



# The NOAA Annual Greenhouse Gas Index (AGGI)

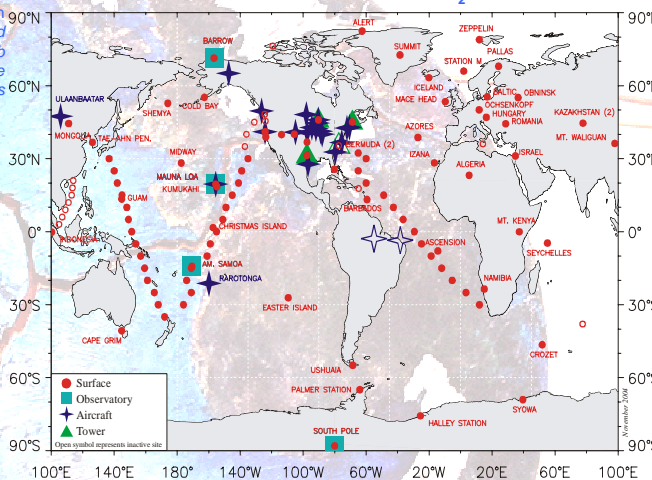
David Hofmann, James Butler, Thomas Conway, Edward Dlugokencky, James Elkins, Kenneth Masarie, Stephen Montzka, Russell Schnell, and Pieter Tans  
NOAA Earth System Research Laboratory, Boulder, Colorado, USA

**Abstract.** For the past 30 years, the U.S. National Oceanic and Atmospheric Administration (NOAA) has monitored climate-forcing and ozone-depleting atmospheric gases. These global measurements have provided input to climate and ozone assessments (e.g., the quadrennial IPCC Climate Reports and WMO/UNEP Ozone Assessments). Recently, efforts to make these data more useful and available have been undertaken through release of the NOAA Annual Greenhouse Gas Index (AGGI), <http://www.esrl.noaa.gov/gmd/aggi> and the Ozone Depleting Gas Index (ODGI) <http://www.esrl.noaa.gov/gmd/odgi>. These indices are designed to enhance the connection between scientists and society by providing a normalized standard that can be easily understood and followed. Measurements are made at baseline climate observatories (Pt. Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and the South Pole) and flask air samples are collected through global networks, including an international cooperative program for carbon gases. The concept of radiative climate forcing is used to determine the AGGI, which is normalized to 1.00 in 1990, the Kyoto Climate Protocol baseline year. For the year 2006, the AGGI was 1.23, i.e. global radiative forcing by long-lived greenhouse gases has increased 23% since 1990. As will be emphasized, the increase in carbon dioxide (CO<sub>2</sub>) alone was about 32% over this time interval. Reductions in the growth rates of methane and the CFCs have effectively tempered the increase of CO<sub>2</sub> since 1990.

## RADIATIVE FORCING OF CLIMATE

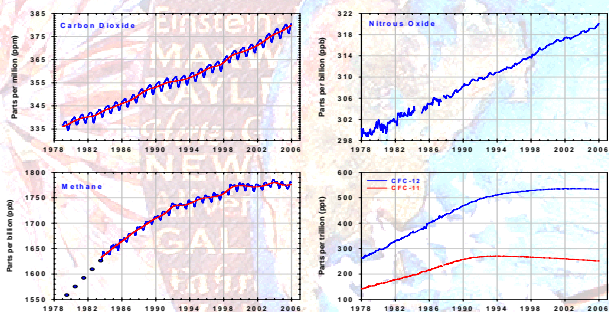
IPCC: An externally imposed perturbation in the radiative energy budget of the Earth climate system, e.g. through changes in solar radiation, changes in the Earth albedo, or changes in atmospheric gases and aerosol particles. *The perturbation that has the largest magnitude and the least scientific uncertainty is the forcing related to changes in atmospheric gases that absorb Earth infrared radiation (greenhouse gases) and that are long-lived and well-mixed in the atmosphere. These "major" greenhouse gases are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and the halocarbons (mainly CFCs).*

## NOAA/ESRL GLOBAL COOPERATIVE CO<sub>2</sub> NETWORK

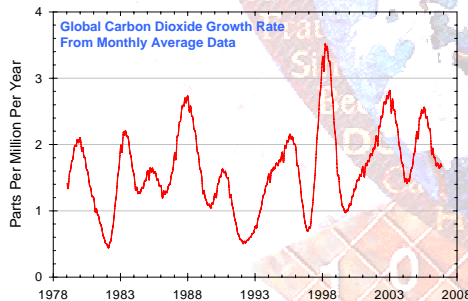
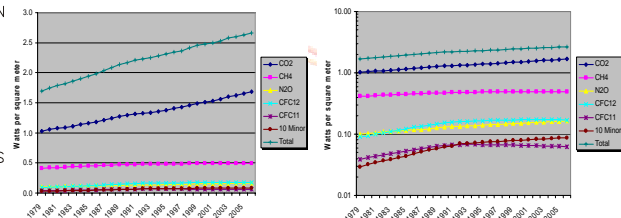


## RADIATIVE FORCING CALCULATIONS

IPCC recommended expressions determined from radiative transfer models are used to convert greenhouse gas changes since 1750 to instantaneous radiative forcing. Only the direct forcing has been calculated. The uncertainty in these estimates is of the order of 5-10%, providing a benchmark for climate forcing. Forcing by short-lived, poorly known species such as atmospheric aerosols and tropospheric ozone, as well as model-dependent indirect effects, have not been included.

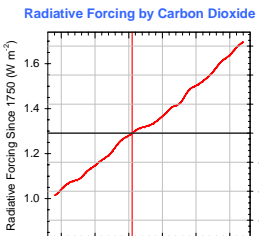
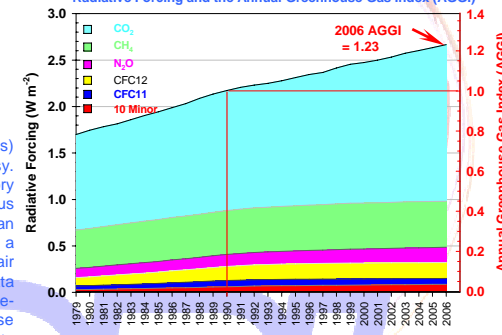


These five gases account for about 97% of the direct radiative forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HFC-22, CFC-113 and CCl<sub>4</sub>.



**Method.** Measurements of the long-lived greenhouse gases – carbon dioxide, methane, nitrous oxide and halocarbons (mainly CFCs) have minimal scientific uncertainty, being independent of climate models, and thus provide a climate benchmark free of controversy. All of these gases have been monitored around the world since the 1970's mainly by NOAA's Earth System Research Laboratory (ESRL), Global Monitoring Division (formerly CMDL), in Boulder, Colorado. To provide the data required for the AGGI, continuous measurements from five baseline climate observatories at Pt. Barrow, Alaska; Mauna Loa, Hawaii; Trinidad Head, California; American Samoa; and at the South Pole are maintained. In addition, flask air samples are collected through several global networks, including a cooperative program for carbon-containing and other greenhouse gases that provides samples from globally widespread clean air sites. All measurements are reported on World Calibration Scales, produced and maintained by NOAA/ESRL in Boulder. These data are used to calculate annual global average concentrations from which changes in radiative forcing of the global climate since the pre-industrial era (1750) for the 28-year period encompassing 1979 through 2006 are determined. This includes all major greenhouse gases and 10 minor halogenated gases. Results are normalized to radiative forcing in 1990, the baseline year for the Kyoto Climate Protocol, to produce the AGGI.

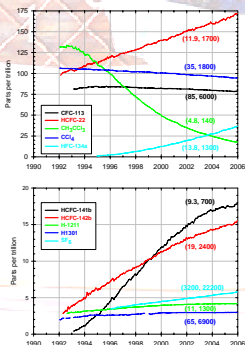
## Radiative Forcing and the Annual Greenhouse Gas Index (AGGI)



Radiative forcing by carbon dioxide, relative to 1750, has increased by about 32% since 1990.

## Minor Greenhouse Gases

Except for HFC-134a which does not contain chlorine or bromine (used in auto air conditioners), these gases are also ozone-depleting gases and are regulated by the Montreal Protocol. In the figure, the lifetime in years and the global warming potential (CO<sub>2</sub> = 1) are given in the brackets.



## SUMMARY AND CONCLUSIONS

- The Annual Greenhouse Gas Index (AGGI), defined as the ratio of the annual post-industrial radiative forcing by long-lived greenhouse gases to that which was present in 1990, was 1.23 for the year 2006, (an increase in total radiative forcing of 23% since 1990).
- Since 1990, the radiative forcing due to CO<sub>2</sub> alone has increased about 32%.
- Of the four major groups of long-lived greenhouse gases that contribute to radiative climate forcing, CO<sub>2</sub> and N<sub>2</sub>O are the only ones that continue to increase at a regular rate.
- The contribution to radiative forcing by methane and CFCs has been nearly constant or declining in recent years. As a consequence, the contribution to the annual increase in the total radiative forcing of long-lived greenhouse gases due to CO<sub>2</sub> is now over 90%, up from about 50% before 1990.
- Had the ozone-depleting gases not been regulated by the Montreal Protocol (1987) and its amendments, climate forcing is estimated to have been as much as 0.2 watt m<sup>-2</sup> higher, or about one-half of the increase in radiative forcing due to CO<sub>2</sub> alone since 1990.

## Interannual Variation in Radiative Forcing by Greenhouse Gases

