

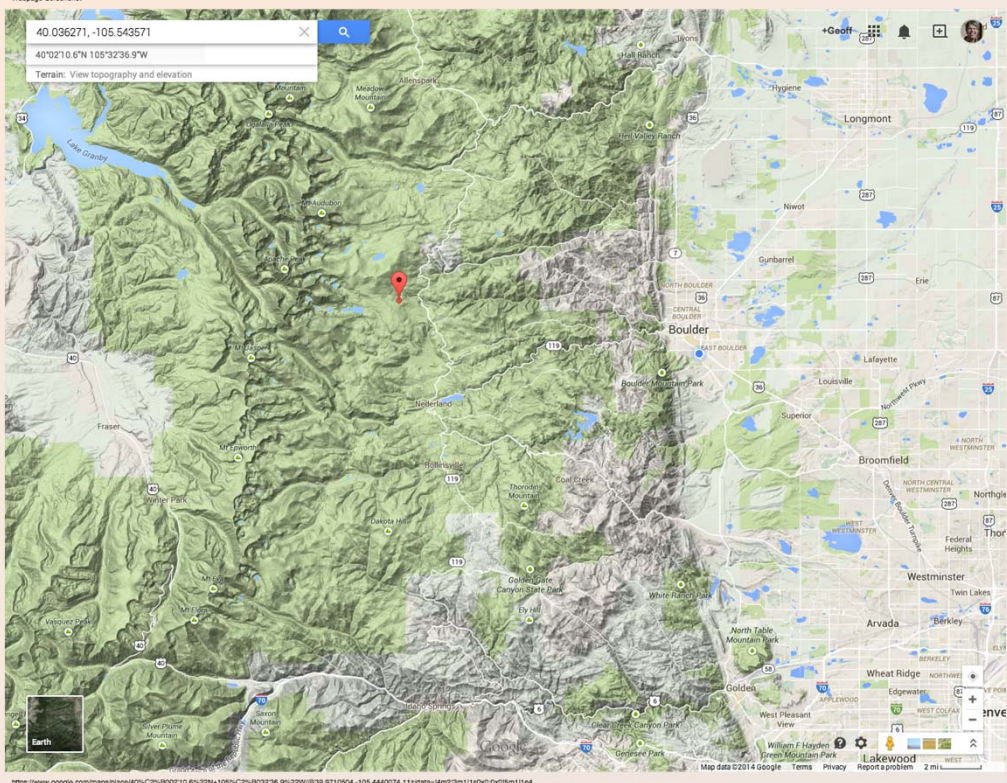
Characterizing the Niwot Ridge, Colorado C1 site: local and regional pollution?

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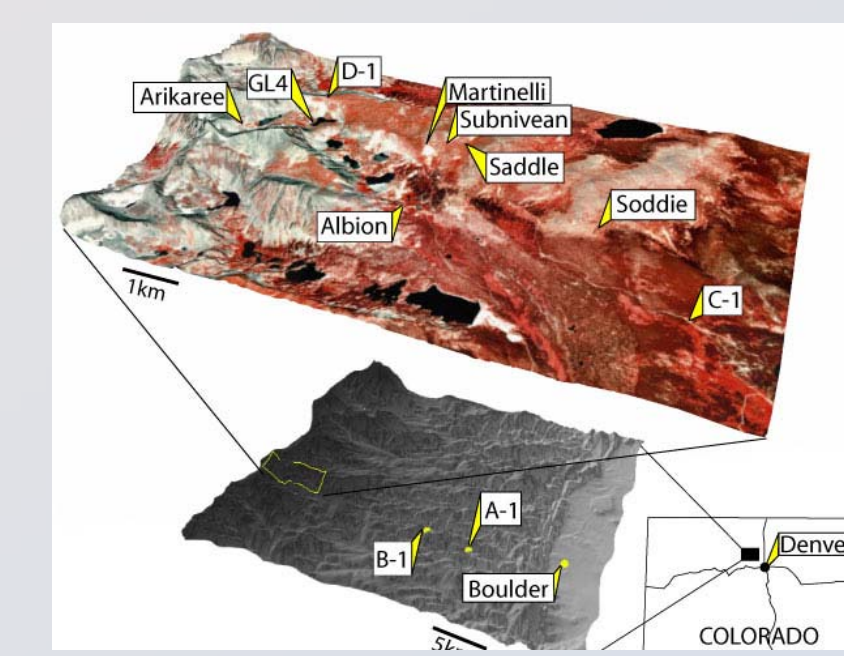
Introduction



Niwot Ridge, Colorado C1 site (red marker)

The University of Colorado/INSTAAR (CU) maintains an alpine research station in the Rocky Mountains west of Boulder, Colorado called Niwot Ridge. There are numerous ecological, biological, hydrological, and atmospheric science research programs conducted at several locations on Niwot Ridge. The GMD Halocarbons group collects samples and makes in situ measurements at two separate locations; Saddle and C1. The C1 site is situated in an alpine forest at 3021 meters above sea level and has been an important location for GMD measurements; from continental background estimates to a clean location to fill cylinders for subsequent use as calibrated air samples. However, occasional pollution events require care in interpreting in situ measurements from C1.

Though the events are not a daily feature they occur in about 1-2% of the C1 air samples depending on the compound. Hourly measurements by gas chromatographs have characterized pollution events as well as daily, monthly, seasonal and annual variations of several trace gases including CFCs, N₂O, SF₆, halon-1211, CCl₄, and CH₂Cl₂. Complementing these measurements, continuous meteorological and ozone data are acquired by CU and GMD respectively. Further investigation into pollution frequency, timing, and wind direction may help constrain clean continental background conditions and provide a better understanding of local and regional pollution.



Complex terrain with alpine and subalpine forest sites.



C1 location

The Niwot Ridge Long Term Ecological Research (LTER) site includes Niwot Ridge, the southern-adjacent Green Lakes Valley, and the University of Colorado's Mountain Research Station (MRS). Niwot Ridge is part of the Roosevelt National Forest and has been designated a United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve and an Experimental Ecology Reserve (USDA Forest Service). The Green Lakes Valley is a part of the City of Boulder Watershed. The MRS is an interdisciplinary facility devoted to the advancement of the study of mountain ecosystems, providing research and educational opportunities for scientists, students, and the general public.

Source: <http://niwot.colorado.edu>

Instrumentation

The NOAA halocarbons group has made in situ measurements with gas chromatographs (GCs) at the C1 site including nitrous oxide (N₂O), the chlorofluorocarbons: CFC-12 (CCl₂F₂), CFC-11 (CCl₃F), and CFC-113 (C₂Cl₃F₃) and the chlorinated solvents: methyl chloroform (CH₂Cl₂) and carbon tetrachloride (CCl₄) since the late 1980s. The instrumentation was upgraded in 2000 to include other trace gases such as SF₆ and halon-

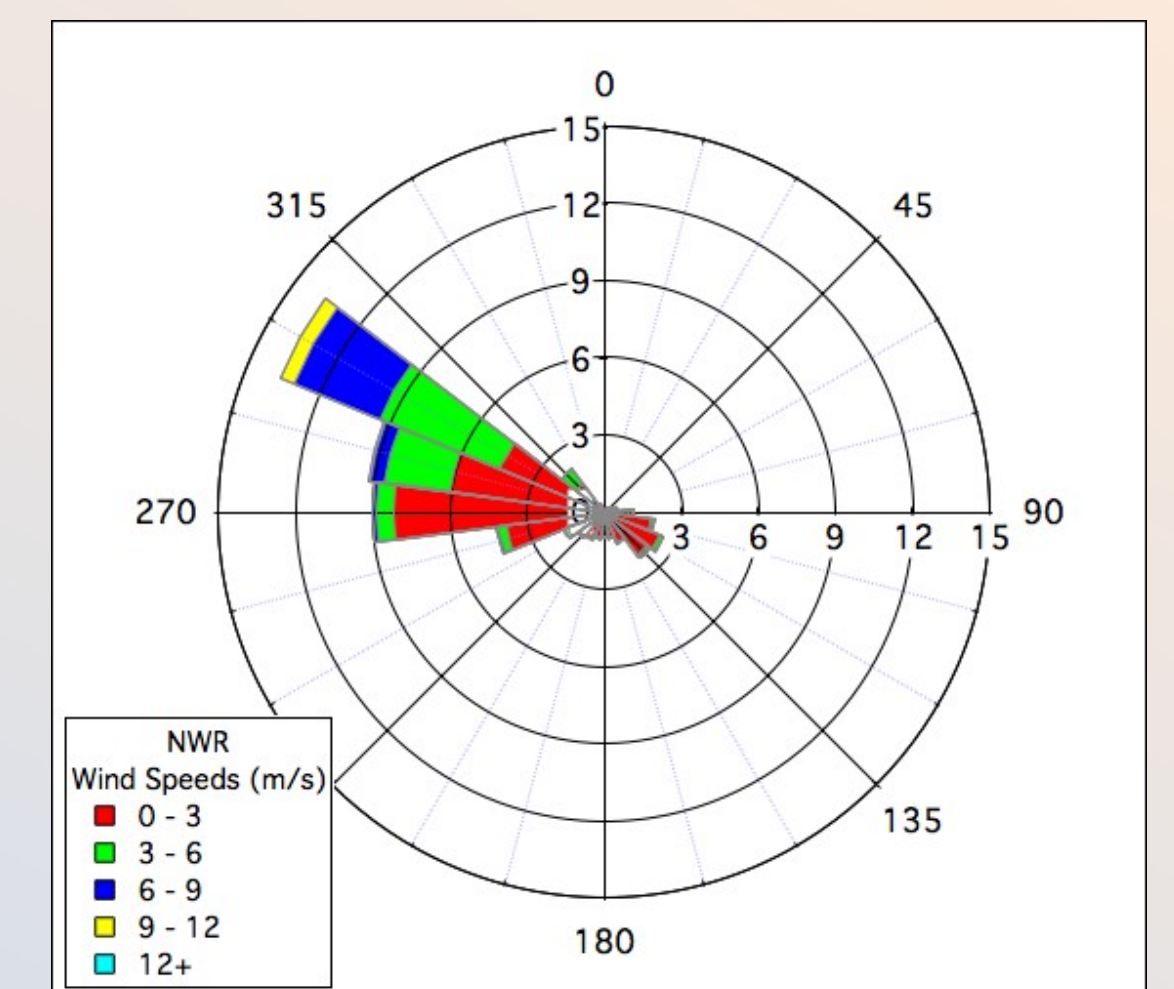
1211 (CBrClF₂). All of these compounds have anthropogenic sources and show periodic enhancements at the C1 site. In addition to the GC measurements, there are continuous measurements of surface ozone (O₃) as well as local meteorological fields such as precipitation, wind speed and direction.



Interior of the Niwot Ridge four channel gas chromatograph.

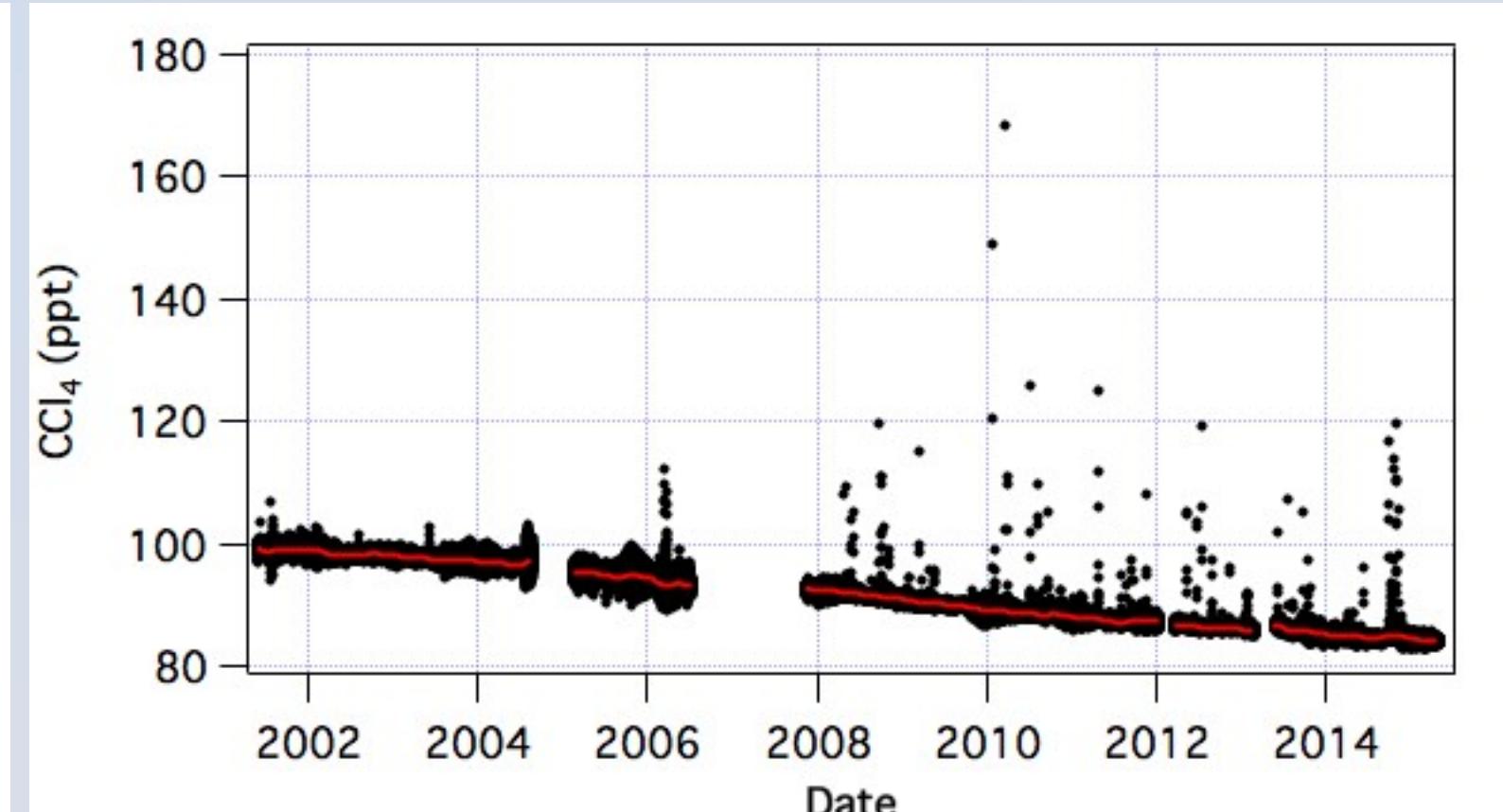
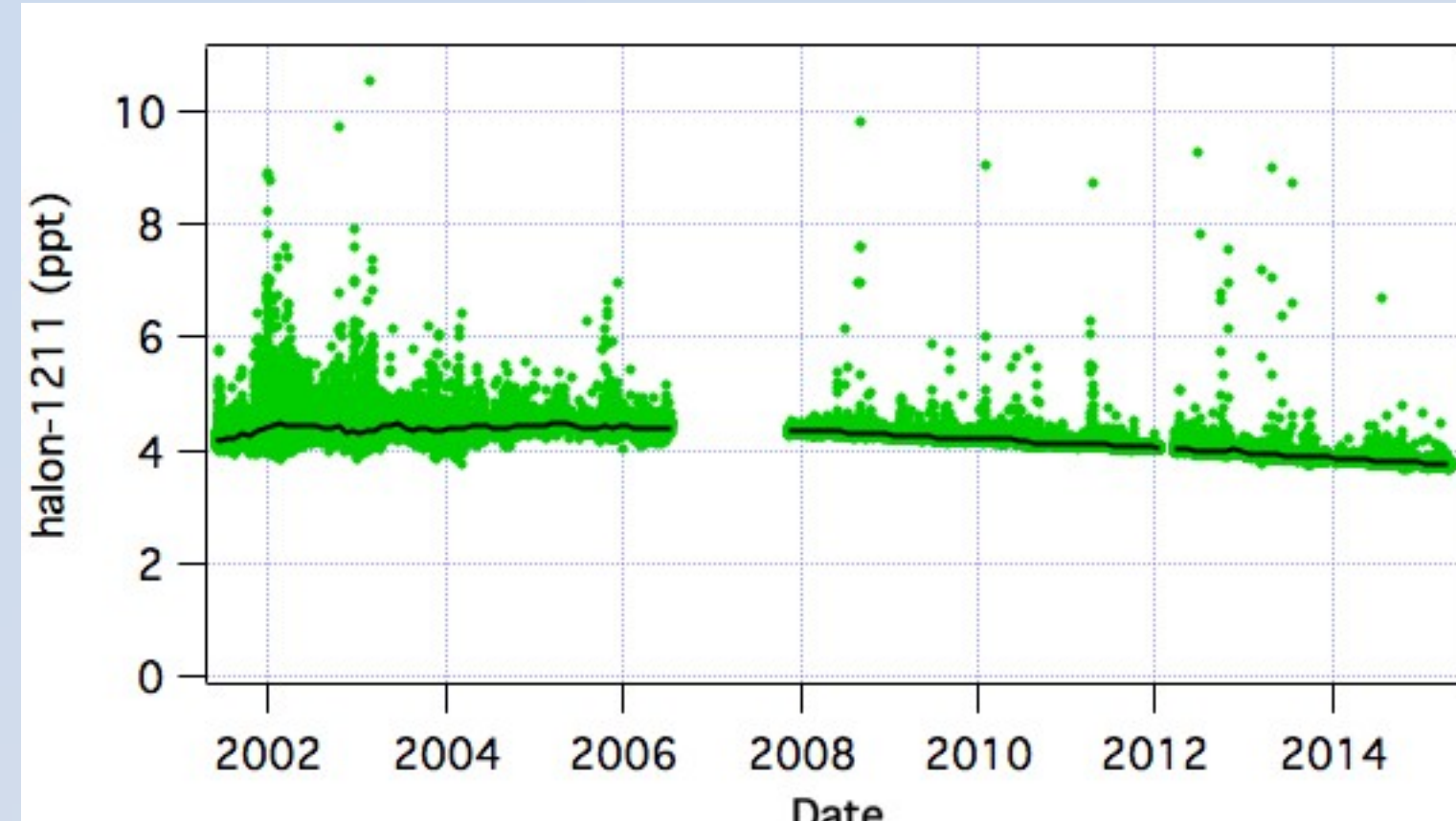
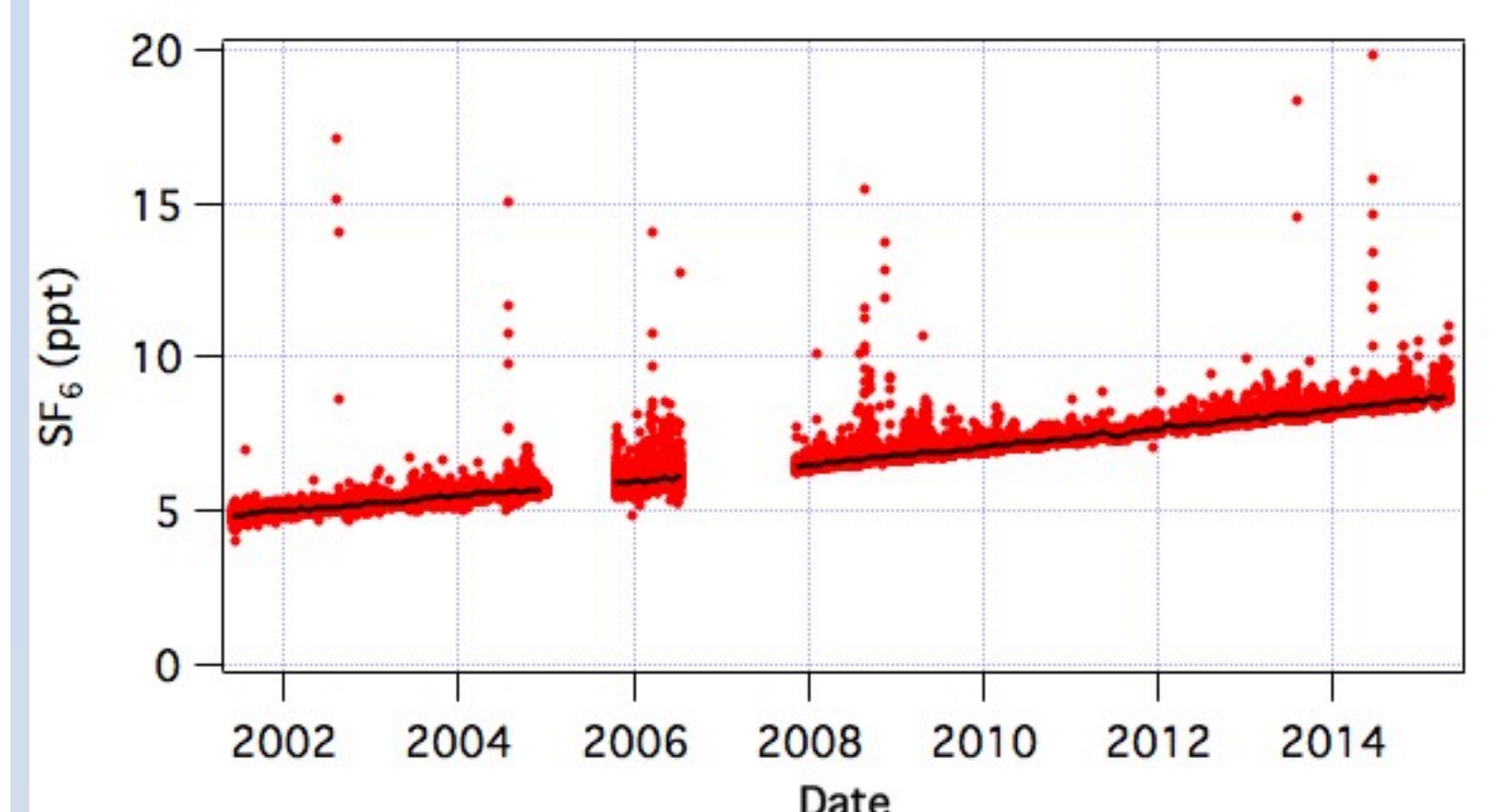
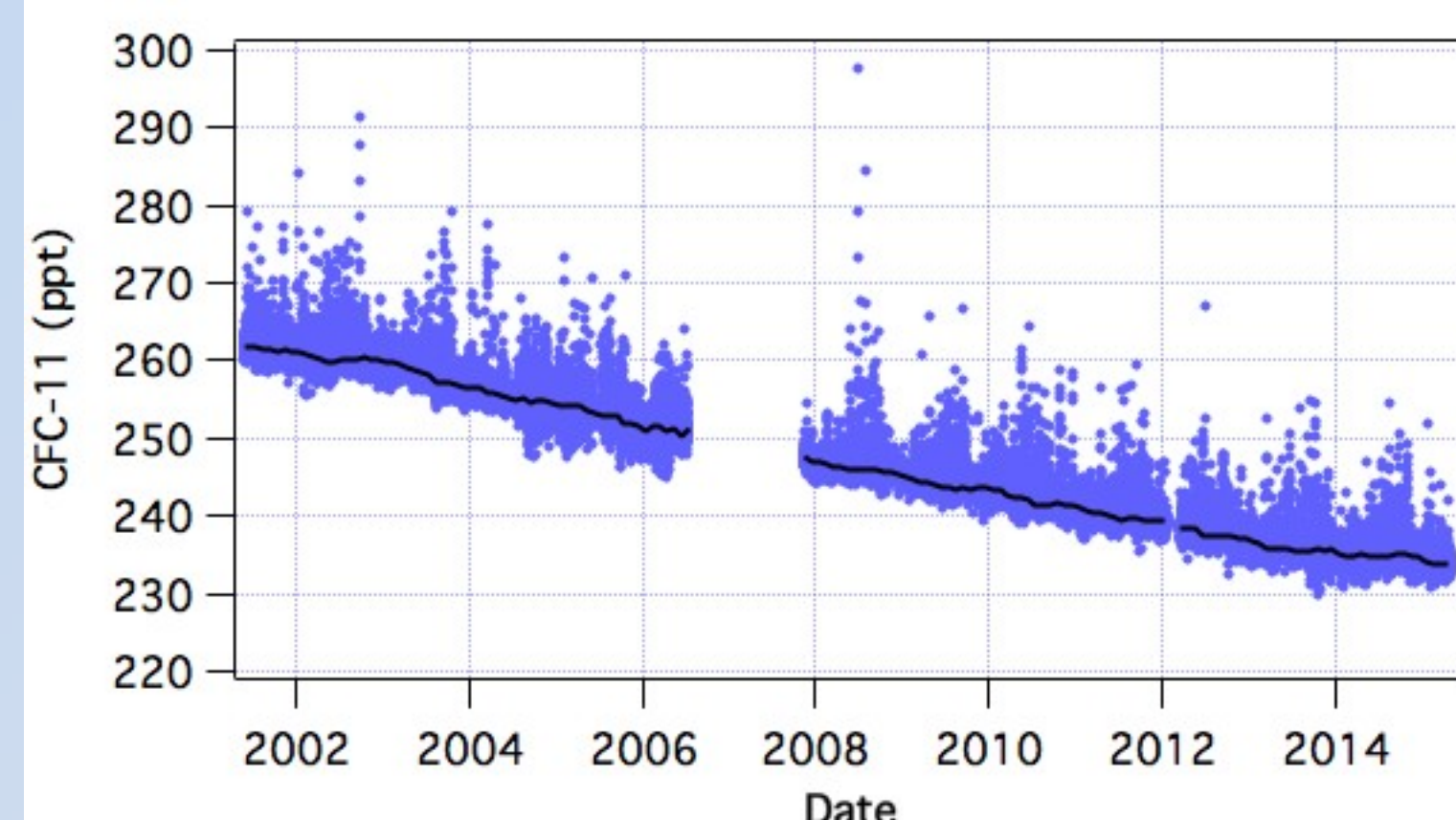
Meteorology

The C1 climate station is located on a ridge-top in a subalpine forest, 9.7 km east of the Continental Divide. Climate data exists from the C1 station from 1953 to present, and includes temperature, relative humidity, solar radiation, barometric pressure, wind speed and direction, precipitation, soil moisture and temperature, snow depth. The prevailing winds are from the northwest to west where typically continental background air is sampled by the gas chromatograph.



C1 wind rose

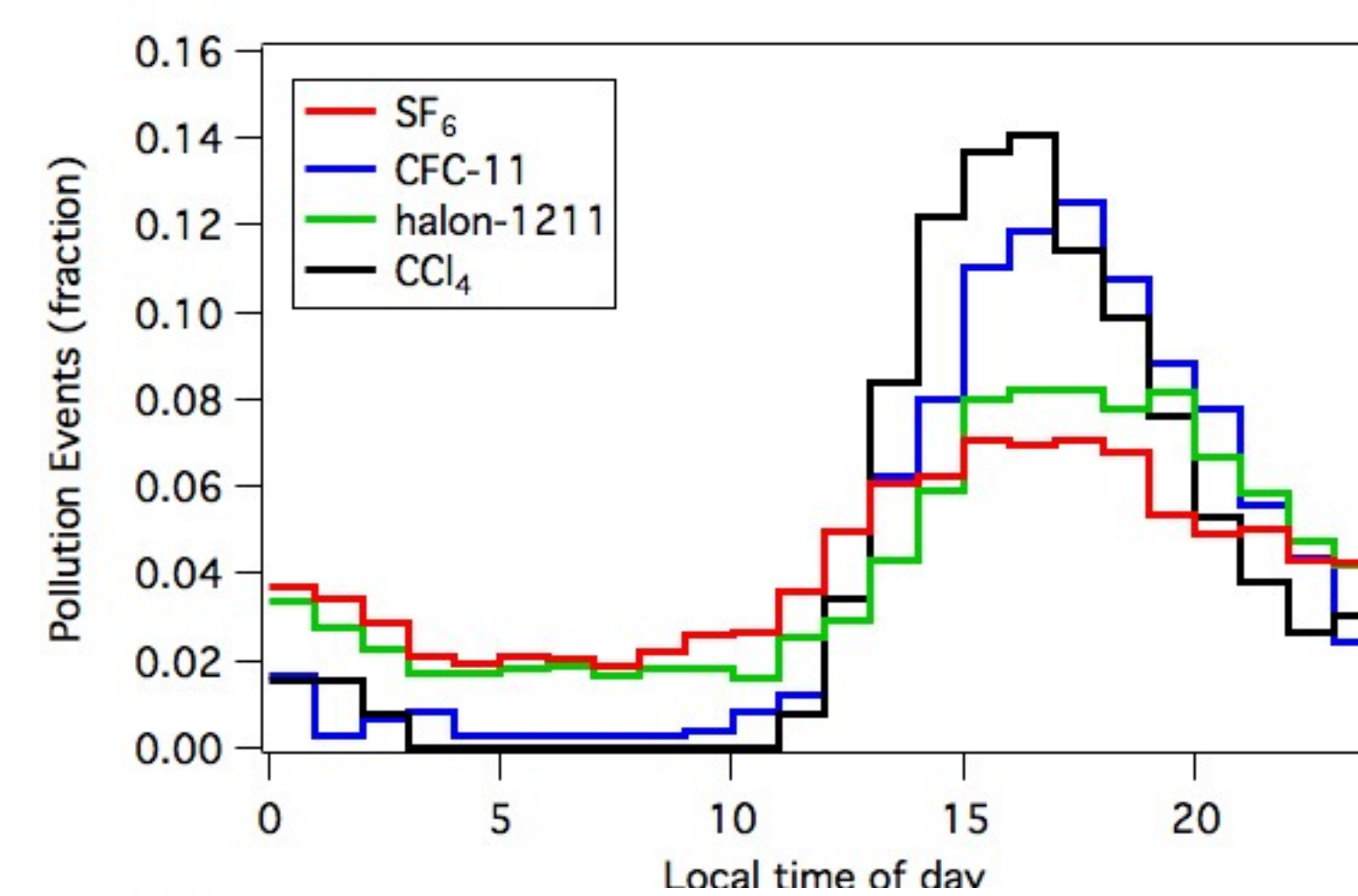
In Situ Data



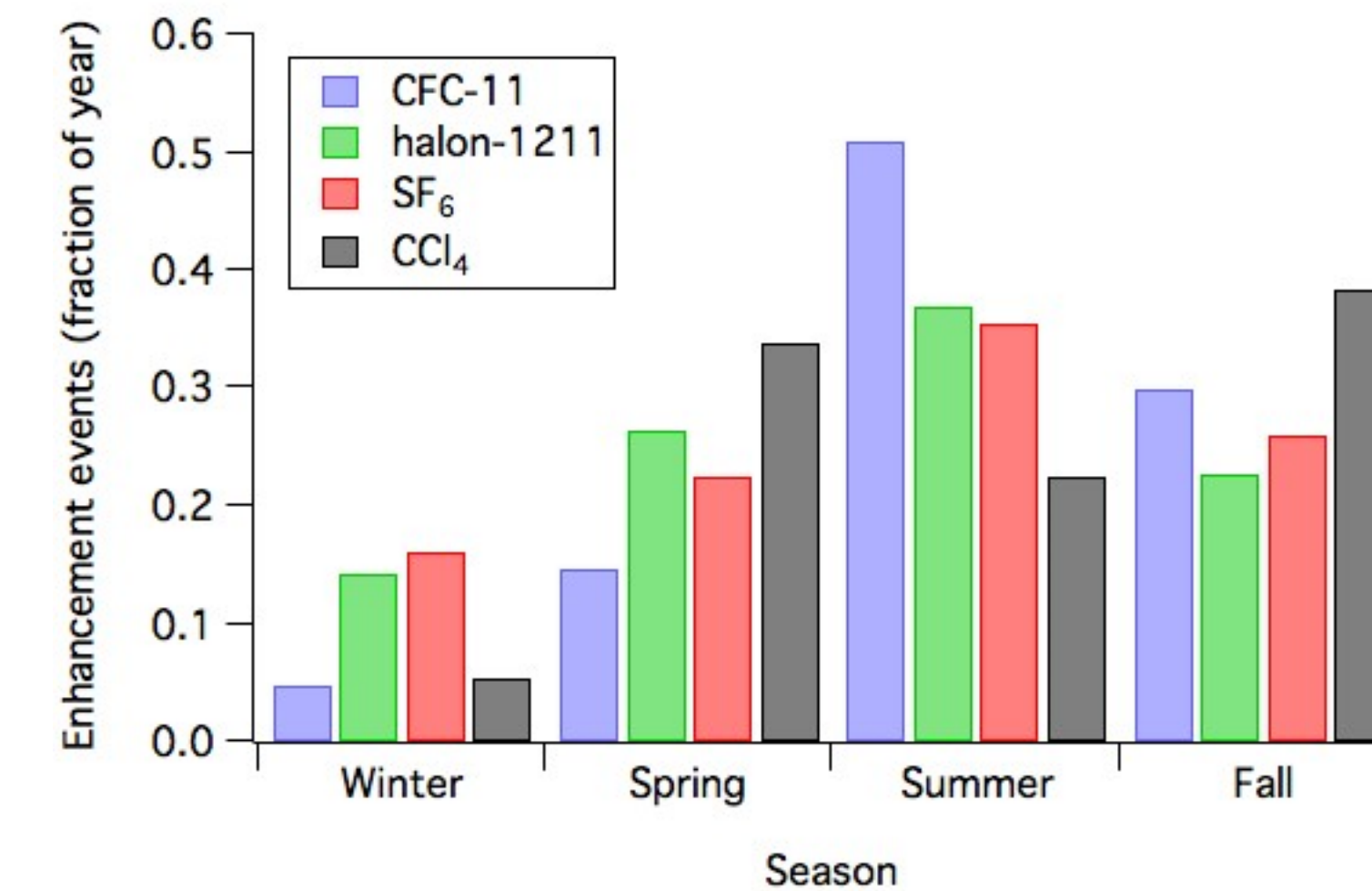
Hourly measurements of four trace gases measured at the Niwot Ridge C1 site with a custom built gas chromatograph (GC). The GC was severely damaged during the summer of 2006 resulting in 16-month data gap while the instrument was repaired. All of these gases have anthropogenic sources usually related to urban areas, however point source emissions (i.e.

halon or CCl₄ fire extinguishers) are possible. About 2% of the CFC-11 measurements at C1 site are polluted; the other gases show polluted events less frequently (< 1% of the samples). The CCl₄ events started in 2007 perhaps due to a local source.

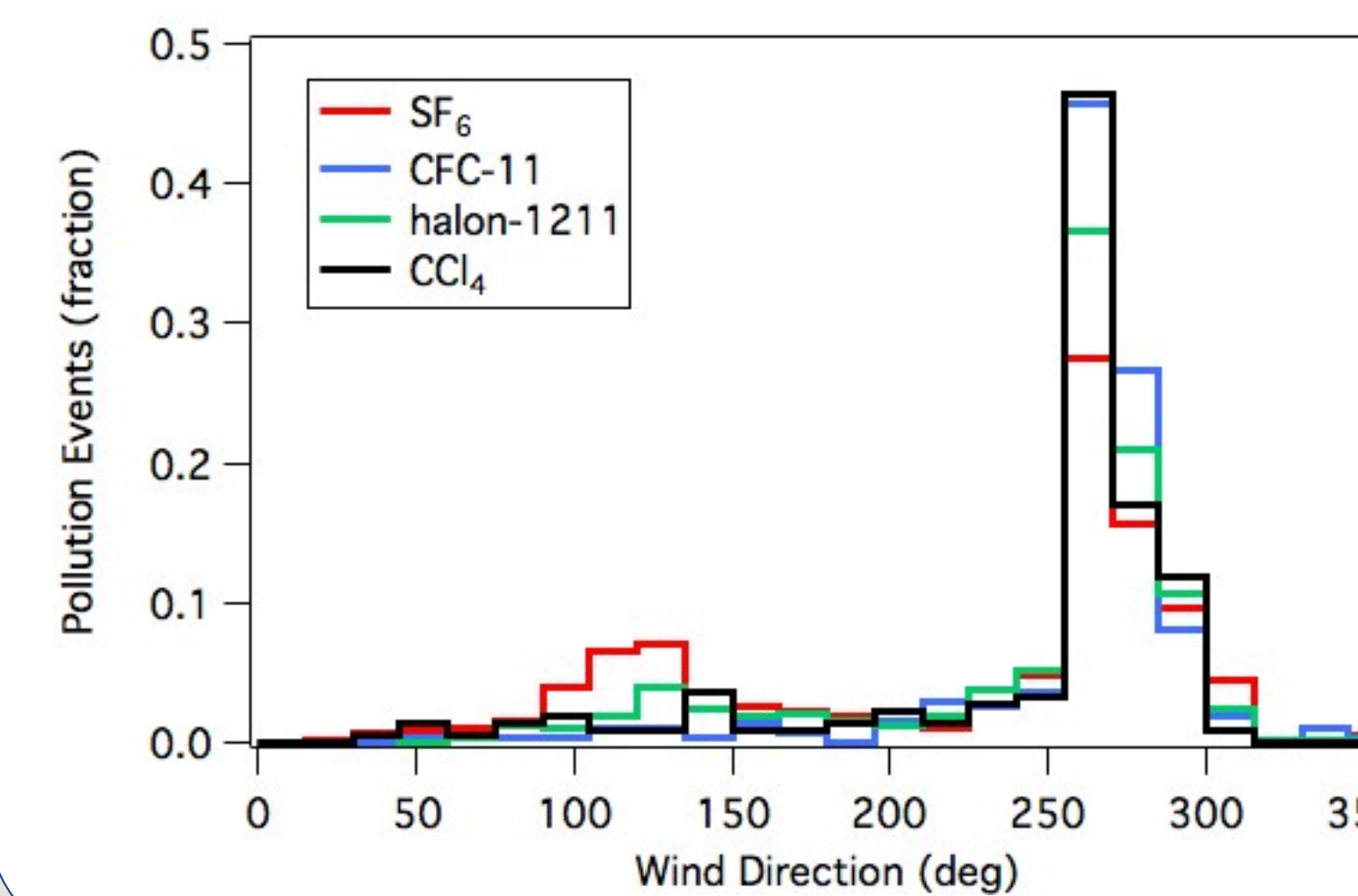
Pollution Frequency and Direction



About 75% of the pollution events are after noon and through out the evening.

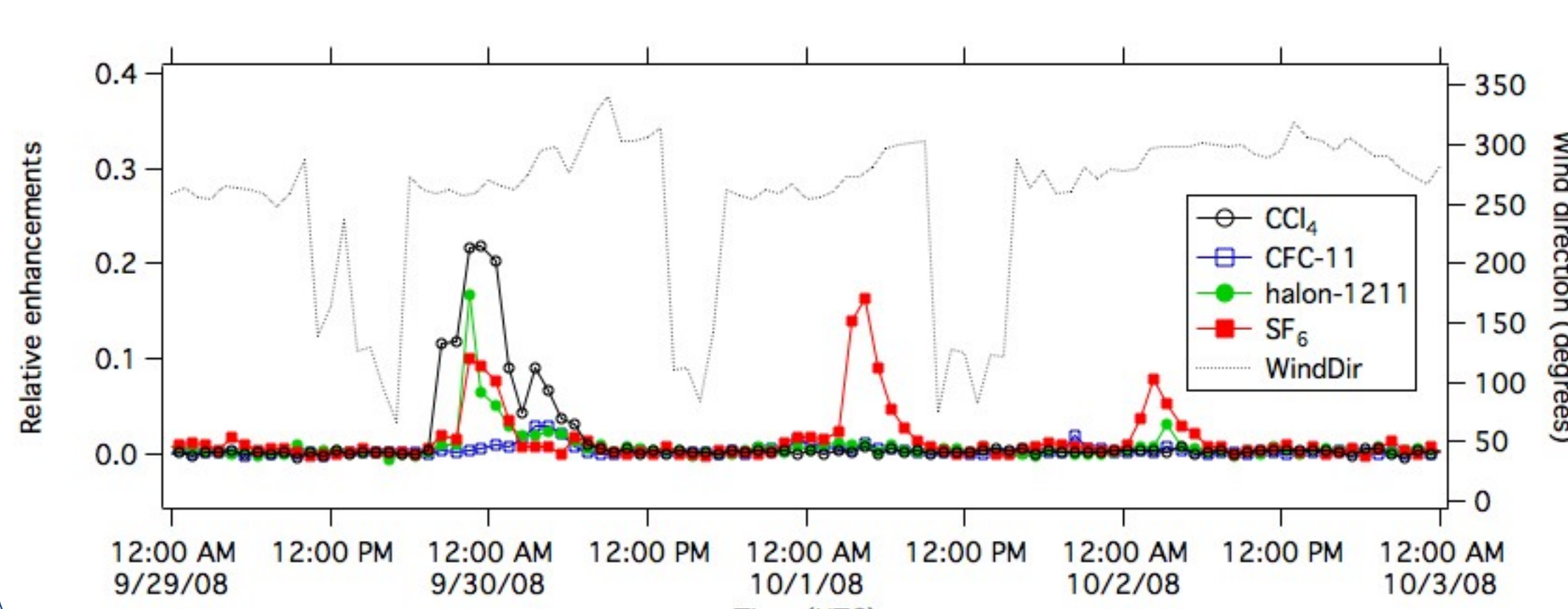
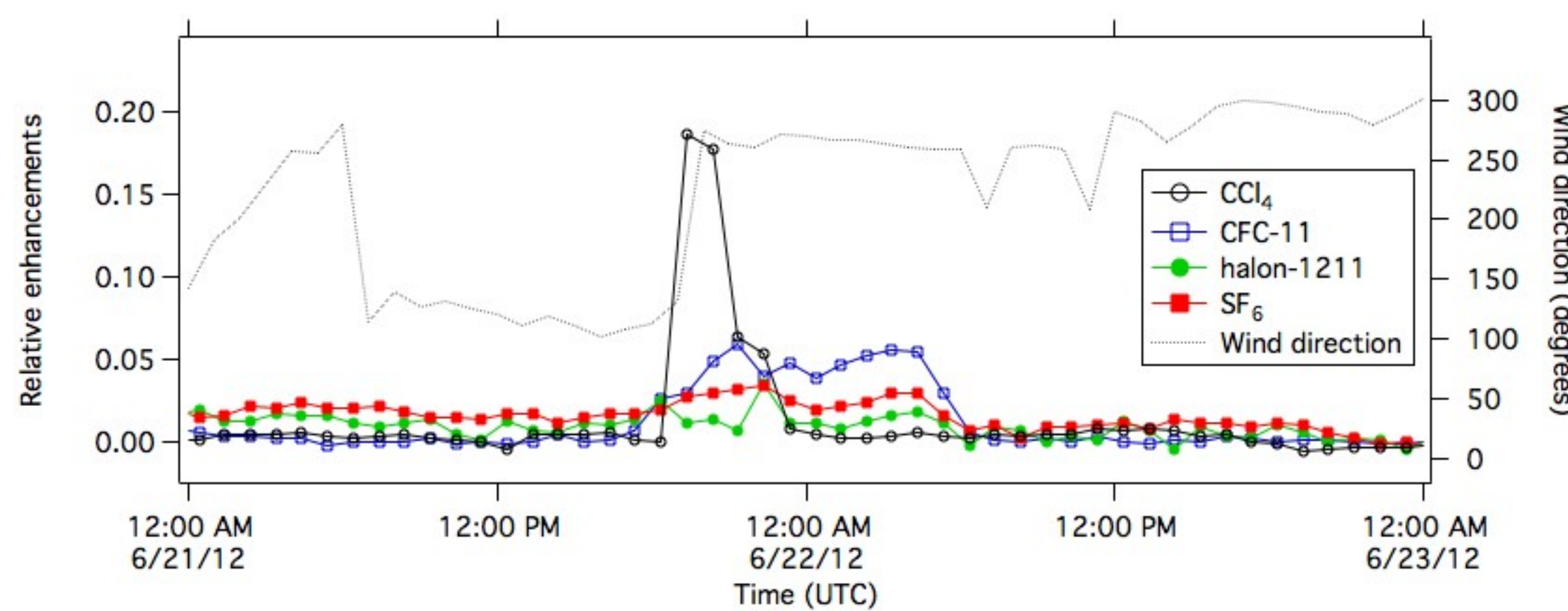
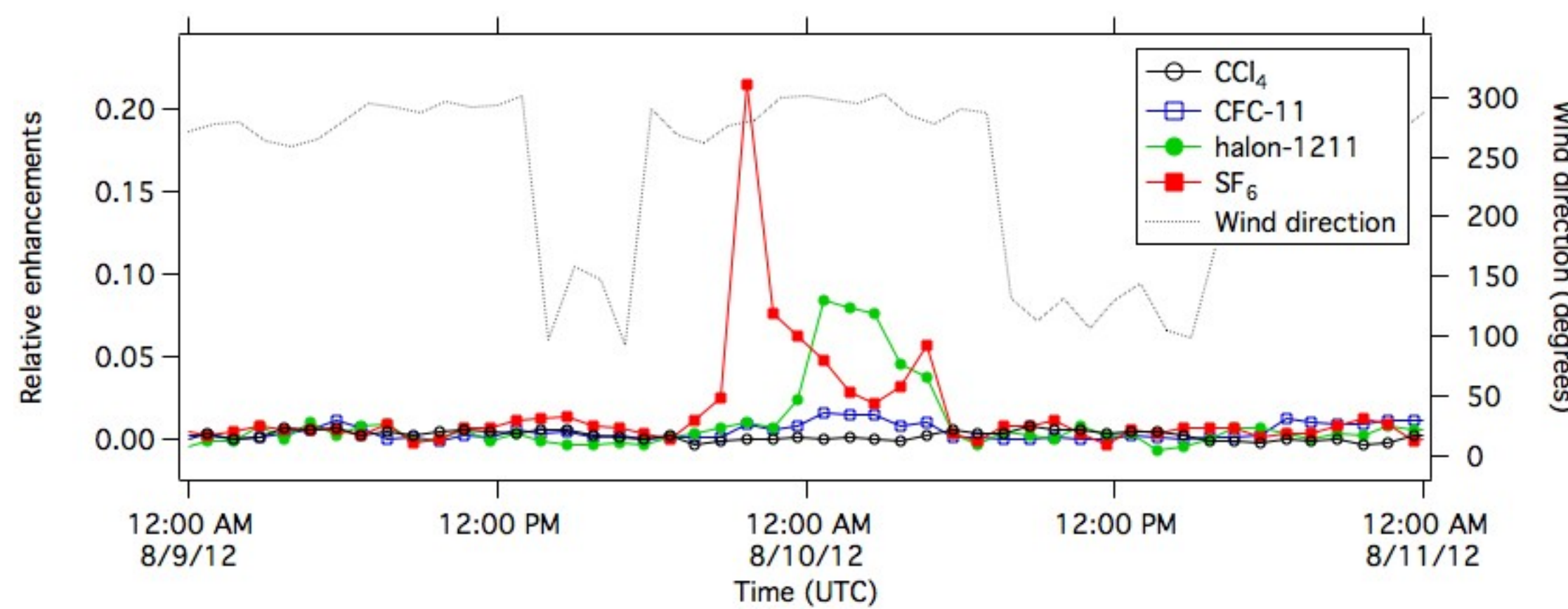


There are fewer pollution events in the winter. CFC-11 sources are industrial air conditioners possibly leading to a maximum of events in the summer time.

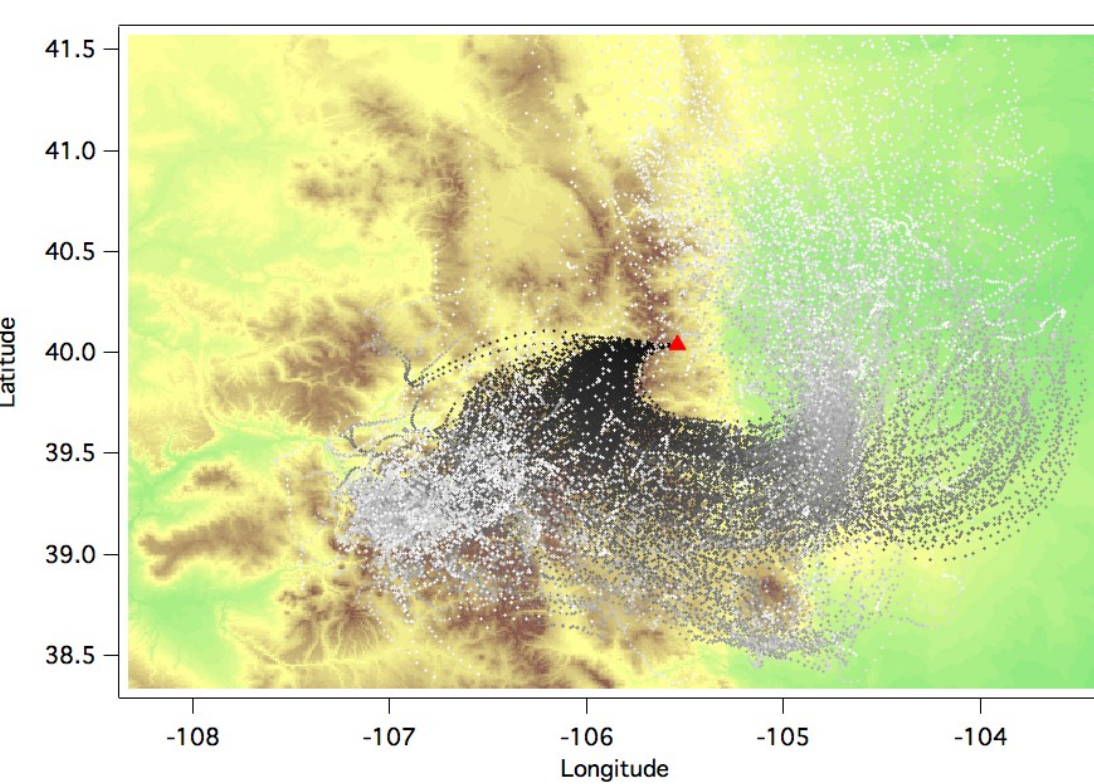


Nearly all of the pollution events are observed when the local wind direction is from the west and wind speeds are below 5 m/s. Trajectories indicate air originating less than 24 hours prior was typically over the Denver and front range metro area (see trajectories)

Individual Pollution Events



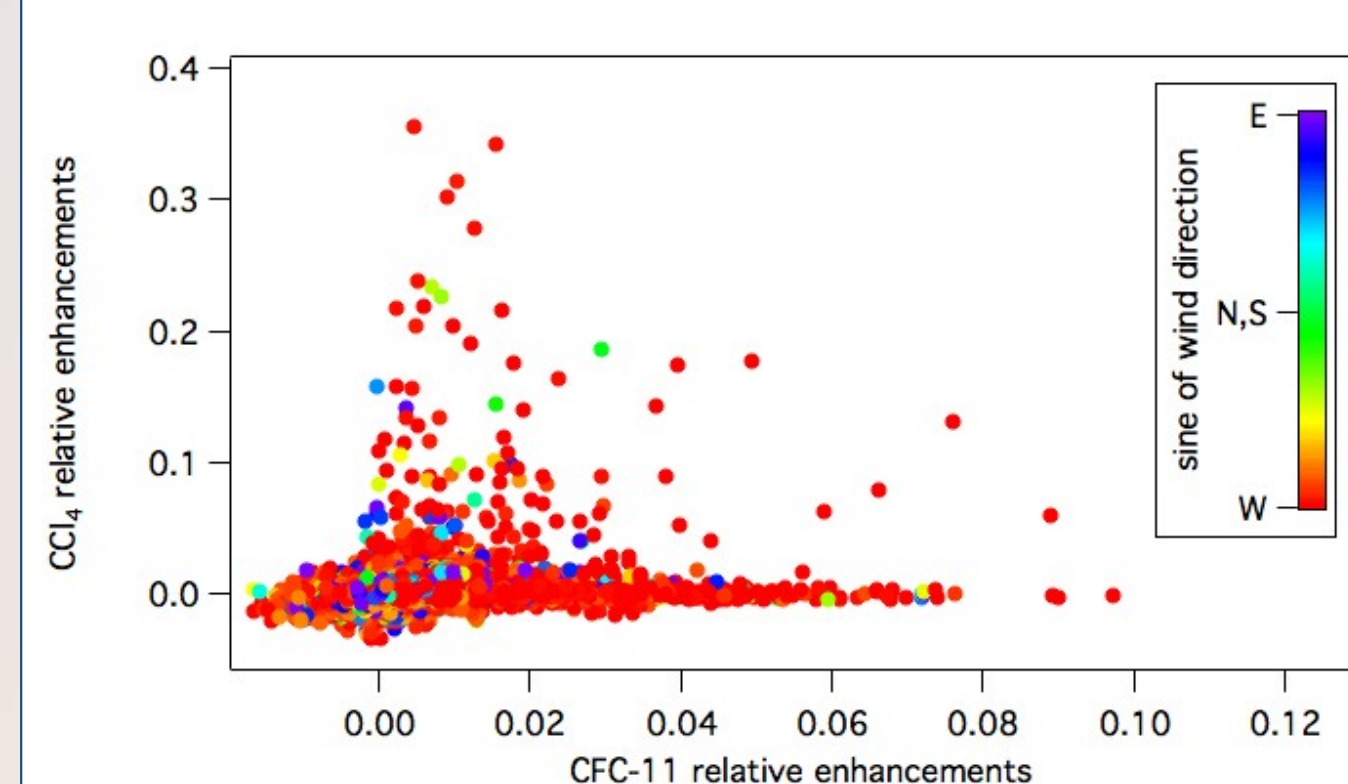
To the left are examples of typical pollution events. Most last from 6-12 hours in the afternoon through the night and contain several compounds indicative of urban air. However, local wind direction shows these events typically come from the west, in the opposite direction of the Denver/Boulder urban corridor.



HYSPPLIT trajectories

The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPPLIT) model driven by the Weather Research & Forecasting (WRF) model is used to investigate backward trajectories. Shown above are 500 particles on 9th of August 2012 1400 UTC and their paths for the previous 24-hours (the scale is black starting at 1 hour and white at 24 hours). These trajectories show in certain circumstances air can originate from the Front Range urban corridor and be swept to the south and back around to the west of Niwot Ridge.

Correlations



The figure above shows the correlation of CCl₄ to CFC-11. Though there are fewer CCl₄ pollution events than CFC-11, most of these events are weakly correlated with enhancements of CFC-11. The color code is the sine function of local wind direction. Most enhancements come from west (red).

Summary

- ✦ The GC at the Niwot Ridge C1 site measures pollution events occasionally (1-2% of the samples) in at least four gases with anthropogenic sources.
- ✦ Most of these events are seen when the local wind direction is from the west away from the Denver metro area.
- ✦ Certain meteorological conditions can sweep urban pollution around the C1 site and appear in westerly winds.
- ✦ Further analysis of WRF-HYSPPLIT trajectories may help quantify regional emissions.