Лабораторная работа №8. Рекуррентные нейронные сети для анализа временных рядов

Данные: Набор данных для прогнозирования временных рядов, который состоит из среднемесячного числа пятен на солнце, наблюдаемых с января 1749 по август 2017. Данные в виде csv-файла можно скачать на сайте Kaggle -> https://www.kaggle.com/robervalt/sunspots/

Задание 1.

Загрузите данные. Изобразите ряд в виде графика. Вычислите основные характеристики временного ряда (сезонность, тренд, автокорреляцию).

In [59]:

```
from tensorflow import keras
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from statsmodels.tsa.arima_model import ARIMA
from matplotlib import pyplot
import numpy as np

k = 'Date'
v = 'Monthly Mean Total Sunspot Number'
data_folder = '../data'

epochs = 200
batch_size = 32
steps = 10
```

In [2]:

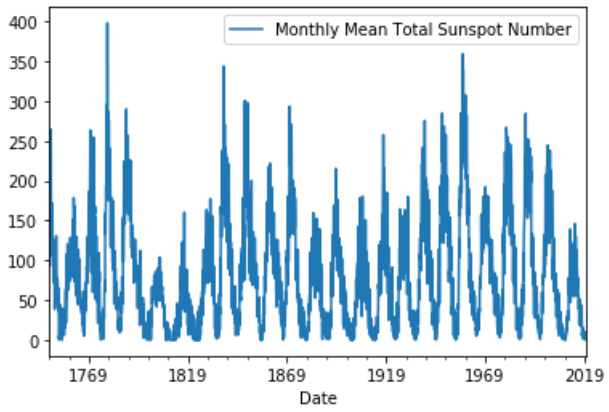
```
df = pd.read_csv(data_folder + '/sunspots/Sunspots.csv', parse_dates=[0], usecols=[1, 2])
```

In [3]:

```
df.plot(x = k, y = v)
```

Out[3]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fad20e105d0>
```

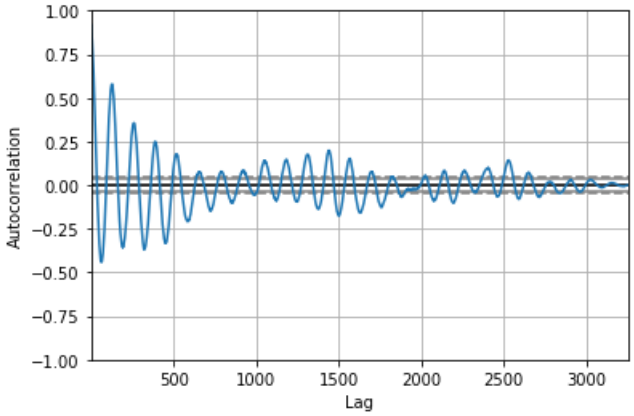


In [4]:

```
pd.plotting.autocorrelation_plot(df[v])
```

Out[4]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fad2050f6d0>
```



Задание 2.

Для прогнозирования разделите временной ряд на обучающую, валидационную и контрольную выборки.

In [5]:

```
train_df, test_df = train_test_split(df, shuffle=False)
train_df, dev_df = train_test_split(train_df, shuffle=False)
```

Задание 3.

Примените модель ARIMA для прогнозирования значений данного временного ряда.

In [6]:

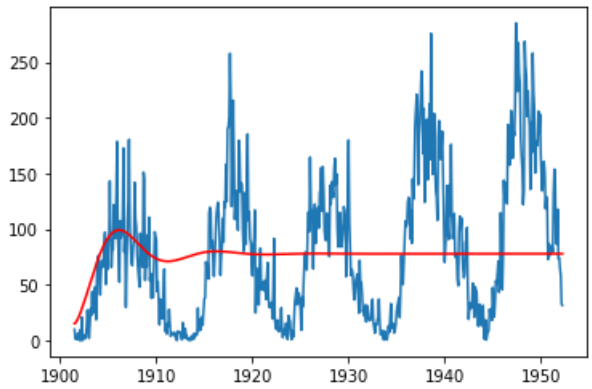
```
model = ARIMA(train_df[v], (5, 0, 3), dates=train_df[k])


results = model.fit()
predictions = results.forecast(steps=len(dev_df))[0]
```

```
/home/yalov4uk/anaconda3/lib/python3.7/site-packages/statsmodels/tsa/base/tsa_model.py:162:
ValueWarning: No frequency information was provided, so inferred frequency M will be used.
  % freq, ValueWarning)
```

In [7]:

```
plt.plot(dev_df[k], dev_df[v])
plt.plot(dev_df[k], predictions, color='red')
pyplot.show()
```



Задание 4.

Повторите эксперимент по прогнозированию, реализовав рекуррентную нейронную сеть (с как минимум 2 рекуррентными слоями).

In [15]:

```
def split_sequence(sequence, steps):
    X, y = [], []
    for i in range(steps, len(sequence)):
        X.append(sequence.iloc[i - steps: i])
        y.append(sequence.iloc[i])
    return np.array(X), np.array(y).reshape((len(y), 1))
```

In [60]:

```
X_train, y_train = split_sequence(train_df[v], steps)
X_dev, y_dev = split_sequence(dev_df[v], steps)

X_train = X_train.reshape((X_train.shape[0], X_train.shape[1], 1))
X_dev = X_dev.reshape((X_dev.shape[0], X_dev.shape[1], 1))
```

In [41]:

```
def model_factory():
    return keras.Sequential([
        keras.layers.LSTM(50, input_shape=X_train.shape[-2:], return_sequences=True),
        keras.layers.LSTM(50),
        keras.layers.Dense(1)
    ])
```

In [50]:

```
def train(model):
    model.compile(loss='mse', optimizer='adam')

    model.fit(X_train, y_train, validation_data=(X_dev, y_dev), epochs=epochs,
              batch_size=batch_size)
```

In [61]:

```
model = model_factory()
train(model)
```

```
Train on 1819 samples, validate on 600 samples
Epoch 1/200
1819/1819 [==============================] - 4s 2ms/sample - loss: 9583.5419 - val_loss: 9188.5197
Epoch 2/200
1819/1819 [==============================] - 1s 616us/sample - loss: 8628.2316 - val_loss:
8621.2831
Epoch 3/200
1819/1819 [==============================] - 1s 766us/sample - loss: 8187.2086 - val_loss:
8207.8790
Epoch 4/200
1819/1819 [==============================] - 1s 789us/sample - loss: 7811.7770 - val_loss:
7824.4481
Epoch 5/200
1819/1819 [==============================] - 2s 893us/sample - loss: 7464.9919 - val_loss:
7464.8805
Epoch 6/200
1819/1819 [==============================] - 1s 803us/sample - loss: 7140.5018 - val_loss:
7136.1935
Epoch 7/200
1819/1819 [==============================] - 1s 706us/sample - loss: 6839.5597 - val_loss:
6821.1881
Epoch 8/200
1819/1819 [==============================] - 1s 818us/sample - loss: 6554.5236 - val_loss:
6526.1454
Epoch 9/200
1819/1819 [==============================] - 1s 752us/sample - loss: 6285.6579 - val_loss:
6247.6681
Epoch 10/200
1819/1819 [==============================] - 2s 854us/sample - loss: 6031.2993 - val_loss:
5984.5743
Epoch 11/200
1819/1819 [==============================] - 2s 835us/sample - loss: 5791.0140 - val_loss:
```

5734.8537
Epoch 12/200
1819/1819 [==============================] - 2s 844us/sample - loss: 5563.4940 - val_loss:
5495.9281
Epoch 13/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 5345.9150 - val_loss: 5274.7461
Epoch 14/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 5140.5308 - val_loss: 5059.5921
Epoch 15/200
1819/1819 [==============================] - 2s 991us/sample - loss: 4944.9609 - val_loss:
4856.1455
Epoch 16/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 4759.1182 - val_loss: 4669.2254
Epoch 17/200
1819/1819 [==============================] - 2s 900us/sample - loss: 4583.6249 - val_loss:
4477.1831
Epoch 18/200
1819/1819 [==============================] - 2s 849us/sample - loss: 4413.3873 - val_loss:
4310.0145
Epoch 19/200
1819/1819 [==============================] - 1s 812us/sample - loss: 4254.4244 - val_loss:
4139.6817
Epoch 20/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 4101.4003 - val_loss: 3976.9374
Epoch 21/200
1819/1819 [==============================] - 2s 878us/sample - loss: 3956.9131 - val_loss:
3828.3031
Epoch 22/200
1819/1819 [==============================] - 2s 851us/sample - loss: 3821.1510 - val_loss:
3689.8498
Epoch 23/200
1819/1819 [==============================] - 2s 912us/sample - loss: 3692.3468 - val_loss:
3547.7166
Epoch 24/200
1819/1819 [==============================] - 2s 915us/sample - loss: 3562.5522 - val_loss:
3413.7658
Epoch 25/200
1819/1819 [==============================] - 2s 972us/sample - loss: 3446.1349 - val_loss:
3294.1370
Epoch 26/200
1819/1819 [==============================] - 2s 890us/sample - loss: 3331.2066 - val_loss:
3177.1057
Epoch 27/200
1819/1819 [==============================] - 2s 938us/sample - loss: 3223.6740 - val_loss:
3067.6447
Epoch 28/200
1819/1819 [==============================] - 1s 541us/sample - loss: 3124.3497 - val_loss:
2962.9977
Epoch 29/200
1819/1819 [==============================] - 2s 874us/sample - loss: 3022.9124 - val_loss:
2857.5213
Epoch 30/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 2930.9543 - val_loss: 2762.4654
Epoch 31/200
1819/1819 [==============================] - 2s 946us/sample - loss: 2843.0595 - val_loss:
2675.0788
Epoch 32/200
1819/1819 [==============================] - 2s 829us/sample - loss: 2761.6877 - val_loss:
2587.2182
Epoch 33/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 2677.7028 - val_loss: 2500.5521
Epoch 34/200
1819/1819 [==============================] - 2s 940us/sample - loss: 2599.1767 - val_loss:
2427.3325
Epoch 35/200
1819/1819 [==============================] - 1s 809us/sample - loss: 2523.1199 - val_loss:
2350.2670
Epoch 36/200
1819/1819 [==============================] - 2s 975us/sample - loss: 2454.3125 - val_loss:
2274.8147
Epoch 37/200
1819/1819 [==============================] - 2s 919us/sample - loss: 2384.6464 - val_loss:
2209.0371
Epoch 38/200
1819/1819 [==============================] - 1s 820us/sample - loss: 2317.6079 - val_loss:
2145.8980
Epoch 39/200

```
Epoch 39/200
1819/1819 [==============================] - 1s 818us/sample - loss: 2252.6209 - val_loss:
2113.3126
Epoch 40/200
1819/1819 [==============================] - 1s 677us/sample - loss: 2202.2142 - val_loss:
2033.4899
Epoch 41/200
1819/1819 [==============================] - 2s 944us/sample - loss: 2136.4937 - val_loss:
1983.5846
Epoch 42/200
1819/1819 [==============================] - 2s 955us/sample - loss: 2081.4988 - val_loss:
1928.7348
Epoch 43/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 2025.7013 - val_loss: 1873.6260
Epoch 44/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1975.1489 - val_loss: 1832.6738
Epoch 45/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1931.1149 - val_loss: 1808.6989
Epoch 46/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1888.7502 - val_loss: 1727.1512
Epoch 47/200
1819/1819 [==============================] - 2s 837us/sample - loss: 1839.9859 - val_loss:
1699.4691
Epoch 48/200
1819/1819 [==============================] - 2s 905us/sample - loss: 1794.7244 - val_loss:
1659.5559
Epoch 49/200
1819/1819 [==============================] - 2s 910us/sample - loss: 1749.0491 - val_loss:
1626.2709
Epoch 50/200
1819/1819 [==============================] - 2s 830us/sample - loss: 1709.0665 - val_loss:
1589.2925
Epoch 51/200
1819/1819 [==============================] - 2s 960us/sample - loss: 1678.6647 - val_loss:
1534.0237
Epoch 52/200
1819/1819 [==============================] - 1s 762us/sample - loss: 1635.6741 - val_loss:
1508.0664
Epoch 53/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1598.7342 - val_loss: 1480.1706
Epoch 54/200
1819/1819 [==============================] - 2s 933us/sample - loss: 1571.5427 - val_loss:
1452.4062
Epoch 55/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1528.7348 - val_loss: 1409.1370
Epoch 56/200
1819/1819 [==============================] - 2s 980us/sample - loss: 1504.0824 - val_loss:
1385.9899
Epoch 57/200
1819/1819 [==============================] - 2s 993us/sample - loss: 1470.7053 - val_loss:
1377.4976
Epoch 58/200
1819/1819 [==============================] - 1s 707us/sample - loss: 1438.4693 - val_loss:
1331.0734
Epoch 59/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1418.1733 - val_loss: 1303.7630
Epoch 60/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1379.9040 - val_loss: 1281.8226
Epoch 61/200
1819/1819 [==============================] - 2s 998us/sample - loss: 1348.5930 - val_loss:
1263.0018
Epoch 62/200
1819/1819 [==============================] - 2s 978us/sample - loss: 1334.3180 - val_loss:
1234.0645
Epoch 63/200
1819/1819 [==============================] - 2s 983us/sample - loss: 1306.9897 - val_loss:
1208.2113
Epoch 64/200
1819/1819 [==============================] - 2s 965us/sample - loss: 1276.3430 - val_loss:
1196.7735
Epoch 65/200
1819/1819 [==============================] - 1s 817us/sample - loss: 1246.7182 - val_loss:
1164.5295
Epoch 66/200
1819/1819 [==============================] - 1s 721us/sample - loss: 1224.0445 - val_loss:
1142.2511
Epoch 67/200
1819/1819 [==============================] - 2s 846us/sample - loss: 1200.6298 - val_loss:
```

```
1128.1019
Epoch 68/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1182.8388 - val_loss: 1093.6086
Epoch 69/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1163.9219 - val_loss: 1093.1863
Epoch 70/200
1819/1819 [==============================] - 1s 631us/sample - loss: 1131.9290 - val_loss:
1100.5040
Epoch 71/200
1819/1819 [==============================] - 2s 962us/sample - loss: 1121.9789 - val_loss:
1059.2869
Epoch 72/200
1819/1819 [==============================] - 2s 940us/sample - loss: 1095.3788 - val_loss:
1037.4078
Epoch 73/200
1819/1819 [==============================] - 2s 999us/sample - loss: 1084.0759 - val_loss:
1018.0207
Epoch 74/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1060.0086 - val_loss: 1013.5856
Epoch 75/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1045.9586 - val_loss: 1007.2250
Epoch 76/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 1024.6749 - val_loss: 1006.4626
Epoch 77/200
1819/1819 [==============================] - 2s 920us/sample - loss: 1009.1891 - val_loss:
959.0310
Epoch 78/200
1819/1819 [==============================] - 1s 697us/sample - loss: 991.4795 - val_loss: 958.1568
Epoch 79/200
1819/1819 [==============================] - 2s 965us/sample - loss: 973.4418 - val_loss: 950.8419
Epoch 80/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 957.4193 - val_loss: 934.4187
Epoch 81/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 952.0547 - val_loss: 921.5261
Epoch 82/200
1819/1819 [==============================] - 2s 935us/sample - loss: 937.3225 - val_loss: 903.6528
Epoch 83/200
1819/1819 [==============================] - 1s 684us/sample - loss: 936.0011 - val_loss: 914.6141
Epoch 84/200
1819/1819 [==============================] - 2s 895us/sample - loss: 915.2164 - val_loss: 895.4050
Epoch 85/200
1819/1819 [==============================] - 2s 941us/sample - loss: 902.3613 - val_loss: 878.3966
Epoch 86/200
1819/1819 [==============================] - 2s 935us/sample - loss: 891.7304 - val_loss: 875.5256
Epoch 87/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 877.7117 - val_loss: 868.1852
Epoch 88/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 870.7147 - val_loss: 878.5602
Epoch 89/200
1819/1819 [==============================] - 2s 952us/sample - loss: 846.9277 - val_loss: 867.4126
Epoch 90/200
1819/1819 [==============================] - 2s 960us/sample - loss: 846.5145 - val_loss: 839.4093
Epoch 91/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 823.3163 - val_loss: 832.7528
Epoch 92/200
1819/1819 [==============================] - 2s 902us/sample - loss: 819.1814 - val_loss: 833.5773
Epoch 93/200
1819/1819 [==============================] - 2s 875us/sample - loss: 802.8226 - val_loss: 846.5163
Epoch 94/200
1819/1819 [==============================] - 2s 987us/sample - loss: 806.3455 - val_loss: 808.3056
Epoch 95/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 782.0390 - val_loss: 805.4567
Epoch 96/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 782.9317 - val_loss: 795.7745
Epoch 97/200
1819/1819 [==============================] - 1s 786us/sample - loss: 765.1599 - val_loss: 789.0347
Epoch 98/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 762.9580 - val_loss: 811.9135
Epoch 99/200
1819/1819 [==============================] - 1s 779us/sample - loss: 752.2338 - val_loss: 801.2699
Epoch 100/200
1819/1819 [==============================] - 2s 967us/sample - loss: 749.0759 - val_loss: 782.0584
Epoch 101/200
1819/1819 [==============================] - 2s 862us/sample - loss: 739.0179 - val_loss: 797.7670
Epoch 102/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 729.4058 - val_loss: 799.1487
Epoch 103/200
```

```
Epoch 103/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 719.7863 - val_loss: 763.2647
Epoch 104/200
1819/1819 [==============================] - 2s 970us/sample - loss: 713.9126 - val_loss: 781.6902
Epoch 105/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 704.9967 - val_loss: 769.5585
Epoch 106/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 699.7495 - val_loss: 767.4335
Epoch 107/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 699.2034 - val_loss: 782.6301
Epoch 108/200
1819/1819 [==============================] - 2s 956us/sample - loss: 695.2523 - val_loss: 769.8416
Epoch 109/200
1819/1819 [==============================] - 1s 709us/sample - loss: 682.4008 - val_loss: 748.5983
Epoch 110/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 679.1537 - val_loss: 739.5064
Epoch 111/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 672.5467 - val_loss: 753.5830
Epoch 112/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 664.1292 - val_loss: 752.0270
Epoch 113/200
1819/1819 [==============================] - 1s 739us/sample - loss: 658.1551 - val_loss: 747.7419
Epoch 114/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 652.3015 - val_loss: 746.6999
Epoch 115/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 646.5960 - val_loss: 738.7539
Epoch 116/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 645.4920 - val_loss: 747.0281
Epoch 117/200
1819/1819 [==============================] - 2s 976us/sample - loss: 640.5023 - val_loss: 734.5042
Epoch 118/200
1819/1819 [==============================] - 2s 981us/sample - loss: 651.9186 - val_loss: 742.8389
Epoch 119/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 637.6898 - val_loss: 747.6180
Epoch 120/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 632.6572 - val_loss: 751.6499
Epoch 121/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 620.7795 - val_loss: 753.5726
Epoch 122/200
1819/1819 [==============================] - 2s 874us/sample - loss: 628.0568 - val_loss: 782.8309
Epoch 123/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 622.3786 - val_loss: 726.3257
Epoch 124/200
1819/1819 [==============================] - 2s 973us/sample - loss: 612.5781 - val_loss: 744.8676
Epoch 125/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 619.6186 - val_loss: 756.2452
Epoch 126/200
1819/1819 [==============================] - 2s 872us/sample - loss: 619.5886 - val_loss: 759.8068
Epoch 127/200
1819/1819 [==============================] - 1s 823us/sample - loss: 605.1471 - val_loss: 747.2674
Epoch 128/200
1819/1819 [==============================] - 2s 975us/sample - loss: 594.0718 - val_loss: 748.4487
Epoch 129/200
1819/1819 [==============================] - 1s 818us/sample - loss: 595.2797 - val_loss: 754.5476
Epoch 130/200
1819/1819 [==============================] - 2s 888us/sample - loss: 587.5274 - val_loss: 745.9202
Epoch 131/200
1819/1819 [==============================] - 2s 970us/sample - loss: 588.5825 - val_loss: 763.0743
Epoch 132/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 582.5541 - val_loss: 752.4545
Epoch 133/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 580.6276 - val_loss: 736.1227
Epoch 134/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 590.4266 - val_loss: 746.5705
Epoch 135/200
1819/1819 [==============================] - 1s 797us/sample - loss: 577.6302 - val_loss: 743.3535
Epoch 136/200
1819/1819 [==============================] - 2s 927us/sample - loss: 569.4631 - val_loss: 752.2826
Epoch 137/200
1819/1819 [==============================] - 2s 981us/sample - loss: 565.8888 - val_loss: 752.4820
Epoch 138/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 568.5767 - val_loss: 769.8948
Epoch 139/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 585.4830 - val_loss: 754.5170
Epoch 140/200
1819/1819 [==============================] - 2s 958us/sample - loss: 561.6029 - val_loss: 752.1355
Epoch 141/200
1819/1819 [==============================] - 2s 917us/sample - loss: 561.2153 - val_loss: 758.6105
```

```
1819/1819 [==============================] - 2s 917us/sample - loss: 561.2153 - val_loss: 758.6105
Epoch 142/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 551.6124 - val_loss: 761.4422
Epoch 143/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 558.0027 - val_loss: 751.6417
Epoch 144/200
1819/1819 [==============================] - 1s 766us/sample - loss: 547.8712 - val_loss: 765.0106
Epoch 145/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 553.2855 - val_loss: 759.2198
Epoch 146/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 561.7305 - val_loss: 772.2987
Epoch 147/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 541.7588 - val_loss: 749.7402
Epoch 148/200
1819/1819 [==============================] - 2s 950us/sample - loss: 551.4094 - val_loss: 762.7736
Epoch 149/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 556.5108 - val_loss: 762.8681
Epoch 150/200
1819/1819 [==============================] - 2s 993us/sample - loss: 541.6066 - val_loss: 760.8850
Epoch 151/200
1819/1819 [==============================] - 2s 871us/sample - loss: 534.9633 - val_loss: 764.2015
Epoch 152/200
1819/1819 [==============================] - 2s 886us/sample - loss: 542.4935 - val_loss: 771.7103
Epoch 153/200
1819/1819 [==============================] - 2s 840us/sample - loss: 543.4751 - val_loss: 785.1794
Epoch 154/200
1819/1819 [==============================] - 1s 752us/sample - loss: 532.7107 - val_loss: 765.0066
Epoch 155/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 532.3839 - val_loss: 769.4889
Epoch 156/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 523.9980 - val_loss: 765.0040
Epoch 157/200
1819/1819 [==============================] - 2s 930us/sample - loss: 517.0886 - val_loss: 770.3256
Epoch 158/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 527.9351 - val_loss: 790.8088
Epoch 159/200
1819/1819 [==============================] - 1s 757us/sample - loss: 533.1190 - val_loss: 783.2787
Epoch 160/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 517.0173 - val_loss: 776.1750
Epoch 161/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 515.1864 - val_loss: 798.6334
Epoch 162/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 545.5638 - val_loss: 811.3667
Epoch 163/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 544.8721 - val_loss: 771.9082
Epoch 164/200
1819/1819 [==============================] - 2s 941us/sample - loss: 513.1319 - val_loss: 774.3595
Epoch 165/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 502.7967 - val_loss: 776.8696
Epoch 166/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 518.5042 - val_loss: 797.1524
Epoch 167/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 527.7395 - val_loss: 787.1454
Epoch 168/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 518.8214 - val_loss: 777.3846
Epoch 169/200
1819/1819 [==============================] - 2s 889us/sample - loss: 515.8101 - val_loss: 780.6678
Epoch 170/200
1819/1819 [==============================] - 2s 882us/sample - loss: 504.8657 - val_loss: 756.6906
Epoch 171/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 507.2018 - val_loss: 778.6268
Epoch 172/200
1819/1819 [==============================] - 1s 819us/sample - loss: 507.9942 - val_loss: 773.8688
Epoch 173/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 501.6209 - val_loss: 775.6439
Epoch 174/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 508.4787 - val_loss: 789.9001
Epoch 175/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 519.9220 - val_loss: 798.9360
Epoch 176/200
1819/1819 [==============================] - 2s 946us/sample - loss: 505.8887 - val_loss: 789.8418
Epoch 177/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 513.2569 - val_loss: 780.0457
Epoch 178/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 504.3741 - val_loss: 791.6274
Epoch 179/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 495.8392 - val_loss: 811.5639
Epoch 180/200
```

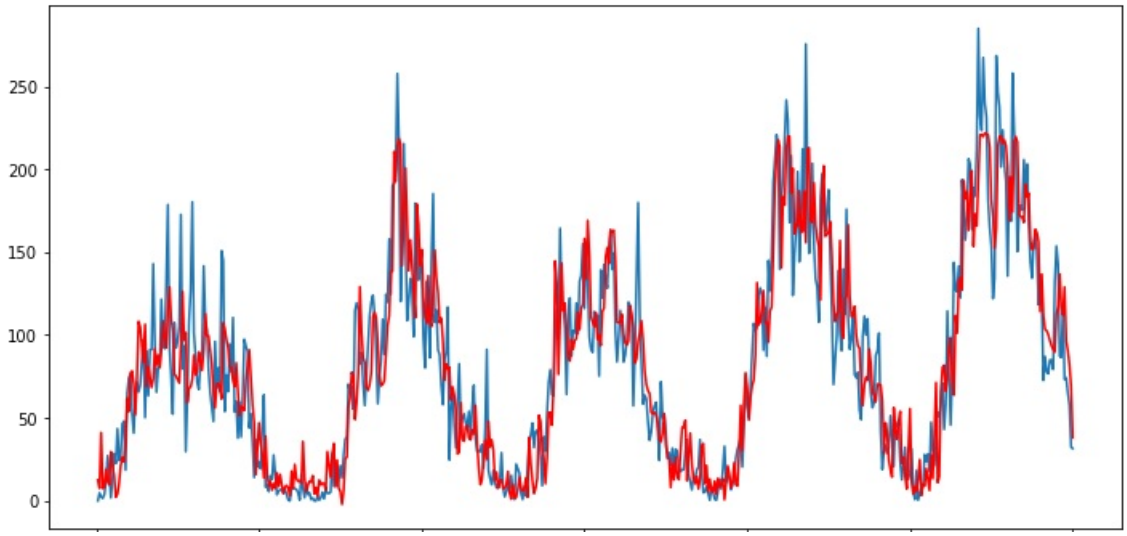
```
Epoch 180/200
1819/1819 [==============================] - 3s 1ms/sample - loss: 499.5105 - val_loss: 789.6865
Epoch 181/200
1819/1819 [==============================] - 2s 963us/sample - loss: 503.0380 - val_loss: 826.2361
Epoch 182/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 504.3325 - val_loss: 805.1897
Epoch 183/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 506.0902 - val_loss: 833.9689
Epoch 184/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 496.8381 - val_loss: 802.5962
Epoch 185/200
1819/1819 [==============================] - 2s 878us/sample - loss: 497.9565 - val_loss: 828.5917
Epoch 186/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 492.4226 - val_loss: 812.7002
Epoch 187/200
1819/1819 [==============================] - 2s 912us/sample - loss: 488.4890 - val_loss: 784.9306
Epoch 188/200
1819/1819 [==============================] - 1s 764us/sample - loss: 491.4178 - val_loss: 788.7584
Epoch 189/200
1819/1819 [==============================] - 1s 814us/sample - loss: 484.1548 - val_loss: 806.0969
Epoch 190/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 482.6576 - val_loss: 846.3963
Epoch 191/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 487.9446 - val_loss: 816.6133
Epoch 192/200
1819/1819 [==============================] - 2s 947us/sample - loss: 483.0335 - val_loss: 805.4659
Epoch 193/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 487.8873 - val_loss: 802.8141
Epoch 194/200
1819/1819 [==============================] - 2s 952us/sample - loss: 485.4883 - val_loss: 833.1775
Epoch 195/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 492.5445 - val_loss: 802.1041
Epoch 196/200
1819/1819 [==============================] - 2s 992us/sample - loss: 472.9243 - val_loss: 806.7954
Epoch 197/200
1819/1819 [==============================] - 2s 997us/sample - loss: 479.1525 - val_loss: 811.1148
Epoch 198/200
1819/1819 [==============================] - 1s 789us/sample - loss: 475.6808 - val_loss: 796.8122
Epoch 199/200
1819/1819 [==============================] - 2s 987us/sample - loss: 477.4408 - val_loss: 823.0045
Epoch 200/200
1819/1819 [==============================] - 2s 1ms/sample - loss: 473.4731 - val_loss: 793.6372
```

In [62]:

```
predictions = model.predict(X_dev, verbose=4)
```

In [64]:

```
times=list(range(1,len(y_dev)+1))
plt.figure(figsize=(12,6))
plt.plot(times, y_dev)
plt.plot(times, predictions, color='red')
pyplot.show()
```




0
100
200
300
400
500
600