AT&T

December 8, 2022

[1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
```

[2]:
```
df = pd.read_csv('data/T.csv')
df.tail()
```

[2]:

	Date	Open	High	Low	Close	Adj Close	Volume
9835	2022-11-28	19.100000	19.150000	18.770000	18.820000	18.820000	27780200
9836	2022-11-29	18.790001	19.030001	18.750000	19.010000	19.010000	24088000
9837	2022-11-30	18.940001	19.280001	18.799999	19.280001	19.280001	59282600
9838	2022-12-01	19.290001	19.400000	19.090000	19.190001	19.190001	31615500
9839	2022-12-02	19.049999	19.059999	18.860001	19.020000	19.020000	33475400

[3]:
```
df.shape
```

[3]:
```
(9840, 7)
```

[4]:
```
df = df[['Date', 'Close']]
```

[5]:
```
df['Date']
```

[5]:
```
0       1983-11-21
1       1983-11-22
2       1983-11-23
3       1983-11-25
4       1983-11-28
           ...
9835    2022-11-28
```

```
9836    2022-11-29
9837    2022-11-30
9838    2022-12-01
9839    2022-12-02
Name: Date, Length: 9840, dtype: object
```

[6]:
```
# Converting object to Date-Time object.

import datetime

def to_date(s):
    spl = s.split('-')
    y, m, d = spl[0], spl[1], spl[2]
    return datetime.datetime(year=int(y), month = int(m), day = int(d))
```

[7]:
```
df['Date'] = df['Date'].apply(to_date)
```

[8]:
```
df['Date']
```

[8]:
```
0       1983-11-21
1       1983-11-22
2       1983-11-23
3       1983-11-25
4       1983-11-28
           …
9835    2022-11-28
9836    2022-11-29
9837    2022-11-30
9838    2022-12-01
9839    2022-12-02
Name: Date, Length: 9840, dtype: datetime64[ns]
```

[9]:
```
# making date the index column

df.index = df.pop('Date')
```

[10]:
```
df.head()
```

[10]:
```
                Close
Date
1983-11-21  3.878713
1983-11-22  3.847243
1983-11-23  3.831508
1983-11-25  3.839376
1983-11-28  3.800038
```

[11]:
```
# plotting the data

plt.plot(df.index, df['Close'])
```

[11]:
```
[<matplotlib.lines.Line2D at 0x29a3877fca0>]
```

[12]:
```
def df_to_windowed_df(dataframe, first_date_str, last_date_str, n=3):
    first_date = to_date(first_date_str)
    last_date  = to_date(last_date_str)
    target_date = first_date

    dates = []
    X, Y = [], []

    last_time = False

    while True:
        df_subset = dataframe.loc[:target_date].tail(n+1)
        if len(df_subset) != n+1:
            print(f'Error: Window of size {n} is too large for date␣
 ↪{target_date}')
            return

        values = df_subset['Close'].to_numpy()
        x, y = values[:-1], values[-1]
```

```
        dates.append(target_date)
        X.append(x)
        Y.append(y)

        next_week = dataframe.loc[target_date:target_date+datetime.
 ↪timedelta(days=7)]
        next_datetime_str = str(next_week.head(2).tail(1).index.values[0])
        next_date_str = next_datetime_str.split('T')[0]
        year_month_day = next_date_str.split('-')
        year, month, day = year_month_day
        next_date = datetime.datetime(day=int(day), month=int(month),␣
 ↪year=int(year))

        if last_time:
            break

        target_date = next_date

        if target_date == last_date:
            last_time = True

    ret_df = pd.DataFrame({})
    ret_df['Target Date'] = dates

    X = np.array(X)

    for i in range(0, n):
        X[:, i]
        ret_df[f'Target-{n-i}'] = X[:, i]

    ret_df['Target'] = Y

    return ret_df

# Start day second time around: '2010-05-19'

windowed_df = df_to_windowed_df(df,
                                '2010-12-01', # start date
                                '2022-12-01', # end date
                                n=3)

windowed_df
```

[12]:

	Target Date	Target-3	Target-2	Target-1	Target
0	2010-12-01	21.095165	20.921450	20.989426	21.359516
1	2010-12-02	20.921450	20.989426	21.359516	21.563444

```
2     2010-12-03  20.989426  21.359516  21.563444  21.518127
3     2010-12-06  21.359516  21.563444  21.518127  21.374622
4     2010-12-07  21.563444  21.518127  21.374622  21.555891
…            …          …          …          …          …
3017  2022-11-25  18.840000  19.000000  19.090000  19.120001
3018  2022-11-28  19.000000  19.090000  19.120001  18.820000
3019  2022-11-29  19.090000  19.120001  18.820000  19.010000
3020  2022-11-30  19.120001  18.820000  19.010000  19.280001
3021  2022-12-01  18.820000  19.010000  19.280001  19.190001

[3022 rows x 5 columns]
```

[13]:
```
def windowed_df_to_date_X_y(windowed_dataframe):
    df_as_np = windowed_dataframe.to_numpy()

    dates = df_as_np[:, 0]
    mid_matrix = df_as_np[:, 1:-1]
    X = mid_matrix.reshape(len(dates), mid_matrix.shape[1], 1)
    y = df_as_np[:, -1]

    return dates, X.astype(np.float32), y.astype(np.float32)

dates, X, y = windowed_df_to_date_X_y(windowed_df)

dates.shape, X.shape, y.shape
```

[13]:
```
((3022,), (3022, 3, 1), (3022,))
```

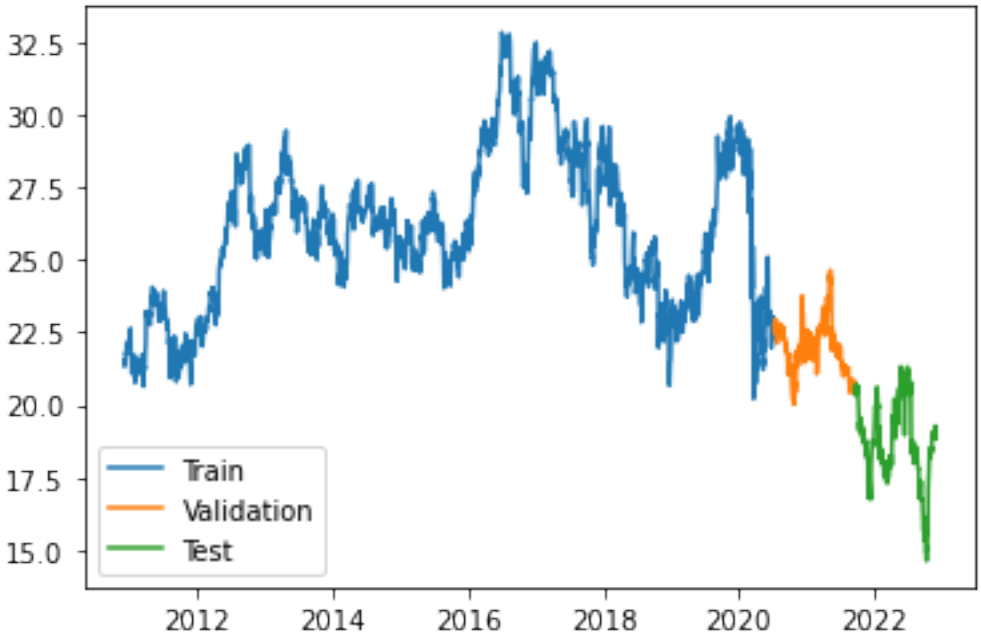
[14]:
```
q_80 = int(len(dates) * 0.8)
q_90 = int(len(dates) * 0.9)

dates_train, X_train, y_train = dates[:q_80], X[:q_80], y[:q_80]
dates_val, X_val, y_val = dates[q_80:q_90], X[q_80:q_90], y[q_80:q_90]
dates_test, X_test, y_test = dates[q_90:], X[q_90:], y[q_90:]

plt.plot(dates_train, y_train)
plt.plot(dates_val, y_val)
plt.plot(dates_test, y_test)

plt.legend(['Train', 'Validation', 'Test'])
```

[14]:
```
<matplotlib.legend.Legend at 0x29a393c2e50>
```



[15]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.optimizers import Adam
from tensorflow.keras import layers

model = Sequential([layers.Input((3, 1)),
                    layers.LSTM(64),
                    layers.Dense(32, activation = 'relu'),
                    layers.Dense(32, activation = 'relu'),
                    layers.Dense(1)])

model.compile(loss = 'mse',
              optimizer = Adam(learning_rate = 0.001),
              metrics = ['mean_absolute_error'])

model.fit(X_train, y_train, validation_data = (X_val, y_val), epochs = 100)
```

```
Epoch 1/100
76/76 [==============================] - 5s 15ms/step - loss: 389.9929 -
mean_absolute_error: 17.9128 - val_loss: 27.5197 - val_mean_absolute_error:
5.1716
Epoch 2/100
76/76 [==============================] - 0s 5ms/step - loss: 8.4137 -
mean_absolute_error: 2.3452 - val_loss: 18.2919 - val_mean_absolute_error:
4.1890
Epoch 3/100
76/76 [==============================] - 0s 4ms/step - loss: 7.1143 -
```

```
mean_absolute_error: 2.1440 - val_loss: 16.0347 - val_mean_absolute_error:
3.9179
Epoch 4/100
76/76 [==============================] - 0s 5ms/step - loss: 5.5531 -
mean_absolute_error: 1.8834 - val_loss: 10.4036 - val_mean_absolute_error:
3.1531
Epoch 5/100
76/76 [==============================] - 0s 5ms/step - loss: 2.6459 -
mean_absolute_error: 1.2611 - val_loss: 2.2425 - val_mean_absolute_error: 1.4461
Epoch 6/100
76/76 [==============================] - 0s 4ms/step - loss: 0.3247 -
mean_absolute_error: 0.4033 - val_loss: 0.1549 - val_mean_absolute_error: 0.3070
Epoch 7/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1533 -
mean_absolute_error: 0.2863 - val_loss: 0.1433 - val_mean_absolute_error: 0.2932
Epoch 8/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1426 -
mean_absolute_error: 0.2750 - val_loss: 0.1175 - val_mean_absolute_error: 0.2606
Epoch 9/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1376 -
mean_absolute_error: 0.2708 - val_loss: 0.1749 - val_mean_absolute_error: 0.3382
Epoch 10/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1365 -
mean_absolute_error: 0.2690 - val_loss: 0.1318 - val_mean_absolute_error: 0.2821
Epoch 11/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1384 -
mean_absolute_error: 0.2729 - val_loss: 0.1137 - val_mean_absolute_error: 0.2562
Epoch 12/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1274 -
mean_absolute_error: 0.2578 - val_loss: 0.0971 - val_mean_absolute_error: 0.2316
Epoch 13/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1199 -
mean_absolute_error: 0.2464 - val_loss: 0.0883 - val_mean_absolute_error: 0.2166
Epoch 14/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1297 -
mean_absolute_error: 0.2611 - val_loss: 0.0826 - val_mean_absolute_error: 0.2074
Epoch 15/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1356 -
mean_absolute_error: 0.2677 - val_loss: 0.3297 - val_mean_absolute_error: 0.5171
Epoch 16/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1252 -
mean_absolute_error: 0.2557 - val_loss: 0.1079 - val_mean_absolute_error: 0.2508
Epoch 17/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1160 -
mean_absolute_error: 0.2414 - val_loss: 0.1011 - val_mean_absolute_error: 0.2399
Epoch 18/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1140 -
mean_absolute_error: 0.2384 - val_loss: 0.0767 - val_mean_absolute_error: 0.1978
```

```
Epoch 19/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1196 -
mean_absolute_error: 0.2468 - val_loss: 0.0794 - val_mean_absolute_error: 0.2029
Epoch 20/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1167 -
mean_absolute_error: 0.2426 - val_loss: 0.1134 - val_mean_absolute_error: 0.2620
Epoch 21/100
76/76 [==============================] - 0s 6ms/step - loss: 0.1195 -
mean_absolute_error: 0.2518 - val_loss: 0.0970 - val_mean_absolute_error: 0.2330
Epoch 22/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1239 -
mean_absolute_error: 0.2542 - val_loss: 0.0875 - val_mean_absolute_error: 0.2178
Epoch 23/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1176 -
mean_absolute_error: 0.2457 - val_loss: 0.0742 - val_mean_absolute_error: 0.1959
Epoch 24/100
76/76 [==============================] - 0s 6ms/step - loss: 0.1266 -
mean_absolute_error: 0.2584 - val_loss: 0.0807 - val_mean_absolute_error: 0.2059
Epoch 25/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1176 -
mean_absolute_error: 0.2461 - val_loss: 0.0883 - val_mean_absolute_error: 0.2227
Epoch 26/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1123 -
mean_absolute_error: 0.2350 - val_loss: 0.0809 - val_mean_absolute_error: 0.2103
Epoch 27/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1148 -
mean_absolute_error: 0.2419 - val_loss: 0.0872 - val_mean_absolute_error: 0.2199
Epoch 28/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1103 -
mean_absolute_error: 0.2349 - val_loss: 0.0838 - val_mean_absolute_error: 0.2135
Epoch 29/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1166 -
mean_absolute_error: 0.2434 - val_loss: 0.1865 - val_mean_absolute_error: 0.3712
Epoch 30/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1155 -
mean_absolute_error: 0.2430 - val_loss: 0.0773 - val_mean_absolute_error: 0.2018
Epoch 31/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1209 -
mean_absolute_error: 0.2494 - val_loss: 0.1193 - val_mean_absolute_error: 0.2764
Epoch 32/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1167 -
mean_absolute_error: 0.2433 - val_loss: 0.0931 - val_mean_absolute_error: 0.2295
Epoch 33/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1177 -
mean_absolute_error: 0.2450 - val_loss: 0.0725 - val_mean_absolute_error: 0.1942
Epoch 34/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1210 -
mean_absolute_error: 0.2524 - val_loss: 0.0795 - val_mean_absolute_error: 0.2073
```

```
Epoch 35/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1096 -
mean_absolute_error: 0.2332 - val_loss: 0.0726 - val_mean_absolute_error: 0.1949
Epoch 36/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1230 -
mean_absolute_error: 0.2538 - val_loss: 0.0804 - val_mean_absolute_error: 0.2081
Epoch 37/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1273 -
mean_absolute_error: 0.2585 - val_loss: 0.0691 - val_mean_absolute_error: 0.1868
Epoch 38/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1075 -
mean_absolute_error: 0.2304 - val_loss: 0.0711 - val_mean_absolute_error: 0.1924
Epoch 39/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1160 -
mean_absolute_error: 0.2445 - val_loss: 0.1097 - val_mean_absolute_error: 0.2612
Epoch 40/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1337 -
mean_absolute_error: 0.2702 - val_loss: 0.1156 - val_mean_absolute_error: 0.2702
Epoch 41/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1221 -
mean_absolute_error: 0.2545 - val_loss: 0.1290 - val_mean_absolute_error: 0.2926
Epoch 42/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1150 -
mean_absolute_error: 0.2414 - val_loss: 0.0925 - val_mean_absolute_error: 0.2316
Epoch 43/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1171 -
mean_absolute_error: 0.2471 - val_loss: 0.0796 - val_mean_absolute_error: 0.2073
Epoch 44/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1147 -
mean_absolute_error: 0.2414 - val_loss: 0.0703 - val_mean_absolute_error: 0.1901
Epoch 45/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1159 -
mean_absolute_error: 0.2426 - val_loss: 0.0742 - val_mean_absolute_error: 0.1992
Epoch 46/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1249 -
mean_absolute_error: 0.2549 - val_loss: 0.0768 - val_mean_absolute_error: 0.2045
Epoch 47/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1142 -
mean_absolute_error: 0.2436 - val_loss: 0.0689 - val_mean_absolute_error: 0.1883
Epoch 48/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1260 -
mean_absolute_error: 0.2565 - val_loss: 0.0753 - val_mean_absolute_error: 0.2036
Epoch 49/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1319 -
mean_absolute_error: 0.2665 - val_loss: 0.0710 - val_mean_absolute_error: 0.1933
Epoch 50/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1213 -
mean_absolute_error: 0.2522 - val_loss: 0.0870 - val_mean_absolute_error: 0.2221
```

```
Epoch 51/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1216 -
mean_absolute_error: 0.2546 - val_loss: 0.1676 - val_mean_absolute_error: 0.3486
Epoch 52/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1206 -
mean_absolute_error: 0.2514 - val_loss: 0.0874 - val_mean_absolute_error: 0.2238
Epoch 53/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1147 -
mean_absolute_error: 0.2430 - val_loss: 0.0706 - val_mean_absolute_error: 0.1928
Epoch 54/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1132 -
mean_absolute_error: 0.2419 - val_loss: 0.0675 - val_mean_absolute_error: 0.1857
Epoch 55/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1096 -
mean_absolute_error: 0.2336 - val_loss: 0.0681 - val_mean_absolute_error: 0.1866
Epoch 56/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1255 -
mean_absolute_error: 0.2575 - val_loss: 0.1368 - val_mean_absolute_error: 0.3060
Epoch 57/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1157 -
mean_absolute_error: 0.2440 - val_loss: 0.0828 - val_mean_absolute_error: 0.2160
Epoch 58/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1156 -
mean_absolute_error: 0.2441 - val_loss: 0.0671 - val_mean_absolute_error: 0.1863
Epoch 59/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1159 -
mean_absolute_error: 0.2452 - val_loss: 0.0721 - val_mean_absolute_error: 0.1961
Epoch 60/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1369 -
mean_absolute_error: 0.2777 - val_loss: 0.0724 - val_mean_absolute_error: 0.1963
Epoch 61/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1137 -
mean_absolute_error: 0.2401 - val_loss: 0.0703 - val_mean_absolute_error: 0.1919
Epoch 62/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1083 -
mean_absolute_error: 0.2315 - val_loss: 0.1150 - val_mean_absolute_error: 0.2717
Epoch 63/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1211 -
mean_absolute_error: 0.2524 - val_loss: 0.0743 - val_mean_absolute_error: 0.2002
Epoch 64/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1131 -
mean_absolute_error: 0.2415 - val_loss: 0.0794 - val_mean_absolute_error: 0.2105
Epoch 65/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1138 -
mean_absolute_error: 0.2410 - val_loss: 0.0910 - val_mean_absolute_error: 0.2307
Epoch 66/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1116 -
mean_absolute_error: 0.2362 - val_loss: 0.0777 - val_mean_absolute_error: 0.2087
```

```
Epoch 67/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1091 -
mean_absolute_error: 0.2330 - val_loss: 0.0841 - val_mean_absolute_error: 0.2187
Epoch 68/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1160 -
mean_absolute_error: 0.2439 - val_loss: 0.0701 - val_mean_absolute_error: 0.1922
Epoch 69/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1134 -
mean_absolute_error: 0.2404 - val_loss: 0.0689 - val_mean_absolute_error: 0.1905
Epoch 70/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1117 -
mean_absolute_error: 0.2362 - val_loss: 0.0665 - val_mean_absolute_error: 0.1851
Epoch 71/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1255 -
mean_absolute_error: 0.2556 - val_loss: 0.0705 - val_mean_absolute_error: 0.1935
Epoch 72/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1172 -
mean_absolute_error: 0.2452 - val_loss: 0.0725 - val_mean_absolute_error: 0.1972
Epoch 73/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1085 -
mean_absolute_error: 0.2329 - val_loss: 0.0823 - val_mean_absolute_error: 0.2151
Epoch 74/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1110 -
mean_absolute_error: 0.2345 - val_loss: 0.0735 - val_mean_absolute_error: 0.1991
Epoch 75/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1215 -
mean_absolute_error: 0.2496 - val_loss: 0.1850 - val_mean_absolute_error: 0.3695
Epoch 76/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1311 -
mean_absolute_error: 0.2628 - val_loss: 0.1181 - val_mean_absolute_error: 0.2782
Epoch 77/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1110 -
mean_absolute_error: 0.2359 - val_loss: 0.0843 - val_mean_absolute_error: 0.2186
Epoch 78/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1318 -
mean_absolute_error: 0.2661 - val_loss: 0.1489 - val_mean_absolute_error: 0.3247
Epoch 79/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1282 -
mean_absolute_error: 0.2640 - val_loss: 0.0663 - val_mean_absolute_error: 0.1852
Epoch 80/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1091 -
mean_absolute_error: 0.2337 - val_loss: 0.0692 - val_mean_absolute_error: 0.1916
Epoch 81/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1079 -
mean_absolute_error: 0.2304 - val_loss: 0.0949 - val_mean_absolute_error: 0.2384
Epoch 82/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1344 -
mean_absolute_error: 0.2689 - val_loss: 0.0666 - val_mean_absolute_error: 0.1868
```

```
Epoch 83/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1200 -
mean_absolute_error: 0.2492 - val_loss: 0.0667 - val_mean_absolute_error: 0.1873
Epoch 84/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1202 -
mean_absolute_error: 0.2480 - val_loss: 0.0817 - val_mean_absolute_error: 0.2139
Epoch 85/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1195 -
mean_absolute_error: 0.2474 - val_loss: 0.0815 - val_mean_absolute_error: 0.2140
Epoch 86/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1173 -
mean_absolute_error: 0.2465 - val_loss: 0.0716 - val_mean_absolute_error: 0.1952
Epoch 87/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1096 -
mean_absolute_error: 0.2306 - val_loss: 0.0688 - val_mean_absolute_error: 0.1891
Epoch 88/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1138 -
mean_absolute_error: 0.2416 - val_loss: 0.0718 - val_mean_absolute_error: 0.1962
Epoch 89/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1212 -
mean_absolute_error: 0.2534 - val_loss: 0.0663 - val_mean_absolute_error: 0.1863
Epoch 90/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1123 -
mean_absolute_error: 0.2378 - val_loss: 0.0765 - val_mean_absolute_error: 0.2060
Epoch 91/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1210 -
mean_absolute_error: 0.2505 - val_loss: 0.0678 - val_mean_absolute_error: 0.1884
Epoch 92/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1104 -
mean_absolute_error: 0.2368 - val_loss: 0.0677 - val_mean_absolute_error: 0.1879
Epoch 93/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1155 -
mean_absolute_error: 0.2421 - val_loss: 0.0959 - val_mean_absolute_error: 0.2389
Epoch 94/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1177 -
mean_absolute_error: 0.2456 - val_loss: 0.1178 - val_mean_absolute_error: 0.2754
Epoch 95/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1242 -
mean_absolute_error: 0.2541 - val_loss: 0.0789 - val_mean_absolute_error: 0.2089
Epoch 96/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1215 -
mean_absolute_error: 0.2513 - val_loss: 0.0904 - val_mean_absolute_error: 0.2315
Epoch 97/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1323 -
mean_absolute_error: 0.2682 - val_loss: 0.0666 - val_mean_absolute_error: 0.1858
Epoch 98/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1119 -
mean_absolute_error: 0.2384 - val_loss: 0.0696 - val_mean_absolute_error: 0.1923
```

```
Epoch 99/100
76/76 [==============================] - 0s 4ms/step - loss: 0.1128 -
mean_absolute_error: 0.2392 - val_loss: 0.0696 - val_mean_absolute_error: 0.1920
Epoch 100/100
76/76 [==============================] - 0s 5ms/step - loss: 0.1121 -
mean_absolute_error: 0.2372 - val_loss: 0.0714 - val_mean_absolute_error: 0.1955
```

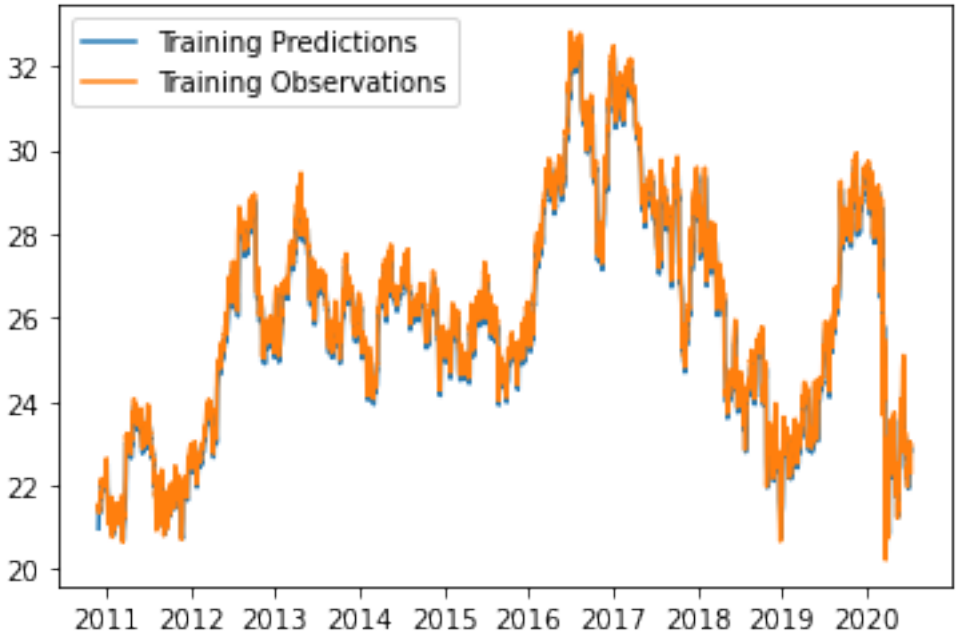
[15]:
```
<keras.callbacks.History at 0x29a42e5aa30>
```

[16]:
```
train_predictions = model.predict(X_train).flatten()

plt.plot(dates_train, train_predictions)
plt.plot(dates_train, y_train)
plt.legend(['Training Predictions', 'Training Observations'])
```

```
76/76 [==============================] - 1s 2ms/step
```

[16]:
```
<matplotlib.legend.Legend at 0x29a48f40a90>
```

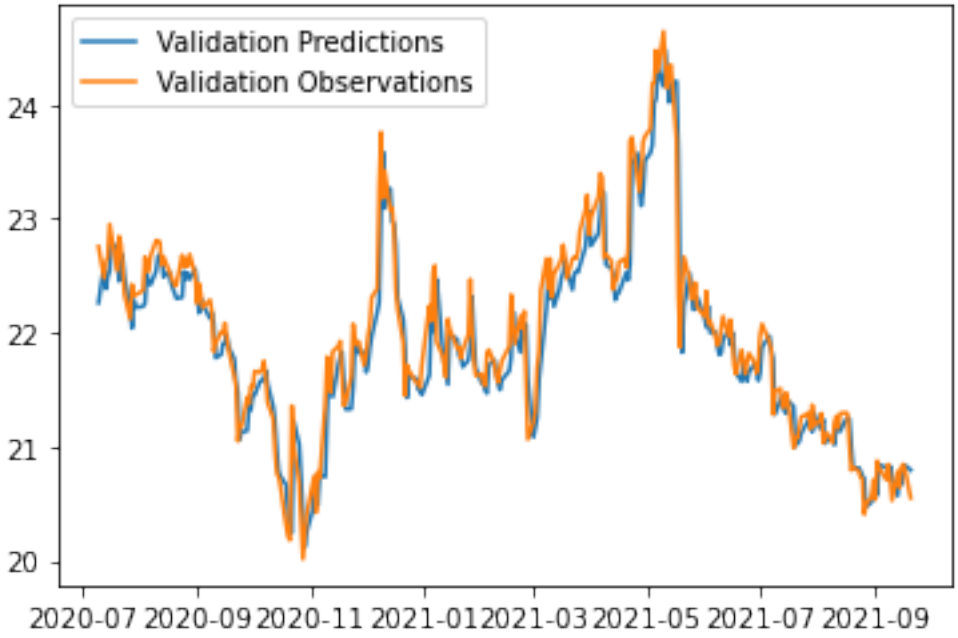


[17]:
```
val_predictions = model.predict(X_val).flatten()

plt.plot(dates_val, val_predictions)
plt.plot(dates_val, y_val)
plt.legend(['Validation Predictions', 'Validation Observations'])
```

```
10/10 [==============================] - 0s 3ms/step
```

[17]: <matplotlib.legend.Legend at 0x29a48f9adc0>

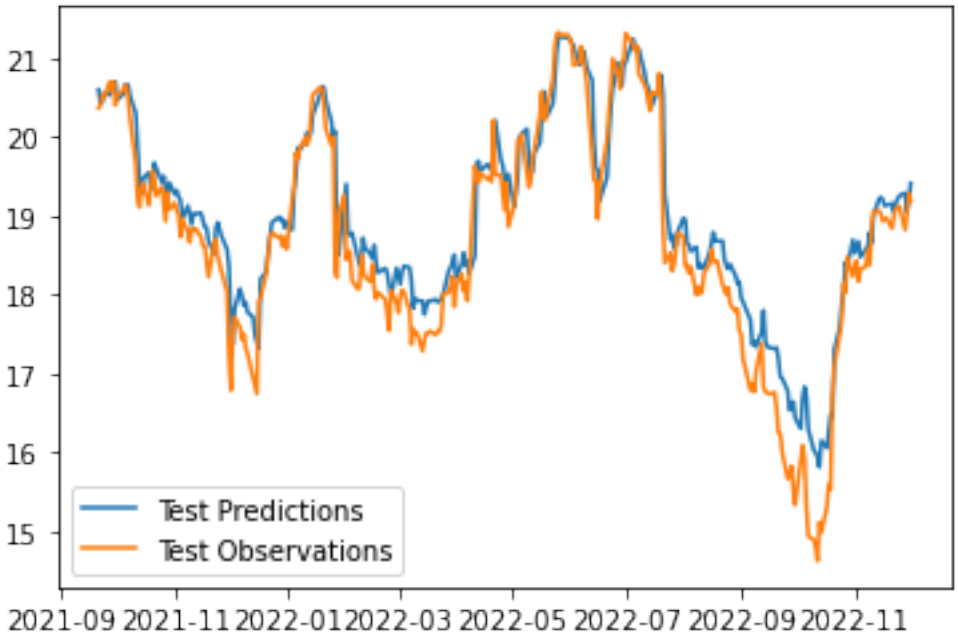


[18]:
```
test_predictions = model.predict(X_test).flatten()

plt.plot(dates_test, test_predictions)
plt.plot(dates_test, y_test)
plt.legend(['Test Predictions', 'Test Observations'])
```

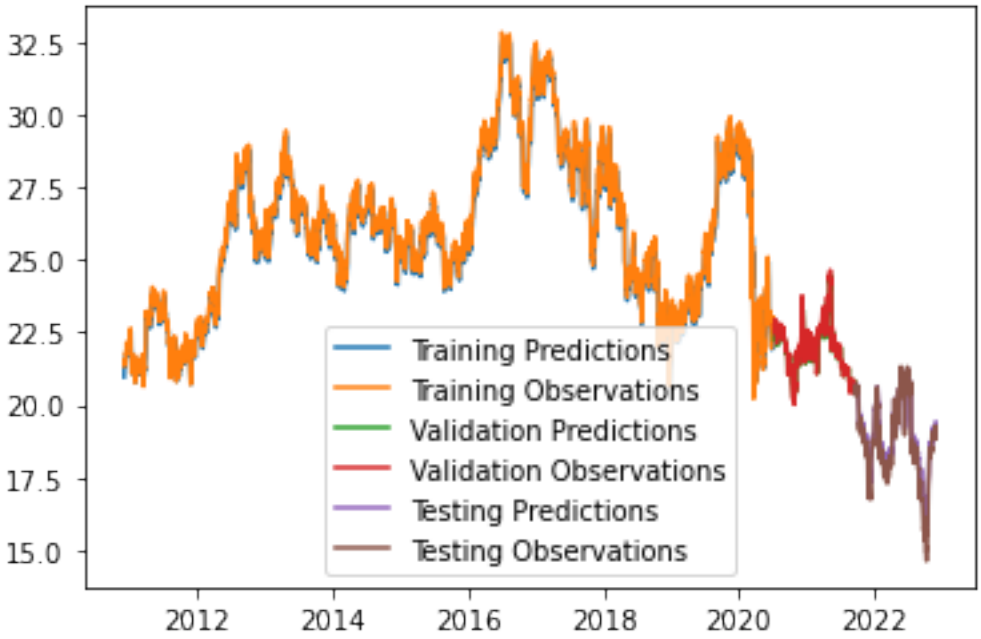
```
10/10 [==============================] - 0s 3ms/step
```

[18]: <matplotlib.legend.Legend at 0x29a4903aee0>



[19]:
```
plt.plot(dates_train, train_predictions)
plt.plot(dates_train, y_train)
plt.plot(dates_val, val_predictions)
plt.plot(dates_val, y_val)
plt.plot(dates_test, test_predictions)
plt.plot(dates_test, y_test)
plt.legend(['Training Predictions',
            'Training Observations',
            'Validation Predictions',
            'Validation Observations',
            'Testing Predictions',
            'Testing Observations'])
```

[19]:
```
<matplotlib.legend.Legend at 0x29a4906abe0>
```



[20]:
```
from copy import deepcopy

recursive_predictions = []
recursive_dates = np.concatenate([dates_val, dates_test])

for target_date in recursive_dates:
    last_window = deepcopy(X_train[-1])
    next_prediction = model.predict(np.array([last_window])).flatten()
    recursive_predictions.append(next_prediction)
    last_window[-1] = next_prediction
```

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[21]:
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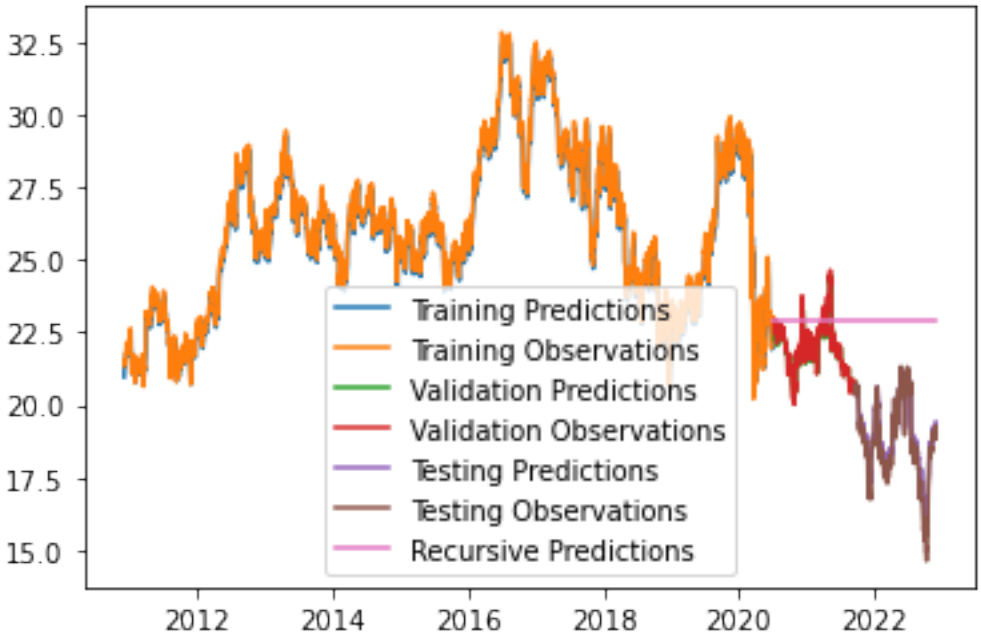
plt.plot(dates_train, train_predictions)
plt.plot(dates_train, y_train)
plt.plot(dates_val, val_predictions)
plt.plot(dates_val, y_val)
plt.plot(dates_test, test_predictions)
plt.plot(dates_test, y_test)
plt.plot(recursive_dates, recursive_predictions)
plt.legend(['Training Predictions',
            'Training Observations',
            'Validation Predictions',
            'Validation Observations',
            'Testing Predictions',
            'Testing Observations',
            'Recursive Predictions'])
```

[21]:
```
<matplotlib.legend.Legend at 0x29a4a253f70>
```


32.5
30.0
27.5
25.0
22.5
20.0
17.5
15.0
2012
2014
2016
2018
2020
2022
Training Predictions
Training Observations
Validation Predictions
Validation Observations
Testing Predictions
Testing Observations
Recursive Predictions