



Global Greenhouse Gas Reference Network

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

The Global Greenhouse Gas Reference Network measures the atmospheric distribution and trends of the three main long-term drivers of climate change, carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), as well as carbon monoxide (CO) which is an important indicator of air pollution. The Reference Network is a part of NOAA's Earth System Research Laboratory in Boulder, Colorado. 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. All measurements of up to ~55 trace gases are subject to stringent quality control procedures, and are directly traceable to internationally accepted calibration scales where possible. In fact, NOAA's Global Greenhouse Gas Reference Network maintains the World Meteorological Organization calibration scales for CO₂, CH₄, CO, N₂O, and SF₆ in air.

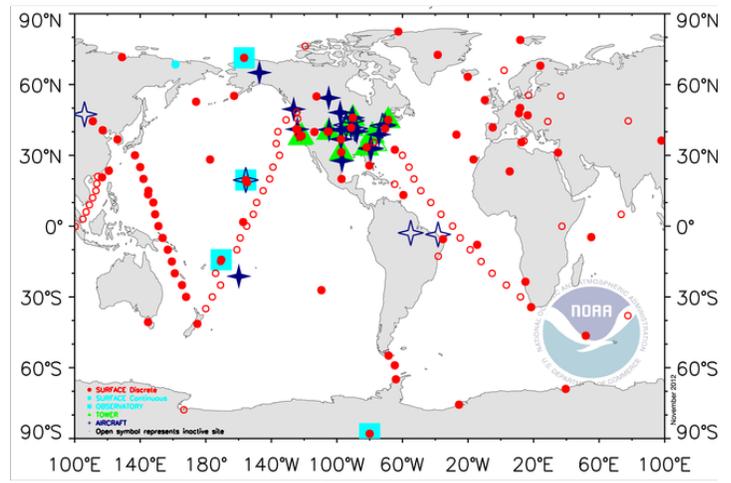


Figure 1

Monthly average carbon dioxide data for the four baseline observatories are plotted in Figure 2. The observed increase, due primarily to CO₂ emissions from fossil fuel burning, is similar at all four remote locations. CO₂ remains in the atmosphere for a very long time, and emissions from any location mix throughout the atmosphere in about one year. The annual oscillations at the two northern hemisphere sites (Barrow, Alaska and Mauna Loa, Hawaii) are due to the seasonal imbalance between the photosynthesis and respiration of plants on land. During the summer photosynthesis exceeds respiration and CO₂ is removed from the atmosphere, whereas outside the growing season respiration exceeds photosynthesis and CO₂ is returned to the atmosphere. The seasonal cycle is strongest in the northern hemisphere because of the presence of the continents. The difference between Mauna Loa and the South Pole has increased over time as the global rate of fossil fuel burning, most of which takes place in the northern hemisphere, has accelerated.

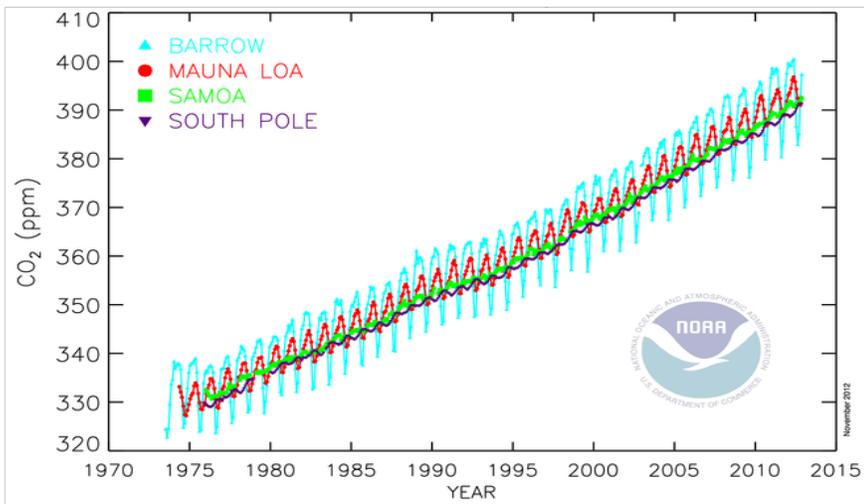


Figure 2

CO₂ is returned to the atmosphere. The seasonal cycle is strongest in the northern hemisphere because of the presence of the continents. The difference between Mauna Loa and the South Pole has increased over time as the global rate of fossil fuel burning, most of which takes place in the northern hemisphere, has accelerated.

A quantity of keen interest for each trace gas is the global-average rate of increase (“growth rate”). The CO₂ and CH₄ growth rates are plotted as a function of time and latitude in Figure 3. The warmer colors (yellow, orange) indicate periods of higher-than average growth rate and the cooler colors (purple, black) indicate periods of lower growth rate. The CO₂ growth rate varies from year to year with a trend toward higher growth

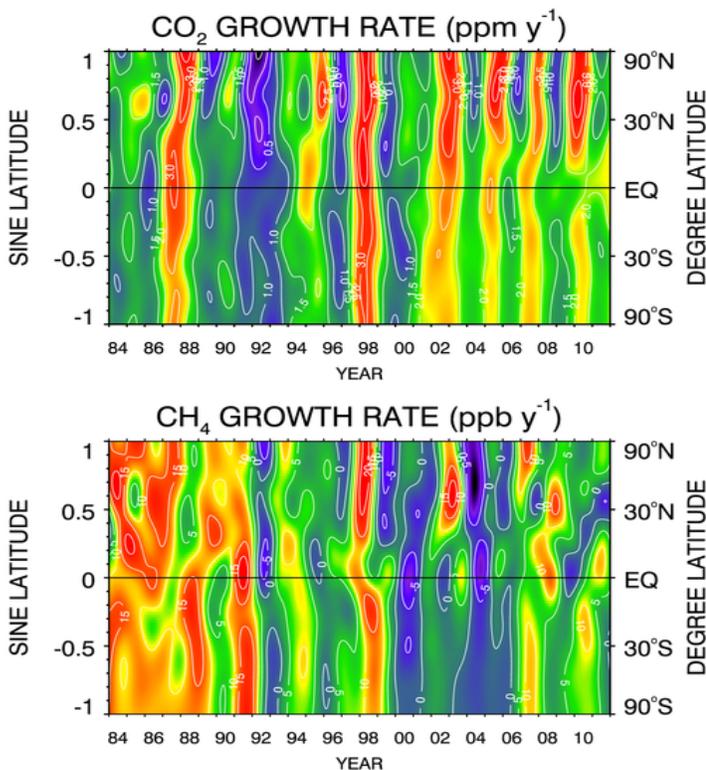


Figure 3

resulting in above average emissions from tropical wetlands.

Understanding the processes that cause the CO₂ and CH₄ growth rate variations and long-term trends is crucial to enable governments and society in general to make informed decisions on energy policy and on mitigating climate change. Long-term projections of CO₂, CH₄, and N₂O depend on future emissions trajectories, which include land use, and on climate feedbacks as they are incorporated into climate-ecosystem models. An example of the latter would be Arctic warming producing CH₄ and CO₂ emissions from melting permafrost, out of our control. 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 CO₂, CH₄, 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 (www.esrl.noaa.gov/gmd/aggi). The carefully calibrated and documented measurements of the Global Greenhouse Gas Reference Network are freely available. They serve as a comparison with measurements made by many other international laboratories, and with regional studies. They are widely used in studies inferring space-time patterns of emissions and removals of greenhouse gases that are optimally consistent with the atmospheric observations. They serve as an early warning for climate “surprises”. 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.

rates since 2000. The CH₄ growth rate slowed during the 1990s and early 2000s, but has accelerated again during 2007-2010.

The annual variations of the CO₂ growth rate are not due to variations in fossil fuel emissions. Figure 4 shows the measured annual atmospheric increase of CO₂ compared to the reported annual fossil fuel emissions. The ups and downs in the atmospheric increase are due to variations in the exchange of CO₂ between the atmosphere, oceans, and land ecosystems. They are primarily due to small annual fluctuations of temperature and precipitation affecting photosynthesis and respiration on land. It is very important to know that the added CO₂ does not disappear, but a portion of it transfers each year from the atmosphere to the oceans and to plants on land. Since CO₂ is an acid, the transfer to the oceans causes the surface oceans to acidify.

The variations in the CH₄ growth rate (Figure 3) are also related to climate anomalies. Analysis of the NOAA data suggests that the recent increase is related to greater-than-average precipitation in tropical regions

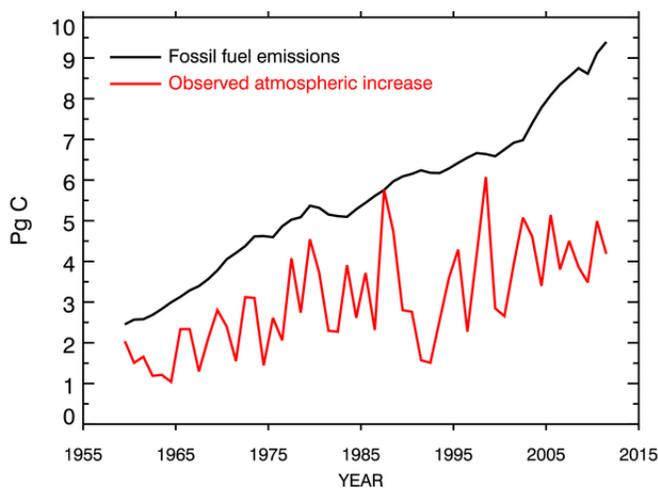


Figure 4