In [29]:
```python
import numpy as np
import pandas as pd
import netCDF4
import xarray as xr
import matplotlib as mpl
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
import math
from scipy.integrate import odeint
```

In [22]:
```python
#1.1
#load and filter the dataset
emission=pd.read_csv('global.1751_2014.csv')
emission['year'] = emission['year'].astype(int)
filter_emission=emission[(emission['year'] >= 1986) & (emission['year'] <= 2
CO2=pd.read_csv('co2_annmean_mlo.csv')
filter_CO2=CO2[(CO2['year'] >= 1986) & (CO2['year'] <= 2004)]
#select the data
filter_emission = filter_emission.iloc[1:, 0:2]
filter_emission['Total C emission (pg)'] = filter_emission['Total carbon emi
data_new = pd.merge(filter_CO2[['year', 'mean']], filter_emission[['year',
#combine the data
data_new['Atmosphere C'] = data_new['mean']
data_new = data_new.drop(columns=['mean'])
data_new['CO2 level in ppm (without the buffer effect)'] = 347
data_new
```

Out[22]:

	year	Total C emission (pg)	Atmosphere C	CO2 level in ppm (without the buffer effect)
0	1987	5.725	349.31	347
1	1988	5.936	351.69	347
2	1989	6.066	353.20	347
3	1990	6.074	354.45	347
4	1991	6.142	355.70	347
5	1992	6.078	356.54	347
6	1993	6.070	357.21	347
7	1994	6.174	358.96	347
8	1995	6.305	360.97	347
9	1996	6.448	362.74	347
10	1997	6.556	363.88	347
11	1998	6.576	366.84	347
12	1999	6.561	368.54	347
13	2000	6.733	369.71	347
14	2001	6.893	371.32	347
15	2002	6.994	373.45	347
16	2003	7.376	375.98	347
17	2004	7.743	377.70	347

In [42]:
```python
#two-box model parameter
k12 = 105 / 740
k21 = 102 / 900
N1 = 740
N2 = 900
N0=740*10**21/12/347
gama=data_new['Total C emission (pg)']

for year in range(1987,2004):
    dN1 = -k12*N1 + k21*N2 + gama[year-1986]
    dN2 =  k12*N1 - k21*N2
    N1 += dN1
    N2 += dN2
    if year != 1986:
        data_new['CO2 level in ppm (without the buffer effect)'][year-1986]=
data_new
```

Out[42]:

	year	Total C emission (pg)	Atmosphere C	CO2 level in ppm (without the buffer effect)
0	1987	5.725	349.31	347.000000
1	1988	5.936	351.69	348.376746
2	1989	6.066	353.20	349.778535
3	1990	6.074	354.45	351.148675
4	1991	6.142	355.70	352.523806
5	1992	6.078	356.54	353.844368
6	1993	6.070	357.21	355.147149
7	1994	6.174	358.96	356.488780
8	1995	6.305	360.97	357.877533
9	1996	6.448	362.74	359.313970
10	1997	6.556	363.88	360.777109
11	1998	6.576	366.84	362.224610
12	1999	6.561	368.54	363.645113
13	2000	6.733	369.71	365.132402
14	2001	6.893	371.32	366.672943
15	2002	6.994	373.45	368.233983
16	2003	7.376	375.98	369.947423
17	2004	7.743	377.70	371.787634

In [71]:
```python
#1.2 with buffer
N1 = 740
N2 = 900
N20= 821
N0=740*10**21/12/347
E=0
data_new['CO2 level in ppm (with buffer)'] =347
for year in range(1986,2004):
    dN1 = -k12*N1 + k21*N20+k21*E*(N2-N20) + gama[year-1986]
    dN2 =  k12*N1 - k21*N20-k21*E*(N2-N20)
    N1 += dN1
    N2 += dN2
```

```
    data_new['CO2 level in ppm (with buffer)'][year-1986]=N1*10**21/12/N0
    E=3.69+1.86*10**(-2)*data_new['CO2 level in ppm (with buffer)'][year-198
data_new
```

```
/var/folders/yx/js3jvr652bx7g_xn_lgjpcy40000gn/T/ipykernel_61494/417976389
7.py:13: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-doc
s/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  data_new['CO2 level in ppm (with buffer)'][year-1986]=N1*10**21/12/N0
```

Out[71]:

	year	Total C emission (pg)	Atmosphere C	CO2 level in ppm (without the buffer effect)	CO2 level in ppm (with buffer)
0	1987	5.725	349.31	347.000000	344.079417
1	1988	5.936	351.69	348.376746	389.412923
2	1989	6.066	353.20	349.778535	380.754686
3	1990	6.074	354.45	351.148675	387.029710
4	1991	6.142	355.70	352.523806	388.464146
5	1992	6.078	356.54	353.844368	391.431804
6	1993	6.070	357.21	355.147149	393.887768
7	1994	6.174	358.96	356.488780	396.564514
8	1995	6.305	360.97	357.877533	399.241289
9	1996	6.448	362.74	359.313970	402.001317
10	1997	6.556	363.88	360.777109	404.801016
11	1998	6.576	366.84	362.224610	407.610714
12	1999	6.561	368.54	363.645113	410.414978
13	2000	6.733	369.71	365.132402	413.303100
14	2001	6.893	371.32	366.672943	416.258372
15	2002	6.994	373.45	368.233983	419.258066
16	2003	7.376	375.98	369.947423	422.435555
17	2004	7.743	377.70	371.787634	425.767810

In [80]:

```
#1.3
data_newest = data_new[data_new['year'] > 1987]
plt.figure(figsize=(10, 6))
# without buffer
plt.plot(data_newest['year'], data_newest['CO2 level in ppm (without the buf
# with buffer effect
plt.plot(data_newest['year'], data_newest['CO2 level in ppm (with buffer)'],
# observation
#plt.scatter(data_newest['year'], data_newest['year']['Atmosphere C'], label
plt.scatter(data_newest['year'], data_newest['Atmosphere C'], color='k', lak

#adjust the plot
plt.title('The CO2 trend predicted and observations (1987-2004)')
plt.xlabel('Year')
plt.ylabel('CO2 Concentration (ppm)')
plt.xticks(range(1987, 2005, 1))
plt.legend()

plt.xlabel('Year')
```

```
plt.ylabel('CO2 Concentration (ppm)')
plt.show()
```

The CO2 trend predicted and observations (1987-2004)