```
!wget https://s3.amazonaws.com/keras-datasets/jena_climate_2009_2016.csv.zip
!unzip jena_climate_2009_2016.csv.zip
```

```
--2024-07-22 00:36:21--  https://s3.amazonaws.com/keras-datasets/jena_climate_2009_2016.csv.zip
Resolving s3.amazonaws.com (s3.amazonaws.com)... 3.5.3.251, 16.182.72.240, 52.217.89.38, ...
Connecting to s3.amazonaws.com (s3.amazonaws.com)|3.5.3.251|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 13565642 (13M) [application/zip]
Saving to: ‘jena_climate_2009_2016.csv.zip’

jena_climate_2009_2 100%[===================>]  12.94M  7.52MB/s    in 1.7s

2024-07-22 00:36:23 (7.52 MB/s) - ‘jena_climate_2009_2016.csv.zip’ saved [13565642/13565642]

Archive:  jena_climate_2009_2016.csv.zip
  inflating: jena_climate_2009_2016.csv
  inflating: __MACOSX/._jena_climate_2009_2016.csv
```

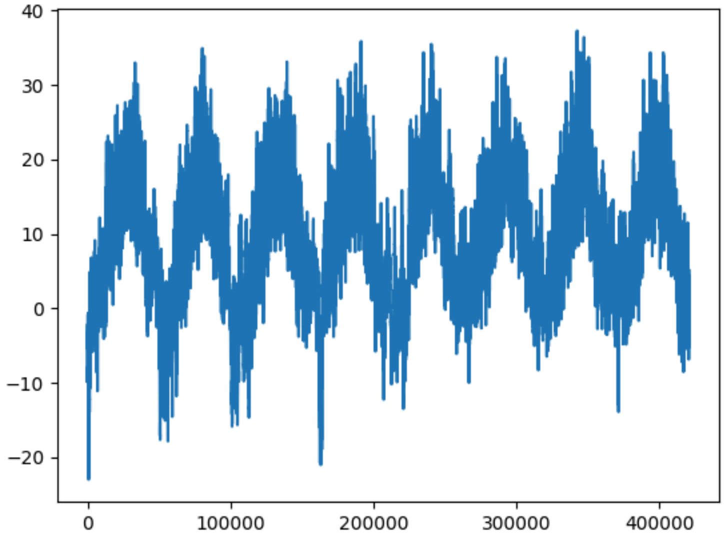
```
import os
fname = os.path.join("jena_climate_2009_2016.csv")

with open(fname) as f:
    data = f.read()

lines = data.split("\n")
header = lines[0].split(",")
lines = lines[1:]
print(header)
print(len(lines))
```

```
['"Date Time"', '"p (mbar)"', '"T (degC)"', '"Tpot (K)"', '"Tdew (degC)"', '"rh (%)"', '"VPmax (mbar)"', '"VPact (mbar)"', '"VPdef
420451
```

```
import numpy as np
temperature = np.zeros((len(lines),))
raw_data = np.zeros((len(lines), len(header) - 1))
for i, line in enumerate(lines):
    values = [float(x) for x in line.split(",")[1:]]
    temperature[i] = values[1]
    raw_data[i, :] = values[:]
```

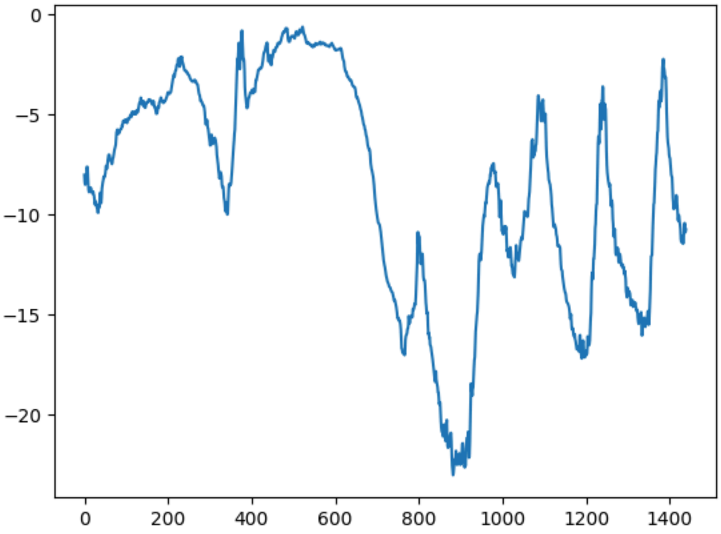
```
from matplotlib import pyplot as plt
plt.plot(range(len(temperature)), temperature)
```

```
[<matplotlib.lines.Line2D at 0x7ba9bad54280>]
```



```
plt.plot(range(1440), temperature[:1440])
```

```
[<matplotlib.lines.Line2D at 0x7ba9b6a748b0>]
```



```
num_train_samples = int(0.5 * len(raw_data))
num_val_samples = int(0.25 * len(raw_data))
num_test_samples = len(raw_data) - num_train_samples - num_val_samples
print("num_train_samples:", num_train_samples)
print("num_val_samples:", num_val_samples)
print("num_test_samples:", num_test_samples)
```

```
num_train_samples: 210225
num_val_samples: 105112
num_test_samples: 105114
```

```
mean = raw_data[:num_train_samples].mean(axis=0)
raw_data -= mean
std = raw_data[:num_train_samples].std(axis=0)
raw_data /= std
```

```
import numpy as np
from tensorflow import keras
int_sequence = np.arange(10)
dummy_dataset = keras.utils.timeseries_dataset_from_array(
    data=int_sequence[:-3],
    targets=int_sequence[3:],
    sequence_length=3,
    batch_size=2,
)

for inputs, targets in dummy_dataset:
    for i in range(inputs.shape[0]):
        print([int(x) for x in inputs[i]], int(targets[i]))
```

```
[0, 1, 2] 3
[1, 2, 3] 4
[2, 3, 4] 5
[3, 4, 5] 6
[4, 5, 6] 7
```

```
sampling_rate = 6
sequence_length = 120
delay = sampling_rate * (sequence_length + 24 - 1)
batch_size = 256

train_dataset = keras.utils.timeseries_dataset_from_array(
    raw_data[:-delay],
    targets=temperature[delay:],
    sampling_rate=sampling_rate,
    sequence_length=sequence_length,
    shuffle=True,
    batch_size=batch_size,
    start_index=0,
    end_index=num_train_samples)

val_dataset = keras.utils.timeseries_dataset_from_array(
    raw_data[:-delay],
    targets=temperature[delay:],
    sampling_rate=sampling_rate,
    sequence_length=sequence_length,
    shuffle=True,
    batch_size=batch_size,
    start_index=num_train_samples,
    end_index=num_train_samples + num_val_samples)

test_dataset = keras.utils.timeseries_dataset_from_array(
    raw_data[:-delay],
    targets=temperature[delay:],
    sampling_rate=sampling_rate,
    sequence_length=sequence_length,
    shuffle=True,
    batch_size=batch_size,
    start_index=num_train_samples + num_val_samples)
```

```
for samples, targets in train_dataset:
    print("samples shape:", samples.shape)
    print("targets shape:", targets.shape)
    break
```

```
samples shape: (256, 120, 14)
targets shape: (256,)
```

Computing the common-sense baseline MAE

```
def evaluate_naive_method(dataset):
    total_abs_err = 0.
    samples_seen = 0
    for samples, targets in dataset:
        preds = samples[:, -1, 1] * std[1] + mean[1]
        total_abs_err += np.sum(np.abs(preds - targets))
        samples_seen += samples.shape[0]
    return total_abs_err / samples_seen

print(f"Validation MAE: {evaluate_naive_method(val_dataset):.2f}")
print(f"Test MAE: {evaluate_naive_method(test_dataset):.2f}")
```

```
Validation MAE: 2.44
Test MAE: 2.62
```

Training and evaluating a densely connected model

```
import keras
from keras import layers
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.Flatten()(inputs)
x = layers.Dense(16, activation="relu")(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_dense.keras",
                                    save_best_only=True)]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
```

```
history = model.fit(train_dataset, epochs=10,
                    validation_data = val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 9s 10ms/step - loss: 12.6169 - mae: 2.7457 - val_loss: 11.5658 - val_mae: 2.7001
Epoch 2/10
819/819 [==============================] - 8s 10ms/step - loss: 9.0949 - mae: 2.3716 - val_loss: 10.3482 - val_mae: 2.5436
Epoch 3/10
819/819 [==============================] - 8s 10ms/step - loss: 8.3441 - mae: 2.2734 - val_loss: 10.0928 - val_mae: 2.5131
Epoch 4/10
819/819 [==============================] - 9s 10ms/step - loss: 7.8413 - mae: 2.2048 - val_loss: 11.4940 - val_mae: 2.6832
Epoch 5/10
819/819 [==============================] - 9s 11ms/step - loss: 7.5344 - mae: 2.1623 - val_loss: 11.8284 - val_mae: 2.7257
Epoch 6/10
819/819 [==============================] - 9s 10ms/step - loss: 7.2655 - mae: 2.1247 - val_loss: 10.5451 - val_mae: 2.5663
Epoch 7/10
819/819 [==============================] - 9s 11ms/step - loss: 7.0483 - mae: 2.0927 - val_loss: 11.1115 - val_mae: 2.6529
Epoch 8/10
819/819 [==============================] - 8s 10ms/step - loss: 6.8763 - mae: 2.0691 - val_loss: 11.0917 - val_mae: 2.6511
Epoch 9/10
819/819 [==============================] - 8s 10ms/step - loss: 6.7404 - mae: 2.0489 - val_loss: 11.3104 - val_mae: 2.6767
Epoch 10/10
819/819 [==============================] - 8s 9ms/step - loss: 6.6355 - mae: 2.0342 - val_loss: 10.4189 - val_mae: 2.5603
```

```
model = keras.models.load_model("jena_dense.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

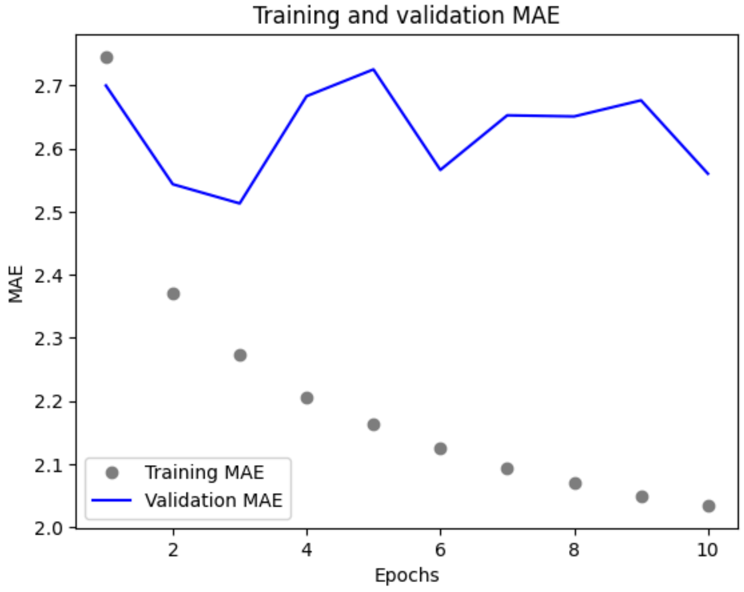
```
405/405 [==============================] - 3s 6ms/step - loss: 11.2569 - mae: 2.6438
Test MAE: 2.64
```

```
model.summary()
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_4 (InputLayer)        [(None, 120, 14)]         0         
                                                                 
 lstm_1 (LSTM)               (None, 16)                1984      
                                                                 
 dropout (Dropout)           (None, 16)                0         
                                                                 
 dense_4 (Dense)             (None, 1)                 17        
                                                                 
=================================================================
Total params: 2001 (7.82 KB)
Trainable params: 2001 (7.82 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
import matplotlib.pyplot as plt
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey",  label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-15-cfa89b244b5a>:7: UserWarning: color is redundantly defined by the '
  plt.plot(epochs, loss,"bo", color="grey",  label="Training MAE")
<ipython-input-15-cfa89b244b5a>:8: UserWarning: color is redundantly defined by the '
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



1D convolutional model

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.Conv1D(8, 24, activation="relu")(inputs)
x = layers.MaxPooling1D(2)(x)
x = layers.Conv1D(8, 12, activation="relu")(x)
x = layers.MaxPooling1D(2)(x)
x = layers.Conv1D(8, 6, activation="relu")(x)
x = layers.GlobalAveragePooling1D()(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
    keras.callbacks.ModelCheckpoint("jena_conv.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 14s 16ms/step - loss: 22.5157 - mae: 3.6792 - val_loss: 15.1129 - val_mae: 3.0754
Epoch 2/10
819/819 [==============================] - 13s 16ms/step - loss: 15.3195 - mae: 3.1093 - val_loss: 15.9912 - val_mae: 3.1743
Epoch 3/10
819/819 [==============================] - 13s 16ms/step - loss: 14.0990 - mae: 2.9791 - val_loss: 14.2328 - val_mae: 2.9749
Epoch 4/10
819/819 [==============================] - 13s 15ms/step - loss: 13.1655 - mae: 2.8778 - val_loss: 14.0730 - val_mae: 2.9718
Epoch 5/10
819/819 [==============================] - 13s 16ms/step - loss: 12.4539 - mae: 2.7975 - val_loss: 13.6871 - val_mae: 2.8999
Epoch 6/10
819/819 [==============================] - 13s 15ms/step - loss: 11.9541 - mae: 2.7389 - val_loss: 16.7237 - val_mae: 3.2250
Epoch 7/10
819/819 [==============================] - 13s 15ms/step - loss: 11.5841 - mae: 2.6953 - val_loss: 16.2268 - val_mae: 3.1634
Epoch 8/10
819/819 [==============================] - 13s 16ms/step - loss: 11.2665 - mae: 2.6588 - val_loss: 13.5815 - val_mae: 2.8894
Epoch 9/10
819/819 [==============================] - 13s 15ms/step - loss: 10.9594 - mae: 2.6206 - val_loss: 12.9581 - val_mae: 2.8177
Epoch 10/10
819/819 [==============================] - 13s 15ms/step - loss: 10.7143 - mae: 2.5914 - val_loss: 13.7678 - val_mae: 2.8976
```

```
model = keras.models.load_model("jena_conv.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

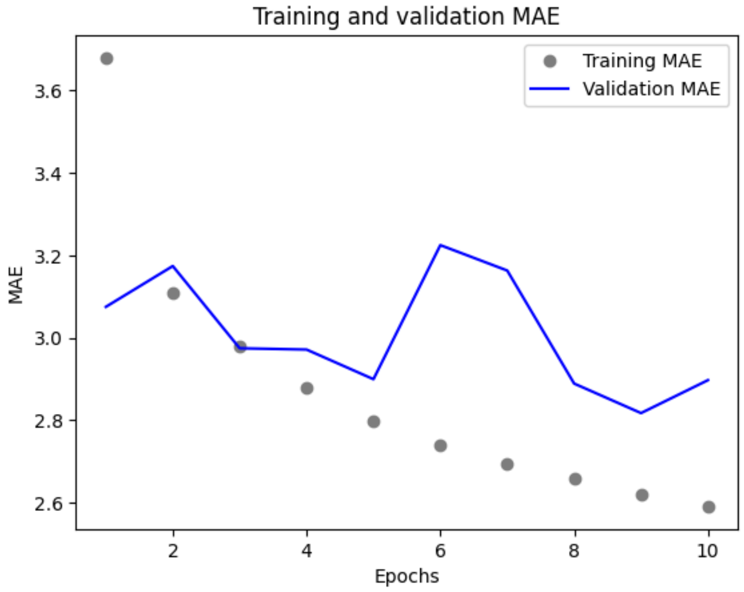
```
405/405 [==============================] - 3s 8ms/step - loss: 14.6499 - mae: 3.0384
Test MAE: 3.04
```

```
model.summary()
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_4 (InputLayer)        [(None, 120, 14)]         0         
                                                                 
 lstm_1 (LSTM)               (None, 16)                1984      
                                                                 
 dropout (Dropout)           (None, 16)                0         
                                                                 
 dense_4 (Dense)             (None, 1)                 17        
                                                                 
=================================================================
Total params: 2001 (7.82 KB)
Trainable params: 2001 (7.82 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-18-b887b99572a7>:6: UserWarning: color is redundantly defined by the '
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-18-b887b99572a7>:7: UserWarning: color is redundantly defined by the '
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



Model on long short term model.

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.LSTM(16)(inputs)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
    keras.callbacks.ModelCheckpoint("jena_lstm.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 46s 54ms/step - loss: 40.3756 - mae: 4.6150 - val_loss: 12.1891 - val_mae: 2.6740
Epoch 2/10
819/819 [==============================] - 43s 52ms/step - loss: 10.8836 - mae: 2.5680 - val_loss: 9.2729 - val_mae: 2.3872
```

```
Epoch 3/10
819/819 [==============================] - 44s 54ms/step - loss: 9.7015 - mae: 2.4343 - val_loss: 9.4580 - val_mae: 2.4124
Epoch 4/10
819/819 [==============================] - 39s 48ms/step - loss: 9.3433 - mae: 2.3860 - val_loss: 9.3026 - val_mae: 2.3846
Epoch 5/10
819/819 [==============================] - 42s 51ms/step - loss: 9.0837 - mae: 2.3502 - val_loss: 9.5579 - val_mae: 2.3993
Epoch 6/10
819/819 [==============================] - 42s 51ms/step - loss: 8.9095 - mae: 2.3227 - val_loss: 9.6277 - val_mae: 2.4076
Epoch 7/10
819/819 [==============================] - 43s 53ms/step - loss: 8.6738 - mae: 2.2900 - val_loss: 9.8604 - val_mae: 2.4282
Epoch 8/10
819/819 [==============================] - 43s 52ms/step - loss: 8.4128 - mae: 2.2592 - val_loss: 9.8222 - val_mae: 2.4188
Epoch 9/10
819/819 [==============================] - 46s 57ms/step - loss: 8.1698 - mae: 2.2263 - val_loss: 10.0534 - val_mae: 2.4477
Epoch 10/10
819/819 [==============================] - 43s 52ms/step - loss: 7.9724 - mae: 2.1983 - val_loss: 10.1506 - val_mae: 2.4524
```

```
model = keras.models.load_model("jena_lstm.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

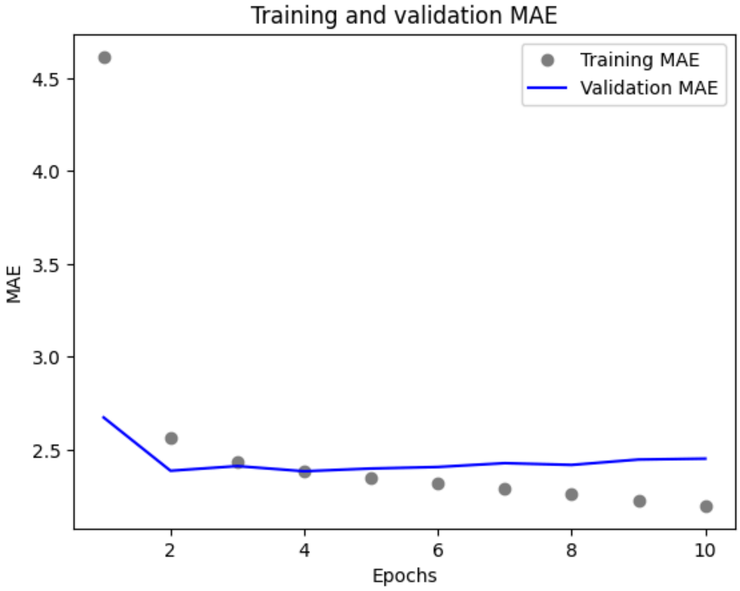
```
405/405 [==============================] - 9s 20ms/step - loss: 11.0166 - mae: 2.5931
Test MAE: 2.59
```

```
model.summary()
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_4 (InputLayer)        [(None, 120, 14)]         0

 lstm_1 (LSTM)               (None, 16)                1984

 dropout (Dropout)           (None, 16)                0

 dense_4 (Dense)             (None, 1)                 17

=================================================================
Total params: 2001 (7.82 KB)
Trainable params: 2001 (7.82 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
import matplotlib.pyplot as plt
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-21-95530881361e>:7: UserWarning: color is redundantly defined by the '
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-21-95530881361e>:8: UserWarning: color is redundantly defined by the '
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



LSTM with dropout regularization

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.LSTM(16, recurrent_dropout=0.25)(inputs)
x = layers.Dropout(0.5)(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_lstm_dropout.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 62s 73ms/step - loss: 50.8587 - mae: 5.3193 - val_loss: 14.1055 - val_mae: 2.8216
Epoch 2/10
819/819 [==============================] - 60s 73ms/step - loss: 20.0957 - mae: 3.4384 - val_loss: 9.9671 - val_mae: 2.4432
Epoch 3/10
819/819 [==============================] - 59s 72ms/step - loss: 18.0908 - mae: 3.2707 - val_loss: 9.5288 - val_mae: 2.4000
Epoch 4/10
819/819 [==============================] - 58s 71ms/step - loss: 17.3134 - mae: 3.2000 - val_loss: 9.5690 - val_mae: 2.4074
Epoch 5/10
819/819 [==============================] - 61s 74ms/step - loss: 16.7479 - mae: 3.1451 - val_loss: 9.7337 - val_mae: 2.4260
Epoch 6/10
819/819 [==============================] - 60s 73ms/step - loss: 16.1844 - mae: 3.0971 - val_loss: 9.4703 - val_mae: 2.3861
Epoch 7/10
819/819 [==============================] - 59s 72ms/step - loss: 15.7871 - mae: 3.0639 - val_loss: 9.5156 - val_mae: 2.4022
Epoch 8/10
819/819 [==============================] - 59s 72ms/step - loss: 15.5861 - mae: 3.0485 - val_loss: 9.2688 - val_mae: 2.3678
Epoch 9/10
819/819 [==============================] - 60s 73ms/step - loss: 15.3483 - mae: 3.0206 - val_loss: 9.1592 - val_mae: 2.3510
Epoch 10/10
819/819 [==============================] - 60s 73ms/step - loss: 15.0331 - mae: 2.9926 - val_loss: 9.3659 - val_mae: 2.3788
```

```
model = keras.models.load_model("jena_lstm_dropout.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

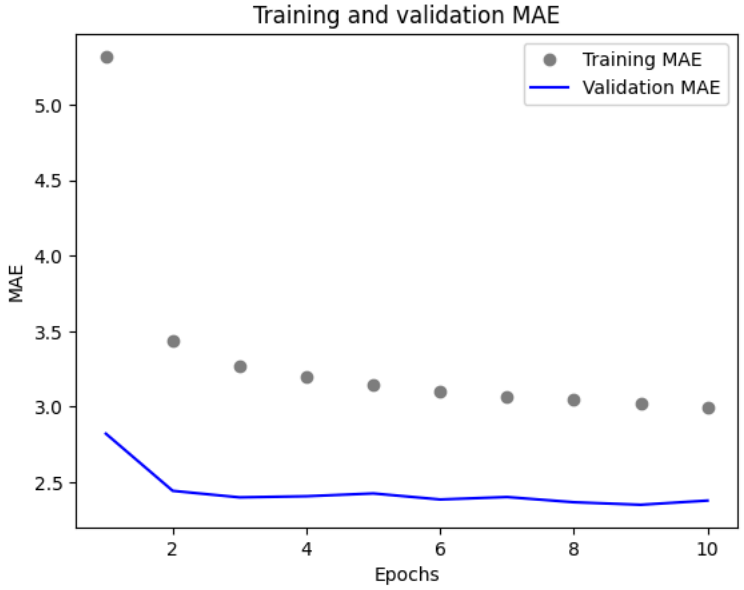
```
405/405 [==============================] - 7s 17ms/step - loss: 10.6921 - mae: 2.5830
Test MAE: 2.58
```

```
model.summary()
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_4 (InputLayer)        [(None, 120, 14)]         0
 lstm_1 (LSTM)              (None, 16)                1984

 dropout (Dropout)          (None, 16)                0

 dense_4 (Dense)            (None, 1)                 17

=================================================================
Total params: 2001 (7.82 KB)
Trainable params: 2001 (7.82 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-28-b887b99572a7>:6: UserWarning: color is redundantly defined by the '
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-28-b887b99572a7>:7: UserWarning: color is redundantly defined by the '
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



LSTM with 16 units

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.LSTM(16, return_sequences=True)(inputs)
x = layers.LSTM(16)(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_LSTM_stacked1.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 94s 112ms/step - loss: 39.8044 - mae: 4.5872 - val_loss: 13.1436 - val_mae: 2.7344
Epoch 2/10
819/819 [==============================] - 88s 107ms/step - loss: 10.3756 - mae: 2.4979 - val_loss: 9.6161 - val_mae: 2.4254
Epoch 3/10
819/819 [==============================] - 84s 102ms/step - loss: 8.8997 - mae: 2.3267 - val_loss: 9.4961 - val_mae: 2.4079
Epoch 4/10
819/819 [==============================] - 86s 105ms/step - loss: 8.3279 - mae: 2.2478 - val_loss: 9.7730 - val_mae: 2.4479
Epoch 5/10
```

```
819/819 [==============================] - 90s 110ms/step - loss: 7.8923 - mae: 2.1891 - val_loss: 9.5072 - val_mae: 2.4166
Epoch 6/10
819/819 [==============================] - 91s 110ms/step - loss: 7.4652 - mae: 2.1314 - val_loss: 10.1777 - val_mae: 2.4978
Epoch 7/10
819/819 [==============================] - 86s 105ms/step - loss: 7.1916 - mae: 2.0917 - val_loss: 10.1427 - val_mae: 2.4901
Epoch 8/10
819/819 [==============================] - 87s 107ms/step - loss: 6.9195 - mae: 2.0483 - val_loss: 10.2893 - val_mae: 2.5108
Epoch 9/10
819/819 [==============================] - 83s 102ms/step - loss: 6.6404 - mae: 2.0028 - val_loss: 10.4150 - val_mae: 2.5247
Epoch 10/10
819/819 [==============================] - 88s 107ms/step - loss: 6.4491 - mae: 1.9732 - val_loss: 10.4229 - val_mae: 2.5295
```

```
model = keras.models.load_model("jena_LSTM_stacked1.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

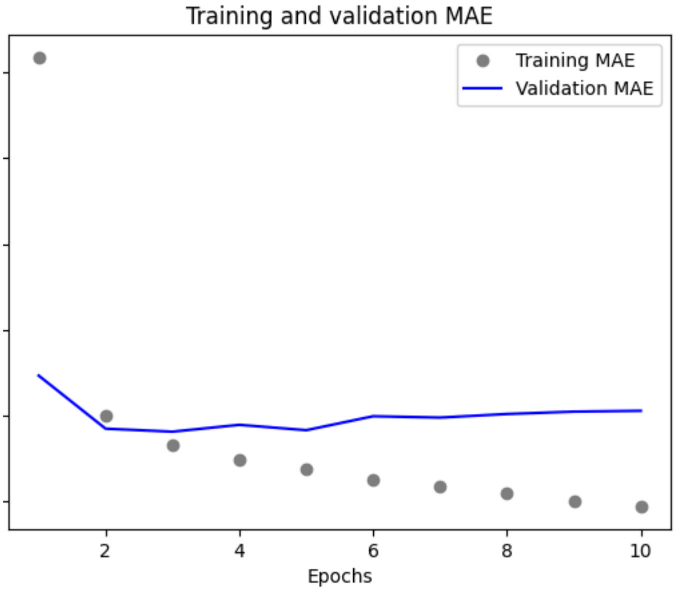
```
405/405 [==============================] - 17s 39ms/step - loss: 10.9590 - mae: 2.6132
Test MAE: 2.61
```

```
model.summary()
```

```
Model: "model_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_5 (InputLayer)        [(None, 120, 14)]         0         
                                                                 
 lstm_2 (LSTM)               (None, 120, 16)           1984      
                                                                 
 lstm_3 (LSTM)               (None, 16)                2112      
                                                                 
 dense_5 (Dense)             (None, 1)                 17        
                                                                 
=================================================================
Total params: 4113 (16.07 KB)
Trainable params: 4113 (16.07 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
ı-input-32-b887b99572a7>:6: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "bo"
lot(epochs, loss,"bo", color="grey", label="Training MAE")
ı-input-32-b887b99572a7>:7: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "b"
lot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



LSTM with 8 units

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.LSTM(8, return_sequences=True)(inputs)
x = layers.LSTM(8)(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_LSTM_stacked3.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 71s 83ms/step - loss: 79.6672 - mae: 6.9297 - val_loss: 41.9105 - val_mae: 4.8610
Epoch 2/10
819/819 [==============================] - 67s 82ms/step - loss: 25.3222 - mae: 3.7306 - val_loss: 14.5148 - val_mae: 2.8567
Epoch 3/10
819/819 [==============================] - 72s 88ms/step - loss: 12.2402 - mae: 2.7046 - val_loss: 9.8037 - val_mae: 2.4165
Epoch 4/10
819/819 [==============================] - 70s 86ms/step - loss: 10.2222 - mae: 2.4900 - val_loss: 9.4375 - val_mae: 2.3967
Epoch 5/10
819/819 [==============================] - 69s 84ms/step - loss: 9.7339 - mae: 2.4286 - val_loss: 9.2758 - val_mae: 2.3739
Epoch 6/10
819/819 [==============================] - 70s 85ms/step - loss: 9.4661 - mae: 2.3968 - val_loss: 9.0749 - val_mae: 2.3388
Epoch 7/10
819/819 [==============================] - 71s 87ms/step - loss: 9.1797 - mae: 2.3638 - val_loss: 9.0719 - val_mae: 2.3556
Epoch 8/10
819/819 [==============================] - 65s 79ms/step - loss: 8.9005 - mae: 2.3300 - val_loss: 9.6113 - val_mae: 2.4051
Epoch 9/10
819/819 [==============================] - 68s 83ms/step - loss: 8.6880 - mae: 2.3016 - val_loss: 9.4603 - val_mae: 2.3912
Epoch 10/10
819/819 [==============================] - 70s 85ms/step - loss: 8.5327 - mae: 2.2812 - val_loss: 9.1119 - val_mae: 2.3499
```

```
model = keras.models.load_model("jena_LSTM_stacked3.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

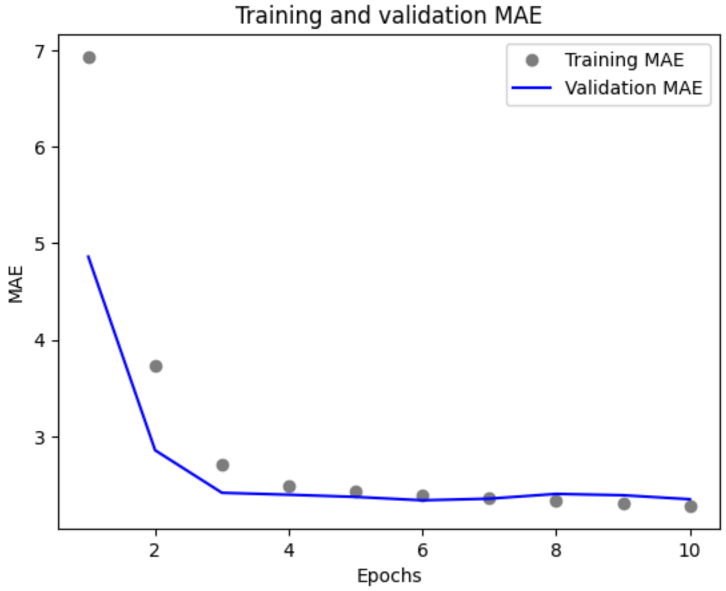
```
405/405 [==============================] - 14s 31ms/step - loss: 10.8064 - mae: 2.5379
Test MAE: 2.54
```

```
model.summary()
```

```
Model: "model_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_6 (InputLayer)        [(None, 120, 14)]         0

 lstm_4 (LSTM)               (None, 120, 8)            736

 lstm_5 (LSTM)               (None, 8)                 544

 dense_6 (Dense)             (None, 1)                 9

=================================================================
Total params: 1289 (5.04 KB)
Trainable params: 1289 (5.04 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-36-b887b99572a7>:6: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "bo'
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-36-b887b99572a7>:7: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "b"
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



LSTM dropout regularization with 8 units

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.LSTM(8, recurrent_dropout=0.5, return_sequences=True)(inputs)
x = layers.LSTM(8, recurrent_dropout=0.5)(x)
x = layers.Dropout(0.5)(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_stacked_LSTM_dropout.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 117s 138ms/step - loss: 71.7768 - mae: 6.4964 - val_loss: 33.6940 - val_mae: 4.2780
Epoch 2/10
819/819 [==============================] - 113s 138ms/step - loss: 31.3996 - mae: 4.1900 - val_loss: 14.0868 - val_mae: 2.8070
Epoch 3/10
819/819 [==============================] - 113s 138ms/step - loss: 24.5703 - mae: 3.7454 - val_loss: 11.1344 - val_mae: 2.5491
Epoch 4/10
819/819 [==============================] - 113s 137ms/step - loss: 22.4889 - mae: 3.5925 - val_loss: 10.3580 - val_mae: 2.4725
Epoch 5/10
819/819 [==============================] - 112s 137ms/step - loss: 21.1321 - mae: 3.4896 - val_loss: 10.5567 - val_mae: 2.5183
Epoch 6/10
819/819 [==============================] - 113s 138ms/step - loss: 20.1514 - mae: 3.4070 - val_loss: 10.1162 - val_mae: 2.4608
Epoch 7/10
819/819 [==============================] - 113s 138ms/step - loss: 19.3798 - mae: 3.3494 - val_loss: 9.6254 - val_mae: 2.4073
Epoch 8/10
819/819 [==============================] - 113s 138ms/step - loss: 18.6922 - mae: 3.2933 - val_loss: 9.3176 - val_mae: 2.3694
Epoch 9/10
819/819 [==============================] - 113s 138ms/step - loss: 18.0582 - mae: 3.2407 - val_loss: 9.5119 - val_mae: 2.3942
Epoch 10/10
819/819 [==============================] - 112s 137ms/step - loss: 17.6397 - mae: 3.2048 - val_loss: 9.3907 - val_mae: 2.3821
```

```
model = keras.models.load_model("jena_stacked_LSTM_dropout.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

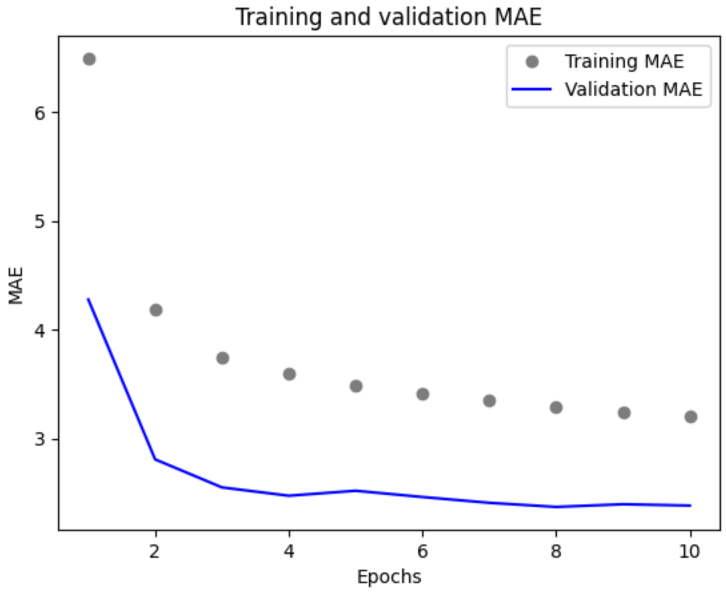
```
405/405 [==============================] - 12s 27ms/step - loss: 10.8822 - mae: 2.5639
Test MAE: 2.56
```

```
model.summary()
```

```
Model: "model_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_10 (InputLayer)       [(None, 120, 14)]         0
 gru (GRU)                   (None, 16)                1536

 dense_10 (Dense)            (None, 1)                 17

=================================================================
Total params: 1553 (6.07 KB)
Trainable params: 1553 (6.07 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-39-b887b99572a7>:6: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "bo'
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-39-b887b99572a7>:7: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "b"
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



Bidirectional Model

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.Bidirectional(layers.LSTM(16))(inputs)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
```

```
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_bidirec_LSTM.keras",
                                    save_best_only=True)
]

model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                     callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 54s 62ms/step - loss: 30.5831 - mae: 3.9660 - val_loss: 11.0872 - val_mae: 2.5946
Epoch 2/10
819/819 [==============================] - 53s 64ms/step - loss: 9.6804 - mae: 2.4257 - val_loss: 9.8813 - val_mae: 2.4341
Epoch 3/10
819/819 [==============================] - 50s 62ms/step - loss: 8.7913 - mae: 2.3034 - val_loss: 9.6049 - val_mae: 2.3979
Epoch 4/10
819/819 [==============================] - 51s 62ms/step - loss: 8.3857 - mae: 2.2491 - val_loss: 9.8103 - val_mae: 2.4275
```

```
Epoch 5/10
819/819 [==============================] - 51s 62ms/step - loss: 7.9856 - mae: 2.2006 - val_loss: 10.5208 - val_mae: 2.4985
Epoch 6/10
819/819 [==============================] - 52s 63ms/step - loss: 7.5670 - mae: 2.1459 - val_loss: 10.5943 - val_mae: 2.5232
Epoch 7/10
819/819 [==============================] - 52s 63ms/step - loss: 7.2250 - mae: 2.0989 - val_loss: 10.5027 - val_mae: 2.5129
Epoch 8/10
819/819 [==============================] - 51s 63ms/step - loss: 6.9977 - mae: 2.0664 - val_loss: 10.5787 - val_mae: 2.5141
Epoch 9/10
819/819 [==============================] - 51s 63ms/step - loss: 6.7796 - mae: 2.0343 - val_loss: 11.2682 - val_mae: 2.6046
Epoch 10/10
819/819 [==============================] - 51s 62ms/step - loss: 6.6259 - mae: 2.0109 - val_loss: 10.9858 - val_mae: 2.5702
```

```
model = keras.models.load_model("jena_bidirec_LSTM.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

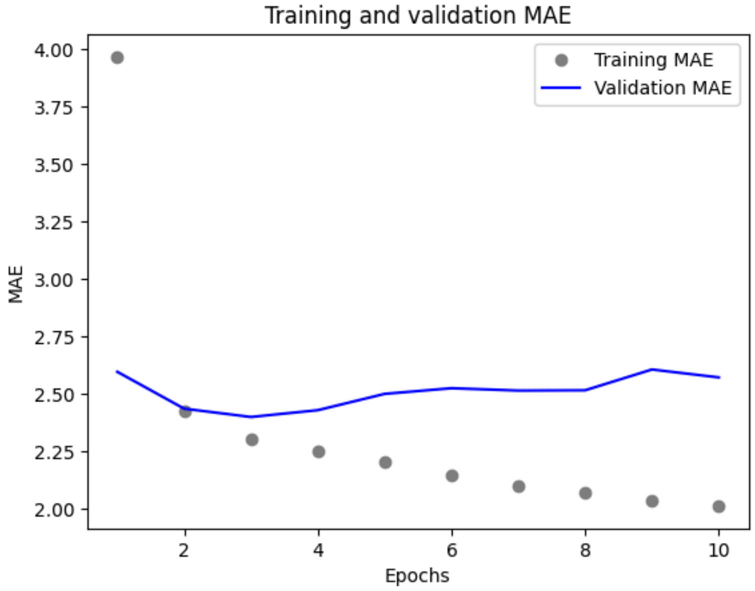
```
405/405 [==============================] - 10s 22ms/step - loss: 10.4643 - mae: 2.5564
Test MAE: 2.56
```

```
model.summary()
```

```
Model: "model_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_10 (InputLayer)       [(None, 120, 14)]         0

 gru (GRU)                   (None, 16)                1536

 dense_10 (Dense)            (None, 1)                 17

=================================================================
Total params: 1553 (6.07 KB)
Trainable params: 1553 (6.07 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-42-b887b99572a7>:6: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "bo'
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-42-b887b99572a7>:7: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "b"
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



1D convent and LSTM Model

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.Conv1D(64, 3, activation='relu')(inputs)
x = layers.MaxPooling1D(3)(x)
x = layers.Conv1D(128, 3, activation='relu')(x)
x = layers.GlobalMaxPooling1D()(x)
x = layers.Reshape((-1, 128))(x)  # Reshape the data to be 3D
x = layers.LSTM(16)(x)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])

callbacks = [
    keras.callbacks.ModelCheckpoint("jena_Conv_LSTM.keras", save_best_only=True)
]

history = model.fit(train_dataset, epochs=10, validation_data=val_dataset, callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 16s 17ms/step - loss: 44.7844 - mae: 4.9988 - val_loss: 26.8447 - val_mae: 4.0124
Epoch 2/10
819/819 [==============================] - 13s 15ms/step - loss: 17.1598 - mae: 3.2025 - val_loss: 21.9196 - val_mae: 3.6945
Epoch 3/10
819/819 [==============================] - 13s 15ms/step - loss: 14.2177 - mae: 2.9231 - val_loss: 22.0025 - val_mae: 3.7253
Epoch 4/10
819/819 [==============================] - 13s 15ms/step - loss: 12.6789 - mae: 2.7559 - val_loss: 23.2176 - val_mae: 3.8812
Epoch 5/10
819/819 [==============================] - 13s 15ms/step - loss: 11.5743 - mae: 2.6224 - val_loss: 22.0175 - val_mae: 3.7623
Epoch 6/10
819/819 [==============================] - 13s 15ms/step - loss: 10.6885 - mae: 2.5158 - val_loss: 23.4542 - val_mae: 3.8383
Epoch 7/10
819/819 [==============================] - 13s 15ms/step - loss: 9.9750 - mae: 2.4246 - val_loss: 24.6049 - val_mae: 3.9469
Epoch 8/10
819/819 [==============================] - 13s 15ms/step - loss: 9.3943 - mae: 2.3479 - val_loss: 25.1038 - val_mae: 3.9433
Epoch 9/10
819/819 [==============================] - 13s 15ms/step - loss: 8.8454 - mae: 2.2732 - val_loss: 24.1686 - val_mae: 3.9631
Epoch 10/10
819/819 [==============================] - 13s 15ms/step - loss: 8.3972 - mae: 2.2131 - val_loss: 26.6889 - val_mae: 4.1492
```

```
model = keras.models.load_model("jena_Conv_LSTM.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

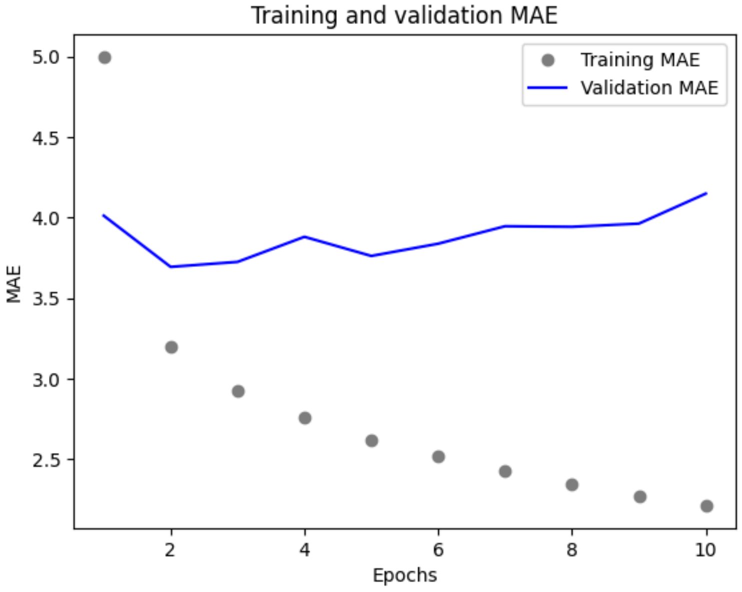
```
405/405 [==============================] - 4s 8ms/step - loss: 22.7639 - mae: 3.7856
Test MAE: 3.79
```

```
model.summary()
```

```
Model: "model_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_10 (InputLayer)       [(None, 120, 14)]         0

 gru (GRU)                   (None, 16)                1536

 dense_10 (Dense)            (None, 1)                 17

=================================================================
Total params: 1553 (6.07 KB)
Trainable params: 1553 (6.07 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")

plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```

```
<ipython-input-45-a53040850538>:6: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "bo'
  plt.plot(epochs, loss,"bo", color="grey", label="Training MAE")
<ipython-input-45-a53040850538>:7: UserWarning: color is redundantly defined by the 'color' keyword argument and the fmt string "b"
  plt.plot(epochs,  val_loss,"b", color="blue", label="Validation MAE")
```



Simple GRU Model

```
inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.GRU(16)(inputs)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
    keras.callbacks.ModelCheckpoint("jena_gru.keras",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse", metrics=["mae"])
history = model.fit(train_dataset,
                    epochs=10,
                    validation_data=val_dataset,
                    callbacks=callbacks)
```

```
Epoch 1/10
819/819 [==============================] - 43s 51ms/step - loss: 37.1329 - mae: 4.3952 - val_loss: 11.6304 - val_mae: 2.5882
Epoch 2/10
819/819 [==============================] - 39s 47ms/step - loss: 10.2817 - mae: 2.4953 - val_loss: 9.2774 - val_mae: 2.3575
Epoch 3/10
819/819 [==============================] - 44s 54ms/step - loss: 9.4925 - mae: 2.4045 - val_loss: 9.3464 - val_mae: 2.3591
Epoch 4/10
819/819 [==============================] - 45s 54ms/step - loss: 9.2424 - mae: 2.3748 - val_loss: 9.8014 - val_mae: 2.4099
Epoch 5/10
819/819 [==============================] - 40s 49ms/step - loss: 9.0399 - mae: 2.3511 - val_loss: 9.2658 - val_mae: 2.3546
Epoch 6/10
819/819 [==============================] - 43s 52ms/step - loss: 8.8501 - mae: 2.3286 - val_loss: 9.4137 - val_mae: 2.3698
Epoch 7/10
819/819 [==============================] - 42s 52ms/step - loss: 8.6593 - mae: 2.3032 - val_loss: 10.0512 - val_mae: 2.4366
Epoch 8/10
819/819 [==============================] - 42s 52ms/step - loss: 8.4868 - mae: 2.2790 - val_loss: 10.0203 - val_mae: 2.4426
Epoch 9/10
819/819 [==============================] - 40s 49ms/step - loss: 8.3234 - mae: 2.2568 - val_loss: 9.9031 - val_mae: 2.4345
Epoch 10/10
819/819 [==============================] - 40s 48ms/step - loss: 8.1856 - mae: 2.2385 - val_loss: 10.1275 - val_mae: 2.4649
```

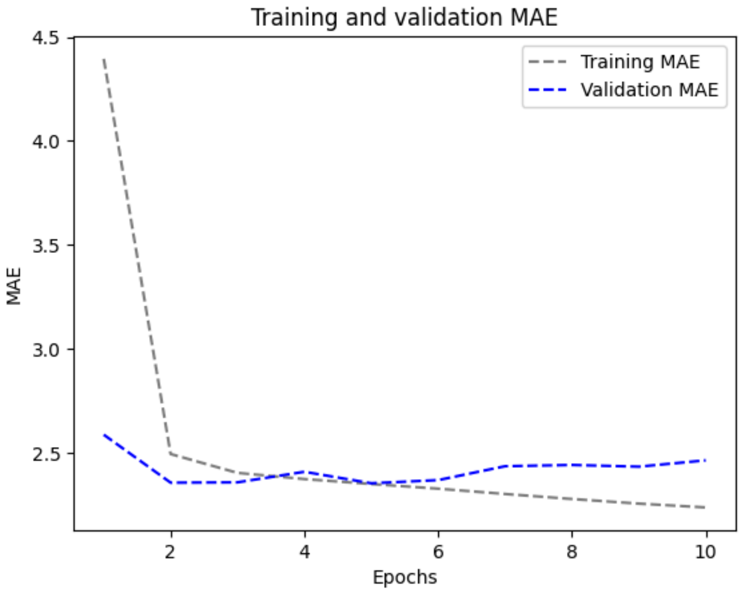
```
model = keras.models.load_model("jena_gru.keras")
print(f"Test MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

```
405/405 [==============================] - 7s 16ms/step - loss: 10.0757 - mae: 2.5063
Test MAE: 2.51
```

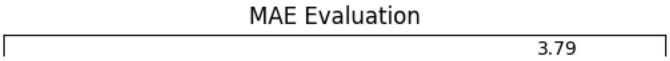
```
model.summary()
```

```
Model: "model_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_10 (InputLayer)       [(None, 120, 14)]         0         
 gru (GRU)                   (None, 16)                1536      
                                                                 
 dense_10 (Dense)            (None, 1)                 17        
                                                                 
=================================================================
Total params: 1553 (6.07 KB)
Trainable params: 1553 (6.07 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
loss = history.history["mae"]
val_loss = history.history["val_mae"]

epochs = range(1, len(loss) + 1)
plt.figure()
plt.plot(epochs, loss, color="grey", linestyle="dashed", label="Training MAE")
plt.plot(epochs,  val_loss, color="blue",linestyle="dashed", label="Validation MAE")
plt.title("Training and validation MAE")
plt.xlabel("Epochs")
plt.ylabel("MAE")
plt.legend()
plt.show()
```



```
import matplotlib.pyplot as plt

Models = ("1","2","3","4","5","6","7","8","9","10","11")
Mae = (2.62,2.64,3.04,2.59,2.58,2.61,2.54,2.56,2.56,3.79,2.51)

# MAE Evaluation
plt.bar(Models, Mae, color="red")
plt.title("MAE Evaluation")
plt.xlabel("Model")
plt.ylabel("MAE")

for (xi, yi) in zip(Models,Mae):
    plt.text(xi, yi, yi, va='bottom', ha='center')

plt.show()
```


MAE Evaluation
3.79