homework_05

May 9, 2020

0.1 Homework 5

[18]:
```
import numpy as np
import pandas as pd
from sklearn import gaussian_process
import matplotlib.pyplot as plt
import matplotlib.style as style
style.use('default')
```

Load the national COVID dataset and solve the exercise using `scikit-learn` library.

[19]:
```
data = pd.read_csv("homework_05_COVID_national_20200421.csv", index_col=0,␣
↪usecols=range(1,10))
# convert index to datetime64 data type
data.index = pd.to_datetime(data.index)
data.head()
```

[19]:

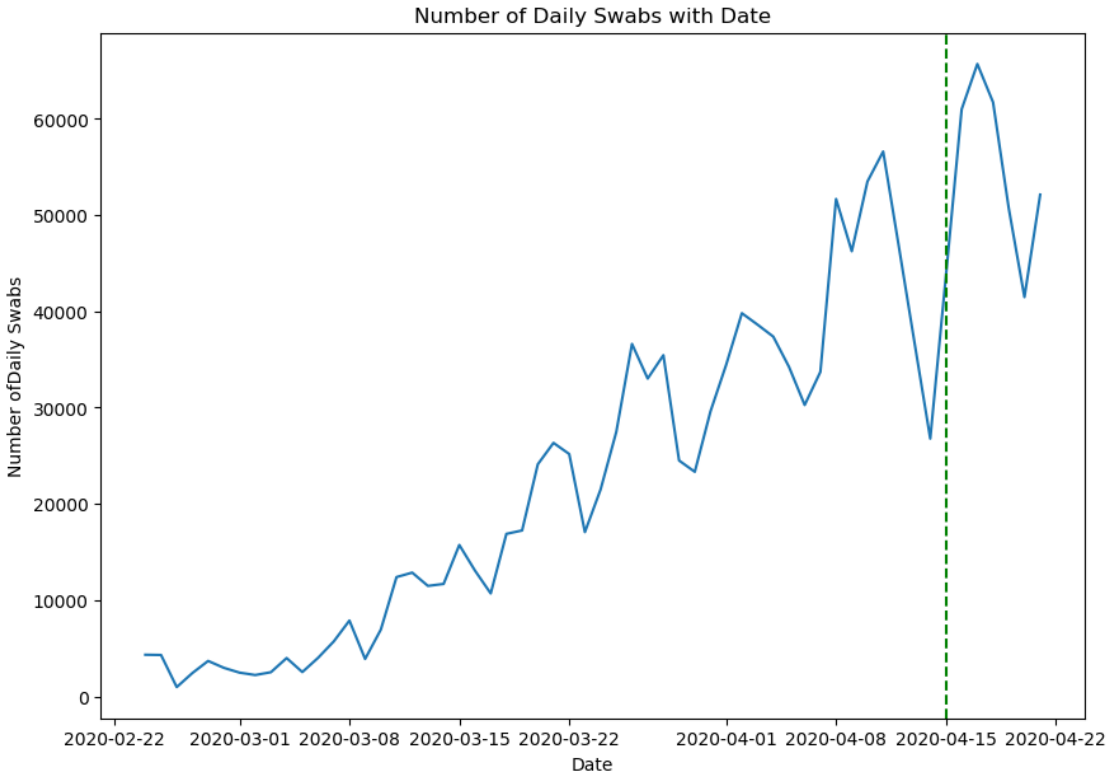
date	deaths	swabs	ICU	hospitalized	new_infections	cumulative_infections	recovered	quarantined
2020-02-24	7	4324	26	101	221	229	1	94
2020-02-25	10	8623	35	114	93	322	1	162
2020-02-26	12	9587	36	128	78	400	3	221
2020-02-27	17	12014	56	248	250	650	45	284
2020-02-28	21	15695	64	345	238	888	46	412

[20]:
```
def calculate_daily(column):
    """This function calculates adn returns daily values from cumulative column␣
↪"""

    cumulative = data[column].values
```

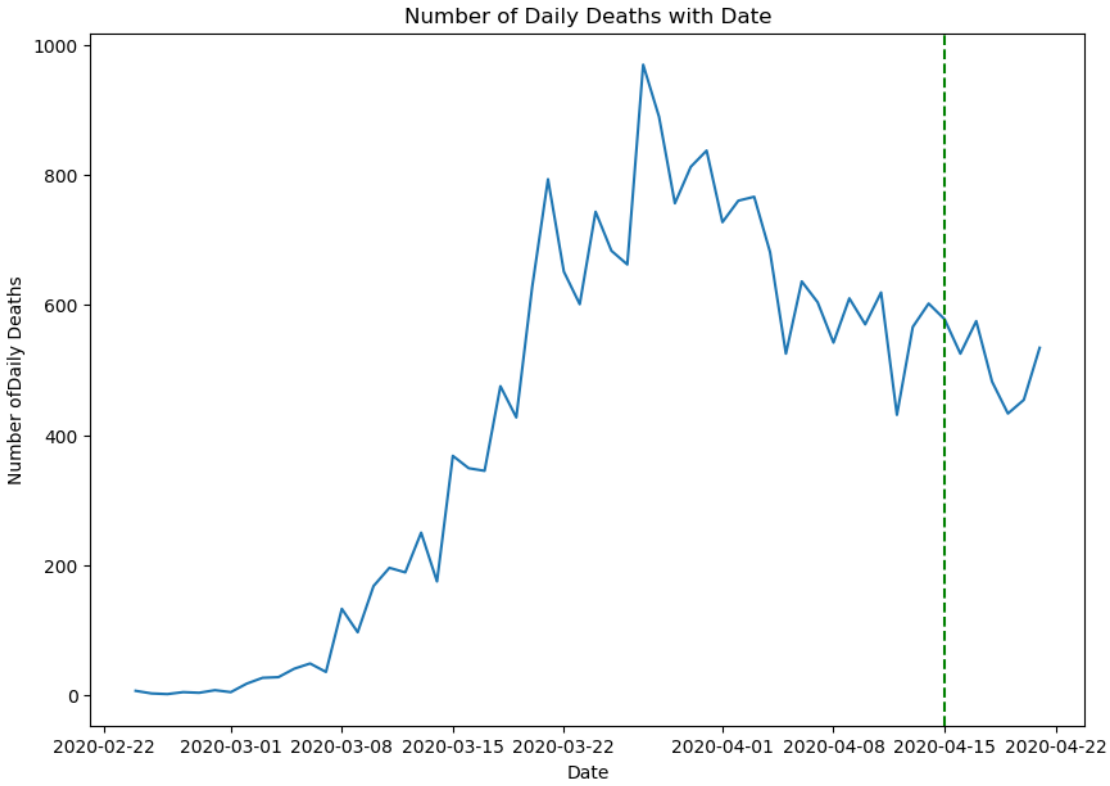
```
    daily = np.array([(cumulative[i+1]-cumulative[i]) for i in␣
↪range(len(data[column])-1)])
    daily = np.insert(daily,0,cumulative[0])
    return daily

daily_swabs = calculate_daily("swabs")
daily_deaths = calculate_daily("deaths")
```

[21]:
```
def plot_wdate(column, array=None, label=None):

    """
    This function plot date and given column name from data
    with the blue vertical line from 2020-04-15 with specified label or given␣
↪array.
    You can use this function either giving array or column name of
    dataframe, please ensure that you give None for other option, as default
    array is none.
    """

    if column != None:
        plt.figure(figsize=(10,7))
        plt.title("Number of "+label+" with Date")
        plt.xlabel("Date")
        plt.ylabel("Number of "+label)
        plt.plot(data.index,data[column])
        plt.axvline(pd.to_datetime("2020-04-15"), linestyle='--', color='g')
    else:
        plt.figure(figsize=(10,7))
        plt.title("Number of "+label+" with Date")
        plt.xlabel("Date")
        plt.ylabel("Number of"+label)
        plt.plot(data.index,array)
        plt.axvline(pd.to_datetime("2020-04-15"), linestyle='--', color='g')
```

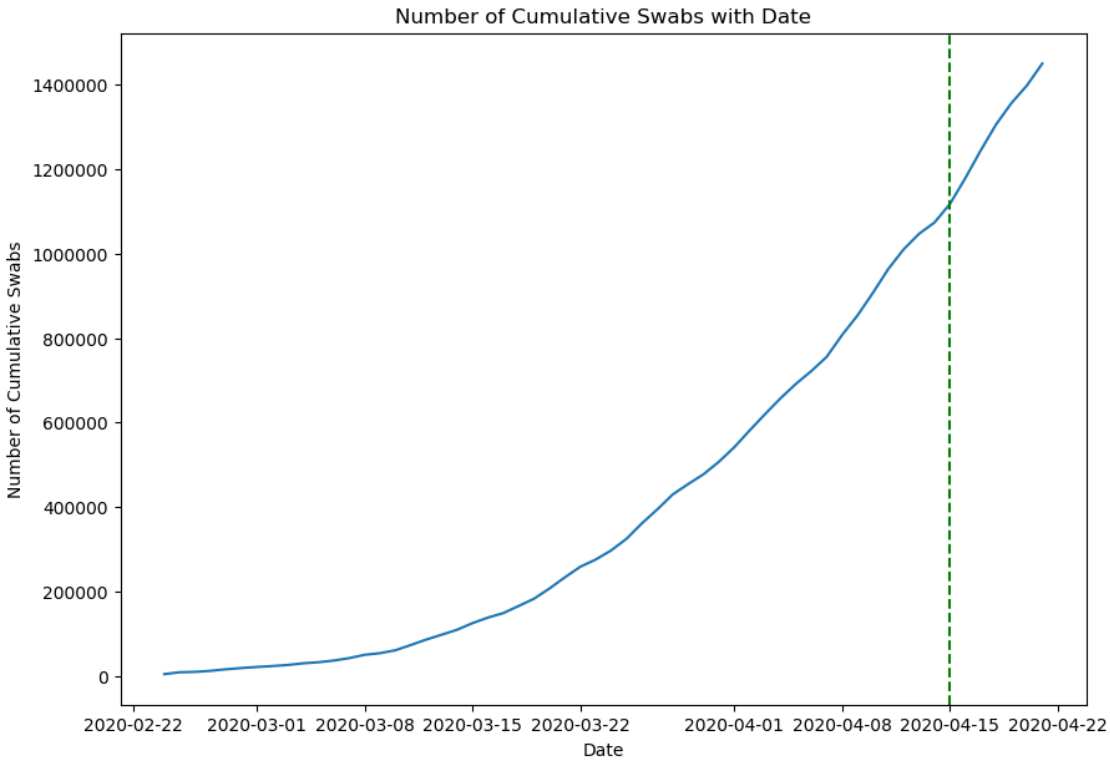
[22]:
```
plot_wdate(column=None, array=daily_swabs, label = "Daily Swabs")
```



[23]:
```
plot_wdate(column=None, array=daily_deaths, label = "Daily Deaths")
```



[24]:
```
plot_wdate(column = "swabs", label = "Cumulative Swabs")
```



1. Perform a train-test split, with observations from the last week corresponding to the test set;

[25]:
```
# Perform a train-test split, with observations from the last week␣
 ↪corresponding to the test set;
sep_idx = data.index.searchsorted(pd.to_datetime("2020-04-15"))
data_early = data.iloc[:sep_idx]
data_late = data.iloc[sep_idx:]
#data_early
#data_late
```

[26]:
```
def dates_to_idx(timelist):

    """Given the date time array converted to scalar values
    by substracting the first date and dividing the week"""

    reference_time = pd.to_datetime("2020-02-24")
    t = (timelist - reference_time) / np.timedelta64(1, 'W')
    return np.asarray(t)

def normalize(column):

    """Normalizing the given column by substracting the first element
```

```
    and dividing it to standard deviation"""

    first = np.mean(column)
    std = np.std(column)
    return (column-first)/ std
```

[27]:
```
data['Rescaled_Date'] = dates_to_idx(data.index)
data['Daily_swabs_normalized'] = normalize(daily_swabs)
data['Daily_deaths_normalized'] = normalize(daily_deaths)
data['Deaths_normalized'] = normalize(data['deaths'])
data['Swabs_normalized'] = normalize(data['swabs'])

data.head()
```

[27]:

date	deaths	swabs	ICU	hospitalized	new_infections	cumulative_infections	recovered	quarantined	Rescaled_Date	Daily_swabs_normalized	Daily_deaths_normalized	Deaths_normalized	Swabs_normalized
2020-02-24	7	4324	26	101	221	229	1	94	0.000000	-1.124108	-1.459049	-1.047312	-1.010717
2020-02-25	10	8623	35	114	93	322	1	162	0.142857	-1.125467	-1.473012	-1.046962	-1.000955
2020-02-26	12	9587	36	128	78	400	3	221	0.285714	-1.306761	-1.476503	-1.046729	-0.998767
2020-02-27	17	12014	56	248	250	650	45	284	0.428571	-1.227231	-1.466031	-1.046146	-0.993256
2020-02-28	21	15695	64	345	238	888	46	412	0.571429	-1.159062	-1.469521	-1.045679	-0.984898

[28]:
```
data.tail()
```

[28]:

date	deaths	swabs	ICU	hospitalized	new_infections	\
2020-04-17	22745	1244108	2812	25786	3493	
2020-04-18	23227	1305833	2733	25007	3491	
2020-04-19	23660	1356541	2635	25033	3047	
2020-04-20	24114	1398024	2573	24906	2256	
2020-04-21	24648	1450150	2471	24134	2729	

date	cumulative_infections	recovered	quarantined	Rescaled_Date	\
2020-04-17	172434	42727	78364	7.571429	
2020-04-18	175925	44927	80031	7.714286	
2020-04-19	178972	47055	80589	7.857143	
2020-04-20	181228	48877	80758	8.000000	
2020-04-21	183957	51600	81104	8.142857	

date	Daily_swabs_normalized	Daily_deaths_normalized	\
2020-04-17	2.212623	0.523746	
2020-04-18	1.996266	0.199098	
2020-04-19	1.397372	0.028047	
2020-04-20	0.895891	0.101355	
2020-04-21	1.474455	0.380621	

date	Deaths_normalized	Swabs_normalized
2020-04-17	1.604705	1.804288
2020-04-18	1.660922	1.944438
2020-04-19	1.711425	2.059574
2020-04-20	1.764376	2.153763
2020-04-21	1.826659	2.272119

[29]:
```
def train_test_split(X, y):
    """Given column name train test split performed with observations
    from the last week target variable depend on given column whether
    train set is Rescaled_Date. It returns trains and tests sets as well as X
    y."""

    X = data[X].values[:,None]
    y = data[y].values
    X_train = X[:len(data_early)]
    y_train = y[:len(data_early)]
    X_test = X[len(data_early):]
    y_test = y[len(data_early):]

    return X, y, X_train, X_test, y_train, y_test
```

[30]:
```
# Train test split for daily number of daily_deaths
X, y, X_train, X_test, y_train, y_test =␣
↪train_test_split(X="Rescaled_Date",y="Daily_deaths_normalized")
```

2. Build a suitable combination of kernels choosing from the ones shown in notebook_05;

Below groups of kernels are defined. Some of them are more complex. They will be all used for predicting desired target variable and best one will be presented with plots. If complex and simple kernels gave similar results, simple one preferred.

[31]:
```
from sklearn.gaussian_process.kernels import RBF, ExpSineSquared,␣
↪RationalQuadratic,WhiteKernel
from sklearn.gaussian_process.kernels import  DotProduct, Matern, ConstantKernel
```

[56]:
```
kernel1 = 10**2 * RBF(length_scale=20) # long term trend
kernel2 = 50 * DotProduct(sigma_0=0.5) # linear regression
kernel3 = 50**2 * Matern(length_scale=50,nu=2.5)
kernel4 = 20**2 * ExpSineSquared(length_scale=20)
```

[88]:
```
kernel5 = 50*kernel2 * 20*kernel1 + WhiteKernel(noise_level=0.1)
kernel6 = kernel2 * kernel2 + WhiteKernel(noise_level=0.1)
kernel7 = 30*kernel2 + 70*kernel3
kernel8 = 100*(30**2 *kernel1) + 30* kernel3
kernel9 = (kernel2 * kernel2) * kernel3 * kernel4 + WhiteKernel(noise_level=0.1)
```

Consider first the column corresponding to the (cumulative) number of deaths.

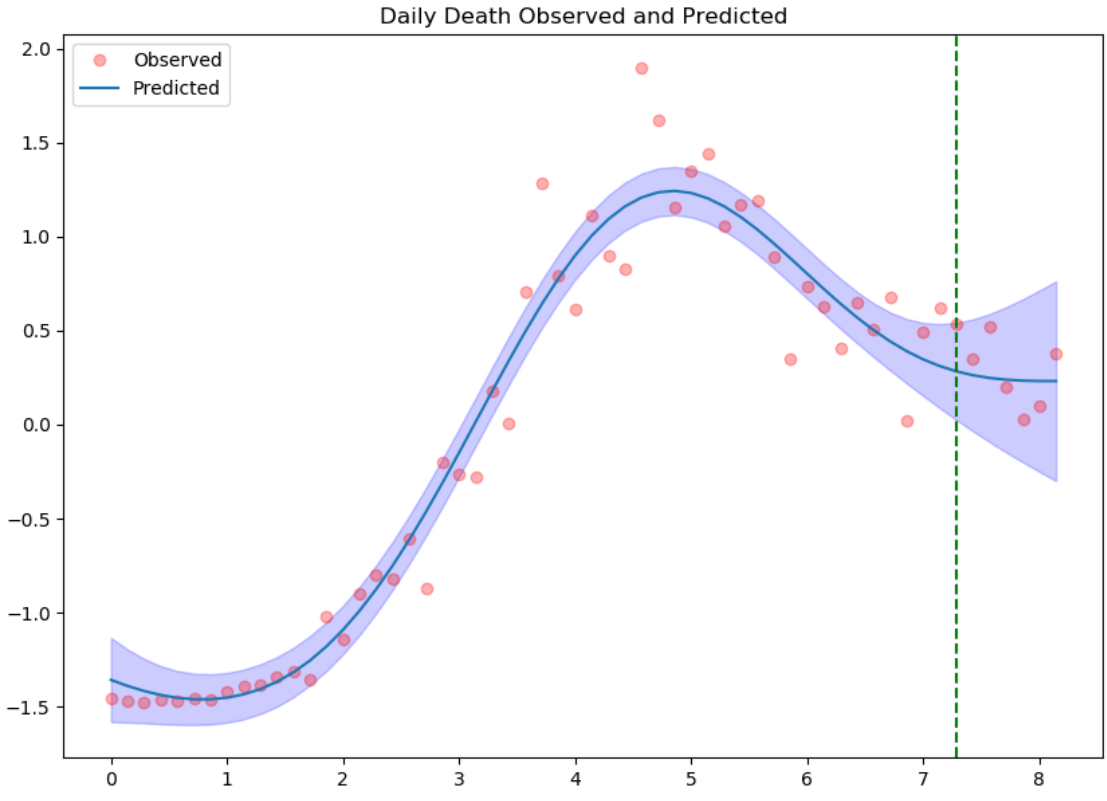
[58]:
```
from sklearn.gaussian_process import GaussianProcessRegressor
```

[59]:
```
def plot_predictions(gp, X:np.array, y:np.array, include_observed=True):

    pred_y, pred_std = gp.predict(X, return_std=True)
    plt.figure(figsize=(10, 7))
    if include_observed:
        plt.plot(X, y, 'ok', alpha = 0.3, label = "Observed",color = "r")
    plt.plot(X, pred_y, label = "Predicted")
    plt.fill_between(X[:,0],
                     pred_y + pred_std,
                     pred_y - pred_std,
                     color = "b", alpha = 0.2)

    if np.allclose(X[:, 0], X):
        plt.axvline(dates_to_idx(pd.to_datetime("2020-04-15")), linestyle='--',␣
↪color='g')
    else:
        plt.axvline(dates_to_idx(pd.to_datetime("2020-04-15")), linestyle='--',␣
↪color='g')
    plt.legend(loc='upper left')
```

[60]:
```
def fit_plot_givekernel(X, y, plot_title,kernel,alpha):

    """This function performs trains test split, fits the data to GP,
    plots the results and gives the optimized kernel and parameters"""

    X, y, X_train, X_test, y_train, y_test = train_test_split(X=X,y=y)

    gp = GaussianProcessRegressor(kernel=kernel, alpha=alpha,
                                  normalize_y=True,
                                  n_restarts_optimizer=3)
    gp.fit(X_train, y_train)
    plot_predictions(gp,X,y)
    plt.title(plot_title)

    print("Optimized Kernel:\n {}".format(gp.kernel_,))
```

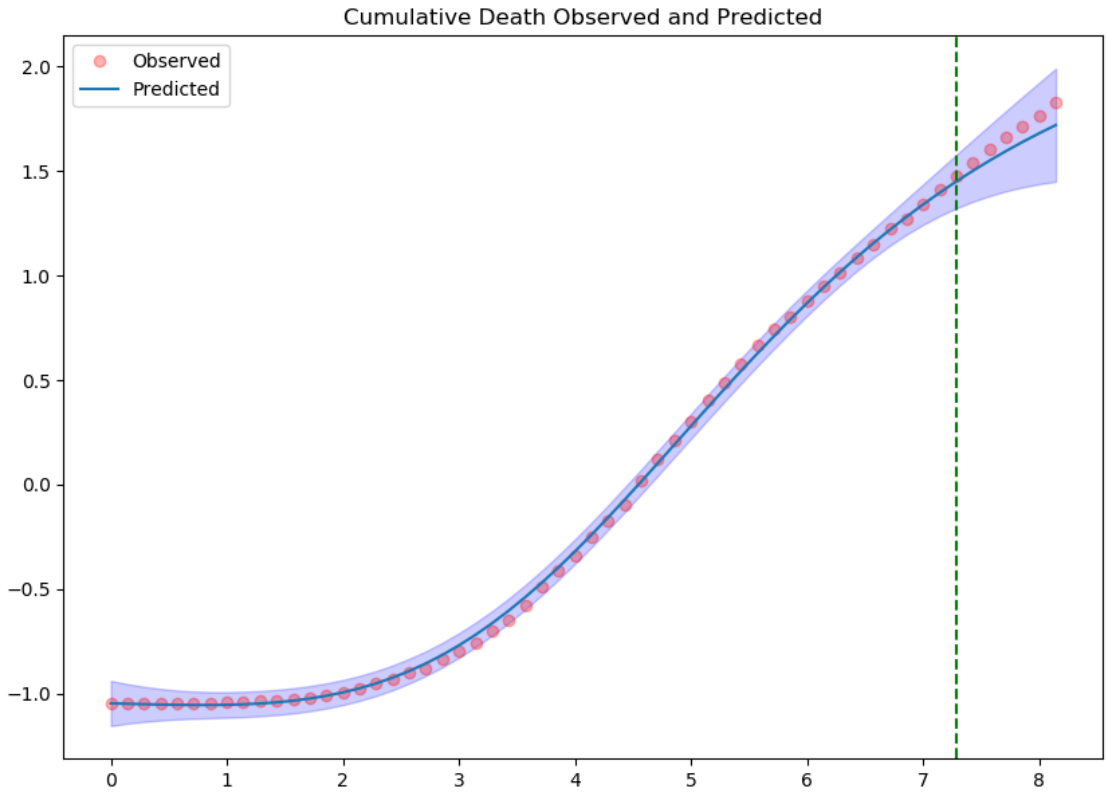
[61]:
```
fit_plot_givekernel(X="Rescaled_Date",y="Daily_deaths_normalized",kernel=kernel4,alpha=0.
↪2,
                        plot_title="Daily Death Observed and Predicted")
```

```
Optimized Kernel:
 0.999**2 * ExpSineSquared(length_scale=0.0223, periodicity=0.0476)
```



[115]:
```
fit_plot_givekernel(X="Rescaled_Date",y="Deaths_normalized",kernel=kernel7,alpha=0.
↪05,
                        plot_title="Cumulative Death Observed and Predicted" )
```

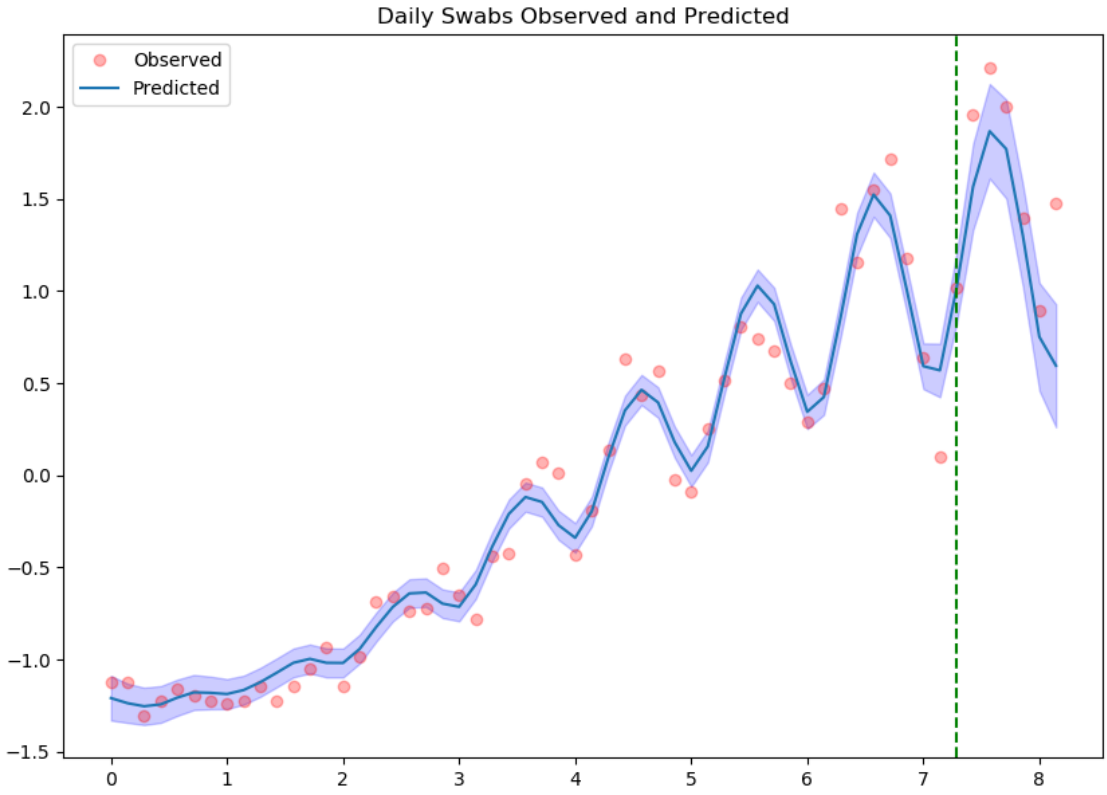
```
Optimized Kernel:
 0.401**2 * 0.518**2 * DotProduct(sigma_0=0.00205) + 0.4**2 * 2.39**2 *
Matern(length_scale=5.01, nu=2.5)
```



3. Fit a GaussianProcessRegressor to predict the daily number of swabs, plot future predictions and compare them to real test data;

[89]:
```
# maybe need to make it bit upper for rgiht side
fit_plot_givekernel(X="Rescaled_Date",y="Daily_swabs_normalized",kernel=kernel9,alpha=0.
↪05,
                        plot_title="Daily Swabs Observed and Predicted")
```

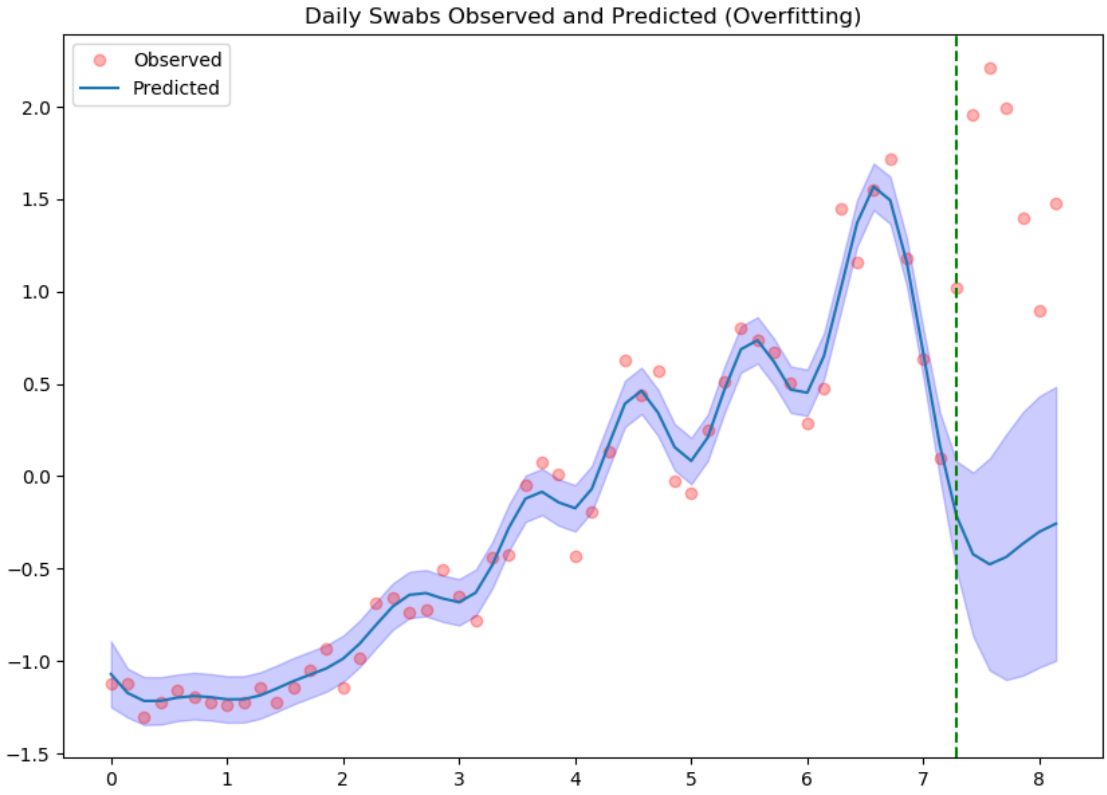
```
Optimized Kernel:
 6.61**2 * DotProduct(sigma_0=2.4) * 0.0938**2 * DotProduct(sigma_0=268) *
0.205**2 * Matern(length_scale=7.53, nu=2.5) * 0.00842**2 *
ExpSineSquared(length_scale=5.6, periodicity=0.0455) +
WhiteKernel(noise_level=1e-05)
```



There is interesting situaiton here, when I tried different kernels most of them gave really good estimation for the data apart from last week. There might be overfitting situation because it performs really good for training set but not for test set. I leave one of them as an example.

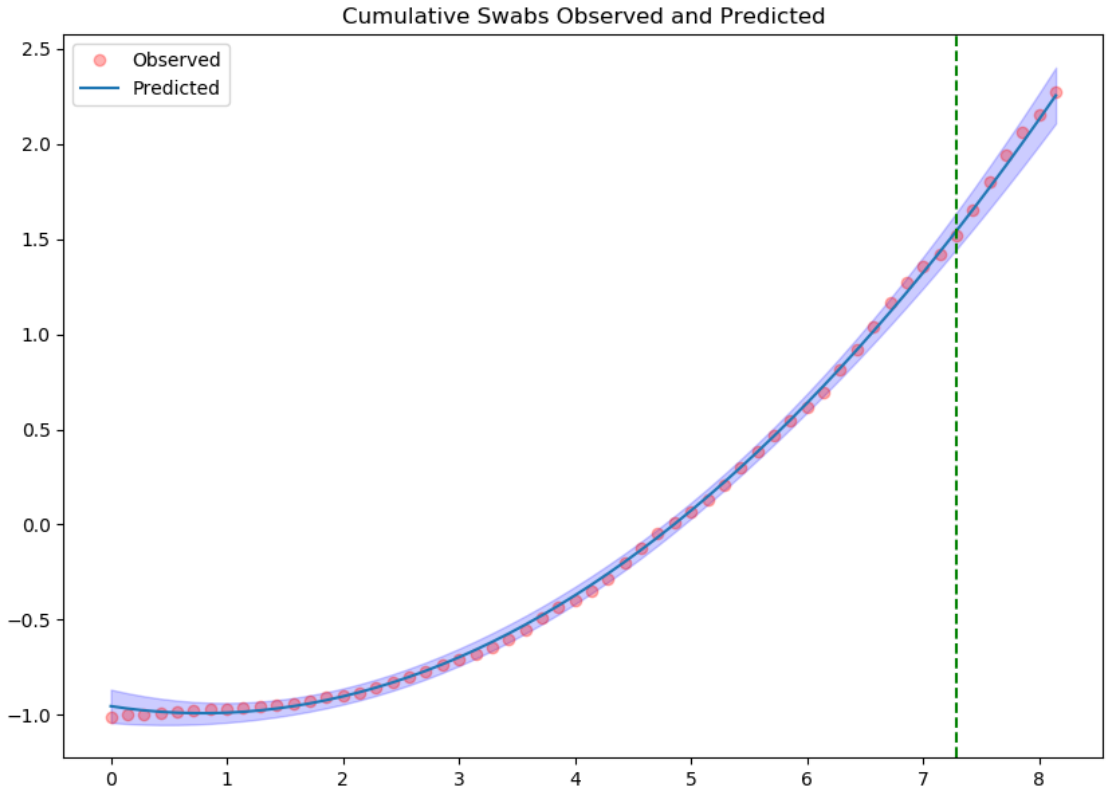
[91]:
```
# maybe need to make it bit upper for rgiht side
fit_plot_givekernel(X="Rescaled_Date",y="Daily_swabs_normalized",kernel=kernel1,alpha=0.
↪05,
                        plot_title="Daily Swabs Observed and Predicted␣
↪(Overfitting)")
```

```
Optimized Kernel:
 0.743**2 * RBF(length_scale=0.416)
```



[102]:
```
#same problem see how to increase right side
fit_plot_givekernel(X="Rescaled_Date",y="Swabs_normalized",kernel=kernel6,alpha=0.
↪05,
                        plot_title="Cumulative Swabs Observed and Predicted")
```

```
Optimized Kernel:
 3.76**2 * DotProduct(sigma_0=3.39) * 0.0136**2 * DotProduct(sigma_0=3.39) +
WhiteKernel(noise_level=1e-05)
```

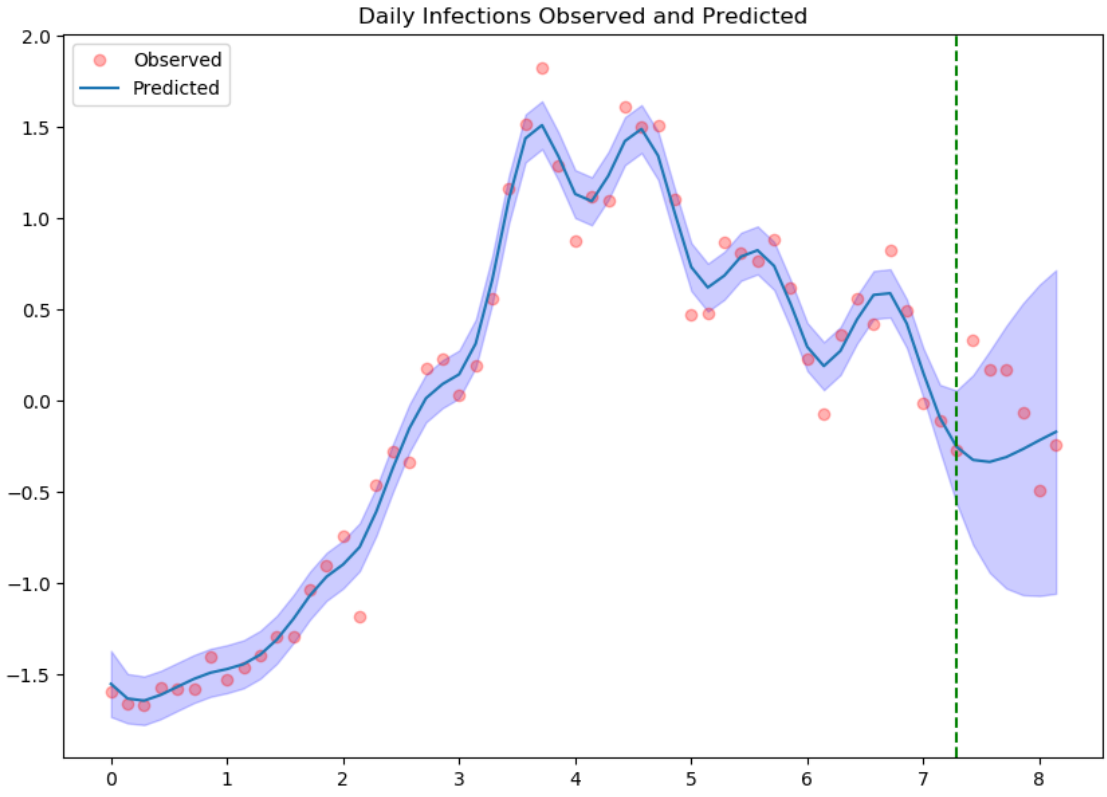


4. Repeat points 1-3 on the daily number of swabs, which can be computed from the cumulative number provided in the dataset.

You are welcome to try out and fit other data streams in the dataset.

[117]:
```
data["infection_normalized"] = normalize(data["new_infections"])
X, y, X_train, X_test, y_train, y_test =␣
↪train_test_split(X="Rescaled_Date",y="infection_normalized")

fit_plot_givekernel(X="Rescaled_Date",y="infection_normalized",kernel=kernel3,alpha=0.
↪05,
                        plot_title="Daily Infections Observed and Predicted")
```

```
Optimized Kernel:
 0.934**2 * Matern(length_scale=0.674, nu=2.5)
```


Daily Infections Observed and Predicted
Observed
Predicted
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
1
2
3
4
5
6
7
8