NOAA GMD Global Greenhouse Gas Reference Network

A Global Cooperative Air Sampling Network Used to Constrain Greenhouse Gas Budgets

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Global Cooperative Air Sampling Network

This network is designed to sample air representative of large well-mixed volumes of the atmosphere at low relative cost. It is well suited for quantitative assessment of the budgets of long-lived greenhouse gases and some reactive species over large spatial scales. Here we describe the sampling network and measurements and give examples of how the data are used.

Sampling

The NOAA GMD Global Cooperative Air Sampling Network started in the late 1960s and currently has 58 sites (Figure 1). Air samples are collected ~weekly by partners at sites in red with a portable sampler and glass flasks (Pictures 1-3). The samples are returned to Boulder, Colorado where pertinent sampling information is recorded into the GMD database.

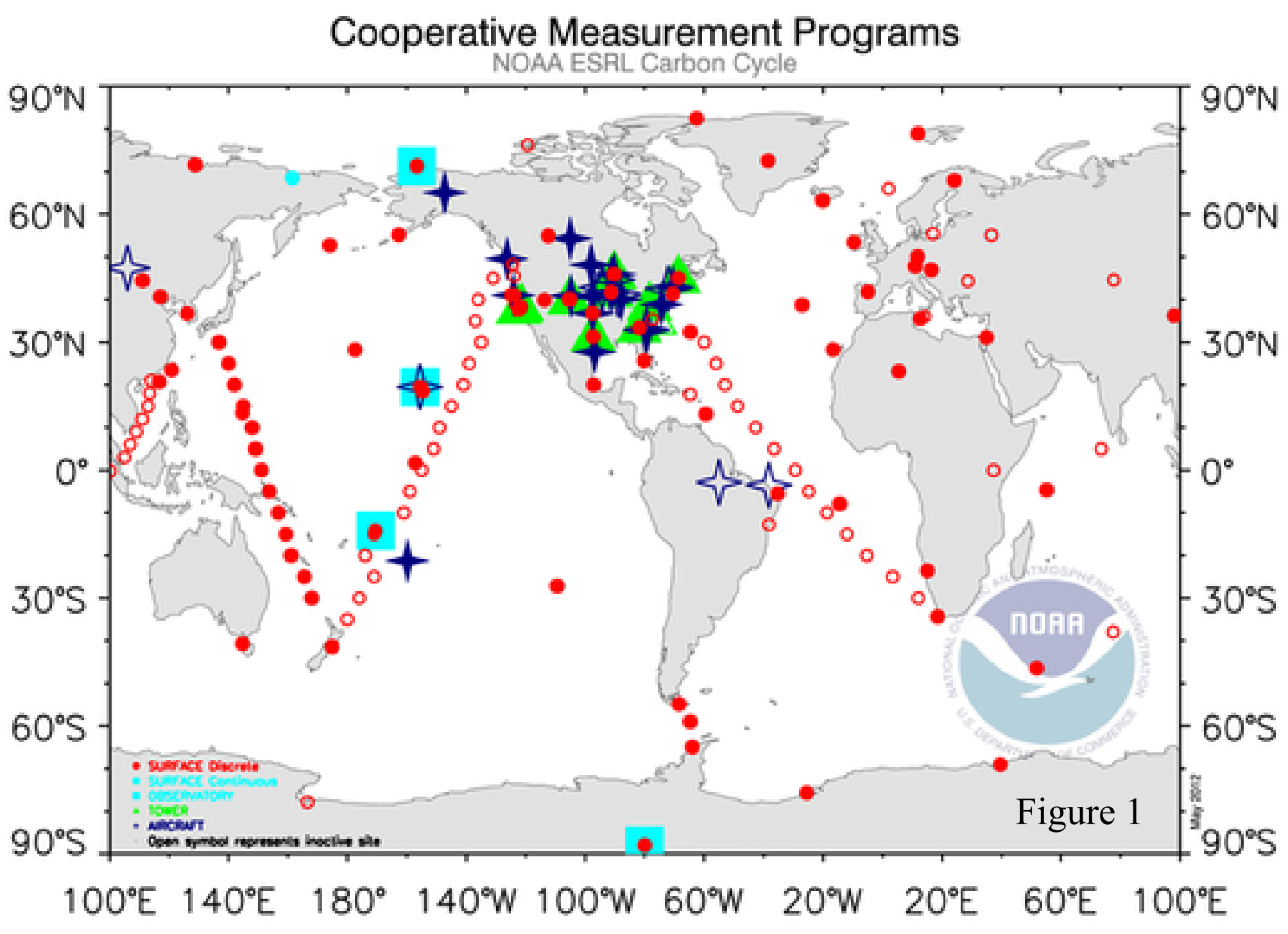

Figure 1

Picture 1: Summit Greenland

Picture 2: Sampler

Picture 3: Glass flasks

Measurements

Samples are typically measured for carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), and hydrogen (H_2) at GMD. Isotopes of CO_2, isotopes of CH_4, a sweet of non-methane hydrocarbons, and $^{14}CO_2$ are measured in some samples at the Institute for Arctic and Alpine Research (INSTAAR).

In addition to measuring atmospheric samples, we also routinely measure whole air in cylinders for quality control. An example is shown in Figure 2.

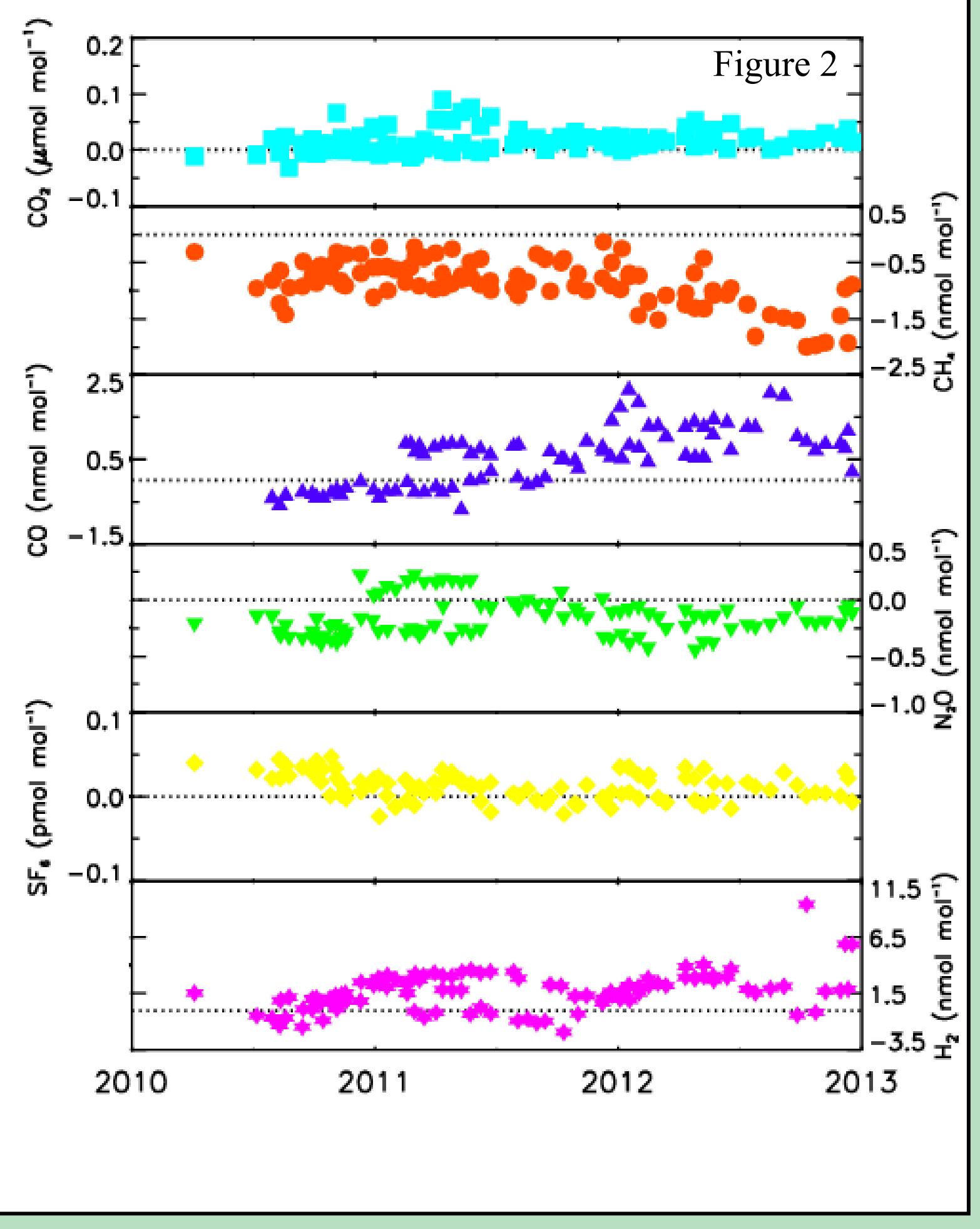

Figure 2

Identifying and Understanding Inter-Annual Variability

- Drivers of inter-annual variability (IAV) are changes in the balance between photosynthesis and respiration.
- $\delta^{13}CO_2$ shows clear signals from the terrestrial biosphere (Figure 3).
- Changes due to variability in ocean fluxes would have $\delta^{13}C$ signals that are a factor of 10 smaller.

Figure 3

Is the Sink for Fossil Fuel CO_2 Decreasing?

- Some studies have suggested declining regional sinks for fossil fuel CO_2.
- Figure 4 shows estimates of anthropogenic CO_2 emissions from inventories, the atmospheric increase in CO_2, and the CO_2 sink.
- A detailed analysis of NOAA and Scripps Institution of Oceanography (SIO) data shows that net global carbon uptake has increased significantly by about 0.05 PgC yr^{-1} and that global carbon uptake doubled, from 2.4±0.8 to 5.0±0.9 PgC yr^{-1} between 1960 and 2010*.

Figure 4*

*Adapted from Ballantyne et. al., Nature, 2012.

Latitude and Longitude Gradients

- Mean difference in CH_4 annual means between each site and South Pole from 1984-2008 are shown in Figure 5.
- The strong north to south gradient of ~150 ppb constrains the latitudinal distribution of CH_4 emissions.
- Longitudinal gradients are also evident. Pacific sites SHM and CBA are ~10 ppb greater than MHD in the Atlantic and BAL is ~10 ppb greater than the Pacific sites.

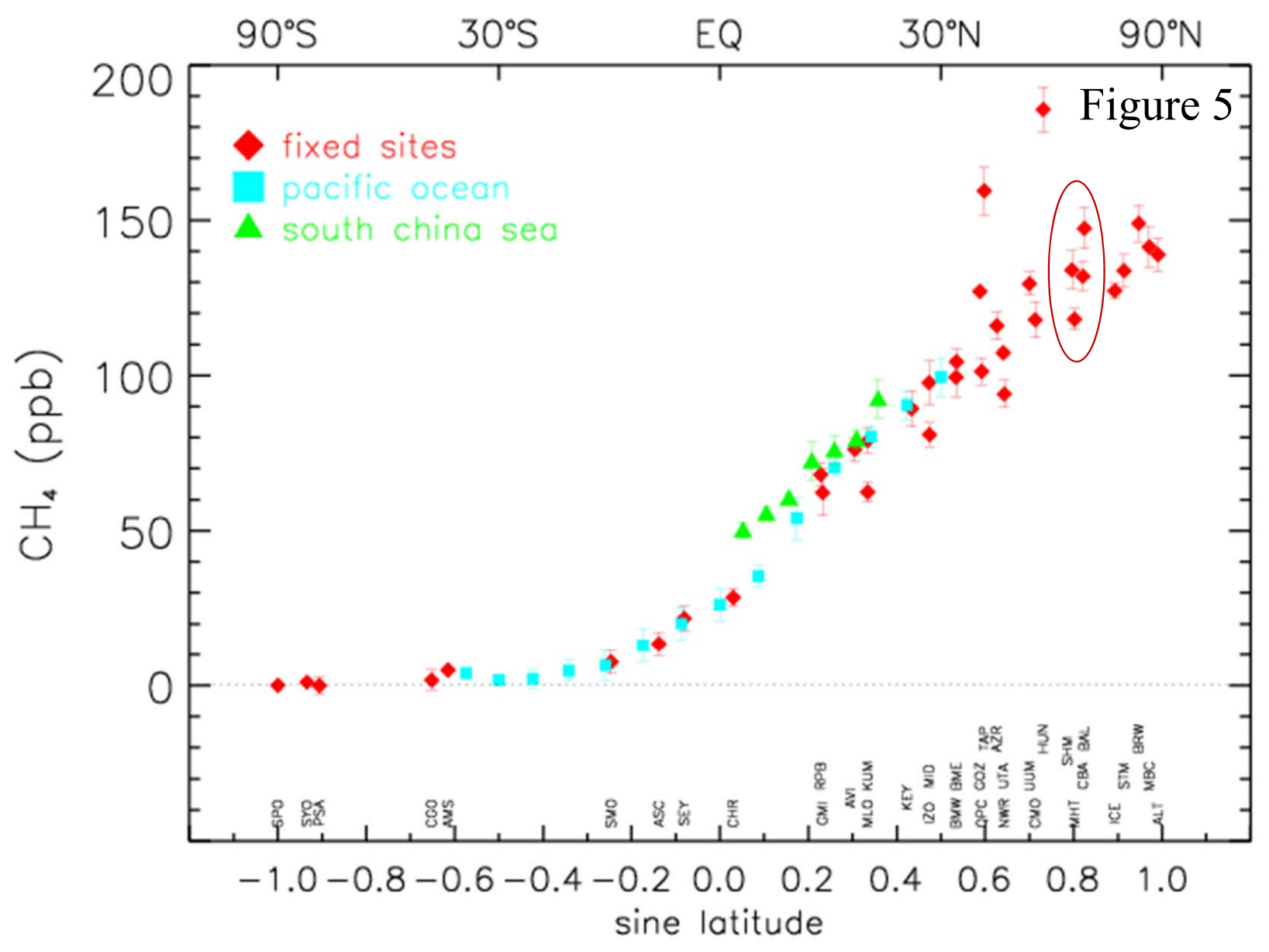

Figure 5

Constraining Total Global Methane Emissions

- Global annual emissions are calculated from:
  Annual Emissions = $d[CH_4]/dt$ + $[CH_4]/\tau$
  where terms in blue (atmospheric burden and its change with time) are from the observations and the lifetime (τ = 9.1 years) is based on CH_3CCl_3 (Figure 6).
- Also plotted in Figure 6 are emissions from a database (EDGAR) with constant annual natural emissions.
- Some variability is because of variability in CH_4 lifetime, not emissions.

Average Emissions = 559 ± 11 Tg CH_4
Trend = 0.5 ± 0.5 Tg CH_4 yr^{-1} (95% c.l.)

Figure 6

Verifying Reported Emissions

- The average rate of increase in the global burden of SF_6 has been 0.24 ppt yr^{-1} (Figure 7, top panel).
- SF_6 annual global emissions calculated from the observed annual atmospheric increases are compared with emissions reported by Annex I countries to the United Nations Framework Convention on Climate Change (UNFCCC) and emissions compiled by the Emission Database for Global Atmospheric Research (EDGAR) (Figure 7, bottom panel).
- Both underestimated emissions reported by Annex I countries and increasing emissions in non Annex I countries contribute to the poor agreement.

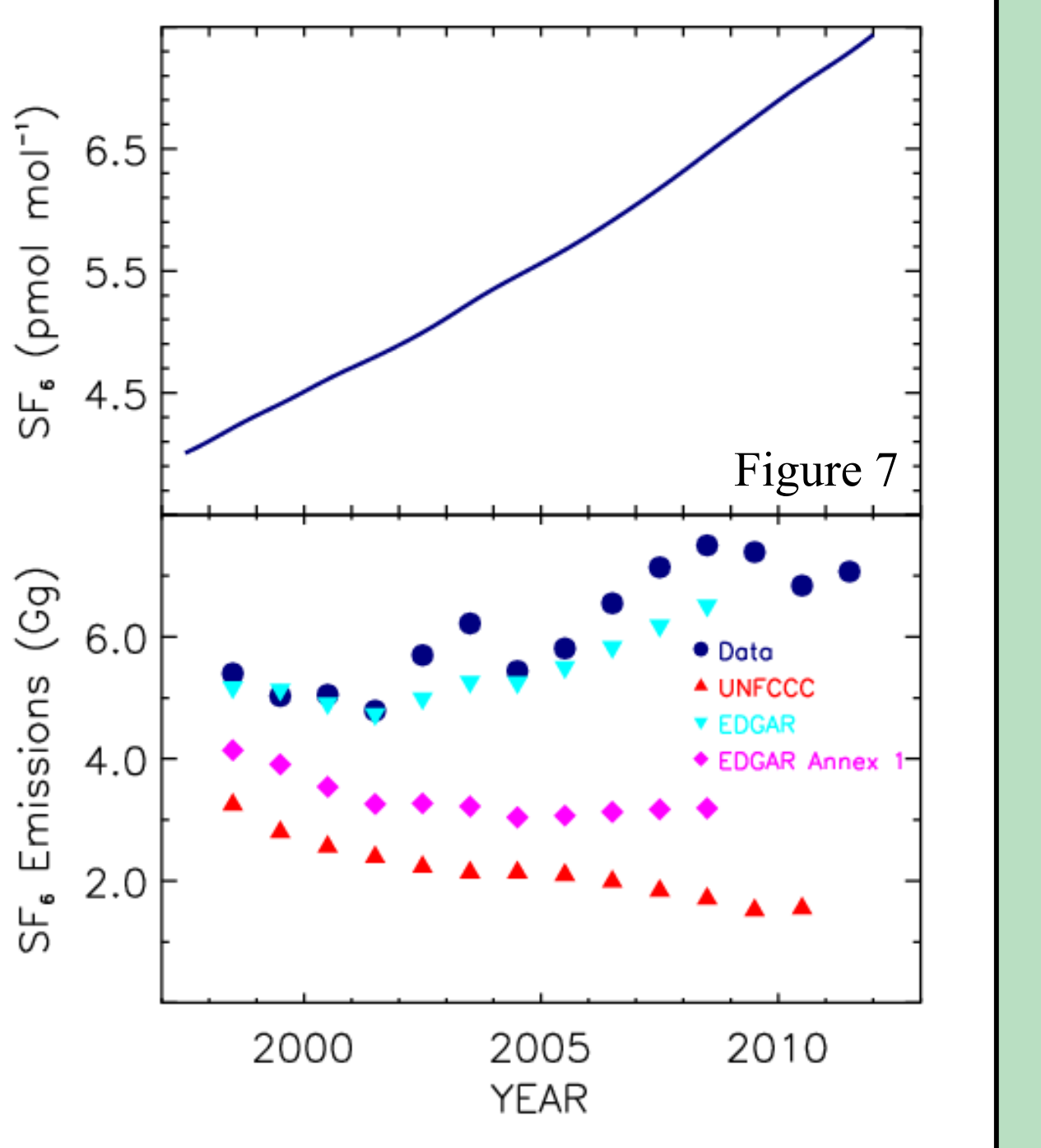

Figure 7

Tracking Changes in CO Emissions

- Figure 8 shows trends in CO for the NH (black circles) and SH (blue circles).
  yellow line = **smooth curve**
  red line = **trend**
  green line = **polynomial**
- A linear fit gives **-0.64±0.05** ppb yr^{-1} for the NH and **0.03±0.03** ppb yr^{-1} for the SH.
- CO has a lifetime of ~3 months so there is minimal transport between the NH and SH.
- These trends show decreasing emissions of CO in the NH.

Figure 8

Conclusions

NOAA GMD has been making high quality measurements of carbon cycle greenhouse gases for more than 4 decades. Measurements from our Global Cooperative Air Sampling Network provide the basis for quantifying long-lived greenhouse gas budgets and reactive species over large spatial and long time scales. The measurements further constrain bottom-up inventories of emissions. Spatial patterns and seasonal variations of the measurements constrain the geographical and temporal distribution of emissions. These observations have been used for nearly every published large scale study of the budgets of CO_2, CH_4, N_2O, SF_6, CO, and H_2. The marine boundary layer reference derived from observations in the cooperative air sampling network are used as boundary conditions in continental and regional scale studies. No satellite sensor nor commercial enterprise can provide the same high quality measurements for such a large range of species with such large intrinsic scientific value.