Analysis of CFC-11 observations

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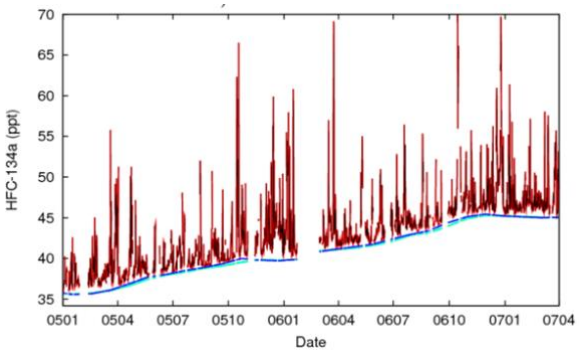
Chlorofluorocarbons (CFCs, methyl chloroform, etc.) have been produced in increasing quantities since the 1930s. They were used as refrigerant in refrigerators and air conditioners, as foam blowing agent, aerosol propellant, and chemical cleaning agent. No adverse effects were known at the time. That changes in 1974 with a landmark paper from Molina and Rowland. They demonstrated that CFCs were broken down in the stratosphere by UV radiation, releasing chlorine atoms that could participate in the catalytic destruction of ozone. Systematic measurements of CFCs and other ozone depleting substances started in 1978 by the Atmospheric Lifetime Experiment (ALE) which was later continued by the GAGE and now the AGAGE (Advanced Global Atmospheric Gases Experiment) network (Prinn et al., 2000).

The network started with long-term precise measurement at five remote sites around the world: Adrigole/Mace Head (Ireland), Trinidad Head (California,), Ragged Point (Barbados), Cape Matatula (Samoa), Cape Grim (Tasmania). It now consist of 13 stations, mostly at remote locations. Measurements are performed on an hourly of two hourly basis all year round. Now, apart from ozone-depleting substances, several greenhouse gases and other man-made and natural substances are also measured.

The concentrations of the CFCs have been decreasing for several years now following emission reductions mandated by the Montreal Protocol. In 2018 it was reported (Montzka et al., 2018) that emissions of CFC-11 continued in eastern Asia. Rigby et al. (2019) used AGAGE measurements from Gosan)South Korea) and Hateruma (Japan) and conformed that the emissions came from China.



The hourly data (see figure) show a long-term background trend and spiked caused by local pollution events from nearby sources. Both the background concentration and spikes contain interesting information.

Task: Analyze the AGAGE CFC-11 data from several stations and time periods to determine the long term background trend and origin of spikes.

1. Define a research question and think of how you are going to address it.

2. Download hourly AGAGE data from (https://agage.mit.edu/; data including pollution events) from CFC-11 from station Mace Head or Adrigole for the year 1980, 1990, 2000, 2010 and the most recent full year. Analyse the data to derive the background concentration. Think what method could be used do derive the background and apply it. One of such methods (to identify pollution events and derive a background) is described in the appendix of 'O Doherty et al. (2001). You can apply your own method or apply that of O'Doherty> Maybe a Fourrier analyses will also yield useful information too.

3. Plot the results and analyze it: determine background concentration, frequency of pollution events, etc. Compare the data from the different years to estimate trends. Try to analyse the origin of the pollution events (you could use another species (CFC-12) and look at correlations to see what you learn from this.

References:

- O'Doherty et al., In situ chloroform measurements at Advanced Global Atmospheric Gases Experiment atmospheric research stations from 1994 to 1998, *Journal of Geophys. Res.,* 106, D17, 20,429-20,445, 2001.
- Montzka et al., An unexpected and persistent increase in global emissions of ozone-depleting CFC-11, *Nature*, 557, 413-417, 2018, doi: 10.1038/s41586-018-0106-2.
- Prinn et al., A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE, *Journal of Geophys. Res.,* 105, D14, 17,751-17,792, 2000.
- Rigby et al., Increase in CFC-11 emissions from eastern China based on atmospheric observations, *Nature*, 2019, doi: 10.1038/s41586-019-1193-4.