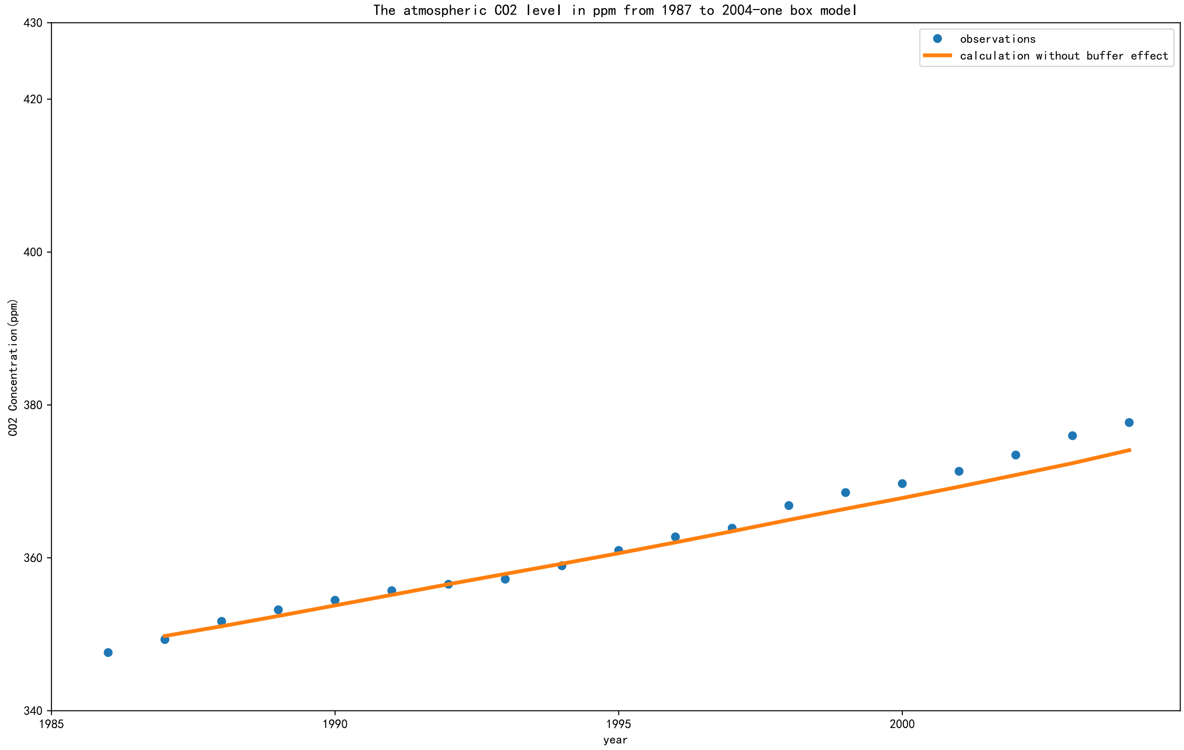
In [1]:

```
#import module
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy import integrate
from scipy.integrate import solve_ivp
from scipy.optimize import curve_fit
from numpy import exp
import glob

#modify the font
#plt.rcParams['配置参数']=[修改值]进行修改
#运行配置参数中的字体（font）为黑体（SimHei）
plt.rcParams['font.sans-serif'] = ['SimHei']
%matplotlib inline
%config InlineBackend.figure_format = 'svg'

#ignore the warnings
import warnings
warnings.filterwarnings('ignore')
```

In [2]:

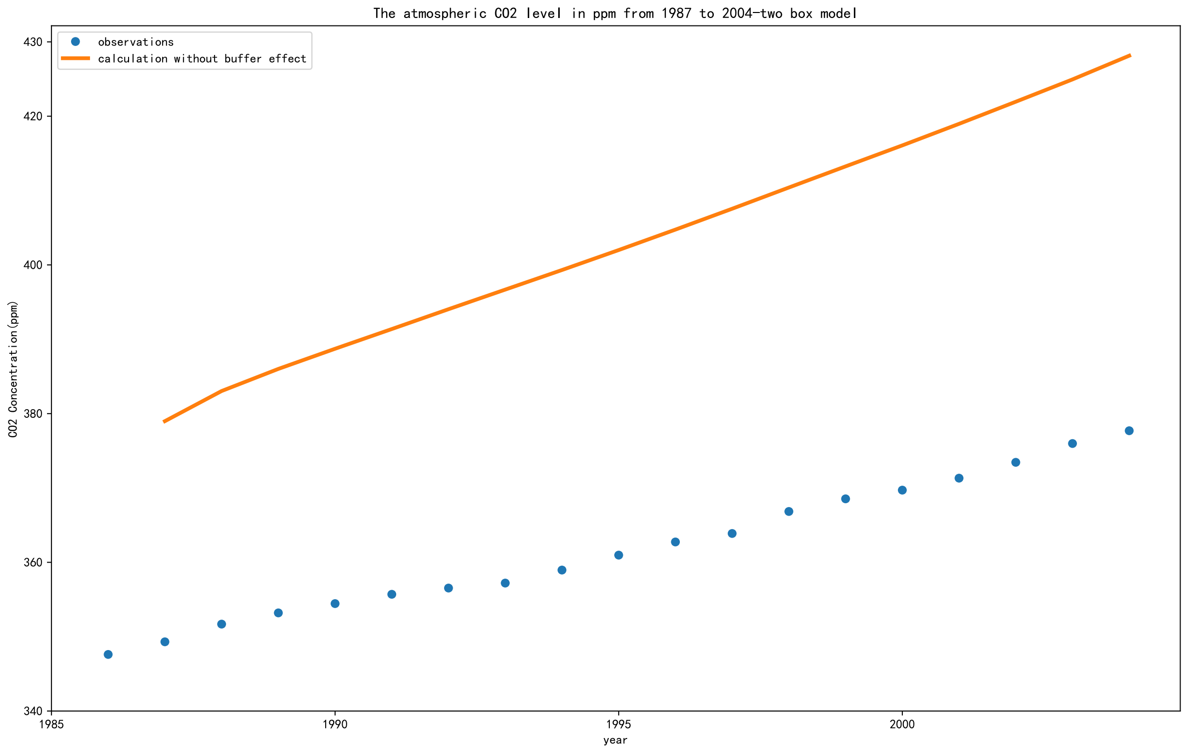
```
#1.1
#read the file
data = pd.read_csv("co2_annmean_mlo.csv",
                   skiprows = 55)
CO2=data.loc[ (data['year'] >1985)&(data['year'] <2005)][['year','mean']]

#define γ (This step is taught by Yin Yuling)
def γ(t):
    #get the fossil fuel data
    data2 = pd.read_csv("global.1751_2008 (3).csv")
    γ=float(data2.loc[ (data2['Year"'] ==int(t))]['Total carbon emissions from foss
    return γ

#define a function to resovel the equation
def fuc(f, t, k12, k21):
    N1,N2=f
    dfdt = [-k12*N1+k21*N2+γ(t),k12*N1-k21*N2]
    return dfdt

k12 = 105/740
k21 = 102/900
f0 = [740/2.13,900/2.13]
t = np.linspace(1985,2004,20)

#solve ODE
f = integrate.odeint(fuc, f0, t, args=(k12,k21))
ans1 = f[2:,0]

#plot (Yin Yuling told me that the results need to plot)
plt.figure(figsize=(16,10),dpi=120)
plt.plot(CO2['year'], CO2['mean'],'o',label='observations', markersize=6)
plt.plot(t[2:], ans1,label='calculation without buffer effect', linewidth=3)
plt.xlabel('year')
plt.ylabel('CO2 Concentration(ppm)')
plt.xticks([1985,1990,1995,2000])
plt.yticks([340,360,380,400,420,430])
plt.legend(loc='best')
plt.title('The atmospheric CO2 level in ppm from 1987 to 2004-one box model')
plt.show()
```



In [3]:

```
#1.2
#read the file
data = pd.read_csv("co2_annmean_mlo.csv",
                   skiprows = 55)
CO2=data.loc[ (data['year'] >1985)&(data['year'] <2005)][['year','mean']]

#define γ (the same as 1.1)
def γ(t):
    #get the fossil fuel data
    data2 = pd.read_csv("global.1751_2008 (3).csv")
    γ=float(data2.loc[ (data2['Year"'] ==int(t))]['Total carbon emissions from foss
    return γ

#define x to caculate the parameter
def x(N1):
    x=3.69+1.86*(1e-2)*N1-1.8*(1e-6)*N1*N1
    return x

#define a function to resovel the equation
def fuc(f, t, k12, k21, N20):
    N1,N2=f
    dfdt = [-k12*N1+k21*(N20+x(N1)*(N2-N20))+γ(t),k12*N1-k21*(N20+x(N1)*(N2-N20))
    return dfdt

k12 = 105/740
k21 = 102/900
N20 = 821/2.13
f0 = [740/2.13,900/2.13]
t = np.linspace(1985,2004,20)

# caculate the ode
f = integrate.odeint(fuc, f0, t, args=(k12,k21,N20))
ans2 = f[2:,0]

#plot
plt.figure(figsize=(16,10),dpi=120)
plt.plot(CO2['year'], CO2['mean'],'o',label='observations', markersize=6)
plt.plot(t[2:], ans2,label='calculation without buffer effect', linewidth=3)
plt.xlabel('year')
```

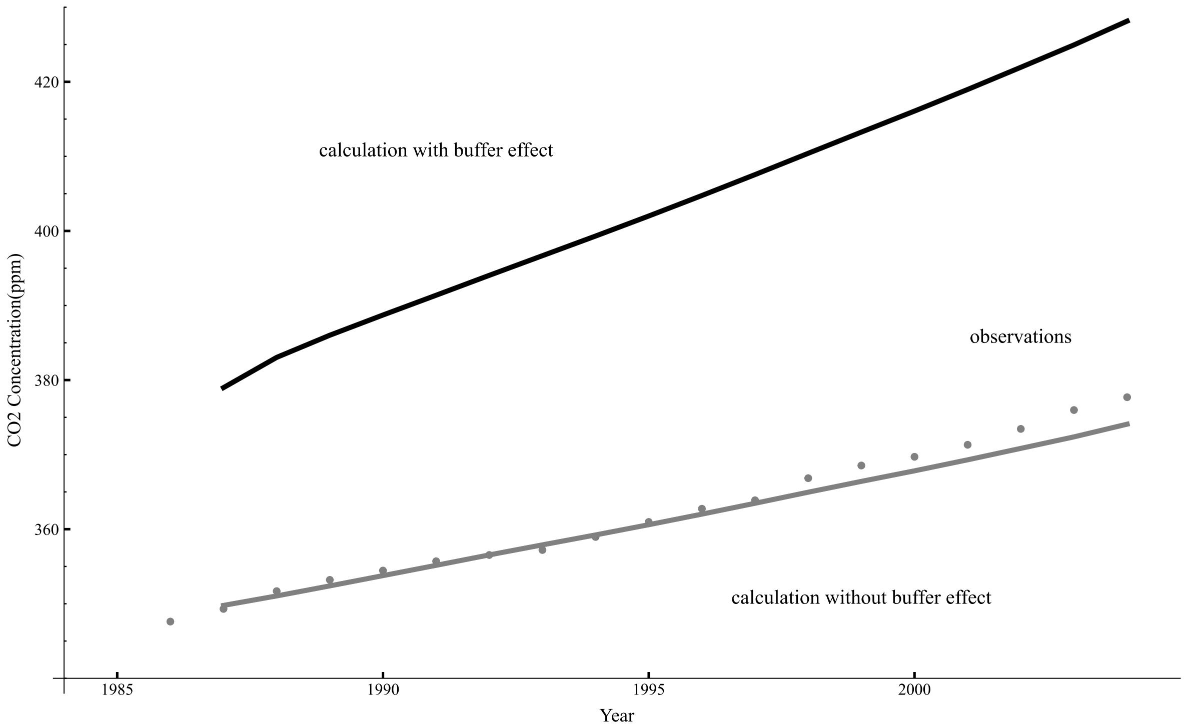
```
plt.ylabel('CO2 Concentration(ppm)')
plt.xticks([1985,1990,1995,2000])
plt.yticks([340,360,380,400,420,430])
plt.legend(loc='best')
plt.title('The atmospheric CO2 level in ppm from 1987 to 2004-two box model')
plt.show()
```



In [8]:

```
#1.3
#Set the Font
plt.rcParams['font.family'] = 'serif'
plt.rcParams['font.serif'] = ['Times New Roman'] + plt.rcParams['font.serif']
plt.rcParams['mathtext.default'] = 'regular'

#Set the figure size
fig = plt.figure(figsize=(16, 10))
ax = fig.add_subplot(1, 1, 1)

#Remove the right border and top border
ax.spines['right'].set_visible(False)
ax.spines['top'].set_visible(False)

#Set the scale and ticks of the coordinate axis
plt.xlim(1983.8,2005)
ax.tick_params(axis='x',which='major',direction='in',width=2,length=5, pad=4,labels
ax.set_xticks(np.arange(1985, 2000 + 5, 5))
ax.set_xticks(np.arange(180, 180 + 2.5, 2.5), minor=True)
ax.set_xlabel('Year',labelpad=8,fontsize=15)
plt.ylim(338,430)
ax.tick_params(axis='y',which='major',direction='in',width=2,length=5, pad=4,labels
ax.tick_params(axis='y',which='minor',direction='in',width=1,length=2)
ax.set_yticks(np.arange(360, 420 + 20, 20))
ax.set_yticks(np.arange(340, 430 + 5, 5), minor=True)
ax.set_ylabel('CO2 Concentration(ppm)',labelpad=8,fontsize=15)

#Set the origin of axes and plot it(ask for Yin Yuling)
ax.spines['bottom'].set_position(('data',340))
ax.spines['left'].set_position(('data',1984))
ax.plot(t[2:], ans1[:],linewidth=4,color='grey',label='calculation without buffer ef
ax.plot(t[2:], ans2[:],linewidth=4,color='k',label='calculation with buffer effect')
ax.scatter(CO2['year'], CO2['mean'],s=32,c='grey',marker='o',lw=0.5,label='observat
```

```
#add the text
ax.text(1999,350,
        "calculation without buffer effect",
        horizontalalignment ='center',
        fontsize = 16,zorder=2)
ax.text(1991,410,
        "calculation with buffer effect",
        horizontalalignment ='center',
        fontsize = 16,zorder=2)
ax.text(2002,385,
        "observations",
        horizontalalignment ='center',
        fontsize = 16,zorder=2)
plt.show()
```



In [ ]: