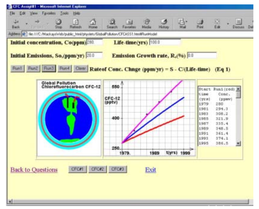

Mass Balance and Atmospheric Chlorofluorocarbon CFC-12:

Using Interactive Models and Data in Introductory Atmospheric Science

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serc.carleton.edu/introgeo/models/

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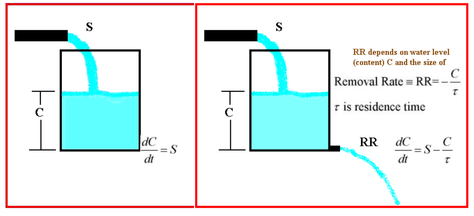
Here we describe using a simple mass balance model to help students better understand past and future projections of CFC-12 in the atmosphere. Our motivation is two-fold. First, the activities described here are designed to help students better understand general principles of mass balance: flow rates, accumulation rates, net accumulation, equilibrium levels, first order loss rate, and time delays. Secondly, chlorine loading in the atmosphere as related to stratospheric ozone depletion and expected ozone recovery.

Water Bucket Interactive Online Model

Learning Objectives: The online interactive water bucket model can be used to help students learn about:
- Flow rates
- Accumulation rates
- First order loss rates
- Equilibrium levels
- Time delays and time constants



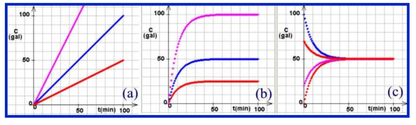


Figure 1. Example output from the online interactive water bucket model.
(a) filling up at different rates w/o leak;
(b) a leaky bucket with different input flow rates;
(c) a leaky bucket with different initial contents.

Explore this model and suggested student activity at:
http://cs.clark.edu/~mac/physlets/GlobalPollution/WaterBucket.htm

Interactive Online Mass Balance Model for Past and Future Projections of Atmospheric CFC-12

Learning Objective: Use a modified version of the water bucket model to:
1. Estimate global emissions of CFC-12
2. Estimate future CFC-12 concentrations with and without emission restrictions.
3. Understand time delays between emissions controls and atmospheric response.

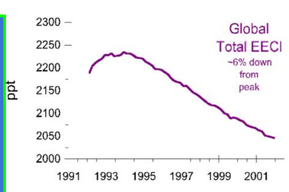
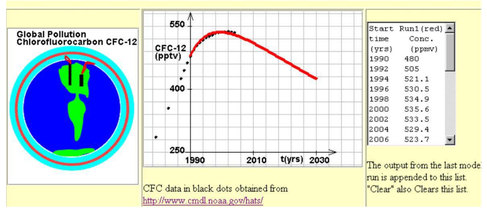


Image From:
http://www.cmdl.noaa.gov/hats/graphs/graphs.html



$$\frac{dC}{dt} = S_0 e^{\alpha t} - \frac{C}{\tau}$$

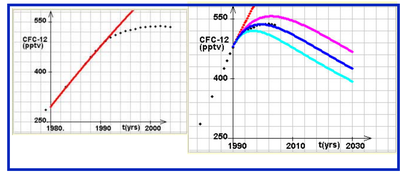
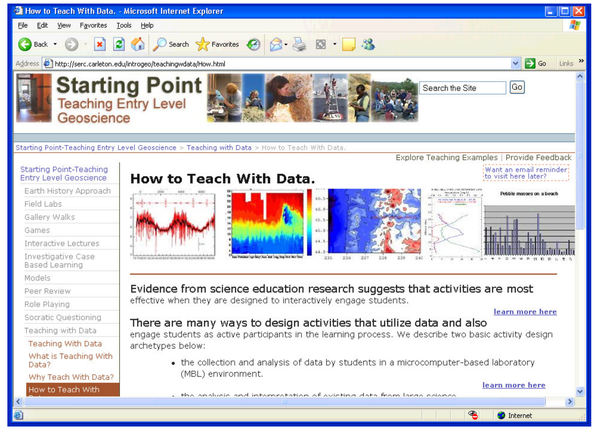


Figure 2. Growth of CFC-12 with constant emissions estimated from 1980 observations (left). Fitting data with different emission reduction scenarios (right)

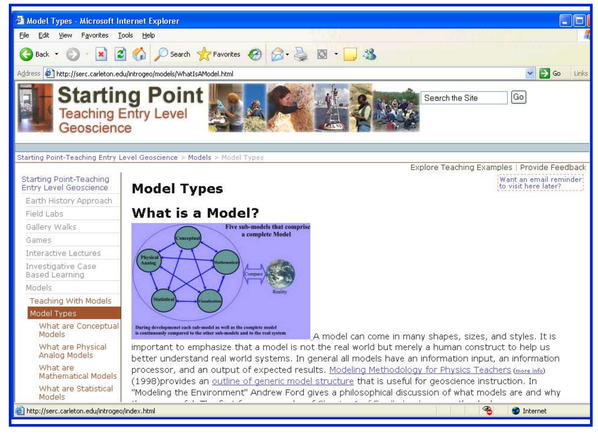
Explore this model and suggested student activity at:
http://cs.clark.edu/~mac/physlets/GlobalPollution/chloroflourocarbons.htm

The "Teaching with Data" and "Teaching with Model" modules are two examples of the many Starting Point modules available through the Science Education Resource Center (SERC). These particular resources are designed for introductory geoscience faculty interested in learning how they can use data and models effectively to enhance student learning. All Starting Point modules intimately integrate pedagogy with solid examples of teaching resources.

"Teaching with Data" provides solid background of available data and data types, describes how data can be used effectively in the classroom, includes resources related to data analysis and visualization, and contains many examples of student centered learning activities that make extensive use of data.



"Teaching with Models" describes what models are and how they can be used effectively in geoscience courses to enhance student learning. This resource module also includes resources on how to use common modeling environments along with many examples of model related interactive learning activities.



Learn more at: http://serc.carleton.edu/introgeo/