In [19]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

In [6]:
```
human_emis = pd.read_csv(r'D:\Sustech\研究生\课程\Environmental programming\ESE5023_
human_emis = human_emis[(human_emis['Year'] >= 1987) & (human_emis['Year'] <= 2004)]
human_emis = human_emis[['Year','Total carbon emission']].reset_index(drop=True)
human_emis
```

Out[6]:

	Year	Total carbon emission
0	1987	5725
1	1988	5936
2	1989	6066
3	1990	6074
4	1991	6142
5	1992	6078
6	1993	6070
7	1994	6174
8	1995	6305
9	1996	6448
10	1997	6556
11	1998	6576
12	1999	6561
13	2000	6733
14	2001	6893
15	2002	6994
16	2003	7376
17	2004	7743

1.1

In [17]:
```
start_atm = 740
start_ocn = 900
stayy = 1987
endyy = 2004
k12 = 105/740
k21 = 102/900
atmlist = []
atmlist_ppm = []
ocnlist = []
for yy in range(stayy, endyy+1):
    gam = human_emis[human_emis['Year'] == yy]
    #the unit of total carbon emission is 10^12g C, so divided by 1000 to PgC
    gamval = gam.iloc[0,1] / 1000
    if yy == stayy:
        dN1 = -k12 * start_atm + k21 * start_ocn + gamval
```

```
        dN2 = k12 * start_atm - k21 * start_ocn
        atmlist.append(start_atm + dN1)
        atmlist_ppm.append((start_atm + dN1) / 2.13)
        ocnlist.append(start_ocn + dN2)
    else:
        yy_atm = atmlist[yy-stayy-1]
        yy_ocn = ocnlist[yy-stayy-1]
        dN1 = -k12 * yy_atm + k21 * yy_ocn + gamval
        dN2 = k12 * yy_atm - k21 * yy_ocn
        atmlist.append(yy_atm + dN1)
        atmlist_ppm.append((yy_atm + dN1) / 2.13)
        ocnlist.append(yy_ocn + dN2)
print(atmlist_ppm)
```

```
[348.69718309859155, 350.0536829082604, 351.44084611781557, 352.8004867167128, 354.1
6822384864224, 355.4836373965159, 356.78296741785744, 358.12247532887113, 359.510116
42127673, 360.9462099618703, 362.40956650246096, 363.85765976261683, 365.27901755439
615, 366.76745874890116, 368.30937996643246, 369.87194552758615, 371.58718537964984,
373.42941644742604]
```

1.2

In [18]:
```
N20 = 821
atmlist_be = []
atmlist_ppm_be = []
ocnlist_be = []
for yy in range(stayy, endyy+1):
    gam = human_emis[human_emis['Year'] == yy]
    #the unit of total carbon emission is 10^12g C, so divided by 1000 to PgC
    gamval = gam.iloc[0,1] / 1000
    if yy == stayy:
        buf_ft = 3.69 + 1.86 * 0.01 * start_atm - 1.80 * 10e-6 * start_atm ** 2
        dN1 = -k12 * start_atm + k21 * (N20 + buf_ft * (start_ocn - N20)) + gamval
        dN2 = k12 * start_atm - k21 * (N20 + buf_ft * (start_ocn - N20))
        atmlist_be.append(start_atm + dN1)
        atmlist_ppm_be.append((start_atm + dN1) / 2.13)
        ocnlist_be.append(start_ocn + dN2)
    else:
        buf_ft = 3.69 + 1.86 * 0.01 * yy_atm - 1.80 * 10e-6 * yy_atm ** 2
        yy_atm = atmlist[yy-stayy-1]
        yy_ocn = ocnlist[yy-stayy-1]
        dN1 = -k12 * yy_atm + k21 * (N20 + buf_ft * (yy_ocn - N20)) + gamval
        dN2 = k12 * yy_atm - k21 * k21 * (N20 + buf_ft * (yy_ocn - N20))
        atmlist_be.append(yy_atm + dN1)
        atmlist_ppm_be.append((yy_atm + dN1) / 2.13)
        ocnlist_be.append(yy_ocn + dN2)
print(atmlist_ppm_be)
```

```
[376.4281364632238, 376.8236767010656, 381.1945781592081, 383.53172624775283, 385.88
816614908956, 388.20246607747, 390.50633912879186, 392.85431746987734, 395.248352048
7961, 397.68609646574976, 400.14848097550873, 402.5953430137077, 405.0175647253129,
407.5100322423532, 410.05625056153855, 412.61608180085994, 415.3255972987047, 418.16
255622267994]
```

1.3

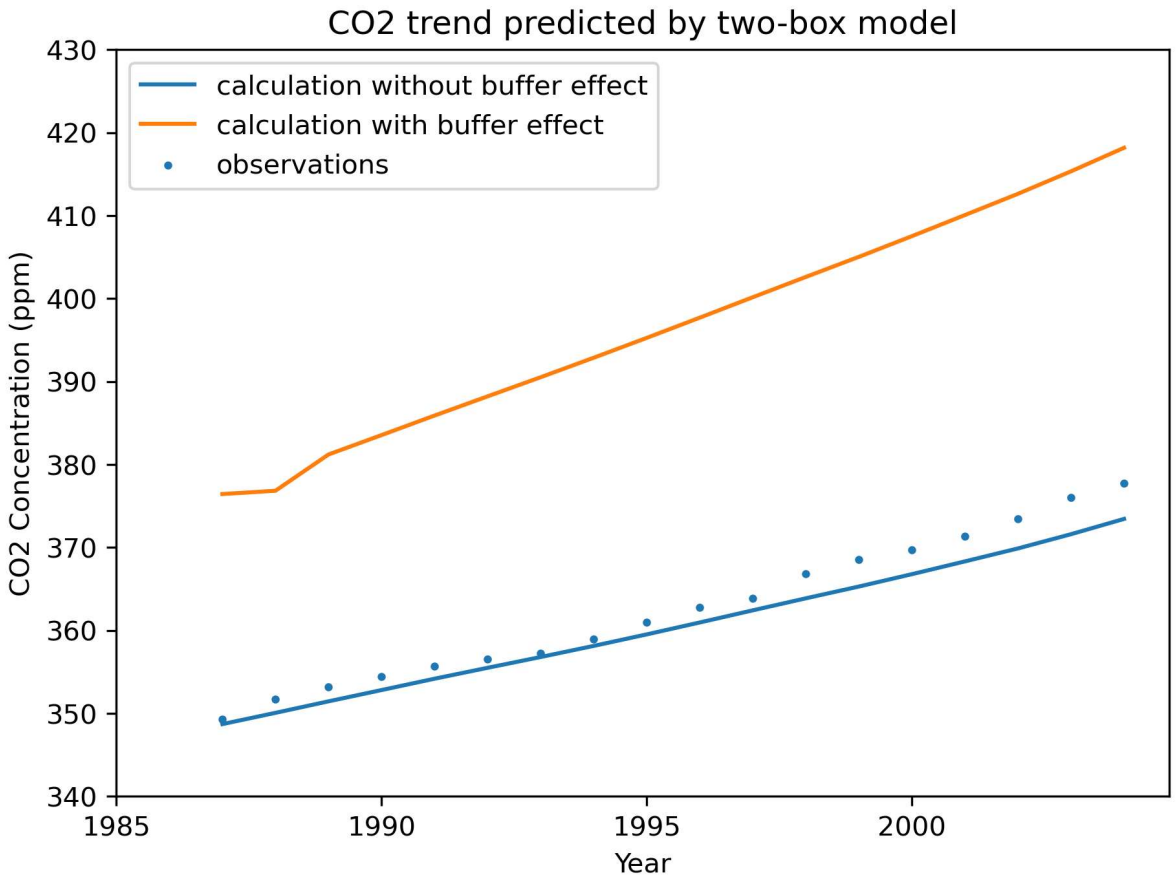
In [29]:
```
mlo = pd.read_csv(r'D:\Sustech\研究生\课程\Environmental programming\ESE5023_Assignm
mlo = mlo[(mlo['year'] >= 1987) & (mlo['year'] <= 2004)].reset_index(drop=True)
mlo
```

Out[29]:

	year	mean	unc
0	1987	349.31	0.12
1	1988	351.69	0.12
2	1989	353.20	0.12
3	1990	354.45	0.12
4	1991	355.70	0.12
5	1992	356.54	0.12
6	1993	357.21	0.12
7	1994	358.96	0.12
8	1995	360.97	0.12
9	1996	362.74	0.12
10	1997	363.88	0.12
11	1998	366.84	0.12
12	1999	368.54	0.12
13	2000	369.71	0.12
14	2001	371.32	0.12
15	2002	373.45	0.12
16	2003	375.98	0.12
17	2004	377.70	0.12

In [40]:
```
fig = plt.figure(figsize=(7,5),dpi=300)
x = np.arange(stayy,endyy+1)
ax1 = fig.add_subplot(111)
ax1.plot(x,atmlist_ppm,label='calculation without buffer effect')
ax1.plot(x,atmlist_ppm_be,label='calculation with buffer effect')
ax1.scatter(x,mlo['mean'],s=4,label='observations')
ax1.set_xticks(np.arange(1985,2005,5))
ax1.set_ylim(340,430)
ax1.set_ylabel('CO2 Concentration (ppm)')
ax1.set_xlabel('Year')
ax1.legend()
ax1.set_title('CO2 trend predicted by two-box model')
```

Out[40]:
```
Text(0.5, 1.0, 'CO2 trend predicted by two-box model')
```


CO2 trend predicted by two-box model
calculation without buffer effect
calculation with buffer effect
observations
CO2 Concentration (ppm)
Year
430
420
410
400
390
380
370
360
350
340
1985
1990
1995
2000

In [ ]: