```
import matplotlib as mpl
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
from sklearn.preprocessing import MinMaxScaler
from scipy import stats
import seaborn as sns
import tensorflow as tf
from tensorflow import keras
import sklearn
import sys
import io

n_steps = 50
forecast = 10

def plot_learning_curves(loss, val_loss):
    plt.figure()
    plt.plot(np.arange(len(loss)), loss, "b.-", label="Training loss")
    plt.plot(np.arange(len(val_loss)), val_loss, "r.-", label="Validation loss")
    plt.gca().xaxis.set_major_locator(mpl.ticker.MaxNLocator(integer=True))
    plt.legend(fontsize=14)
    plt.xlabel("Epochs")
    plt.ylabel("Loss")
    plt.grid(True)

#LOAD DATA
data_west = pd.read_csv('denoised_data_1015_north.csv')
data_west_o = np.array(data_west.FLOW)
# #EXRTEND DATA
array_to_concatinate = data_west_o[288:]
for iter in range (35):
    data_west_o = np.concatenate([data_west_o,array_to_concatinate])

# #SCALE AND RESHAPE DATA
scaler = MinMaxScaler()
array = data_west_o.reshape(-1, 1)
array_scaled = scaler.fit_transform(array)
flow_reshaped = array_scaled[:(len(array_scaled) - (len(array_scaled) % (n_steps+forecast
print(flow_reshaped.shape)

# #TRAIN SET, VALIDATION SET, TEST SET
test = int(0.7 * flow_reshaped.shape[0])
valid = int(0.9 * flow_reshaped.shape[0])

X_train= flow_reshaped[:test, :n_steps] #first 50, last 10
X_valid = flow_reshaped[test:valid, :n_steps]
X_test = flow_reshaped[valid:, :n_steps]

#prepare targets
Y = np.empty((flow_reshaped.shape[0], n_steps, forecast))
for step_ahead in range(1, forecast + 1):
    Y[:, :, step_ahead - 1] = flow_reshaped[:, step_ahead:step_ahead + n_steps, 0]

y_train = Y[:test]
y_valid = Y[test:valid]
y_test = Y[valid:]

# # NEW MODEL TO FIT HYPERPARAMETERS
model = keras.models.Sequential([
    keras.layers.SimpleRNN(20, return_sequences=True, input_shape=[None, 1]),
    keras.layers.SimpleRNN(20, return_sequences=True),
    keras.layers.TimeDistributed(keras.layers.Dense(forecast))
])

def last_time_step_mse(Y_true, Y_pred):
    return keras.metrics.mean_squared_error(Y_true[:, -1], Y_pred[:, -1])

model.compile(loss="mse", optimizer="adam",  metrics=[last_time_step_mse])
```

```
early_stopping_cb = keras.callbacks.EarlyStopping(patience=10, restore_best_weights=True)
history = model.fit(X_train, y_train, epochs=700,
                    validation_data=(X_valid, y_valid), callbacks=[early_stopping_cb])

model.save("rnn_1014_norht.h5")
plot_learning_curves(history.history["loss"], history.history["val_loss"])


#50 minutes forecast
flow_unscaled = array[:(len(array) - (len(array) % (n_steps + forecast)))].reshape(-1, (n
y_test_unscaled = flow_unscaled[valid:, n_steps:, 0]
y_real_rescaled = y_test_unscaled[-1, :].reshape(-1, 1)
print(y_real_rescaled.shape)

flow_not_reshaped = array[:(len(array) - (len(array) % (n_steps+forecast)))]

#flow prediction
y_pred = model.predict(X_test[-1, :].reshape(-1, n_steps, 1)) #shape (1, 50, 10)
y_pred = y_pred[-1,-1,:].reshape(-1,1)
y_pred_rescaled = scaler.inverse_transform(y_pred).reshape(-1, 1) #shape (10, 1)
print(y_pred_rescaled.shape)

#time
time_not_reshaped = np.array(data_west['TIME'][:(len(data_west['TIME']) - (len(data_west[
time_reshaped = np.array(data_west['TIME'][:(len(data_west['TIME']) - (len(data_west['TIM
    reshape(-1, (n_steps+forecast), 1)

valid_time = int(0.9 * time_reshaped.shape[0])
y_time_test = time_reshaped[valid_time:, n_steps:, 0]
print(y_time_test[-1, :].shape)

def plot_prediction(y_real_resacled, y_pred_rescaled, flow_not_reshaped, time_not_reshape
    plt.figure()
    plt.title("50 minutes prediction", fontsize=14)
    plt.plot(time_not_reshaped[-300:-forecast], flow_not_reshaped[-300:-forecast], 'b-')
    plt.plot(y_time_test[-1, :], y_real_resacled, 'ro-', label = 'Real values')
    plt.plot(y_time_test[-1, :], y_pred_rescaled, 'gx-', label = 'Predicted values')
    plt.legend(loc="upper left")
    plt.xlabel("Time")
    plt.ylabel('Volume')

plot_prediction(y_real_rescaled, y_pred_rescaled, flow_not_reshaped, time_not_reshaped, y

plt.show()
```

```
(10132, 60, 1)
Train on 7092 samples, validate on 2026 samples
Epoch 1/700
7092/7092 [==============================] - 4s 534us/sample - loss: 0.0392 - 
Epoch 2/700
7092/7092 [==============================] - 4s 498us/sample - loss: 0.0123 - 
Epoch 3/700
7092/7092 [==============================] - 4s 521us/sample - loss: 0.0114 - 
Epoch 4/700
7092/7092 [==============================] - 3s 488us/sample - loss: 0.0111 - 
Epoch 5/700
7092/7092 [==============================] - 4s 503us/sample - loss: 0.0110 - 
Epoch 6/700
7092/7092 [==============================] - 4s 500us/sample - loss: 0.0109 - 
Epoch 7/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0109 - 
Epoch 8/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0108 - 
Epoch 9/700
7092/7092 [==============================] - 3s 493us/sample - loss: 0.0107 - 
Epoch 10/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0107 - 
Epoch 11/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0107 - 
Epoch 12/700
7092/7092 [==============================] - 3s 493us/sample - loss: 0.0107 - 
Epoch 13/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0106 - 
Epoch 14/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0107 - 
Epoch 15/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0106 - 
Epoch 16/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0106 - 
Epoch 17/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0106 - 
Epoch 18/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0106 - 
Epoch 19/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0106 - 
Epoch 20/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0106 - 
Epoch 21/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0105 - 
Epoch 22/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0106 - 
Epoch 23/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0105 - 
Epoch 24/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0105 - 
Epoch 25/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0105 - 
Epoch 26/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0104 - 
Epoch 27/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0104 - 
Epoch 28/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0104 - 
Epoch 29/700
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Epoch 29/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0103 - l
Epoch 30/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0103 - l
Epoch 31/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0102 - l
Epoch 32/700
7092/7092 [==============================] - 4s 497us/sample - loss: 0.0102 - l
Epoch 33/700
7092/7092 [==============================] - 4s 496us/sample - loss: 0.0102 - l
Epoch 34/700
7092/7092 [==============================] - 4s 494us/sample - loss: 0.0101 - l
Epoch 35/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0101 - l
Epoch 36/700
7092/7092 [==============================] - 3s 469us/sample - loss: 0.0101 - l
Epoch 37/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0101 - l
Epoch 38/700
7092/7092 [==============================] - 3s 488us/sample - loss: 0.0101 - l
Epoch 39/700
7092/7092 [==============================] - 3s 470us/sample - loss: 0.0101 - l
Epoch 40/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0100 - l
Epoch 41/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0100 - l
Epoch 42/700
7092/7092 [==============================] - 3s 466us/sample - loss: 0.0100 - l
Epoch 43/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0100 - l
Epoch 44/700
7092/7092 [==============================] - 4s 494us/sample - loss: 0.0100 - l
Epoch 45/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0100 - l
Epoch 46/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0100 - l
Epoch 47/700
7092/7092 [==============================] - 3s 491us/sample - loss: 0.0099 - l
Epoch 48/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0099 - l
Epoch 49/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0099 - l
Epoch 50/700
7092/7092 [==============================] - 4s 501us/sample - loss: 0.0099 - l
Epoch 51/700
7092/7092 [==============================] - 4s 497us/sample - loss: 0.0099 - l
Epoch 52/700
7092/7092 [==============================] - 4s 500us/sample - loss: 0.0099 - l
Epoch 53/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0099 - l
Epoch 54/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0099 - l
Epoch 55/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0099 - l
Epoch 56/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0098 - l
Epoch 57/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0098 - l
Epoch 58/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0098 - l
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Epoch 59/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0098 - 
Epoch 60/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0098 - 
Epoch 61/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0098 - 
Epoch 62/700
7092/7092 [==============================] - 3s 477us/sample - loss: 0.0097 - 
Epoch 63/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0097 - 
Epoch 64/700
7092/7092 [==============================] - 4s 494us/sample - loss: 0.0097 - 
Epoch 65/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0097 - 
Epoch 66/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0096 - 
Epoch 67/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0096 - 
Epoch 68/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0096 - 
Epoch 69/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0095 - 
Epoch 70/700
7092/7092 [==============================] - 4s 502us/sample - loss: 0.0095 - 
Epoch 71/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0095 - 
Epoch 72/700
7092/7092 [==============================] - 4s 500us/sample - loss: 0.0094 - 
Epoch 73/700
7092/7092 [==============================] - 3s 491us/sample - loss: 0.0095 - 
Epoch 74/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0095 - 
Epoch 75/700
7092/7092 [==============================] - 3s 493us/sample - loss: 0.0094 - 
Epoch 76/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0094 - 
Epoch 77/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0093 - 
Epoch 78/700
7092/7092 [==============================] - 4s 496us/sample - loss: 0.0093 - 
Epoch 79/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0092 - 
Epoch 80/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0092 - 
Epoch 81/700
7092/7092 [==============================] - 3s 472us/sample - loss: 0.0091 - 
Epoch 82/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0091 - 
Epoch 83/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0090 - 
Epoch 84/700
7092/7092 [==============================] - 3s 473us/sample - loss: 0.0089 - 
Epoch 85/700
7092/7092 [==============================] - 3s 473us/sample - loss: 0.0088 - 
Epoch 86/700
7092/7092 [==============================] - 3s 470us/sample - loss: 0.0087 - 
Epoch 87/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0087 - 
Epoch 88/700
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7092/7092 [==============================] - 3s 469us/sample - loss: 0.0086 - l
Epoch 89/700
7092/7092 [==============================] - 3s 458us/sample - loss: 0.0086 - l
Epoch 90/700
7092/7092 [==============================] - 3s 484us/sample - loss: 0.0085 - l
Epoch 91/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0085 - l
Epoch 92/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0085 - l
Epoch 93/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0084 - l
Epoch 94/700
7092/7092 [==============================] - 3s 469us/sample - loss: 0.0083 - l
Epoch 95/700
7092/7092 [==============================] - 3s 467us/sample - loss: 0.0084 - l
Epoch 96/700
7092/7092 [==============================] - 3s 469us/sample - loss: 0.0083 - l
Epoch 97/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0084 - l
Epoch 98/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0083 - l
Epoch 99/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0082 - l
Epoch 100/700
7092/7092 [==============================] - 3s 467us/sample - loss: 0.0082 - l
Epoch 101/700
7092/7092 [==============================] - 3s 462us/sample - loss: 0.0082 - l
Epoch 102/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0082 - l
Epoch 103/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0082 - l
Epoch 104/700
7092/7092 [==============================] - 3s 473us/sample - loss: 0.0082 - l
Epoch 105/700
7092/7092 [==============================] - 3s 472us/sample - loss: 0.0081 - l
Epoch 106/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0081 - l
Epoch 107/700
7092/7092 [==============================] - 3s 466us/sample - loss: 0.0081 - l
Epoch 108/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0081 - l
Epoch 109/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0080 - l
Epoch 110/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0080 - l
Epoch 111/700
7092/7092 [==============================] - 3s 467us/sample - loss: 0.0080 - l
Epoch 112/700
7092/7092 [==============================] - 3s 462us/sample - loss: 0.0080 - l
Epoch 113/700
7092/7092 [==============================] - 3s 477us/sample - loss: 0.0079 - l
Epoch 114/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0080 - l
Epoch 115/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0079 - l
Epoch 116/700
7092/7092 [==============================] - 3s 469us/sample - loss: 0.0079 - l
Epoch 117/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0079 - l
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Epoch 118/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0079 - l
Epoch 119/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0079 - l
Epoch 120/700
7092/7092 [==============================] - 3s 488us/sample - loss: 0.0078 - l
Epoch 121/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0078 - l
Epoch 122/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0078 - l
Epoch 123/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0078 - l
Epoch 124/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0078 - l
Epoch 125/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0077 - l
Epoch 126/700
7092/7092 [==============================] - 4s 497us/sample - loss: 0.0078 - l
Epoch 127/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0077 - l
Epoch 128/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0077 - l
Epoch 129/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0078 - l
Epoch 130/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0077 - l
Epoch 131/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0077 - l
Epoch 132/700
7092/7092 [==============================] - 4s 494us/sample - loss: 0.0076 - l
Epoch 133/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0076 - l
Epoch 134/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0076 - l
Epoch 135/700
7092/7092 [==============================] - 3s 492us/sample - loss: 0.0077 - l
Epoch 136/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0076 - l
Epoch 137/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0076 - l
Epoch 138/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0076 - l
Epoch 139/700
7092/7092 [==============================] - 3s 486us/sample - loss: 0.0076 - l
Epoch 140/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0076 - l
Epoch 141/700
7092/7092 [==============================] - 4s 498us/sample - loss: 0.0076 - l
Epoch 142/700
7092/7092 [==============================] - 3s 490us/sample - loss: 0.0075 - l
Epoch 143/700
7092/7092 [==============================] - 4s 504us/sample - loss: 0.0076 - l
Epoch 144/700
7092/7092 [==============================] - 3s 489us/sample - loss: 0.0076 - l
Epoch 145/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0075 - l
Epoch 146/700
7092/7092 [==============================] - 3s 477us/sample - loss: 0.0075 - l
Epoch 147/700
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7092/7092 [==============================] - 3s 486us/sample - loss: 0.0075 - l
Epoch 148/700
7092/7092 [==============================] - 3s 487us/sample - loss: 0.0075 - l
Epoch 149/700
7092/7092 [==============================] - 4s 511us/sample - loss: 0.0075 - l
Epoch 150/700
7092/7092 [==============================] - 3s 481us/sample - loss: 0.0075 - l
Epoch 151/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0074 - l
Epoch 152/700
7092/7092 [==============================] - 3s 478us/sample - loss: 0.0074 - l
Epoch 153/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0074 - l
Epoch 154/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0074 - l
Epoch 155/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0074 - l
Epoch 156/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0074 - l
Epoch 157/700
7092/7092 [==============================] - 3s 472us/sample - loss: 0.0074 - l
Epoch 158/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0074 - l
Epoch 159/700
7092/7092 [==============================] - 3s 482us/sample - loss: 0.0074 - l
Epoch 160/700
7092/7092 [==============================] - 3s 485us/sample - loss: 0.0074 - l
Epoch 161/700
7092/7092 [==============================] - 3s 493us/sample - loss: 0.0074 - l
Epoch 162/700
7092/7092 [==============================] - 4s 496us/sample - loss: 0.0074 - l
Epoch 163/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0074 - l
Epoch 164/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0074 - l
Epoch 165/700
7092/7092 [==============================] - 3s 471us/sample - loss: 0.0074 - l
Epoch 166/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0073 - l
Epoch 167/700
7092/7092 [==============================] - 3s 470us/sample - loss: 0.0073 - l
Epoch 168/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0073 - l
Epoch 169/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0073 - l
Epoch 170/700
7092/7092 [==============================] - 3s 474us/sample - loss: 0.0073 - l
Epoch 171/700
7092/7092 [==============================] - 3s 471us/sample - loss: 0.0073 - l
Epoch 172/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0073 - l
Epoch 173/700
7092/7092 [==============================] - 3s 468us/sample - loss: 0.0073 - l
Epoch 174/700
7092/7092 [==============================] - 3s 471us/sample - loss: 0.0072 - l
Epoch 175/700
7092/7092 [==============================] - 3s 476us/sample - loss: 0.0073 - l
Epoch 176/700
7092/7092 [==============================] - 3s 479us/sample - loss: 0.0073 - l
```

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Epoch 177/700
7092/7092 [==============================] - 3s 467us/sample - loss: 0.0072 - 
Epoch 178/700
7092/7092 [==============================] - 3s 475us/sample - loss: 0.0072 - 
Epoch 179/700
7092/7092 [==============================] - 3s 480us/sample - loss: 0.0073 - 
Epoch 180/700
7092/7092 [==============================] - 3s 483us/sample - loss: 0.0072 - 
(10, 1)
(10, 1)
(10,)
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