

## CFC Modeling assignment

Go to <http://cs.clark.edu/~mac/physlets/GlobalPollution/CFCASS1.htm> for data and interactive model.

**Objective:** Use the NOAA/CMDL data graphs to estimate the global average concentration of CFC-12 from 1979 to 1995 and to see how the rate of increase has changed over these years.

Real Data: Reading The Graph of Figure 1.

**Q1:** What are the global average concentration of CFC-12 in 1979, 1983, 1987, 1991, and 1995?

1979:

1983:

1987:

1991:

1995:

**Q2:** Does the concentration of CFC-12 appear to be increasing as much in 1995 as it was in 1980? Explain.

**Q3:** Is the CFC-12 concentration in the Northern hemisphere higher or lower than in the Southern hemisphere?

Why is this true?

**Q4:** If the atmospheric life-time of CFC-12 were only a few months, instead of 100 years, would the difference between Northern and Southern hemisphere concentrations be larger or smaller than in present observations? Explain your reasoning. (hint: it takes a year or two for Northern hemisphere air to mix with Southern hemisphere air.)

**For the following questions you should run the Model.**

**Objective:** Compare the CFC-12 concentrations from NOAA/CMDL observations with those predicted by a global mass balance model to estimate the average emission source ( $S$  in ppt/yr) of CFC-12 into the atmosphere for different time intervals.

For **Q5** through **Q9** click on CFC#1 to set up graph. Data from a global average CFC-12 data set have been transferred to this graph, six points space 4 years apart between 1979

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and 1999. This allows you to use the model to better understand the observations. Use 100 years for atmospheric lifetime of CFC-12 for all simulations.

**Q5:** Change the emissions ( $S_0$ ) to get the best fit between the model and the first two data points [1979 and 1983]. What value of  $S_0$  gives the best fit to these two points? Use your subjective judgment to obtain the best fit as oppose to some statistical test.

Best fit  $S_0$ :

**Q6:** Change the emissions  $S_0$  and the initial concentration  $C_0$  to get the best fit between the model and the second and third data points [1983 and 1987]. What value of  $S_0$  and  $C_0$  gives the best fit for 1983 and 1987 data?

$S_0$ :

$C_0$ :

**Q7:** Based on the above results, would you say that the emissions of CFC-12 from factories were increasing or decreasing between 1979 and 1987?

**Q8:** Now change  $C_0$ , and  $S_0$  to get the best fit between the model and observations for the first **four** data points [1979, 1983, 1987, & 1991]. Remember use a lifetime of 100 years. What values of  $C_0$  and  $S_0$  give the best fit to all four years?

$S_0$ :

$C_0$ :

**Q9:** Based on your comparison of model projections from 1991 to 1999 and observations would you say the emissions of CFC-12 increased or decreased from 1991 to 1999?

**Objectives:** Explore the future projections of CFC-12 if the emission source strength remained at in 1980s value into the future.

**For Q10 through Q13 click on CFC#2 to set up graph.** Assume that  $C_0=280$ ppt (its 1979 value),  $S_0 =20$ ppt/year an average value based on the data, and  $R=0.0$  (constant value of  $S$ ).

**Q10:** For these values what is the concentration 100 years after the run starts (in 2079)?

**Q11:** What would be the final equilibrium concentration of CFC-12 if the emission source were kept fixed at 20 ppt/year? (hint: you should be able to calculate this without using the model if you remember that  $C_{eq}=S \tau$ )

**Q12:** If through international agreements the CFC-12 emissions were **cut in half** to 10 ppt/yr (instead of 20) what would be the CFC-12 concentration in the year 2079?

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How much larger is this than the 1979 value? (use a ratio so you can say how many *times* larger)

**Q13:** Based on the knowledge that significant stratospheric ozone loss was linked to CFC concentrations in the early 1990s when the CFC-12 concentration was about 460 ppt, discuss the merits of the international policy described in Q12. Specifically address:  
1. Whether the emission reduction is large enough to halt the stratospheric ozone loss and  
2. whether you would expect the stratospheric ozone hole to grow larger or to get smaller under this "50% -emission-reduction" policy.

**Objective:** Explore future CFC-12 concentrations with assumed scenarios of emission reduction rates.

**For Q14 through Q19 click on CFC#3 to set up graph.** This graph assumes that an initial CFC-12 concentration  $C_0=480$  ppt (its 1991 value) and the 1991 emissions are  $S_0=20$ (ppt/year), an average value based on our previous data analysis.

The Montreal Protocol (revised in Copenhagen in 1992) called for the complete phase out of F-12. The questions below relates to accomplishing this task.

**Q14:** Let  $R=0.0$  (no growth in emissions so  $S$  is fixed at its 1991 value of 20 ppt/yr). How long after 1991 does it take the concentration of CFC-12 to double? (Click clear before running and then read the numerical output from the model in the table at right)

**Q15:** Let  $R=-10.0$  (emission reduction of 10% per year after 1991). How long does it take before the concentration of CFC-12 gets back to its 1991 value of 480 ppt. What is the maximum value of CFC-12 reached after 1991? (Again, click clear before running and then read the numerical output from the model in the table at right)

time to get back to 480 ppt: \_\_\_\_\_

Max CFC-12 concentration: \_\_\_\_\_

**Q16:** repeat Q15 for  $R=-20.0$   
time to get back to 480 ppt: \_\_\_\_\_

Max CFC-12 concentration: \_\_\_\_\_

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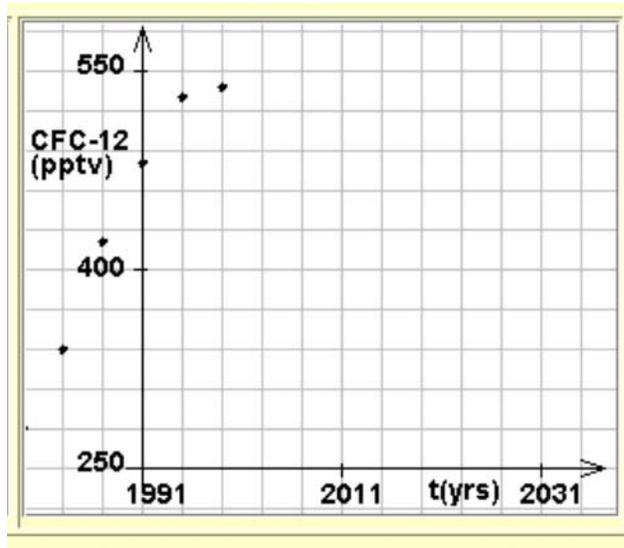
**Q17:** repeat Q15 for  $R=-100.0$ . This corresponds to the complete phase out of CFC-12 after 1 year.

time to get back to 480 ppt: \_\_\_\_\_

Max CFC-12 concentration: \_\_\_\_\_

**Q18:** The actual CFC-12 concentrations are show in black dots. Which value of  $R$  best fits the observed 1991 and 1999 CFC-12 concentration values?

**Q19:** Run the 4 simulations corresponding to the 4 different  $R$  values all on the same graph. Using the Run1 ( $R=-10$ ), Run2 ( $R=-20$ ), Run3 ( $R=-100$ ), and Run4 (your best fit) buttons makes this easy. Print out this graph and turn this in with the rest of your assignment or make a sketch on the axes below. Using the Alt-PrntScrn keys allows you to copy the screen to the computer's clipboard and then it can be easily pasted into a word processing document. Clearly label each curve with its corresponding  $R$  value.



**Objectives:** The questions below are intended help synthesize the ideas presented earlier and to show how these concepts are related to real world applications.

**Q20:** The following ordered pairs of ( $S_0$  in ppt/yr,  $R$  in%) with  $C_0=480$  ppt are used to run the model starting from 1991 to estimate future CFC-12 concentrations.  $A=(20, -5)$ ,  $B=(20,+5)$ ,  $C=(0,80)$ ,  $D=(0,0)$ , &  $E=(20,-10)$ . Rank each from highest to lowest year 2031 concentration. Run the model to check your answers.

Highest				lowest

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**Q21:** A friend tells you that a particular global pollutant is under control now since industry has stopped increasing production (emissions rate increase is zero,  $R = 0.0$ ) for this pollutant. What three key pieces of information would you need to know before you could respond to your friend's assertion and estimate future concentrations of this pollutant?

- 1.
- 2.
- 3.

**Q22:** A speaker from a local factory states that the emissions from their factory are very clean since most of it is water vapor and steam. Give example of at least two other questions worth asking this person regarding the emissions from their factory?

**Q23:** Evaluate the merits of the following hypothetical argument. *Use at least one result from a model run in your evaluation. Also consider conditions over the next 100 years.*

In the late 1970s observations indicated that atmospheric concentrations of CFC-12 were increasing and that this increase could result in ozone depletion and possibly global warming. Because of this, world governments agreed to hold **emissions** of CFC-12 (**S**) fixed at their 1980 level with the idea that this will help control future concentrations and curtail negative environmental impacts.