In [6]:

```
import scipy
import pandas as pd
import numpy as np
from scipy import constants
from scipy.interpolate import UnivariateSpline
from numpy import exp
from scipy import integrate
import numpy as np
import matplotlib.pyplot as plt
import numpy as np
%matplotlib inline
from scipy.integrate import odeint
```

In [7]:

```
df1=pd.read_csv('global.1751_2014.csv')
df1
```

Out[7]:

	Year	total	Carbon emissions from gas fuel consumption	Carbon emissions from liquid fuel consumption	Carbon emissions from solid fuel consumption	Carbon emissions from cement production	Carbon emissions from gas flaring	Per cap carb emissio (met tons carbc after 19 on
0	1751	3	0	0	3	0	0	N:
1	1752	3	0	0	3	0	0	N:
2	1753	3	0	0	3	0	0	N:
3	1754	3	0	0	3	0	0	N:
4	1755	3	0	0	3	0	0	N:
...	...	...	...	...	...	...	...	
259	2010	9128	1696	3107	3812	446	67	1.
260	2011	9503	1756	3134	4055	494	64	1.
261	2012	9673	1783	3200	4106	519	65	1.
262	2013	9773	1806	3220	4126	554	68	1.
263	2014	9855	1823	3280	4117	568	68	1.

264 rows × 8 columns

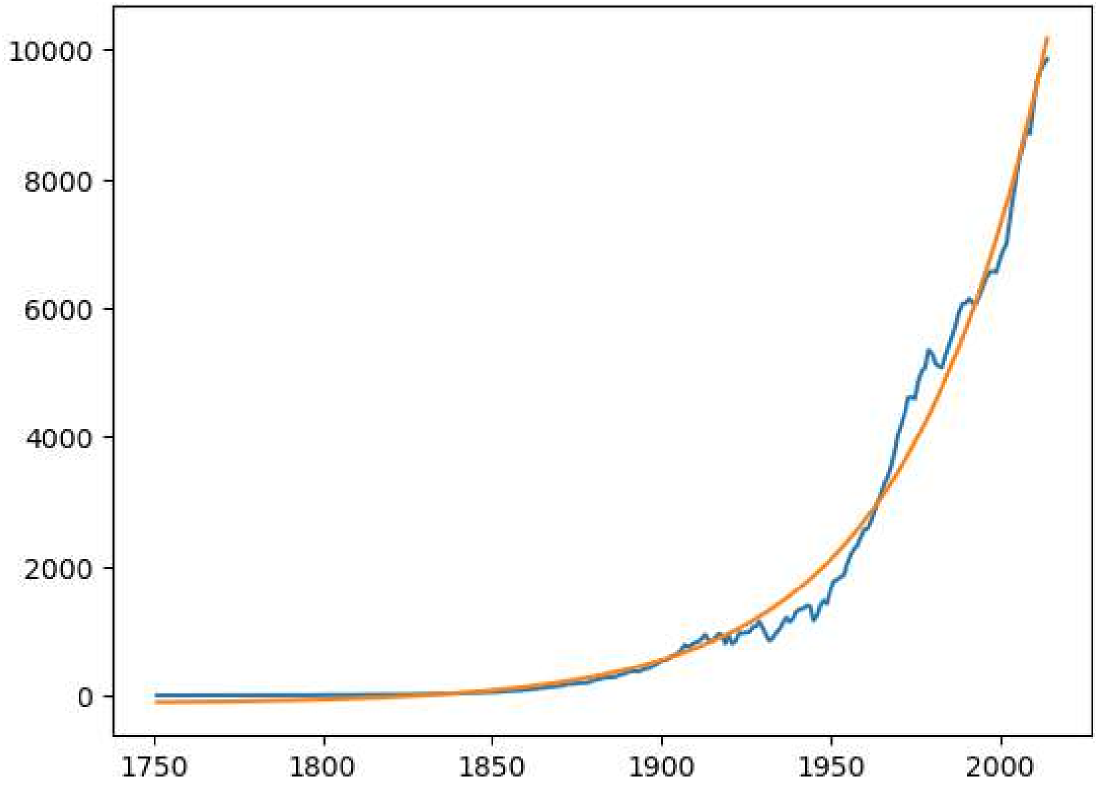
In [8]:

```
#这道题求助了赵望超
import scipy.optimize as optimize
# 对其进行指数拟合y=exp(a1*x+a2)+a3，得到化石燃料排放的二氧化碳随时间变化的曲线
def fossil_emiss(x,a1,a2,a3): # 定义拟合的函数
    return np.exp(a1*x+a2)+a3
# 设置拟合的初始值
a1=0.1
a2=0.1
a3=0
p0=[a1,a2,a3]
#这里编辑了原文件，原表名太长了
df1['Year'] = df1['Year'].astype(float)
df1['total'] = df1['total'].astype(float)
# 调用拟合函数
para,cov=optimize.curve_fit(fossil_emiss,df1['Year'],df1['total'],p0=p0)

# 计算拟合后的结果
y_fit=[fossil_emiss(a,*para) for a in df1['Year']]

# 画真实值和拟合后的图
plt.plot(df1['Year'],df1['total'])
plt.plot(df1['Year'],y_fit)

plt.show()
print(para)
```




```
[ 2.39596800e-02 -3.90147674e+01 -1.22229282e+02]
```

In [9]:

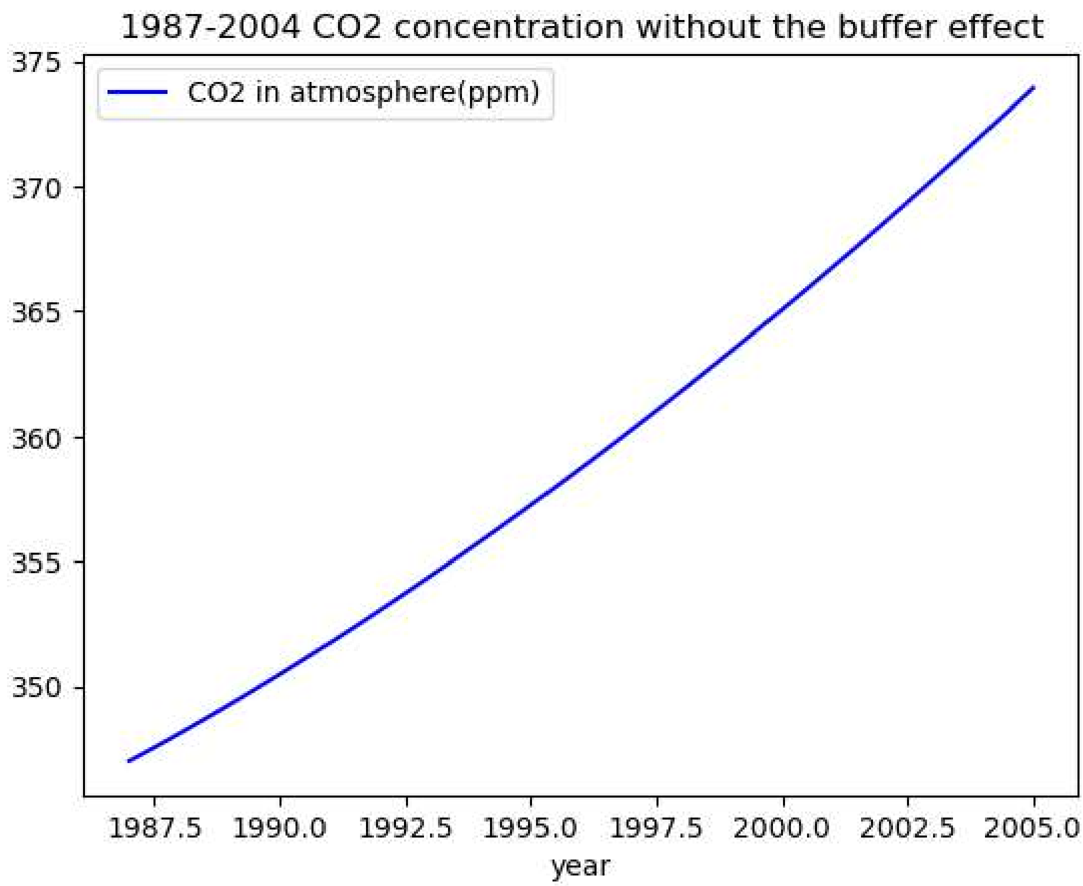
```
# 定义没有buffer效应的碳循环函数
def model1(y,t,k12,k21):
    N1,N2,a = y#a是γ
    dydt=[-k12*N1+k21*N2+a,k12*N1-k21*N2, 2.39596800e-02*a+2.39596800e-02*1.222
    return dydt
```

In [12]:

```
# 设置初始值
t1=np.linspace(1987, 2005)
a=fossil_emiss(t,*para)
k12=105/740
k21=102/900
N1=740*1000
N2=900*1000
y0=[N1,N2,a[0]]
#转化单位
sol = odeint(model1, y0, t, args=(k12,k21))/1000/740*347
```

In [13]:

```
# 画图
from matplotlib.ticker import MaxNLocator
plt.plot(t1, sol[:, 0], 'b', label='CO2 in atmosphere(ppm)')
plt.legend(loc='best')
plt.xlabel('year')
# 设置横坐标轴刻度为整数
#plt.gca().xaxis.set_major_locator(MaxNLocator(integer=True))
plt.title('1987-2004 CO2 concentration without the buffer effect')
plt.show()
```



In [14]:

```
# 定义有buffer效应的函数
def model2(y,t,k12,k21,N0):
    N1,N2,a2 = y
    bf=3.69+1.86e-2*(N1/740/1000*347)-1.8e-6*((N1/740/1000*347)**2) #buffer fac
    dydt=[-k12*N1+k21*(N0+bf*(N2-N0))+a2,
          k12*N1-k21*(N0+bf*(N2-N0)),
          2.39596800e-02*a2+2.39596800e-02*1.22229282e+02]
    return dydt
```

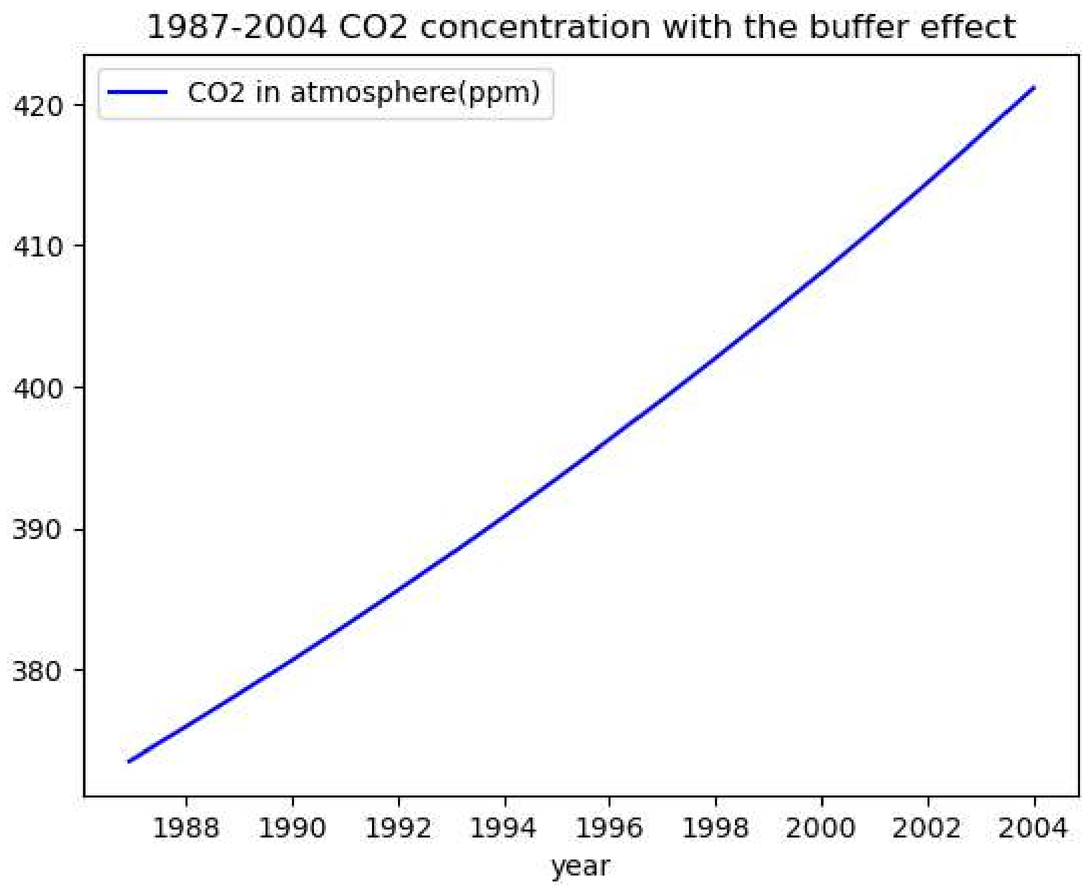
In [15]:

```
# 设置初始值
t2=np.linspace(0, 253, 253)+1751
a2=fossil_emiss(t2,*para)

k12=105/740
k21=102/900
N0=821*1000
N1=618*1000
N2=821*1000
y0=[N1,N2,a2[0]]
sol2 = odeint(model2, y0, t2, args=(k12,k21,N0))/740/1000*347 #计算微分方程，并且
```

In [16]:

```
# 画图
plt.plot(t2[235:253], sol2[235:253,0], 'b', label='CO2 in atmosphere(ppm)')
plt.legend(loc='best')
plt.xlabel('year')
plt.gca().xaxis.set_major_locator(MaxNLocator(integer=True))
plt.title('1987-2004 CO2 concentration with the buffer effect')
plt.show()
```



In [17]:

```
# 导入观测值数据
df2=pd.read_csv('co2_annmean_mlo.csv')
df2
```

Out[17]:

	year	mean	unc
0	1959	315.98	0.12
1	1960	316.91	0.12
2	1961	317.64	0.12
3	1962	318.45	0.12
4	1963	318.99	0.12
...	...	...	...
59	2018	408.72	0.12
60	2019	411.65	0.12
61	2020	414.21	0.12
62	2021	416.41	0.12
63	2022	418.53	0.12

64 rows × 3 columns

In [18]:

```
# 画图
plt.plot(t, sol[:, 0], 'b') # without buffer effect
plt.plot(t2[235:253], sol2[235:253,0], 'r') # with buffer effect
plt.scatter(df2['year'][28:46],df2['mean'][28:46]) # observed data

plt.legend(['without buffer effect','with buffer effect','observed'],loc='best')
plt.xlabel('year')
plt.gca().xaxis.set_major_locator(MaxNLocator(integer=True)) # 设置横坐标轴刻度为
plt.title('1987-2004 CO2 concentration in atmosphere (ppm)')
plt.show()
# 不考虑buffer效应时比观测值低估，可能是由于人为源排放拟合时有一定的低估，因此积分
```