2009 NOAA/ESRL GLOBAL MONITORING ANNUAL CONFERENCE

David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305 USA

Wednesday, May 13th, 2009 AGENDA

(Only presenter's name is given; please refer to abstract for complete author listing)

- ***07:00*** ***Conference Registration Opens – lunch order fee collected at registration table.***

- ***08:00-08:30*** ***Morning Breakfast – Coffee, tea, fruit, bagels & donuts served***

Page No.

- ***Session 1*** ***Setting the Stage –*** *Chaired by Russ Schnell*

- ***10:15-10:30*** ***Morning Break***

- ***Session 2*** ***Halocarbons & Other Traces Species –*** *Chaired by James Elkins*

- ***12:00-13:15*** ***Catered Lunch Service – Outreach Classroom GB-124 (pre-payment of $10.00 required)***

- ***Session 3*** ***Carbon Cycle Gases, Session 1 –*** *Chaired by Pieter Tans*

- ***14:45-15:00*** ***Afternoon Break***

- ***Session 4*** ***Carbon Cycle Gases, Session 2*** *– Chaired by Andy Jacobson*

- ***16:45-18:30*** ***Poster Session (DSRC Cafeteria) with appetizers & refreshments***

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- ***Session 5*** ***Observatories and Global Measurements*** *– Chaired by Brian Vasel*

- ***10:15-10:30*** ***Morning Break***

- ***Session 6*** ***Ozone (and Global Measurements continued)*** *– Chaired by Bryan Johnson*

- ***12:00-13:00*** ***Catered Lunch Service – Outreach Classroom GB-124 (pre-payment of $10.00 required)***

- ***Session 7*** ***Solar Radiation and Aerosols*** *– Chaired by Patrick Sheridan*

- ***14:45-15:00*** ***Afternoon Break***

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- ***Session 8*** ***Upper Troposphere and Stratosphere (and a new direction)*** *– Chaired by Sam Oltmans*

Closing: Dr. James H. Butler (ESRL)

Abstract book solicitation, editing, preparation and printing: Misti Hinson, James Salzman, Kirk Thoning, Brian Vasel, Dan Endres, Tom Mefford, Miyuki Kaffroath, and Bill Cushman.

Prospects for a Low Carbon Energy Future

M.B. McElroy

Center for Earth & Planetary Physics, Harvard University, Pierce Hall, Cambridge, MA 02138; 617-495-2351, E-mail: mbm@seas.harvard.edu

The abundance of CO_2 is demonstrably higher now than at any time over the past 650,000 years and is likely over the next few decades to rise to levels not seen since dinosaurs roamed the Earth 50 million years ago. The increase in the abundance of CO_2 and a variety of other so-called greenhouse gases (notably CH_4 and N_2O) has resulted in a serious perturbation to the global energy balance. The Earth is now radiating significantly less energy to space than it absorbs from the sun. The extra heat, stored largely in the ocean, is responsible for important changes in global and regional climate with consequences, which though difficult to predict in detail, are surely serious. This paper will discuss potential options for a low-carbon energy future. Options to be discussed include prospects for carbon capture and sequestration with particular attention to the potential for an energy future based largely on electricity produced from a combination of wind, solar and geothermal sources complemented to an extent by nuclear. Particular attention will be directed at the challenges faced by large developing countries such as China and India, the former now having surpassed the U.S. as the world's largest national source of greenhouse gas emissions.

Michael B. McElroy is the Gilbert Butler Professor of Environmental Studies in the Department of Earth & Planetary Sciences at Harvard University. He obtained a Ph. D. in Applied Mathematics, at Queen's University, Belfast, Northern Ireland. Previous positions include post doctoral work at the University of Wisconsin at Madison; Co-founder of Atmospheric and Environmental Research; Chairman, MEDEA, Task Force appointed by Vice-President Gore to advise on Environmental Aspects of U.S. Intelligence; and former Director of the Harvard University Center for the Environment. Michael has authored or co-authored over 200 publications on topics such as planetary atmospheres, oceanography, stratospheric ozone depletion, air quality, climate change, carbon dioxide budgets, renewable energy's implications on climate, environmental problems in developing countries and one book, The Atmospheric Environment: Effects of Human Activity, Princeton University Press (2002).

Michael received AGU's James B. Macelwane Award (1968), NASA Public Service Medal (1978) and the George Ledlie Prize from Harvard University.

An Update on Climate Services

C.J. Koblinsky

NOAA Climate Program Office, 1315 East West Hwy Room: 12837 Building: SSMC3, Silver Springs, MD 20910; 301-734-1200, E-mail: chester.j.koblinsky@noaa.gov

Dr. Chet Koblinsky is Director of NOAA's Climate Program Office. His responsibilities include a broad range of climate science and services programs, ranging from observations and data systems, research, model development, predictions, and impacts research to delivery of information. He manages NOAA’s competitive climate research and observations programs.

Objective Verification of Greenhouse Gas Emissions and Removals

P.P. Tans

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6678, E-mail: Pieter.Tans@noaa.gov

In the near future policies are expected to be enacted to greatly reduce emissions of greenhouse gases, especially of CO_2. Their success should be observable at background sites such as Mauna Loa as a decreasing rate of the CO_2 build up, followed by a subsequent decline. It is very likely that the observed decline will be less, perhaps substantially, than hoped for. Which of these policies are not meeting their objectives? Because of some very long residence times, of CO_2 especially, we cannot afford failure. The challenge is to provide measurements that can quantify emissions on much smaller spatial scales, such as on the state and county level. Experience shows that we cannot rely solely on inventories that are often based on self-reporting. An outline will be given of a data assimilation approach, in which data from quite different sources are brought together in a coherent framework, in order to optimize the contribution from each data type and maximize the reliability of the overall results.

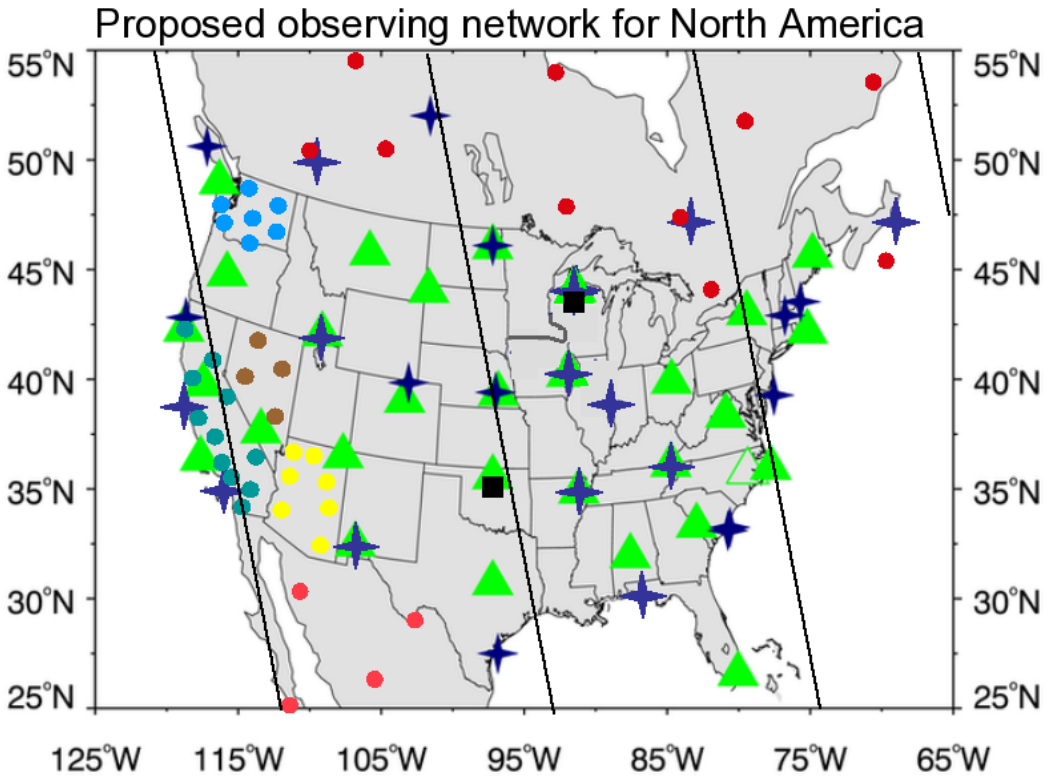

Figure 1. Conceptual design of network. Triangles: tall towers; stars: regular aircraft profiles; circles: regional and national networks; squares: upward looking spectrometers; lines: daily satellite orbits.

Atmospheric Emissions of Sulfur Hexafluoride: A Challenge for the Future

J.W. Elkins[1], G.S. Dutton[2], B.D. Hall[1], D.F. Hurst[2], F.L. Moore[2], D.J. Mondeel[2], J.D. Nance[2] and E.J. Dlugokencky[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6224, E-mail: james.w.elkins@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Atmospheric sulfur hexafluoride (SF_6) has become one of the fastest growing minor greenhouse gases since the development of the NOAA ESRL Annual Greenhouse Gas Index (AGGI, base year = 1990). Its total radiative forcing could become a major concern in the near future. On a per molecule basis, it is almost 22,200 times more effective as an infrared absorber than carbon dioxide (CO_2), but its global mixing ratio is much less where global mean mixing ratios are almost 6.5 parts-per-trillion (ppt) compared to 385 parts-per-million for CO_2. It is used almost exclusively as an electric insulating gas for the distribution of electric power. It also has a long atmospheric lifetime, estimated between 500 and 3200 years. Over the past two years, the atmospheric growth rate has accelerated from an average of 0.21 ppt year to 0.31 ppt year. The major problem with dielectric gases used in power distribution is that there is no known environmentally friendly substitute for SF_6. Mankind's demand for electricity over the long term will grow with population. A switch from less fossil fuel technology to more alternative energy sources like wind, solar, tidal action, and biofuels will still require SF_6. This talk will highlight recent observations from NOAA ESRL's flask and *in situ* ground base networks, along with recent airborne regional and global campaigns.

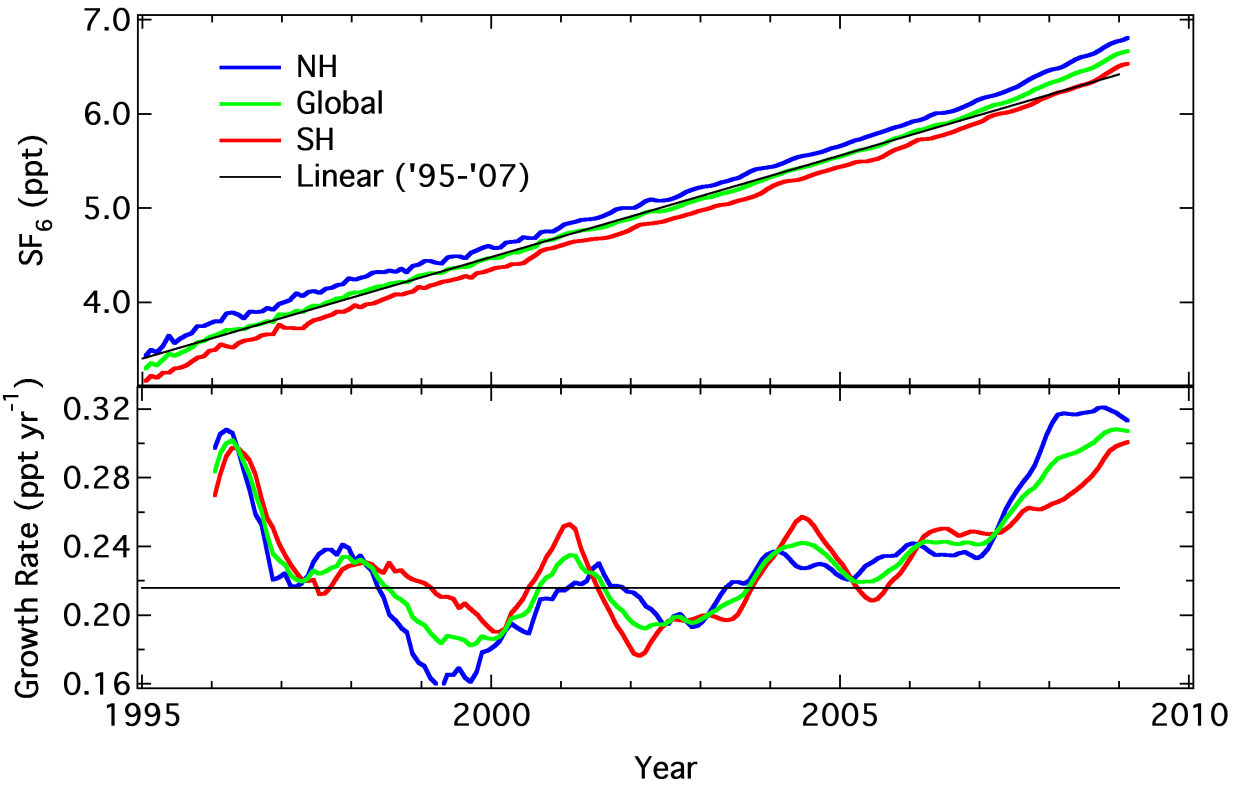

Figure 1. Global and Hemispheric Means of SF_6 (top panel), Respective growth rate, noting clear departure from linear growth in 2007 (bottom panel).

NOAA's Science On a Sphere - The Ideal Way to Display Global Data

B. Russell

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6759, E-mail: beth.russell@noaa.gov

Science On a Sphere® (SOS) is a room-sized, global display system that uses computers and video projectors to display planetary data on a six foot globe. Invented by Dr. Alexander MacDonald, Director of the NOAA Earth System Research Laboratory (ESRL), SOS is installed in over 35 locations around the world, including science museums, universities, planetariums and aquariums. Over 250 datasets can be shown on the sphere ranging from climate models to movement of tectonic plates to sea surface height anomalies. Many NOAA datasets, including datasets from ESRL Global Monitoring Division (GMD), are shown at the SOS sites around the world. This provides valuable exposure for NOAA's research. CarbonTracker, from GMD, has been shown in many museums and was recently highlighted on SOS at an exhibit for the National Science Teachers Association annual conference. Continued growth of the SOS dataset library is supported by researchers making their global data available for SOS. Once generated, new data is then made available to all SOS sites with a brief description of the data so that is can be shown and taught in all the SOS venues. SOS promotes environmental literacy by displaying NOAA's Earth science data in a way that engages and educates audiences of all ages. In a survey at the McWane Science Center in Birmingham, AL, 100% agreed that the Science on a Sphere® images made a complex topic more understandable and 82% agreed that they learned something new from the exhibit.

Figure 1. School groups regularly visit the Earth System Research Laboratory (ESRL) to see Science On a Sphere (SOS) in the Planet Theater. Tom LeFebvre, of ESRL's Global Systems Division, is seen here giving a presentation of SOS to a class of captivated 5th graders. NOAA photo by Will von Dauster.

PFC Emissions from Global and Australian Aluminium Production Using AGAGE Data

P. Fraser[1], J. Muhle[2], C. Trudinger[1], A. Ganesan[2], B. Dunse[1], B. Miller[3,2], C. Harth[2], P. Krummel[1], P. Salameh[2], R. Weiss[2], P. Steele[1] and R. Prinn[4]

[1]Light Metals Flagship, Commonwealth Scientific & Industrial Research Organization, Marine and Atmospheric Research, Aspendale, Victoria 3195, Australia; +61393994613, E-mail: paul.fraser@csiro.au
[2]Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92037
[3]NOAA Earth System Research Laboratory, Boulder, CO 80305
[4]Department of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Cambridge, MA 02139

Perfluorocarbons (PFC-14: CF_4, PFC-116: C_2F_6) are powerful greenhouse gases released during the production of aluminium and from the electronic industry. PFCs remain in the atmosphere for 1000s of years and are targeted for controls in global and Australian strategies to reduce greenhouse gas emissions. In Australia, PFCs account for about 20% of the greenhouse gases released at the smelter during the production of aluminium, the remaining 80% being carbon dioxide from the production (15%) and consumption (65%) of carbon anodes during the electrolysis of alumina ($2Al_2O_3 + 3C \rightarrow 6Al + 3CO_2$) (Keniry, 2007). Global production of primary aluminium is growing at 8% per year, driven by the huge demand in China (Figure 1), currently growing at about 20-35% per year. Australian aluminium production (6% of global) is growing at 2% per year (IAI, 2008). AGAGE global atmospheric observations of PFCs can be used to calculate time-dependent global PFC emissions, which, when coupled with information on global aluminium production and the emission of PFCs from the electronics industry, lead to time-dependent, globally-averaged PFC emission factors for aluminium production (Mühle et al., 2008). Atmospheric PFC observations made at Cape Grim, Tasmania (*in situ*, air archive, 1978-2008), and at Aspendale, Victoria (2006-2008) and on Antarctic air tapped in ice and firn (1840-2000), using a Medusa GC-MS system (Miller et al., 2008), are used to deduce time-dependent Australian PFC emissions and emission factors (Fraser et al., 2007). The global and Australian aluminium industries have set a target of reducing PFC emission factors (PFC released per tonne of aluminium produced) by 80% from 1990 levels by 2010.

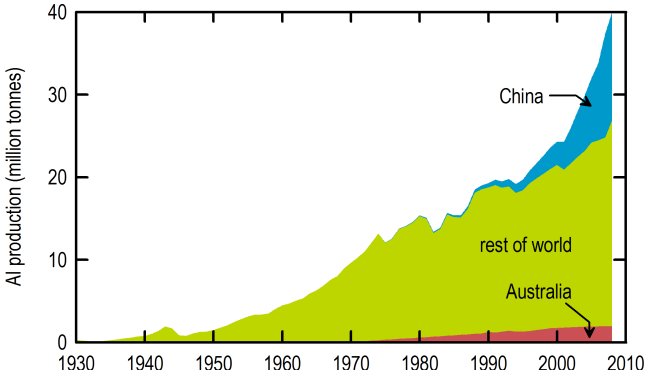

Figure 1. Global aluminium production (IAI, 2008).

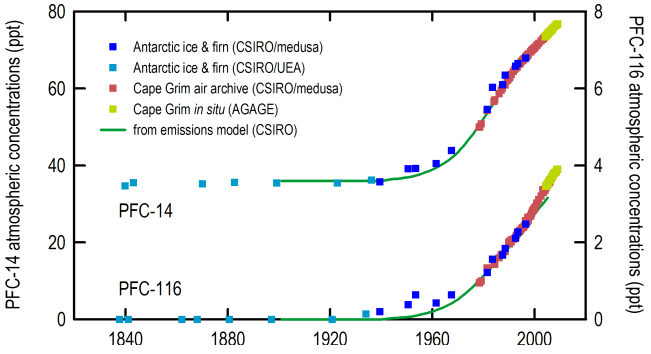

Figure 2. PFCs in the Southern Hemisphere from AGAGE measurements at Cape Grim, on the Cape Grim air archive and on air samples from Antarctic firn and ice (Fraser et al., 2007). CF_4 data are in the SIO 2005 scale, C_2F_6 data in the preliminary SIO 2007 scale.

Towards an Understanding of Inter-Annual Variations in Tropospheric OH Since 1998 from Observations of Reduced Trace Gases

S. Montzka[1], E. Dlugokencky[1], M. Krol[2], J. Lelieveld[3] and P. Jockel[3]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6657, E-mail: steve.montzka@noaa.gov
[2]Institute for Marine and Atmospheric Research, Utrech University, Utrecht, Netherlands
[3]Max Planck Institute for Chemistry, Mainz, Germany

Can the oxidizing capacity of the atmosphere, as controlled by the hydroxyl radical (OH), change by 10 to 20% from year to year? Or is the global OH abundance buffered against large interannual variations in emissions by biomass burning, industrial pollution, solar radiation, water vapor, and other OH sources and sinks? Past work suggests a wide range of potential sensitivities and, therefore, accurate projections of future atmospheric changes are problematic. Studies of methyl chloroform observations made in the 1980s and 1990s suggest OH could be highly sensitive to interannual variations in the atmospheric environment. Such variations are difficult to reconcile with the rather low variability observed for atmospheric methane. Furthermore, model studies suggest a much lower sensitivity for OH to such changes in precursors and sinks because of balancing effects by chemical and transport processes.

We have argued recently that methyl chloroform (CH_3CCl_3) observations since 1998 should provide a more precise estimate of OH interannual variability because errors associated with large atmospheric gradients and emissions have become small. Our analysis shows, for example, that OH variations inferred from CH_3CCl_3 since 1998 are much smaller than during earlier decades. But has the precision of the analysis improved to the point that OH variability over the past decade can be accurately discerned? Do results from different trace gases provide a consistent picture regarding the magnitude and phase of OH variations? What do model calculations suggest? How consistent are inferences regarding OH variability when one considers results for CH_3CCl_3 from different laboratories, different emissions histories, or model analyses of varying sophistication, especially given that atmospheric mixing ratios of CH_3CCl_3 are now quite small (10 ppt)? This presentation will focus on addressing these questions and improving our understanding of the stability of the atmosphere's oxidation capacity.

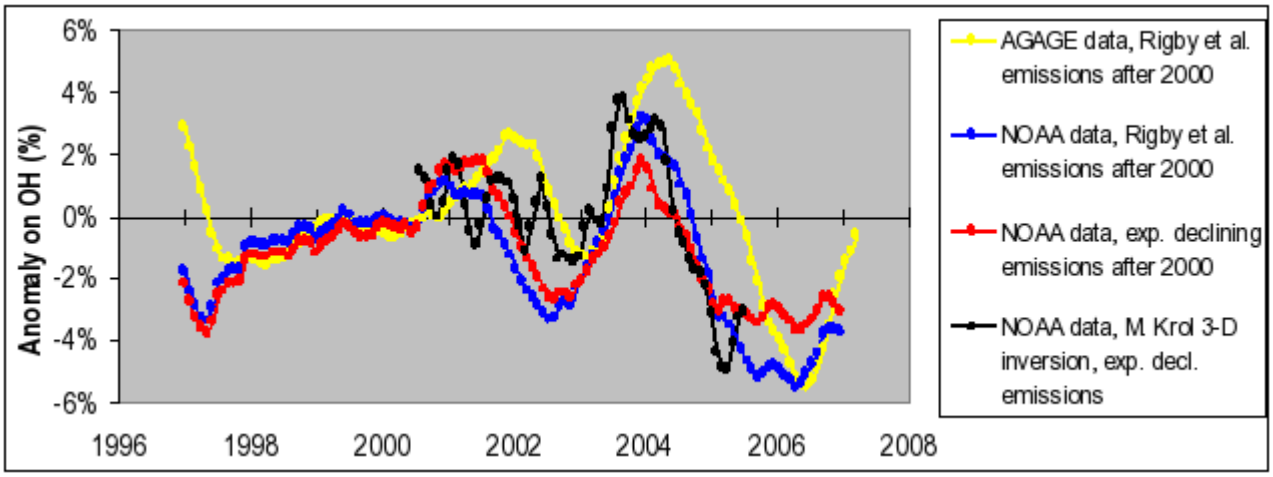

Figure 1. Estimates of anomalies on OH derived from independent global surface measurements of CH_3CCl_3 (yellow line: AGAGE from Prinn et al., 2005; and blue line: NOAA); two different emission histories for CH_3CCl_3 since 2000: exponentially declining at 20%/yr or from Rigby et al. (2008) (yellow and blue lines); and two different modeling approaches: a simple 1-box analysis (Montzka et al., 2000) and a 3-D inversion with inter-annually varying meteorology (Krol et al. 2003) (black line).

Regional Estimates of CH_4 and N_2O Emissions from Central California

M.L. Fisher[1], C. Zhao[1], A.E. Andrews[2], L. Bianco[2], E. Dlugokencky[2], J. Kofler[3], J. Eluszkiewicz[4], C. MacDonald[5] and T. Nehrkorn[4]

[1]Lawrence Berkeley National Laboratory, MS 90K-125 1 Cyclotron Rd., Berkeley, CA 94720; 510-486-5539, E-mail: mlfischer@lbl.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[4]Atmospheric and Environmental Research, Inc., Lexington, MA 02421
[5]Sonoma Technology, Inc., Petaluma, CA 94954

Methane and nitrous oxide mixing ratios measured at a tall-tower are compared to model predictions to estimate surface emissions of CH_4 and N_2O from Central California for the October, 2007 to September, 2008. Predicted mixing ratios are calculated based on spatially resolved a priori CH_4 and N_2O emissions and simulated atmospheric trajectories. The atmospheric trajectories, along with surface footprints, are computed using the Weather Research and Forecast (WRF) coupled to the Stochastic Time-Inverted Lagrangian Transport (STILT) model. An uncertainty analysis is performed to provide quantitative uncertainties in estimated emissions. Linear regressions of modeled and measured mixing ratios obtain slopes near unity for CH_4 but some what less than unity for N_2O, suggesting that actual CH_4 emissions were within 25% of the inventory estimates but N_2O emissions were underestimated. A Bayesian source sector analysis obtains CH_4 posterior scaling factors for different sources, suggesting that several of the sources (e.g., landfills, natural gas use, petroleum production, crops, and wetlands) are roughly consistent with inventory estimates but livestock emissions are ~80% higher than the inventory estimates. A Bayesian "region" analysis is also carried out for CH_4 and N_2O emissions using 13 sub-regions within California. Only regions near the tower are significantly constrained by the tower measurements, but CH_4 emissions from the south Central Valley appear to be underestimated in a manner consistent with the under-prediction of livestock emissions. A pseudo-experiment using predicted CH_4 signals is also performed to explore the uncertainty reductions that might be obtained if additional tower measurements were made in a network of tall-tower stations in California, showing that it should be possible to provide high-accuracy retrievals of surface CH_4 emissions for multiple regions.

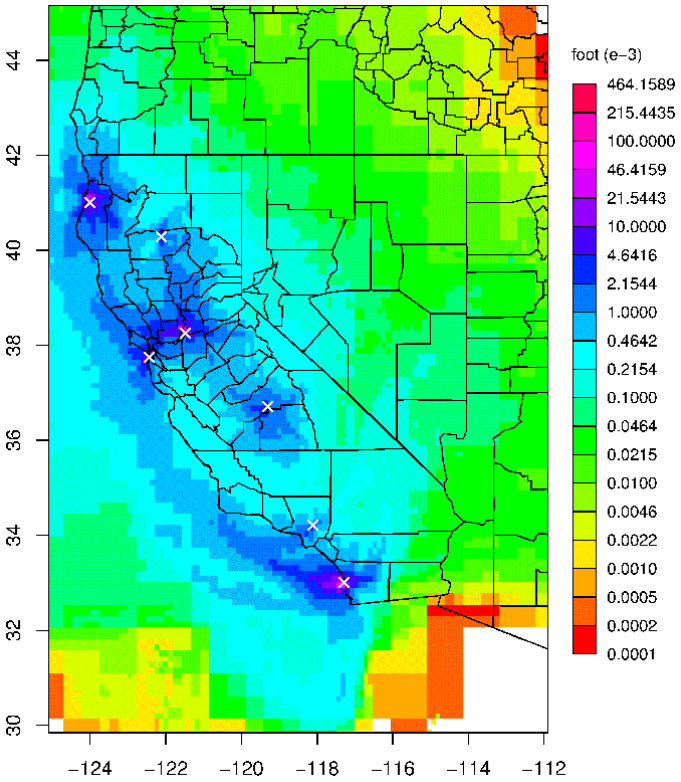

Figure 1. The monthly mean footprint maps for seven tower stations (each marked with an x) simulated for Oct, 2007.

Tetrafluoromethane in the Global Atmosphere

J. Mühle[1], B.R. Miller[1,6], P.K. Salameh[1], C.M. Harth[1], B.R. Greally[2], S. O'Doherty[2], A. Ganesan[3], C.M. Trudinger[4], L.W. Porter[5], L.P. Steele[4], P.B. Krummel[4], V.V. Petrenko[1,7], M. Rigby[3], P.G. Simmonds[2], P.J. Fraser[4], R.G. Prinn[3] and R.F. Weiss[1]

[1]Scripps Institution of Oceanography, 9500 Gilman Dr. 0244, La Jolla, CA 92093; 858-534-2599, E-mail: jens@gaslab.ucsd.edu
[2]School of Chemistry, University of Bristol, Bristol BS8 1TS, United Kingdom
[3]Department of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Cambridge, MA 02139
[4]Commonwealth Scientific & Industrial Research Organization, Marine and Atmospheric Research, Aspendale, VIC 3195, Australia
[5]Centre for Australian Weather and Climate Research, Bureau of Meteorology, Melbourne, Victoria 3001, Australia
[6]NOAA Earth System Research Laboratory, Boulder, CO 80303
[7]Insitute for Arctic and Alpine Research, University of Colorado, Boulder, CO 80309

Tetrafluoromethane (CF_4) has been measured with high precision (<0.3%) and accuracy (~1%) *in situ* and in archived air samples from both hemispheres using the Medusa GC/MS developed for the Advanced Global Atmospheric Gases Experiment (AGAGE) program. CF_4 has increased from ~50 to ~77 ppt from 1978 to 2008 in the Southern Hemisphere and from ~46 to ~78 ppt from 1973 to 2008 in the Northern Hemisphere (Figure 1). Based on the SIO-2005 calibration scale, developed at the Scripps Institution of Oceanography, the abundance of this potent and long-lived greenhouse gas is ~7% lower than previously reported, but CF_4 is still by far the most abundant perfluorinated trace gas. Pre-industrial abundances of CF_4 were determined in air extracted from Greenland ice (12–19 kyr BP) and Antarctic firn.

It is known that CF_4 is released mainly from primary aluminum production and from semiconductor and flat panel display production. Its large pre-industrial abundance has been explained by emissions from fluorites and granites in the continental lithosphere. With the AGAGE 2-D 12-box model we determined that global anthropogenic CF_4 emissions peaked at ~19 Gg/yr in the early to mid-1980s (Figure 2) – along with strong increases in primary aluminum production. Emissions declined to ~12 Gg/yr in the mid-1990s, probably due to reduced emissions from the aluminum industry, and have been flat at ~11 Gg/yr since ~1990, reflecting a balance of improved technology versus increased production in the aluminum industry, and emissions from the electronics industry. Global emissions prior to ~1995 are clearly underestimated in the EDGAR inventory.

It is difficult to quantify the contributions of these different sources, particularly due to ill-defined emission factors and substantially increasing but poorly known aluminum production in Asia. High-frequency *in situ* CF_4 data from the new AGAGE-affiliated station in Korea (Gosan, Jeju Island, Seoul National University) will enable us to better quantify regional Asian emissions, and thus help to resolve the contributions to the global CF_4 flux from these important sources.

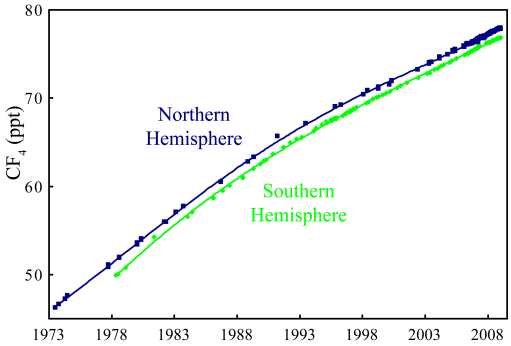

Figure 1. CF_4 (ppt) in the Northern and Southern Hemisphere from archive and *in-situ* measurements.

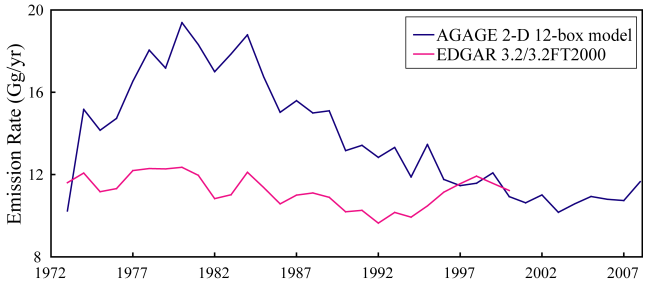

Figure 2. Global CF_4 emissions (Gg/yr).

Observations of Non-CO_2 Greenhouse Gases Over North America from the NOAA ESRL Carbon Cycle Group Aircraft Project

C. Sweeney[1], A. Karion[1], L. Bruhwiler[2], T. Conway[2], E. Dlugokencky[2], D. Guenther[1], K. Masarie[2], B. Miller[1], S.A. Montzka[2], P. Lang[2], D. Neff[1], P. Novelli[2], P. Tans[2] and S. Wolter[1]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-4771, E-mail: colm.sweeney@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

The NOAA ESRL Carbon Cycle Group Aircraft Project has been making measurements of CO_2, CH_4 CO, N_2O and SF_6 for more than 4 years at 16 sites around North America. A compilation of vertical profiles from 500 m above ground level to 8000 m of these gases relative to trends observed at Mauna Loa Observatory gives a unique look at potential sources and sinks of each gas as well as the large scale circulation that drives longitudinal and latitudinal gradients observed for each gas. In this study we will focus on the vertical and horizontal distribution of CH_4, CO, N_2O and SF_6 over North America to understand the transport of non-CO_2 greenhouse gases out of mid-latitude boundary layer to high latitude regions.

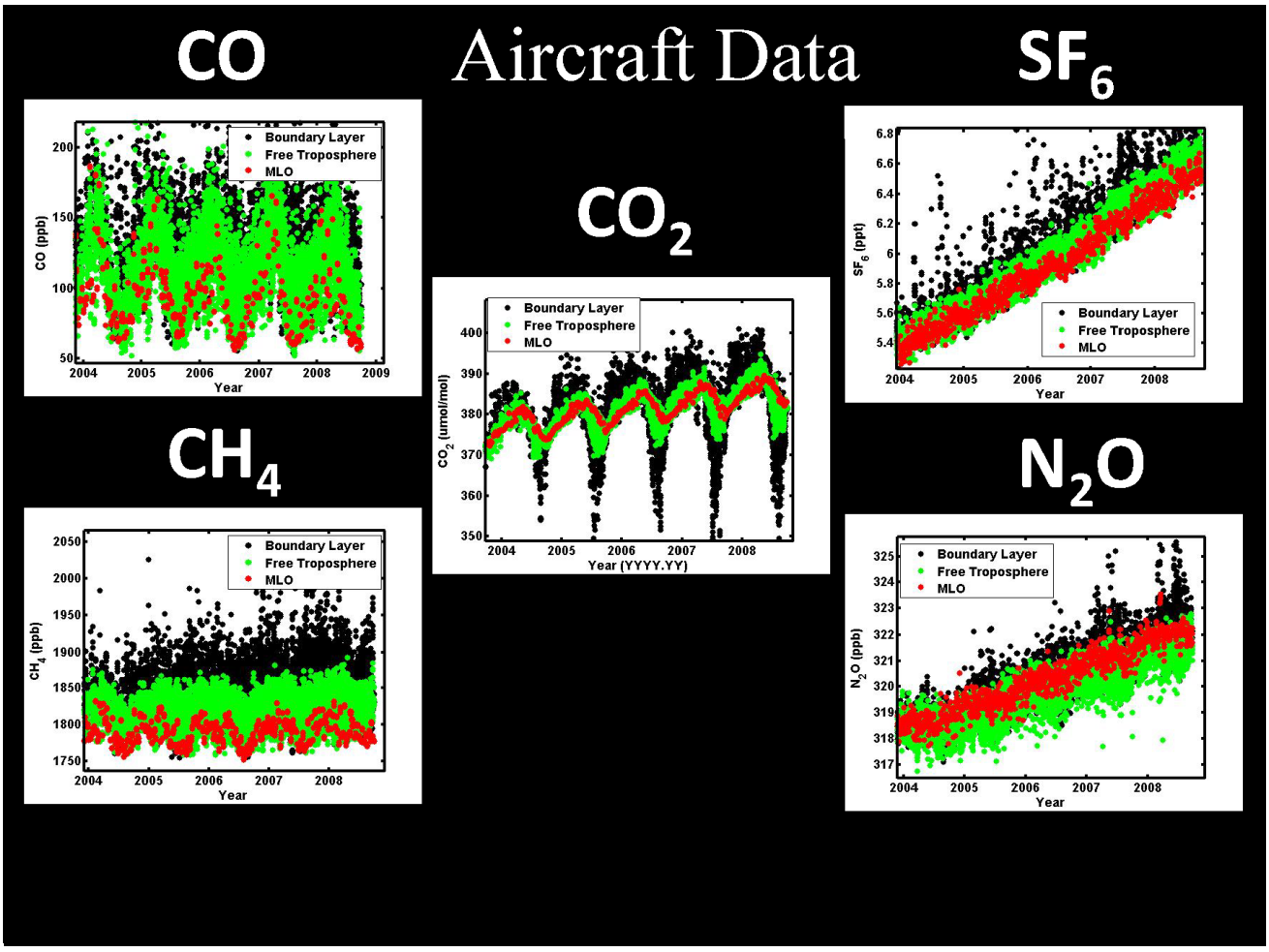

Figure 1. CO_2, CH_4, CO, N_2O and SF_6 measurements made over North America by the NOAA ESRL Carbon Cycle Group Aircraft Project in the last 10 years. Red shows measurements made at Mauna Loa Observatory (MLO), green dots shows free troposphere measurements and black dots show measurements below 1500 magl.

In Memory of Derek Cunnold

10 July 1940 – 18 April 2009

Derek Cunnold died suddenly and unexpectedly in Dunwoody, Georgia on Saturday, 18 April 2009. He was an internationally recognized and respected expert regarding the science of Earth's protective ozone layer, the use of satellite measurements and computer models to study this complex layer, and the interpretation of global atmospheric measurements to determine the sources and sinks of ozone-depleting and greenhouse gases. He also collaborated extensively with many scientists at NOAA, and whose loss will be felt deeply by them on a personal and professional level. He co-founded the international Advanced Global Atmospheric Gases Experiment (AGAGE) that has observed trace gases continuously over the globe for the past 31 years. He received the NASA Medal for Outstanding Achievement in 1992, was a Lead Author for the United National Environment Programme/World Meteorological Organization (UNEP/WMO) 2006 Scientific Assessment of Ozone Depletion, and was a member of nine NASA international satellite experiment teams. He joined the faculty at Georgia Tech in 1979, became a Full Professor in 1997, and was Chair of the School of Earth and Atmospheric Sciences from 1997 to 1999, and was conferred Professor Emeritus in 2006. He was an outstanding mentor for students and young scientists at both Georgia Tech and other institutions, including NOAA. Many have described him as "a gentleman and a scholar." He is survived by his wife Susan, daughters Carolyn and Alison and son David, their spouses, three grandchildren, a brother and a sister, and their spouses.

His long-term collaborator, Professor Ron Prinn at MIT, comments that "Derek's intelligence, insight, scientific achievements, unselfish service, and quiet, wise, and effective leadership will be deeply missed, but never forgotten, by me and his many scientific colleagues and admirers around the world."

Oral tributes will be presented.

Space-Based Measurements for Long-Term Global Monitoring of Atmospheric CO_2

D. Crisp

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; 818-687-9939, E-mail: David.Crisp@jpl.nasa.gov

Measurements of reflected sunlight in near infrared CO_2 and O_2 absorption bands with instruments such as the recently launched Japanese IBUKI TANSO-Fourier Transform Spectrometer (FTS) provide new opportunities for long-term, global, space-based monitoring of CO_2 and other greenhouse gases. These measurements must be thoroughly validated to demonstrate their accuracy and range of validity. Prior to the failure of the NASA Orbiting Carbon Observatory (OCO) launch, the OCO team developed a comprehensive validation strategy, designed to relate these space based measurements to the World Meteorological Organization (WMO) CO_2 standard that is maintained by NOAA ESRL Global Monitoring Division. A critical element of this strategy was the Total Carbon Column Observing Network (TCCON), which uses high resolution FTS's to measure the absorption of direct sunlight by CO_2 and O_2, in the same spectral regions used by the TANSO-FTS (Figure 1). Over-flights of TCCON stations by aircraft carrying *in situ* instruments calibrated with WMO referenced gases have been used to validate the TCCON results. CO_2 profiles extending from the boundary layer to the middle troposphere are integrated to derive a value of XCO_2. Simultaneous TCCON FTS and TANSO-FTS measurements are then compared to transfer the WMO standard to the spacecraft measurements. To further validate these space-based measurements, they can be assimilated into global carbon source/sink inversion models to derive near-surface CO_2 fields that can be validated against measurements from the Cooperative Air Sampling Network. We now plan to use these methods to assist in the validation of IBUKI results.

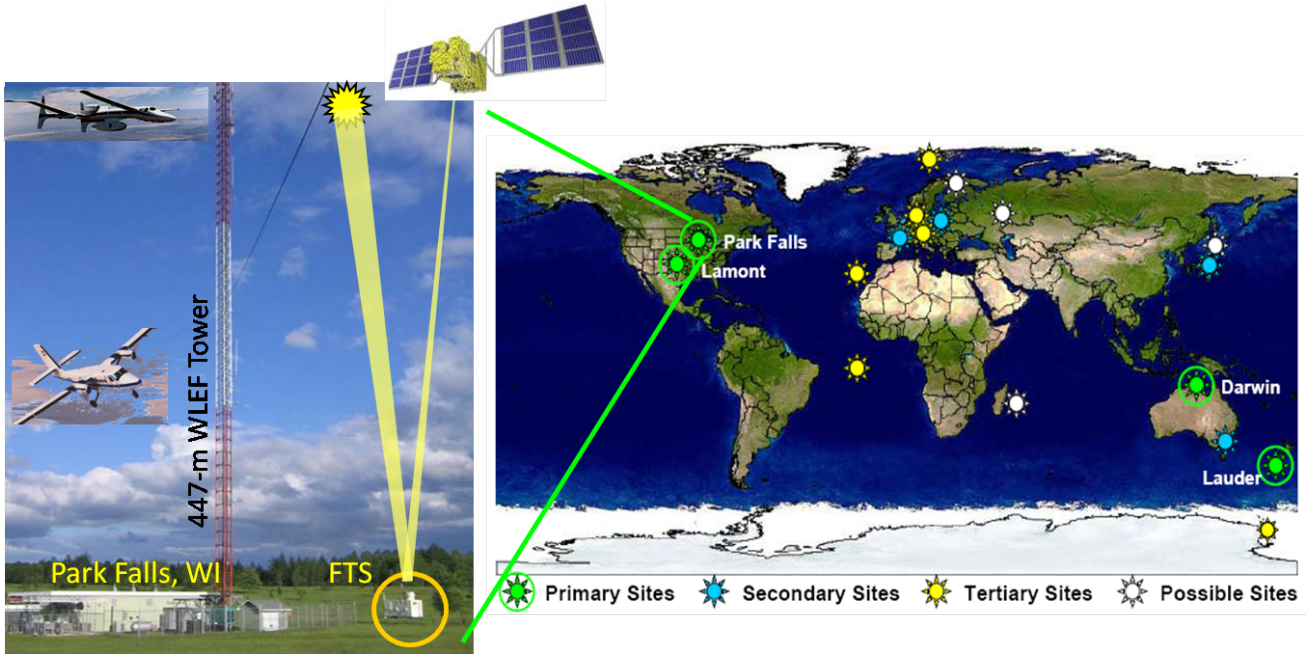

Figure 1. (Left) TCCON station at Park Falls, WI shown adjacent to the WLEF Tower. (Right) Map of TCCON stations.

CO_2 Vertical Profiles from Simultaneous Retrievals of Near Infrared and Thermal Infrared Satellite Data

C. Miller[1], S. Kulawik[1], K. Bowman[1], L. Kuai[2], V. Natraj[2], R. Shia[2] and Y. Yung[2]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, ; 818-393-6294, E-mail: charles.e.miller@jpl.nasa.gov
[2]California Institute of Technology, Pasadena, CA 91125

We are developing atmospheric CO_2 vertical profile data products from simultaneous retrievals of near infrared and thermal infrared satellite observations (Figure 1). These data will significantly improve the estimation of atmospheric carbon sources and sinks by providing powerful observational constraints on vertical as well as horizontal and temporal distributions of atmospheric CO_2 in data assimilation and data fusion approaches. Accurate vertical transport is essential within the source/sink inversion to avoid systematic flux errors of up to 2 GtC/yr since convection over land is strongly correlated in time with photosynthesis, the dominant surface sink for CO_2.

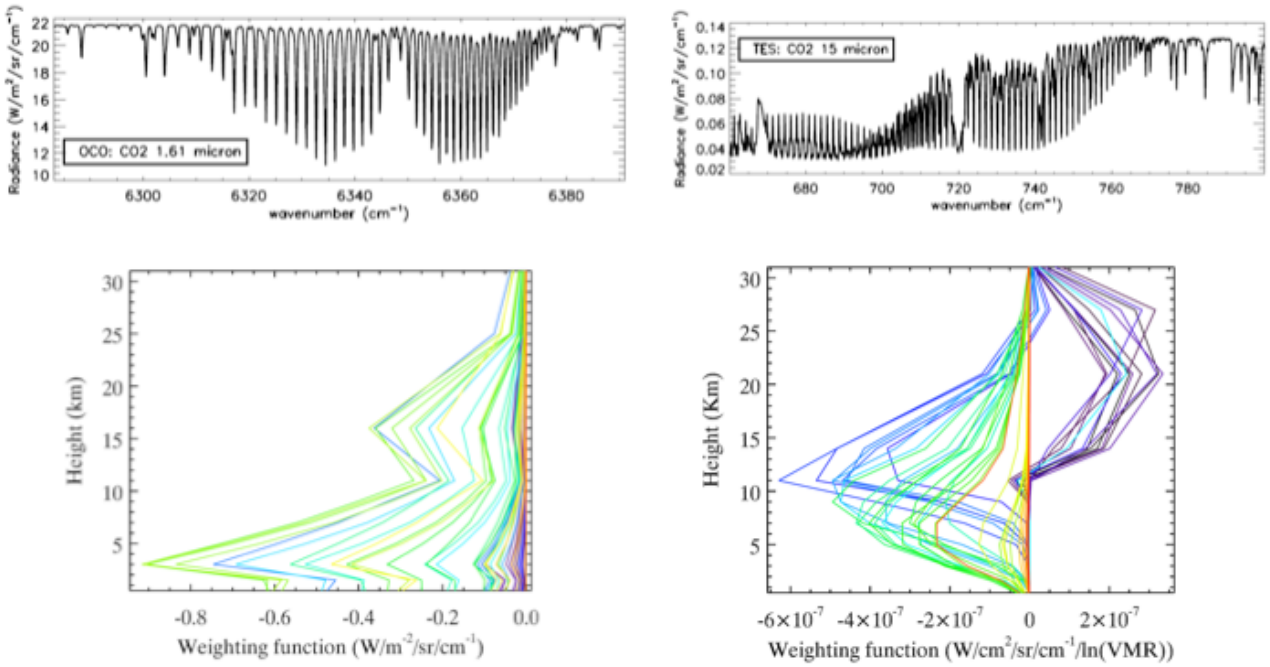

Figure 1. Spectra (top) and averaging kernels (bottom) for simulated space-based near infrared and infrared atmospheric CO_2 observations. Simulations are based on NASA's Orbiting Carbon Observatory (OCO, left) and Thermal Emission Spectrometer (TES, right) instruments. The complementarity of the vertical components in the two averaging kernels provides multiple degrees of freedom for signal in the CO_2 vertical profile solution. Similar results are possible using (nearly) simultaneous thermal emission observations from the Atmospheric Infrared Sounder (AIRS), or from collocated near infrared and thermal infrared observations of JAXA's GOSAT (IBUKI) sensors.

Global Distribution of CO_2 in Mid Troposphere from the Atmospheric Infrared Sounder (AIRS) Measurements Suggests Greater Cross Equator Exchange

Y.L. Yung[1], R.L. Shia[1], X. Jiang[2], M.C. Liang[3], K.F. Li[4], L. Kuai[4], M. Chahine[5], E.T. Olsen[5] and L. Chen[5]

[1]Division of Geological and Planetary Sciences, California Institute of Technology, 150-21 Caltech, Pasadena, CA 91125; 626-395-6940, E-mail: yly@gps.caltech.edu
[2]Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX 77204
[3]Research Center for Environmental Changes, Academia Sinica, Nankang, Taipei 115, Taiwan
[4]Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125
[5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109

The Atmospheric Infrared Sounder (AIRS) enables us to monitor the global distribution and transport of middle tropospheric CO_2 over oceans, land and the poles (Chahine et al., 2008). Mid tropospheric CO_2 retrieved by AIRS shows a substantial spatiotemporal variability that is supported by aircraft flash sampling measurements (Matsueda et al., 2002; Machida et al. 2008). These data can be used to constrain the cross equator exchange of CO_2. The uncertainties in the cross equator exchange of CO_2 affect the reliability of the estimations of the CO_2 sources and sinks in both hemispheres (Tans et al., 1990 and Fan et al., 1998). We use the Caltech/JPL 2-D chemistry and transport model (Shia et al., 2006) to simulate the mid troposphere CO_2. The model is used to calculate the cross equator transport of CO_2. Preliminary results indicate more inter-hemispheric transport than that implied by the ground-based data. Implications for CO_2 abundance and distribution in the southern hemisphere are discussed.

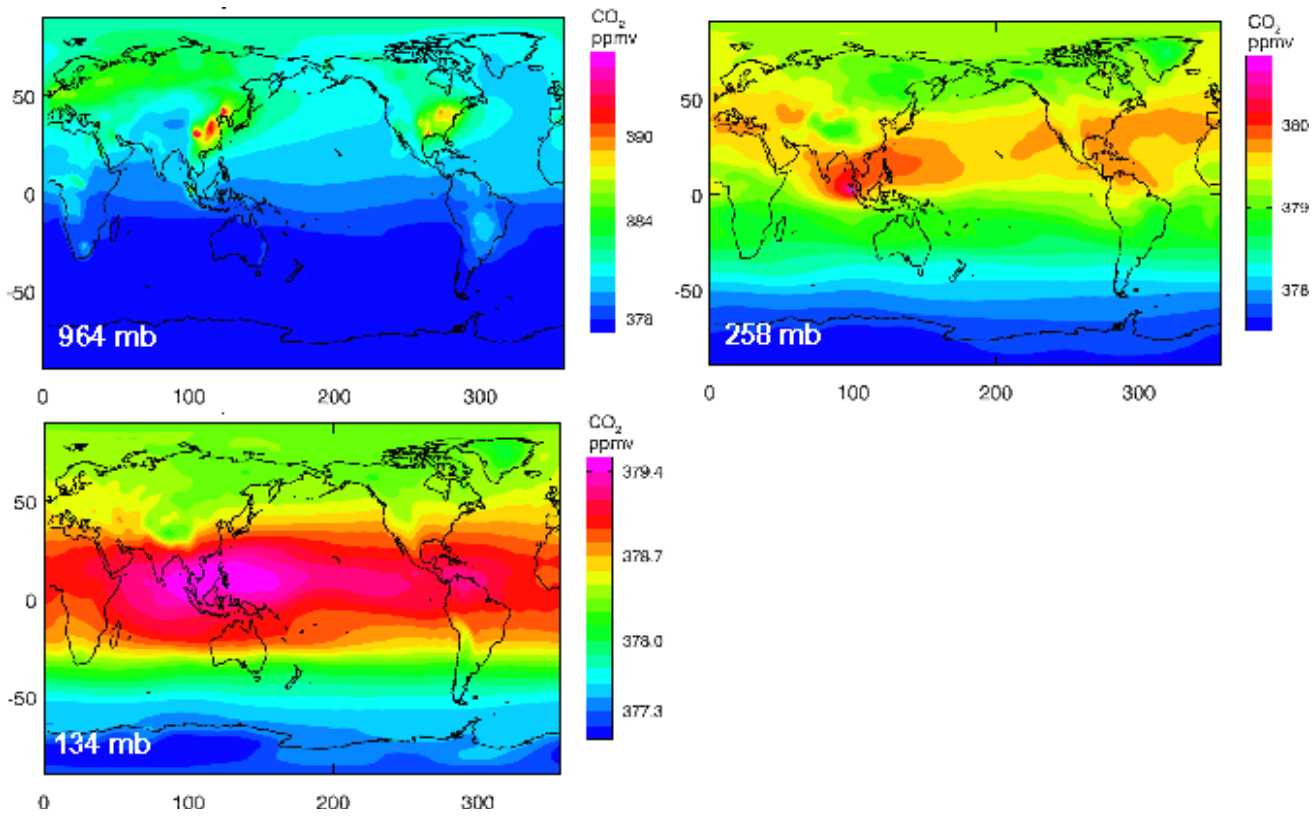

Figure 1. CO_2 distribution simulated from MOZART. Three levels (964mb, 258mb and 134mb) are shown.

Validation of Six Years of Mid-Tropospheric CO_2 Data from the Atmospheric Infrared Sounder AIRS

E. Olsen[1], M.T. Chahine[1], L.L. Chen[1], X. Jiang[2], T.S. Pagano[1] and Y.L. Yung[3]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; 818-354-4443, E-mail: edward.t.olsen@jpl.nasa.gov
[2]University of Houston, Houston, TX 77204
[3]California Institute of Technology, Pasadena, CA 91125

The retrieved distributions of mid-tropospheric CO_2 from the Atmospheric Infrared Sounder using the Vanishing Partial Derivative algorithm are compared to *in situ* measurements by commercial and research aircraft and to retrievals by land-based upward-looking Fourier Transform Interferometers. Estimates of AIRS CO_2 accuracy depend on the type and proximity of the measurements to the satellite footprint but remain between 1-2 ppm, under clear and cloudy conditions and over both land and oceans, between latitudes 30°S and 80°N. The seasonal phases are captured and the latitude variability in amplitude is validated. Also, the rate of growth of CO_2 over the six-year period is computed between 60°N-60°S latitudes as 2.02±0.08 ppm/year.

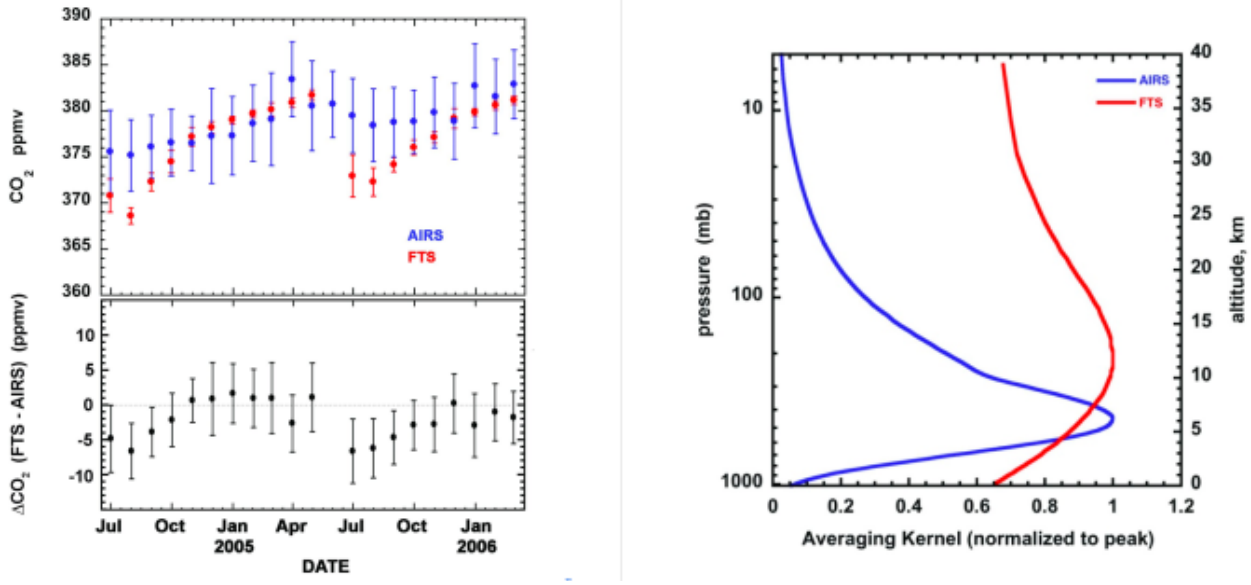

Figure 1. Seasonal variation of monthly average AIRS retrieved CO_2 within 250 km of Park Falls, Wisconsin compared to monthly average Park Falls Fourier Transform Spectrometer measured total column CO_2 and their differences.

High Resolution CO_2 Transport Modeling System WRF-VRPM and Its Application in Interpretation of CO_2 Measurements

R. Ahmadov[1], C. Gerbig[1], R. Kretschmer[1], D. Pillai[1], C. Rödenbeck[1], T. Koch[1] and G. Pétron[2]

[1]Max-Planck-Institute for Biogeochemistry, P.O.Box 100164, Jena 07701, Germany; +49-3641-576361, E-mail: rahmadov@bgc-jena.mpg.de
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

The global scale coarse resolution atmospheric models that are used in the inversions of CO_2 have difficulties to properly resolve complex mesoscale circulations around continental measurement sites. Moreover vertical mixing and boundary layer dynamics over the continent remain a big challenge for all transport models. In order to better understand the impact of mesoscale transport effects and vertical mixing on atmospheric CO_2 distributions, we have used the Weather Research and Forecasting (WRF) model coupled to the diagnostic biosphere model Vegetation Photosynthesis and Respiration Model (VPRM), which provides high-resolution biospheric CO_2 fluxes based on MODIS satellite vegetation indices. We have run WRF-VPRM for different seasons in 2005 and 2007, covering the intensive measurement periods of the Carbo Europe Regional Experiment Strategy (CERES) campaign held in the South West of France.

Here we present the model validation for CO_2 and a wide range of meteorological fields obtained on surface and aircraft platforms during the campaign. In addition we have compared the modeled CO_2 concentration time series against observations at two towers operated during the campaign - Biscarosse (40 m high) and Bellegarde (56 m high) located in the vicinity of the coastline and inland respectively. The comparison against meteorological data reveals the ability of WRF to capture the small mesoscale flows which have also a strong impact on CO_2 measurements at the towers. This work shows how the near-field of these towers play an important role in the formation of the measured concentration signals. We also have investigated the vertical mixing of CO_2 by using different planetary boundary layer (PBL) parameterization schemes available in WRF. The results reveal that using more advanced PBL schemes within the high-resolution modeling framework enables us to better characterize the vertical distribution of CO_2, especially in stable boundary layer during nighttime. Thus only with high resolution modeling tools such as WRF-VPRM can a large fraction of the CO_2 continuous data be properly used in inversion studies at the global and regional scales.

Finally we discuss the perspectives of WRF-VPRM applications for several North American CO_2 monitoring sites and measurement intensives operated by NOAA ESRL.

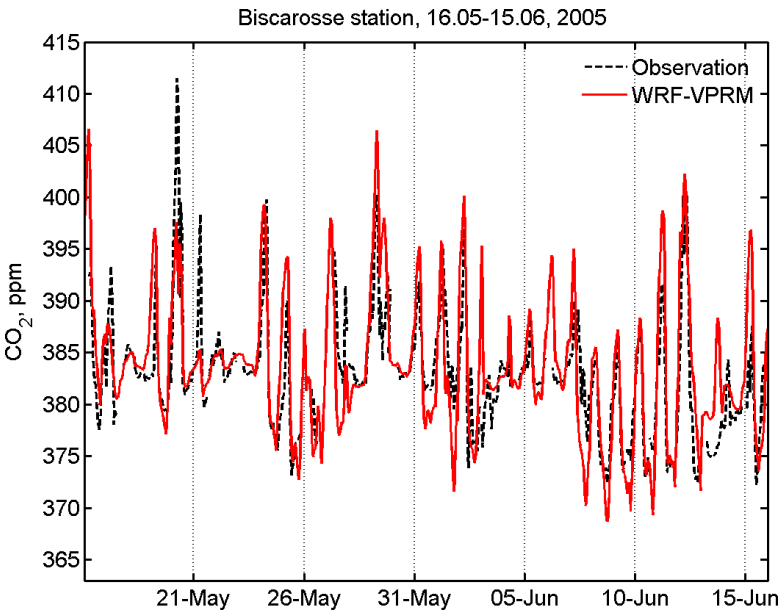

Figure 1. Comparison of hourly CO_2 concentration time series from the Biscarosse tower and the WRF-VPRM model.

When Is the Permafrost Carbon Tipping Point?

K. Schaefer[1], T. Zhang[1] and L. Bruhwiler[2]

[1]National Snow and Ice Data Center, University of Colorado, Boulder, CO 80309; 303-492-8869, E-mail: kevin.schaefer@nsidc.org
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

Permafrost in the Arctic contains as much as 950 Gt of organic matter, frozen since the last ice age 20,000-30,000 years ago. As permafrost thaws in the 21st century, this organic matter will decay, increasing atmospheric carbon dioxide and amplifying the climate warming rate, creating a positive permafrost carbon feedback on climate. The permafrost carbon tipping point occurs when respiration due to the decay of thawed permafrost organic matter overpowers enhanced plant uptake due to longer growing seasons, changing the Arctic from a carbon sink to a source. The permafrost carbon tipping point represents an abrupt change in high latitude carbon balance and signals the start of the permafrost carbon feedback. None of the combined carbon-climate models used in the Fourth IPCC Assessment account for the permafrost carbon feedback in their projections of 21st century climate. We add permafrost carbon dynamics to the Simple Biosphere/Carnegie-Ames-Stanford Approach (SiBCASA) model and use the ERA40 reanalysis as input weather. To represent future climate change, we scale the ERA40 air temperature assuming a linear, 4 °C century^{-1} temperature increase in the Arctic between 2000 and 2200. Point simulations indicate that even a modest increase in active layer depth could result in local tipping points by 2100. We expand this analysis to the entire Arctic region and estimate the timing of the permafrost carbon tipping point and the potential strength of the permafrost carbon feedback in terms of the amount of carbon released into the atmosphere by 2200.

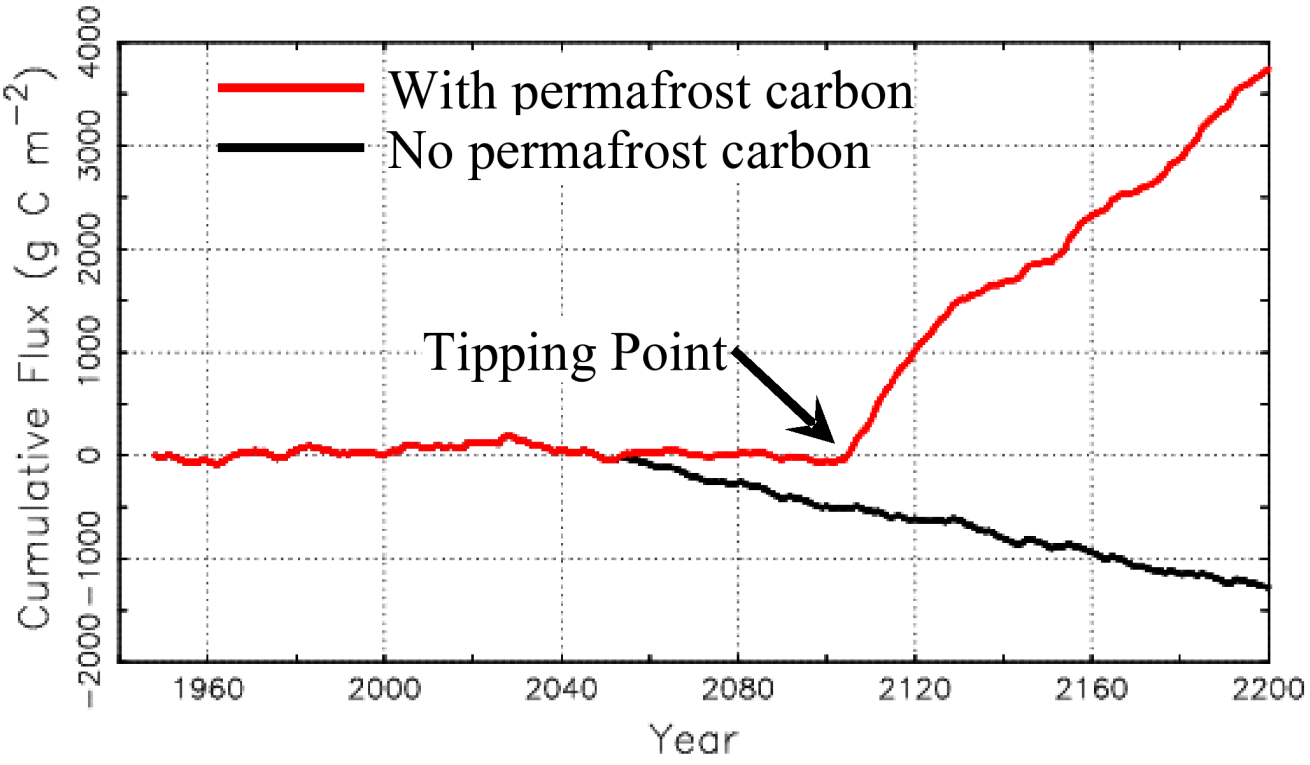

Figure 1. Cumulative simulated net carbon flux for a point in central Siberia (positive is net release to the atmosphere). The simulation without permafrost carbon (black) shows cumulative net uptake driven by longer growing seasons. The simulation with permafrost carbon shows a distinct tipping point in 2105 where respiration due to the decay of permafrost carbon overpowers the enhanced uptake due to longer growing seasons.

Measurements of Greenhouse Gases in the Russian Arctic

A.I. Reshetnikov, N.N. Paramonova, V.I. Privalov, A.V. Zinchenko and V.V. Ivachov

Main Geophysical Observatory, 7 Karbyshev Street, Saint Petersburg 194021, Russia; +8122978670, E-mail: alexR35@mail.ru

Carbon dioxide and methane are significant greenhouse gases and as such, large contributors to global warming. Russia covers about 17.8 million km^2 of land surface, much of it large expanses of boreal forests and tundra underlain by permafrost and large expanses of swamp land in West Siberia. In addition, extensive natural gas and oil deposits and extraction operations in the high Arctic have great potential to influence local and global atmospheric concentrations of carbon dioxde and methane. Below are presented the results of GHG measurements at the Russian Arctic stations Teriberka (69° 12' N, 35° 06' E) and New Port (67° 42' N, 72° 51' E) during 2003-2008, and data from the "Akademik Fedorov" ship route in the Arctic ocean during IPY cruises in 2007 - 2008. In Fig 1a are presented monthly CO_2 concentrations from the New Port and Teriberka Stations, and global MBL values from NOAA data. The large amplitude of the mixing ratio in the Russian station measurements most likely reflect the oil and gas burning in oil fields located about 1000 km to south. In Fig 1b are presented similar data for methane. The large amplitude of the methane mixing ratio are likely caused by both natural leaks and production in gas deposits located 80 – 250 km to the South. Data from GHG flasks sampled during the "Arademik Fedorov " transects up to the North Pole are represented in Fig 2a, and data from GHG flasks sampling during a transect from the Western Russian Arctic to Murmansk are presented in Fig 2b.

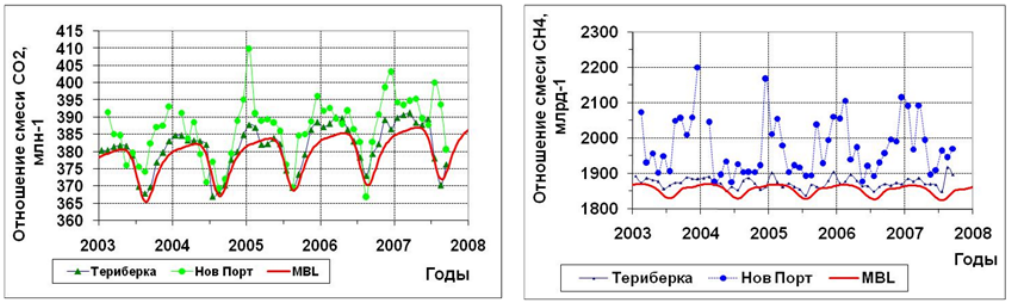

Figure 1. a) Monthly CO_2 mixing ratios at the New Port and Teriberka Stations and in the global MBL. The large amplitude of CO_2 mixing ration observed at New Port is likely caused by the oil and gas burning in fields located about 1000 km to the south, b) Monthly CH_4 concentrations at the same station are likely caused by CH_4 leakage from a large gas field.

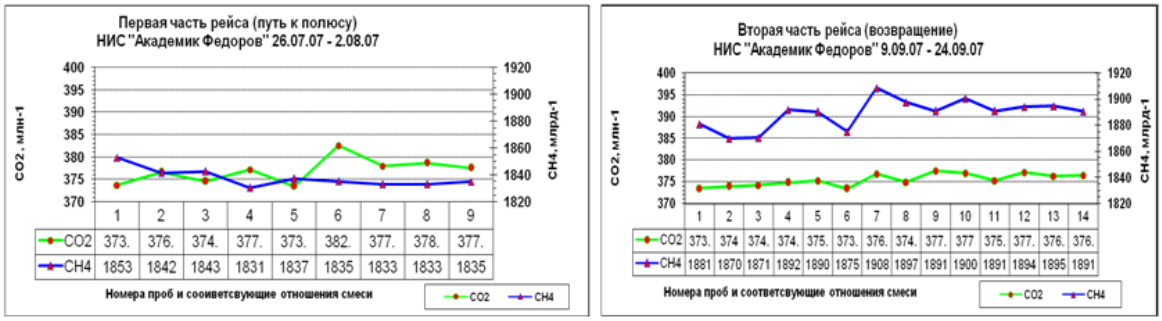

Figure 2. Data for flask sampling analysis at two parts of the "Arademik Fedorov" ship route: a) Arctic Coast to the North Pole, and b) In the Arctic ocean from 180 degrees west to Murmansk.

Development of the FIM (Flow-Following Finite Volume Icosahedral Model) Global Model Toward an Earth System Model Including Inline Treatment of Aerosols and Trace Gases

S.G. Benjamin[1], G.A. Grell[2], R. Bleck[2], J.L. Lee[1], J.W. Bao[1], T.G. Smirnova[2], J.M. Brown[1], T.B. Henderson[3], J.F. Middlecoff[3], C.W. Harrop[2], N. Wang[3], A.E. MacDonald[1] and A.R. Jacobson[2]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6387, E-mail: stan.benjamin@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]Cooperative Institute for Research in Atmospheres, Colorado State University, Ft Collins, CO 80521

Development of the FIM, ESRL's new global model, is now being extended beyond medium-range weather forecasts to include aerosols and trace gases. The FIM uniquely combines 3 key modeling design components (icosahedral horizontal grids, isentropic-hybrid vertical coordinate, finite volume numerics), all critical to provide improved transport over existing models (e.g. Global Forecast System – GFS). The isentropic-hybrid vertical coordinate is "flow-following" in that the vertical coordinate surfaces follow isentropic (constant potential temperature) surfaces through most of the atmosphere, from mid-troposphere upward to the model top (current testing at ~60 km). This design greatly reduces cross-coordinate transport and resulting artificial numerical dispersion over that in most other atmospheric models. Atmospheric forecasts from the FIM now generally match those from the NCEP GFS model, necessary for planned inclusion of FIM as part of NCEP's Global Ensemble Forecast System. The FIM-chem inline coupled model is now in development, starting with a simple aerosol model from the GOCART including a global emissions inventory. (demo FIM-chem 3-day forecast in figure below). ESRL scientists from all four divisions are planning toward extension of FIM-chem to add trace gases, and also working toward a possible ocean component, and new land-surface, cloud, and boundary-layer parameterizations. This gives FIM potential for becoming an Earth Systems Model research tool, as well as having a real-time prediction capability.

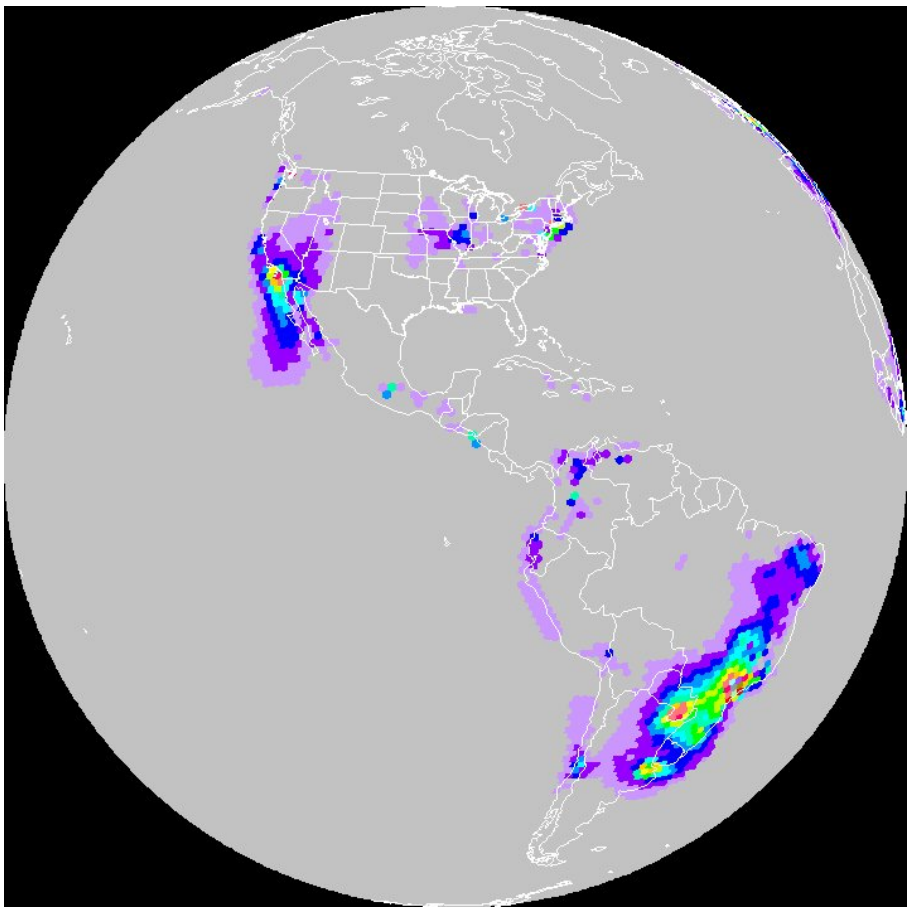

Figure 1. 3-day forecast of organic carbon aerosol at approximately 120 hPa above surface from preliminary FIM-chemistry global model developed in ESRL.

The Temporal and Spatial Distribution of Carbon Dioxide Emissions from Fossil-Fuel Use in North America

J.S. Gregg[1], L.M. Losey[2], R.J. Andres[3], T.J. Blasing[3] and G. Marland[3]

[1]Department of Geography, University of Maryland, College Park, MD 20742
[2]Department of Space Studies, University of North Dakota, Grand Forks, ND 58202
[3]Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Refinements in temporal and spatial resolution of North American fossil-fuel carbon dioxide (CO_2) emissions provide additional information about anthropogenic aspects of the carbon cycle. Seasonal and spatial patterns are distinctive components of anthropogenic carbon emissions. The pattern of fossil-fuel-based CO_2 emissions on a monthly scale has greater temporal and spatial variability than the flux aggregated to the national annual level. The U.S. comprises the majority of North American fossil carbon emissions and the amplitude of the seasonal flux in emissions in the U.S. is greater than the total mean monthly emissions in both Canada and Mexico. Nevertheless, Canada and Mexico have distinctive seasonal patterns. For the continent, the monthly pattern of emissions vary on a both north-south and east-west gradient, and evolve through time. For many areas in North America, the magnitude of the month-to-month variation is larger than the total annual emissions from land use change, making the characterization of emissions patterns essential to understanding humanity's influence on the carbon cycle.

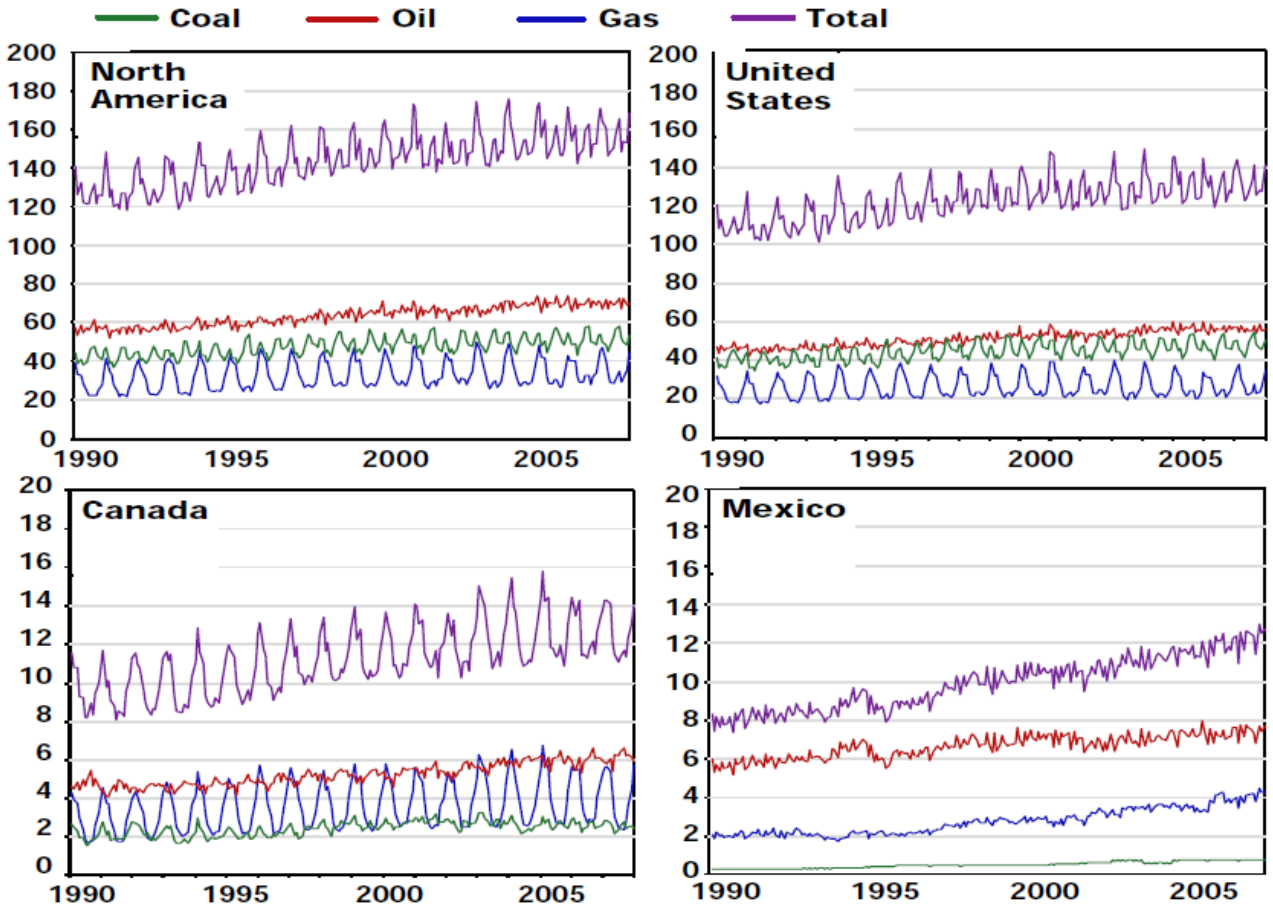

Figure 1. Monthly fossil fuel carbon emissions for North America, the U.S., Canada, and Mexico, by fuel type. Note that Canada and Mexico plots use a y-axis different from the one used for the North America and the U.S.

Vertical Profiles of CO_2, CH_4 and Other Trace Gases Above the Brazilian Amazon

J.B. Miller[1], L.V. Gatti[2], M.T.S. Felippe[2], P.P. Tans[3] and A. Crotwell[1]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-7739, E-mail: john.b.miller@noaa.gov
[2]Instituto de Pesquisas Energeticas e Nucleares (IPEN), Sao Paulo, Brazil
[3]NOAA Earth System Research Laboratory, Boulder, CO 80305

Since 2004, the NOAA ESRL Global Monitoring Division (GMD) has engaged in a very active collaboration with the IPEN Atmospheric Chemistry Laboratory focused on analyzing air samples collected above the Brazilian Amazon. The Amazon basin is both one of the most poorly sampled regions of the globe and at the same time one of the most critical to understand present day global greenhouse gas budgets and future climate feedbacks. In order to better study Amazonian greenhouse gas budgets, a copy of the GMD high precision, well-calibrated greenhouse gas analysis system (MAGICC) was built and installed at IPEN in April 2004. Between 2004 and 2008, more than 1500 samples have been collected above two sites in eastern and central Amazonia. These samples have been analyzed for CO_2, CH_4, CO, H_2, N_2O and SF_6 mole fractions. Our primary method of analysis has been to calculate the difference between the continental mole fractions and those measured in the tropical Atlantic by GMD at Ascension Island and Barbados. Using a simplified conception of atmospheric transport, we have calculated net surface fluxes between the coast and our sites. As can be seen in Figure 1, we see large enhancements of methane that translate to much larger fluxes than previously believed. In addition to the simplified flux calculations, we have also used regional and global inverse models to calculate surface fluxes. A flux calculation for CO_2 using the CarbonTracker inverse model is shown in Figure 2. The addition of the Amazonian observations substantially changes both the shape of the seasonal cycle and the annual net carbon flux, relative to the standard CarbonTracker results. The collaboration between NOAA and IPEN has proved very fruitful and has provided a unique dataset with which to analyze Amazonian greenhouse gas budgets.

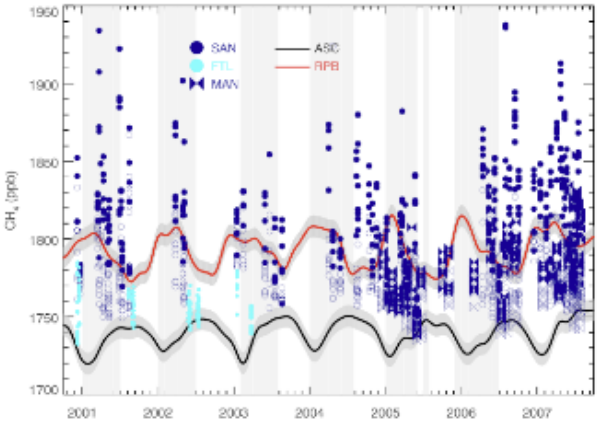

Figure 1. CH_4 above Amazonian sites (blue symbols) compared to Atlantic background sites (black and red lines, with gray uncertainty bands). Vertical gray bars indicate wet season months near Santarem (SAN). Filled and empty symbols are those below and above 1500m, respectively.

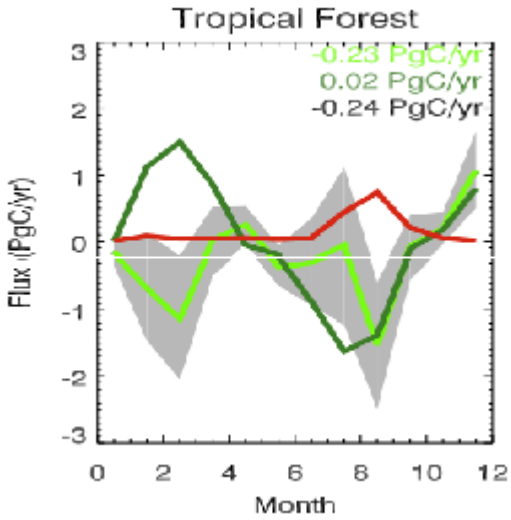

Figure 2. Net CO_2 flux in CarbonTracker's South America Tropical Forest region, before (dark green) and after (light green) including data from SAN (for 2007). The red curve is the unoptimized biomass burning flux, and the gray error band represents statistical uncertainty of the flux result.

Is Atmospheric Methane on the Rise Again?

E. Dlugokencky[1], P. Lang[1], K. Masarie[1], A. Crotwell[2], L. Bruhwiler[1], L. Emmons[3], S. Montzka[1] and J. White[4]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6228, E-mail: ed.dlugokencky@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]National Center for Atmospheric Research, Boulder, CO 80307
[4]Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309

Methane (CH_4) is the most important greenhouse gas influenced by human activities after CO_2. Its chemistry results in additional indirect climate effects from production of tropospheric O_3, which also affects air quality, and stratospheric H_2O. Natural emissions of CH_4, from Arctic wetlands and hydrates, are susceptible to changing climate, and they have the potential to cause strong positive climate feedbacks.

From 1999 to 2006, the global burden of atmospheric CH_4 remained nearly constant (see Figure), except for a small increase resulting from increased boreal biomass burning during 2002 and 2003. Since 2006, globally averaged CH_4 increased by ~13 ppb. Does this increase signal the start of increased emissions in the Arctic from permafrost or hydrates because of warming climate, or is it from increased emissions from coal production and waste processing in rapidly growing economies in Asia? We suspect it is neither.

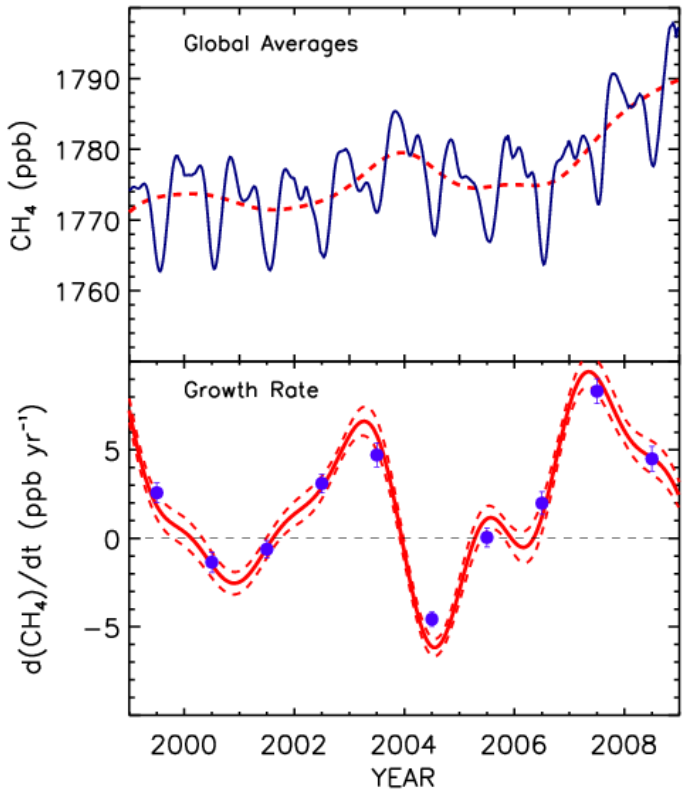

Figure 1. Preliminary globally averaged CH_4 mole fractions (blue) and trend (red) (top panel); instantaneous growth rate (red) and annual increase (blue) (bottom panel).

During 2007, globally averaged CH_4 increased by 8.3 ppb. High northern latitudes and the tropics showed the largest increases. The increase in CH_4 at high northern latitudes was accompanied by lower than average $\delta^{13}C$ in CH_4 from Alert, Canada during late-summer, which suggests greater than normal CH_4 emissions from wetlands. While NOAA surface CO data from the same samples analyzed for CH_4 suggest little potential contribution to the increase in CH_4 from biomass burning, MOPITT (Measurements Of Pollution In The Troposphere) observed positive CO anomalies up to ~90 ppb at 700 hPa during late-2006 over SE Asia. These signals may not have been observed at NOAA surface sites, because our sites may not be properly positioned to sample them.

During 2008, CH_4 at high northern latitudes remained at approximately 2007 levels, but a significant increase in CH_4 was observed in the tropics. Globally, CH_4 increased by 4.5 ppb. The causes of this increase are not clear, but La Niña conditions were observed starting in mid-2007, waned somewhat during late-2007, and then intensified during 2008. These conditions often have increased precipitation associated with them in SE Asia and eastern Amazonia. Increased precipitation would have resulted in increased emissions from tropical wetlands, the largest CH_4 source in the global budget. Other potential contributors are increased inter-hemispheric exchange, which would increase SH CH_4, and changes in [OH] that affect the CH_4 lifetime.

AGAGE and CSIRO Measurements of Recent Global Methane Growth

M. Rigby[1], R.Prinn[1], P. Fraser[2], P. Simmonds[2], J. Huang[1], R. Langenfelds[2], D. Cunnold[3], P. Steele[2], P. Krummel[2], R. Weiss[4], S. O'Doherty[5], P. Salameh[4], H. Wang[3], C. Harth[4], J. Mühle[4] and L. Porter[6]

[1]Center for Global Change Science, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02139; 617-258-0838, E-mail: mrigby@mit.edu
[2]Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research, Aspendale, Victoria, Australia
[3]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA 30332
[4]Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093
[5]School of Chemistry, University of Bristol, Bristol, United Kingdom
[6]Australian Government Bureau of Meteorology, Melbourne, Victoria, Australia

Measurements by the Advanced Global Atmospheric Gases Experiment (AGAGE) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) show renewed growth of atmospheric methane from early 2007 to present. This rise follows almost a decade of relatively stable global methane levels and has occurred at all monitoring locations almost simultaneously. A two-dimensional model of atmospheric chemistry and transport is used to optimally estimate the increase in emissions required to produce such a rise. If annually repeating hydroxyl radical concentrations are assumed, we find that emissions rose by similar levels in both hemispheres during 2007. The 2007 global emissions were found to be elevated by approximately 25Tg/yr compared to the 10-year average. Mean emissions during 2008 were estimated to be lower than in 2007, but still higher than the average (by approximately 15Tg/yr), with the Northern hemisphere accounting for most of the 2008 emissions anomaly.

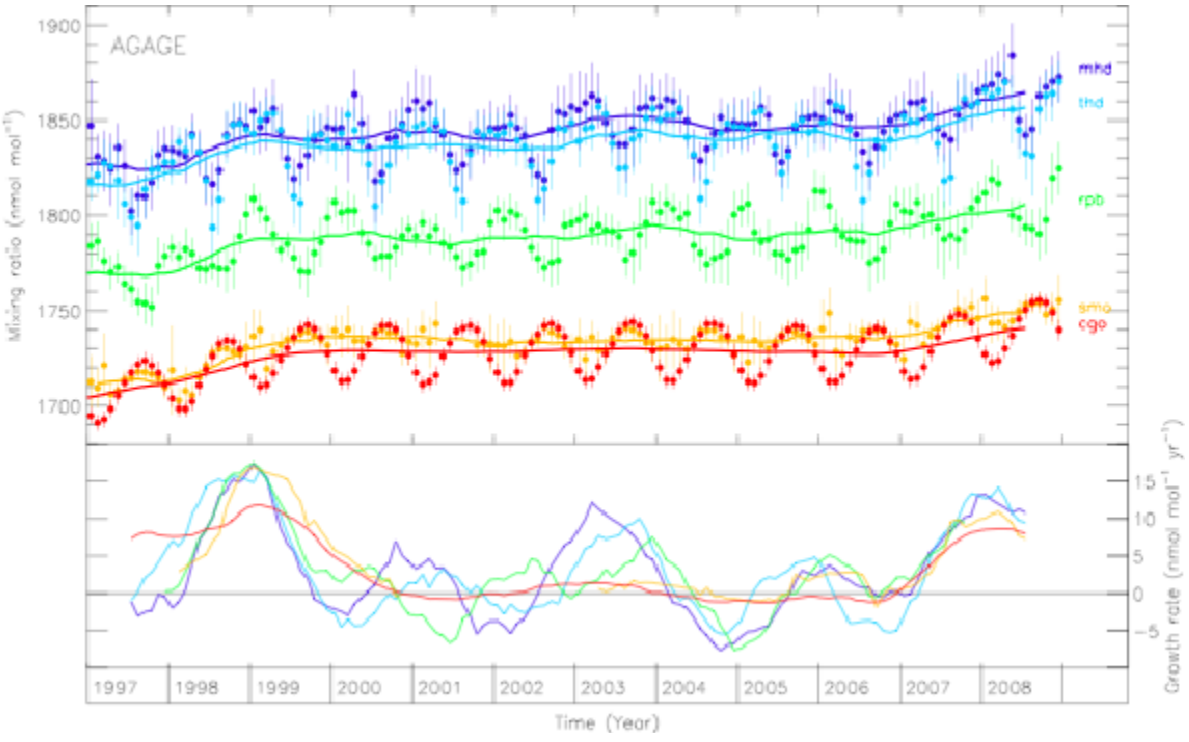

Figure 1. AGAGE monthly baseline methane mole fraction, January 1997 to December 2008 measured at Mace Head, Ireland (mhd), Trinidad Head, California (thd), Ragged Point, Barbados (rbp), Cape Matatula, American Samoa (smo) and Cape Grim, Tasmania (cgo). The thick line in the upper panel shows the annual running mean mole fraction. The lower panel shows the annual average growth rate at each site. Error bars and growth rate are calculated as in Rigby et al. (2008) Renewed Growth of Atmospheric Methane, Geophys. Res. Lett., 35, L22805.

U.S. Climate Reference Network: Current Status and Future Directions

S. LeDuc and M. Palecki

National Climatic Data Center, 151 Patton Ave., Asheville, NC 28801; 828-271-4848, E-mail: sharon.leduc@noaa.gov

The USCRN deployment in the continental U.S. was completed in September 2008, with a network of 114 stations at 107 locations (Figure 1). This spatial distribution is sufficient to explain 98% of the variance of the annual U.S. temperature average and 95% of the variance of the annual U.S. precipitation total. The locations were chosen with great care at very stable sites that are intended to remain rural and unchanged for the next 50-100 years. Therefore, between the site selection and the science-based observation techniques adhering to the best principles for climate observation, the USCRN climate records will not be required to be homogenized going forward, providing a premier time series record of national climate change as it occurs. The USCRN will also be valuable for climate monitoring from daily to annual scales, providing accurate assessments of climate extremes, cumulative variables such as heating and cooling degree days, and, in the near future, high-quality soil moisture and soil temperature observations. A deployment of 30 USCRN stations to Alaska is in progress, and the impending rollout of the USHCN-M regional climate change pilot project in the Southwest is based on USCRN practices.

Early observations from the first seven years of the USCRN will be examined to illustrate the value and utility of this science-based approach to climate observation. Triple configurations of both temperature sensors and precipitation gauge depth measurements insure data quality by providing independent measurements that can be cross-checked continuously, and also safeguard continuity against the failure or replacement of a single instrument. A new USCRN climate science project is beginning to take shape to supplement the ongoing instrumentation science work. Some of the near-term plans for this project will be presented, including the development of temperature and precipitation pseudo-normals, threading time series of historical observations to USCRN data, and exploring USCRN observations relevant to satellite and modeling calibration/validation. Outreach is taking place to encourage more use of USCRN observations in the climate stakeholder communities, and data access has been made easier for external users.

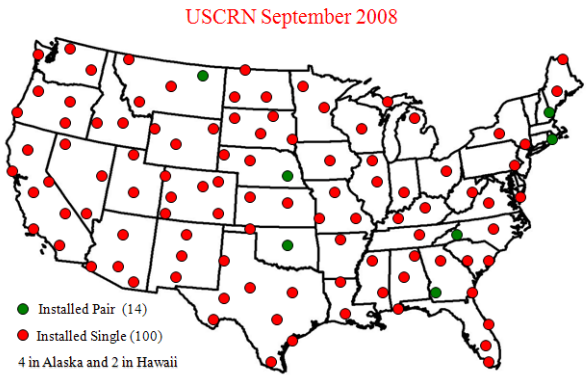

Figure 1. Location map for USCRN stations and network growth from 2004 to 2008 completion.

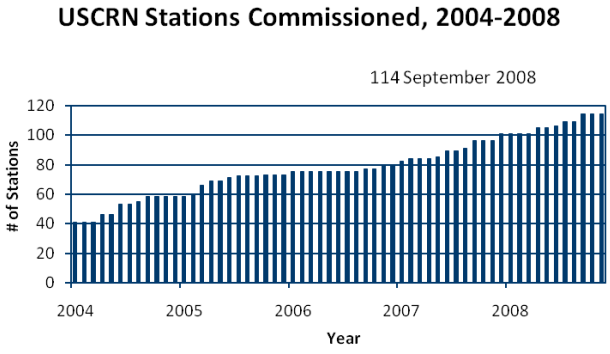

Figure 2. Time Series of Station Commissioning.

Primary Study on the Characteristics of Trace Gases in a Clean Area of North China

B. Jianhui, W. Gengchen and W. Pucai

Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China; 86-10-82995079, E-mail: bjh@mail.iap.ac.cn

During 22 May, 2005 to 31 December, 2007, continuous measurements of some trace gases at Xinglong station (150 km northeast of Beijing city), atmospheric background observation network of Chinese Academy of Sciences were carried out. Some basic characteristics and variation regularities of O_3, NOx (NO,NO_2), CO_2, SO_2, and their concentrations were obtained. In general, O_3 displayed a higher concentration in June and September, and the lowest concentration in December. NOx indicated the lowest concentration in August, and slowly increased during August to December, the ratio of NO to NOx is very low. SO_2 showed the lowest concentration in July, and then increased gradually. CO_2 exhibited the lowest concentration in August. During September 10 to November 11 of 2005, solar spectral radiation was measured at Xinglong Station. UV radiation, the important energy source to control ozone production and depletion, displayed obvious diurnal and daily variations. Though UV and O_3 have some similar diurnal and daily variations, no good correlation can be found between them during the period of September to November, which showed their relationship is complicated. In more detail, daily maximum of hourly averages of UV was earlier than that of O_3 for most conditions, which indicated that UV energy is the triggering energy for O_3 formation. In order to better understand O_3 chemistry and photochemistry, solar radiation, O_3 and its precursors of NOx, VOCs (Volatile Organic Compounds), and aerosols should be measured synthetically.

Based on the measurements, good air quality at Xinglong Station is in July and August. Recently, the fast developments in industry, agriculture, economy and traffic in Beijing city and its surrounding cities will bring changes to trace gases in these areas. Xinglong Station can be considered as a good and unique atmospheric background station for the comprehensive study on solar radiation, atmospheric chemistry & photochemistry, aerosols (especially secondary organic compounds), and how and in what extent the human activities influence the atmospheric environments, solar radiation and its spectrum at the Earth's surface, and so on. Thus, it's important to carry out a long-term monitoring of trace gases, VOCs, solar radiation, aerosols, meteorological parameters, and study the basic physical and chemical & photochemical processes in the real atmosphere deeply and thoroughly, some unimportant processes may become more important than we thought before. Meanwhile, reliable and long-term integrated dataset is very valuable for models data input and models validation. So, the collaboration especially international collaboration is a better way for us to understand basic physical, chemical & photochemical processes in North China/different sites in the world.

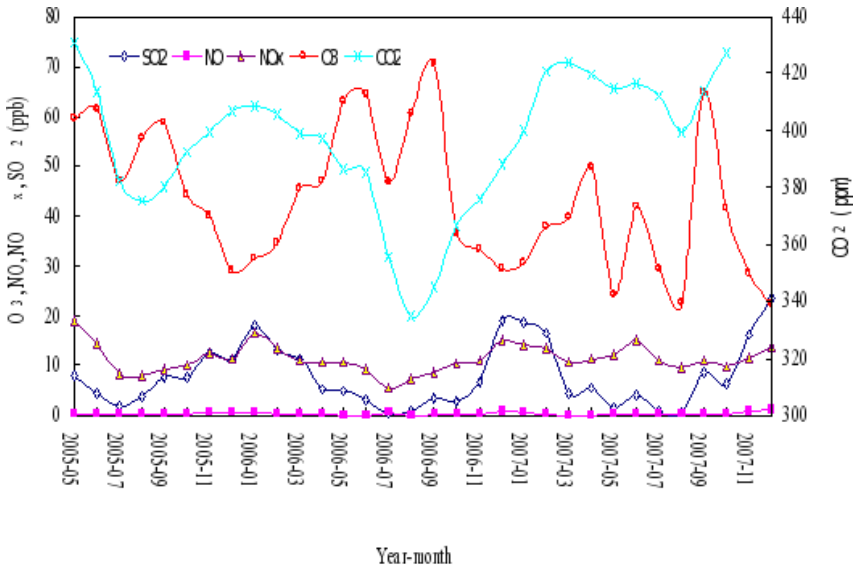

Figure 1. Monthly variations of trace gas concentrations at XingLong Station.

Overview of Chemical and Physical Measurements at Lulin Atmospheric Background Station (LABS, 2,862m MSL) in Taiwan, East Asia Since 2006

N.H. Lin[1], J.L. Wang[2], C.T. Lee[3], G.R. Sheu[1] and S.H. Wang[1]

[1]Department of Atmospheric Sciences, National Central University, Chung-Li 320, Taiwan; +886-3-4254069, E-mail: nhlin@cc.ncu.edu.tw
[2]Department of Chemistry, National Central University, Chung-Li 320, Taiwan
[3]Graduate Institute of Environmental Engineering, National Central University, Chung-Li 320, Taiwan

The Lulin Atmospheric Background Station (LABS) in Taiwan held its grand opening for operation on 13 April 2006. It is located at the Mt. Lulin (2,862 m MSL; 23° 28'07"N, 120°52'25"E) in central Taiwan. The LABS is unique because its location and altitude can enhance the global network of GAW (Global Atmosphere Watch) in the Southeast Asian region where no high-elevation baseline station is available. Our site is located between the GAW Waliguan station (3,810 m) in Tibetian plateau and Mauna Loa Observatory (3,397m) in Hawaii. Trajectory study indicates that this site provides us a great chance to observe a variety of air mass originated from contaminated or clear source regions, giving a distinctive contrast of atmospheric changes. Present continuous operations include precipitation chemistry, aerosol chemistry, trace gases (CO, O_3, CFCs, VOCs), mercury, atmospheric radiation, and meteorological variables. Till present time, the average concentrations of CO, O_3 and PM10 are about 121 ppb, 34 ppb and 10 μg m^{-3}, respectively. The average pH value of precipitation is 5.73. The average concentrations of mercury such as GEM, RGM and PHg are about 1.78 ng m^{-3}, 41.65 pg m^{-3} and 8.96 pg m^{-3}, respectively. The average aerosol optical depth is 0.101. The background concentrations of CO, O_3 and PM10 are estimated to be about 82 ppb, 28 ppb and 6 μg m^{-3}, respectively. About 32% of the days in a year can be defined to be polluted. Especially in March, the concentrations of above three pollutants show twice higher than their background values. To summarize the results, the maximum concentration of pollutants generally occurred during spring time, especially in March, corresponding to the biomass burning from SE Asia.

Figure 1. Lulin Atmospheric Background Station (LABS).

Year-Round Measurements and Interpretations at Greenland Environmental Observatory at Summit (GEOSummit)

R. Banta[1], J. McConnell[1], T. Cahill[2], J. Burkhart[3,4] and R. Bales[4]

[1]Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89512; 775-673-7442, E-mail: ryan.banta@dri.edu
[2]University of California at Davis, Davis, CA 95616
[3]Norwegian Institute for Air Research, Kieller, Norway 2027, Norway
[4]University of California at Merced, Merced, CA 95343

Long-term year-round sampling of the Arctic atmosphere and surface snow provide insight to the relationship between aerosol and snow chemical compositions. Ongoing research at the Greenland Environmental Observatory, Summit Station (GEOSummit) includes high temporal resolution year-round measurements of snow accumulation and spatial variability, IC and ICP-MS trace-element measurements of surface-snow and snow-pit samples, DRUM aerosol size and S-XRF elemental composition, and other meteorological and snow properties. These measurements allow for a better understanding of the timing and magnitude of the seasonal cycles in elemental concentrations that are deposited and preserved in the snow pack, some of which have not been previously reported. These records were analyzed using a multivariate factor analysis model called Positive Matrix Factorization (PMF) to identify unique source factors representative of sea salt, dusts, and other potential sources such as biomass burning. These source factors exhibited distinct seasonal cycles with significant year-to-year variability. Snow accumulation rates were concurrently measured, thereby aiding the evaluation of wet and dry deposition as well as quantifying the inter-annual variability in snow accumulation. In addition, using the Lagrangian Particle Dispersion Model (LPDM) FLEXPART, source regions of specific events that transport pollution or dust from North America and/or Asia can be identified. Continuous longer-term records are necessary for evaluating links between aerosol and snow chemistry to geophysical processes with multi-year periodicities (e.g. AO, AMO, etc). Future plans include continuing research measurements at GEOSummit (5-yr continuation proposal submitted) to better characterize elemental concentrations in snow and aerosols, annual to decadal variability in snowfall, and connections with atmospheric circulation and transport.

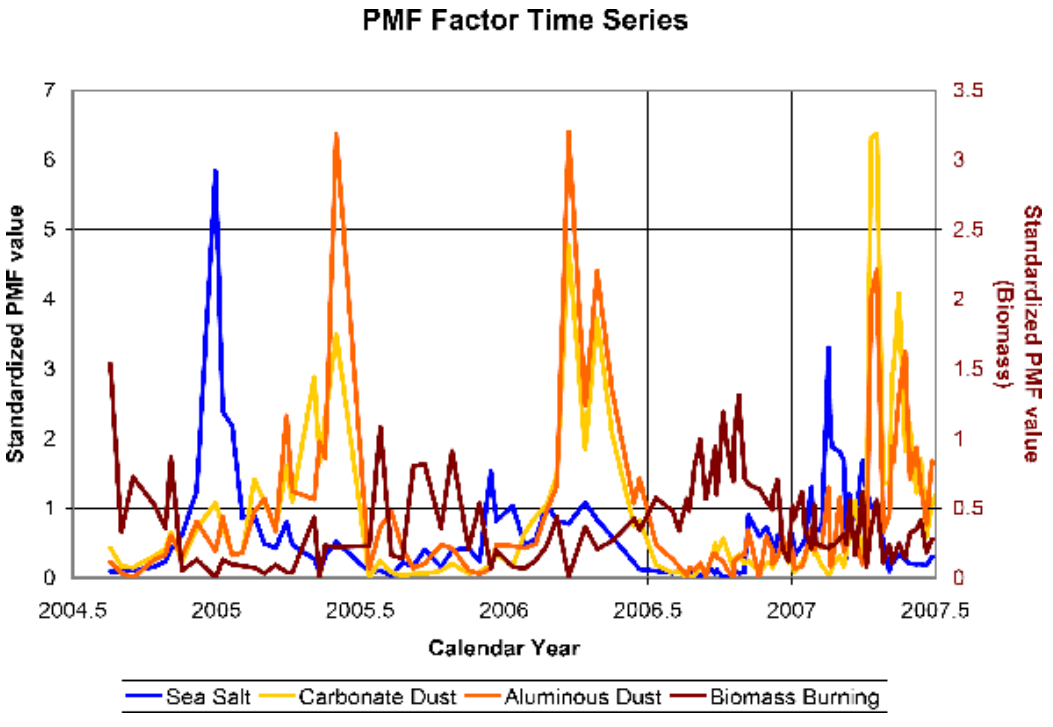

Figure 1. Time series of PMF source factors attributed to sea salt, carbonate dust, aluminous dust, and biomass burning. Note the strong seasonality and inter-annual variability of the source factors.

Measurements of Ambient Mercury and Related Species at the Mauna Loa Observatory 2002-2008

L. Alvarez-Aviles[1], M.S. Landis[1], D. Kuniyuki[2] and A. Colton[1,2]

[1]U.S. Environmental Protection Agency, 109 T.W. Alexander Drive, Research Triangle Park, NC 27711; 919-541-3330, E-mail: Alvarez-Aviles.Laura@epamail.epa.gov
[2]NOAA Earth System Research Laboratory, Mauna Loa Observatory, Hilo, HI 96720

EPA ORD and NOAA ESRL initiated measurements of gaseous elemental mercury (Hg^0), divalent reactive gaseous mercury (RGM), and particulate bound mercury (Hg(p)) in 2002 at the Mauna Loa Observatory (MLO). Collocated elemental carbon, O_3 and SO_2 measurements were subsequently initiated in 2004. NOAA ESRL O_3 data was used to complete our data set from 2002 - 2004. Hg^0 concentrations ranged between 0.3 and 2.9 ng m^{-3}, and average ± standard deviation was 1.6 ± 0.5 ng m^{-3}; Hg(p) concentrations ranged between 1 - 1900 pg m^{-3}, and RGM ranged between 0.6 - 360 pg m^{-3}. Periods when Hg(p) is anti-correlated to Hg^0 are also periods when ozone is anti-correlated to Hg^0 (2002 - 2003), suggesting that air masses sourcing ozone differ from that of Hg^0, possibly of stratospheric origin. The majority of SO_2 impacting Mauna Loa is expected to be of volcanic origin. SO_2 correlation with Hg^0 suggests that we observed significant Hg^0 during periods of volcanic activity, while anti-correlation periods indicate long distance transport influences for Hg^0 in contrast to the more regional volcanic influences for SO_2. Elemental carbon is a good indicator of anthropogenic sources and is mostly correlated to Hg^0, suggesting that most Hg^0 observed at MLO is of anthropogenic origin. This study is still in early stages of data analysis and validation, a complete presentation of the data and detailed analysis will be presented.

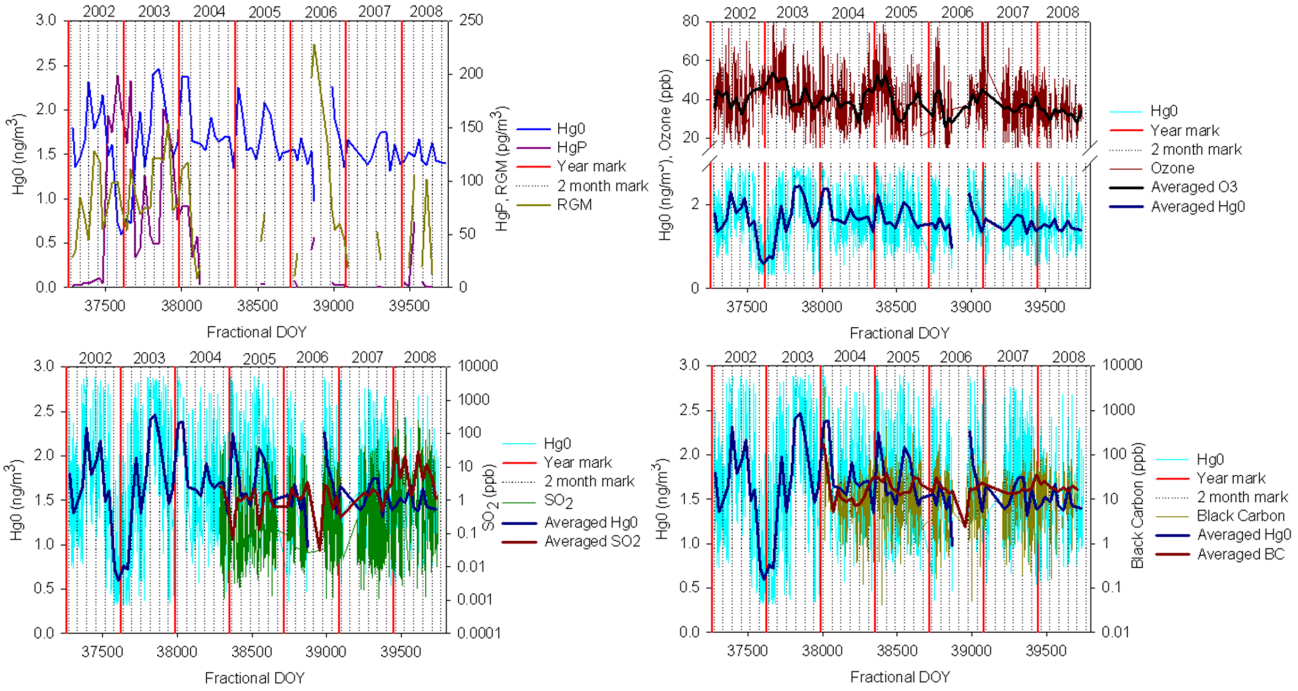

Figure 1. Hg^0, HgP, RGM, ozone, SO_2 and black carbon concentration trends in Mauna Loa, Hawaii in 2002 – 2008. The solid thick lines represent the monthly average and the lighter solid line is the 3 hour resolution measurement for the chemical specie.

Interpreting Total Gaseous Mercury Observations with Lagrangian and Eulerian Atmospheric Models: A Canadian Perspective

J.C. Lin, D. Wen and J.J. Sloan

University of Waterloo, 200 University Ave. W, Waterloo, ON N2L3G1, Canada; 519-888-4567x3325, E-mail: jcl@uwaterloo.ca

Total gaseous mercury (TGM) concentrations at monitoring sites in Canada were simulated using the Stochastic Time-Inverted Lagrangian Transport (STILT) model. The model was modified in this work to deal with Hg depositions and high stack Hg emissions. The model-predicted Hg concentrations were compared with observations, as well as with the results from an Eulerian-based (CMAQ) simulation, in which the same emission and meteorology inputs were used. The comparisons show that STILT predicted Hg concentrations show better agreement with observations than those predicted by CMAQ. Furthermore, Fourier spectra indicated that high-frequency variability in the Eulerian model was severely damped while captured by the Lagrangian approach, due to the latter's ability to account for near-field influences. STILT was also applied to quantitatively assess relative importance of different upstream source regions for the selected episodes. The results indicated that the substantial source regions of the observed low Hg concentrations were some nearby cities and towns in Northeastern Ontario, and that elevated observations at three sites were mainly due to the contributions of significant point sources and areas in Southern Ontario, Ohio, Virginia and Michigan. Additionally, this work has illustrated the potential of STILT to interpret and identify source regions of pollutants in the future.

Figure 1. Locations of the three monitoring sites: Burnt Island, Egbert and Point Petre.

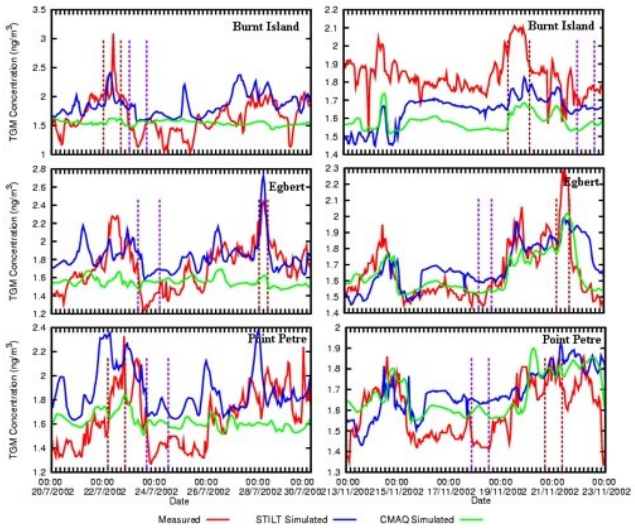

Figure 2. Total Gaseous Mercury (TGM) concentration comparisons among observed (red), STILT modeled (blue), and CMAQ-modeled (green) for two simulation periods: Jul 20-29 (right) and Nov 13-22 (left), 2002 for Burnt Island (top), Egbert (middle) and Point Petre (bottom).

Measurements of the Stable Isotopologues of Water Vapor at Mauna Loa for Monitoring the Atmospheric Water Cycle

D. Noone[1], J. Galewsky[2], J. Barnes[3], Z. Shark[2], D. Toohey[4] and J. Worden[5]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-735-6073, E-mail: dcn@colorado.edu
[2]Department of Earth and Planetarty Science, University of New Mexico, Albuquerque, NM 87131
[3]NOAA Earth System Research Laboratory, Mauna Loa Observatory, Hilo, HI 96720
[4]Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO 80309
[5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CO 91109

Measurements of the isotopic composition of water vapor reflect the history of air mass mixing and cloud processes influencing the vapor as it moves through evaporation and transpiration. This comes about because heavy isotopologues of water (i.e, HDO and $H_2{}^{18}O$) have a different vapor pressure than normal (lighter) H_2O, and as such they prefer to remain in the condensed phase during both condensation and evaporation. Continuous measurements of H_2O $H_2{}^{18}O$ and HDO were made at Mauna Loa for four weeks in October 2008 using three laser-based spectroscopic analyzers. Figure 1 shows that at Mauna Loa the isotopic composition dramatically captures the dramatic diurnal transition between air influenced by the marine boundary layer during day and free troposphere air at night. Closer examination shows that this transition is almost reversible, yet the isotopic signature of clouds is evident and suggests cloud processes play a role in the energy budget that maintains the MBL. The very dry and isotopically depleted free-troposphere air indicates that the humidity is set though ice cloud processes either in the midlatitudes or in the upper troposphere within the Inter-Tropical Convergence Zone. Moistening of the troposphere near Mauna Loa occurs in association with detrainment from warm convection, as is exemplified by an “atmospheric river” event that was observed in the second half of the field period. This work establishes that commercially available isotopic vapor analyzers are both capable of monitoring the isotopic composition at NOAA baseline stations, that the calibrated measurements are of remarkable high precision, and that the data can be used to establish new understanding of the atmospheric water cycle.

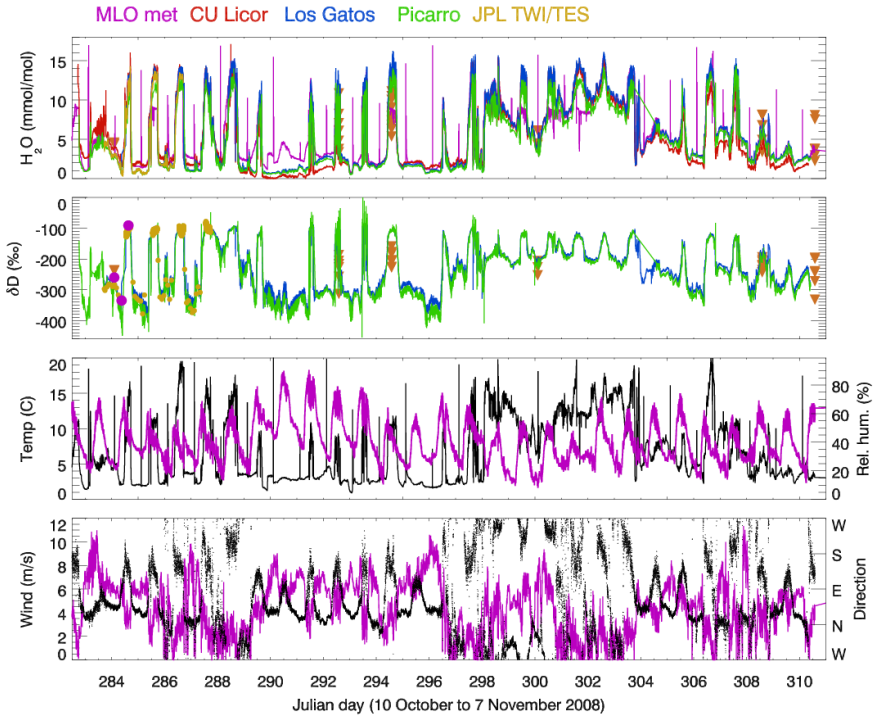

Figure 1. Time series of a) water vapor volume mixing ratio, b) dD of water vapor c) station temperature (magenta) and relative humidity (black) and d) wind speed (magenta) and direction (black dots) at Mauna Loa from 10 October to 6 November 2008. Panel a and b include all observations from station meteorological dew point hygrometer (magenta), Licor 7000 IRGA (red), LGR WVIA (blue), Picarro IWVA (green), JPL-TWI (orange circles), TES satellite FTIR (gold triangles) and 3 flasks (magenta circles).

Air Quality Implications of Ozone in Air Entering the West Coast of North America

D.D. Parrish, K.C. Aikin, S.J. Oltmans and B.J. Johnson

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-5274, E-mail: David.D.Parrish@noaa.gov

Ozone measurements conducted by the Global Monitoring Division at Trinidad Head, California provide a unique opportunity to evaluate the impact that background ozone transported ashore has on air quality over the North American continent. The northern Sacramento Valley lies ≈160 km inland from Trinidad Head. This valley is designated as a non-attainment area for the California state ozone standard, and the observed maximum mixing ratios indicate that the area will also violate the new 75 ppbv National Ambient Air Quality Standard (NAAQS). Figure 1 shows that the summertime surface air flowing ashore from the Pacific Ocean carries average ozone mixing ratios of ≈30 ppbv, which are well below the NAAQS. However, in summer (the season of the highest ozone in inland areas) there is a strong vertical gradient in ozone. The average ozone at 2 km altitude exceeds 50 ppbv, and one standard deviation above the average exceeds 70 ppbv. Thus, if air from 2 km altitude were mixed to the surface of the northern Sacramento Valley, the transported background ozone would significantly affect the surface ozone. The coastal mountain range separates the valley from the marine environment and its crest is at elevations of ≥1 km, so such mixing is expected. We will use correlations between the Trinidad Head sonde data and northern Sacramento Valley surface site data to show that such downward mixing does indeed occur, and we will argue that background ozone alone is sufficient for NAAQS violations. If correct, the implications of this conclusion are profound. Local or state efforts will not be adequate to achieve the NAAQS for ozone, at least in the northern Sacramento Valley. Additional international efforts to reduce background ozone at northern mid-latitudes will be required for effective control of violations.

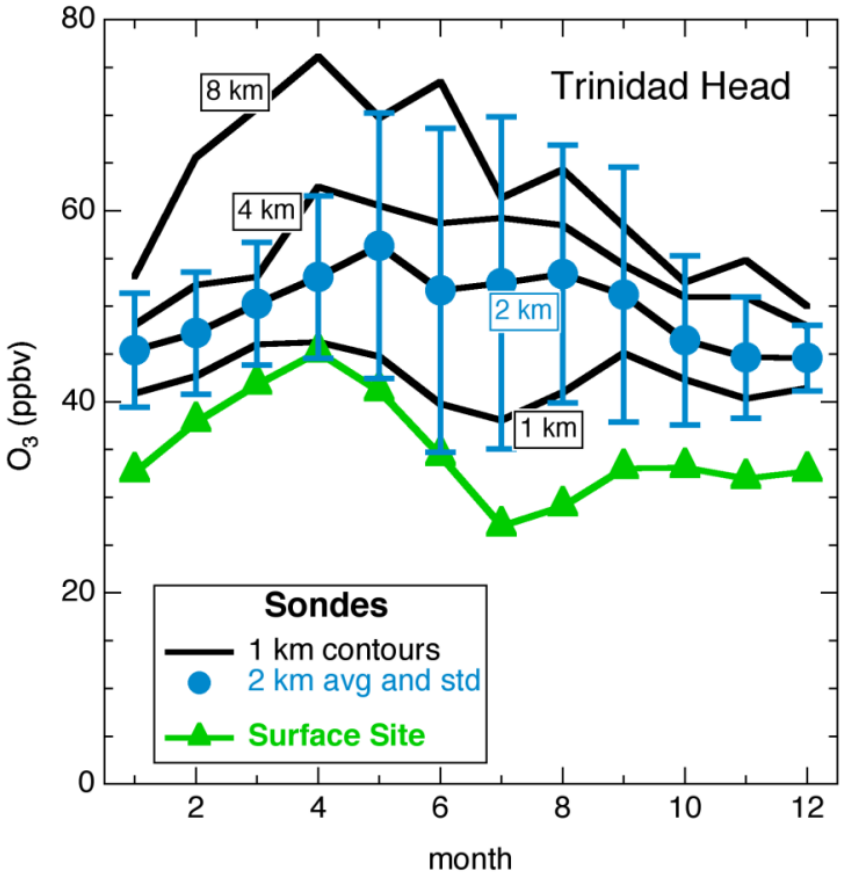

Figure 1. Monthly average O_3 mixing ratios from ESRL Global Monitoring Division measurements at Trinidad Head, CA. Results from the Trinidad Head Baseline Observatory surface site (100 m ASL elevation) are compared with the vertical profiles from the weekly ozonesondes. The 1 km contours from the ozonesondes are 200 m averages about the indicated altitude. The error bars indicate the standard deviations about the averages at 2 km altitude.

Reactive, Anthropogenic Trace Gases at the German GAW Site Hohenpeissenberg: Trends and Variability on Various Time Scales

C. Plass-Duelmer and S. Gilge

German Meteorological Service, Albin Schwaiger Weg 10, Hohenpeissenberg, Bavaria 82383, Germany; +49-8805-956140, E-mail: christian.plass-duelmer@dwd.de

Atmospheric trace gases show variability on daily, weekly, seasonal and longer time scales due to natural and anthropogenic factors. At Hohenpeissenberg, a global station of the GAW program situated in rural southern Germany, a broad range of different atmospheric trace gases, e.g. VOC, CO, NO, NO_2, SO_2, O_3, OH, has been measured continuously since the mid or end 1990s. Thus, time series of 10 or more years are available now (Figure 1). This enables us to describe the variability and trends and start to analyse the factors of impact. Weekday – weekend comparisons allow a direct estimation of relative changes in anthropogenic emissions (Figure 2). Such differences are significant and increase with shorter life-times of the respective compounds, e.g. xylene concentrations on Sundays are factor 2 lower than during working days. Winter-summer ratios of directly-emitted, anthropogenic compounds generally depend on a combination of changing sources, sinks and transport. Observed winter-summer ratios are mostly between 2 and 6 which are smaller than the summer-winter ratios of OH – radicals of about 8. Trends of the anthropogenic trace gases indicate declining concentrations for most VOC and CO. For NOx, however, concentrations did not decline significantly which is in contrast to current emission inventories.

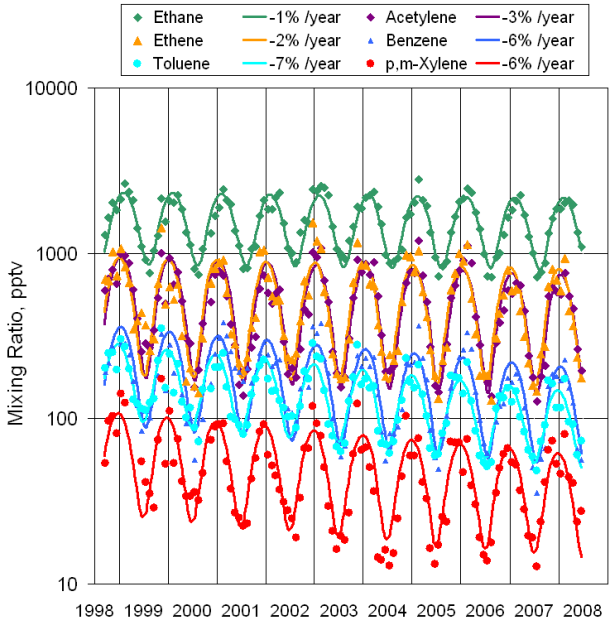

Figure 1. Time series of selected NMHC and trends obtained from a sine-fit to the monthly mean mixing ratios.

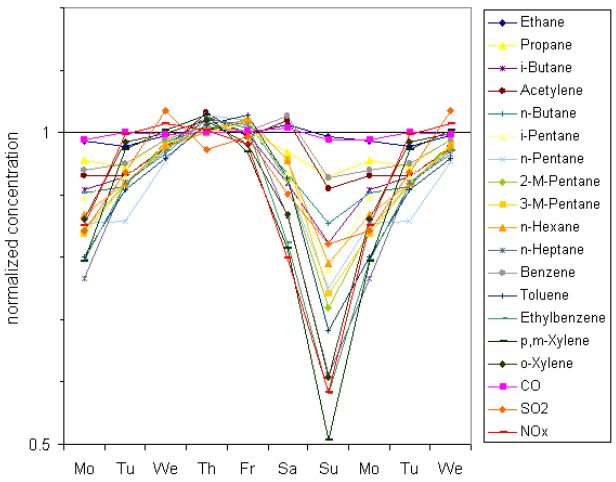

Figure 2. Weekly variation of anthropogenic trace gases at Hohenpeissenberg (daily averages of all data).

Uptake of Ozone-Depleting Halogenated Gases to the Snow-Covered Surface at Niwot Ridge, CO

D. Helmig[1], E. Apel[2], D. Blake[3], L. Ganzeveld[4], B.L. Lefer[5], S. Meinardi[3] and A.L. Swanson[3,6]

[1]Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309; 303-492-2509, E-mail: detlev.helmig@colorado.edu
[2]National Center for Atmospheric Research, Boulder, CO 80307
[3]Department of Earth System Science, University of California, Irvine, CA 92697
[4]Department of Environmental Sciences, Wageningen University and Research Center, Wageningen, Netherlands
[5]Earth and Atmospheric Sciences Department, University of Houston, Houston, TX 77204
[6]Department of Chemistry, Northrop Grumman Space Technology, Redondo Beach, CA 90278

Whole air samples were drawn from four heights within the deep winter snowpack at Niwot Ridge, Colorado, during a one-week experiment in March, 2005, and subsequently analyzed by gas chromatography. Two adjacent plots with similar snow cover were sampled, one over natural, vegetated soil, and a second one where the ground was covered with a Tedlar/Teflon film isolating the snowpack from the soil. Samples were also collected from an ambient air inlet above the snow surface. This comparison allowed for studying chemical and physical effects occurring inside the snowpack itself versus effects of soil processes on concentrations and fluxes within and through the snowpack. Here, we focus on findings for a series of halogenated compounds which are of interest for the stratospheric halogen burden and its ozone-depleting potential, i.e. CFC-11, CFC-12, CFC-113, HCFC-22, HCFC-141b, HCFC-142b, methylchloride, tetrachloromethane, methylchloroform, 1,2-dichloroethane, methylbromide, dibromomethane, and bromoform. All of these species were found at lower, i.e. depleted concentrations in the snow, indicating that the snow and/or soil constitute a sink for these gases. A series of other species, including chloroform and dichlorobromomethane, displayed contrasting, i.e. higher concentrations inside the snow, indicating a formation of these gases and release into the atmosphere from this snow-covered environment. Microbial activities below this deep, winter snowpack were determined to be the driving mechanism behind these gas sources and sinks. A snowpack gas diffusion model was applied to develop preliminary gas flux estimates at the snow-atmosphere interface. These flux results were then incorporated into a simple box model to assess the potential contribution of the sink strength of the determined snowpack uptake rates to budgets and atmospheric lifetime estimates of these halogenated gases.

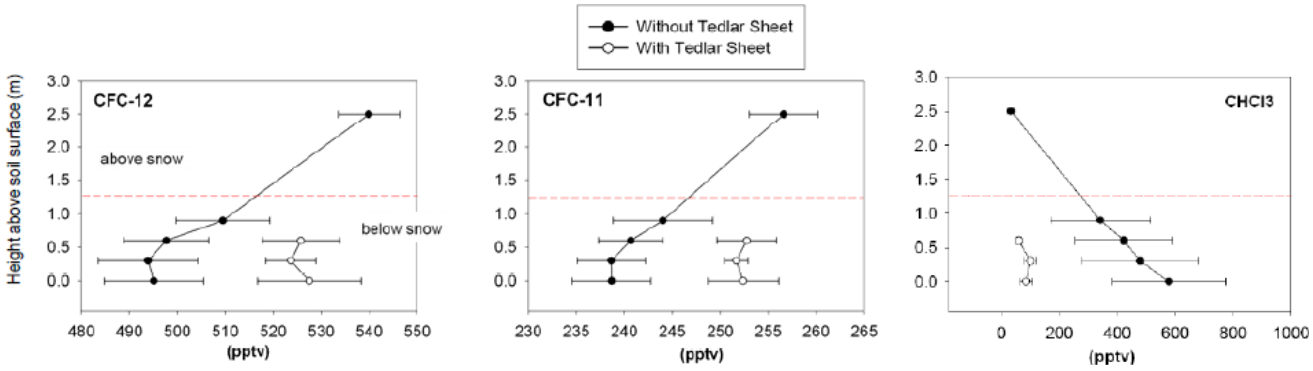

Figure 1. Concentration profiles of CFC-12, CFC-11, and $CHCl_3$ in air samples withdrawn from inlets above and within the snow. The red, staggered line depicts the top of the snowpack surface, which was at 1.3 m above ground. Data are mean values from ~ 3-5 samples collected from each inlet, with horizontal error bars indicating the variability (standard deviation) of each subset of data.

Springtime Tropospheric Ozone in the Arctic from Surface and Ozonesonde Observations

S.J. Oltmans[1], B.J. Johnson[1], D.W. Tarasick[2], A.M. Thompson[3] and J.M. Harris[4]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6676, E-mail: Samuel.J.Oltmans@noaa.gov
[2]Environment Canada, Toronto, Ontario M3H 5T4, Canada
[3]Department of Meteorology, Penn State University, University Park, PA 16802
[4]Science and Technology Corporation, Boulder, CO 80302

During 2008 a number of campaigns focused on Arctic atmospheric composition and the processes that control it. In conjunction with the Arctic Research of the Composition of the Troposphere from Aircraft and Satellite (ARCTAS) project a network of ozone profiling sites carried out near-daily observations during April 2008 and June-July 2008 using balloon-borne ozonesondes as part of the Arctic Intensive Ozonesonde Network Study (ARCIONS). Many of these intensive measurements were done at locations with multi-year ozonesonde observations providing an opportunity for comparison with the 2008 measurements. A notable difference in the spring of 2008 from the longer term observations was the paucity of boundary layer ozone depletion events at the Arctic Ocean coastal locations (Barrow, Resolute, Eureka). At Barrow, Alaska the 35-year record of surface ozone measurements showed that 2008 had the second-lowest occurrence of these events both for the month of April and the spring season (March-April-May) as a whole. The possible meteorological conditions responsible for this year-to-year variability are investigated.

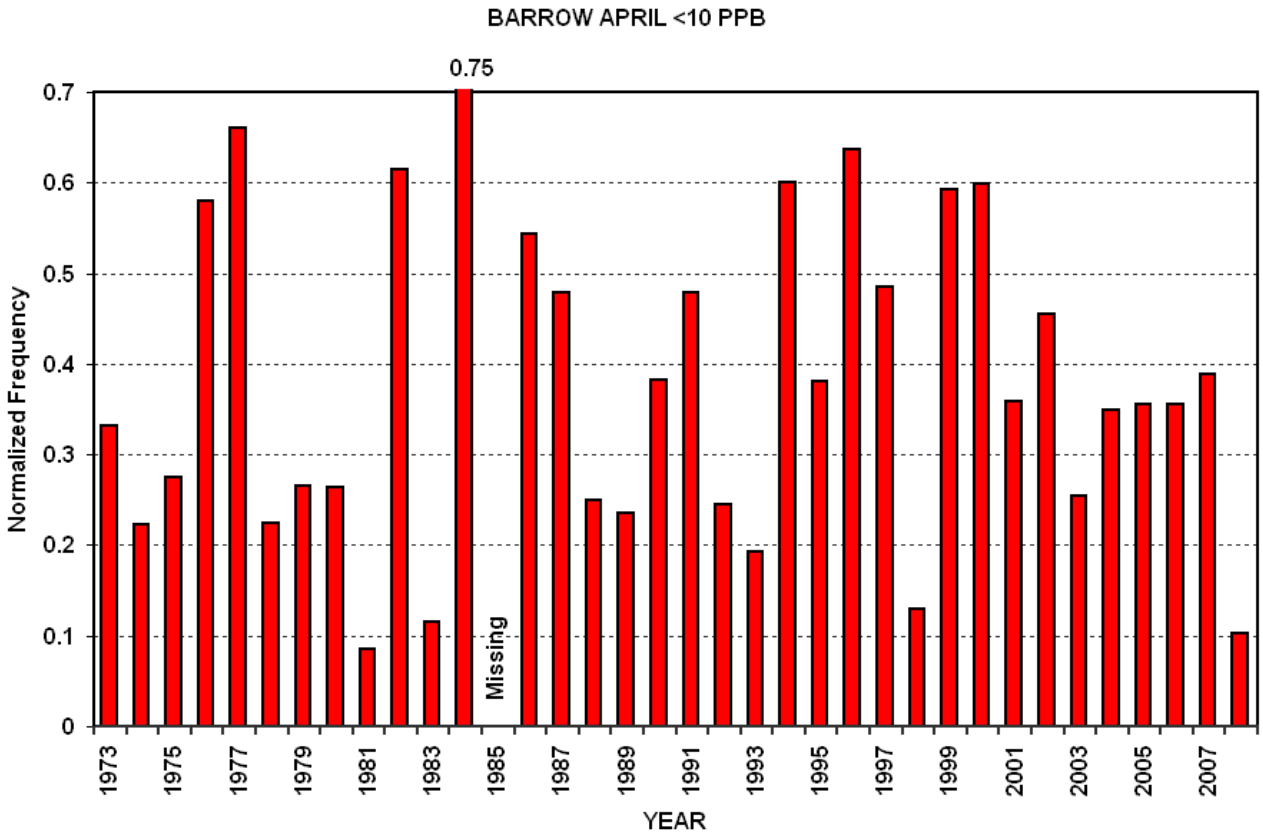

Figure 1. Number of hours with ozone ≤10 ppbv normalized to the number of hourly observations during the month of April for the period 1973-2008.

Increasing Mid-Tropospheric Ozone Above Western North America During Springtime

O. Cooper[1], D.D. Parrish[2], A. Stohl[3], M. Trainer[2], P. Nedelec[4], V. Thouret[2], J.P. Cammas[1], S.J. Oltmans[2], B.J. Johnson[2], D. Tarasick[5], T. LeBlanc[6], I.S. McDermid[6], D. Jaffe[7], R. Gao[2], J. Stith[8], T. Ryerson[2], K. Aikin[1] and T. Campos[8]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-3599, E-mail: owen.r.cooper@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Norwegian Institute for Air Research, Kjeller N-2-27, Norway
[4]Laboratoire dAerologie,CNRS – OMP, Toulouse 31400, France
[5]MSC/Environment Canada, Downsview, Ontario M3H5T4, Canada
[6]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109
[7]University of Washington - Bothell, Bothell, WA 98011
[8]National Center for Atmospheric Research, Boulder, CO 80305

The interannual variability of mid-tropospheric ozone above western North America has been investigated from *in situ* measurements collected during springtime, 1995-2008. Data were compiled from all available ozonesondes, a ground-based ozone lidar, MOZAIC commercial aircraft profiles, and research aircraft profiles from a variety of field campaigns. For consistency, all profiles were averaged to a regular 20km x 20km x 200m grid, resulting in a 14-year total of 57,500 ozone data points between 3-8 km. Using all available data in the 3-8 km altitude range, a least squares line fit through the median ozone values for each year yields an ozone increase of 6 ppbv/decade, significant at the 99% confidence interval. To examine the impact of the interannual variability of transport pathways, 15-day FLEXPART retroplumes were calculated for every measurement (a total of 2.3 billion trajectory particles were used in this analysis). The transport history of each measurement, as described by the retroplumes, was used to remove all data points with a significant influence from the stratosphere or North American surface emissions regions. The increase of ozone associated with background mid-tropospheric air entering western North America is 7 ppbv/decade, significant at the 99% confidence interval. The primary transport pathway of these air masses stretches from east Asia to North America in the 20-40 degree latitude band. On-going analysis of the retroplumes is aimed at determining if the ozone increase is associated with a broad hemispheric ozone increase or transport from east Asia.

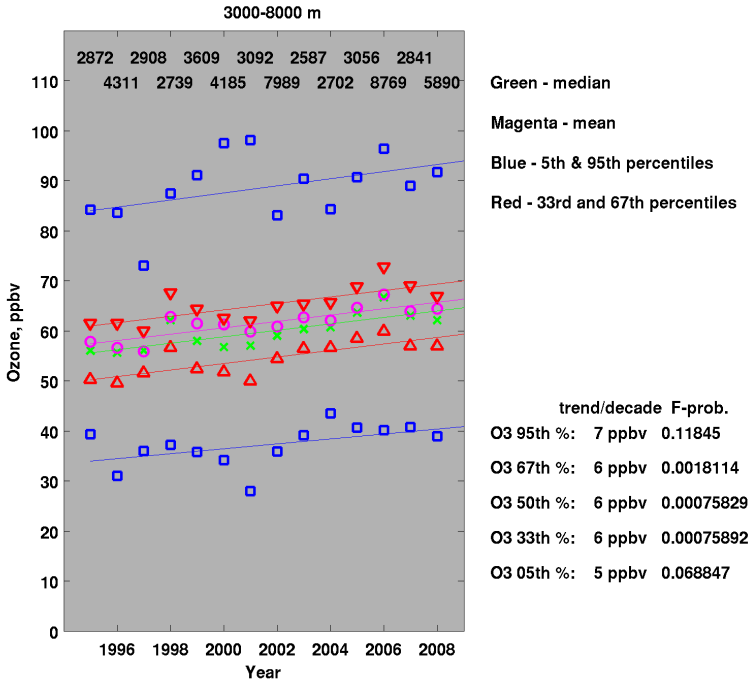

Figure 1. Mid-tropospheric (3000-8000 m) ozone above western North America from all available ozonesondes, lidar stations and aircraft measurements during April-May, 1995-2008. Shown are the means (circles), medians (x), 33rd and 67th percentiles (triangles), and 5th and 95th percentiles (squares) for each year with linear regression lines. The ozone increase per decade is shown to the right, with the linear regression significant at the 99% confidence level for the 33rd, 50th and 67th percentiles.

Updated Outcomes for Greenhouse Gases from China GAW Stations and Near Future Implementation

L. Zhou, L.X. Liu, S.X. Fang, F. Zhang, B. Yao, M. Wen, L. Xu, S. Gu, K.P. Zang and X.C. Zhang

Chinese Academy of Meteorological Sciences (CAMS), China Meteorological Administration (CMA), 46 Zhongguancun Nandajie, Beijing 100081, China; 86-10-58995279, E-mail: zhoulx@cams.cma.gov.cn

Updated outcomes for weekly paired flask samples and *in-situ* measurement program from China GAW stations were presented. Near future monitoring implementation and proposed transfer of the 'Carbon Tracker' model technology and possible vertical profiling of greenhouse gases in background regions of China were introduced. In order to establish a unified Chinese atmospheric greenhouse gases and related tracers observing system, the CMA is keen to work with relevant institutions through further and intensive cooperation especially under the GAW framework. The observing system will be very well calibrated relative to the international WMO standard scale, which is necessary for making proper and full use of the data. The high quality data from background regions of China is essential for integrated database and for modelers to improve our understanding of the carbon cycle and predict how the atmosphere and climate will evolve in the future as a result of human activities.

Figure 1. Newly established *in-situ* monitoring system at the China GAW stations Waliguan (WLG, 36.29°N, 100.90°E, 3816m asl), Shangdianzi (SDZ, 40.39°N, 117.07°E, 293.9m asl), Lin'an (LA, 30.3°N, 119.73ºE, 138m asl), Longfengshan (LSF, 44.73ºN, 127.6ºE, 310m asl) and Lab analysis/calibration system in Beijing. People showed in the pictures are some of the contributors.

NOAA's Potential to Support Renewable Energy

M. Marquis

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-4487, E-mail: Melinda.Marquis@noaa.gov

The intersection of energy independence, national security, climate, and the economy poses a daunting challenge to the United States and the world. The long-term solutions must include the development of carbon-free renewable energy (RE) sources that are sustainable and economically viable. The current U.S. energy system obtains most of its energy from coal, natural gas, oil, and nuclear plants, with a small contribution from renewable sources (mostly hydropower). Within the next few decades, the U.S. energy system is anticipated to change dramatically. Fossil fuels will have decreased in importance, either through the implementation of climate-oriented policies, or simply because the rate at which we can extract fossil fuels will have decreased, while extraction costs will have risen commensurately. The striking difference between today's U.S. energy system and that for ~2030 is the much greater dependence on renewable energy (RE) production, and the dependence of this production on processes in the atmosphere and ocean. The development of large numbers of wind and solar energy farms depends on a better understanding of the spatial and temporal distribution of wind and solar resources. The integration of wind and solar energy into the electric grid, and demands for transmission and storage, will require very accurate wind and cloud forecasts. On longer time scales, inter-annual and decadal climate variability and change may affect each of these renewable resources. Further, research is needed to determine the inadvertent effect of removing large amounts of atmospheric energy on the environment, weather and climate of varying temporal and spatial scales. Building an efficient and stable national energy supply system in which RE sources contribute significantly will require better meteorological observations, forecasts, analysis tools, and understanding of climate-related issues that are optimized for the renewable energy industry. NOAA's historical responsibility for and expertise in deploying national observing networks, predicting weather and improving forecast models, and understanding and predicting climate, "to meet our nation's economic, social, and environmental needs" is at the nexus of the energy-climate-economy challenge. During the past two years, intensified collaboration with other government agencies, university scientists, and the renewable energy industry, NOAA has identified key steps it can take to support the accelerated development of RE, especially wind and solar energy, in the United States. By hastening the deployment of RE within the United States, NOAA will advance the nation's energy security and independence, boost the economy by the creation of many good jobs that cannot be exported, and reduce emissions of carbon dioxide.

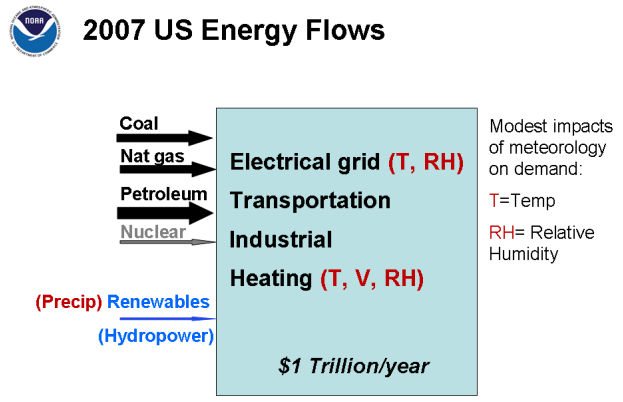

Figure 1. The current U.S. energy system relies primarily on fossil fuel energy sources, and has only a negligible dependence of meteorology on supplying energy.

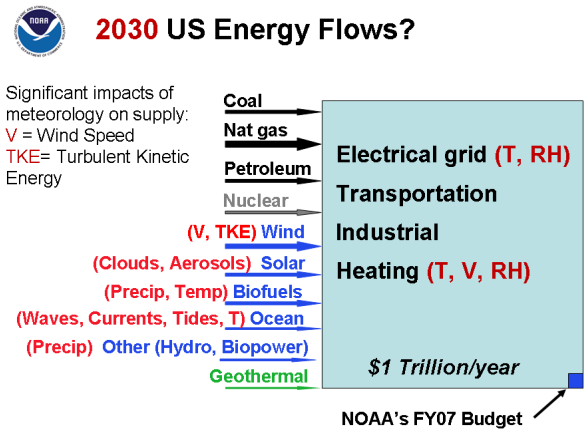

Figure 2. The U.S. energy system in a few decades (~2030) is expected to incorporate large amounts of renewable energy sources, which are heavily dependent on meteorology.

Comparison of Model Predictions of Aerosol Radiative Properties with Long-Term Measurements

J.A. Ogren[1], P. Ginoux[2], E.J. Andrews[3], P. Sheridan[1] and A. Jefferson[3]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6210, E-mail: John.A.Ogren@noaa.gov
[2]NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08540
[3]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Long-term measurements of aerosol radiative properties at a wide range of locations reveal systematic dependencies on aerosol loadings. Aerosols in the cleanest air at any given location tend to be more highly absorbing and more effective at scattering radiation back to space, i.e., they have the lowest single-scattering albedos and the highest hemispheric backscattering fractions. One hypothesis for this behavior is that the cleanest air is a result of scavenging by clouds followed by removal by precipitation. Field studies in a number of locations have shown that the unscavenged particles in clouds indeed have lower single-scattering albedos and higher backscattering fractions than the particles in adjacent, cloud-free air. As a further test of the hypothesis, the statistical behavior of aerosol radiative properties calculated with a global chemical transport model are compared with the long-term observations at sites representative of Arctic, rural continental, marine, and free tropospheric aerosols. The calculations use a version of the GFDL AM2 model, modified to include online aerosols and nudged with the NCEP re-analysis. The results of this measurement-model comparison will be discussed and examined for their implications that the observed systematic dependence of aerosol radiative properties on aerosol amount is caused by cloud scavenging and removal.

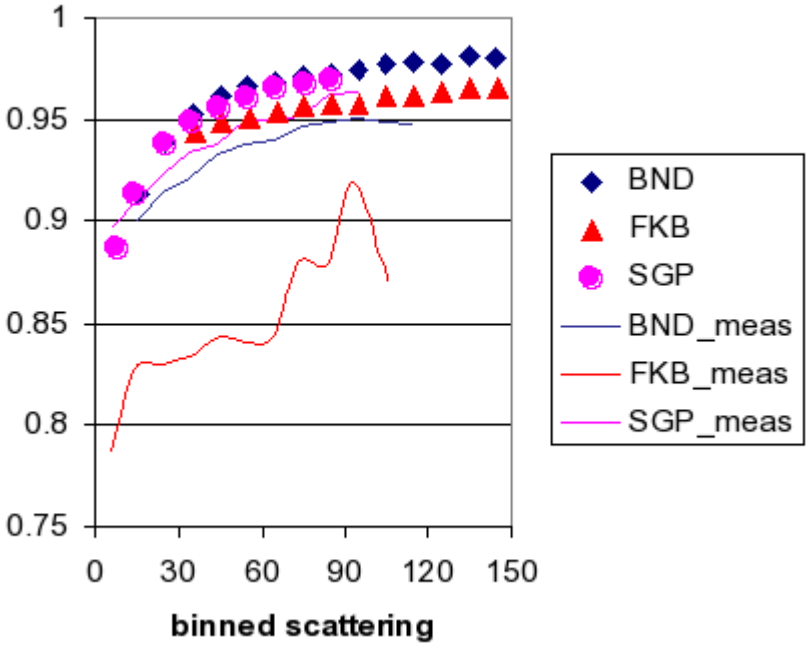

Figure 1. Comparison of systematic relationship between aerosol single-scattering albedo and aerosol amount (light scattering) at three continental sites, measured (solid lines) vs. model results (symbols). The model reproduces the systematic behavior, but not the value of the single-scattering albedo.

Trends and Properties of Tropospheric Aerosols That Undergo Long-Range Transport to the North American Arctic

P. Quinn[1], G.E. Shaw[2], T.S. Bates[1], K. Schulz[1], A. Jefferson[3], J.A. Ogren[3] and J.F. Burkhart[4]

[1]NOAA Pacific Marine Environment Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115; 206-526-6892, E-mail: patricia.k.quinn@noaa.gov
[2]University of Alaska, Fairbanks, AK 99775
[3]NOAA Earth System Research Laboratory, Boulder, CO 80305
[4]Norwegian Institute for Air Research, Kjeller 2027, Norway

Tropospheric aerosol particles undergo long range transport from the mid-latitudes to the Arctic each winter and spring. Once in the Arctic, aerosols may impact regional climate in several ways. Aerosols can affect climate directly by scattering and absorbing incoming solar radiation and indirectly by acting as cloud condensation nuclei and altering cloud properties. In addition, absorbing aerosol that is deposited onto ice and snow can lower the surface albedo and enhance the ice-albedo feedback mechanism. Measurements of aerosol properties relevant to climate forcing (chemical composition, light scattering, and light absorption) have been made by NOAA at Barrow, AK (71.3°N) for over a decade. In addition, for much of this same time period, measurements of aerosol chemical composition have been made at the three more southern Alaskan sites of Poker Flat (65°N), Denali National Park (63.5°N), and Homer (59.7°N). Measurements of sulfate at Barrow reveal a decreasing trend over the past decade of about 1.6% per year for the month of April. This decrease is similar to what has been observed for aerosol light scattering over the same period. Concentrations of sulfate during the Arctic Haze season are highest at Barrow as the Brooks Range hinders transport to the more southerly sites. During the summer, however, concentrations are highest at Homer as a result of biogenic activity. Trends in other species also will be presented and compared for the four sites. In addition, aerosol properties measured at Barrow will be compared to those measured in the European Arctic during the ICEALOT cruise in spring of 2008.

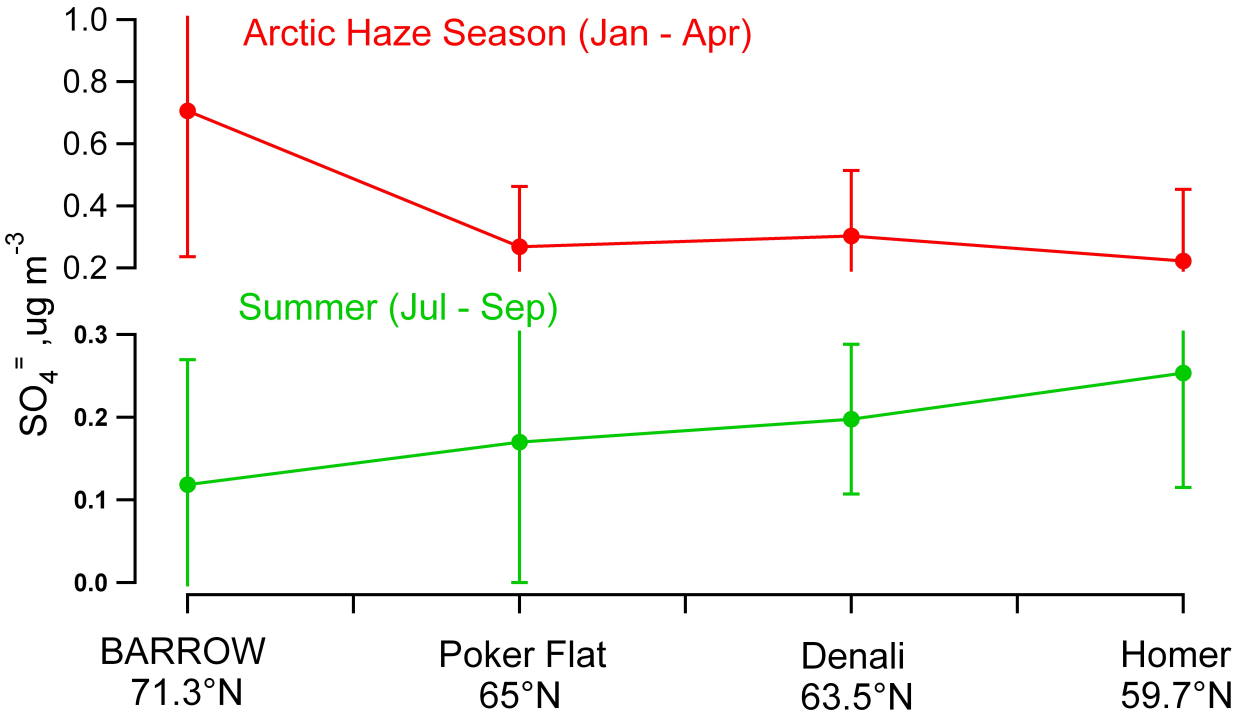

Figure 1. Measurements of non-sea salt SO_4 at four sites in Alaska for the Arctic Haze season (Jan – Apr) and Summer (Jul – Sep).

Relating OC/EC Data from Two National Monitoring Networks

W.H. White

University of California, Crocker Nuclear Laboratory, Davis, CA 95616; 530-752-1213, E-mail: white@crocker.ucdavis.edu

IMPROVE (Interagency Monitoring of PRotected Visual Environments) is a particle sampling network designed to track regional haze in rural and remote locations. CSN (Chemical Speciation Network) is a particle sampling network designed to support health studies and source apportionment of urban air pollution. Both networks use thermal-optical analyses to determine "elemental" and "organic" carbon in 24-hour samples collected on quartz filters. Differences in their sampler designs, filter handling, analytical protocols and data reduction nevertheless yield significant differences in their reported concentrations. This paper examines the empirical relationships that can be observed in data from several years of collocated monitoring at 12 urban sites, and their implications for integrative data interpretation.

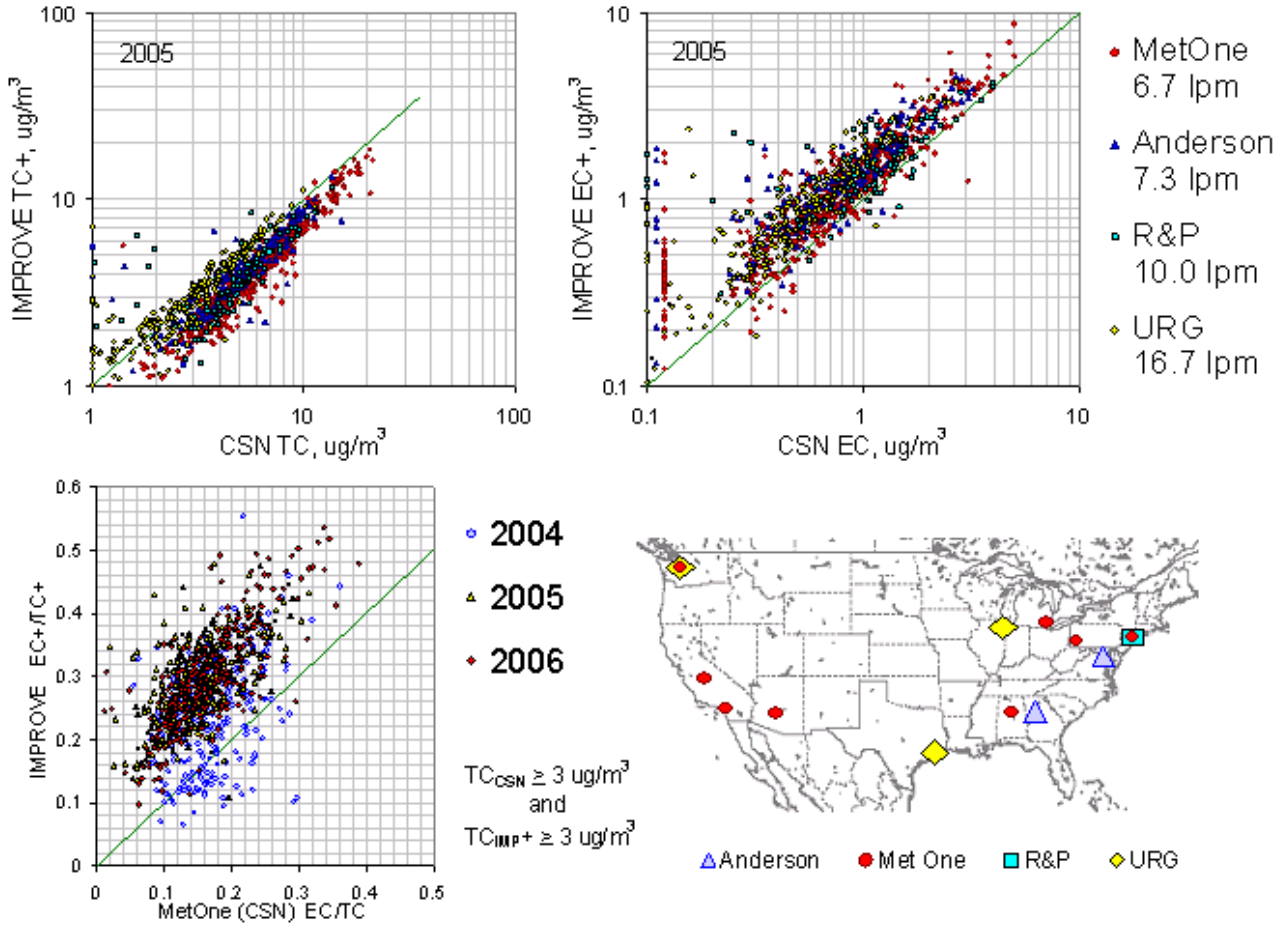

Figure 1. Comparisons of IMPROVE and CSN data from collocated monitoring at 12 urban locations (map, bottom right). IMPROVE generally reports more EC than CSN, and less TC than CSN (top); the differences vary with CSN sampler for TC (left), but not for EC (right). The minimum fraction of TC reported as EC by IMPROVE increased in 2005 (bottom left), when aging analytical instruments were replaced. CSN concentrations are reported with no adjustment for sampling artifacts; the "artifact corrections" that are subtracted from reported IMPROVE concentrations were accordingly added back in for these comparisons.

The Ratio of Total Aerosol Carbon to Sulfate in the Free Troposphere at MLO

B. Huebert, S. Howell and J. Zhuang

University of Hawaii, Department of Oceanography, Honolulu, HI 96720; 808-956-6896, E-mail: huebert@hawaii.edu

There are very few locations from which to make time-series measurements of free tropospheric aerosols, so MLO's location has a unique value. We have measured inorganic aerosol anions and cations and nitric acid vapor nightly at MLO for two decades. We find that Total Carbon (TC) maximizes in the springtime, just as sulfate, nitrate, and calcium do. This is attributed to Asian outflow. However, the TC concentrations at MLO are considerably smaller than those measured in the FT from aircraft during ACE-Asia, suggesting that chemical transport models might not be underestimating OC by as much as Heald et al. (2005) suggest. The ratio of TC to SO_4 is usually well below one at MLO, in sharp contrast to the higher values just off the Asian coast. Every week or so in the winter we see peaks as large as 0.5 µg TC/sm^3, but monthly average concentrations (Figure 1) are less than 0.1 ug TC/sm^3 in all months but April (0.25) and August (0.15).

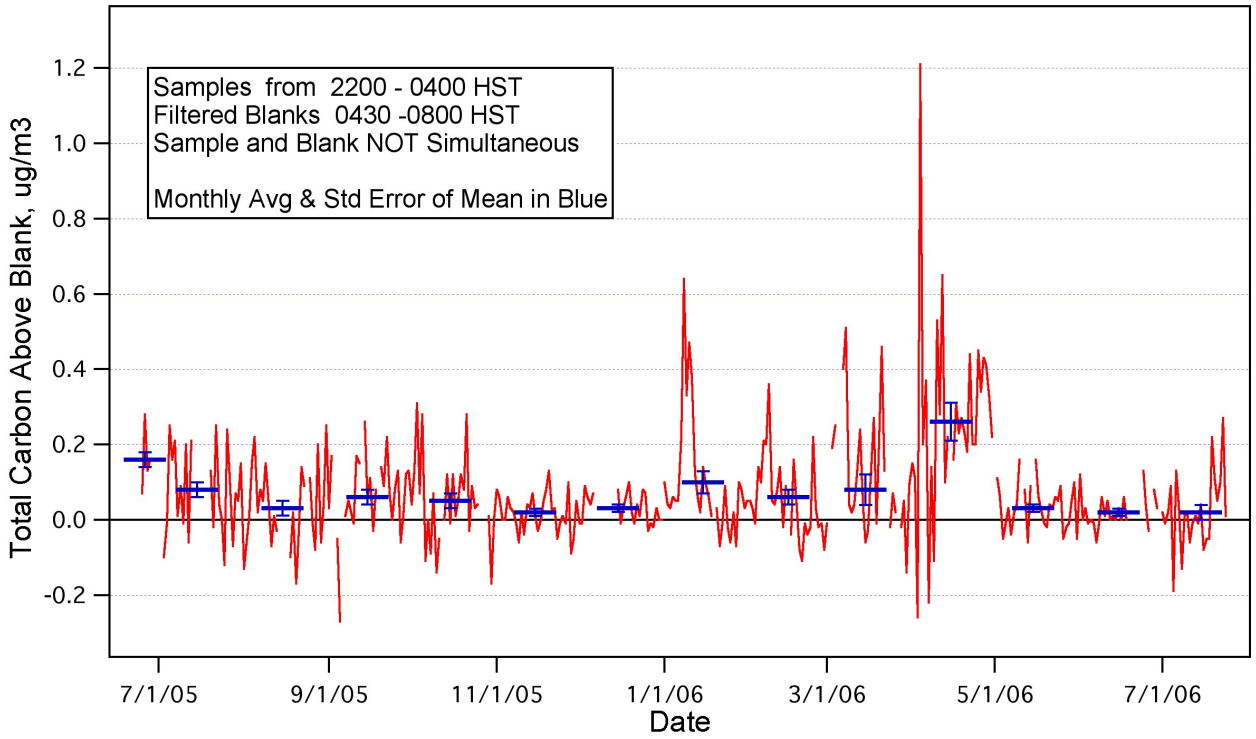

Figure 1. Daily (including noise) and monthly-averaged concentrations of Total Carbon at MLO.

Solar Radiation Data from Citizen Surface Stations Worldwide

R.B. Chadwick[1] and J.R. Chadwick[2]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6318, E-mail: Russell.B.Chadwick@noaa.gov
[2]Lockheed Martin, Colorado Springs, CO 80920

Since mid-February, 2009, downwelling solar radiation data from nearly one thousand surface stations, owned and operated by citizens worldwide, have been collected in an online database. The station locations are shown in Figure 1 below. The quality of these data are not well known and have not been studied. This presentation will give the results of a preliminary study on the comparison of some of these data with data from regularly calibrated NOAA Surface Radiation stations at seven sites around the country. More details are given at http://www.wxqa.com/lum_search.htm

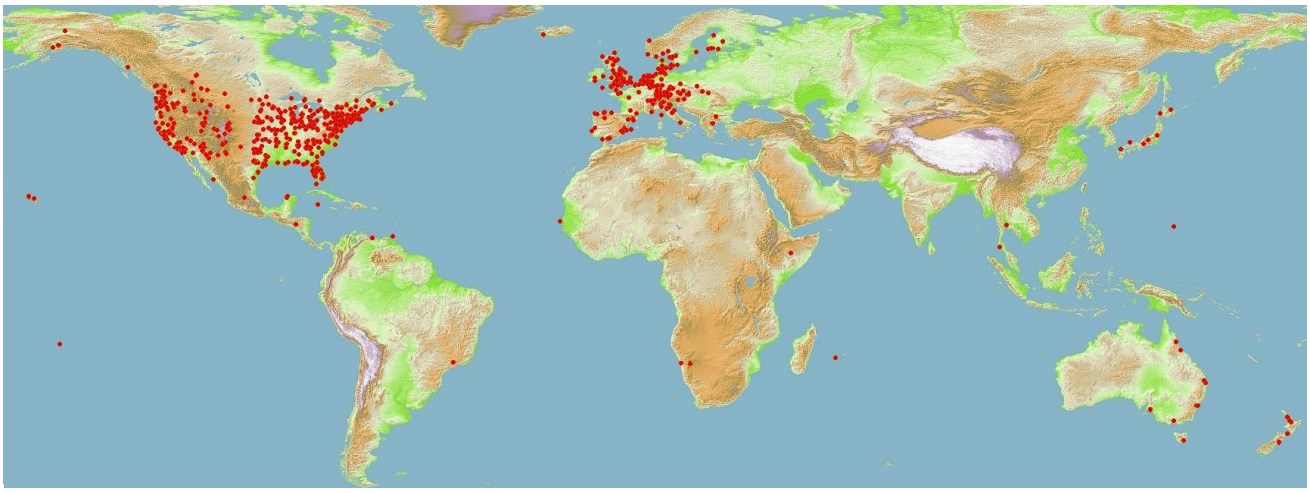

Figure 1. Locations of citizen surface stations contributing solar radiation data.

Surface Radiation at Globally Remote Sites: From Dimming and Brightening to Warming

E.G. Dutton[1], D. Nelson[1], D. Longenecker[2], M. Wild[3], R.S. Stone[2] and J. Wendell[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6660, E-mail: ells.dutton@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]Swiss Technical Institute, Zurich, Switzerland

Consistent, long-term, surface radiation observations have been acquired by ESRL from a remote, globally-distributed and climatically-diverse network for more than 30 years for the solar component and 15 years for the thermal IR. The downwelling solar and IR irradiances are major components of the net surface energy budget and are indicative of variations in atmospheric composition as well as the resulting impacts on atmospheric energetics influencing weather and climate. Each of the records, solar and IR from this and other networks have previously indicated interesting variations that warrant further monitoring. The solar irradiance records have indicated larger than anticipated decadal variations, first decreases in the early portion of the record, prior to the mid 1980s, then changing to increases. These features that have been referred to as "Global Dimming then Brightening", where the term "global" was originally intended to refer to the observed quantity at a particular site. Because a majority of reporting sites around the world appeared to be seeing a similar phenomenon, discussions arose at to whether the term "Global" could be appropriately applied in planetary or worldwide sense. An update on the most recent worldwide surface-base data as it applies to a possible extension of the brightening phase will be provided. The potential role of aerosols and recently suggested aerosol trends in explaining these variations will also be considered. However, taken over the entire period of record not net change in surface solar irradiance can be seen in the longest ESRL data. These variations also have a potential impact on renewable solar energy applications. Regarding the thermal or IR irradiance records, the continued evaluation of the anticipated and previously observed upward trends have now been compared to related results from 22 of the IPCC AR-4 GCM models. The relative agreement between the range of individual models and the observations can be used as one indicator of the model performance given that the comparison is appropriate considering spatial representativeness differences. The globally remote surface IR observations suggest a best-estimate rate of growth that exceeds the consensus of the 22 AR-4 models but that is in close agreement with a small subset of the models displaying the highest IR growth rates over the period of the observations, as shown in Fig. 1.

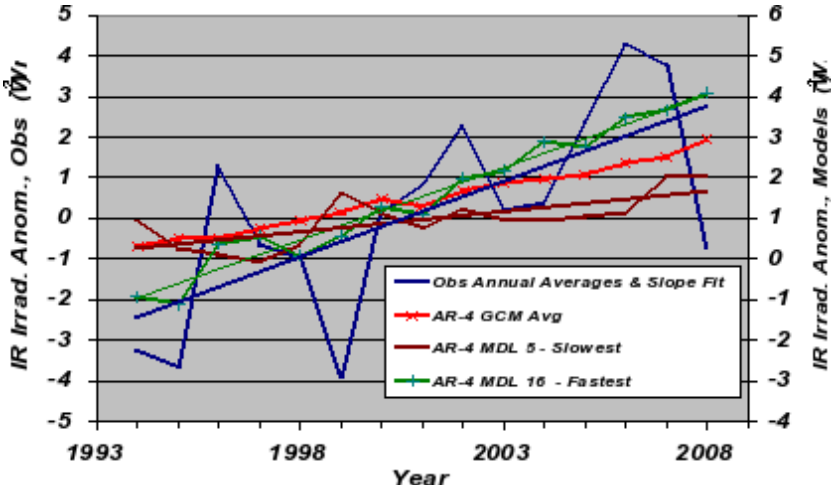

Figure 1. Comparison of IPCC AR4-modeled and ESRL-observed surface downwelling IR radiation, annual average anomalies averaged over 5 globally remote surface sites and corresponding model grid boxes. Right Y-axis shifted to account for different anomaly base periods.

A New Look at Antarctic Ozone Hole Recovery

D. Hofmann[1], S. Oltmans[2], B. Johnson[2] and J. Harris[3]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6966, E-mail: David.J.Hofmann@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Science and Technology Corporation, Boulder, CO 80305

There have been a number of estimates of when the Antarctic Ozone Hole will recover. These generally include two milestones following the cessation of ozone decline (which occurred about 2000), statistically significant evidence for the beginning of recovery (an ozone increase), and full recovery to 1980 ozone levels. The first attempt (Hofmann et al, 1997), using early estimates for the time evolution of Equivalent Chlorine (chlorine and bromine effects combined), gave approximately 2010 and 2050 for the two milestones. Improved estimates of Effective Equivalent Stratospheric Chlorine (EESC) levels for the future (Newman et al., 2006) indicated that the two recovery milestones for the area of the ozone hole (area within the 220 DU ozone contour) would be considerably later (2024 and 2068).

We have reanalyzed the ESRL Global Monitoring Division South Pole ozonesonde data for the 1986-2008 period (see figure 1 for 2006) and found that an exponential ozone loss rate during the September 7 to October 7 period best describes the data in most years. The exponential ozone loss rate (%/day) peaks sharply in the 16-18 km region (see figure 2), slightly below the observed active chlorine (ClO) peak of about 20-22 km. A parametric model using EESC and the stratospheric area of temperatures below the polar stratospheric cloud threshold was used to estimate ozone hole recovery from a South Pole ozone loss rate perspective. The model suggests a threshold EESC value (when ozone loss rate becomes >0) of about 2 ppmv and a saturation EESC value (above which the 16-18 km ozone loss rate does not increase any longer) of about 3.75 ppmv (which occurred about 1993). Two recovery milestones can be defined, when the 16-18 km ozone loss rate comes out of saturation and when full recovery is attained. These are, respectively, 2030-2032 and 2065-2070. It is estimated that the expected stratospheric cooling related to climate change will lengthen the recovery period by one to two years at most.

Hofmann, D.J., S.J. Oltmans, J.M. Harris. B.J. Johnson, and J.A. Lathrop, Ten years of Ozonesonde measurements at the south pole: Implications for recovery of springtime Antarctic ozone, *J. Geophys. Res.*, 102, 8931-8943, 1997.

Newman, P.A., E.R. Nash, S.R. Kawa, S.A. Montzka, and S.M. Schauffler, When will the Antarctic ozone hole recover? *Geophys. Res. Lett.*, 33, L12914, dot:10.1029/2005GL025232, 2006.

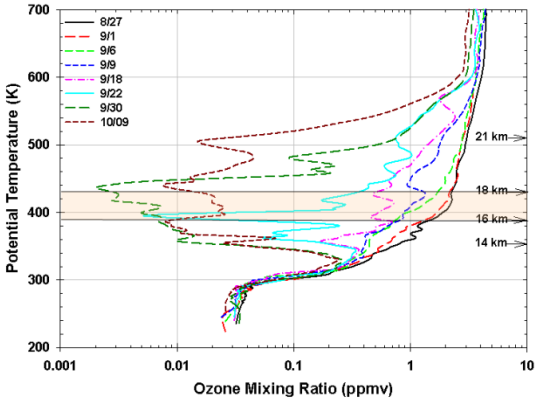

Figure 1. Ozone mixing ratio profiles at South Pole in 2006 during the formation of the ozone hole. The tan band marks the 16-18 km altitude region where the ozone loss rate is maximum.

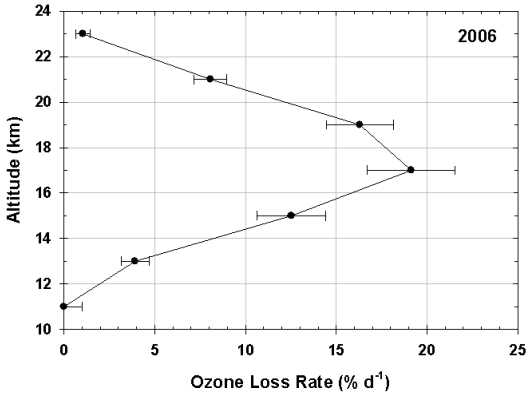

Figure 2. The ozone loss rate profile during September 7 to October 7 in 2006. The profile peaks at the astonishing rate of 15-20% per day in the 16-18 km region.

Toward a More Accurate Estimate of Global Stratospheric Aerosol Surface Area Density. Is It Important?

T. Deshler[1], J.L. Mercer[1], M. Kovilakam[1], D.J. Hofmann[2], J.M. Rosen[1], S. Solomon[2], J.F. Lamarque[3], P.J. Young[4], R.W. Portmann[2] and J.S. Daniel[2]

[1]University of Wyoming, Department of Atmospheric Science, 1000 E. Univ. Ave., Laramie, WY 82071; 307-766-2006, E-mail: deshler@uwyo.edu
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]National Center for Atmospheric Research, Boulder, CO 80303
[4]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Stratospheric aerosol, controlled primarily by the transport of tropospheric sulfur bearing molecules into the stratosphere, play important roles in the chemical and radiational balance of the atmosphere. While these aerosol are important radiationally only following major volcanic eruptions, chemically they play an important role in controlling NOx, ClOx, and HOx abundances, and thus O_3, during periods of both volcanic activity and long volcanic quiescence, such as now. Our current climatology of stratospheric aerosol is based primarily on the SAGE (1979-1982) and SAGE II (1985-2005) satellite records. In addition to these long-term global measurements there are several long-term lidar records (São José dos Campos, Brazil; Mauna Loa, Hawaii; Hampton, Virginia; and Garmisch-Partenkirchen, Germany), and *in situ* size distribution measurements from a number of sites, but primarily from Laramie, Wyoming.

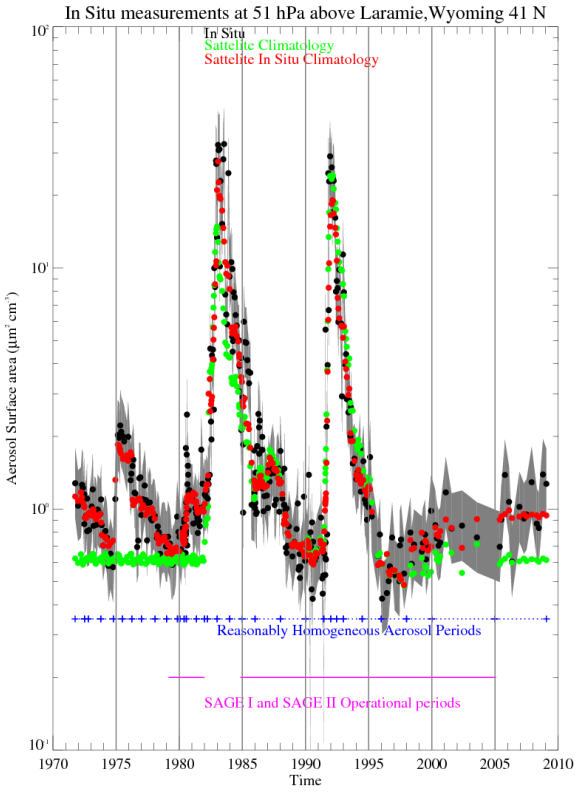

Figure 1. Stratospheric aerosol surface area densities from *in situ* measurements above Laramie, from the current surface area density climatology based on SAGE measurements (green), and from the SAGE climatology modified by comparison with the *in situ* measurements. The SAGE and SAGE II operational periods are shown as well as the time periods used to subdivide the record (in blue).

The *in situ* and SAGE II records of aerosol surface area density (SAD) compare favorably during periods of moderate to high aerosol loading, but diverge during periods of stratospheric background, *in situ* (SAD) ~ 2 * SAGE (SAD). In addition the *in situ* record precedes and antecedes the SAGE record. The present SAD climatology in use in the modeling community is based on the SAGE records with simple extrapolations applied prior to 1979 and post 2005. The *in situ* record extends from 1971 to 2009. Here the *in situ* record is compared to the SAD climatology above Laramie to form a temporally dependent "corrected" SAD profile. This correction, adjusted to account for transport differences between the northern and southern hemisphere (primarily important for Fuego in 1974), is then applied to produce a "corrected" global SAD climatology from 1971-2009. The corrections become important for the extrapolated periods and the periods of volcanic quiescence in the present climatology. Experimental runs of the community atmosphere model, with the chemical package, using the standard and corrected SAD climatology are in progress. The impact of the corrected SAD climatology on modeled stratospheric ozone over the past 38 years will be compared to model predictions using the standard climatology. During this time chlorine has ranged from pre ozone-hole levels to its recent stratospheric maximum. Results from this comparison will be shown along with the basis for the corrected climatology.

The GCOS Reference Upper Air Network (GRUAN)

H. Vömel[1], F.H. Berger[1], H.J. Diamond[2], J. Dykema[3], F.J. Immler[1], D. Goodrich[4], W. Murray[4], T. Peterson[2], D. Seidel[2], M. Sommer[1], D. Sistsserson[5], P. Thorne[6] and J. Wang[7]

[1]Deutscher Wetterdienst, Am Observatorium 12, Tauche / Lindenberg 15848, Germany; +49-33677-60244, E-mail: Holger.Voemel@dwd.de
[2]NOAA National Climatic Data Center, Silver Spring, MD 20901
[3]Harvard University, Cambridge, MA 02138
[4]NOAA Climate Program Office, Silver Spring, MD 20901
[5]Argonne National Laboratory, Argonne, IL 54511
[6]Met Office Hadley Centre, Exeter EX1 3PB, United Kingdom
[7]National Center for Atmospheric Research, Boulder, CO 80304

The global upper-air observing network has provided observations for operational weather forecasting for decades, but these observations have shown to be limited to understand upper air climate change. Consequently, the scientific community faces uncertainty on such key issues as the trends of upper air temperature or water vapor. To address these shortcomings, and to ensure that future upper air climate records will be more useful than records to date, the Global Climate Observing System (GCOS) program initiated the GCOS Reference Upper Air Network (GRUAN). This network will provide reference observations of a number of essential climate variables in the troposphere and stratosphere, in particular temperature and water vapor. When fully implemented, GRUAN will be a network of about 30 observatories with a representative sampling of global climatic regions. The network will strongly build on existing networks and utilize existing capabilities, while expanding on upper-air reference observations of key climate variables, such as temperature, water vapor, geopotential height, wind, and a number of additional parameters. GRUAN will strongly focus on vertically resolved measurement uncertainties as a tool for quality quantification. It will use a combination of routine and specialized radiosondes together with complementary remote sensing instrumentation to assure long-term stability, to identify observational weaknesses, and to manage instrumental change, which is one of the most difficult challenges for long-term climate observations. The network will not be globally complete but will serve to constrain and adjust data from more spatially comprehensive global observing systems including satellites and the current radiosonde networks.

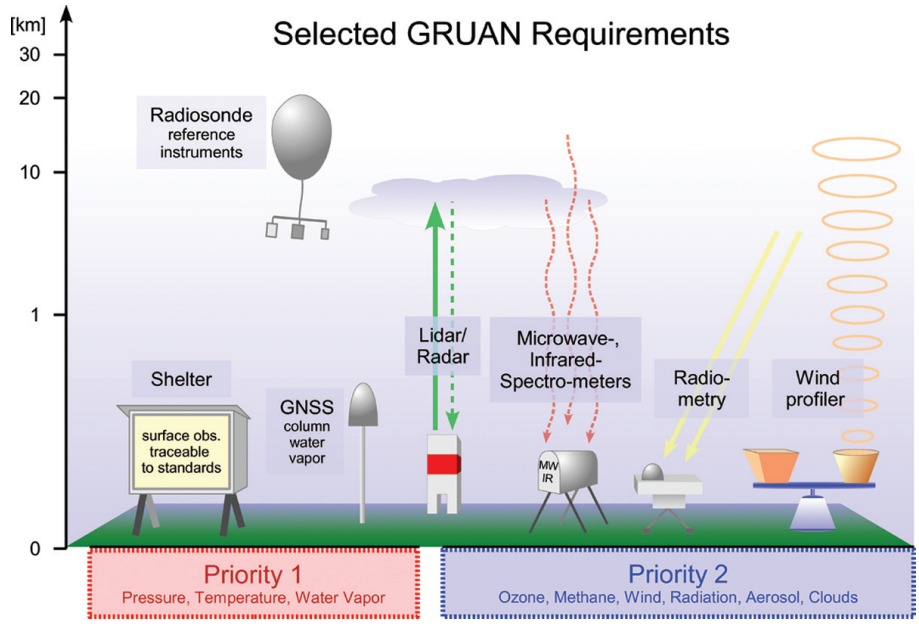

Figure 1. Proposed instrument suite at a typical GRUAN site.

Evidence for Recent Stratospheric Circulation Changes from Multiple Measurement Sources

E. Ray[1], F. Moore[1], J. Elkins[2], D. Hurst[1], K. Rosenlof[1], A. Engel[3] and S. Oltmans[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-7628, E-mail: eric.ray@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Institute for Atmosphere and Environment, J.W. Goethe University, Frankfurt 60325, Germany

Measured indicators of stratospheric circulation changes have been difficult to attain due to a lack of sufficient long-term stratospheric measurements. Several such datasets do exist however and each of them, such as stratospheric water vapor mixing ratios measured over Boulder, CO, suggest that changes have occurred in the stratosphere over the last 25 years. We show that the changes seen in the measured or measurement-based indicators of stratospheric circulation, including stratospheric water vapor measurements, a residual circulation calculation and age of air estimates, are consistent with each other. Collectively these datasets help to describe the two main features of recent stratospheric circulation changes: (1) a trend of increasing water vapor mixing ratios and age of air from 1980-2000, and (2) a large, persistent shift during the year 2000 towards increased mass flux in the lower stratosphere, decreased water vapor mixing ratios and decreased age of air. Global climate models have been unable to reproduce either the correct trend or the subsequent large shift in the stratospheric circulation. It is likely that these stratospheric changes are driven by changes in tropospheric wave activity that induces changes in both mean circulation and mixing between the tropics and extratropics. We will include a brief analysis of Eliassen-Palm flux divergence statistics calculated from the NCEP Reanalysis dataset as an indicator of wave driving of the stratosphere to begin to analyze the cause of the changes. We will also look for changes in measured stratospheric tracer-tracer correlations that can only occur due to circulation changes. These observed changes in the stratosphere provide a large constraint on global climate models and it is clearly important to more fully understand their causes.

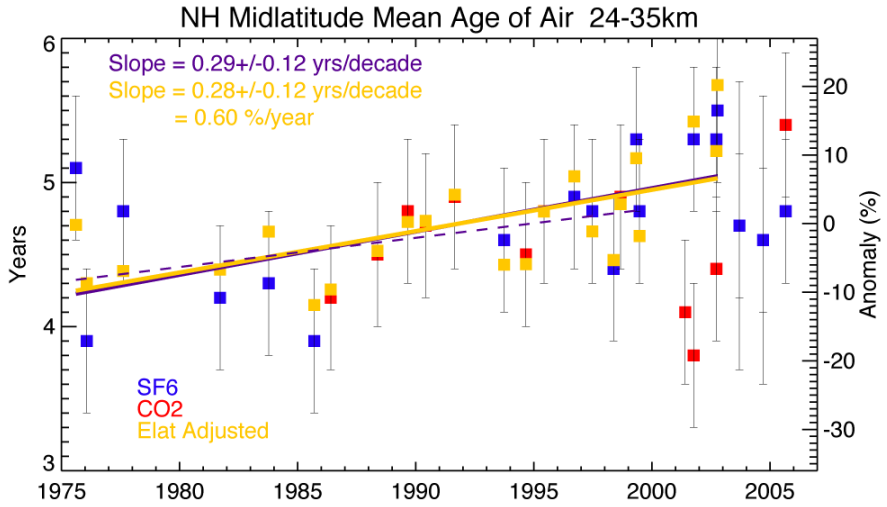

Figure 1. The figure shows mean ages in the 24-35 km altitude range calculated from SF_6 (blue squares) and CO_2 (red squares) measurements taken in various locations in the NH midlatitudes (Engel et al., 2008). Since the equivalent latitudes of the measurements ranged from 28-57°N we adjusted the mean age values by removing the linear fit of mean age vs. elat to reduce any bias in the trend related to measurement location. The yellow squares in the figure are the equivalent latitude adjusted mean ages. The calculated linear fits from 1975-2002 are very similar and are significantly positive whether using the original or elat adjusted mean ages. The main difference is that the goodness of fit is reduced by over 30% in the fit to the elat adjusted ages indicating that the spread in the data is significantly reduced by the equivalent latitude adjustment.

UV Products from NOAA-EPA Brewer (NEUBrew) Network

P. Kiedron, P. Disterhoft, K. Lantz, I. Petropavlovskikh and S. Stierle

Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-4937, E-mail: peter.kiedron@noaa.gov

The NEUBrew network is a collaborative monitoring and research effort between NOAA ESRL and EPA's Office of Air Quality, Planning and Standards (OAQPS). The network was established in the last half of 2006 by deploying MKIV Brewer spectroradiometers at six sites throughout the U.S. (University of Houston, TX, Table Mt., Boulder, CO, University of Colorado's Mountain Research Station, Niwot Ridge, CO, Rayleigh, NC, Bondville, IL, and Ft. Peck, MT). Each spectroradiometer was calibrated radiometrically and calibrated for the ozone retrieval. An optimized schedule to obtain the maximal duty cycle was developed. It includes measurements of O_3 and SO_2 columns from direct sun and zenith radiance; dawn and dusk Umkehr measurements, zenith radiance NO_2 measurements and UV global irradiance scans in the 286.5 - 363.0 nm range. Data processing includes extensive automated diagnostic tools. The results in graphical form are available via the web page[1] and the text files via the public ftp site[2]. UV irradiance went through first two levels of quality control: irradiances are radiometrically calibrated with CUCF lamps, corrected for artifacts and corrected for internal stray light. Irradiances are used to calculate erythema and UV index.

The UV index is compared with the 5-day forecast from the National Climate Prediction Center (NCEP). Umkehr data are processed daily to retrieve up to two (AM and PM) ozone vertical profiles. An additional extrapolation method was implemented to assess inter-annual ozone variability in troposphere. Ozone column level 2 data use a correction of the extraterrestrial constant (ETC) based on daily internal lamp measurements. Results are compared with daily OMI ozone. For some instruments that exhibited throughput drift of solar blind $NiSO_4$ filter, the correction is significant. Additionally, the ETC is verified against results from Langley plots. Raw data from O_3 and NO_2 measurements will also be used to retrieve aerosol optical depth (AOD) in 310 – 320-nm region and in 430-nm region.

[1] http://esrl.noaa.gov/gmd/grad/neubrew/
[2] ftp://ftp.srrb.noaa.gov/pub/data/neubrew/data/products/

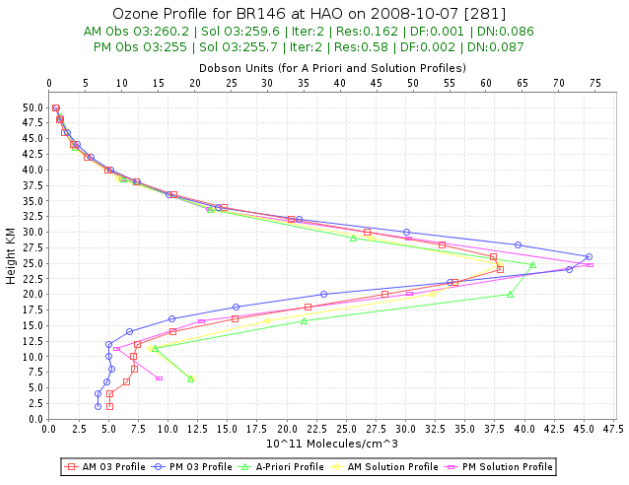

Figure 1. Ozone vertical profile retrieved with Umkehr method.

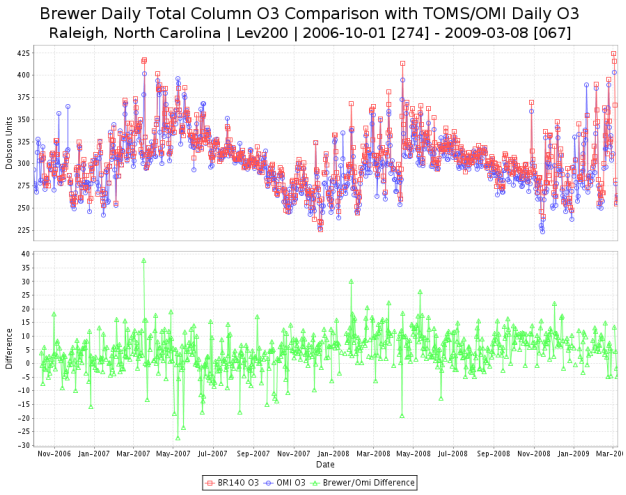

Figure 2. Daily average ozone column level 2 compared with OMI ozone.

Applications of COSMIC Radio Occultation for Climate Monitoring

S. Ho[1], Y.H. Kuo[1], D. Hunt[1], C. Rocken[1], W. Schreiner[1], S. Sokolovskiy[1], R.A. Anthes[1] and K.E. Trenberth[2]

[1]University Corporation for Atmospheric Research, COSMIC Program, P.O. Box 3000, Boulder, CO 80307; 303-497-2922, E-mail: spho@ucar.edu
[2]National Center for Atmospheric Research, Boulder, CO 80307

Global Positioning System (GPS) Radio Occultation (RO) is a powerful remote sensing technique to provide global all-weather vertical profiles of refractivity, which is a function of temperature, water vapor and pressure. The six-satellite COSMIC mission was successfully launched in April 2006. After the satellites were deployed to operational orbits, ~1,500-2,000 GPS RO soundings are available over the globe every 24 hours. The early phase of the COSMIC mission, when these six COSMIC receivers were closely located, provided a unique opportunity to test the precision of GPS RO measurements, because the independent RO signals travelled through nearly the same atmospheric paths. Comparisons from two COSMIC receivers show that the ranges of median values of dry temperature difference from surface to 30 km are within 0.05 K, and as small as 0.02 K from 3 km to 25 km. The precision of better than 0.05 K in the mean confirms that RO data are benchmark climate observations, and are ideally suited to monitoring climate variability and trends from the surface to 30 km. Applications of COSMIC RO data for climate monitoring are presented.

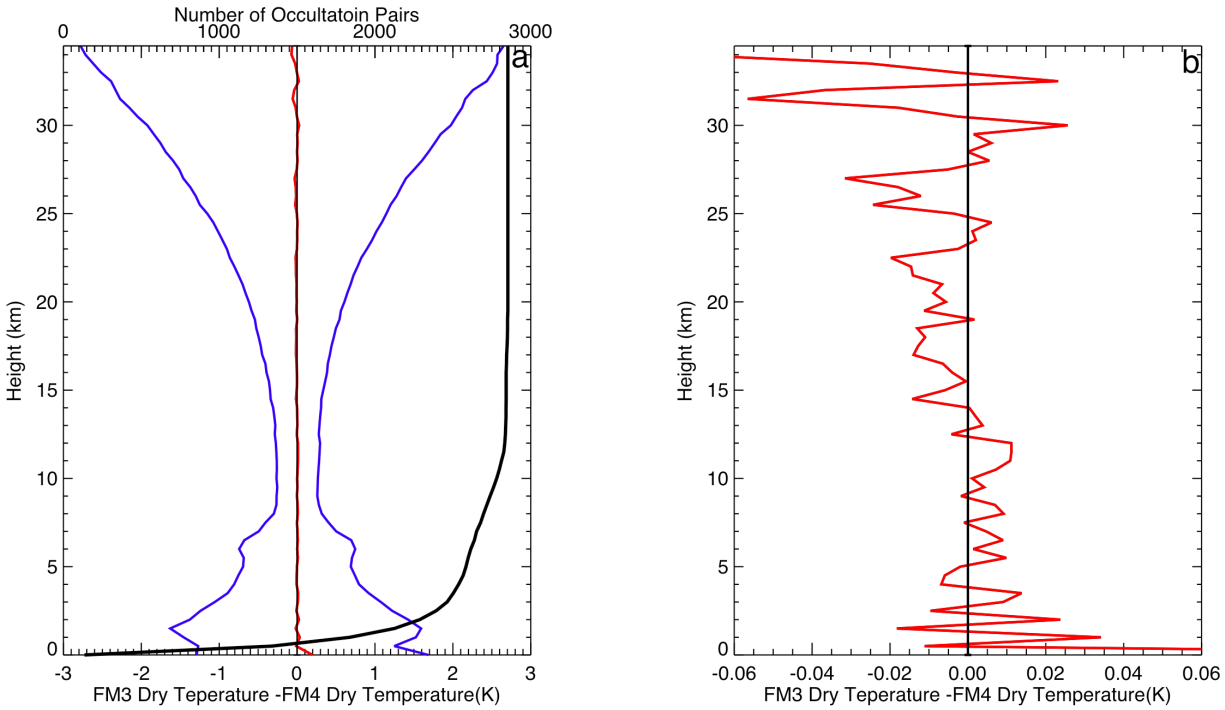

Figure 1. (a) The median and the median absolute deviation (MAD) of the dry temperature difference between two COSMIC satellites (FM3 and FM4) from 2006, day 111 through 300 where the distance between FM3-FM4 receivers is within 10 km. The red line is median, the blue line is MAD, and the black line is the number of the FM3-FM4 profile pairs used in the comparison at various vertical levels. (b) The median of the dry temperature difference between FM3-FM4 as in (a) but on a much smaller temperature scale in x-axis.

Behavior of Some TC-4 Atmospheric Parameters Measured by Balloonsondes and NASA Aircraft

A. Pino[1], S. Guerra[1], D. Castillo[1], A. Maturell[1], J. Espinoza[2], H. Samudio[1] and L. Jordán[1]

[1]Laboratory of Atmospheric Physics of the University of Panama, Ave. Simon Bolivar, El Cangrejo, Republic of Panama; 011-507-523-5328, E-mail: atmosfer@ancon.up.ac.pa
[2]Panama Canal Authority, Hydrometeorology Department, Republic of Panama

The Laboratory of Atmospheric Physics of the University of Panama collaborated with NASA TC-4 field campaign during July and August, 2007. To study the profiles of some atmospheric parameters, balloonsondes were launched twice daily from San José, Costa Rica and Las Tablas, Panama. One of these parameters is relative humidity whose daily vertical structure is associated with tropical deep convection. Relative humidity behavior through upper troposphere and lower stratosphere is very important in order to assess the contribution of water vapor to climate change, since water vapor is the most powerful greenhouse gas. Relative humidity, temperature and ozone profiles obtained from data collected with sondes launched from Panama and Costa Rica, during TC-4, are analyzed. Relative humidity profiles show inversion layers near 550 mb which are linked with deep convection processes occurred previously. Radiative forcing from maritime anvil cirrus plays an important role in the modulation of climate change, since these clouds have a cooling effect as a consequence of scattering incoming sunlight by cirrus ice crystals. But these clouds also have a warming effect due to the fact that they absorb upwelling thermal infrared radiation emitted from the surface. During TC-4, several coordinated flights of ER-2 (over the cirrus layer) and DC-8 aircraft (below the cirrus layer) were planned. A discussion of the incoming solar radiation budget as well as the thermal infrared radiation budget measured during the coordinated flights occurred on August 6, 2007, will be presented.

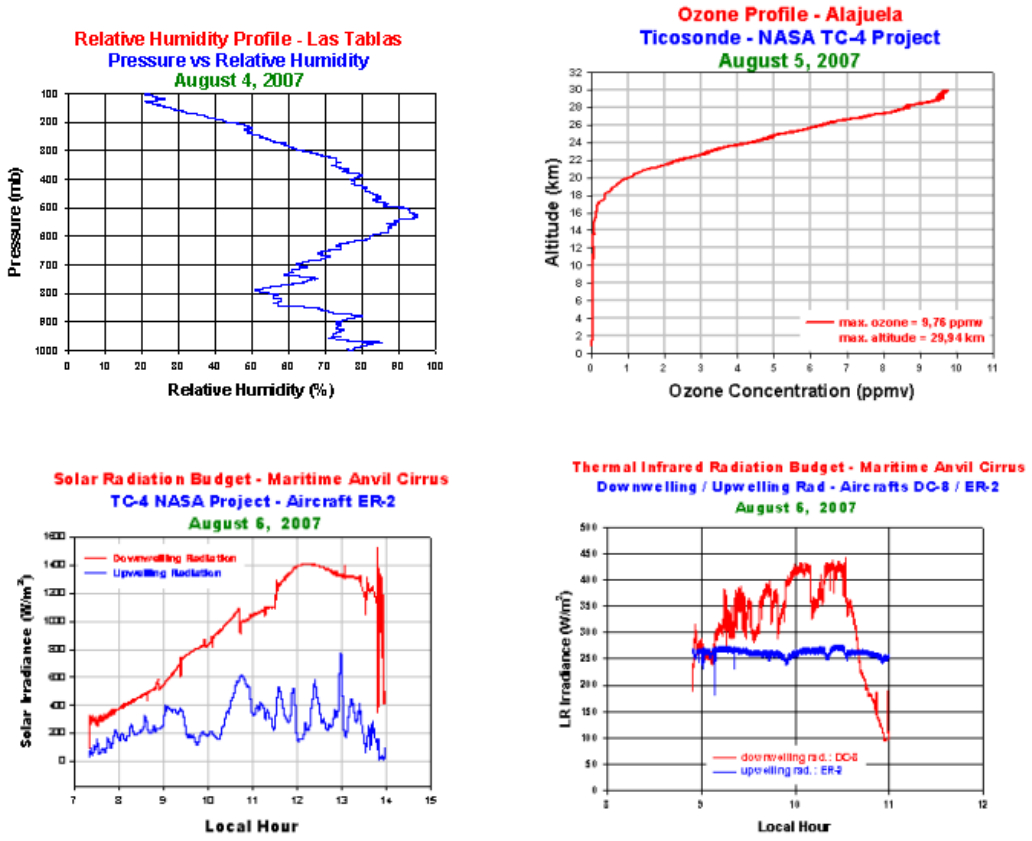

Figure 1. a) Relative humidity profile (Las Tablas). b) Ozone Profile (Alajuela). c) Solar Radiation Budget (Maritime Anvil Cirrus). d) Thermal infrared radiation budget (Maritime Anvil Cirrus).

Rapid Photochemical Production of Ozone at High Concentrations in a Rural Site During Winter

R.C. Schnell[1], S.J. Oltmans[1], M.S. Endres, J.V. Molenar[3], R.R. Neely[4] and A.B. White[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6733, E-mail: russell.c.schnell@noaa.gov
[2]Wyoming Department of Air Quality, Cheyenne, WY 82002
[3]Air Resource Specialists, Fort Collins, CO 80525
[4]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Ozone is an air pollutant that can cause severe respiratory health effects. Photochemical ozone production near the Earth's surface is considered a summertime, urban phenomenon, where hourly average ozone concentrations may exceed 150 ppb compared to background values of ~50 ppb, and wintertime U.S. ozone concentrations are generally 35-50 ppb. We have recently documented rapid, diurnal, wintertime, cold temperature, photochemical ozone production in the rural Upper Green River Basin (UGRB), Wyoming, in the vicinity of the Jonah-Pinedale Anticline (JPA) natural gas field, at air temperatures as low as -17°C. In these events, hourly average ozone concentrations rise from 10-30 ppb at night to >140 ppb shortly after solar noon, under the influence of a stagnant, high pressure system that promotes cold temperatures, low wind speeds and limited cloudiness. Under these conditions, intense, shallow temperature inversions develop in the lowest 100m of the atmosphere, that trap high concentrations of ozone precursors at night. During daytime, photolytic ozone production then leads to rapid daytime photolytic ozone production. We have recently also observed this phenomenon in NE Wyoming near a coal mining area, in a natural gas field in northern New Mexico, and in an urban area (Logan, Utah).

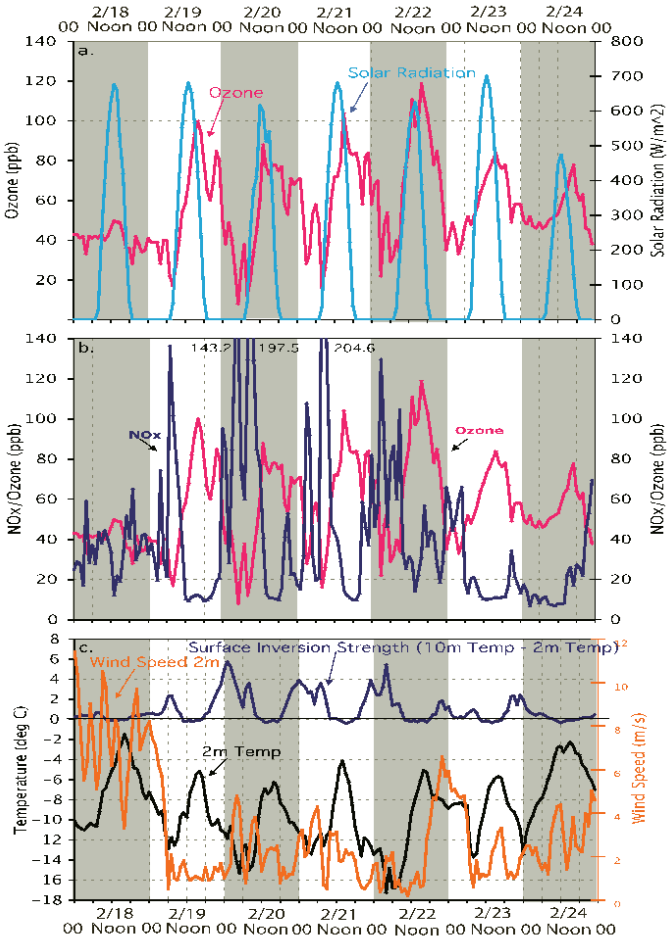

Figure 1. Hourly average solar radiation, ozone, NOx and temperature data for the Jonah air quality monitoring site, Feb 18-25, 2008 showing rapid ozone production closely tracking solar radiation with a 1-2 hour time lag and associated NOx, temperatures and winds.

2009 NOAA/ESRL GLOBAL MONITORING ANNUAL CONFERENCE

David Skaggs Research Center, Cafeteria
325 Broadway, Boulder, Colorado 80305 USA

POSTER SESSION AGENDA

(Only presenter's name is given; please refer to abstract for complete author listing)

Wednesday, May 13th, 2009: 1645-1830

- ***Carbon Cycle***

P-1 The Cape Verde Atmospheric Observatory (CVAO) Observatório Atmosferico De Cabo Verde: Humberto Duarte Fonseca – *K.A. Read (University of York, UK)*

P-2 Long-Term Decline in Global Ethane Levels, 1984-2008 – *I. Simpson (University of California, Irvine)*

P-3 Validation of *In Situ* Measurements for Analysis of CO_2, CH_4, and H_2O in Aircraft – *C. Sweeney (University of Colorado/CIRES)*

P-4 Vertical Profiles of CO, CH_4, and CO_2 above Poker Flat, Alaska, Molokai, Hawaii, and Rarotonga, Cook Islands – *P. Novelli (ESRL)*

P-5 Carbon Tracker – CH_4 – *L. Bruhwiler (ESRL)*

P-6 Quantifying CH_4 Emissions with Airborne Differential Absorption LIDAR Data – *S.V. Stearns (ITT, Space Division)*

P-7 Column CO_2 Estimates at ARM-SGP – *M.L. Fischer (Lawrence Berkeley National Lab)*

P-8 Comparison of LM3V and Carbon Tracker Data: Initial Results – *N. Golaz (Princeton Environmental Institute)*

P-9 Identification of Greenhouse Gas Source Signatures in the San Francisco Bay Area Using *In Situ* Aircraft Measurements – *A. Karion (University of Colorado/CIRES)*

P-10 Reconciling Modeled Ocean Carbon Fluxes with Atmospheric ^{13}C Observations – *C. Alden (University of Colorado/INSTAAR)*

P-11 Quantification of Fossil Fuel CO_2 Emissions from East Asia Using Atmospheric Observations of $^{14}CO_2$ – *J. Turnbull (ESRL)*

P-12 Carbon Tracker: Sensitivity to Potential Systematic Bias in CO_2 Observations – *K .Masarie (ESRL)*

P-13 Data Quality and Continuity for the ESRL/GMD Tall Tower Network – *A. Andrews (ESRL)*

P-14 Interpreting Dense CO_2 Measurements: Ensemble Filters vs. Variational Data Assimilation – *D. Baker (Colorado State University/CIRA)*

P-15 High Latitude Carbon Exchange Estimated From Co-Variation of CO_2 and Potential Temperature – *G. Keppel-Aleks (California Institute of Technology)*

P-16 Observing Regional CO_2 Plumes with an Airborne Differential LASER Absorption System – *T.S. Zaccheo (Atmospheric and Environmental Research, Inc.)*

P-17 On-Road Study of Colorado Front Range Greenhouse Gases Distribution and Sources – *G. Petron (University of Colorado/CIRES)*

- ***Ozone***

P-18 Continuous Tower-Based Tropospheric Ozone Measurements – *L.C. Patrick (University of Colorado/CIRES)*

P-19 Statistical Analysis and Estimation of the External Effects on the Total Ozone Field Over Russia in 1973-2007 – *E.A. Titova (Main Geophysical Observatory)*

P-20 Long-Term Ozone Trends in Umkehr Measurements at Japanese Stations – *K. Miyagawa (Japan Meteorological Agency)*

P-21 Boundary Layer Ozone Depletion Events Measured by Ozonesondes at Barrow, AK in 2009 – *B. Johnson (ESRL)*

P-22 Boulder and the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) – *D. Hurst (University of Colorado/CIRES)*

- ***Halocarbons and Other Trace Species***

P-23 Long-Term Monitoring and Trends of Halocarbons – *G.S. Dutton (University of Colorado/CIRES)*

P-24 A Comparison of Seasonal Cycles in Nitrous Oxide Among Different Monitoring Networks – *C.D. Nevison (University of Colorado/INSTARR)*

P-25 New Estimates of Global Sulfur Hexafluoride Emissions Using AGAGE and NOAA Measurements – *M. Rigby (Center for Global Change Sciences, MIT)*

P-26 Isotopic Constraints on the Global Budget of Atmospheric Nitrous Oxide: Analysis of Recent Data – *Y.L. Yung (California Institute of Technology)*

P-27 Improvements to the NOAA/GMD Cryogenic Frost Point Hygrometer (FPH), New Digital Control – *E. Hall (University of Colorado/CIRES)*

P-28 On the Definition of a European Baseline for Climate Altering Halogenated Gases – *F. Furlani (University of Urbino, Institute of Physics)*

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POSTER SESSION AGENDA (continued)

(Only presenter's name is given; please refer to abstract for complete author listing)

Wednesday, May 13th, 2009: 1645-1830

- ***Halocarbons and Other Trace Species (continued)***

P-29 Snapshot of Atmospheric Trace Gases "Pole to Pole" – Results From the HIPPO – *B.R. Miller (University of Colorado/CIRES)*
P-30 Global Trends in SF_6 from the Halocarbon Flask Sampling Network – *B. Hall (ESRL)*
P-31 START-08 and HIPPO: Airborne Projects of the HATS Group in ESRL/GMD – *F.L. Moore (University of Colorado/CIRES)*

- ***Aerosols and Radiation***

P-32 Decadal Brightening of Downwelling Shortwave in the Continental U.S. – *J. Augustine (ESRL)*
P-33 Shortwave Spectral Radiative Closure Studies at the ARM Southern Great Plains Climate Research Facility – *J. Delamere (Atmospheric & Environmental Research, Inc.)*
P-34 Aerosol Climatology for the ARM Climate Research Facility in North-Central Oklahoma: 1992-2008 – *J. Michalsky (ESRL)*
P-35 The NOAA/ESRL Airborne Aerosol Observatory: Climatology and Seasonal Variations of Aerosol Properties Over Central Illinois – *P. Sheridan (ESRL)*
P-36 The NOAA/ESRL Collaborative Global Surface Aerosol Monitoring Network – *P. Sheridan (ESRL)*
P-37 Measurements of Sub-Micron Particles Using an Ultra-High Sensitivity Aerosol Spectrometer (UHSAS) from the Mauna Loa Observatory during HAVAIKI, October and November, 2009 – *D.W. Toohey (University of Colorado)*
P-38 Synoptic Transport of Anthropogenic BC to the Arctic – *S. Sharma (Environment Canada)*
P-39 Spatial and Temporal Variations of Aerosol Optical and Chemical Properties at Five Canadian Sites – *S. Sharma (Environment Canada)*
P-40 Using a Camera LIDAR and Nephelometer for Aerosol Profiling – *J. Barnes (ESRL)*
P-41 Aerosol Single Scattering Albedo from Direst-to-Diffuse UV Solar Irradiance at the Table Mountain NEUBrewer Site – *K. Lantz (University of Colorado/CIRES)*

- ***Observatories, Cooperative Measurements and Global Databases***

P-42 Micro-Pulse LIDAR Network (MPLNET) Status and LIDAR Observations from the NOAA ESRL Trinidad Head Observatory Site – *T. Berkoff (Goddard Earth Science and Technology Center)*
P-43 Comparison of Barrow, AK and Tiksi, Russia Climate Variability Using Historical Meteorological Records – *L. Matrosova (University of Colorado/CIRES)*
P-44 The International Arctic Systems for Observing the Atmosphere – Synergistic Potentials with the NOAA Baseline Observatories – *T. Uttal (ESRL)*
P-45 A Real Time Display of Meteorological Parameters from the NOAA ESRL Baseline Observatories – *D. Endres (ESRL)*
P-46 Long-Term Climate Variability in the Area Surrounding Tiksi, Russia – *A. Makshtas (Arctic and Antarctic Research Institute)*
P-47 ARM Climate Research Facilities on the North Slope of Alaska: An Update on Field Campaigns, Instruments, and Team Changes in 2008, IOPs and Changes in Facilities Planned for 2009 – *M.D. Ivey (Sandia National Laboratories)*
P-48 Chemical Precipitation on the Russian Arctic Territory – *A.I. Polischuk (Main Geophysical Observatory)*
P-49 Detection and Characterization of Systematic Errors in Atmospheric Models – *S. Gutman (ESRL)*
P-50 Zero Waste: A Practical and Effective Approach to Reducing Human Impacts on Climate – *M.J. Heller (University of Colorado/CIRES)*
P-51 Wind-Flow Characteristics at the Heights of Modern Wind Turbines from LIDAR Measurements – *Y.L. Pichugina (University of Colorado/CIRES)*
P-52 The Nonhydrostatic Icosahedral Model – *Jin-l Lee (ESRL)*
P-53 Ozone Characteristics on Mt. Kenya and Nairobi (Kenya) – *J. Nguyo (Kenya Meteorological Department)*
P-54 Hardware and Software Improvements to the Epply Solar Tracker – *A. Jordan (Science Technology Corporation)*
P-55 Carbon Monoxide as an Indicator of Ozone Concentration – *J. Mitei (Kenya Meteorological Department)*
P-56 Temporal Patterns on Stratospheric Ozone and Nitric Oxide over a Tropical Station and their Connection to Sea Surface Temperatures – *M. Muthama (Department of Meteorology, University of Nairobi)*
P-57 Climate Change Signals and Global Atmospheric Watch Activities in Kenya – *C.C.Okuku (Kenya Meteorological Department)*

The Cape Verde Atmospheric Observatory (CVAO) Observatório Atmosferico De Cabo Verde: Humberto Duarte Fonseca

K.A. Read[1], A.C. Lewis[1], J.D. Lee[1], S.J. Moller[2], L.M. Neves[3], A. Mahajan[4], H. Oetjen[4], J.M.C. Plane[4] and L.J. Carpenter[2]

[1]National Centre for Atmospheric Science, University of York, Department of Chemistry, York YO105DD, United Kingdom; 0044-1904-43256, E-mail: km519@york.ac.uk
[2]University of York, York YO105DD, United Kingdom
[3]Instituto de Nacional de Meteorologia and Geofisica, Mindelo CP15, Cape Verde
[4]University of Leeds, Leeds LS2 9JT, United Kingdom

The Cape Verde Atmospheric Observatory (16.848°N, 24.871°W), a subtropical marine boundary layer atmospheric monitoring station situated at Calhau on the island of São Vicente, has been in operation since October 2006. Almost continuous measurements of the trace gases O_3, CO, NMVOC, NO, NO_2, NOy, (including more recently PANs, alkyl nitrates, nitrate aerosol, and HNO_3) have been obtained. Halocarbons (University of Bristol, UK) have been added to the suite in addition to various physical and chemical measurements of aerosol (Leibniz-Institut für Troposphärenforschung, Leipzig, Germany), and greenhouse gases such as CO_2, CH_4, N_2O, and SF_6 (Max Planck Institute fur Biogeochemistry, Jena, Germany). Over the last three years the observatory has supported additional short-term measurements of IO, BrO (University of Leeds, UK, University of Heidelberg, Germany), radiometry, and aerosol filtration, and has also been host to some campaign-style field measurements (RHaMBLe Reactive Halogens in the Marine Boundary Layer) project in Spring/Summer 2007: http://www.york.ac.uk/capeverde/RHaMBLe.html and SOS (Seasonal Oxidant Study) project in 2009: http://www.york.ac.uk/capeverde/SOS.html. The site is a contributing site to the GAW (Global Atmospheric Watch: http://gaw.empa.ch/gawsis/) network with data regularly uploaded to the WDCGG (World Data Centre for Greenhouse Gases: http://gaw.kishou.go.jp/wdcgg/) and in November 2006 it took part in an audit of the NMVOC measurements, executed by the Central Calibration Laboratory, IMK-IFU, Garmisch-Partenkirchen, Germany. Audits for the other measurements will hopefully follow this year. Funding has been granted until 2011 through various initiatives such as NCAS (National Centre for Atmospheric Science as National Capability: http://www.ncas.ac.uk/), and TENATSO (http://tenatso.ifm-geomar.de/) but provided the site meets expectations with regard to data quality and relevance, further funding will be sought to establish it as a continuing long-term observatory. If you are interested in "doing science" at the CVAO please contact Katie Read at km519@york.ac.uk. The site web pages can be found at www.york.ac.uk/capeverde.

Figure 1. The CVAO complete with newly erected wind turbine.

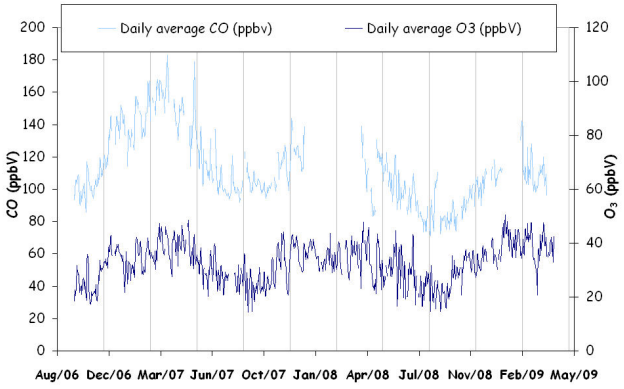

Figure 2. Daily average O_3 and CO measurements from the CVAO.

Long-Term Decline in Global Ethane Levels, 1984-2008

I. Simpson, S. Meinardi, F.S. Rowland and D. Blake

University of California at Irvine, Irvine, CA 92697; 403-529-6089, E-mail: isimspon@uci.edu

Ethane is the most abundant non-methane hydrocarbon in the remote atmosphere. In an estimated budget of 15 Tg C yr^{-1}, it is believed to have two anthropogenic sources (biomass burning, 5.6 Tg C yr^{-1}, and fossil fuel, 4.8 Tg C yr^{-1}) and two natural sources (vegetation, 4.0 Tg C yr^{-1}, and oceans, 0.8 Tg C yr^{-1}) [IPCC, 2001]. As part of our long-term global monitoring network, which is based on seasonal whole air sampling using 2-L stainless steel canisters, we have measured the global ethane mixing ratio almost every season since 1984. During the past two decades there has been a remarkable long-term decline in global ethane levels of roughly 180 pptv (23%), from 791 ± 19 pptv in 1986 to 611 ± 10 pptv in 2008 (±1σ) (Figure 1). This long-term decline, which was more pronounced prior to 2000, is superimposed with short-term fluctuations every 3½ to 4½ years that are reminiscent of the short-term fluctuations in methane's growth rate. Because methane and ethane share only two common anthropogenic sources (biomass burning and fossil fuel) these results place important qualitative and quantitative constraints on the causes of methane's changing growth rate. Indeed, our most recent preliminary analysis using December 2008 data suggests that, for the first time in 24-years of simultaneous measurements, ethane and methane may be deviating from one another. These and other results will be discussed in the poster.

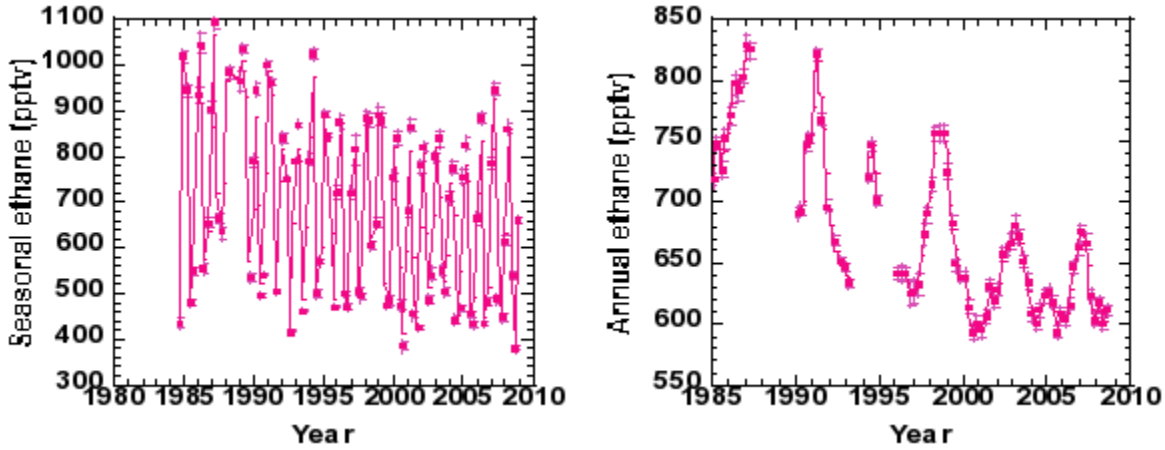

Figure 1. Global seasonal ethane mixing ratios (left) and global annual ethane mixing ratios (right) from Sep 1984 to Dec 2008. Each annual mixing ratio is plotted at the temporal mid-point of the year from which the average was calculated (e.g. Aug 1, 2008 for [Mar 2008 to Dec 2008]). The data are fit by an interpolated curve, i.e. a curve that passes through the data points and matches the slope at those points.

Validation of *In Situ* Measurements for Analysis of CO_2, CH_4 and H_2O in Aircraft

C. Sweeney[1] and E. Crosson[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado 80309; 303-497-4771, E-mail: colm.sweeney@noaa.gov
[2]Picarro Inc, Sunnyvale, CA 94085

As the NOAA ESRL Carbon Cycle Group Aircraft Project grows there has been a significant effort to develop the capability to make *in situ* measurements of CO_2, CH_4 and CO for short-term campaigns as well as long-term monitoring. In particular, we are currently focused on participating with In-Service Aircraft for the Global Observing System (IAGOS) which will utilize both Airbus A340 and A330 aircraft for regular sampling throughout Europe, Asia and North America on commercial aircraft. The goal of this development project has been to create an instrument which is stable under conditions where ambient temperature, humidity and pressure are likely to change rapidly. Because access to the instrument will be limited, the need for consumables will have to be limited. The instrument must therefore be able to accurately measure air that has not been chemically or cryogenically dried and with minimized reliance on standards. The result of putting 10 instruments on commercial aircraft could provide up to 21,000 profiles per year which would be an enormous increase over the current 450 profiles collected at 16 sites around North America each year.

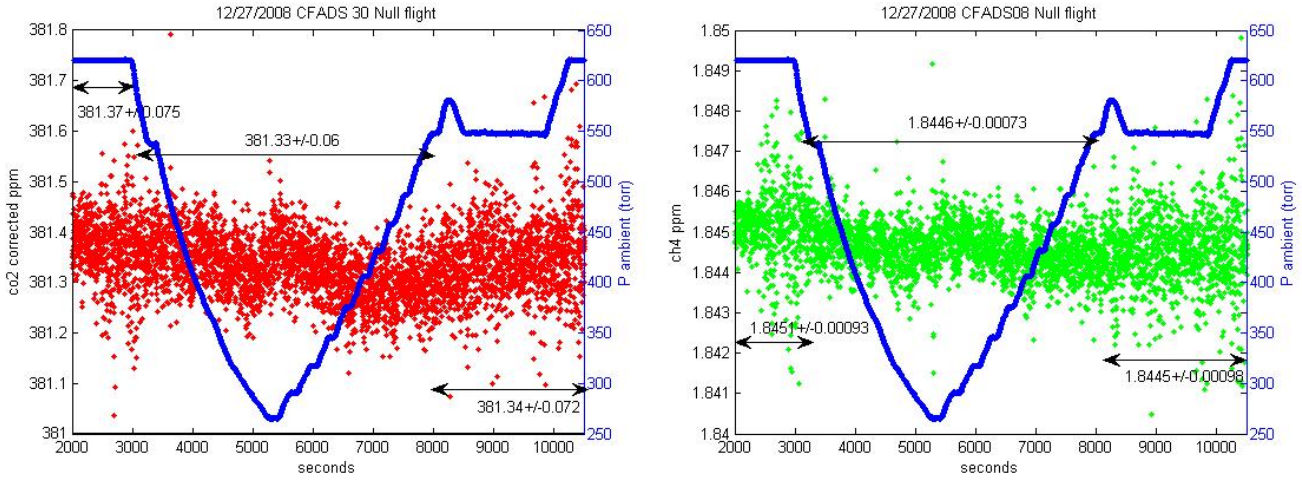

Figure 1. Null test for flight in Cessna 210 over Briggsdale, CO on December 27, 2008 for CO_2 and CH_4. By sampling a single standard for the duration of the 2.5 hour flight it can be shown that the instrument pressure (blue line) and ambient temperature (not shown but varied by 10°C) resulted in only small changes in the instrument noise or bias throughout the duration of the flight.

Vertical Profiles of CO, CH_4 and CO_2 Above Poker Flats, Alaska, Molokai, Hawaii and Rarotonga, Cook Islands

P. Novelli[1], T.J. Conway[1], E.J. Dlugokencky[1], D.W. Guenther[2], P.M. Lang[1] and K.A. Masarie[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6974, E-mail: paul.c.novelli@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Between 1999 and 2007 vertical profiles of carbon monoxide (CO) were measured as part of the validation plan for the MOPITT instrument (positioned on the TERRA satellite). Air samples were collected bimonthly with 300-500 m resolution between 0.5 and 8 km above Poker Flats, Alaska (PFA; 65.1°N 147.5°W), Molokai, Hawaii (HAA; 21.4°N 157.2°W) and 0.5 and 6km above Rarotonga Cook Islands (RTA; 21.2°S 159.6°W). CO_2 and CH_4 were also measured in the air samples. The seven-year timeseries provide a rare picture of the vertical distributions, seasonal cycles and interannual changes of these gases. Here we will compare results from Alaska, Hawaii and Rarotonga. A key feature of the over 750 measured profiles is their high degree of temporal and spatial variability. Within a profile, discreet enhancements in one species are often mirrored in the other carbon gases suggesting a common source or transport from source areas. Above Poker Flats and Molokai, the seasonal cycles of the three gases are well defined. The timing of the seasonal maximum and minimum at altitude lagged up to a month behind the surface and amplitudes of the cycles decreased with altitude. In the low Southern Hemisphere, the seasonal amplitude was greater at altitude and more similar in timing throughout the column. Seasonal cycles of CO_2 simulated with the TM5 (a chemical transport model) compare well with the measurements.

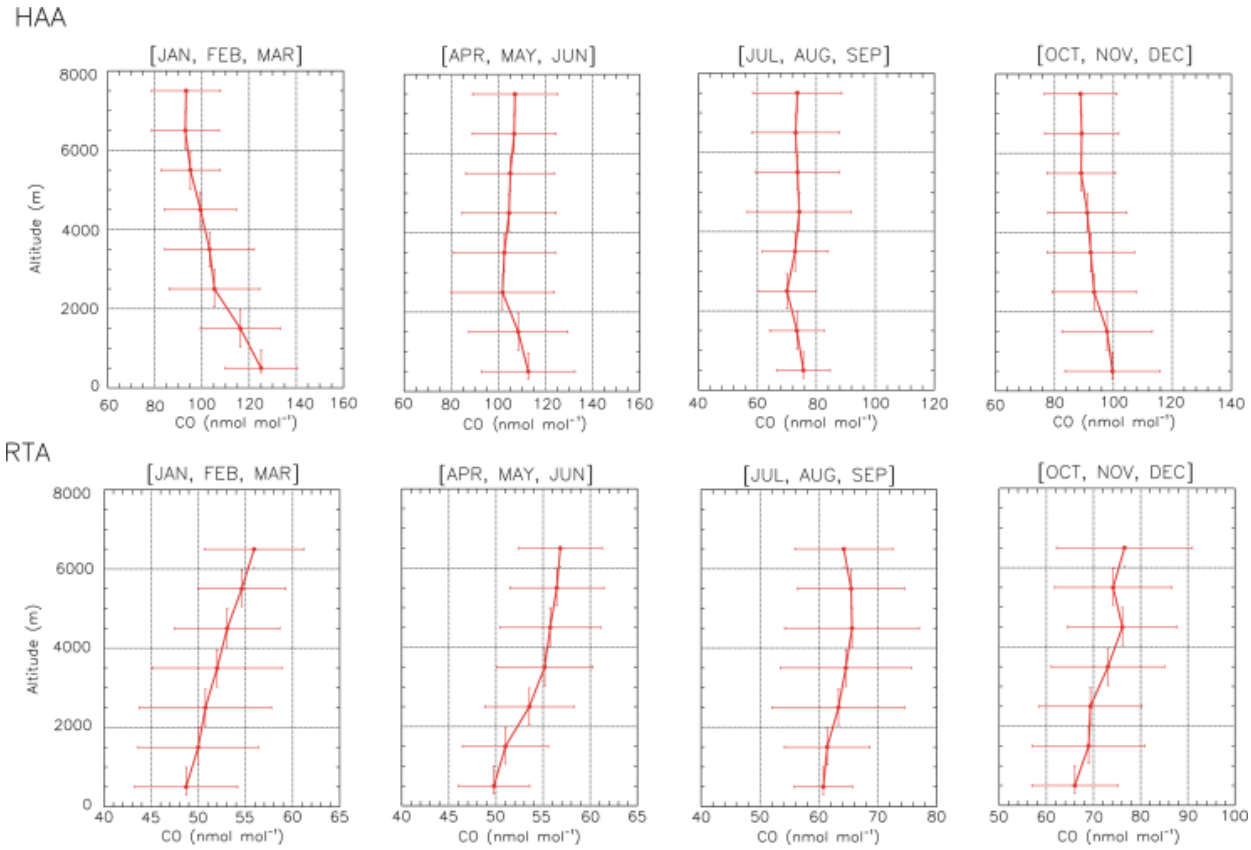

Figure 1. Seasonally averaged vertical profiles of CO above HAA and RTA. Mixing ratios above HAA show a decrease with altitude in winter, likely due to vertical mixing of polluted surface air. CO tends to increase above RTA suggesting transport from either the NH or South America and Africa.

Carbon Tracker - CH_4

L. Bruhwiler, E. Dlugokencky, K. Masarie and P. Tans

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6921, E-mail: lori.bruhwiler@noaa.gov

We present first results from an assimilation system designed to produce ongoing estimates of atmospheric methane sources and sinks using ESRL network observations, the TM5 atmospheric transport model and an ensemble Kalman Smoother. The inversion covers the time period 2000 through 2007. Notable features of the flux estimates include interannual variability of emissions from wetlands, and a shift of maximum emissions towards later in the growing season for high Northern Boreal regions. We examine the partitioning of the methane budget between anthropogenic and natural sources, as well as the attribution of interannual variability.

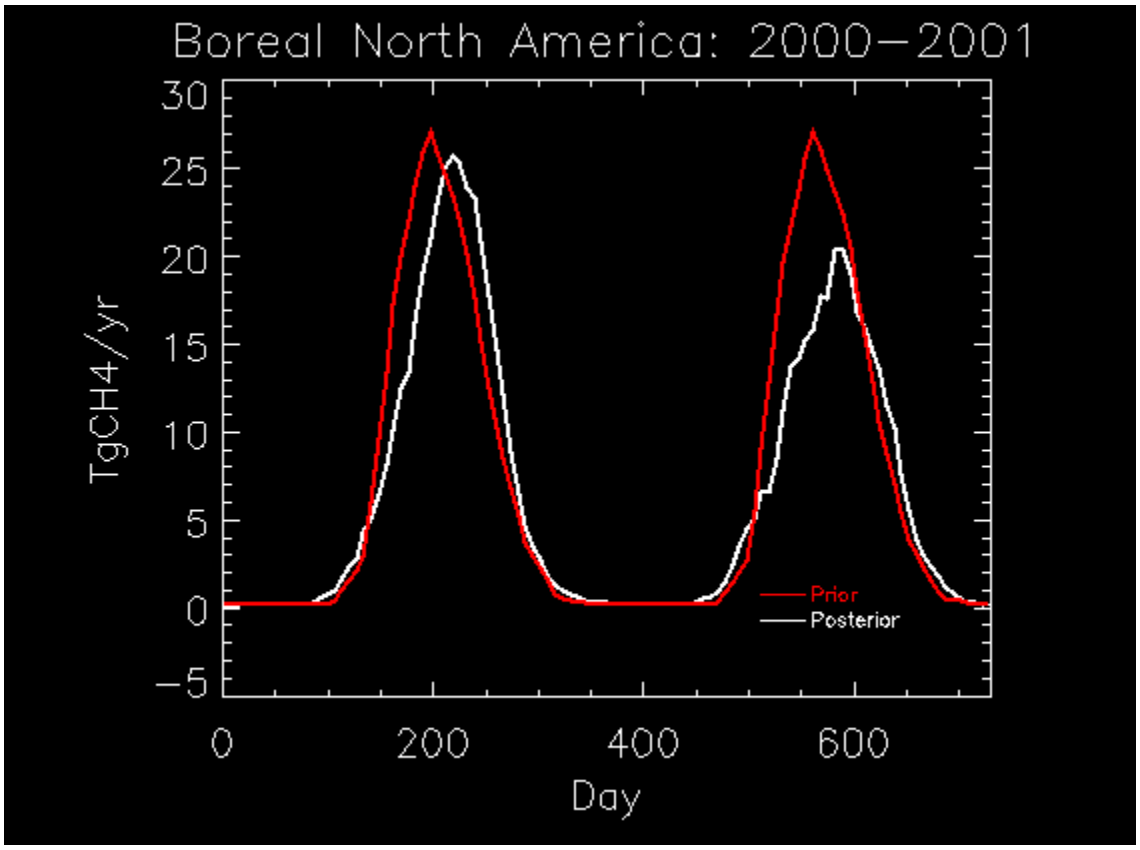

Figure 1. Estimated methane fluxes from Boreal North American wetlands for two years. The maximum emissions are shifted later in the growing season, and the fluxes vary considerably between the two years.

Quantifying CH_4 Emissions with Airborne Differential Absorption Lidar Data

S.V. Stearns[1], J. Lippert[2] and D. Brake[1]

[1]International Telephone & Telegraph, Space Systems Division, 2600 Park Tower Drive, Suite 601, Vienna, VA 22180; 703-342-1623, E-mail: steven.stearns@itt.com
[2]Far Field Consulting, Rochester, NY 14606

A new laser-based technique for airborne quantification of methane emission rates has been developed and in early tests has proven to be quick and efficient. Methane is the second most important anthropogenic greenhouse gas in the atmosphere. Sources of methane include emissions from landfills, natural gas production, transportation and distribution, coal mining, coal bed methane development, and agriculture. Methane emissions which are diffuse or poorly located have traditionally been difficult or impossible to quantify with existing techniques. The CH_4 plume quantification technique uses airborne differential absorption lidar (DIAL) data collected using ITT's Airborne Natural Gas Emission Lidar (ANGEL) Service combined with wind data. During a series of flight tests in April 2008, the quantification technique proved to be accurate within 28% in calculating the emission rate of known calibration leaks. Over the past 18 months, working with 3 separate commercial pipeline owners in the United States and Canada, researchers have quantified a total of 66 simulated pipeline leaks. Airborne estimates matched the calibrated release rates within a factor of two >73% of the time. The major source of error in measuring emission using airborne DIAL data is in the accuracy of the associated wind data. In March 2009, for the first time airborne DIAL data was used to estimate methane emissions from a landfill in upstate New York (Fig. 1). A single landfill was measured to be emitting between 800 and 2,100 tons of methane per year. Work is underway to extend this work to include airborne CO_2 DIAL measurements.

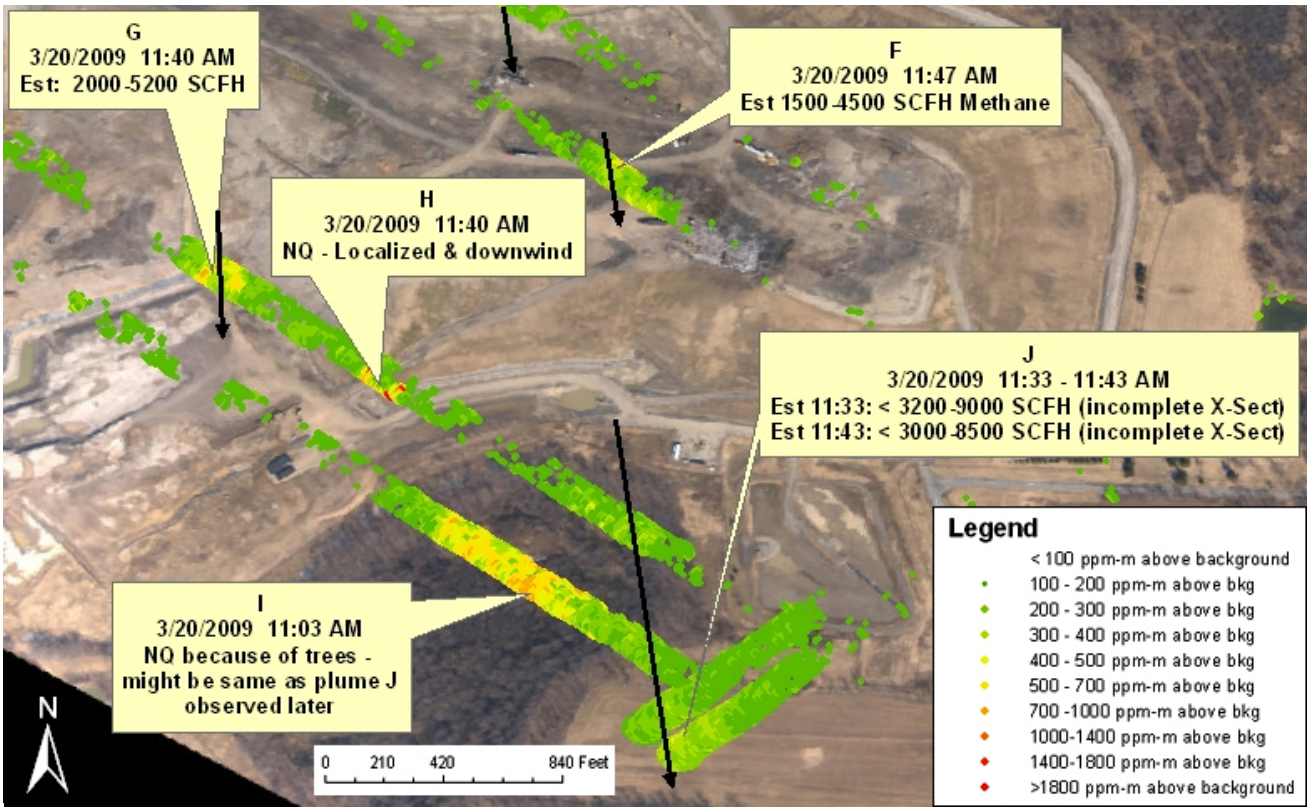

Figure 1. Quantification of multiple CH_4 plumes from an operating landfill using airborne DIAL data. Measurements were collected in 6 separate passes and CH_4 concentrations above background are represented in shades of green, yellow and red. Wind data for this collection was obtained from the closest NWS weather station.

Column CO_2 Estimates at ARM-SGP

M.L. Fischer[1], D. Wunsch[2], S. Biraud[1], J.L. Blavier[3], N. Honsowetz[2], G. Keppel-Aleks[2], C.E. Miller[3], C.M. Roehl[2], C. Sweeney[4], J. Smith[5], G.C. Toon[3], M.S. Torn[1] and P.O. Wennberg[2]

[1]Lawrence Berkeley National Laboratory, MS 90K-125, 1 Cyclotron Rd., Berkeley, CA 94720; 510-486-5539, E-mail: mlfischer@lbl.gov
[2]California Institute of Technology, Pasadena, CA 91125
[3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109
[4]NOAA Earth Systems Research Laboratory, Boulder, CO 80305
[5]Atmospheric Observing Systems, Boulder, CO 80301

We report on column CO_2 estimates from the ARM Climate Research Facility in the Southern Great Plains (36.6053° N, 97.4891° W, near Lamont, Oklahoma). Data include multi-year variations in midday near-surface (60 m) CO_2 mixing ratios, a multi-year record of periodic CO_2 profiles (to ~ 5 km) from a small aircraft, and initial column CO_2 retrievals made with a Fourier transform spectrometers (FTS) deployed at the SGP site. Using *in situ* CO_2 mixing ratio measurements, we estimate column CO_2 over time and compare with the FTS retrievals. We also evaluate the temporal variations in estimated column CO_2 at SGP as well as the relative contributions to variation with altitude along the vertical profile. These results provide an initial evaluation of the FTS retrievals at ARM-SGP in preparation for comparisons with future validation of GOSAT.

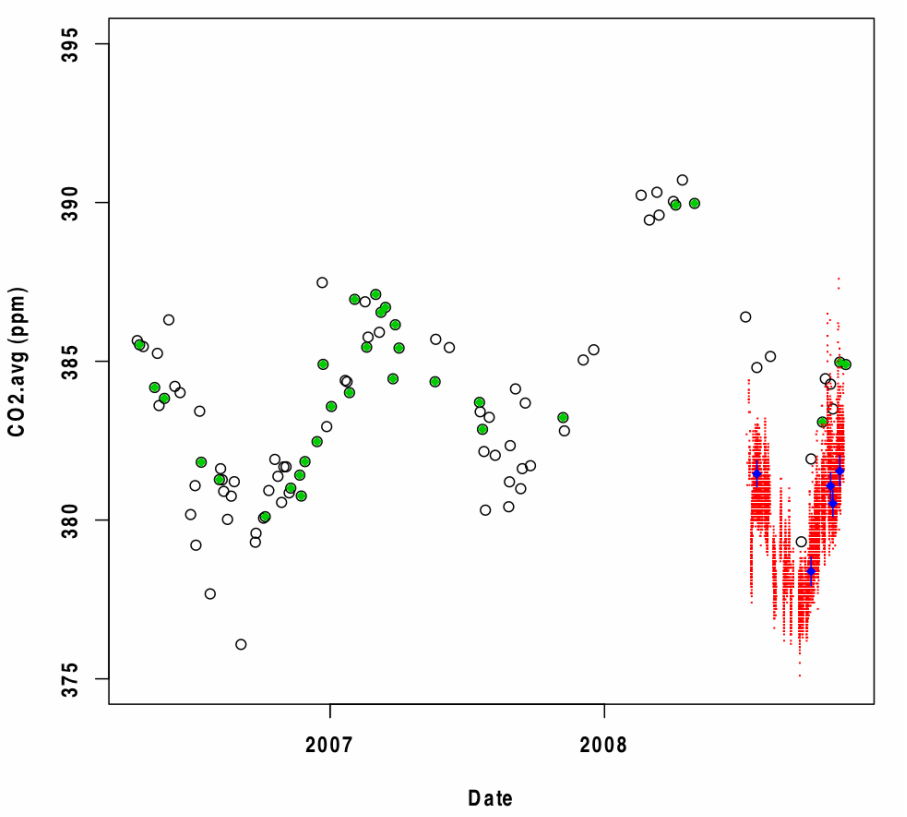

Figure 1. Column average CO_2 mixing ratio from the combination tower and airborne flask measurements (0.3 to ~ 5 km) for morning (open circles) and afternoon (green circles) samples, full column estimates from a Fourier transform spectrometer for all retrievals (red) and averaged into 1 hr bins surrounding airborne measurements (blue).

Comparison of LM3V and Carbon Tracker Data: Initial Results

N. Golaz[1], S. Mikaloff-Fletcher[2], S. Malyshev[3], J. Sheffield[4], J.L. Sarmiento[5] and S.W. Pacala[3]

[1]Princeton Environmental Institute, Princeton University, 300 Forrestal Road, Sayre Hall, Princeton, NJ 08544; 609-258-5260, E-mail: ngolaz@princeton.edu
[2]National Institute of Water and Atmospheric Research, Wellington 14-901, New Zealand
[3]Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544
[4]Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544
[5]Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ 08544

We use the Dynamic Vegetation Model LM3V - jointly developed at NOAA GFDL and Princeton University - to simulate ecosystem dynamics and exchanges of water, energy and CO_2 between land and atmosphere, and compare these results with the NOAA ESRL Carbon Tracker model. LM3V includes 5 vegetation carbon pools (leaf, sapwood, heart wood, fine root, virtual leaf) and 2 soil carbon pools (fast and slow soil carbon). The model uses a simple characterization of biodiversity, which includes 5 vegetation type (C3 cold grass, C4 warm grass, temperate deciduous forest, tropical broad leaf forest and evergreen coniferous forest). The model is forced by the High-Resolution Global Dataset, which was specifically developed for land surface modeling. The size of the model grid cell is flexible, and each cell can be further divided into 4 tiles, which track the dynamics of the primary, cropland, pasture and secondary vegetation for land-use transitions. We perform a series of experiments with LM3V to investigate the model sensitivity to parameter settings and to external forcing. Model results are compared with the Carbon Tracker output, which can be used to fine tune the model with the parameters that are most sensitive. Initial results suggest that NPP and GPP are sensitive to many of the parameters related to tropical vegetation type.

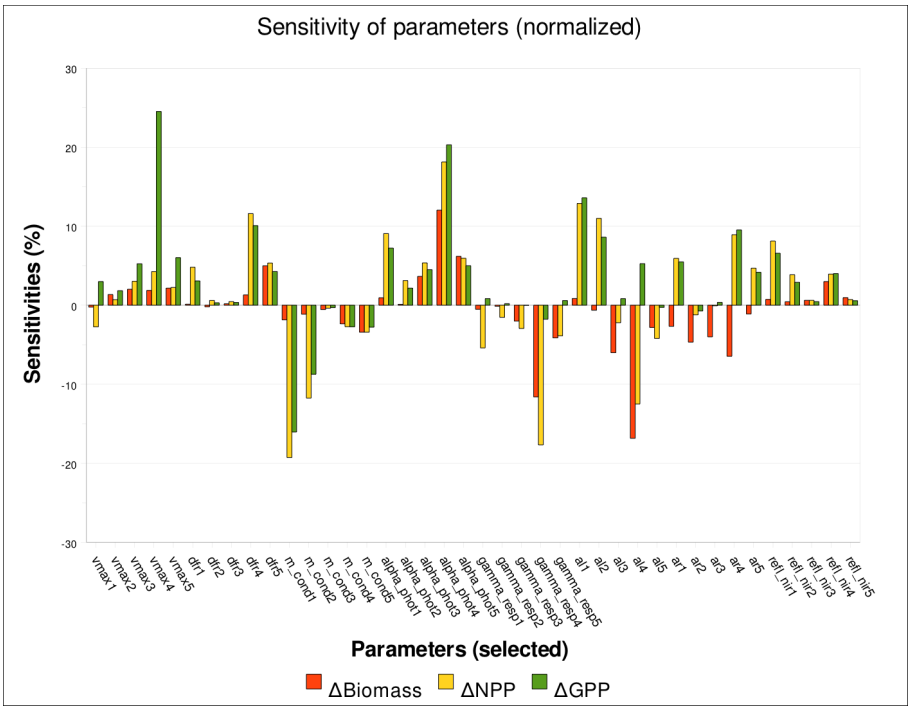

Figure 1. Sensitivity of parameters due to perturbations from the mean state of a control run. Because most of the parameters are non-linear, sensitivities of each parameter may differ from a different mean state. The maximum velocity of carboxylase (Vmax) of C4 warm grass affects NPP and GPP in the opposite direction and is a good parameter for tuning the GPP/NPP ratio. The bulk water conductance parameter (dfr) is not always as sensitive as previously believed. The “dfr” for C3 cold grass (dfr2) and C3 temperate deciduous forests (df3) are not sensitive from this mean state.

Identification of Greenhouse Gas Source Signatures in the San Francisco Bay Area Using *In Situ* Aircraft Measurements

A. Karion[1], M. Fischer[2], C. Sweeney[1], I. Faloona[3] and S. Saripalli[4]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6668, E-mail: Anna.Karion@noaa.gov
[2]Lawrence Berkeley National Laboratory, Berkeley, CA 94720
[3]University of California at Davis, Davis, CA 95616
[4]Kalscott Engineering, Lawrence, KS 66046

Quantification of specific sources and sinks of greenhouse gases is necessary for validation of emission flux estimates and supports recent efforts to regulate greenhouse gas emissions. *In situ* atmospheric measurements provide a valuable contribution to the effort of quantifying sources and sinks. In this study, continuous *in situ* measurements of carbon dioxide, methane, and carbon monoxide were made from a light aircraft in the San Francisco Bay area between June 17 and June 24, 2008 and again between February 24 and March 7, 2009. In addition to the continuous measurements, twelve flask samples were taken on each flight using NOAA ESRL Programmable Flask Packages. These samples provided measurements of a variety of additional atmospheric trace gases, including N_2O, H_2, benzene, HCFCs, and additional halocarbons. Atmospheric transport and footprints for the flight tracks in 2008 have been computed using the Stochastic Time-Inverted Lagrangian Transport (STILT) model driven by customized output from the Weather Research and Forecasting (WRF) model, allowing for an analysis of the origin of the various air masses observed. Large signals were observed during the campaign: urban air plumes with highly correlated CO_2, CH_4 and CO, as well as agricultural signatures with enhanced CH_4 coincident with depleted CO_2. The flights of June 2008 captured a large signal from the northern California wildfires as well, enabling the comparison of the signatures from the fires to those of other sources. The flights in February and March of 2009 were targeted around known local sources of CO_2 and CH_4 affecting the continuous NOAA and LBL measurements on the tall tower at Walnut Grove, CA.

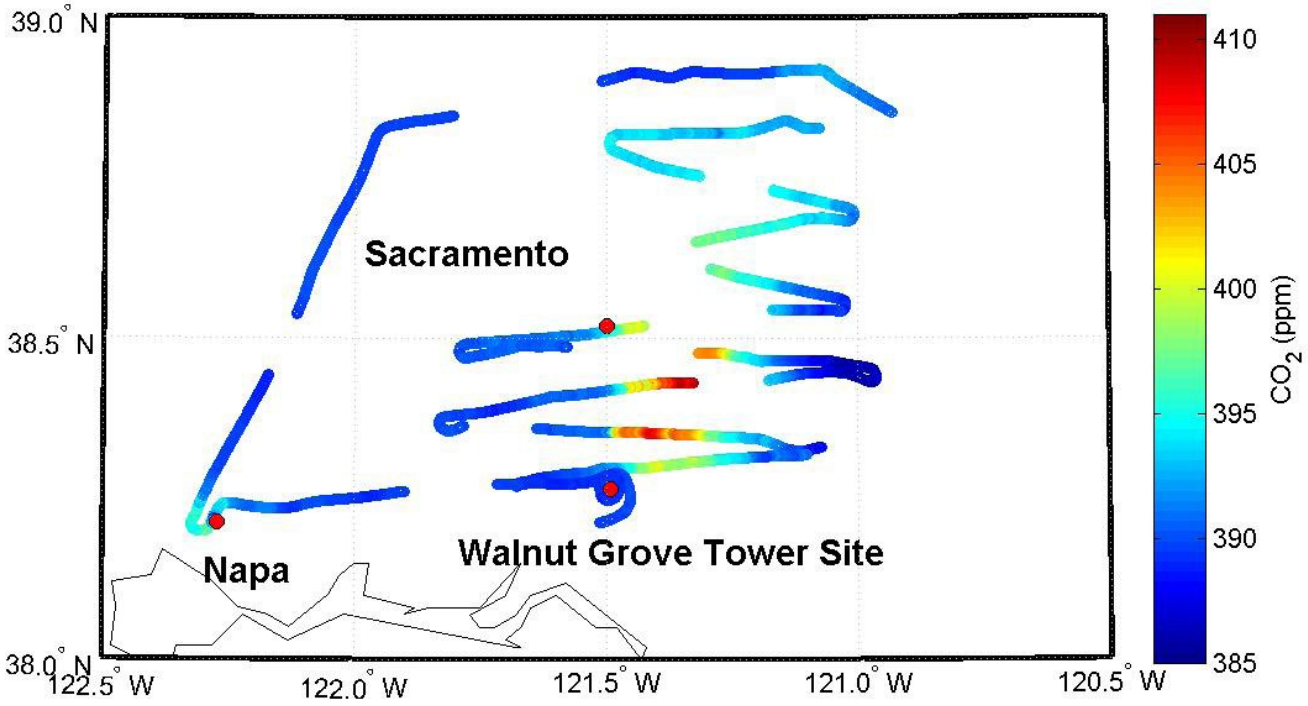

Figure 1. Continuous CO_2 measurements downwind of Sacramento made on February 27, 2009.

Reconciling Modeled Ocean Carbon Fluxes With Atmospheric ^{13}C Observations

C. Alden[1], J. White[1] and J.B. Miller[2]

[1]Institute of Arctic and Alpine Research, University of Colorado, Campus Box 450, Boulder, CO 80309; 719-930-5281, E-mail: caroline.alden@colorado.edu
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

As atmospheric greenhouse gas concentrations rise, researchers seek to identify how Earth's climate and carbon cycle are affected. To close the atmospheric CO_2 budget, several major fluxes must be accounted for: fossil fuel, ocean, and land, and ^{13}C can be a useful tools in distinguishing them. One drawback to this method is that photosynthesis and respiration are not contemporaneous, and because the ^{13}C of atmospheric CO_2 is being continuously depleted through the burning of ^{12}C-rich fossil fuels, there is an isotopic "disequilibrium flux" between CO_2 moving into and out of the ocean and land reservoirs. In this study, we use a combination of atmospheric CO_2 and $^{13}CO_2$ data, fossil fuel emission estimates, and recent ocean model results for the ocean CO_2 flux, within a box-inverse model. We calculate time series of land flux, disequilibrium flux and photosynthetic fractionation from 1991 through 2006. Initial findings reveal that if ocean variability is as small as is suggested by the ocean model, and the isotopic variability is forced into the disequilibrium flux, then the resulting disequilibrium flux has very large interannual variability (~35 PgC‰/yr), and an increasing trend. An intriguing possibility is that both the ocean model predictions and the atmospheric measurements can be satisfied by driving the variability into the photosynthetic fractionation term, εab. Under this scenario, relatively small interannual variations in net carbon exchange of C3 and C4 vegetation would be sufficient to explain the otherwise seemingly incongruent nature of the ocean model results and atmospheric observations. Best estimates of land, ocean, and disequilibrium fluxes, as well as photosynthetic fractionation and C4 net terrestrial exchange will be presented.

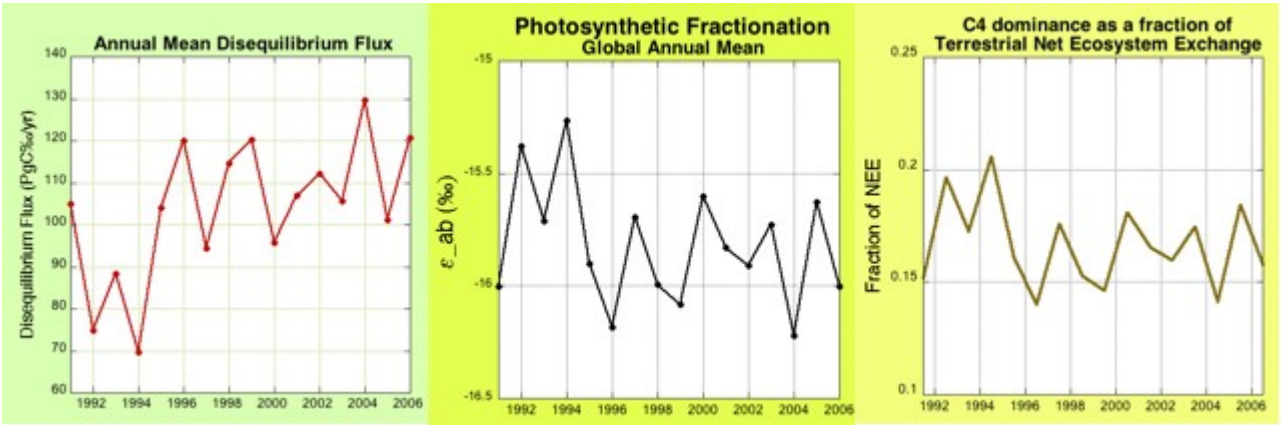

Figure 1. Disequilbrium flux is derived from ocean model results and atmospheric observations in a box-inverse model. The subsequent plots are end-member scenarios in which all disequilbrium flux variability is driven into εab and C4 dominance, respectively.

Quantification of Fossil Fuel CO_2 Emissions from East Asia Using Atmospheric Observations of $\Delta^{14}CO_2$

J. Turnbull[1], P. Tans[1], J. Miller[2], S. Lehman[3], G. Petron[2] and J. Gregg[4]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-4836, E-mail: jocelyn.turnbull@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]Institute of Alpine and Arctic Research, University of Colorado, Boulder, CO 80309
[4]Department of Geography, University of Maryland, College Park, MD 20740

Fossil fuel CO_2 emissions are the largest annual net source of CO_2 to the atmosphere, and accurate quantification of these emissions is essential to furthering our understanding of the global carbon cycle. Currently, these fossil fuel CO_2 (CO_2ff) emissions are estimated from economic inventories of fossil fuel use reported by governments and industry. Measurements of the radioactive isotope ^{14}C in CO_2 ($\Delta^{14}CO_2$) provide an independent method of constraining CO_2ff emissions, since fossil fuel derived CO_2, unlike other CO_2 sources, is devoid of ^{14}C. Emissions from East Asia in recent years are of particular interest, since they contribute ~25% of global total emissions, and are rapidly growing by 8-10% per year, but with an estimated uncertainty of ±20% on the annual total (compared to ±3-5% for European and North American emissions). We quantitatively determine recently added CO_2ff in samples from the NOAA ESRL cooperative sampling network at sites in East Asia, focusing on Tae-Ahn Peninsula, South Korea (TAP), which typically sees air which has recently passed over northern China and Korea. Samples typically contain a few ppm of CO_2ff from China, and in some samples, Korea contributes up to 20 ppm of CO_2ff; these values are much larger than the detection limits of the method. The observed CO_2 also shows large variability due to biospheric CO_2 exchange, even in winter, so that CO_2 measurements alone cannot accurately estimate CO_2ff. We compare the observational results with estimates of CO_2ff from a Lagrangian particle dispersion model (FLEXPART) and a prior estimate of CO_2ff emissions, examining our ability to model atmospheric transport for this region, and ultimately, to validate the reported emissions and determine quantitative uncertainties on the emissions.

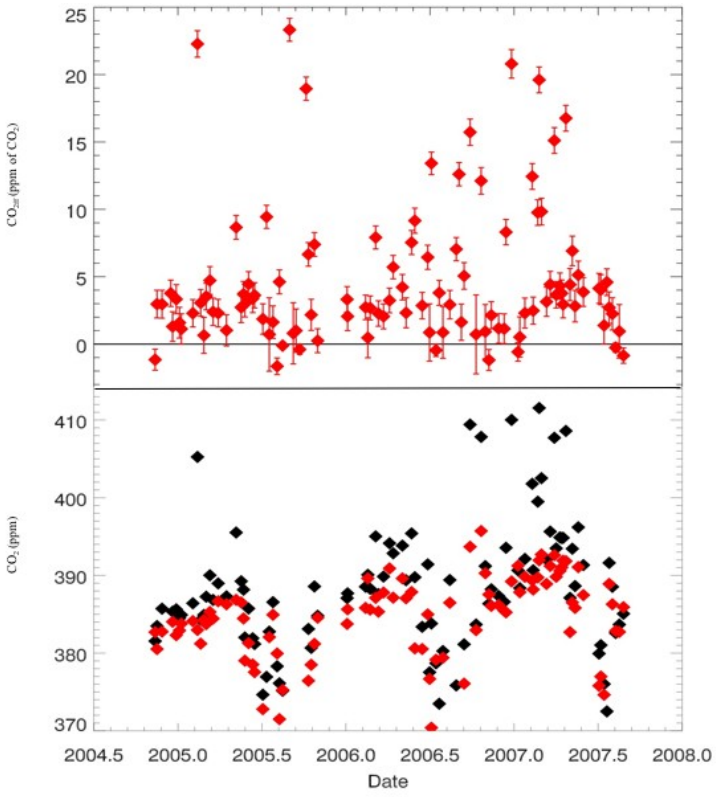

Figure 1. Top panel: Recently added fossil fuel CO_2 (CO_2ff) at TAP, calculated relative to a free tropospheric background. Error bars are the measurement uncertainty. Bottom panel: Total CO_2 mixing ratio measured in the same samples at TAP (black points). When the CO_2ff contribution in each sample is subtracted, the red points reveal a seasonal cycle driven by biospheric CO_2 exchange.

CARBONTRACKER: Sensitivity to Potential Systematic Bias in CO_2 Observations

K. Masarie[1], A. Andrews[1], L. Bruhwiler[1], A.R. Jacobson[2], J.B. Miller[2], W. Peters[3], G. Petron[2] and P. Tans[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6270, E-mail: kenneth.masarie@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]Wageningen Research University, Wageningen, Netherlands

CarbonTracker is a combined observing and modeling system that estimates CO_2 uptake and release at the Earth's surface over time. CarbonTracker uses high-precision atmospheric CO_2 observations to optimize derived surface flux estimates based on our current understanding of CO_2 exchanges between the atmosphere, ocean and terrestrial biosphere. Sources of uncertainty in CarbonTracker flux estimates likely include biases in 1) the prescribed emission inventories; 2) the prior emission estimates derived from process models; 3) the atmospheric transport model; 4) the flux optimization scheme; and 5) the observational network. Unknown systematic biases are of critical concern as they may produce incorrect emission estimates. Several studies are underway to specifically assess biases and uncertainty as requested by last year's CarbonTracker Science Review team. Here we explore the sensitivity of CarbonTracker emission estimates to potential biases within observational records. We perform several simulations where we introduce systematic offsets for a fixed period of time at selected sites and compare emission estimates with those from the current CT2008 release (carbontracker.noaa.gov). Sensitivity depends both on the site's proximity to source regions and the existence of other measurement sites nearby. Here we present results from simulations using CO_2 observations from the LEF tall tower in Wisconsin. We find that a +1.0 ppm systematic offset introduced to the 2004 LEF data leads to a 0.13 Pg C (17%) reduction in terrestrial uptake in temperate North America and a corresponding increase in uptake in temperate Eurasia. We discuss these results and how they scale when more realistic biases may exist in observations.

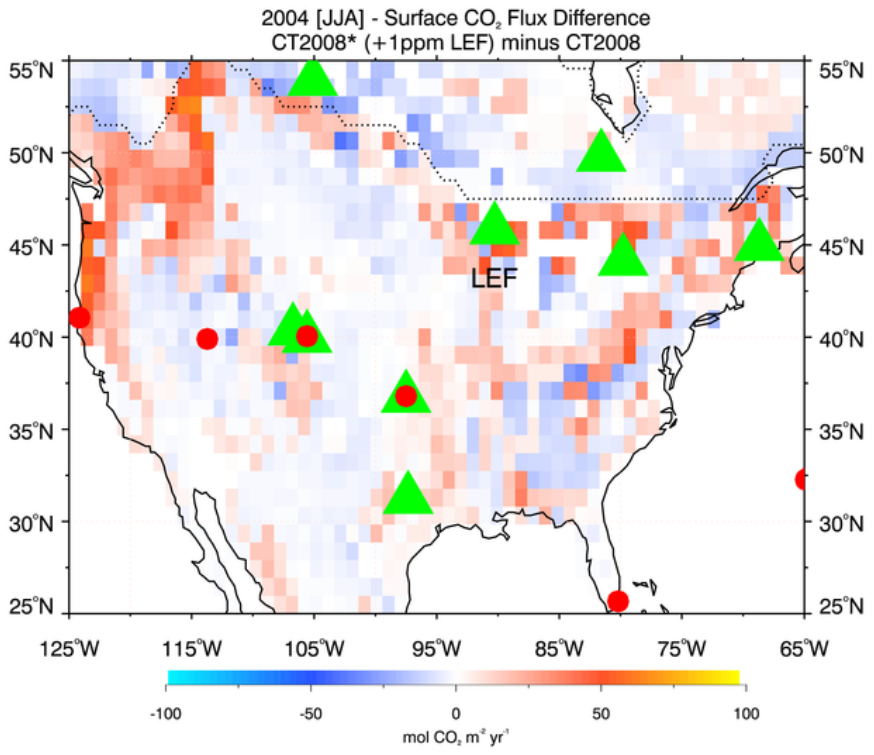

Figure 1. Shows summer 2004 surface CO_2 flux differences, CT2008* minus CT2008, where CT2008* is a CarbonTracker run that includes an introduced +1 ppm systematic offset to the 2004 LEF quasi-continuous CO_2 atmospheric measurements and CT2008 is the current CarbonTracker release. Warm colors indicate that CT2008* estimates less surface CO_2 uptake by the terrestrial biosphere than CT2008; cool colors indicate greater surface uptake; and white indicates no difference. Quasi-continuous tower sites (green triangles) and weekly surface measurement sites (red circles) included in the assimilation are shown.

Data Quality and Continuity for the ESRL GMD Tall Tower Network

A. Andrews[1], J. Kofler[2], J. Williams[3], K. Masarie[1], M. Trudeau[2], D. Kitzis[2], C. Zhao[2] and D. Chao[2]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6773, E-mail: Arlyn.Andrews@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]Science and Technology Corporation, Boulder, CO 80305

New *in situ* instrumentation for measuring CO_2 and CO was developed to facilitate the expansion of the ESRL GMD Tall Tower Network. The first of the new analysis systems was deployed in May 2006 to the WKT site near Moody, TX. Since then, nearly identical systems have been deployed to six other sites across the U.S. The systems are fully automated and extensive engineering data is recorded and tracked using elaborate quality control algorithms. Eight calibration standards are deployed with each instrument, five of which are dedicated to CO_2 and three for CO. The calibration suite includes a "target" gas for each molecule. The target tank is routinely measured but is not used to compute the calibration polynomial. The repeatability of the target measurements and the agreement between measured and assigned target values are key indicators of measurement precision and system performance. Six of the sites are also equipped with automated flask sampling systems, and comparison of data from the *in situ* and flask sampling systems is another measure of data quality. We will present an overview of the data quality across the network and also a summary of common failure modes and instrument downtime for each site. We will also evaluate the calibration stability in order to determine whether calibration gas usage can be reduced.

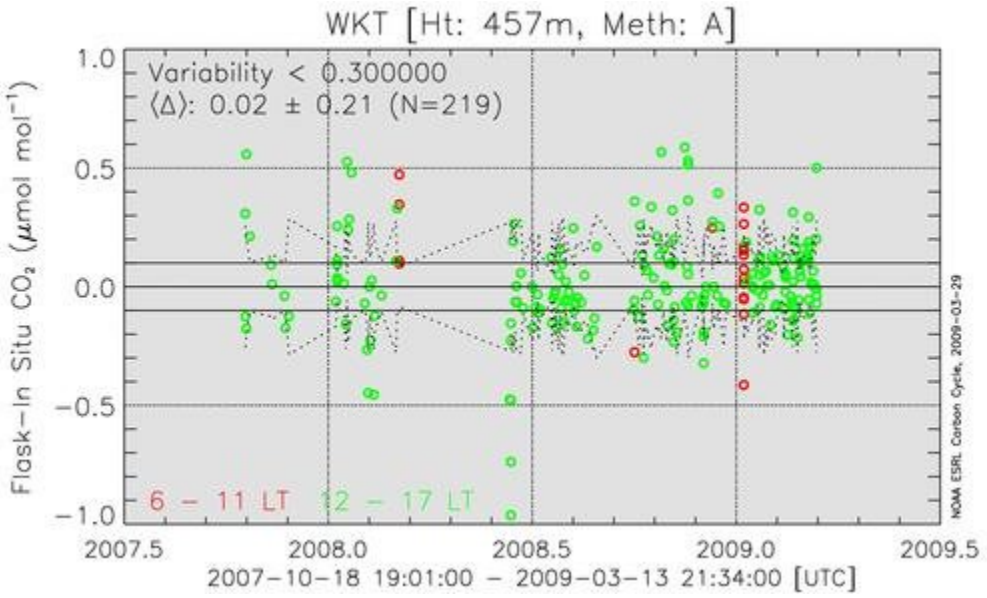

Figure 1. Flask versus *in situ* comparison for the WKT site. Data have been selected for periods when data from the *in situ* analyzer indicate low atmospheric variability (1s < .3ppm over 60 minutes). The mean difference is 0.02 +/- 0.21ppm for 219 samples. The colors indicate time of day as described in the lower left corner of the graph.

Interpreting Dense CO_2 Measurements: Ensemble Filters Vs. Variational Data Assimilation

D. Baker

Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 80523; 970-491-8785, E-mail: baker@cira.colostate.edu

With the recent launching of the GOSAT satellite, atmospheric CO_2 concentration measurements of sufficient density to estimate sources and sinks on regional scales should soon be available. This presents a computational challenge: how can we make the most use of the data (by solving for surface fluxes or carbon model parameters the finest spatial and temporal resolution as the data allow) without overwhelming our computational resources? Two types of methods have been targeted to do this: ensemble filtering methods, such as the fixed-lag (ensemble) Kalman smoother (EnKF) used in CarbonTracker, and variational data assimilation methods, which use an approach similar to the "4D-Var" methods of numerical weather prediction. Here, we compare the relative merits of the two approaches. In terms of the total computational effort, the variational methods are more efficient, by a factor proportional to the number of flux time steps retained in the EnKF state. However, because the EnKF is highly parallelizable, it should have the edge in terms of run time. Both methods provide a similar low-rank estimate of the flux covariance; in terms of the "square-root" of the covariance, the ensemble methods compute a single column per ensemble member, the variational methods a single column per iteration of the optimization method. The accuracy of the variational approach has been verified using simulation studies; here we use similar simulations ("OSSEs") to quantify the ability of satellite measurements to improve surface CO_2 flux estimates (Figure 1). Similar studies should be done to validate the ensemble methods: it is not at all clear that they will do as well, given that there is no iterative refinement of the estimate with respect to the data. Finally, we describe a resolution-refinement approach that will allow the variational method to estimate fluxes at resolutions of 1x1 deg (lon/lat) and finer, globally; preliminary simulation results are shown.

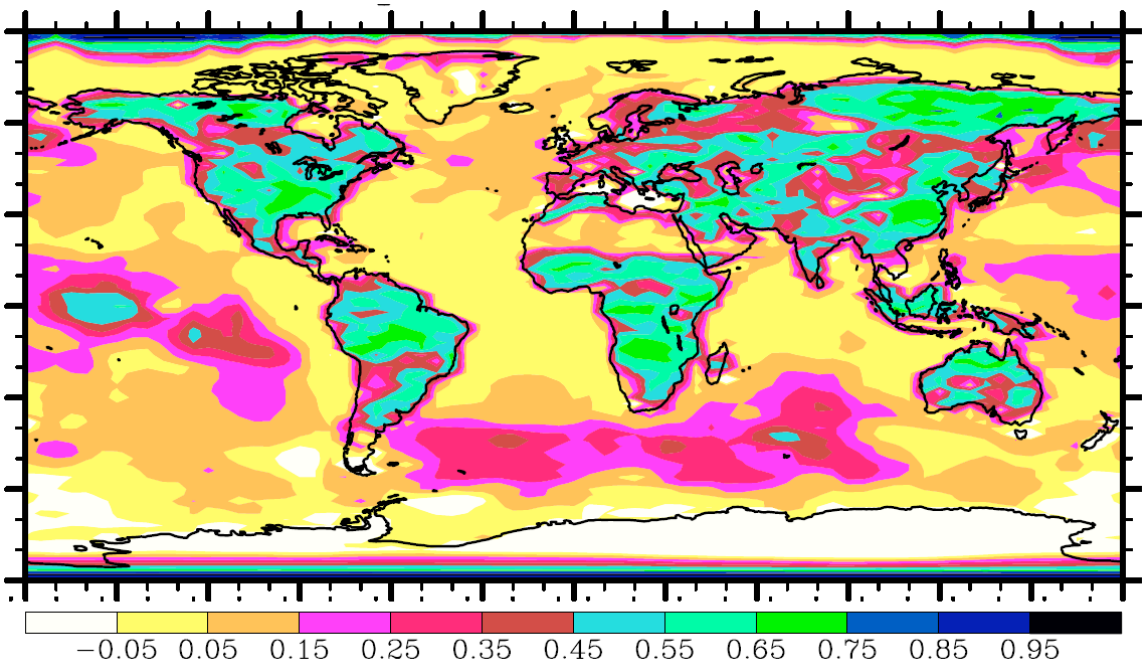

Figure 1. Improvement in weekly land and ocean CO_2 flux estimates at 5x2 deg (lon/lat) expected from measurements from the Orbital Carbon Observatory (OCO) over a prior guess taken from process models, as simulated using our variational data assimilation system after 25 iterations of the minimization. The reduction in the uncertainty due to only random errors is given; biases and other systematic error sources degrade the results further.

High-Latitude Carbon Exchange Estimated from Co-Variation of CO_2 and Potential Temperature

G. Keppel-Aleks[1], P.O. Wennberg[1], T. Schneider[1] and S.A. Vay[2]

[1]California Institute of Technology, 1200 E California Blvd, Pasadena, CA 91125; 626-395-6293, E-mail: gka@gps.caltech.edu
[2]NASA Langley Research Center, Hampton, VA 23681

Simulations of the vertically averaged mixing ratio of carbon dioxide, show both weak seasonal cycle amplitude and weak spatial and temporal variations, influenced by variations in local exchanges with the surface. In contrast, observations made *in situ* from aircraft and by infrared solar spectrometry from the ground show that summertime variations over North America are much larger than previously thought. We show that these variations result from synoptic weather systems that advect large-scale gradients in free-tropospheric CO_2. Simulations with the AM2 general circulation model show that the observed variations can be accounted for if the amplitude of northern hemisphere land exchange exceeds 35 Pg annually, a flux much larger than indicated by biosphere models. Because such biosphere models are used in inversion calculations to determine long-term changes in carbon stocks on land from measurements of CO_2 concentrations, our findings imply revised estimates of CO_2 sources and sinks.

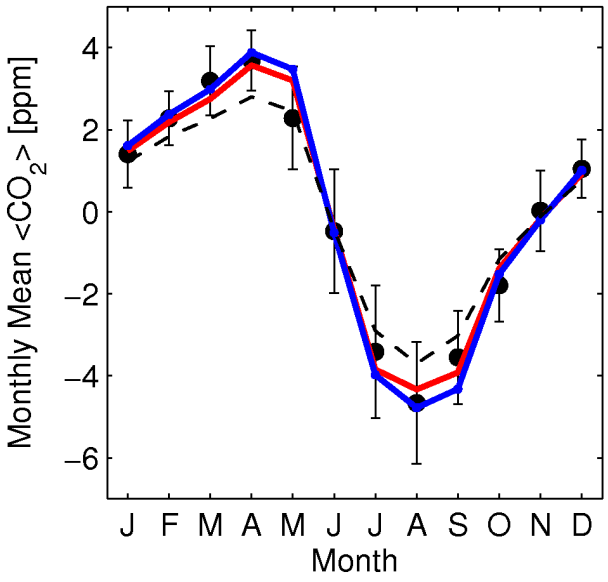

Figure 1. Monthly mean, detrended from ground-based spectrometer (black circles), plotted with monthly mean from AM2 using CASA as boundary conditions (black dashed line), and from AM2 using northern land fluxes enhanced by 30% (red) and 40% (blue). Seasonal cycle is underestimated by 25% using CASA atmosphere-biosphere exchange.

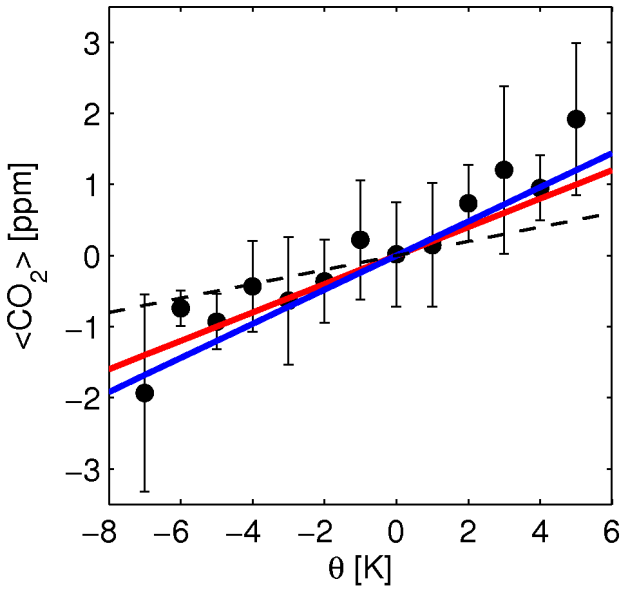

Figure 2. July-August filtered plotted against filtered 700 hPa potential temperature (θ). Symbols as in Figure 1. The relationship provides an estimate of the north-south gradient during the growing season. Simulations driven by CASA biosphere-atmosphere exchange underestimate the gradient by a factor of 2. For both seasonal cycle amplitude and implied north-south gradient, simulations best match the observations when biosphere-atmosphere fluxes are enhanced at high northern latitudes.

Observing Regional CO_2 Plumes with an Airborne Differential Laser Absorption System

T.S. Zaccheo[1], M.E. Dobbs[2] and E. Browell[3]

[1]Atmospheric and Environmental Research, Inc. AER, 131 Hartwell Ave, Lexington, MA 02421; 781-761-2292, E-mail: szaccheo@aer.com
[2]International Telephone and Telegraph, Space Systems Divsion, Fort Wayne, IN 46818
[3]NASA Langley Research Center, Hampton, VA 23681

A new laser-based technique for quantitative airborne monitoring of carbon dioxide (CO_2) column amounts has been developed, and extensive testing has shown that this system provides high-precision CO_2 column measurements with RMS error less than 1.5 ppm. This unique airborne development and test environment combines a fiber laser-based instrument designed and developed jointly by ITT and NASA Langley Research Center (LaRC) to measure CO_2 column amounts, with collocated NIST-traceable *in-situ* measurements of atmospheric CO_2 profiles, surface/atmospheric temperature, moisture and pressure information obtained from rawin/radiosonde launched in conjunction with the flight campaigns, and validated line-by-line radiative transfer (RT) modeling tools. This not only provided assessment of instrument performance, but also a robust method for instrument calibration. Collocated instrument and *in-situ* measurements provide a natural mechanism for preliminary instrument calibration, and enable extending the test flight data to demonstrate the preliminary performance of this instrument's capability to measure/monitor changes in CO_2 on a regional scale. In this work, we outline the data collection and calibration methods, and demonstrate how this measurement technique can be used to measure/monitor changes in CO_2 concentrations on a regional basis over a mixed terrain and environmental conditions. The figure below illustrates calibrated science data obtained as part of our extensive April 2008 flight campaign over the Norfolk/Suffolk, VA area. This region has diverse terrain/environmental settings, and includes both terrestrial/oceanic settings as well as rural/urban environments. This figure demonstrates dramatic localized changes in CO_2 column amounts and CO_2 plumes based on small scale changes in terrain/environment. Future campaigns will be designed to further develop this analysis, and may include incorporating these data into high-fidelity region scale modeling of CO_2 sources and sinks.

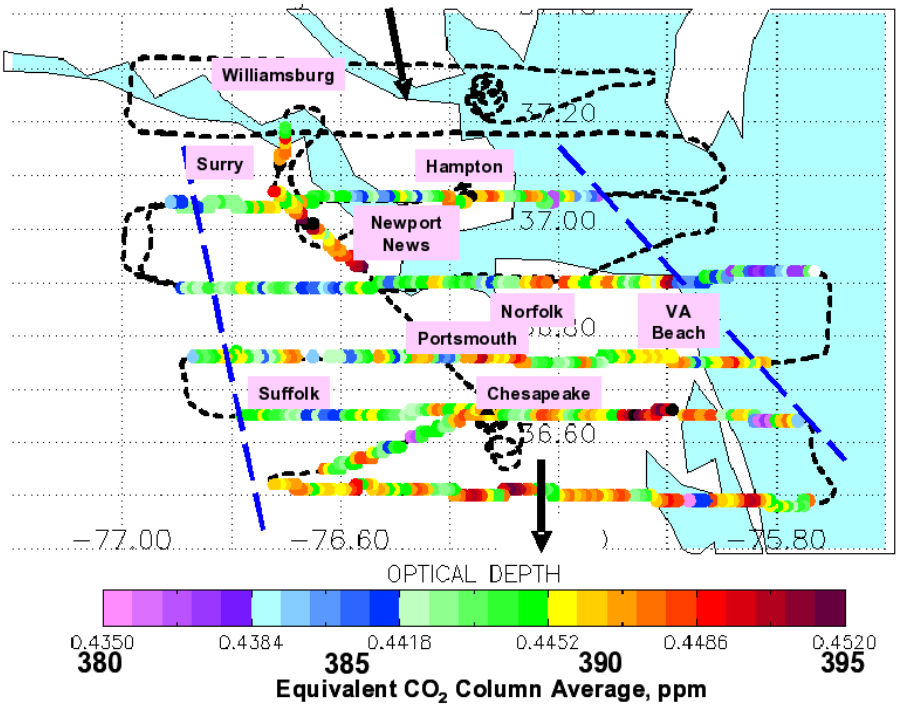

Figure 1. Observed variation in CO_2 column amounts from airborne laser absorption measurements acquired over the Norfolk/Suffolk, VA region in April 2008. This figure illustrates flight path and individual CO_2 column measurements that show distinct localized variations in CO_2 concentrations or plumes.

On-Road Study of Colorado Front Range Greenhouse Gases Distribution and Sources

G. Petron[1], A. Hirsch[2], A. Karion[1], J. Kofler[1], C. Sweeney[1], A. Andrews[3], B. Miller[1], L. Miller[1], S. Montzka[3], W. Kolodzey[4], L. Patrick[1], M. Trainer[3], G. Frost[1], T. Ryerson[3] and P. Tans[3]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-4890, E-mail: gabrielle.petron@noaa.gov
[2]National Renewable Energy Laboratory, Golden, CO 80401
[3]NOAA Earth System Research Laboratory, Boulder, CO 80305
[4]University of Michigan, Ann Arbor, MI 48109

The Global Monitoring Division and Chemical Sciences Division of the NOAA Earth System Research Laboratory have teamed up over the summer 2008 to experiment with a new measurement strategy to characterize greenhouse gases distribution and sources in the Colorado Front Range. Combining expertise in greenhouse gases measurements and in local to regional scales air quality study intensive campaigns, we have built the 'Hybrid Lab'. A continuous CO_2 and CH_4 cavity ring down spectroscopic analyzer (Picarro, Inc.), a CO gas-filter correlation instrument (Thermo Environmental, Inc.) and a continuous UV absorption ozone monitor (2B Technologies, Inc., model 202SC) have been installed securely onboard a 2006 Toyota Prius Hybrid vehicle with an inlet bringing in outside air from a few meters above the ground. To better characterize point and distributed sources, air samples were taken with a Portable Flask Package (PFP) for later multiple species analysis in the lab. A GPS unit hooked up to the ozone analyzer and another one installed on the PFP kept track of our location allowing us to map measured concentrations on the driving route using Google Earth. The Hybrid Lab went out for several drives in the vicinity of the NOAA Boulder Atmospheric Observatory (BAO) tall tower located in Erie, Colorado and covering areas from Boulder, Denver, Longmont, Fort Collins and Greeley. Enhancements in CO_2, CO and destruction of ozone mainly reflect emissions from traffic. Methane enhancements however are clearly correlated with nearby point sources (landfill, feedlot, natural gas compressor ...) or with larger scale air masses advected from the NE Colorado, where oil and gas drilling operations are widespread. The multiple species analysis (hydrocarbons, CFCs, HFCs) of the air samples collected along the way brings insightful information about the methane sources at play. We will present results of the analysis and interpretation of the Hybrid Lab Front Range Study and conclude with perspectives on how we could adapt the measurement strategy to study more quantitatively GHG anthropogenic emissions in Denver Basin.

Figure 1. NOAA ESRL Hybrid Mobile Lab for the Summer 2008 Front Range Emissions Study.

Continuous Tower-Based Tropospheric Ozone Measurements

L.C. Patrick[1], S.J. Oltmans[2], J.C. Williams[1], A.E. Andrews[2], J. Kofler[1] and D.E. Wolfe[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6823, E-mail: laura.patrick@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

As well as its role as a greenhouse gas, tropospheric ozone plays a pivotal part in the chemistry of the lower atmosphere. Photochemical and chemical reactions involving ozone drive many nocturnal and diurnal chemical processes. Metropolitan area ozone concentrations are frequently monitored, but continuous measurement of background concentrations found in rural areas is also necessary. In order to understand background levels and influences of local ozone sources, we installed two monitors at NOAA's Boulder Atmospheric Observatory in Erie, Colorado. Continuous measurements were taken at the surface and at a 300-meter height on the tower starting in July 2008. In combination with concurrent wind and humidity measurements, we investigate diurnal, monthly and seasonal patterns from July 2008 – May 2009. We employ HYSPLIT, a dispersion model, to investigate sources of high ozone events during this period. Additionally, profiles of various constituents measured at the tower are compared.

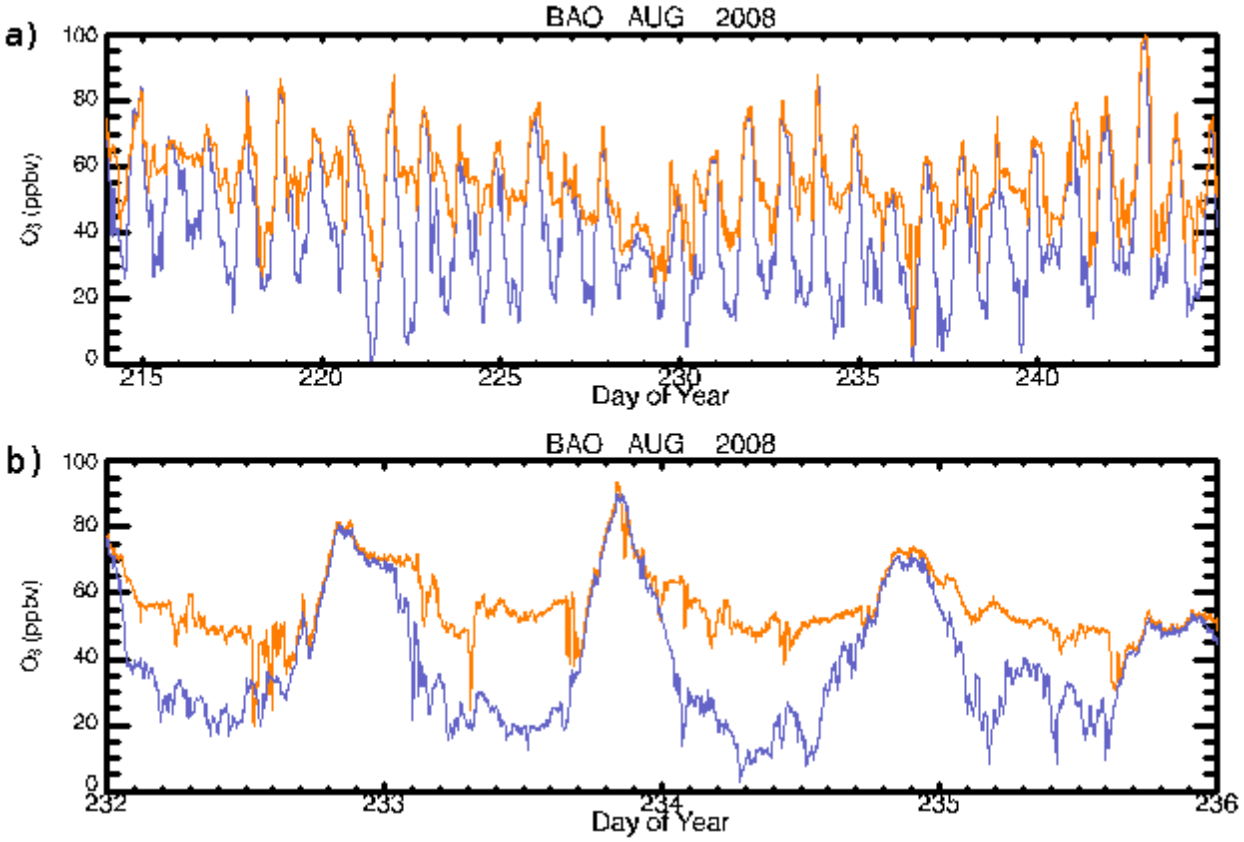

Figure 1. Measurements of ozone mixing ratios from UV-absorption instruments at surface (blue) and 300 m (orange). Shown in a) is the hour-averaged diurnal variation during August 2008 and b) shows the 5-minute averages of August 20 - 24, 2008. The spread of mixing ratio values at night reveals that the tower-mounted instrument is out of the nighttime boundary layer.

Statistical Analysis and Estimation of the External Effects on the Total Ozone Field Over Russia in 1973-2007

E.A. Titova, I.L. Karol, A.M. Shalamyansky, L.P. Klyagina and A.A. Solomatnikova

Main Geophysical Observatory, 7 Karbyshev Street, Saint Petersburg 194021, Russia; 78122978668, E-mail: karol@main.mgo.rssi.ru

Thirty-five years of ground-based data are used to study the external effects on the total ozone (TO) over Russia, averaged seasonally (December-March, June-August) and annually. Discriminant and spectral analysis of TO time series is performed to isolate and distinguish the separate effects of the eleven-year solar cycle, the Quasi-biennial Oscillation (QBO), the Arctic oscillation, the El Nino-Southern oscillation (ENSO), the winter Arctic lower stratosphere temperature interannual variations on TO fields and to identify the spatial differences in the analyzed processes. During the winter months, the negative AO, the warm stratosphere and the westerly QBO years are statistically well-separated from the years when all the factors happen to be in their opposite phases. Being of roughly comparable difference between phases (35 DU, 28 DU, 26 DU respectively) these factors constitute the dominant effects on the ozone layer in the winter hemisphere. Spectra as well as discriminants of the June-August total ozone indicate a strong influence of the QBO and the eleven-year solar cycle in the summer months with the QBO prevailing in the Asian regions. All the results are significant at 95% level as confirmed by the Monte-Carlo test. The discrimination is performed better at the lower level of the other intervening factors, thus relatively small effects of ENSO and Solar cycle came out to be statistically indeterminate in the winter months with many underlying processes at work. Nevertheless discriminant analysis as described by Schneider and Held, 2001, is a powerful method of multivariate analysis which allows both temporal and spatial representation of the data, while simpler methods, e.g. Student's t-test, could not yield quantitative results of the same range. The physical grounds of the statistically established effects are proposed and discussed.

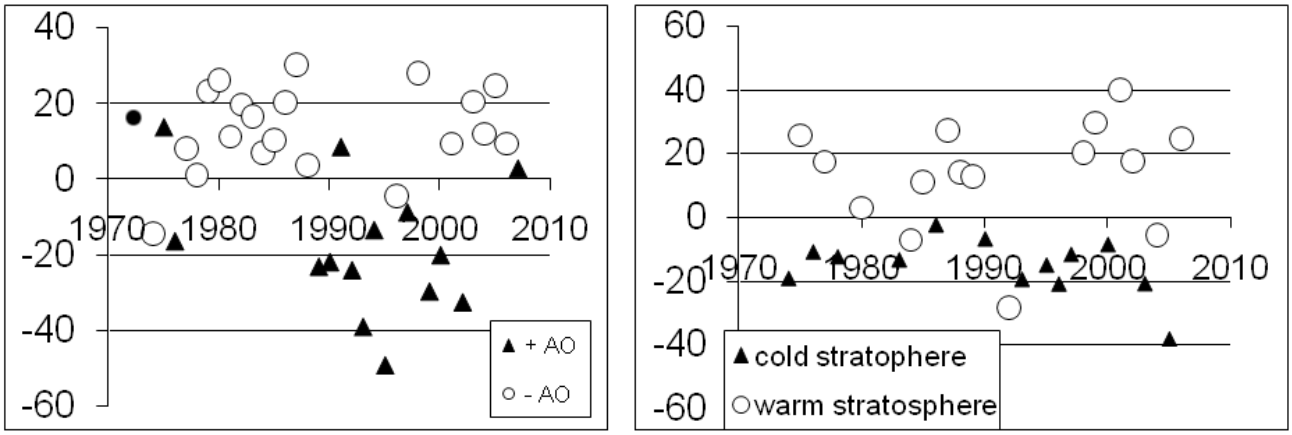

Figure 1. Canonical variates (DU) of Total Ozone time series for Arctic Oscillation phases and stratosphere temperature groups.

Long-Term Ozone Trends in Umkehr Measurements at Japanese Stations

K. Miyagawa[1], T. Sasaki[2] and C. Kobayashi[3]

[1]Ozone and Radiation Section, Japan Meteorological Agency, Asian Regional Dobson Calibration Center, Aerologi, Tsukuba, Ibaraki 305-0052, Japan; 81-29-851-2572, E-mail: miyagawa@met.kishou.go.jp
[2]Japan Meteorological Agency, Utsunomiya, Tochigi 321, Japan
[3]Japan Meteorological Agency, Tokyo, Otemachi 100-8122, Japan

Umkehr observations have been made routinely at Japanese stations at Sapporo, Tsukuba, and Naha, and at the Antarctic station, Syowa, for more than 50 years. The discontinuous gaps in Japanese Umkehr data record have been associated with instrument replacements. Therefore, N-value data were recently reevaluated based on instrument intercomparisons. The data analysis revealed systematic errors that depend on solar zenith angle, total ozone, and other instrumental factors. The UMK04 ozone profile retrieval algorithm is applied in the processing of all reevaluated N-value time-series. We present a long-term ozone trend determined from the newly re-processed Umkehr ozone profiles. The long-term trend in upper stratospheric ozone is discussed in this paper. Long-term variations of the ozone amount derived by UMK04 algorithm in the combined 8 and 9 layers at Sapporo, Tsukuba, Naha and Syowa are shown in the Figure 1. Linear trends in two separate periods 1970 (or 1977) -1996 and 1996-2008 are also shown for each station. Trend analyses suggest a significant decrease in the upper stratosphere over Japan during the 1980s. The upper stratospheric ozone levels at Tsukuba Station have shown a steady increase at 5%/decade rate after 1996. At the same time, a 7.7%/decade decrease in ozone is found in Umkehr data taken at Sapporo Station, which indicates an even stronger ozone depleting rate as compared to ozone depletion rates prior to 1996. Over the Antarctic station Syowa, upper stratospheric ozone has been at a low level since 1990s. Especially low values can be seen in the last few years. Observed difference in the upper stratospheric ozone changes may be reflecting the latitude dependence of ozone depletion.

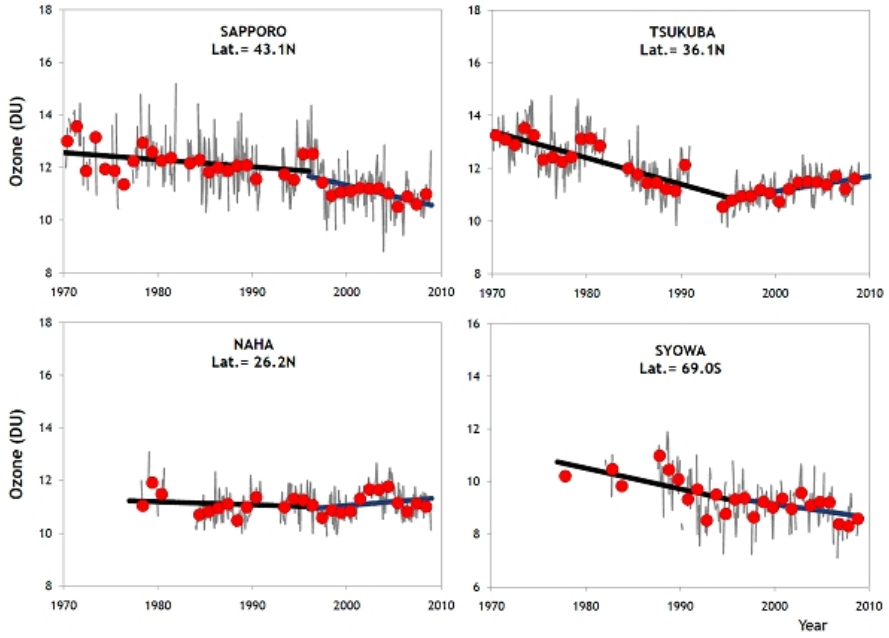

Figure 1. Long-term variations of ozone amount in 8+9 layers. Linear trend fit is derived after removing effects such as solar activity, QBO, and atmosphere turbidity. A gray line shows monthly average and red circle shows average of the year. Solid lines show linear trends from 1970 (or 1977) to 1996 and from 1996 to 2008. Periods interfered by volcanic eruptions, El Chichon (1982-1983) and Mt. Pinatubo (1992-1993), were removed from the analysis.

Boundary Layer Ozone Depletion Events Measured by Ozonesondes at Barrow, Alaska in 2009

B. Johnson, S.J. Oltmans and J. Booth

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6842, E-mail: bryan.johnson@noaa.gov

NOAA ESRL Global Monitoring Division, in partnership with Environment Canada, launched 25 ozonesondes at the Barrow Observatory from March 12 to April 15, 2009 as part of the international multidisciplinary study called OASIS (Ocean - Atmosphere - Sea Ice - Snowpack). During polar sunrise, the icepack is considered to be a major source of bromine that leads to rapid ozone depletion events within the boundary layer. Surface ozone monitors at Barrow Observatory have recorded these events since the site was established in 1973. During March and April, ozone can quickly drop from a typical 30 to 40 ppbv to 0 to 10 ppbv for a few hours or 1-2 days. However, the vertical extent is not well known. Therefore, ozonesondes were launched every other day and as often as daily during ozone depletion events to determine the height at which the low ozone occurs over the snow-packed region. Figure 1 shows a major event on March 12, 2009 when near-zero ozone was measured up to 300 meters above the surface. In sharp ozone transitions as these, the actual ozone gradient is much sharper than the ozonesonde sensor can measure due to the typical rise rate (4-5 m/s) of the balloon and slow response time (1/e of 20 seconds) of the sonde sensor. Therefore new methods to slow the rise rate of the balloon to 0.5 to 2 m/s were used to obtain a more accurate ozone transition region.

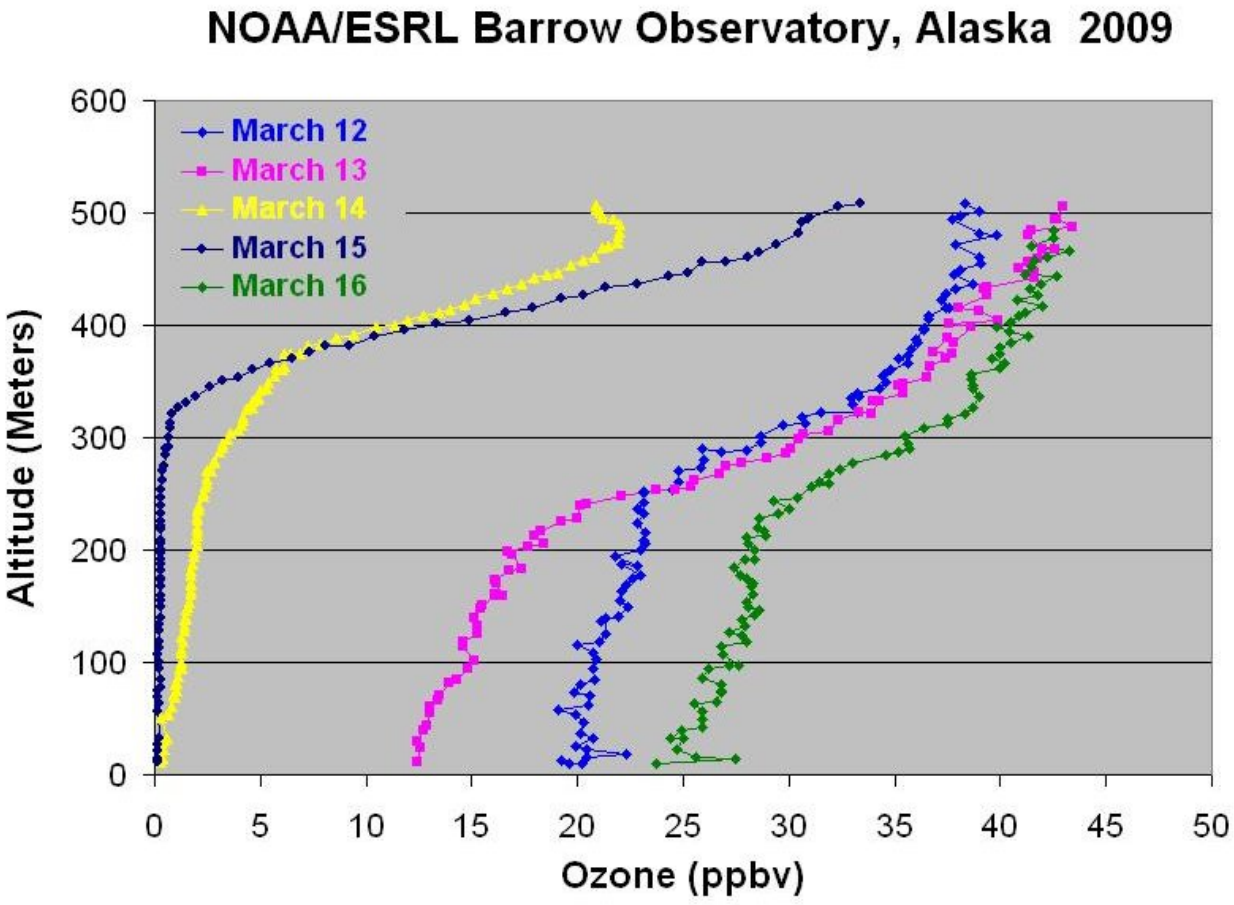

Figure 1. Ozonesonde profiles (surface to 500 meters) showing near-zero ozone within the boundary layer during an ozone depletion event.

Boulder and the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)

D. Hurst[1], E.G. Hall[1], A.F. Jordan[1], B.J. Johnson[2], J. Wang[3] and S.J. Oltmans[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-7003, E-mail: Dale.Hurst@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]National Center for Atmospheric Research, Earth Observing Laboratory, Boulder, CO 80301

Upper air temperature, humidity and wind records from existing global observing systems have too many inconsistent uncertainties to be useful in climate models and trend analyses. These observations have predominantly been made in support of weather research and forecasting, not to construct self-consistent, longer-term data records. The concept of the GRUAN is built upon the need for improving the precision, accuracy and long-term stability of climate observations made by the existing global upper air network (GUAN) such that high-quality, internally consistent climatologies can be produced. Boulder has been proposed as one of about 10 initial GRUAN sites around the globe, thanks to the many high-quality, long-term measurement programs in the area. First and foremost are NOAA ESRL's weekly soundings of temperature, pressure, and ozone or water vapor (or both) using balloon-borne instruments launched at the NCAR Marshall field site. ESRL also maintains two nearby Baseline Surface Radiation Network sites, Table Mountain and the Boulder Atmospheric Observatory (BAO), which measure all GRUAN surface radiation variables. These existing observation systems and the experienced scientific teams who operate and maintain them make Boulder an ideal candidate reference site. The GRUAN's strict criteria for calibration, intercomparison and validation of measurements will require some important additions to ESRL's measurement programs at these sites. The radiosondes currently in use will soon be augmented with the "best currently available technology" production radiosondes and each sounding sensor will be "ground truthed" immediately before launch. GPS retrievals of precipitable water vapor and microwave radiometric profiles of temperature and water vapor will enable intercomparison and validation of upper air measurements.

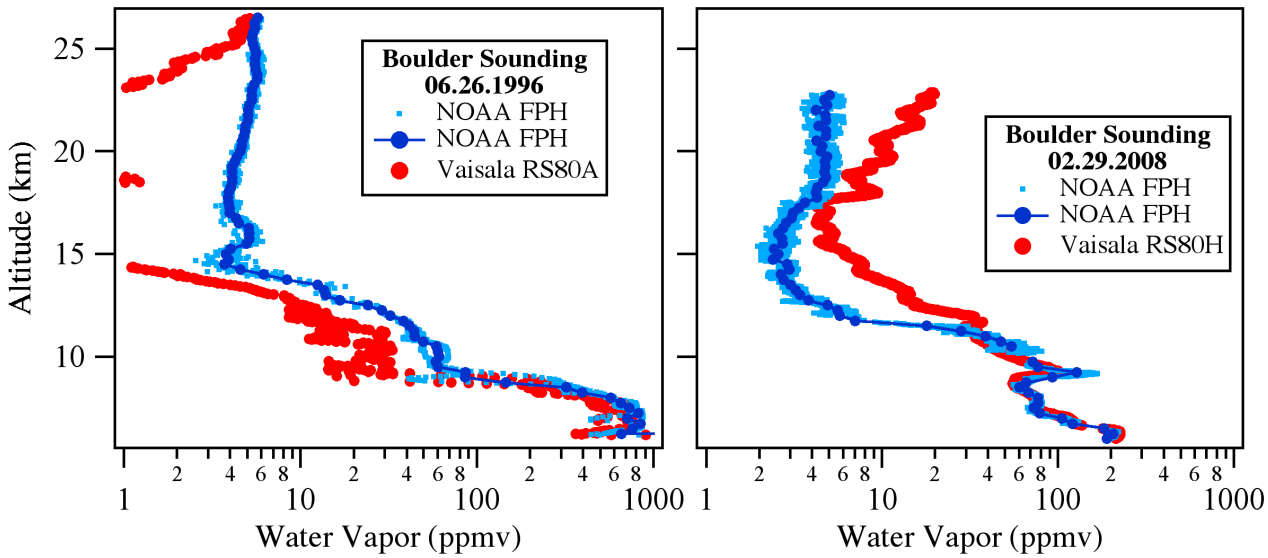

Figure 1. Water vapor mixing ratio profiles from NOAA frostpoint hygrometers (cyan and blue) and Vaisala RS80 radiosondes with A- and H-Humicap sensors (red) over Boulder, CO. The Vaisala Humicap sensors are known to be prone to measurement errors arising from contamination and degradation during storage, have increasingly long response times at cold temperatures, and typically don't respond accurately to frostpoints lower than -65°C.

Long-Term Monitoring and Trends of Halocarbons

G.S. Dutton[1], J.W. Elkins[2], J.D. Nance[1], B.D. Hall[2], D.J. Mondeel[1], J.H. Butler[2] and S.A. Montzka[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6086, E-mail: geoff.dutton@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

In the mid-1970s, the fledgling Geophysical Monitoring for Climate Change (GMCC) program started and made a commitment to measure and monitor trace gases. As GMCC grew into a division and then a premier laboratory (NOAA ESRL), the trace gas measurement programs evolved into groups with separate programs. Today's Halocarbons and other Atmospheric Trace Species (HATS) group measures 40+ atmospheric trace gases via flasks or *in situ* methods at surface sites and aboard airborne platforms. There are several instruments and programs that have made measurements of the same gases such as chloroflourcarbon-11 (CFC-11), CFC-12 and nitrous oxide (N_2O). Multiple measurements of the same gases can sometimes lead to confusion when determining what measurement to use for analysis.

This presentation will provide assimilated global trace gas data from several measurement programs including flasks and *in situ* methods. Many of these measurements are used in the NOAA ESRL products, Annual Greenhouse Gas Index (AGGI) and the Ozone Depleting Gas Index (ODGI). This presentation will also report on recent trends in the most abundant halogenated gases.

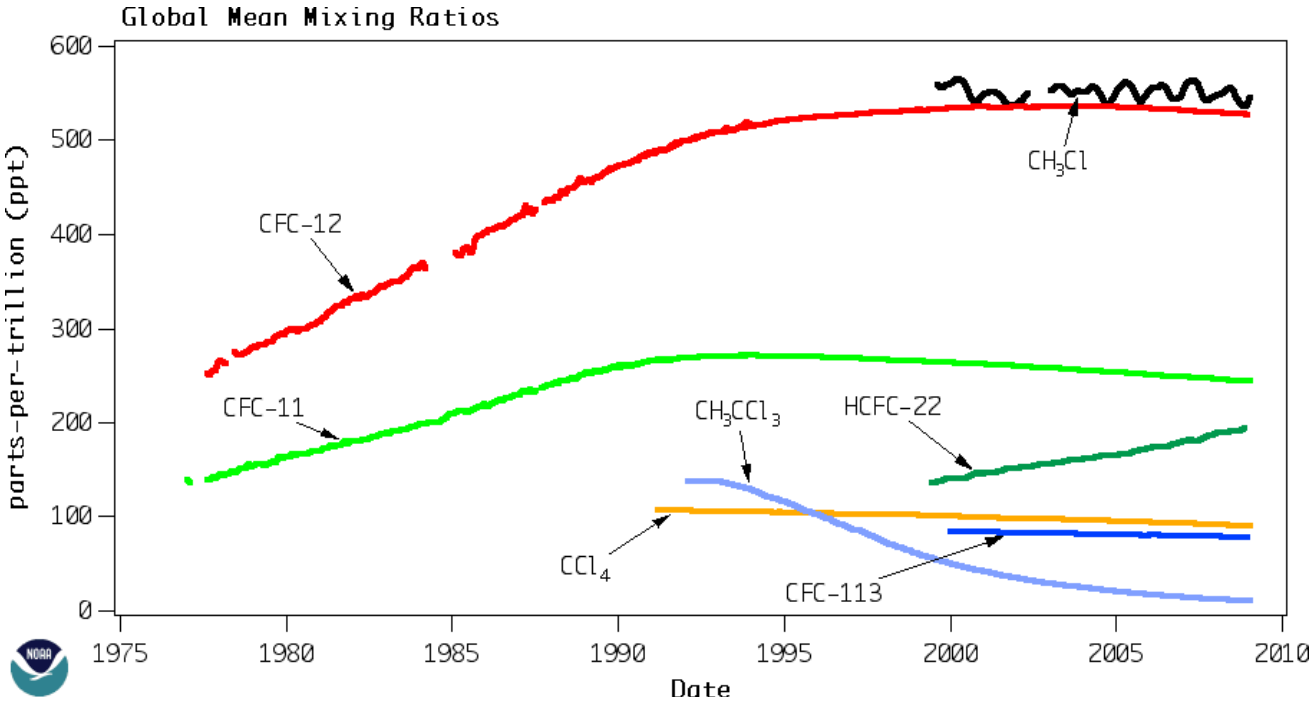

Figure 1. Four measurement programs were combined to calculate global mean mixing ratios for CFC-11 and CFC-12. As the trace gas programs evolved more halogenated gases were added in the mid to late 1990s.

A Comparison of Seasonal Cycles in Nitrous Oxide Among Different Monitoring Networks

C. Nevison

Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309; 303-497-1621, E-mail: nevison@ucar.edu

The seasonal cycle of atmospheric nitrous oxide (N_2O) reflects stratospheric, transport and biogeochemical influences. With peak-to-trough amplitudes well under 1% of the mean tropospheric mixing ratio, N_2O seasonal cycles are difficult to detect. NOAA CCGG provides by far the largest global network of atmospheric N_2O measurements, but tends to show larger seasonal cycles in the southern hemisphere than other monitoring networks, including NOAA HATS, AGAGE and CSIRO. This poster examines possible reasons for the differences in N_2O seasonal cycles among networks and the likelihood of separating transport and stratospheric influences on these cycles from biogeochemical signals.

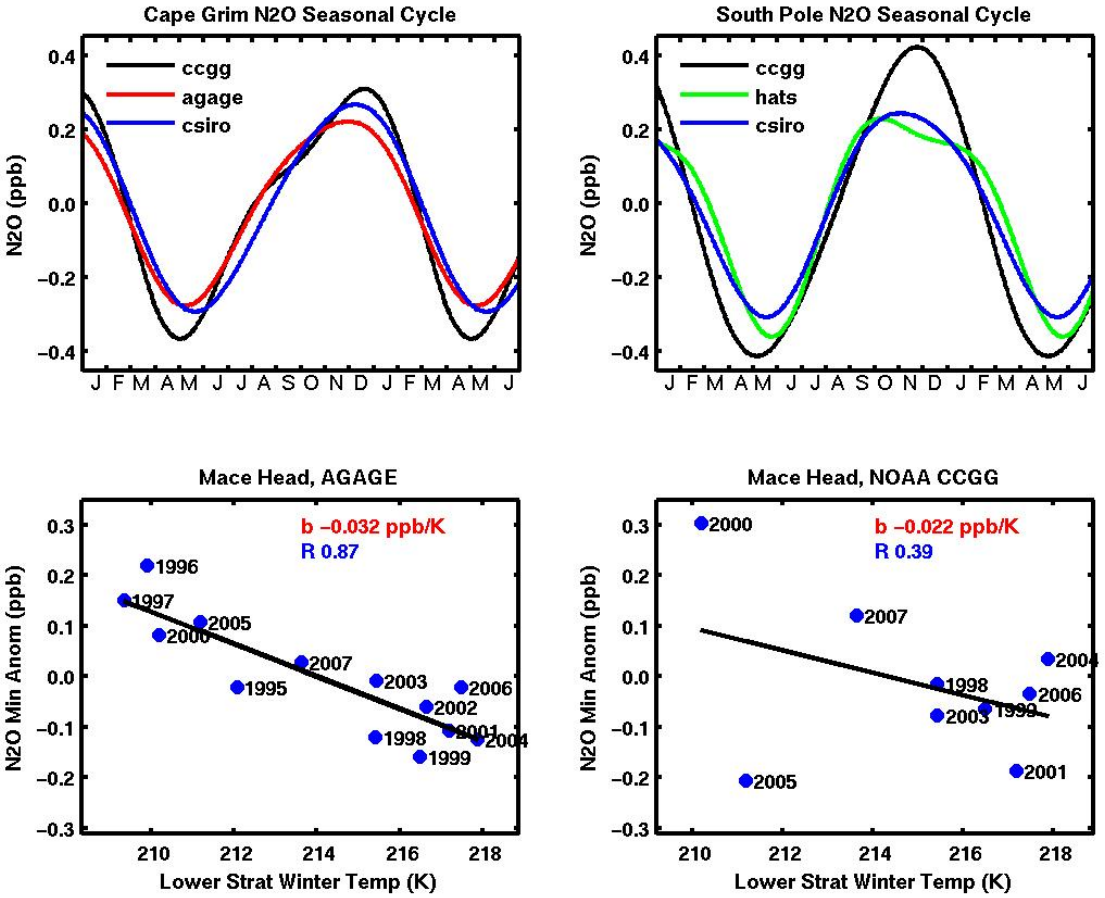

Figure 1. Mean seasonal cycles in N_2O derived from harmonic fits to detrended data from three different monitoring networks at: a) Cape Grim Tasmania, 1997-2003, b) South Pole, 2001-2007, c-d) N_2O seasonal minimum anomaly at Mace Head, Ireland plotted against mean January-March 100 hPa 60-90N temperature, c) AGAGE data from 1994-2007, d) NOAA CCGG data from 1998-2007. Since wintertime lower stratospheric temperature is a proxy for the strength of the seasonal descent of N_2O-depleted air from the stratosphere, with greater descent occurring in warm years, panels c-d suggest that interannual variability in N_2O seasonal cycles may primarily reflect stratospheric rather than biogeochemical influences at some stations and that the detection of these influences may differ among networks.

New Estimates of Global Sulfur Hexafluoride Emissions Using AGAGE and NOAA Measurements

M. Rigby[1], R. Prinn[1], E. Dlugokencky[2], J. Mühle[3], R. Weiss[3], C. Harth[3], P. Fraser[4], P. Krummel[4], P. Steele[4], P. Simmonds[5], S. O'Doherty[5] and B. Greally[5]

[1]Center for Global Change Science, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02139; 617-258-0838, E-mail: mrigby@mit.edu
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093
[4]Centre for Australian Weather and Climate Research, CSIRO Marine and Atmospheric Research, Aspendale, Victoria, Australia
[5]School of Chemistry, University of Bristol, Bristol, United Kingdom

We present a 'top-down' estimate of sulfur hexafluoride (SF_6) emissions for 2004 – 2006. A global emission rate of 5.6 ± 0.4 Gg/yr is derived, which is approximately 9% higher than predicted by the Emissions Database for Atmospheric Research for the year 2000 (EDGAR v3.2). The sensitivity of daily SF_6 mole fractions to changes in emission rate from ten source regions was found using the Model for Ozone and Related chemical Tracers (MOZART v4.5 at 1.8x1.8 degree resolution). These sensitivities were used with measurements from the Advanced Global Atmospheric Gases Experiment (AGAGE) and NOAA flask and *in-situ* networks to optimally constrain emissions. Preliminary inversion results indicate that emissions from Eastern Asia and the United States may be underestimated in the inventory, whilst Europe's emissions may be overestimated.

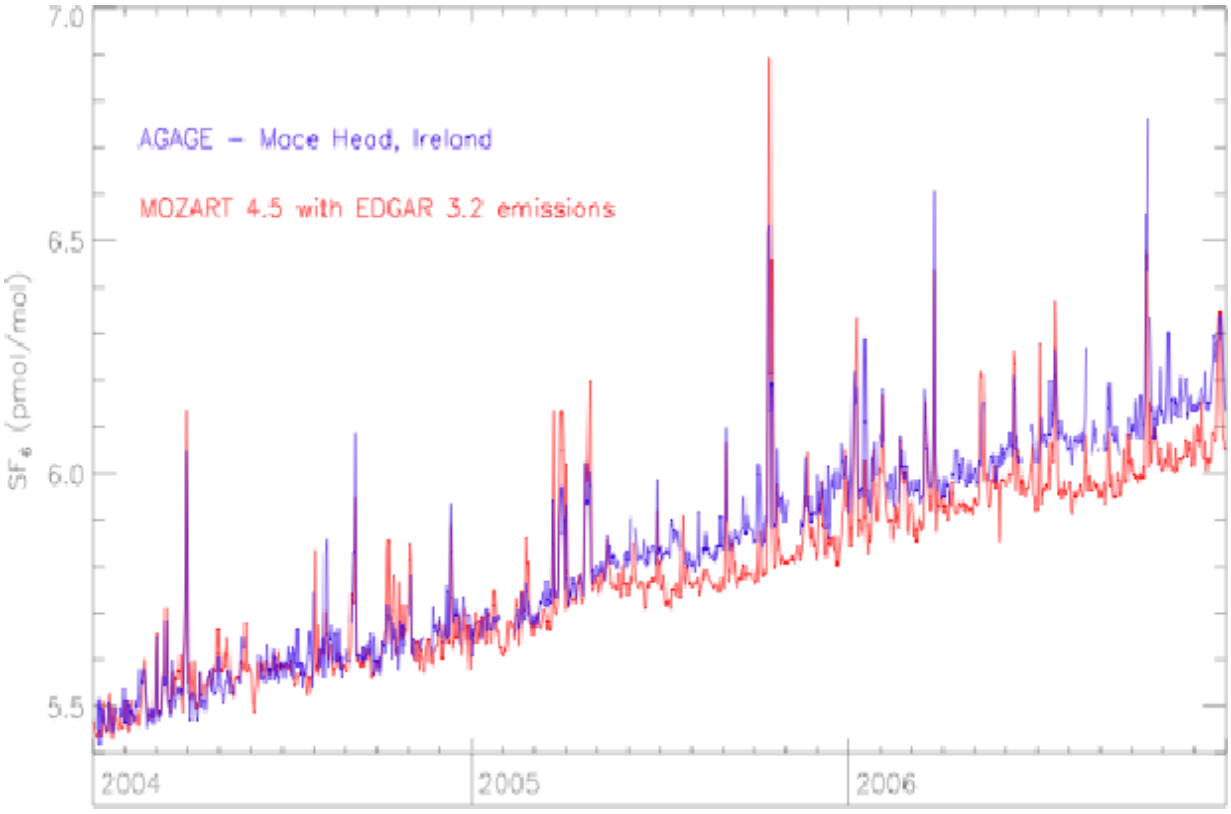

Figure 1. Daily mean AGAGE SF_6 mole fraction at Mace Head, Ireland (blue line), and simulated mole fraction at the same location using MOZART 4.5 with EDGAR 3.2 emissions (red line), 2004 - 2006. The figure shows that the model captures the variability at this site well. However, an underestimate of the rate of increase in the modeled Northern hemisphere (NH) background can be seen, consistent with an underestimate of the NH emission rate in the inventory. Pollution events are generally over-estimated by the model, which may suggest an over-estimate of nearby (European) emissions.

Isotopic Constraints on the Global Budget of Atmospheric Nitrous Oxide: Analysis of Recent Data

Y.L. Yung[1], R.L. Shia[1] and M.C. Liang[2]

[1]Division of Geological and Planetary Sciences, California Institute of Technology, 150-21 Caltech, Pasadena, CA 91125; 626-395-6940, E-mail: yly@gps.caltech.edu
[2]Research Center for Environmental Changes, Academia Sinica, Nankang, Taipei 115, Taiwan

We developed a simple box model for nitrous oxide (N_2O) that is based on laboratory kinetics measurements and constrained to reproduce the age of air in the stratosphere from the Caltech/JPL two-dimensional model of the terrestrial atmosphere. The model assumes that the primary sources of N_2O are the land, the ocean and agriculture, and the primary sink is destruction in the stratosphere. Additional N_2O sources include those from rivers, estuaries and coastal zones as well as fossil fuel combustion and industrial processes, as recommended by IPCC [2007]. The model also explores the consequences of a climate-related acceleration of the Brewer-Dobson circulation that transports N_2O from the troposphere to the stratosphere. The model includes all the commonly studied isotopologues and isotopomers of N_2O and can account for most of known observations. These observations include the abundances and trends of the isotopologues and isotopomers of N_2O since the Pre-Industrial Era. Isotopic analysis narrows the uncertainty range of the model budget. See Figs 1 and 2.

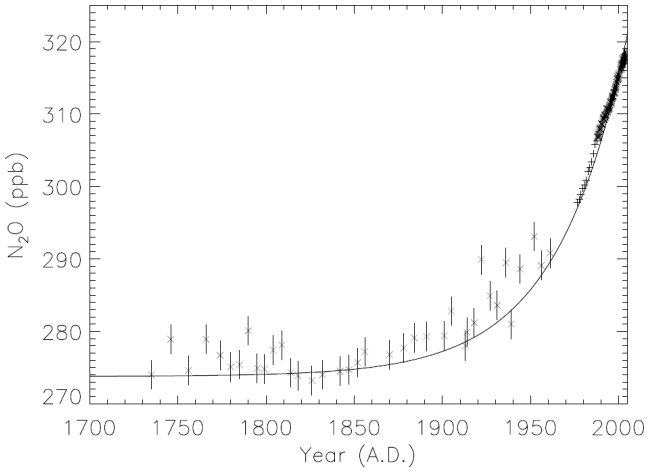

Figure 1. Comparison of N_2O concentrations from 1700 to the present between the Baseline Model (solid line) and data. Crosses: Machida et al. [1995]. Khalil and Rasmussen [1992]. More recent data from NOAA CMDL.

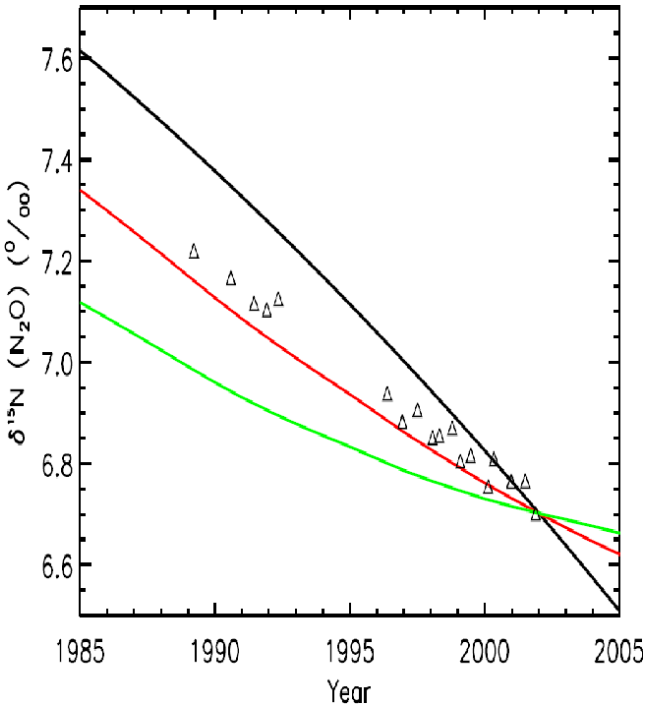

Figure 2. Comparison of specific isotopic change for $\delta^{15}N(N_2O)$ between the Baseline Model (black line), Standard Model (red line) and Extended model (green line) and data (Roeckmann and Levin 2005) from 1990 to 2002 A.D.

Improvements to the NOAA ESRL GMD Cryogenic Frostpoint Hygrometer (FPH) – New Digital Control

E. Hall[1], A. Jordan[2], D. Hurst[2], S. Oltmans[3] and J. Wendell[3]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-4288, E-mail: emrys.hall@noaa.gov
[2]Science and Technology Corporation, Boulder, CO 80305
[3]NOAA Earth System Research Laboratory, Boulder, CO 80305

Research and development started 4 years ago in February 2005 transforming the historic analog NOAA cryogenic FPH into a digitally-controlled instrument. The basic optical and thermodynamic fundamentals still used in today's hygrometer were developed in 1956 and have undergone few major changes over the years. The electronics have changed as necessary and as parts became obsolete. This poster will focus on the improvements the new digital hygrometer boasts over its predecessor in weight, performance, and cost. Adding a microcontroller to the electronics increases the versatility, allows for advanced measurement techniques, and creates new complex control schemes that were unrealistic for the older analog hygrometer. The analog instruments were flown monthly at Boulder from 1980 and at Lauder, New Zealand from 2004 until early 2008 when both sites began launching the new digital NOAA FPH. Comparisons of NOAA FPH data with balloon-borne data from the University of Colorado Cryogenic Frostpoint Hygrometer (CU-CFH) and vertical retrievals from satellite-based measurements from the NASA Earth Observing System (EOS) Microwave Limb Sounder (MLS) show good agreement. This instrument remains a work in progress and there are many future plans and improvements that will be addressed.

Figure 1. Emrys Hall about to launch one of the digitally controlled NOAA ESRL GMD cryogenic frostpoint hygrometers with an attached ozonesonde from Marhsall Field Site near Boulder, CO.

On the Definition of a European Baseline for Climate Altering Halogenated Gases

F. Furlani[1], J. Arduini[2], D. Cava[3], M. Maione[2] and U. Giostral[2]

[1]University of Urbino, Institute of Physics, Campus Sogesta, Urbino 61029, Italy; +00390722303316, E-mail: michela.maione@uniurb.it
[2]University of Urbino, Institute of Chemical Sciences, Urbino 61029, Italy
[3]National Research Council, Institute of Atmospheric Sciences and Climate, Lecce Section, Str. Prov. Lecce - Monteroni, Italy

Starting from 2002, 27 halogenated greenhouse gases are continuously monitored at the atmospheric research station “O. Vittori” located on the top of Monte Cimone, Northern Apennines, Italy (2165 m asl), using a GC-MS instrument equipped with an automating sampling and enrichment unit, allowing us to perform a chromatographic run of ambient air every second hour. That in the frame of the SOGE (System for Observation of halogenated Greenhouse gases in Europe) network, an integrated system based on a combination of observations and models. One of the aims of the network is to provide long-term European observations of halogenated greenhouse gases in order to assess atmospheric baseline trends and annual growth rates. Establishing the baseline is particularly challenging in a station like Monte Cimone characterised by a complex meteorological and source field. The approach proposed is based on the identification of the lowest concentration values in a given temporal range to which a Δc representing variation due to instrumental error is added. This approach has been tested using data from a less complex situation (sea level, not influenced by strong emission fields) and the obtained baselines have been compared against those already determined for that specific site using a different approach available in the open literature. Trends are evaluated by using a non-linear regression function, able to take into account both annual and seasonal variation. A new regression function relating the seasonal amplitude to the concentration of the investigated compound is proposed. The new regression function gives better R2 values for compounds characterized by a shorter lifetime.

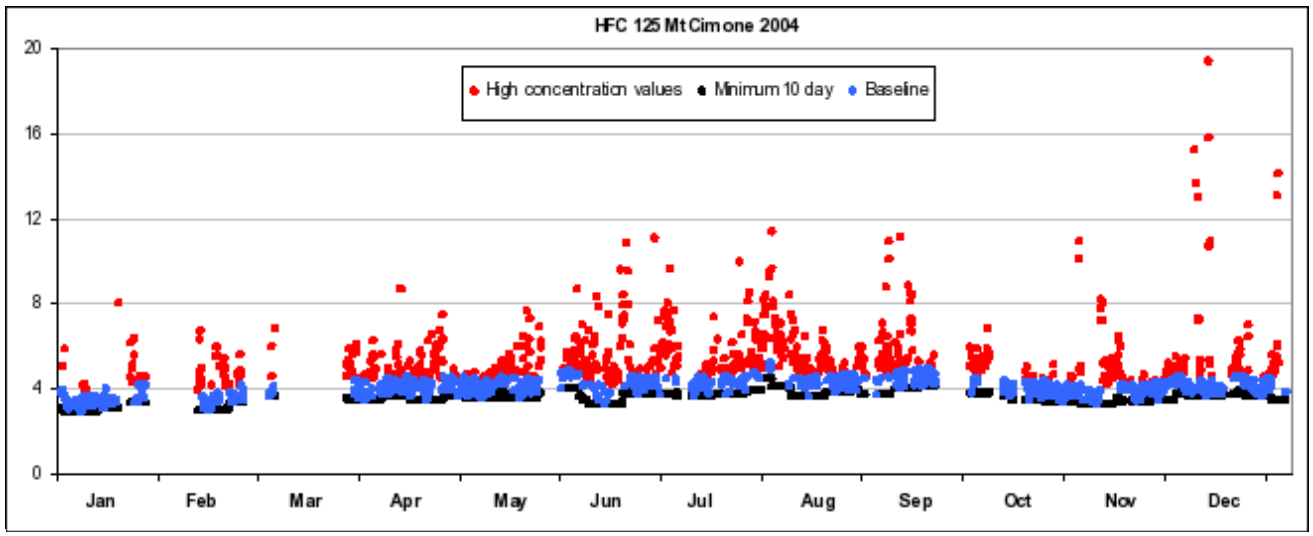

Figure 1. One year of continuous measurements of HFC-125 at Monte Cimone.

Snapshot of Atmospheric Trace Gases "Pole to Pole" – Results from the HIPPO1

B.R. Miller[1], F. Moore[1], L. Miller[2], S.A. Montzka[3], E. Atlas[4], J.B. Miller[1], B.H. Vaughn[5], S.E. Michel[5], P. Lang[3], K. Sours[1], C. Sweeney[1], D. Guenther[1], S. Wolter[1], J. Higgs[2], S. Davis[1], D. Nance[1], E. Dlugokencky[3], P. Novelli[3], T. Conway[3], P. Tans[3], J.W. Elkins[3] and S. Wofsy[6]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6624, E-mail: ben.r.miller@noaa.gov
[2]Science and Technology Corporation, Boulder, CO 80305
[3]NOAA Earth System Research Laboratory, Boulder, CO 80305
[4]Rosenstiel School of Marine Atmospheric Science, Miami, FL 33149
[5]Insitute for Arctic and Alpine Research, University of Colorado, Boulder, CO 80309
[6]Department of Earth and Planetary Sciences and the Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138

Results from flask samples taken during the first mission (January 2009) of a planned five-mission "Pole to Pole" campaign provide an unprecedented snapshot view of ~40 atmospheric trace gas distributions throughout much of the troposphere. Using the Carbon Cycle Greenhouse Gases group's programmable flask packages, 233 whole air samples were acquired and analyzed for CO_2, CO, CH_4, N_2O, H_2, SF_6, non-methane hydrocarbons, halocarbons and sulfur compounds. Trace gas distribution patterns derived from the interplay of transport, chemistry and/or source/sink distributions are evident across hemispheric scales and through atmospheric regimes that include the open Pacific Ocean and North America and from near-surface (200m) up to regions of stratospheric influence (14,400m). The multitude of measured atmospheric compounds, spanning a wide range of lifetimes, growth rates and source/sink distributions, provide insight into chemistry and transport processes.

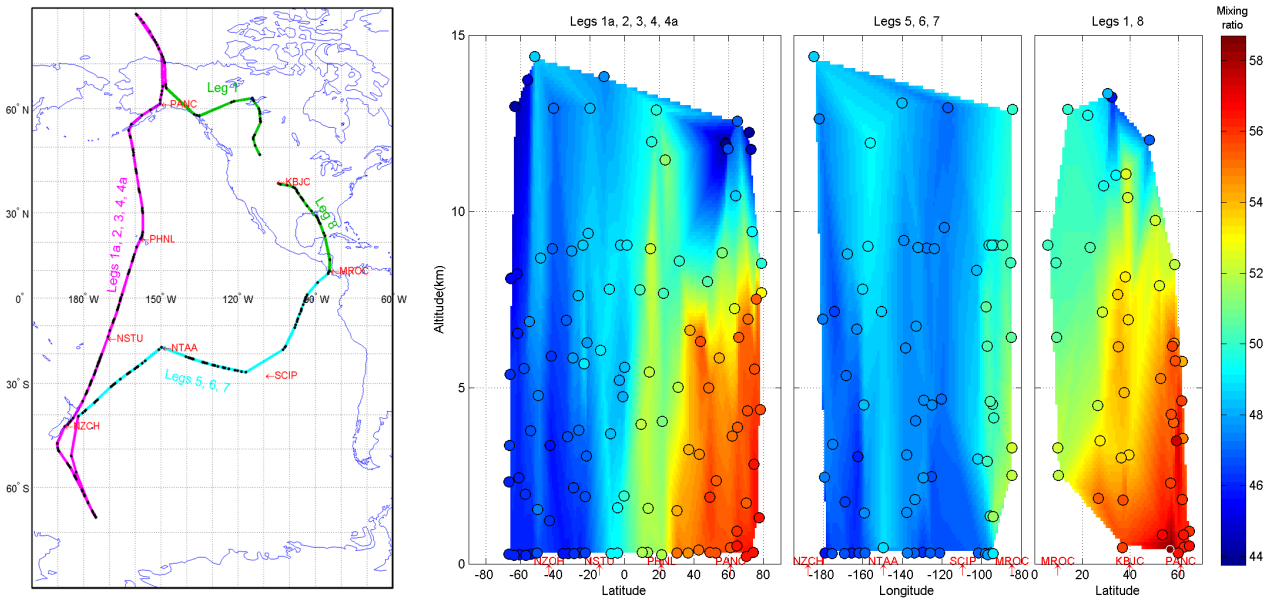

Figure 1. HIPPO January 2009. Left-most panel shows flight track with black dots indicating the 233 flask sampling locations along the 8 flight legs. The sampling began in Billings, Montana and proceeded in a counter-clockwise direction ending in Boulder, Colorado. Black circles in the three right panels indicate the altitude (km) and latitude or longitude for those same samples. The colors within the black circles denote the measured HFC-134a mixing ratio in parts-per-trillion (see colorbar). A surface was fitted to the measurements to produce interpolated values between data points to serve as an aid for the eye in grouping data and should not be misconstrued as indicating atmospheric "features". Airport locations (in red) are PANC Anchorage, AK; PHNL Honolulu, HI; NSTU Pago Pago, AS; NZCH Christchurch, NZ; NTAA Tahiti; SCIP Easter Island; MROC Costa Rica.

Global Trends in SF_6 from the Halocarbon Flask Sampling Network

B. Hall[1], D. Mondeel[2], D. Nance[2], G. Dutton[2], J. Butler[1] and J. Elkins[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-7011, E-mail: Bradley.Hall@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Tropospheric mixing ratios of sulfur hexafluoride (SF_6), a very long-lived greenhouse gas, have been increasing steadily over the last few decades. The NOAA Earth System Research Laboratory has maintained programs to monitor SF_6 in the background atmosphere. As part of one such program, air samples have been collected at eight sites throughout the world since 1994 and three additional sites added later. These samples are compared to compressed gas standards prepared gravimetrically at NOAA. The SF_6 calibration scale has recently been updated, resulting in small changes to the NOAA SF_6 scale. Flask data from the Halocarbon sampling network have been updated to reflect these changes. Atmospheric SF_6 data from this program indicate that the atmospheric growth rate of SF_6 has increased in recent years. An analysis of these data and those from other sampling programs, along with reported SF_6 emissions, will be presented in an effort to understand these recent trends.

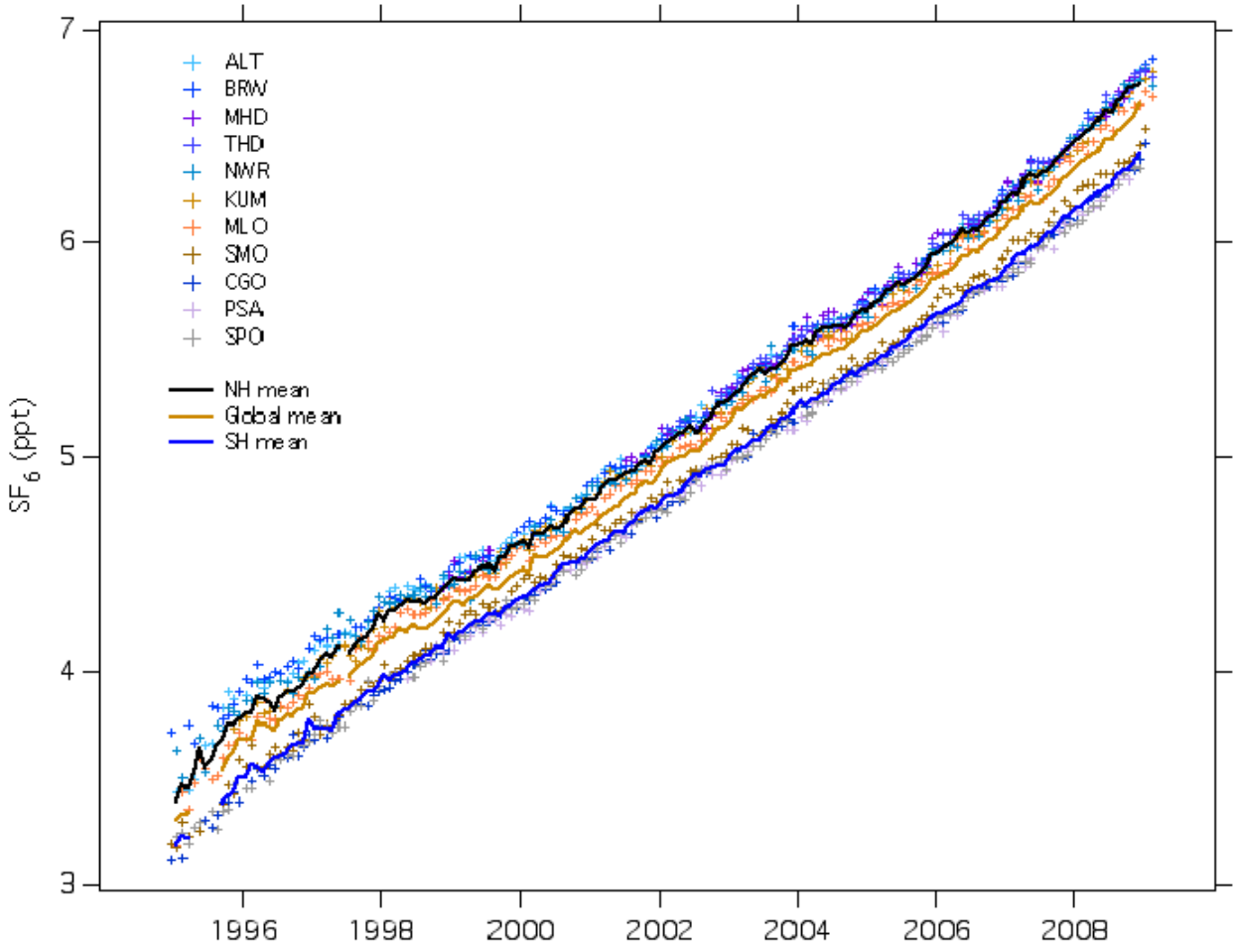

Figure 1. Background atmospheric SF_6 (ppt) from eleven NOAA flask sampling sites.

START-08 and HIPPO: Airborne Projects of the HATS Group in ESRL GMD

J. Elkins[1], F. Moore[2], D. Hurst[2], G. Dutton[2], B. Hall[1], J. Nance[2], S. Montzka[1], B. Miller[2], L. Miller[2], C. Siso[2], D. Mondeel[2], L. Patrick[2], S. Oltmans[1], D. Guenther[2], M. Heller[2], J. Higgs[3], D. Neff[2], C. Sweeney[2] and S. Wolter[2]

[1]NOAA Earth System Research Laboratory, Boulder, CO 80305
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-7068, fred.moore@noaa.gov
[3]Science and Technology Corporation, Boulder, CO 80305

Over the last two years the HATS group has been involved in two high profile projects using the NSF Gulfstream jet operated out of the Rocky Mountain Regional Airport (formerly known as Jeffco). These projects are being managed by the Research Aviation Facility (RAF). The *PANTHER, *UCATS, and *NWAS instrument packages were all involved in measuring gases that play major roles in ozone depletion and or climate forcing (CFC's, HCFC's, HFC's, Hydrocarbons, N_2O, SF_6, CO, CO_2, CH_4, O_3, H_2O, and H_2). The START-08 (Stratosphere-Troposphere Analyses of Regional Transport 2008) project focused on the Stratosphere-Troposphere interface region, from the extra tropics to high latitudes. START-08 samples were collected primarily over North America. The HIAPER Pole-to-Pole Observations of greenhouse gases mission (HIPPO) focuses on global processes such as land-ocean boundary layer interactions with the free troposphere, and inter hemispheric exchange process. HIPPO samples were collected in repeated vertical profiles throughout most of the troposphere from very high northern latitudes to very high southern latitudes. We will present a poster containing a light overview of the instrumentation used and the project goals.

* PANTHER: The PAN and other Trace Hydrohalocarbon ExpeRiment
* UCATS: Unmanned aircraft systems Chromatograph for Atmospheric Trace Species
* NWAS: NOAA Whole Air Sampler

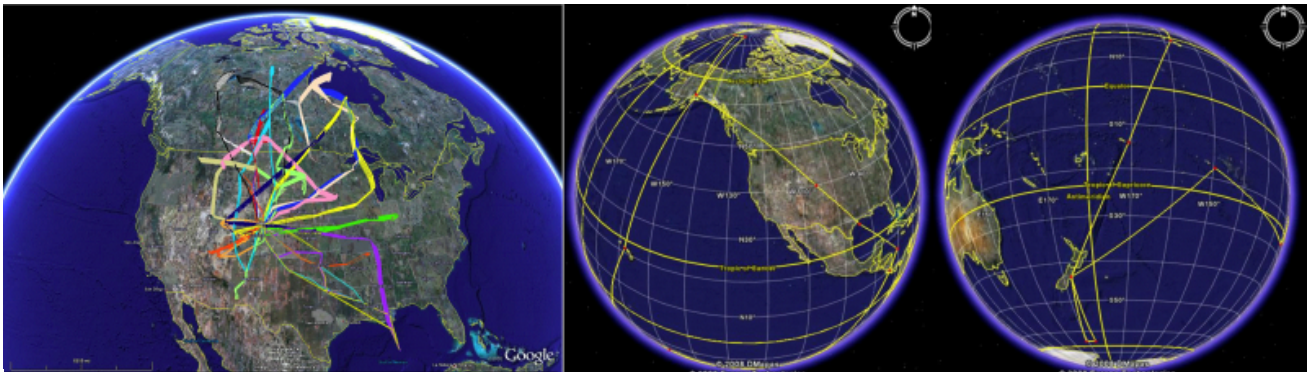

Figure 1. Google earth plots of the NSF Gulf Stream flight tracks for 18 START-08 research flights over North America, and 11 HIPPO research flights that acquired over 60 vertical profiles with near Pole-to-Pole coverage.

Decadal Brightening of Downwelling Shortwave in the Continental U.S.

J.A. Augustine[1], C.N. Long[2], E. Dutton[1], W. Wiscomb[3], M. Wild[4], S.A. McFarlane[2] and C.J. Flynn[2]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6415, E-mail: John.A.Augustine@noaa.gov
[2]Atmospheric Radiation Measurement Program, Pacific Northwest Laboratory, Richland, WA 99352
[3]Brookhaven National Laboratory, Upton, NY 11973
[4]ETH Zurich, Institute for Atmospheric and Climate Science, Zurich, Switzerland

Recent studies have reported decreases in downwelling solar irradiance of 2-3 Wm^{-2}/decade at the earth's surface from the 1960s through the early 1990s, and referred to that phenomenon as "global dimming." Our study, as well as others who used worldwide BSRN data, reveal a "brightening" of about the same magnitude from 1992 through the early 2000s, discounting Pinatubo effects. There is disagreement on whether changes in clouds or aerosols caused the observed brightening. To address this problem, we use data from the ARM Central Facility in Oklahoma and ESRL's national SURFRAD network. Seasonal and annual averages were computed in a way that minimized the effects of bad or missing data. A clear-sky identification algorithm was applied to separate the effects of aerosols and clouds. At the ARM site, increases of +3Wm^{-2} for clear-sky and +6 Wm^{-2}/decade for all sky conditions were observed from 1996 through 2007, with the greatest increases in the diffuse component for both. Seasonally, the greatest brightening occurred in the winter and fall, with dimming occurring in spring. These annual and seasonal shortwave trends are anticorrelated with cloud cover. All sites exhibit an increase in global irradiance, with an aggregate average of +7.8 Wm^{-2}/decade (see figure), also with most of the increase in the diffuse. Most of these irradiance increases were accompanied by decreases in cloud cover both in the daytime and night (only one site showed an increase in cloudiness). Model calculations show that an inordinately large aerosol optical depth of 0.2 would be required to increase the clear-sky diffuse by the +3Wm^{-2}/decade that was observed for clear skies at the ARM site. The increase in national average clear-sky diffuse was even greater at +4.5Wm^{-2}/decade. These analyses strongly indicate that changes in cloud cover are largely responsible for the observed brightening over the U.S.

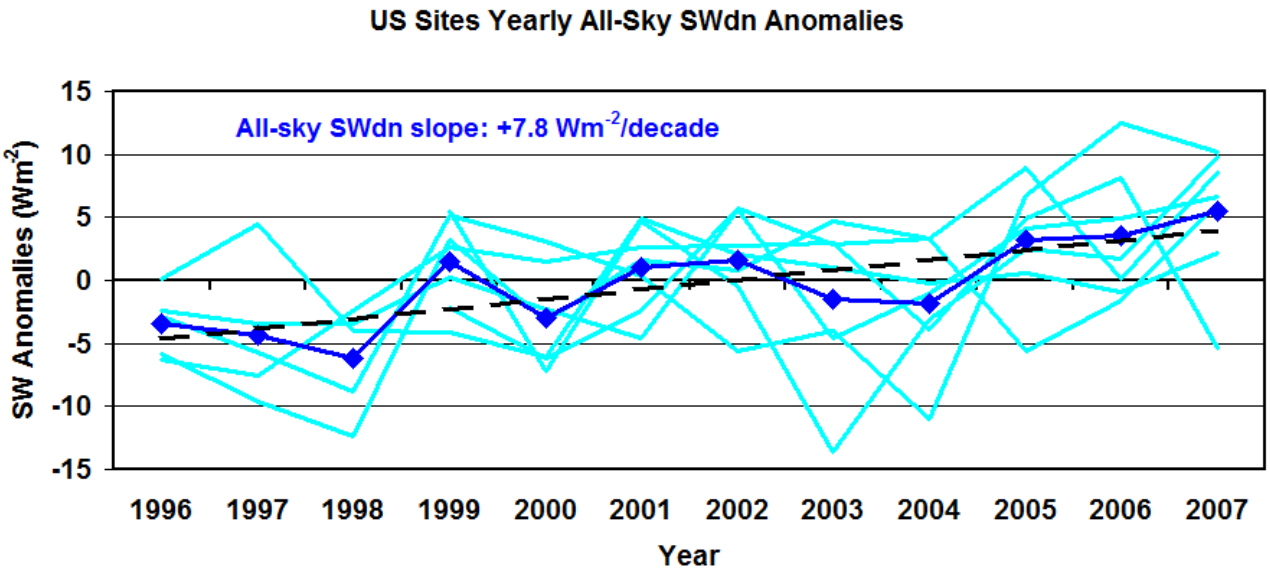

Figure 1. Annual average anomalies of all-sky downwelling solar irradiance for the ARM Central Facility and six SURFRAD stations (light blue). The dark curves represents the aggregate average (dark blue) and corresponding least squares fit (dashed).

Shortwave Spectral Radiative Closure Studies at the ARM Southern Great Plains Climate Research Facility

J.S. Delamere[1], J. Michalsky[2], P.W. Kiedron[3] and E.J. Mlawer[1]

[1]Atmospheric and Environmental Research, Inc., Lexington, MA 02421; 303-497-4754, E-mail: jdelamer@aer.com
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

The Department of Energy Atmospheric Radiation Measurement (ARM) Program's commitment to collecting spectrally resolved radiometric measurements and coincident atmospheric state measurements at its climate research facilities has enabled extensive radiative closure studies across the electromagnetic spectrum. The concept for radiative closure experiments using spectral measurements and line-by-line radiative transfer model calculations has been successfully used to: 1) validate and improve continuum absorption models and spectral line parameters used in line-by-line models, 2) assess the ability to define the atmospheric state used in the model calculations and 3) assess the quality of the radiation observations themselves. The design of the radiative closure experiment allows all three of these aspects to be simultaneously addressed.

This poster will detail results from recent shortwave radiative closure studies performed between direct-beam transmittances derived from the rotating shadowband spectroradiometer (RSS) irradiance measurements (360–1050 nm) and corresponding calculations performed by the Code for High Resolution Accelerated Radiative Transfer (CHARTS); the spectral line parameters are obtained from the current HITRAN database and the water vapor continuum model MT_CKD utilized. The comparisons are used to evaluate the accuracy and inter-band consistency of water vapor absorption parameters in three adjacent water vapor bands centered at 720, 820, and 940 nm. The goal of this effort is to improve the accuracy of these parameters, which would in turn improve global climate model calculations.

A parallel analysis has focused on the assessment of measured/retrieved aerosol properties in cloud-free conditions using both RSS transmittances and shortwave spectroradiometer (SWS) zenith radiance measurements (350-2170 nm). Measurements from an independent radiometer are used to derive aerosol optical depth; aerosol single scattering albedo and asymmetry parameters are derived from *in situ* measurements. A range of aerosol loading, surface conditions, and solar positions are included in the study. Initial results show approximate agreement between the RSS-derived transmittances and those from the CHARTS calculations.

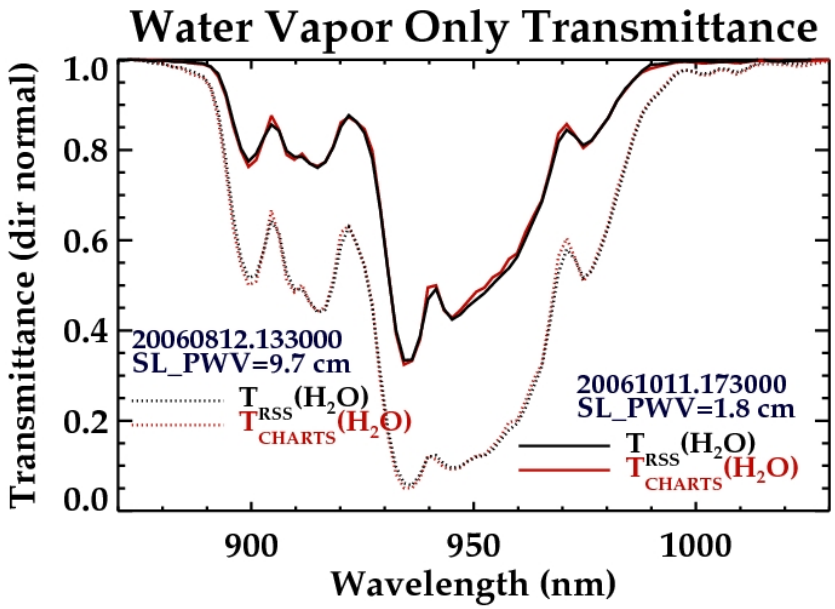

Figure 1. Comparison of RSS-derived transmittance (black) and LBLRTM/CHARTS-calculated transmittance (red) for 940-nm water vapor band for two different water vapor loadings.

Aerosol Climatology for the ARM Climate Research Facility In North-Central Oklahoma: 1992 - 2008

J. Michalsky[1], F. Denn[2], C. Flynn[3], G. Hodges[4], P. Kiedron[4], A. Koontz[3], J. Schlemmer[5] and S. Schwartz[6]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6360, E-mail: joseph.michalsky@noaa.gov
[2]Science Systems and Applications, Inc, Hampton, VA 23693
[3]Pacific Northwest National Laboratory, Richland, WA 99352
[4]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[5]Atmospheric Sciences Research Center, SUNY Albany, Albany, NY 12203
[6]Brookhaven National Laboratory, Upton, NY 11973

Aerosol optical depth (AOD) has been measured at the Atmospheric Radiation Measurement (ARM) central facility near Lamont, Oklahoma, since the fall of 1992. Most of the data presented are from the multi-filter rotating shadowband radiometer (MFRSR), however, as many as four simultaneous AOD measurements have been made routinely at the site including sun-pointing sunradiometry. Comparisons are shown. The early part of this 16-year record had a disturbed stratosphere with residual Mt. Pinatubo aerosols, followed by the cleanest stratosphere in decades. As such the last 13 years of the record reflect changes that have occurred predominantly in the troposphere. The field calibration technique is briefly described and compared to Langley calibrations from Mauna Loa Observatory. A modified cloud-screening technique is introduced that increases the number of daily-averaged AODs retrieved annually to about 250 days compared to 175 days when a more conservative method was employed in earlier studies. AODs are calculated when the air mass is less than six, i.e., when the sun's elevation is greater than 9°. The more inclusive cloud-screen and the use of most of the daylight hours yield a data set that can be used to more faithfully represent the true aerosol climate for a site. The diurnal aerosol cycle is examined seasonally to assess the effects of aerosol climatology measurements based on less frequent sampling such as those from satellites.

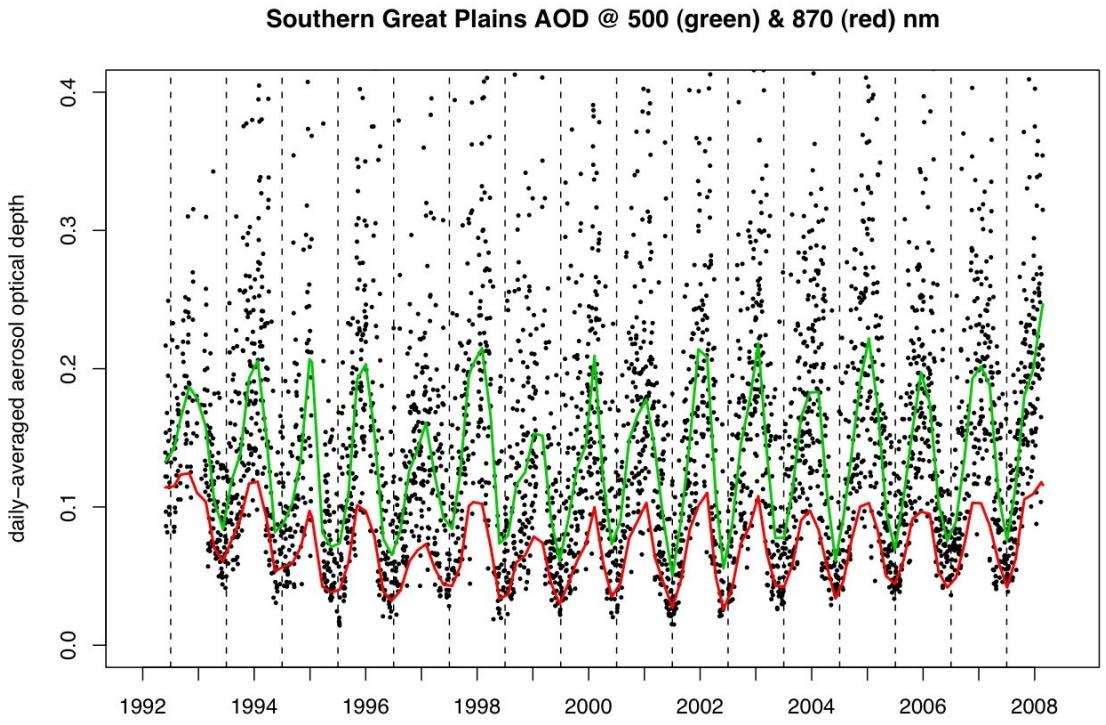

Figure 1. Black points are over 4000 daily averages of AOD at 500 nm. Green and red lines are lowess estimates of the seasonal behavior of the AODs at 500 and 870 nm, respectively.

The NOAA Earth System Research Laboratory Airborne Aerosol Observatory: Climatology and Seasonal Variation of Aerosol Properties Over Central Illinois

P. Sheridan[1], B. Andrews[2] and J. Ogren[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6672, E-mail: patrick.sheridan@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

In June of 2006, ESRL began conducting regular (2-3 times per week) light aircraft measurements over central Illinois. The program is the Airborne Aerosol Observatory (AAO), and the platform is a Cessna T206H aircraft. The primary objective of this program is to obtain a climatology of aerosol properties aloft for evaluating aerosol radiative forcing and testing chemical transport models. Through the end of March 2009 (~33 months), 334 research flights have been conducted, most of these over the Bondville surface station. Statistical distributions and climatologies of aerosol properties have been compiled for the set of AAO research flights. While insufficient to determine long-term trends, the nearly three years of data permit us to begin to understand seasonal variation of the aerosols over central Illinois. Low altitude fly-bys of the Bondville station show that surface measurements of aerosol extinction are representative of aerosols in the lowest km of the column. Although individual profiles can be quite variable, the climatological profile of single-scattering albedo shows very little variation in the vertical. Comparisons of AAO aerosol data have been made with measurements collected on another Cessna 206 aircraft flying a similar aerosol package in profiles over Oklahoma. Comparisons of AAO measurements with Aeronet sunphotometer and CALIPSO satellite-borne lidar data will also be discussed.

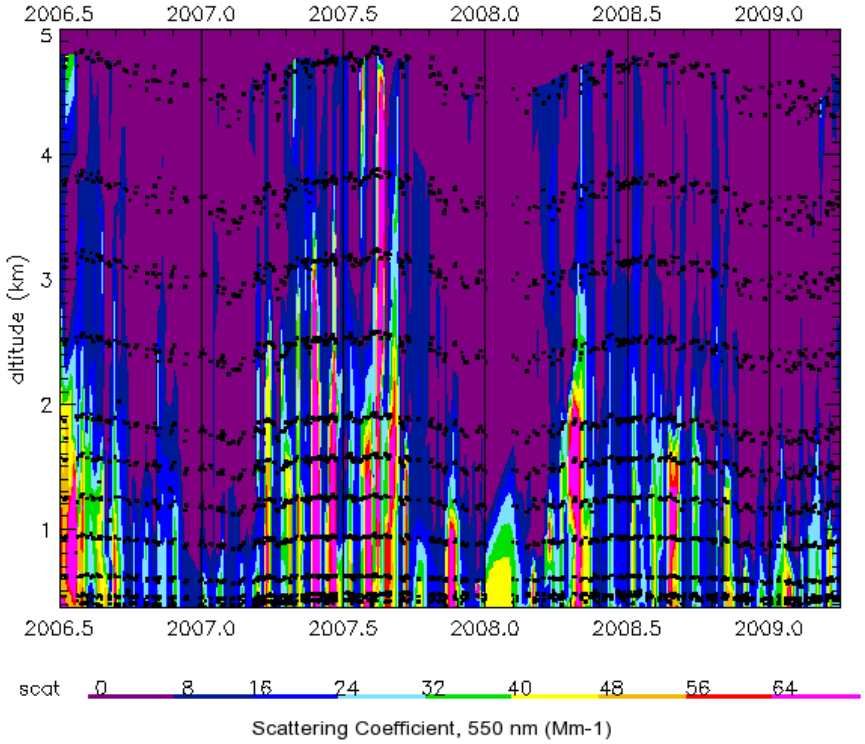

Figure 1. Contour plot of dry aerosol light scattering coefficient (550 nm) vs. time measured by the AAO over central Illinois. Black dots represent individual level flight segments. Seasonal variation in the scattering data is evident, with larger scattering coefficients extending to greater heights above the surface in the spring through fall time frame. Elevated aerosol layers are relatively rare during the winter months. Boundary layer aerosols and aerosol layers aloft tend to last over synoptic (i.e., days to weeks) time scales, consistent with build up and removal by meteorological events.

The NOAA ESRL Collaborative Global Surface Aerosol Monitoring Network

P.J. Sheridan[1], E. Andrews[2], A. Jefferson[2] and J.A. Ogren[1]

[1]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6672, E-mail: patrick.sheridan@noaa.gov
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

The NOAA Earth System Research Laboratory maintains five Baseline Observatories to monitor the atmospheric background levels of trace gases and aerosols. Measurements at these remote sites permit us to determine to what extent the global backgrounds are changing over time. Since aerosols are perturbed near the sources, these Observatories are in prime locations to assess baseline changes to the atmospheric aerosol. With the recent interest in anthropogenic aerosol radiative forcing and its effects on climate forcing, ESRL has expanded its network of surface measurement sites to locations that are at times influenced significantly by anthropogenic emissions. This long-term strategy should permit the determination of how much of the forcing at these locations is caused by human activities. In order to reduce the uncertainties associated with extrapolating relatively few discrete observations up to regional or global scales, many more stations in different climatological regions are needed. Unfortunately, there is no way ESRL's budget can fully fund such an endeavor. The primary way we have been able to expand the network to include another major anthropogenic aerosol source region (southeast Asia), the region considered the bellwether of global climate change (the Arctic), and other perturbed areas is to foster collaborations between NOAA ESRL and interested organizations in the U.S. and around the world. The collaborations we have developed present advantages for both parties, and the data collected are directly comparable with that from other stations in the network. This poster describes the essence of these collaborations.

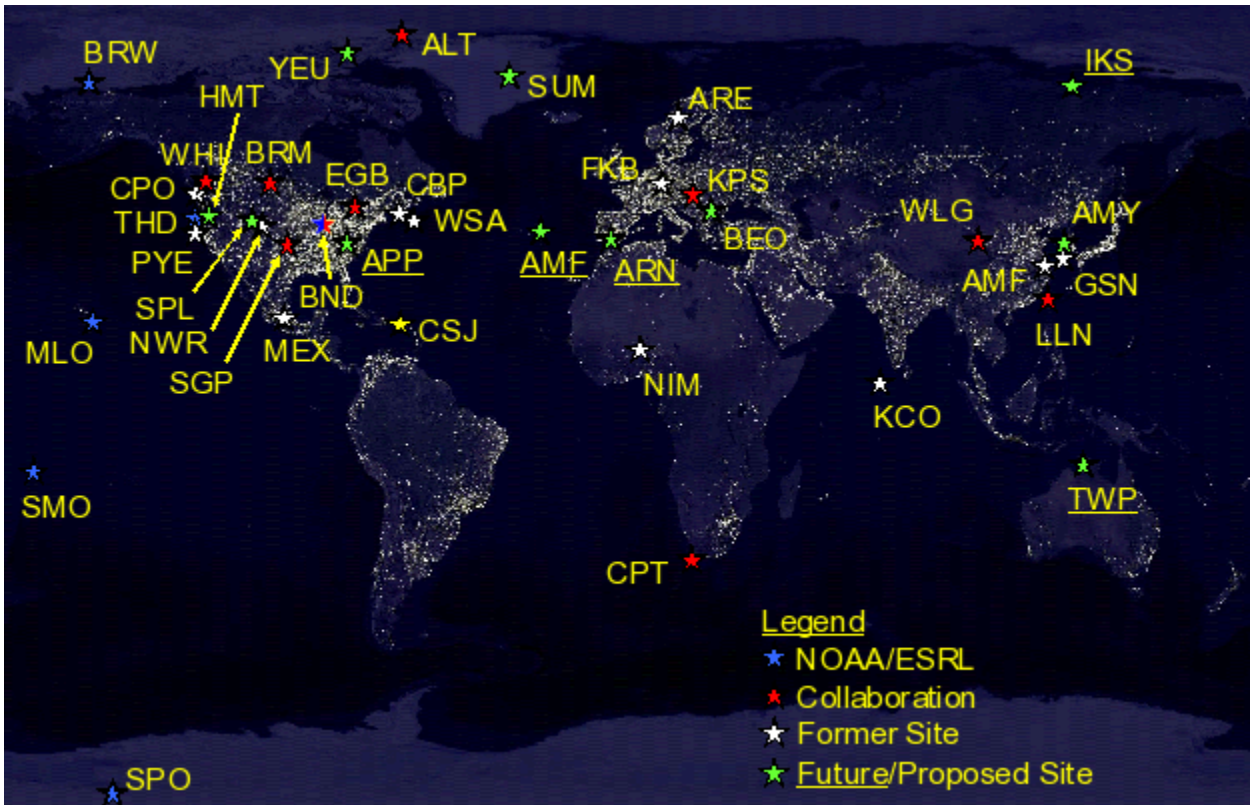

Figure 1. The NOAA ESRL Collaborative Global Surface Aerosol Monitoring Network.

Measurements of Sub-Micron Particles Using an Ultra-High Sensitivity Aerosol Spectrometer (UHSAS) from the Mauna Loa Observatory During HAVAIKI, October and November, 2009

D.W. Toohey[1], D.C. Noone[2], B. Gandrud[3] and J.E. Barnes[4]

[1]Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO 80309; 303-735-0002, E-mail: toohey@colorado.edu
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[3]Droplet Measurement Technologies, Boulder, CO 80301
[4]NOAA Earth System Research Laboratory, Mauna Loa Observatory, Hilo, HI 96720

During October 2009 an Ultra-High Sensitivity Aerosol Spectrometer (UHSAS, Droplet Measurement Technologies, Boulder, CO) sampled sub-micron aerosols (55 nm < D < 1000 nm) with 10-second resolution at the NOAA Mauna Loa Observatory in support of the goals of the Hawaii Vapor Isotope Knowledge Experiment (HAVAIKI). HAVAIKI was a focused campaign designed to test the responses of three *in situ* water vapor isotope instruments that were under development and potentially close to market. Following this campaign, the UHSAS remained at the Observatory for the month of November to examine correlations between sulfur dioxide and particulate matter (PM) as a demonstration for closure in the sulfate/PM budget during periods of upslope conditions when volcanic fog ("vog") prevailed at the station. These high-resolution aerosol measurements were designed to provide an independent 'axis' for interpretations of air-mass origins for interpretations of variations in isotopes of water vapor, as well as a means to test the performance of the UHSAS under conditions varying from sampling of dry, free-tropospheric air to recently lofted, and relatively wet, boundary layer air. This poster will present an overview of the measurements to illustrate the value of high-resolution aerosol measurements for interpretations of water vapor isotopes, and preliminary results during particle nucleation events that are consistent with the formation of sulfate aerosols by rapid oxidation of sulfur dioxide in sunlight. An example of observations in a particle nucleation event is shown in Figure 1.

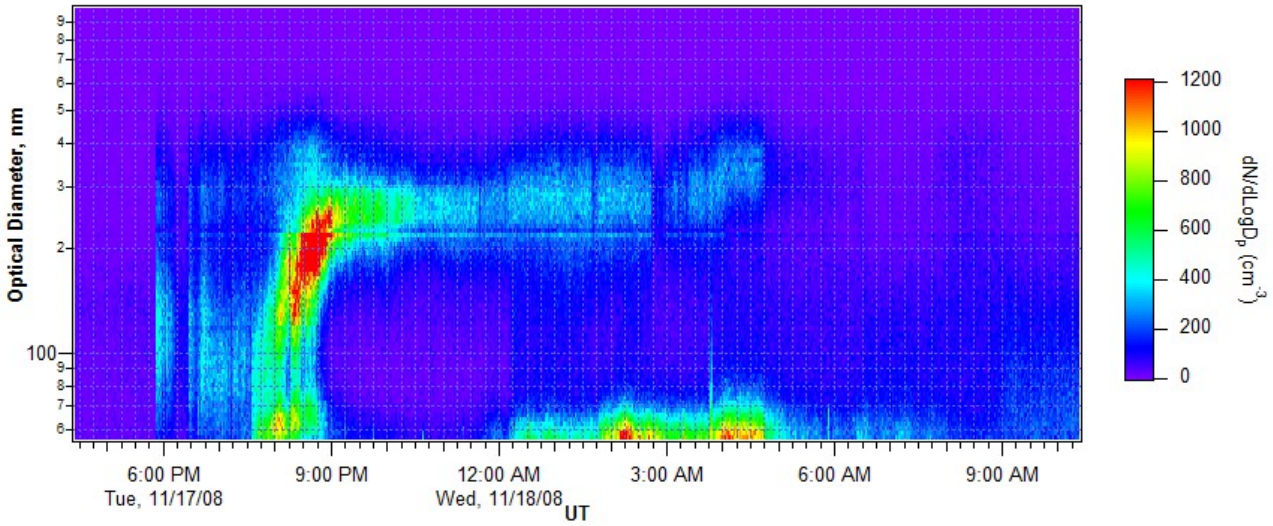

Figure 1. Observations of sub-micron particles on November 17, 2009 from the Mauna Loa Observatory.

Synoptic Transport of Anthropogenic BC to the Arctic

S. Sharma and M. Ishizawa

Environment Canada, 4905 Dufferin Street, Toronto, Ontario M3H 5T4, Canada; 416-739-5820, E-mail: sangeeta.sharma@ec.gc.ca

Synoptic transport of black carbon (BC) from different source regions at the temperate latitudes to the Arctic is explored. Major source regions such as Eurasia (Europe and Former Soviet Union (FSU)), North America and China impact the Arctic during the Arctic haze period as the pollution is transported northward. Figures 1a and 1b show BC emissions compiled from 1990 to 2005 using Cooke et al., 1999's methodology based on United Nations fuel consumption dataset. Emissions from FSU declined in early 90s due to the collapse of Soviet Union. However, since 1998, BC emissions are on the rise in all regions. Here we address the question: are BC emissions or atmospheric transport governing factors controlling BC concentrations in the Arctic? Figure 1c shows a time series of equivalent black carbon (EBC) from *in-situ* measurements at four sites situated in different regions of the Arctic. The sites showed strong synoptic variability in the concentration time series. Among the three coastal sites, Barrow (71.3°N, 156.6°W) is situated on the northern tip of Alaska, Alert (82.3°N, 62.5°W) is in the high Canadian Arctic, Ny Alesund (78.5°N, 11.5°W) is on the Svalbard archipelago north of mainland Europe, and Summit is located on the high plateau of Greenland at 3000 m aMSL (72.6°N, 38.3°W). Interannual variation in the EBC concentrations, from 2002 to 2007, is very similar at these sites in spite of their geographical locations. This suggests that the interannual variation in the synoptic transport to these sites is similar. We used an atmospheric transport model (NIES, National Institute for Environmental Studies) to look at the relative impact of different source regions on these four Arctic sites. The decay of BC is approximated as exponential decay with e-folding time of 10 days. The first scenario, when BC emissions were kept constant while varying the meteorology, revealed the inter-annual variability in EBC due to atmospheric transport at all sites. BC emissions and transport were variable in the second scenario for 27 years, which provided trends in EBC at all sites. The relative contribution from different source regions at Alert indicated a decrease (~30%) in the impact of Eurasian sources and increase (~50%) in North America sources. Simulation results for the other sites will also be discussed.

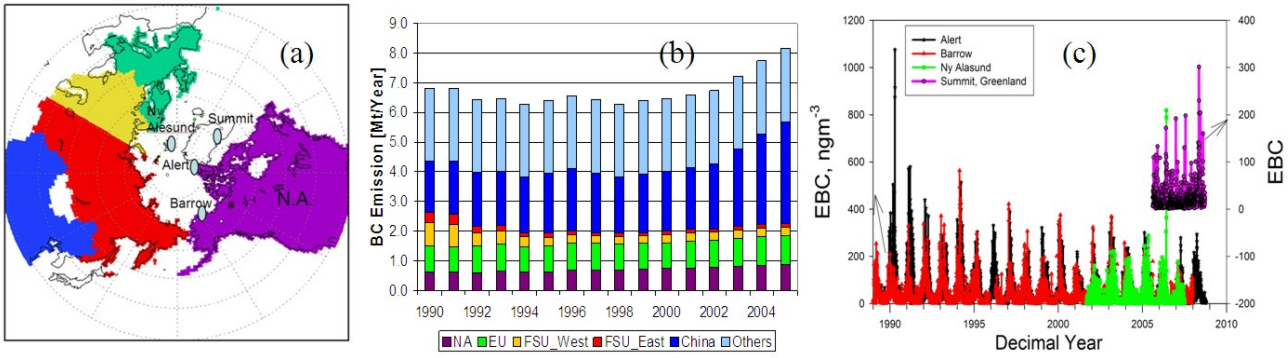

Figure 1. Masks were created to estimate BC emissions inventory in Megatonnes/yr for different source regions (a,b), *in-situ* measurements of EBC at four sites (c).

Spatial and Temporal Variations of Aerosol Optical and Chemical Properties at Five Canadian Sites

S. Sharma and R. Leaitch

Environment Canada, 4905 Dufferin Street, Toronto, Ontario M3H 5T4, Canada; 416-739-5820, E-mail: sangeeta.sharma@ec.gc.ca

Aerosol optical properties are related to its various chemical components; black carbon absorbs radiation while sulfate and organic carbon are efficient light scatterers. Spatial and temporal variations of the optical and chemical properties are presented at five different sites across Canada that are influenced by emissions from regional sources superimposed on continental background aerosols for 2005-2007: (1) Alert, Nunavut at the northern tip of Ellesmere Island in the high Arctic (influence by "Arctic haze"); (2) BERMSTT, Saskatchewan in the southern edge of the Canadian boreal forest (summer influence by forest fires, biogenic sources); (3) Fraserdale, a forested site in Ontario and located in the southern perimeter of the Hudson Bay Lowlands (summer influence by forest fires, biogenic, anthropogenic); (4) Egbert, Ontario in the rural region located about 80 km north of Toronto (influence by anthropogenic and biogenic - higher concentrations when winds from south but clean air-masses when winds from north); and (5) Whistler, British Columbia at the altitude of 2,180 m MSL in the Pacific Ranges of the Coast Mountains (regional sources and trans-pacific transport of Asian source influence in the spring). The median (mean) aerosol light extinction are 6.2 (7.3) Mm^{-1} at Alert, 7.1 (10.4) Mm^{-1} at Whistler, 7.1 (15.4) Mm^{-1} at BERMSTT, 7.5 (14.2) Mm^{-1} at Fraserdale and 8.5 (17.7) Mm^{-1} at Egbert, respectively. Mass scattering efficiencies for all data are in the range 4.4 to 7.1 m^2g^{-1} at ambient relative humidity. Influence of forest fire increased MSE to 21 m^2g^{-1} as shown in data at BERMSTT site most likely due to larger particle sizes released by fires.

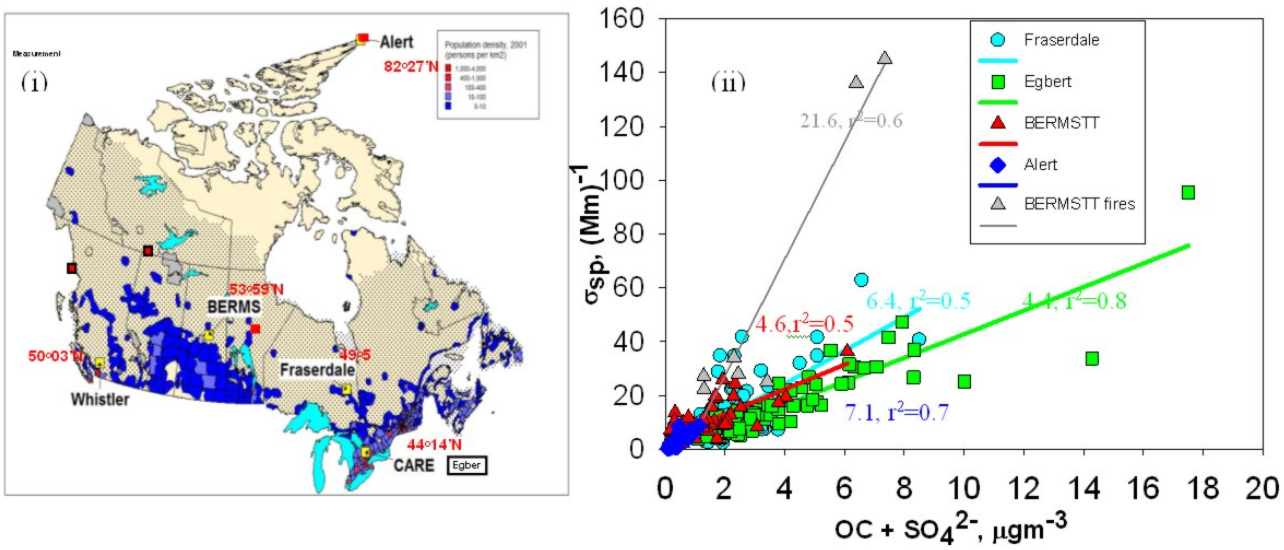

Figure 1. (i) Map showing 5 Canadian Aerosol Baseline Measurement sites, (ii) Aerosol light scattering at 550 nm & at ambient R.H. as a function of organic carbon derived from TOT thermal technique and sulfate from weekly integrated samples at 5 Canadian sites from 2005-2007.

Using a Camera Lidar and Nephelometer for Aerosol Profiling

N.C.P. Sharma[1], J.E. Barnes[2], T.B. Kaplan[2] and A.D. Clark[3]

[1]Department of Physics and Earth Science, Central Connecticut State University, 1615 Stanley Street, New Britain, CT 06050
[2]NOAA Earth System Research Laboratory, Mauna Loa Observatory, Hilo, HI 96720; 860-832-2278, sharmanim@ccsu.edu
[3]Department of Oceanography, University of Hawaii, Honolulu, HI 96822

A bistatic lidar configuration of a wide-angle camera (100 degrees) and vertically pointed laser was used to profile aerosols at a coastal site. The site, on the eastern tip of the Big Island of Hawaii, is influenced by both marine boundary layer aerosols and breaking waves. Two nephelometers were located at 7 and 25 meters above sea level to compare directly with the CLidar (camera lidar). The high altitude resolution of the CLidar (0.5 meter) allowed a direct measurement of the Extinction/Side-Scatter ratio to be measured. At 7 meters, changes in aerosol were tracked quite well by the CLidar. At 25 meters the aerosol was fairly constant and a useful comparison could only be made on average values. The CLidar results showed a steep gradient (decreasing with altitude) in the aerosol extinction from 7 meters to about 35 meters. The gradient continued to 200 meters at a lower value. This result was useful in characterizing the environment for the *in-situ* aerosol sampling. Two aerosol phase functions were used to convert the single-angle CLidar scatter to extinction. One was a NASA/Aeronet-derived function representing the marine boundary layer from a Lanai, Hawaii coastal site. The other phase function was measured by a polar nephelometer on Oahu, Hawaii and represented breaking waves. The measured function gave the best fit to the nephelometer data. The total aerosol optical depth calculated with the Aeronet phase function was 0.068, similar to the Lanai yearly average of 0.078 at 500 nm.

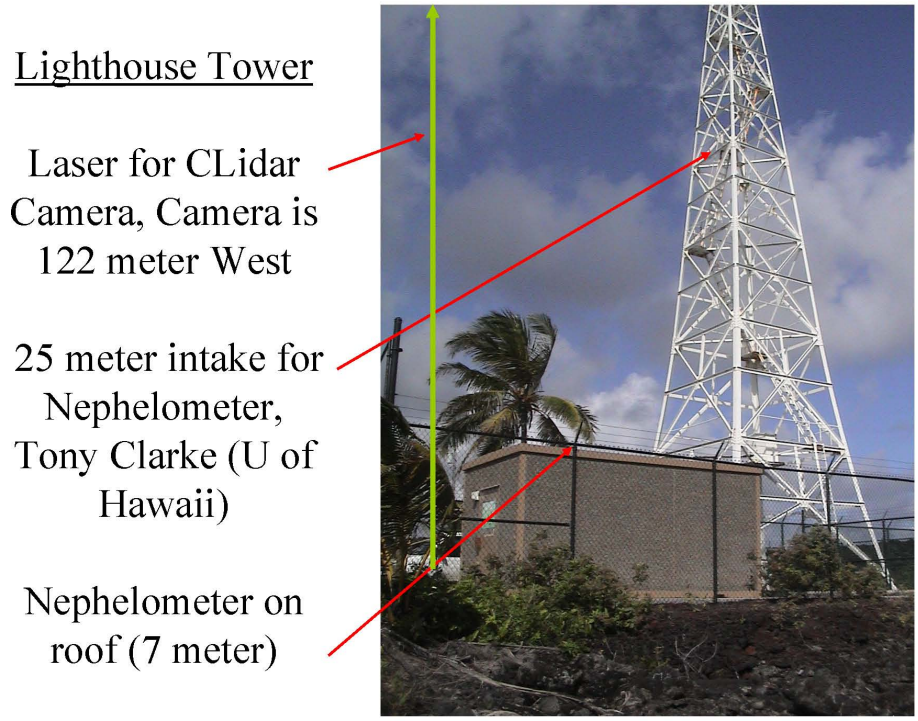

Figure 1. The Cape Kumukahi marine boundary-layer flask sampling site on the eastern tip of the Big Island of Hawaii. The measurements were made about 400-500 meters from breaking waves on the coast.

Aerosol Single Scattering Albedo from Direct-to-Diffuse UV Solar Irradiance at the Table Mountain NEUBrew Site

K. Lantz[1], P. Kiedron[1], I. Petropavlovskikh[1], P. Disterhoft[1] and J. Michalsky[2]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-7280, E-mail: Kathy.o.lantz@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

Direct and diffuse UV solar irradiance measurements are used to retrieve UV aerosol single scattering albedo during cloud-free periods. The direct-to-diffuse ratio is an indicator of atmospheric conditions and can provide information on aerosol loading, changing surface albedo, and cloud conditions. Six NOAA Environmental Protection Agency Brewer spectrophotometer (NEUBrew) sites are located across the continental U.S. in Boulder, CO, Bondville, IL, Fort Peck, MT, Houston, TX, Mountain Research Station, CO, and Raleigh, NC. Each site has a UV Multi-Filter rotating shadow-band radiometer (UV-MFRSR) measuring direct and diffuse solar irradiance in seven 2-nm wide bands, i.e. 300, 305, 311, 317, 325, and 368 nm. The NEUBrew site located near Boulder, CO has the advantage of having a collocated UV-Rotating Shadowband Spectrograph (UV-RSS) measuring diffuse and direct solar irradiance from 290 – 400 nm, up- and down-welling UV broadband radiometers for surface albedo measurements and is in proximity to a AERONET site. Radiative transfer model calculations (TUV) combined with the direct-to-diffuse solar irradiance (DDR) from the UV-Rotating Shadowband Spectrograph (UV-RSS) and the UV-MFRSR are used to retrieve aerosol single scattering albedo (SSA) under a variety of atmospheric conditions. For the radiative transfer calculations, total ozone measurements are obtained from a collocated Brewer spectrophotometer that is part of the NEUBrew Network.

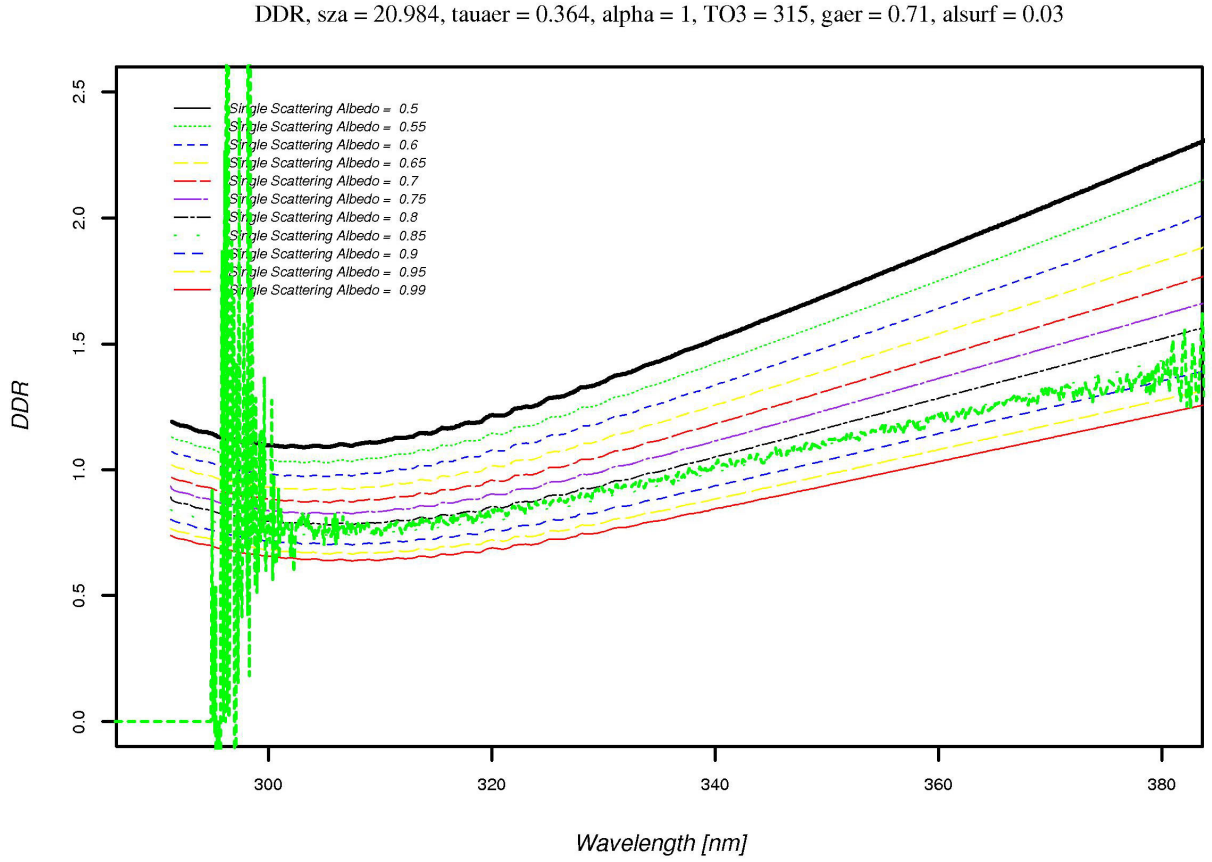

Figure 1. Direct-to-diffuse solar irradiance (DDR) from the UV-Rotating Shadowband spectrograph at a solar zenith angle of 21° (solid green) compared with TUV radiative transfer calculations of DDR as a function of aerosol single scattering albedo using measured input properties for other aerosol properties and surface albedo.

Micro-Pulse Lidar Network (MPLNET) Status and Lidar Observations from the NOAA ESRL Trinidad Head Observatory Site

T. Berkoff[1], J. Barnes[2], M. Ives[3], L. Belcher[4], B. Vasel[5], B. Andrews[6] and J. Welton[7]

[1]Goddard Earth Science and Technology Center, UMBC, NASA GSFC, Greenbelt, MD 20771; 301-614-5770, E-mail: timothy.a.berkoff@nasa.gov
[2]NOAA Earth System Research Laboratory, Mauna Loa Observatory, Hilo, HI 96720
[3]Humboldt State University, Arcata, CA 95519
[4]Science Systems & Applications, Inc., Greenbelt, MD 20771
[5]NOAA Earth System Research Laboratory, Boulder, CO 80305
[6]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[7]NASA Goddard Space Flight Center, Greenbelt, MD 20771

The Mirco-Pulse Lidar Network (MPLNET) comprises over 16 sites around the globe where vertical profiles of visible wavelength atmospheric backscatter measurements are recorded continuously over multi-year periods of time. These results contribute to climate change studies and provide ground validation for satellite sensors in the Earth Observing System (EOS) and related modeling efforts. MPLNET is a federated network, and is composed of NASA sites, and others run by partner research groups from around the world. NOAA ESRL baseline observatories contribute two lidar sites to the network: Trinidad Head, California (operated by Humboldt State University) and the South Pole Atmospheric Research Observatory. The Trinidad Head lidar has been in operation since spring 2005, and has collected over 1.5 million profiles of atmospheric backscatter at mid-visible wavelength of 523 nm. The coastal location of the Trinidad Head site is impacted by a variety of aerosol types including marine, intercontinental transport over the Pacific, and other sources. Interpretations of column measurements from satellites and ground sensors, as well *in-situ* measurements, are enhanced significantly when the vertical distribution of aerosol matter is known. Example cases of MPLNET data products will be presented illustrating some of the new web-based user-interface tools to display and present such data. This will include preliminary analysis of inter-continental transport of aerosol layers observed at the Trinidad Head site, with comparisons to satellite and surface observations of these same events.

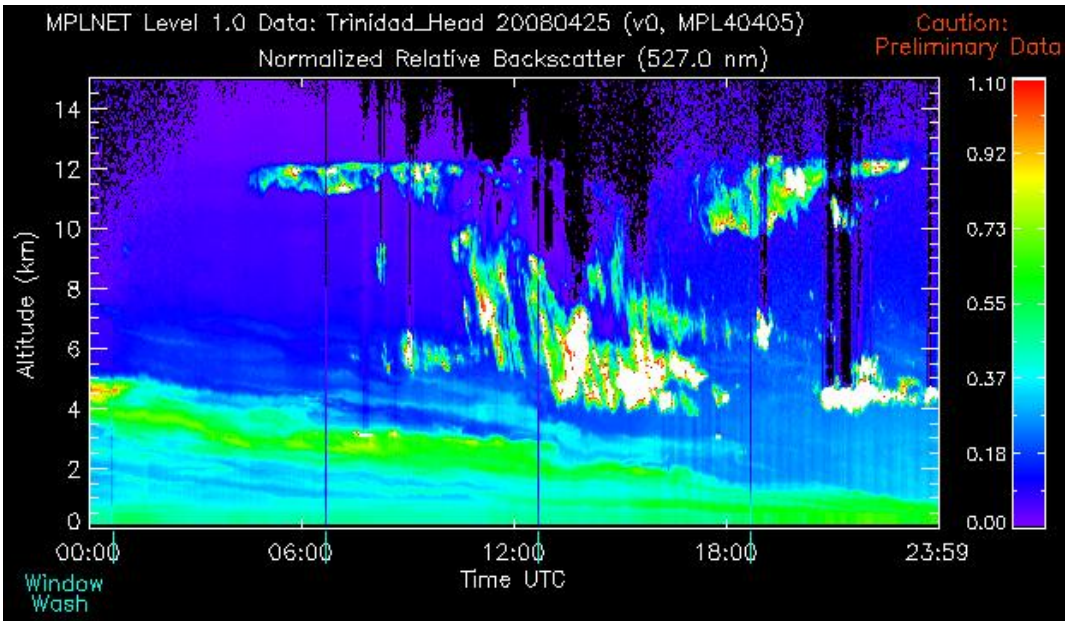

Figure 1. MPLNET normalized relative backscatter image for the Trinidad Head (California) lidar on April 25, 2008. On this day, the lidar reveals multi-layer clouds and a 4 km (at 00:00 UTC) layer that descends towards the surface as the day progresses. This layer is attributed to smoke transported across the Pacific from Russian wildfires in late April 2008.

Comparison of Barrow, Alaska and Tiksi, Russia Climate Variability Using Historical Meteorological Records

L. Matrosova[1], T. Uttal[2], A.P. Makshtas[3] and N.Y. Ivanov[3]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6130, E-mail: ludmila.e.matrosova@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Arctic and Antarctic Research Institute, Roshydromet, St. Petersburg 199397, Russian Federation

A digital archive of the historical Tiksi meteorological station data (1936 to present) has recently been created for air surface temperature, surface pressure, wind velocity, and cloudiness. A detailed analysis of the Tiksi data has been performed showing the influences of synoptic systems and cloudiness on temperature trends and shore fast ice cycles (presented as a companion paper in this session). In this study, the identical statistical methods are applied to the Barrow, Alaska meteorological data sets.

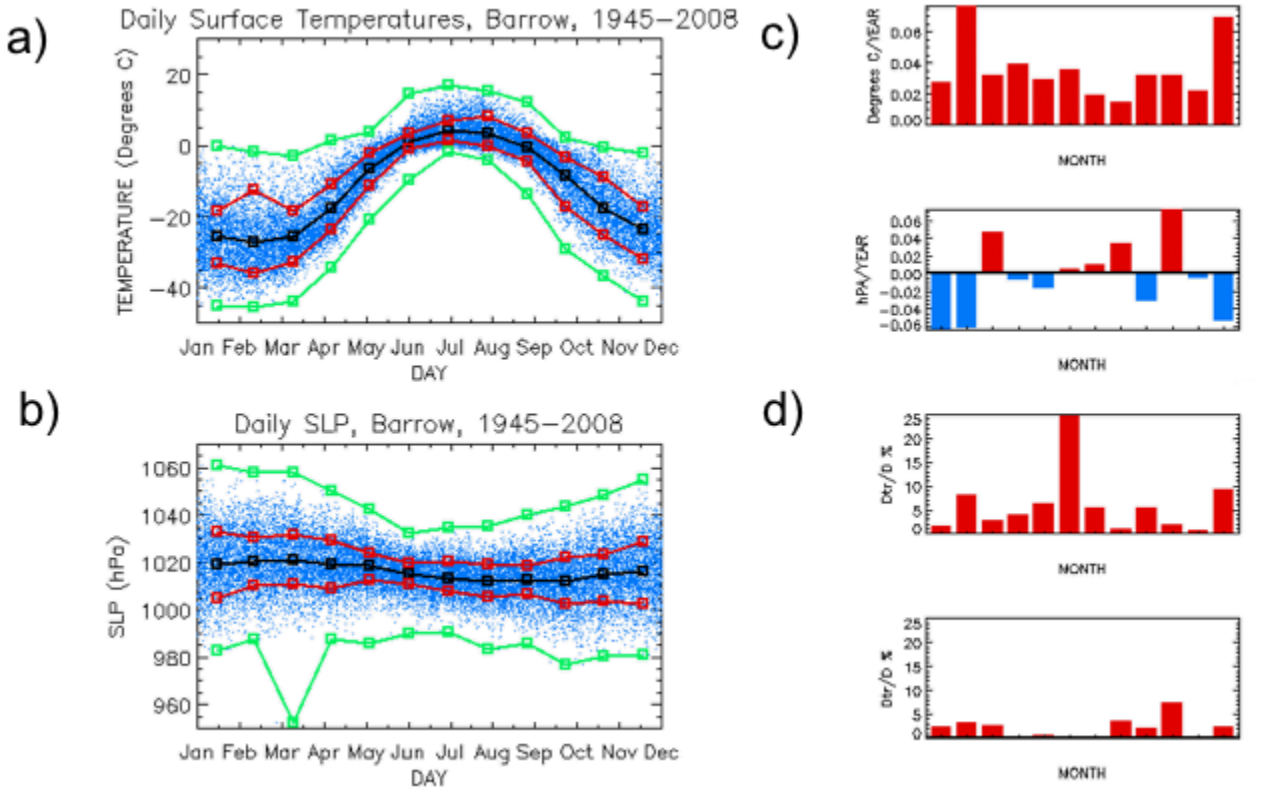

Figure 1. a) Time series of surface air temperature observations: daily values - blue dots, monthly means - black, extreme values from daily observations - green, extreme values from monthly means - red. b) the same, but for sea level pressure c) Linear trends found in the time series of monthly means of surface air temperature (top) and sea level pressure (bottom) for Barrow, 1945-2008 d) Coefficient of determination for the time series of surface air temperature (top) and sea level pressure (bottom) monthly means for Barrow, 1945-2008.

The International Arctic Systems for Observing the Atmosphere - Synergistic Potentials with the NOAA Baseline Observatories

T. Uttal and L. Darby

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6409, E-mail: Taneil.Uttal@noaa.gov

The NOAA Global Monitoring Division operates 5 Baseline Observatories roughly along a longitude line between Barrow, Alaska and the South Pole, Antarctica. These are all NOAA staffed facilities with observational and science programs focused on the study of atmospheric gases, aerosol particles, solar radiation, ozone depletion and baseline air quality. The International Arctic Systems for Observing the Atmosphere (IASOA) program has similar objectives with the focus on a ring of Observatories in the Arctic region. This program has similar objectives but different requirements as it integrates the activities of facilities in the 8 Arctic nations to achieve a high level of coordinated atmospheric observational capabilities for climate studies. A primary focus of the program is WMO endorsed programs such as Baseline Surface Radiation Networks (BSRN), Global Atmosphere Watch (GAW) and Arctic Monitoring and Assessment Program (AMAP). Barrow, Alaska is a key site that links the two Observatory systems. These two Observatory Systems provide tremendous potential for global scale monitoring and evaluation of climate changes.

Figure 1. Member Observatories of the International Arctic Systems for Observing the Atmosphere.

A Real Time Display of Meteorological Parameters From the NOAA ESRL Baseline Observatories

D. Endres

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-4521, E-mail: dan.endres@noaa.gov

NOAA ESRL maintains a network of 5 baseline observatories around the world with the mission to acquire, evaluate, and make available, accurate, long-term, continuous records of atmospheric gases, aerosol particles, and solar radiation which affect climate, the ozone layer, and baseline air quality, in temporal and spatial scales that allow causes of change to be understood. Basic to all measurements made at the observatories is meteorologic data. The 5 observatories measure wind speed, wind direction, temperature, pressure, and humidity. The poster presented here is a first generation display that shows the most commonly asked for met data by the general public. This includes station identity, temperature, wind speed and wind chill. A programmable LED display is fed a real time data stream from a central computer with data provided by the 5 observatories. The program controlling the LED sign can be modified to allow for the display of any of the available real time data from each site. Mixing ratios of gases, solar radiation data, and aerosol parameters can all be displayed as requested.

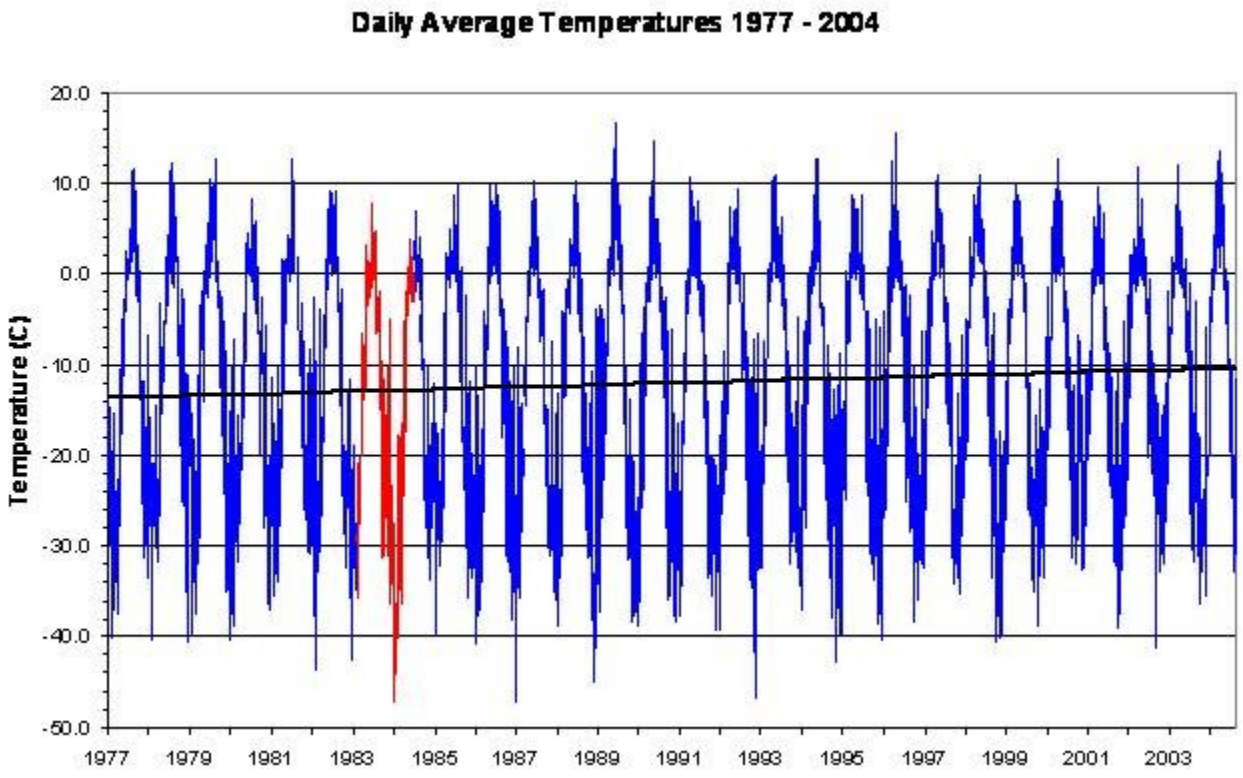

Figure 1. Temperature data from the NOAA ESRL Barrow Baseline Observatory showing a warming trend of .1C over the last 25 years. The data in red are suspect due to a bad calibration.

Long-Term Climate Variability in the Area Surrounding Tiksi, Russia

A. Makshtas[1], N. Ivanov[1], R. Bekriaev[1], S. Shutilin[1] and T. Uttal[2]

[1]Arctic and Antarctic Research Institute, 38 Bering Street, Saint Petersburg 199397, Russian Federation; +7-812-355-6163, E-mail: maksh@aari.nw.ru
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

A Hydrometeorological Observatory is being developed in Tiksi, Russia as a contribution to the International Polar Year. The Tiksi Observatory will be part of an International Network of Arctic Observatories including Barrow, Alert-Eureka, New-Alesund, Summit, Pallas, and Abisko. Creation of this network with coordinated, intercomparable long-term meteorological observations is motivated by the need to understand the well-documented phenomenon of polar amplified climate warming and the vulnerability of Arctic ecosystem to anthropogenic modifiers. This study investigates the representativeness of the Tiksi location by comparing Tiksi climate data to 2 other stations, Kazachie and Kusur, in the Northern region of Yakutia. These stations are located to the east and south of Tiksi at a distance of about 150 km with continuous data since 1909. For Kusur some additional information is available back to 1820. Tiksi data is available since 1936. A synoptic analysis of meteorological processes at Tiksi, Kusur, and Kazachie has been performed for air temperature, atmospheric surface pressure and total cloudiness for period 1936 - 2007 years on monthly, seasonal and diurnal time scales. The average monthly correlation between Tiksi-Dusur and Tiksi-Kazachie are high, generally > 0.8 (Table 1). This allows linear regression to reconstruct air temperature and surface pressure in Tiksi between 1909 (the start of the Kusur and Kazachie data records) and 1936 (the start of the Tiksi data record). The reconstructed temperature record does not reveal a significant positive trend for the period 1909 - 2007. The month with the strongest positive trend is April (< +0.09 °C/10 years); conversely in some months, negatives trends are as larges as -0.18 °C/10 years.

Station	Month	T	P	N_A		
				1*	2*	3*
Tiksi – Kusur	1	0.89	0.98	0.39	0.42	0.40
	2	0.63	0.82	0.42	0.45	0.48
	3	0.91	0.97	0.69	0.75	0.77
	4	0.84	0.94	0.61	0.67	0.72
	5	0.85	0.92	0.23	0.23	0.22
	6	0.76	0.93	0.49	0..53	0.54
	7	0.72	0.90	0.44	0.51	0..59
	8	0.89	0.92	0.40	0.38	0.42
	9	0.96	0.98	0.43	0.43	0.39
	10	0.95	0.97	0.43	0.48	0.47
	11	0.93	0.96	0.29	0.37	0.37
	12	0.85	0.97	0.40	0.41	0.43
Tiksi – Kazachie	1	0.89	0.92	0.33	0.34	0.38
	2	0.73	0.86	0.44	0.40	0.42
	3	0.95	0.97	0.45	0.49	0.50
	4	0.96	0.97	0.65	0.66	0.67
	5	0.91	0.96	0.39	0.37	0.38
	6	0.72	0.92	0.51	0.52	0.52
	7	0.76	0.90	0.60	0.65	0.65
	8	0.92	0.93	0.53	0.55	0.54
	9	0.95	0.96	0.61	0.61	0.60
	10	0.92	0.97	0.49	0.49	0.48
	11	0.90	0.97	0.32	0.34	0.33
	12	0.88	0.96	0.31	0.31	0.34

Figure 1. Correlation of Tiksi-Kusar and Tiksi-Kazachie Monthly Temperature, Pressure and Cloud Fraction.

ARM Climate Research Facilities on the North Slope of Alaska: An Update on Field Campaigns, Instruments, and Team Changes in 2008, IOPs and Changes in Facilities Planned for 2009

M.D. Ivey[1], J. Verlinde[2], S. Richardson[2], B.D. Zak[1] and J. Zirzow[1]

[1]Sandia National Laboratories, Org. 6338 MS 0734, P.O. Box 5800, Albuquerque, NM 87185; 505-284-9092, E-mail: mdivey@sandia.gov
[2]The Pennsylvania State University, Department of Meteorology, University Park, PA 16802

To provide greater research capability for the global scientific community, the Department of Energy designated the Atmospheric Radiation Measurement Program's scientific infrastructure and data archive as a national user facility: the ARM Climate Research Facility (ACRF). ACRF's role is to provide infrastructure support for climate research to the scientific community. DOE's climate research programs, with focus on clouds and aerosols and their impact on the radiative budget, define the research scope supported by the Facility. Since 1998, the North Slope of Alaska (NSA) ACRF site, with facilities in the towns of Barrow and Atqasuk, has provided data about cloud and radiative processes at high latitudes.

This poster will highlight events at the NSA Facilities in 2008 and upcoming events in 2009. The current International Polar Year 2007-2008 extends through March of 2009, and this past year has seen a number of IPY-related measurement campaigns on the North Slope of Alaska.

The Indirect and Semi-Direct Aerosol Campaign (ISDAC) that occurred in April 2008, included instrumented flights over the Barrow ACRF Facility as well as extensive ground-based measurements there. Results from ISDAC will be presented during scheduled sessions at the 2009 Science Team Meeting. The ISDAC field campaign included coordinated measurements with NASA and NOAA.

The NSA Pyranometer IR Loss Study was extended through the winter of 2008. This study focuses on corrections needed for Pyranometer IR measurements at North Slope Facilities and the effects of ventilation and heating on Pyranometer measurements.

Intensive Operating Periods and field campaign measurements for the coming year include the collection of precipitation to determine the effect of sea ice on Arctic precipitation and cloud radar comparisons and calibration activities.

Upcoming changes to the ACRF North Slope Facilities include addition of several new permanent instruments, leased office and lab space in the recently-opened Barrow Arctic Research Center, and new staff members on the Operations Team in Barrow.

Figure 1. NOAA Barrow GMD Facility (closest), DOE ARM Climate Research Facility (middle), USGS Magnetic Observatory (farthest).

Chemical Precipitation on the Russian Arctic Territory

A. Polischuk, N. Pershina and P. Svistov

Main Geophysical Observatory, Karbysheva Ulitsa 7, Saint Petersburg 194021, Russia; 812-297-86-70, E-mail: polisch@main.mgo.rssi.ru

Precipitation chemistry remains a major environmental issue in several parts of the world (e.g., Eastern North America, Southeast Asia, and Europe) due to concerns over acid deposition, eutrophication, trace metal deposition, ecosystem health, biogeochemical cycling, and global climate change. For the estimation of the influence of emissions on the Arctic territory there needs to be included regular measurements of chemical precipitation (wet depositions). In Global Atmosphere Watch (GAW) the following compounds are recommended for analysis precipitation samples: pH, conductivity, sulphate, nitrate, chloride, ammonium, sodium, potassium, magnesium and calcium. Data from Tiksi is printed below.

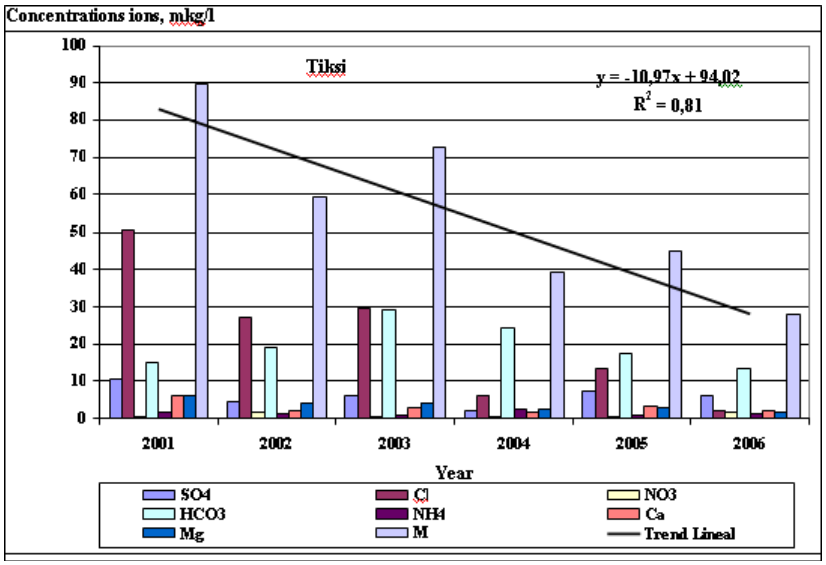

Figure 1. Concentrations main ions in precipitation at the Tiksi Station for 2001-2006 years.

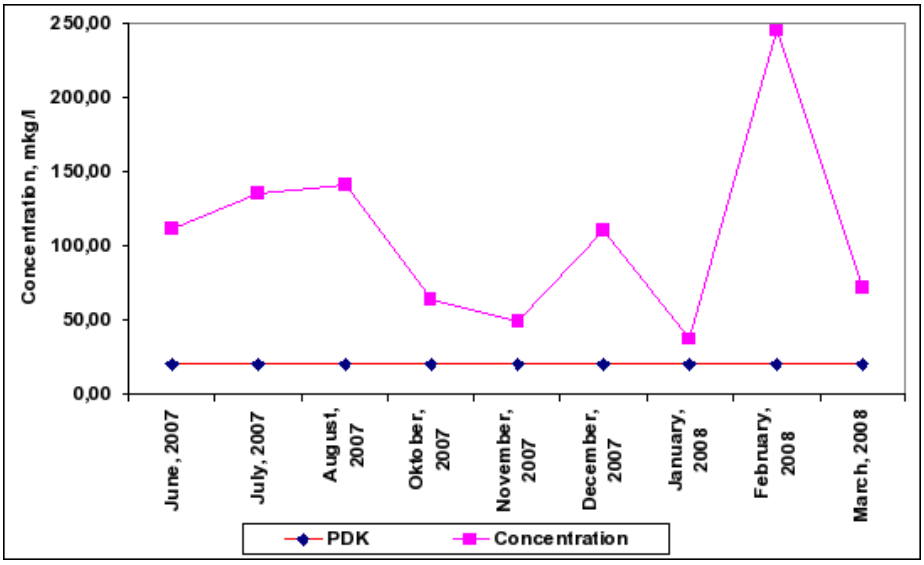

Figure 2. The concentrations of nickel in precipitation, Station NP-35 (IPY), 2007-2008 years.

Detection and Characterization of Systematic Errors in Atmospheric Models

S.I. Gutman and D.L. Birkenheuer

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-7031, E-mail: Seth.I.Gutman@noaa.gov

Modern numerical weather prediction models typically use 3 or 4 dimensional variational assimilation (3D or 4DVAR) to define their initial conditions. In most cases, variational assimilation techniques assume that the distribution of observation and model errors are statistically normal and unbiased. Recent work at ESRL's Global System Division has detected clear evidence of systematic errors in the analysis and prediction of total atmospheric column precipitable water vapor (TPW) in operational NWP models over the continental U.S. Because of the importance of water vapor in weather and climate processes, the weather forecasting and climate monitoring/prediction communities share a mutual interest in identifying and correcting systematic moisture errors in both observations and predictive models. This presentation describes how these errors were detected and how they appear to propagate with time.

Figures 1 and 2 illustrate the differences between an operational NCEP global model (the GFS presented in the top panel of both figures) that does not assimilate GPS TPW and a synoptic model (NAM or WRF-NMM in the bottom panel of both figures) that does. Of special note is the fact that the NAM uses the GFS to define the initial conditions at the boundary. We note with great interest the existence of a dry bias of the GFS model with respect to GPS during the warm seasons, and how these differences do not significantly change over a 12-h period. In contrast, the NAM does not appear to have a significant seasonal bias in either the analysis or 12-h prediction of TPW, but the standard deviation of the differences grows in 12-h to be almost (but not quite) identical to the GFS.

Because the cause(s) of these errors are not well understood, we propose that this is a fertile area for collaborative research within ESRL.

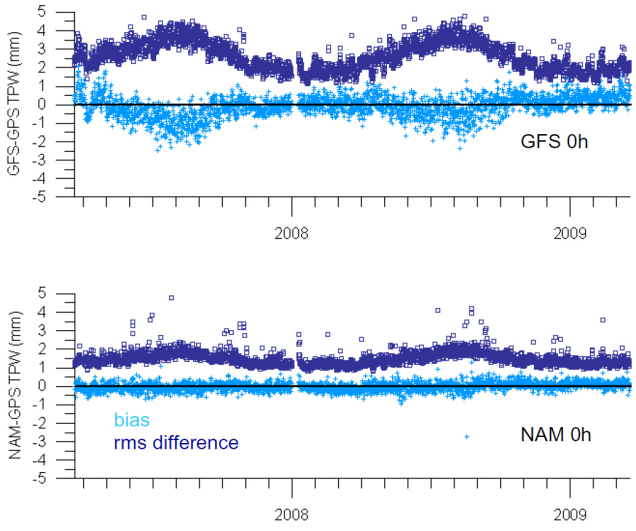

Figure 1. Difference between NWP model analyses & GPS retrievals of TPW valid at 0, 6, 12, & 18 UTC at about 300 sites over CONUS between March 2007 and March 2009. GFS-GPS (top) and NAM-GPS (bottom).

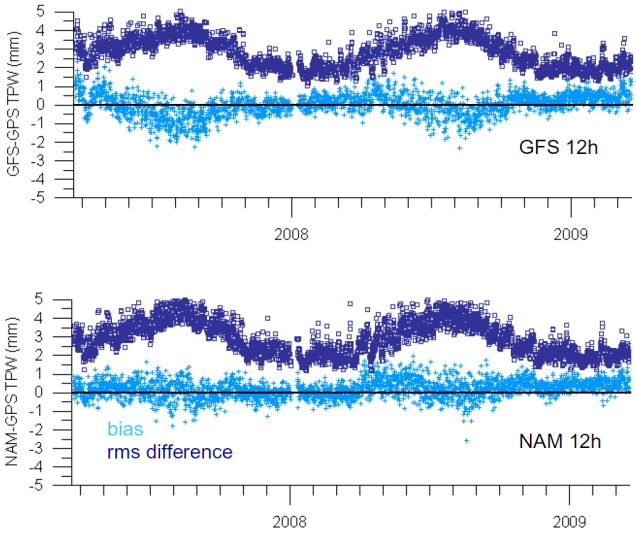

Figure 2. Differences between 12-h model forecasts & GPS retrievals of TPW at the same sites and times evaluated in Figure 1.

Zero Waste: A Practical and Effective Approach to Reducing Human Impacts on Climate

M. Heller[1], E. Dlugokencky[2] and K.M. Bailey[3]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-4728, E-mail: molly.heller@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Eco-Cycle, Boulder, CO 80308

Recycling began in the United States in the early-1970s due to a growing awareness of population and environmental pressures upon our ecosystems. Since then, curbside recycling programs have expanded and become mainstream, and some communities are accepting compostable materials at curbside. Even though almost 80% of the materials thrown away by Americans are recyclable, our recycling rate is just 28% (EPA). The remaining materials, more than 137 Mt (106 tons) (EPA), are primarily hauled to landfills where organic materials break down in an anaerobic process that produces methane (CH_4). Landfills are a major source of anthropogenic CH_4, a greenhouse gas, contributing to climate change. CH_4 is 72 times more effective at capturing infrared radiation than carbon dioxide (CO_2) over a 20-year period, making it a good target for short-term reductions in climate forcing. Composting organic materials, such as yard trimmings, non-recyclable paper, and food scraps, releases biogenic CO_2 instead of CH_4, reducing our impact on climate. Composting also creates a valuable soil amendment that conserves water, prevents erosion, reduces pesticide use, and stores carbon in soils. The U.S. has the potential to decrease landfill-based methane emissions by 406 Mt CO_2 equivalent per year by 2030 by dramatically reducing our waste stream to the landfill. A new zero waste program in the U.S. "would reduce greenhouse gas emissions the equivalent of closing one-fifth of the existing 417 coal-fired power plants" (Stop Trashing the Climate, Platt, B., et al). Figures 1 and 2 show the Business As Usual scenario and the Zero Waste Approach to disposing of waste in the U.S. By 2030, 90% of domestic waste could be diverted from landfills to recycling and composting, achieving a 7% cut in equivalent CO_2 emissions. The David Skaggs Research Center expanded its recycling program to include composting in October 2008. Since then, we have diverted 70% of our waste from the landfill through composting and recycling. NOAA's Earth System Research Laboratory is at the forefront of climate research and understands how important it is to reduce our impacts on the planet. By adopting a zero waste program, we are seeing how very little effort can make a difference in our greenhouse gas emissions while also conserving resources, protecting ecosystems, and reducing pollution.

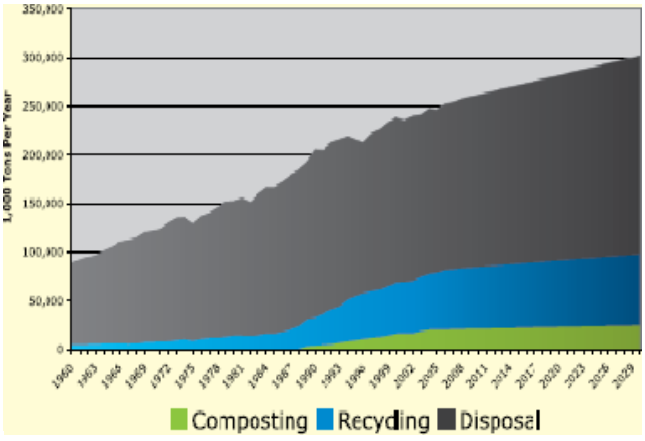

Figure 1. Business As Usual Recycling, Composting, and Disposal.

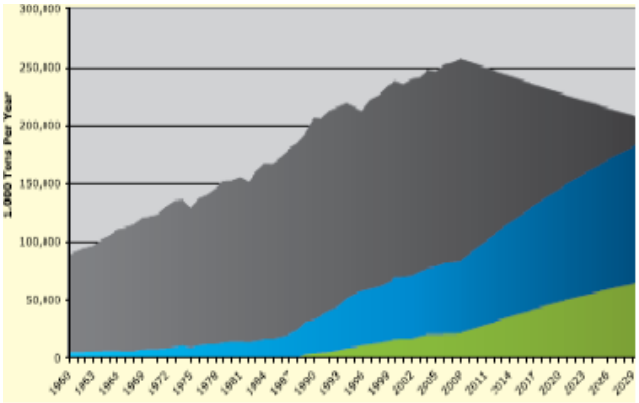

Figure 2. Zero Waste Approach. Source: B. Platt and H. Bhalala from Stop Trashing the Climate.

Wind-Flow Characteristics at the Heights of Modern Wind Turbines from Lidar Measurements

Y.L. Pichugina[1], R.M. Banta[2], W.A. Brewer[2], M. Hardesty[2], N.D. Kelley[3], S.P. Sandberg[2] and B.J. Jonkman[3]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-6863, E-mail: yelena.pichugina@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]National Wind Technology Center, National Renewable Energy Laboratory, Golden, CO 80401

The nascent wind-energy industry is heavily dependent on meteorological conditions. Locating new wind energy farms is fraught with uncertainty regarding their economic viability. In addition, wind turbines frequently fail sooner than their claimed life expectancy, and it is believed that this may be due to local wind-shear and turbulence levels that exceed those predicted by current theory and models. Almost no routine wind and other meteorological data exist in the 30-300 m layer, the lower portion of which is occupied by wind turbines, except the twice-daily rawinsonde observations. As a result, the accuracy of the numerical and analytical models is unknown or needs to be validated by high-quality measurements. Therefore, a strong requirement exists for new datasets that adequately describe the atmospheric boundary layer structure at the heights of modern and future wind-turbines.

Recently, remote sensing instruments have become a valuable alternative for wind-energy needs, by providing wind and turbulence measurements with sufficient vertical and time resolution.

One such instrument, the High-Resolution Doppler Lidar (HRDL), a scanning system developed at the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL). The HRDL has been used in meteorological applications to study air quality and dynamic processes in the atmospheric boundary layer, including very strong and frequent nocturnal low-level jets over flat terrain in the Great Plains and extreme atmospheric events such as passages of cold fronts. The ability of HRDL to provide accurate measurements of wind and turbulence conditions at multi-megawatt turbine heights above the range of tower measurements makes this instrument a powerful tool for wind-energy related studies. Better knowledge of wind regimes at the turbine heights can significantly reduce the uncertainty in wind resource assessment, electricity production and structural safety of turbine hardware, and thus decrease turbine operational and maintenance costs.

Detailed analysis of HRDL measured wind and turbulence profiles, wind flow statistics over the Great Plains, along with some examples of atmospheric events that can impose critical loads on wind turbines, will be given.

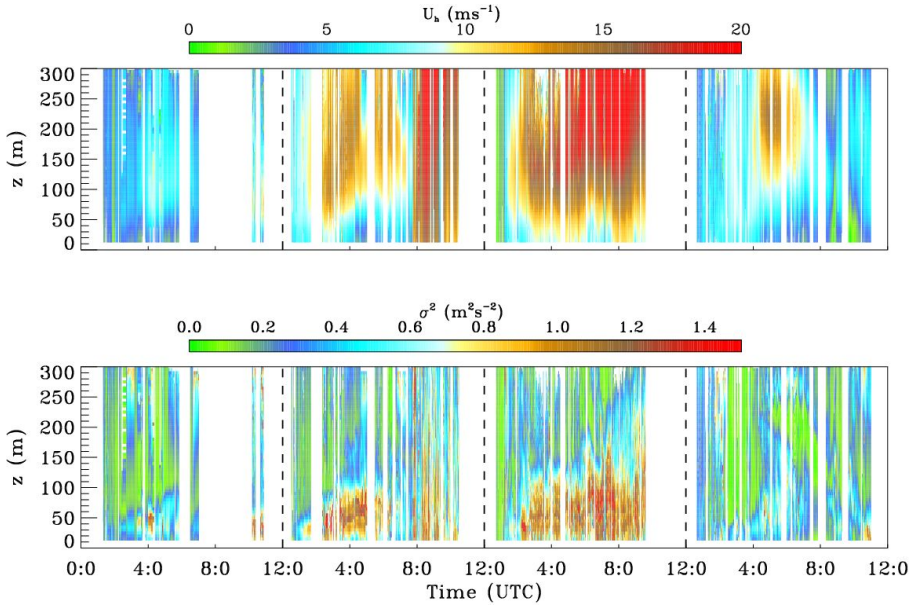

Figure 1. Time-height cross sections of (top) mean horizontal wind and (bottom) variance, calculated from HRDL measurements illustrate significant differences in the magnitude of wind and turbulence for consecutive nights in September 2003.

The Nonhydrostatic Icosahedral Model

J. Lee and A.E. MacDonald

NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6097, E-mail: jin.lee@noaa.gov

The Earth System Research Laboratory (ESRL) is developing a new global finite-volume Nonhydrostatic Icosahedral Model, named the NIM, for earth system modeling, and weather and climate prediction. The model uses innovations in model formulation similar to those of the hydrostatic Flow-following Icosahedral Model (FIM) developed by ESRL and now being tested for future use by the National Weather Service as part of their operational global prediction ensemble. Innovations from the FIM used in the NIM include:

- A local coordinate system remapped to a plane for each grid point,
- Grid points in a linear horizontal loop that allow any horizontal point sequence,
- Flux Corrected Transport formulated based on the high-order (3rd Order) Adams-Bashforth scheme to maintain conservative positive definite transport,
- All differentials evaluated as line integrals around the cells,
- Strict conservation of passive tracers to the round-off limit, and
- Computational design to allow for scalability to hundreds of thousands of processors.

The FIM and NIM models use finite-volume techniques pioneered by S. J. Lin of GFDL. The NIM will use the vertically Lagrangian coordinate system developed by Lin. It will use the Earth System Modeling Framework and be part of a modeling system being developed by ESRL, GFDL and AOML. Numerical design goals of the NIM include the development of Piecewise Parabolic third order differencing and Vandermonde polynomials allowing high-order approximations of local variables in the horizontal, and a Lagrangian Riemann Solver for vertical differencing. NIM will have the capability to run globally at kilometer scale resolution, which would allow convective macro-phenomena like the Madden-Julien Oscillation to be explicitly predicted. Other important properties include the high conservation needed for earth system modeling of chemistry and aerosols.

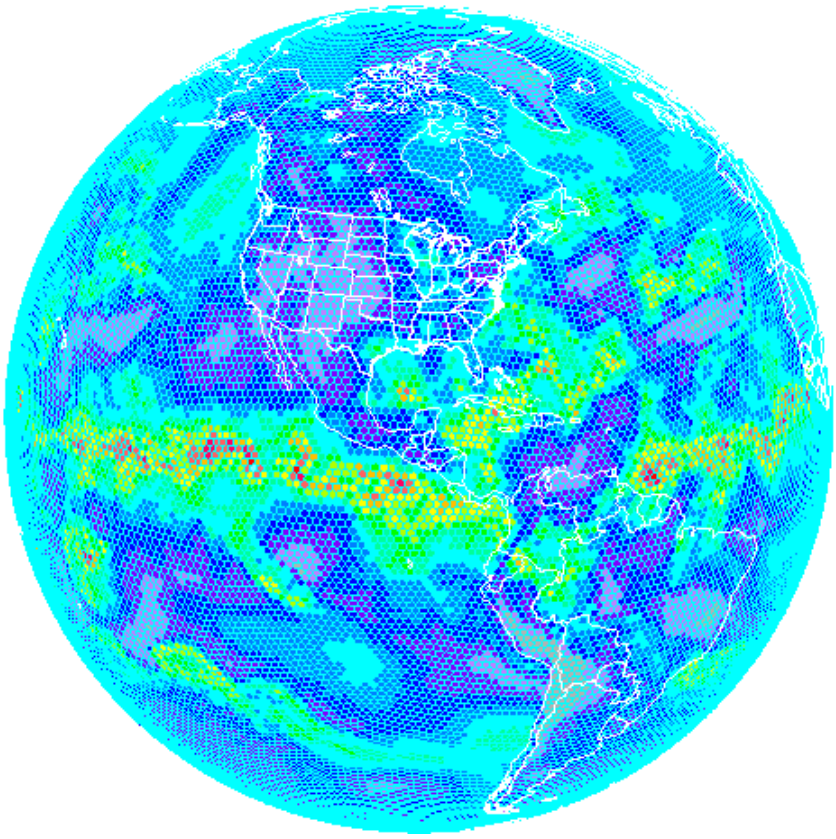

Figure 1. The figure shows FIM 24-h forecast integrated cloud water superimposed on a icsoahedral grid.

Ozone Characteristics on Mt. Kenya and Nairobi (Kenya)

J. Nguyo[1], C. Mutai[2] and P. Bundi[3]

[1]Kenya Meteorological Department, Nairobi, Kenya; +254-20-3867880, E-mail: nguyo2000@yahoo.com
[2]Climate Prediction Services and Air Pollution, Nairobi, Kenya
[3]Institute of Training and Research Centre, University of Nairobi, Nairobi, Kenya

GAW site in Mt. Kenya (37.18° E, 0° 3´ S and 3,897 meters ASL), is located 500m above the timeline on the gently rising north-west facing slope of the mountain. There are no anthropogenic air pollution sources in the vicinity of the station, making the site suitable for baseline measurements of atmospheric trace gases and aerosols. Throughout the year, the Mt. Kenya GAW site is influenced by distinctly different air masses from both hemispheres covering most of the western Indian Ocean making it suitable for further long-term investigators of tropical atmosphere.

Nairobi (1° 18' S, 36° 45' E 1795 M ASL) data for 2008 both from ozone sounding and Dobson Spectrophotometer was analyzed. Ozone sounding indicated that the largest concentrations of ozone occurs approximately above 14 km and the maximum ozone values occurs between 26-28 km above the surface. The Dobson data analysis shows low value of ozone in ONDJ (October, November, December and January – Rainy season) and high values in JJA (June, July and August – cold dry season). This raises questions of tropospheric ozone variations in tropical countries (where Kenya lies) and its seasonal contribution to the total ozone column in the atmosphere, given the fact that stratospheric ozone experience insignificant variation either seasonally or annually. The high altitude Mt. Kenya station ozone is influenced by long range transport of gases from biomass burning and their products from southern Africa, Saharan and Arabian region that leads to increased carbon monoxide (CO) concentration.

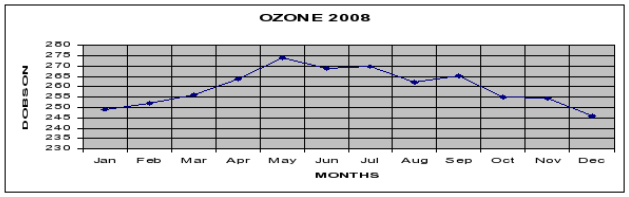

Figure 1. Annual characteristics of ozone measurement using Dobson Photospectrometer in Nairobi in the year 2008.

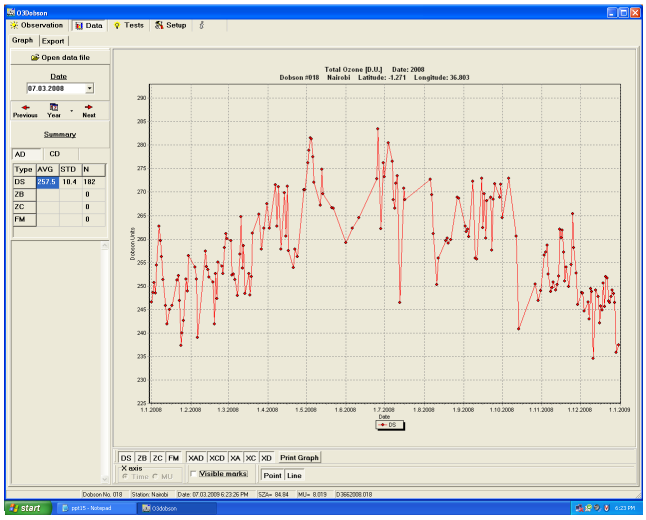

Figure 2. Daily averages of ozone as measured using the Dobson instrument in Nairobi in 2008.

Hardware and Software Improvements to the Eppley Solar Tracker

A. Jordan[1], J. Wendell[2], E. Dutton[2], E. Hall[3] and D. Hurst[3]

[1]Science Technology Corporation, 325 Broadway, Boulder, CO 80305; 303-497-4781, E-mail: allen.jordan@noaa.gov
[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

The old housings for the Eppley Solar Trackers at NOAA have long needed a set of improvements to make them usable for modern instruments. The original motors included with the housings could not handle the burden of heavy instruments, which would cause inaccuracies to develop in the tracking movement. There was also an issue of the trackers miscalculating the number of revolutions traversed, which could end up snapping wires internally after several windings. Through the efforts of Jim Wendell and Allen Jordan, both the hardware and software of the trackers has been greatly improved. The new stepper motors are capable of driving a very heavy load and maintaining smooth movement with precise control. Combined with the gearing ratio of the trackers, these motors are able to make 4,915,200 steps per revolution. The ability to move in increments of $7.3E^{-5}$ degrees allows for highly accurate solar tracking. An embedded processor is used to control motor movement and calculate the position of the sun using GPS coordinates and time. The firmware allows for motor acceleration and deceleration when moving to far away sun positions on initialization. From there on, future sun positions are calculated to fine-tune movement speeds. Hall-effect sensors are used to detect starting positions for each motor in order to maintain accurate movement and prevent motor windup from snapping wires. The firmware also implements a serial port terminal interface allowing for various commands to be executed, including moving to custom positions and exercising new sets of gears to reduce lashing. Implementing these changes provides for an affordable, highly accurate sun tracker. Buying a comparable device commercially would cost several times more, and require time to change connection options for existing instruments.

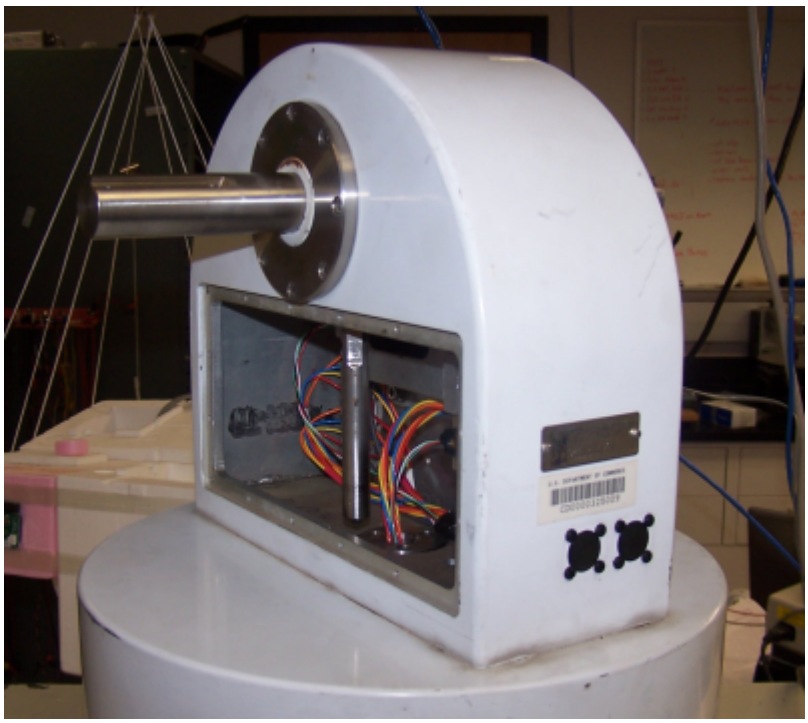

Figure 1. A modified Eppley Solar Tracker being tested in the lab.

Carbon Monoxide as an Indicator of Ozone Concentration

J. Mitei

Kenya Meteorological Department, P.O. Box 30259-00100, Nairobi 00100, Kenya; 020-3867880, E-mail: jokimi@yahoo.com

The increase in tropospheric ozone has been identified to be a serious and critical cause of concern world over. Inter-Governmental Panel for climate change (IPCC) and World Meteorological Organization (WMO) assessment reports have predicted large increases in tropospheric ozone (O_3) resulting from the emissions of O_3 precursors. Ground level concentrations of O_3 have been increasing steadily since the industrial revolution. Ozone concentration has risen by 1-2% per year in the industrialized countries of the northern hemisphere. Most of the countries of Western Europe, eastern and mid-western region of USA and eastern Asia are found to show the highest background concentrations of O_3. Most developing countries are facing increasingly severe air pollution problems due to recent emphasis on economic liberalization leading to rapid increases in industrialization and urbanization, biomass burning, indiscriminate deforestation, and poor farming mechanisms among others. Mount Kenya is a unique site having high concentrations of organic ozone forming precursors due to: frequent fires by farmers who want to prepare their farms for the next planting season, game park policy makers who want to allow fresh growth of vegetation and grass to improve primary production for the game, people looking for extra land for settlement and urbanization, people logging from the forest for economic benefit and most important un-checked wild fires. The increased fire activities within the Mt Kenya region therefore has continuously contributed to the high release of carbon monoxide because of the incomplete combustion of biomass materials thus making it a high contributor to the high tropospheric ozone amounts in the region. CO being an unstable readily reacts with oxygen in the atmosphere to produce CO_2 and an atom of oxygen as in the equation $CO + O_2 = CO_2 + O$-. The unstable O atom reacts with oxygen gas to form O_3 gas. Then the next reaction will favor production of ozone because of low temperatures on the mountain hence high ozone concentration observed. In comparison with Ozone observation done at the Nairobi city national meteorological centre the ozone values at Mt Kenya are higher. This is because: 1. The altitude of the Mt Kenya is high hence there is mixing of tropospheric and stratospheric ozone due to atmospheric instability common in this area. 2. Atmospheric pollutant including ozone from as far as South Africa reaching the Mt Kenya region.

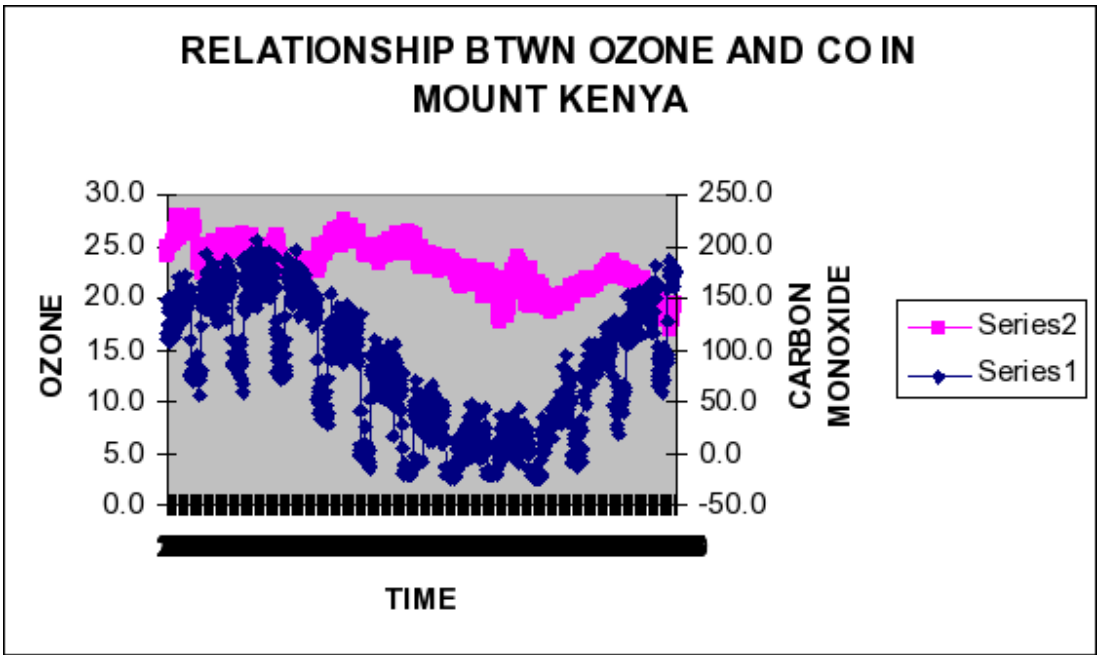

Figure 1. Relationship between Ozone and CO in Mount Kenya.

Climate Change Signals and Global Atmosphere Watch Activities in Kenya

C.C. Okuku

Kenya Meteorological Department, Nairobi, Kenya; +254-020-3867880, E-mail: colnex2004@yahoo.co.uk

Kenya is located on longitudes 34°-42° E and latitude 3.5°N/S. The public concern about global warming, climate variability and change, atmospheric pollution and ozone depletion has been growing. Temperature and rainfall data for 40 years was analyzed. There is increasing trend in both maximum and minimum temperature indicating global warming. Rainfall exhibits increasing trend in some areas while decreasing in the main agricultural highlands of Kisii and Kericho. The rising sea level at Mombasa and Lamu, shrinking glacier on Mt. Kenya and drying of rivers are all signals of climate change. Nairobi surface ozone as measured by weekly Ozonesonde flights since 1998 at an altitude of 1795 meters is increasing while the Mt. Kenya baseline surface Ozone at an altitude of 3800 meters is decreasing. The carbon monoxide from Mt. Kenya has a bi-annual cycle. Aerosols at Mt. Kenya GAW station indicate increasing trend as the station is mainly affected by air masses from both hemispheres at different times of the year. All these are attributable to climate change This paper also investigated the linkages between climate change and atmospheric pollution measurements at Mt. Kenya baseline station i.e. O_3, CO and aerosols.

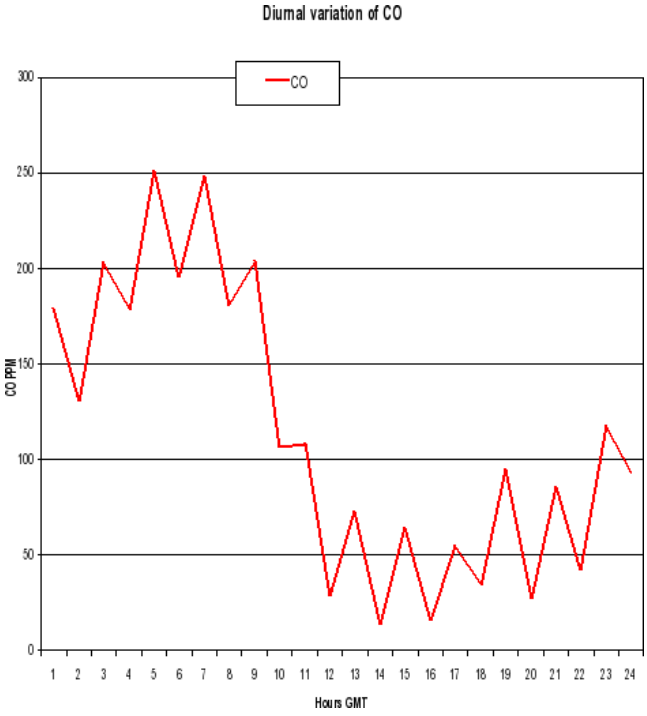

Figure 1. Diurnal variation of Mt. Kenya CO.

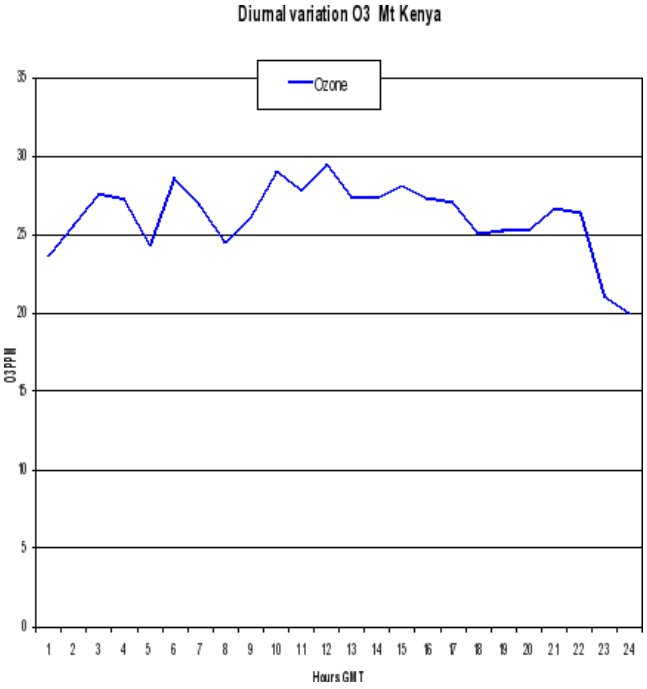

Figure 2. Diurnal variation of Mt. Kenya O_3.

Temporal Patterns of Stratospheric Ozone and Nitric Oxide Over a Tropical Station and Their Connection to Sea Surface Temperatures

N. Muthama and J. Ogaja

Department of Meteorology, University of Nairobi, P.O. Box 30197 00100, Nairobi, Kenya 00100, Kenya; +254-20-4441045, E-mail: jmuthama@uonbi.ac.ke

Ozone data from Balloon-borne ozone profiles from SHADOZ Nairobi station (1°S, 36°E) were obtained on a weekly basis for the period 1998 to 2009. Data on NO from the Halogen Occultation Experiment (HALOE) NO datasets and Stratospheric ozone data from Global Chemical Weather forecast system is also collected for the same period 2000 to 2009 and are used for investigating the temporal patterns of O_3 and NO.

The datasets were analyzed at the level between 18km and 28km (considered to be the tropical lower stratosphere) to indicate seasonal variability with no significant long-period trend in the lower tropical stratosphere.

Nitric Oxide (NO) reacts with O_3 in the stratosphere and is the main naturally occurring regulator of Stratospheric O_3, a linear relationship between O_3 and Nitrous Oxide (N_2O) - precursor of NO has been used to estimate polar winter O_3 loss from data taken in the lower stratosphere. In this regard the relationship at the tropical lower stratosphere is investigated. A correlation coefficient analysis produces no significant relationship between O_3 and NO at the tropical lower stratospheric level.