Forecasting Evapotranspiration using RNN - LSTM

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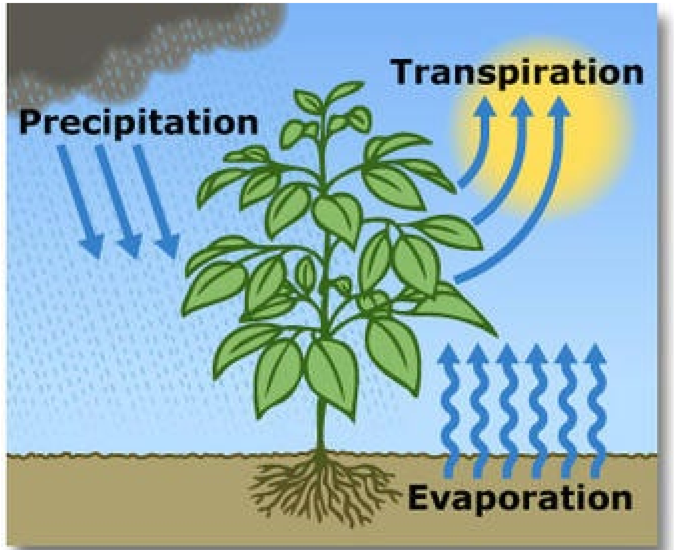
Civil & Environmental Engineering

Evapotranspiration

According to USGS:

“In general, evapotranspiration is the sum of evaporation and transpiration.”



Source: www.usgs.gov

Some applications of Evapotranspiration:

- Climate and cloud formation
  (*Shukla and Mintz*, 1982; *Rabin et al.*, 1990; *Mölders and Raabe*, 1996)
- Agricultural management
  (*Allen et al.*, 1998; *Farahani et al.*, 2007; *Allen et al.*, 2011)
- Water resources management
  (*Bastiaanssen et al.*, 2005; *Anderson et al.*, 2012)
- Detection of drought and heat waves
  (*Rind et al.*, 1990; *Vicente-Serrano et al.*, 2010; *Miralles et al.*, 2014; *Otkin et al.*,2010)

HIGH PLAINS
REGIONAL CLIMATE CENTER

Penman Monteith Equation

Allen et al., 1998

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma(900/(T+273)U(e_s - e_a))}{\Delta + \gamma(1 + 0.34U)}$$

ET_o = Reference Evapotranspiration (mm/day)

Δ = Slope Vapor Pressure Curve (kPa°C^{-1})

R_n = Net radiation at the crop surface (MJ m^{-2} day^{-1})

G = Soil Heat Flux (MJ m^{-2} day^{-1})

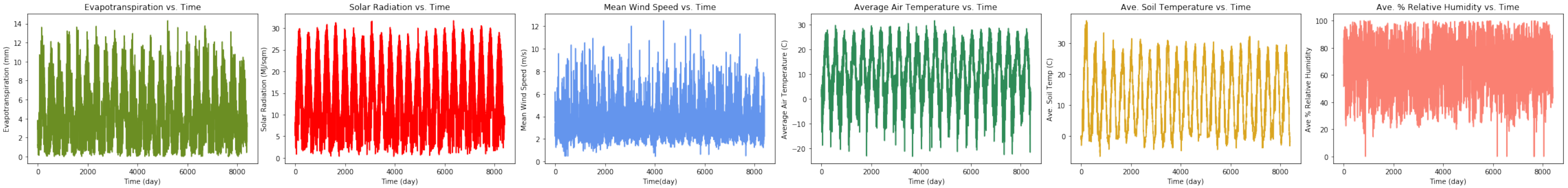
γ = Psychrometric Constant (kPa°C^{-1})

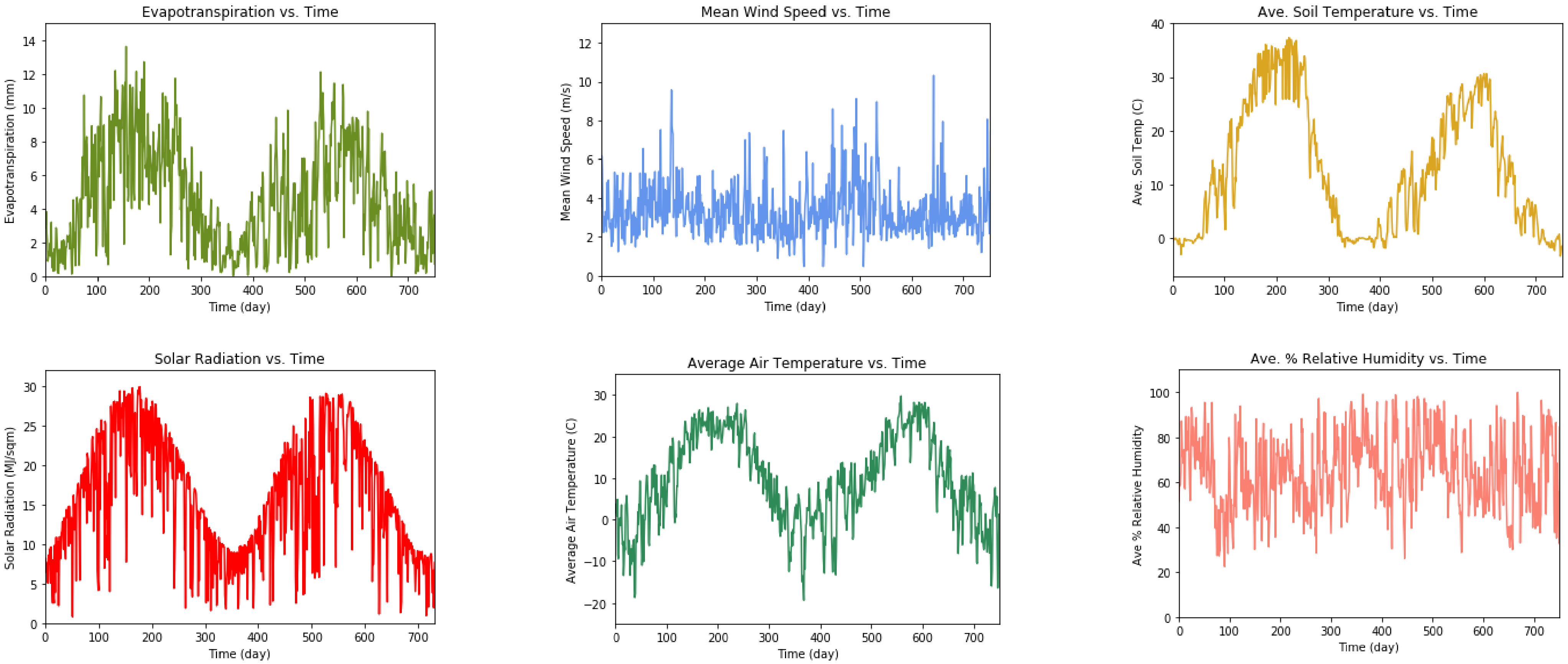
T = Mean Daily Air Temperature at the reference height of 2 m (°C)

U = Wind Speed at 2 m height (m s^{-1})

e_s = Saturation Vapor Pressure (kPa)

e_a = Actual Vapor Pressure (kPa)


Evapotranspiration vs. Time
Evapotranspiration (mm)
Time (day)
Solar Radiation vs. Time
Solar Radiation (MJ/sqm)
Time (day)
Mean Wind Speed vs. Time
Mean Wind Speed (m/s)
Time(day)
Average Air Temperature vs. Time
Average Air Temperature (C)
Time (day)
Ave. Soil Temperature vs. Time
Ave. Soil Temp (C)
Time (day)
Ave. % Relative Humidity vs. Time
Ave % Relative Humidity
Time (day)


Evapotranspiration vs. Time
Evapotranspiration (mm)
Time (day)
Mean Wind Speed vs. Time
Mean Wind Speed (m/s)
Time (day)
Ave. Soil Temperature vs. Time
Ave. Soil Temp (C)
Time (day)
Solar Radiation vs. Time
Solar Radiation (MJ/sqm)
Time (day)
Average Air Temperature vs. Time
Average Air Temperature (C)
Time (day)
Ave. % Relative Humidity vs. Time
Ave % Relative Humidity
Time (day)

RNN - LSTM

https://colab.research.google.com/drive/1B1vvZMdlLjEwsxzrNjrMx4viNctib6go

```
#define timesteps and features
ntimesteps = 30
nfeatures = 6
```

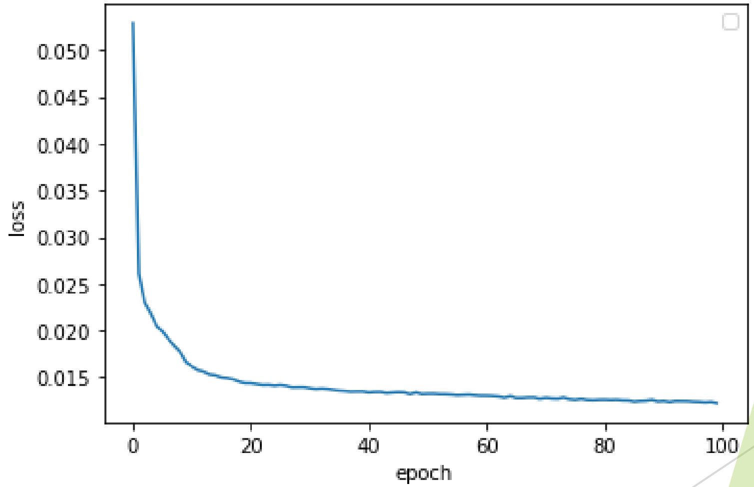
```
model = Sequential()

model.add(LSTM(units=30,return_sequences=True, input_shape=(ntimesteps,nfeatures)))
model.add(Dropout(0.1))
model.add(LSTM(units=30, return_sequences=True))
model.add(Dropout(0.1))
model.add(LSTM(units=30, activation = 'sigmoid'))
model.add(Dropout(0.1))
model.add(Dense(6))
model.compile(loss='mean_squared_error', optimizer='adam')
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm (LSTM)                  (None, 30, 30)            4440
_________________________________________________________________
dropout (Dropout)            (None, 30, 30)            0
_________________________________________________________________
lstm_1 (LSTM)                (None, 30, 30)            7320
_________________________________________________________________
dropout_1 (Dropout)          (None, 30, 30)            0
_________________________________________________________________
lstm_2 (LSTM)                (None, 30)                7320
_________________________________________________________________
dropout_2 (Dropout)          (None, 30)                0
_________________________________________________________________
dense (Dense)                (None, 6)                 186
=================================================================
Total params: 19,266
Trainable params: 19,266
Non-trainable params: 0
```

```
[ ] hist = model.fit(x_train,y_train, epochs=100, batch_size=32, verbose=1)
```

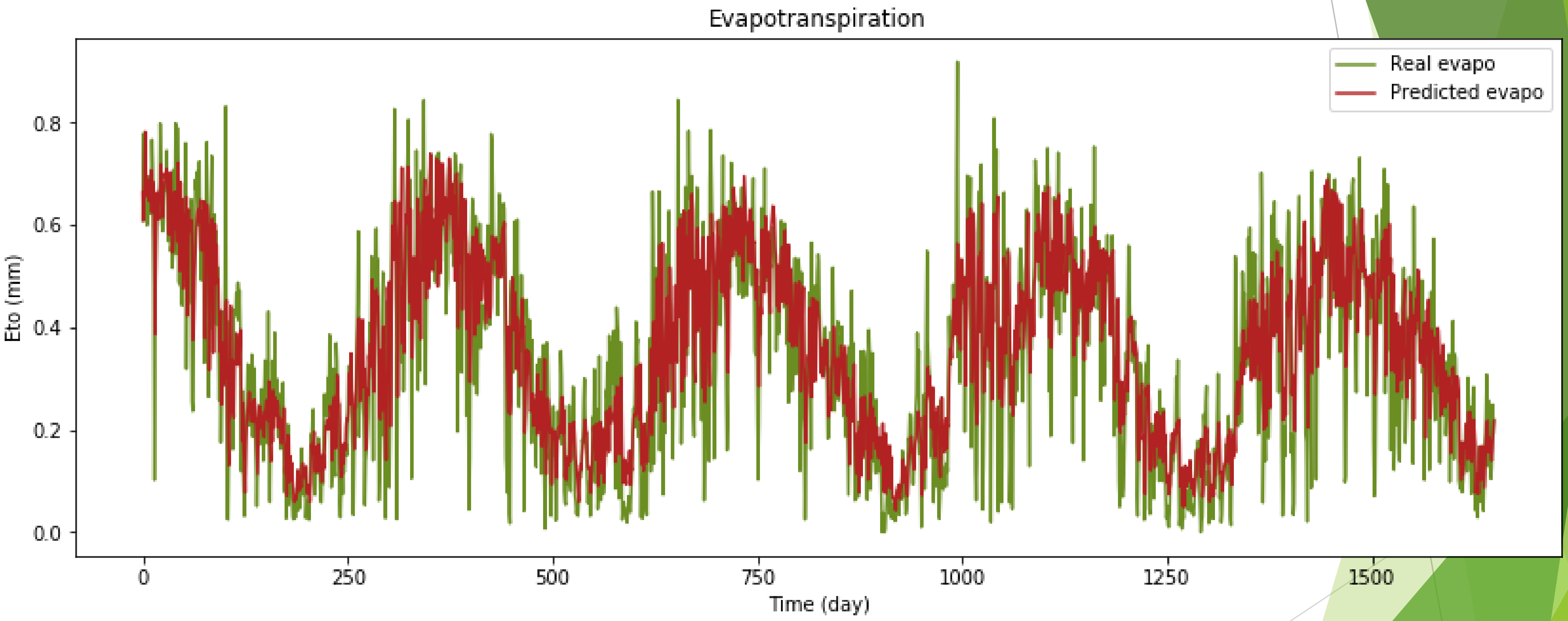
```
Epoch 98/100
6686/6686 [==============================] - 31s 5ms/sample - loss: 0.0123
Epoch 99/100
6686/6686 [==============================] - 31s 5ms/sample - loss: 0.0124
Epoch 100/100
6686/6686 [==============================] - 31s 5ms/sample - loss: 0.0122
```



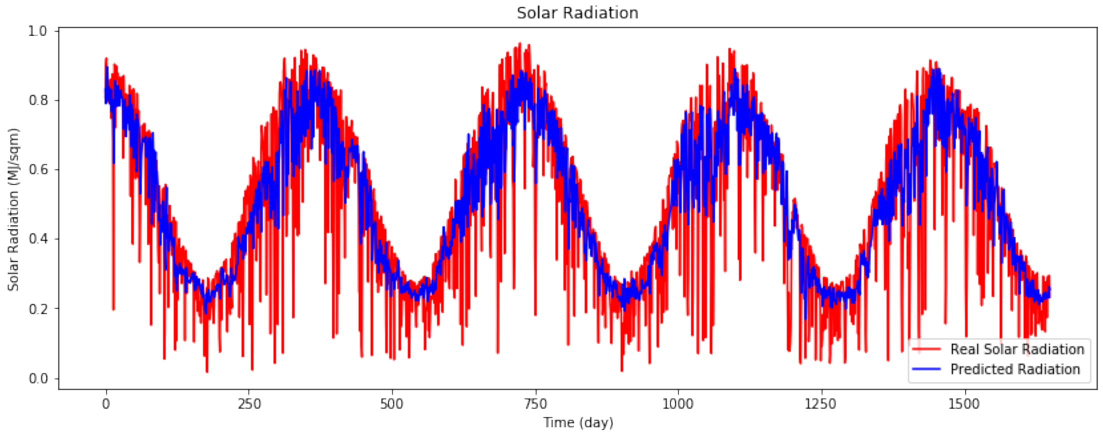

```
test_loss = model.evaluate(x_test, y_test)
print(test_loss)
```

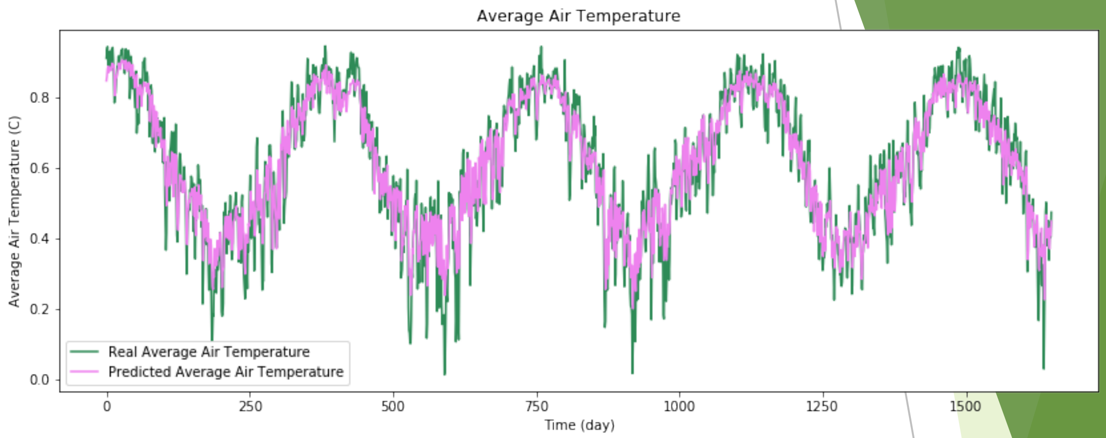
```
1650/1650 [==============================] - 2s 1ms/sample - loss: 0.0114
0.011365549738772891
```

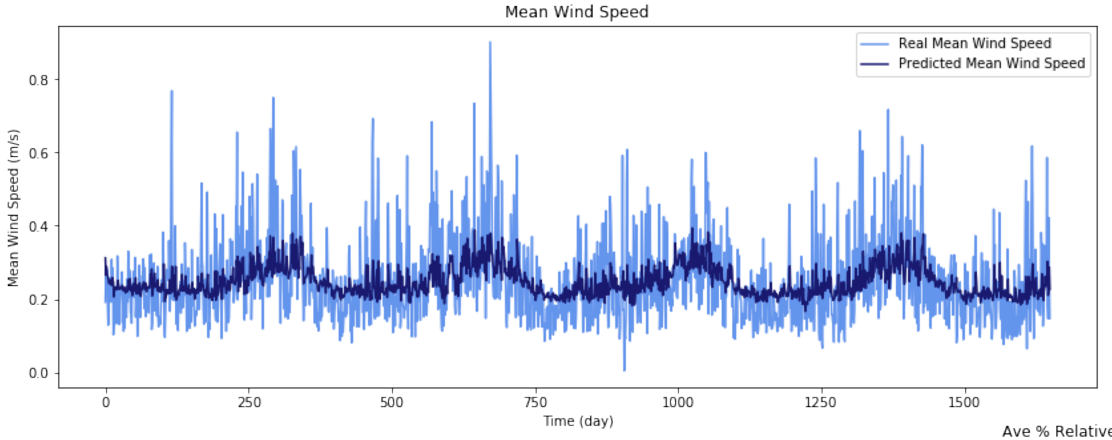
Results

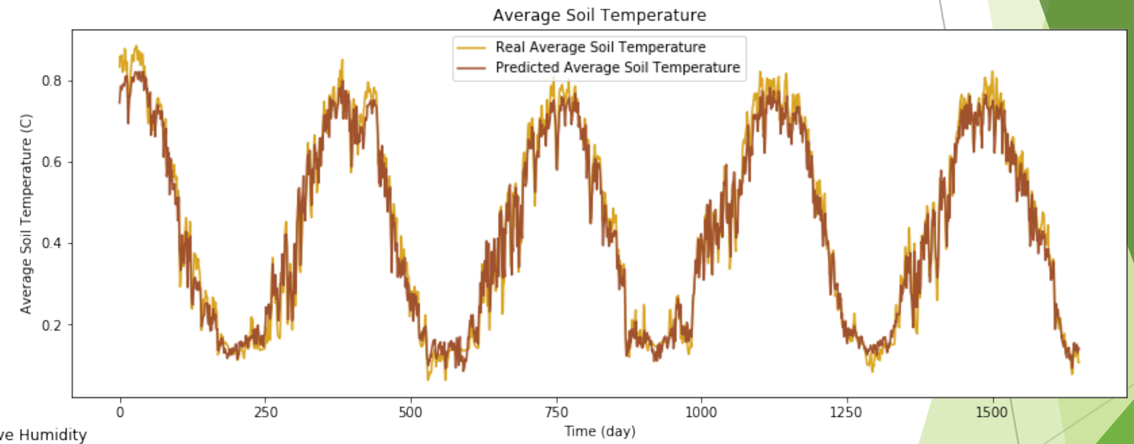

Evapotranspiration
Real evapo
Predicted evapo
Eto (mm)
0.0
0.2
0.4
0.6
0.8
0
250
500
750
1000
1250
1500
Time (day)

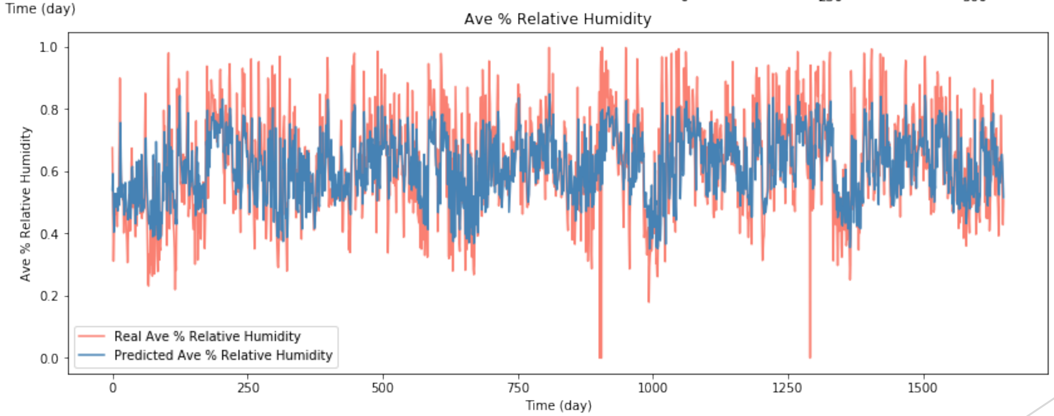
Results


Solar Radiation
1.0
0.8
0.6
0.4
0.2
0.0
Solar Radiation (MJ/sqm)
0
250
500
750
1000
1250
1500
Time (day)
Real Solar Radiation
Predicted Radiation


Average Air Temperature
0.8
0.6
0.4
0.2
0.0
Average Air Temperature (C)
0
250
500
750
1000
1250
1500
Time (day)
Real Average Air Temperature
Predicted Average Air Temperature


Mean Wind Speed
0.8
0.6
0.4
0.2
0.0
Mean Wind Speed (m/s)
0
250
500
750
1000
1250
1500
Time (day)
Real Mean Wind Speed
Predicted Mean Wind Speed


Average Soil Temperature
0.8
0.6
0.4
0.2
Average Soil Temperature (C)
0
250
500
750
1000
1250
1500
Time (day)
Real Average Soil Temperature
Predicted Average Soil Temperature


Ave % Relative Humidity
1.0
0.8
0.6
0.4
0.2
0.0
Ave % Relative Humidity
0
250
500
750
1000
1250
1500
Time (day)
Real Ave % Relative Humidity
Predicted Ave % Relative Humidity

Conclusions and Recommendation

- RNN – LSTM can be a effective program in predicting or forecasting the mean values of evapotranspiration and other time-series data.
- Improving the program via training it to detect the anomalies in data for more accurate results.
- Develop a more accurate RNN – LSTM program in order to use for weather/rainfall, drought forecast, and for agricultural practices.

References

- Hanson, R. (2016, Dec. 9).Evapotranspiration and Droughts. Retrieved from https://geochange.er.usgs.gov/sw/changes/natural/et/
- Fisher, J. B., et al. (2017). The future of evapotranspiration: Global requirements for ecosystem functioning, carbon and climate feedbacks, agricultural management, and water resources, *Water Resour. Res., 53, 2618-2626*, doi:10.1002/ 2016WR020175.
- U.S. Geological Survey (n.d.). Evapotranspiration and the Water Cycle. Retrieved from https://www.usgs.gov/special-topic/water-science-school/science/evapotranspiration-and-water-cycle?qt-science_center_objects=0#qt-science_center_objects