NOAA GMD Research

The NOAA Global Monitoring Division (GMD) plays a critical leadership role in the global atmospheric monitoring community. GMD scientists have unique and globally recognized expertise in making sustained atmospheric observations over decades, interpreting those observations, and communicating their findings to other researchers and the public. Without observations like these the science community would struggle to diagnose how the climate system functions as climate change unfolds, now and into the far future.

The first two GMD research themes are related to the Grand Challenges of the World Climate Research Programme (WCRP). The third theme is a legal requirement under the 1990 Clean Air Act.

Research Theme #1: Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Today's anthropogenic climate change is largely driven by increasing greenhouse gases (GHGs) in the atmosphere, modified to some extent by the distribution of aerosols and aerosol properties. To understand the influence of changing atmospheric composition on climate change and minimize its eventual magnitude, society needs the best possible information on the trends, distributions, emissions and removals of greenhouse gases. It is necessary to develop a solid scientific understanding of their natural cycles, and how human management and the changing climate influence those cycles. Our atmospheric measurements can also provide fully transparent and objective quantification of emissions, supporting national and regional emissions reduction policies and generating trust in international agreements.

The NOAA Global Monitoring Division (GMD) is a world leader in producing the regional to global-scale, long-term measurement records that allow quantification of the most important drivers of climate change today. Global monitoring of atmospheric greenhouse gases, in particular carbon dioxide (CO_2), has been part of NOAA's mission for over 50 years. GMD provides and interprets high-accuracy measurements of the history of the global abundance and spatial distribution of a suite of long-lived greenhouse gases. The spatial distributions, together with models of the winds and mixing (derived from weather forecasts) allow us to infer time-dependent patterns of emissions/removals that are consistent with our observations. Because the measurements are calibrated they stand on their own, and can be used far into the future with better models, and also to compare with satellite retrievals of column-averaged GHGs that cannot be calibrated, but still need to be used together with calibrated data.

NOAA measurements of climatically important gases began in the late 1960s and expanded in the mid-to-late 1970s for CO_2, nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and upper atmospheric water vapor. Over the years other gases and isotopic ratios have been added, including methane (CH_4), carbon monoxide (CO), hydrogen (H_2), numerous hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), methyl halides, and sulfur hexafluoride (SF_6). GMD produces and maintains global standards for most of the climate-relevant gases. The use of common standards enables measurements by different methods, and by different countries and organizations to be used together, greatly increasing the value of the international cooperative measurement system.

Research Theme #2: Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions

Changes in the radiative energy balance at Earth's surface and at the top of the atmosphere result from forcing by greenhouse gases, aerosols, and related changes in the global atmospheric circulation. The distribution of clouds is the primary influence on the surface radiation budget and is sensitive to changes in the circulation, but the nature of the response of different cloud types in different climatic regions is uncertain. Cloud radiative properties are also sensitive to aerosol particles which are highly variable in space, time, and composition. Their role in radiative forcing is complex and can be either positive or negative and, in addition to their impacts on clouds, can influence the climate directly via long term changes in light absorption and scattering. The uncertainty in cloud responses to climate forcing constituents, either through direct interaction with aerosols or through circulation changes, is the primary factor limiting our ability to narrow estimates of the climate sensitivity (the warming resulting from a change in a climate forcing agent).

GMD observatories host long-term measurements of globally representative, climate-critical radiation variables such as the continuous measurement of the solar energy reaching Mauna Loa Observatory that began in 1958, the longest such record on Earth. Broadband measurements of incoming and outgoing solar and terrestrial radiation are made in the U.S. and at global baseline observatories to quantify the surface radiation balance and to track changes in cloud radiative properties. GMD has focused on the direct radiative effects of aerosols with measurements of aerosol optical properties that began in the 1970s. In response to the finding that anthropogenic aerosols create a significant perturbation in the earth's radiative balance on regional scales, GMD expanded its aerosols research program to include stations for monitoring aerosol properties in regions where significant aerosol forcing was anticipated.

To support these measurements, GMD maintains calibration facilities tied to the world standards and also shares calibration services with collaborators worldwide. GMD and its national and international partners have made substantial improvements in the accuracy of both solar and infrared measurements over the past 25 years, allowing detection of small changes in the radiation balance that have dramatic consequences for weather and climate. GMD also provides leadership to the international aerosol and surface radiation monitoring communities by providing technical expertise, calibrations, consistent sampling and measurement protocols, and open source data acquisition, processing, visualization and editing software.

Research Theme #3: Guiding Recovery of Stratospheric Ozone

Depletion of stratospheric ozone can result in enhanced UV radiation levels that increase skin cancer rates and adversely affect organisms and ecosystems. Concern over these effects provided impetus for ratifying the 1987 Montreal Protocol, enacting the U.S. Clean Air Act of 1990, and initiating GMD's global-scale monitoring of stratospheric ozone and the gases responsible for its destruction.

GMD has developed a carefully designed network to monitor variations in ozone, ozone-depleting substances, stratospheric aerosols, and UV radiation. GMD research has been critical in determining long-term changes in concentrations of stratospheric ozone and chemicals causing ozone depletion. Our unique long-term observational records have led to an improved understanding of the production and fate of stratospheric ozone and the compounds and processes that influence ozone's abundance. These advances have furthered our understanding of the fundamental atmospheric processes affecting stratospheric ozone and provide usable information to policy makers for guiding the recovery of the ozone layer.

GMD conducts year round balloon-borne vertical structure and total column optical measurements of ozone over the South Pole. During the winter (preceding the early springtime Antarctic "ozone hole"), satellites are unable to measure polar ozone without sunlight. GMD monitors stratospheric ozone at lower latitudes and in the Arctic, measures the gases responsible for depletion of stratospheric ozone, and monitors changes in ultraviolet radiation that is controlled by the amount of ozone in the stratosphere. As such, understanding the production and fate of ozone and the ozone-depleting compounds is a focal point of GMD research.

Ground based measurements of total-column ozone have been made for over 50 years with the Dobson spectrophotometer; the 14-station GMD Cooperative Dobson Network is a significant portion of the global Dobson network as are the six GMD balloon-borne ozonesonde stations. These stratospheric ozone measurements, along with the GMD greenhouse gas, surface ozone, aerosols, radiation and halocarbons measurement networks, are linked to the world calibration standards maintained by GMD as are a preponderance of the stations in other international global networks.

Three gases that make a significant contribution to stratospheric ozone depletion, CFC-11, CFC-12 and N_2O, have been monitored by GMD since the mid-1970s. Since then, numerous additional CFCs, HCFCs, 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 methyl bromide and methyl chloride have natural contributions as well.

Supporting Infrastructure #1: Calibrations and Standards

Accurate and reliable calibrations are an essential component of all high-quality measurement programs. This is particularly true of measurements made to carry out research within GMD. Bias or drift in reference materials can have a significant impact on our ability to interpret measured spatial gradients and trends. Further, for data from multiple instruments or measurement networks to be interpreted together, they must be linked to common calibration scales.

GMD calibration activities support measurements of greenhouse gases, ozone depleting gases, column ozone, and solar radiation. GMD serves as the World Meteorological Organization, Global Atmosphere Watch (WMO/GAW) Central Calibration Laboratory for five gases (CO_2, CH_4, N_2O, SF_6, CO), and serves as the World Calibration Center for Dobson ozone (total column ozone). The goal is to minimize bias among measurements made within the WMO/GAW network, of which NOAA GMD is a major contributor. GMD performs research on the preparation of primary standards, scale development, scale propagation, and comparison. In practice, GMD offers trace gas reference materials and calibration services to WMO/GAW and other partners, calibrates WMO Dobson standard instruments by the Langley method, and WMO regional standard instruments and other Dobson instruments in North America by direct comparison, and calibrates standard ultra-violet lamps to promote compatibility in solar radiation measurements. Much of this work is done on a cost-reimbursable or cost-sharing basis.

GMD collaborates with other institutions to compare and improve traceability, including National Metrology Institutes (such as NIST), the Bureau of International Weights and Measures (BIPM), WMO/GAW central facilities, and others that maintain long-term measurement programs. The Central UV Calibration Facility is a joint NOAA/NIST project.

Supporting Infrastructure #2: Atmospheric Baseline Observatories

At the core of the Global Monitoring Division's global observation networks are the Atmospheric Baseline Observatories (ABOs). GMD's four ABOs are strategically located far from human influence and local pollutants, to prevent contamination and sample the cleanest air possible. The long-term measurements from the ABOs are considered among the best in the world for understanding background atmospheric composition.

The ABOs are the only sites where measurements from GMD's three research themes converge; NOAA instruments supporting greenhouse gas and carbon cycle feedback, surface radiative energy budget, and stratospheric ozone research are co-located in these remote locations. Four decades of data are critical to GMD's understanding of atmospheric changes over time. Data from the ABOs are downloaded by thousands of researchers, resource managers, and policy makers and viewed by tens of thousands of people every year.

Not only are the ABOs critical for GMD research, they are also the backbone measurement sites for the WMO/GAW network and support numerous cooperative research projects. Being staffed by full-time NOAA and university employees, the ABOs provide world-class scientific support to U.S. state and federal agencies, universities, and foreign researchers. Collaboration at the ABOs encourages data collection beyond GMD's research scope enhancing NOAA's understanding of the atmosphere.

Barrow: The Barrow Observatory (BRW), established in 1973, is located on the northern most point of the United States. It is about 8km northeast of the village of Utqiaġvik (formerly Barrow) and has a prevailing east-northeast wind off the Beaufort Sea.

Mauna Loa: The Mauna Loa Observatory (MLO), originally established in 1956, is located on the north flank of the Mauna Loa Volcano at 3,397 masl on the Big Island, Hawaii. GMD is currently the steward of 8 acres of land where buildings for MLO are located.

American Samoa: The American Samoa Observatory (SMO), established in 1974, is located on Cape Matutula, the northeastern tip of American Samoa. The observatory is situated on a 26.7-acre site that receives prevailing winds off the ocean.

South Pole: The South Pole Observatory (SPO), originally established in 1957, is located on Antarctica's polar plateau at 2,840 masl. SPO is the primary tenant of the NSF's Atmospheric Research Observatory, a building upwind of the main station on the border of the internationally recognized and managed Clean Air Sector. The NSF provides housing and logistical support for GMD's research at South Pole.