The CARVE Tower and the Barrow Observatory:
Ground-based trace gas observing systems for detection of Arctic and Boreal change

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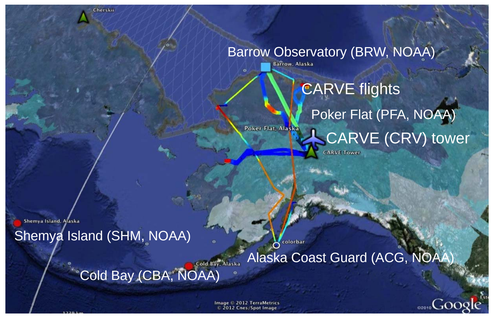
1.Background

The large reservoir of below-ground organic carbon in the Arctic and Boreal region (ABR) permafrost, combined with large observed and predicted temperature changes, leads to the expectation of increasing surface emissions of CO_2 and/or CH_4 this century. However, the near-term response of northern ecosystems could be enhanced ecosystem productivity and carbon sequestration via, among other causes, longer growing seasons and encroachment of woody species into Arctic tundra. Regardless of the temporal evolution of carbon (both CO_2 and CH_4) sources and sinks in the ABR, monitoring these changes at regional (~10^5 – 10^6 km^2) scales using trace gas mixing and isotopic ratios will be a critical complement to detailed process-based studies at the plot scale and remote sensing of the land surface.

2. Measurements

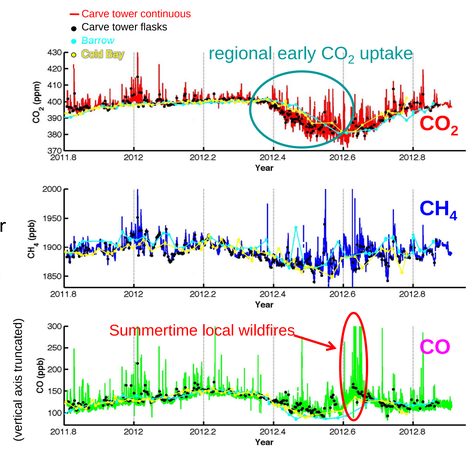
We have deployed a trace-gas measurement system capable of daily or more frequent observations of more than 50 trace gas species, including CO_2, CH_4 and their stable and radioactive isotopic ratios. The measurements were initiated as part of the Carbon in Arctic Reservoirs Vulnerability Experiment (**CARVE**) and come from a 30 m tower located on a ridge in central Alaska. Measurements at NOAA's Barrow Observatory have been ongoing since 1971 (CO_2) and 1986 (CH_4).



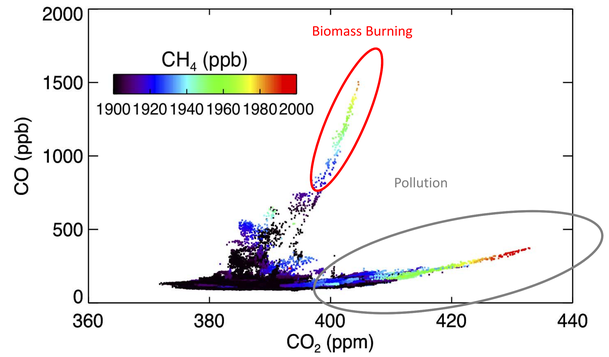
The CARVE tower is a valuable addition to the CARVE aircraft flights, the NOAA ACG flights (see flight tracks), and other NOAA global network sites, including Barrow Observatory (BRW).

3. Annual Cycle

Time series for one full year of measurements at the CARVE tower outside Fairbanks. Incidents of high CO (>1000 ppb) occurred during a local fire in the summer of 2012. Colored lines and black points are CARVE tower data; the Barrow (light blue) and Cold Bay (yellow) data are shown for comparison. The regional signal in CO_2 is apparent in the early uptake compared with Barrow and Cold Bay, while CH_4 does not differ significantly.

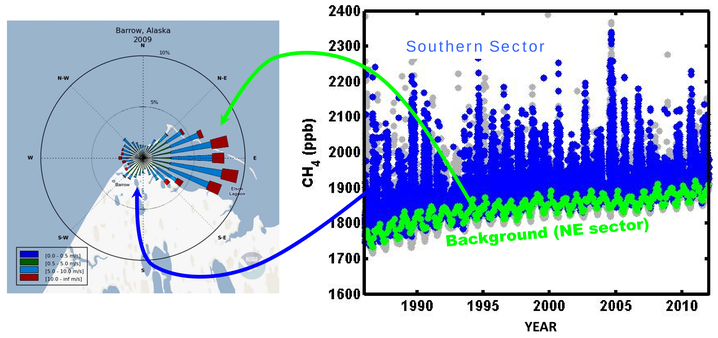


4. CARVE Tower (Fairbanks): CO vs. CO_2



One full year of measured CO mole fraction as a function of CO_2 mole fraction (left) highlights two source categories – local summertime fires and wintertime combustion related pollution from the nearby city of Fairbanks.

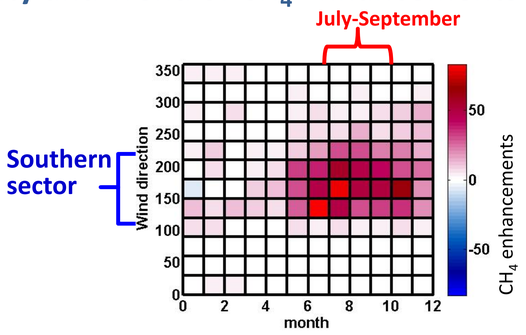
5. Barrow: CH_4 Enhancements by Wind Sector



Southern sector (blue) shows consistent enhancement above background (green).

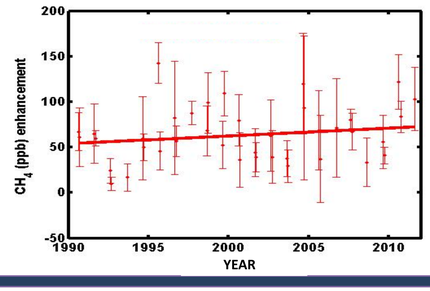
6. Barrow: Seasonality and Trend of CH_4 Enhancements

Average enhancements of >70 ppb from the southern sector in July, August, September (right). The strong seasonality suggests that the CH_4 emissions are mostly from biogenic sources, such as wetlands or permafrost thaw. They are likely to be more active in summer and early fall. Methane from natural gas usage and extraction is unlikely to be very seasonal.



The CH_4 enhancements from the Southern sector over background show (perhaps) a slight trend over the past 20 years (~0.9/yr) (right).

The temperature at Barrow has warmed significantly trended upwards during the same period.



7. Conclusions

We present trace gas measurements from a 30-m tower outside Fairbanks, AK for one full calendar year beginning in October 2011. Footprint analysis (not shown) suggests that mole fractions measured at the tower are influenced by large swaths of central Alaska, although in winter anthropogenic emissions from the city of Fairbanks are evident. In summer, as expected, we observe a large drawdown of CO_2. Our continuous tower measurements complement the episodic aircraft flights for the detection of trace gas emissions expected from warming permafrost.

NOAA's Barrow Observatory, where CH_4 has been measured since 1986, puts the CARVE Tower measurements into temporal and spatial context. A wind sector analysis of the Barrow CH_4 measurements indicates that CH_4 enhancements from the Southern sector are mostly of biogenic origin and may have trended slightly upwards for the past 20 years.

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