Example: COVID-2019 data for US (cities and states)

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I am still taking some data from John Hopkins university [1]. However, the format for the US data is different and not consistent. So the database may be updated in the next few days.

As far as I know (at last on 2020-03-04), no data for the recovered cases are (yet) available. The function fit_SEIQRDP is modified to account for this possibility.

The fitting is also slightly different than in the case where R is available: The (pseudo) death rate is first fitted and the coefficient identified this way are only allowed to change by +/-5 %. This is a pseudo death rate because the number of Confirmed-Deaths is used instead of Quarantined. The main fitting is then done using the heavily-constrained kappa values.

[1] https://github.com/CSSEGISandData/COVID-19

Database access

The parameters are here taken as constant except the death rate and recovery rate.

```
clearvars;close all;clc;
[tableConfirmed,tableDeaths,tableRecovered,time] = getDataCOVID_US();
timeRef = time;
```

Case of an entire state

Every city in one state is selected and the cases are added

```
Location = 'Washington'; % Find every cities in Washington state
% Location = 'New York'; % Find every cities in New York state
try
    indC = find(contains(tableConfirmed.Province_State,Location)==1);
    indD = find(contains(tableDeaths.Province_State,Location)==1);
catch exception
    searchLoc = strfind(tableConfirmed.Province_State,Location);
    indC = find(~cellfun(@isempty,searchLoc))   ;

    searchLoc = strfind(tableDeaths.Province_State,Location);
    indD = find(~cellfun(@isempty,searchLoc))    ;
end

% disp(tableConfirmed(indC,1:2))


% Initialisation
Confirmed = 0;
Deaths = 0;
Npop = 0;
for ii=1:numel(indC)
    Confirmed =  Confirmed + table2array(tableConfirmed(indC(ii),12:end));
end

for ii=1:numel(indD)
    Deaths =  Deaths + table2array(tableDeaths(indD(ii),13:end));
    Npop= Npop + table2array(tableDeaths(indD(ii),12)); % population (dummy number here
end
```

Initial conditions for the fitting

```
% If the number of confirmed Confirmed cases is small, it is difficult to know whether
% the quarantine has been rigorously applied or not. In addition, this
% suggests that the number of infectious is much larger than the number of
% confirmed cases
time = timeRef;
minNum= round(0.25*max(Confirmed)); % 5% of the maximal number of confirmed is used for
Deaths(Confirmed<=minNum)=[];
time(Confirmed<=minNum)= [];
Confirmed(Confirmed<=minNum)=[];

fprintf(['Population = ',num2str(Npop),' \n'])
```

```
Population = 7614893
```

```
% Definition of the first estimates for the parameters
alpha_guess = 0.05;
beta_guess = 0.8; % Infection rate
LT_guess = 5; % latent time in days
Q_guess = 0.5; % rate at which infectious people enter in quarantine
lambda_guess = [0.1,0.1,10]; % recovery rate
kappa_guess = [0.01,0.01,10]; % death rate

guess = [alpha_guess,...
    beta_guess,...
    1/LT_guess,...
    Q_guess,...
    lambda_guess,...
    kappa_guess];

E0 = 0.25*Confirmed(1); % Initial number of exposed cases. Unknown but unlikely to be z
I0 = 0.5*E0; % Initial number of infectious cases. Unknown but unlikely to be zero.
Q0 = Confirmed(1)-Deaths(1);
```

```
R0 = Deaths(1); % Unknown but unlikely to be zero. Taken as equal to the number of deat
D0 = Deaths(1);

% Parameter estimation with the lsqcurvefit function[alpha1,beta1,gamma1,delta1,Lambda1
    [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,lambdaFun,kappaFun] = ...
        fit_SEIQRDP(Confirmed-Deaths,[],Deaths,Npop,E0,I0,time,guess,'Display','off');
```

```
Warning:  No data available for "Recovered"
```

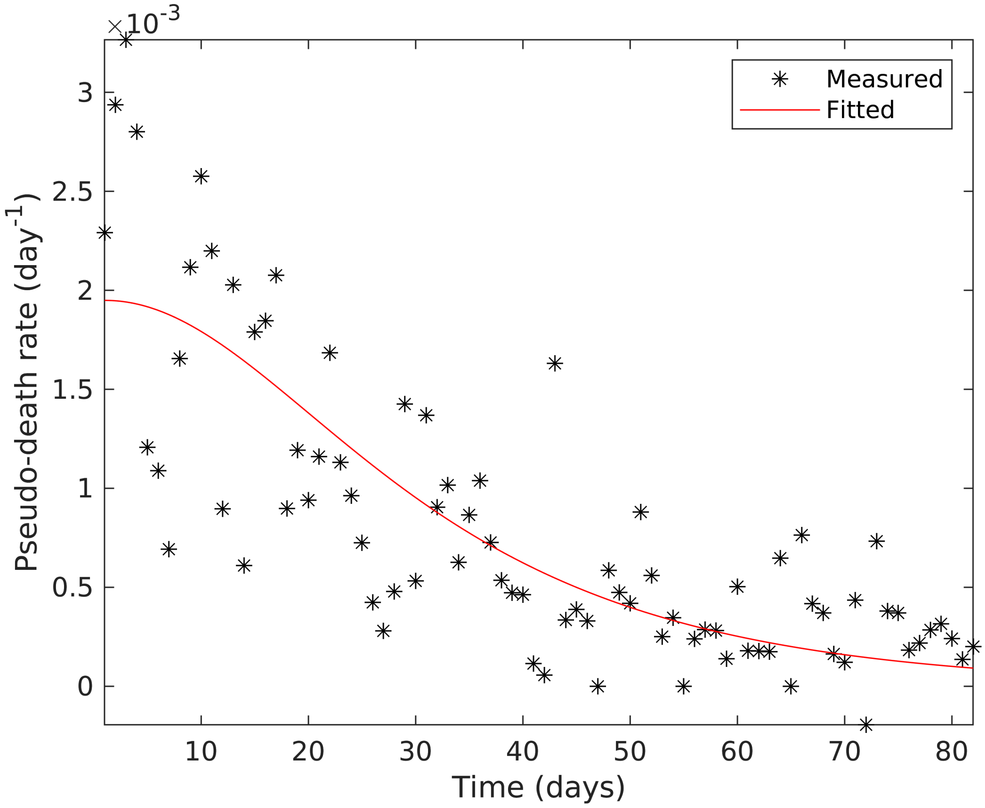
Simulate the epidemy outbreak based on the fitted parameters

```
dt = 1/24; % time step
time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(10)));
N = numel(time1);
t = [0:N-1].*dt;
[S,E,I,Q,R,D,P] = SEIQRDP(alpha1,beta1,...
    gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R0,D0,t,lambdaFun,kappaFun);
```

Display the fitted and measured (pseudo) death rates

This is a "pseudo" death rate because it si calculated based on (Q(t)+R(t)) and not only from Q(t).

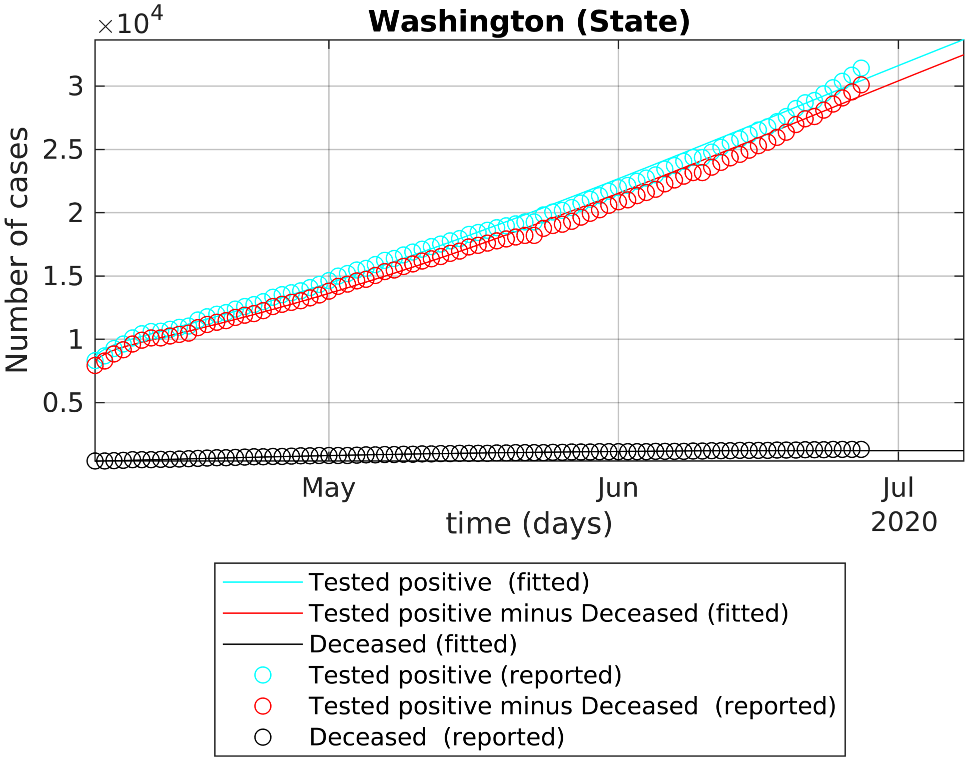
```
checkRates(time,Confirmed-Deaths,[],Deaths,kappaFun,lambdaFun,Kappa1,Lambda1);
```



Comparison of the fitted and real data

```
figure
```

```
semilogy(time1,Q+R+D,'c',time1,Q+R,'r',time1,D,'k');
hold on
semilogy(time,Confirmed,'co',time,Confirmed-Deaths,'ro',time,Deaths,'ko');
% ylim([0,1.1*Npop])
ylabel('Number of cases')
xlabel('time (days)')
leg = {'Tested positive  (fitted)','Tested positive minus Deceased (fitted)',...
    'Deceased (fitted)',...
    'Tested positive (reported)',...
    'Tested positive minus Deceased  (reported)','Deceased  (reported)'};
legend(leg{:},'location','southoutside')
set(gcf,'color','w')
grid on
axis tight
title([Location,' (State)'])
set(gca,'yscale','lin')
```



Example of a single city

```
time = timeRef;

fprintf(['Most recent update: ',datestr(time(end)),'\n'])
```

```
Most recent update: 27-Jun-2020
```

```
Location = 'New York City, New York, US';
```

```
try
    indC = find(contains(tableConfirmed.Combined_Key,Location)==1);
    indD = find(contains(tableDeaths.Combined_Key,Location)==1);
catch exception
    searchLoc = strfind(tableConfirmed.Combined_Key,Location);
    indC = find(~cellfun(@isempty,searchLoc))   ;

    searchLoc = strfind(tableDeaths.Combined_Key,Location);
    indD = find(~cellfun(@isempty,searchLoc))    ;
end

disp(tableConfirmed(indC,11));
```

```
            Combined_Key
    ________________________________

    "New York City, New York, US"
```

```
indC = indC(1);
indD  = indD(1);

Deaths = table2array(tableDeaths(indD,13:end));
Confirmed = table2array(tableConfirmed(indC,12:end));
Npop= table2array(tableDeaths(indD,12)); % population (dummy number here)
```

Initial conditions for the fitting

```
% If the number of confirmed Confirmed cases is small, it is difficult to know whether
% the quarantine has been rigorously applied or not. In addition, this
% suggests that the number of infectious is much larger than the number of
% confirmed cases
minNum= round(0.25*max(Confirmed)); % 5% of the maximal number of confirmed is used for
Deaths(Confirmed<=minNum)=[];
time(Confirmed<=minNum)= [];
Confirmed(Confirmed<=minNum)=[];

fprintf(['Population = ',num2str(Npop),' \n'])
```

```
Population = 8336817
```

```
% Definition of the first estimates for the parameters
alpha_guess = 0.05;
beta_guess = 0.8; % Infection rate
LT_guess = 5; % latent time in days
Q_guess = 0.5; % rate at which infectious people enter in quarantine
lambda_guess = [0.1,0.1,10]; % recovery rate
kappa_guess = [0.01,0.01,10]; % death rate

guess = [alpha_guess,...
    beta_guess,...
    1/LT_guess,...
    Q_guess,...
    lambda_guess,...
    kappa_guess];
```

```
E0 = 0.25*Confirmed(1); % Initial number of exposed cases. Unknown but unlikely to be z
I0 = 0.5*E0; % Initial number of infectious cases. Unknown but unlikely to be zero.
Q0 = Confirmed(1)-Deaths(1);
R0 = Deaths(1); % Unknown but unlikely to be zero. Taken as equal to the number of deat
D0 = Deaths(1);

% Parameter estimation with the lsqcurvefit function[alpha1,beta1,gamma1,delta1,Lambda1
    [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,lambdaFun,kappaFun] = ...
        fit_SEIQRDP(Confirmed-Deaths,[],Deaths,Npop,E0,I0,time,guess,'Display','off');
```

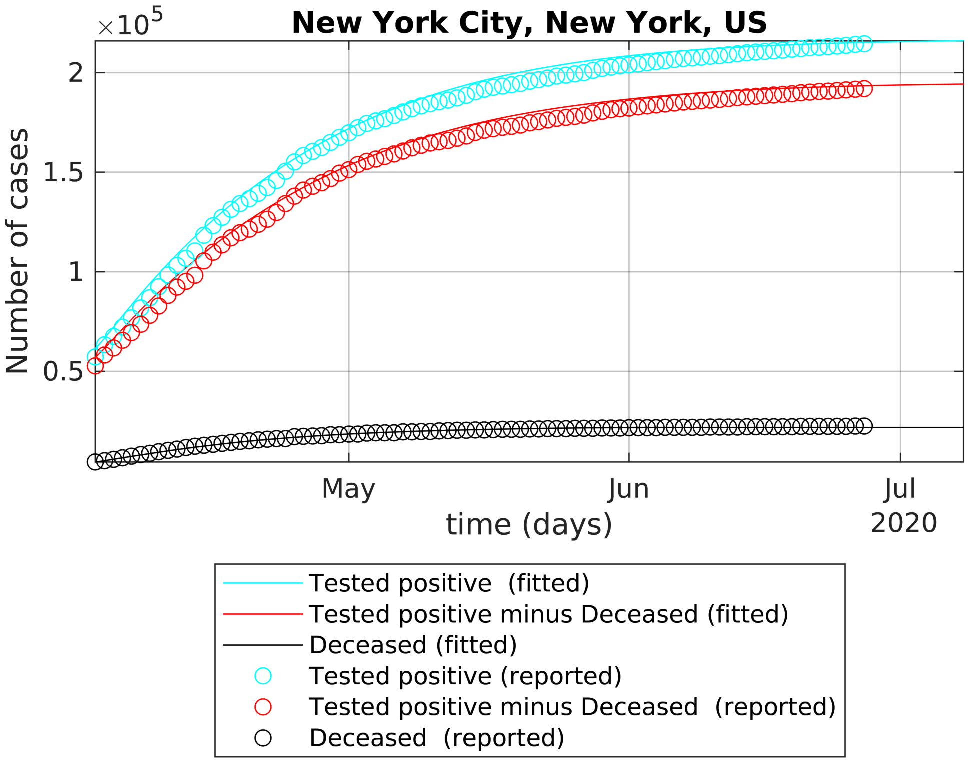
```
Warning:  No data available for "Recovered"
```

Simulate the epidemy outbreak based on the fitted parameters

```
dt = 1/24; % time step
time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(10)));
N = numel(time1);
t = [0:N-1].*dt;
[S,E,I,Q,R,D,P] = SEIQRDP(alpha1,beta1,...
    gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R0,D0,t,lambdaFun,kappaFun);
```

Comparison of the fitted and real data

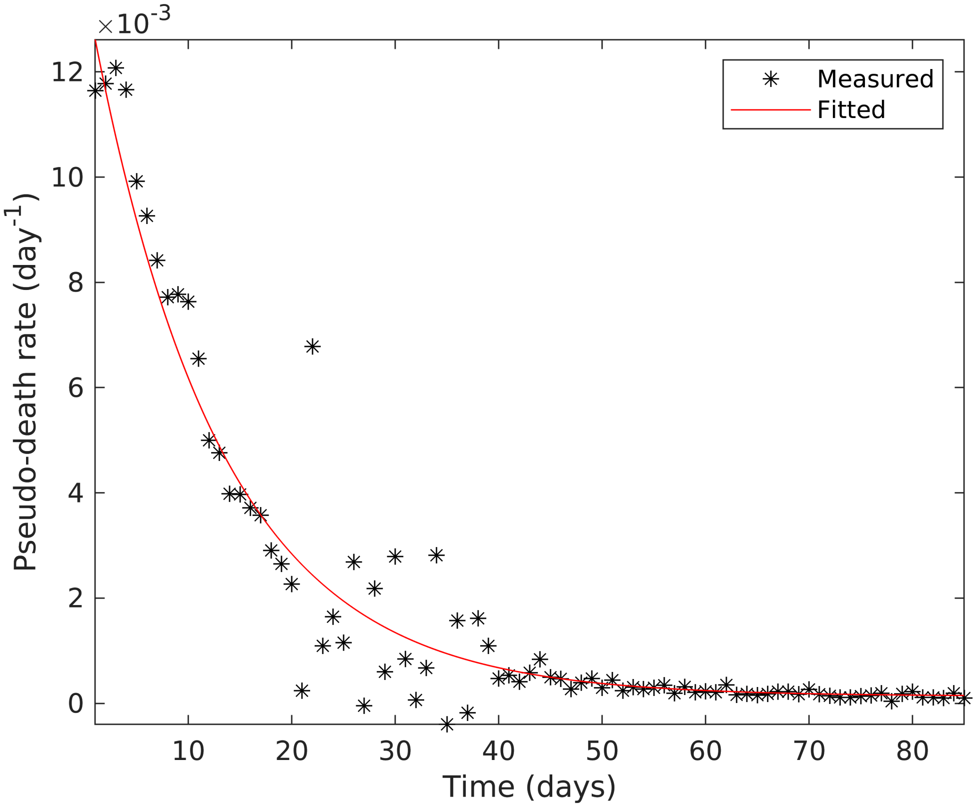
```
figure
semilogy(time1,Q+R+D,'c',time1,Q+R,'r',time1,D,'k');
hold on
semilogy(time,Confirmed,'co',time,Confirmed-Deaths,'ro',time,Deaths,'ko');
% ylim([0,1.1*Npop])
ylabel('Number of cases')
xlabel('time (days)')
leg = {'Tested positive  (fitted)','Tested positive minus Deceased (fitted)',...
    'Deceased (fitted)',...
    'Tested positive (reported)',...
    'Tested positive minus Deceased  (reported)','Deceased  (reported)'};
legend(leg{:},'location','southoutside')
set(gcf,'color','w')
grid on
axis tight
title([Location])
set(gca,'yscale','lin')
```



Display the fitted and measured (pseudo) death rates

This is a "pseudo" death rate because it si calculated based on (Q(t)+R(t)) and not only from Q(t).

```
checkRates(time,Confirmed-Deaths,[],Deaths,kappaFun,lambdaFun,Kappa1,Lambda1);
```



Case of multiple cities

The fitting is more challenging and uncertainties are indCreased because the number of recovered is unknown. In particular, the sensitivity on the initial guess is quite high. I have limited trust in the results provided by fit_SEIQRDP.

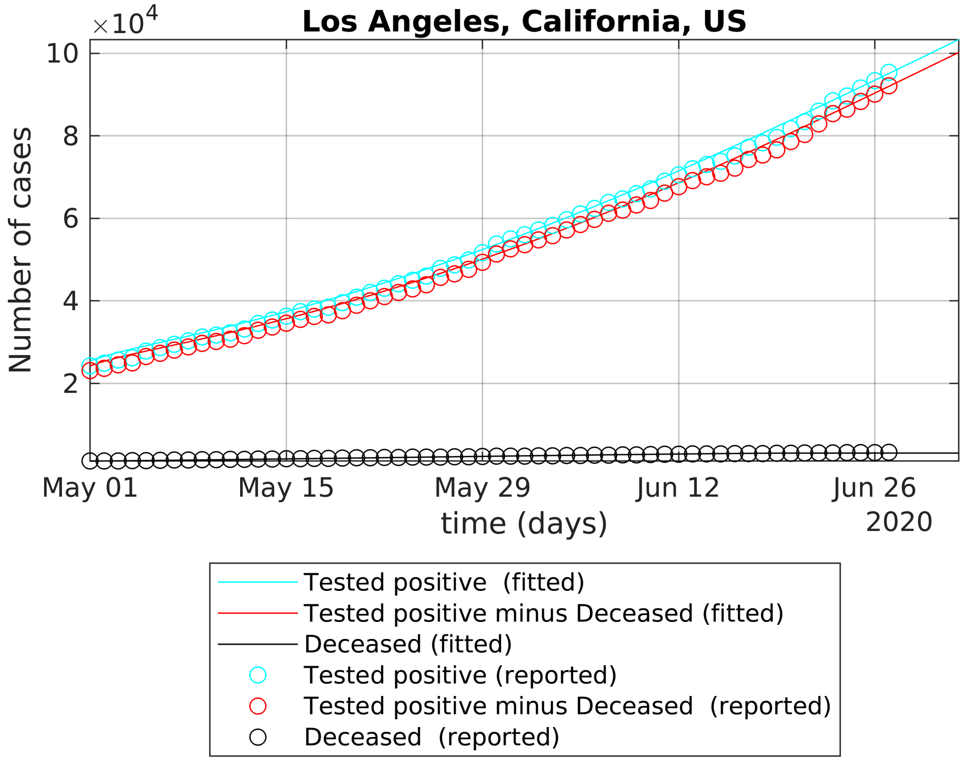
```
time = timeRef;
fprintf(['Most recent update: ',datestr(time(end)),'\n'])
```

```
Most recent update: 27-Jun-2020
```

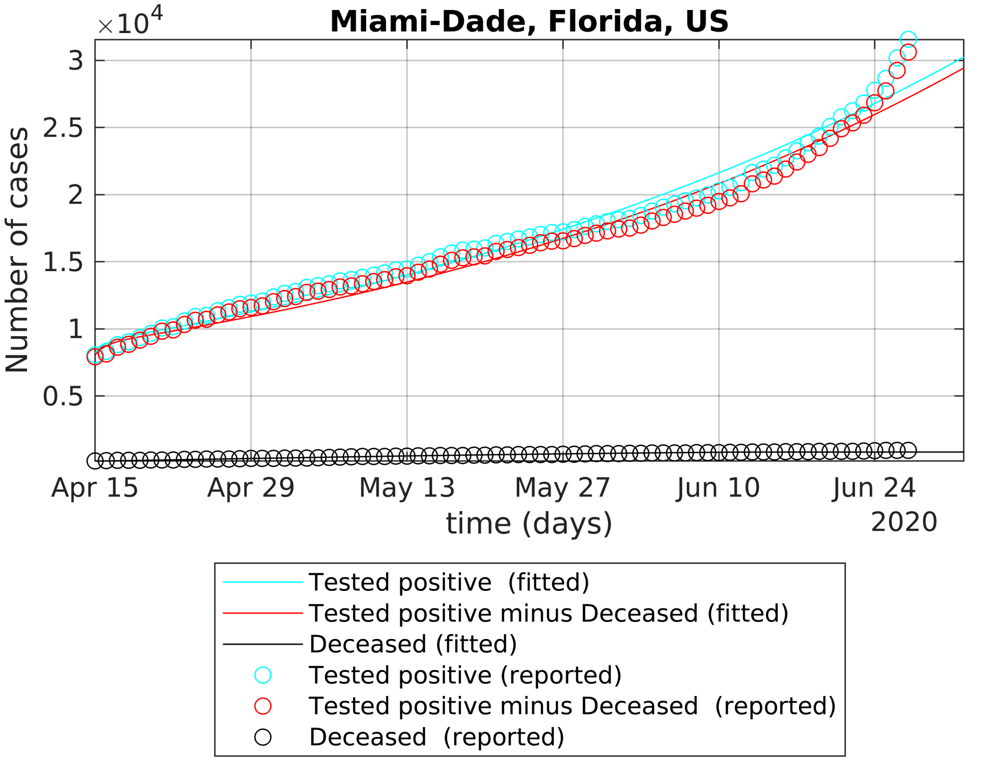
```
for ii = 2:numel(tableConfirmed.Combined_Key)

    Location = tableConfirmed.Combined_Key(ii);

    indC = find(strcmpi(tableConfirmed.Combined_Key,Location)==1);
    indD = find(strcmpi(tableDeaths.Combined_Key,Location)==1);

    Deaths = table2array(tableDeaths(indD,13:end));
    Confirmed = table2array(tableConfirmed(indC,12:end));
    Npop= table2array(tableDeaths(indD,12)); % p

    if Npop == 0
%         warning('Unreal population found. A dummy variable is used instead')
        Npop = 1e6; % dummy population is used instead
    end
    time = timeRef;
    minNum= round(0.25*max(Confirmed)); % 5% of the maximal number of confirmed is used
    Deaths(Confirmed<=minNum)=[];
    time(Confirmed<=minNum)= [];
    Confirmed(Confirmed<=minNum)=[];


    if minNum>6000 && numel(Confirmed) >30 % more than 30 days of good data
        disp(tableConfirmed(indC,11));
        fprintf(['Population = ',num2str(Npop),' \n'])
        % Definition of the first estimates for the parameters
        alpha_guess = 0.1;
        beta_guess = 0.8; % Infection rate
        LT_guess = 5; % latent time in days
        Q_guess = 0.5; % rate at which infectious people enter in quarantine
        lambda_guess = [0.08,0.1,0.1]; % recovery rate
        kappa_guess = [0.07,0.03,10]; % death rate

        guess = [alpha_guess,...
            beta_guess,...
            1/LT_guess,...
            Q_guess,...
            lambda_guess,...
            kappa_guess];

        E0 = 0.25*Confirmed(1); % Initial number of exposed cases. Unknown but unlikely
        I0 = 0.5*E0; % Initial number of infectious cases. Unknown but unlikely to be z
        Q0 = Confirmed(1)-Deaths(1);
        R0 = Deaths(1); % Unknown but unlikely to be zero. Taken as equal to the number
        D0 = Deaths(1);

        % Parameter estimation with the lsqcurvefit function
        [alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,lambdaFun,kappaFun] = ...
            fit_SEIQRDP(Confirmed-Deaths,[],Deaths,Npop,E0,I0,time,guess,'Display','off

        dt = 1/24; % time step
        time1 = datetime(time(1)):dt:datetime(datestr(floor(datenum(now))+datenum(4)));
        N = numel(time1);
        t = [0:N-1].*dt;
        [S,E,I,Q,R,D,P] = ...
            SEIQRDP(...
            alpha1,beta1,gamma1,delta1,Lambda1,Kappa1,Npop,E0,I0,Q0,R0,D0,t,lambdaFun,k


        figure
        semilogy(time1,Q+R+D,'c',time1,Q+R,'r',time1,D,'k');
        hold on
        semilogy(time,Confirmed,'co',time,Confirmed-Deaths,'ro',time,Deaths,'ko');
        % ylim([0,1.1*Npop])
        ylabel('Number of cases')
        xlabel('time (days)')
        leg = {'Tested positive  (fitted)','Tested positive minus Deceased (fitted)',..
            'Deceased (fitted)',...
            'Tested positive (reported)',...
```

```
                'Tested positive minus Deceased  (reported)','Deceased  (reported)'};
            legend(leg{:},'location','southoutside')
            set(gcf,'color','w')
            grid on
            axis tight
            title([Location])
            set(gca,'yscale','lin')

            % PLot the pseudo death rate
%             checkRates(time,Confirmed-Deaths,[],Deaths,kappaFun,lambdaFun,Kappa1,Lambda1)
            pause(0.01)
        end
end
```

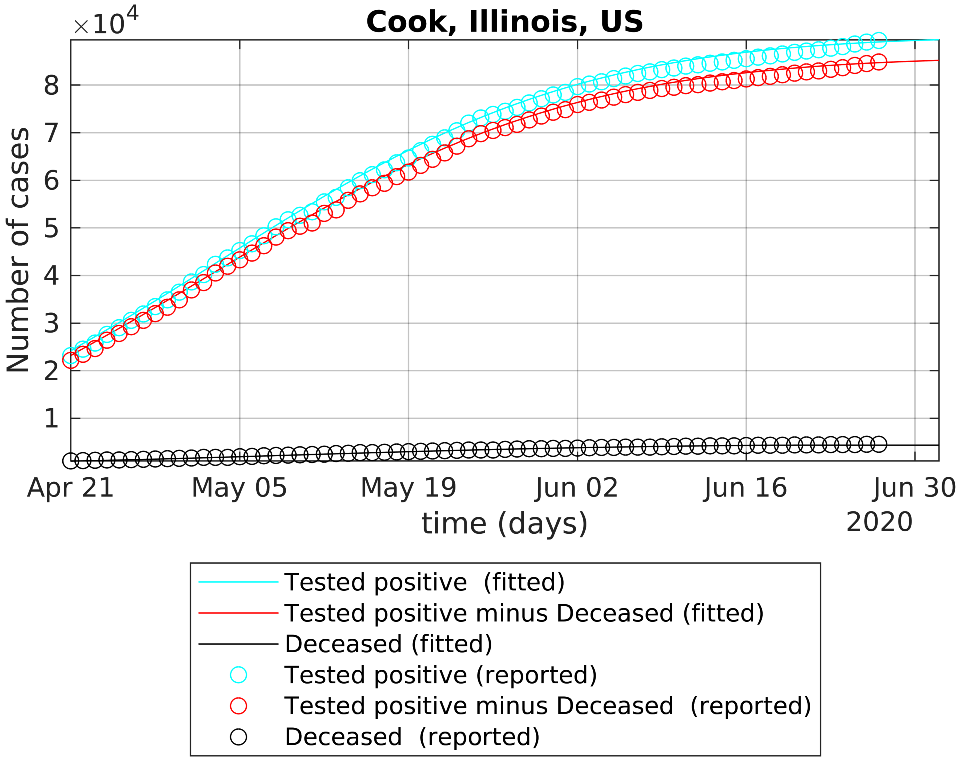
```
          Combined_Key
    ______________________________

    "Los Angeles, California, US"
Population = 10039107
Warning:  No data available for "Recovered"
```



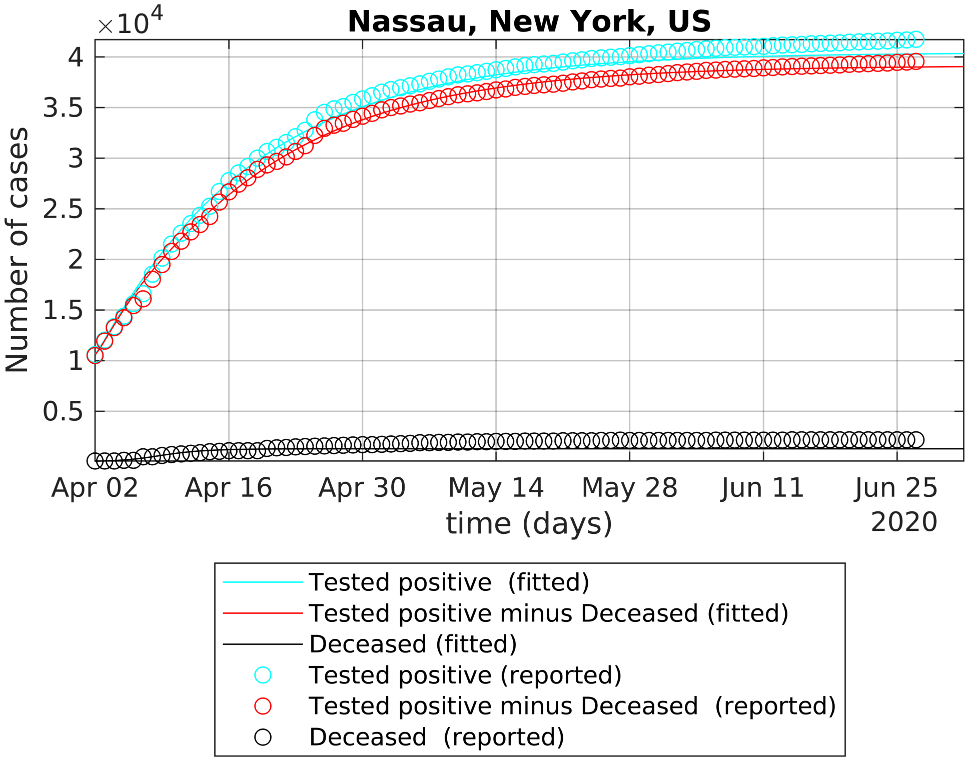
```
        Combined_Key
    __________________________

    "Miami-Dade, Florida, US"
Population = 2716940
Warning:  No data available for "Recovered"
```



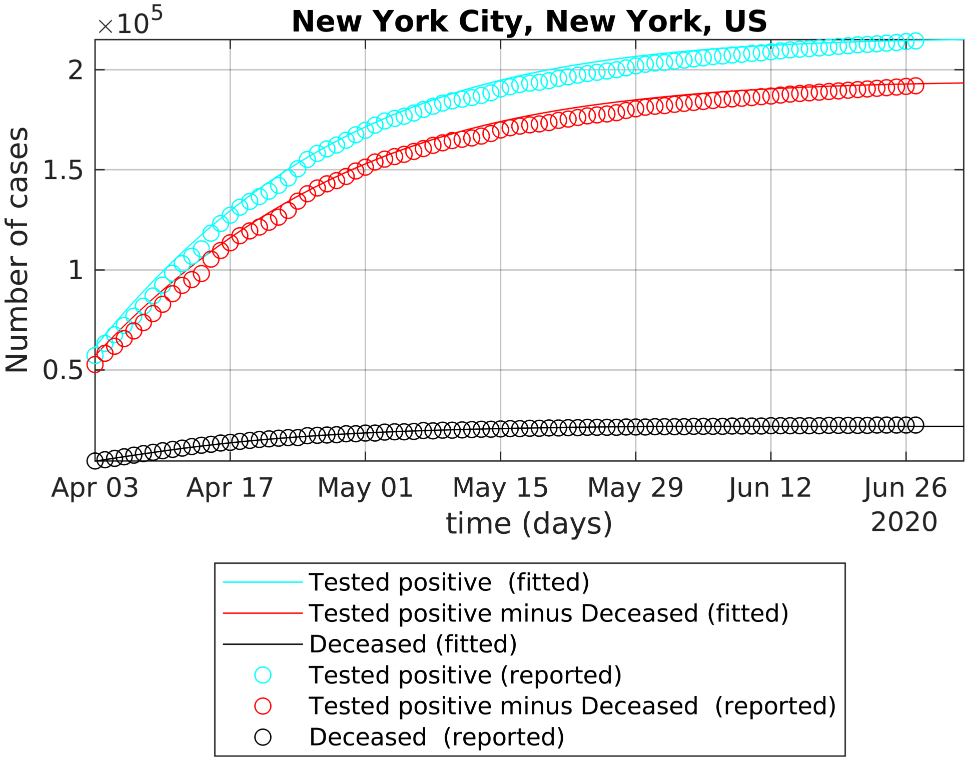
```
        Combined_Key
    ____________________

    "Cook, Illinois, US"
Population = 5150233
Warning:  No data available for "Recovered"
```



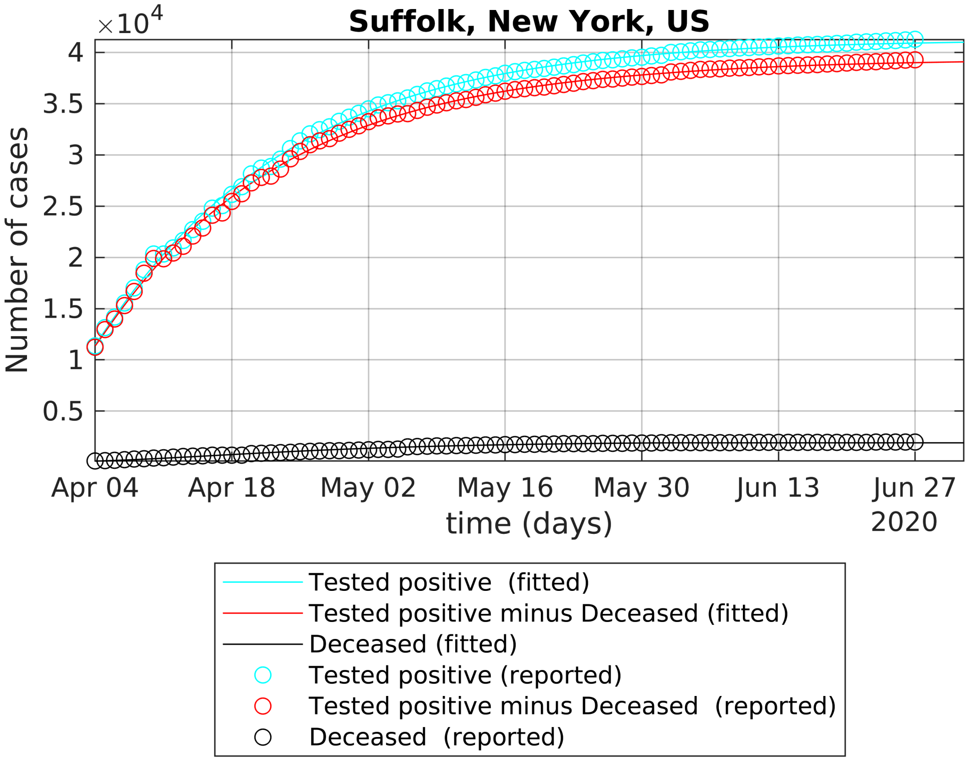
```
          Combined_Key
    ______________________

    "Nassau, New York, US"
Population = 1356924
Warning:  No data available for "Recovered"
```



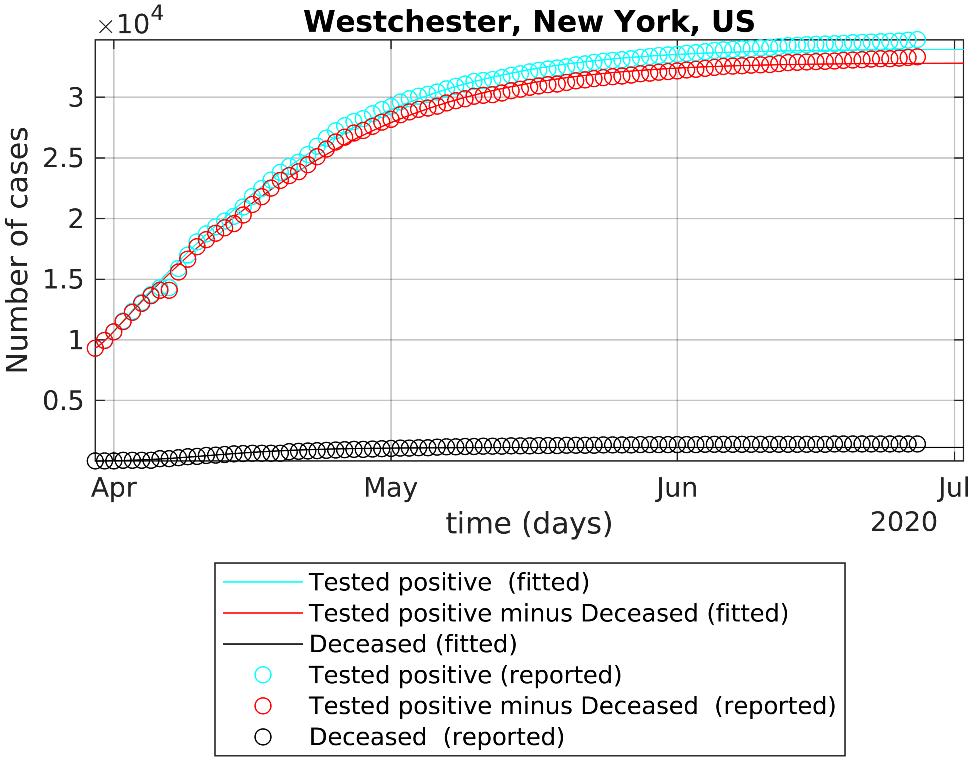
```
             Combined_Key
    ______________________________

    "New York City, New York, US"
Population = 8336817
Warning:  No data available for "Recovered"
```



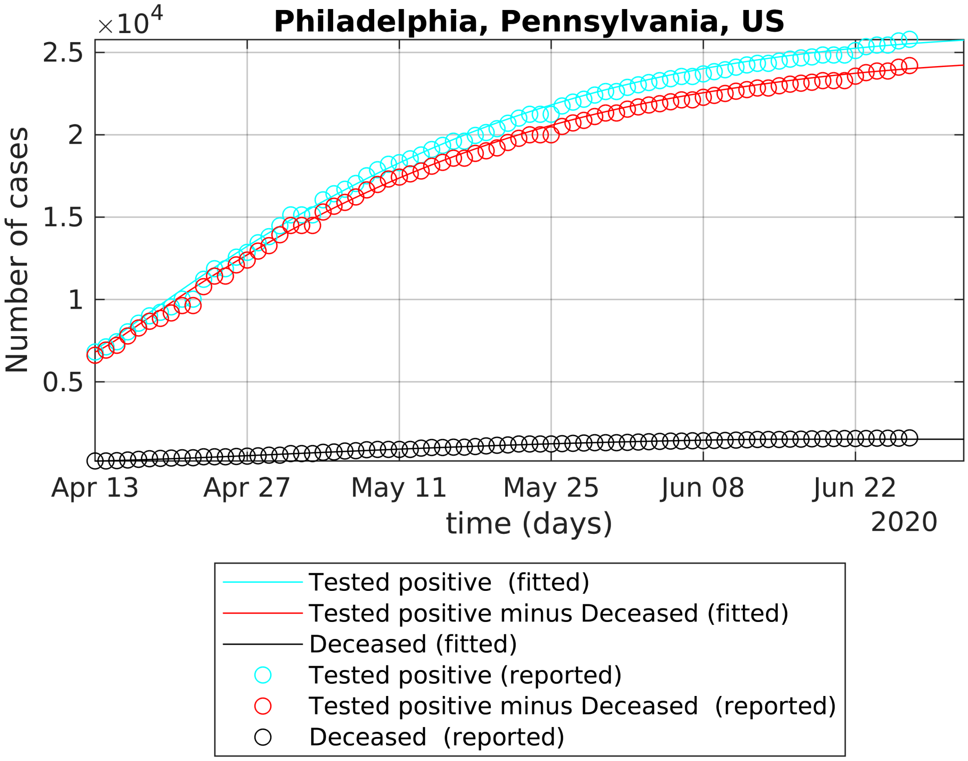
```
        Combined_Key
    _______________________

    "Suffolk, New York, US"
Population = 1476601
Warning:  No data available for "Recovered"
```



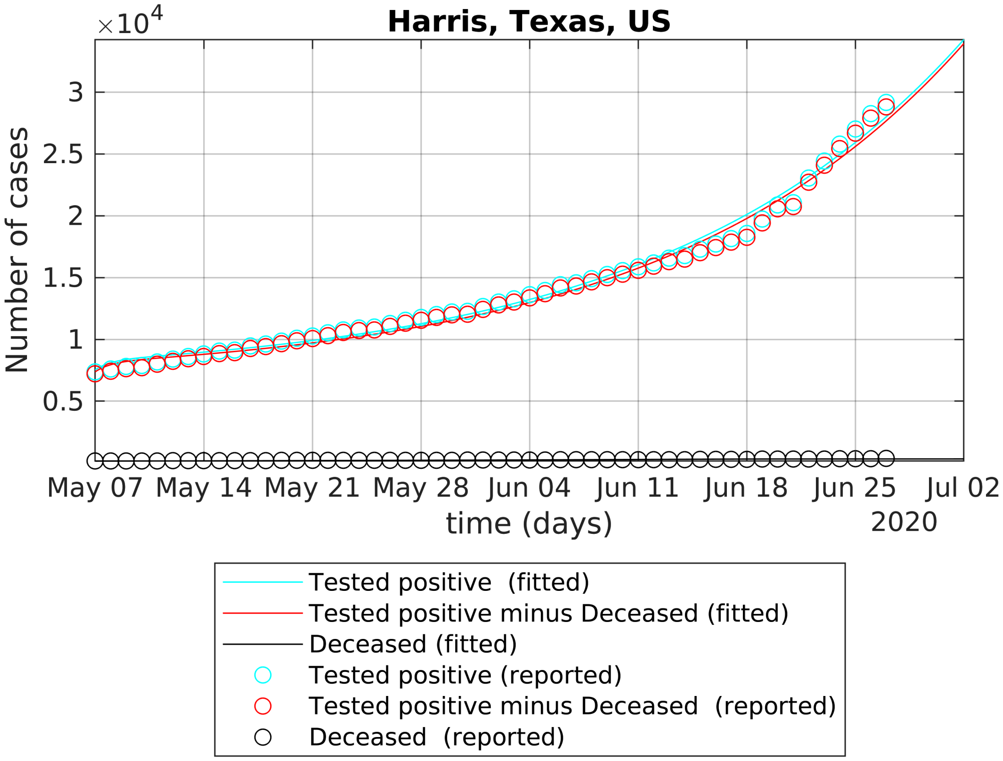
```
            Combined_Key
    ______________________________

    "Westchester, New York, US"
Population = 967506
Warning:  No data available for "Recovered"
```



```
               Combined_Key
    ___________________________________

    "Philadelphia, Pennsylvania, US"
Population = 1584064
Warning:  No data available for "Recovered"
```



```
    Combined_Key
  ___________________

  "Harris, Texas, US"
Population = 4713325
Warning:  No data available for "Recovered"
```



Harris, Texas, US
×10^4
3
2.5
2
1.5
1
0.5
Number of cases
May 07
May 14
May 21
May 28
Jun 04
Jun 11
Jun 18
Jun 25
Jul 02
2020
time (days)
Tested positive (fitted)
Tested positive minus Deceased (fitted)
Deceased (fitted)
Tested positive (reported)
Tested positive minus Deceased (reported)
Deceased (reported)