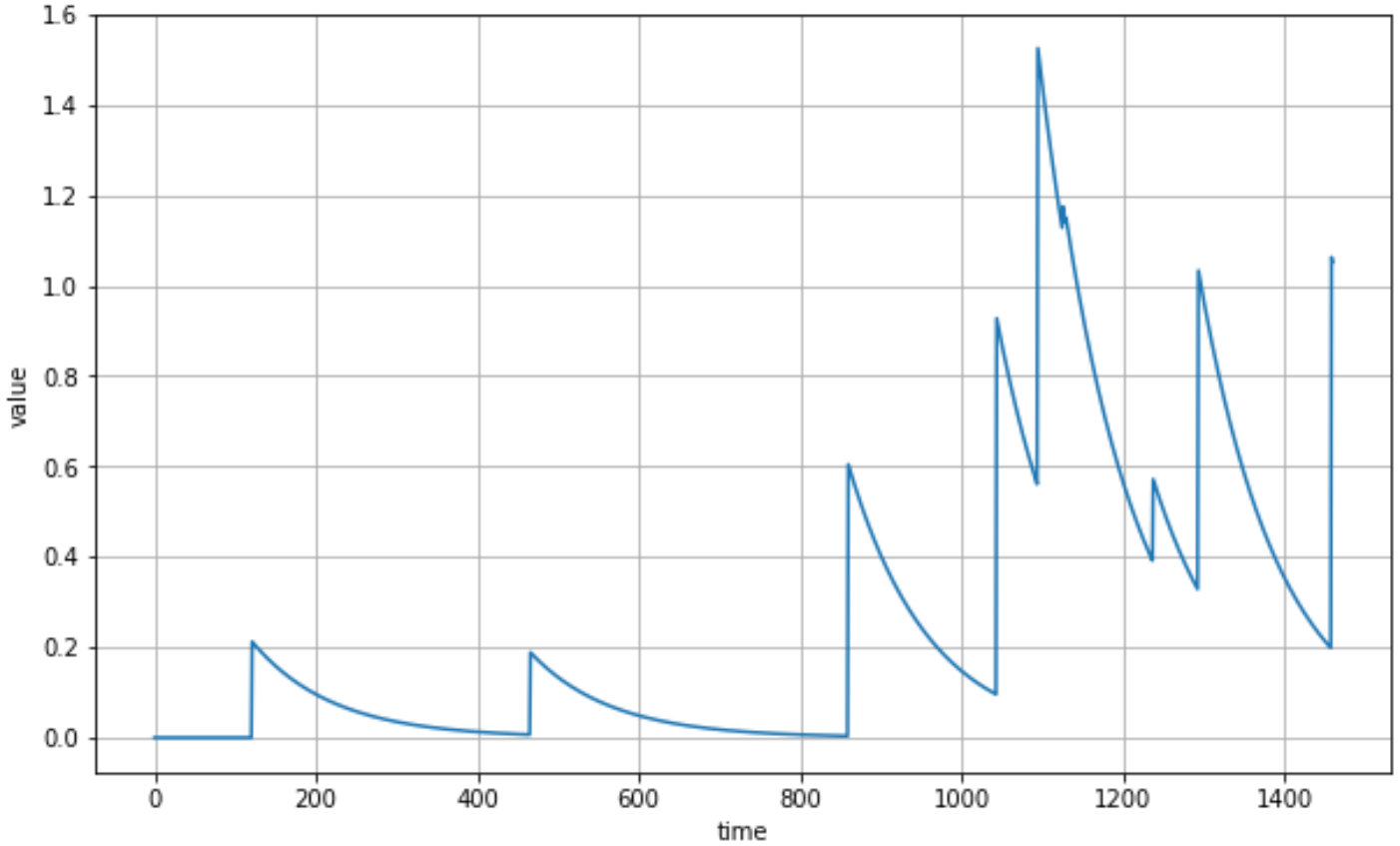
Chart Created by lmoroney@


February 2019
March 2019
April 2019
May 2019
June 2019

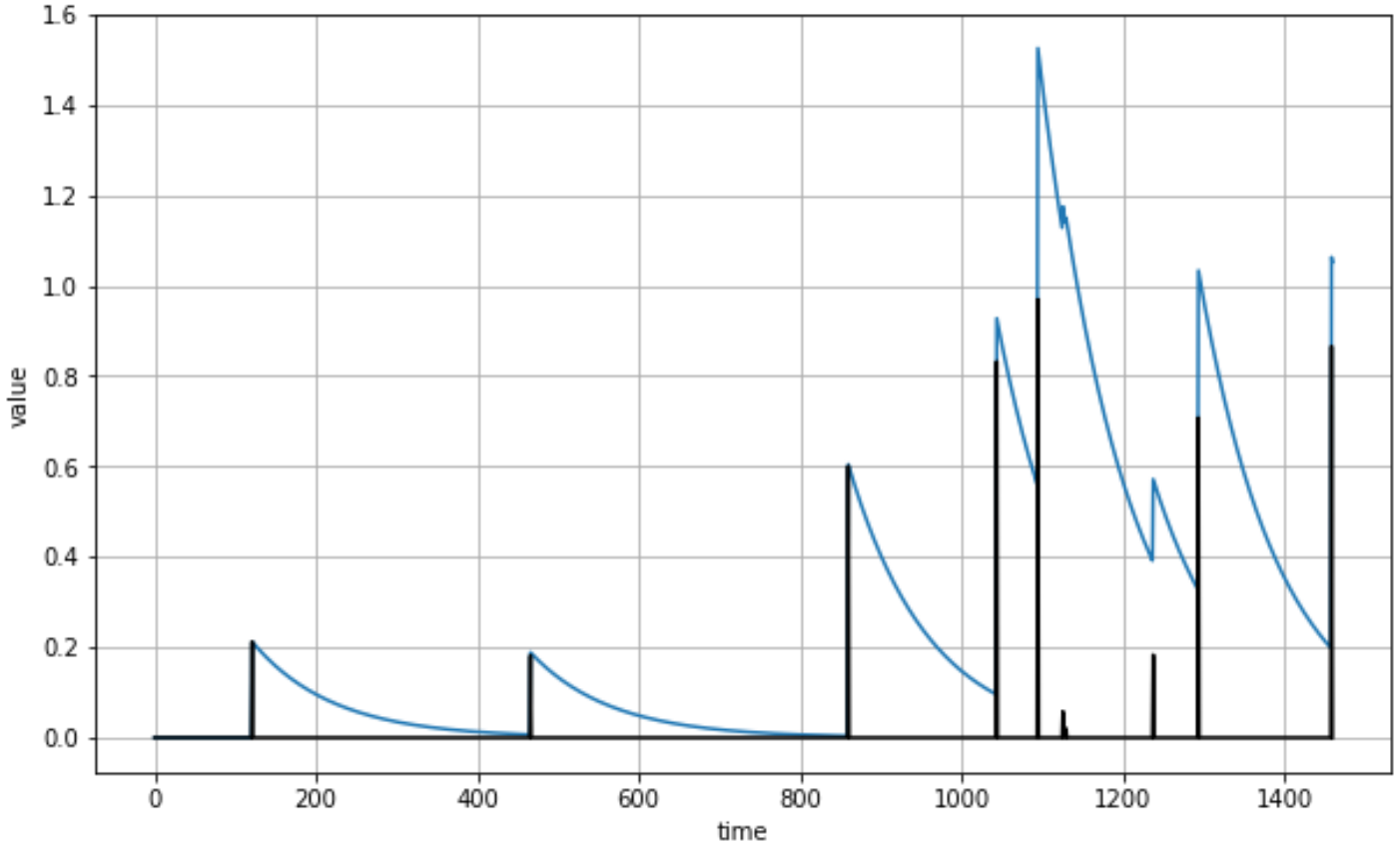

120
100
80
60
40
20
0
−20
value
0
200
400
600
800
1000
1200
1400
time


3
2
1
0
−1
−2
value
0
25
50
75
100
125
150
175
200
time

Autocorrelation



$v(t) = 0.99 \times v(t-1)$ + occasional spike



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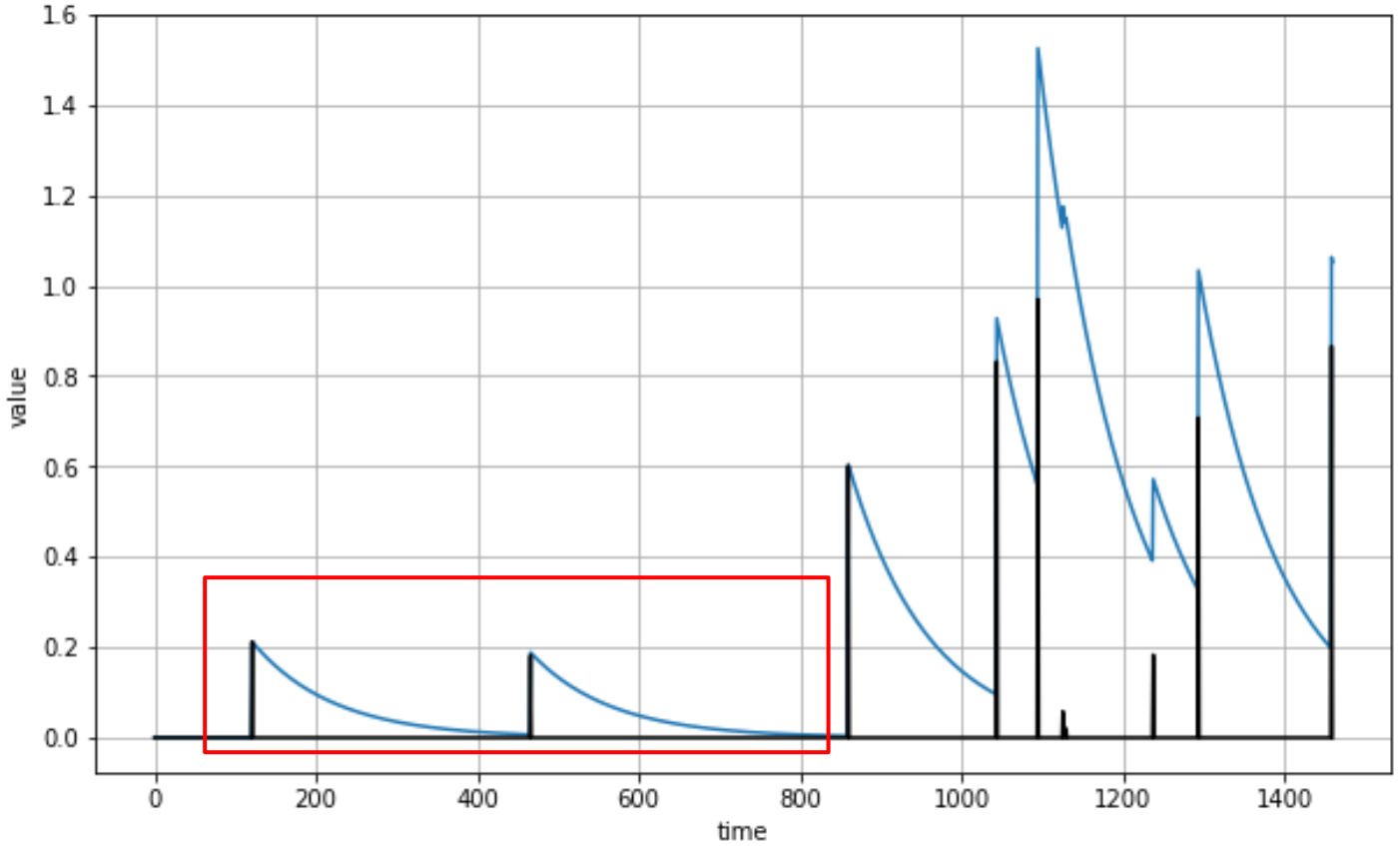
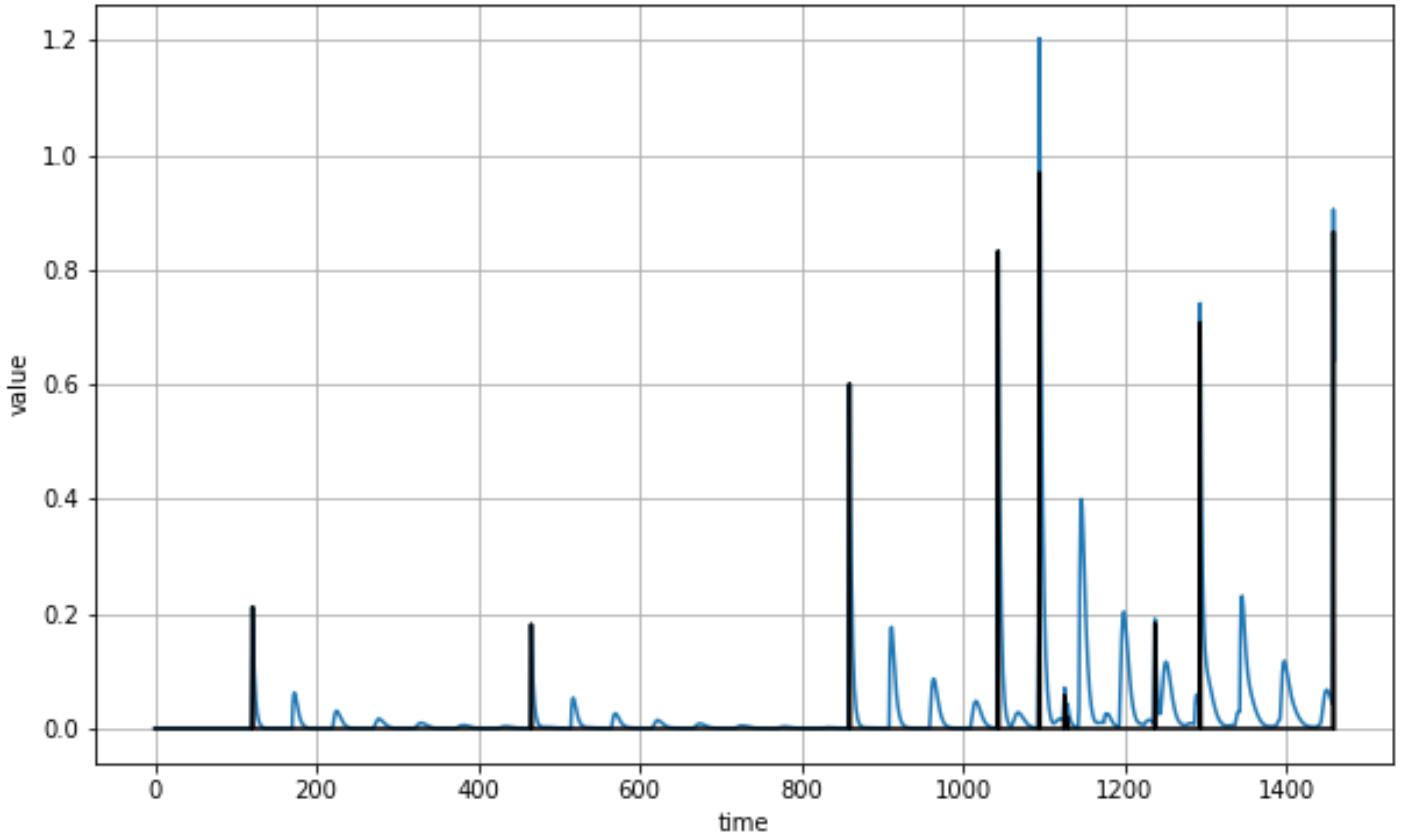
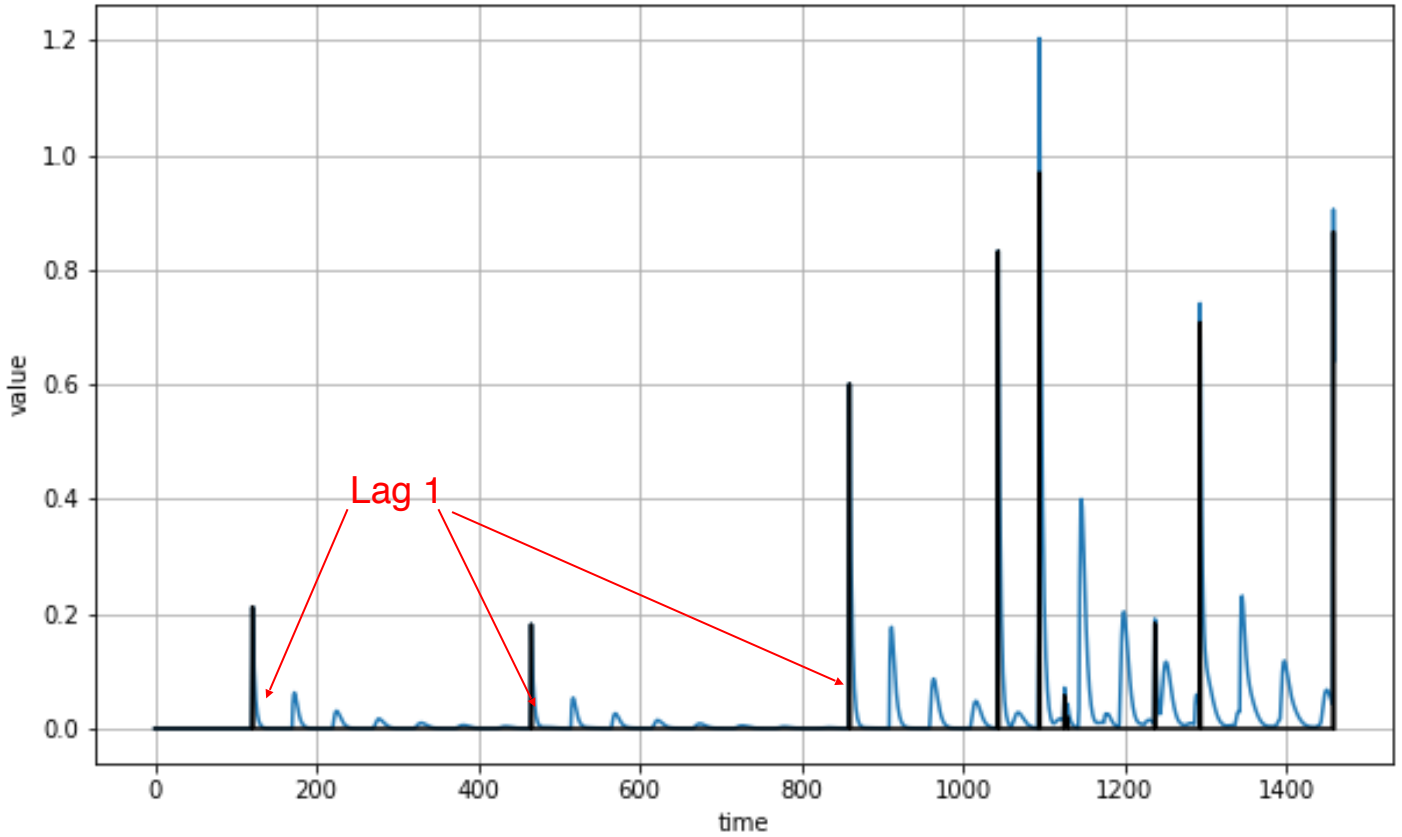


$$v(t) = 0.7 \times v(t-1) + 0.2 \times v(t-50) + \text{occasional spike}$$



$v(t) = 0.7 \times v(t-1) + 0.2 \times v(t-50)$ + occasional spike



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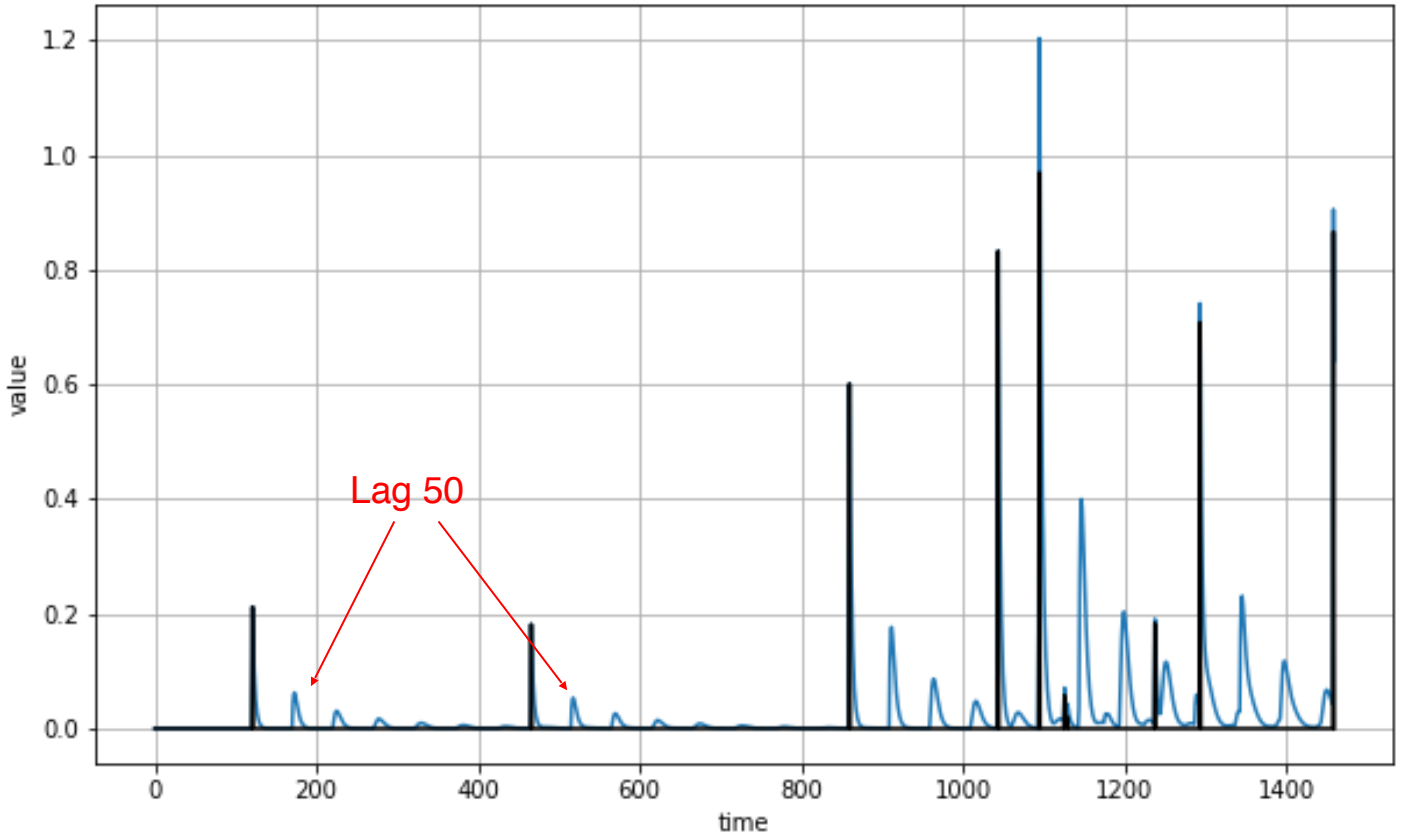
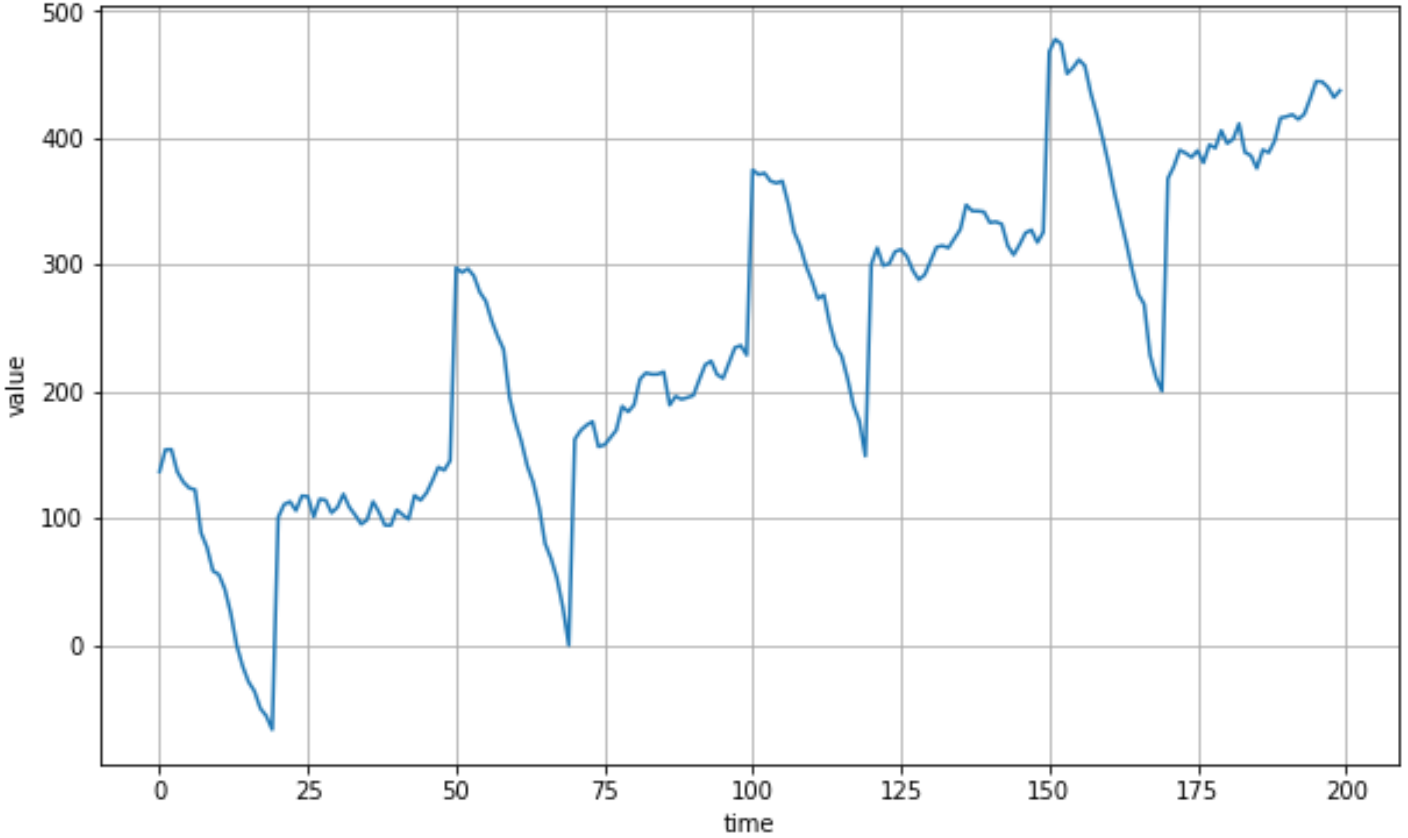
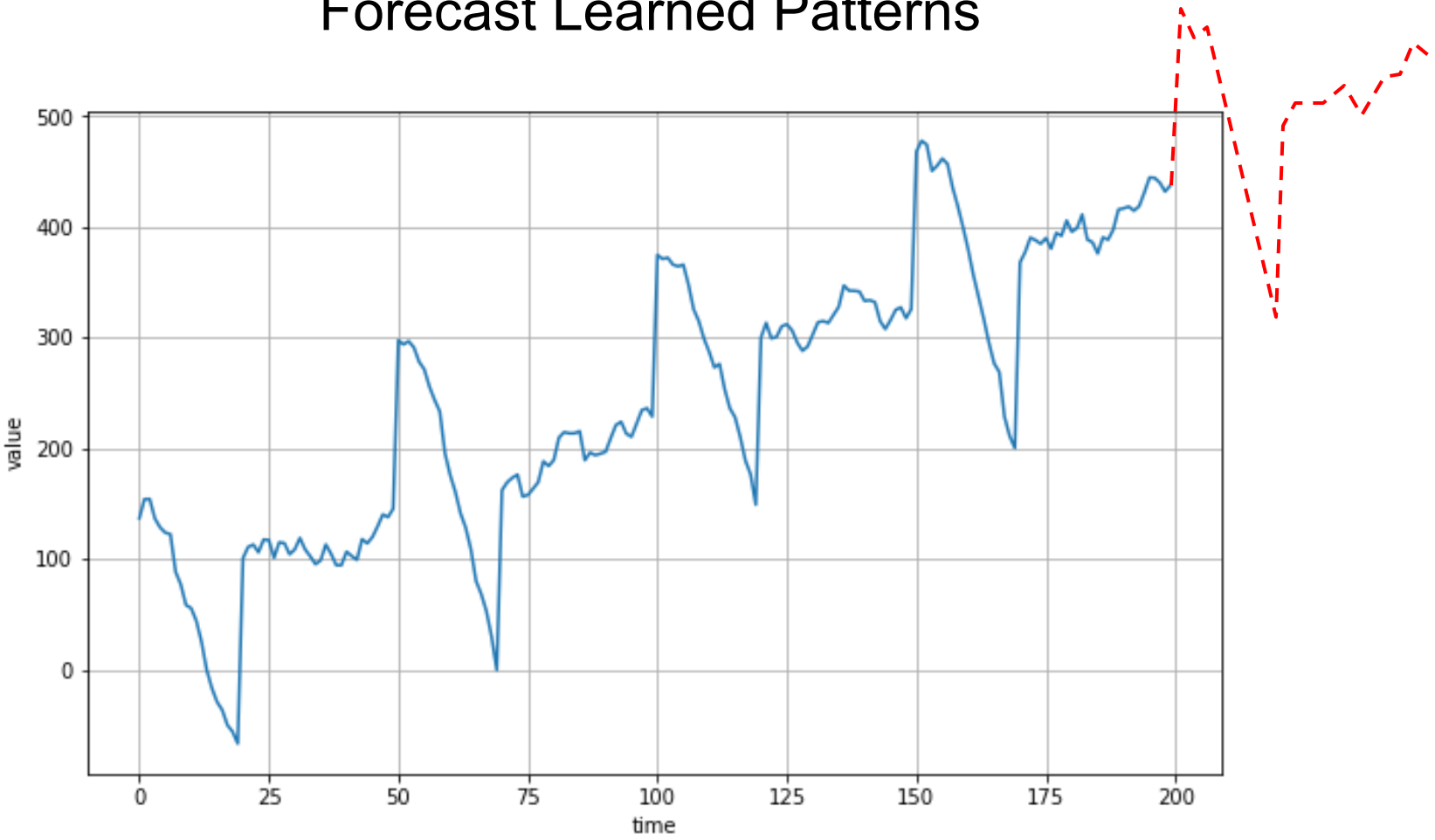


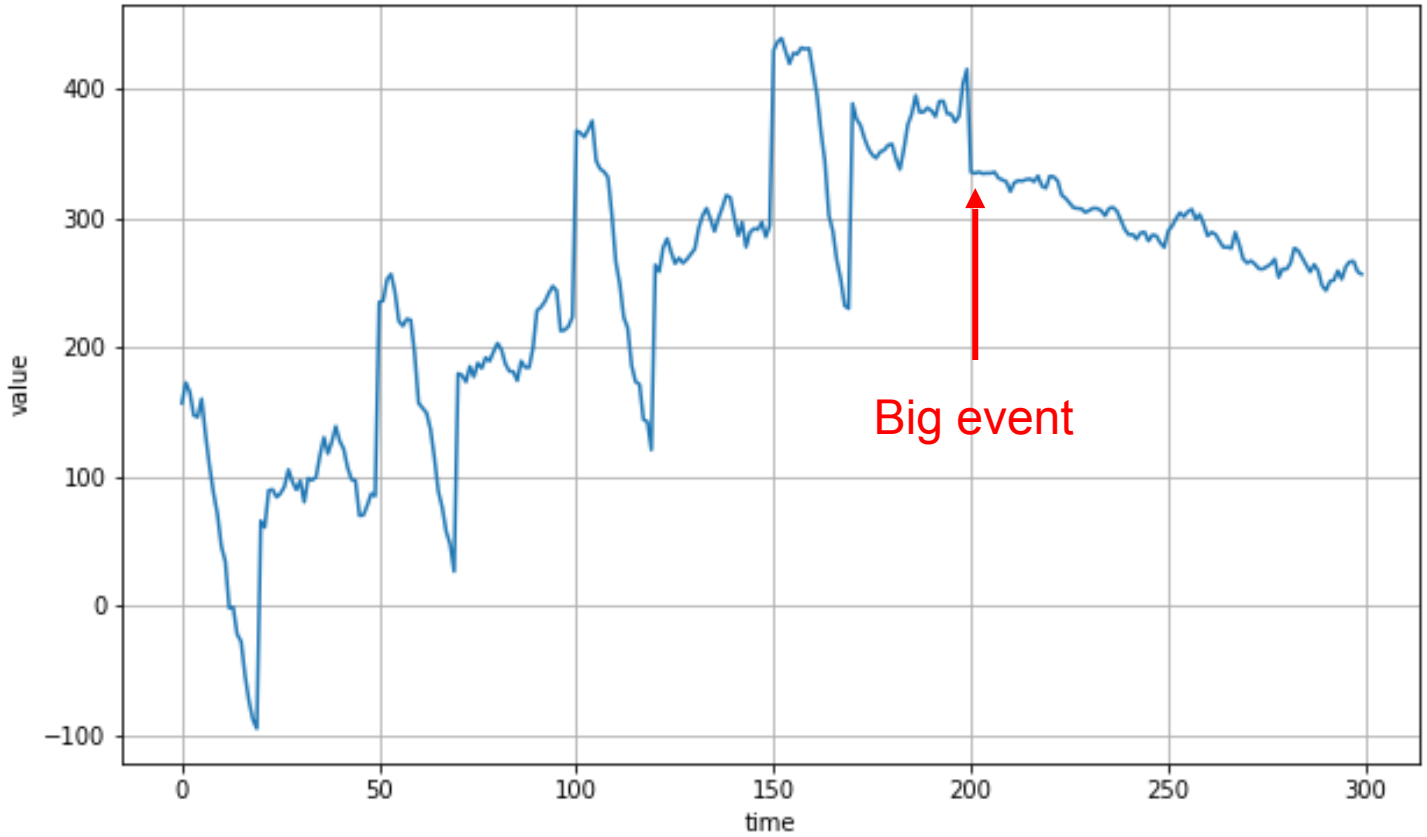
Trend + Seasonality + Autocorrelation + Noise



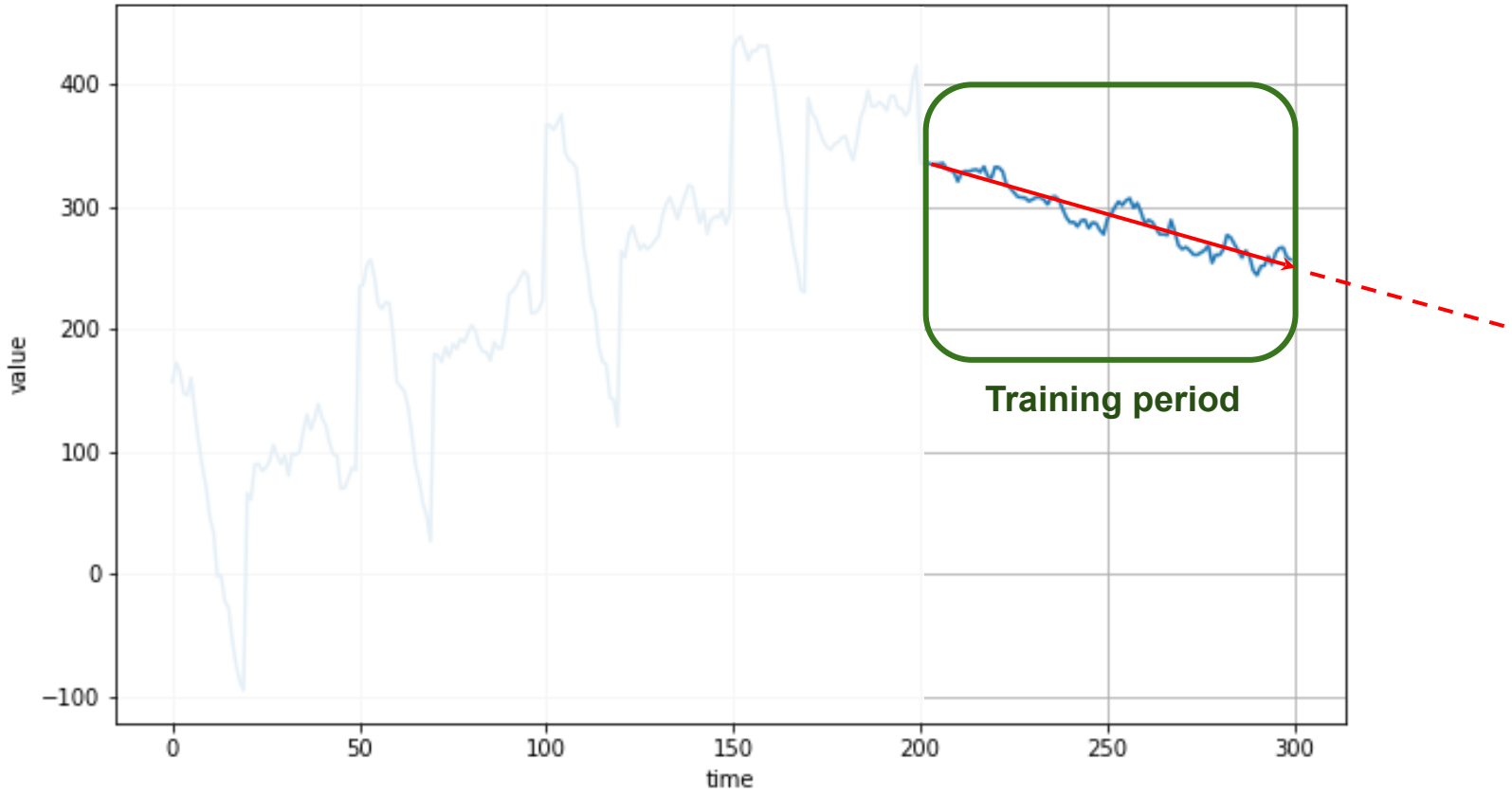
Forecast Learned Patterns



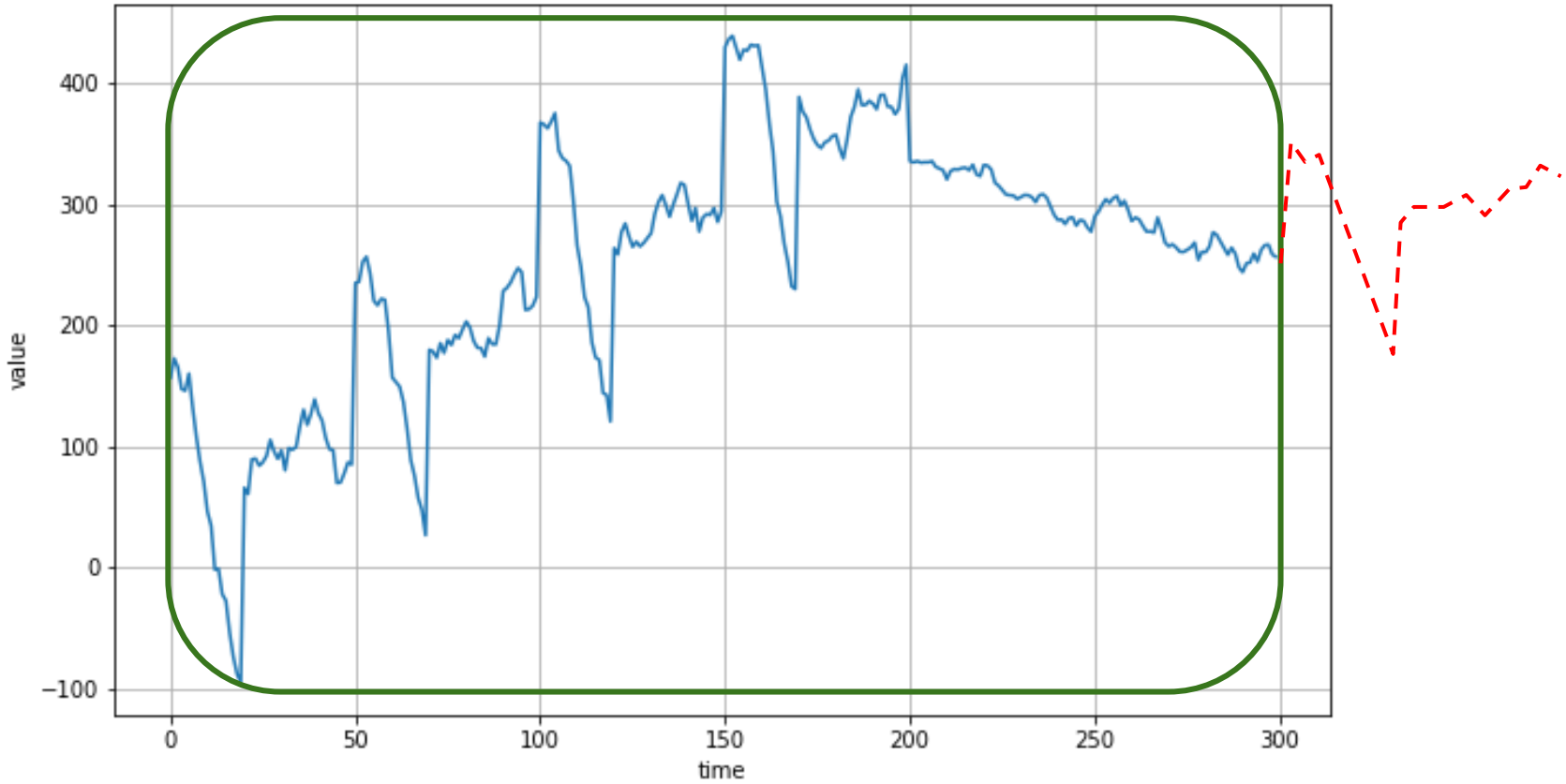
Non-Stationary Time Series



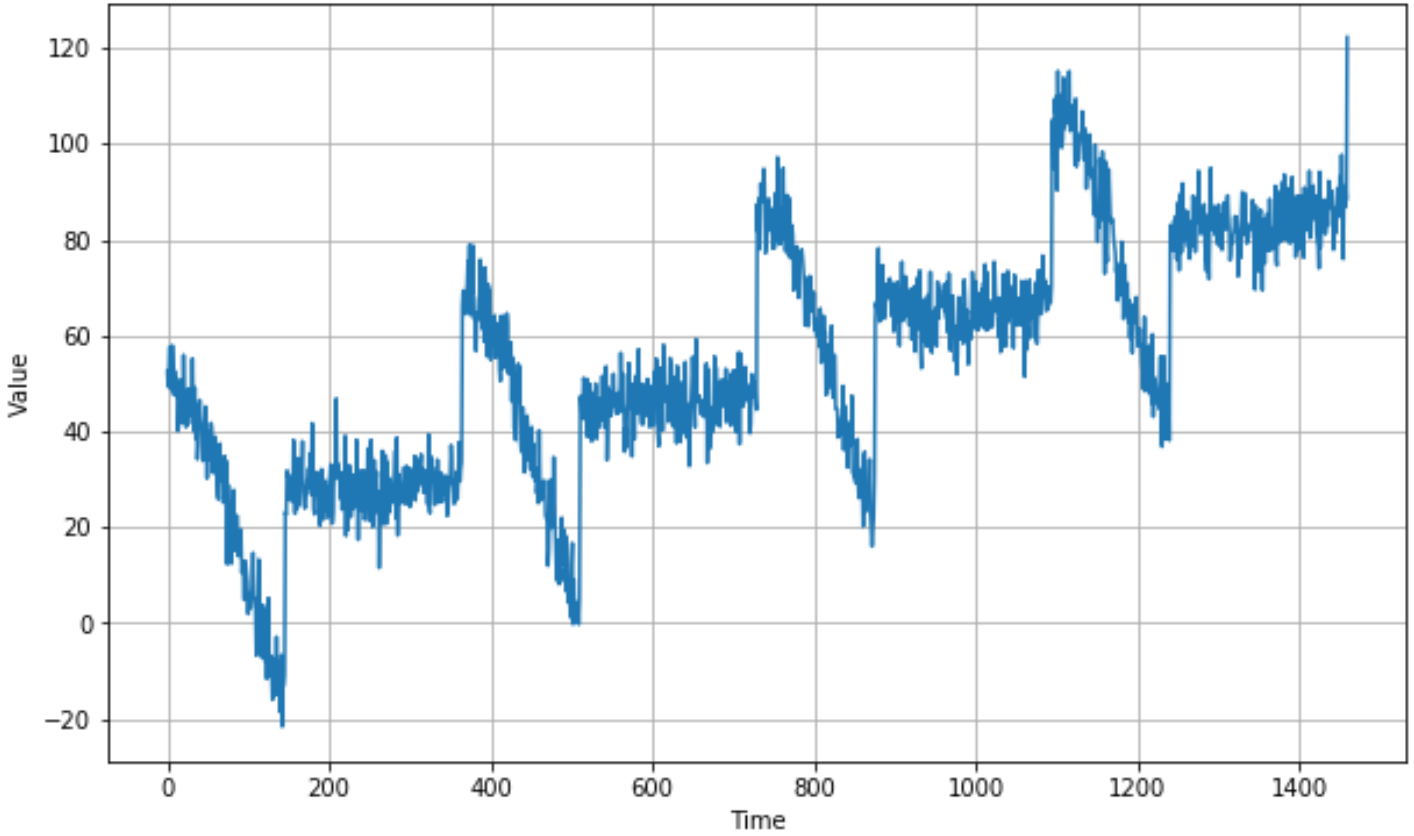
Non-Stationary Time Series



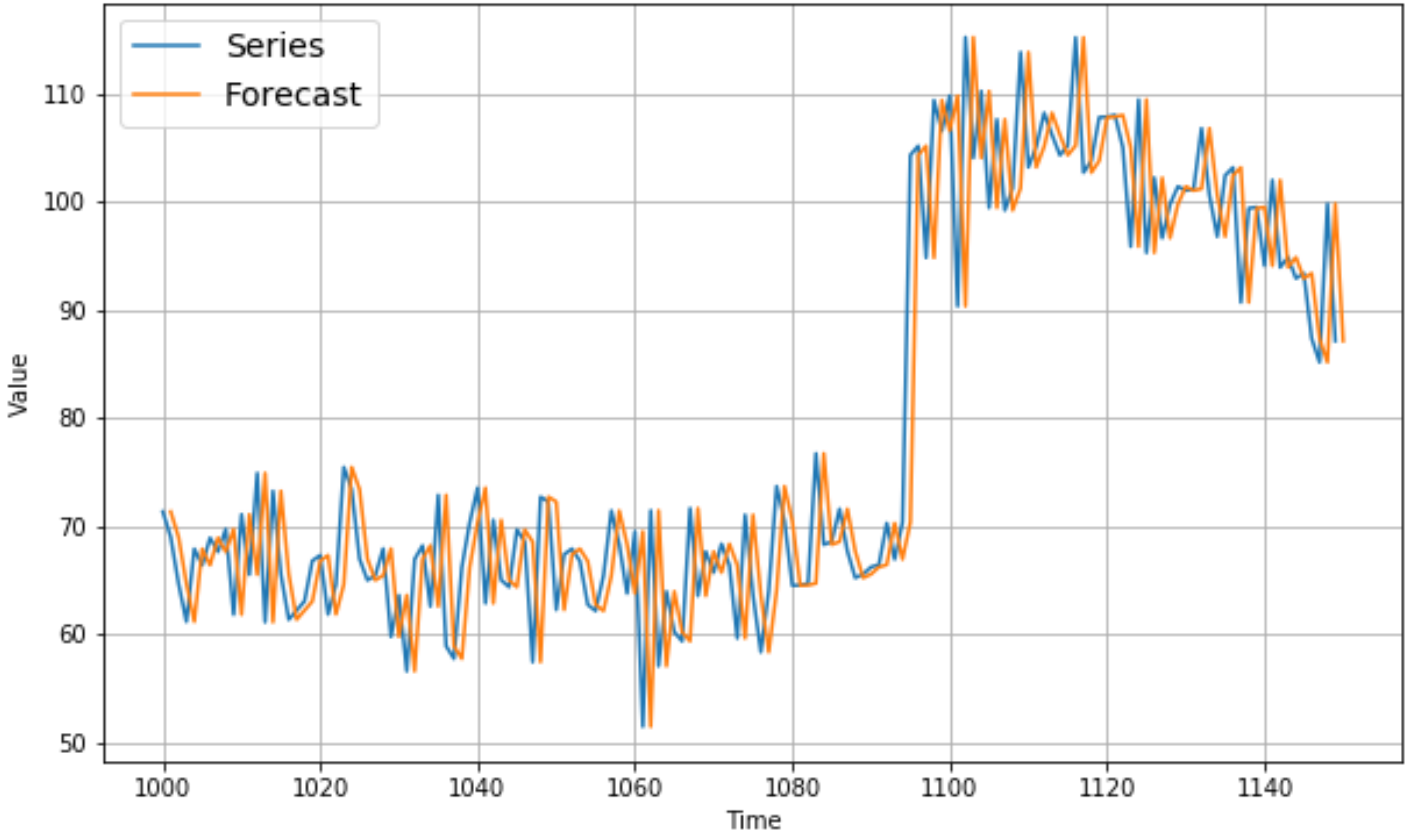
Non-Stationary Time Series



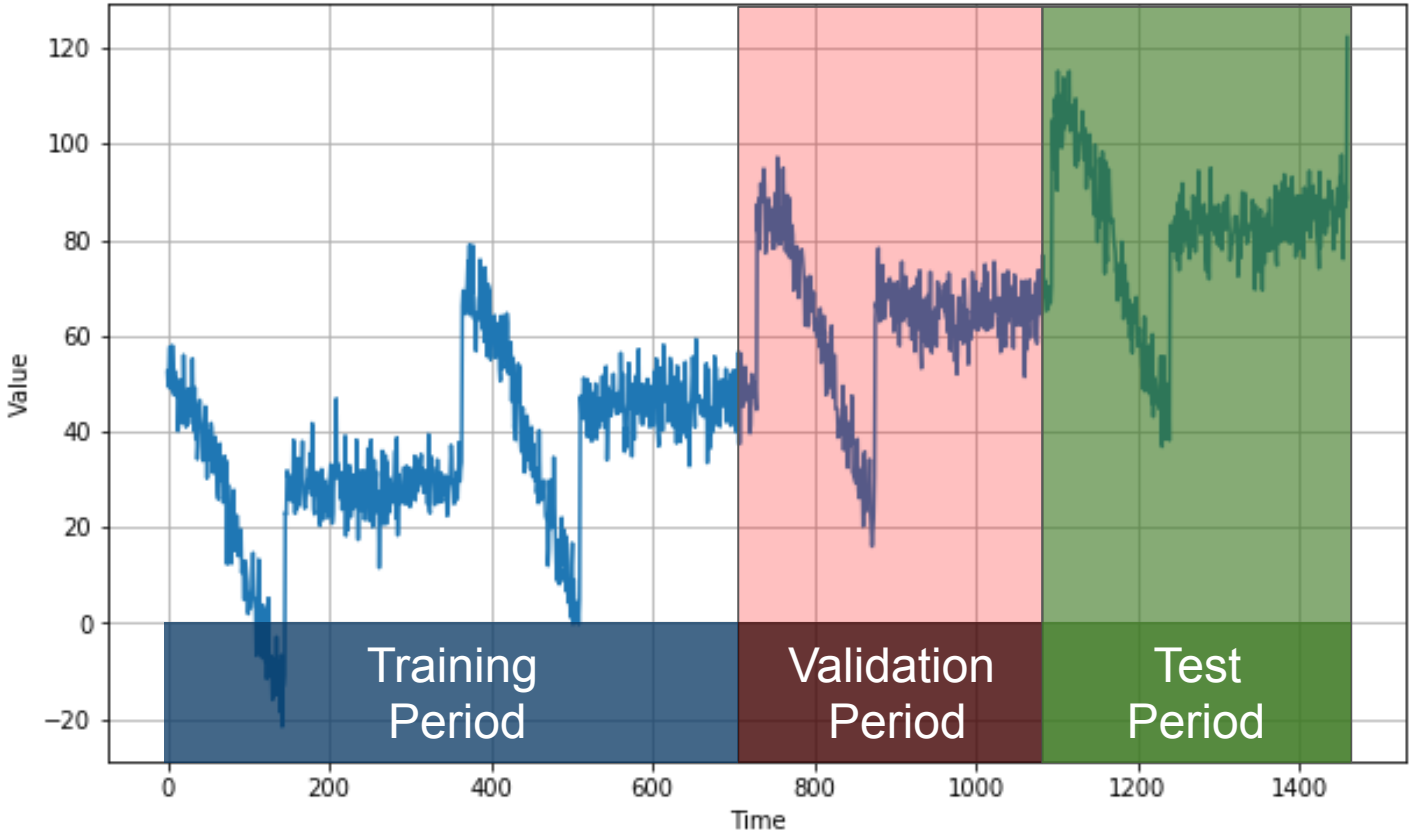
Trend + Seasonality + Noise



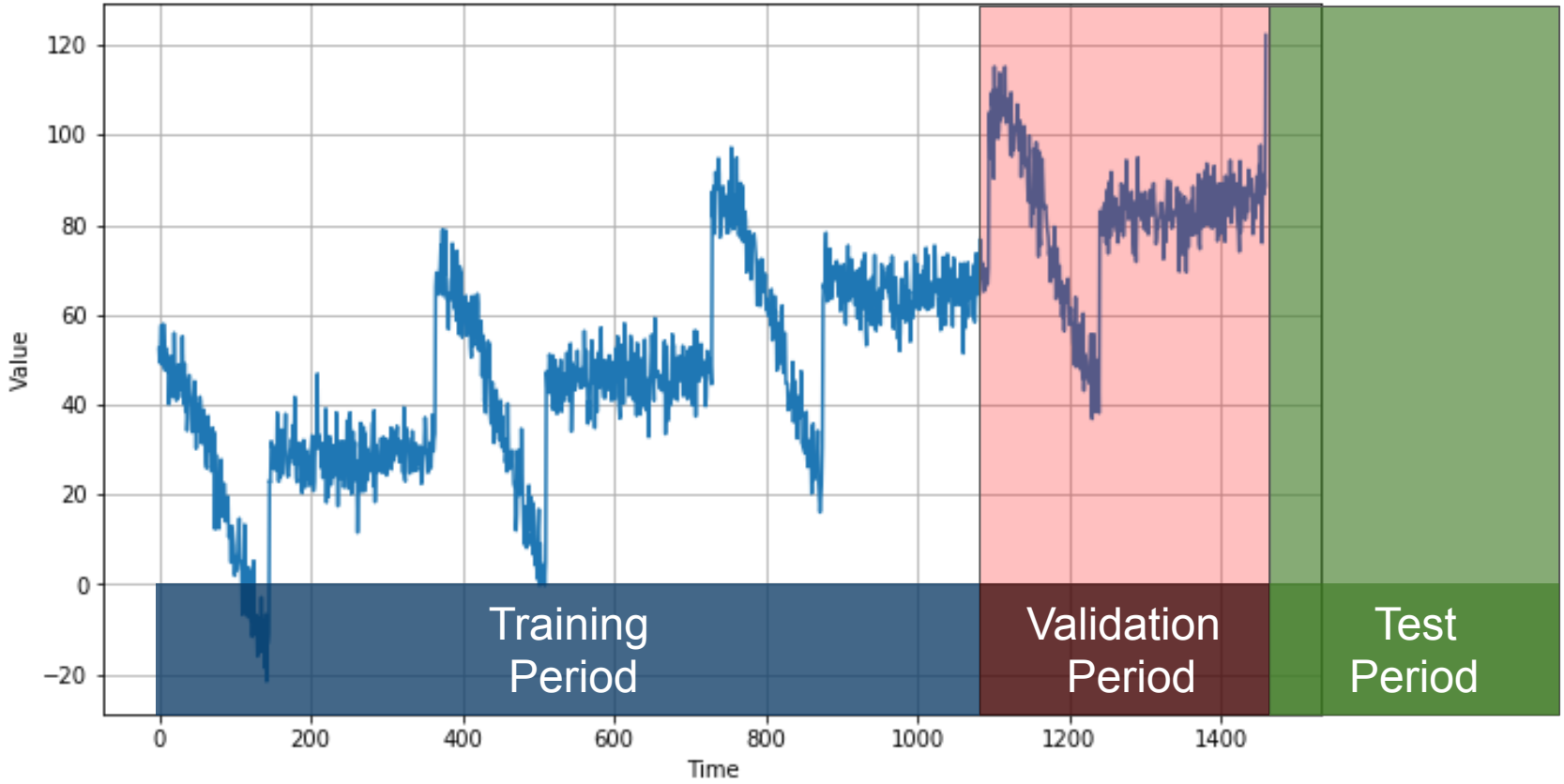
Naive Forecasting



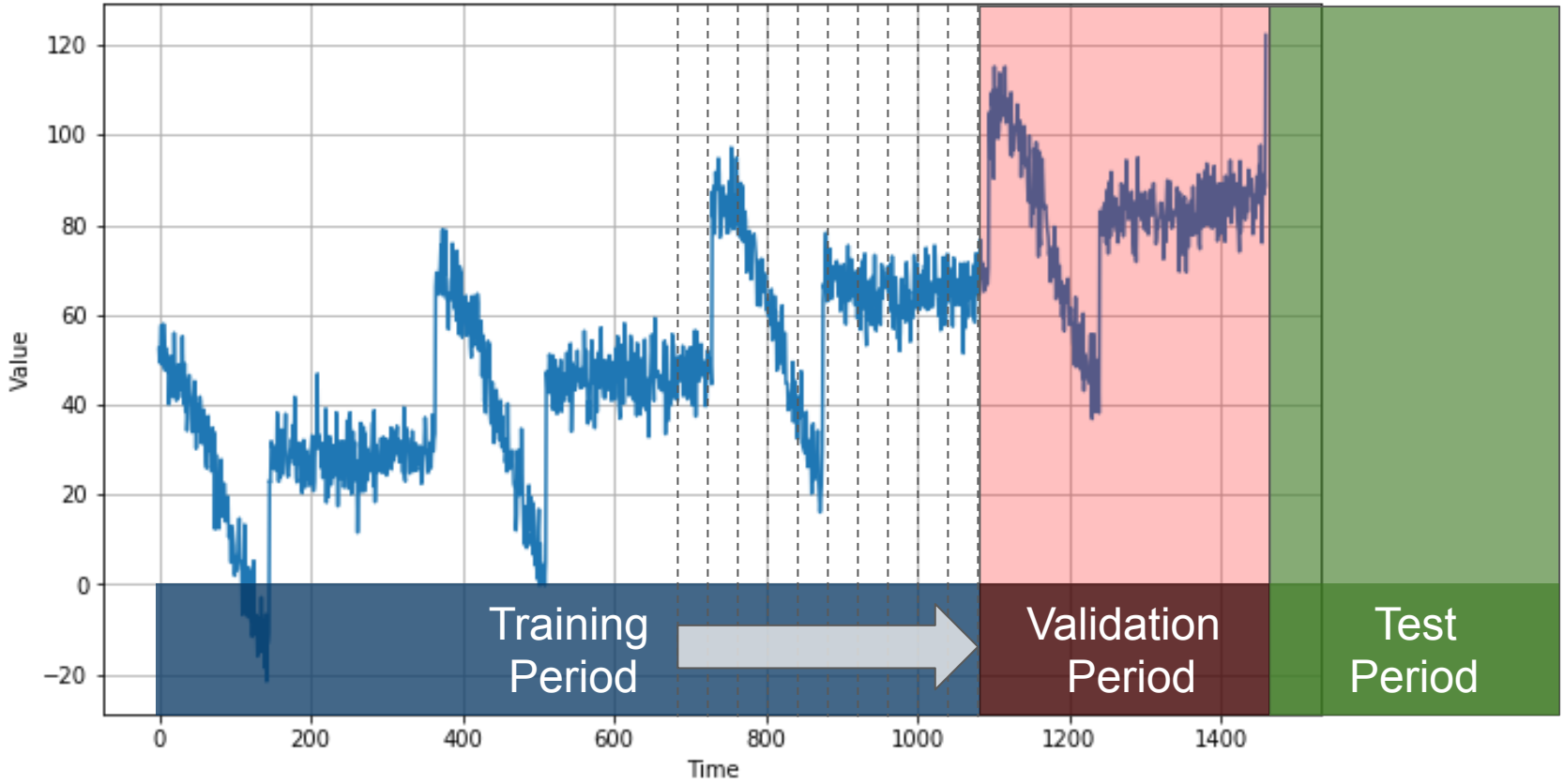
Fixed Partitioning



Fixed Partitioning



Roll-Forward Partitioning



Metrics

```
errors = forecasts - actual

mse = np.square(errors).mean()

rmse = np.sqrt(mse)

mae = np.abs(errors).mean()

mape = np.abs(errors / x_valid).mean()
```

Metrics

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errors = forecasts - actual

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Metrics

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errors = forecasts - actual

mse = np.square(errors).mean()

rmse = np.sqrt(mse)

mae = np.abs(errors).mean()

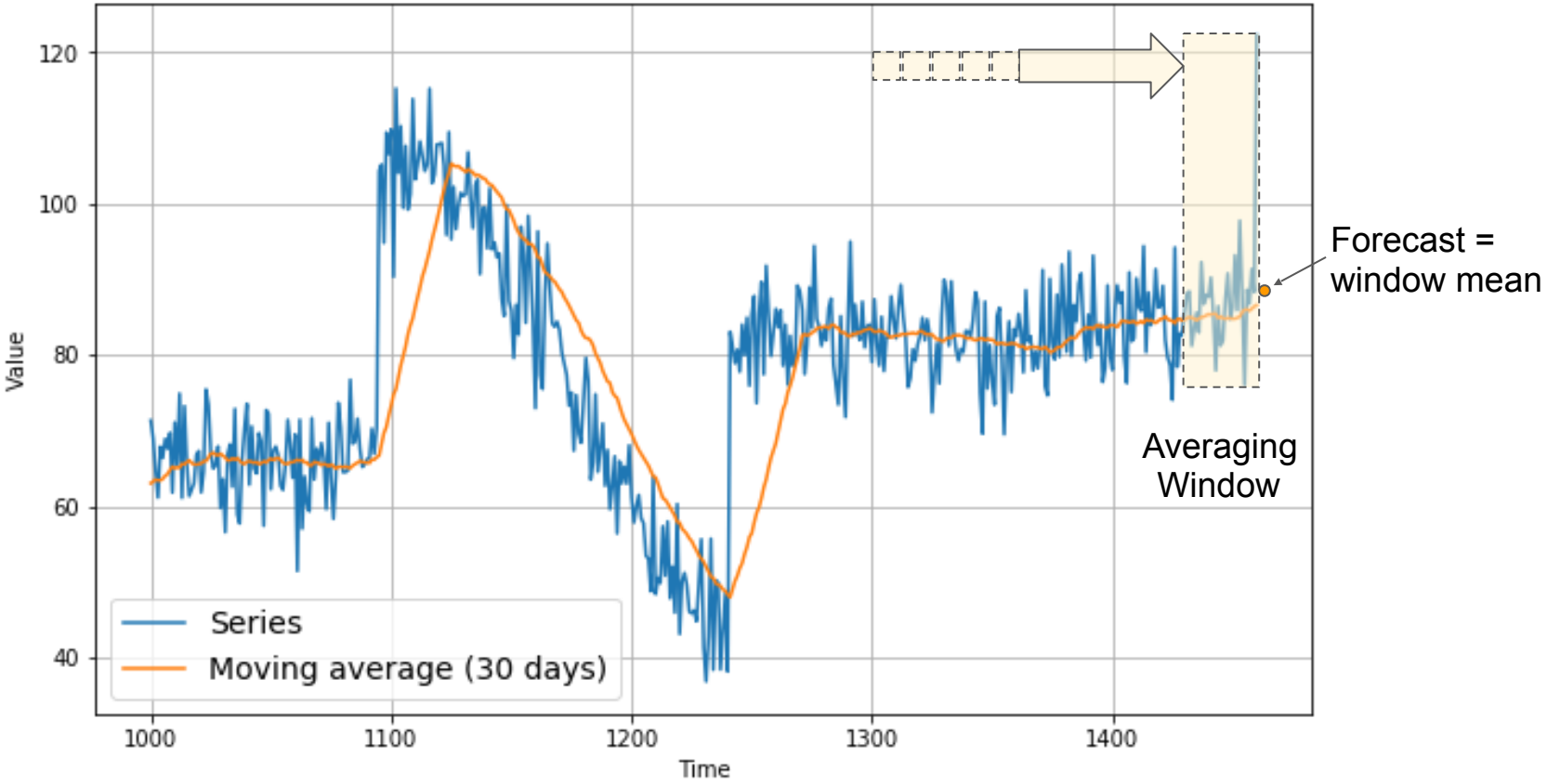
mape = np.abs(errors / x_valid).mean()
```

Naive Forecast MAE

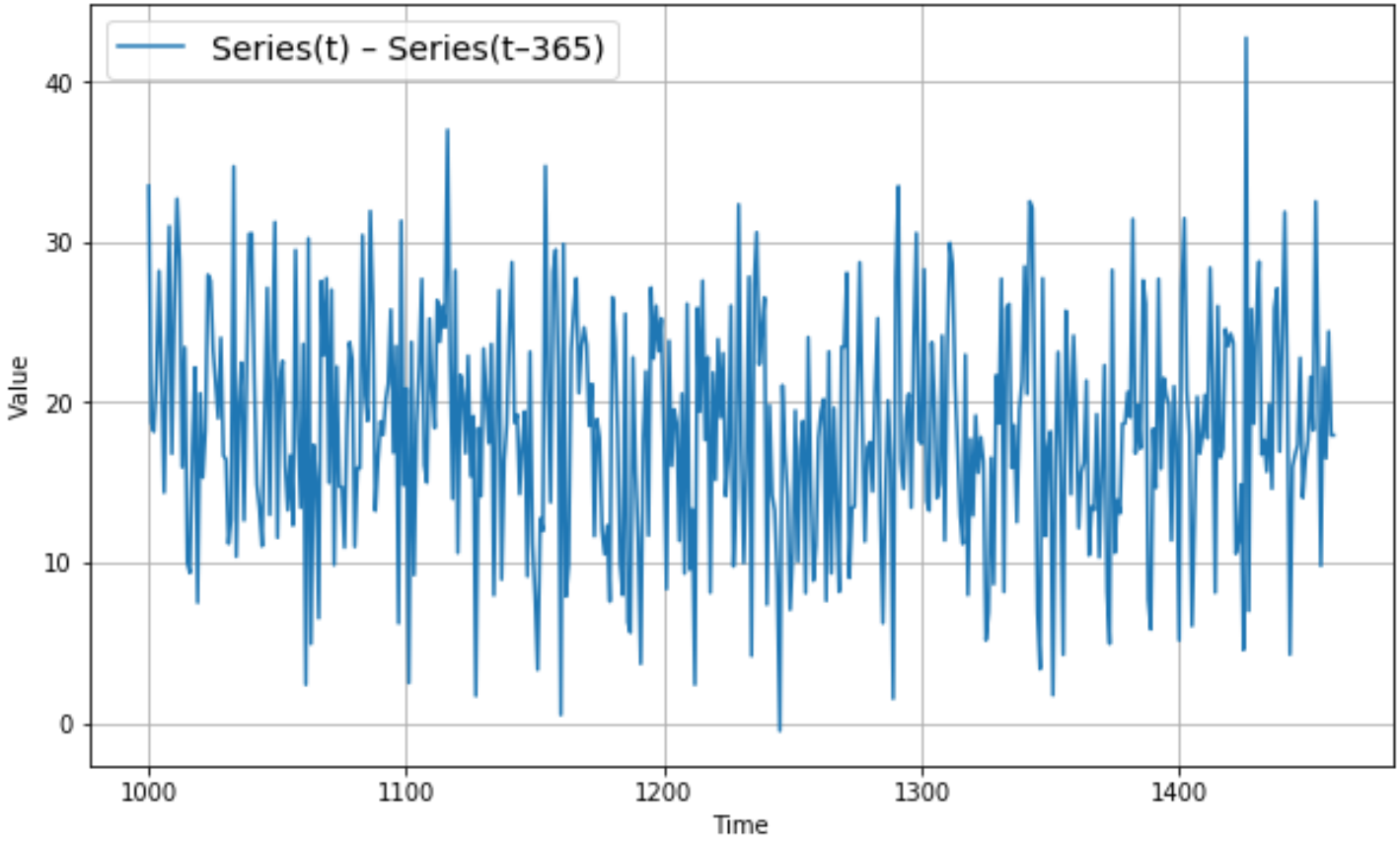
```
keras.metrics.mean_absolute_error(x_valid, naive_forecast).numpy()
```

```
5.937908515321673
```

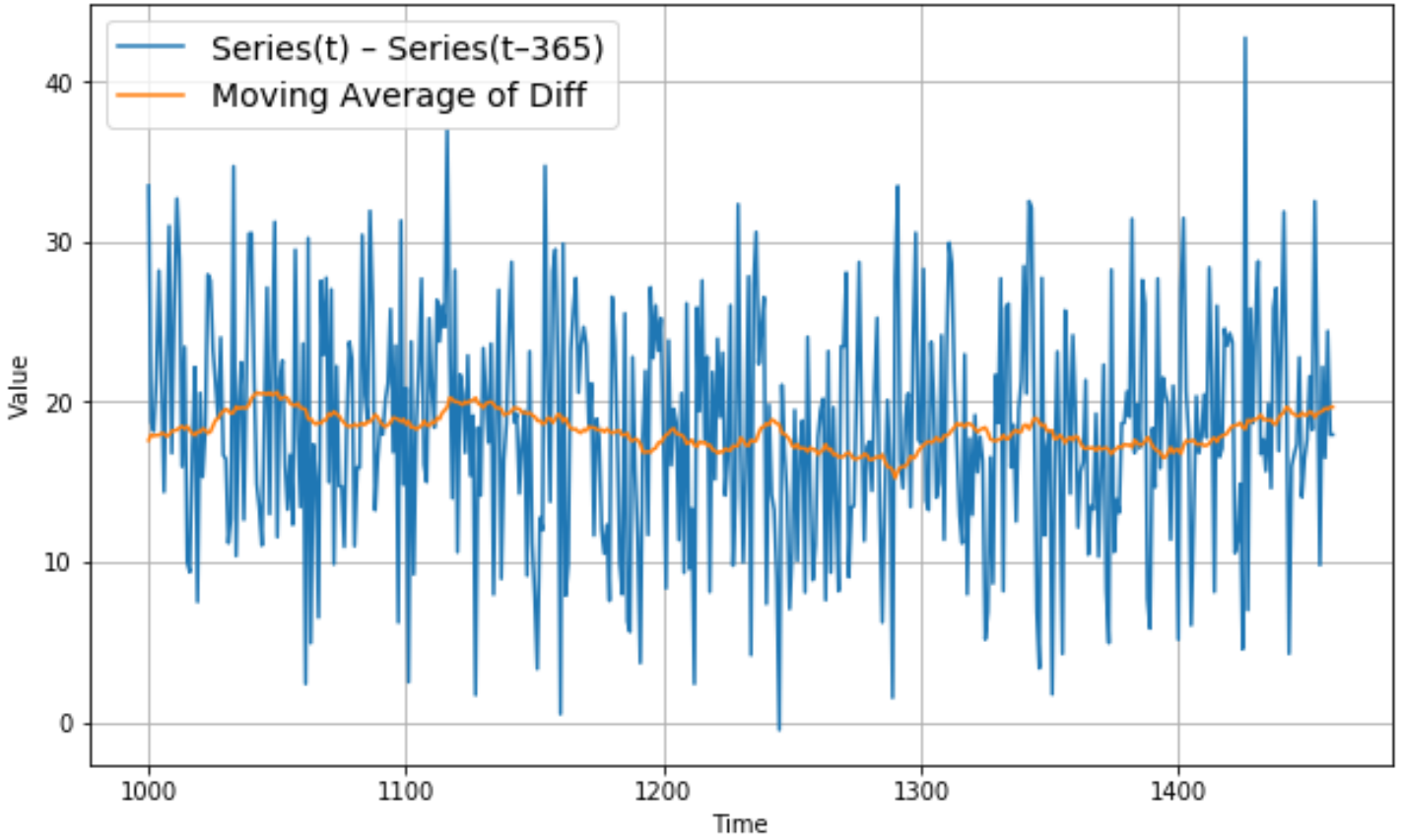
Moving Average



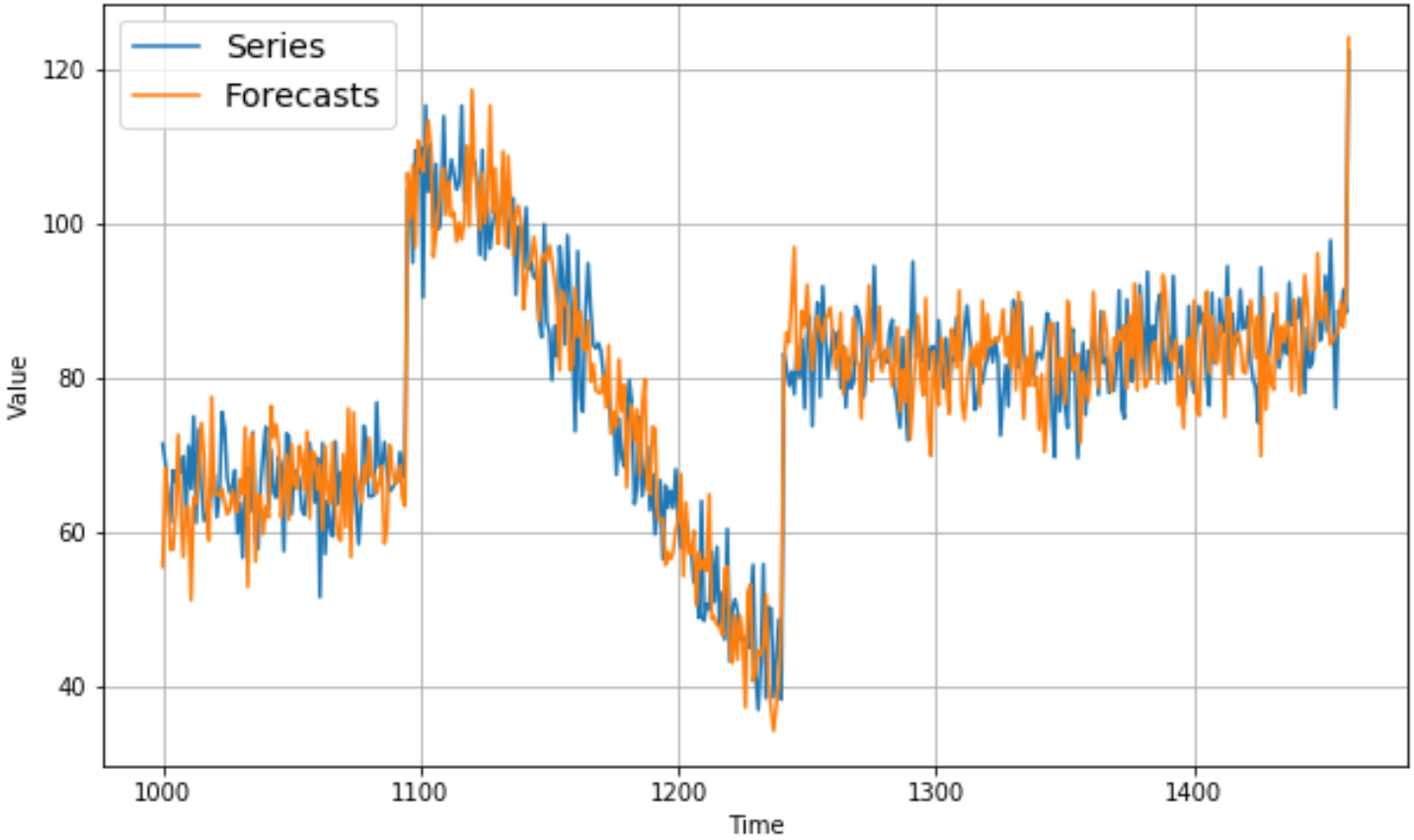
Differencing



Moving Average on Differenced Time Series

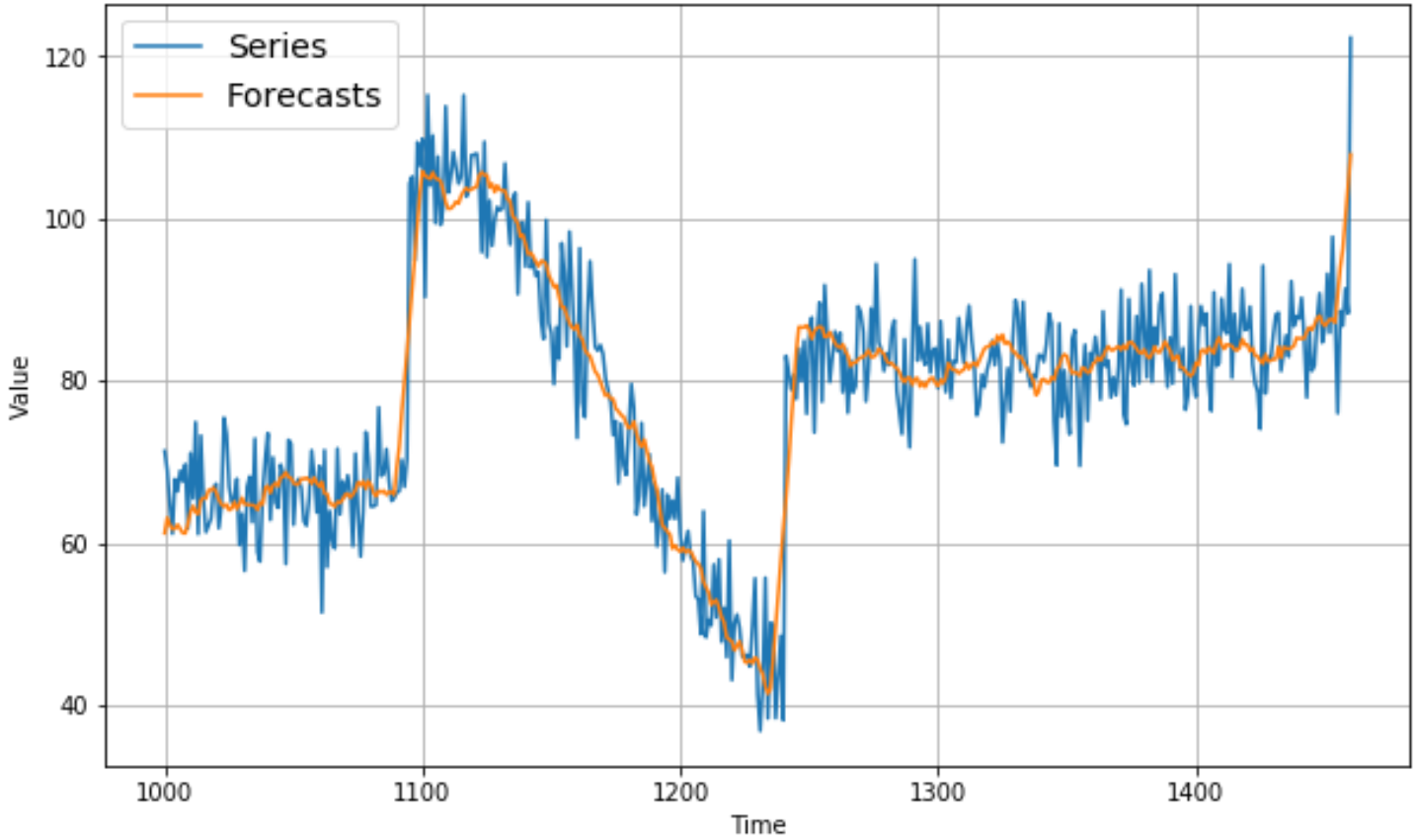


Restoring the Trend and Seasonality



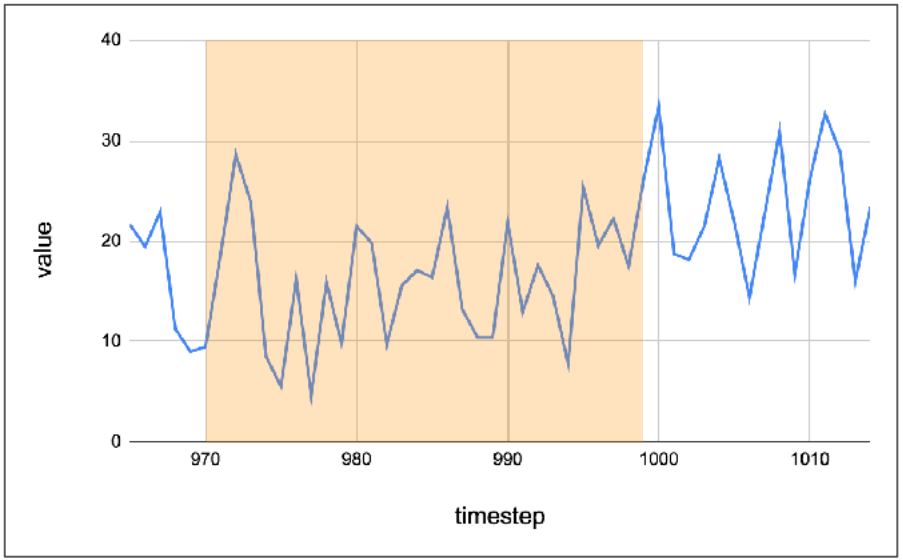
Forecasts = moving average of differenced series + series(t – 365)

Smoothing Both Past and Present Values

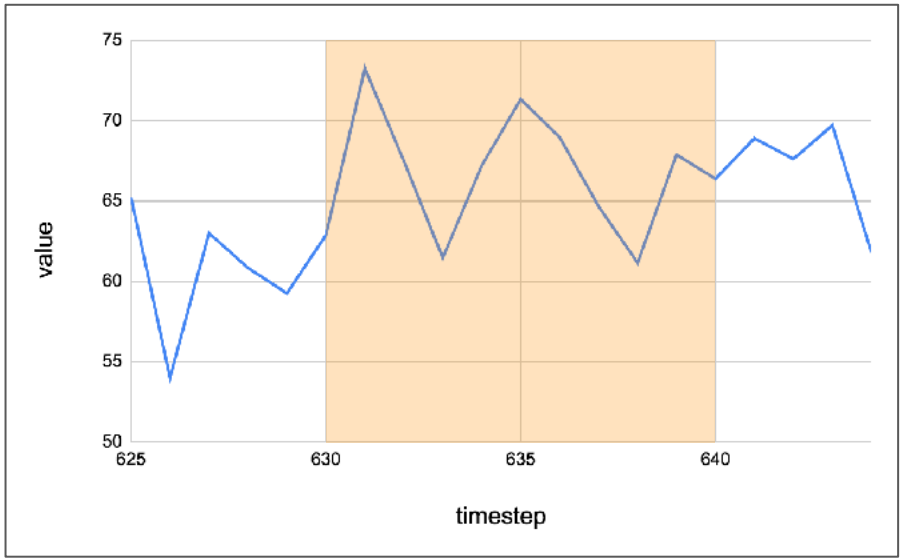


Forecasts = trailing moving average of differenced series + centered moving average of past series (t – 365)

Trailing Moving Average of Differenced Series
(zoomed at t_{1000} , window size = 30)



Centered Moving Average of Past Series (t - 365)
(zoomed at t_{635} , window size = 11)



$TMA_{t1000} = (v_{t970} + v_{t971} + v_{t972} + \ldots v_{t999}) / 30$

$CMA_{t635} = (v_{t630} + v_{t631} + v_{t632} + \ldots. v_{t640}) / 11$

forecast at $t_{1000} = TMA_{t1000} + CMA_{t635}$