

Global Monitoring Division

NOAA GMD Legislative Drivers and Research to Applications (R2A)

2013-2017 Review

May 21-24, 2018



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NOAA GMD Legislative Drivers

Clean Air Act 1990 Title IV and Title VI, 42 U.S.C. § 7401 et seq.: “...NOAA shall monitor, and not less often than every 3 years following November 15, 1990, submit a report to Congress on the current average tropospheric concentration of chlorine and bromine and on the level of stratospheric ozone depletion.”

Global Change Research Act of 1990, 15 U.S.C. 2921 et seq.: Ensures the establishment of global measurements and worldwide observations...

Global Climate Protection Act of 1990, 7 U.S.C. § 6701 et seq.: Requires research in climate change needed to protect the environment.

National Climate Program Act, 15 U.S.C. 2901-2908, at 2904(d) (4), et seq.: ...authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis, authorizes measures for increasing international cooperation.

U. N. Framework Convention on Climate Change (UNFCCC): Requires better quantification of the agents that force climate change by contributing research results and providing expertise to the assessments.

Montreal Protocol on Substances that Deplete the Ozone Layer (and subsequent amendments): Requires an assessment every four years of the state of the ozone layer, its recovery, and the amounts and origins of ozone depleting substances that drive the ozone layer changes.

Global Earth Observation System of Systems (GEOS): endorses the Global Earth Observation System of Systems (GEOS) 10-Year Implementation Plan.

Full List in Detail in 3 following pages if interested.



Legislation:

- *Federal Records Act as amended, 44 U.S.C. §3101 et seq.*: Responsible for the establishment of the National Weather Records Center which archives and services U.S. weather and climate records.
- *Data Quality Act, Public Law 106-554, Section 515, 2001*: Requires that the U.S. government assure the quality of the information disseminated.
- *36 C.F.R., Chapter XII National Archive and Records Administration (NARA) Records and Guidelines*: Stipulates that data maintained for legal purposes and in the national interests must be archived using NARA standards.
- *National Weather Service Organic Act, 15 U.S.C. § 313*: Ensures there are atmospheric, oceanic, and terrestrial measurements suitable for establishing and recording U.S. Climate Conditions.
- *National Climate Program Act, 15 U.S.C. 2901-2908, at 2904(d) (4), et seq.*: Requires that one program element will be the provision of "useful and readily available information on a continuing basis." It authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis. In addition, the act authorizes measures for increasing international cooperation in climate research, monitoring, analysis, and data dissemination.
- *Global Change Research Act of 1990, 15 U.S.C. 2921 et seq.*: Ensures the establishment of global measurements and worldwide observations, and requires an early and continuing commitment to the establishment and maintenance of worldwide observations and related data and information systems.
- *Coastal Zone Management Act (CZMA) of 1972, 16 U.S.C. 1450 et seq. (amended 1990 and 1996)*: Requires understanding and predicting long-term climate change which may have large impacts in the Coastal zone such as global warming and associated sea level rise.
- *Clean Air Act 1990 Title IV and Title VI, 42 U.S.C. § 7401 et seq.*: Amendment to the Clean Air Act mandates that "the Administrators of the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration shall monitor, and not less often than every 3 years following November 15, 1990, submit a report to Congress on the current average tropospheric concentration of chlorine and bromine and on the level of stratospheric ozone depletion."
- *Global Climate Protection Act of 1990, 7 U.S.C. § 6701 et seq.*: Requires research in climate change needed to protect the environment.
- *Oceans Act 2000 (PL 106-256)*: Led to the Congressionally-mandated report of the U.S. Commission on Ocean Policy and the Executive response, the U.S. Ocean Action Plan of 2005: Requires federal agencies to participate in building a Global Earth Observation Network that includes integrated oceans observations. The U.S. is implementing this through the Integrated Ocean Observation System (IOOS), the Integrated Earth Observation System (IEOS), and participation in GEOSS.
- *Consolidated Appropriations Act, 2005, Public Law No. 108-447, 118 Stat. 2908 (Dec. 8, 2004), incorporates S. 1218, the Oceans and Human Health Act*: "Establish[es] a Federal research program that examines ocean resources and their applications to human health." The Act aims to "...ensure that any integrated ocean and Coastal observing system provides information necessary to monitor, predict and reduce marine public health problems including: (A) baseline observations of physical ocean properties to monitor climate variation; (B) measurement of oceanic and atmospheric variables to improve prediction of severe weather events; ..."

U.S. Executive Branch and NOAA Directives and Other Guidelines:

- *Strategic Plan for the U. S. Integrated Earth Observations System (IEOS), USGEO Report, 2005:* This plan addresses the policy-related, technical, and fiscal components of a U.S. integrated Earth observation system.
- *President's Security and Prosperity Program of North America Initiative (SPP):* SPP is a trilateral agreement among the U.S., Canada, and Mexico signed in March 2005. One of the many facets of the agreement relevant to the Climate Program involves "enhancing the joint stewardship of our environment... through cooperation and information sharing."
- *U.S. Ocean Action Plan/ Charting the Course for Ocean Science for the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy (2007):* Administration's response to the U.S. Commission on Ocean Policy Report: To accomplish actions within the Ocean Action Plan requires the access to and use of archived (new and historical) quality observations of essential climate and ocean variables. The ORPP calls for deployment of "a robust ocean observing system that can describe the actual state of the ocean."
- *Department Administrative Order (DAO) 212-2 Information Technology Handbook:* This handbook defines data management and related activities as: identifying the information needed; defining and documenting data requirements; coding and structuring the data; designing the database; selecting and using the most effective storage technology; collecting the data; processing the data; disseminating the information and facilitating user access; protecting the data against damage and unauthorized access; and archiving and disposing of the data.

Interagency and International Agreements:

- *International Council of Scientific Unions (ICSU) guidelines/policy regarding World Data Centers (WDC) – National Climatic Data Center WDC for Meteorology and Paleoclimatology:* Requires archiving and access to data collected by internationally sponsored observation and research programs. Allows for the active exchange of climate data with foreign countries to support research and other activities.
- *U. N. Framework Convention on Climate Change (UNFCCC):* Requires better quantification of the agents that force climate change by contributing research results and providing expertise to the assessments.
- *Montreal Protocol on Substances that Deplete the Ozone Layer (and subsequent amendments):* Requires an assessment every four years of the state of the ozone layer, its recovery, and the amounts and origins of ozone depleting substances that drive the ozone layer changes.
- *Global Earth Observation System of Systems (GEOSS):* Third Earth Observation Summit held in Brussels, 16 February 2005, endorsing the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan. Summarizes the essential steps to be undertaken over the next decade by nations, and intergovernmental, international, and regional organizations, to establish a coordinated and comprehensive sustained earth observations system and defines associated fundamental socio-economic benefits supported by a GEOSS approach to observations and monitoring.

Mission Requirements:

- Establish an Agency Records Center for U.S. Weather and Climate records. (*Federal Records Act*)
- Provide long-term preservation of the Nation's Climate Record. (*Federal Records Act, Data Quality Act, National Climate Program Act, NARA Records and Guidelines, ICSU World Data Center Guidelines & Policy, and U.S. Ocean Action Plan*)
- Provide climate data and information that meets rigorous scientific standards for quality.
- (*Data Quality Act, Coastal Zone Management Act, and U.S. Ocean Action Plan*)
- Provide NOAA customers access to Climate Data and Information (timely, easy, and convenient) related to the state and changing state of the climate system in a variety of formats. (*Federal Records Act, National Climate Program Act, NARA Records and Guidelines, ICSU World Data Center Guidelines & Policy, Consolidated Appropriations Act, and U.S. Ocean Action Plan*)
- Monitor and assess the climate system through adequate quality observations and measurements of atmospheric, ocean, and select terrestrial "essential climate (state) variables". (*Global Change Research Act, National Climate Program Act, National Weather Service Organic Act, Coastal Zone Management Act, and U.S. Ocean Action Plan*)
- Improve quantification of the forces and feedback systems bringing about changes in the earth's climate and related systems. (*Global Change Research Act, Global Climate Protection Act of 1990, Oceans Act 2000, Climate Change Science Program, U.N. Framework Convention on Climate Change, Montreal Protocol, Global Earth Observation System of Systems*)

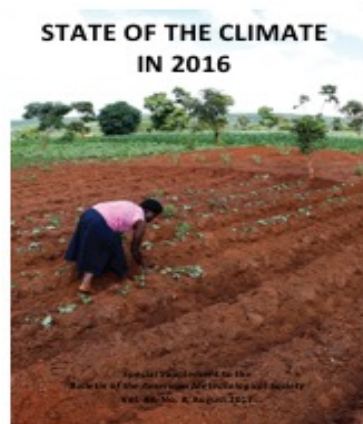
Research to Applications (R2A)

NOAA is a science-based service agency. NOAA's ability to meet its mission through the delivery of continually improved products and services relies on the conversion of the best available research and development (R&D) endeavors into operation and application products, commercialization, and other uses.

NOAA's Office of Oceanic and Atmospheric Research (OAR) is charged with delivering information, products, and tools to meet the needs of the other NOAA Line Offices, the academic community, and a variety of other key stakeholders. A significant component of meeting this charge is to ensure the efficient transition of OAR's research to applications or operations. NOAA defines a transition project as "The collective set of activities necessary to transfer a research result, or collection of research results, to operational status or to an information service."

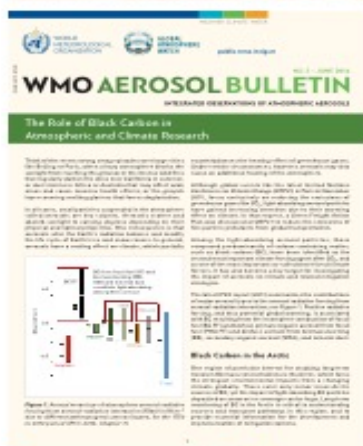
The Global Monitoring Division informs applied work through research to address societal challenges. GMD transitions projects through the public dissemination of atmospheric measurements, release of our research through scientific publications, and participation in scientific assessments. GMD also develops innovative technologies and systems that are transitioned to various applications and industry. Listed below are R2A projects and products in GMD that have successfully completed transition to one or more applications.

<p>STATE OF THE CLIMATE IN 2012</p>   <p>Special Supplement to the Bulletin of the American Meteorological Society Vol. 94, No. 8, August 2013</p>	<p>Chapter Editor: Bradley Hall GMD Authors: Lori Bruhwiler, Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Stephen Montzka</p>
<p>STATE OF THE CLIMATE IN 2013</p>  <p>Special Supplement to the Bulletin of the American Meteorological Society Vol. 95, No. 7, July 2014</p>	<p>Chapter Editor: Dale Hurst GMD Authors: John Augustine, Lori Bruhwiler, Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Kathleen Lantz, Stephen Montzka, Robert Stone</p>
<p>STATE OF THE CLIMATE IN 2014</p>  <p>Special Supplement to the Bulletin of the American Meteorological Society Vol. 96, No. 7, July 2015</p>	<p>Chapter Editor: Dale Hurst GMD Authors: Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Kathleen Lantz, Stephen Montzka, Irina Petropavlovskikh</p>
<p>STATE OF THE CLIMATE IN 2015</p>  <p>Special Supplement to the Bulletin of the American Meteorological Society Vol. 97, No. 8, August 2016</p>	<p>Chapter Editor: Dale Hurst GMD Authors: Molly Crotwell, Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Kathleen Lantz, Stephen Montzka, Irina Petropavlovskikh</p> <p>GMD long-term records of greenhouse gases, ozone-depleting gases, stratospheric ozone, stratospheric water vapor, ozone profiles and solar radiation were extensively used in the report. Reference to GMD publications and analyses were numerous. Significant changes in the one of its kind GMD long-term stratospheric water vapor record were noted.</p>



Chapter Editor: Dale Hurst
GMD Authors: John Augustine, Edward Dlugokencky, James Elkins, Dale Hurst, Bryan Johnson, Kathleen Lantz, Steve Montzka, Irina Petropavloskikh

GMD long-term records of greenhouse gases, ozone-depleting gases, stratospheric ozone, stratospheric water vapor, ozone profiles and solar radiation were extensively used in the report. Reference to GMD publications and analyses were numerous.



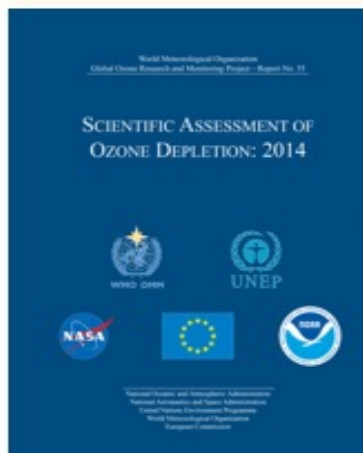
The Aerosol Bulletin provides general information on the aerosol component of GAW and focuses on specific components or applications of GAW aerosol measurements.

The bulletin focused on Black Carbon (BC) in the Arctic, considered the second most important climate forcing agent after carbon dioxide in the Arctic. GMD has the longest record of BC in the Arctic (since 1983). The two basic instruments used to measure BC in the Arctic were developed with GMD funding and expertise.



The Aerosol Bulletin provides general information on the aerosol component of GAW and focuses on specific components or applications of GAW aerosol measurements.

This bulletin focused on measurements of volcanic aerosols and presented data from the GMD Boulder stratospheric aerosol lidar. The Mauna Loa stratospheric aerosol lidar has been in continuous operation since 1974 and has unique data on the large El Chichon and Pinatubo eruptions as well as many smaller volcanoes and aerosols from Asia.



Steve Montzka, GMD, was a Chapter 1 author of the report. GMD scientists Geoffrey Dutton, James Elkins, Dale Hurst, Steve Montzka and Irina Petropavlovskikh were contributing authors and reviewers.

GMD ozonesonde, Dobson ozone spectrophotometer, Umkehr and lidar measurements formed core data sets for the analyses going into the report. GMD maintains the WMO calibration standard for Dobson ozone measurements and a GMD scientist invented the ozonesonde instrument.



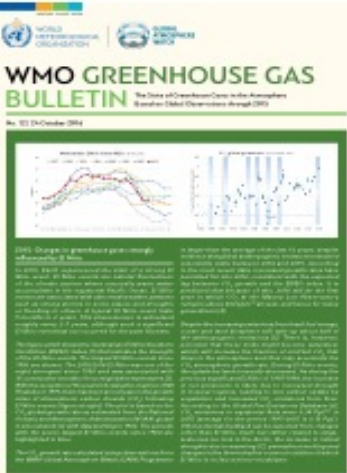
Andrew Croftwell, James Elkins, Thomas Conway, Kirk Thoning, Duane Kitzis, Pieter Tans, Steve Montzka, Ken Masarie, Edward Dlugokencky, James Butler and Geoff Dutton were referenced as providing GMD data and publications cited in the report.

Seven of the nine data graphics presented in the report were of GMD data including the Annual Greenhouse Gas Index (AGGI) and the long term carbon dioxide, methane and halocarbon trends.



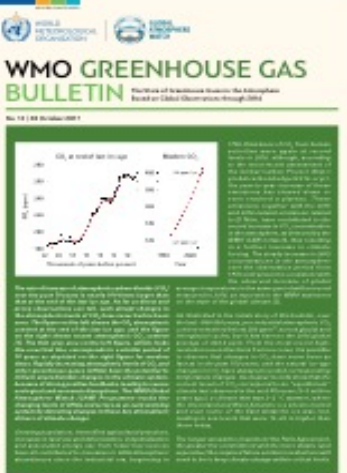
References and links to GMD web sites for greenhouse gases, AGGI, halocarbons, stratospheric water vapor, nitrous oxide and publications on greenhouse gases were used in the report.

Eight of the nine graphs in the bulletin come from GMD data and web sites.



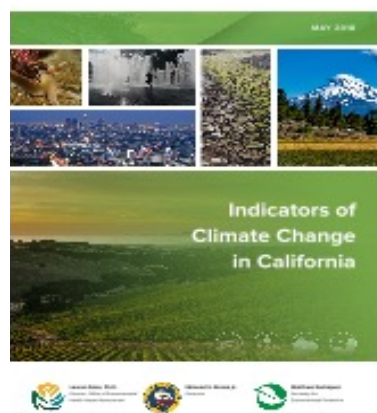
References and links to GMD web sites for greenhouse gases, AGGI, halocarbons, stratospheric water vapor, nitrous oxide and publications on greenhouse gases.

Six of the nine graphs in the bulletin come from GMD data and web sites.



References and links to GMD web sites for greenhouse gases, AGGI, halocarbons and publications on greenhouse gases.

At least 50% of the data and graphs presented in the bulletin are from or based on GMD data. Ten of the 13 graphs/photos in the bulletin are from GMD data and web sites.



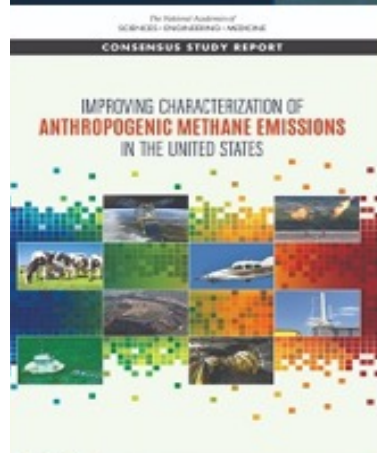
GMD contributors: Edward Dlugokencky and Pieter Tans.

GMD data are used and referenced throughout the report.



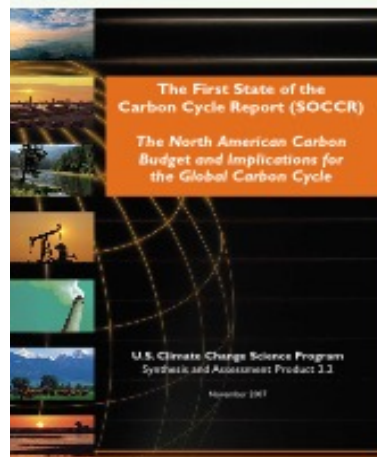
Edward Dlugokencky: Lead Author
Pieter Tans: Reviewer and Editor

GMD data and graphics are used throughout the report and especially in Chapter 2 (Observations: Atmosphere and Surface) and Chapter 6 (Carbon and Other Biogeochemical Cycles).



Lori Bruhwiler, GMD: National Academy Report Committee Member, contributing author and reviewer

Extensive use of GMD global surface network, airborne profile and gas and oil field monitoring and research data on methane.



James Butler, GMD, was a member of the Carbon Cycle Interagency Working Group that produced the report.

Much of the historic carbon dioxide concentration data discussed in the report was based on GMD continuous data records, some of which date back 50 years.

GMD Research to Applications 2013--2017

GMD Project Name	Thing Transitioned <i>What, exactly, was the thing transitioned from point A to point B?</i>	Purpose of Transition <i>What application was the transition intended to improve?</i>	To Where		Comments
			Sample Organization		
Aerosol Data - NOAA Federated Aerosol Network	Approximately 18 variables measured and over 285 data sets available (globally).	The Federated Aerosol Network is a component of WMO Global Atmosphere Watch (GAW) that provides robust data from a global network of sites using similar instrumentation and consistent approaches. Assist in model development.	WMO World Data Center for Aerosols (WDCA), hosted by NILU, Norway, http://ebas.nilu.no/		http://esrl.noaa.gov/gmd/dv/data/?category=Aerosols . The NOAA GMD global aerosol measurement network is the only one of its type on Earth and the data used by modelers, air pollution agencies, policy makers and scientists. It focuses primarily on aerosol optical properties and the direct aerosol effect.
Aerosol Software	Custom, open source (linux-based) software package (CPD3) for data acquisition, processing, visualization, editing, analysis and archiving aerosol data from NOAA and partner stations.	The CPD3 software package used throughout the NOAA Federated Aerosol Network was developed to facilitate consistent and robust data processing over the NOAA Federated Aerosol Network.	Primarily WMO partner research organizations that monitor aerosols on a long-term basis and submit their data to the WDCA		https://www.esrl.noaa.gov/gmd/aero/sw.html
AirCore	Atmospheric sampling system that samples the atmosphere and preserves a profile of the trace(s) gas of interest.	Widespread vertical profiles of CO ₂ , CH ₄ , and other greenhouse gases for validation of satellite retrievals and development of Earth System and carbon models.	Southwest Research Institute, and several research organizations worldwide		Developed and patented at NOAA, this sampling tool makes it possible to collect and analyze a vertical (or horizontal) core of the atmosphere, retaining the integrity of the vertical profile. Used and tested as a means for validating satellite retrievals of CO ₂ and CH ₄ . One company (SWRI) is interested in routinely flying a miniaturized version on a SUV and in the process of testing; several of our international partners are adapting it for similar studies in their nations and regions.

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AMAP Assessment 2015: Methane as an Arctic Climate Forcer	Extensive description of GMD methane observations in the Arctic and what can be learned about Arctic Methane Emissions.	The purpose of the report was to review current understanding of the Arctic methane budget, and to make recommendations of how this understanding can be furthered.	Arctic Monitoring and Assessment Program		https://www.amap.no/documents/doc/AMAP-Assessment-2015-Methane-as-an-Arctic-climate-forcer/1285
Annual Greenhouse Gas Index (AGGI)	Accumulated radiative forcing from long-lived Greenhouse Gases. The NOAA Annual Greenhouse Gas Index (AGGI) measures the commitment society has already made to living in a changing climate. It is based on the highest quality atmospheric observations of GMD and from partner sites around the world. Its uncertainty is very low.	Product used annually in EPA Annual Report on the Environment. Selected as a National Physical Indicator of Climate Change in support of the National Assessments. Update of the WMO Annual Greenhouse Gas Bulletin, which is distributed worldwide in 5 languages. Updated product on climate.gov website.	EPA's Climate Change Indicators in the U.S. Report USGCRP and others		http://esrl.noaa.gov/gmd/aggi/ (NOAA); https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing (EPA) http://esrl.noaa.gov/gmd/aggi/ (NOAA); https://www.globalchange.gov/browse/indicators/indicator-annual-greenhouse-gas-index (USGCRP)
Atmospheric Baseline Observatory Network	Use of facilities at 4 globally distributed and manned observatories by other NOAA LOs, U.S. agencies, U.S. universities, and international partners.	The data collected at the observatories cover up to 250 different measurements, many of them collected continuously and transmitted to end users and the public in real time.	WMO Global Atmosphere Watch, Geneva OAR/Climate Program Office/climate.gov		The AGGI stands alone in the document as a NOAA product based on NOAA data -- http://esrl.noaa.gov/gmd/aggi/ (NOAA); http://www.wmo.int/pages/prog/arep/gaw/ghg/GHbulletin.html (WMO) http://esrl.noaa.gov/gmd/aggi/ (NOAA-GMD); https://toolkit.climate.gov/tool/annual-greenhouse-gas-index-aggi (NOAA CPO) Data are used by many agencies, universities, industries and especially scientists monitoring the changing composition of the atmosphere and the global radiation balance.

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Atmospheric Tomography Mission (ATom)	Atmospheric sampling of ozone, ozone depleting gases, greenhouse gases, and tracers of atmospheric transport spanning nearly pole-to-pole and vertically from the surface to 12 km.	Samples were used to improve understanding of large-scale atmospheric transport and atmospheric chemistry and the fate of pollutant transport to remote areas of the globe.	Global research community, NOAA and NASA data archives. https://daac.ornl.gov/		Numerous publications are expected once the 4-yr mission is complete.
Boulder GRUAN site	Vertical profiles of T, P, winds, ozone and water vapor from balloon-borne radiosondes, ozonesondes and frost point hygrometers.	Climate data records are built on long-term, internally consistent measurements of essential climate variables (ECVs). GRUAN strives to compile climate data records from 25-30 global sites.	Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)		Traditionally, balloon-borne measurements of T and P were performed for the application of numerical weather prediction, with frequent and systematic changes to instrumentation. Consequently the measurements cannot be compiled into climate data records without substantial efforts to minimize intermittent biases and step-jumps. GRUAN is improving the accuracy and internal consistency of upper atmospheric measurements of ECVs, through strict operating procedures and centralized data processing, to create climate data records.
Carbon Cycle Data	Approximately 10 compounds measured routinely at ~80 sites and over 1350 data sets available (globally).	The GMD Global Greenhouse Gas Reference Network measures the atmospheric distribution and trends of carbon dioxide (CO ₂), methane (CH ₄), and nitrous oxide (N ₂ O), and carbon monoxide (CO), an important indicator of air pollution. Data from individual sites are frequently downloaded and used in publications.	Global research community, World Data Centre of Greenhouse Gases. Disseminated in WMO WDCGG Data Summary and made available on line at Japan Meteorological Agency		Data source for dozens of papers published in the refereed literature every year. http://esrl.noaa.gov/gmd/dv/data/?category=Greenhouse%2BGases

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Carbon Tracker	Products such as Carbon Weather, global carbon fluxes, etc. Carbon Tracker is a CO2 measurement and modeling system developed by NOAA to keep track of sources (emissions to the atmosphere) and sinks (removal from the atmosphere) of carbon dioxide around the world.	Carbon Tracker is constrained by NOAA's CO2 and CH4 monitoring network. NOAA's version has a strong focus on North America; other nations and regions are adapting the code to incorporate their more granular observing systems in their nations and regions.	e.g., Wageningen University Meteorology and Air Quality Department, Utrecht, Netherlands		The code is available on the GMD website and is a template for various versions that focus on large-scale regions, e.g., Europe, Asia, and China. Different partners use our code and observations, select specific regions for foci, and update accordingly with our global data and their supplemental, regional data. Following are their websites -- http://esrl.noaa.gov/gmd/ccgg/carbontracker/ and https://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/ (NOAA); http://www.carbontracker.eu/ (Europe); http://www.nimr.go.kr/2/carbontracker/index.html (Asia)
Carbon Tracker - CH4	Estimates of methane emissions for natural and anthropogenic sources constrained by NOAA GMD methane observations and bottom-up estimates of methane emissions using a state of the art global transport model.	The purpose of Carbon Tracker-CH4 is to further the understanding of the global methane budget.	Carbon Tracker-CH4 results were documented in peer-reviewed literature, and were contributed to the Global Carbon Project Methane studies.		see https://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/ . Note that resource limitations have prevented updates to this product.
CO2 Mauna Loa Trends	The Mauna Loa Data record, which NOAA makes available daily, are viewed at this site for the most up-to-date information on CO2.	The "iconic" climate record shared in near real time with the global research community and the public.	WMO/GAW, numerous press reports, Climate.gov		http://esrl.noaa.gov/gmd/ccgg/trends/ (GMD); http://www.climate.gov/news-features/understanding-climate/2013-state-climate-carbon-dioxide-tops-400-ppm (CPO). Supported many news articles in NYTimes, Washington Post, CNN, et al. et al. as CO2 went over 400 ppm. The CO2 data measured at Mauna Loa constitute the longest record of direct measurements of CO2 in the atmosphere.

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Continuous Light Absorption Photometer (CLAP)	Atmospheric sampling system that measures atmospheric aerosol light absorption at three visible wavelengths.	The CLAP instrument improves and makes more consistent the measurement of aerosol light absorption in the atmosphere at Federated Aerosol Network sites around the world.	This technology was successfully transferred to the private sector and Brechtel Manufacturing, Inc., Hayward, CA is now manufacturing and selling a commercial instrument (Tricolor Absorption Photometer, TAP) based on the CLAP design.	https://www.esrl.noaa.gov/gmd/aero/instrumentation/clap_desc.html
Global CO ₂ record	Long-term trend of CO ₂ from all remote marine boundary layer sites in NOAA's global monitoring network. Uses of the data set are varied (scientists, managers, policy makers, educators, public).	National Indicator for Climate Change in support of the most recent National Climate Assessment	USGCRP	http://esrl.noaa.gov/gmd/ccgg/trends/global.html (NOAA) ; https://www.globalchange.gov/browse/indicators/indicator-atmospheric-carbon-dioxide (USGCRP)
Global Ozone Profile Data	Ozone profile data from balloon borne ozonesondes.	Ozone data are used in UV models and UV forecasts as well as in ozone research.	World Ozone and Ultraviolet Radiation Data Center (WOUDC)	Global stratospheric ozone controls the amount of UV reaching the Earth's surface. GMD maintains a global network of balloon borne ozonesonde sites with weekly balloons. Ozone profile data disseminated globally and used on a regular basis for satellite verification, health alerts, research and monitoring of ozone layer recovery.
Global Total Column Ozone Data	Ozone total column data from Dobson Spectrophotometers.	Ozone data used in UV models and UV forecasts as well as in ozone research.	World Ozone and Ultraviolet Radiation Data Center (WOUDC)	GMD maintains the Dobson global standard. The ozone profile data is disseminated globally. Data used on a regular basis for satellite verification, health alerts, research and monitoring of the ozone layer recovery.
Globally and zonally averaged atmospheric CH ₄ time series. Similar records available for other greenhouse gases and related tracers.	Long-term trend of CH ₄ from remote marine boundary layer sites in NOAA's cooperative global air sampling network. Uses of the data set are varied (scientists, managers, policy makers, educators, public).	Indicator of atmospheric CH ₄ 's contribution to climate change for national and international climate assessments.		https://www.esrl.noaa.gov/gmd/ccgg/mbl/ ; https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/

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GLOBAL VIEW data products	A gridded distribution of CO2 and CH4 data based on GMD's monitoring network and updated annually. Data products designed to enhance spatial and temporal distribution of atmospheric observations of CO2, CH4 and other related measurements.	GLOBALVIEW products are specifically intended as tools for use in carbon cycle modeling studies.	Used in publications by numerous scientists and modelers around the world	http://esrl.noaa.gov/gmd/ccgg/globalview/ Referenced in several publications every year by partners around the world studying the carbon cycle. It is one of the critical pieces for initializing, developing, and validating models.	
IPCC Fifth Assessment Report Contributions	Lead authorship of chapters, Review Editor, Topic Editors, Scientific expertise. Comprehensive, multi-year data sets of GMD's global average greenhouse gas observations, ozone, surface radiation, and aerosols.	The Fifth Assessment Report (AR5) provided a clear and up to date view of the current state of scientific knowledge relevant to climate change. Working Group I provides the physical science basis of climate change.	Intergovernmental Panel on Climate Change, Fifth Assessment Report, Working Group I and Executive Summary	Quintennial Assessment (approx). These assessments inform the parties to the UN Framework Convention on Climate Change, who seek guidance in setting forward plans and programs internationally and institutionally in their efforts to mitigate and adapt to climate change. The U.S. is a signatory.	
Mobile SURFRAD sites	Two regional mobile SURFRAD stations measure surface radiation budget (upwelling and downwelling shortwave and longwave radiation), direct normal irradiance (DNI), global horizontal irradiance (GHI), spectral aerosol optical depth, cloud fraction, and spectral surface albedo.	Regional, shorter term studies for: 1) Verification and data assimilation (solar forecasting); 2) Surface radiation budget and aerosol radiative forcing (climate research); 3) Satellite verification (solar and IR radiation, AOD, NDVI, Land Surface Temperature, surface albedo); 4) Aerosol optical depth (verification of estimates of PM2.5 for Air Quality).	NOAA/NESDIS/STAR	GOES-R Satellite Verification; http://campaign.arm.gov/itcap/ - DOE ARM TCAP campaign, http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html - Satellite Verification Studies - Data archive for DISCOVER-AQ (Colorado, Texas, California)	

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Monitoring Water Vapor in the Upper Troposphere and Stratosphere	High-resolution water vapor profile data from balloon-borne frost point hygrometers.	Upper atmospheric water vapor data are used in climate models, to validate satellite-based water vapor measurements, and in climate research.	Network for the Detection of Atmospheric Composition Change (NDACC)		Changes in the abundance of water vapor in the upper troposphere and stratosphere strongly influence global surface temperature. GMD maintains three globally-distributed sites where balloon-borne frost point hygrometers are launched every 2-4 weeks. Water vapor profile data are disseminated via the NDACC data repository.
National Academy of Sciences Report, "Improving Characterization of Anthropogenic Methane Emissions in the United States"	Extensive description of GMD methane observations from global to regional scales. Summary of what was learned from GMD and other measurements. Author contribution from GMD.	The purpose of the report was to review current understanding of the U.S. methane budget, and to make recommendations of where future progress can be made.	National Academy of Sciences		The report may be downloaded from https://www.nap.edu/catalog/24987/improving-characterization-of-anthropogenic-methane-emissions-in-the-united-states
ObsPack Data Products	Brings together direct atmospheric greenhouse gas measurements, prepares them with specific applications in mind, and packages and distributes them in a set of self-documenting files.	Observation Package (ObsPack) data products are intended to stimulate and support carbon cycle modeling studies.	Used in publications by numerous scientists and modelers around the world		http://esrl.noaa.gov/gmd/ccgg/obspack/ - Recently developed by NOAA's Global Monitoring Division, this product is gradually replacing GlobalView, as more and more modelers want real data for their models, rather than a smoothly gridded data set. Hundreds of downloads since 2013. Currently an essential data set for validating CO2 retrievals from NASA's Orbiting Carbon Observatory 2 (OCO-2) satellite.
Oil and gas field data methane emissions	In situ GMD measurements showing large emissions of methane from oil and gas fields have led to new State of CO regulations on allowable methane emissions from these extraction activities. These regulations were made law in February 2014. Additional GMD studies have shown similar high methane emissions in TX, NM and UT. National regulations are being considered.	Methane emitted to the atmosphere during fossil fuel extraction operations is a valuable lost resource and a potent greenhouse gas. If more than 4% of production is lost, the climate benefits of switching from coal to gas fuel for electricity generation is lost.	Colorado Air Quality Control Commission		Colorado is the first U.S. state to control methane emissions from fossil fuel extraction. The problem was brought to light from pioneering oil and gas field ground and airborne methane emission studies conducted by the NOAA Global Monitoring Division. The first scientific publications and many of the subsequent key measurements of elevated methane over Colorado gas and oil fields were published by GMD scientists. Other states are now formulating methane emission regulations using the Colorado template and NOAA is conducting measurements over fields in TX, ND and NM. U.S. EPA is considering nationwide Federal regulations on methane emissions. http://www.colorado.gov/cdphe/faqcc-regs

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Oil and Gas Methane Emission Research	Coordinated bottom-up and top-down CH4 emission quantification.	Identify causes of differences between top-down and bottom-up estimates	DOE and oil and gas Industry sponsored project to further understand quantification methods and documented differences in outcomes. Research partners included CO School of Mines, DOE NREL, CSU, AECOM	Top-down emission estimates have often been larger than inventories. Some have attributed the difference to superemitters not accounted for in inventories. Our study in the Fayetteville showed that the top-down approach is representative of midday peak emissions when episodic short-term maintenance venting occurs. A time and spatially resolved inventory is able to match the top-down results.
Oil and Gas (O&G) Methane Emission Research	Four Corners Methane Hotspot.	Quantify methane emissions using aircraft mass balance and attribute emissions to various potential sources. Compare with published satellite based estimates.	Local stakeholders interested in the research outcomes include O&G operators, energy and air agencies in NM, CO as well as Southern Ute Indian Tribe, Navajo Nation, Ute Mountain Ute Tribe, and Jicarilla and Apache Tribe.	The aircraft mass balance paper has been published and a follow-up paper on sources and emission attribution in the San Juan Basin will be submitted this summer.
Oil and Gas Methane Emission Research	Leak Detection from Aircraft in a US Shale gas play.	Leak detection is currently done by ground-based teams using IR cameras which are time intensive, require site access, do not give quantitative results, require trained professionals, and are likely ineffective given that most of leaked emissions come from a small subset of facilities.	Industry sponsored project to compare two different airborne techniques and the traditional ground IR surveys in terms of leaks detected, quantified and cost benefit analysis of 3 approaches.	This is a novel area of research and a scientific paper is in review.

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Oil and Gas (O&G) Methane Emission Research	Top-down estimation of CH4 emissions for several US O&G basins.	CH4 and VOC emission estimates for O&G industry.	States and EPA use inventory models to estimate emissions of greenhouse gases and ozone precursors. Most top-down studies showed higher emissions than estimated by inventories. The CH4 and VOC emission models used by States and the EPA have been progressively and extensively revised since 2011. New emission regulations have also been put in place, including new Leak Detection and Repair requirements.		The top-down regional emission estimation based on aircraft mass-balance technique is an independent approach to quantify emissions and evaluate emission inventories. Top-down field campaigns have been funded by EDF, NSF, DOE, O&G industry to support the EPA effort to revised its greenhouse gas inventory. Results have been published in scientific papers.
Oil and Gas (O&G) Volatile Organic Compounds (VOC) Emissions and Health Impacts	Identify and quantify emissions of air toxics from oil and gas operations.	Investigate new 20+ O&G well pad emissions and ambient levels in nearby communities. Assess if current setback distances are protecting population from exposure to high levels of air toxics.	NSF Sustainability Research Network sponsored project. Interdisciplinary research with > 11 contributing groups.		VOC and air toxics emissions from crude oil, condensate, natural gas and produced water operations are still not well characterized. With the co-development of housing and O&G operations in the CO Front Range, it is important to collect measurements to assess potential impacts.
Ozone-Depleting Gas Index (ODGI)	Index of combined ozone depletion potential from all ozone-depleting gases.	To make publicly available a simple measure of society's success in addressing stratospheric ozone depletion, by computing the decline in ozone-depleting potential from all long-lived, ozone-depleting gases.	EPA Report on the Environment		http://esrl.noaa.gov/gmd/odgi/ ; Data on gases used in this index are employed by numerous researchers and policy makers. The index summarizes ozone-depleting gases and is the template for a similar compilation in the Ozone Assessment.

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NASA Aircraft Data Archive, Cloud1	HATS airborne data from 1991 to the present, including manned aircraft, balloon, and unmanned aircraft systems (UAS, Altair and Global Hawk); CCGG airborne data from ATom Mission, 2016-present.	This archive is used to calibrate global climate model with precise airborne satellite and ground truth NASA satellites for NASA's Upper Atmospheric Research Program, Earth Venture Science, Tropospheric programs.	NASA's Earth Science Program Office (ESPO) started the archive	NIST, NOAA, EPA, NSF, NASA, Smithsonian, WMO, ENEA (Italy), NIWA (New Zealand) are additional users.	
National Academy of Sciences Report, "Improving Characterization of Anthropogenic Methane Emissions in the United States"	Extensive description of GMD methane observations from global to regional scales. Summary of what was learned from GMD and other measurements. Author contribution from GMD.	The purpose of the report was to review current understanding of the U.S. methane budget, and to make recommendations of where future progress can be made.	National Academy of Sciences	The report may be downloaded from https://www.nap.edu/catalog/24987/improving-characterization-of-anthropogenic-methane-emissions-in-the-united-states	
PERSEUS GC/MS instrument	GMD adapted cryogenic preconcentration of hydrocarbons and halocarbons from atmospheric samples, followed by removal of interfering substances (particularly CO ₂ , O ₂ , N ₂ , noble gases) to allow the highest level sensitivity and reproducibility of analytes.	The new method has allowed GMD to perform high accuracy measurements of ethane (as well as other species), both on the remote, global scale as well as in areas of Oil & Gas exploration.	Partners include Environment Canada; DOE (e.g., RPSEA); INSTAAR/University of Colorado; CSD/NOAA; Industrial (e.g., Southwestern Energy Co., Chevron Co., Statoil Co., American Gas Association, XTO Energy Inc.); NASA, NSF.	Ethane, along with certain other hydrocarbons, is a particularly useful tracer of Oil & Gas emissions, and aids in the attribution of sources in methane studies. Our flask measurements are also valuable in comparisons with in-situ ethane instruments, which typically have less precision and stability.	
Profiles of ozone-depleting gases and their replacements over the continental U.S.	Atmospheric sampling of ozone-depleting gases and their replacements of the U.S. from the surface to 5 km.	Provide top-down emissions estimates for the continental U.S.	Global research community	Independent top-down estimates of emissions of ozone-depleting gases and their replacements are used to improve bottom-up, inventory-based estimates for reporting.	

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Programmable Flask Package (PFP)	System for manual or automatic sampling of ambient air for later analysis of trace gas concentrations and isotopic ratios.	Sampling and analysis of air at surface sites, tall towers and aircraft to characterize gas concentrations around the world.	Constructed by High Precision Devices (Boulder) and used by numerous research organizations worldwide (e.g., INPE, Brazil)	
Publications and Governments Using GMD Data Outside NOAA	GMD data are made freely available to the world and used in alerts, newscasts, daily/weekly summary reports, and publications to inform the public, policy makers, politicians, educators and scientists. GMD data form the core of Environmental Assessments.	NOAA GMD data show that the composition of the atmosphere is changing rapidly. It is important that these data be analyzed and disseminated to the broadest global audience in a timely manner.	Literally 1,000s of users around the Earth, in some cases, on a daily basis. For instance, an article in the New York Times on President Obama's Climate Action Plan.	Over 10 years, NOAA GMD data has been credited as the source in papers on: Ozone = 4,871; Solar radiation = 931; Aerosols = 348; Carbon Cycle = 3,467, and the NOAA GMD Baseline Atmospheric Observatories credited with supporting measurements used by scientists and governments in papers and reports = 6,215 times.
Revised Global Methane Emissions	Repartitioning of global CH4 emissions between natural and anthropogenic sources.	CH4, the second most important long-lived greenhouse gas, has been increasing in the global atmosphere since 2007. Global long-term observations of CH4 and delta-13CH4 provide unique constraints on different CH4 sources and how they have changed over time. The early detection of major shifts in the global C cycle is also paramount.	Understanding factors influencing global methane levels are key to understanding and predicting future climate forcing. Global methane also impacts background tropospheric ozone and OH levels.	A more accurate methane budget allows a better understanding of sources as well as planning and assessment of emission mitigation. Oil, gas and coals emissions are larger than in previously published budgets but they have not changed significantly in recent years.
Solar Calculator	A tool to predict the actual observed values of sunrise, sunset, solar noon, and solar position from any location on the globe.	Research community resource for instrument calibrations and alignments globally.	Massachusetts Institute of Technology	Used by scientists worldwide; its results appear in the published literature or on websites operated by partners. General public uses it; FBI used it to capture an alleged criminal in 2012-2013. http://esrl.noaa.gov/gmd/grad/solcalc/

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Solar Radiation Data	Approximately 20 variables measured and over 135 data sets available (globally).	The GMD Solar Radiation group involved in observational and theoretical research of Earth's surface & atmospheric radiation budgets, focusing on the extent and cause of observed radiation and climate variations, and collaborating with other research groups making satellite observations and climate model calculations.	World Radiation Data Center, St. Petersburg, Russia		http://esrl.noaa.gov/gmd/dv/data/?category=Radiation http://wrdc-mgo.nrel.gov/ (monthly submission)
Standards - Central UV Calibration Facility	Highly accurate and long-term repeatable calibrations and characterizations of UV monitoring instruments.	The Central UV Calibration Facility is a joint project between NOAA & NIST. Mission: to provide highly accurate and long-term repeatable calibrations and characterizations of UV monitoring instruments.	USDA/Colorado State University/UV-B Monitoring and Research Program (UVMRP)		USDA website: http://uvb.nrel.colostate.edu/UVB/index.jsf NIST, NOAA, EPA, NSF, NASA, Smithsonian, WMO, ENEA (Italy), NIWA (New Zealand) are additional users.
Standards - Dobson Regional Standards	Calibration of JMA and BoM Dobson Regional Standards in Boulder	Ensures globally traceable and compatible measurements for validating satellite retrievals of total and stratospheric ozone.	WMO partners with scientists investigating total ozone.		Dobson #83 is housed in Boulder and used to calibrate all Dobson ozone measurements worldwide through WMO coordinated comparison activities.

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Standards - NOAA Scales	NOAA ESRL GMD maintains calibration scales for 21 minor gases (outside of the CCL).	NOAA maintains the Mole Fraction scale for a specified gas in air for the global research community.	Gas standards are used by atmospheric scientists and chemical oceanographers around the world to study lesser greenhouse gases and ensure that their measurements will be compatible.	There are two sets of worldwide standards for many halocarbons. NOAA maintains one set and Scripps Institution of Oceanography maintains another to support (1) CFC measurements in the ocean and (2) NASA's AGAGE program of surface measurements of ozone-depleting substances. Every 6 months results using the two sets of standards and networks are compared to understand small differences and determine if problems are emerging.
Standards - WMO Global Scales	GMD is World Meteorological Organization (WMO), Global Atmosphere Watch (GAW) Central Calibration Laboratory (CCL) for CO ₂ , CH ₄ , N ₂ O, SF ₆ , and CO.	A WMO Central Calibration Laboratory is responsible for maintaining and distributing the WMO Mole Fraction scale for a specified gas in air to the global research community.	WMO partners and other partners and scientists investigating greenhouse gases, private and public sectors.	WMO sets up regional calibration centres that use NOAA standards to propagate the scale to researchers in their regions (e.g., SE Asia, China, Europe, etc.). http://www.esrl.noaa.gov/gmd/ccl/ (NOAA) ; http://www.empa.ch/ (Switzerland); http://ds.data.jma.go.jp/gmd/wcc/wcc.html (Japan); others
State of the Climate Report	Comprehensive atmospheric observations, data sets, analysis, and author contributions by GMD to the annual State of the Climate Report.	Annual updates of atmospheric composition in BAMS State of the Climate Report. The report is read worldwide and GMD contributions on atmosphere have expanded through time. 425 authors from 57 countries, uses climate indicators to track patterns, changes, and trends of global climate system. Indicators reflect thousands of measurements from multiple independent data sets.	NOAA/NESDIS/National Center for Environmental Information	This report gets considerable attention in the U.S. and worldwide, as it is a regular, annual issue of the Bulletin of the American Meteorological Society. All of GMD's data sets (2000) are analyzed by GMD and sections and summaries written for the report. GMD scientists are chapter authors and the lead editor for atmospheric composition.

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SURFRAD Aerosol Optical Depth Data Archival	Aerosol optical depth for six visible spectral channels.	Aerosol optical depth measurements made at the surface validate satellite estimates of AOD and contribute to the global inventory.	GAW archive at the World Data Centre for Aerosols	https://www.gaw-wdca.org/	
SURFRAD NESDIS GOES Comparison	SURFRAD radiation data downloaded daily by NOAA/NESDIS/STAR (Center for Satellite Applications and Research).	SURFRAD data are used for daily comparison to NESDIS/STAR GOES-based estimates of surface radiation.	NOAA/NESDIS/STAR	https://www.star.nesdis.noaa.gov/smcd/emb/radiation/gsip-v3_vs_php	
SURFRAD Radiation Data Archival	Surface radiation budget data from seven U.S. stations.	Surface radiation measurements are worldwide are used to validate satellite estimates and weather and climate models.	Baseline Surface Radiation Network (BSRN) archive in Bremerhaven, Germany	http://bsrn.awi.de/	
SURFRAD Radiation Data Archival	Surface radiation budget data from seven U.S. stations.	Surface radiation measurements are worldwide are used to validate satellite estimates and weather and climate models.	NOAA National Center for Environmental Information	https://www.ncdc.noaa.gov	
SURFRAD Radiation Data Archival	Surface radiation budget data from seven U.S. stations.	Surface radiation measurements are worldwide are used to validate satellite estimates and weather and climate models.	World Radiation Data Center, St. Petersburg, Russia	http://wrdc.mgo.rssi.ru/	

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SURFRAD Sites	Seven long-term SURFRAD stations provide independent measures of upwelling and downwelling, solar and infrared measurements, direct and diffuse solar, photosynthetically active radiation, UVB, spectral solar, and meteorological parameters.	SURFRAD observations have been used for evaluating satellite-based estimates of surface radiation, and for validating hydrologic, weather prediction, and climate models; modelers; publications.	NASA Langley's Earth Observing System	http://www-cave.larc.nasa.gov/
U.S. National Climate Assessment -- Publications, Data	Scientific expertise; contributions through the Carbon Interagency Working Group of the U.S. Global Change Research Program.	NOAA played a critical role in the development, authorship, and delivery of the report, with many scientists and staff helping develop technical inputs and climate scenarios.	U.S. Global Change Research Program	Quadrennial Assessment. Official report to Congress as part of the U.S. Global Change Research Act, but also made available publicly. NOAA provides the most comprehensive sets of greenhouse gas data for this.
Wintertime ozone in rural Wyoming and Utah	Knowledge of the causes and timing of high wintertime ozone production in rural Wyoming and Utah associated with oil and gas production.	Wintertime ozone production over oil and gas fields in rural WY and Utah has put portions of the state into EPA non-compliance. GMD scientists published the first scientific papers identifying causes & timing of winter ozone production phenomenon. WY subsequently put in place regulations on oil and gas field emissions, resulting in a drop in winter ozone exceedances.	Wyoming and Utah Departments of Environmental Quality and Utah	The States of Wyoming and Utah, NOAA, EPA, Bureau of Reclamation and oil and gas companies funded extensive studies of the winter ozone production problem as EPA regulations require the development and implementation of an ozone mitigation program. The oil and gas industry has subsequently spent in excess of \$0.5 Billion on emission controls and successful ozone mitigation efforts.

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WMO Aerosol Bulletin	GMD Aerosol Group contributes to the Aerosol Bulletin pages on a periodic basis, including co-authoring and publishing reports on standard operating procedures (e.g., https://library.wmo.int/opac/index.php?lvl=notice_display&id=6643#-WwMP7q3X3ys) and serving on the Scientific Advisory Group for Aerosols of the Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO).	The Aerosol Bulletin serves to consolidate global aerosol measurements into a single use document for the global aerosol scientific community.	WMO/GAW Aerosol Working Group	http://www.wmo.int/pages/prog/arep/gaw/AerosolBulletin.html	
WMO Antarctic Ozone Hole Bulletins	The state and progression of the annual South Pole Ozone Hole as it is occurring.	Ex. Six bulletins came out monthly in 2013 reporting on progress and understanding of the ozone hole. Strong use of GMD data.	WMO Global Atmosphere Watch, Geneva	Tracks the annual South Pole Ozone Hole formation and recovery. Distributed around the Earth in six languages. GMD provides the only column data from the South Pole and data during the 6 month dark period when satellites are unable to measure Antarctic ozone.	
WMO Greenhouse Gas Bulletin	Information, Data, Authorship	Disseminating brief, global summaries and analysis of greenhouse gas trends and distributions. Distributed worldwide in five languages.	WMO Global Atmosphere Watch, Geneva	The World Data Centre for Greenhouse Gases (WDCGG) is one of the WDCs under the GAW programme. It gathers, archives and provides data on greenhouse gases (CO ₂ , CH ₄ , CFCs, N ₂ O, surface ozone, etc.) and related gases (CO, NO _x , SO ₂ , VOC, etc.) in the atmosphere and ocean.	
WMO WDCGG Data Summary	GMD greenhouse gas data sets transitioned to World Data Centre for Greenhouse Gases.	Reports the latest status of greenhouse and some reactive gases in the atmosphere.	Japan Meteorological Agency	This data repository captures data not explicitly collected in other World Data Centers but there is some overlap.	

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WMO/UNEP Scientific Assessment of Ozone Depletion	Co-authors, contributors, and review editors of chapters and GMD's global data on stratospheric ozone trends and trends of all ozone-depleting gases. Scientific expertise.	The most recent WMO/UNEP assessment contains the most up-to-date understanding of ozone depletion. It reflects the thinking of hundreds of international scientific experts. Source of atmospheric data: NOAA ESRL GMD and CSD and NASA.	UNEP Ozone Secretariat	This Quadrennial Assessment informs the Parties to the Montreal Protocol on Substances that Deplete Stratospheric Ozone. It also is used to support a Congressional requirement of NOAA and NASA to report every 3 years on the status of stratospheric ozone and the substances that deplete it -- in support of the Clean Air Act of 1990.