Objective and Transparent Quantification of Emissions

Pieter Tans, NOAA Earth System Research Laboratory, Boulder, CO
Scott Lehman, Institute for Arctic and Alpine Research, University of Colorado, Boulder, CO

For more than four decades NOAA has operated the world's largest atmospheric observing system for greenhouse gases. It is now called the Global Greenhouse Gas Reference Network (GGGRN). We measure the atmospheric distribution and trends of the three primary long-term drivers of climate change, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as carbon monoxide (CO), which is an important indicator of air pollution. The measurement program includes around-the-clock measurements at four baseline observatories and eight tall towers, while discrete air samples are regularly collected by volunteers at more than 50 ground sites and from small aircraft, mostly in North America. Samples are returned to Boulder for analysis and up to ~55 trace gases are measured, all subject to stringent quality control procedures. The results are directly traceable to globally accepted calibration scales where possible. In fact, GGGRN maintains the World Meteorological Organization (WMO) calibration scales for CO_2, CH_4, CO, N_2O, and SF_6 -in-air. This enables the international community to merge their data, greatly increasing the value of each data set and the whole.

GGGRN produces authoritative and well-documented data that are universally used by international climate scientists and policy makers. The network was started in the early 1970s to create a record of increasing greenhouse gases (GHGs). The emergent spatial patterns, along with models of atmospheric transport derived from weather forecasts, permit us to estimate the magnitudes of emissions and removals of GHGs at large spatial scales. In this way we're able to track how uptake and release from the oceans and terrestrial ecosystems is responding to climate change and to direct human activities. This effort includes, for example, monitoring the response of Arctic ecosystems to permafrost melting and the response of the Amazon to drought.

Since 1990 INSTAAR has collaborated very closely with NOAA by making very precise measurements of isotopic ratios of CO_2 and CH_4. The ratios retain information about the sources. For example, CO_2 from the oceans is slightly enriched in ^{13}C relative to CO_2 coming from terrestrial ecosystems. Similarly CH_4 from oil and gas is enriched in ^{13}C relative to CH_4 from rice fields, natural wetlands and life stock. The two laboratories operate as a single tightly integrated observing system.

In the 2015 Paris climate accord, most nations committed to substantial emissions reductions while in the U.S. several states and many cities remain committed to these reduction targets. Progress towards targets is based on self-reporting, using economic statistics and other "on the ground" emissions accounting methods. A physical quantification method, based on what is actually observed in the atmosphere, and which is fully transparent and can be replicated, would help to facilitate trust in agreements and to evaluate the effectiveness of related policies. In the case of CO_2, the observed variations are a mixture of recent fossil fuel emissions on the one hand, and uptake and release by plants and soils on the other. The only technique that cleanly separates the two is radiocarbon (^{14}C) in CO_2. This is due to the fact that CO_2 from combustion of fossil fuels, formed from organic material millions of years old, is ^{14}C free, while CO_2 from natural terrestrial sources and from the oceans has very nearly the same ^{14}C fraction as the atmosphere. Thus small ^{14}C dilutions downwind of cities provide a quantitative estimate of the component of CO_2 from recent fossil fuel burning. ^{14}C makes fossil CO_2 "visible". We have been making these measurements at the required high accuracy since 2005. Expanding the NOAA sampling network and obtaining a dedicated Accelerator Mass Spectrometer (AMS) to deliver ~5000 such high accuracy measurements per year has been identified by the U.S. *National Academy* as the most reliable means of quantifying U.S. national and regional emissions of CO_2 from fossil fuel use. Indeed, observing system simulation experiments indicate with such sample coverage, changes in U.S. national and regional emissions can be quantified to an accuracy of 1% in one year. The system model is global in scope, allowing for international emissions verification if sample coverage were expanded. Similarly, emissions from individual states and large cities can be monitored if sampling is further concentrated in these areas.

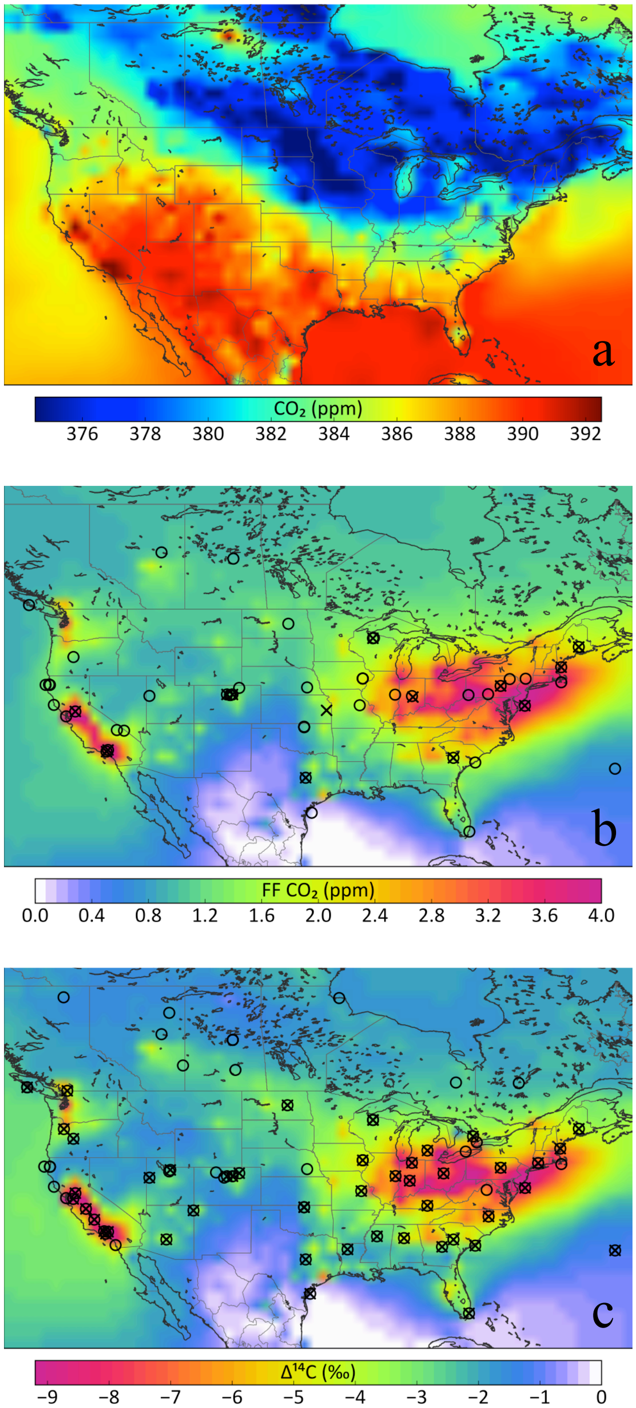

Figure 1. Near surface distributions of total CO_2 (*a*), fossil fuel derived CO_2 (*b*), and D^{14}C (*c*) over N. America for July 2010 from NOAA *CarbonTracker,* with current (*b*) and planned (*c*) sampling sites. ^{14}C (in CO_2) provides a measurement field that can be traced back to emissions at the surface. Satellites produce vertical column integrals in which signals from surface emissions as in (a) are strongly diluted and in any case, cannot separate fossil (b) from biological emissions/removals.

Further information on the web:

www.esrl.noaa.gov/gmd/ccgg/

instaar.colorado.edu/research/labs-groups/stable-isotope-laboratory/

www.esrl.noaa.gov/gmd/ccgg/trends/

www.esrl.noaa.gov/gmd/ccgg/carbontracker/

instaar.colorado.edu/research/labs-groups/laboratory-for-ams-radiocarbon-preparation-and-research/