2.9. DATA INTEGRATION (GLOBALVIEW)

Systematic observations of atmospheric CO_2 continue to play an essential role in advancing our understanding of the global carbon cycle. Atmospheric transport models run in the "inverse" mode and are used to estimate the magnitude and distribution of the sources of CO_2 by requiring that the modeled spatial and temporal patterns are consistent with the observations. Results from recent inverse modeling studies debate both the magnitude and distribution of the midnorthern latitude terrestrial sink. The studies agree that the most important limitation to this approach is the sparseness of observations. The growing need for greater temporal and spatial coverage requires the integration of existing observations made by different laboratories into larger merged data sets. A major challenge is ensuring that the spatial and temporal patterns observed among independent measurement records are due to emissions as affected by atmospheric mixing and transport and not because of differences in calibration scales or experimental methods.

In 1995 CCGG established the Cooperative Atmospheric Data Integration Project for carbon dioxide. Participants from 18 laboratories in 12 countries contribute their up-to-date high-precision CO_2 records from land-surface, aircraft, ship, and tower sites (Figure 2.25). These data are used to construct *Globalview-CO_2* [2000], a globally consistent data product for use with carbon cycle modeling studies (http://www.cmdl.noaa.gov/ccgg/globalview/index.html. Globalview-CO_2 consists of statistical summaries of atmospheric variability, average diurnal and seasonal patterns, and smoothed representations of the observations. The product, which is updated annually, contains no actual data. Since Globalview-CO_2 was first introduced in 1996, more than 1200 electronic requests (≈26 per month) have been made from more than 35 countries.

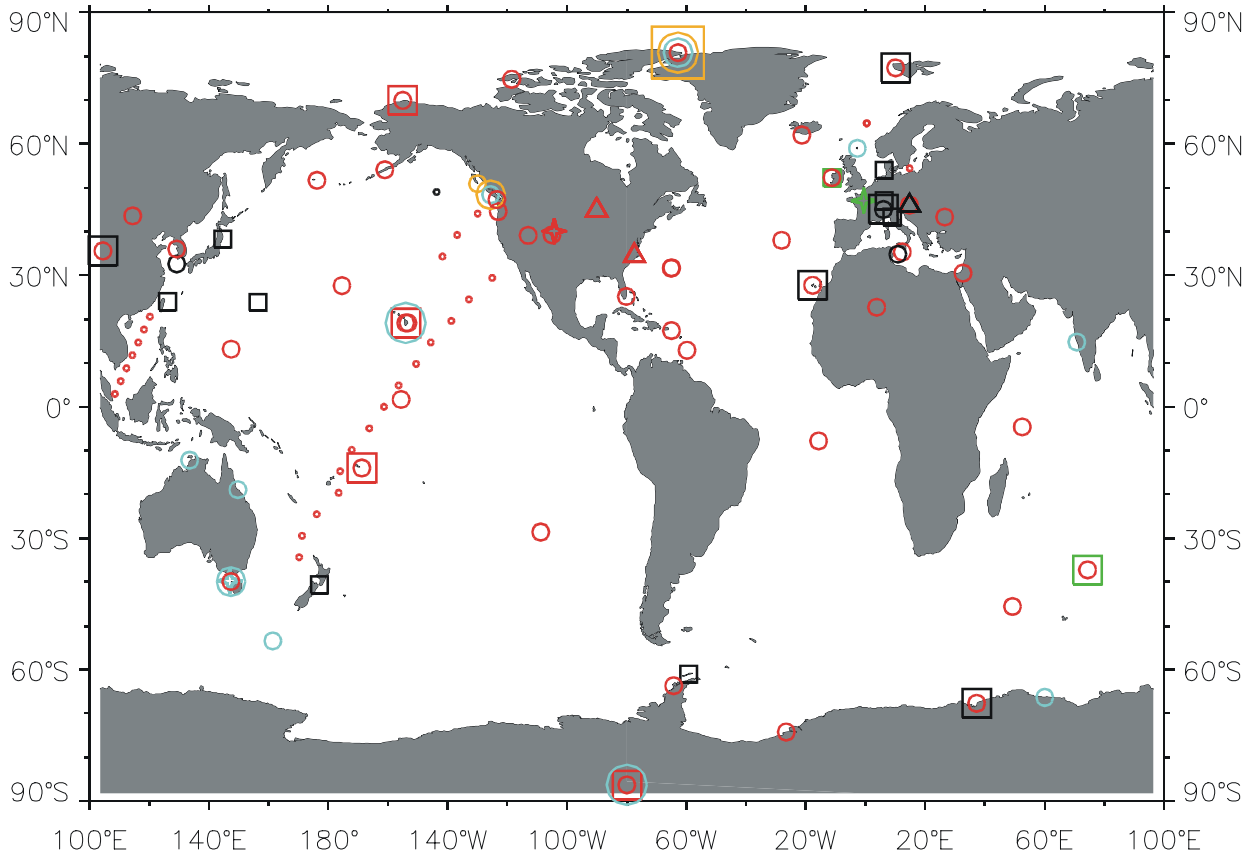

Fig. 2.25. The Cooperative Atmospheric Data Integration Project for CO_2 includes observations from land-surface discrete (○) and continuous sites (□), ships (o), aircraft (✧), and towers (Δ). Laboratories contributing four or more measurement records are identified by color. Active participants include CMDL (red); CSIRO, Australia (blue); LSCE, France (green); AES, Canada (orange); IOS, Canada; CAMS, China; UBA/IUP-HD, Germany; HMS, Hungary; CESI, IMS, and ENEA, Italy; JMA and NIPR, Japan; METRI/SNU, Republic of Korea; NIWA, New Zealand; INM, Spain; MISU, Sweden. Co-located independent sampling programs are critical for assessing comparability among atmospheric records.

A major focus of the integration project is to assess the level of comparability among observations produced by different laboratories. Nearly 2 decades ago, the CO_2 community stated that interpreting spatial and temporal gradients of CO_2 would require a level of agreement among laboratories to within 0.1 ppm [*World Meteorological Organization (WMO)*, 1981]. To assess consistency among independent measurement programs, CMDL conducted periodic intercomparison experiments (round robins) whereby more than 20 laboratories measured air from a set of traveling high-pressure cylinders. Results from the 1995-1996 intercomparison experiment show that all laboratories contributing to Globalview-CO_2 are consistent to within 0.2 ppm [*Peterson et al.*, 1999]. These experiments are critical for assessing each laboratory's ability to make high-precision CO_2 measurements and maintain a calibration scale. However, they are not designed to compare different sample collection, storage, and extraction methods that are potential sources of uncertainty when making atmospheric measurements. Thus agreement among laboratories based on comparisons of high-pressure cylinders does not necessarily imply comparability among their atmospheric CO_2 records. To complement the round-robin experiments, ongoing InterComParison (ICP) experiments were established whereby participating laboratories compare more directly the atmospheric measurements themselves. CCGG has ongoing ICP programs with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia; Atmospheric Environment Service (AES), Canada; National Institute for Water and Atmospheric Research (NIWA), New Zealand; and HATS (U.S.). For the moment, only the ICP program with CSIRO is providing enough detail to properly assess comparability.

The effectiveness of an ICP program depends on several essential features. First, participants must view ICP activity as an additional level of quality control whereby measurements are routinely scrutinized. Potential problems identified by the collaborating laboratory should not be viewed as an embarrassment but as proof that the ICP is working effectively. Second, the ICP activity is an ongoing long-term program of routine (at least weekly) comparisons of atmospheric samples. Third, the ICP program must include supporting measurements (e.g., control samples) that can be used to narrow possible causes when differences are observed. Fourth, the ICP program should have minimal impact on daily operations. This is accomplished only if participating laboratories have advanced data management tools in place. Analysis of ICP samples and processing and data exchange between laboratories must be automatic and routine. ICP results must be summarized automatically and made readily available to participants. Timely feedback improves the likelihood that potential problems are detected early.

The CSIRO and NOAA flask air ICP program began in 1992 and has served as a model for subsequent ICP programs [*Hofmann et al.*, 1996]. The program includes the essential features described previously and demonstrates the difficulties in establishing and maintaining measurement comparability between independent laboratories. Figure 2.26 shows the level of agreement between NOAA and CSIRO measurements of the same air in a glass flask for CO_2, $\delta^{13}C$ (CO_2), CH_4, and CO. The observed variability in the differences demonstrates the need for ongoing and frequent intercomparisons. The level of agreement among CO_2 measurements combined with supporting evidence (e.g., round-robin results and pair agreement) suggests that

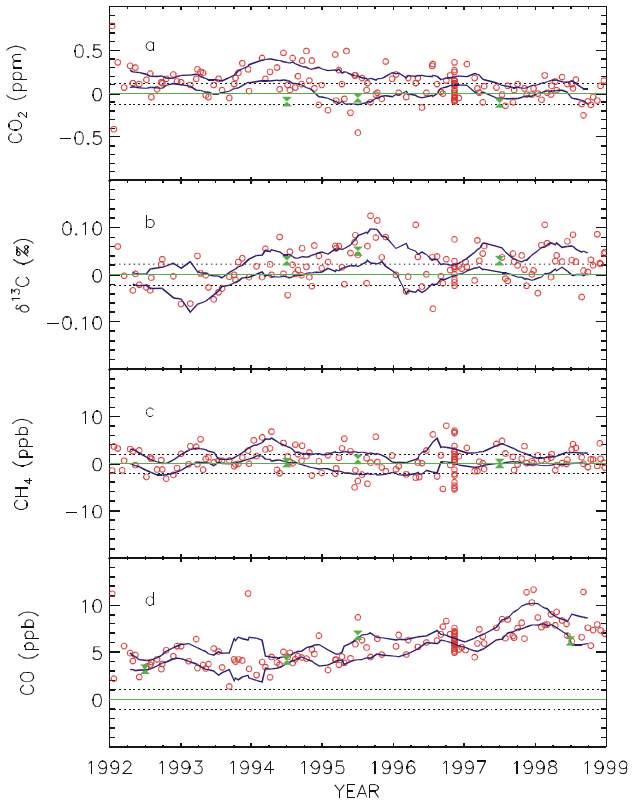

Fig. 2.26. (a-d) Differences (CSIRO minus NOAA) between independent measurements of the same air in ICP flasks for the period 1992-1999 (open circles). The mean differences (CSIRO minus NOAA) determined from multiple intercalibrations of air in high-pressure cylinders are shown as solid green hourglass symbols and plotted at the middle of the year in which the analyses took place. The dotted lines about the zero difference line represent the 67% confidence limits about the mean NOAA flask pair difference (excluding ICP flasks and mates) at Cape Grim. The band defined by solid lines represents 2 standard errors (95% confidence limit) from the mean of the residuals determined from a smooth curve fitted to the distribution. A 6-month window centered at each difference value is used to compute the standard error for that value.

NOAA and CSIRO network measurements of CO_2 are comparable to within 0.2 ppm (0.06%). Differences in the independent measurements of $\delta^{13}C$ show significant variability with time and are not yet fully understood. Methane measurements from NOAA and CSIRO network samples are comparable to within 1 ppb (0.04%) and have been integrated with observations from other laboratories to produce *Globalview-CH_4* [1999]. Differences in the independent measurements of CO show a systematic offset of about 5 ppb from 1992 to 1994. The difference increases at a rate of about 1 ppb yr^{-1} from 1995 to 1998 and appears to stabilize again in 1999. Results from high pressure cylinder intercomparison experiments are consistent with the ICP results suggesting that the problem is likely related to the maintenance of the internal CO calibration scale in one or both laboratories. Both NOAA and CSIRO are working to understand the causes of these differences.