Global Greenhouse Gas Reference Network

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

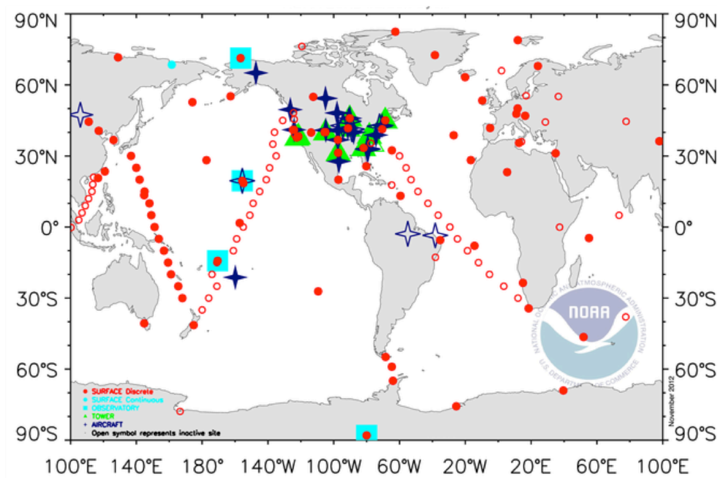

Figure 1

The Global Greenhouse Gas Reference Network (GGGRN) measures the atmospheric distribution and trends of the three main 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 4 baseline observatories (Figure 1, light blue squares) and 8 tall towers (green triangles), air samples collected by volunteers at more than 50 sites (red dots), and air samples collected regularly from small aircraft mostly in North America (dark blue crosses). The air samples are returned to Boulder for analysis. Up to ~55 trace gases are measured, all subject to stringent quality control procedures. The results are directly traceable to internationally accepted calibration scales where possible. In fact, NOAA's GGGRN maintains the World Meteorological Organization (WMO) calibration scales for CO_2, CH_4, CO, N_2O, and SF_6 -in-air.

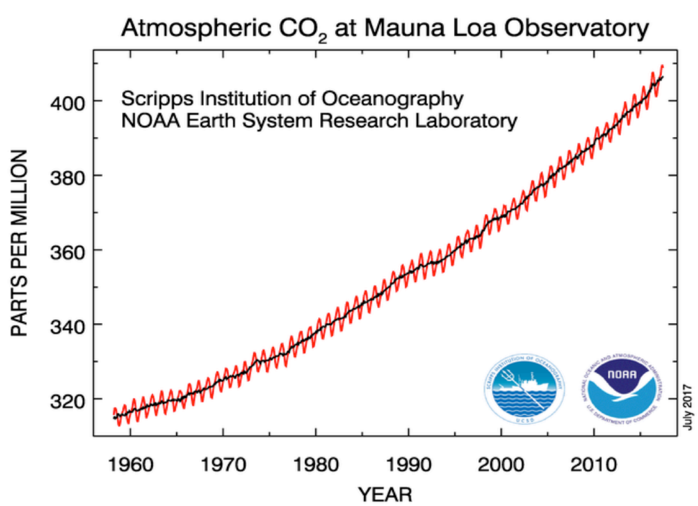

Figure 2

Monthly average carbon dioxide data at the oldest and most widely known observatory are plotted in Figure 2. The observed increase, due almost entirely to CO_2 emissions from fossil fuel burning, is similar everywhere else in the world. CO_2 remains in the atmosphere for a very long time, and emissions from any location will mix throughout the atmosphere in about one year. The annual oscillations are due to net CO_2 uptake during the growing season in the northern hemisphere. It is an amazing fact that global annual emissions of CO_2 from fossil fuel burning are larger than growing season *net* uptake by *all* crops, forests, grasslands, tundra, etc. in the northern hemisphere. The data also show that the CO_2 increase during both 2015 and 2016 was 3 ppm per year, the highest ever recorded. The average rate of increase over the last decade is at least 200 times faster than changes due to natural processes, as recorded in ice cores over the last 800,000 years.

The global network reveals spatial and temporal patterns of concentrations as a function of latitude and time (Figure 3). The warmer colors (purple, red, orange) indicate periods of higher-than-average growth rate and the cooler colors (blue, green) indicate periods of lower growth rate. The CO_2 growth rate growth rate varies from year to year with a trend toward higher values since 2000. The long-term increase of the CO_2 growth rate is due to increasing emissions from the combustion of fossil fuels. The latter remained at approximately the same record high level from 2012 through 2015. On top of this higher "baseline" there were two exceptional years, 2015 and 2016, each of which set new global temperature records. For CO_2 the 2015-16 "anomaly" appears to have been driven by tropical latitudes and northern mid-latitudes. The high growth rate observed during 2016 in the Arctic lags the mid-latitudes by several months. The emissions are spreading from mid latitudes to the Arctic, and are therefore likely not caused in the Arctic.

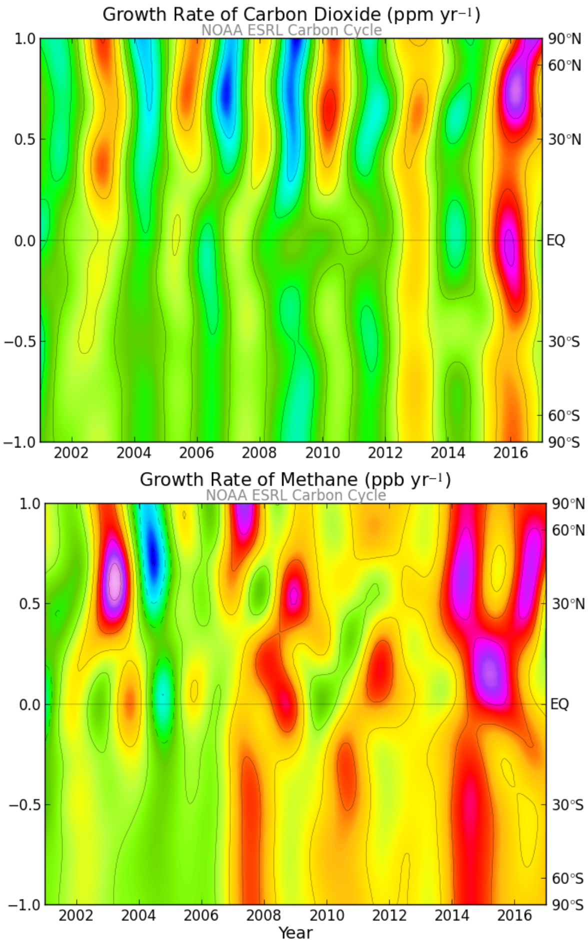

Figure 3

The CH_4 growth rate slowed during the 1990s and early 2000s, but has accelerated again during 2007-2016. The annual variations in the CH_4 growth rate are also related to climate anomalies. Analysis of the NOAA data suggests that most of increase since 2007 is related to greater than average precipitation in tropical regions resulting in above average emissions from tropical wetlands. For 2014-16 there is clearly also a strong northern mid-latitude component, but no evidence of increased emissions in the Arctic possibly due to warming of organic-rich permafrost soils and/or CH_4 hydrate accumulations, except perhaps in 2007. These measurements will serve as an early warning if Arctic warming gives rise to large emissions of CH_4 and CO_2, out of our direct control, as is being widely expected by scientists.

Understanding the processes that cause the CO_2 and CH_4 growth rate variations and long-term trends is crucial to enabling governments and society in general to make informed decisions on energy policy and on mitigating climate change. Long-term projections of CO_2, CH_4, and N_2O depend on future emissions trajectories, which include land use, and on climate feedbacks as they are incorporated in climate-ecosystem models. An example of the latter would be Arctic warming producing CH_4 and CO_2 emissions from melting permafrost. For the models to be credible, it is necessary (but not sufficient) that they reproduce the recent past as we have observed it.

The atmospheric (and other) data leave no doubt that the increases of CO_2, CH_4, and many other greenhouse gases are entirely due to human activities, and that our influence on the heat balance of the Earth continues to grow every year. (www.esrl.noaa.gov/gmd/aggi). The calibrated and well documented measurements of the GGGRN are freely available. They form the foundation of the WMO Global Atmosphere Watch program, by serving as a comparison with measurements made by more than 15 international laboratories, and with regional studies. They are universally used in studies inferring space-time patterns of emissions/removals of greenhouse gases that are consistent with the atmospheric observations. The calibrated observations are also indispensable for the ongoing evaluation of remote sensing technologies. Greenhouse gas abundances derived from optical absorption measurements from space can never be calibrated because one cannot control the abundance of the gases being estimated, nor can we control potential interfering factors in the optical path. Systematic biases need to be discovered and controlled to unprecedentedly stringent levels. This cannot be done without greatly expanded calibrated measurements. The U.S. and other nations have invested several billion dollars in satellite remote sensing for greenhouse gases, but at this point the investment may turn out to be mostly wasted.

Calibrated measurements are also necessary to provide objective and transparent estimates of area emissions, like cities and oil/gas plays. NOAA/ESRL participates in campaigns that target both. These estimates are independent of emissions inventories that are often self-reported. This capability is crucial to emissions reduction policies, both national and international. The addition of a large set of continuing carbon-14 measurements enables us to uniquely attribute CO_2 variations to fossil emissions, cleanly separated from all other (natural) sources.