

1. LSTM

Preprocessing

```
In [ ]: import pandas as pd  
import numpy as np
```

```
In [ ]: df_g = pd.read_csv("Dataset C/GOOGL.csv")
```

```
In [ ]: df_g.head()
```

```
Out[ ]:
```

	Date	Open	High	Low	Close	Adj Close	Volume
0	2004-08-19	50.050049	52.082081	48.028027	50.220219	50.220219	44659000
1	2004-08-20	50.555557	54.594593	50.300301	54.209209	54.209209	22834300
2	2004-08-23	55.430431	56.796795	54.579578	54.754753	54.754753	18256100
3	2004-08-24	55.675674	55.855584	51.836838	52.487488	52.487488	15247300
4	2004-08-25	52.532532	54.054054	51.991993	53.053055	53.053055	9188600

```
In [ ]: df_g.columns
```

```
Out[ ]: Index(['Date', 'Open', 'High', 'Low', 'Close', 'Adj Close', 'Volume'], dtype='object')
```

```
In [ ]: df_g.shape
```

```
Out[ ]: (3932, 7)
```

```
In [ ]: df_i = pd.read_csv("Dataset C/INTC.csv")
```

```
In [ ]: df_i.head()
```

```
Out[ ]:      Date    Open    High     Low    Close   Adj Close   Volume
0 1980-03-17  0.325521  0.330729  0.325521  0.325521  0.204750  10924800
1 1980-03-18  0.325521  0.328125  0.322917  0.322917  0.203112  17068800
2 1980-03-19  0.330729  0.335938  0.330729  0.330729  0.208026  18508800
3 1980-03-20  0.330729  0.334635  0.329427  0.329427  0.207207  11174400
4 1980-03-21  0.322917  0.322917  0.317708  0.317708  0.199836  12172800
```

```
In [ ]: df_i.columns
```

```
Out[ ]: Index(['Date', 'Open', 'High', 'Low', 'Close', 'Adj Close', 'Volume'], dtype='object')
```

```
In [ ]: df_i.shape
```

```
Out[ ]: (10098, 7)
```

```
In [ ]: df_g = pd.read_csv("Dataset C/GOOGL.csv", parse_dates=['Date'], index_col=['Date'])
df_i = pd.read_csv("Dataset C/INTC.csv", parse_dates=['Date'], index_col=['Date'])
```

```
In [ ]: df_g.head()
```

```
Out[ ]:      Open    High     Low    Close   Adj Close   Volume
Date
2004-08-19  50.050049  52.082081  48.028027  50.220219  50.220219  44659000
2004-08-20  50.555557  54.594593  50.300301  54.209209  54.209209  22834300
2004-08-23  55.430431  56.796795  54.579578  54.754753  54.754753  18256100
2004-08-24  55.675674  55.855854  51.836838  52.487488  52.487488  15247300
2004-08-25  52.532532  54.054054  51.991993  53.053055  53.053055  9188600
```

```
In [ ]: df_i.head()
```

```
Out[ ]:
```

	Open	High	Low	Close	Adj Close	Volume
Date						
1980-03-17	0.325521	0.330729	0.325521	0.325521	0.204750	10924800
1980-03-18	0.325521	0.328125	0.322917	0.322917	0.203112	17068800
1980-03-19	0.330729	0.335938	0.330729	0.330729	0.208026	18508800
1980-03-20	0.330729	0.334635	0.329427	0.329427	0.207207	11174400
1980-03-21	0.322917	0.322917	0.317708	0.317708	0.199836	12172800

```
In [ ]: df_g.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 3932 entries, 2004-08-19 to 2020-04-01
Data columns (total 6 columns):
 #   Column      Non-Null Count  Dtype  
--- 
 0   Open        3932 non-null    float64
 1   High         3932 non-null    float64
 2   Low          3932 non-null    float64
 3   Close        3932 non-null    float64
 4   Adj Close    3932 non-null    float64
 5   Volume       3932 non-null    int64  
dtypes: float64(5), int64(1)
memory usage: 215.0 KB
```

```
In [ ]: df_g.shape
```

```
Out[ ]: (3932, 6)
```

```
In [ ]: df_i.info()
```

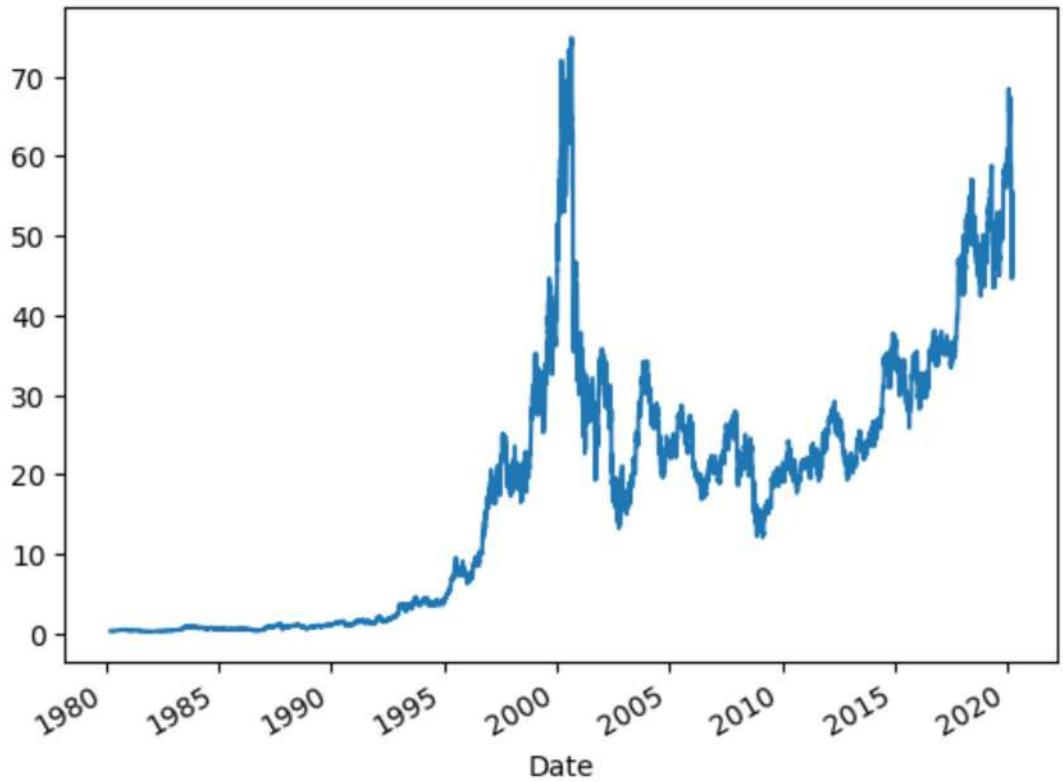
```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 10098 entries, 1980-03-17 to 2020-04-01
Data columns (total 6 columns):
 #   Column      Non-Null Count  Dtype  
--- 
 0   Open        10098 non-null   float64 
 1   High         10098 non-null   float64 
 2   Low          10098 non-null   float64 
 3   Close        10098 non-null   float64 
 4   Adj Close    10098 non-null   float64 
 5   Volume       10098 non-null   int64  
dtypes: float64(5), int64(1)
memory usage: 552.2 KB
```

```
In [ ]: df_i.shape
```

```
Out[ ]: (10098, 6)
```

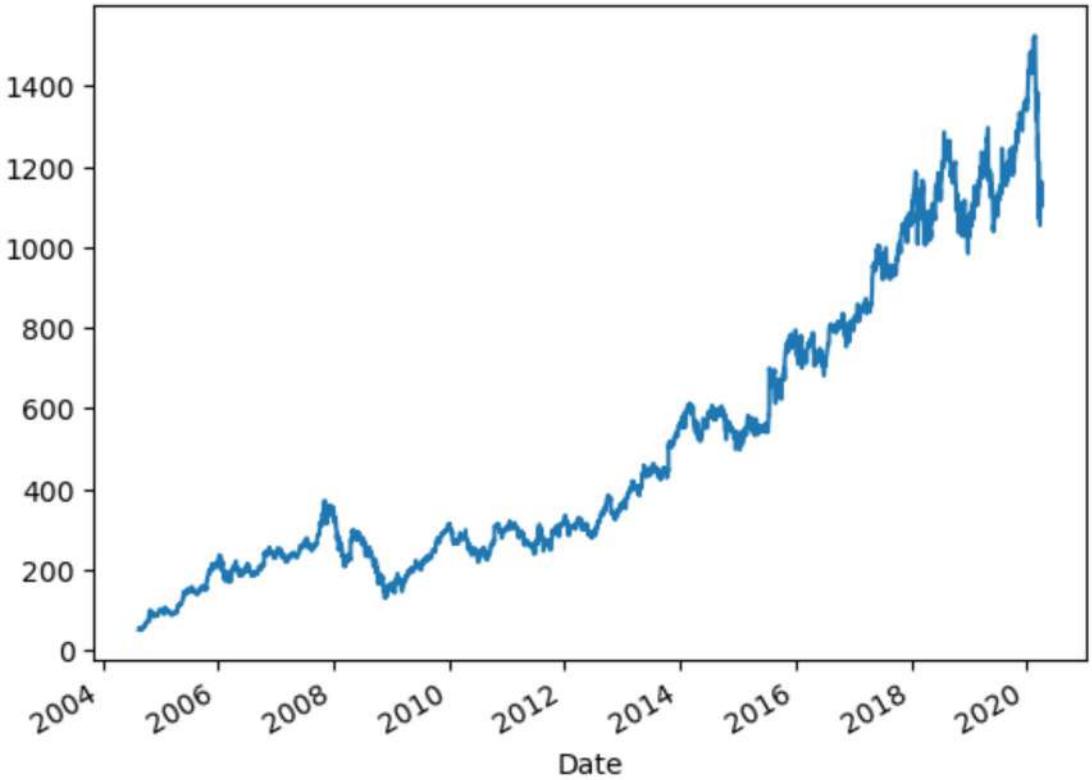
```
In [ ]: temp = df_i['Close']
temp.plot()
```

```
Out[ ]: <Axes: xlabel='Date'>
```



```
In [ ]: temp = df_g['Close']
temp.plot()
```

```
Out[ ]: <Axes: xlabel='Date'>
```



```
In [ ]: dfgoog = pd.DataFrame(df_g['Close'])  
dfint = pd.DataFrame(df_i['Close'])
```

```
In [ ]: dfgoog
```

Out[]:

	Close
	Date
2004-08-19	50.220219
2004-08-20	54.209209
2004-08-23	54.754753
2004-08-24	52.487488
2004-08-25	53.053055
...	...
2020-03-26	1162.920044
2020-03-27	1110.260010
2020-03-30	1146.310059
2020-03-31	1161.949951
2020-04-01	1102.099976

3932 rows × 1 columns

In []: dfint

Out[]:

[Close](#)

Date	Close
1980-03-17	0.325521
1980-03-18	0.322917
1980-03-19	0.330729
1980-03-20	0.329427
1980-03-21	0.317708
...	...
2020-03-26	55.540001
2020-03-27	52.369999
2020-03-30	55.490002
2020-03-31	54.119999
2020-04-01	51.880001

10098 rows × 1 columns

```
In [ ]: import datetime
def str_to_datetime(s):
    return datetime.datetime.strptime(s, "%Y-%m-%d")
```

```
In [ ]: [[1] [2] [3] [4] [5]] [6]
[[2] [3] [4] [5] [6]] [7]
[[3] [4] [5] [6] [7]] [8]
```

```
In [ ]: def window(dataframe, first_datestr, last_datestr, n):
    first_date = str_to_datetime(first_datestr)
    last_date = str_to_datetime(last_datestr)

    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[0])
    next_date = datetime.datetime.strptime(next_datetime_str.split(' ')[0], '%Y-%m-%d')

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

ret_df['Target'] = Y

return ret_df
```

GOOGL LSTM

```
In [ ]: from sklearn.preprocessing import MinMaxScaler  
scaler = MinMaxScaler(feature_range=(0,1))  
dfgoog['Close'] = scaler.fit_transform(dfgoog['Close'].values.reshape(-1,1))
```

```
In [ ]: windowed_goog = window(dfgoog,"2004-08-26","2020-04-01",5)  
windowed_goog
```

Out[]:

	Target Date	Target-0	Target-1	Target-2	Target-3	Target-4	Target
0	2004-08-26	0.000112	0.002817	0.003187	0.001649	0.002033	0.002681
1	2004-08-27	0.002817	0.003187	0.001649	0.002033	0.002681	0.002084
2	2004-08-30	0.003187	0.001649	0.002033	0.002681	0.002084	0.000679
3	2004-08-31	0.001649	0.002033	0.002681	0.002084	0.000679	0.000801
4	2004-09-01	0.002033	0.002681	0.002084	0.000679	0.000801	0.000081
...
3922	2020-03-26	0.719829	0.690361	0.680814	0.732265	0.713015	0.754579
3923	2020-03-27	0.690361	0.680814	0.732265	0.713015	0.754579	0.718873
3924	2020-03-30	0.680814	0.732265	0.713015	0.754579	0.718873	0.743317
3925	2020-03-31	0.732265	0.713015	0.754579	0.718873	0.743317	0.753922
3926	2020-04-01	0.713015	0.754579	0.718873	0.743317	0.753922	0.713340

3927 rows × 7 columns

```
In [ ]: def getXY(windowed_dataframe):  
    df_as_np = windowed_dataframe.to_numpy()  
  
    dates = df_as_np[:,0]
```

```
middle_matrix = df_as_np[:, 1:-1]
X = middle_matrix.reshape((len(dates), middle_matrix.shape[1], 1))
Y = df_as_np[:, -1]

return dates, X.astype(np.float32), Y.astype(np.float32)
```

```
In [ ]: dates, X, y = getXY(windowed_goog)
dates.shape, X.shape, y.shape
```

```
Out[ ]: ((3927,), (3927, 5, 1), (3927,))
```

```
In [ ]: dates
```

```
Out[ ]: array([Timestamp('2004-08-26 00:00:00'), Timestamp('2004-08-27 00:00:00'),
               Timestamp('2004-08-30 00:00:00'), ...,
               Timestamp('2020-03-30 00:00:00'), Timestamp('2020-03-31 00:00:00'),
               Timestamp('2020-04-01 00:00:00')], dtype=object)
```

```
In [ ]: q_80 = int(len(dates) * .8)
q_90 = int(len(dates) * .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:]
```

```
In [ ]: import matplotlib.pyplot as plt
plt.plot(dates_train, y_train)
plt.plot(dates_val, y_val)
plt.plot(dates_test, y_test)
plt.legend(["Train", "Validation", "Test"])
```

```
Out[ ]: <matplotlib.legend.Legend at 0x1729829eb50>
```



```
In [ ]: import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense, Dropout, Input
from tensorflow.keras.optimizers import Adam, SGD
from tensorflow.keras import layers
from keras.callbacks import EarlyStopping
```

Base Model

```
In [ ]: modelbase = Sequential()
modelbase.add(Input((5,1)))
modelbase.add(LSTM(units=50, activation='relu', return_sequences=False))
modelbase.add(Dense(1))
modelbase.compile(optimizer='adam', loss='mean_squared_error', metrics=['mean_absolute_error'])
```

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

Epoch 1/100
99/99 1s 3ms/step - loss: 0.0212 - mean_absolute_error: 0.1063 - val_loss: 5.4133e-04 - val_mean_absolute_error: 0.0180
Epoch 2/100
99/99 0s 1ms/step - loss: 6.5350e-05 - mean_absolute_error: 0.0060 - val_loss: 3.5890e-04 - val_mean_absolute_error: 0.0156
Epoch 3/100
99/99 0s 1ms/step - loss: 4.6602e-05 - mean_absolute_error: 0.0048 - val_loss: 2.8198e-04 - val_mean_absolute_error: 0.0131
Epoch 4/100
99/99 0s 1ms/step - loss: 4.6047e-05 - mean_absolute_error: 0.0047 - val_loss: 3.4638e-04 - val_mean_absolute_error: 0.0152
Epoch 5/100
99/99 0s 1ms/step - loss: 4.6767e-05 - mean_absolute_error: 0.0047 - val_loss: 2.4577e-04 - val_mean_absolute_error: 0.0116
Epoch 6/100
99/99 0s 1ms/step - loss: 4.1165e-05 - mean_absolute_error: 0.0045 - val_loss: 2.6232e-04 - val_mean_absolute_error: 0.0124
Epoch 7/100
99/99 0s 1ms/step - loss: 3.9138e-05 - mean_absolute_error: 0.0045 - val_loss: 2.4621e-04 - val_mean_absolute_error: 0.0117
Epoch 8/100
99/99 0s 1ms/step - loss: 4.8355e-05 - mean_absolute_error: 0.0048 - val_loss: 2.4547e-04 - val_mean_absolute_error: 0.0116
Epoch 9/100
99/99 0s 1ms/step - loss: 4.6183e-05 - mean_absolute_error: 0.0045 - val_loss: 2.9189e-04 - val_mean_absolute_error: 0.0135
Epoch 10/100
99/99 0s 1ms/step - loss: 5.1705e-05 - mean_absolute_error: 0.0047 - val_loss: 2.4905e-04 - val_mean_absolute_error: 0.0119
Epoch 11/100
99/99 0s 1ms/step - loss: 4.2526e-05 - mean_absolute_error: 0.0046 - val_loss: 3.1496e-04 - val_mean_absolute_error: 0.0143
Epoch 12/100
99/99 0s 995us/step - loss: 4.3396e-05 - mean_absolute_error: 0.0048 - val_loss: 2.7706e-04 - val_mean_absolute_error: 0.0130
Epoch 13/100
99/99 0s 1ms/step - loss: 4.5103e-05 - mean_absolute_error: 0.0047 - val_loss: 2.4693e-04 - val_mean_absolute_error: 0.0117
Epoch 14/100
99/99 0s 1ms/step - loss: 4.3718e-05 - mean_absolute_error: 0.0046 - val_loss: 2.4903e-04 - val_mean_absolute_error: 0.0117

```
ute_error: 0.0118
Epoch 15/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 4.5593e-05 - mean_absolute_error: 0.0045 - val_loss: 2.4701e-04 - val_mean_absolute_error: 0.0116
Epoch 16/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 3.7650e-05 - mean_absolute_error: 0.0044 - val_loss: 2.5102e-04 - val_mean_absolute_error: 0.0114
Epoch 17/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 4.1383e-05 - mean_absolute_error: 0.0046 - val_loss: 2.5871e-04 - val_mean_absolute_error: 0.0123
Epoch 18/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 4.5807e-05 - mean_absolute_error: 0.0047 - val_loss: 2.4860e-04 - val_mean_absolute_error: 0.0117
Epoch 19/100
99/99 ━━━━━━ 995us/step - loss: 4.8716e-05 - mean_absolute_error: 0.0049 - val_loss: 2.4936e-04 - val_mean_absolute_error: 0.0115
Epoch 20/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.5132e-05 - mean_absolute_error: 0.0045 - val_loss: 2.6247e-04 - val_mean_absolute_error: 0.0125
Epoch 21/100
99/99 ━━━━━━ 0s 1ms/step - loss: 5.1341e-05 - mean_absolute_error: 0.0047 - val_loss: 2.5541e-04 - val_mean_absolute_error: 0.0115
Epoch 22/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.4352e-05 - mean_absolute_error: 0.0045 - val_loss: 2.5902e-04 - val_mean_absolute_error: 0.0115
Epoch 23/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.8303e-05 - mean_absolute_error: 0.0049 - val_loss: 2.6273e-04 - val_mean_absolute_error: 0.0125
Epoch 24/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.4837e-05 - mean_absolute_error: 0.0047 - val_loss: 2.7512e-04 - val_mean_absolute_error: 0.0117
Epoch 25/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.8805e-05 - mean_absolute_error: 0.0043 - val_loss: 3.1740e-04 - val_mean_absolute_error: 0.0124
Epoch 26/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.0761e-05 - mean_absolute_error: 0.0045 - val_loss: 2.5572e-04 - val_mean_absolute_error: 0.0122
Epoch 27/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.1634e-05 - mean_absolute_error: 0.0045 - val_loss: 2.8543e-04 - val_mean_absolute_error: 0.0118
Epoch 28/100
```

```
99/99 ----- 0s 1ms/step - loss: 4.0398e-05 - mean_absolute_error: 0.0045 - val_loss: 2.8630e-04 - val_mean_absolute_error: 0.0118
Epoch 29/100
99/99 ----- 0s 1ms/step - loss: 4.0209e-05 - mean_absolute_error: 0.0047 - val_loss: 3.8786e-04 - val_mean_absolute_error: 0.0139
Epoch 30/100
99/99 ----- 0s 1ms/step - loss: 3.7344e-05 - mean_absolute_error: 0.0044 - val_loss: 3.0695e-04 - val_mean_absolute_error: 0.0122
Epoch 31/100
99/99 ----- 0s 1ms/step - loss: 3.4384e-05 - mean_absolute_error: 0.0042 - val_loss: 2.6522e-04 - val_mean_absolute_error: 0.0116
Epoch 32/100
99/99 ----- 0s 995us/step - loss: 4.0668e-05 - mean_absolute_error: 0.0045 - val_loss: 2.9763e-04 - val_mean_absolute_error: 0.0120
Epoch 33/100
99/99 ----- 0s 980us/step - loss: 3.7618e-05 - mean_absolute_error: 0.0043 - val_loss: 3.9725e-04 - val_mean_absolute_error: 0.0139
Epoch 34/100
99/99 ----- 0s 1ms/step - loss: 4.6301e-05 - mean_absolute_error: 0.0046 - val_loss: 2.8213e-04 - val_mean_absolute_error: 0.0119
Epoch 35/100
99/99 ----- 0s 1ms/step - loss: 4.3414e-05 - mean_absolute_error: 0.0048 - val_loss: 2.6665e-04 - val_mean_absolute_error: 0.0117
Epoch 36/100
99/99 ----- 0s 1ms/step - loss: 3.6675e-05 - mean_absolute_error: 0.0043 - val_loss: 2.6533e-04 - val_mean_absolute_error: 0.0116
Epoch 37/100
99/99 ----- 0s 1ms/step - loss: 4.2950e-05 - mean_absolute_error: 0.0048 - val_loss: 2.5156e-04 - val_mean_absolute_error: 0.0120
Epoch 38/100
99/99 ----- 0s 1ms/step - loss: 4.1424e-05 - mean_absolute_error: 0.0045 - val_loss: 2.6607e-04 - val_mean_absolute_error: 0.0116
Epoch 39/100
99/99 ----- 0s 1ms/step - loss: 3.9068e-05 - mean_absolute_error: 0.0044 - val_loss: 2.8120e-04 - val_mean_absolute_error: 0.0117
Epoch 40/100
99/99 ----- 0s 1ms/step - loss: 4.0737e-05 - mean_absolute_error: 0.0045 - val_loss: 2.6255e-04 - val_mean_absolute_error: 0.0116
Epoch 41/100
99/99 ----- 0s 1ms/step - loss: 3.9422e-05 - mean_absolute_error: 0.0044 - val_loss: 5.0142e-04 - val_mean_absolute_error: 0.0162
```

Epoch 42/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.7340e-05 - mean_absolute_error: 0.0044 - val_loss: 3.7103e-04 - val_mean_absolute_error: 0.0134
Epoch 43/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.3345e-05 - mean_absolute_error: 0.0045 - val_loss: 2.5401e-04 - val_mean_absolute_error: 0.0117
Epoch 44/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.6320e-05 - mean_absolute_error: 0.0044 - val_loss: 2.7954e-04 - val_mean_absolute_error: 0.0117
Epoch 45/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.6639e-05 - mean_absolute_error: 0.0043 - val_loss: 4.3314e-04 - val_mean_absolute_error: 0.0147
Epoch 46/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.4840e-05 - mean_absolute_error: 0.0041 - val_loss: 6.4841e-04 - val_mean_absolute_error: 0.0195
Epoch 47/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.9766e-05 - mean_absolute_error: 0.0047 - val_loss: 3.5045e-04 - val_mean_absolute_error: 0.0130
Epoch 48/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.6971e-05 - mean_absolute_error: 0.0043 - val_loss: 2.5983e-04 - val_mean_absolute_error: 0.0116
Epoch 49/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.7019e-05 - mean_absolute_error: 0.0047 - val_loss: 3.2558e-04 - val_mean_absolute_error: 0.0125
Epoch 50/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.7474e-05 - mean_absolute_error: 0.0042 - val_loss: 3.8779e-04 - val_mean_absolute_error: 0.0138
Epoch 51/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.0195e-05 - mean_absolute_error: 0.0044 - val_loss: 6.7954e-04 - val_mean_absolute_error: 0.0202
Epoch 52/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.4393e-05 - mean_absolute_error: 0.0041 - val_loss: 3.6200e-04 - val_mean_absolute_error: 0.0132
Epoch 53/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.5347e-05 - mean_absolute_error: 0.0041 - val_loss: 2.6674e-04 - val_mean_absolute_error: 0.0116
Epoch 54/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.5142e-05 - mean_absolute_error: 0.0043 - val_loss: 2.4593e-04 - val_mean_absolute_error: 0.0114
Epoch 55/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.2907e-05 - mean_absolute_error: 0.0041 - val_loss: 3.7846e-04 - val_mean_absolute_error:

```
ute_error: 0.0136
Epoch 56/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.4929e-05 - mean_absolute_error: 0.0044 - val_loss: 3.2151e-04 - val_mean_absolute_error: 0.0124
Epoch 57/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.3941e-05 - mean_absolute_error: 0.0041 - val_loss: 3.7328e-04 - val_mean_absolute_error: 0.0135
Epoch 58/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.3832e-05 - mean_absolute_error: 0.0041 - val_loss: 4.3234e-04 - val_mean_absolute_error: 0.0148
Epoch 59/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.5358e-05 - mean_absolute_error: 0.0042 - val_loss: 2.3831e-04 - val_mean_absolute_error: 0.0111
Epoch 60/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.9458e-05 - mean_absolute_error: 0.0043 - val_loss: 4.7222e-04 - val_mean_absolute_error: 0.0158
Epoch 61/100
99/99 ━━━━━━ 0s 1ms/step - loss: 4.2187e-05 - mean_absolute_error: 0.0045 - val_loss: 2.8474e-04 - val_mean_absolute_error: 0.0117
Epoch 62/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.7357e-05 - mean_absolute_error: 0.0044 - val_loss: 3.6939e-04 - val_mean_absolute_error: 0.0135
Epoch 63/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.2928e-05 - mean_absolute_error: 0.0041 - val_loss: 2.5621e-04 - val_mean_absolute_error: 0.0112
Epoch 64/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.5888e-05 - mean_absolute_error: 0.0042 - val_loss: 2.3556e-04 - val_mean_absolute_error: 0.0110
Epoch 65/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.1147e-05 - mean_absolute_error: 0.0040 - val_loss: 3.3624e-04 - val_mean_absolute_error: 0.0127
Epoch 66/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.1674e-05 - mean_absolute_error: 0.0041 - val_loss: 3.2751e-04 - val_mean_absolute_error: 0.0125
Epoch 67/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.4851e-05 - mean_absolute_error: 0.0042 - val_loss: 5.3863e-04 - val_mean_absolute_error: 0.0176
Epoch 68/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.2301e-05 - mean_absolute_error: 0.0040 - val_loss: 3.4701e-04 - val_mean_absolute_error: 0.0130
Epoch 69/100
```

99/99 ━━━━━━━━ 0s 1ms/step - loss: 3.3555e-05 - mean_absolute_error: 0.0041 - val_loss: 3.0920e-04 - val_mean_absolute_error: 0.0122
Epoch 70/100
99/99 ━━━━━━ 0s 1ms/step - loss: 3.1371e-05 - mean_absolute_error: 0.0040 - val_loss: 5.1916e-04 - val_mean_absolute_error: 0.0174
Epoch 71/100
99/99 ━━━━ 0s 1ms/step - loss: 3.2813e-05 - mean_absolute_error: 0.0041 - val_loss: 2.9875e-04 - val_mean_absolute_error: 0.0120
Epoch 72/100
99/99 ━━━━ 0s 1ms/step - loss: 3.1179e-05 - mean_absolute_error: 0.0040 - val_loss: 2.0559e-04 - val_mean_absolute_error: 0.0105
Epoch 73/100
99/99 ━━━━ 0s 1ms/step - loss: 3.0237e-05 - mean_absolute_error: 0.0039 - val_loss: 2.8286e-04 - val_mean_absolute_error: 0.0117
Epoch 74/100
99/99 ━━━━ 0s 1ms/step - loss: 2.7940e-05 - mean_absolute_error: 0.0037 - val_loss: 3.0554e-04 - val_mean_absolute_error: 0.0122
Epoch 75/100
99/99 ━━━━ 0s 1ms/step - loss: 3.0091e-05 - mean_absolute_error: 0.0038 - val_loss: 2.3603e-04 - val_mean_absolute_error: 0.0107
Epoch 76/100
99/99 ━━━━ 0s 1ms/step - loss: 3.1357e-05 - mean_absolute_error: 0.0040 - val_loss: 1.8690e-04 - val_mean_absolute_error: 0.0097
Epoch 77/100
99/99 ━━━━ 0s 1ms/step - loss: 3.1022e-05 - mean_absolute_error: 0.0040 - val_loss: 4.0637e-04 - val_mean_absolute_error: 0.0151
Epoch 78/100
99/99 ━━━━ 0s 1ms/step - loss: 3.1736e-05 - mean_absolute_error: 0.0041 - val_loss: 1.8487e-04 - val_mean_absolute_error: 0.0108
Epoch 79/100
99/99 ━━━━ 0s 1ms/step - loss: 4.1379e-05 - mean_absolute_error: 0.0044 - val_loss: 1.8721e-04 - val_mean_absolute_error: 0.0096
Epoch 80/100
99/99 ━━━━ 0s 1ms/step - loss: 2.8451e-05 - mean_absolute_error: 0.0039 - val_loss: 2.0579e-04 - val_mean_absolute_error: 0.0099
Epoch 81/100
99/99 ━━━━ 0s 1ms/step - loss: 3.0803e-05 - mean_absolute_error: 0.0037 - val_loss: 1.8161e-04 - val_mean_absolute_error: 0.0094
Epoch 82/100
99/99 ━━━━ 0s 1ms/step - loss: 2.8777e-05 - mean_absolute_error: 0.0037 - val_loss: 1.8536e-04 - val_mean_absolute_error: 0.0095

Epoch 83/100
99/99 0s 1ms/step - loss: 3.7523e-05 - mean_absolute_error: 0.0042 - val_loss: 2.0081e-04 - val_mean_absolute_error: 0.0098
Epoch 84/100
99/99 0s 1ms/step - loss: 3.2833e-05 - mean_absolute_error: 0.0037 - val_loss: 1.5105e-04 - val_mean_absolute_error: 0.0089
Epoch 85/100
99/99 0s 1ms/step - loss: 2.9467e-05 - mean_absolute_error: 0.0039 - val_loss: 1.5860e-04 - val_mean_absolute_error: 0.0088
Epoch 86/100
99/99 0s 1ms/step - loss: 2.6961e-05 - mean_absolute_error: 0.0036 - val_loss: 1.4342e-04 - val_mean_absolute_error: 0.0090
Epoch 87/100
99/99 0s 1ms/step - loss: 2.6814e-05 - mean_absolute_error: 0.0036 - val_loss: 1.4722e-04 - val_mean_absolute_error: 0.0094
Epoch 88/100
99/99 0s 1ms/step - loss: 2.6160e-05 - mean_absolute_error: 0.0036 - val_loss: 1.9035e-04 - val_mean_absolute_error: 0.0097
Epoch 89/100
99/99 0s 2ms/step - loss: 2.9317e-05 - mean_absolute_error: 0.0039 - val_loss: 1.6999e-04 - val_mean_absolute_error: 0.0091
Epoch 90/100
99/99 0s 1ms/step - loss: 3.1856e-05 - mean_absolute_error: 0.0040 - val_loss: 1.3172e-04 - val_mean_absolute_error: 0.0082
Epoch 91/100
99/99 0s 1ms/step - loss: 2.9806e-05 - mean_absolute_error: 0.0037 - val_loss: 1.4803e-04 - val_mean_absolute_error: 0.0085
Epoch 92/100
99/99 0s 1ms/step - loss: 2.8514e-05 - mean_absolute_error: 0.0037 - val_loss: 1.4828e-04 - val_mean_absolute_error: 0.0096
Epoch 93/100
99/99 0s 2ms/step - loss: 4.4796e-05 - mean_absolute_error: 0.0047 - val_loss: 1.4341e-04 - val_mean_absolute_error: 0.0083
Epoch 94/100
99/99 0s 1ms/step - loss: 2.5219e-05 - mean_absolute_error: 0.0035 - val_loss: 1.4086e-04 - val_mean_absolute_error: 0.0083
Epoch 95/100
99/99 0s 1ms/step - loss: 2.8595e-05 - mean_absolute_error: 0.0038 - val_loss: 1.2537e-04 - val_mean_absolute_error: 0.0079
Epoch 96/100
99/99 0s 1ms/step - loss: 2.5369e-05 - mean_absolute_error: 0.0034 - val_loss: 1.3580e-04 - val_mean_absolute_error:

```
    ute_error: 0.0082
Epoch 97/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 2.6265e-05 - mean_absolute_error: 0.0036 - val_loss: 1.2756e-04 - val_mean_absol
    ute_error: 0.0080
Epoch 98/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 2.9455e-05 - mean_absolute_error: 0.0037 - val_loss: 1.1268e-04 - val_mean_absol
    ute_error: 0.0077
Epoch 99/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 2.7629e-05 - mean_absolute_error: 0.0036 - val_loss: 1.4222e-04 - val_mean_absol
    ute_error: 0.0086
Epoch 100/100
99/99 ━━━━━━━━ 0s 1ms/step - loss: 2.8067e-05 - mean_absolute_error: 0.0037 - val_loss: 1.0993e-04 - val_mean_absol
    ute_error: 0.0074

Out[ ]: <keras.src.callbacks.history.History at 0x1723df59d10>
```

```
In [ ]: train_pred = modelbase.predict(X_train).flatten()

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

99/99 ━━━━━━━━ 0s 1ms/step
```

```
Out[ ]: <matplotlib.legend.Legend at 0x172a8dc7f90>
```

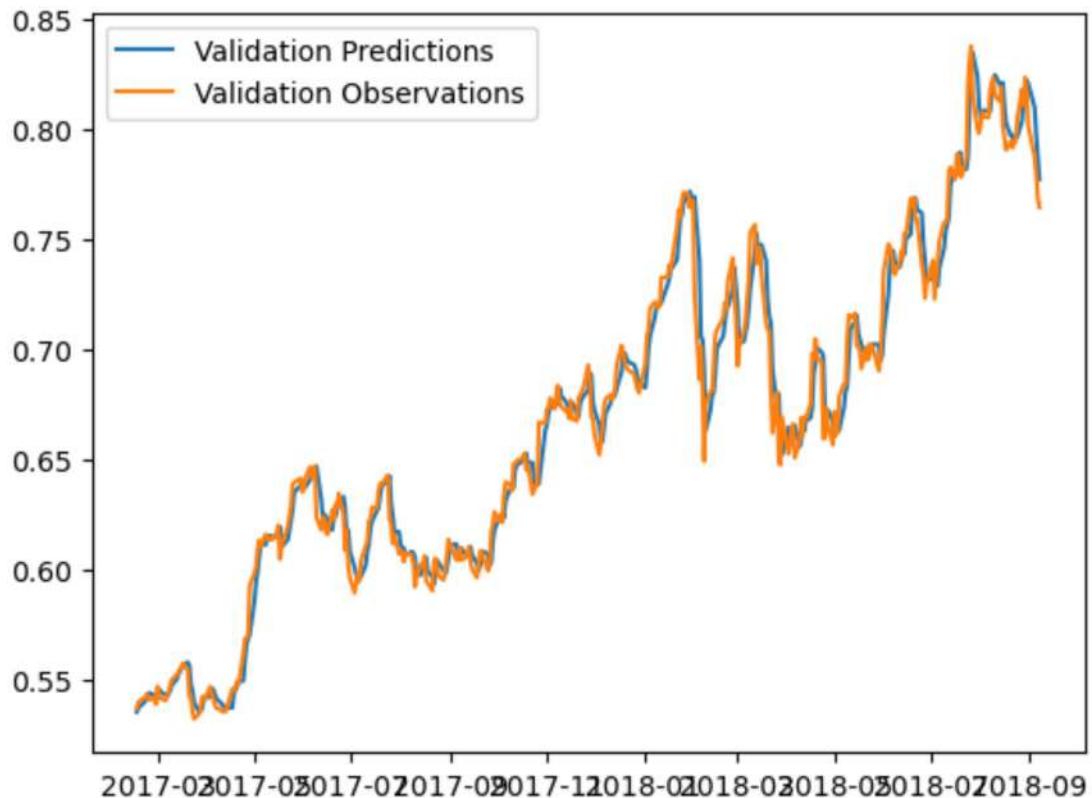


```
In [ ]: val_pred = modelbase.predict(X_val).flatten()

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

13/13 ━━━━━━ 0s 542us/step

```
Out[ ]: <matplotlib.legend.Legend at 0x172a8e2ba10>
```

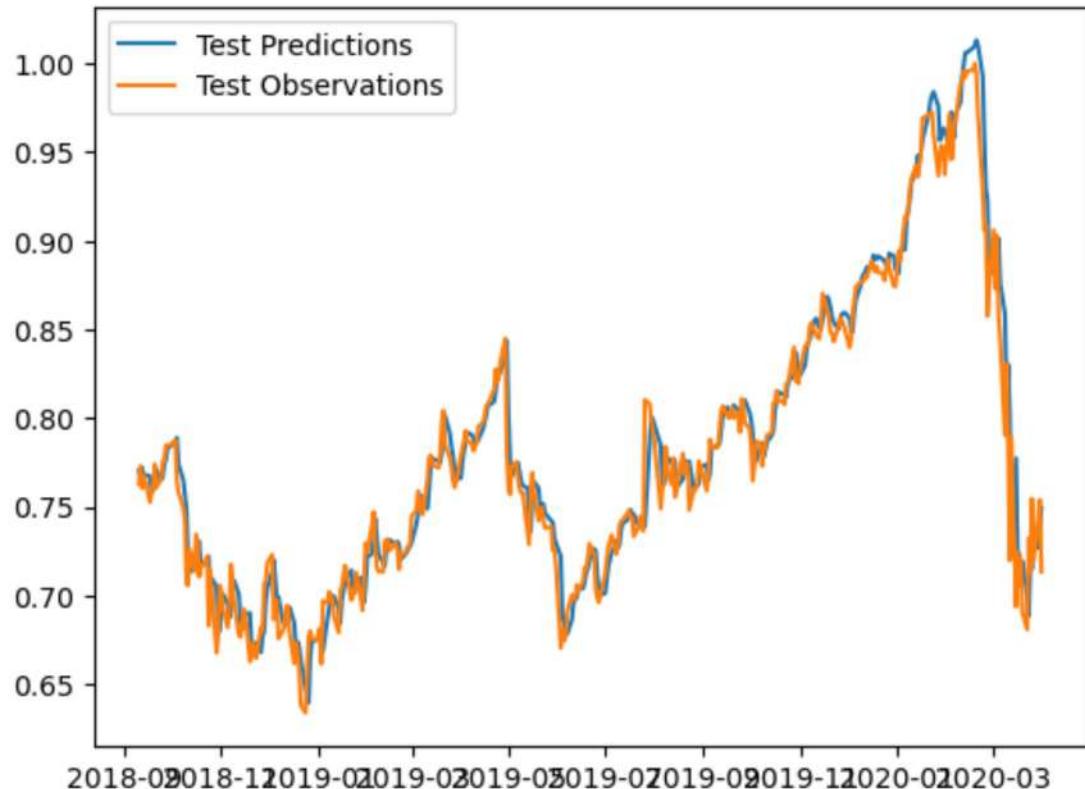


```
In [ ]: test_pred = modelbase.predict(X_test).flatten()

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

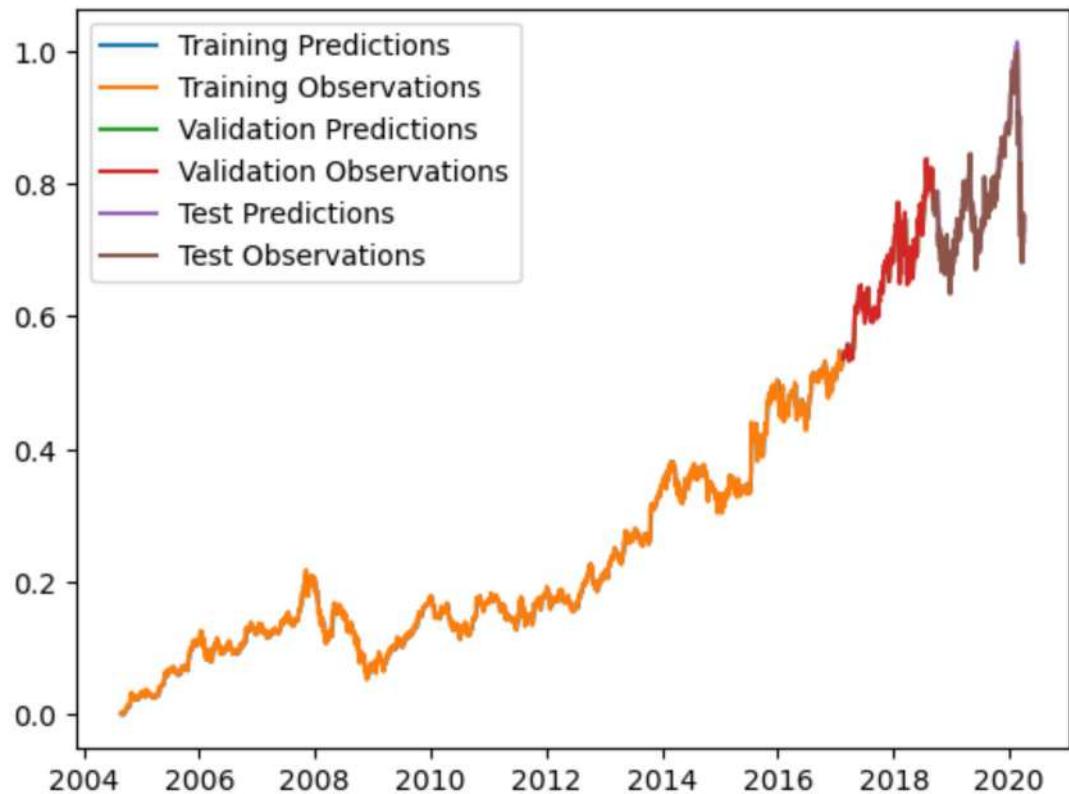
13/13 ━━━━━━━━ 0s 625us/step

```
Out[ ]: <matplotlib.legend.Legend at 0x172a8e54fd0>
```



```
In [ ]: plt.plot(dates_train, train_pred)
plt.plot(dates_train, y_train)
plt.plot(dates_val, val_pred)
plt.plot(dates_val, y_val)
plt.plot(dates_test, test_pred)
plt.plot(dates_test, y_test)
plt.legend(['Training Predictions', 'Training Observations',
           'Validation Predictions', 'Validation Observations',
           'Test Predictions', 'Test Observations'])
```

```
Out[ ]: <matplotlib.legend.Legend at 0x172aa030990>
```



Modified Model

```
In [ ]: model3 = Sequential([layers.Input((5,1)),
    layers.LSTM(128),
    layers.Dense(64, activation='relu'),
    layers.Dense(1)])
model3.compile(loss='mse',
    optimizer=Adam(learning_rate=0.001),
    metrics=['mean_absolute_error'])
early_stopping = EarlyStopping(monitor='val_mean_absolute_error', patience=10, restore_best_weights=True)
model3.fit(X_train, y_train, validation_data=(X_val, y_val), epochs = 100 , callbacks=early_stopping)
```

Epoch 1/100
99/99 1s 3ms/step - loss: 0.0095 - mean_absolute_error: 0.0581 - val_loss: 3.1000e-04 - val_mean_absolute_error: 0.0124
Epoch 2/100
99/99 0s 2ms/step - loss: 4.2748e-05 - mean_absolute_error: 0.0046 - val_loss: 2.7413e-04 - val_mean_absolute_error: 0.0117
Epoch 3/100
99/99 0s 2ms/step - loss: 4.3642e-05 - mean_absolute_error: 0.0046 - val_loss: 2.6911e-04 - val_mean_absolute_error: 0.0116
Epoch 4/100
99/99 0s 2ms/step - loss: 4.6000e-05 - mean_absolute_error: 0.0047 - val_loss: 2.3196e-04 - val_mean_absolute_error: 0.0112
Epoch 5/100
99/99 0s 2ms/step - loss: 4.5567e-05 - mean_absolute_error: 0.0046 - val_loss: 2.3260e-04 - val_mean_absolute_error: 0.0110
Epoch 6/100
99/99 0s 2ms/step - loss: 4.1561e-05 - mean_absolute_error: 0.0046 - val_loss: 2.5068e-04 - val_mean_absolute_error: 0.0112
Epoch 7/100
99/99 0s 2ms/step - loss: 4.1372e-05 - mean_absolute_error: 0.0045 - val_loss: 2.2409e-04 - val_mean_absolute_error: 0.0109
Epoch 8/100
99/99 0s 2ms/step - loss: 4.6413e-05 - mean_absolute_error: 0.0046 - val_loss: 2.1831e-04 - val_mean_absolute_error: 0.0109
Epoch 9/100
99/99 0s 2ms/step - loss: 4.7175e-05 - mean_absolute_error: 0.0049 - val_loss: 2.2850e-04 - val_mean_absolute_error: 0.0115
Epoch 10/100
99/99 0s 2ms/step - loss: 4.3310e-05 - mean_absolute_error: 0.0046 - val_loss: 2.1993e-04 - val_mean_absolute_error: 0.0112
Epoch 11/100
99/99 0s 2ms/step - loss: 5.0630e-05 - mean_absolute_error: 0.0052 - val_loss: 3.1205e-04 - val_mean_absolute_error: 0.0130
Epoch 12/100
99/99 0s 2ms/step - loss: 4.9110e-05 - mean_absolute_error: 0.0049 - val_loss: 2.1242e-04 - val_mean_absolute_error: 0.0105
Epoch 13/100
99/99 0s 2ms/step - loss: 3.7673e-05 - mean_absolute_error: 0.0042 - val_loss: 2.1516e-04 - val_mean_absolute_error: 0.0111
Epoch 14/100
99/99 0s 2ms/step - loss: 3.5894e-05 - mean_absolute_error: 0.0042 - val_loss: 6.6814e-04 - val_mean_absolute_error:

```
ute_error: 0.0219
Epoch 15/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 6.8147e-05 - mean_absolute_error: 0.0057 - val_loss: 1.9420e-04 - val_mean_absolute_error: 0.0102
Epoch 16/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 3.4862e-05 - mean_absolute_error: 0.0041 - val_loss: 2.0522e-04 - val_mean_absolute_error: 0.0109
Epoch 17/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.2580e-05 - mean_absolute_error: 0.0048 - val_loss: 2.2251e-04 - val_mean_absolute_error: 0.0106
Epoch 18/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.3365e-05 - mean_absolute_error: 0.0047 - val_loss: 1.8569e-04 - val_mean_absolute_error: 0.0099
Epoch 19/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 3.2511e-05 - mean_absolute_error: 0.0040 - val_loss: 1.8453e-04 - val_mean_absolute_error: 0.0098
Epoch 20/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.5520e-05 - mean_absolute_error: 0.0047 - val_loss: 3.1943e-04 - val_mean_absolute_error: 0.0150
Epoch 21/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.3948e-05 - mean_absolute_error: 0.0047 - val_loss: 3.3362e-04 - val_mean_absolute_error: 0.0154
Epoch 22/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.0565e-05 - mean_absolute_error: 0.0045 - val_loss: 2.0286e-04 - val_mean_absolute_error: 0.0109
Epoch 23/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 3.6471e-05 - mean_absolute_error: 0.0041 - val_loss: 2.2808e-04 - val_mean_absolute_error: 0.0119
Epoch 24/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.1536e-05 - mean_absolute_error: 0.0046 - val_loss: 5.9018e-04 - val_mean_absolute_error: 0.0216
Epoch 25/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.8002e-05 - mean_absolute_error: 0.0049 - val_loss: 1.9428e-04 - val_mean_absolute_error: 0.0107
Epoch 26/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 3.1814e-05 - mean_absolute_error: 0.0041 - val_loss: 2.0240e-04 - val_mean_absolute_error: 0.0103
Epoch 27/100
99/99 ━━━━━━━━ 0s 2ms/step - loss: 4.1095e-05 - mean_absolute_error: 0.0045 - val_loss: 1.5411e-04 - val_mean_absolute_error: 0.0090
Epoch 28/100
```

99/99 ━━━━━━━━ 0s 2ms/step - loss: 3.9645e-05 - mean_absolute_error: 0.0045 - val_loss: 3.7119e-04 - val_mean_absolute_error: 0.0167
Epoch 29/100
99/99 ━━━━━━ 0s 2ms/step - loss: 4.2939e-05 - mean_absolute_error: 0.0048 - val_loss: 1.5325e-04 - val_mean_absolute_error: 0.0092
Epoch 30/100
99/99 ━━━━ 0s 2ms/step - loss: 4.1507e-05 - mean_absolute_error: 0.0042 - val_loss: 1.6964e-04 - val_mean_absolute_error: 0.0093
Epoch 31/100
99/99 ━━━━ 0s 2ms/step - loss: 2.9377e-05 - mean_absolute_error: 0.0037 - val_loss: 1.5838e-04 - val_mean_absolute_error: 0.0095
Epoch 32/100
99/99 ━━━━ 0s 2ms/step - loss: 3.4985e-05 - mean_absolute_error: 0.0042 - val_loss: 1.5253e-04 - val_mean_absolute_error: 0.0093
Epoch 33/100
99/99 ━━━━ 0s 2ms/step - loss: 3.6131e-05 - mean_absolute_error: 0.0042 - val_loss: 1.6153e-04 - val_mean_absolute_error: 0.0092
Epoch 34/100
99/99 ━━━━ 0s 2ms/step - loss: 3.0904e-05 - mean_absolute_error: 0.0039 - val_loss: 1.7580e-04 - val_mean_absolute_error: 0.0097
Epoch 35/100
99/99 ━━━━ 0s 2ms/step - loss: 3.6921e-05 - mean_absolute_error: 0.0041 - val_loss: 1.3540e-04 - val_mean_absolute_error: 0.0083
Epoch 36/100
99/99 ━━━━ 0s 2ms/step - loss: 3.5792e-05 - mean_absolute_error: 0.0043 - val_loss: 1.6933e-04 - val_mean_absolute_error: 0.0095
Epoch 37/100
99/99 ━━━━ 0s 2ms/step - loss: 3.0914e-05 - mean_absolute_error: 0.0040 - val_loss: 1.3362e-04 - val_mean_absolute_error: 0.0082
Epoch 38/100
99/99 ━━━━ 0s 2ms/step - loss: 2.7184e-05 - mean_absolute_error: 0.0038 - val_loss: 2.8296e-04 - val_mean_absolute_error: 0.0135
Epoch 39/100
99/99 ━━━━ 0s 2ms/step - loss: 3.4151e-05 - mean_absolute_error: 0.0042 - val_loss: 3.1008e-04 - val_mean_absolute_error: 0.0153
Epoch 40/100
99/99 ━━━━ 0s 2ms/step - loss: 2.8312e-05 - mean_absolute_error: 0.0036 - val_loss: 1.5330e-04 - val_mean_absolute_error: 0.0097
Epoch 41/100
99/99 ━━━━ 0s 2ms/step - loss: 3.4462e-05 - mean_absolute_error: 0.0042 - val_loss: 1.2869e-04 - val_mean_absolute_error: 0.0085

Epoch 42/100
99/99 ━━━━━━ 0s 2ms/step - loss: 3.4916e-05 - mean_absolute_error: 0.0043 - val_loss: 1.9693e-04 - val_mean_absolute_error: 0.0116
Epoch 43/100
99/99 ━━━━━━ 0s 2ms/step - loss: 3.4778e-05 - mean_absolute_error: 0.0044 - val_loss: 1.1499e-04 - val_mean_absolute_error: 0.0078
Epoch 44/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.8773e-05 - mean_absolute_error: 0.0036 - val_loss: 1.0974e-04 - val_mean_absolute_error: 0.0076
Epoch 45/100
99/99 ━━━━━━ 0s 2ms/step - loss: 3.0725e-05 - mean_absolute_error: 0.0041 - val_loss: 1.0761e-04 - val_mean_absolute_error: 0.0074
Epoch 46/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.4618e-05 - mean_absolute_error: 0.0035 - val_loss: 1.2511e-04 - val_mean_absolute_error: 0.0085
Epoch 47/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.6192e-05 - mean_absolute_error: 0.0037 - val_loss: 1.2335e-04 - val_mean_absolute_error: 0.0080
Epoch 48/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.5188e-05 - mean_absolute_error: 0.0035 - val_loss: 1.0814e-04 - val_mean_absolute_error: 0.0074
Epoch 49/100
99/99 ━━━━━━ 0s 2ms/step - loss: 3.2243e-05 - mean_absolute_error: 0.0040 - val_loss: 1.0869e-04 - val_mean_absolute_error: 0.0077
Epoch 50/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.4833e-05 - mean_absolute_error: 0.0036 - val_loss: 1.2293e-04 - val_mean_absolute_error: 0.0085
Epoch 51/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.1813e-05 - mean_absolute_error: 0.0033 - val_loss: 1.6196e-04 - val_mean_absolute_error: 0.0098
Epoch 52/100
99/99 ━━━━━━ 0s 2ms/step - loss: 3.2193e-05 - mean_absolute_error: 0.0043 - val_loss: 2.2613e-04 - val_mean_absolute_error: 0.0121
Epoch 53/100
99/99 ━━━━━━ 0s 2ms/step - loss: 3.0445e-05 - mean_absolute_error: 0.0039 - val_loss: 1.5516e-04 - val_mean_absolute_error: 0.0101
Epoch 54/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.9266e-05 - mean_absolute_error: 0.0037 - val_loss: 9.8255e-05 - val_mean_absolute_error: 0.0071
Epoch 55/100
99/99 ━━━━━━ 0s 2ms/step - loss: 2.9587e-05 - mean_absolute_error: 0.0038 - val_loss: 1.5319e-04 - val_mean_absolute_error:

```
ute_error: 0.0100
Epoch 56/100
99/99 0s 2ms/step - loss: 2.4621e-05 - mean_absolute_error: 0.0035 - val_loss: 1.3589e-04 - val_mean_absolute_error: 0.0087
Epoch 57/100
99/99 0s 1ms/step - loss: 2.0416e-05 - mean_absolute_error: 0.0031 - val_loss: 4.0643e-04 - val_mean_absolute_error: 0.0182
Epoch 58/100
99/99 0s 2ms/step - loss: 2.8580e-05 - mean_absolute_error: 0.0039 - val_loss: 9.8569e-05 - val_mean_absolute_error: 0.0072
Epoch 59/100
99/99 0s 2ms/step - loss: 2.3188e-05 - mean_absolute_error: 0.0033 - val_loss: 9.2879e-05 - val_mean_absolute_error: 0.0068
Epoch 60/100
99/99 0s 2ms/step - loss: 2.0145e-05 - mean_absolute_error: 0.0031 - val_loss: 9.1789e-05 - val_mean_absolute_error: 0.0068
Epoch 61/100
99/99 0s 2ms/step - loss: 2.1894e-05 - mean_absolute_error: 0.0033 - val_loss: 1.2754e-04 - val_mean_absolute_error: 0.0085
Epoch 62/100
99/99 0s 2ms/step - loss: 3.4435e-05 - mean_absolute_error: 0.0043 - val_loss: 9.2323e-05 - val_mean_absolute_error: 0.0068
Epoch 63/100
99/99 0s 2ms/step - loss: 2.1659e-05 - mean_absolute_error: 0.0033 - val_loss: 9.4361e-05 - val_mean_absolute_error: 0.0070
Epoch 64/100
99/99 0s 2ms/step - loss: 2.3865e-05 - mean_absolute_error: 0.0034 - val_loss: 1.0596e-04 - val_mean_absolute_error: 0.0077
Epoch 65/100
99/99 0s 2ms/step - loss: 2.6644e-05 - mean_absolute_error: 0.0038 - val_loss: 9.0741e-05 - val_mean_absolute_error: 0.0067
Epoch 66/100
99/99 0s 2ms/step - loss: 2.2578e-05 - mean_absolute_error: 0.0032 - val_loss: 2.0855e-04 - val_mean_absolute_error: 0.0123
Epoch 67/100
99/99 0s 2ms/step - loss: 2.2665e-05 - mean_absolute_error: 0.0033 - val_loss: 9.3157e-05 - val_mean_absolute_error: 0.0069
Epoch 68/100
99/99 0s 2ms/step - loss: 2.5480e-05 - mean_absolute_error: 0.0036 - val_loss: 1.1875e-04 - val_mean_absolute_error: 0.0085
Epoch 69/100
```

```
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.1471e-05 - mean_absolute_error: 0.0032 - val_loss: 1.0734e-04 - val_mean_absolute_error: 0.0076
Epoch 70/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.3212e-05 - mean_absolute_error: 0.0032 - val_loss: 8.9679e-05 - val_mean_absolute_error: 0.0066
Epoch 71/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.1523e-05 - mean_absolute_error: 0.0031 - val_loss: 9.0516e-05 - val_mean_absolute_error: 0.0067
Epoch 72/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 3.3871e-05 - mean_absolute_error: 0.0041 - val_loss: 1.0388e-04 - val_mean_absolute_error: 0.0077
Epoch 73/100
99/99 ━━━━━━━━━━ 0s 1ms/step - loss: 2.4834e-05 - mean_absolute_error: 0.0034 - val_loss: 9.4505e-05 - val_mean_absolute_error: 0.0070
Epoch 74/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.4910e-05 - mean_absolute_error: 0.0036 - val_loss: 3.0235e-04 - val_mean_absolute_error: 0.0153
Epoch 75/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.2565e-05 - mean_absolute_error: 0.0033 - val_loss: 1.6848e-04 - val_mean_absolute_error: 0.0107
Epoch 76/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.5279e-05 - mean_absolute_error: 0.0035 - val_loss: 9.2285e-05 - val_mean_absolute_error: 0.0068
Epoch 77/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 1.8816e-05 - mean_absolute_error: 0.0030 - val_loss: 1.0584e-04 - val_mean_absolute_error: 0.0075
Epoch 78/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.4839e-05 - mean_absolute_error: 0.0034 - val_loss: 1.2304e-04 - val_mean_absolute_error: 0.0084
Epoch 79/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 3.3421e-05 - mean_absolute_error: 0.0042 - val_loss: 9.9936e-05 - val_mean_absolute_error: 0.0072
Epoch 80/100
99/99 ━━━━━━━━━━ 0s 2ms/step - loss: 2.0935e-05 - mean_absolute_error: 0.0031 - val_loss: 1.5011e-04 - val_mean_absolute_error: 0.0099
```

Out[]: <keras.src.callbacks.history.History at 0x172b85eeb10>

In []: train3_pred = model3.predict(X_train).flatten()
plt.plot(dates_train, train3_pred)

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

99/99 ━━━━━━ 0s 2ms/step

Out[]: <matplotlib.legend.Legend at 0x172bb0add90>

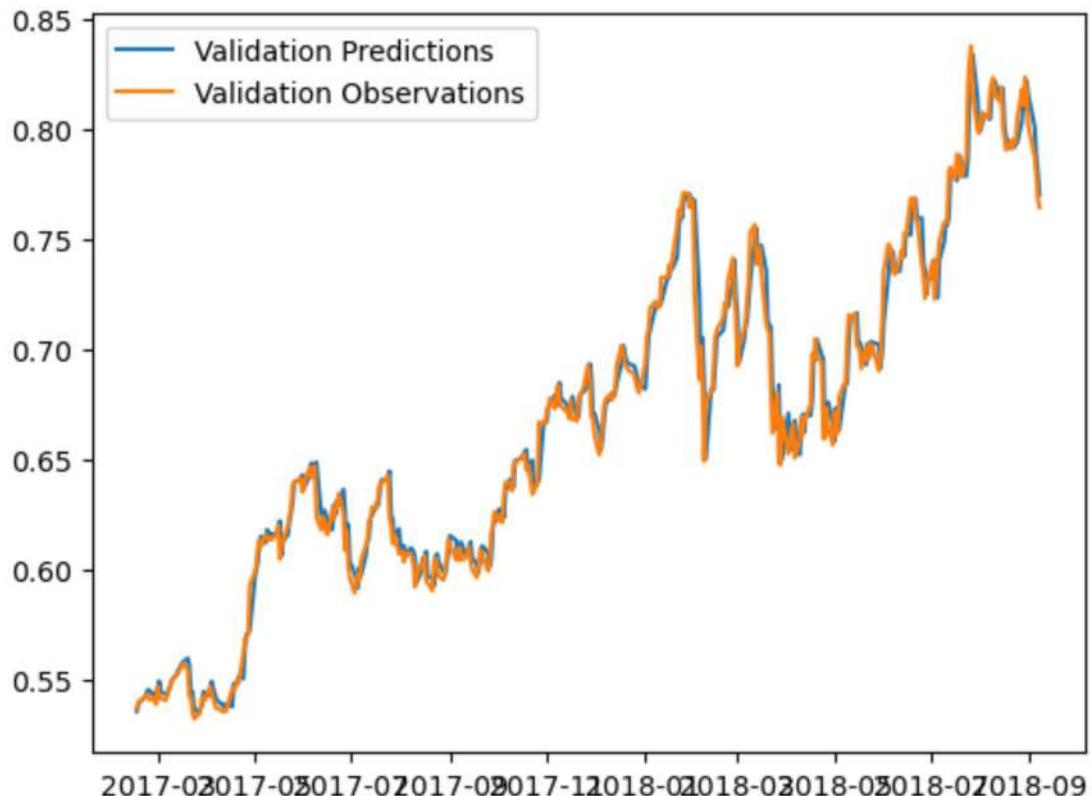


```
In [ ]: val3_pred = model3.predict(X_val).flatten()

plt.plot(dates_val, val3_pred)
plt.plot(dates_val, y_val)
plt.legend(['Validation Predictions', 'Validation Observations'])
```

13/13 ━━━━━━ 0s 876us/step

Out[]: <matplotlib.legend.Legend at 0x172bb1e5d90>

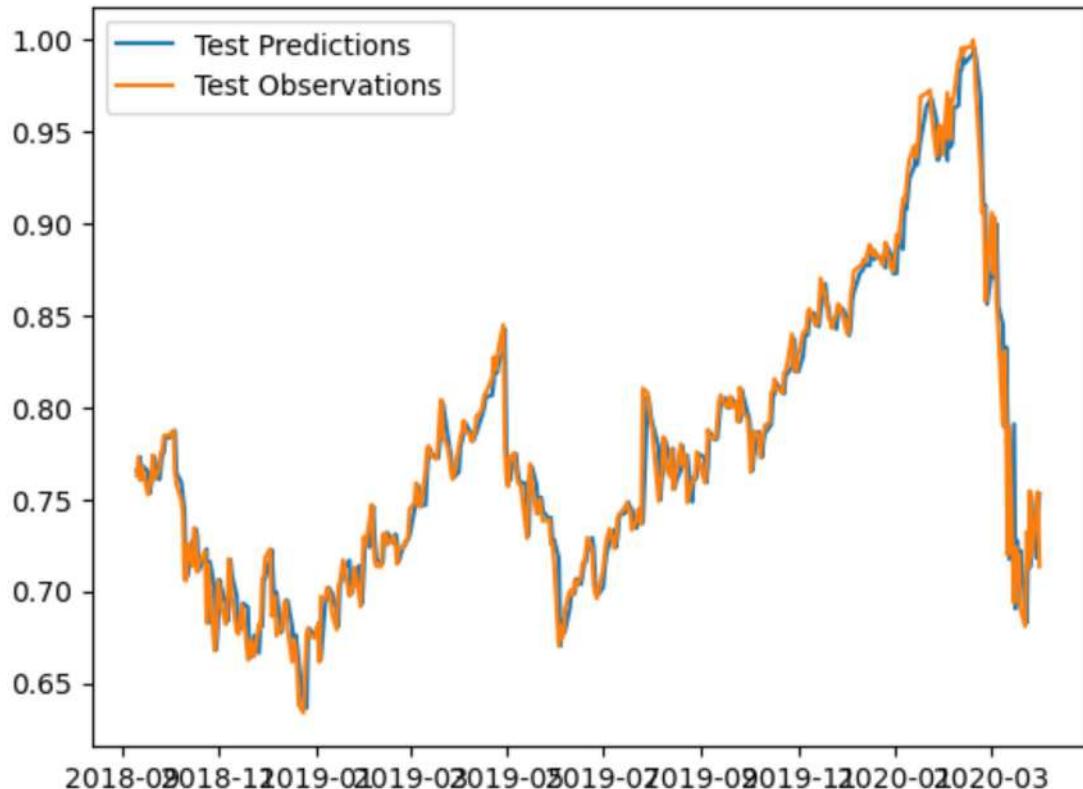


```
In [ ]: test3_pred = model3.predict(X_test).flatten()

plt.plot(dates_test, test3_pred)
plt.plot(dates_test, y_test)
plt.legend(['Test Predictions', 'Test Observations'])
```

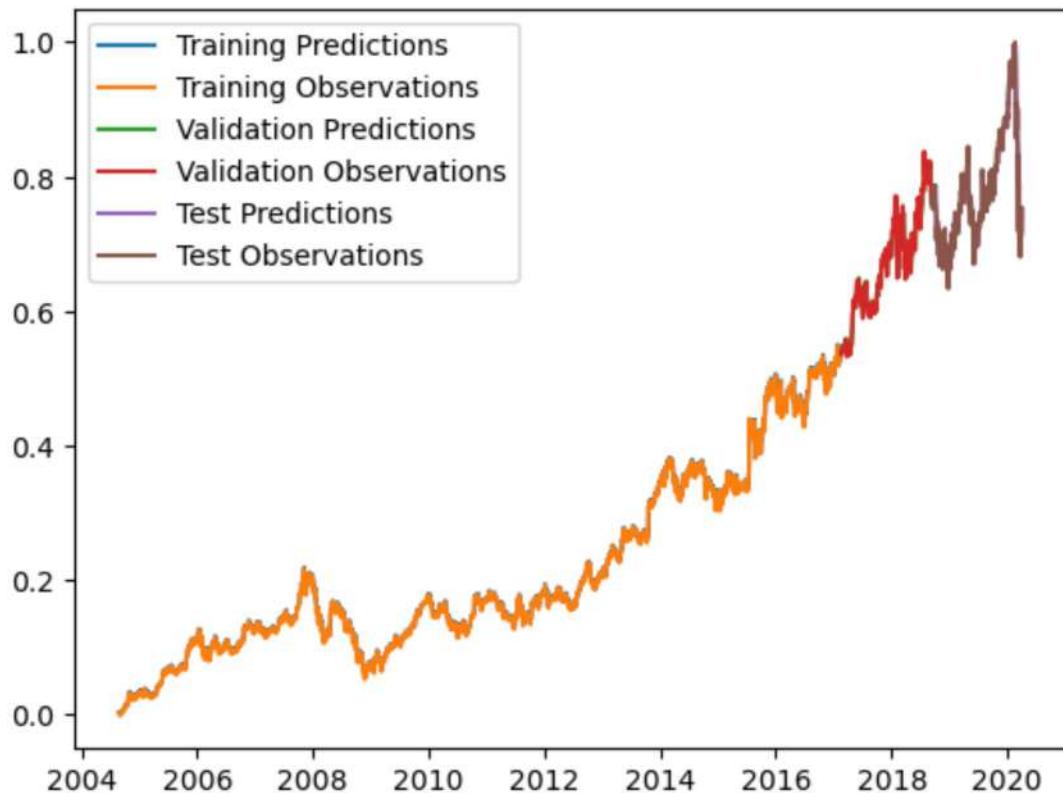
13/13 ━━━━━━━━ 0s 708us/step

```
Out[ ]: <matplotlib.legend.Legend at 0x172baf8d0d0>
```



```
In [ ]: plt.plot(dates_train, train3_pred)
plt.plot(dates_train, y_train)
plt.plot(dates_val, val3_pred)
plt.plot(dates_val, y_val)
plt.plot(dates_test, test3_pred)
plt.plot(dates_test, y_test)
plt.legend(['Training Predictions', 'Training Observations',
           'Validation Predictions', 'Validation Observations',
           'Test Predictions', 'Test Observations'])
```

```
Out[ ]: <matplotlib.legend.Legend at 0x172bb0ee510>
```



RMSE, MAE, MAPE Evaluation

```
In [ ]: from sklearn.metrics import mean_squared_error, mean_absolute_error
```

```
In [ ]: def calculate_metrics(y_true, y_pred):  
    rmse = np.sqrt(mean_squared_error(y_true, y_pred))  
    mae = mean_absolute_error(y_true, y_pred)  
    mape = np.mean(np.abs((y_true - y_pred) / y_true)) * 100  
    return rmse, mae, mape
```

```
In [ ]: rmse_base, mae_base, mape_base = calculate_metrics(y_test, test_pred)  
rmse_opt, mae_opt, mape_opt = calculate_metrics(y_test, test3_pred)
```

```
In [ ]: print(f'Base Model - RMSE: {rmse_base}, MAE: {mae_base}, MAPE: {mape_base}')
```

```
In [ ]: print(f'Modified Model - RMSE: {rmse_opt}, MAE: {mae_opt}, MAPE: {mape_opt}')
```

Base Model - RMSE: 0.016850896179676056, MAE: 0.011358620598912239, MAPE: 1.4774334616959095

Modified Model - RMSE: 0.0164326224476099, MAE: 0.010888946242630482, MAPE: 1.420182641595602

```
In [ ]: improvement_rmse = ((rmse_base - rmse_opt) / rmse_base) * 100
```

```
In [ ]: improvement_mae = ((mae_base - mae_opt) / mae_base) * 100
```

```
In [ ]: improvement_mape = ((mape_base - mape_opt) / mape_base) * 100
```



```
In [ ]: print(f'Improvement RMSE: {improvement_rmse:.2f}%')
```

```
In [ ]: print(f'Improvement MAE: {improvement_mae:.2f}%')
```

```
In [ ]: print(f'Improvement MAPE: {improvement_mape:.2f}%')
```

Improvement RMSE: 2.48%

Improvement MAE: 4.13%

Improvement MAPE: 3.88%

INTC LSTM

```
In [ ]: scaler = MinMaxScaler(feature_range=(0,1))
```

```
In [ ]: dfint['Close'] = scaler.fit_transform(dfint['Close'].values.reshape(-1,1))
```

```
In [ ]: windowed_intc = window(dfint,"1980-03-24","2020-04-01",5)
```

```
In [ ]: windowed_intc
```

Out[]:

	Target Date	Target-0	Target-1	Target-2	Target-3	Target-4	Target
0	1980-03-24	0.001465	0.001430	0.001535	0.001517	0.001360	0.001273
1	1980-03-25	0.001430	0.001535	0.001517	0.001360	0.001273	0.001291
2	1980-03-26	0.001535	0.001517	0.001360	0.001273	0.001291	0.001256
3	1980-03-27	0.001517	0.001360	0.001273	0.001291	0.001256	0.001116
4	1980-03-28	0.001360	0.001273	0.001291	0.001256	0.001116	0.001273
...
10088	2020-03-26	0.612437	0.610964	0.661192	0.698964	0.683695	0.741022
10089	2020-03-27	0.610964	0.661192	0.698964	0.683695	0.741022	0.698562
10090	2020-03-30	0.661192	0.698964	0.683695	0.741022	0.698562	0.740352
10091	2020-03-31	0.698964	0.683695	0.741022	0.698562	0.740352	0.722002
10092	2020-04-01	0.683695	0.741022	0.698562	0.740352	0.722002	0.691999

10093 rows × 7 columns

In []: `dates, X, y = getXY(windowed_intc)`
`dates.shape, X.shape, y.shape`

Out[]: ((10093,), (10093, 5, 1), (10093,))

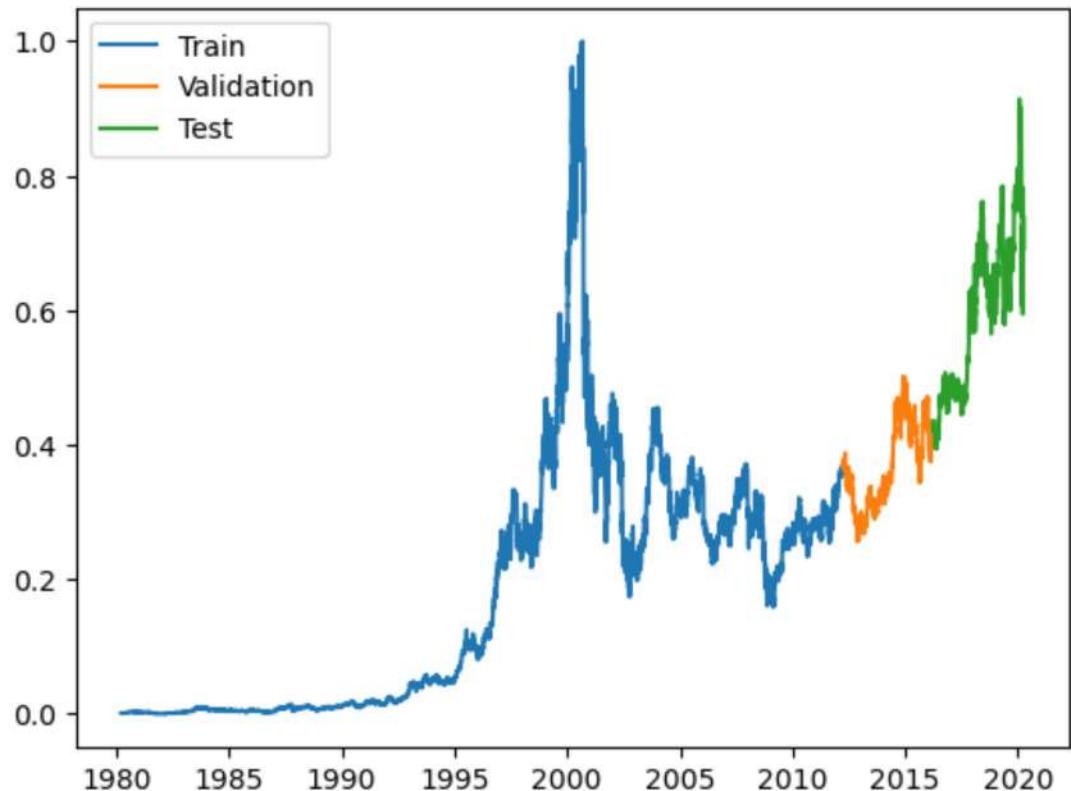
In []: `q_80 = int(len(dates) * .8)`
`q_90 = int(len(dates) * .9)`

`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:]`

In []: `plt.plot(dates_train, y_train)`
`plt.plot(dates_val, y_val)`
`plt.plot(dates_test, y_test)`

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

Out[]: <matplotlib.legend.Legend at 0x171452eca10>



Base Model

```
In [ ]: modelbase = Sequential()
modelbase.add(Input((5,1)))
modelbase.add(LSTM(units=50, activation='relu', return_sequences=False))
modelbase.add(Dense(1))
modelbase.compile(optimizer='adam', loss='mean_squared_error', metrics=['mean_absolute_error'])
modelbase.fit(X_train, y_train, validation_data=(X_val, y_val), epochs = 100)
```

Epoch 1/100
253/253 1s 1ms/step - loss: 0.0137 - mean_absolute_error: 0.0652 - val_loss: 1.1034e-04 - val_mean_absolute_error: 0.0080
Epoch 2/100
253/253 0s 889us/step - loss: 1.2074e-04 - mean_absolute_error: 0.0059 - val_loss: 7.3789e-05 - val_mean_absolute_error: 0.0065
Epoch 3/100
253/253 0s 907us/step - loss: 1.5278e-04 - mean_absolute_error: 0.0068 - val_loss: 9.3386e-05 - val_mean_absolute_error: 0.0077
Epoch 4/100
253/253 0s 903us/step - loss: 1.2141e-04 - mean_absolute_error: 0.0064 - val_loss: 8.4922e-05 - val_mean_absolute_error: 0.0073
Epoch 5/100
253/253 0s 937us/step - loss: 1.4344e-04 - mean_absolute_error: 0.0069 - val_loss: 9.6112e-05 - val_mean_absolute_error: 0.0077
Epoch 6/100
253/253 0s 899us/step - loss: 1.3348e-04 - mean_absolute_error: 0.0067 - val_loss: 6.9268e-05 - val_mean_absolute_error: 0.0064
Epoch 7/100
253/253 0s 903us/step - loss: 1.3453e-04 - mean_absolute_error: 0.0068 - val_loss: 6.0772e-05 - val_mean_absolute_error: 0.0059
Epoch 8/100
253/253 0s 919us/step - loss: 1.2610e-04 - mean_absolute_error: 0.0063 - val_loss: 2.0948e-04 - val_mean_absolute_error: 0.0126
Epoch 9/100
253/253 0s 899us/step - loss: 1.0820e-04 - mean_absolute_error: 0.0063 - val_loss: 6.0456e-05 - val_mean_absolute_error: 0.0058
Epoch 10/100
253/253 0s 1ms/step - loss: 1.0523e-04 - mean_absolute_error: 0.0059 - val_loss: 6.1327e-05 - val_mean_absolute_error: 0.0061
Epoch 11/100
253/253 0s 907us/step - loss: 1.1498e-04 - mean_absolute_error: 0.0059 - val_loss: 5.1517e-05 - val_mean_absolute_error: 0.0054
Epoch 12/100
253/253 0s 923us/step - loss: 1.1259e-04 - mean_absolute_error: 0.0065 - val_loss: 5.7878e-05 - val_mean_absolute_error: 0.0059
Epoch 13/100
253/253 0s 881us/step - loss: 1.1195e-04 - mean_absolute_error: 0.0063 - val_loss: 5.9326e-05 - val_mean_absolute_error: 0.0060
Epoch 14/100
253/253 0s 885us/step - loss: 9.0953e-05 - mean_absolute_error: 0.0054 - val_loss: 6.4941e-05 - val_mean_absolute_error: 0.0054

```
bsolute_error: 0.0061
Epoch 15/100
253/253 0s 897us/step - loss: 9.1076e-05 - mean_absolute_error: 0.0054 - val_loss: 5.0310e-05 - val_mean_a
bsolute_error: 0.0053
Epoch 16/100
253/253 0s 1ms/step - loss: 1.1567e-04 - mean_absolute_error: 0.0060 - val_loss: 1.0653e-04 - val_mean_abs
olute_error: 0.0087
Epoch 17/100
253/253 0s 929us/step - loss: 9.9089e-05 - mean_absolute_error: 0.0056 - val_loss: 1.0927e-04 - val_mean_a
bsolute_error: 0.0086
Epoch 18/100
253/253 0s 933us/step - loss: 9.4332e-05 - mean_absolute_error: 0.0057 - val_loss: 1.3292e-04 - val_mean_a
bsolute_error: 0.0099
Epoch 19/100
253/253 0s 959us/step - loss: 1.0027e-04 - mean_absolute_error: 0.0056 - val_loss: 1.0817e-04 - val_mean_a
bsolute_error: 0.0087
Epoch 20/100
253/253 0s 957us/step - loss: 9.6314e-05 - mean_absolute_error: 0.0057 - val_loss: 4.4868e-05 - val_mean_a
bsolute_error: 0.0050
Epoch 21/100
253/253 0s 953us/step - loss: 9.1903e-05 - mean_absolute_error: 0.0054 - val_loss: 4.1454e-05 - val_mean_a
bsolute_error: 0.0048
Epoch 22/100
253/253 0s 1ms/step - loss: 8.2493e-05 - mean_absolute_error: 0.0049 - val_loss: 4.7943e-05 - val_mean_abs
olute_error: 0.0051
Epoch 23/100
253/253 0s 939us/step - loss: 8.8429e-05 - mean_absolute_error: 0.0049 - val_loss: 4.0749e-05 - val_mean_a
bsolute_error: 0.0047
Epoch 24/100
253/253 0s 1ms/step - loss: 8.4444e-05 - mean_absolute_error: 0.0053 - val_loss: 4.7153e-05 - val_mean_abs
olute_error: 0.0052
Epoch 25/100
253/253 0s 935us/step - loss: 8.4328e-05 - mean_absolute_error: 0.0055 - val_loss: 5.0694e-05 - val_mean_a
bsolute_error: 0.0054
Epoch 26/100
253/253 0s 953us/step - loss: 8.1071e-05 - mean_absolute_error: 0.0050 - val_loss: 4.9909e-05 - val_mean_a
bsolute_error: 0.0054
Epoch 27/100
253/253 0s 929us/step - loss: 8.0512e-05 - mean_absolute_error: 0.0053 - val_loss: 8.3118e-05 - val_mean_a
bsolute_error: 0.0073
Epoch 28/100
```

```
253/253 ━━━━━━━━ 0s 953us/step - loss: 7.9137e-05 - mean_absolute_error: 0.0051 - val_loss: 1.5044e-04 - val_mean_absolute_error: 0.0108
Epoch 29/100
253/253 ━━━━━━━━ 0s 939us/step - loss: 9.1582e-05 - mean_absolute_error: 0.0054 - val_loss: 4.0891e-05 - val_mean_absolute_error: 0.0048
Epoch 30/100
253/253 ━━━━━━━━ 0s 1ms/step - loss: 8.9624e-05 - mean_absolute_error: 0.0053 - val_loss: 7.6076e-05 - val_mean_absolute_error: 0.0071
Epoch 31/100
253/253 ━━━━━━━━ 0s 927us/step - loss: 8.8859e-05 - mean_absolute_error: 0.0054 - val_loss: 9.7151e-05 - val_mean_absolute_error: 0.0083
Epoch 32/100
253/253 ━━━━━━━━ 0s 927us/step - loss: 8.9076e-05 - mean_absolute_error: 0.0057 - val_loss: 4.2435e-05 - val_mean_absolute_error: 0.0048
Epoch 33/100
253/253 ━━━━━━━━ 0s 931us/step - loss: 7.1760e-05 - mean_absolute_error: 0.0047 - val_loss: 4.6884e-05 - val_mean_absolute_error: 0.0052
Epoch 34/100
253/253 ━━━━━━━━ 0s 935us/step - loss: 7.5967e-05 - mean_absolute_error: 0.0052 - val_loss: 3.9342e-05 - val_mean_absolute_error: 0.0047
Epoch 35/100
253/253 ━━━━━━━━ 0s 1ms/step - loss: 6.7706e-05 - mean_absolute_error: 0.0048 - val_loss: 4.4724e-05 - val_mean_absolute_error: 0.0050
Epoch 36/100
253/253 ━━━━━━━━ 0s 943us/step - loss: 8.0929e-05 - mean_absolute_error: 0.0054 - val_loss: 4.0734e-05 - val_mean_absolute_error: 0.0048
Epoch 37/100
253/253 ━━━━━━━━ 0s 951us/step - loss: 8.1496e-05 - mean_absolute_error: 0.0049 - val_loss: 3.7282e-05 - val_mean_absolute_error: 0.0045
Epoch 38/100
253/253 ━━━━━━━━ 0s 921us/step - loss: 9.4336e-05 - mean_absolute_error: 0.0052 - val_loss: 6.1066e-05 - val_mean_absolute_error: 0.0061
Epoch 39/100
253/253 ━━━━━━━━ 0s 933us/step - loss: 8.9087e-05 - mean_absolute_error: 0.0055 - val_loss: 3.6327e-05 - val_mean_absolute_error: 0.0045
Epoch 40/100
253/253 ━━━━━━━━ 0s 937us/step - loss: 7.6649e-05 - mean_absolute_error: 0.0050 - val_loss: 5.0957e-05 - val_mean_absolute_error: 0.0055
Epoch 41/100
253/253 ━━━━━━━━ 0s 1ms/step - loss: 7.1925e-05 - mean_absolute_error: 0.0048 - val_loss: 3.6742e-05 - val_mean_absolute_error: 0.0045
```

```
Epoch 42/100
253/253 0s 949us/step - loss: 7.6330e-05 - mean_absolute_error: 0.0052 - val_loss: 4.2786e-05 - val_mean_absolute_error: 0.0049
Epoch 43/100
253/253 0s 935us/step - loss: 6.7615e-05 - mean_absolute_error: 0.0049 - val_loss: 3.5914e-05 - val_mean_absolute_error: 0.0044
Epoch 44/100
253/253 0s 923us/step - loss: 7.4271e-05 - mean_absolute_error: 0.0048 - val_loss: 4.5088e-05 - val_mean_absolute_error: 0.0052
Epoch 45/100
253/253 0s 907us/step - loss: 6.9772e-05 - mean_absolute_error: 0.0048 - val_loss: 6.4385e-05 - val_mean_absolute_error: 0.0063
Epoch 46/100
253/253 0s 911us/step - loss: 8.5809e-05 - mean_absolute_error: 0.0050 - val_loss: 3.9791e-05 - val_mean_absolute_error: 0.0047
Epoch 47/100
253/253 0s 1ms/step - loss: 6.5528e-05 - mean_absolute_error: 0.0045 - val_loss: 3.4354e-05 - val_mean_absolute_error: 0.0043
Epoch 48/100
253/253 0s 949us/step - loss: 7.0425e-05 - mean_absolute_error: 0.0046 - val_loss: 3.5733e-05 - val_mean_absolute_error: 0.0044
Epoch 49/100
253/253 0s 939us/step - loss: 6.5819e-05 - mean_absolute_error: 0.0046 - val_loss: 3.4107e-05 - val_mean_absolute_error: 0.0043
Epoch 50/100
253/253 0s 941us/step - loss: 5.9367e-05 - mean_absolute_error: 0.0043 - val_loss: 1.6106e-04 - val_mean_absolute_error: 0.0115
Epoch 51/100
253/253 0s 947us/step - loss: 7.1581e-05 - mean_absolute_error: 0.0049 - val_loss: 5.0396e-05 - val_mean_absolute_error: 0.0055
Epoch 52/100
253/253 0s 1ms/step - loss: 6.9700e-05 - mean_absolute_error: 0.0047 - val_loss: 3.3352e-05 - val_mean_absolute_error: 0.0042
Epoch 53/100
253/253 0s 923us/step - loss: 6.9892e-05 - mean_absolute_error: 0.0045 - val_loss: 3.9784e-05 - val_mean_absolute_error: 0.0047
Epoch 54/100
253/253 0s 935us/step - loss: 7.5646e-05 - mean_absolute_error: 0.0048 - val_loss: 3.2989e-05 - val_mean_absolute_error: 0.0042
Epoch 55/100
253/253 0s 929us/step - loss: 6.6132e-05 - mean_absolute_error: 0.0047 - val_loss: 3.6206e-05 - val_mean_absolute_error: 0.0047
```

```
bsolute_error: 0.0044
Epoch 56/100
253/253 0s 943us/step - loss: 6.6867e-05 - mean_absolute_error: 0.0044 - val_loss: 3.3446e-05 - val_mean_a
bsolute_error: 0.0042
Epoch 57/100
253/253 0s 923us/step - loss: 7.0504e-05 - mean_absolute_error: 0.0047 - val_loss: 3.3513e-05 - val_mean_a
bsolute_error: 0.0042
Epoch 58/100
253/253 0s 1ms/step - loss: 6.5636e-05 - mean_absolute_error: 0.0044 - val_loss: 6.7461e-05 - val_mean_abs
olute_error: 0.0067
Epoch 59/100
253/253 0s 921us/step - loss: 6.4403e-05 - mean_absolute_error: 0.0048 - val_loss: 4.3146e-05 - val_mean_a
bsolute_error: 0.0049
Epoch 60/100
253/253 0s 899us/step - loss: 7.2443e-05 - mean_absolute_error: 0.0049 - val_loss: 9.5495e-05 - val_mean_a
bsolute_error: 0.0084
Epoch 61/100
253/253 0s 959us/step - loss: 7.4095e-05 - mean_absolute_error: 0.0048 - val_loss: 4.7473e-05 - val_mean_a
bsolute_error: 0.0053
Epoch 62/100
253/253 0s 939us/step - loss: 5.9918e-05 - mean_absolute_error: 0.0044 - val_loss: 4.6888e-05 - val_mean_a
bsolute_error: 0.0053
Epoch 63/100
253/253 0s 1ms/step - loss: 6.2026e-05 - mean_absolute_error: 0.0043 - val_loss: 3.3284e-05 - val_mean_abs
olute_error: 0.0042
Epoch 64/100
253/253 0s 901us/step - loss: 5.9307e-05 - mean_absolute_error: 0.0044 - val_loss: 3.2511e-05 - val_mean_a
bsolute_error: 0.0041
Epoch 65/100
253/253 0s 913us/step - loss: 6.2100e-05 - mean_absolute_error: 0.0045 - val_loss: 3.6675e-05 - val_mean_a
bsolute_error: 0.0045
Epoch 66/100
253/253 0s 905us/step - loss: 6.4782e-05 - mean_absolute_error: 0.0043 - val_loss: 4.5269e-05 - val_mean_a
bsolute_error: 0.0051
Epoch 67/100
253/253 0s 893us/step - loss: 6.5045e-05 - mean_absolute_error: 0.0044 - val_loss: 9.6436e-05 - val_mean_a
bsolute_error: 0.0085
Epoch 68/100
253/253 0s 897us/step - loss: 6.9951e-05 - mean_absolute_error: 0.0047 - val_loss: 7.0548e-05 - val_mean_a
bsolute_error: 0.0069
Epoch 69/100
```

```
253/253 ━━━━━━━━ 0s 1ms/step - loss: 6.3644e-05 - mean_absolute_error: 0.0044 - val_loss: 3.2853e-05 - val_mean_absolute_error: 0.0042
Epoch 70/100
253/253 ━━━━━━━━ 0s 913us/step - loss: 6.9522e-05 - mean_absolute_error: 0.0048 - val_loss: 3.2469e-05 - val_mean_absolute_error: 0.0041
Epoch 71/100
253/253 ━━━━━━━━ 0s 893us/step - loss: 6.1303e-05 - mean_absolute_error: 0.0043 - val_loss: 3.4040e-05 - val_mean_absolute_error: 0.0043
Epoch 72/100
253/253 ━━━━━━━━ 0s 951us/step - loss: 6.7231e-05 - mean_absolute_error: 0.0044 - val_loss: 3.4251e-05 - val_mean_absolute_error: 0.0043
Epoch 73/100
253/253 ━━━━━━━━ 0s 937us/step - loss: 6.4125e-05 - mean_absolute_error: 0.0045 - val_loss: 3.2120e-05 - val_mean_absolute_error: 0.0041
Epoch 74/100
253/253 ━━━━━━━━ 0s 993us/step - loss: 7.1013e-05 - mean_absolute_error: 0.0047 - val_loss: 6.1332e-05 - val_mean_absolute_error: 0.0063
Epoch 75/100
253/253 ━━━━━━━━ 0s 1ms/step - loss: 6.5008e-05 - mean_absolute_error: 0.0046 - val_loss: 3.2722e-05 - val_mean_absolute_error: 0.0041
Epoch 76/100
253/253 ━━━━━━━━ 0s 913us/step - loss: 6.4352e-05 - mean_absolute_error: 0.0046 - val_loss: 3.4404e-05 - val_mean_absolute_error: 0.0042
Epoch 77/100
253/253 ━━━━━━━━ 0s 903us/step - loss: 6.5181e-05 - mean_absolute_error: 0.0046 - val_loss: 5.9375e-05 - val_mean_absolute_error: 0.0062
Epoch 78/100
253/253 ━━━━━━━━ 0s 915us/step - loss: 6.1145e-05 - mean_absolute_error: 0.0045 - val_loss: 3.5564e-05 - val_mean_absolute_error: 0.0044
Epoch 79/100
253/253 ━━━━━━━━ 0s 915us/step - loss: 5.6118e-05 - mean_absolute_error: 0.0042 - val_loss: 6.3383e-05 - val_mean_absolute_error: 0.0064
Epoch 80/100
253/253 ━━━━━━━━ 0s 1ms/step - loss: 7.0788e-05 - mean_absolute_error: 0.0047 - val_loss: 3.3917e-05 - val_mean_absolute_error: 0.0043
Epoch 81/100
253/253 ━━━━━━━━ 0s 885us/step - loss: 6.5394e-05 - mean_absolute_error: 0.0047 - val_loss: 5.2713e-05 - val_mean_absolute_error: 0.0056
Epoch 82/100
253/253 ━━━━━━━━ 0s 889us/step - loss: 6.3643e-05 - mean_absolute_error: 0.0046 - val_loss: 8.9019e-05 - val_mean_absolute_error: 0.0080
```

```
Epoch 83/100
253/253 0s 895us/step - loss: 6.9976e-05 - mean_absolute_error: 0.0045 - val_loss: 8.4059e-05 - val_mean_absolute_error: 0.0077
Epoch 84/100
253/253 0s 883us/step - loss: 6.6090e-05 - mean_absolute_error: 0.0047 - val_loss: 3.9101e-05 - val_mean_absolute_error: 0.0046
Epoch 85/100
253/253 0s 1ms/step - loss: 5.9503e-05 - mean_absolute_error: 0.0043 - val_loss: 3.8131e-05 - val_mean_absolute_error: 0.0046
Epoch 86/100
253/253 0s 957us/step - loss: 6.0716e-05 - mean_absolute_error: 0.0043 - val_loss: 4.2014e-05 - val_mean_absolute_error: 0.0049
Epoch 87/100
253/253 0s 895us/step - loss: 7.0765e-05 - mean_absolute_error: 0.0047 - val_loss: 3.5801e-05 - val_mean_absolute_error: 0.0044
Epoch 88/100
253/253 0s 919us/step - loss: 6.1907e-05 - mean_absolute_error: 0.0044 - val_loss: 3.8995e-05 - val_mean_absolute_error: 0.0046
Epoch 89/100
253/253 0s 881us/step - loss: 7.2285e-05 - mean_absolute_error: 0.0051 - val_loss: 4.3057e-05 - val_mean_absolute_error: 0.0051
Epoch 90/100
253/253 0s 881us/step - loss: 6.3261e-05 - mean_absolute_error: 0.0045 - val_loss: 4.9141e-05 - val_mean_absolute_error: 0.0054
Epoch 91/100
253/253 0s 1ms/step - loss: 7.4787e-05 - mean_absolute_error: 0.0044 - val_loss: 3.2207e-05 - val_mean_absolute_error: 0.0041
Epoch 92/100
253/253 0s 903us/step - loss: 6.0182e-05 - mean_absolute_error: 0.0042 - val_loss: 4.5003e-05 - val_mean_absolute_error: 0.0053
Epoch 93/100
253/253 0s 919us/step - loss: 6.0484e-05 - mean_absolute_error: 0.0043 - val_loss: 3.2437e-05 - val_mean_absolute_error: 0.0041
Epoch 94/100
253/253 0s 897us/step - loss: 6.2242e-05 - mean_absolute_error: 0.0045 - val_loss: 3.2325e-05 - val_mean_absolute_error: 0.0041
Epoch 95/100
253/253 0s 915us/step - loss: 7.3433e-05 - mean_absolute_error: 0.0048 - val_loss: 4.7426e-05 - val_mean_absolute_error: 0.0054
Epoch 96/100
253/253 0s 1ms/step - loss: 6.7762e-05 - mean_absolute_error: 0.0047 - val_loss: 3.3013e-05 - val_mean_absolute_error: 0.0047
```

```
olute_error: 0.0041
Epoch 97/100
253/253 ━━━━━━━━ 0s 891us/step - loss: 6.5125e-05 - mean_absolute_error: 0.0043 - val_loss: 3.6317e-05 - val_mean_a
bsolute_error: 0.0045
Epoch 98/100
253/253 ━━━━━━━━ 0s 905us/step - loss: 9.2142e-05 - mean_absolute_error: 0.0054 - val_loss: 3.5992e-05 - val_mean_a
bsolute_error: 0.0045
Epoch 99/100
253/253 ━━━━━━━━ 0s 901us/step - loss: 5.8614e-05 - mean_absolute_error: 0.0042 - val_loss: 5.8580e-05 - val_mean_a
bsolute_error: 0.0061
Epoch 100/100
253/253 ━━━━━━━━ 0s 895us/step - loss: 6.2183e-05 - mean_absolute_error: 0.0043 - val_loss: 3.2938e-05 - val_mean_a
bsolute_error: 0.0041

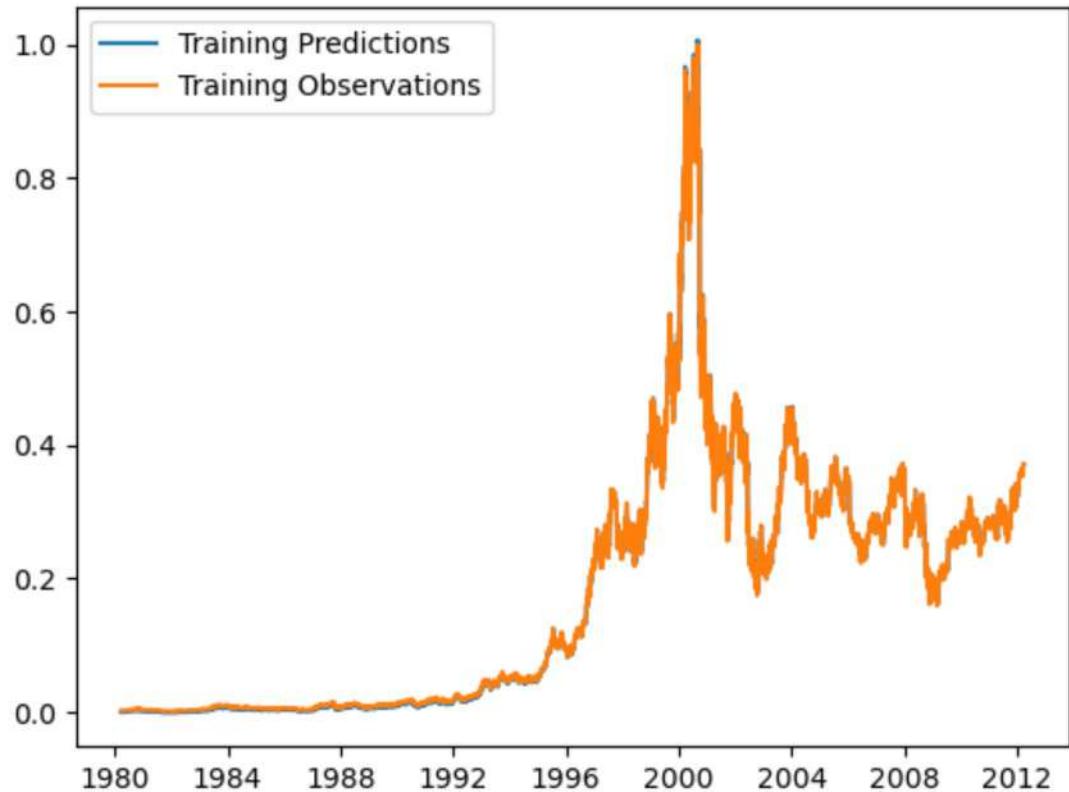
Out[ ]: <keras.src.callbacks.history.History at 0x1723e1fe910>
```

```
In [ ]: train_pred = modelbase.predict(X_train).flatten()

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

253/253 ━━━━━━━━ 0s 802us/step

Out[ ]: <matplotlib.legend.Legend at 0x172bde38050>
```

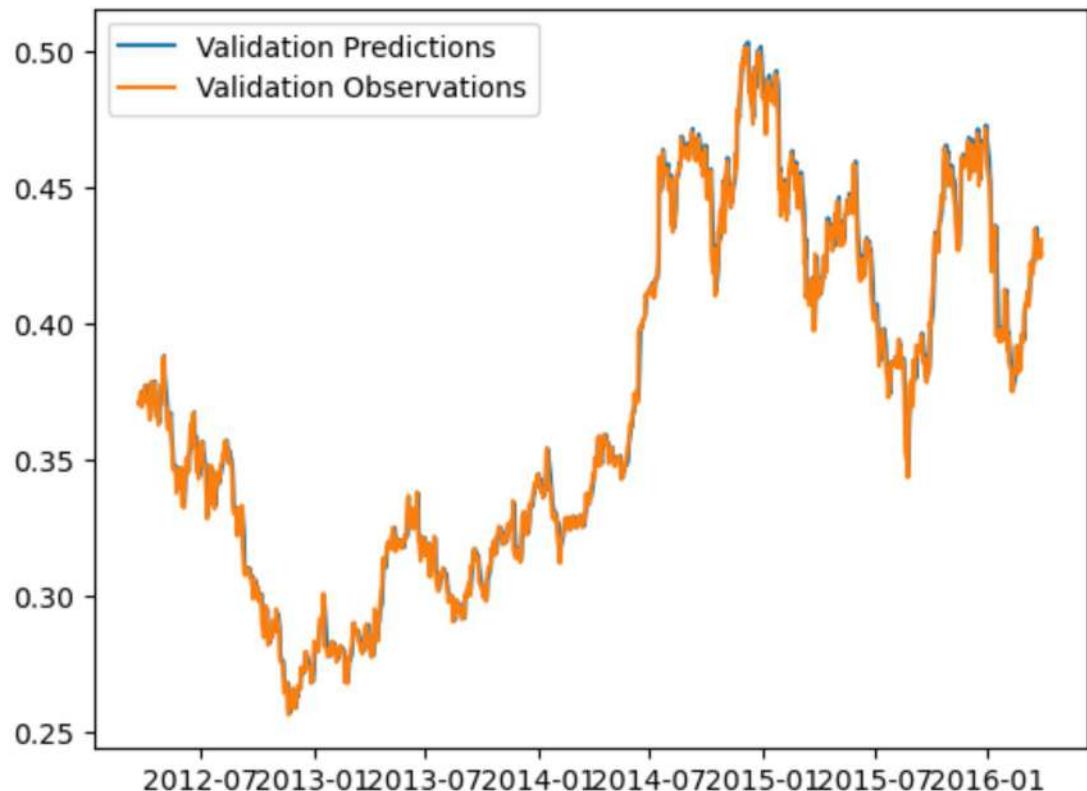


```
In [ ]: val_pred = modelbase.predict(X_val).flatten()

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

32/32 ━━━━━━ 0s 468us/step

```
Out[ ]: <matplotlib.legend.Legend at 0x172bbad8cd0>
```

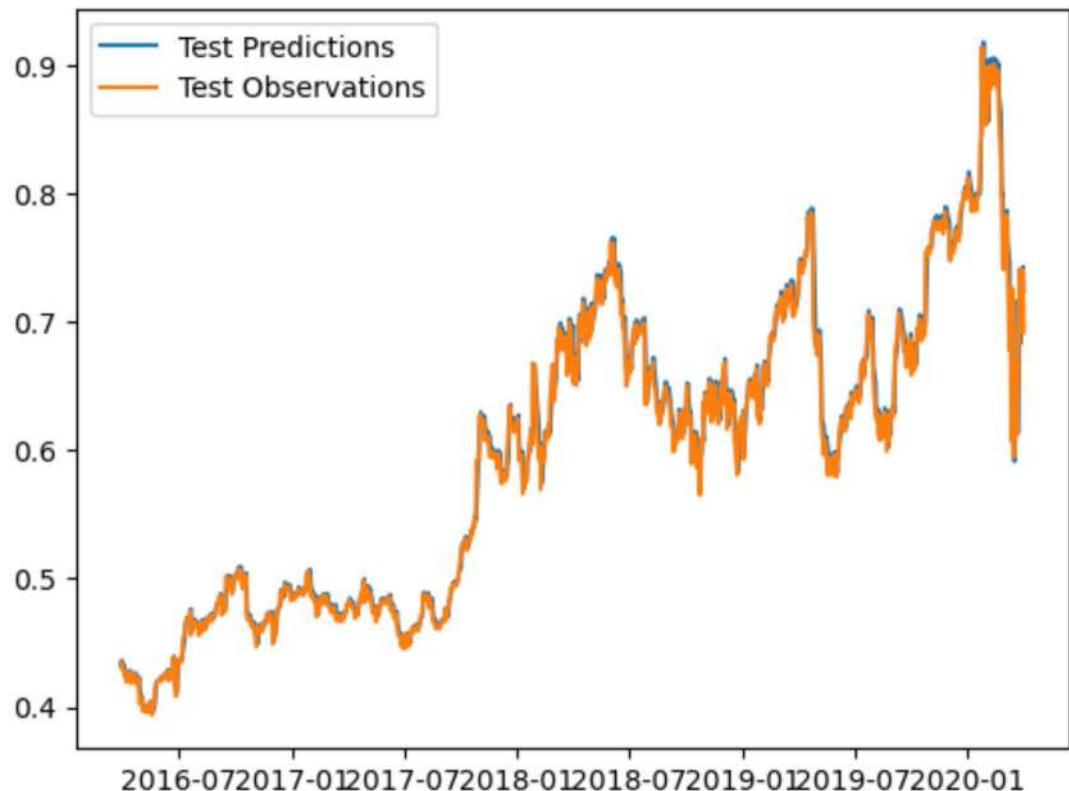


```
In [ ]: test_pred = modelbase.predict(X_test).flatten()

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

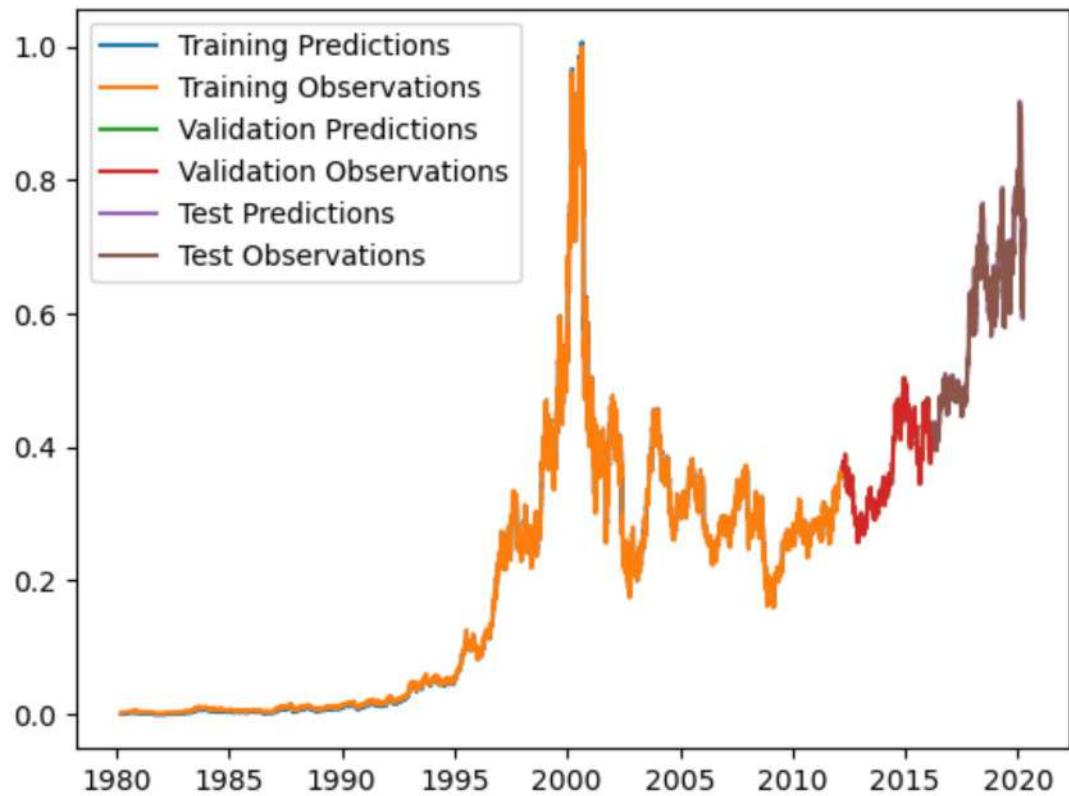
32/32 ━━━━━━ 0s 484us/step

```
Out[ ]: <matplotlib.legend.Legend at 0x172be2bc290>
```



```
In [ ]: plt.plot(dates_train, train_pred)
plt.plot(dates_train, y_train)
plt.plot(dates_val, val_pred)
plt.plot(dates_val, y_val)
plt.plot(dates_test, test_pred)
plt.plot(dates_test, y_test)
plt.legend(['Training Predictions', 'Training Observations',
           'Validation Predictions', 'Validation Observations',
           'Test Predictions', 'Test Observations'])
```

```
Out[ ]: <matplotlib.legend.Legend at 0x172bb4b6390>
```



Modified Model

```
In [ ]: model3 = Sequential([layers.Input((5,1)),
    layers.LSTM(128),
    layers.Dense(64, activation='relu'),
    layers.Dense(1)])
model3.compile(loss='mse',
    optimizer=Adam(learning_rate=0.001),
    metrics=['mean_absolute_error'])
early_stopping = EarlyStopping(monitor='val_mean_absolute_error', patience=10, restore_best_weights=True)
model3.fit(X_train, y_train, validation_data=(X_val, y_val), epochs = 100 , callbacks=early_stopping)
```

Epoch 1/100
253/253 2s 2ms/step - loss: 0.0084 - mean_absolute_error: 0.0400 - val_loss: 6.9615e-05 - val_mean_absolute_error: 0.0062
Epoch 2/100
253/253 0s 2ms/step - loss: 1.4915e-04 - mean_absolute_error: 0.0072 - val_loss: 6.6393e-05 - val_mean_absolute_error: 0.0062
Epoch 3/100
253/253 0s 2ms/step - loss: 1.4913e-04 - mean_absolute_error: 0.0070 - val_loss: 1.1414e-04 - val_mean_absolute_error: 0.0088
Epoch 4/100
253/253 0s 1ms/step - loss: 1.2968e-04 - mean_absolute_error: 0.0065 - val_loss: 8.6740e-05 - val_mean_absolute_error: 0.0075
Epoch 5/100
253/253 0s 2ms/step - loss: 1.3145e-04 - mean_absolute_error: 0.0065 - val_loss: 1.4730e-04 - val_mean_absolute_error: 0.0097
Epoch 6/100
253/253 0s 2ms/step - loss: 1.1952e-04 - mean_absolute_error: 0.0067 - val_loss: 3.1803e-04 - val_mean_absolute_error: 0.0164
Epoch 7/100
253/253 0s 1ms/step - loss: 1.2057e-04 - mean_absolute_error: 0.0064 - val_loss: 5.4830e-05 - val_mean_absolute_error: 0.0056
Epoch 8/100
253/253 0s 2ms/step - loss: 1.2572e-04 - mean_absolute_error: 0.0072 - val_loss: 4.8499e-05 - val_mean_absolute_error: 0.0052
Epoch 9/100
253/253 0s 2ms/step - loss: 1.0839e-04 - mean_absolute_error: 0.0062 - val_loss: 1.0949e-04 - val_mean_absolute_error: 0.0085
Epoch 10/100
253/253 0s 2ms/step - loss: 9.5503e-05 - mean_absolute_error: 0.0056 - val_loss: 6.1924e-05 - val_mean_absolute_error: 0.0061
Epoch 11/100
253/253 0s 1ms/step - loss: 1.0068e-04 - mean_absolute_error: 0.0060 - val_loss: 5.3519e-05 - val_mean_absolute_error: 0.0057
Epoch 12/100
253/253 0s 2ms/step - loss: 9.2819e-05 - mean_absolute_error: 0.0056 - val_loss: 9.1155e-05 - val_mean_absolute_error: 0.0078
Epoch 13/100
253/253 0s 2ms/step - loss: 7.9233e-05 - mean_absolute_error: 0.0052 - val_loss: 7.9204e-05 - val_mean_absolute_error: 0.0072
Epoch 14/100
253/253 0s 1ms/step - loss: 7.6755e-05 - mean_absolute_error: 0.0053 - val_loss: 6.0584e-05 - val_mean_absolute_error: 0.0072

```
olute_error: 0.0059
Epoch 15/100
253/253 0s 2ms/step - loss: 9.5944e-05 - mean_absolute_error: 0.0058 - val_loss: 3.4546e-05 - val_mean_abs
olute_error: 0.0043
Epoch 16/100
253/253 0s 2ms/step - loss: 7.5362e-05 - mean_absolute_error: 0.0052 - val_loss: 4.5437e-05 - val_mean_abs
olute_error: 0.0051
Epoch 17/100
253/253 0s 1ms/step - loss: 8.5821e-05 - mean_absolute_error: 0.0056 - val_loss: 4.5592e-05 - val_mean_abs
olute_error: 0.0051
Epoch 18/100
253/253 0s 2ms/step - loss: 6.5618e-05 - mean_absolute_error: 0.0049 - val_loss: 1.5538e-04 - val_mean_abs
olute_error: 0.0111
Epoch 19/100
253/253 0s 2ms/step - loss: 8.8805e-05 - mean_absolute_error: 0.0056 - val_loss: 3.6787e-05 - val_mean_abs
olute_error: 0.0045
Epoch 20/100
253/253 0s 2ms/step - loss: 6.8271e-05 - mean_absolute_error: 0.0046 - val_loss: 6.6858e-05 - val_mean_abs
olute_error: 0.0065
Epoch 21/100
253/253 0s 2ms/step - loss: 7.4548e-05 - mean_absolute_error: 0.0054 - val_loss: 1.5001e-04 - val_mean_abs
olute_error: 0.0111
Epoch 22/100
253/253 0s 2ms/step - loss: 9.1184e-05 - mean_absolute_error: 0.0061 - val_loss: 3.7307e-05 - val_mean_abs
olute_error: 0.0046
Epoch 23/100
253/253 0s 2ms/step - loss: 7.5566e-05 - mean_absolute_error: 0.0051 - val_loss: 3.5240e-05 - val_mean_abs
olute_error: 0.0043
Epoch 24/100
253/253 0s 1ms/step - loss: 7.7004e-05 - mean_absolute_error: 0.0055 - val_loss: 8.2950e-05 - val_mean_abs
olute_error: 0.0077
Epoch 25/100
253/253 0s 1ms/step - loss: 7.2470e-05 - mean_absolute_error: 0.0052 - val_loss: 3.6687e-05 - val_mean_abs
olute_error: 0.0044
```

Out[]: <keras.src.callbacks.history.History at 0x172be1ce110>

In []: train3_pred = model3.predict(X_train).flatten()
plt.plot(dates_train, train3_pred)
plt.plot(dates_train, y_train)

```
plt.legend(['Training Predictions', 'Training Observations'])
```

253/253 ━━━━━━ 0s 1ms/step

Out[]: <matplotlib.legend.Legend at 0x172c0e69b10>

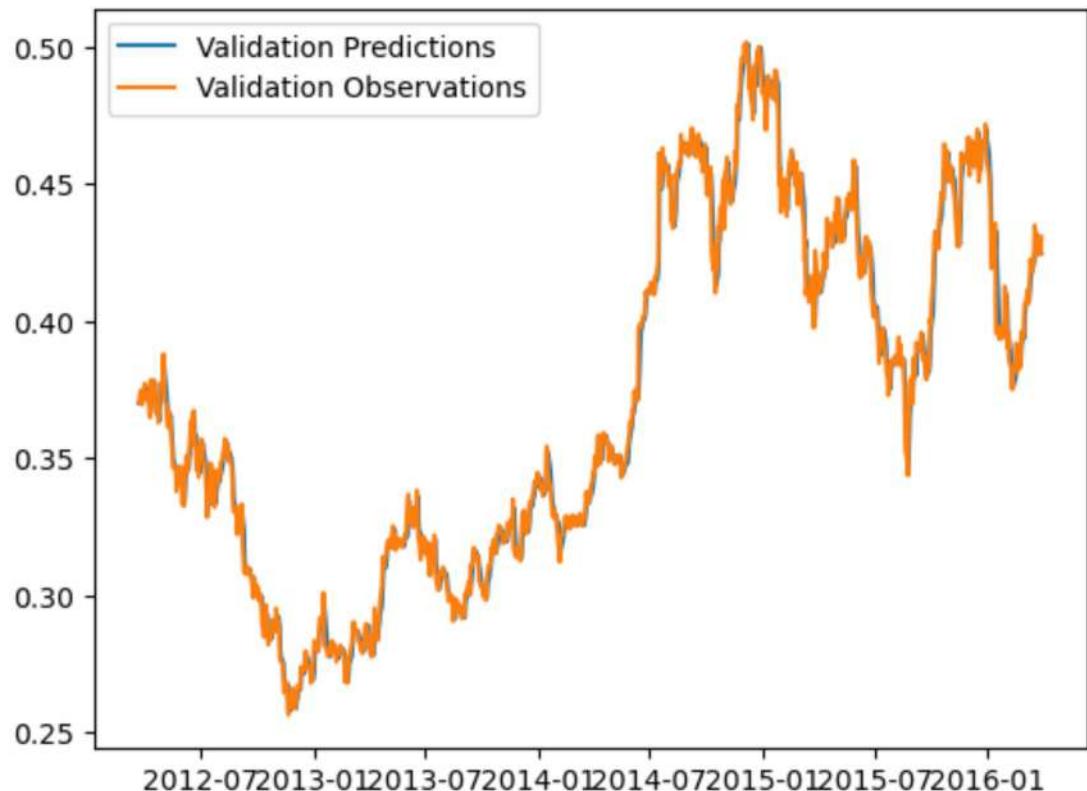


```
In [ ]: val3_pred = model3.predict(X_val).flatten()

plt.plot(dates_val, val3_pred)
plt.plot(dates_val, y_val)
plt.legend(['Validation Predictions', 'Validation Observations'])
```

32/32 ━━━━━━ 0s 742us/step

Out[]: <matplotlib.legend.Legend at 0x172c0ebba10>

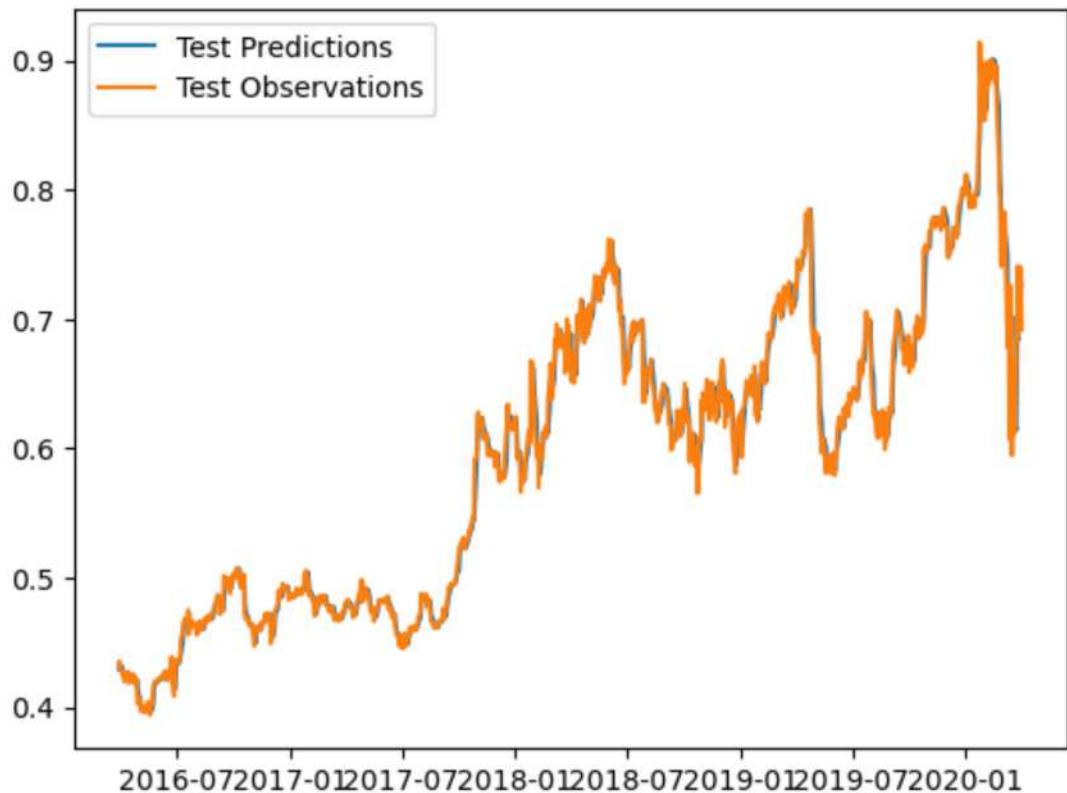


```
In [ ]: test3_pred = model3.predict(X_test).flatten()

plt.plot(dates_test, test3_pred)
plt.plot(dates_test, y_test)
plt.legend(['Test Predictions', 'Test Observations'])
```

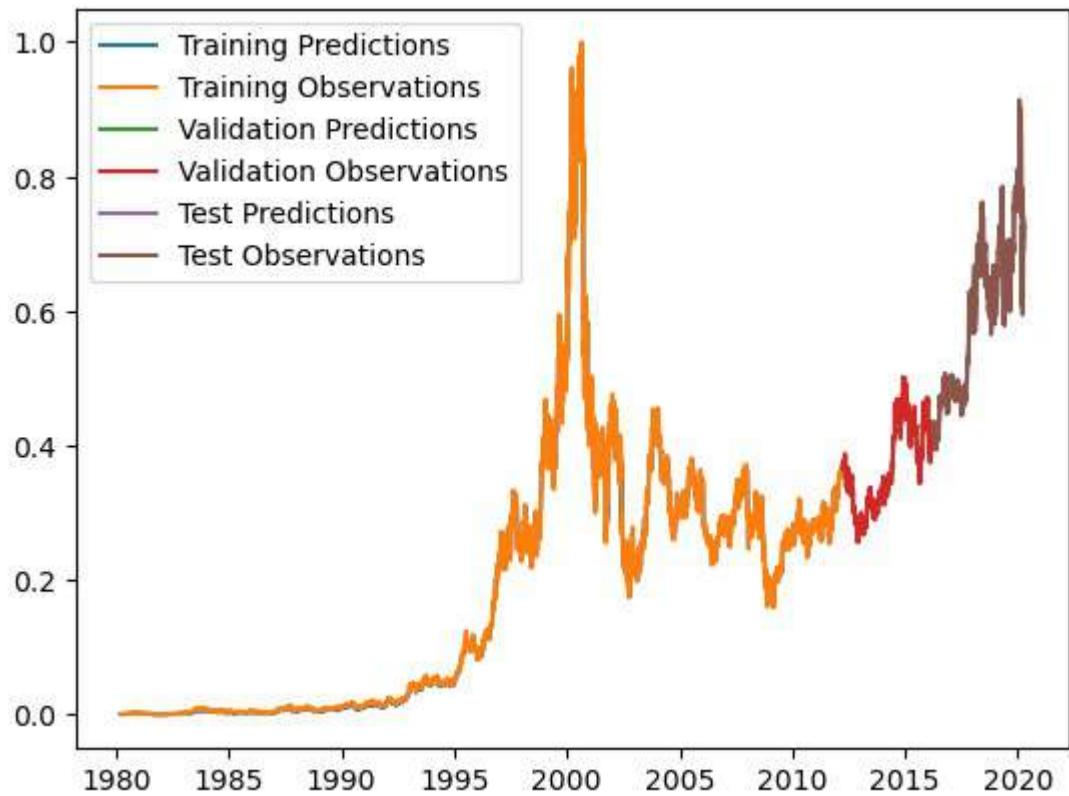
32/32 ━━━━━━━━ 0s 743us/step

```
Out[ ]: <matplotlib.legend.Legend at 0x172c2051290>
```



```
In [ ]: plt.plot(dates_train, train3_pred)
plt.plot(dates_train, y_train)
plt.plot(dates_val, val3_pred)
plt.plot(dates_val, y_val)
plt.plot(dates_test, test3_pred)
plt.plot(dates_test, y_test)
plt.legend(['Training Predictions', 'Training Observations',
           'Validation Predictions', 'Validation Observations',
           'Test Predictions', 'Test Observations'])
```

```
Out[ ]: <matplotlib.legend.Legend at 0x172c20a5d90>
```



```
In [ ]: rmse_base, mae_base, mape_base = calculate_metrics(y_test, test_pred)
rmse_opt, mae_opt, mape_opt = calculate_metrics(y_test, test3_pred)
improvement_rmse = ((rmse_base - rmse_opt) / rmse_base) * 100
improvement_mae = ((mae_base - mae_opt) / mae_base) * 100
improvement_mape = ((mape_base - mape_opt) / mape_base) * 100
print(f'Base Model - RMSE: {rmse_base}, MAE: {mae_base}, MAPE: {mape_base}')
print(f'Modified Model - RMSE: {rmse_opt}, MAE: {mae_opt}, MAPE: {mape_opt}')
print(f'Improvement RMSE: {improvement_rmse:.2f}%')
print(f'Improvement MAE: {improvement_mae:.2f}%')
print(f'Improvement MAPE: {improvement_mape:.2f}%')
```

Base Model - RMSE: 0.013601954095065594, MAE: 0.008153075352311134, MAPE: 1.3119694776833057
Modified Model - RMSE: 0.013043520040810108, MAE: 0.008025477640330791, MAPE: 1.2942193076014519
Improvement RMSE: 4.11%
Improvement MAE: 1.57%
Improvement MAPE: 1.35%