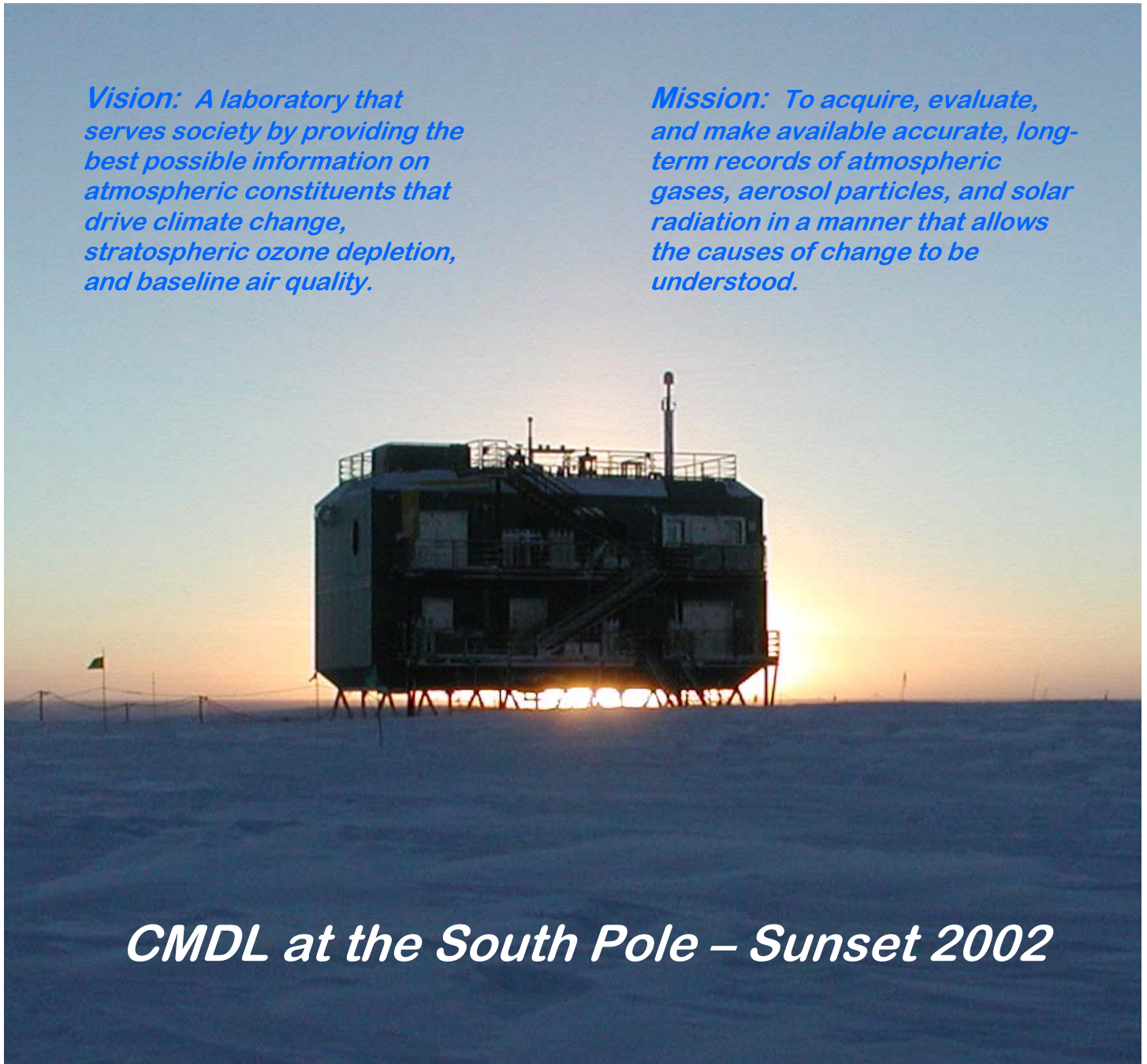


# *Climate Monitoring & Diagnostics Laboratory*

## **Operating Plan: 2002-2006**

*Vision: A laboratory that serves society by providing the best possible information on atmospheric constituents that drive climate change, stratospheric ozone depletion, and baseline air quality.*

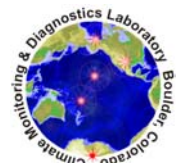
*Mission: To acquire, evaluate, and make available accurate, long-term records of atmospheric gases, aerosol particles, and solar radiation in a manner that allows the causes of change to be understood.*



***CMDL at the South Pole – Sunset 2002***

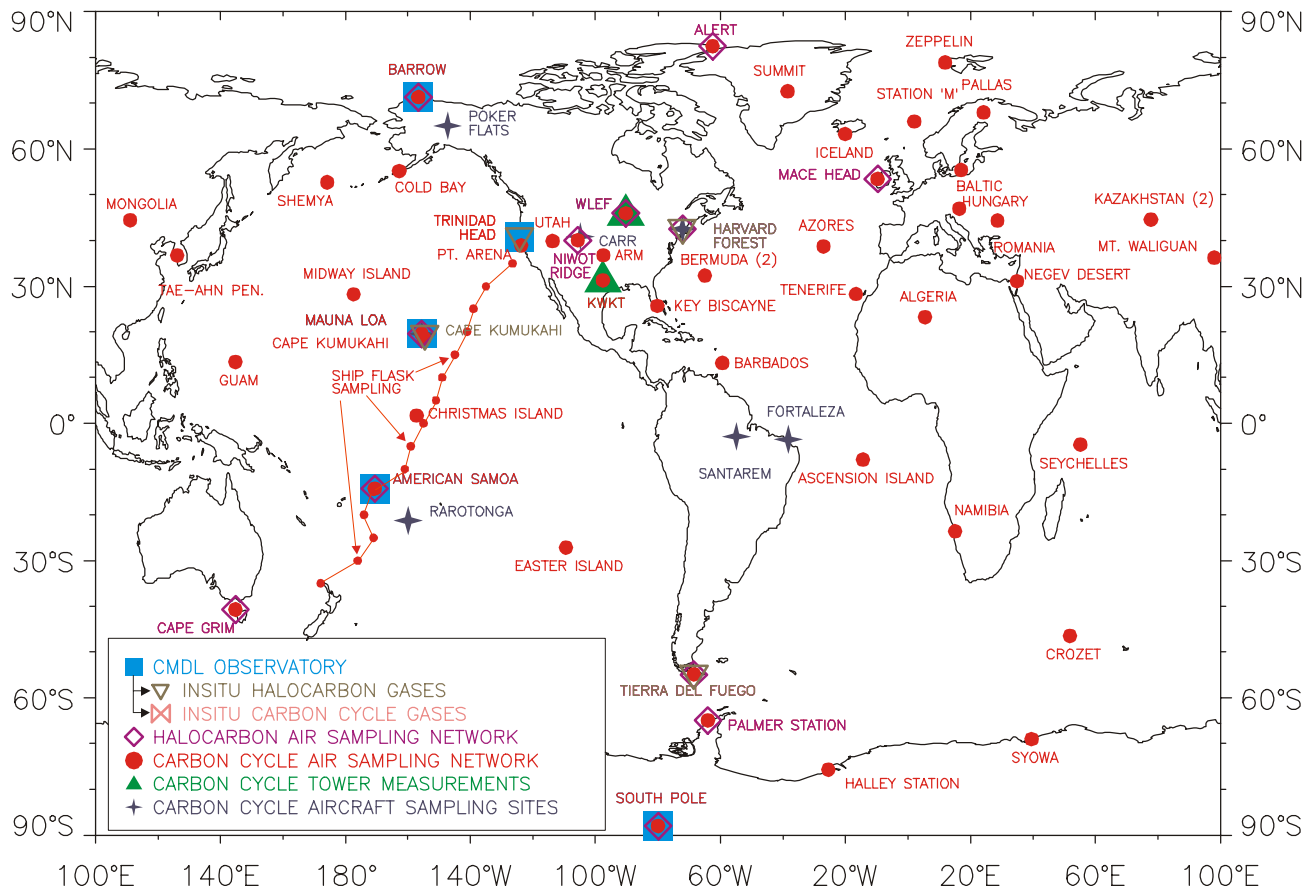


**Office of Oceanic & Atmospheric Research  
National Oceanic & Atmospheric Administration  
U. S. Department of Commerce**

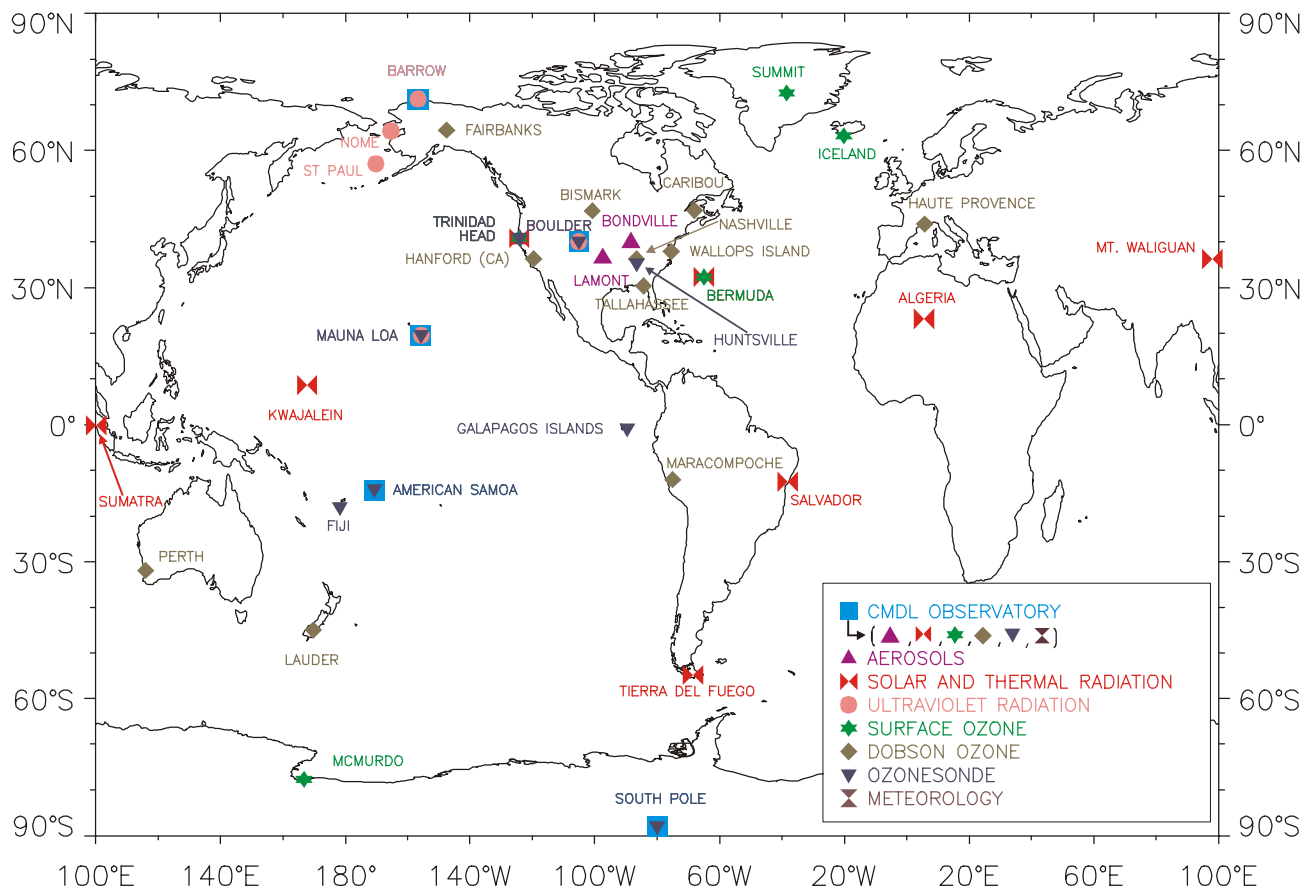


# CMDL GLOBAL MONITORING SITES

Carbon Cycle and Halocarbon Gases



Ozone, Aerosols, Solar Radiation, and Meteorology





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Photograph taken by Wilfred von Dauster



David Skaggs Research Center, Boulder, Colorado, home of the Climate Monitoring and Diagnostics Laboratory. CMDL is located on the top two floors of the south wing, Block D, (on the left). The domes on the roof are used for CMDL's Dobson spectrophotometers, radiation measurements and the stratospheric aerosol lidar.





## Overview

### *Introduction*

The Climate Monitoring and Diagnostics Laboratory (CMDL), one of 12 environmental research laboratories or centers of the NOAA Office of Oceanic and Atmospheric Research (OAR), conducts research along three main themes—Global Climate Forcing, Stratospheric Ozone Depletion, and Baseline Air Quality. The research supports the missions of NOAA and of OAR.

In addressing the three research themes, CMDL provides continuous high-quality measurements of carbon dioxide, carbon monoxide, methane, nitrous oxide, ozone, chlorofluorocarbons and other ozone depleting gases, solar radiation, and aerosols at sites around the world.

CMDL's main laboratories and offices are housed in the David Skaggs Research Center in Boulder, Colorado. It is here that flask air samples, collected worldwide, are analyzed, instruments are developed and improved, data are processed, and calibration scales are maintained. CMDL works closely with other NOAA laboratories in Boulder, as well as those in other parts of the country.

The backbone of the CMDL measurement program is its network of Baseline Observatories at Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; South Pole, Antarctica; and most recently, Trinidad

Head, California. Some of the measurements, for example at Mauna Loa and South Pole, date back to 1957. Much of CMDL's research is conducted from ground-based stations, but in efforts to understand the origin, fate, and history of atmospheric constituents, measurements are also made from ships, a variety of aircraft including NASA's ER-2, and on samples of air collected from polar snowpack.

To ensure high quality and continuity, calibration scales maintained in Boulder are the foundation of measurements made by CMDL and other organizations. CMDL is central in providing calibrations for measurements of climatically important variables, so that worldwide networks of data can be reported on a uniform basis.

### *Active Research*

Scientists at CMDL are involved in international efforts not only to make and calibrate measurements, but also to analyze and summarize data needed to assess progress on key environmental issues. CMDL data are integral components of the Intergovernmental Panel

on Climate Change (IPCC) reports and the WMO/ UNEP Scientific Assessments of Ozone Depletion. CMDL scientists are active contributors to and co-authors of these reports. CMDL data are often used for developing global models and for ground-truthing measurements by satellites.



**Dobson ozone spectrophotometer calibration.**



## Overview

### *A Path Toward Environmental Stewardship*

The availability of globally distributed, well-calibrated measurements of ozone and ozone-depleting gases, many a result of CMDL research, made international scientific assessments of stratospheric ozone depletion possible. These scientific assessments led to the Montreal Protocol, regulating the production of substances that deplete the ozone layer. We now expect global-ozone depletion and the “ozone hole” over Antarctica to disappear around mid-21<sup>st</sup> century. This is a success story, but its progress requires continual observation.

Earth’s climate also appears to be changing, driven in good part by a growing and increasingly active human population. Climate change feedbacks will affect the fluxes of other climatically important gases, some of which are involved in stratospheric ozone depletion. Air-quality, already impacted on regional scales by urban growth and changing land use, also will be affected by climate change in ways that will require continued observation.

CMDL’s role in NOAA’s environmental stewardship portfolio will continue to be one of long-term surveillance of atmospheric constituents which force climate, deplete ozone, and affect baseline air quality. Only with this information can progress toward a healthy, sustainable environment be evaluated.

### *Who Benefits?*

Determining the nature of the full range of climate forcing agents will allow a more certain projection of future climate. The well-being of mankind depends on it, from economic security to personal safety. Determining the extent and cause of variability in carbon dioxide uptake, particularly in North America, will allow our elected officials to make science-based decisions on carbon emission and sequestration strategies.

The public believes that the cause of depletion of the ozone layer has been determined, that the cure has been administered, and that in time the layer will heal. This is true only if replacements for certain chemicals now being used as substitutes for the CFCs are found and implemented. It is NOAA’s task, assigned by the Clean Air Act of 1990, to monitor both the ozone layer and the chemicals that have damaged it.

Finally, concern for the air quality of our country, and measures to improve it, must be based on knowledge not only of our emissions but also of the emissions entering our country. CMDL will remain at the forefront of these research areas, providing data products needed for determining trends and evaluating the causes and feedbacks of these trends in an atmospheric environmental system that is intricately interwoven.

#### **Some major findings published by CMDL scientists have:**

- documented the global distribution and trends of carbon dioxide and methane,
- identified the northern hemisphere terrestrial biosphere as a large sink for carbon dioxide,
- reported the turnaround of ozone-depleting chlorine in the atmosphere,
- found that the ocean is a sink for a number of ozone-depleting gases,
- provided a 20<sup>th</sup> century history of climatically important gases in the atmosphere from analysis of air trapped in polar snowpack,
- determined the nonvolcanic, background level of stratospheric aerosols,
- reported dramatic changes in the global growth rates of atmospheric methane and carbon dioxide,
- documented the 15-year history of the ozone hole with balloon measurements at the South Pole,
- and established a clear correlation between total column ozone and ultraviolet radiation.



# Vision and Mission

## *NOAA, OAR, and CMDL Missions*

CMDL’s vision and mission support the broader objectives of NOAA’s Strategic Plan and are aligned with the vision and mission of the Office of Oceanic and Atmospheric Research (OAR).

### *NOAA Strategic Plan Elements*

CMDL’s monitoring and research generally fall under the NOAA Strategic Plan Element to “Predict and Assess Decadal to Centennial Change” although much of the research at CMDL is relevant to other time scales included in the Strategic Plan. For example, interannual variations in the carbon dioxide growth rate are of major importance in studying carbon dioxide sources and sinks. Interannual climate variations, such as those caused by the El Niño phenomenon, have an effect on sources and sinks of climatically important gases.

Objectives under the NOAA Decadal to Centennial Change Element applicable to CMDL are:

- Characterize the Forcing Agents of Climate Change
- Ensure a Long-Term Climate Record
- Guide the Rehabilitation of the Ozone Layer
- Provide the Scientific Basis for Improved Air Quality

### *OAR Vision and Mission*

#### *OAR Vision:*

A society that uses the results of our research as the scientific basis for more productive and harmonious relationships between humans and their environment.

#### *OAR Mission:*

To conduct research, develop products, and provide scientific information and leadership toward fostering NOAA’s evolving environmental and economic mission.

The NOAA Research (OAR) Plan to carry out this mission designates specific Strategies and Actions. Those relevant to CMDL are:

#### *Strategy:*

Create new climate products and services.

#### *Actions:*

- Meet increasing national demands for integrated climate information products and services by converting advances in research to practical applications.
- Provide comprehensive, long-term monitoring of greenhouse gases and information about their characteristics to assist in decision making.

#### *Strategy:*

Enhance atmospheric products and services.

#### *Actions:*

Provide the foundation for a national air-quality predictive system focusing on regional populations and sensitive ecosystems.

### *CMDL Vision and Mission*

#### *CMDL Vision:*

**A laboratory that serves society by providing the best possible information on atmospheric constituents that drive climate change, stratospheric ozone depletion, and baseline air quality.**

#### *CMDL Mission:*

**To acquire, evaluate, and make available accurate, long-term records of atmospheric gases, aerosol particles, and solar radiation in a manner that allows the causes of change to be understood.**

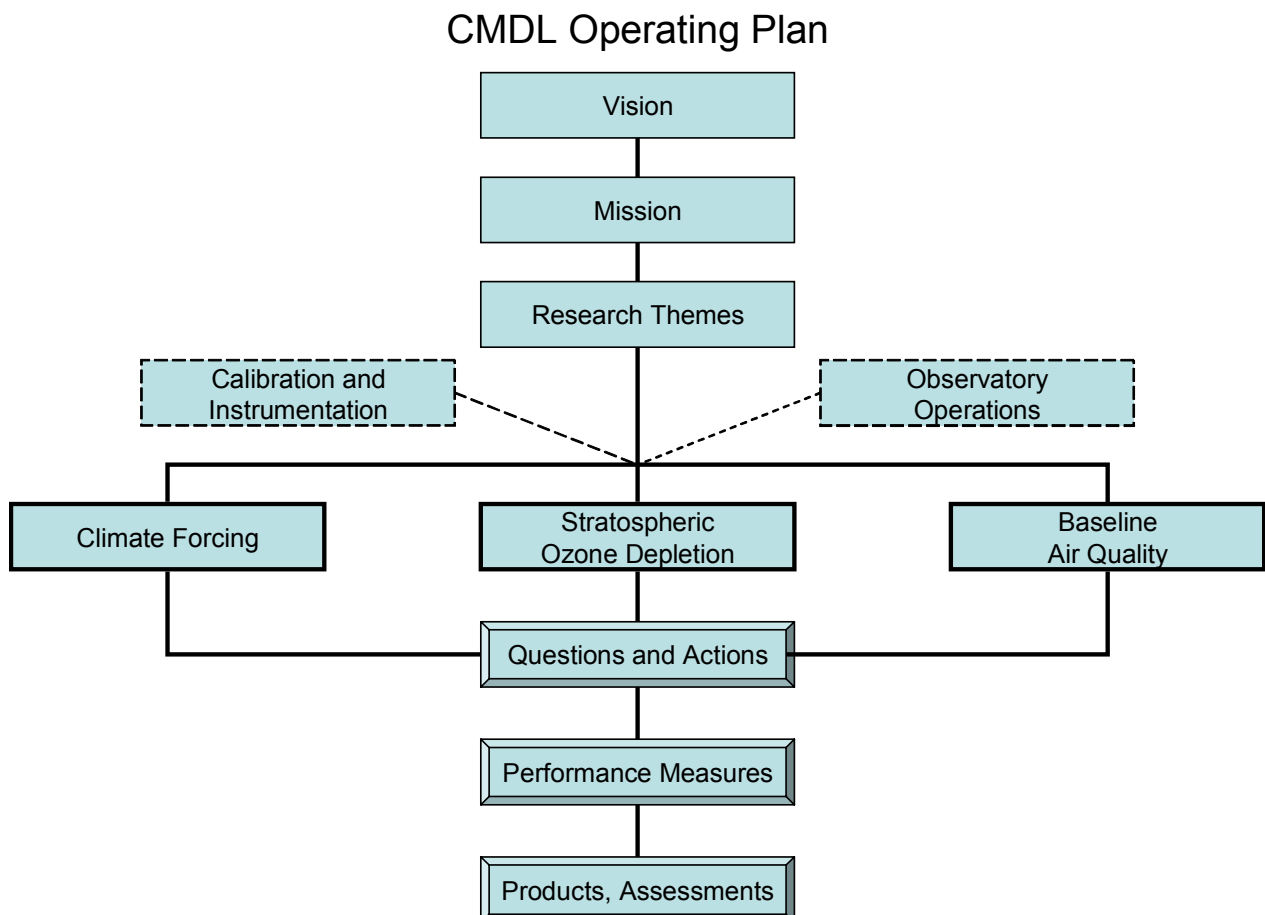


# Vision and Mission

## *CMDL Strategy and Actions*

The research strategy and actions to fulfill this vision and carry out the mission involve continuing and expanding measurements, developing new and better instruments, maintaining and expanding calibration scales, making available data of the highest possible quality, publishing results, and participating in international evaluation and assessment efforts. These research strategies and actions are elaborated upon in this document and form CMDL's Operating Plan for the next 5 years.

Imbedded in this operating plan are imperatives of the President's Climate Change Research Initiative (CCRI), for example, research on the North American carbon cycle, extension of the global carbon dioxide network, and augmentation of research on aerosol forcing of climate and stratospheric water vapor. Although the level of activities in this new program has not been determined, it is clear that CMDL will play a major role in this important initiative.





### *Key Research Areas*

CMDL's mission involves answering key scientific questions in three areas of research — ***Climate Forcing, Ozone Depletion, and Air Quality***. By asking critical scientific questions and conducting detailed and carefully designed research addressing these three themes, CMDL scientists provide a basis for assessing the prospects of change in the global climate or in the health of the atmosphere, both of which can significantly affect human health and well-being across the globe.



Launching an ozonesonde.

### *Climate Forcing*

To slow the rate of anthropogenic-induced climate change in the 21<sup>st</sup> century and to minimize its eventual magnitude, societies will need to manage the climate forcing factors that are directly influenced by human activities, in particular greenhouse gas and aerosol emissions. For effective management of these species, a solid scientific understanding of their natural cycles and the processes that influence those cycles is necessary. Atmospheric measurements are the touchstone of theories or models describing these cycles. Providing a sound basis for important societal decisions requires a global effort, one that involves studying numerous gases, particles, and atmospheric radiation on appropriately designed spatial and temporal scales.

### *Greenhouse Gases*

NOAA measurements of climatically important gases began on an expanded scale in the mid-1970s for carbon dioxide (CO<sub>2</sub>), nitrous oxide (N<sub>2</sub>O), chlorofluorocarbons (CFC's), and ozone (O<sub>3</sub>). Over the years a number of other gases have been added, including methane (CH<sub>4</sub>), carbon monoxide (CO), hydrogen (H<sub>2</sub>), hydrochlorofluorocarbons (HCFC's), hydrofluorocarbons (HFC's), methyl halides, and sulfur hexafluoride (SF<sub>6</sub>).

In collaboration with the Institute for Arctic and Alpine Research (INSTAAR) of the University of Colorado, CMDL now routinely monitors carbon isotopic ratios of CO<sub>2</sub> and CH<sub>4</sub>. CMDL measures the evolving distributions of these gases through its global cooperative air sampling network (see inside front cover). Understanding the interactions of the atmosphere with the land and ocean is key to understanding the natural cycles of atmospheric gases and requires going beyond the earth's surface. Thus, in addition to widespread, frequent, fixed surface-level measurements, CMDL also studies the processes driving greenhouse gas cycles from very tall communication towers, planes, trains, and ships.





# Research Theme - Climate Forcing (continued)

## Aerosols

The original objective of “baseline” aerosol measurements was to detect a response to changing conditions on a global scale. Since the inception of the program (1960s) our understanding of the behavior of atmospheric aerosols has improved considerably. In response to the finding that anthropogenic aerosols create a significant perturbation in the earth’s radiative balance on regional scales, CMDL expanded its aerosol research program (1992) to include aerosol monitoring stations in regions where significant aerosol forcing was expected.

The goals of this regional-scale monitoring program are to characterize the means, variabilities, and trends of climate-forcing properties of different types of aerosols, and to understand the factors that control these properties. An important aspect of this sampling strategy is linking chemical measurements to physical measurements. CMDL’s aerosol measurements also provide ground-truth data for satellite measurements and inputs for global models.

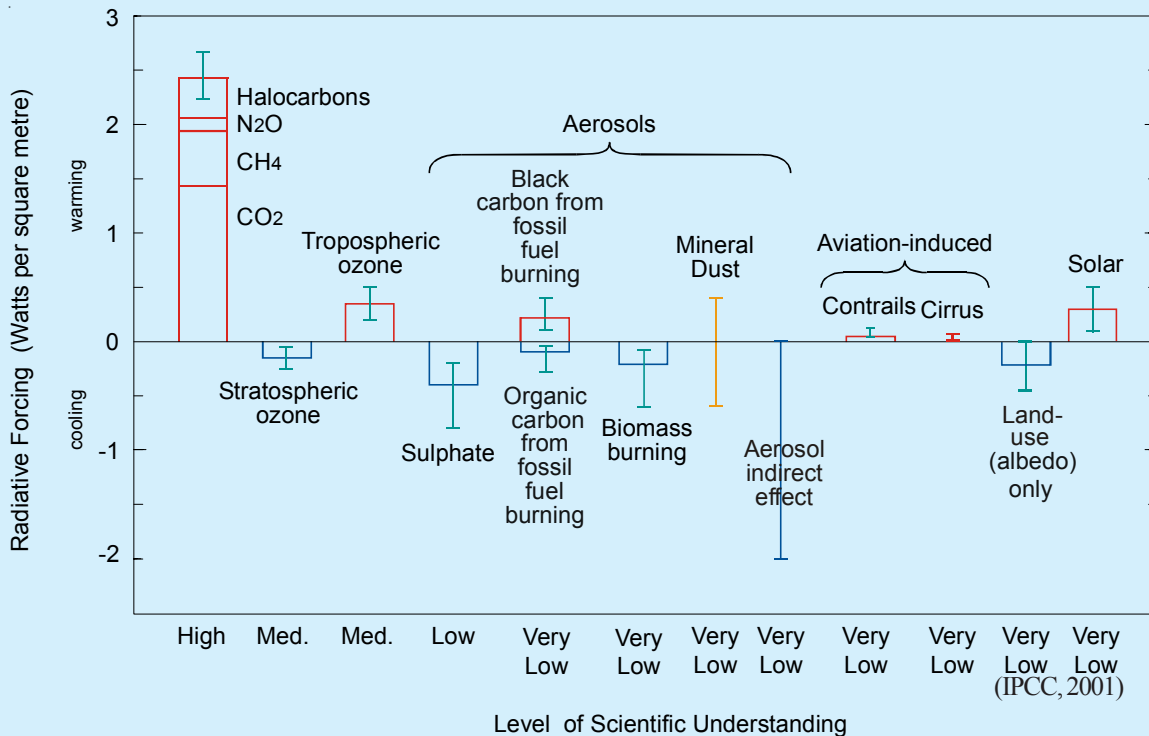
## Radiation

The combined effects of climate forcing lead ultimately to alteration of the earth’s radiation budget. Broadband irradiance, as routinely measured by CMDL, is intended primarily to provide benchmarks of climatic processes. Forced changes in irradiance are not only affected by changing concentrations of constituents or other external sources, but also by changes in water vapor and clouds.

Ancillary measurements of the atmospheric thermodynamic state and composition are necessary to resolve sources of irradiance variability. Data records of sufficient duration are expected to reveal the extent of irradiance variations over time that reflect a combination of cause and effect of climate change.

With reference to the following graphic from the IPCC 2001 report, CMDL conducts monitoring and research in all radiatively important aspects of climate forcing except land-use albedo.

The global mean radiative forcing of the climate system for the year 2000, relative to 1750.





## Research Theme - Climate Forcing (continued)

### Scientific Questions Related to Climate Forcing

- What is the response of the carbon cycle to human perturbations?
- What are the long-term trends and year-to-year variations in the terrestrial and oceanic sources and sinks of greenhouse gases?
- What is the contribution of noncarbon gases and aerosols to climate forcing?
- How will future climate change affect the fluxes of climatically important gases?
- What are the direct effects of climate change on the radiation budget?
- What controls aerosol radiative and cloud-nucleating properties?
- What drives the changing growth rate of gases such as methane?

### Actions and Impacts

CMDL plans the following actions:

- **Continue climate-related observations at CMDL observatories and cooperative sampling sites.**

*Impact: The records of climate forcing agents, some extending back 44 years, will continue to be available for models that project future climate and to assess progress on climate change mitigation actions.*

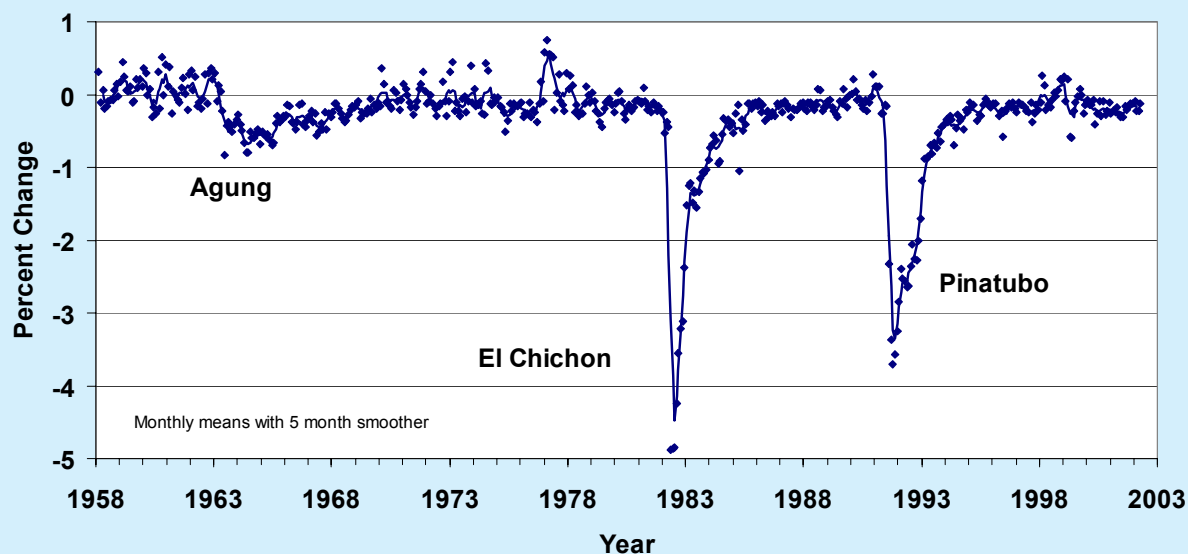
- **Establish a carbon-observing network over North America.**

*Impact: From atmospheric measurements,*

*the North American continent has been estimated to be a major carbon sink in some years but the uncertainty is high and surface carbon inventory assessments are not in agreement. The new observing network would reduce the uncertainties and provide information useful for policy makers.*

- **Continue conducting measurements from ships and expand measurements to ocean buoys to obtain a better understanding of carbon gases and oceanic gas fluxes.**

*Impact: An understanding of oceanic sources and sinks of major climate forcing gases is critical in understanding and projecting future global climate.*



Net solar radiation at Mauna Loa Observatory, relative to 1958, showing the effects of major volcanic eruptions. Annual variations are due to transport of Asian dust and air pollution to Hawaii.



## Research Theme - Climate Forcing (continued)

- **Collaborate with other laboratories in establishing new measurement sites.**

*Impact: The global climate observing system will be expanded, providing regional fluxes of climatically important data, while building scientific capacity.*

- **Add perfluorocarbons (PFC's), including  $CF_4$  and  $C_2F_6$ , to the observing system.**

*Impact: There is little information on the global distribution of PFCs. These gases have potential as long-term contributors to climate forcing because of their high per-molecule radiative forcing and long atmospheric lifetimes.*

- **Replace aging surface ozone monitoring equipment at the Baseline Observatories and increase the number of monitoring sites.**

*Impact: Replacing old ozone analyzers at existing stations and adding new sites on the west and east coast of the U.S. would increase the reliability and scope of surface ozone measurements (which may be impacted by industrial activity in Asia).*

- **Maintain and improve the accuracy and representativeness of radiation data, expand the ancillary data collection, and extend analysis of existing and newly acquired data.**

*Impact: A greater understanding of radiation observations in the absence of model calculations, and vice versa, can be established to fill gaps in the climate record.*



Vertical profiles of carbon cycle gases are conducted from communications towers and aircraft.



## Ozone Depletion

Research by CMDL has been critical in determining the degree of the depletion of stratospheric ozone and the trends of the compounds causing this depletion. CMDL determines the vertical extent of depletion over Antarctica (the ozone hole), makes a significant contribution to world-wide, ground-based measurements of total-column ozone, and monitors the gases responsible for depleting stratospheric ozone. Understanding the production and fate of ozone and the compounds that deplete it has been and remains a focal point of CMDL research.

The discovery of a major stratospheric ozone layer event (the ozone hole) over Antarctica in 1985 fueled interest in ozone depletion as a potential health and ecological threat related to increased solar ultraviolet radiation. Intensified research of this phenomenon followed and led ultimately to the strengthening of the Montreal Protocol, restricting or banning industrial production of chlorinated and brominated compounds causing the depletion.

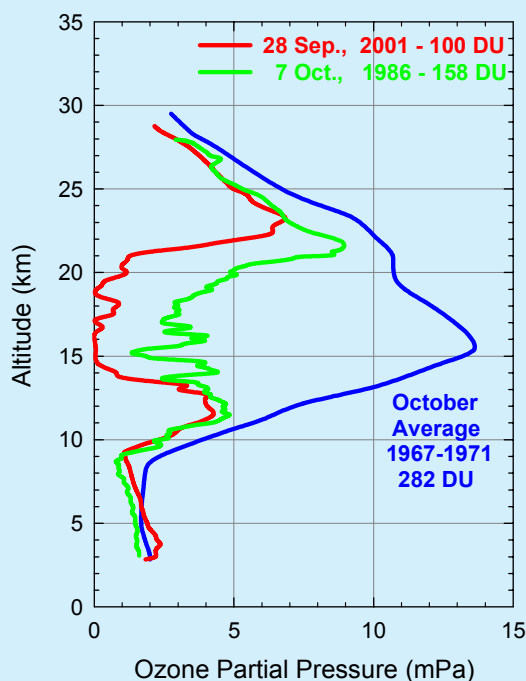


CMDL South Pole ozone/ H<sub>2</sub>O balloon launch.

## Stratospheric Ozone Measurements

Measurements of total-column ozone have been made for over 40 years with the Dobson spectrophotometer. The 16-station CMDL Cooperative Dobson Network is a significant portion of the global Dobson network making ground-based, column-ozone measurements. Almost all of these stations are linked to the world calibration standard maintained by CMDL. Six of the Dobson instruments are automated to provide ozone vertical profiles using the Umkehr technique and eight balloon-borne ozonesonde stations, including the South Pole, provide ozone profiles to an altitude of ~32 km.

From this strong complement of ozone-measuring techniques, it has been possible to measure the decline in ozone over the past two decades at mid-latitudes of the northern hemisphere and the tropics and to characterize the dramatic ozone depletion over Antarctica. CMDL also monitors spectral UV at several sites and has shown the expected anti-correlation between ozone and UV.



South Pole ozone at maximum depletion.



# Research Theme - Ozone Depletion (continued)

## Ozone-Depleting Gases

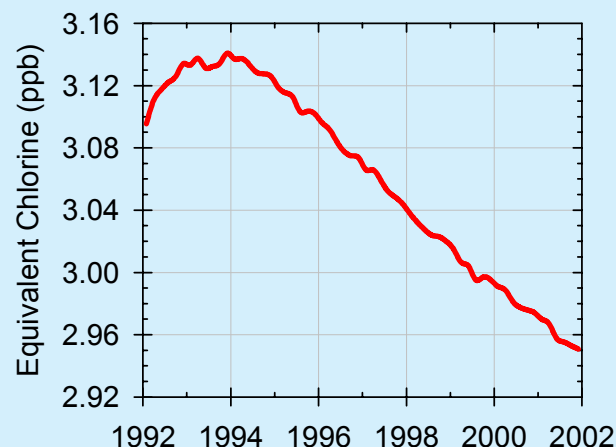
Three gases that make a significant contribution to stratospheric ozone depletion, CFC-11, CFC-12 and N<sub>2</sub>O, have been monitored by CMDL since the mid-1970s. Since then, numerous additional CFC's, HCFC's, and other halogenated gases have been incorporated into the measurement program as the number of monitoring sites increased. Most of the gases that are responsible for depleting stratospheric ozone are anthropogenic, but some, such as CH<sub>3</sub>Br and CH<sub>3</sub>Cl, have natural contributions as well.

Not only do scientists at CMDL monitor the trends and distributions of these gases in the atmosphere, but they also investigate their sources and sinks. CMDL's research extends to the troposphere, the stratosphere, the ocean, the polar snowpack, and terrestrial ecosystems in an effort to understand and predict the atmospheric behavior of these gases.

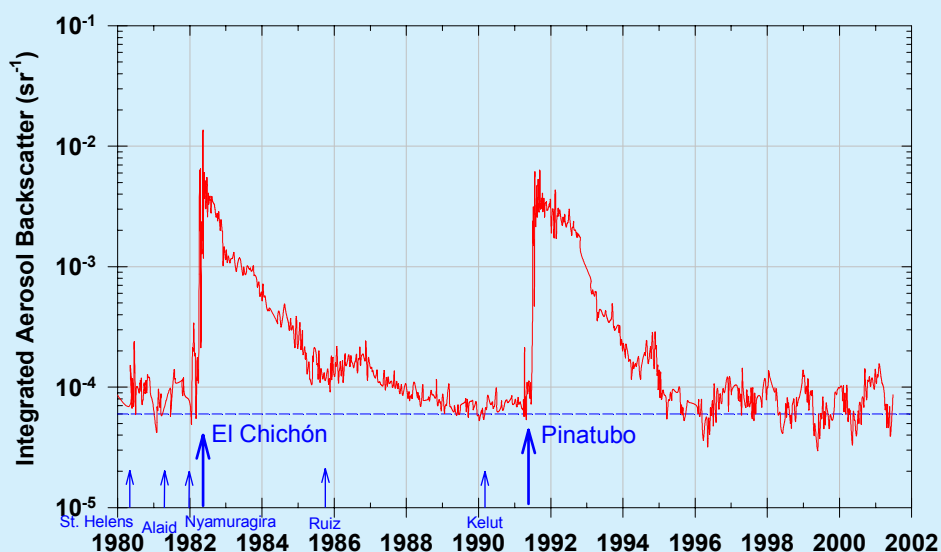
## Stratospheric Aerosols

Ozone depletion, through halogen-related chemistry, is facilitated by increased stratospheric particles as

provided by stratospheric clouds in the polar regions and globally by volcanic eruptions. In order to study the volcanic aerosol-ozone interaction, CMDL monitors stratospheric aerosol with lidars at Boulder and Mauna Loa with an additional system being implemented in Samoa. Modeling suggests that with present halogen levels, a major eruption such as that of Pinatubo in 1991 could decrease total column ozone by as much as 10% at mid-latitudes.



**Global equivalent atmospheric chlorine (all chlorine and bromine compounds), now decreasing because of the Montreal Protocol.**



**Lidar measurements at Mauna Loa Observatory showing the integrated laser light backscattered from the 15-33 km region of the stratosphere. Volcanic eruptions which perturbed the stratosphere and increased the stratospheric aerosol loading are indicated.**



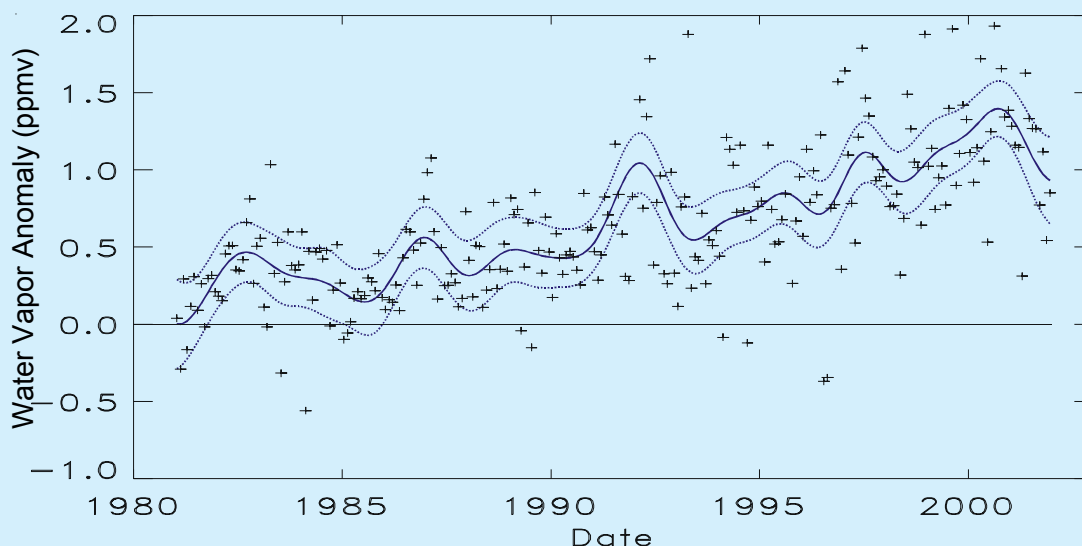
## Research Theme - Ozone Depletion (continued)

### Stratospheric Water Vapor

Utilizing balloon-borne frost-point hygrometers, CMDL has detected an approximately 1% per year increase in stratospheric water vapor at Boulder, Colorado, since 1980. Besides implications for climate change, increased water vapor can affect the rate of chemical ozone loss, for example, by increasing the incidence of polar stratospheric clouds. Satellite measurements of water vapor, although not of adequate length for accurate trend determination, suggest that the increase may extend to other latitudes.



Measuring sea-air fluxes of trace gases.



Increasing water vapor trend at 16-24 km over Boulder, Colorado, determined with the CMDL balloon-borne frost-point hygrometer. The crosses are measurements, the continuous smooth curve is a statistical fit to the data, and the dotted curves are plus and minus one standard deviation.

#### Scientific Questions Related to Ozone Depletion

- Will stratospheric ozone recover as anticipated?
- Will total equivalent atmospheric chlorine continue to decline?
- What are the contributions to inorganic bromine in the stratosphere?
- How will future ozone variability affect UV radiation at the earth's surface?
- Will further increases in stratospheric water vapor exacerbate ozone depletion?
- Will the next major volcanic eruption decrease stratospheric ozone?



# Research Theme - Ozone Depletion (continued)

## Actions and Impacts

- **Maintain and improve the current total ozone and ozone profiling network.**

*Impact: CMDL total column, Umkehr, and ozonesonde profile records go back a minimum of 15 years and will provide the basis for detecting the anticipated recovery of stratospheric ozone.*

- **Continue monitoring the distributions and trends of gases involved in stratospheric ozone depletion.**

*Impact: Regulations are in place on some ozone-depleting substances and new regulations will come into effect on replacement compounds in 20 years. The total equivalent chlorine from these gases has been declining but must be monitored to ensure that the regulations continue to have the desired effect.*

- **Continue measurements of the oceanic and terrestrial fluxes of methyl halides and short-lived halocarbons.**

*Impact: Continued surveillance will allow the detection of feedbacks from climate change that may take place and alter oceanic fluxes and concentrations of the methyl halides and short-lived gases that contribute to stratospheric bromine.*

- **Continue cooperative work with NASA toward understanding the processes depleting ozone in the stratosphere.**

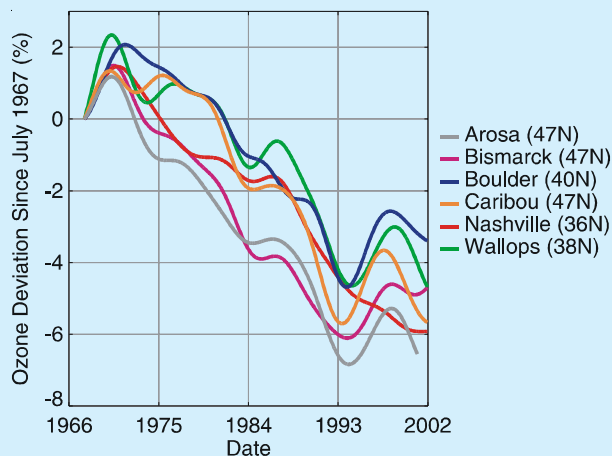
*Impact: CMDL designed and built instruments used for measurements from a NASA ER-2. The instrumental designs developed in these programs are used in replacing old technology at CMDL's surface observing sites.*

- **Improve water vapor instrumentation and expand the measurement program.**

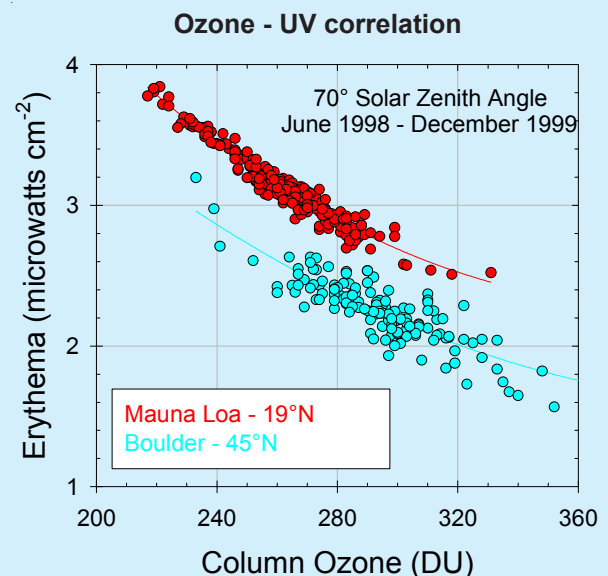
*Impact: Simplification of production of the current balloon-borne cryogenic hygrometer will allow for more frequent measurements. Expansion of measuring sites will allow the determination of whether the increase in stratospheric water vapor observed at Boulder is global in nature.*

- **Continue monitoring UV radiation and stratospheric aerosols at existing sites.**

*Impact: Combined with ozone measurements, the correlation between ozone and UV under differing atmospheric conditions can be studied. Stratospheric aerosol measurements following major volcanic eruptions will allow for the determination of their affects on ozone and climate.*



**Stratospheric ozone depletion from several Dobson instruments at northern mid-latitudes.**





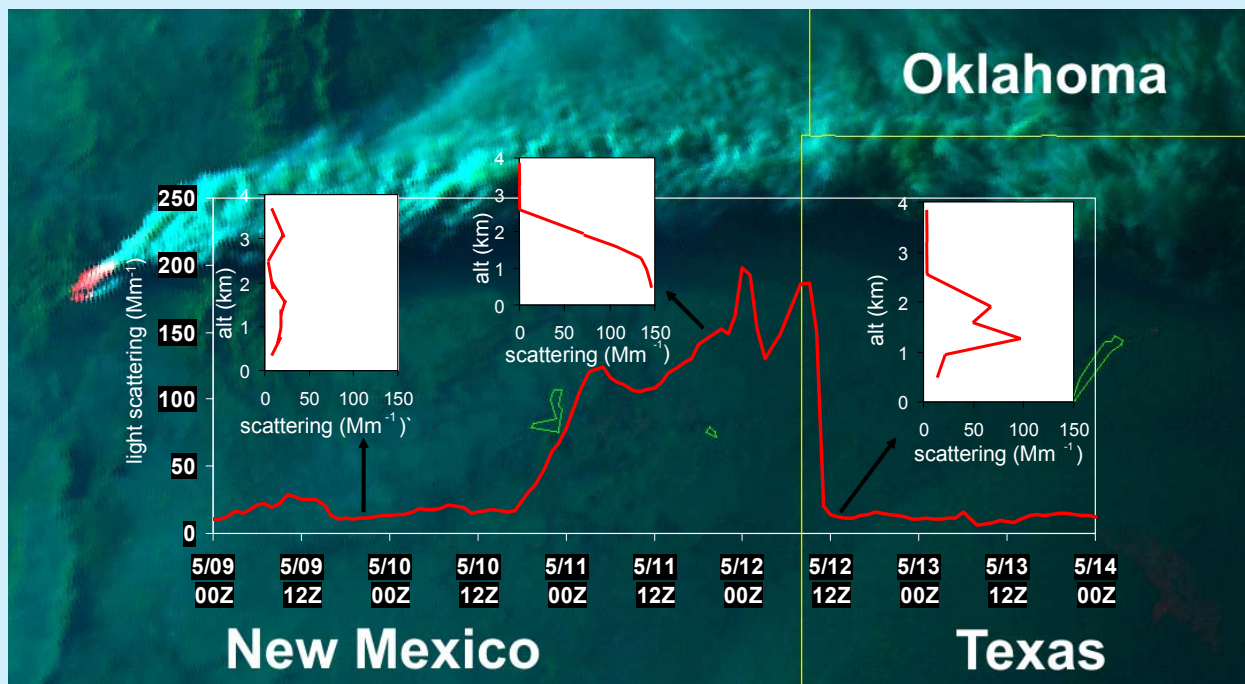
## Air Quality

Although much of CMDL's effort has been focused on obtaining long-term measurements of the remote atmosphere, it has been necessary to make observations at sites that are influenced regionally in order to understand the distribution and nature of the sources of climatically important gases. Examples include sampling sites at Harvard Forest, Massachusetts, and Niwot Ridge, Colorado, on ~500 meter towers in North Carolina, Wisconsin, and Texas, and at polluted sites in the central U.S.

It has become even more apparent in recent years that air masses can carry pollution long distances, over which compounds are transformed during

transport. Large-scale pollution and dust from Asia, for example, is transported at midaltitude across the Pacific Ocean in a matter of days and impacts sites in the United States. Fires in Central America send smoke plumes across Mexico and the South-Central U.S., and dust from Africa regularly reaches the eastern U.S. CMDL is in the process of implementing a new baseline station at Trinidad Head, California, in order to monitor incoming air pollution from Asia.

The importance of large-scale transport in affecting overall air quality and its impacts on public health is only beginning to be appreciated. CMDL will study intercontinental transport events and improve our understanding of their impacts.



Transport of smoke from Los Alamos, May 2000, measured by CMDL at the Southern Great Plains ARM site along with vertical aerosol profiles from a CMDL aircraft program.

### Scientific Questions Related to Air Quality

- Is intercontinental transport of pollutants influencing the distribution of chemicals and particles over the United States and its adjacent oceans?
- To what extent will increasing concentrations of atmospheric aerosols affect air quality?
- How is air quality affected by background or “natural” trace species?
- How are the atmospheric budgets of CO and H<sub>2</sub> affected by source and oxidative processes?





## Research Theme - Air Quality (continued)

### *Actions and Impacts*

- **Establish West Coast Observatory at Trinidad Head, California.**

*Impact: Measurement of pollution incident on the west coast of the U.S. will provide information on changing air quality baselines in the future.*

- **Initiate measurements of aerosol optical depth at the West Coast Observatory.**

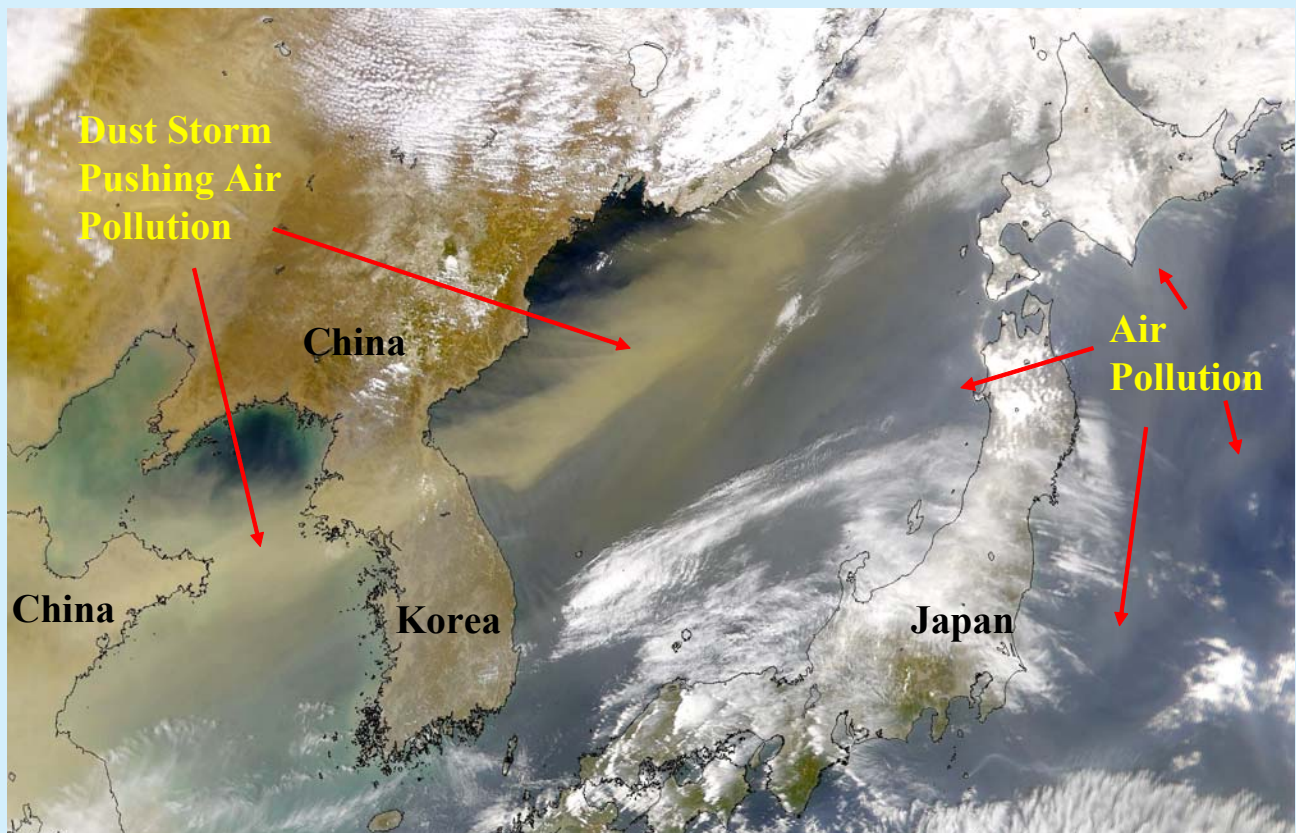
*Impact: These measurements will allow determination of the particulate loading of air arriving on the U.S. west coast prior to interaction with the inhabited portion of the continent and, combined with other aerosol optical properties determined on the surface and from aircraft profiles, will determine effects on the radiation budget.*

- **Initiate measurements of hydrocarbons, PAN, CO, H<sub>2</sub>, and other species involved in air quality issues at the West Coast Observatory.**

*Impact: Hydrocarbons and PAN play important roles in regulating tropospheric ozone. CMDL's Trinidad Head Observatory is well suited for these measurements because it samples both remote and regionally influenced air.*

- **Continue operations with CMDL's movable aerosol sampling system.**

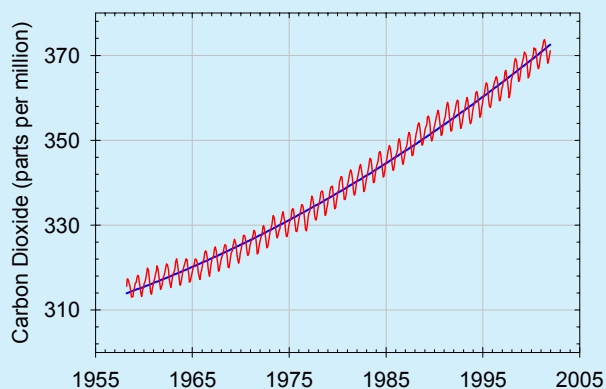
*Impact: Deploying the CMDL movable aerosol sampling system along the Gulf Coast of the U.S. will provide information on aerosol particles as they enter the country and deployment in the eastern U.S. will allow analysis of particles associated with dust from Africa.*



Asian dust storm and air pollution that impacted the U.S., April 2001



## Baseline Observatories



Mauna Loa carbon dioxide record.

The backbone of CMDL's measurement network has been its Baseline Observatories located at Point Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and the South Pole. These observatories were established in order to provide sampling of the most remote air on the planet so that the true "background atmosphere" could be monitored. Since then, the sampling network has expanded considerably through numerous collaborative associations.

While some of these additional sites may serve only for obtaining weekly samples, others, such as Niwot Ridge, Colorado, are sampled intensively by CMDL, and yet others, such as Alert, Canada, and Cape Grim, Australia, involve close collaborations with the cooperating agencies. The network today provides global coverage of the remote atmosphere and a number of sites well suited for assessing the distributions and fluxes of the measured gases, aerosols, and radiation.

In response to the need to obtain more information on regional air quality and transport of pollutants, CMDL has established a new observatory at Trinidad Head, located on the Pacific coast in Northern California. The site is ideal for monitoring air masses coming in from the west, allowing for analyses of trace constituents in air before it

undergoes continental influence. The first measurements began in April 2002 in support of the Intercontinental Transport and Chemical Transformation (ITCT) Program. Such baseline measurements will be important for regulations related to the quality of air in the U.S. and, combined with measurements off the east coast of the U.S., in determinations of the carbon dioxide source/sink characteristics of North America.

### *Mauna Loa, Hawaii (Established 1957)*

The Mauna Loa Baseline Observatory is located at 3397 m above sea level on the north flank of the Mauna Loa volcano massif and consists of two main research buildings and five subordinate structures. The facility is manned and supported by a staff of seven and is considered the world premier long-term atmospheric monitoring facility. A new Network for the Detection of Stratospheric Change (NDSC) building (4000 ft<sup>2</sup>) was constructed in 1997, effectively doubling research space at the facility. A new 500 ft<sup>2</sup> building housing the University of New Hampshire wind lidar program was completed in December 2001. Mauna Loa will undoubtedly take on new programs as scientific questions arise and better instrumentation becomes available. At present Mauna Loa has the facilities, power, communications, and staff for moderate growth in scientific programs.



Mauna Loa Observatory facing North.



## Baseline Observatories (continued)

### *Point Barrow, Alaska (Established 1973)*

The Point Barrow Observatory is located 6 miles southeast of Barrow near sea level and is staffed by two permanent employees. This facility conducts numerous continuous monitoring activities, including hosting 21 cooperative programs with universities and other government agencies. The main station building was upgraded in 1996 and a new garage and tank storage building were constructed in 2001 in phase two of a three-phase plan for maintaining the station as the leading atmospheric research facility in the Arctic.

In 2004, new housing for the Barrow staff will be constructed to replace the present 1970s-era modular housing units. Within the past decade, the number of scientific programs has doubled at the Barrow Observatory with half of the new research activity comprising cooperative research projects. At present the Barrow facility has reached physical capacity and cannot support additional research programs without expansion of facilities.

Plans are underway to construct a new main observatory building by 2005. This building will also have space to accommodate National Environmental Satellite Data and Information Services (NESDIS) polar satellite downlink equipment.



**Barrow Observatory from the meteorological tower.**

### *Cape Matatula, American Samoa (Established 1973)*

The Samoa baseline station is located on Cape Matatula at the eastern end of Tutuila Island, American Samoa, 26 miles east of the capital city Pago Pago, and is staffed by two employees. The Station Chief position is filled by a NOAA Corps Officer. The facility consists of a main building and two smaller outbuildings in which CMDL makes the same suite of scientific measurements as conducted at the other observatories.

An old, nonfunctioning solar array was refurbished in 2001 and installed on a newly built carport roof to now provide 30% of the daytime electricity requirements of the station. Two staff houses were completely refurbished in 2001 and a new generator (10kva) installed as back-up power for the station.

High-speed internet access for the observatory is a primary goal and will become a reality in mid-2002. Major repairs to the concrete roof of the main observatory building will be undertaken in 2003. The growth of scientific programs at Samoa has not paralleled that of the other stations. This is likely because of the remote location of the site.



**Samoa Observatory from the meteorological tower.**



## Baseline Observatories (continued)

### *South Pole, Antarctica (Established 1957)*

The South Pole Station is located at the Amundsen-Scott station at the South Pole at an elevation of 2837 m above sea level on the polar ice cap. The CMDL instrumentation is located in a new building (1998), the Atmospheric Research Observatory, supplied and maintained by the National Science Foundation.

Two staff operate the CMDL facility and are assigned to the South Pole for 1-year terms of service. The Station Chief position is filled by a NOAA Corps Officer when available.

In the austral spring of 2003, an intensive campaign of releasing twice as many ozonesondes as normal will occur over 3 months to monitor the initiation of the ozone hole. There are space, power, and staff resources for a number of additional, moderately sized scientific programs at the South Pole Atmospheric Research Observatory.

A new ozonesonde balloon launch facility will be built at South Pole and should be available by 2006, which is also the date that the new main South Pole support and accommodation facility will be completed.



**South Pole Observatory - Sunset 2001.**

### *Trinidad Head, California (Established 2002)*

Located on a point jutting into the ocean along the remote north coast of California, Trinidad Head is ideally suited for atmospheric measurements. Much of the time the site experiences baseline conditions, but it also allows for the monitoring of regionally influenced air, affected mainly by forested lands, but to a lesser extent, air having a small urban influence.

An instrumented trailer was installed in April 2002 allowing measurements of aerosols, surface ozone, radiation, and flask sampling for halocarbons and carbon cycle gases. Within a year, weekly airborne vertical profile measurements of carbon cycle gases will be collected in flasks above and upwind of Trinidad Head. CMDL's measurements will provide a continuous baseline of pollution and climate forcing agents in air entering the U.S.

Further plans include installing a GCMS for measuring PAN, hydrocarbons, and certain halocarbons. Additional measurements will be included as the Observatory matures. Already, at this location, Scripps Institution of Oceanography is operating two in situ instruments, one as part of the Advanced Global Atmospheric Gases Experiment (AGAGE), the other for measuring changes in atmospheric oxygen concentration.



**Trinidad Head viewed from the southwest.**



# Calibration and Instrument Development

## Calibration

An important element of CMDL's operations is the calibration of atmospheric measurements. Because much of what is measured is low in concentration and because measurements are made globally with many instruments, it is imperative that calibrations be of the highest quality. CMDL maintains calibration scales for a number of gases and atmospheric properties, frequently intercalibrating with other agencies and organizations to ensure consistent measurements across the globe.

### Carbon Cycle Gases

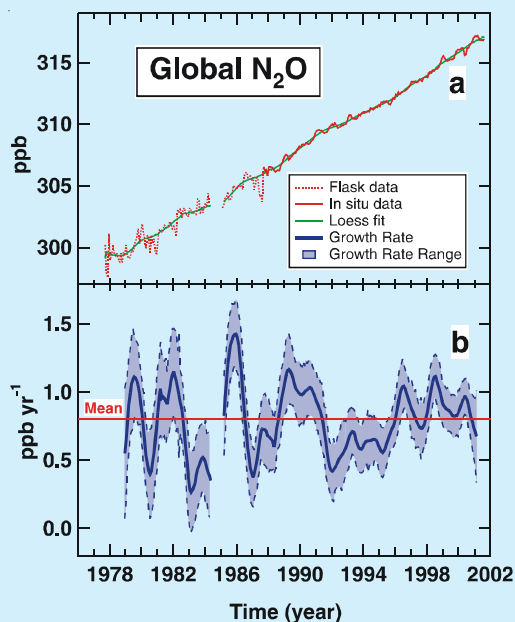
CMDL maintains the WMO Mole Fraction Scale for CO<sub>2</sub> and for CO. Calibrated reference gas mixtures are made available for purchase by other laboratories. The scales are maintained by annually making absolute calibrations of the mole fraction of these gases in dry air in cylinders, designated as primaries, that are kept for decades. The calibration of the primaries is transferred to other cylinders by comparisons with standard methods such as infrared absorption or gas chromatography.

Plans for the future include:

- Maintain the WMO Mole Fraction Scale for CO<sub>2</sub>, and provide calibrated reference gas mixtures to outside research organizations.
- Participate in ongoing intercomparison activities with outside research groups, in which analyses of real air samples are compared to determine differences between laboratories and measurement networks.
- Participate in development of new sensors and analysis systems for very accurate and precise measurements of CO<sub>2</sub> at surface stations and aboard ships, buoys and aircraft.

### Halocarbons, Nitrous Oxide, Sulfur Hexafluoride

Except for PAN, all CMDL trace gas calibration scales are tied to gravimetrically prepared standards produced in the CMDL trace gas standards laboratory. Working with Scripps Institution of Oceanography and Essex Cryogenics, members of the standards project have assisted industry in producing a Department of Transportation certified, 35-liter electropolished cylinder capable of holding 60 atmospheres pressure. These cylinders are more stable for methyl halides and other gases than the Aculife-IV treated aluminum cylinders currently in use at the stations.



### Atmospheric nitrous oxide accumulation and growth rate.

Plans for the future include:

- Continuing intercalibrations with outside research organizations.
- Using the new, more stable cylinders where possible.
- Upgrading the gravimetric balances to more precise gravimetric comparators.
- Adding calibration scales for additional gases as the needs arise.



## Calibration and Instrument Development (continued)

### *Ozone*

The World Standard Dobson instrument is maintained by CMDL. Almost all of the operational instruments in the global Dobson network are linked to this standard either through direct comparison or through intercomparison with a regional or national standard that is compared to the World Standard Dobson. Calibration of the World Standard is maintained through annual observations at Mauna Loa Observatory.

Plans for the future include:

- Maintaining the World Standard Dobson instrument and carrying out regular absolute calibrations at Mauna Loa Observatory.
- Conducting international intercomparison campaigns to propagate the standard calibration scale throughout the global Dobson network.
- Establishing a National Institute of Standards and Technology (NIST) calibrated standard ozone photometer as the CMDL network standard for surface ozone and ozonesonde observations.
- Establishing the CMDL chilled-mirror hygrometer as a standard for comparison with radiosonde and lidar water vapor measurements.

### *Radiation*

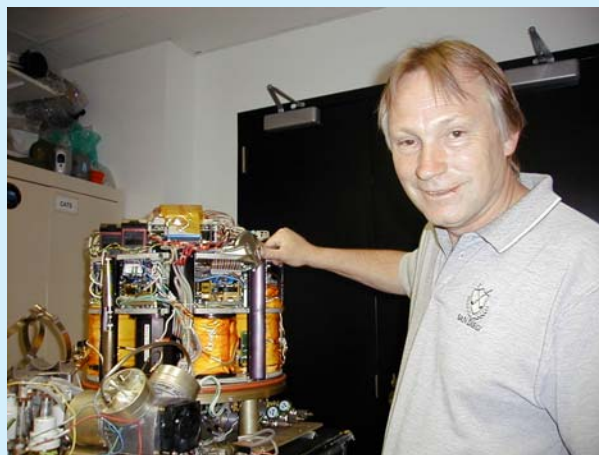
The radiation field has historically lagged in the development of reference standards compared to many other meteorological variables. CMDL has been actively involved in advances in all aspects of broadband irradiance measurement and maintains the U.S. Regional Solar Calibration Facility of the WMO. Significant effort each year goes into maintenance of this calibration capability along with design and testing of improved measurement methods.

### *Instrument Development*

CMDL is a leader in the development of instrumentation for environmental chemical measurements. These developments have improved dramatically upon the frequency and precision of measurements necessary for monitoring the atmosphere. This is an ongoing process involving improvements of instrumentation for old measurements as well as new instruments for new constituents or different applications.



**The operation of the CMDL primary solar calibration standard and associated radiometers is being checked in preparation for clear-sky conditions.**



**Balloon-borne gas chromatograph developed by CMDL.**



## Calibration and Instrument Development (continued)

### Examples of Instrumentation Developed at CMDL:

- **A 20-sample automatic aircraft air-sampling system** for CO<sub>2</sub>, CH<sub>4</sub>, CO, H<sub>2</sub>, N<sub>2</sub>O, and SF<sub>6</sub>.
- **Rapid sampling, multiple-channel gas chromatographs** designed for deployment on high-speed aircraft, such as NASA's ER-2, and high-altitude balloon gondolas. These lightweight systems condense sampling times to about 1 minute and maintain consistent analyses over a wide range of temperatures and pressures experienced in flight. The design was later modified for instruments now deployed for continuous operation at CMDL's Baseline Observatories and other sampling sites.
- **A sea-going gas chromatograph-mass spectrometer** designed for continuous underway measurement of 25-30 trace gases in the atmosphere and surface water. The system, which traps samples at -80°C and injects them at +200°C into a cooled column in a temperature-programmed oven, requires no liquid nitrogen and can operate for months on end.
- **An automated airborne aerosol sampling system** that allows routine vertical profiling of aerosol properties that cannot be measured with remote sensing methods. The costs are kept low (~\$600/profile) by eliminating the need for an instrument operator; instead, the onboard computer uses a GPS receiver to control instrument operation during the flight.
- **A miniaturized aerosol lidar** capable of monitoring the stratospheric aerosol layer was developed and tested with the large lidar system at Mauna Loa Observatory. The miniature system has been making measurements at Boulder, Colorado, for several years. Additional systems will be deployed at the Samoa Observatory and, in a cooperative program, at the equator in South America if funding for the latter can be obtained.



Mauna Loa stratospheric aerosol lidar in operation at night. The vertical green streak is the laser beam.



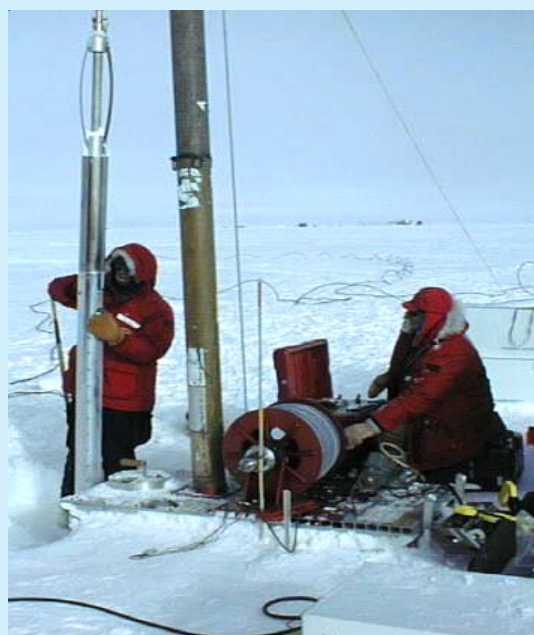
A 12-compound gas chromatograph developed and built by CMDL for operation at the baseline stations.



# Research Platforms



CMDL's research is conducted from ships, tall towers, high-altitude aircraft, trains, and polar snowpack in efforts to identify sources and sinks of atmospheric constituents.



CMDL and collaborators sampling century old air from the South Pole snowpack.



The photo on the left as it appeared in "Ripley's Believe It Or Not!"





## People and Outreach

### *The Work Force*

CMDL employs a federal workforce of 53 employees who work closely with 34 scientists from the University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES). CIRES Research Associates work side-by-side with NOAA federal scientists in CMDL's laboratories and in the field, sharing in both the research efforts and the presentation of results at conferences and in publications. The collaboration with CIRES provides CMDL easy access to a broad range of expertise in the academic community. When federal vacancies become available, it is not uncommon for

a CIRES Research Associate to be the leading candidate for the position. Today, many CMDL federal scientists were trained at CMDL as CIRES Research Associates.

CMDL collaborates with scientists and technicians from over 60 universities and agencies in the collection of samples and operation of instruments at the numerous field sites other than the observatories. CMDL is also involved in collaborative projects around the world – projects ranging from designing instruments, to making measurements at the observatories, to studies from aircraft, ships, and temporary field sites.



**Sampling trace gas emissions from greenhouse plants.**



**Flask analysis for carbon cycle gases.**



**Rigging the observatory tower at Trinidad Head.**



**Measuring atmospheric halocarbons in flask samples.**



## People and Outreach (continued)

### *Outreach*

Informing the public about what is being done, why, and its significance for the well-being of our citizens is an important duty of a federal agency. Included in CMDL's outreach effort is an emphasis on K-12 education so that young people are exposed to the environmental sciences. Since the Boulder Laboratories are located in the midst of a thriving university town, there are numerous opportunities for CMDL scientists to interact with students and the general public.

The four CMDL observatories are also engaged in outreach activities, and their locations provide a unique opportunity to educate and inform societies located in remote areas as well. Numerous visitors to the observatories also aid in carrying our message to the general public.



**CMDL staff teaching school children about air pollution measurements.**

CMDL scientists participate in events such as science fairs and the annual ocean bowl, presenting talks to elementary and secondary school children in the classroom, and inviting domestic and international visitors to the laboratory for tours. For example, scientists at CMDL are collaborating with

students at Sinte Gleska University, a Native American University in South Dakota, to broaden their understanding of atmospheric sciences. A Rosebud Sioux university student will spend the summer of 2002 working at CMDL and further collaborative efforts are being planned. The observatories provide special opportunities for educating the public. The South Pole winterover crew responds to e-mail queries from classrooms throughout the world about life in Antarctica. Educational activities conducted at Mauna Loa and Point Barrow Observatories directly involve students at local schools. The Samoa Observatory staff has been involved with the tribal communities of the island, fostering a sense of unity.

The success of scientific research conducted at CMDL depends on educating the public and providing forums to bring scientists and the community together. It is critical that our citizens realize the importance of CMDL's work so that their elected representatives can help determine the direction of scientific research and provide the sustenance for continuation of long-term climate monitoring.



**Mauna Loa Observatory staff teaching Hawaiian students how to build air quality monitoring equipment for the Hawaii VOGNET (volcanic smog network) supported by Mauna Loa Observatory and operated by high schools on the Big Island.**



### CMDL 5-year Operating Plan - Performance Measures

The important research questions have been stated and actions to address these questions have been formulated. In order to help determine progress, a CMDL 5-year Operating Plan with Performance Measures has been prepared.

#### Climate Forcing

- PMC1:** Improvement in our understanding of the processes that determine the atmospheric burdens of major trace gases influencing the earth's climate.
- PMC2:** Acquisition of atmospheric data needed to quantify the natural cycles of carbon gases and nitrous oxide.
- PMC3:** Verification of emissions of natural and anthropogenic gases on large, regional scales.
- PMC4:** Acquisition of measurements of aerosol properties that, when combined with chemical transport models, radiative transfer models, and global satellite observations, will allow evaluation of the anthropogenic climate forcing by aerosols.
- PMC5:** Acquisition of atmospheric radiation measurements of sufficient accuracy and duration to help evaluate the aggregate radiative effects of an altered climate forcing.

#### Ozone Depletion

- PMO1:** Detection of the recovery of the ozone layer through continued monitoring.
- PMO2:** Studies of the emissions and trends of ozone-depleting trace gases as their atmospheric burdens decrease.
- PMO3:** Assessment of the fluxes of short-lived, ozone-depleting brominated and iodinated gases from the ocean and terrestrial systems.
- PMO4:** Provision of a long term, accurate record of surface UV radiation.
- PMO5:** Improvement in the precision and global extent of the estimate of changes in stratospheric water vapor.

#### Air Quality

- PMA1:** Assessment of variations in the background air quality prior to interaction with the North American continent.
- PMA2:** Provision of spectral solar irradiance observations in support of investigations involving visible aerosol loading and investigations of photochemical reaction rates.
- PMA3:** Characterization of the radiative, chemical, and microphysical properties of aerosols entering the U.S.

#### Observatory Infrastructure

1. Improvements at the Barrow, Mauna Loa, Samoa, and South Pole Observatories.
2. Full implementation of the Trinidad Head Observatory programs.



## Performance Measures (continued)

### Keeping Score

To keep track of how well we are doing in meeting our performance measures we have, as a group, developed an extensive set of quarterly milestones to gauge our success along the way. Some of these milestones are optimistic and rely on resources that we don't presently have but believe will be made available through NOAA Research Initiatives (some have already been proposed for the FY2004 budget, many related to the President's Climate Change Research Initiative). However, they are also realistic scientific outcomes of which we are fully capable of. They range from making data available on a regular basis, to publications, field programs, new instruments, measurements of new constituents, new measurement sites, implementation of the North American Carbon Cycle Observing System, and new observatory facilities. We list the numerical distributions below. (see Appendix for actual milestones)

#### Milestones by Quarter:

	Q1	Q2	Q3	Q4	TOTAL
2002		2	4	6	12
2003	12	10	13	15	50
2004	7	6	7	6	26
2005	5	5	6	5	21
2006	3	2	3	8	16
TOTAL	27	25	33	40	125

#### Milestones by Group: \*

	AERA	CCGG	HATS	OZWV	OBOP	TOTAL
2002	1	5	3	2	1	12
2003	5	13	13	6	13	50
2004	4	4	7	5	6	26
2005	4	4	4	3	5	20
2006	4	2	3	1	7	17
TOTAL	18	28	30	17	32	125

#### Milestones by Research Theme:

	Climate Forcing	Ozone Depletion	Air Quality	Observatory Infrastructure	TOTAL
2002	6	3	2	1	12
2003	21	13	3	13	50
2004	10	8	2	6	26
2005	8	6	2	5	21
2006	5	2	2	7	16
TOTAL	50	32	11	32	125

\*AERA: Aerosols and Radiation

CCGG: Carbon Cycle and Greenhouse Gases

HATS: Halocarbons and other Atmospheric Trace Species

OZWV: Ozone and Water Vapor

OBOP: Observatory Operations



### *Climate Forcing*

**PMCI:** *Improvement in our understanding of the processes that determine the atmospheric burdens of major trace gases influencing the earth's climate.*

Milestones:

- 2002Q4: Publish a paper on the CO<sub>2</sub> growth rate, zonal sources and sinks derived from a two dimensional model, and the relation to climate variability.
- 2002Q4: Publish analysis of observed trace gas variations over Hawaii.
- 2003Q1: Publish papers on the results of the Chequamegon Ecosystem-Atmosphere Study examining the processes that regulate atmosphere/forest exchange of carbon dioxide in a northern temperate forest ecosystem.
- 2003Q2: Upgrade the surface ozone analyzers at the CMDL observatories and add a NIST ozone calibration standard at CMDL.
- 2003Q4: Publish a paper analyzing the implications for air-sea gas exchange of the combined atmospheric records of CO<sub>2</sub> and its isotopic ratio.
- 2004Q3: Publish an analysis of measurements of atmospheric N<sub>2</sub>O and SF<sub>6</sub> from the CMDL CCGG Cooperative Air Sampling Network.
- 2004Q3: Publish an analysis of tropospheric ozone trends.

**PMC2:** *Acquisition of atmospheric data needed to quantify the natural cycles of carbon gases and nitrous oxide.*

Milestones:

- 2002Q2: Publish all measurements obtained in the previous year from the cooperative global air sampling network (approximately 8000 separate air samples) and from six continuous data sites.
- 2002Q3: Update Globalview, a compilation of quality-controlled CO<sub>2</sub> data from 20 laboratories in 13 countries, with an additional year of data.
- 2002Q3: Publish updated CO standard scale and global CO trends.
- 2002Q3: Publish a unified data set of all nitrous oxide data for the polar stratosphere of the year 2000.
- 2003Q1: Improve the WMO mole fraction scale for CO maintained by CMDL.
- 2003Q1: Publish a paper on the WMO mole fraction scale for CO<sub>2</sub> maintained by CMDL.
- 2003Q1: Archive nitrous oxide, halocarbon, and other trace gas data with the WMO Greenhouse Gas Data Center in Tokyo, Japan.
- 2003Q2: Publish details of the CMDL CCGG gravimetric CH<sub>4</sub> reference gas scale developed in collaboration with the HATS group.



## Appendix - FY2002-2006 Performance Milestones

- 2003Q2: Publish all measurements obtained in the previous year from the cooperative global air sampling network (approximately 8000 separate air samples) and from six continuous data sites.
- 2003Q2: Publish trends of atmospheric nitrous oxide showing the importance of tropical land and oceanic sources.
- 2003Q3: Update Globalview, a compilation of quality-controlled CO<sub>2</sub> data from 20 laboratories in 13 countries, with an additional year of data.
- 2003Q3: Begin sampling on Volunteer Observing Ships in the Pacific, Atlantic, and Southern Ocean.
- 2003Q3: Publish revised estimate for the atmospheric lifetime of sulfur hexafluoride (a strong IR absorber) based on stratospheric measurements.
- 2003Q4: Begin sampling at six additional international land-based sites.
- 2003Q4: Begin collecting regular vertical profiles of CO<sub>2</sub> and other trace gases at six sites in North America.
- 2003Q4: Add other trace gases to the measurements of CO<sub>2</sub> at two existing tall tower measurement sites in the U.S. Begin one new tall tower in the southeastern U.S.
- 2003Q4: Publish sulfur hexafluoride trends and compare with emissions.
- 2004Q1: Publish revised lifetimes of nitrous oxide and methane from stratospheric measurements.
- 2004Q2: Publish all measurements obtained in the previous year from the cooperative global air sampling network (approximately 8000 separate air samples) and from six continuous data sites.
- 2004Q2: Measure tropospheric nitrous oxide in the Amazonian Basin in Brazil.
- 2004Q3: Update Globalview, a compilation of quality-controlled CO<sub>2</sub> data from 20 laboratories in 13 countries, with an additional year of data.
- 2004Q4: Begin vertical profiles at two additional sites in North America, intensify sampling at existing sites.
- 2005Q1: Publish implications to tropospheric OH of revised methyl chloroform lifetime as emissions level off or approach zero.
- 2005Q2: Publish all measurements obtained in the previous year from the cooperative global air sampling network (approximately 8000 separate air samples) and from six continuous data sites.
- 2005Q2: Add perfluorocarbons (another strong IR absorber) to the in situ GC-MS measurements of the halocarbon network.
- 2005Q3: Update Globalview, a compilation of quality-controlled CO<sub>2</sub> data from 20 laboratories in 13 countries, with an additional year of data.
- 2005Q4: Begin vertical profiles at seven new sites in North America, and intensify sampling at existing sites.
- 2005Q4: Start continuous measurements on nine tall towers in the U.S.
- 2006Q1: Complete high accuracy set of carbon dioxide, methane, and carbon monoxide gravimetric standards.
- 2006Q2: Publish all measurements obtained in the previous year from the cooperative global air sampling network (approximately 8000 separate air samples) and from six continuous data sites.
- 2006Q3: Update Globalview, a compilation of quality-controlled CO<sub>2</sub> data from 20 laboratories in 13 countries, with an additional year of data.



## Appendix - FY2002-2006 Performance Milestones

***PMC3: Verification of emissions of natural and anthropogenic gases on large, regional scales.***

Milestones:

- 2003Q1: Publish a paper outlining a strategy for monitoring surface fluxes at regional scales (hundreds of km) of CO<sub>2</sub> over North America by using continuous monitoring of CO<sub>2</sub> mixing ratios on a network very tall towers.
- 2003Q2: Publish an update of changes in CH<sub>4</sub> global growth rate with arguments suggesting the role of decreased emissions from the fossil fuel sector in the former Soviet Union.

***PMC4 Acquisition of measurements of aerosol properties that, when combined with chemical transport models, radiative transfer models, and global satellite observations, will allow evaluation of the anthropogenic climate forcing by aerosols.***

Milestones:

- 2003Q3: Publish a 2-year climatology of the vertical profile of aerosol radiative properties over the Southern Great Plains site in Oklahoma.
- 2003Q3: Implement and compare radiative transfer models capable of accounting for vertically varying aerosol optical properties.
- 2004Q3: Publish a comparison of aerosol measurements at CMDL surface stations with model calculations of the measured parameters.
- 2004Q4: Publish the results of the modeled radiative effects of aerosol optical properties observed by the CMDL aerosol project.
- 2005Q1: Begin a 3-year program of systematic measurements of aerosol properties above the U.S. from a light airplane.
- 2006Q4: Publish a report of the first year of airborne aerosol measurements over the U.S.

***PMC5: Acquisition of atmospheric radiation measurements of sufficient accuracy and duration to help evaluate the aggregate radiative effects of an altered climate forcing.***

Milestones:

- 2003Q1: Complete an assessment of the state of development of international radiation measurement reference standards and supply a report to the international community.
- 2004Q2: Publish an analysis of the radiative impact of clouds on surface irradiance as observed at the CMDL field sites over the past 3 decades.
- 2005Q4: Participate in an evaluation of the ability of global general circulation climate models to replicate the surface radiation features observed at CMDL and related sites.
- 2006Q4: Develop an airborne radiometer suitable for accurate net broadband flux measurements over the long-term with minimal maintenance while deployed on a global fleet of climate/weather monitoring aircraft.



### *Ozone Depletion*

#### ***PMO1: Detection of the recovery of the ozone layer through continued monitoring.***

##### Milestones:

- 2002Q4: Publish an analysis of South Pole total column and vertical profile ozone observations.
- 2003Q2: Install an aerosol lidar at Samoa in the renovated NWS building.
- 2003Q3: Update ozone trends from the CMDL Cooperative Dobson network.
- 2004Q1: Establish Samoa Observatory as a Network for the Detection of Stratospheric Change (NDSC) cooperative measurement site.
- 2004Q2: Add the U.S. Brewer UV network to the U.S. total column ozone-measuring network by providing ozone calibrations for the Brewer instruments.
- 2004Q3: Update ozone trends from the CMDL Cooperative Dobson network.
- 2005Q3: Publish analysis of the ozone trends from the CMDL Cooperative Dobson network.
- 2005Q3: Update ozone trends from the CMDL Cooperative Dobson network.
- 2006Q3: Update ozone trends from the CMDL Cooperative Dobson network.

#### ***PMO2: Studies of the emissions and trends of ozone-depleting trace gases as their atmospheric burdens decrease.***

##### Milestones:

- 2002Q3: Participate in the NASA CRYSTAL-FACE experiment in Southern Florida to study the effect of sub-tropical clouds in climate change and ozone depletion.
- 2002Q4: Publish emission estimates of ozone depleting chemicals from Trans-Siberian train measurements.
- 2003Q1: Complete error analysis using Monte Carlo techniques on standard preparation.
- 2003Q1: Publish the historical trend of carbonyl sulfide, a source of the stratospheric aerosol layer, from Antarctic firn (compressed snow).
- 2003Q1: Measure stratospheric air from Ft. Sumner, New Mexico, to determine the structure of the lower most stratosphere and transport from the tropics.
- 2003Q2: Publish stratospheric measurements showing the isolation of the polar stratospheric vortex in 1999-2000.
- 2003Q3: Publish stratospheric trends of organic halogens showing the time lag behind the tropospheric maximum that occurred in 1994.
- 2003Q4: Report on the Radiatively Important Trace Species (RITS) finalized in situ halocarbon measurement.





## Appendix - FY2002-2006 Performance Milestones

2004Q2: Publish high resolution flask and in situ observations of the substitute halocarbons.

2004Q4: Install methyl halide in situ measurements at CMDL tall tower sites.

2005Q1: Complete preparation of a set of high-accuracy halon 1301 gravimetric standards.

***PMO3: Assessment of the fluxes of short-lived, ozone-depleting brominated and iodinated gases from the ocean and terrestrial systems.***

Milestones:

2003Q3: Publish iodinated and brominated trace gas measurements in the oceanic surface waters and marine air.

2003Q4: Publish a map of net oceanic saturation of methyl bromide to highlight regions of sources and sinks for atmospheric methyl bromide.

2004Q1: Publish atmospheric trends of atmospheric methyl bromide and methyl chloride.

2004Q1: Publish stratospheric measurements of brominated and chlorinated compounds.

2005Q3: Publish ocean sink strength for atmospheric carbon tetrachloride.

2006Q4: Publish a review of trace gas exchange between the atmosphere and ocean.

***PMO4: Provision of a long term, accurate record of surface UV radiation.***

Milestones:

2003Q1: Establish Boulder as a Network for the Detection of Stratospheric Change (NDSC) cooperative ozone and UV measurement site.

2003Q4: Establish stable funding and support for ongoing long-term observations of high-resolution solar UV spectra at a minimum of two sites which will extend existing records.

2006Q3: Complete an analysis and publication of the relationship between spectral UV variations and vertically resolved ozone amounts.

***PMO5: Improvement in the precision and global extent of the estimate of changes in stratospheric water vapor.***

Milestones:

2003Q3: Increase the frequency of balloon water vapor profile measurements at Boulder.

2004Q1: Add a tropical and southern midlatitude site for making balloon profile measurements of water vapor.

2005Q3: Update trends in stratospheric water vapor at Boulder.



## Appendix - FY2002-2006 Performance Milestones

### *Air Quality*

***PMA1: Assessment of variations in the background air quality prior to interaction with the North American continent.***

Milestones:

- 2002Q4: Establish two sites for measuring surface ozone downwind of Asia and of North America (Trinidad Head, California and Bermuda).
- 2003Q2: Install new gas chromatograph with mass spectrometer at Trinidad Head or Mauna Loa to study Asian pollution events of short lived hydrocarbons and halocarbons.
- 2003Q4: Implement ozone measurements on aircraft flights as part of the CMDL 'vertical observatories' and carbon cycle profiling network .
- 2004Q1: Publish carbonyl sulfide and methyl halide pollution events from Asia and Hawaii observed with Mauna Loa in situ instruments.
- 2006Q1: Add new in situ mass spectrometric measurements of short lived trace gases at another west coast site and an east coast site.

***PMA2: Provision of spectral solar irradiance observations in support of investigations involving visible aerosol loading and investigations of photochemical reaction rates.***

Milestones:

- 2003Q4: Complete installation of improved direct solar beam sunphotometers at CMDL sites for the measurement of aerosol optical depth.
- 2005Q2: Investigate the impact of observed UV spectra resulting from variation in ozone and aerosols on the photochemical production rates relevant to air quality.

***PMA3: Characterization of the radiative, chemical, and microphysical properties of aerosols entering the U.S.***

Milestones:

- 2002Q2: Establish aerosol measurements at the new CMDL baseline station at Trinidad Head.
- 2004Q2: Begin a one-year period of measurements of aerosols entering the southern U.S. at a site along the Gulf Coast.
- 2005Q2: Publish a comparison of aerosol properties leaving Asia with aerosol properties entering the western U.S.
- 2006Q3: Publish a report on the air quality effects of aerosols entering the southern U.S. from the Gulf of Mexico.



## Appendix - FY2002-2006 Performance Milestones

### *Observatory Infrastructure*

#### *Barrow Milestones*

- 2003Q1: Acquire title to 100 acres of government land adjacent to the Barrow Observatory for future expansion.
- 2003Q4: Have a reliable T-1 internet connection to Barrow Observatory in operation.
- 2004Q4: Move into two newly built, modern houses for the Barrow Observatory.
- 2005Q1: Employe a Barrow native in a scientific capacity at the Barrow Observatory.
- 2006Q4: Move into a new 2400 ft<sup>2</sup> Barrow Baseline Observatory Building.

#### *Mauna Loa Milestones*

- 2003Q1: Have in place a T-1 connection to the Mauna Loa Observatory. All telephone and data communications to MLO are via microwave.
- 2003Q3: Complete construction of a permanent building at Cape Kumukahi, Hawaii, to provide sea level atmospheric measurements for comparison to Mauna Loa measurements at 3397 m above sea level.
- 2003Q4: Begin construction planning phase of a Mauna Loa solar array facility to provide complete daylight power needs to the station (about 30 kva). This would be the largest solar power installation at any federal facility in the U.S.
- 2004Q3: Have in place a T-2 internet connection at the MLO mountain site.
- 2004Q4: Acquire new ozonesonde preparation and balloon launch facilities in Hilo.
- 2005Q1: Acquire new leased office and shop facilities in Hilo or have a funded plan in place to construct such facilities.
- 2005Q4: Upgrade the electrical power distribution system at MLO.
- 2006Q2: Acquire an additional eight acres of land from the State of Hawaii doubling the area of the MLO Observatory grounds.
- 2006Q4: Begin the construction phase of rebuilding and expanding the original MLO Main Observatory building constructed in 1957.

#### *Samoa Milestones*

- 2003Q2: Have Samoa as a designated billet for a NOAA Corps officer.
- 2003Q3: Begin the construction phase of replacing the 12-story cliff stairs at the Samoa Observatory facility.
- 2003Q4: Acquire an ozonesonde preparation and lidar support building at or near the Pago Pago Samoa airport.



## Appendix - FY2002-2006 Performance Milestones

- 2003Q4: Have a 256k internet link in operation at the Samoa facility.
- 2004Q3: Double the number of cooperative projects using the Samoa facility compared to 2002.
- 2004Q4: Have a professional staff member of Samoan descent working at the observatory.
- 2005Q2: Add additional solar cells to the existing Samoa Observatory solar power installation to provide 100% daytime electricity to the facility.
- 2006Q1: Obtain funding to either repair the Samoa Observatory or to build a new one.
- 2006Q4: Be in a position to replace the near sea-level sampling buildings at the Samoa Observatory.

### *South Pole Milestones*

- 2003Q3: Have a new aerosol system installed and operating at the South Pole.
- 2003Q3: Have a new meteorology data system in operation at South Pole.
- 2006Q3: Be in a position to move to a new/refurbished ozonesonde launch facility in association with the new South Pole Station completion.

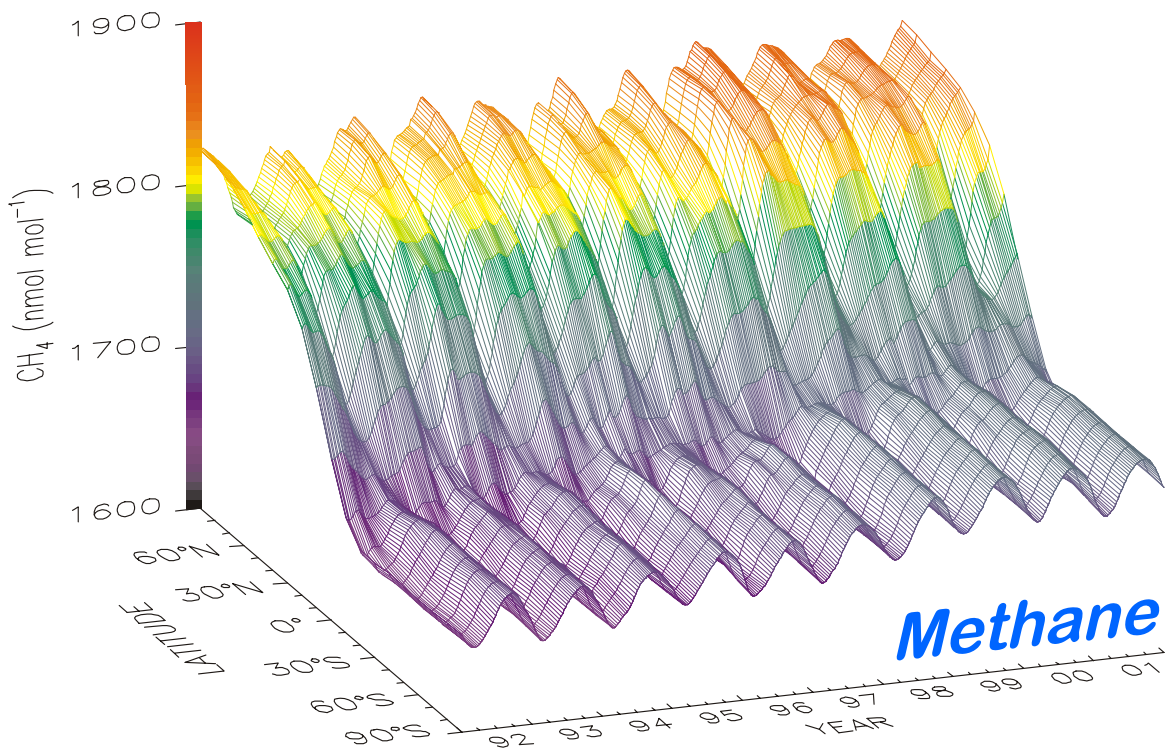
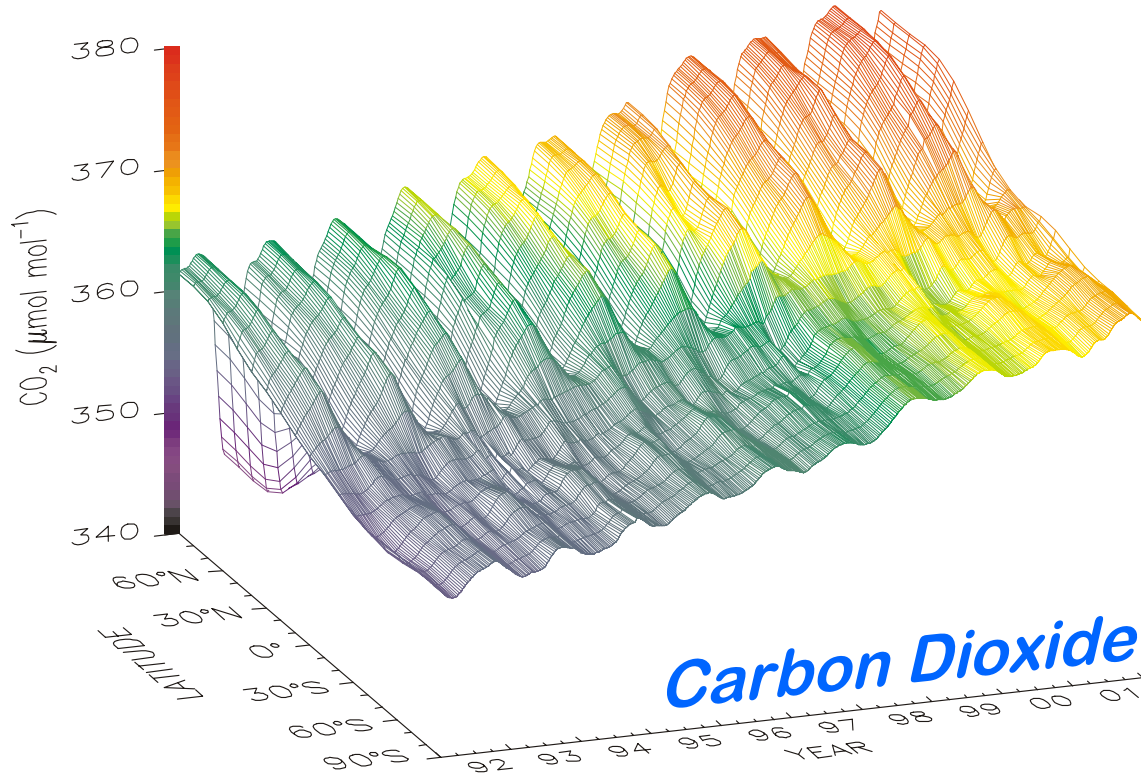
### *Trinidad Head, California Milestones*

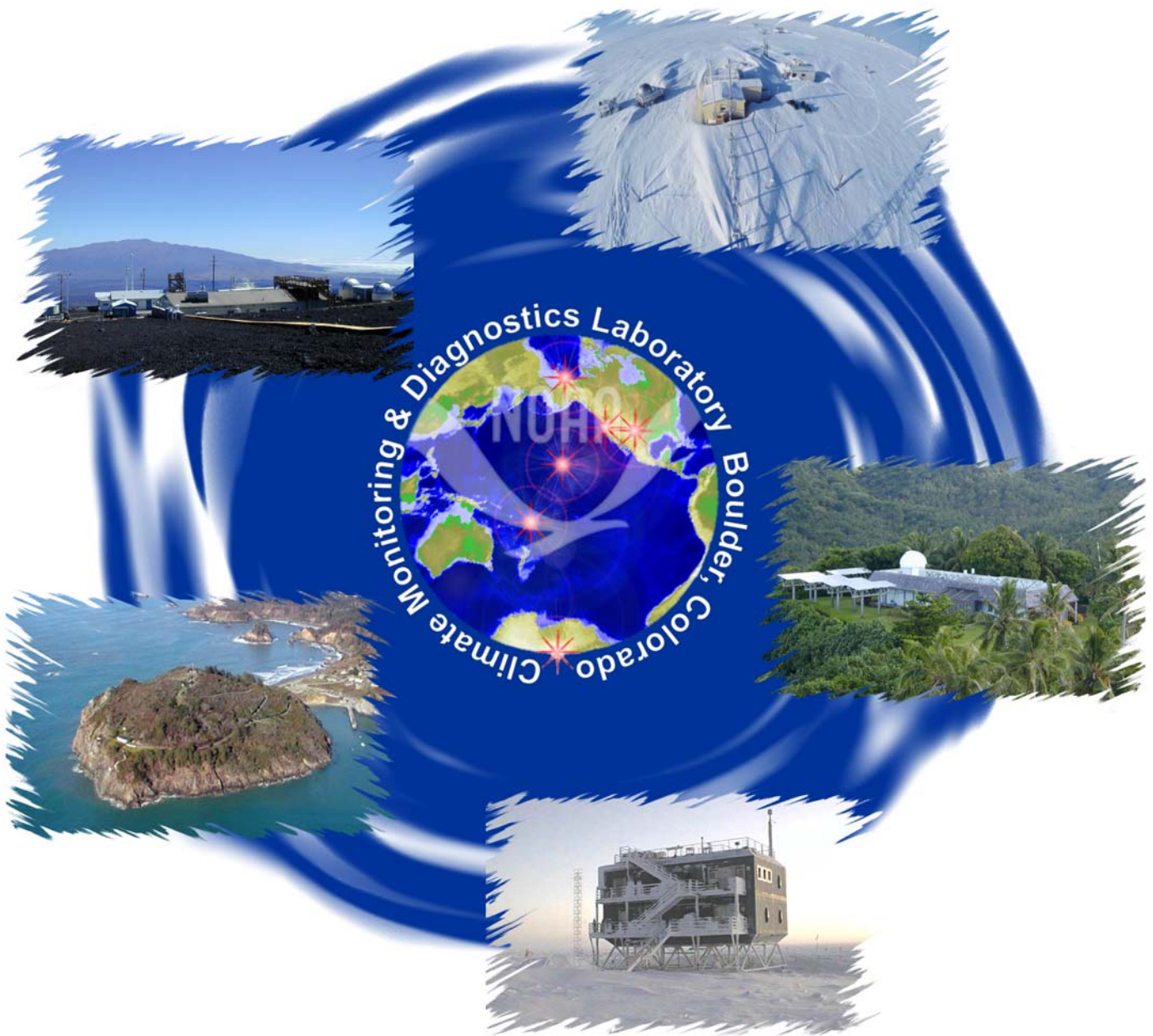
- 2002Q4: Be into a routine monitoring pattern at the Trinidad Head station.
- 2003Q2: Have Trinidad Head staffed by a NOAA Corps officer on an assigned billet.
- 2003Q4: Conduct twice weekly vertical profiles of gases and aerosols above Trinidad Head.
- 2004Q1: Be in a position to double the size of the research facilities at Trinidad Head.
- 2005Q4: Have double the number of programs in operation at Trinidad Head as in 2003.
- 2006Q4: Have a Trinidad Head companion high-altitude site either in Northern California or Southern Oregon.

**The old NOAA / CMDL Clean Air Facility  
(1977 - 1997) at the South Pole.**



# CMDL Global Measurements





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