III. NDACC Cooperating Networks

The NDACC recognizes the importance of scientific cooperation with independently operating regional, hemispheric, or global measurement and analysis networks whose heritage and capabilities were developed external to NDACC. These networks often have set up their own quality assurance guidelines, operational requirements, and data archiving policies, and independant national or international recognition. Rather than attempting to bring an interested external network under the NDACC umbrella as an operational component, it has been more practical and appropriate to designate such a network as an "NDACC Cooperating Network". The desired collaborative measurement and analysis activities can thereby be fostered through mutual data access and mutual steering group representation. A protocol for Cooperating Network affiliation can be found on the NDACC web site http://www.ndacc.org/.

The following independent networks have finalized agreements with NDACC for scientific collaboration as NDACC Cooperating Networks.

AERONET (AErosol RObotic NETwork**)**
http://aeronet.gsfc.nasa.gov/

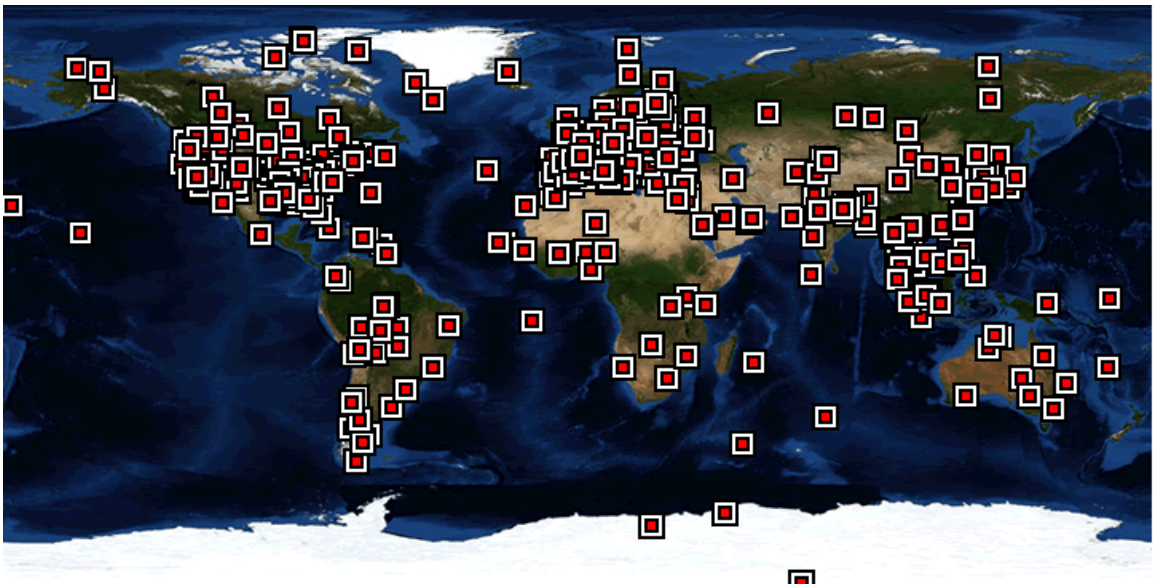

Figure 1: AERONET site distribution in 2014

The AERONET (AErosol RObotic NETwork) Program (*Holben et al*., 1998) is a federation of ground-based, remote-sensing aerosol networks established by NASA and the University of Lille 1 and is greatly expanded by collaborators from national agencies, institutes, universities, individual scientists, and partners. The Program provides a long-term, continuous, and readily accessible public domain database of aerosol optical, microphysical, and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases. The Network imposes:

- standardization of instruments,
- calibration,
- processing, and
- distribution.

AERONET collaboration provides globally distributed observations at over 500 sites of spectral aerosol optical depth (AOD), inversion products, and precipitable water in diverse aerosol regimes. Aerosol optical depth data are computed for three data quality levels: Level 1.0 (unscreened), Level 1.5 (cloud-screened), and Level 2.0 (cloud-screened and quality-assured). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality checks.

Holben B.N., T.F. Eck, I. Slutsker, D. Tanre, J.P. Buis, A. Setzer, E. Vermote, J.A. Reagan, Y. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, and A. Smirnov, AERONET - A federated instrument network and data archive for aerosol characterization, *Rem. Sens. Environ. 66*, 1-16, 1998.

AGAGE (Advanced Global Atmospheric Gases Experiment)
http://agage.mit.edu/

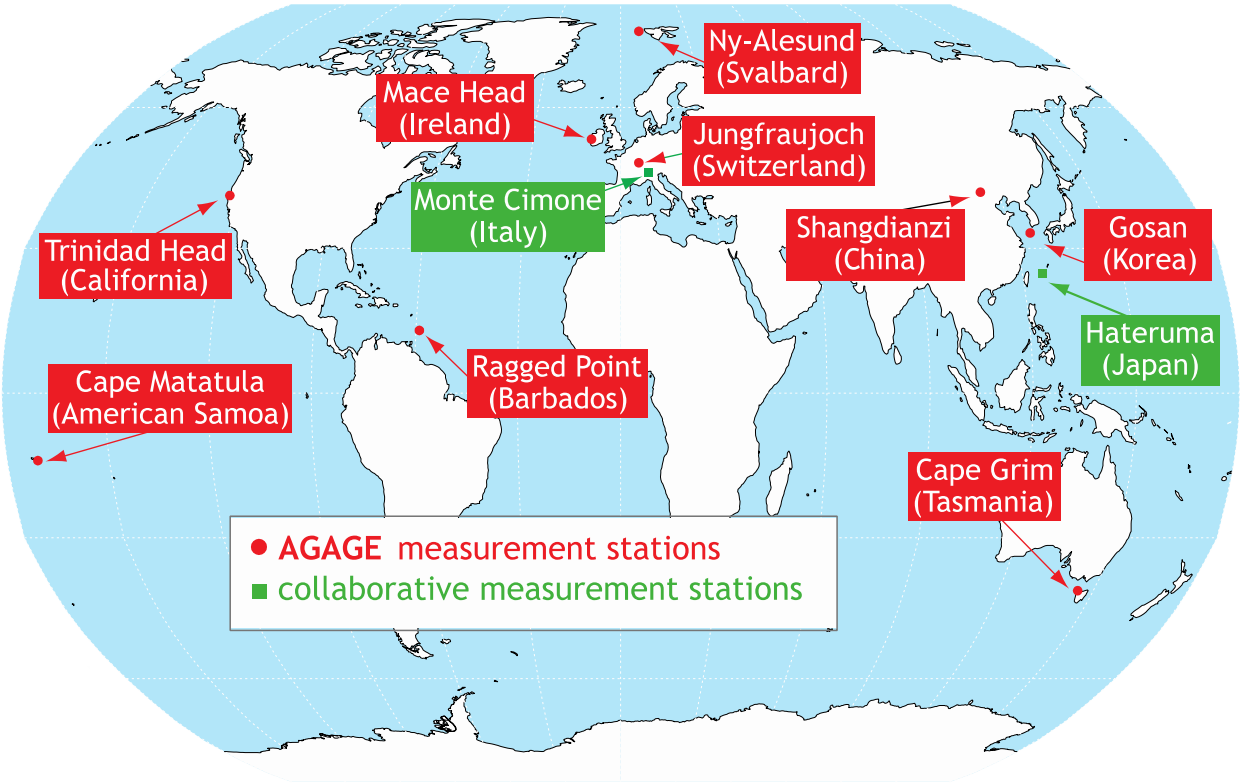

Figure 2: AGAGE measurement sites

AGAGE performs real-time, high-frequency measurements of approximately 50 trace gases at stations around the world, and interprets these measurements using three-dimensional models and inverse theory to further understanding of ozone depletion and climate change and to address verification issues arising from the Montreal (ozone) and Kyoto (climate) Protocols. AGAGE utilizes the Medusa GC-MS and GC-multi-detector instruments, and is distinguished by its capability to measure at high frequency all the important species in the Montreal Protocol and all non-CO_2 gases in the Kyoto Protocol. The scientific objectives of AGAGE are important in furthering understanding of global chemical and climatic phenomena. They are:

(1) To determine optimally from observations the global rates of emission and/or destruction (i.e., lifetimes) of anthropogenic chlorocarbons, chlorofluorocarbons (CFCs), bromocarbons, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) that contribute most of the reactive halogen to the stratosphere and/or are strong infrared absorbers.
(2) To document accurately global distributions and temporal behaviors of the biogenic/anthropogenic gases important in climate change and/or ozone depletion: methane, nitrous oxide, carbon monoxide, hydrogen, methyl chloride, and methyl bromide.
(3) To determine optimally the average concentrations and trends of tropospheric hydroxyl radicals from the rates of destruction of atmospheric methyl chloroform, HFCs, and HCFCs deduced from their measured mole fractions together with estimates of their emissions.

(4) To determine optimally, from atmospheric observations and estimates of their destruction rates, the magnitudes and distributions by region of surface sources/sinks for these gases.
(5) To provide accurate data on the global accumulation of these trace gases, which are used to test the synoptic/regional/global-scale circulations predicted by three-dimensional models.
(6) To provide global and regional measurements of methane, carbon monoxide, and hydrogen, that together with estimates of hydroxyl levels, can be used to test primary atmospheric oxidation pathways at mid-latitudes and the tropics.

Professor R. Prinn (MIT) is the principal investigator for overall leadership and coordination of AGAGE, and for data processing and theoretical analysis for all AGAGE gases. Professor R. Weiss (SIO, UCSD) is the principal investigator for the experimental components of AGAGE with specific responsibility for the Cape Matatula, Samoa and Trinidad Head, CA stations and for absolute calibration at the La Jolla, CA laboratory. Dr. S. O'Doherty (University of Bristol) is the PI for the Mace Head, Ireland and Ragged Point, Barbados stations. Mr. P. Krummel (CSIRO) is the PI for the Cape Grim, Tasmania, Australia station, the Cape Grim air archive, and inter-comparisons with other laboratories. The PI's of the affiliated stations are as follows: Dr. S. Reimann (EMPA) is the PI for the AGAGE-affiliated station at Jungfraujoch, Switzerland. Dr. C. Lunder is the PI for the Ny-Ålesund, Norway AGAGE-affiliated station. Dr. M. Maione (U. Urbino) is the PI for the Monte Cimone, Italy AGAGE-affiliated station. Dr. T.Saito (NIES) is the PI for the Hateruma Island, Japan and Cape Oichi-ishi, Japan AGAGE-affiliated stations. Dr. S.-Y. Park (Kyungpook Natl. Univ.) is the PI for the AGAGE-affiliated station at Gosan, S. Korea. Dr. L. Zhou (CAMS, CMA) is the PI for the Shangdianzi, China AGAGE-affiliated station. Dr. R. Wang (GaTech) is the Global Network Scientist in charge of meteorology-related data processing and archiving, along with Drs. J. Huang and M. Rigby. Contact information for these individuals and other Station Scientists and Global Network Scientists is available at the AGAGE website.

BSRN (Baseline Surface Radiation Network)
http://www.bsrn.awi.de/

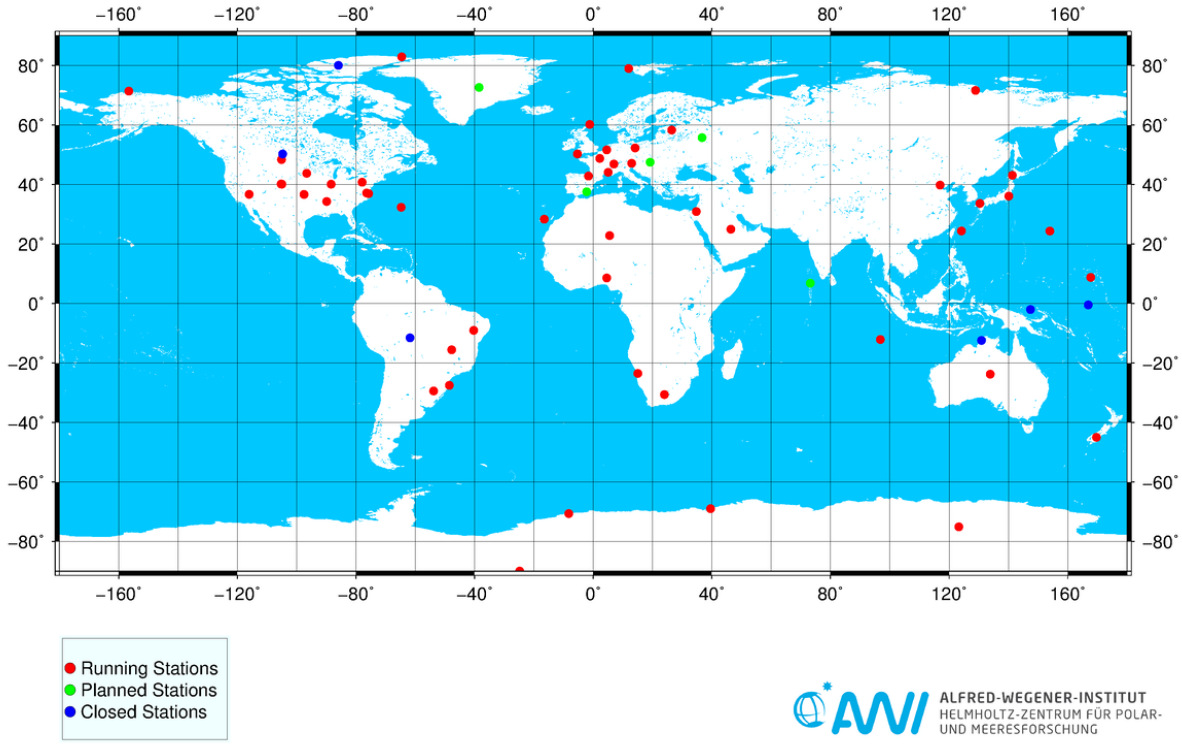

Figure 3: Running, planned and closed BSRN stations, March 2015

The Baseline Surface Radiation Network (BSRN) provides near-continuous, long-term, *in situ*, Earth-surface, broadband irradiances (solar and thermal infrared), and certain related parameters from a network of more than 50 globally diverse sites. The observed data are collected, processed, and reviewed by the individual sites' scientists, and subsequently provided to the Network's central data archive and dissemination center, the World Radiation Monitoring Center (WRMC), located at the Alfred Wagner Institute (AWI) in Bremerhaven, Germany.

BSRN closely links to NDACC in that atmospheric composition is a primary determinant of the non-geometric variability of the surface-received irradiances observed by BSRN. BSRN encourages, but does not require, nearby simultaneous observations of aerosol optical depth, water vapor, and ozone at its sites. Some sites overlap between the two networks, but most do not.

The BSRN was conceived and implemented in the late 1980s by the World Climate Research Program (WCRP, sponsored by WMO, ICSU, and IOC), with the collected data intended to be utilized for climate research applications; in particular, satellite product validation, climate model comparisons, and establishment of regional radiation climatologies, all in support of Earth radiation budget studies. In the mid 1990s, BSRN was included under the WCRP program called The Global Energy and Water Experiment (GEWEX). By the late 1990s, BSRN was designated as a contributing network the WMO Global Atmospheric Watch (GAW) Programme,

and in the early 2000s was designated as the Global Baseline Surface Radiation Network of the Global Climate Observing System (GCOS).

Irradiance data collected and provided by the BSRN derive from instrumentation and operating practices that fulfill specifications developed by BSRN that are intended to provide the highest possible quality data from remote, continuously operated field sites. Each participating site has a designated Site Scientist, who is responsible for the operation of the site and the quality of the final data product submitted to the central archive at AWI.

To fulfill its institutional obligations to respond to the broader climate/scientific community, BSRN reports and answers annually to the GEWEX Radiation Panel, currently chaired by Prof. Christian Kummerow, and the GCOS/Atmospheric Observations Panel for Climate (AOPC) chaired by Dr. Adrian Simmons. Dr. Joseph Michalsky (NOAA) provides the overall international management of the BSRN. The AWI BSRN Archive (also called the World Radiation Monitoring Center) is under the direction of Dr. Gert König-Langlo. All data are interactively available for any scientist who accepts the data release guidelines.

BSRN sites are typically sponsored by the host country's national government or, in some cases, other public or private institutions. The sites; participation in BSRN is generally considered part of the countries' contribution and obligation to the UN and other international sponsoring organizations.

Ohmura, A., E. G. Dutton, B. Forgan and 12 co-authors, 1998: Baseline Surface Radiation Network (BSRN)/WCRP): New precision radiometry for climate research. *Bull. Amer. Meteoro. Soc. 79*, 2115- 2136.

König-Langlo, G. , Sieger, R. , Schmithüsen, H. , Bücker, A. , Richter, F. and Dutton E.G. 2013: The Baseline Surface Radiation Network and Its World Radiation Monitoring Centre at the Alfred Wegener Institute. www.wmo.int/pages/prog/gcos/Publications/gcos-174.pdf.

GRUAN (GCOS Reference Upper Air Network)
http://www.dwd.de/gruan

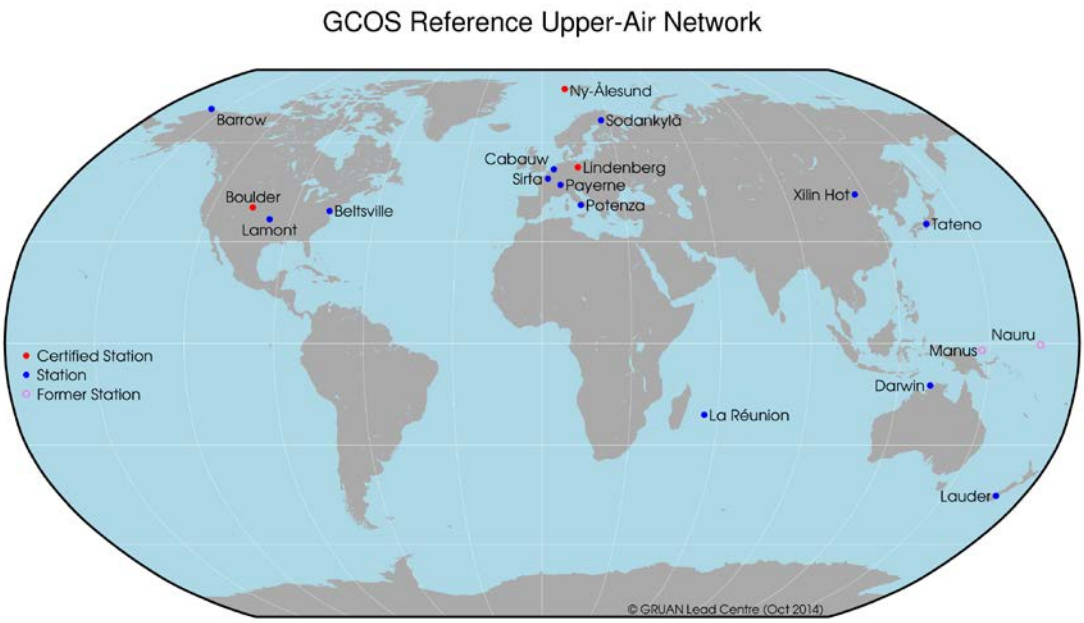

Figure 4: GRUAN Stations as of 2014

The GCOS (Global Climate Observing System) Reference Upper-Air Network (GRUAN) is an international reference-observing network, designed fill an important gap in the current global observing system. GRUAN measurements provide long-term, high-quality climate data records from the surface, through the troposphere, and into the stratosphere. These are used to determine trends, constrain and calibrate data from more spatially comprehensive observing systems (including satellites and current radiosonde networks), and provide appropriate data for studying atmospheric processes.

Target requirements for accuracy, stability, and vertical resolution have been defined for a range of essential climate variables, as well as the necessary measurement regimens required to meet the needs of intended users of GRUAN data. The Working Group on GRUAN, which meets annually at implementation and coordination meetings, provides oversight of GRUAN. A periodically reviewed implementation plan guides the activities of the Working Group. Operational support is provided through the GRUAN Lead Centre, hosted at the Meteorological Observatory at Lindenberg (Germany), supported by the National Meteorological Service, Deutscher Wetterdienst. Task teams on radiosondes, GNSS precipitable water, measurement schedules and associated site requirements, ancillary measurements, and site representation further support the Working Group and Lead Centre. Formal GRUAN operating procedures, including formal site assessment and certification, are documented in the GRUAN Manual and Guide.

The first GRUAN data product (the RS92 radiosonde data product) is available to users via NOAA/NCDC. An initial set of candidate GRUAN sites has been identified, and some sites already have had their RS92 radiosonde programs GRUAN certified. GRUAN is envisaged as a

global network of eventually 30 to 40 sites that, to the extent possible, builds on existing observational networks and capabilities, including those of NDACC. Criteria to guide the expansion and design of GRUAN have been developed through a dedicated network design workshop to ensure that the Network evolves in a way to meet the goals of GRUAN. The report from this workshop can be obtained at http://www.dwd.de/EN/research/international_programme/gruan/download/gruan_rp-4.pdf?__blob=publicationFile&v=3

HATS (NOAA/ESRL/GMD Halocarbons and other Atmospheric Trace Species) Network
http://www.esrl.noaa.gov/gmd/hats/

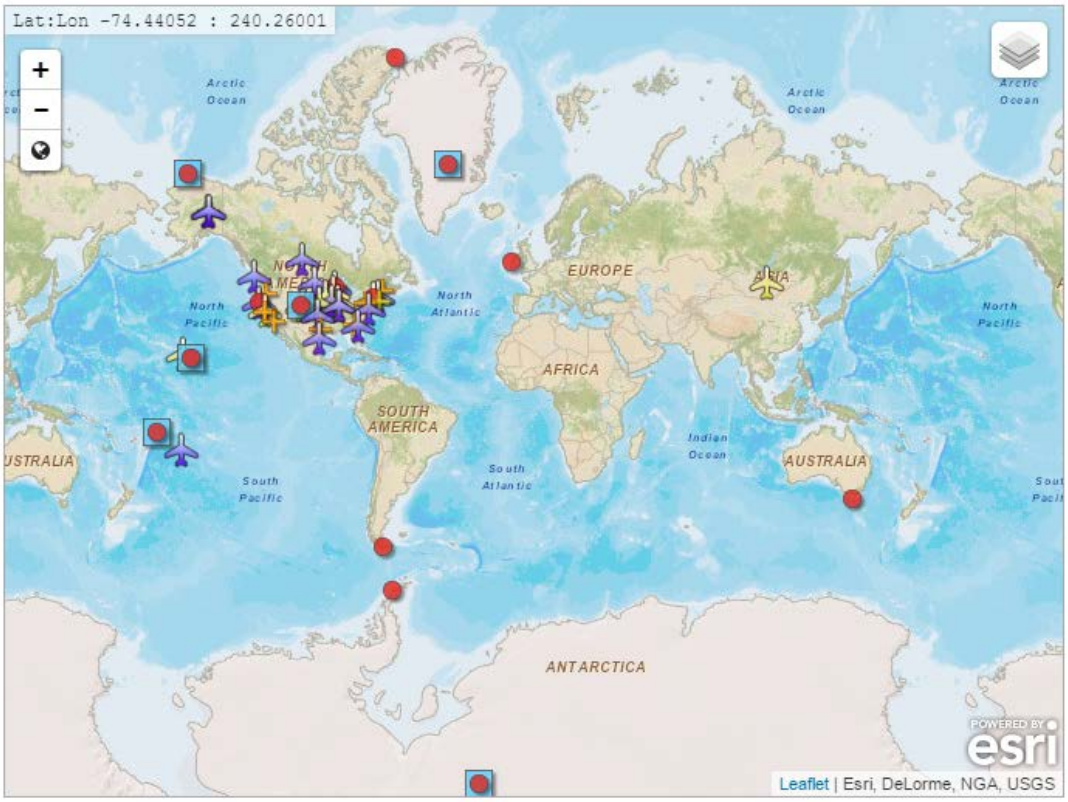

Figure 5: HATS Stations. Circles=flask sites, boxes=in situ sites, planes=airborne sites. For more details: see http://www.esrl.noaa.gov/gmd/hats/network.php. Credit ESRL GMD

The National Oceanic and Atmospheric Administration's Earth System Research Laboratory (NOAA/ESRL) maintains a global *in situ* and flask network for the measurement and analysis of halocarbons and other atmospheric trace gases. The network started in 1977 with three trace gases (nitrous oxide, CFC-11, CFC-12) at five flask locations, and has grown to include over 40 trace gases at over 30 locations and airborne campaigns that include both flask and *in situ* monitoring. The purpose of this work is to study atmospheric trace gases that affect climate change, stratospheric ozone depletion, and air quality from observations at NOAA and cooperating stations. Some atmospheric trace gases (e.g., SF_6) are used as atmospheric clocks to provide important information on atmospheric transport. Areas of common interest with NDACC include the (1) species measured by Fourier Transform Infrared Spectrometers (halocarbons, O_3, HCl, HF, CO, N_2O, CH_4), water vapor, ozone, and Lidar instruments; and (2) collocated stations at Barrow, Boulder, Mauna Loa, Summit, American Samoa, Palmer, and South Pole.

The analyses of flask samples and *in situ* data are conducted within the Global Monitoring Division (GMD) in Boulder, Colorado, USA. Through collaborations with the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF),

NOAA/ESRL operates a number of *in situ* and flask collection instruments from NASA and NSF high-altitude, manned, and unmanned (UAS) aircraft up to 21 km, and balloon platforms up to 32 km. These measurements have been associated with high-altitude campaigns that have spanned the globe since 1991. HATS began vertical profiling of many trace gases from flask samples collected on NOAA-operated, small aircraft (<=25000 ft asl) in 2004. These measurements now include 25 sites.

The HATS Network measures over 40 trace gases in the atmosphere, including nitrous oxide (N_2O); chlorofluorocarbons (CFCs, CFC-11, -12, -113, -115); hydrochlorofluorocarbons (HCFCs, HCFC-22, -141b, -142b); hydrofluorocarbons (HFCs, HFC-134a, 143a,152a, 125, 32, 227ea, 365mfc); methyl halides (CH_3Cl, CH_3Br, CH_3I); chlorinated ($CHCl_3$, CH_3CCl_3, CCl_4, C_2Cl_4, CH_2Cl_2); and brominated ($CHBr_3$, CH_2Br_2) solvents; sulfur gases (COS, SF_6); and selected hydrocarbons (C_2H_2, C_3H_8, nC_4H_{10}, C_5H_{12}, nC_5H_{12}, C_6H_6, nC_6H_{14}). Water vapor (H_2O) and ozone (O_3) also have been measured on NASA airborne campaigns since 2005. *In situ* atmospheric H_2, CO, and CH_4 are measured at Summit, Greenland, and during most high-altitude airborne campaigns.

NOAA HATS provides data to calculate atmospheric indices, including the Annual Greenhouse Gas Index (AGGI), Ozone Depleting Gases Index (ODGI), equivalent effective chlorine, total bromine, and total fluorine in the atmosphere. This research has resulted in numerous peer-reviewed publications, and has contributed to international assessments of climate and ozone depletion. Data are available via anonymous ftp, and discussions are available at the HATS website.

Dr. James W. Elkins, Group Chief, is responsible for the Network and airborne measurements within the HATS group. Dr. Stephen A. Montzka is the Principal Investigator responsible for the gas chromatograph and mass selection detection of flask samples collected from stations located globally, and also from regional aircraft that sample the troposphere. Dr. Bradley D. Hall is the Principal Investigator in charge of trace-gas standards research, and the preparation of most of the Group's trace gas standards. Geoffrey S. Dutton is the Principal Investigator responsible for *in situ* measurements at stations located at Pt. Barrow, Alaska; Summit, Greenland; Niwot Ridge, Colorado; Mauna Loa, Hawaii; Cape Matatula, American Samoa; and South Pole, Antarctica. Drs. Fred L. Moore and Eric J. Hintsa are Co-P.I.s responsible for high-altitude airborne measurements on NASA aircraft.

Of the many sites noted on the HATS web page, the following are relevant to NDACC interests.

Station Name	Stn Code	Lat	Long	Elev. (masl)	BS Flask Site	N-BS Flask Site (start - end)	Aircraft PNS (sampling start-end)
Summit, Greenland	SUM	72.6°N	38.4°W	3209	X		
Alert, Canada	ALT	82.5°N	62.3°W	210	X		
Barrow, AK, USA	BRW	71.3°N	156.6°W	27	X *		
Poker Flat, AK, USA	PFA	65.1°N	147.3°W				4/09 -
CARVE Experiment, USA	CRV	65.0°N	147.6°W	643		10/11 -	
CARVE Experiment, USA	CRV	60-71°N	144-164°W				3/11 -
	ACG	57- 86°N	130-170°W				4/09 - ***

East Trout Lake, Canada	ETL	54.3°N	105.0°W				10/05 -
Mace Head, Ireland	MHD	53.3°N	9.9°W	42	X		
Estevan Pt, Canada	ESP	49.6°N	126.4°W				3/05 -
Dahlen, ND, USA	DND	48.1°N	98.0°W				9/04 -
Ulaanbaatar, Mongolia	ULB	47.4°N	106.0°E				11/04 – 3/09 **
Park Falls, WI, USA	LEF	45.9°N	90.3°W	868	X		
Park Falls, WI, USA	LEF	45.9°N	90.3°W	716		10/06 -	6/05 - **-
Argyle, ME, USA	AMT	45.0°N	68.7°W	157		11/08 -	
Fairchild, WI, USA	FWI	44.7°N	91.0°W				9/04- 11/05
Mt Bachelor Obs, USA	MBO	44.0°N	121.7°W	2742		10/11 -	
Worcester, MA, USA	NHA	43.0°N	70.6°W				10/05 -
Bradgate, IA, USA	BGI	42.8°N	94.4°W				9/04 – 11/05
Harvard Forest, MA, USA	HFM	42.5°N	72.2°W	340	X		
Rowly, IA, USA	RIA	42.4°N	91.8°W				9/04 -
West, Branch, IA, USA	WBI	41.7°N	91.4°W	620		6/07 -	
Oglesby, IL, USA	OIL	41.3°N	88.9°W				9/04- 11/05
Trinidad Head, CA, USA	THD	41.0°N	124.1°W	120	X		11/04 - -
Niwot Ridge, CO, USA	NWR	40.1°N	105.5°W	3475	X *		
Lewisburg, PA, USA	LEW	40.9°N	76.9°W	256		6/13 -	
Beaver Crossing, NE, USA	BNE	40.8°N	97.2°W				9/04 -
Briggsdale, CO, USA	CAR	40.4°N	104.3°W				1/05 -
Airborne Aer. Obs, IL, USA	AAO	40.1°N	88.56°W				6/06-9/09 **
Boulder, CO, USA	BAO	40.1°N	105.0°W	1884		8/07 -	
Homer, IL, USA	HIL	40.1°N	87.9°W				9/04 -
Niwot Ridge Forest, CO, USA	NWF	40.0°N	105.6°W	3052 or 3073		2/06 – 11/09	
Indianapolis, IN, USA	INX	39.8°N	86.0°W	406		10/10 -	10/10 -
Cape May, NJ, USA	CMA	38.8°N	74.3°W				9/05 -
Walnut Grove, CA, USA	WGC	38.3°N	121.5°W	91 or 483		6/07 -	
San Francisco, CA, USA	STR	37.8°N	122.5°W	486		10/ 07	
S. Great Plains, OK, USA	SGP	36.8°N	97.5°W				3/06 - **-
Beech Isl., SC, USA	SCT	33.4°N	81.8°W	420		8/08 -	
Mt. Waliguan, China	WLG	36.3°N	100.9°E	3890	X		
Mt Wilson Obs, USA	MWO	34.2°N	118.1°W	1774		4/10 -	
Charleston, SC, USA	SCA	32.8°N	79.6°W				10/05 -
Moody, TX, USA	WKT	31.3°N	97.3°W	708		8/ 06 -	
Negev Desert, Israel	WIS	30.9°N	34.9°E	482	X		
Sinton, TX, USA	TGC	27.7°N	96.9°W				2/05 -
Molokai Island, HI, USA	HAA	21.2°N	159.0°W				8/06 – 4/08 -
Cape Kumukahi, HI, USA	KUM	19.5°N	154.8°W	39	X		
Mauna Loa, HI, USA	MLO	19.5°N	155.6°W	3433	X *		
Tutuila, American Samoa	SMO	14.2°S	170.6°W	77	X *		
Rarotonga, Cook Islands	RTA	21.0°S	159.8°W				9/07 -
Cape Grim, Australia	CGO	40.7°S	144.7°E	164	X		
Palmer St, Antarctica	PSA	64.6°S	64.0°W	15	X		
South Pole, Antarctica	SPO	90°S		2837	X *		

BS Flask Site: *Background Surface Flask Sites (Weekly frequency at most sites, a mix of stainless-steel and glass flasks; altitude of air intake indicated.)*

N-BS Flask Site: *Non-Background Surface Flask Sites (Tower sites - approximately daily glass flasks):*
Aircraft PNS: *Aircraft Profiling Network Sites - Dates of duration are indicated for Version 3 pfps only (COS data obtained). All flight plans include sampling to 25000 ft asl, except as indicated.*

*In situ, once an hour.
** Max altitude routinely < 25000 ft
*** Not in winter

MPLNET (Micro Pulse Lidar Network)
http://mplnet.gsfc.nasa.gov/

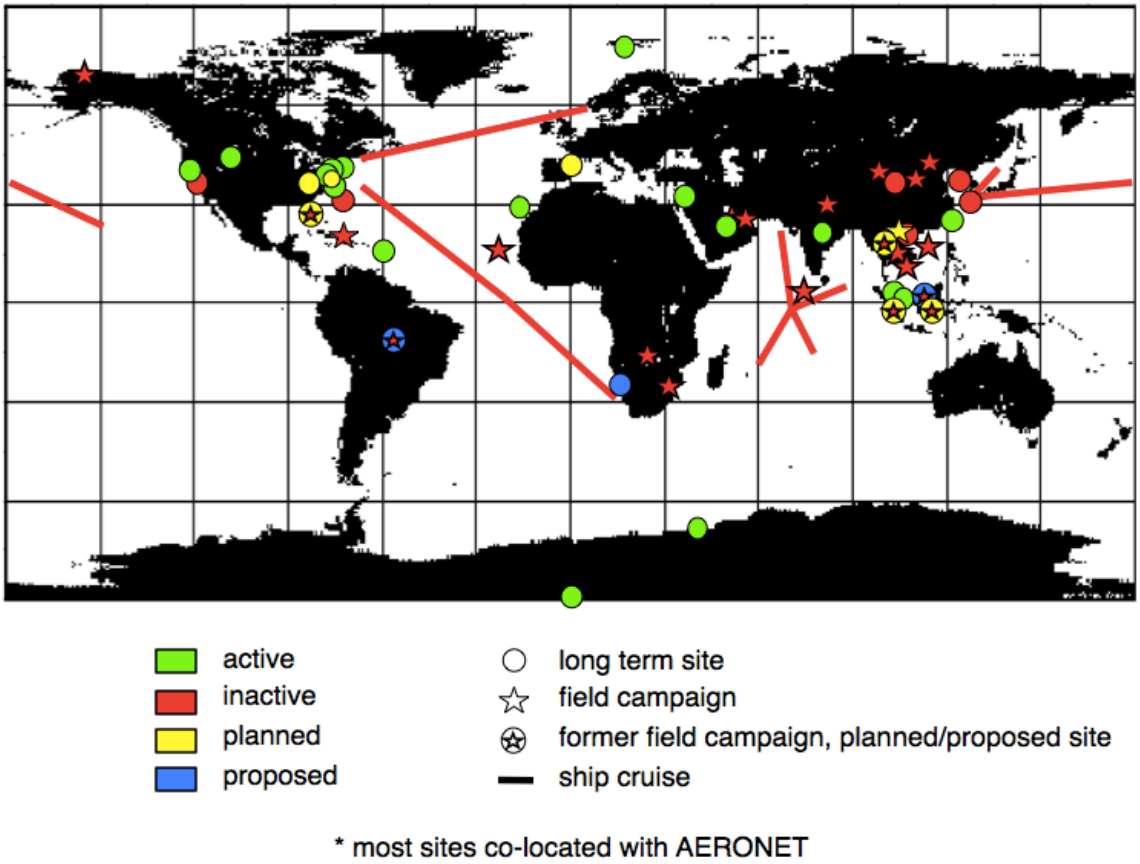

Figure 6: MPLNET Stations

The NASA Micro Pulse Lidar Network (MPLNET) [Welton *et al.*, 2001] is a ground based network of Micro Pulse Lidar (MPL) [Spinhirne *et al*., 1995] instruments collocated with sun photometers in the NASA Aerosol Robotic Network (AERONET) [Holben *et al*., 1998]. MPLNET and AERONET are federated networks of instruments designed to collect aerosol and cloud data using standardized data processing algorithms and a central archive and distribution system. MPLNET data provide information on the vertical distribution and properties of aerosol and cloud layers. MPLNET instrument calibrations and Level 1 signal processing algorithms are described by Campbell *et al*. [2002] and Welton and Campbell [2002]. Level 1 data are acquired at 1-minute temporal and 75-meter vertical resolutions. MPLNET data products also include near-real-time (no quality assurance) Level 1.5 data and final-quality-assured Level 2 data containing layer heights and aerosol properties. The planetary boundary layer height and aerosol top height products are discussed in Lewis *et al*. [2013] and Campbell *et al.* [2003], respectively. Thick low cloud heights are determined from derivatives of the Level 1 signal, and high cloud heights are based on Campbell *et al*. [2008]. The temporal resolutions of the layer products are: cloud (1 minute), PBL (5 minutes), and aerosol (20 minutes). Aerosol products also include profiles of aerosol backscatter, extinction, and aerosol optical depth (AOD), and the column aerosol lidar ratio. Aerosol products are derived using 20-minute, cloud-screened Level 1

profiles centered on AERONET AOD observation times. The AERONET AOD is used to constrain the retrieval of the aerosol backscatter profile, and compute a final lidar ratio [Welton *et al*., 2000]. Quality-assured Level 2 MPLNET aerosol products are generated using Level 2 AERONET AOD, profiles of molecular backscatter derived from air density provided by NCEP reanalysis, and the following data screening standards: MPL instrument temperature within 2˚ C of the original optical alignment temperature, a minimum of 16 cloud-free signal profiles during the 20-minute signal average (80%), and derived lidar ratio errors less than 30%. MPLNET Level 2 aerosol products have been validated numerous times. The most recent and comprehensive validation was presented in Schmid *et al*. [2006], concluding MPLNET Level 2 aerosol extinction profile accuracy within 20%. MPLNET data and more information on the project are available at the MPLNET website.

Campbell, J. R., D. L. Hlavka, E. J. Welton, C. J. Flynn, D. D. Turner, J. D. Spinhirne, V. S. Scott, and I. H. Hwang, Full-time, eye-safe cloud and aerosol lidar observation at Atmospheric Radiation Measurement Program sites: Instrument and data processing, *J. Atmos. Oceanic Technol.*, *19*, 431-442, 2002.

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Holben B. N., T. F. Eck, I. Slutsker, D. Tanre, J. P. Buis, A. Setzer, E. Vermote, J. A. Reagan, Y. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, and A. Smirnov, AERONET - A federated instrument network and data archive for aerosol characterization, *Rem. Sens. Environ.*, *66*, 1-16, 1998.

Lewis, J. R., E. J. Welton, A. M. Molod, and E. Joseph, Improved boundary layer depth retrievals from MPLNET, *J. Geophys. Res. Atmos.*, *118* (*17*), 9870-9879, 2013.

Schmid, B., R. Ferrare, C. Flynn, R. Elleman, D. Covert, A. Strawa, E. J. Welton, D. Turner, H. Jonsson, J. Redemann, J. Eilers, K. Ricci, A. G. Hallar, M. Clayton, J. Michalsky, A. Smirnov, B. Holben, and J. Barnard, How well do state-of-the-art techniques measuring the vertical profile of tropospheric aerosol extinction compare?, *J. Geophys. Res*., *111* (*D05S07*), 2006.

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Welton, E. J., K. Voss, H. Gordon, *et al.*, Ground-based lidar measurements of aerosols during ACE-2: Instrument description results and comparisons with other ground-based airborne measurements, *Tellus B, 52*, 635-650, 2000.

Welton, E. J., and J. R. Campbell, Micro-pulse lidar signals: Uncertainty analysis, *J. Atmos. Oceanic Technol., 19*, 2089-2094, 2002.

SHADOZ (Southern Hemisphere Additional Ozonesondes) Network
http://croc.gsfc.nasa.gov/shadoz/frame_home.html

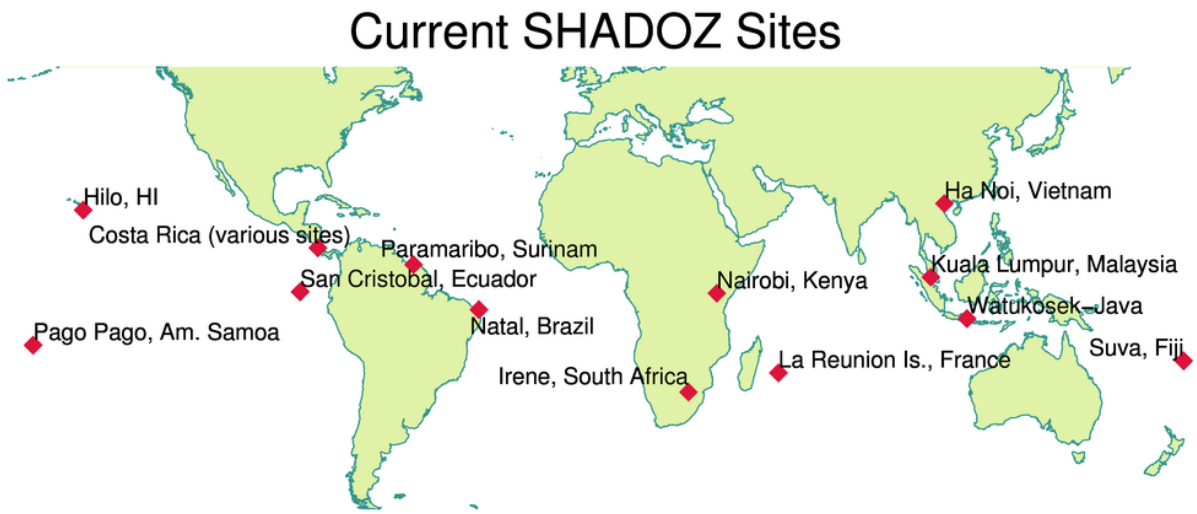

Figure 7: SHADOZ Stations

The Southern Hemisphere Additional Ozonesondes (SHADOZ) is a project to augment balloon-borne ozonesonde launches, and to archive data from tropical and subtropical operational sites. The project was initiated in 1998 by the NASA/Goddard Space Flight Center, with NOAA and international co-investigators in Europe, South America, Asia, and Africa. There are currently thirteen operational stations in the Network. The collective data set provides the first profile climatology of tropical ozone in the equatorial region, enhances validation studies aimed at improving satellite remote sensing techniques for tropical ozone estimations, and serves as an educational tool for students, especially in the participating countries. As a flexible archive, SHADOZ has grown and evolved as scientific needs and research questions change. In addition to the NDACC link, SHADOZ data are transmitted regularly to the WOUDC , and are archived in HDF for the satellite user community at the Aura Validation Data Center.

Data are collected and available publicly at the SHADOZ official website. The Principal Investigator of SHADOZ is Anne Thompson of NASA's Goddard Space Flight Center. The Archiver and Webmaster is Jacquie Witte, also at NASA/Goddard. Station locations, Co-Investigator contacts, and technical details of the operations are also archived at the website.

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Thompson, A. M., J. C. Witte, S. J. Oltmans, F. J. Schmidlin, J. A. Logan, M. Fujiwara, V. W. J. H. Kirchhoff, F. Posny, G. J. R. Coetzee, B. Hoegger, S. Kawakami, T. Ogawa, J. P. F. Fortuin,

and H. M. Kelder, Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998-2000 tropical ozone climatology 2. Tropospheric variability and the zonal wave-one, *J. Geophys. Res.*, *108*, 8241, doi: 10.1029/2002JD002241, 2003.

Thompson, A. M., J.C . Witte, H. G. J. Smit, S. J. Oltmans, B. J. Johnson, V. W. J H. Kirchhoff, and F. J. Schmidlin, Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998-2004 tropical ozone climatology: 3. Instrumentation, station-to-station variability, and evaluation with simulated flight profiles, *J. Geophys. Res.*, *112*, doi: 10.1029/2005JD007042, 2007.

Thompson**,** A. M., *et al.*, Southern Hemisphere Additional Ozonesondes (SHADOZ) ozone climatology (2005-2009): Tropospheric and tropical tropopause layer (TTL) profiles with comparisons to OMI-based ozone products, *J. Geophys. Res*., *117***,** doi: 10.1029/2010JD016911, 2012.

TCCON (Total Column Carbon Observing Network)
http://www.tccon.caltech.edu/

Figure 8: TCCON Stations

The Total Carbon Column Observing Network (TCCON) is a network of ground-based Fourier Transform Spectrometers recording direct solar spectra in the near-infrared spectral region. The project was initiated in 2004 with support from NIWA (New Zealand) and NASA (US). It has expanded to international co-investigators across the world. The primary data products are high-precision total columns of CO_2 and CH_4. Other gases including HDO, CO and N_2O are also retrieved and archived.

Sites for the network span the globe to provide diverse and targeted data for use as validation sites for the GOSAT and OCO-2 CO_2 observing satellites, as well as monitoring the seasonal cycle and long-term evolution of CO_2 and CH_4.

The Network shares common methodologies, technical issues, and membership with the NDACC FTIR Working Group. The Network aims to provide a temporally dense, globally consistent data coverage network-wide by using a common retrieval technique. The retrieved columns are tied to the ground-based in situ networks by scaling to (in situ) balloon and aircraft profiles.

Details and data can be found at the TCCON website. TCCON data are also available from the Carbon Dioxide Information and Analysis Center (CDIAC). The latest TCCON information, including site details, can be found at the TCCON Wiki. Chair of TCCON is Paul Wennberg; co-chairs are Justus Notholt (Europe / Africa) and David Griffith (East Asia, Tropical Western Pacific, Australia, and New Zealand).

The primary reference for TCCON is:
D. Wunch, G.C. Toon, J.-F.L. Blavier, R.A. Washenfelder, J. Notholt, B.J. Connor, D.W.T. Griffith, V. Sherlock, P.O. Wennberg. The Total Carbon Column Observing Network. Phil. Trans. R. Soc. A (2011) 369, doi:10.1098/rsta.2010.0240

A running tabulation of papers that use TCCON data is also available.