Observation System Requirements to Support Greenhouse Gas Management Strategies

7 September 2009

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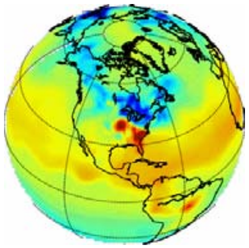
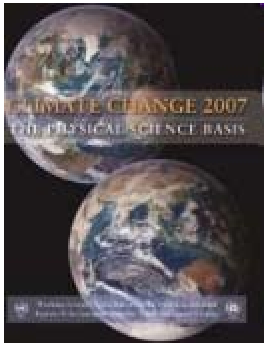
Outline

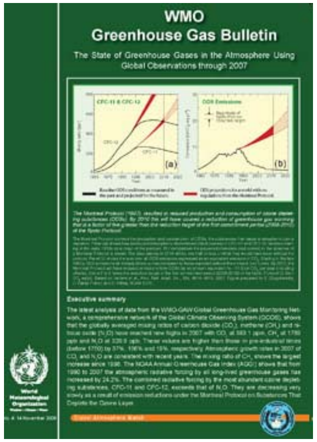
- Global Greenhouse Gas Monitoring Today
- An Emerging Need – Emission Reduction
- Verifying the Outcome of Emission reduction efforts
- Observing Challenges
- Need to examine measurement criteria

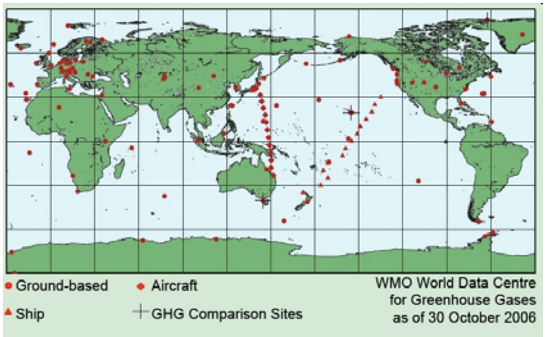
Global Greenhouse Gas Monitoring Structure

- "Purpose" of Experts' Meetings
  - Promote new techniques
  - Address issues of standardization and quality assurance
  - Broaden scope to other climate-relevant trace gases and proxies.
- Tools we have to implement recommendations
  - WMO GAW framework
  - SAG, GAWSIS
  - 152 sites report GHG data to WDC
  - WDC, CCL, WCC for GHGs
- Products supported
  - WDC products & national network products (e.g., NOAA, CSIRO)
  - WMO reports and pubs
  - GHG bulletin
  - CarbonTracker, CarbonTracker-EU, Other reanalyses
- Customers
  - Scientists
    - IPCC
    - National Assessments
  - Educators
  - General public (e.g., NGOs, press, etc.)







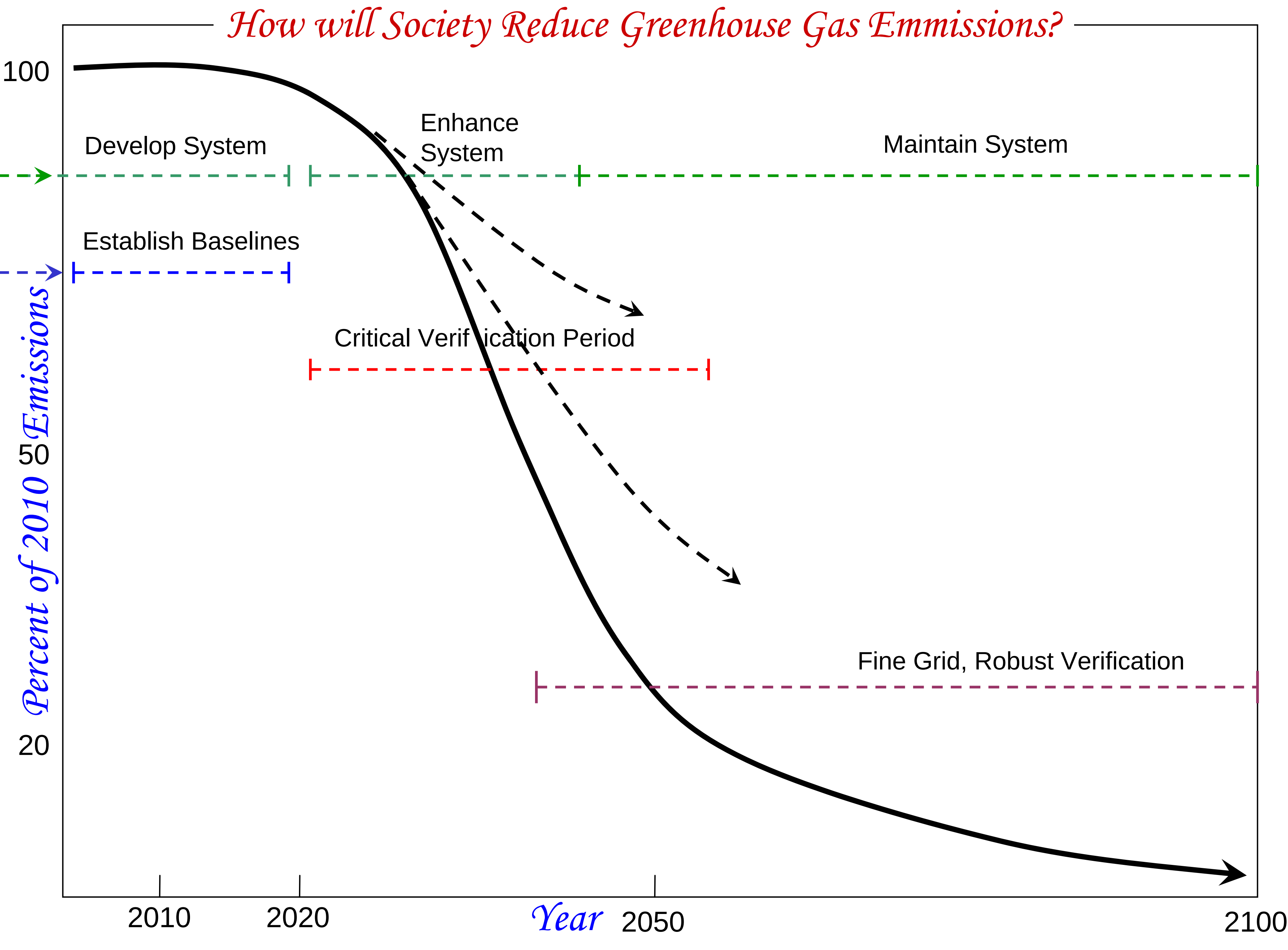


GAW Strategic Goals

- Improve measurements programme for better geographical and temporal coverage and for near real time monitoring capability,
- Complete the quality assurance/quality control system,
- Improve availability of data and promote their use,
- Improve communication and co-operation between all GAW components and with the scientific community,
- Identify and clarify changing roles of GAW components,
- Maintain present and solicit new support and collaborations for the GAW programme,
- Intensify capacity building in developing countries,
- Enhance the capabilities of NMHSs in providing urban-environmental air quality services.

An emerging challenge for the U.S. and the world

- Society is advancing efforts to reduce CO_2 emissions now
  - Copenhagen agreement anticipated
  - US & Australia on board
  - National & state laws and policies are emerging
- Mitigation efforts will vary by nation, region, & emission sector (energy, industry, etc.), and will be diverse in their approach
- Large-scale emission reduction approaches (e.g., international, national, state) require independent, scientific verification of the outcome of policies implemented
  - Stratospheric Ozone
  - Acid Rain
  - Air Quality
  - Nuclear Test Ban Treaty
- The complexity & variability of the carbon cycle, the scale of problem, and the number of GHGs make this a significant challenge for GHG emission reduction


How will Society Reduce Greenhouse Gas Emmissions?
100
50
20
Percent of 2010 Emissions
Develop System
Enhance System
Maintain System
Establish Baselines
Critical Verif ication Period
Fine Grid, Robust Verification
2010
2020
Year
2050
2100

Verification: Providing Objective, Science-based Information to Support Policy & Implementation

- International Agreements
  - Reliable, trusted information will help guide policy decisions at the highest levels
  - Will inform decisions regarding needs for adjustments or amendments to existing agreements
  - Will provide the information necessary to ensure a globally successful effort
- National Laws
  - National policies to balance GHG emission reduction efforts or offsets will require periodic verification of their outcome
  - GHG information specific to regions and economic sectors can ensure continuance or expansion of strategies that are working and aid in adjusting those that are not
- Inventory Validation
  - Reliable GHG information will help inform inventory reporting and measurements
  - Can help improve national inventories
  - Can help inform the design and evaluation of mitigation strategies
- GHG trading markets
  - With or without trading, carbon and other GHGs will acquire considerable value
  - Independent outcome verification would help investors be secure in their investments
  - Would ensure that the goal of GHG trading would stay on target

Carbon Crucible

What are the data and modeling requirements for gauging the success of mitigation strategies in reducing greenhouse gas emissions?

Melinda Marquis[1,2*] and Pieter Tans[2]

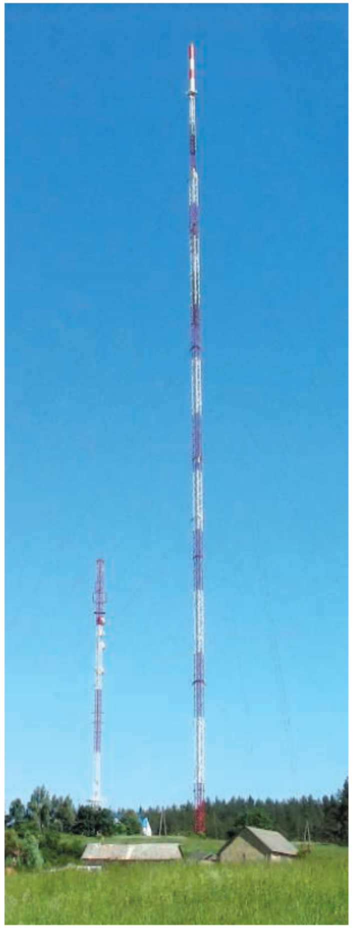
Atmospheric measurements show that the carbon dioxide (CO_2) concentration in the atmosphere is currently ~385 parts per million (ppm) and rising fast. But this value is a global average that tells us nothing about the regional distribution of greenhouse gas emissions. As the world embraces myriad mitigation strategies, it must gauge which strategies work and which do not. Gaining such understanding will require a greenhouse gas monitoring system with enough accuracy and precision to quantify objectively the progress in reducing emissions, including regional efforts like those in California, New England, and elsewhere.

The current sparse network of observation sites across North America and elsewhere allows us to resolve annual continental fluxes of CO_2. But successful mitigation requires fluxes to be resolved within much smaller regions—on the order of the size of a European country such as France or a U.S. state such as Kansas. Current ground-based measurement technology can provide the required precision, but the number of measurements is insufficient. Data are collected by numerous agencies around the world, yet an integrated system is needed that uses all available data and ensures rigorous quality control for data collection and data analysis.

A powerful way to use all these data is in a data assimilation system, which combines diverse (and often sparse or incomplete) data and models into a unified description of a physical/biogeochemical system consistent with observations. Components of such systems include models of terrestrial photosynthesis (removal of CO_2, called a sink) and respiration (a source of CO_2), models of ecosystem emissions and uptake of other greenhouse gases, models of gas exchange between atmosphere and oceans, and models of gas emissions from wildfires—all grounded in observations.

The current grid scale for such assimilation systems—such as CarbonTracker, the first data assimilation system to provide CO_2 flux estimates (*1*, *2*)—is limited to ~100 km or larger, primarily due to computer resource limitations. Currently sparse atmospheric greenhouse gas data force us to make the assumption that source variations are coherent over very large spatial scales. More observation sites would make the systems more strongly data-driven. Data assimilation systems also need more refined estimates of fossil fuel emissions, and better process understanding to provide greater detail in emission patterns. Lastly, better models of atmospheric transport will increase the resolution and decrease biases of the data assimilation system. Our ability to distinguish between distant and nearby sources and sinks is limited by how accurately transport models reflect details of the terrain, winds, and atmospheric mixing near the observation sites.

National emissions inventories (which are required by the U.N. Framework Convention on Climate Change) are key data sets for assimilation systems. Inventories are mostly based on economic statistics, which are used to estimate how much of each greenhouse gas enters or leaves the atmosphere (*3*). They are reasonably accurate for CO_2 from fossil fuels (within ~10%) in many developed countries but less so in developing countries and on regional scales. Inventory emission estimates are much less reliable for other CO_2 sources, such as deforestation, and for other major greenhouse gases; for example, the contributions of natural wetlands, rice farming, and cattle to the global methane



The advantages of height. Atmospheric measurements are made on the tall tower (300 m). The tower, located near Bialystok in eastern Poland, is part of the CarboEurope tall tower network. Similar networks exist in North America and more sparsely in other parts of the world.

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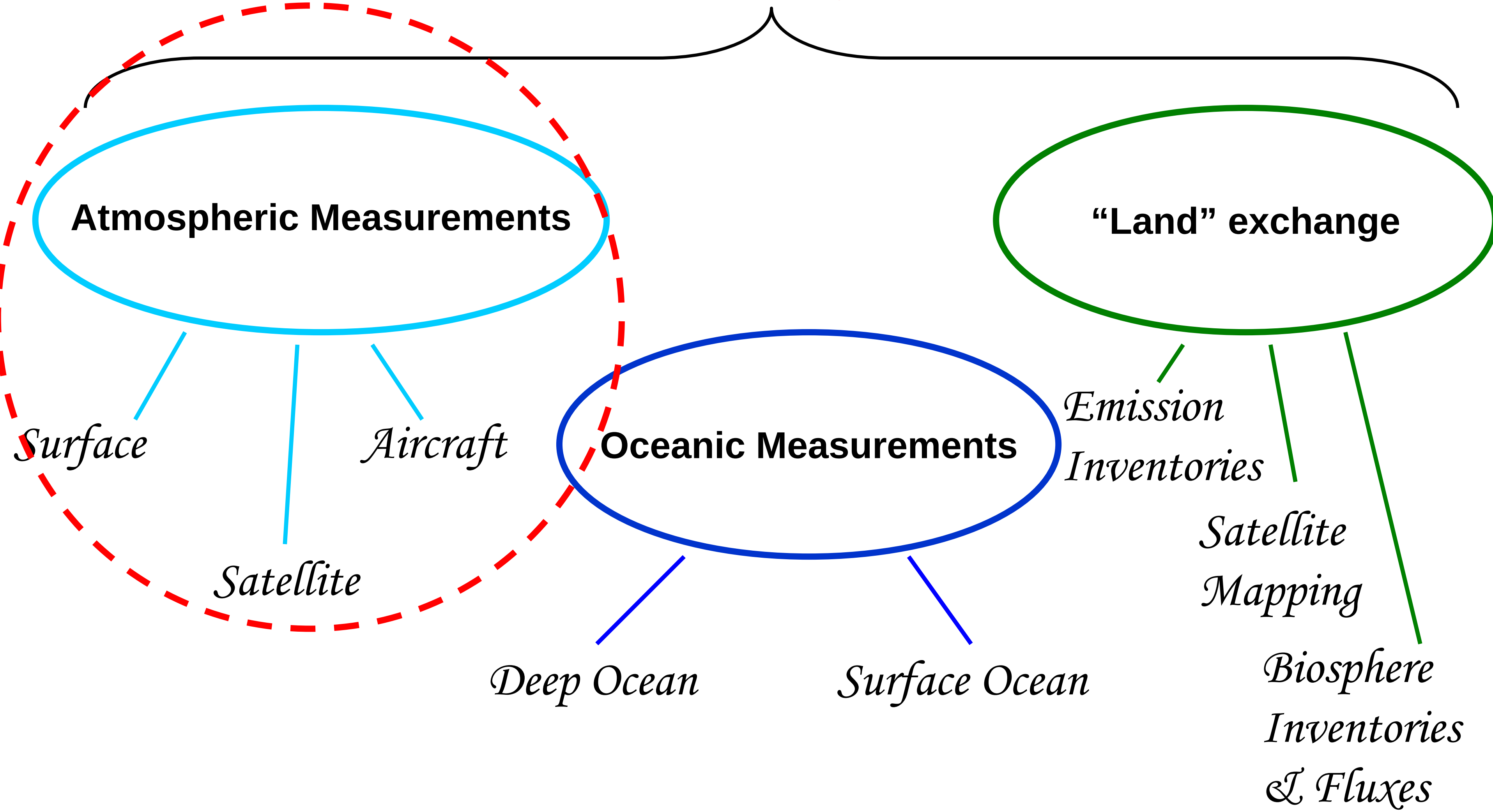
25 APRIL 2008 VOL 320 SCIENCE www.sciencemag.org
Published by AAAS

Carbon Crucible – The Future Demands New and Expanded Approaches

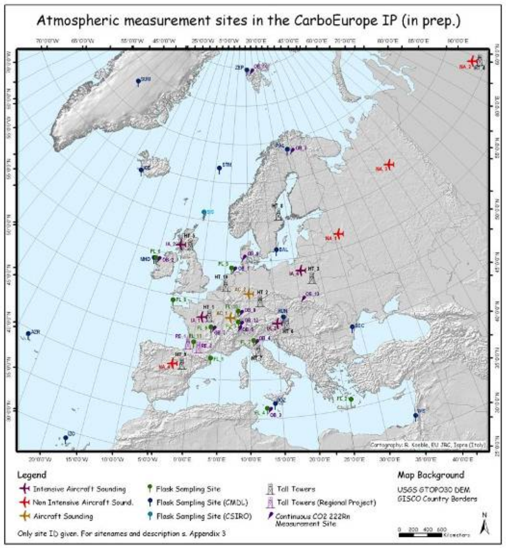
- Increased Observations
- Improved Transport Models
- Enhanced Reanalysis

Integration and Product Development (Reanalysis)

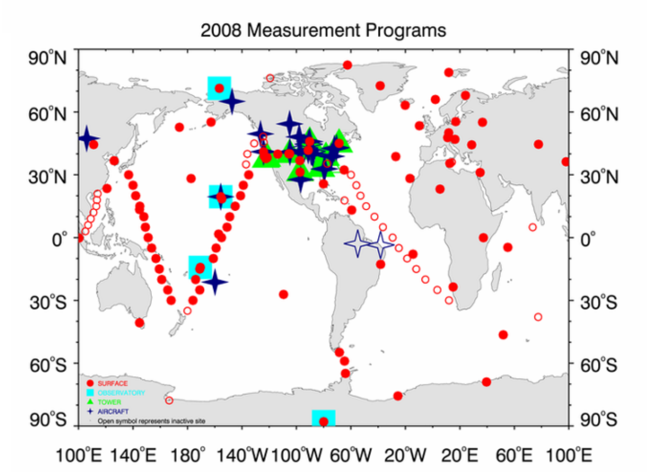


Surface-based Networks

CarboEurope



NOAA



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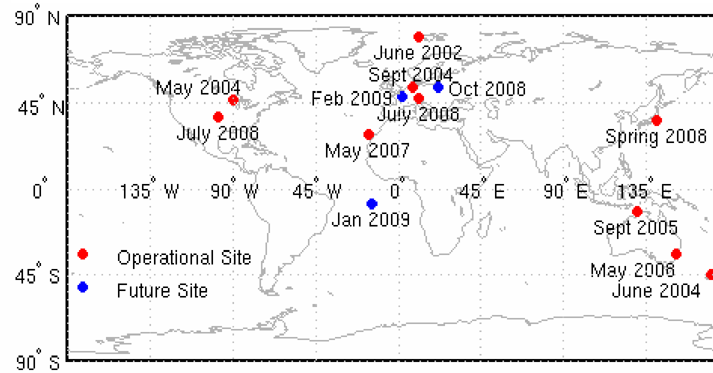
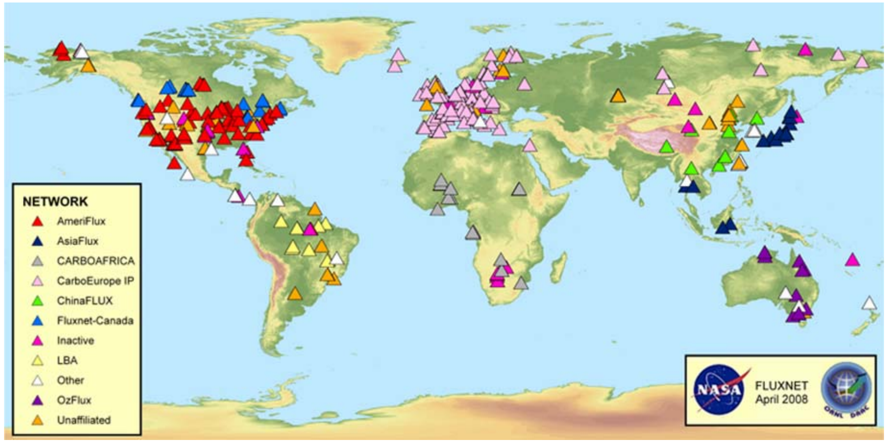
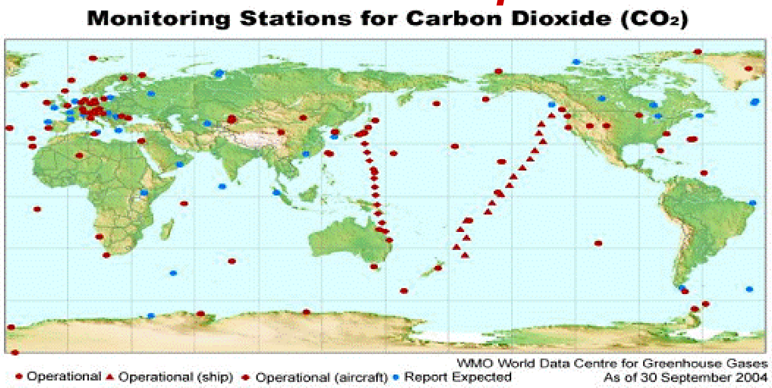


FluxNet



WMO Global Atmospheric Watch



Recording Earth's Vital Signs

Fifty years ago, continuous measurements of atmospheric carbon dioxide were begun at Mauna Loa, Hawaii.

Ralph F. Keeling

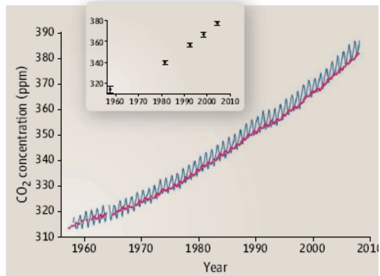
This year marks the 50th anniversary of the start of the Mauna Loa CO_2 record, the longest continuous record of CO_2 in the atmosphere. Initiated by my father, Charles D. Keeling of the Scripps Institution of Oceanography, the record provided the first compelling evidence that the concentration of CO_2 in the atmosphere was rising. It has become an icon of the human imprint on the planet and a continuing resource for the study of the changing global carbon cycle. The Mauna Loa story (*1*) provides a valuable lesson on the importance of continuous Earth observations in a time of accelerating global change.

At the outset, the decision to place the instrument at Mauna Loa was a gamble. Existing measurements suggested that atmospheric CO_2 concentrations varied widely depending on the place and time. Given this variability, could a meaningful record be recovered from an instrument parked in one location? Among the skeptics was Roger Revelle, then director of the Scripps Institution of Oceanography. Revelle would eventually become one of the record's strongest champions. Initially, however, he urged that priority be given to a one-time survey of CO_2 variability using ships and airplanes. Such a survey could be repeated a decade or so later to look for long-term changes.

My father was armed with evidence from his postdoctoral research that the CO_2 concentration in the remote atmosphere was a lot less variable than previously believed (*2*). He also had a strong ally in Harry Wexler of the U.S. Weather Bureau, who envisioned a central role for the newly established Mauna Loa Observatory (see the photo) in the major field program planned for the International Geophysical Year of 1957–1958.

The value of the Mauna Loa data soon was apparent (*3*). By the second year, a regular seasonal cycle was evident, reflecting the "breathing" of land plants in the Northern Hemisphere. Together with a more limited CO_2 data set from the South Pole, begun in 1957, the record documented a global rising trend attributable to the burning of fossil fuels worldwide (see the graph). In the 1960s and 1970s, the curve was seen by countless scientists, some of whom were drawn to study the science of global warming by the curve's ominous rise.

What if CO_2 had been measured only via repeated global surveys, as envisioned by Revelle? As the inset in the graph shows, a CO_2 record degraded to include only one point every decade or two loses its convincing message. Variations from survey to survey may be instrumental artifacts, or the apparent trend may be a random fluctuation. As a recent study of ocean currents in the North Atlantic has shown, resolving trends from repeated surveys can be perilously difficult (*4*).



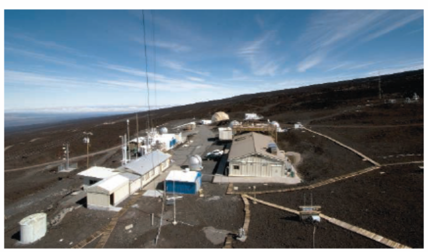
The value of continuous data. Within a few years, the continuous Mauna Loa (blue) and South Pole (red) records provided convincing evidence that CO_2 was rising. If CO_2 had been measured only as often as surveys of the North Atlantic overturning circulation (*4*), it would have taken decades to obtain convincing evidence (**inset**).

The Scripps CO_2 program was shut down briefly in 1964 following congressionally mandated budget cuts. A more serious challenge loomed in the 1970s, when my father was asked to draw a line between the part of the CO_2 program that was basic research and the part that constituted "routine monitoring"; the routine activities would be transferred to a government agency. My father did not comply with the request.

In the 1970s, the Scripps CO_2 program expanded to an array of eight stations distributed globally. A large part of the effort was being expended not in routine data collection, but in the messier process of identifying and eliminating systematic errors. As the records grew, additional features emerged, such as a link between interannual CO_2 fluctuations and El Niño events (*5*) and changes in the amplitude of the seasonal cycle with time (*6*). Were these features real or artifacts? There was no way to be sure without revisiting the fundamentals of the instrumentation, performing new calibrations, and reprocessing all of the records. This cycle was repeated many times as scientific interests evolved.

The distinction between research and routine monitoring may seem clear when applied to an activity like weather forecasting, but in the case of a program aimed at tracking long-term change, "research" and "operations" cannot be separated cleanly. Finding and correcting for the inevitable systematic biases is a job for scientists who understand the measurement technology, are passionate about data integrity, and are motivated to unravel how the Earth system operates.

The Mauna Loa experience also illustrates the critical need for redundancy. From the outset the Mauna Loa record was backed by the parallel record from the South Pole. In 1960, a second record was begun at Mauna Loa, based on flasks shipped back to Scripps for analysis. It is an inescapable fact that if you are trying to track changes over time, you only get one chance to measure each point. To prove you got it right, you must take measurements in multiple ways. And the challenge may come decades later. A recently



The Mauna Loa Observatory.

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www.sciencemag.org SCIENCE VOL 319 28 MARCH 2008
Published by AAAS

Learning from Long Term Records

- A call for sustained, continuous measurements of greenhouse gases
- A warning of the importance of maintaining an on-going war on measurement bias

Observing Challenges

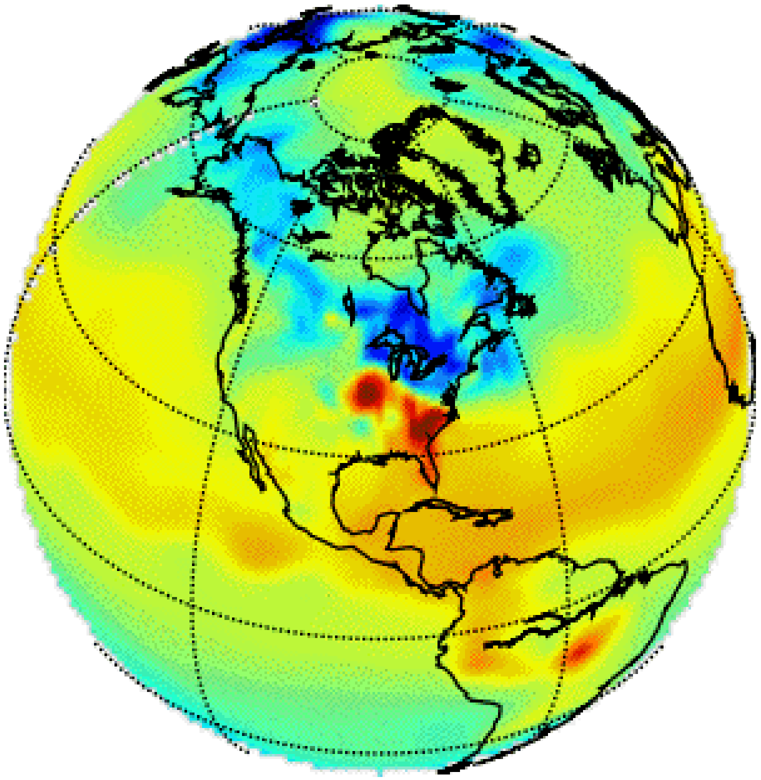
- In situ sampling
  - Flasks
  - Continuous, in-situ sampling and analysis
- Remote sensing
  - Fourier-transform spectrometers (e.g., TCCON)
  - Satellites
- Direct Emission Measurements
  - Individual sources
  - Collective sources
- Non-point sources
- Offsets

How to set criteria?

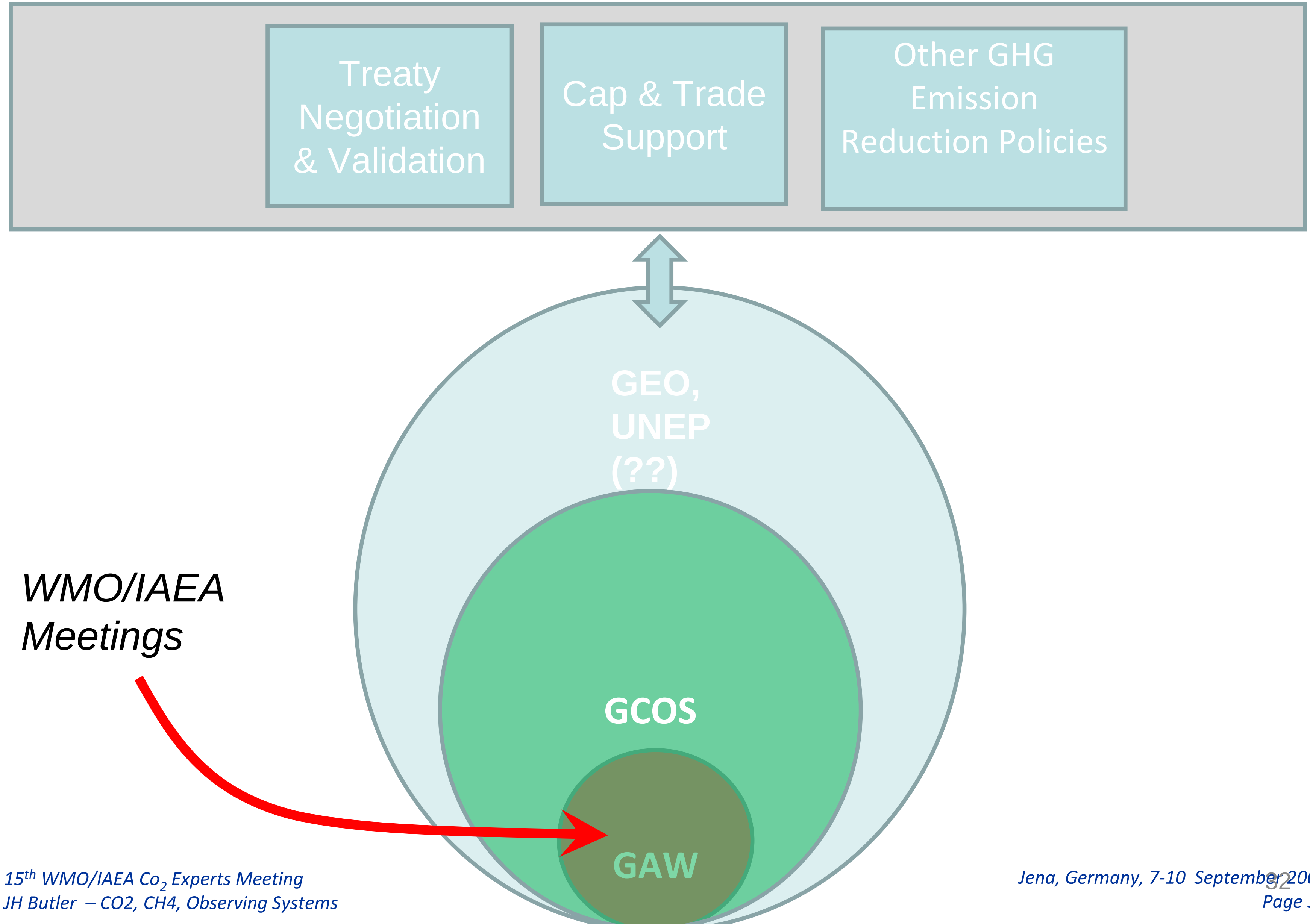
(Comparability and Accuracy for Emerging Technologies)

- Criteria for flask and in-situ sampling have historically been the focus of these meetings
- With the emerging need for verifying GHG emissions
  - How to fend off potential bias from remote sampling systems?
  - How should we define comparability for remote sensing measurements?
  - Should the requirement for quality of the measurement depend upon the need for that measurement?
  - How will data management and product development be affected?
- Do we need deeper engagement of the inventory and satellite communities to address these questions?
- Do we need deeper engagement of the reanalysis community to address these and other questions?

Questions?



Backup Slides


Treaty Negotiation & Validation
Cap & Trade Support
Other GHG Emission Reduction Policies
GEO, UNEP (??)
GCOS
GAW
WMO/IAEA Meetings