Climate Monitoring and Diagnostics Laboratory (CMDL

Recent, Major Accomplishments

Abstracted Descriptions of Major CMDL Accomplishments (prior 5 years)

List 3-5 major accomplishments for your laboratory. If accomplishment occurred more than 2 years ago, cite recent progress. Please specify importance of accomplishment, who have been the major users and what has been the benefit to the taxpayer.

Identification of the Northern Hemispheric Terrestrial Carbon Sink: Underpinnings of the North American Carbon Program ***(U.S. Department of Commerce Gold Medal Award, 2000)***

CMDL scientists established and maintained over the past few decades the world's largest, most comprehensive, precise, and accurate network for the measurement of CO_2 and other climatically important gases in the atmosphere. Publications of data from this network identified the northern hemispheric, land-based sink for atmospheric carbon and quantified North America as the largest contributor to this loss, a loss that exceeds the national emissions of CO_2 from burning of fossil fuels. This observational and scientific program forms the base of the new North America Carbon Plan designed to improve our understanding of how this removal of CO_2 from the atmosphere works. The measurements and analyses from CMDL provide a crucial element to this research. Because carbon-based fuels underpin our entire energy system, the social and economic implications of this work are huge. In guiding our future, policy-makers must be able to weigh options based upon the best available science.

Documenting the Rise and Decline of Ozone-Depleting Compounds in the Atmosphere ***(Department of Commerce Silver Medal Award, 1997; NOAA/OAR Outstanding Scientific Paper awards 1996; 1998 (2); 1999 (2))***

CMDL scientists published the first and a subsequent series of award-winning papers documenting and dissecting the rise, turnover, and decline of ozone-depleting gases in the atmosphere. These publications were based upon the unique, long-term measurements made globally by CMDL and underscore the significance of human activities in the rise and, now the decline of these gases in the atmosphere. These products stress the importance of continued adherence to emission reduction requirements of the U.S. Clean Air Act and the international Montreal Protocol for the downward trends to continue. Reversing the trend in ozone depletion has the potential to measurably improve the health of human populations and natural ecosystems; doing so requires continued high-quality observation, analysis, and assessment by scientists invested in understanding these processes.

Discovery and Documentation of the Increase in Stratospheric Water Vapor ***(NOAA/OAR Outstanding Scientific Paper Award, 2002)***

CMDL's balloon-borne observations at Boulder, Colorado, led to the discovery and documentation of the increase of water vapor in the stratosphere. This observational record from Boulder is unique, as it constitutes the longest, continuous record of stratospheric water vapor, a gas that is implicated in ozone depletion, stratospheric chemistry, and climate forcing. National and international scientific assessments of ozone and climate change have cited this work as fundamental to determining the role of stratospheric water vapor in ozone depletion and climate change. Our understanding of this and other trends has direct bearing on important policy decisions relevant to reducing or mitigating human impacts on the earth's climate.

Documenting the Distribution and Growth Rate of Atmospheric Methane *(Department of Commerce Bronze Medal, 1998; NOAA/OAR Outstanding Paper Awards, 1995, 1998, 2001)*

CMDL Scientists published a series of timely and significant reports on the global distribution and growth rate of atmospheric methane, a gas that is implicated in both the greenhouse effect and ozone depletion. Key findings include the first report of a slowdown in the growth of atmospheric methane concentrations, a later report of the observations showing that atmospheric concentrations of this gas were leveling off, and, most recently, a report that the global burden had stabilized from 1999-2002. These published reports have put substantial constraints on the global methane budget by significantly enhancing our understanding of the global behavior of the gas, and guiding our interpretation of its sources and sinks. This research gives policy-makers the information necessary to make educated decisions on how to mitigate future impacts of methane on climate and background air quality.

Identification of the Non-Volcanic Background Stratospheric Aerosol

Stratospheric aerosols accelerate ozone depletion, but also directly force a cooling of the earth's atmosphere. The question of whether a stratospheric sulfate aerosol layer would exist in the absence of major volcanic eruptions, which inject large amounts of sulfur into the stratosphere, had not been answered until recently. Following the decay of sulfate aerosol from the 1991 Pinatubo volcanic eruption, no major eruptions capable of perturbing global stratospheric aerosol levels have occurred. During this unprecedented period, CMDL scientists were able to study and evaluate the behavior of stratospheric aerosol over Mauna Loa, Hawaii, in an attempt to assess the relative contributions of natural and human-driven processes to this climatically important feature of the stratosphere. The study shows that natural sulfurous gases cannot account for the background stratospheric aerosol and that human contributions of sulfur must be significant. This information allows for a better assessment of the climatic impacts of mainstream and alternative energy use, a needed element for future energy-policy decisions.

Supporting Descriptions and Background for Recent Major Accomplishments by CMDL

Identification of the Northern Hemispheric Terrestrial Carbon Sink: Underpinnings of the North American Carbon Program *(U.S. Department of Commerce Gold Medal Award 2000)*

Since the mid-1970s, CMDL, has built and operated the largest global network of measurements of carbon dioxide (CO_2) and several other long-lived trace gases important to the earth's climate. Data from this network revealed, when used in combination with measurements of the partial pressure of dissolved CO_2 in ocean surface waters and a model of atmospheric transport, that there must be a very large net annual uptake of carbon into terrestrial ecosystems of the northern hemisphere [Tans et al., 1990]. The uptake was estimated to be several tens of percent of total global emissions from the burning of fossil fuels. The surprising result has stimulated an enormous amount of still ongoing research into possible mechanisms. The hypothesis of the terrestrial sink was confirmed by later measurements of the $^{13}C/^{12}C$ ratio of carbon dioxide from the CMDL observing network [Ciais et al., 1995], and by independently measured patterns of the ratio of oxygen to nitrogen in the atmosphere [Keeling et al. 1996; Battle et al., 2000]. Furthering these objectives, in 1995 CMDL launched GLOBALVIEW, a compilation of high-quality atmospheric CO_2 data that is updated annually and is almost universally used by anyone trying to model the global carbon cycle. The 2003 release combines records from 23 laboratories from 15 different countries. Using GLOBALVIEW a study identified the North American continent as the largest contributor to the northern hemisphere terrestrial sink [Fan et al., 1998] with the sink possibly as large as total fossil fuel emissions from the continent. The U.S. multi-agency North American Carbon Program, which is now in its starting phase, is designed to answer the major questions about the location, magnitude, and mechanisms of the terrestrial sink on this continent. CMDL plays a central role in this program.

A solid understanding and quantification of the mechanisms driving the carbon cycle is indispensable for managing carbon. The problem of global climate change cannot be tackled without successful management of the carbon cycle, because CO_2 is the strongest, manmade climate-forcing factor. CO_2 has a residence time in the atmosphere-ocean-biosphere system of thousands of years. Policy-makers ultimately must weigh options such as emissions reductions, stimulation of natural uptake into oceans and biosphere, prevention of unintended release from those reservoirs, and deliberate sequestration of CO_2 into geological formations, to make sound decisions. The socio-economic implications are huge because carbon-based fuels underpin our energy system. CMDL provides a crucial element to our increasing understanding and will provide quantification of the effectiveness of carbon management strategies.

Discovery and Documentation of the Increase in Stratospheric Water Vapor *(NOAA/OAR Outstanding Scientific Paper Award in 2002*

CMDL's balloon-borne observations at Boulder, Colorado, led to the discovery and documentation of the rise in stratospheric water vapor [Oltmans and Hofmann, 1995; Oltmans et al., 2000]. The observational record from Boulder is unique and constitutes the longest, continuous record of stratospheric water vapor, a gas that is implicated in ozone depletion, stratospheric chemistry, and climate forcing. Measurements of water vapor in the drier portions of the atmosphere, particularly in the region above 5 km, are difficult. The inability of conventional radiosondes to obtain such measurements and the generally high cost of suitable techniques has left a data gap in this region that CMDL is working to fulfill. Increases in water vapor in the stratosphere lead to stratospheric cooling, which accelerates ozone depletion by promoting formation of ozone-depleting particles at the poles or in association with volcanic emissions. However, stratospheric water vapor also causes a significant warming at earth's surface. Water vapor in the atmosphere is the largest contributor to the greenhouse effect and it is the primary source of hydroxyl radical, which is intricately involved in atmospheric chemistry. In global climate models, nearly half of the projected increase in temperature is due to a doubling of carbon dioxide results from the concomitant effects of increased water vapor.

An adequate understanding of climate and ozone change requires an understanding of the trends of water in the upper troposphere and stratosphere. National and international scientific assessments of ozone and climate change, necessary for important policy decisions, have cited this work in determining the role of stratospheric water vapor in ozone depletion and climate change. A better understanding of this and other causes of climate change can lead to more cost-effective prevention and mitigation strategies.

Documenting the Distribution and Growth Rate of Atmospheric Methane *(Department of Commerce Bronze Medal, 1998; NOAA/OAR Outstanding Paper Awards, 1995, 1998, 2001)*

CMDL Scientists published a series of significant reports on the global distribution and growth rates of atmospheric methane based upon data from the CMDL global sampling network. These reports have all put substantial constraints on the global methane budget, giving policy-makers information necessary to make educated decisions on how to mitigate future impacts of CH_4 on climate and background air quality. Key findings include an initial slowdown in the rate of increase of atmospheric methane concentrations [Steele et al., 1992], a later explanation of the observations showing that the system was approaching equilibrium and the abundance of atmospheric CH_4 stabilizing [Dlugokencky et al., 1998], and most recently, a report that the global burden of CH_4 was stable over the period 1999-2002 [Dlugokencky et al., 2003]. The study of methane impinges directly on a number of atmospheric and societal issues. For example, an important assumption in this work was that the abundance of a strong atmospheric oxidant called hydroxyl radical was not changing; later studies by CMDL supported this assumption [Montzka et al., 2000]. Also, a dramatic decrease in CH_4 growth rate in the northern hemisphere during 1992 was the first indication of decreased fossil fuel emissions from the former Soviet Union after the collapse of the Soviet economy [Dlugokencky et al., 1994, 2003]. A large increase in the methane growth rate during 1991 was attributed to the eruption of Mt. Pintaubo [Dlugokencky et al., 1996], showing that emissions of SO_2 and aerosol from the volcanic eruption decreased methane loss rates. During 1998, the CMDL data again showed an abrupt and global increase in the methane growth rate [Dlugokencky et al., 2001] suggesting that the increase resulted from higher- and wetter-than-normal conditions in wetland regions at high northern latitudes and in the southern tropics.

Identification of the Non-Volcanic Background Stratospheric Aerosol. From a long-term study of the stratosphere over Mauna Loa using a laser-radar (LIDAR), CMDL scientists have determined that the northern mid-latitudes are a likely source of human-generated sulfur compounds which enter the stratosphere in the tropics. Large, explosive volcanic eruptions, such as those of El Chichon in 1982 or Pinatubo in 1991, are the dominant source of sulfur-containing compounds in the stratosphere for a few years after the eruption. These particles backscatter sunlight and force climate at the Earth's surface into a temporary cooling mode which amounts to as much as 4 watts per square meter, or about twice the post-industrial carbon dioxide warming. Until recently, little has been known about the possible existence of background, non-volcanic concentrations of stratospheric sulfate aerosol. Following the decay of aerosol from the 1991 Pinatubo volcanic eruption, no major eruptions, capable of perturbing global stratospheric aerosol levels have occurred. During this unprecedented period, from 1996 to 2003, CMDL scientists were able to study and evaluate the behavior of stratospheric aerosol over Mauna Loa, Hawaii, in an attempt to assess the relative contributions of natural and human-driven processes to this climatically important feature of the stratosphere. Early data identified the stratospheric decay rate of the Pinatubo aerosol (~1 year decay constant) and also identified a significant influence of the Quasi-Biennial Oscillation on the background aerosol level following the Pinatubo decay (Barnes and Hofmann, 1997). A later study, reflecting the continued observations during this unusual, quiescent period which followed, confirmed the existence of a background aerosol level and clearly established a seasonal variation in this level (Barnes and Hofmann, 2001). This work implicated an input of sulfur to the stratosphere in the tropics and when compared to models of sulfur input to the stratosphere, showed that naturally produced compounds and aircraft emissions could account for only a small fraction of the observed amounts of sulfur in the stratosphere. The studies suggest strongly that other human contributions of sulfur, for example sulfur dioxide from the surface, must be significant. This information allows for a better assessment of the climatic impacts of mainstream and alternative energy use, a needed element for future energy-policy decisions.