CS4701_Regional_Climate_Forecast_with_ANN_final

May 22, 2021

1 CS4701: Regional Weather Forcast with ANN

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1.1 Abstract

In this project, we are developing a weather forecasting tool that aims to predict key regional weather parameters based on historical data. Various Artificial Neural Network methods are used in comparison to extract trends and predict patterns of the regional weather sequences. Multiple data visualization and analysis techniques are employed to aid feature engineering, feature selection, and model selection processes. Validation and test methods are employed to evaluate and compare the performance of the tool.

1.1.1 External Libraries

[485]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from netCDF4 import Dataset
import xarray as xr

# for ML
from sklearn.preprocessing import StandardScaler, MinMaxScaler, RobustScaler,␣
 ↪PolynomialFeatures
from keras.models import Sequential
from keras.layers import LSTM,Dense ,Dropout, Bidirectional
from sklearn.metrics import mean_squared_error

## for plotting
import matplotlib.pyplot as plt
import seaborn as sns
import statsmodels.api as sm
from statsmodels.tsa.stattools import adfuller

import warnings
warnings.filterwarnings("ignore")
```

1.2 1. Data

1.2.1 1.1 Basic data

This is a data gateway for downloading customized GCMs (Global Climate Models)datasets, downsacled using MACA method (Multivariate Adaptive Constructed Analogs). This method enables us to retrive historical metrological datasets as far as 1950 and with a resolution up to 4km. *This gateway is currently not in use by this project, where we instead directly import MACA datasets about the Finger Lakes AVA.

[ ]:
```
lat_target=45.0
lon_target=360-117.0
```

[ ]:
```
pathname = 'http://thredds.northwestknowledge.net:8080/thredds/dodsC/
↪agg_macav2metdata_huss_BNU-ESM_r1i1p1_historical_1950_2005_CONUS_daily.nc'
```

[ ]:
```
filehandle=Dataset(pathname,'r',format="NETCDF4")
lathandle=filehandle.variables['lat']
lonhandle=filehandle.variables['lon']
timehandle=filehandle.variables['time']
datahandle=filehandle.variables['specific_humidity']
```

[ ]:
```
time_num=365
timeindex=range(0,time_num,1)
time=timehandle[timeindex]
lat = lathandle[:]
lon = lonhandle[:]
```

[ ]:
```
#find indices of target lat/lon/day
lat_index = (np.abs(lat-lat_target)).argmin()
lon_index = (np.abs(lon-lon_target)).argmin()
#check final is in right bounds
if(lat[lat_index]>lat_target):
        if(lat_index!=0):
                lat_index = lat_index - 1
if(lat[lat_index]<lat_target):
        if(lat_index!=len(lat)):
                lat_index =lat_index +1
if(lon[lon_index]>lon_target):
        if(lon_index!=0):
                lon_index = lon_index - 1
if(lon[lon_index]<lon_target):
        if(lon_index!=len(lon)):
                lon_index = lon_index + 1
lat=lat[lat_index]
lon=lon[lon_index]
```

[ ]:
```
data = datahandle[timeindex,lat_index,lon_index]
```

[ ]:
```
days = np.arange(0,len(time))
fig = plt.figure()
ax = fig.add_subplot(111)
ax.set_xlabel(u'Day of Year')
ax.set_ylabel(u'Specific Humidity(kg/kg)')
ax.set_title(u'1950 Daily Specific Humidity(BNU-ESM) ,\n %4.2f\u00b0N, %4.
↪2f\u00b0W' % (lat, abs(360-lon)))
ax.ticklabel_format(style='plain')
ax.plot(days,data,'b-')
plt.savefig("myPythonGraph.png")
plt.show()
```

1.2.2 1.2 Import Data

Import MACA datasets about the Finger Lakes AVA regional GCMs.

[3]:
```
# Fucntion for reading datasets
def read_file(file):
    df = pd.read_csv(file, sep=',',header=0, encoding='unicode_escape')
    return df

# Encode date to the number of days from 1/1/2020
def encode_date(df):
    return (pd.to_datetime(df['date']).rsub(pd.Timestamp('2006/1/1')).dt.
↪days)*(-1)
```

[489]:
```
from google.colab import drive
import os
drive.mount('/content/drive', force_remount=True)

path = os.path.join(os.getcwd(), "drive", "My Drive",␣
↪"Regional-Climate-Forecast-with-ANN")
```

[ ]:
```
df_his_daily = read_file(os.path.join(path, 'MACA_41.9795 Latitude, -76.9813␣
↪Longitude_2006-2019.csv'))
df_cur_daily = read_file(os.path.join(path,'MACA_41.9795 Latitude, -76.9813␣
↪Longitude_2019-2020.csv'))
df_future_daily = read_file(os.path.join(path,'MACA_41.9795 Latitude, -76.9813␣
↪Longitude_2020-2021.csv'))
df_his_daily['date'] = encode_date(df_his_daily)
```

[478]:
```
#Without Google Colab
df_his_daily = read_file('MACA_41.9795 Latitude, -76.9813 Longitude_2006-2019.
↪csv')
df_cur_daily = read_file('MACA_41.9795 Latitude, -76.9813 Longitude_2019-2020.
↪csv')
```

```
df_future_daily = read_file('MACA_41.9795 Latitude, -76.9813 Longitude_2020-2021.
↪csv')
# df_his_daily['date'] = encode_date(df_his_daily)
```

1.3 2. Feature Engineering

In this section, we analyze and visualize different features of the data to get a sense of what we are working with. These visualization show the distinct patterns of different features in the training set from 2006 to 2019. It also shows where anomalies are present, which will be addressed during normalization.

[482]:
```
# Intially extract features
his_pcp = df_his_daily[['Precipitation(mm)']]
his_max_temp = df_his_daily[['Daily Maximum Near-Surface Air Temperature(K)']]
cur_pcp = df_cur_daily[['Precipitation(mm)']]
cur_max_temp = df_cur_daily[['Daily Maximum Near-Surface Air Temperature(K)']]
future_pcp = df_future_daily[['Precipitation(mm)']]
future_max_temp = df_future_daily[['Daily Maximum Near-Surface Air␣
↪Temperature(K)']]

# Cut off the last year
his_pcp = his_pcp[4748:]
his_max_temp = his_max_temp[4748:]
cur_pcp = cur_pcp[:365]
cur_max_temp = cur_max_temp[:365]
future_pcp = future_pcp[:365]
future_max_temp = future_max_temp[:365]
```

[311]:
```
# functions for visualizing numerical data distributions
def check_distribution_conti(dtf, x):
    fig, ax = plt.subplots(nrows=1, ncols=2,  sharex=False, sharey=False)
    fig.suptitle(x, fontsize=20)
    ### distribution
    ax[0].title.set_text('distribution')
    variable = dtf[x].fillna(dtf[x].mean())
    breaks = np.quantile(variable, q=np.linspace(0, 1, 11))
    variable = variable[ (variable > breaks[0]) & (variable <
                        breaks[10]) ]
    sns.distplot(variable, hist=True, kde=True, kde_kws={"shade": True},␣
↪ax=ax[0])
    des = dtf[x].describe()
    ax[0].axvline(des["25%"], ls='--')
    ax[0].axvline(des["mean"], ls='--')
    ax[0].axvline(des["75%"], ls='--')
    ax[0].grid(True)
    des = round(des, 2).apply(lambda x: str(x))
```

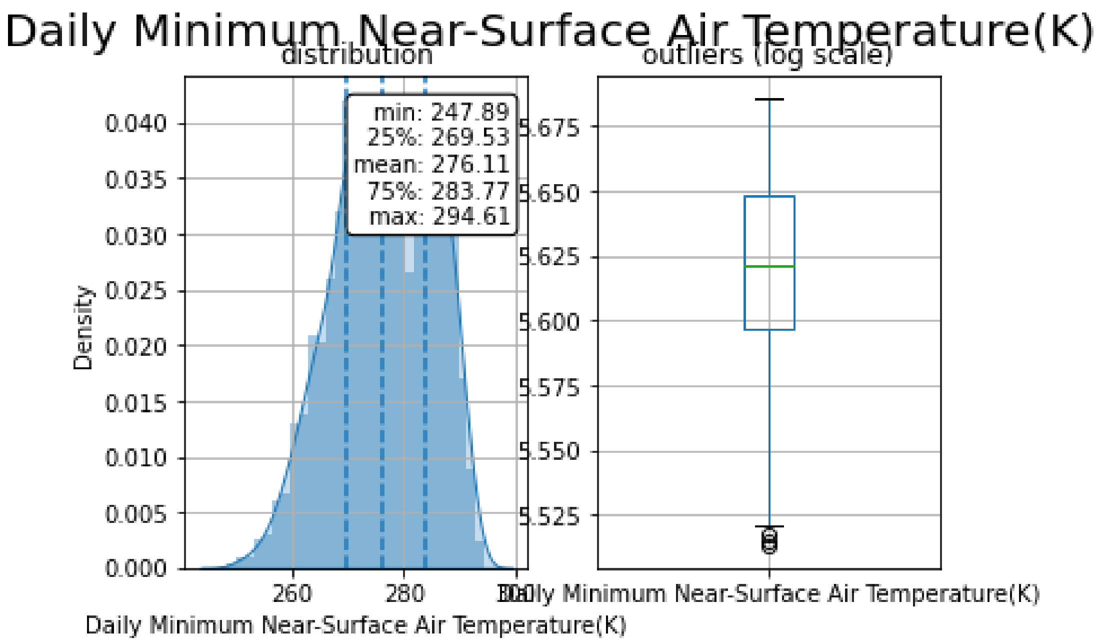
```
    box = '\n'.join(("min: "+des["min"], "25%: "+des["25%"], "mean:␣
↪"+des["mean"], "75%: "+des["75%"], "max: "+des["max"]))
    ax[0].text(0.95, 0.95, box, transform=ax[0].transAxes, fontsize=10,␣
↪va='top', ha="right", bbox=dict(boxstyle='round', facecolor='white', alpha=1))
    ### boxplot
    ax[1].title.set_text('outliers (log scale)')
    tmp_dtf = pd.DataFrame(dtf[x])
    tmp_dtf[x] = np.log(tmp_dtf[x])
    tmp_dtf.boxplot(column=x, ax=ax[1])
    plt.show()

# functions for visualizing bivariant distribution between a categorical feature␣
↪and a numerical feature
def check_bivariant_cat(dtf, cat, num):
    fig, ax = plt.subplots(nrows=1, ncols=3,  sharex=False, sharey=False)
    fig.suptitle(cat+"   vs   "+num, fontsize=20)

    ### distribution
    ax[0].title.set_text('density')
    for i in dtf[cat].unique():
        sns.distplot(dtf[dtf[cat]==i][num], hist=False, label=i, ax=ax[0])
    ax[0].grid(True)
    ### stacked
    ax[1].title.set_text('bins')
    breaks = np.quantile(dtf[num], q=np.linspace(0,1,11))
    tmp = dtf.groupby([cat, pd.cut(dtf[num], breaks, duplicates='drop')]).size().
↪unstack().T
    tmp = tmp[dtf[cat].unique()]
    tmp["tot"] = tmp.sum(axis=1)
    for col in tmp.drop("tot", axis=1).columns:
         tmp[col] = tmp[col] / tmp["tot"]
    tmp.drop("tot", axis=1).plot(kind='bar', stacked=True, ax=ax[1],␣
↪legend=False, grid=True)
    ### boxplot
    ax[2].title.set_text('outliers')
    sns.catplot(x=cat, y=num, data=dtf, kind="box", ax=ax[2])
    ax[2].grid(True)
    plt.show()
```

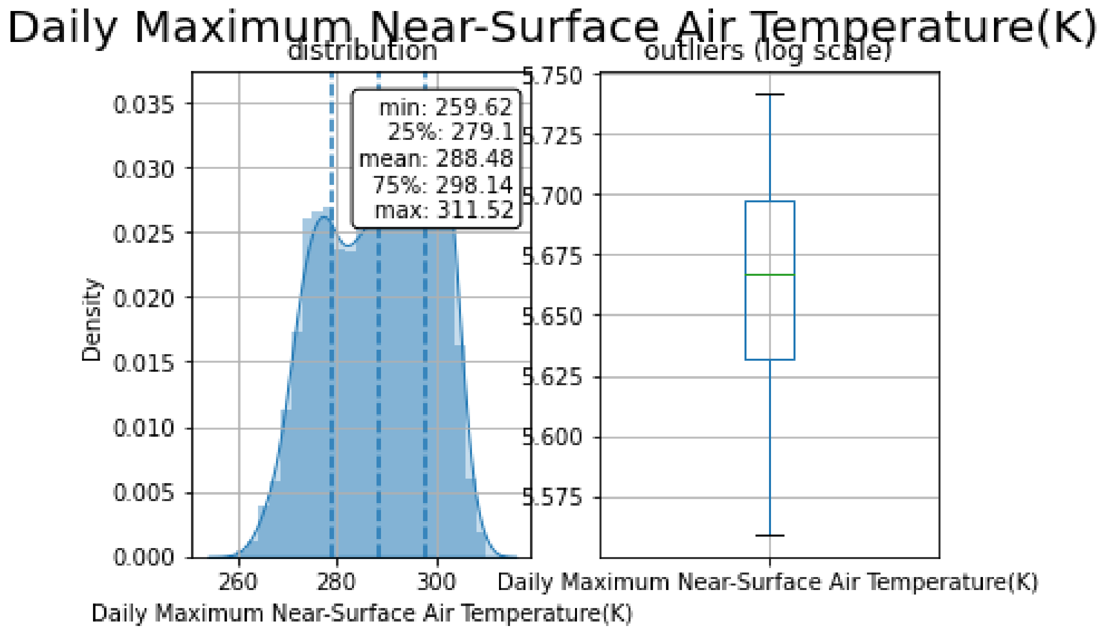
[471]:
```
titles = [
    "Daily Minimum Near-Surface Air Temperature(K)",
    "Daily Maximum Near-Surface Air Temperature(K)",
    "Daily Mean Near-Surface Specific Humidity(kgkg-1)",
    "vpd(kPa)",
    "Precipitation(mm)",
]
```

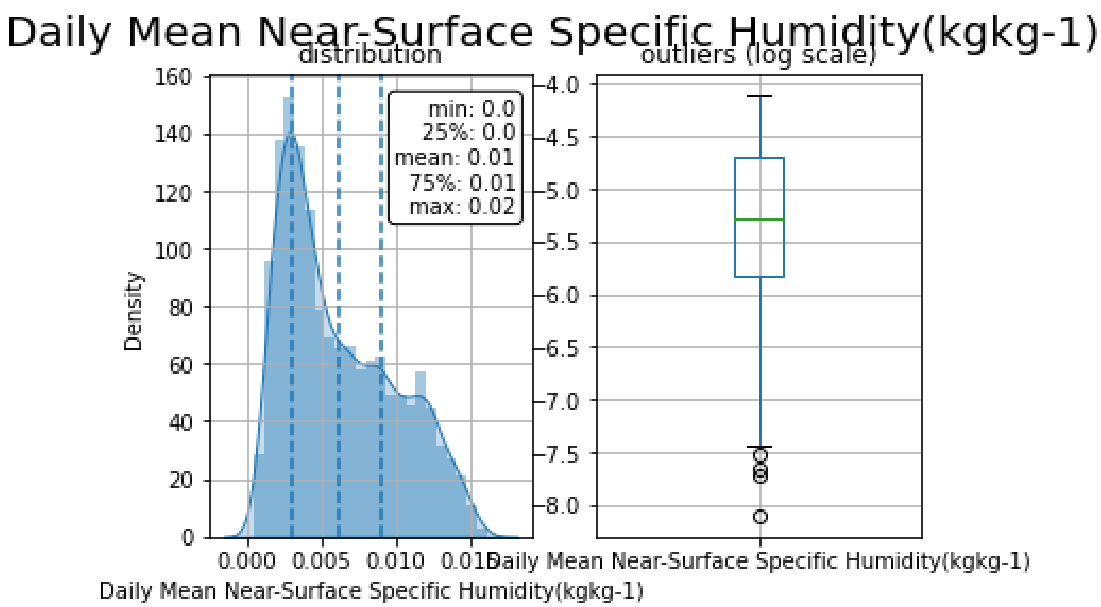
```
feature_keys = [
    "Daily Minimum Near-Surface Air Temperature(K)",
    "Daily Maximum Near-Surface Air Temperature(K)",
    "Daily Mean Near-Surface Specific Humidity(kgkg-1)",
    "vpd(kPa)",
    "Precipitation(mm)",
]

colors = [
    "blue",
    "orange",
    "green",
    "red",
    "purple",
]



# Function for visualizing data distribution
def show_raw_visualization(data):
    time_data = data["date"]
    fig, axes = plt.subplots(
        nrows=3, ncols=2, figsize=(15, 20), dpi=80, facecolor="w", edgecolor="k"
    )
    for i in range(len(feature_keys)):
        key = feature_keys[i]
        c = colors[i % (len(colors))]
        t_data = data[key]
        t_data.index = time_data
        t_data.head()
        ax = t_data.plot(
            ax=axes[i // 2, i % 2],
            color=c,
            title="{} - {}".format(titles[i], key),
            rot=25,
        )
        ax.legend([titles[i]])
    plt.tight_layout()

# Function for visualizing correlation heatmap
def show_heatmap(data):
    plt.matshow(data.corr())
    plt.xticks(range(data.shape[1]), data.columns, fontsize=14, rotation=90)
    plt.gca().xaxis.tick_bottom()
    plt.yticks(range(data.shape[1]), data.columns, fontsize=14)

    cb = plt.colorbar()
    cb.ax.tick_params(labelsize=14)
```

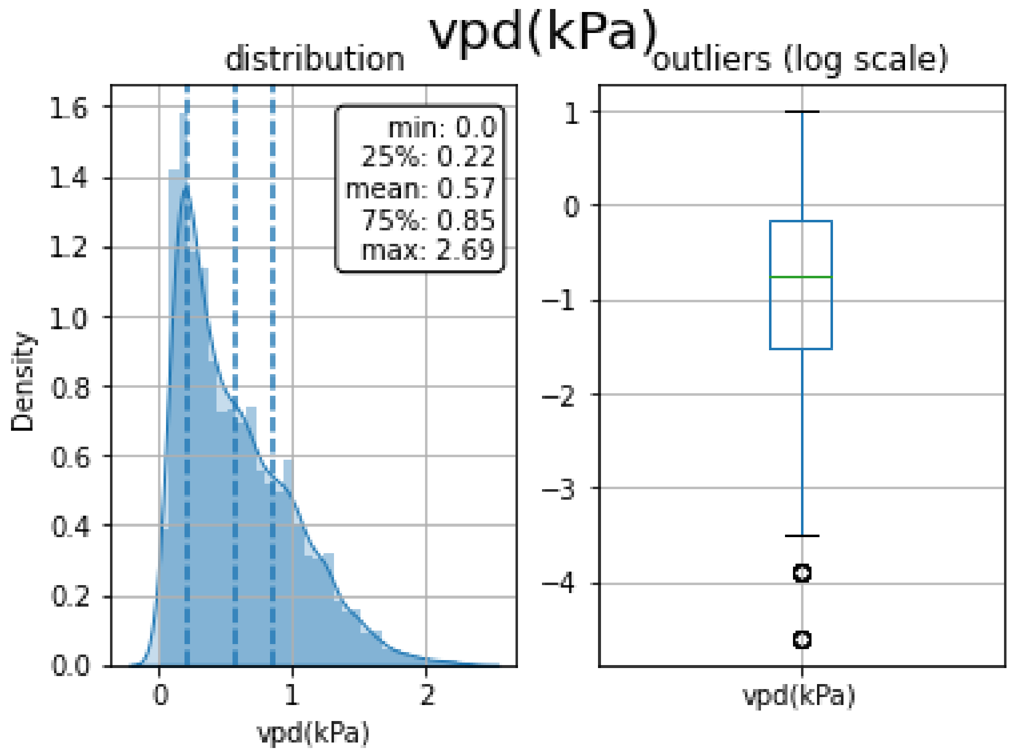
```
    plt.title("Feature Correlation Heatmap", fontsize=14)
    plt.show()
```

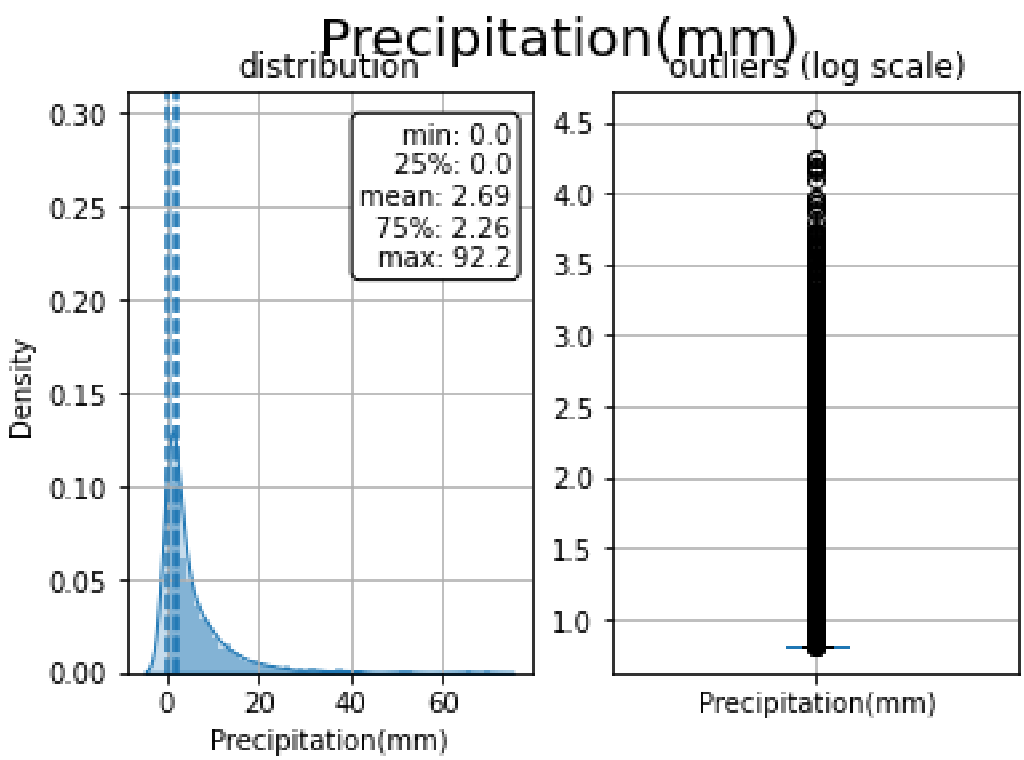
[481]:
```
check_distribution_conti(df_his_daily, 'Daily Minimum Near-Surface Air␣
 ↪Temperature(K)')
check_distribution_conti(df_his_daily, 'Daily Maximum Near-Surface Air␣
 ↪Temperature(K)')
check_distribution_conti(df_his_daily, 'Daily Mean Near-Surface Specific␣
 ↪Humidity(kgkg-1)')
check_distribution_conti(df_his_daily, 'vpd(kPa)')
check_distribution_conti(df_his_daily, 'Precipitation(mm)')
```



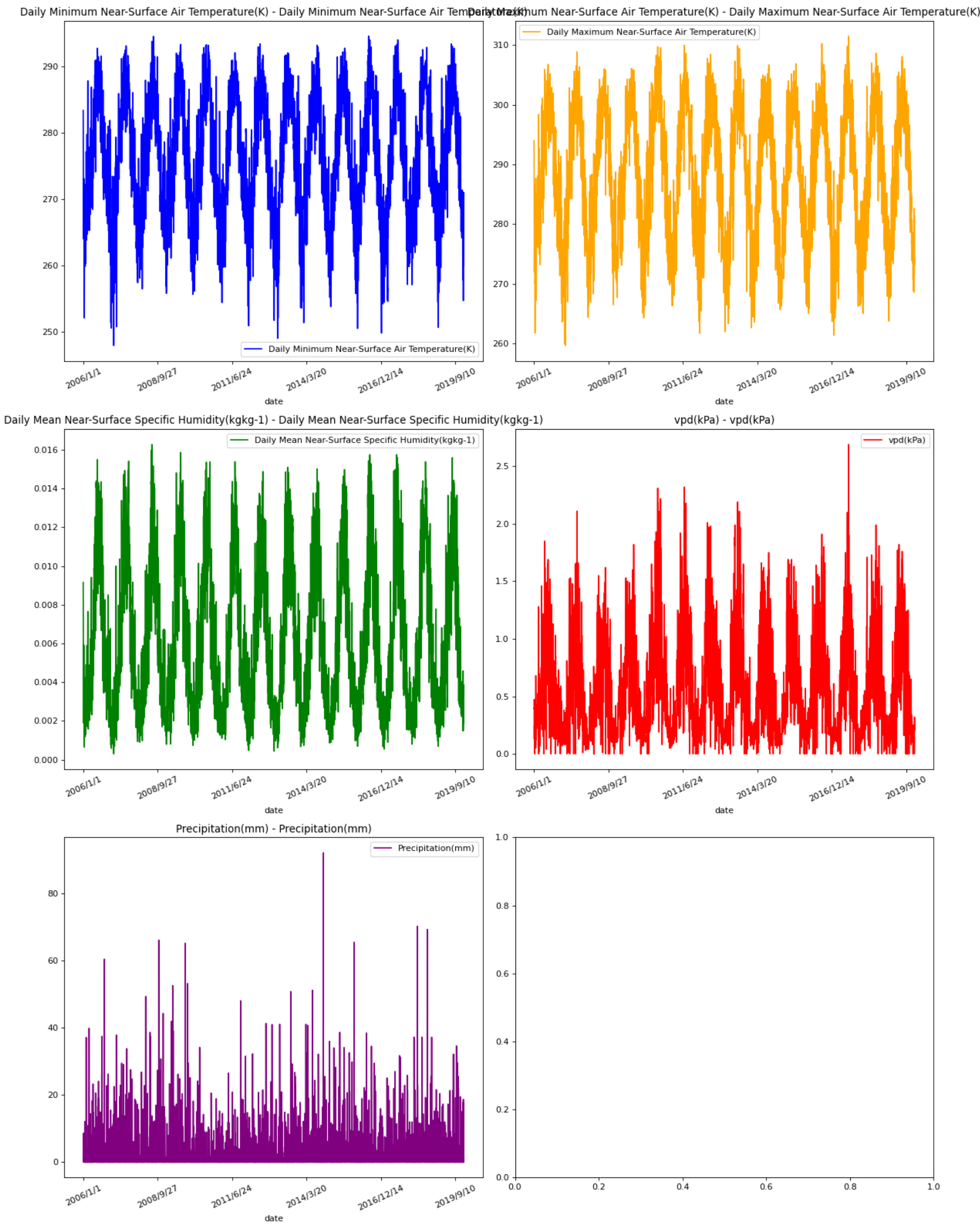

Daily Maximum Near-Surface Air Temperature(K)
distribution
outliers (log scale)
min: 259.62
25%: 279.1
mean: 288.48
75%: 298.14
max: 311.52
Density
Daily Maximum Near-Surface Air Temperature(K)
Daily Maximum Near-Surface Air Temperature(K)


Daily Mean Near-Surface Specific Humidity(kgkg-1)
distribution
outliers (log scale)
min: 0.0
25%: 0.0
mean: 0.01
75%: 0.01
max: 0.02
Density
Daily Mean Near-Surface Specific Humidity(kgkg-1)
Daily Mean Near-Surface Specific Humidity(kgkg-1)

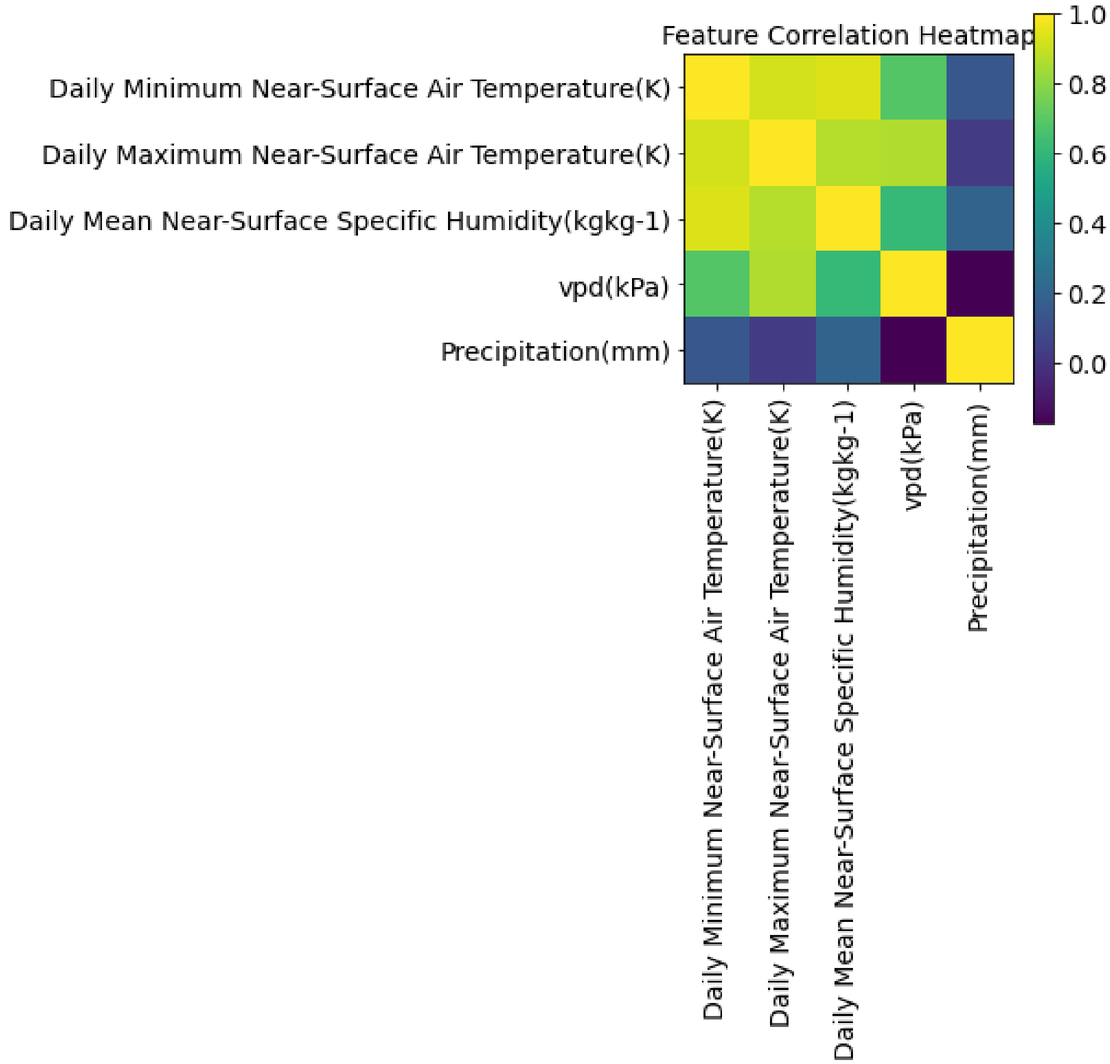

vpd(kPa)
distribution
outliers (log scale)
min: 0.0
25%: 0.22
mean: 0.57
75%: 0.85
max: 2.69
Density
vpd(kPa)
vpd(kPa)


Precipitation(mm)
distribution
outliers (log scale)
min: 0.0
25%: 0.0
mean: 2.69
75%: 2.26
max: 92.2
Density
Precipitation(mm)
Precipitation(mm)

[469]:
```python
show_raw_visualization(df_his_daily)
```

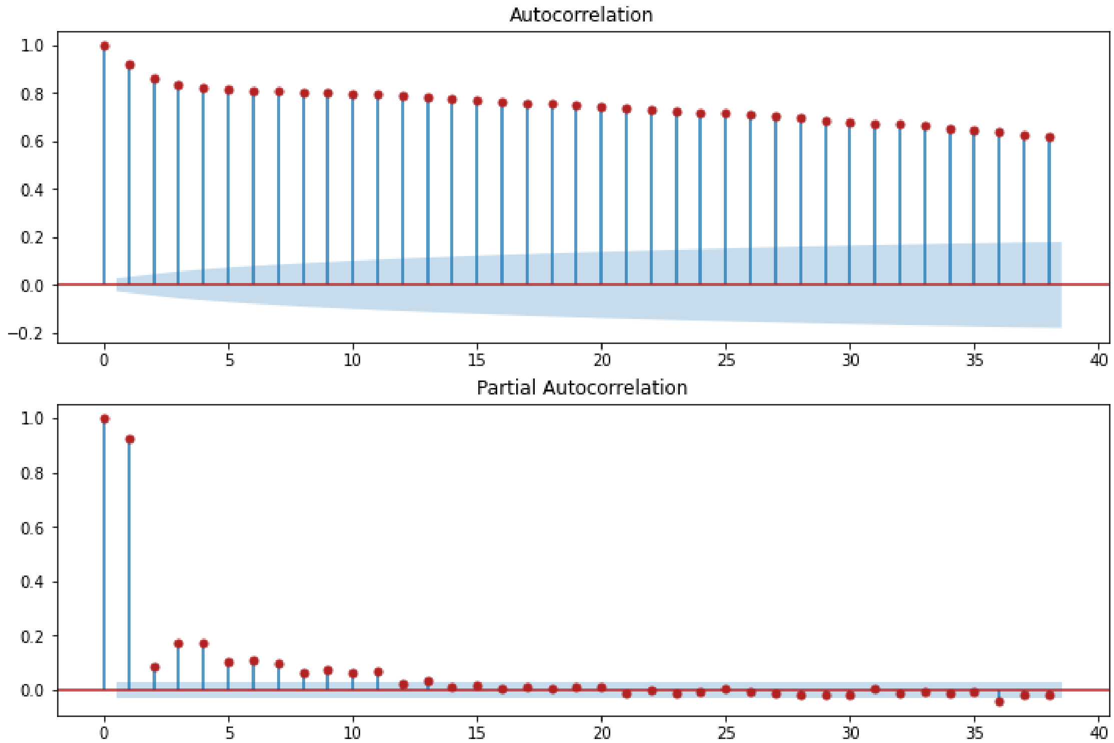


[480]:
```python
show_heatmap(df_his_daily.drop('date', 1))
```



[486]:

```
# Check if the timeseries in the data is staionary
fig = plt.figure(figsize=(12,8))
ax1 = fig.add_subplot(211)
fig = sm.graphics.tsa.plot_acf(df_his_daily['Daily Maximum Near-Surface Air␣
↪Temperature(K)'], ax=ax1,color ='firebrick')
ax2 = fig.add_subplot(212)
fig = sm.graphics.tsa.plot_pacf(df_his_daily['Daily Maximum Near-Surface Air␣
↪Temperature(K)'], ax=ax2,color='firebrick')
```



[488]:
```
# Perform AD Fuller Test on the data to test if the timeseries is stationary
result = adfuller(df_his_daily['Daily Maximum Near-Surface Air Temperature(K)'])
print('ADF Statistic on the entire dataset: {}'.format(result[0]))
print('p-value: {}'.format(result[1]))
print('Critical Values:')
for key, value in result[4].items():
    print('\t{}: {}'.format(key, value))
```

```
ADF Statistic on the entire dataset: -4.471451655114319
p-value: 0.0002213634266702279
Critical Values:
        1%: -3.4316328616522527
        5%: -2.862106888575586
        10%: -2.5670717550557476
```

1.4 3.Train RNN for Predicting Tempreture

In this section, we train and evaluate a Pytorch RNN model in predicting Daily Maximum Near-Surface Air Temperature(K)

[332]:
```
import torch
import torch.nn as nn
```

1.4.1 3.1 Data preprocessing

[443]:
```
# Data normalization
sc = MinMaxScaler(feature_range=(0,1))
```

[444]:
```
train_dataset = his_max_temp
testdataset = cur_max_temp
```

[445]:
```
train_dataset = sc.fit_transform(train_dataset)
x_train = []
y_train = []
n_future = 1
n_past = 30 # Past 30 days
for i in range(0,len(train_dataset)-n_past-n_future+1):
    x_train.append(train_dataset[i : i + n_past ])
    y_train.append(train_dataset[i + n_past : i + n_past + n_future ])
x_train , y_train = np.array(x_train), np.array(y_train)
```

[446]:
```
# Preprocessing test data
testdataset = sc.transform(testdataset)
x_test = []
y_test = []
n_future = 1
n_past = 30
for i in range(0,len(testdataset)-n_past-n_future+1):
    x_test.append(testdataset[i : i + n_past])
    y_test.append(testdataset[i + n_past : i + n_past + n_future, 0])
x_test , y_test = np.array(x_test), np.array(y_test)
x_test = np.reshape(x_test, (x_test.shape[0] , x_test.shape[1], 1) )
```

[447]:
```
x_test_tensor = torch.Tensor(x_test)
y_test_tensor = torch.Tensor(y_test)
x_train_tensor = torch.Tensor(x_train)
y_train_tensor = torch.Tensor(y_train)
```

[429]:
```
x_train_tensor.shape
```

[429]:
```
torch.Size([335, 30, 1])
```

1.4.2 3.2 Train model

[430]:
```
class RNN(nn.Module):
        def __init__(self, input_dim, hidden_dim, layer_dim, output_dim): # Add␣
 ↪relevant parameters
                super(RNN, self).__init__()
                self.input_dim = input_dim
                self.hidden_dim = hidden_dim
                self.layer_dim = layer_dim
```

```
                self.output_dim = output_dim
                self.rnn = nn.RNN(input_dim, hidden_dim, layer_dim,␣
 ↪batch_first=True, nonlinearity='relu')
                #torch.nn.init.kaiming_normal_(self.rnn.weight_ih_l0,␣
 ↪nonlinearity='relu')
                #torch.nn.init.kaiming_normal_(self.rnn.weight_hh_l0,␣
 ↪nonlinearity='relu')
                self.lastlayer = nn.Linear(hidden_dim, output_dim)
                self.softmax = nn.LogSoftmax(dim=1)
                self.loss = nn.MSELoss()

        def compute_Loss(self, predicted_vector, gold_label):
                return self.loss(predicted_vector.float(), gold_label.
 ↪float())

        def forward(self, inputs):
                # begin code
                #print(inputs)
                output, final_hidden = self.rnn(inputs)
                #output = output[:,-1]
                final_output = self.lastlayer(output).squeeze(-1)  #[np.
 ↪arange(inputs.size(0)),seq_length-1,:]
                #final_output = final_output.squeeze(-1)
                #print(final_output)
                #print(final_output.shape)
                predicted_vector = torch.mode(final_output,1).values
                #print(predicted_vector)
                # end code
                return predicted_vector

        def load_model(self, save_path):
                self.load_state_dict(torch.load(save_path))

        def save_model(self, save_path):
                torch.save(self.state_dict(), save_path)
```

[431]:
```
model = RNN(input_dim=1, output_dim=1, hidden_dim=12, layer_dim=1)
n_epochs = 1000
lr=0.1
criterion = nn.MSELoss()
optimizer = torch.optim.Adam(model.parameters(), lr=lr)
for epoch in range(1, n_epochs + 1):
    optimizer.zero_grad() # Clears existing gradients from previous epoch
    #input_seq.to(device)
    output = model(x_train_tensor)
    #print(output)
    #print(y_train_tensor.view(-1))
```

```
    y_train_tensor = y_train_tensor.view(-1)  #.type(torch.LongTensor)
    #output = (output.unsqueeze(-1))
    loss = criterion(output.float(), y_train_tensor.float())
    loss.backward() # Does backpropagation and calculates gradients
    optimizer.step() # Updates the weights accordingly

    if epoch%10 == 0:
        print('Epoch: {}/{}.............'.format(epoch, n_epochs), end=' ')
        print("Loss: {:.4f}".format(loss.item()))
```

```
Epoch: 10/1000... Loss: 0.1007
Epoch: 20/1000... Loss: 0.0585
Epoch: 30/1000... Loss: 0.0398
Epoch: 40/1000... Loss: 0.0337
Epoch: 50/1000... Loss: 0.0298
Epoch: 60/1000... Loss: 0.0281
Epoch: 70/1000... Loss: 0.0279
Epoch: 80/1000... Loss: 0.0277
Epoch: 90/1000... Loss: 0.0276
Epoch: 100/1000... Loss: 0.0276
Epoch: 110/1000... Loss: 0.0276
Epoch: 120/1000... Loss: 0.0276
Epoch: 130/1000... Loss: 0.0276
Epoch: 140/1000... Loss: 0.0276
Epoch: 150/1000... Loss: 0.0276
Epoch: 160/1000... Loss: 0.0276
Epoch: 170/1000... Loss: 0.0276
Epoch: 180/1000... Loss: 0.0276
Epoch: 190/1000... Loss: 0.0276
Epoch: 200/1000... Loss: 0.0276
Epoch: 210/1000... Loss: 0.0276
Epoch: 220/1000... Loss: 0.0276
Epoch: 230/1000... Loss: 0.0276
Epoch: 240/1000... Loss: 0.0276
Epoch: 250/1000... Loss: 0.0276
Epoch: 260/1000... Loss: 0.0276
Epoch: 270/1000... Loss: 0.0276
Epoch: 280/1000... Loss: 0.0276
Epoch: 290/1000... Loss: 0.0276
Epoch: 300/1000... Loss: 0.0276
Epoch: 310/1000... Loss: 0.0276
Epoch: 320/1000... Loss: 0.0276
Epoch: 330/1000... Loss: 0.0276
Epoch: 340/1000... Loss: 0.0276
Epoch: 350/1000... Loss: 0.0276
Epoch: 360/1000... Loss: 0.0276
Epoch: 370/1000... Loss: 0.0276
Epoch: 380/1000... Loss: 0.0276
```

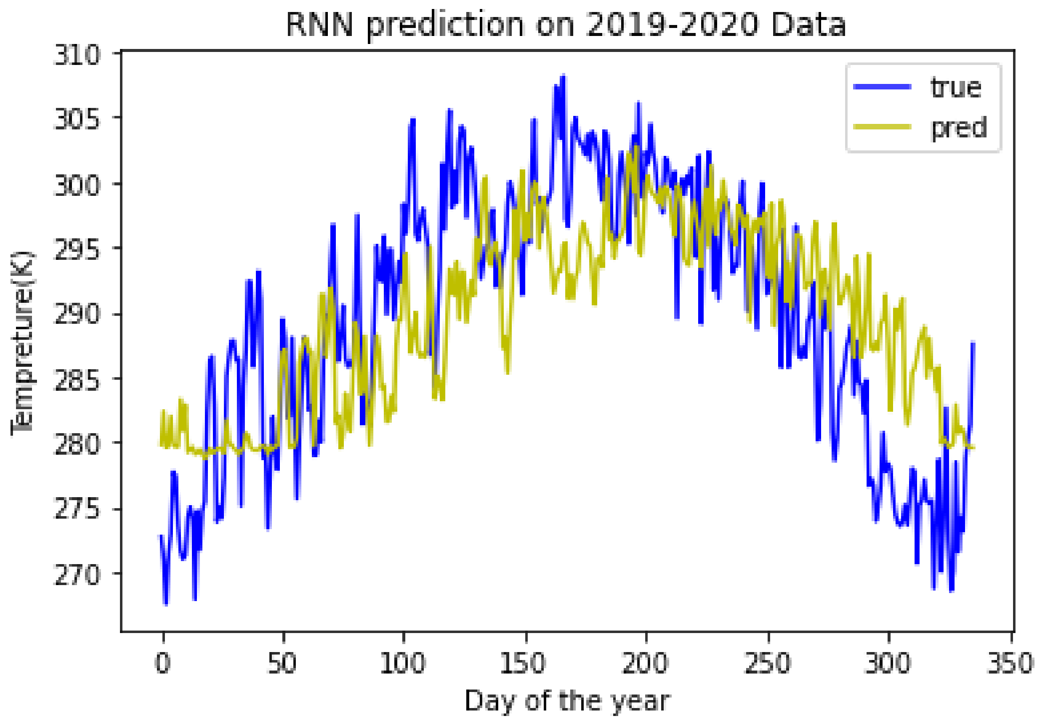
```
Epoch: 390/1000... Loss: 0.0276
Epoch: 400/1000... Loss: 0.0276
Epoch: 410/1000... Loss: 0.0276
Epoch: 420/1000... Loss: 0.0276
Epoch: 430/1000... Loss: 0.0276
Epoch: 440/1000... Loss: 0.0276
Epoch: 450/1000... Loss: 0.0276
Epoch: 460/1000... Loss: 0.0276
Epoch: 470/1000... Loss: 0.0276
Epoch: 480/1000... Loss: 0.0276
Epoch: 490/1000... Loss: 0.0276
Epoch: 500/1000... Loss: 0.0276
Epoch: 510/1000... Loss: 0.0276
Epoch: 520/1000... Loss: 0.0276
Epoch: 530/1000... Loss: 0.0276
Epoch: 540/1000... Loss: 0.0276
Epoch: 550/1000... Loss: 0.0276
Epoch: 560/1000... Loss: 0.0276
Epoch: 570/1000... Loss: 0.0276
Epoch: 580/1000... Loss: 0.0276
Epoch: 590/1000... Loss: 0.0276
Epoch: 600/1000... Loss: 0.0276
Epoch: 610/1000... Loss: 0.0276
Epoch: 620/1000... Loss: 0.0276
Epoch: 630/1000... Loss: 0.0276
Epoch: 640/1000... Loss: 0.0276
Epoch: 650/1000... Loss: 0.0276
Epoch: 660/1000... Loss: 0.0276
Epoch: 670/1000... Loss: 0.0276
Epoch: 680/1000... Loss: 0.0276
Epoch: 690/1000... Loss: 0.0276
Epoch: 700/1000... Loss: 0.0276
Epoch: 710/1000... Loss: 0.0276
Epoch: 720/1000... Loss: 0.0276
Epoch: 730/1000... Loss: 0.0276
Epoch: 740/1000... Loss: 0.0276
Epoch: 750/1000... Loss: 0.0276
Epoch: 760/1000... Loss: 0.0276
Epoch: 770/1000... Loss: 0.0276
Epoch: 780/1000... Loss: 0.0276
Epoch: 790/1000... Loss: 0.0276
Epoch: 800/1000... Loss: 0.0276
Epoch: 810/1000... Loss: 0.0276
Epoch: 820/1000... Loss: 0.0276
Epoch: 830/1000... Loss: 0.0276
Epoch: 840/1000... Loss: 0.0276
Epoch: 850/1000... Loss: 0.0276
Epoch: 860/1000... Loss: 0.0276
```

```
Epoch: 870/1000... Loss: 0.0276
Epoch: 880/1000... Loss: 0.0276
Epoch: 890/1000... Loss: 0.0276
Epoch: 900/1000... Loss: 0.0276
Epoch: 910/1000... Loss: 0.0276
Epoch: 920/1000... Loss: 0.0276
Epoch: 930/1000... Loss: 0.0276
Epoch: 940/1000... Loss: 0.0276
Epoch: 950/1000... Loss: 0.0276
Epoch: 960/1000... Loss: 0.0276
Epoch: 970/1000... Loss: 0.0276
Epoch: 980/1000... Loss: 0.0276
Epoch: 990/1000... Loss: 0.0276
Epoch: 1000/1000... Loss: 0.0276
```

1.4.3 3.3 Test and Evaluation

[452]:
```
pred = model(x_test_tensor)
pred = pred.cpu().detach().numpy()
pred = sc.inverse_transform(pred.reshape(-1, 1))
y_test = sc.inverse_transform(y_test)
mse = mean_squared_error(y_test, pred)
print('MSE for Tempreture Prediction using RNN: ', mse)
plt.plot(y_test, color = 'b', label = "true")
plt.plot(pred, color = 'y', label = "pred")
plt.ylabel('Tempreture(K)')
plt.xlabel('Day of the year')
plt.title("RNN prediction on 2019-2020 Data")
plt.legend()
plt.show()
```

```
MSE for Tempreture Prediction using RNN:  54.48186965591475
```



1.5 4. Train LSTM for Predicting Tempreture

In this section, we train and evaluate a LSTM RNN model in predicting Daily Maximum Near-Surface Air Temperature(K)

1.5.1 4.1 Data preprocessing

[233]:
```
# Data normalization
sc = MinMaxScaler(feature_range=(0,1))
```

[234]:
```
# Preprocessing train data
x_train = []
y_train = []
n_future = 1 # 1 future day
n_past = 30 # 30 past days
training_set = his_max_temp
training_set = sc.fit_transform(training_set)
for i in range(0,len(training_set)-n_past-n_future+1):
    x_train.append(training_set[i : i + n_past, 0])
    y_train.append(training_set[i + n_past : i + n_past + n_future, 0])
x_train , y_train = np.array(x_train), np.array(y_train)
x_train = np.reshape(x_train, (x_train.shape[0] , x_train.shape[1], 1) )
```

1.5.2 4.2 Train Model

[236]:
```
# Train LSTM model
regressor = Sequential()
regressor.add(Bidirectional(LSTM(units=30, return_sequences=True, input_shape =
↪(x_train.shape[1],1) ) ))
regressor.add(Dropout(0.2))
regressor.add(LSTM(units= 30 , return_sequences=True))
regressor.add(Dropout(0.2))
regressor.add(LSTM(units= 30 , return_sequences=True))
regressor.add(Dropout(0.2))
regressor.add(LSTM(units= 30))
regressor.add(Dropout(0.2))
regressor.add(Dense(units = n_future,activation='linear'))
regressor.compile(optimizer='adam', loss='mean_squared_error',metrics=['acc'])
regressor.fit(x_train, y_train, epochs=500,batch_size=32 )
```

```
Epoch 1/500
11/11 [==============================] - 0s 35ms/step - loss: 0.1459 - acc:
0.0030
Epoch 2/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0399 - acc:
0.0030
Epoch 3/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0285 - acc:
0.0030
Epoch 4/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0255 - acc:
0.0030
Epoch 5/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0257 - acc:
0.0030
Epoch 6/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0223 - acc:
0.0030
Epoch 7/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0202 - acc:
0.0030
Epoch 8/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0192 - acc:
0.0030
Epoch 9/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0191 - acc:
0.0030
Epoch 10/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0196 - acc:
0.0030
Epoch 11/500
```

```
11/11 [==============================] - 0s 28ms/step - loss: 0.0200 - acc:
0.0030
Epoch 12/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0179 - acc:
0.0030
Epoch 13/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0186 - acc:
0.0030
Epoch 14/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0175 - acc:
0.0030
Epoch 15/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0190 - acc:
0.0030
Epoch 16/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0192 - acc:
0.0030
Epoch 17/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0175 - acc:
0.0030
Epoch 18/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0175 - acc:
0.0030
Epoch 19/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0178 - acc:
0.0030
Epoch 20/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0178 - acc:
0.0030
Epoch 21/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0155 - acc:
0.0030
Epoch 22/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0173 - acc:
0.0030
Epoch 23/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0178 - acc:
0.0030
Epoch 24/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0173 - acc:
0.0030
Epoch 25/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0159 - acc:
0.0030
Epoch 26/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0179 - acc:
0.0030
Epoch 27/500
```

```
11/11 [==============================] - 0s 29ms/step - loss: 0.0171 - acc:
0.0030
Epoch 28/500
11/11 [==============================] - 0s 34ms/step - loss: 0.0164 - acc:
0.0030
Epoch 29/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0155 - acc:
0.0030
Epoch 30/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0143 - acc:
0.0030
Epoch 31/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0162 - acc:
0.0030
Epoch 32/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0154 - acc:
0.0030
Epoch 33/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0166 - acc:
0.0030
Epoch 34/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0154 - acc:
0.0030
Epoch 35/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0149 - acc:
0.0030
Epoch 36/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0164 - acc:
0.0030
Epoch 37/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0138 - acc:
0.0030
Epoch 38/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0153 - acc:
0.0030
Epoch 39/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0141 - acc:
0.0030
Epoch 40/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0141 - acc:
0.0030
Epoch 41/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0143 - acc:
0.0030
Epoch 42/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0133 - acc:
0.0030
Epoch 43/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0138 - acc:
0.0030
Epoch 44/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0145 - acc:
0.0030
Epoch 45/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0151 - acc:
0.0030
Epoch 46/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0135 - acc:
0.0030
Epoch 47/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0132 - acc:
0.0030
Epoch 48/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0139 - acc:
0.0030
Epoch 49/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0148 - acc:
0.0030
Epoch 50/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0142 - acc:
0.0030
Epoch 51/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0158 - acc:
0.0030
Epoch 52/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0170 - acc:
0.0030
Epoch 53/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0148 - acc:
0.0030
Epoch 54/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0159 - acc:
0.0030
Epoch 55/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0145 - acc:
0.0030
Epoch 56/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0144 - acc:
0.0030
Epoch 57/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0136 - acc:
0.0030
Epoch 58/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0136 - acc:
0.0030
Epoch 59/500
```

```
11/11 [==============================] - 0s 28ms/step - loss: 0.0136 - acc:
0.0030
Epoch 60/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0147 - acc:
0.0030
Epoch 61/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0145 - acc:
0.0030
Epoch 62/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0144 - acc:
0.0030
Epoch 63/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0135 - acc:
0.0030
Epoch 64/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0124 - acc:
0.0030
Epoch 65/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0121 - acc:
0.0030
Epoch 66/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0141 - acc:
0.0030
Epoch 67/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0139 - acc:
0.0030
Epoch 68/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0147 - acc:
0.0030
Epoch 69/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0129 - acc:
0.0030
Epoch 70/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0145 - acc:
0.0030
Epoch 71/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0134 - acc:
0.0030
Epoch 72/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0138 - acc:
0.0030
Epoch 73/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0129 - acc:
0.0030
Epoch 74/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0124 - acc:
0.0030
Epoch 75/500
```

```
11/11 [==============================] - 0s 29ms/step - loss: 0.0133 - acc:
0.0030
Epoch 76/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0121 - acc:
0.0030
Epoch 77/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0139 - acc:
0.0030
Epoch 78/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0132 - acc:
0.0030
Epoch 79/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0126 - acc:
0.0030
Epoch 80/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0135 - acc:
0.0030
Epoch 81/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0121 - acc:
0.0030
Epoch 82/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0128 - acc:
0.0030
Epoch 83/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0130 - acc:
0.0030
Epoch 84/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0124 - acc:
0.0030
Epoch 85/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0120 - acc:
0.0030
Epoch 86/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0139 - acc:
0.0030
Epoch 87/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0126 - acc:
0.0030
Epoch 88/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0124 - acc:
0.0030
Epoch 89/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0125 - acc:
0.0030
Epoch 90/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0129 - acc:
0.0030
Epoch 91/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0126 - acc:
0.0030
Epoch 92/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0128 - acc:
0.0030
Epoch 93/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0128 - acc:
0.0030
Epoch 94/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0125 - acc:
0.0030
Epoch 95/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0135 - acc:
0.0030
Epoch 96/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0117 - acc:
0.0030
Epoch 97/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0134 - acc:
0.0030
Epoch 98/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0127 - acc:
0.0030
Epoch 99/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0126 - acc:
0.0030
Epoch 100/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0127 - acc:
0.0030
Epoch 101/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0123 - acc:
0.0030
Epoch 102/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0115 - acc:
0.0030
Epoch 103/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0122 - acc:
0.0030
Epoch 104/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0148 - acc:
0.0030
Epoch 105/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0127 - acc:
0.0030
Epoch 106/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0121 - acc:
0.0030
Epoch 107/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0125 - acc:
0.0030
Epoch 108/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0118 - acc:
0.0030
Epoch 109/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0120 - acc:
0.0030
Epoch 110/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0131 - acc:
0.0030
Epoch 111/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0118 - acc:
0.0030
Epoch 112/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0131 - acc:
0.0030
Epoch 113/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0117 - acc:
0.0030
Epoch 114/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0123 - acc:
0.0030
Epoch 115/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0126 - acc:
0.0030
Epoch 116/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0126 - acc:
0.0030
Epoch 117/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0130 - acc:
0.0030
Epoch 118/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0127 - acc:
0.0030
Epoch 119/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0113 - acc:
0.0030
Epoch 120/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0125 - acc:
0.0030
Epoch 121/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0124 - acc:
0.0030
Epoch 122/500
11/11 [==============================] - 0s 32ms/step - loss: 0.0121 - acc:
0.0030
Epoch 123/500
```

```
11/11 [==============================] - 0s 31ms/step - loss: 0.0135 - acc:
0.0030
Epoch 124/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0117 - acc:
0.0030
Epoch 125/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0124 - acc:
0.0030
Epoch 126/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0122 - acc:
0.0030
Epoch 127/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0118 - acc:
0.0030
Epoch 128/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0120 - acc:
0.0030
Epoch 129/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0109 - acc:
0.0030
Epoch 130/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0110 - acc:
0.0030
Epoch 131/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0108 - acc:
0.0030
Epoch 132/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0114 - acc:
0.0030
Epoch 133/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0134 - acc:
0.0030
Epoch 134/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0129 - acc:
0.0030
Epoch 135/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0126 - acc:
0.0030
Epoch 136/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0122 - acc:
0.0030
Epoch 137/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0109 - acc:
0.0030
Epoch 138/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0123 - acc:
0.0030
Epoch 139/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0134 - acc:
0.0030
Epoch 140/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0109 - acc:
0.0030
Epoch 141/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0111 - acc:
0.0030
Epoch 142/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0115 - acc:
0.0030
Epoch 143/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0122 - acc:
0.0030
Epoch 144/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0117 - acc:
0.0030
Epoch 145/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0122 - acc:
0.0030
Epoch 146/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0117 - acc:
0.0030
Epoch 147/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0100 - acc:
0.0030
Epoch 148/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0113 - acc:
0.0030
Epoch 149/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0113 - acc:
0.0030
Epoch 150/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0113 - acc:
0.0030
Epoch 151/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0113 - acc:
0.0030
Epoch 152/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0122 - acc:
0.0030
Epoch 153/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0107 - acc:
0.0030
Epoch 154/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0110 - acc:
0.0030
Epoch 155/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0104 - acc:
0.0030
Epoch 156/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0113 - acc:
0.0030
Epoch 157/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0121 - acc:
0.0030
Epoch 158/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0112 - acc:
0.0030
Epoch 159/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0104 - acc:
0.0030
Epoch 160/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0107 - acc:
0.0030
Epoch 161/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0115 - acc:
0.0030
Epoch 162/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0124 - acc:
0.0030
Epoch 163/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0118 - acc:
0.0030
Epoch 164/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0099 - acc:
0.0030
Epoch 165/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0114 - acc:
0.0030
Epoch 166/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0116 - acc:
0.0030
Epoch 167/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0120 - acc:
0.0030
Epoch 168/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0107 - acc:
0.0030
Epoch 169/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0107 - acc:
0.0030
Epoch 170/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0118 - acc:
0.0030
Epoch 171/500
```

```
11/11 [==============================] - 0s 31ms/step - loss: 0.0113 - acc:
0.0030
Epoch 172/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0113 - acc:
0.0030
Epoch 173/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0113 - acc:
0.0030
Epoch 174/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0121 - acc:
0.0030
Epoch 175/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0109 - acc:
0.0030
Epoch 176/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0113 - acc:
0.0030
Epoch 177/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0110 - acc:
0.0030
Epoch 178/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0106 - acc:
0.0030
Epoch 179/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0108 - acc:
0.0030
Epoch 180/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0116 - acc:
0.0030
Epoch 181/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0116 - acc:
0.0030
Epoch 182/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0119 - acc:
0.0030
Epoch 183/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0111 - acc:
0.0030
Epoch 184/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0120 - acc:
0.0030
Epoch 185/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0122 - acc:
0.0030
Epoch 186/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0119 - acc:
0.0030
Epoch 187/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0109 - acc:
0.0030
Epoch 188/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0108 - acc:
0.0030
Epoch 189/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0113 - acc:
0.0030
Epoch 190/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0112 - acc:
0.0030
Epoch 191/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0116 - acc:
0.0030
Epoch 192/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0130 - acc:
0.0030
Epoch 193/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0111 - acc:
0.0030
Epoch 194/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0116 - acc:
0.0030
Epoch 195/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0107 - acc:
0.0030
Epoch 196/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0106 - acc:
0.0030
Epoch 197/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0116 - acc:
0.0030
Epoch 198/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0114 - acc:
0.0030
Epoch 199/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0106 - acc:
0.0030
Epoch 200/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0114 - acc:
0.0030
Epoch 201/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0113 - acc:
0.0030
Epoch 202/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0112 - acc:
0.0030
Epoch 203/500
```

```
11/11 [==============================] - 0s 30ms/step - loss: 0.0108 - acc:
0.0030
Epoch 204/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0104 - acc:
0.0030
Epoch 205/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0108 - acc:
0.0030
Epoch 206/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0099 - acc:
0.0030
Epoch 207/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0109 - acc:
0.0030
Epoch 208/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0104 - acc:
0.0030
Epoch 209/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 210/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 211/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 212/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0106 - acc:
0.0030
Epoch 213/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0107 - acc:
0.0030
Epoch 214/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0105 - acc:
0.0030
Epoch 215/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0111 - acc:
0.0030
Epoch 216/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0108 - acc:
0.0030
Epoch 217/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0108 - acc:
0.0030
Epoch 218/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0108 - acc:
0.0030
Epoch 219/500
```

```
11/11 [==============================] - 0s 33ms/step - loss: 0.0108 - acc:
0.0030
Epoch 220/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0098 - acc:
0.0030
Epoch 221/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0105 - acc:
0.0030
Epoch 222/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 223/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0111 - acc:
0.0030
Epoch 224/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0112 - acc:
0.0030
Epoch 225/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0108 - acc:
0.0030
Epoch 226/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0103 - acc:
0.0030
Epoch 227/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 228/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 229/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0100 - acc:
0.0030
Epoch 230/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0106 - acc:
0.0030
Epoch 231/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0113 - acc:
0.0030
Epoch 232/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0108 - acc:
0.0030
Epoch 233/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0103 - acc:
0.0030
Epoch 234/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0107 - acc:
0.0030
Epoch 235/500
```

```
11/11 [==============================] - 0s 28ms/step - loss: 0.0112 - acc:
0.0030
Epoch 236/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0107 - acc:
0.0030
Epoch 237/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0104 - acc:
0.0030
Epoch 238/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0104 - acc:
0.0030
Epoch 239/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0103 - acc:
0.0030
Epoch 240/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0098 - acc:
0.0030
Epoch 241/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0100 - acc:
0.0030
Epoch 242/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0105 - acc:
0.0030
Epoch 243/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0108 - acc:
0.0030
Epoch 244/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0105 - acc:
0.0030
Epoch 245/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0107 - acc:
0.0030
Epoch 246/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0107 - acc:
0.0030
Epoch 247/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0099 - acc:
0.0030
Epoch 248/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0104 - acc:
0.0030
Epoch 249/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0105 - acc:
0.0030
Epoch 250/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0112 - acc:
0.0030
Epoch 251/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 252/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0107 - acc:
0.0030
Epoch 253/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 254/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 255/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 256/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 257/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0109 - acc:
0.0030
Epoch 258/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0103 - acc:
0.0030
Epoch 259/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0106 - acc:
0.0030
Epoch 260/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 261/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0107 - acc:
0.0030
Epoch 262/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0109 - acc:
0.0030
Epoch 263/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 264/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 265/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0101 - acc:
0.0030
Epoch 266/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0097 - acc:
0.0030
Epoch 267/500
```

```
11/11 [==============================] - 0s 31ms/step - loss: 0.0108 - acc:
0.0030
Epoch 268/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0103 - acc:
0.0030
Epoch 269/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0104 - acc:
0.0030
Epoch 270/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0107 - acc:
0.0030
Epoch 271/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 272/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0100 - acc:
0.0030
Epoch 273/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 274/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 275/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 276/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0104 - acc:
0.0030
Epoch 277/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 278/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0103 - acc:
0.0030
Epoch 279/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0104 - acc:
0.0030
Epoch 280/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 281/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 282/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 283/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 284/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 285/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 286/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 287/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0113 - acc:
0.0030
Epoch 288/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0117 - acc:
0.0030
Epoch 289/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0110 - acc:
0.0030
Epoch 290/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 291/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0105 - acc:
0.0030
Epoch 292/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 293/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 294/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 295/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 296/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0106 - acc:
0.0030
Epoch 297/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0108 - acc:
0.0030
Epoch 298/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0104 - acc:
0.0030
Epoch 299/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0107 - acc:
0.0030
Epoch 300/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0105 - acc:
0.0030
Epoch 301/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 302/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0103 - acc:
0.0030
Epoch 303/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0097 - acc:
0.0030
Epoch 304/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 305/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 306/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 307/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 308/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 309/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 310/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 311/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0106 - acc:
0.0030
Epoch 312/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0096 - acc:
0.0030
Epoch 313/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 314/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0103 - acc:
0.0030
Epoch 315/500
```

```
11/11 [==============================] - 0s 28ms/step - loss: 0.0094 - acc:
0.0030
Epoch 316/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0104 - acc:
0.0030
Epoch 317/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0093 - acc:
0.0030
Epoch 318/500
11/11 [==============================] - 0s 30ms/step - loss: 0.0099 - acc:
0.0030
Epoch 319/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0093 - acc:
0.0030
Epoch 320/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0109 - acc:
0.0030
Epoch 321/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 322/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 323/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0099 - acc:
0.0030
Epoch 324/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 325/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 326/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 327/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 328/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 329/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 330/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 331/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 332/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 333/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 334/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0094 - acc:
0.0030
Epoch 335/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 336/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 337/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 338/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0095 - acc:
0.0030
Epoch 339/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0100 - acc:
0.0030
Epoch 340/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0097 - acc:
0.0030
Epoch 341/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0098 - acc:
0.0030
Epoch 342/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0097 - acc:
0.0030
Epoch 343/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0098 - acc:
0.0030
Epoch 344/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 345/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 346/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 347/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 348/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0095 - acc:
0.0030
Epoch 349/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0095 - acc:
0.0030
Epoch 350/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0100 - acc:
0.0030
Epoch 351/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0102 - acc:
0.0030
Epoch 352/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0100 - acc:
0.0030
Epoch 353/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 354/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 355/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 356/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 357/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 358/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 359/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 360/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 361/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 362/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 363/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 364/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0091 - acc:
0.0030
Epoch 365/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0103 - acc:
0.0030
Epoch 366/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0091 - acc:
0.0030
Epoch 367/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0097 - acc:
0.0030
Epoch 368/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0097 - acc:
0.0030
Epoch 369/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 370/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0097 - acc:
0.0030
Epoch 371/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 372/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0101 - acc:
0.0030
Epoch 373/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 374/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 375/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0093 - acc:
0.0030
Epoch 376/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0088 - acc:
0.0030
Epoch 377/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 378/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0094 - acc:
0.0030
Epoch 379/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 380/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 381/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 382/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0097 - acc:
0.0030
Epoch 383/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0100 - acc:
0.0030
Epoch 384/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0096 - acc:
0.0030
Epoch 385/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 386/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 387/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 388/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 389/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 390/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 391/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0091 - acc:
0.0030
Epoch 392/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 393/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 394/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 395/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0099 - acc:
0.0030
Epoch 396/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 397/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 398/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 399/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 400/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 401/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0090 - acc:
0.0030
Epoch 402/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0088 - acc:
0.0030
Epoch 403/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 404/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0094 - acc:
0.0030
Epoch 405/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 406/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 407/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 408/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 409/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 410/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 411/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 412/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 413/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 414/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0087 - acc:
0.0030
Epoch 415/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0094 - acc:
0.0030
Epoch 416/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0092 - acc:
0.0030
Epoch 417/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0092 - acc:
0.0030
Epoch 418/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 419/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 420/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 421/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0086 - acc:
0.0030
Epoch 422/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 423/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 424/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0098 - acc:
0.0030
Epoch 425/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 426/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0091 - acc:
0.0030
Epoch 427/500
```

```
11/11 [==============================] - 0s 27ms/step - loss: 0.0091 - acc:
0.0030
Epoch 428/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 429/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 430/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 431/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 432/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 433/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0102 - acc:
0.0030
Epoch 434/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 435/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 436/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 437/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 438/500
11/11 [==============================] - 0s 31ms/step - loss: 0.0089 - acc:
0.0030
Epoch 439/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 440/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0096 - acc:
0.0030
Epoch 441/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0084 - acc:
0.0030
Epoch 442/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 443/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0083 - acc:
0.0030
Epoch 444/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0087 - acc:
0.0030
Epoch 445/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 446/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 447/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 448/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0088 - acc:
0.0030
Epoch 449/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 450/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0088 - acc:
0.0030
Epoch 451/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 452/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 453/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 454/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 455/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 456/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0089 - acc:
0.0030
Epoch 457/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0085 - acc:
0.0030
Epoch 458/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 459/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0086 - acc:
0.0030
Epoch 460/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 461/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0091 - acc:
0.0030
Epoch 462/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0084 - acc:
0.0030
Epoch 463/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 464/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0092 - acc:
0.0030
Epoch 465/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0089 - acc:
0.0030
Epoch 466/500
11/11 [==============================] - 0s 29ms/step - loss: 0.0085 - acc:
0.0030
Epoch 467/500
11/11 [==============================] - 0s 28ms/step - loss: 0.0084 - acc:
0.0030
Epoch 468/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0095 - acc:
0.0030
Epoch 469/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0087 - acc:
0.0030
Epoch 470/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0087 - acc:
0.0030
Epoch 471/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 472/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0090 - acc:
0.0030
Epoch 473/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 474/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0086 - acc:
0.0030
Epoch 475/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0094 - acc:
0.0030
Epoch 476/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 477/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0082 - acc:
0.0030
Epoch 478/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0086 - acc:
0.0030
Epoch 479/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 480/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 481/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0093 - acc:
0.0030
Epoch 482/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0084 - acc:
0.0030
Epoch 483/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0084 - acc:
0.0030
Epoch 484/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 485/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0081 - acc:
0.0030
Epoch 486/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0088 - acc:
0.0030
Epoch 487/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0081 - acc:
0.0030
Epoch 488/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0089 - acc:
0.0030
Epoch 489/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0088 - acc:
0.0030
Epoch 490/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 491/500
```

```
11/11 [==============================] - 0s 26ms/step - loss: 0.0082 - acc:
0.0030
Epoch 492/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0087 - acc:
0.0030
Epoch 493/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0092 - acc:
0.0030
Epoch 494/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0087 - acc:
0.0030
Epoch 495/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0081 - acc:
0.0030
Epoch 496/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0081 - acc:
0.0030
Epoch 497/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0085 - acc:
0.0030
Epoch 498/500
11/11 [==============================] - 0s 27ms/step - loss: 0.0086 - acc:
0.0030
Epoch 499/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0080 - acc:
0.0030
Epoch 500/500
11/11 [==============================] - 0s 26ms/step - loss: 0.0082 - acc:
0.0030
```

[236]:
```
<tensorflow.python.keras.callbacks.History at 0x13a2a2dfa60>
```

1.5.3 4.3 Test and Evaluate

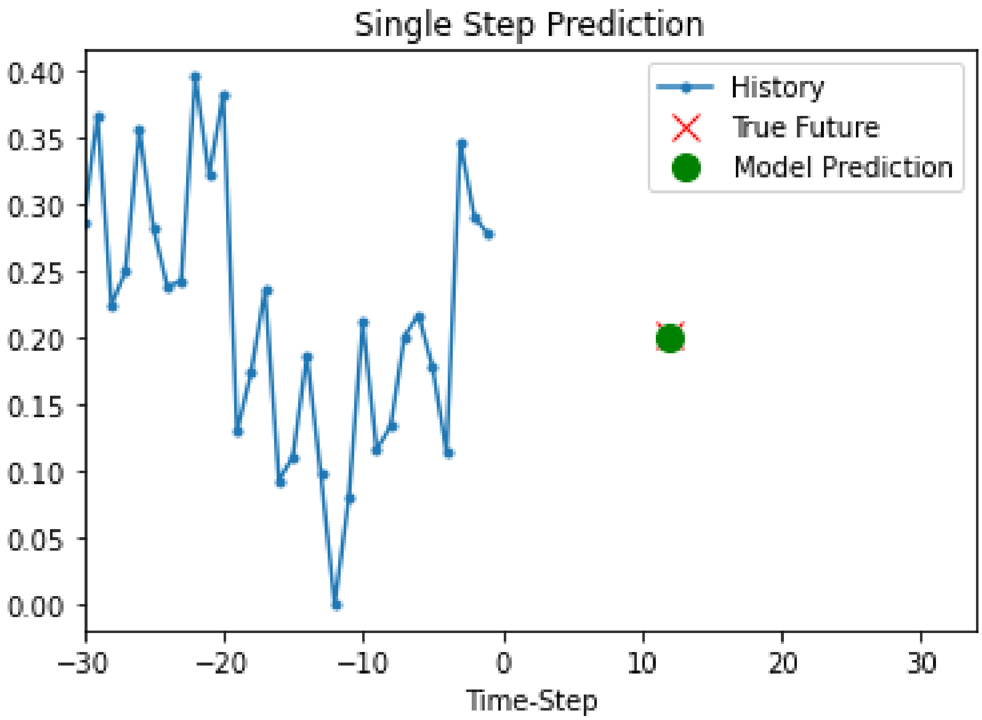
1) Evaluate performance with single step prediction of Tempreture on the 31th day of 2019

[276]:
```
# Plot single step prediction
# Modified from: Team, K. (n.d.). Keras documentation: Timeseries forecasting␣
↪for weather prediction. Keras. https://keras.io/examples/timeseries/
↪timeseries_weather_forecasting/.
def show_plot(plot_data, delta, title):
    labels = ["History", "True Future", "Model Prediction"]
    marker = [".-", "rx", "go"]
    time_steps = list(range(-(plot_data[0].shape[0]), 0))
    if delta:
        future = delta
    else:
        future = 0
```

```
    plt.title(title)
    for i, val in enumerate(plot_data):
        if i:
            plt.plot(future, plot_data[i], marker[i], markersize=10,␣
↪label=labels[i])
        else:
            plt.plot(time_steps, plot_data[i].flatten(), marker[i],␣
↪label=labels[i])
    plt.legend()
    plt.xlim([time_steps[0], (future + 5) * 2])
    plt.xlabel("Time-Step")
    plt.show()
    return
```

[288]:
```
# Preprocessing test data
testdataset = cur_max_temp[:31]
testdataset = sc.transform(testdataset)
x_test = []
y_test = []
n_future = 1
n_past = 30
for i in range(0,len(testdataset)-n_past-n_future+1):
    x_test.append(testdataset[i : i + n_past, 0])
    y_test.append(testdataset[i + n_past : i + n_past + n_future, 0])
x_test , y_test = np.array(x_test), np.array(y_test)
x_test = np.reshape(x_test, (x_test.shape[0] , x_test.shape[1], 1) )
```

[299]:
```
show_plot(
        [x_test[0], y_test[0], regressor.predict(x_test)[0]],
        12,
        "Single Step Prediction",
    )
```



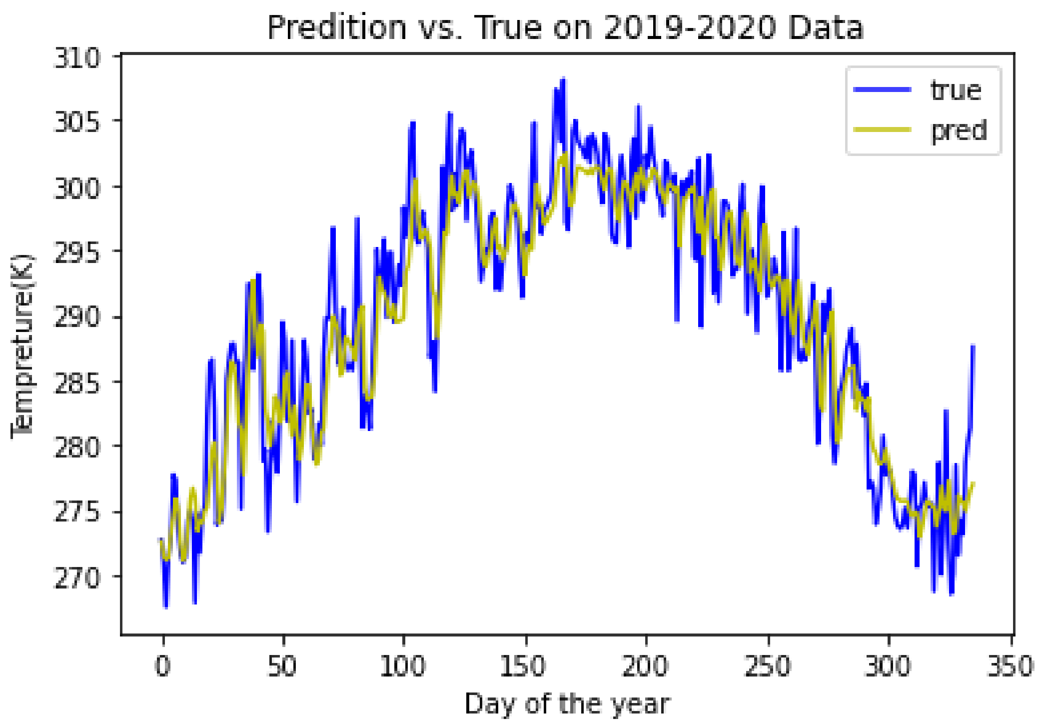
2) Evaluate performance with 2019-2020 test set

[300]:
```
# Preprocessing test data
testdataset = cur_max_temp
testdataset = sc.transform(testdataset)
x_test = []
y_test = []
n_future = 1
n_past = 30
for i in range(0,len(testdataset)-n_past-n_future+1):
    x_test.append(testdataset[i : i + n_past, 0])
    y_test.append(testdataset[i + n_past : i + n_past + n_future, 0])
x_test , y_test = np.array(x_test), np.array(y_test)
x_test = np.reshape(x_test, (x_test.shape[0] , x_test.shape[1], 1) )
```

[301]:
```
# Making prediction and evaluation
pred_30 = regressor.predict(x_test)
pred_30 = sc.inverse_transform(pred_30)
y_test = sc.inverse_transform(y_test)
mse = mean_squared_error(y_test, pred_30)
print('MSE for Tempreture Prediction using LSTM: ', mse)
plt.plot(y_test, color = 'b', label = "true")
plt.plot(pred_30, color = 'y', label = "pred")
plt.ylabel('Tempreture(K)')
```

```
plt.xlabel('Day of the year')
plt.title("LSTM prediction on 2019-2020 Data")
plt.legend()
plt.show()
```

```
MSE for Tempreture Prediction using LSTM:  14.898463512340081
```



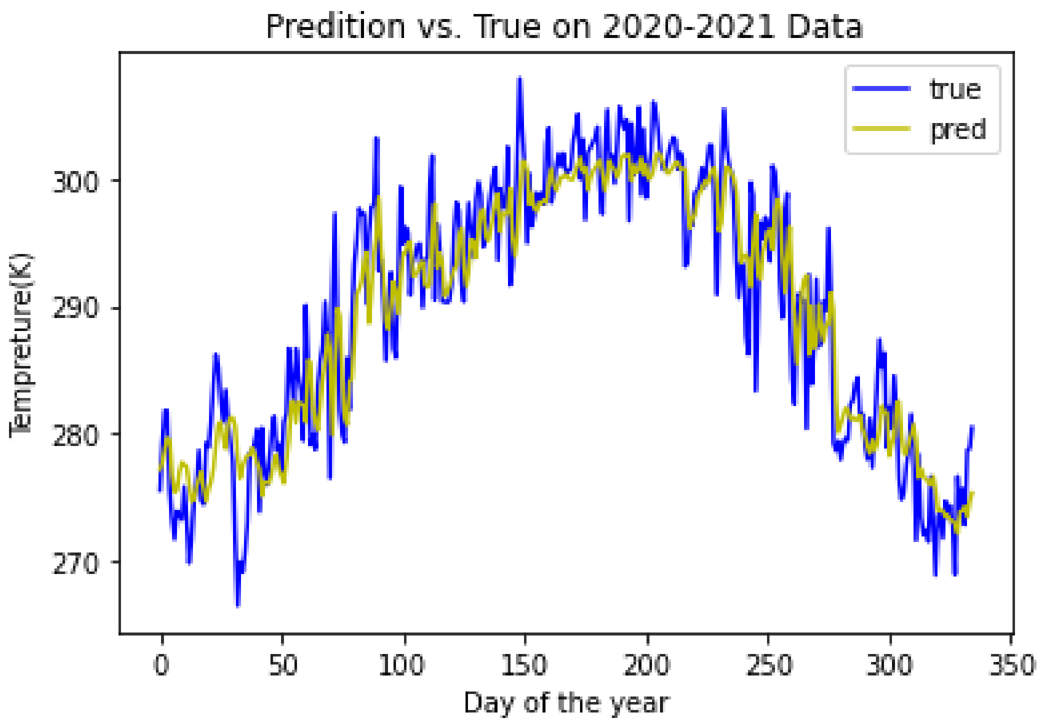
3) Evaluate performance with 2020-2021 test set

[302]:
```
# Preprocessing test set
testdataset = future_max_temp
testdataset = sc.transform(testdataset)
x_test = []
y_test = []
n_future = 1
n_past = 30
for i in range(0,len(testdataset)-n_past-n_future+1):
    x_test.append(testdataset[i : i + n_past, 0])
    y_test.append(testdataset[i + n_past : i + n_past + n_future, 0])
x_test , y_test = np.array(x_test), np.array(y_test)
x_test = np.reshape(x_test, (x_test.shape[0] , x_test.shape[1], 1) )
```

[303]:
```
# Making prediction and evaluation
pred_2021 = regressor.predict(x_test)
```

```
pred_2021 = sc.inverse_transform(pred_2021)
y_test = sc.inverse_transform(y_test)
mse = mean_squared_error(y_test, pred_2021)
print('MSE for Tempreture Prediction using LSTM: ', mse)
plt.plot(y_test, color = 'b', label = "true")
plt.plot(pred_2021, color = 'y', label = "pred")
plt.ylabel('Tempreture(K)')
plt.xlabel('Day of the year')
plt.title("LSTM prediction on 2020-2021 Data")
plt.legend()
plt.show()
```

```
MSE for Tempreture Prediction using LSTM:  16.6580981560278
```



1.6 References:

Kosandal, R. (2020, January 5). Weather forecasting with Recurrent Neural Networks. Medium. https://medium.com/analytics-vidhya/weather-forecasting-with-recurrent-neural-networks-1eaa057d70c3. Team, K. (n.d.). Keras documentation: Timeseries forecasting for weather prediction. Keras. https://keras.io/examples/timeseries/timeseries_weather_forecasting/. Fatmakursun. (2020, January 28). Rain Forecasting with Artificial Neural Network. Kaggle. https://www.kaggle.com/fatmakursun/rain-forecasting-with-artificial-neural-network. Pietro, M. D. (2020, December 8). Machine Learning with Python: Regression. Medium. https://towardsdatascience.com/machine-learning-with-python-regression-complete-tutorial-

47268e546cea. Paialunga, P. (2021, April 18). Weather forecasting with Machine Learning, using Python. Medium. https://towardsdatascience.com/weather-forecasting-with-machine-learning-using-python-55e90c346647.