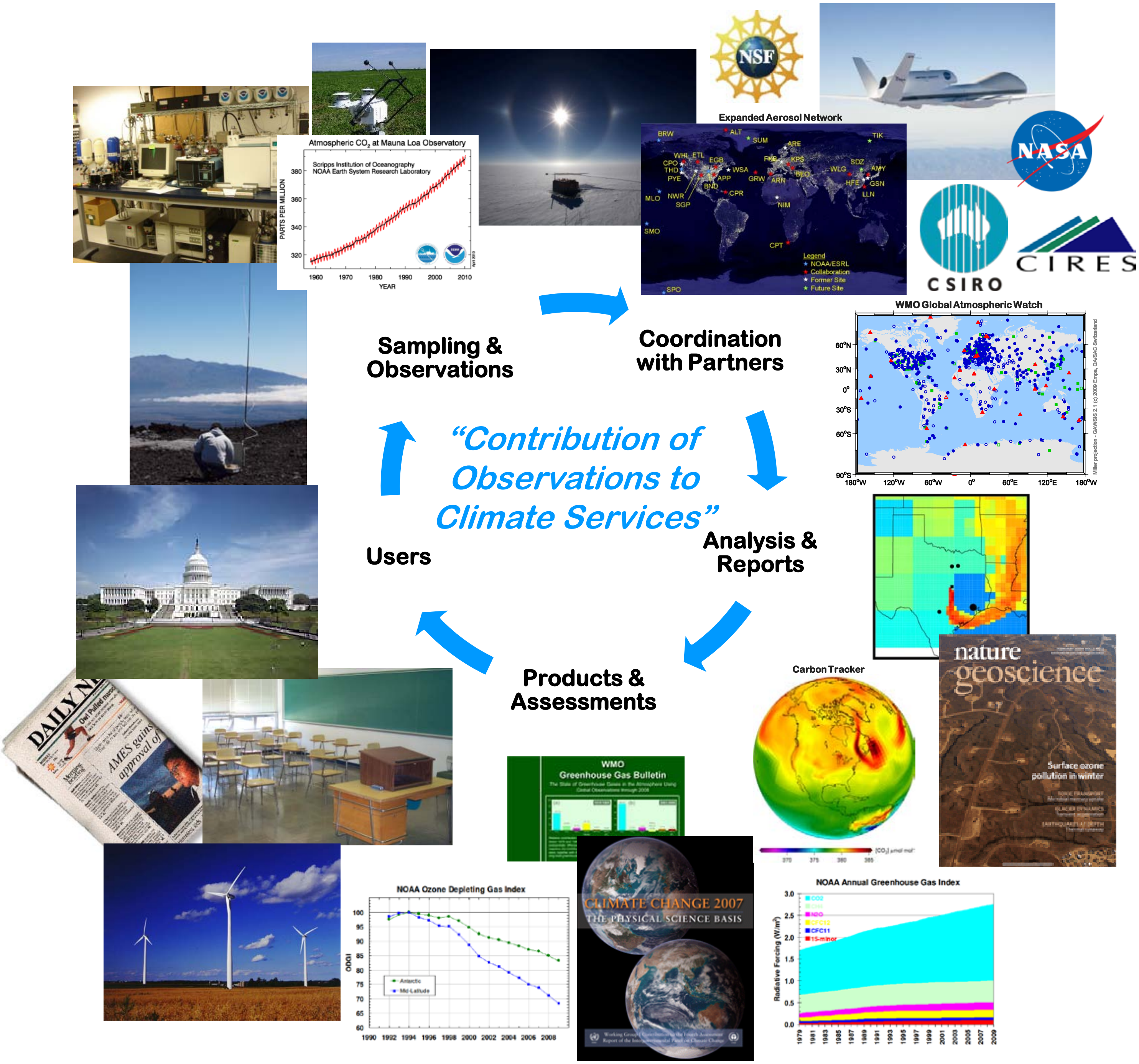
Global Monitoring Annual Conference 2010

Boulder, Colorado, May 18th - 19th



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"Contribution of Observations to Climate Services"

Analysis & Reports

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Users

PROGRAM & ABSTRACTS

Hosted by:
NOAA Earth System Research Laboratory
Global Monitoring Division

Mission of the Global Monitoring Division:

To acquire, evaluate, and make available accurate, long-term records of atmospheric gases, aerosol particles, and solar radiation in a manner that allows the causes of change to be understood.

Conference Website:

http://www.esrl.noaa.gov/gmd/annualconference/

Purpose of the Global Monitoring Annual Conference:

To bring together preeminent scientists to discuss the latest findings in climate research and how to integrate science, observations and services to better serve society.

Terms of use:

This report may be cited as:

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Cover info:

Conceptual representation of how observations, research, partnerships, and analyses work to provide climate information and services.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Earth System Research Laboratory
325 Broadway – David Skaggs Research Center
Boulder, Colorado 80303-3337

NOAA Earth System Research Laboratory
2010 Global Monitoring Annual Conference

May 18-19, 2010
Boulder, Colorado

We at the NOAA's Earth System Research Laboratory, Global Monitoring Division, would like to welcome you to our 2010 Global Monitoring Annual Conference. Annually, this conference brings in scientists from various agencies, universities, and international organizations to share the latest information on global monitoring trends and new approaches to obtaining long-term records of climate and the atmospheric constituents that force changes in climate. The theme for this year's conference is ***Observational Contributions for Climate Services***. The concept of providing climate services is relatively new and is brought on by the global recognition that climate is changing and that society everywhere will have to address both the causes and consequences of climate change. These needs will exist no matter how emerging state, national, and international policies and agreements ultimately play out. Defining and developing services requires a close interplay between scientists who conduct climate-relevant research and those elements of society that need support. Today scientists are looking at which emerging questions require long-term observational records to best support national and international climate services. Attended this year by nearly 200 scientists, including almost 100 from universities and U.S. agencies other than NOAA and over 20 from 17 countries on five continents, the conference will address issues relating to climate change, ozone depletion, air quality, solar radiation, and renewable energy needs. Monitoring at all levels (ground based, *in situ* and satellite) will be addressed, as well as the use of reanalysis for integrating observations and producing relevant and timely products. The goal of the conference is to encourage thought about how long-term data sets we obtain in many ways can be used to support climate services, be they for information, education, adaptation, or mitigation.

The conference agenda is posted at http://www.esrl.noaa.gov/gmd/annualconference/, along with abstracts from 104 presentations and posters being discussed at the conference.

Thank you for attending and we look forward to a high-quality group of presentations and vigorous interaction among colleagues.

James H. Butler

James H. Butler, Director
Global Monitoring Division

In Memoriam

David J. Hofmann

1937-2009

Laboratory Director: 1996-2007

David Hofmann's long and prolific scientific career centered on the basics. His approach to research was simple in concept, based on observations, and often yielding fundamental conclusions. He was committed to using the right measurements, paying attention to detail, and addressing the broad issues that arose from those measurements. His dedication and initiative led to the development of several of the measurement programs and instruments used today. After 25 years at the University of Wyoming, he accepted the position of chief scientist at NOAA/CMDL in 1991. In 1996 he accepted the position as director of CMDL, where he guided research in the laboratory for over 11 years. In his effort to connect the research we do with the needs of society, he used our suite of high-quality measurements to develop NOAA's annual greenhouse gas index and the ozone depleting gas index. He was awarded the DOC's Silver Medal for creating the greenhouse gas index in 2008.

Dave loved conducting research in Antarctica. Over a period of 30 years, he traveled to the continent 19 times. Soon after the Antarctic ozone hole was reported, Dave drew on his ballooning expertise and polar experience to develop better instruments. He and his group at University of Wyoming deployed to McMurdo Station in 1986 to measure the extent of the ozone layer's destruction. These measurements were instrumental in establishing the important link between ozone loss and heterogeneous chemistry on polar stratospheric cloud particles.

The scientific and societal benefits that have resulted from Dave's work pay tribute to his influence within the scientific community. We will miss Dave, but his legacy of quality and relevance remains with us.

In Memoriam

James T. Peterson

1940-2010

Laboratory Director 1981-1989

Jim Peterson received his B.S in Geophysics for the University of Minnesota in 1963 and his MS and PhD in Atmospheric Sciences from the University of Wisconsin in 1968. Jim and his family came to Boulder, CO to join NOAA's GMCC Atmospheric Research Laboratory in 1977. At the time the laboratory had about 75 researchers and technicians. In 1981 he was named the director of the laboratory and under his leadership the laboratory embarked on 8 years of program expansion and development. Jim recruited bright, new scientists into the laboratory who knew their areas of expertise better than most in the new and fast emerging science of global warming and climate change. Jim had the foresight to know that the laboratory needed such talent and expertise and many of these scientists are still with the lab today. As a result of his actions, today the same laboratory has grown to become one of the premier atmospheric research laboratories in the world, with a staff of more than 120, respected world-wide for the work and research that they do.

Jim was well published in all of the major atmospheric journals and wrote the 1978 Encyclopedia Britannica treatise on Urban Climate. As Director of the laboratory, he traveled the world giving presentations at symposiums and scientific conventions successfully promoting the work and research findings of the laboratory.

Jim was a great family man, a friend and a scientist and so much more. We will miss him.

NOAA Atmospheric Baseline Observatories

Barrow, Alaska (est. 1973), 71.32˚ North, 156.61˚ West

Trinidad Head, California (est. 2002), 41.05˚ North, 124.15˚ West

Mauna Loa, Hawaii (est. 1957), 19.53˚ North, 155.57˚ West

Cape Matatula, American Samoa (est. 1974), 14.24˚ South, 170.56˚ West

South Pole, Antarctica (est. 1957), 90.00˚ South, 24.80˚ West

Summit, Greenland (est. 2010), 72.58˚ North, 38.48˚ West

2010 NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE

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

Tuesday Morning, May 18th, 2010 AGENDA

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

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

- ***07:30 -08:15*** ***Morning Breakfast – Coffee, tea, fruit, bagels & donuts served***

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P. Tans (NOAA/ESRL)..........1
08:45 - 09:00 New Results from the NOAA ESRL Collaborative Tall Tower Network for Monitoring Carbon Dioxide and Related Gases
*A. Andrews (NOAA/*ESRL)..........2
09:00 - 09:15 Indianapolis Flux Project (INFLUX): Development, Improvement and Assessment of Methods to Quantify Greenhouse Gas Emissions at the Urban Scale
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09:15 - 09:30 Detecting Saturation in the Ocean Carbon Sink
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- ***Session 2*** ***Carbon Cycle Gases Session 2 –*** *Chaired by Pieter Tans*

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10:30 - 10:45 Global Atmospheric Methane and Ethane: Updated Mixing Ratios and Trends (1984-2009)
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(pre-payment of $10.00 required at registration table)

2010 NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE

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

Tuesday Afternoon, May 18th, 2010 AGENDA

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

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J. Klausen (Empa, Switzerland).......13

13:30 - 13:45 Atmospheric CO_2 Observations from Space (ACOS): Preliminary Results from Greenhouse Gas Observing Satellite (GOSAT) Data Analysis
D. Crisp (JPL, California Institute of Technology).......14

13:45 - 14:00 7.5 Years of Atmospheric Infrared Sounder (AIRS) Mid-Tropospheric CO_2 -Validations and Applications
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J. Elkins (NOAA/ESRL).......24

- ***17:00 - 20:00 Poster Session (DSRC Cafeteria) with appetizers & refreshments***

Have You Seen the Economic Recession in the Atmospheric CO_2 Record?

P. Tans

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

Many times during 2008 and 2009, we have been asked the question whether we have detected a slowing growth rate or even a decrease in atmospheric CO_2. Although in many cases the question is based on a misconception about the relation between emissions and atmospheric CO_2, historical emissions inventories do show the effect of events like the Great Depression and World War II. Year to year variations of the growth rate of CO_2 are dominated by natural variations of terrestrial sources/sinks responding to variations of climate. The number of years required to detect with confidence, a change in global emissions of a given magnitude is estimated. The most important factor is our degree of quantitative understanding of natural exchange of carbon between the atmosphere and terrestrial biosphere and oceans. The latter also permits an estimate of future atmospheric CO_2 excess as a result of all emissions until the present, on a country by country basis.

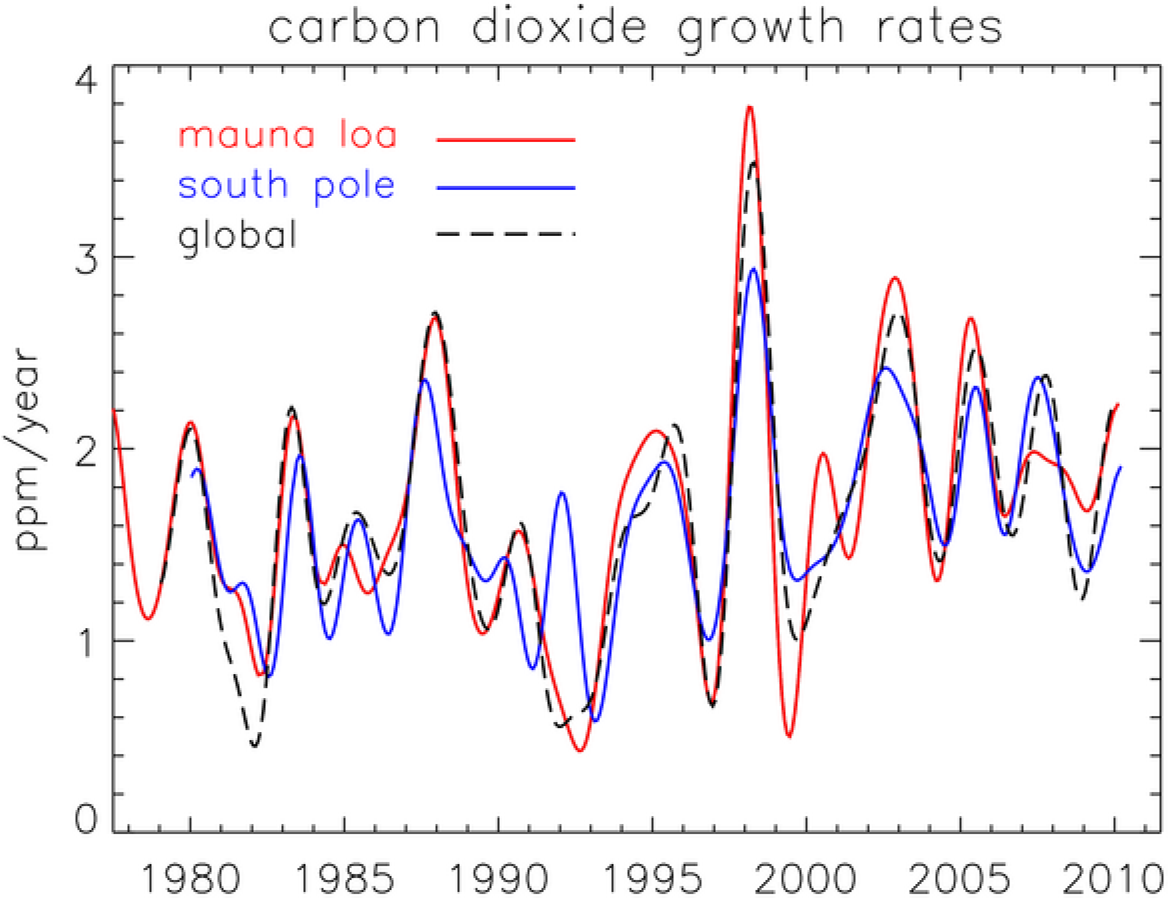

Figure 1. Comparison of the observed rate of increase of atmospheric CO_2 at two background stations with the global average estimated from marine boundary layer sites. The rate of increase expressed in ppm/yr can be turned into billion metric tons of carbon in the global atmosphere through multiplying by 2.124.

New Results from the NOAA ESRL Collaborative Tall Tower Network for Monitoring Carbon Dioxide and Related Gases

A.E. Andrews[1], J.D. Kofler[2], J.C. Williams[3], M.E. Trudeau[4], P.S. Bakwin[1], C. Zhao[2], K.A. Masarie[1], D.H. Neff[2], D.R. Kitzis[2], P.P. Tans[1], K.J. Davis[5], A.R. Desai[6], S.C. Wofsy[7], W.J. Munger[7], D.J. Wolfe[1], M.L. Fischer[8], M.J. Parker[9], S.D. Wekker[10], C.O. Stanier[11], G. Petron[2], A.M. Michalak[12], J. Eluszkiewicz[13], T. Nehrkorn[13], K.R. Gurney[14], W. Peters[15] and A.R. Jacobson[2]

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[5]Department of Meteorology, Penn State University, University Park, PA 16802
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[11]University of Iowa, Iowa City, IA 52242
[12]University of Michigan, Ann Arbor, MI 48109
[13]Atmospheric and Environmental Research, Inc., Lexington, MA 02421-3136
[14]Purdue University, West Lafayette, IN 47907
[15]Department of Environmental Sciences, Wageningen University & Research Center, Wageningen, Netherlands

NOAA ESRL began making measurements from tall towers in the 1990s in order to extend long-term carbon-cycle gas monitoring to continental areas. Existing television, radio and cell phone towers are utilized as sampling platforms for *in situ* and flask sampling of CO_2 and other atmospheric trace gases, including CO. Tall tower CO_2 mixing ratio measurements are sensitive to upwind fluxes over scales of hundreds of kilometers. Such measurements therefore place strong constraints on estimates of regional scale carbon budgets. CO is an indicator of combustion, and elevated levels can result from urban or industrial emissions or from biomass burning. CO data contribute to the interpretation of CO_2 measurements by helping to identify and quantify pollution episodes. The tall tower sites are part of the North American Carbon Program and are a primary data source for ESRL's CarbonTracker CO_2 data assimilation system. The network has become a highly collaborative enterprise, with contributions from a host of university, private sector, and government partners. The sites are equipped with high-precision semi-continuous CO_2 and CO analyzers, and most also have automated flask sampling equipment that collects an air sample approximately once per day. We will present important features of the data from each site, including seasonal and diurnal cycles and daytime vertical gradients for CO_2 and CO. We have used the Stochastic Time Inverted Lagrangian Transport model to compute sampling footprints for each site. The footprints are combined with optimized fluxes from CarbonTracker and with the Vulcan inventory to estimate the contributions of ecosystem, fire, ocean and fossil fuel fluxes.

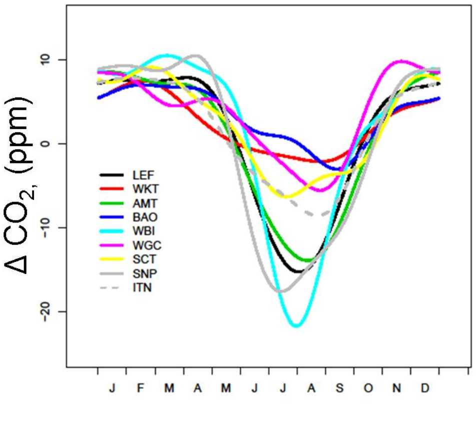

Figure 1. The mean seasonal cycle of CO_2 observed at the tall towers. An estimated background value representing the CO_2 concentration before the air encountered the continent was subtracted from the data in order to isolate the variability associated with North American emissions and uptake. The result is the signal that drives data assimilation and inverse model estimates of the North American carbon budget.

Indianapolis Flux Project (INFLUX): Development, Improvement and Assessment of Methods to Quantify Greenhouse Gas Emissions at the Urban Scale

P. Shepson[1], K. Gurney[1], O. Cambaliza[1], C. Sweeney[2], J. Turnbull[3], G. Petron[2], N. Miles[4], S. Richardson[4] and T. Lauvaux[4]

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[3]NOAA Earth System Research Laboratory, Boulder, CO 80305
[4]Pennsylvania State University, University Park, PA 16802

INFLUX was recently funded by the National Institute of Standards and Technology, to develop and assess methods of quantifying greenhouse gas emissons at the urban scale, using Indianapolis as the test site. The primary project goal is to develop better technique/approach for measurement of urban-scale greenhouse gas emission fluxes. Top-down atmospheric measurements will be obtained from aircraft flights and towers, and compared with bottom-up estimates from the Hestia block-level fossil fuel CO_2 emission inventory for Indianapolis. Measurement methodologies will be developed, with quantified uncertainties.

Indianapolis was chosen for this experiment, because it provides an excellent location to evaluate our ability to use top-down atmospheric observations to constrain urban-scale greenhouse gas emissions. Indianapolis is a medium-sized city, with fossil fuel CO_2 (CO_2ff) emissions of ~3.4 MtC yr^{-1}, providing a large enough signal to be readily detectable in the atmosphere. Indianapolis is located far from any other metropolitan areas, so the signal from Indianapolis can be isolated with relative ease. The terrain is flat, making the meteorology relatively simple. The Hestia bottom-up CO_2ff inventory product for Indianapolis is the highest resolution emission inventory available for any city in the world, allowing comparison of the bottom-up and top-down methods, to evaluate and improve uncertainties in both.

40 aircraft flights are planned over the two year duration of the project. Aircraft measurements will be made from a small plane, equipped with an ALAR system for continuous meteorological measurements, a Picaro cavity ring-down system for continuous CO_2, CH_4 and CO measurements, and 12-24 flask measurements per flight, for a host of trace gases including CO_2, CH_4, CO, $\Delta^{14}CO_2$ (used to estimate fossil fuel CO_2), stable isotopes of CO_2 and a suite of halocarbons and hydrocarbons. Two cell phone towers (>100m height) will be equipped for continuous measurements of CO_2, CH_4 and CO, and integrated flask sample measurements. Integrated flask samples will be collected as pooled samples of air collected only during appropriate meteorological conditions over each two week period. The current experimental period is two years.

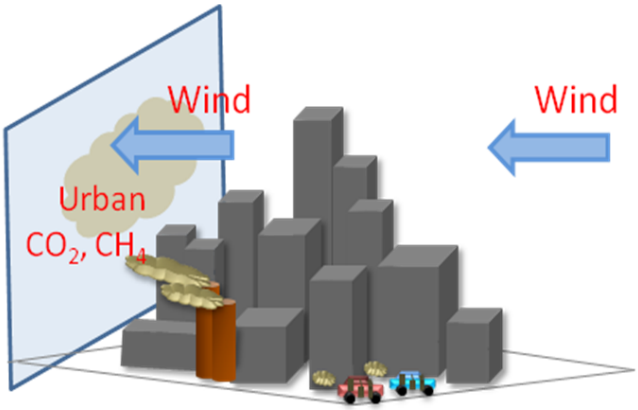

Figure 1. Visualization of urban plume experiment. As airmass travels over urban air area it picks up CO_2 and CH_4 emissions. These emissions are captured by the plane flying downwind of the plume.

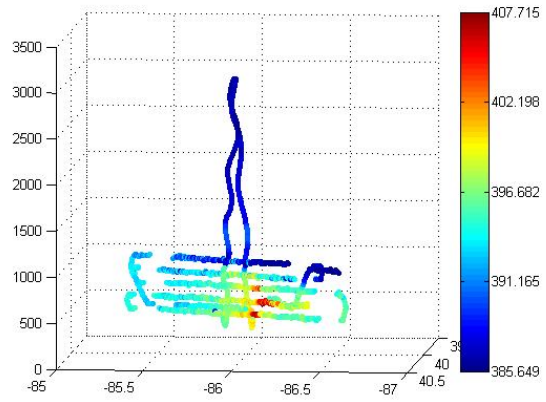

Figure 2. Actual measurements of CO_2 downwind of Indianapolis in April of 2007. The 10 ppm enhancements in the center of the plume make detecting CO_2 emissions from Indianapolis very easy.

Detecting Saturation in the Ocean Carbon Sink

A.R. Jacobson

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303-497-4916, E-mail: andy.jacobson@noaa.gov

Recently, the 4.5 million observations used to create the Takahashi et al. (2009) surface ocean $p\mathrm{CO}_2$ climatology were released to the scientific community. This collection of individual $p\mathrm{CO}_2$ observations has never before been available to researchers outside the ocean carbon community, and this opportunity has generated innovative new lines of research. In this presentation, I demonstrate a new method for the fusion of $p\mathrm{CO}_2$ data, which manifest all the intense variability of the upper ocean, with ocean interior carbon data, which through ocean inverse methods provide a strong constraint on long-term mean surface fluxes of CO_2. With some climatological flux information coming from interior observations, the obligation of surface observations to constrain long-term means by themselves is reduced. The surface observations can more fully express their interannual and mesoscale variability in this framework, and I model that variability in terms of satellite observables such as sea surface temperature. I use this technique to evaluate multi-decadal trends in global surface ocean $p\mathrm{CO}_2$, in order to test recent claims that the ocean carbon sink is saturating.

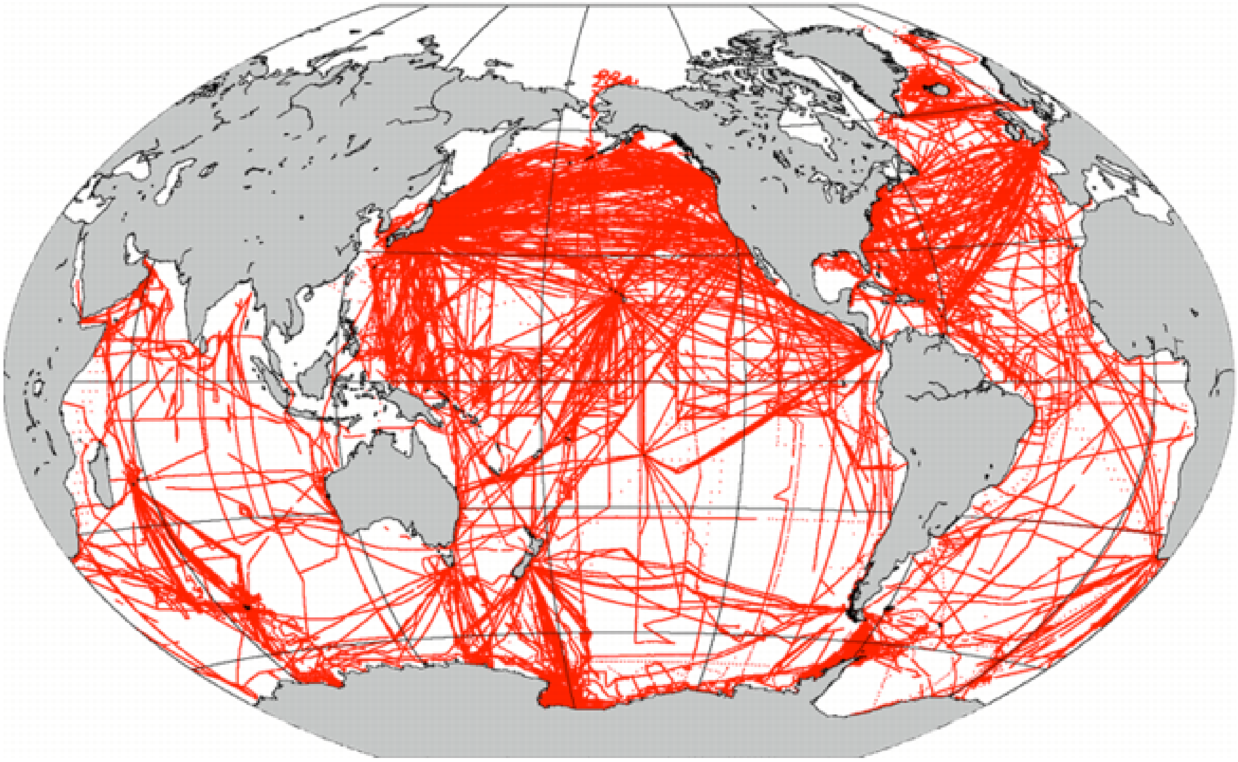

Figure 1. Locations of the more than 4.5 million surface ocean $p\mathrm{CO}_2$ observations during 1968-2008 in the recently released Takahashi et al. (2009) database.

Annual Migrations of North American Centroids of Carbon Emissions from Fossil Fuels – What Do They Reveal About Causes and Future Trends?

J. Gregg[1], R.J. Andres[2] and T.J. Blasing[2]

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[2]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Mapping seasonal and regional components of North American fossil-fuel carbon emissions provides clues as to causes and potential future changes in some anthropogenic aspects of the overall carbon cycle. Gregg et al. (2009) have calculated monthly carbon emissions from fossil fuels in Mexico and from each state/province in Canada and the United States to facilitate studies of the changing North American carbon budget. Their report includes a figure (reproduced in modified form as Fig. 1, below) showing the seasonal migrations of the centroids of carbon emissions from coal, oil, natural gas, and total fossil fuel combustion on the North American continent. Here we explore how these migrations reflect seasonal changes in geographical patterns of energy supply, demand, and resulting carbon emissions in various regions of the continent. By providing insights on important variables to monitor, the results should be useful to policy makers and planners as well as carbon-cycle modelers.

Reference: Gregg, J.S., L.M. Losey, R.J. Andres, T.J. Blasing and G. Marland. (2009). The Temporal and Spatial Distribution of Carbon Dioxide Emissions from Fossil-Fuel Use in North America. Journal of Applied Meteorology and Climatology, 48(12) 2528-2542.

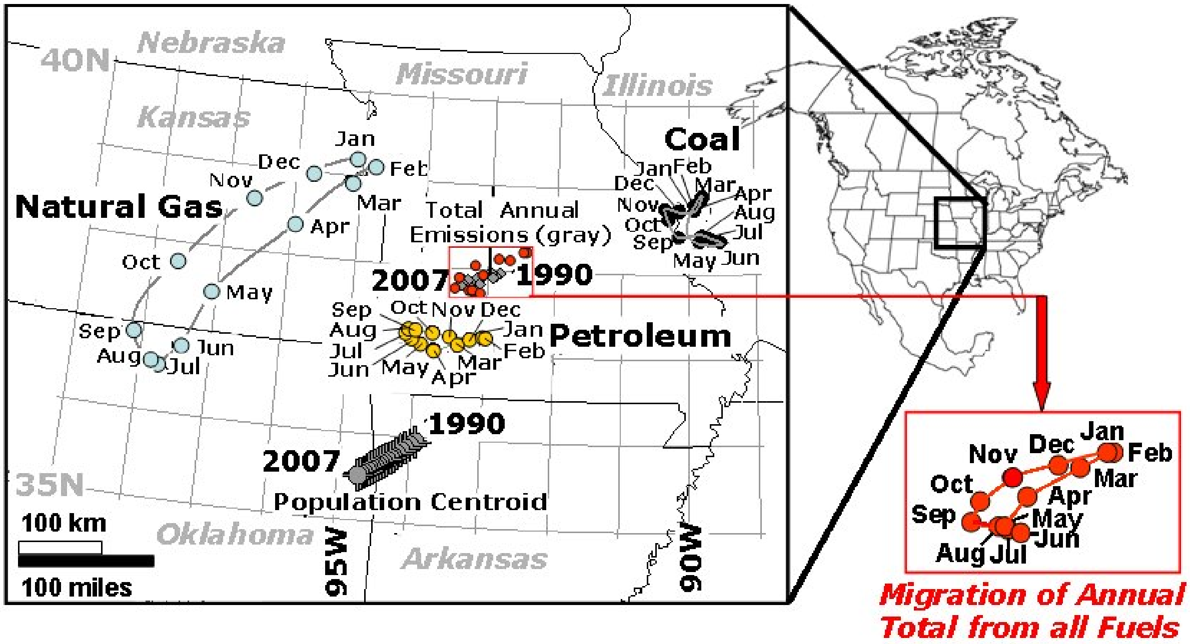

Figure 1. Annual migrations of the centroids of North American carbon emissions from coal products (black), petroleum products (gold), natural gas products (blue), and the total of all products (red), based on their 1990-2007 average spatial positions for each calendar month. West-southwesterly migration of the centroid of annual emissions (no monthly components) from all fuels from 1990-2007 is shown in gray, and overlaps the red dots representing the location of the centroid of all fuels collectively for each calendar month. The North American population centroid and its migration from 1990-2007 is also shown. Population figures used are from the U.S. Census Bureau (2001), Statistics Canada (2001), and the Instituto Nacional de Estadística y Geografía (INEGI) (2001).

A Long-Term Perspective on Recent Increases in Atmospheric CH_4 Abundance

E. Dlugokencky[1], P.M. Lang[1], K.A. Masarie[1], A. Crotwell[2], L. Bruhwiler[1], L. Emmons[3] and P. Bergamaschi[4]

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After CO_2, methane (CH_4) is the most important greenhouse gas influenced by human activities. 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 permafrost and hydrates are susceptible to changing climate. These sources recently received attention in the media because of their potential to cause strong positive climate feedbacks. But how much of this attention is warranted?

From 1999 to 2006, the global burden of atmospheric CH_4 remained nearly constant (red line, top panel of Figure 1). During 2007 and 2008, globally averaged CH_4 increased by ~13 ppb. Do these increases signal the start of increased emissions in the Arctic from permafrost or hydrates because of warming climate? We found that the likely drivers of these increases are greater than average wetland CH_4 emissions at high northern latitudes during 2007 because of exceptionally warm temperatures and in the tropics during 2007 and 2008 because of greater than normal precipitation in wetland regions during a La Niña. These increases result from interannual variations in temperature and precipitation (i.e., weather), which may be in part the result of long-term climate change, but there is yet no evidence for large permanent increases in CH_4 emissions. For 2009, our preliminary estimate of the global increase is ~4 ppb.

When evaluating these recent changes in atmospheric CH_4 burden, it is useful to consider the long-term behavior of CH_4. About a decade ago, we showed that if OH concentrations had been constant over the period of our observations, then total global CH_4 emissions had been constant. The observed decrease in CH_4 growth rate is consistent with a system approaching steady state, where the time constant of that approach is the CH_4 atmospheric lifetime (τ). Is this model of long-term behavior still consistent with the data today? The approach to steady state for this system, with zeroth-order source and pseudo-first-order loss, is given by: $[CH_4](t) = [CH_4]_{ss}-([CH_4]_{ss}-[CH_4]_0)e^{-t/\tau}$. By fitting this equation (**green line**) to the global averages, we find $[CH_4]_{ss} \approx 1799$ ppb and $\tau \approx 9$ yr. The lifetime determined from this fit is in good agreement with values determined independently based on methyl chloroform observations. For more than two decades, atmospheric CH_4 has looked like a system approaching steady state; super-imposed on the decline in growth rate are significant variations. Understanding the processes driving these variations will improve our ability to predict how CH_4 emissions in the Arctic will respond to changing climate. So far, the evidence suggests recent increases in CH_4 are part of natural climate variability and not evidence for strong climate feedbacks in the Arctic.

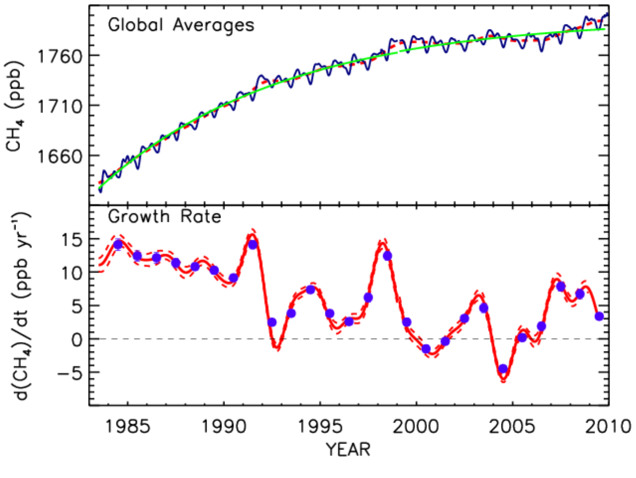

Figure 1. Globally averaged CH_4 mole fractions (blue), trend (red), and exponential fit (green; see text) (top panel); deseasonalized instantaneous growth rate (red) and annual increase (blue) (bottom panel). Results for 2009 are preliminary.

Global Atmospheric Methane and Ethane: Updated Mixing Ratios and Trends (1984-2009)

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University of California/Irvine has performed continuous global measurements of methane (CH_4), ethane (C_2H_6) and many other trace gases since 1978. Here we present updated global mixing ratios and trends for CH_4 and C_2H_6 using data collected until September 2009. Our measurements show a global CH_4 burden of 1787.8 ± 0.6 ppbv for the year, ending in September 2009, with a corresponding global growth rate of 5.5 ± 0.9 ppbv yr^{-1}. The renewed increases in methane's growth rate during the past few years (with growth rate peaks of 5.9 ± 0.9 pptv yr^{-1} in early 2007 and 7.9 ± 0.9 ppbv in late 2008) follow a period of near-zero CH_4 growth in 2005-2006 (Figure 1). For ethane, the global C_2H_6 burden was 601 ± 10 pptv for the year ending in September 2009, and the global C_2H_6 mixing ratio has shown a long-term decline throughout our 30-year record, with significant year-to-year fluctuations that have almost always coincided with changes in methane's growth rate. Very interestingly, for the first time in two decades, the global CH_4 and C_2H_6 trends have now dissociated from each other, beginning in 2008. The two most recent CH_4 peaks were driven primarily by growth in the tropics, which was also the case for ethane in 2007 but not in 2008. This shows that the most recent increase in the CH_4 growth rate was minimally influenced by biomass burning or fossil fuel sources.

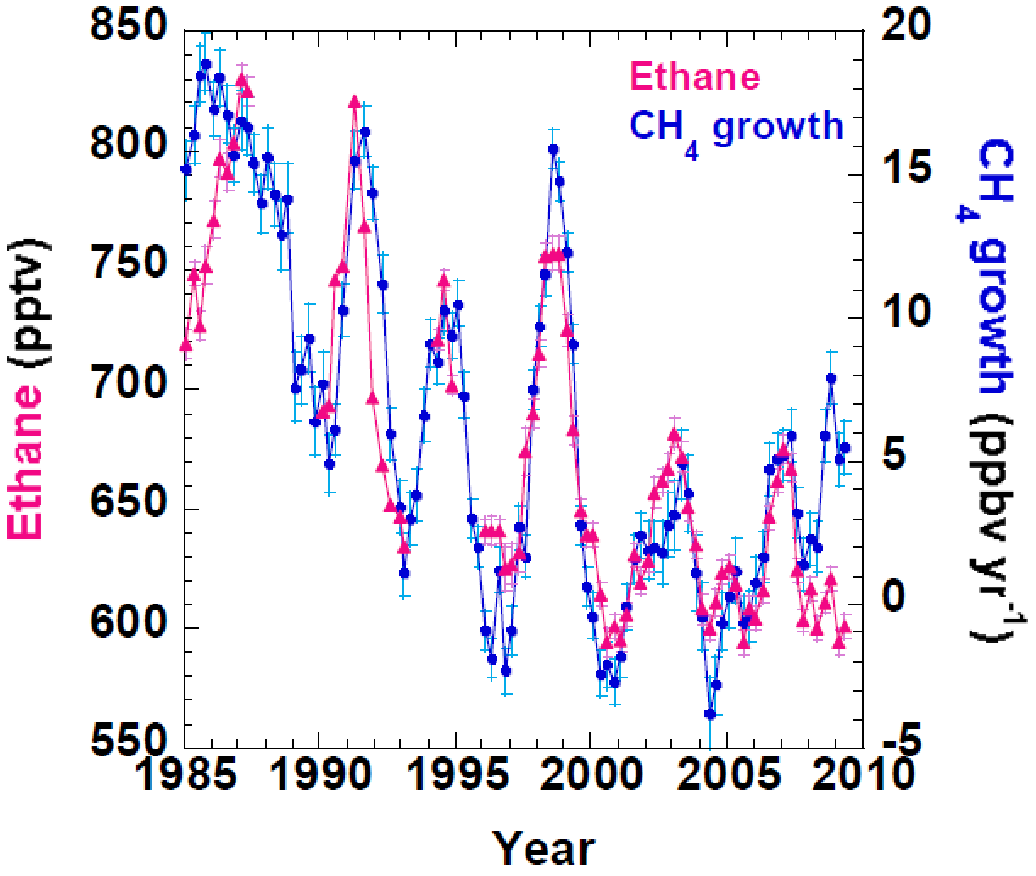

Figure 1. Global annual C_2H_6 mixing ratio (pink triangles) and CH_4 growth rate (blue circles) from September 1984 – September 2009. The data are plotted as running global annual averages at the temporal mid-point of the year during which the average was calculated (e.g. May 1, 2009 for [December 2008 to September 2009]).

A 20th Century Atmospheric History of Ethane and Implications for the Methane Budget

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Atmospheric ethane is an abundant non-methane hydrocarbon derived primarily from fossil fuels, biofuel use, and biomass burning. The primary loss pathway is through reaction with hydroxyl radical, which controls the lifetime and seasonality of ethane in the troposphere (~1-2 months during summer). Firn air results from South Pole and West Antarctic Ice Sheet-Divide, Antarctica show that ethane mixing ratios in the high southern latitudes increased from ~80 ppt in 1920 to ~280 ppt in the 1980s, then declined to the present day level of ~210 ppt over the last 20 years. Firn air measurements at Summit, Greenland are consistent with the timing of this increase, stabilization, and decline. At Summit, ethane levels increased from ~1.7 ppb to 2 ppb between 1950-1980, followed by a decline to the present day level of about 1.4 ppb between 1980-2000. The ramp-up and decline in atmospheric ethane was about 8-10 times larger in the northern hemisphere than in the southern hemisphere, indicating the observed variability is largely driven by changes in fossil fuel emissions. Interestingly, the late 20th Century decline in ethane coincides with a decrease in the atmospheric growth rate of methane, suggesting a common cause. The most likely explanation is a reduction in hydrocarbon emissions during the production, transport, storage, and/or use of fossil fuels. Assuming a fixed methane to ethane ratio for the fossil fuel source, the reduction in fossil fuel emissions required to explain the 1980-2000 ethane decline is much larger than that needed to explain the observed decline in the methane growth rate over the same period. Possible alternative explanations include changes in the ratio of methane/ethane emitted from fossil fuels or changes in the atmospheric abundance of chlorine atoms, which preferentially oxidize ethane relative to methane compared to their respective reaction rates with hydroxide.

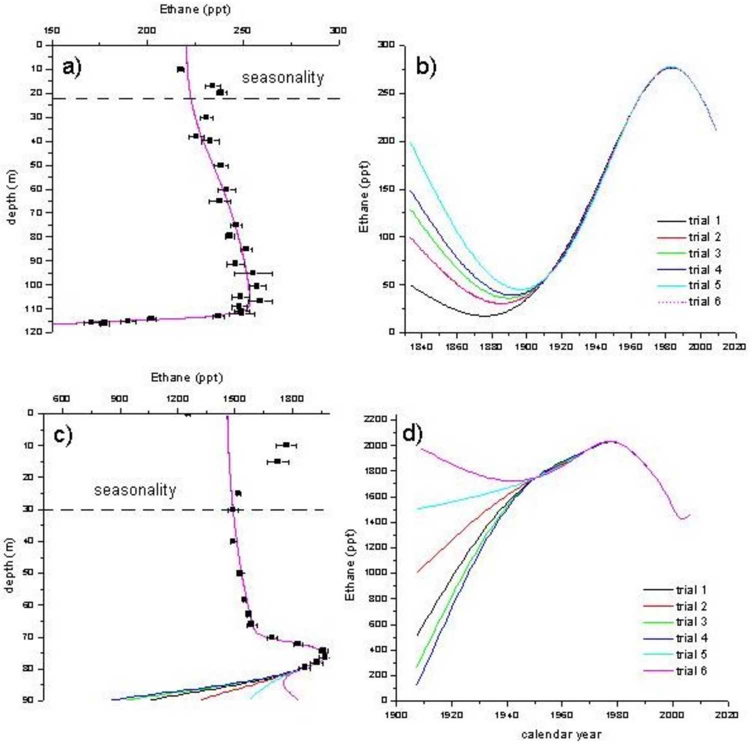

Figure 1. Atmospheric ethane histories for the past century derived from firn air measurements at South Pole (a and b) and Summit, Greenland (c and d). Fits to the firn air measurements were determined using a 1-D firn diffusion model (figures a and c for South Pole and Summit, respectively). The various curves show optimized fits using different starting conditions (see legend, trials 1-6 in panels b and d). At South Pole, all the fits converge from 1920 onward, indicating that the atmospheric history from 1920-present is insensitive to assumptions about preindustrial ethane levels (figure b). The Summit firn data constrain the ethane variability between 1950-2000 (figure d).

Seasonal Variations in CH_4 and N_2O Emissions from Central California

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Methane and nitrous oxide mixing ratios measured at two tall-towers (Mt Sutro and Walnut Grove) in Central California are compared with model predictions to estimate surface emissions of CH_4 and N_2O from December, 2007 to November, 2008. Predicted mixing ratios are calculated based on spatially resolved *a priori* CH_4 and N_2O emissions and simulated atmospheric trajectories. Meteological fields are computed using the Weather Research and Forecast (WRF2.2) with a parameterization developed at the NOAA for simulations in California. Surface influence functions (footprints) are then calculated using the Stochastic Time-Inverted Lagrangian Transport model driven by the WRF output. Predicted winds and boundary layer heights compare favorably with measurements from radar wind profilers in the Central Valley. Footprints calculated for well-mixed periods at 91m on the Walnut Grove, California (WGC) tower vary with seasonal meteorology; broader footprints are obtained in winter due to more north-south winds, while narrower footprints oriented in the west direction area obtained in spring, fall, and particularly summer. Coupled with *a priori* emission models, predicted CH_4 and N_2O signals are computed and compared with measured mixing ratios. Predicted CH_4 is found to be statistically consistent with the measurements in winter but significantly under-predicted during the summer. Examination of the summer footprints reveals channeling from the Bay Area through the Sacramento delta to the WGC tower. This suggests that emissions from the Bay Area and the Delta region are likely stronger in summer or more concentrated on the footprint than in the inventory map. For N_2O, predicted mixing ratios are consistently lower than measured, suggesting that N_2O emissions are significantly underestimated. Further analysis will provide an update on predicted emissions from the Bay Area and Central Valley.

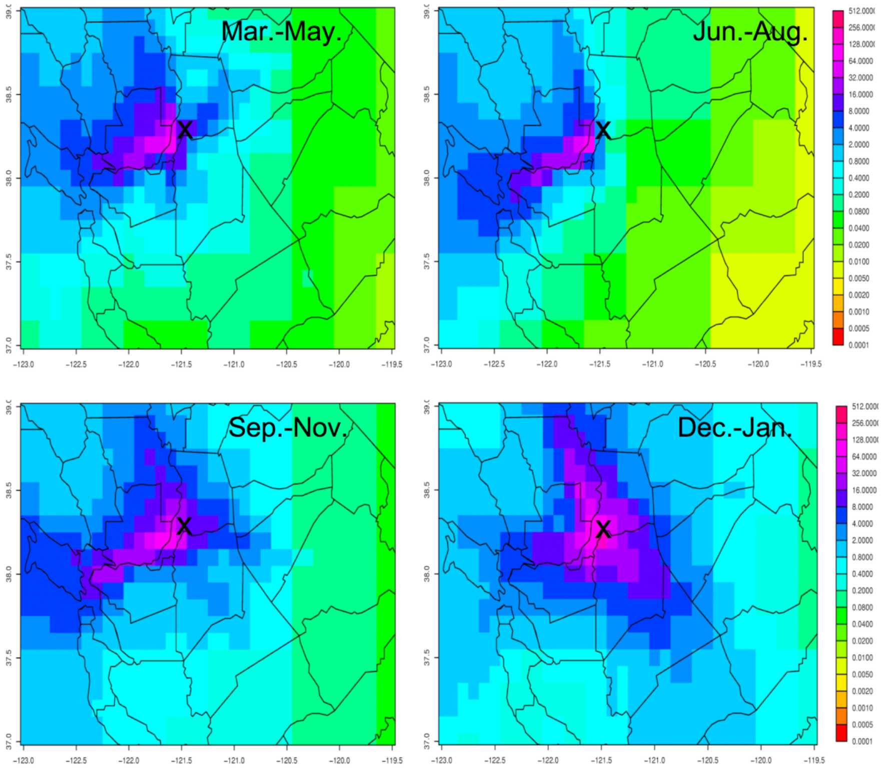

Figure 1. Seasonal well-mixed period footprints for 91m sample height on Walnut Grove Tower (marked with x) for December, 2007 to November, 2008.

Measurement and Parameterization of Sea-Air Trace Gas Transfer Using Micrometeorological Techniques: A Decade of Progress

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In May-June 1998 a team of the NOAA and university scientists executed the first motion-corrected, direct covariance measurements of the transfer velocity of CO_2 from a ship in the joint NOAA National Science Foundation (NSF) Gas Exchange field program, GasEx1998. Since then, CO_2 observations have been repeated in two subsequent GasEx field programs (2001 and 2008). Furthermore, the development of fast sensors for Dimethylsulfide (DMS) and Ozone has permitted similar direct measurements of transfer velocities for those gases in a series of NOAA and NSF-sponsored field programs. These observations have yielded insights into the physics of near-surface oceanic processes driving gas transfer over the ocean. This has led to the development of the NOAA Cuppled Ocean Atomsphere Response Experiment (COARE) gas transfer algorithm, which can be applied generally to most gases with known solubility and Schmidt number (air and water). In this talk we will discuss the measurement technology, recent field programs, and provide a synthesis of progress to date. Figure 1 shows a summary of observations of gas transfer velocity for CO_2 and DMS from this series of field projects.

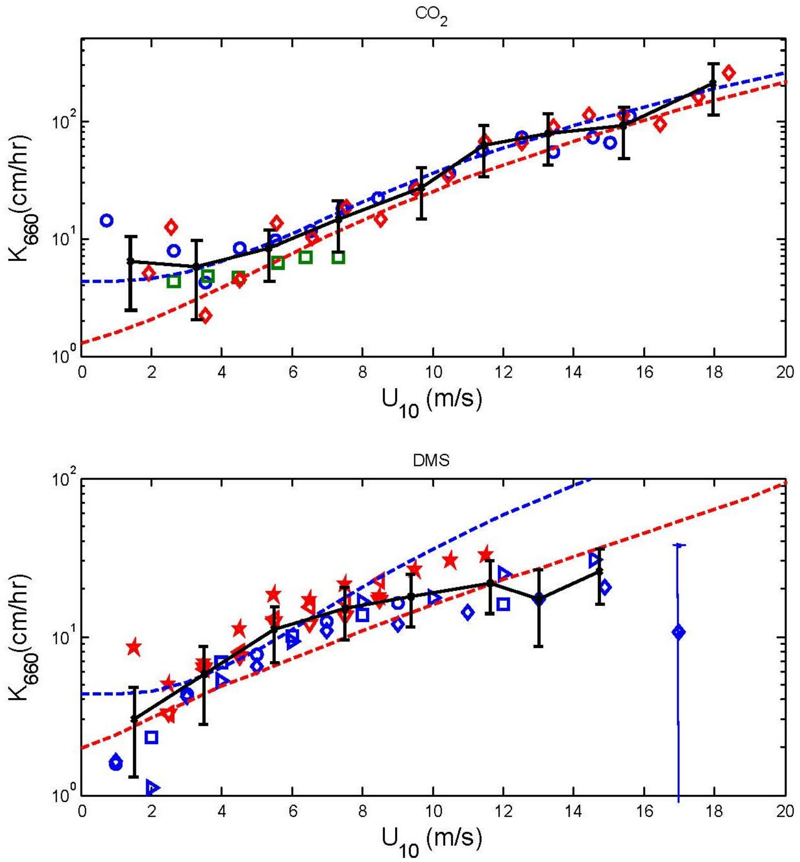

Figure 1. Gas transfer coefficients as a function of 10m neutral wind speed from direct surface-based observations. The black line is the mean of the data sets; the error bars are statistical estimates of the uncertainty in the mean. Upper panel CO_2 symbols are: circle - GASEX98, square - GASEX01, diamond - GASEX08. The parameterizations shown are: blue dashed line - McGillis et al 2001, red dashed line - NOAA/COARE CO_2. Lower panel DMS symbols are: square - Sargasso, circle - TAO, right triangle - Department of Geological and Environmental Engineering, diamond - GASEX08, left triangle - Wecoma 04, down triangle - Knorr 06, pentagram - Knorr 07 (red symbol data courtesy E. Saltzman). The parameterizations shown are: blue dashed line - McGillis et al 2001, red dashed line - NOAA/COARE DMS.

$^{13}C/^{12}C$ Isotopic Constraints on Inter-Continental Transport of Fossil Fuel CO_2 & Black Carbon (BC) Aerosols

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The fossil fuel fraction-weighted carbon isotopic compositions for the top 9 countries in emissions (http//:cdiac.ornl.gov) have been calculated from 1990 to 2008. In contrast to a homogenized global mean value of $\delta^{13}C_{FF}$, it was noticed that there is actually a large difference in $\delta^{13}C_{FF}$ between China/India (around -25‰) and other nations (between -27‰ to -33‰), indicating the differences in structure of Fossil Fuel (FF) usage in those countries and the impact from different stages of their economic development (Figs. 1 and 2). With the rapid economic developments of China and other South Asian countries (e.g. India) over the last 10 years, the influence of FF emissions from China/India has been largely increasing on both regional and global scales. Could those influences be recorded in the C isotopic compositions ($\delta^{13}C$) of the atmospheric CO_2 and BC aerosols, the two important components in FF emissions?

To identify and verify those FF influences with a focus on Asia-Pacific Transport, the $\delta^{13}C$ measurements in the atmospheric CO_2 and BC aerosols at various locations in North America (e.g. Alert, Barrow, Estevan Point, Sable Island, Bermuda), North Pacific Ocean (e.g., Mauna Loa) and Asia (e.g., Beijing, China; Tae-ahn Peninsula, South Korea) have been analyzed. The results show that FF emission signals can be recorded in the $^{13}C/^{12}C$ isotopic compositions of the atmospheric CO_2 and BC aerosols and that the FF CO_2 signals from Asia could be transported across Pacific Ocean to North America.

The work suggests that high precision $^{13}C/^{12}C$ isotope measurements in air CO_2 and BC samples can be used, as independent methods, to identify/verify FF signals and their influences on both regional and global scales when the corresponding emission sources are isotopically distinguishable. The results could be also used to constrain transport models for quantifying the relative contributions of air masses from different source regions.

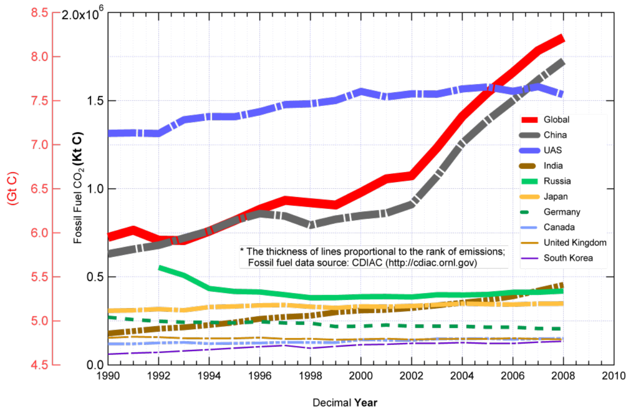

Figure 1. Fossil fuel CO_2 emission (Gt C) of top-9 countries in the world (in black Y axis) over the period from 1990 to 2008. The global mean is plotted again the red axis.

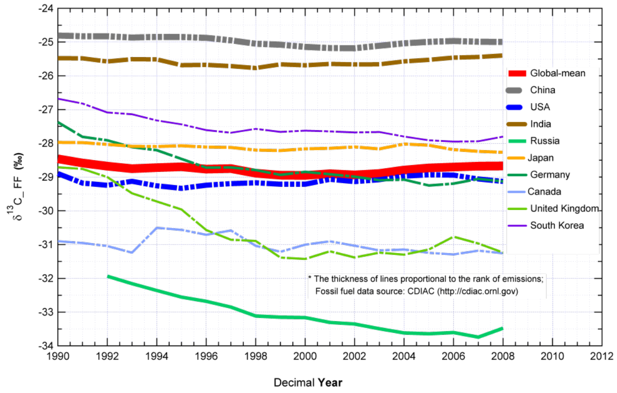

Figure 2. Fossil fuel mass fraction weighted carbon isotopic compositions ($\delta^{13}C_{FF}$ on VPDB scale) of the top-9 countries in the world over the period from 1990 to 2008. The global mean is in red.

Radiocarbon (^{14}C) Traces the Fossil and Biogenic Components of Total CO_2

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Δ^{14}C, the ratio of radiocarbon to total carbon, is a theoretically ideal tracer for recently added fossil fuel CO_2, because fossil fuel is ^{14}C-free. In contrast, all other carbon reservoirs that exchange CO_2 with the atmosphere, like the terrestrial biosphere and the oceans, are relatively rich in ^{14}C. Since 2004, NOAA ESRL and the University of Colorado Institute for Arctic and Alpine Research (INSTAAR) Radiocarbon Laboratory have worked together to make high precision (< 2 ‰) Δ^{14}C measurements. Our two sites in the eastern USA, Portsmouth, NH (NHA) and Cape May, NJ (CMA) exhibit large CO_2 signals from anthropogenic and biogenic fluxes. Using $\Delta^{14}CO_2$, however, we are able to partition the boundary layer CO_2 signal into biogenic and fossil fuel components. Once separated, these signals are independently useful. The biological signal can be used directly to infer the uptake and release of carbon by the biosphere, and the fossil signal can constrain anthropogenic emissions of CO_2, without the use of inventories, which can never be as recent as the measurements. Furthermore, the derived fossil fuel CO_2 signal is closely related to boundary layer enhancements of many air quality tracers like CO, SF_6, CFC-replacement compounds, and solvents like benzene. These relationships can exist for total CO_2, but we will show that they are biased because of the biogenic contribution. Having established a relationship between fossil fuel CO_2 and these tracers, we estimate their emissions by scaling the measured fossil-CO_2 tracer emission ratios to the well-known U.S. fossil fuel CO_2 inventory. Finally, we will show that a multi-tracer proxy of fossil CO_2 can be formed from the observed correlations. Such a multi-proxy tracer might serve as a low cost and widespread adjunct to actual ^{14}C observations.

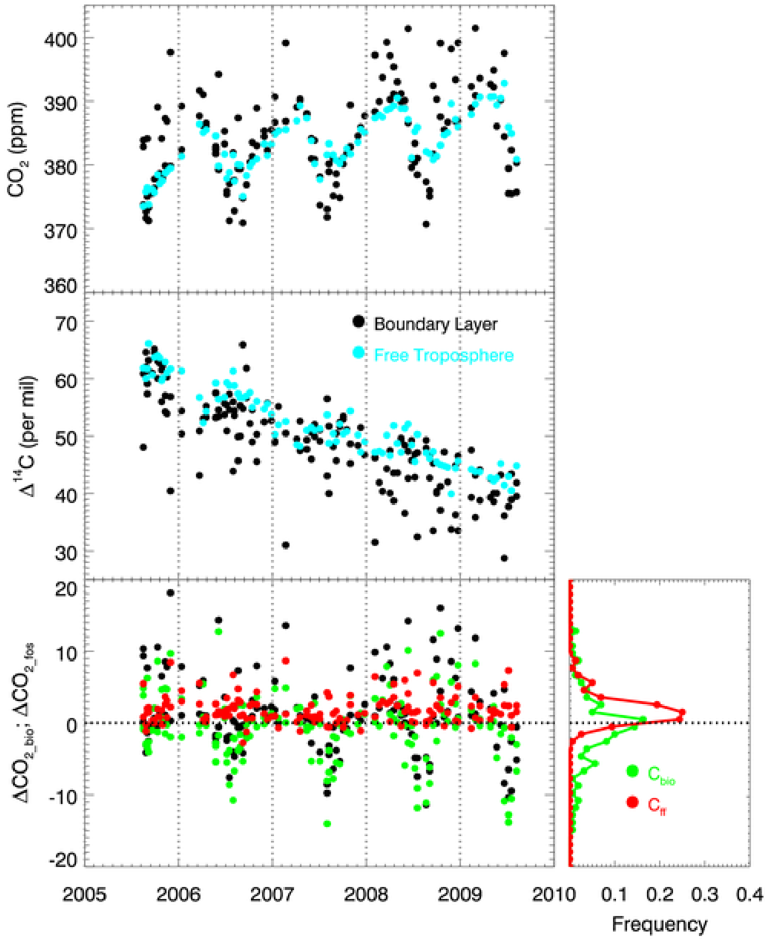

Figure 1. Fossil and biospheric CO_2 signals for boundary layer (PBL) aircraft air samples above (NHA) and (CMA). Top and middle panels show PBL (black) and a composite free troposphere (blue) reference time series for CO_2 and $\Delta^{14}CO_2$, respectively. Note that whereas for CO_2, the PBL values are both above and below the reference, for Δ^{14}C, the values are generally below the reference, showing the influence of fossil fuel emissions. The bottom panel shows the PBL-reference time series for CO_2 (black; C_{tot}) and the Δ^{14}C-derived values of the biological (green; C_{bio}) and fossil (red; C_{ff}) components. Even in winter, there are significant contributions from both biospheric and fossil fuel CO_2 to the total. In summer, C_{tot} underestimates the full extent of the photosynthetic drawdown of CO_2 shown by C_{bio}. The fourth panel shows the overall distribution of C_{bio} and C_{ff}.

Inter-Annual Variability of CO and CH_4 Observations Interpreted by a Global Lagrangian Transport Model

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A Lagrangian particle dispersion model (based on FLEXPART, Version 8.0) was set up to simulate global CO and CH_4 concentrations. Three million particles were constantly advected forward in time and allowed to pick up emissions during surface contact. Concentrations in the model were driven by 8-daily emission fields that reflect variability in biomass burning. Degradation of CO and CH_4 (and CO production from CH_4) was taken into account using an OH climatology with monthly resolution and pressure and temperature dependent reaction rates. Next to the less diffusive character of the Lagrangian context, the benefit of this approach is the potential to analyse contributions to the concentrations at receptor sites not only by source region and source category (as could be done in the Eulerian context as well) but also by age of an air mass. This age is given by the transport time from a certain source region.

Here we analyse a multi-year run of the model (2001-2007) and discuss inter-annual variability of CO and CH_4 as observed within the World Meteorological Organization/Global Atmosphere Watch (GAW) programme. In total 60 observational data sets of CO and 69 data sets for CH_4 were analysed. Monthly receptor concentrations at the sites' location were extracted from the model. Changes and anomalies in source region contributions at these sites were revealed and exceptional transport pathways highlighted.

In the Lagrangian context it is necessary to sum contributions of individual particles over a certain period of time to derive a robust concentration estimate at a given location in space. The temporal resolution of receptor concentrations is therefore limited by the number of particles passing through a receptor volume. We demonstrate the ability of our model setup to realistically simulate concentration variability at receptor sites on a day-to-day basis. This capability is further proven by the successful simulation of previously studied inter-continental transport events with duration of one to two days.

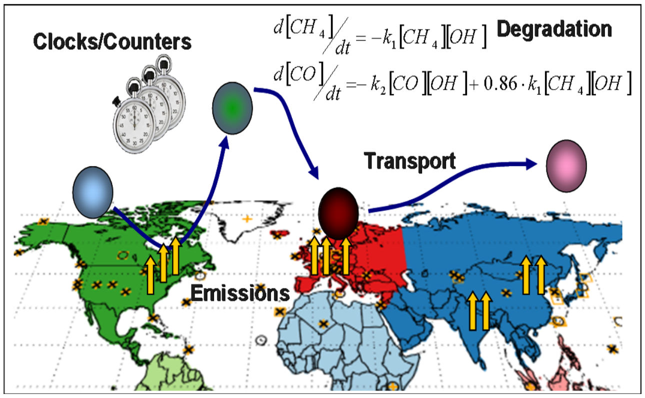

Figure 1. Conceptional representation of the model showing the model elements (global) transport, emissions (from 6 source regions plus the ocean), degradation (coupling CO and CH_4 to OH), and Clocks/Counters (needed to derive age spectra and source contributions at receptor points).

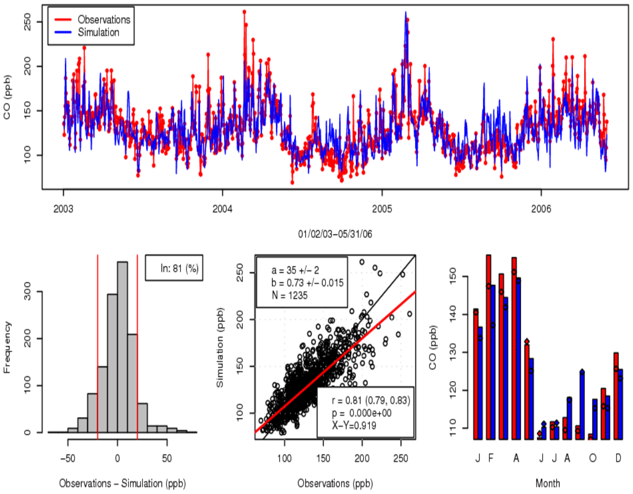

Figure 2. Comparison of model and observation for CO measurements at GAW station Jungfraujoch in the Swiss Alps.

Atmospheric CO_2 Observations from Space (ACOS): Preliminary Results from Greenhouse Gas Observing Satellite (GOSAT) Data Analysis

D. Crisp and The ACOS Team

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The NASA Orbiting Carbon Observatory (OCO) and Japanese GOSAT teams formed a close partnership during the development phases of these two missions. The objectives of this collaboration were to cross calibrate the OCO and GOSAT Thermal and Near Infrared Sensor for Carbon Observatories (TANSO) Fourier Transform Spectrometer (FTS) measurements, and to cross validate the OCO and GOSAT CO_2 retrievals against common reference standards to facilitate the joint use of these two data sets in studies of the carbon cycle. After the loss of the OCO spacecraft, NASA reformulated the OCO science team as the ACOS team to (i) meet the NASA's obligations to its GOSAT partners, (ii) recover some of the science knowledge expected from OCO, and (iii) validate the OCO retrieval algorithms in a realistic operational environment. This final objective took on greater significance when the U.S. Congress authorized a restart of the OCO project and the President's 2010 budget proposal included funding to produce a "carbon copy" of OCO that could be ready for launch by February 2013.

The GOSAT and ACOS teams conducted their first joint vicarious calibration campaign in Railroad Valley, Nevada from 23 Jun – 6 Jul, 2009. Results from this experiment and the subsequent coordinated over-flights of Railroad Valley with the Airborne Visible/Infrared Imaging Spectrometer instrument on the NASA ER2 on 10/9/2010 are being used to track changes in the radiometric calibration of the GOSAT TANSO-FTS instrument. The ACOS and GOSAT teams are validating GOSAT XCO2 retrievals with near-simultaneous measurements from the Total Column Carbon Observing Network (TCCON) measurement. While these comparisons still show biases, the amplitude of these biases are decreasing steadily over time as the retrieval algorithms improve. The standard deviations of the ACOS XCO2 estimates are now approaching the GOSAT accuracy requirement of 1% (~4 ppm) on regional scales. Ongoing investigations of spatially invariant spectroscopic residuals in the GOSAT retrievals are providing insights into the systematic errors that must be addressed to meet the much more stringent 0.3% (1ppm) regional scale uncertainties for OCO-2.

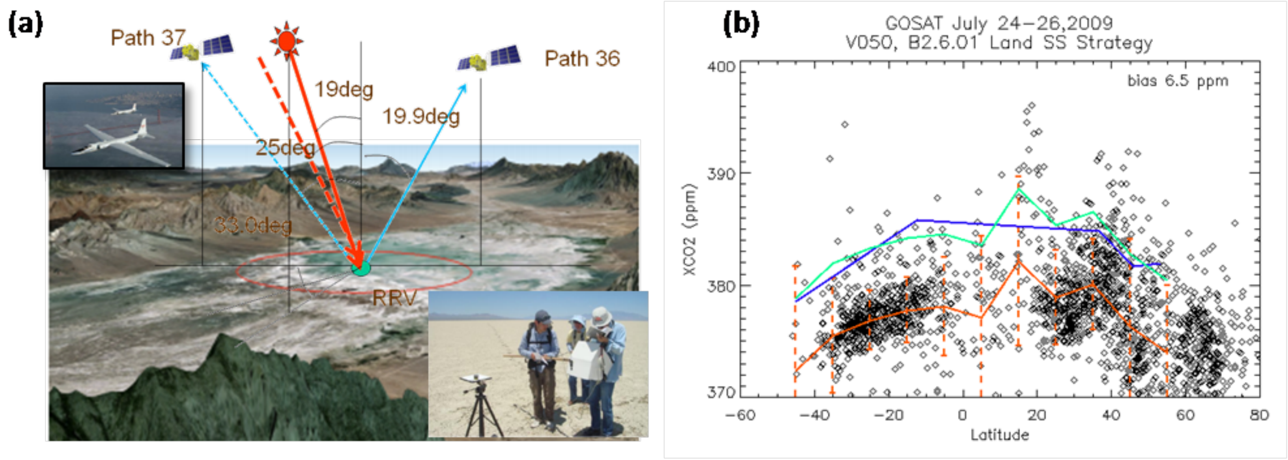

Figure 1. (a) Major components of the vicarious calibration campaign shown over a Google Map of Railroad Valley, Nevada, including satellite overpasses, ground-based observers and aircraft overflights. The next vicarious calibration campaign is scheduled for June 2010. (b) Pole to pole retrievals of XCO2 by the ACOS team for GOSAT 3-day repeat cycle in July 2009. There is currently a 6.5 ppm bias between the ACOS and TCCON retrievals, but the latitude distribution of XCO2 is clearly reproduced, with regional scale standard deviations of 2.5 to 4 ppm.

7.5 Years of Atmospheric Infrared Sounder (AIRS) Mid-Tropospheric CO_2 - Validations and Applications

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The AIRS enables us to monitor for the first time the global distribution and transport of middle-tropospheric CO_2 day and night, over oceans and land. Mid tropospheric CO_2 retrieved by the AIRS shows a substantial spatiotemporal variability that is supported by *in situ* aircraft measurements [Chahine et al., 2008]. The distribution of middle tropospheric CO_2 is strongly influenced by surface sources and large scale circulations such as the mid-latitude jet streams and by synoptic weather systems, most notably in the summer hemisphere. In addition, the effects of stratosphere troposphere exchange are observed during a final stratospheric warming event.

The retrieved AIRS mid-tropospheric CO_2 are compared to *in situ* measurements by commercial and research aircraft and to retrievals by land based upward looking Fourier Transform Interferometers. Validation of AIRS CO_2 data with respect to *in situ* observations has demonstrated the retrieval accuracy is better than 2 ppm. The average annual trend for the increase of mid-tropospheric CO_2 between 2003 and 2008 is ~2 ppm/year. We will focus on the significance of the retrieved CO_2 results by establishing their quantitative bounds on the random and systematic errors. This is of paramount importance for their use in modeling efforts to understand the sources and sinks and the lifting of CO_2 from surface layers into the free troposphere.

The AIRS CO_2 products may be downloaded from the Goddard Earth Science Data and Information Services Center. Access links to the products are provided on the web page: http://airs.jpl.nasa.gov/AIRS_CO2_Data

Data Format: Hierarchical Data Format (HDF)-Earth Observing System (EOS) Swath (L2) and HDF-EOS Grid (L3), Global Coverage: -180° ≤ longitude ≤ +180°, -60° ≤ latitude ≤ +90°, User Document Included.

AIRS Level 2 CO_2 Products:

- Nominal nadir resolution: 100km x 100km
- Data Content: Date, upper-tropospheric, lat, long, land fraction, solar zenith angle, CO_2 (ppm), CO_2 error measure by spatial coherence QA (ppm) and CO_2 averaging kernel (100 levels)

AIRS Level 3 CO_2 Products:

- Spatial Grid: 2° latitude by 2.5° longitude
- Time Granularity: daily, 8-day and calendar monthly

A Sixteen-Year Record of Global Natural Gas Flaring Derived from Satellite Data

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We have produced annual estimates of national and global gas flaring and gas flaring efficiency from 1994 through 2009 using low light imaging data acquired by the Defense Meteorological Satellite Program (DMSP). Gas flaring is a widely used practice for the disposal of associated gas in oil production and processing facilities where there is insufficient infrastructure for utilization of the gas (primarily methane). Improved utilization of the gas is key to reducing global carbon emissions to the atmosphere. The DMSP estimates of flared gas volume are based on a calibration developed with a pooled set of reported national gas flaring volumes and data from individual flares. Flaring efficiency was calculated as the volume of flared gas per barrel of crude oil produced. Global gas flaring has remained largely stable over the past fifteen years, in the range of 140 to 170 billion cubic meters (BCM). The 2009 gas flaring estimate of 145 BCM represents 22% of the natural gas consumption of the USA with a potential retail market value of $50 billion. The 2009 flaring added an estimated 311 million metric tons of carbon dioxide equivalent into the atmosphere. The DMSP estimated gas flaring volumes indicate that global gas flaring has declined by 19% since 2005, led by gas flaring reductions in Russia and Nigeria, the two countries with the highest gas flaring levels. The DMSP data indicate that global flaring increased by 5% in 2009, with more than 85% of the increase occurring in Russia. It is anticipated that the capability to estimate gas flaring volumes based on satellite data will spur improved utilization of gas that was simply burnt as waste in previous years.

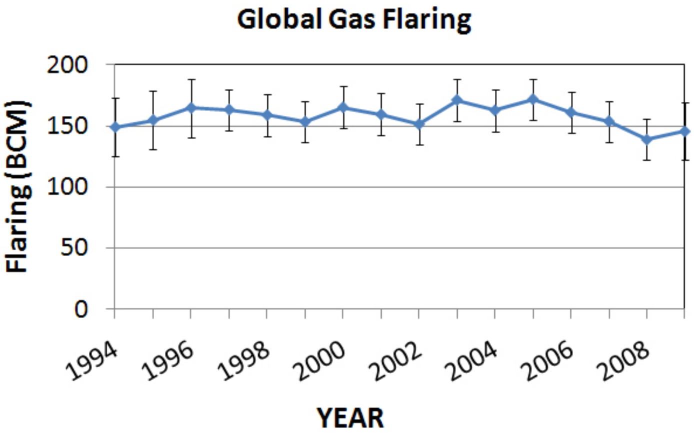

Figure 1. Global gas flaring estimates from 1994 through 2009.

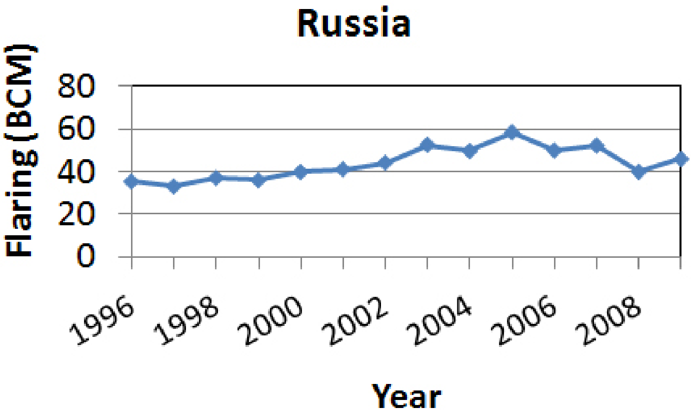

Figure 2. Gas flaring estimates for Russia from 1994 through 2009.

Atmospheric Observations of Carbon Monoxide (CO) and Fossil Fuel CO_2 Emissions from a Medium Sized City: Sacramento, California

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Accurate measurement of recently added fossil fuel carbon dioxide (CO_2ff) in the atmosphere is needed not only to quantify CO_2ff emissions, but also aids in understanding emissions of other anthropogenic trace gases. We use measurements of the radiocarbon content of atmospheric CO_2 ($\Delta^{14}CO_2$) to determine recently added CO_2ff in flask samples taken by aircraft over and downwind of Sacramento, California on February 27 and March 6, 2009. We determine the CO to CO_2ff emission ratio from the flask measurements as 14 ± 1 ppbCO/ppmCO_2ff (figure 1). Our results support the bottom-up inventory estimate of 15.4 ppbCO/ppmCO_2ff obtained from the CEPAM (CO) and Vulcan (CO_2ff) databases for the Sacramento region. However, if total CO_2 enhancement is assumed to represent CO_2ff in the urban plume, the CO:CO_2 ratio is much lower (figure 1), and would have suggested lower overall CO emissions. We use the ^{14}C-derived CO:CO_2ff emission ratio to obtain a high resolution CO_2ff record from continuous CO observations made on the February 27, 2009, flight. Comparison with total CO_2 mole fraction, also measured continuously in the same flight, shows that while CO_2ff emissions dominate the CO_2 variability in the Sacramento plume, they are not sufficient to explain all of the CO_2 variability, indicating some contribution from biospheric CO_2 (CO_2bio) exchange. Furthermore, within the Sacramento plume, a positive CO_2bio flux is observed, indicating net respiration and/or biofuel use. Conversely, CO_2bio is negative outside the urban plume, indicating net photosynthetic uptake in the rural Sacramento Valley. In a second flight, on March 6, 2009, the same type of analysis, using only the flask samples, shows that CO_2bio within the city was negative.

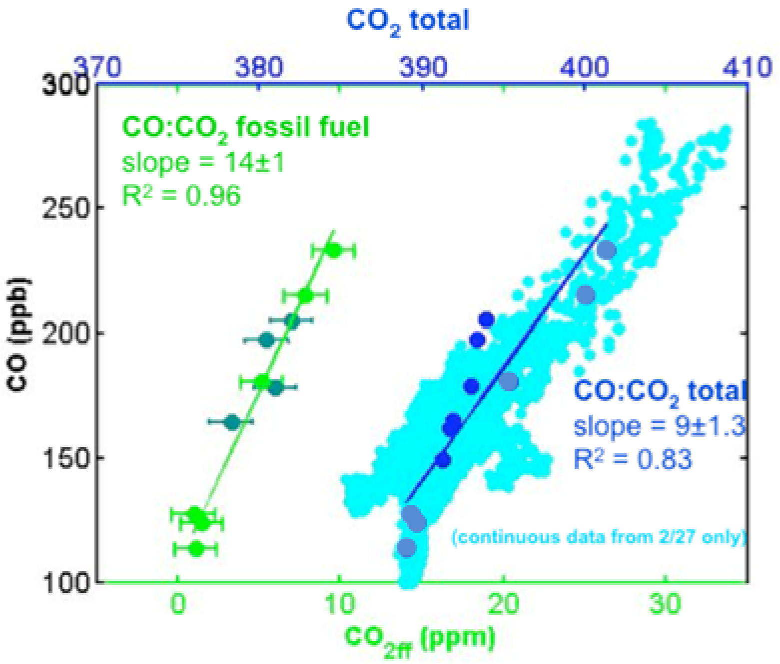

Figure 1. Relationship between CO_2ff (green symbols, bottom axis) and CO, and between total CO_2 (blue symbols, top axis) and CO. Flask measurements are the large circles, with the different shades indicating the two flights. The small, light blue circles are continuous measurements made on February 27, 2009. The lines are the best fit to the combined datasets, and the slopes are the obtained CO:CO_2ff or CO:CO_2total emission ratio.

CHF_3 (HFC-23) Emission Trend Response to $CHClF_2$ (HCFC-22) Production and Recent Emission Abatement Measures

B.R. Miller[1], M. Rigby[2], P. Krummel[3], P. Steele[3], L. Porter[4], M. Leist[3], P. Fraser[3], A. McCulloch[5], C. Harth[6], P. Salameh[6], J. Mühle[6], R. Weiss[6], R. Prinn[2], S. ODoherty[5], B. Greally[5] and P. Simmonds[5]

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CHF_3 (HFC-23) is an inevitable by-product of $CHClF_2$ (HCFC-22) production for use in air conditioning/refrigeration and as feedstock in fluoropolymer manufacture. CHF_3 has limited use in small emissive and non-emissive markets and thus historically this ‘waste’ gas was simply vented to the atmosphere following production at $CHClF_2$ plants. Concern over its high Global Warming Potential of 14,800 (100-year horizon) has lead to international efforts to curb its emissions. We present emission and production estimates for both gases based on observations of lower-tropospheric CHF_3 and $CHClF_2$ mole fractions at the Advanced Global Atmospheric Gases Experiment (AGAGE) network of five remote *in situ* Gas Chromatography/Mass Selective Detector instruments and in archived air samples. We quantitatively attribute recent changes in CHF_3 production to various sources.

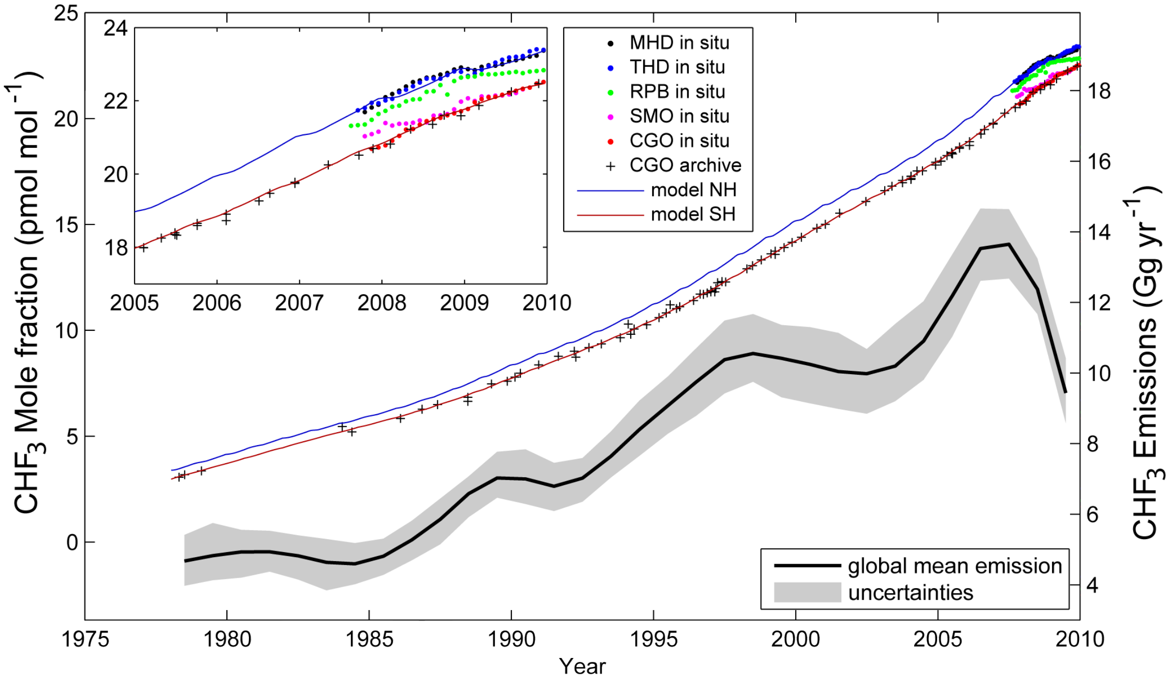

Figure 1. AGAGE *in situ* atmospheric observations (2007-2009) of CHF_3 at global monitoring sites and in the Cape Grim air archive (1978-2009) show a historically accelerating growth with a marked deceleration since 2006 (left axis). Inversion using the AGAGE 2D 12-box model yields CHF_3 emission estimates (right axis). The sharp increase in CHF_3 emissions during 2004-2006 results from a dramatic increase in $CHClF_2$ production in Article 5 countries (predominantly China and India). The sharp decrease in CHF_3 emissions since 2006 reflects a decrease in global $CHClF_2$ production, destruction (incineration) of >6 Gg CHF_3 yr^{-1} by Article 5 countries (China, India, South Korea, Argentina and Mexico) participation in the United Nations Framework Convention on Climate Change’s Clean Development Mechanism and emission reduction efforts by non-Article 5 countries.

Measurements of Greenhouse Gases and Halogenated Compounds at Gosan (Jeju Island, Korea) for Understanding Emissions in East Asia

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East Asia is a major source region for anthropogenic emissions of many greenhouse gases (GHGs) and halogenated compounds, important for their role in stratospheric ozone depletion and global warming. Here, we present measurements of GHGs and halogenated compounds performed at Gosan, located on the southwestern tip of Jeju Island, Korea, for understanding the emissions of these species in East Asia. Measurements performed at Gosan include flask measurements of CO_2 (in association with the Scripps CO_2 program; since 1990), continuous measurements of CO_2 (LoFlo instrument; since November 2007), and a wide range of halogenated compounds including various chlorofluorocarbons (CFCs), halons, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons, perfluorinated compounds, sulfur hexafluoride, and other chlorinated and brominated compounds (Medusa instrument in association with the Advanced Global Atmospheric Gases Experiment Network; since November 2007). Analysis of wind trajectories arriving at Gosan show that the measurements can reflect pollution events from the major source regions in China, Korea, Japan, and Taiwan. In addition “baseline” concentrations can be observed in the clean air from the Siberian regions or from the oceans to the south. Efforts to quantify the emissions of halogenated compounds from the East Asian countries/regions have been performed using both advanced inversion techniques and relatively simple ratio techniques, and confirm the region’s major role in the global budgets for these compounds. Future research will focus on refining current emission estimation techniques and extending them to other greenhouse gases.

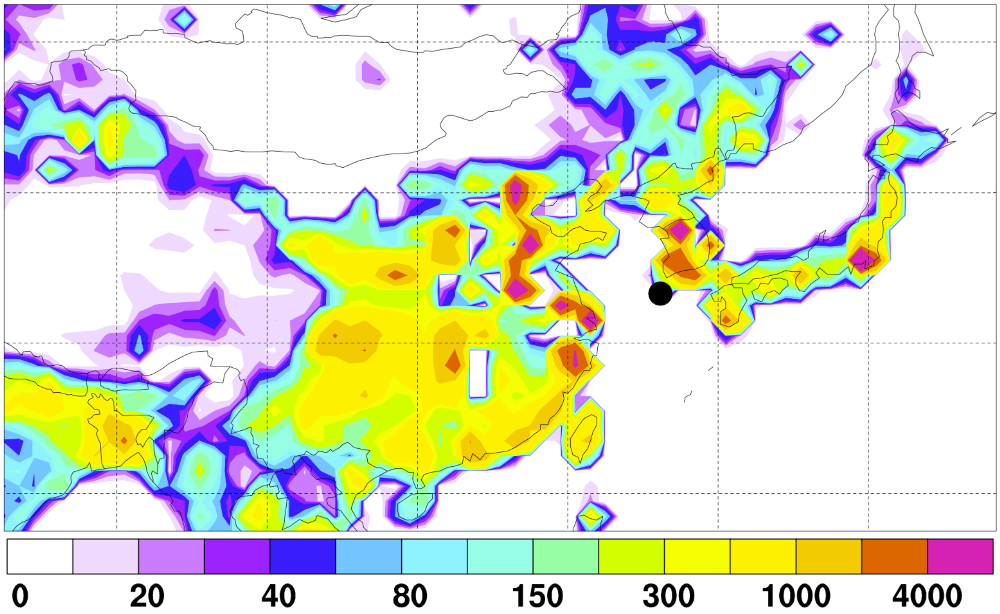

Figure 1. Emissions of HCFC-22 ($CHClF_2$) derived for 2008 using measurements at Gosan (shown in black circle) and inverse modeling using the FLEXPART model. Results show that emissions of this species is specially high in populated/industrialized regions of China and Korea where it is widely used in refrigeration and air conditioning. For Japan, use of HCFC-22 is banned under the Montreal protocol, however emissions may continue from old equipment still in use.

A Study of Ambient Mercury in the Marine Free Troposphere

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The NOAA Mauna Loa Observatory (MLO) in Hawaii was ideal to investigate high marine free troposphere ambient mercury transformation and transportation processes. We measured gaseous elemental mercury (Hg0), divalent reactive gaseous mercury (RGM), particulate bound mercury (Hg(p)), O_3, SO_2 and elemental carbon in high resolution from 2002 – 2009. We found no overall trend of increase or decrease for ambient mercury, but found great temporal variability when working with high resolution data. Hg0 concentrations ranged from 0.2 – 11 ngm^{-3} and geometric mean ± geometric standard deviation of 1.6 ± 1 ngm^{-3}. Hg(p) concentrations ranged between 2 – 536 pgm^{-3}, 15 ± 4 pgm^{-3} and RGM ranged between 2 – 241 pgm^{-3}, 6 ± 2 pgm^{-3}. The variability in ambient mercury concentration was due to rapid changes or air masses arriving at MLO with differing past chemical history and age. We classified air masses arriving at MLO as young and old, which relates to their local and long distances origins. Younger air masses show that chemical transformation of Hg0 is possible in the marine free troposphere. Older air masses serve as a storage and transportation media of ambient mercury. Older air masses also show a convoluted chemical history of ambient mercury at high altitude, product of chemical reactions, mixing of low tropospheric and stratospheric air masses and heterogeneous chemistry while in transport.

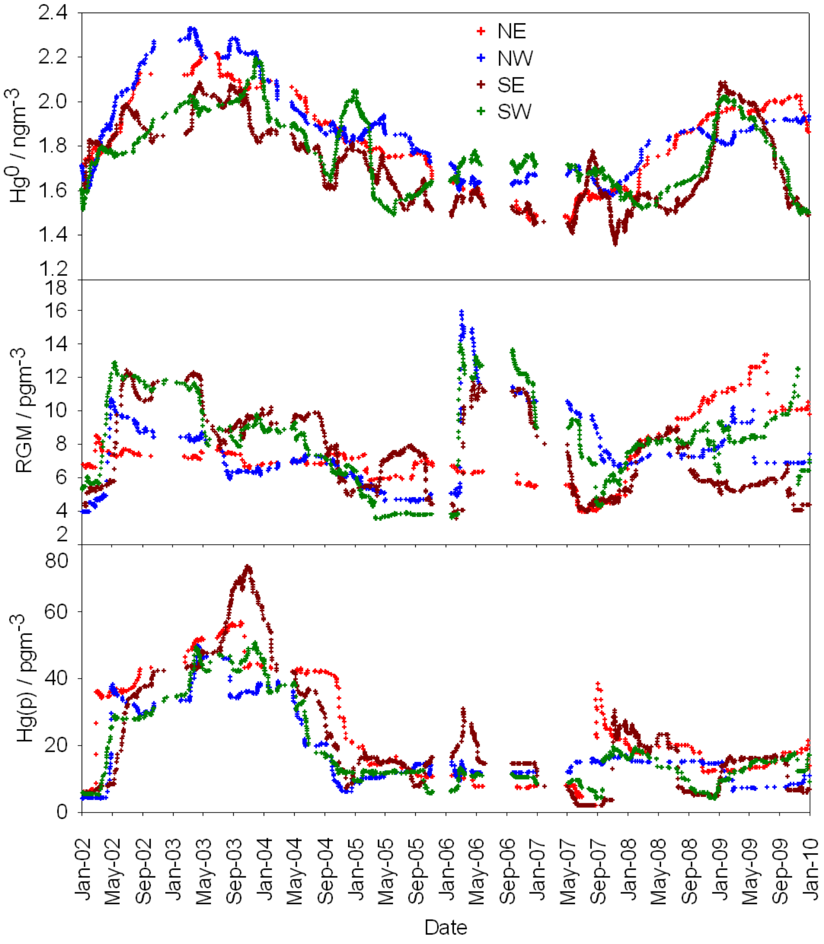

Figure 1. Hg0, Hg(p), and RGM concentration time series by wind direction collected at MLO, Hawaii from 2002 – 2009.

Measurement of Volatile Organic Compounds (VOCs) in Marine Air at Cape Grim Using Proton Transfer Reaction Mass Spectrometey (PTR-MS)

S. Lawson, I. Galbally, E. Dunne, J. Gras and P. Krummel

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PTR-MS is a promising new approach for measuring VOCs in global background air. The World Meteorological Organization/Global Atmospheric Watch has specified that PTR-MS can be used for measuring isoprene, terpenes, acetonitrile, methanol, ethanol, acetone and dimethyl sulphide (DMS) in the background atmosphere. We briefly present a critical examination of the underlying assumptions that PTR-MS can unequivocally identify and quantify these compounds in global background air.

We present high time resolution VOC observations made using PTR-MS at the Cape Grim Baseline Station, Tasmania (41°S) in January-February 2006, November-December 2007 and April 2008. VOCs measured include DMS, isoprene, isoprene oxidation products (methyl vinyl ketone and methacrolein), methanol and acetone. VOC concentrations at Cape Grim are compared to measurements of clean oceanic air elsewhere in the world. PTR-MS benzene measurements during a local biomass burning event are compared to parallel benzene measurements made using Advanced Global Atmospheric Gases Experiment Medusa, Gas Chromatography-Mass Spectometry.

Diurnal cycles of VOCs in clean oceanic air at Cape Grim are explored and show a clear diurnal cycle of DMS with a daytime minima and night time maxima that agrees well with the observations from Cape Grim reported by Ayers et al, (Figure 1). A diurnal cycle of isoprene with a daytime maxima is also observed in November-December (Figure 2).

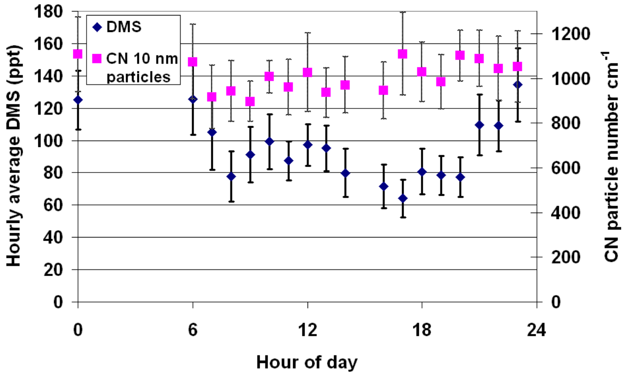

Figure 1. Concentration of DMS and CN 10 nm particle number presented as an average for each hour of the day from 12 days with clean marine air in December 2007.

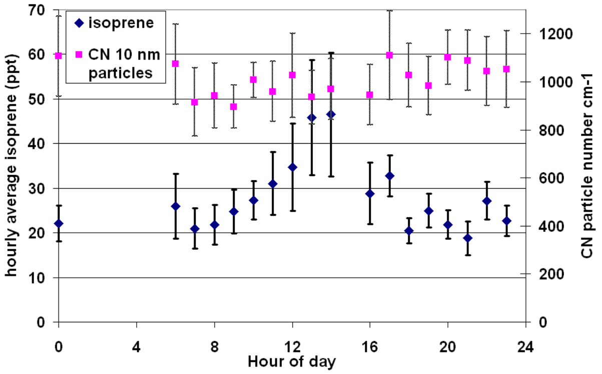

Figure 2. Concentration of isoprene and CN 10 nm particle number presented as an average for each hour of the day from 12 days with clean marine air in December 2007.

Nonmethane Hydrocarbons at the NOAA ESRL Cooperate Network Flask Sampling Sites and Their Use for Site and Atmospheric Transport Evaluation

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[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

Atmospheric lifetimes of Volatile Organic Compounds (VOC) depend on their chemical structure and therefore vary by molecule. Consequently, analyses of anthropogenically emitted VOC can be applied as a powerful tool for assessing impacts and transport times of polluted air to remote sites. The series of short chain atmospheric non-methane hydrocarbons (NMHC) is particularly valuable. Their lifetimes span days (i.e. hexane) to several months (ethane), thereby providing a wide dynamic range for studying atmospheric processes. NMHC have been measured since 2004 in flask samples collected bi-weekly at more than 40 of the NOAA Carbon Cycle Network sites. This growing data record has allowed defining the seasonal and geographical background of NMHC in the global atmosphere. At a number of sites, deviations from background behavior can be clearly identified and be attributed to local pollution influences. These findings provide critical insight for evaluation of data of other greenhouse gases monitored at these stations. Five arctic sites (north of the Arctic Circle) (Fig. 1) participate in this program. Despite the fact that sources of VOC are small in the arctic environment, ambient background levels and seasonal cycles of these compounds are larger than in any other remote environment on Earth. This feature makes NMHC data a sensitive tool for investigating transport and pollution import into the Arctic. The available observations provide convincing evidence for the rapid transport and mixing of the arctic atmosphere and that the elevated NMHC levels are determined by anthropogenic and biomass burning emissions originating from lower latitude regions of the Northern Hemisphere.

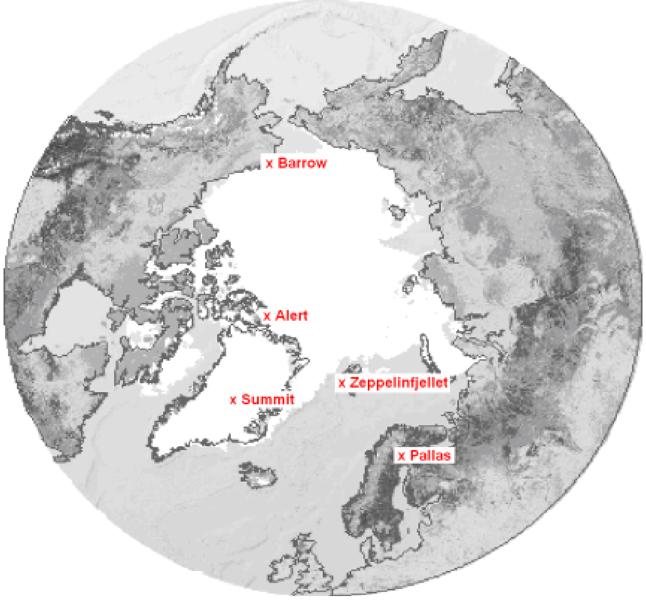


Figure 1. Location of arctic sites participating in the NOAA-Institute of Arctic & Alpine Research NMHC monitoring (Barrow, AK; Alert, Nunavut; Svalberg (Zeppelinfjellet), Spitzbergen; Pallas, Finland, and Summit, Greenland).

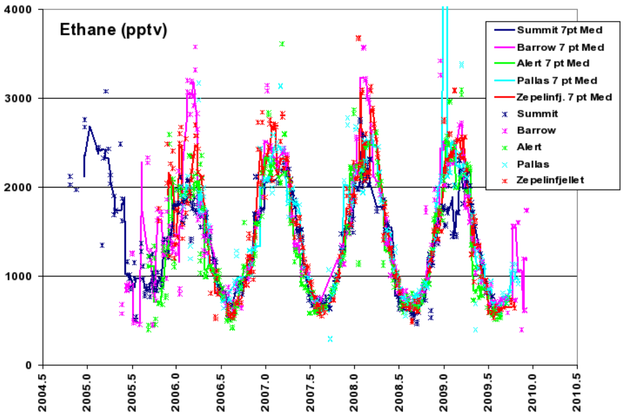


Figure 2. Record of five years of ethane measurements from NMHC monitoring locations.

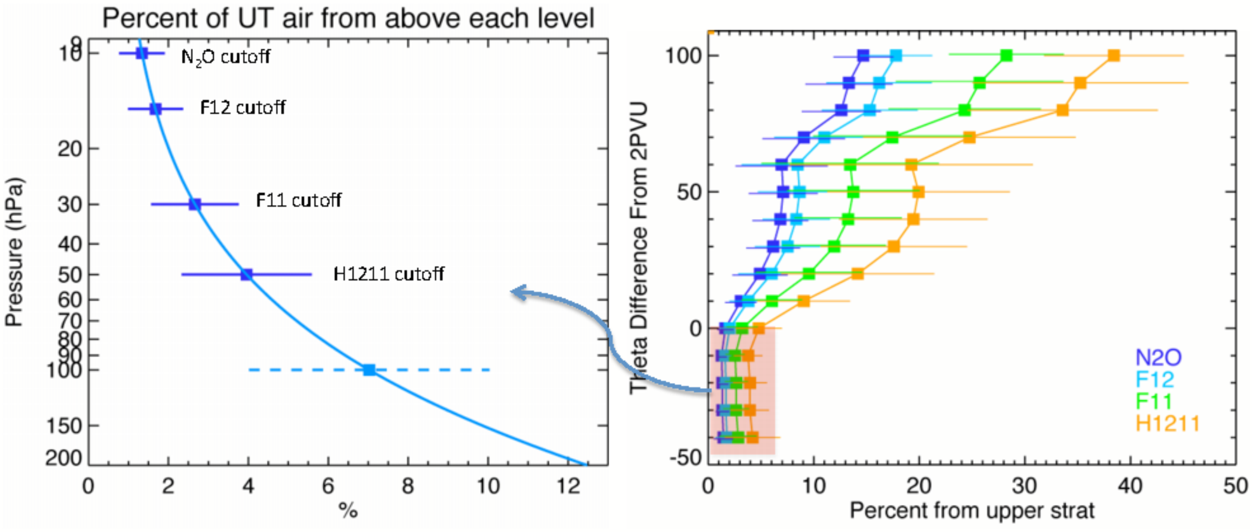
Unique Transport Diagnostics from Airborne *In Situ* Trace Gas Measurements

E. Ray[1], F. Moore[1], K. Rosenlof[1] and J. Elkins[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

We describe several unique transport diagnostics based on *in situ* trace gas measurements from aircraft and balloon platforms. These transport diagnostics include quantifying the fraction of air in the upper troposphere and lowermost stratosphere (UT/LS) that has come from the stratospheric 'overworld', calculating transport time scales and surface origins of air in the UT/LS and estimating multi-year to multi-decadal changes in the stratospheric mean meridional circulation and horizontal mixing. These diagnostics have relevance for understanding a number of important processes in the atmosphere and are particularly important to compare to global chemistry-climate model output.

Stratospheric Fraction Profiles



Extratropical UT air contains a mixture of 4-10% air from above 100 hPa and 0.5-2% from above 10 hPa.

Figure 1. Fractions of air in the lowermost stratosphere and upper troposphere that have come from above various levels in the stratosphere calculated from photolytic tracer correlations.

Preliminary Results from the First Atmospheric Study on the NASA Global Hawk Unmanned Aircraft Systems (UAS)

J.W. Elkins[1], E.J. Hintsa[2], F. Moore[2], G.S. Dutton[2] and B.D. Hall[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

NOAA ESRL scientists participated on the first autonomous, high altitude (>60kft), long-range (21,000 km), long endurance (>30 hours) aircraft to observe the atmosphere using the NASA Global Hawk UAS. Two NOAA ESRL instruments were operated on the Global Hawk Pacific Mission (GloPac) in March-April 2010. Results presented here will focus on the airborne gas chromatograph that is called the UAS Chromatography for Atmospheric Species (UCATS). It has two gas chromatograph channels that can be swapped out to measure different trace gases, for example, carbon monoxide, methane, hydrogen, nitrous oxide, sulfur hexafluoride, chlorofluorocarbons 11 and 12, and halon-1211, and a 0.2 Hz response ozone ultraviolet absorption photometer.

The U.S. Air Force gave NASA two of the original Global Hawks. The GloPac mission is the first civilian-based research project involving these planes. NASA, NOAA, and Northrop Grumman, the aircraft's manufacturer, are funding the mission. GloPac is comprised of at most five long-range flights over the Pacific Ocean and one remote Arctic flight based out of NASA Dryden Flight Research Center at Edwards Air Force Base, California. We will report on our preliminary UCATS findings. Monitoring of these "greenhouse gases" on the ground and at altitude helps climate modelers verify models and predict future climate change.

For more information: http://www.espo.nasa.gov/glopac/

Figure 1. Global Hawk UAS (left) and Operations Center (right). Photos courtesy of NASA.

2010 NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE

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

Wednesday Morning, May 19th, 2010 AGENDA

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

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

- ***07:30 - 08:15 Morning Breakfast – Coffee, tea, fruit, bagels & donuts served***

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- ***Session 5*** ***Keynote and Elements of Emerging Services*** – *Chaired by James Butler*

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08:45 - 09:00 *Keynote Questions and Answers*
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09:00 - 09:15 Recent Increases in Global HFC-23 Emissions and the Contribution of HFCs and HCFCs to Radiative Forcing
S. Montzka (NOAA/ESRL)..26
09:15 - 09:30 Top-Down Validation of European Halocarbon Emission Inventories
S. Reimann (Empa, Switzerland)...*27*
09:30 - 09:45 Integrating Observations and Inventories to Improve Emission Estimates: A Framework for Global Synthesis
R. Duren (JPL, California Institute of Technology)...28

- ***09:45 - 10:15 Morning Break***

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10:30 - 10:45 Downscaling of Advanced Microwave Scanning Radiometer (AMSR-E) Soil Moisture Using Thermal Sensors and a Physically-Based Model
C. Hsu (University of Colorado/CIRES)..30
10:45 - 11:00 Decadal Variations in Surface Radiation Budget Observations: An Unexpected Trend for the U.S.
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J. Michalsky (NOAA/ESRL)..32
11:15 - 11:30 A Characterization of Arctic Aerosols as Derived from Airborne Observations and Their Influences on the Surface Radiation Budget
R. Stone (University of Colorado/CIRES)..33
11:30 - 11:45 Assessing the 'Full Spectral' Potential Radiative Impact of Arctic Aerosols: Dust, Smoke, Haze
G. Anderson (NOAA/ESRL)...34

- ***11:45 - 13:00 Catered Lunch Service – Outreach Classroom GB-124***
(pre-payment of $10.00 required at registration table)

2010 NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE

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

Wednesday Afternoon, May 19th, 2010 AGENDA

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

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- ***Session 7*** ***Aerosols*** *– Chaired by John Ogren*

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14:00 - 14:15 The NOAA ESRL Airborne Aerosol Observatory: Climatology and Seasonal Variation of Aerosol Properties Over Central Illinois
P. Sheridan (NOAA/ESRL)......39

14:15 - 14:30 Climate Services, WMO and GAW Observations
L. Jalkanen (WMO, Switzerland)......40

- ***14:30 - 15:00 Afternoon Break***

- ***Session 8*** ***Ozone & Water Vapor*** *– Chaired by Sam Oltmans*

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S. Oltmans (NOAA/ESRL)......41

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15:30 - 15:45 Using the Relationship Between Mean 500-Millibar (Mb) Heights and Mean Surface Ozone Concentrations in Colorado to Decompose Ozone Times Series and Evaluate the Impacts of Changes in Precursor Emissions
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M. Kurylo (University of Maryland/Goddard Earth Science and Technology Center)......45

16:15 - 16:30 The "Boulder Record": 30 Years of Water Vapor Vertical Profiles Over Boulder, Colorado
D. Hurst (University of Colorado/CIRES)......46

16:30 - 16:45 Laboratory Evaluation of the Effect of Nitric Acid on Chilled Mirror Hygrometer Measurements in the Upper Troposphere (UT)/Lower Stratosphere (LS)
T. Thornberry (University of Colorado/CIRES)......47

- **Closing Remarks** *– Dr. James H. Butler (NOAA/ESRL)*

Observations and Monitoring: The Challenge of Science to Services

T.R. Karl

NOAA National Climatic Data Center, Asheville, NC 28801; 828-271-4476, E-mail: Thomas.R.Karl@noaa.gov

NOAA's proposed new Climate Service has an important challenge related to delivering information on the state and changing state of the climate system. The NOAA Climate Service must address the observations needed to adequately monitor the climate, infuse the best science available into its monitoring, and yet have the operational mindset to deliver information on time, every time, that is understandable and useful to a diverse set of stakeholders from scientists to policy makers and the general public. NOAA's Annual State of the Climate Report will be used to identify and draw out several issues and opportunities related to this challenge.

Figure 1. Thomas Karl currently serves as director of NOAA’s National Climatic Data Center in Asheville, N.C., and interim director of NOAA's Climate Service. Karl is a fellow of the American Meteorological Society and has recently completely his term as President. He is also a fellow of the American Geophysical Union and has published more than 150 peer-reviewed articles and several books as editor and contributor. He has received many awards and recognition for his work in services and scientific contributions in climate-related work including: two Presidential Rank Awards, five Gold Medals from the Department of Commerce and two Bronze Medals; the American Meteorological Society's Suomi Award; National Associate of the National Academy of Sciences; the NOAA Administrator's Award, and several others. He has served as Editor of the Journal of Climate (1997-2000) and has been the Convening and Lead Author and Review Editor of all the major Intergovernmental Panel on Climate Change assessments since 1990, which were recently awarded the Nobel Peace Prize. He was Co-Chair of the U.S. National Assessment and the recent Global Climate Change Impacts in the U.S. State of Knowledge Report and a number of other assessments produced by the U.S. Climate Change Science Program. He has received a B.S. in Meteorology from Northern Illinois University, a M.S. in Meteorology from the University of Wisconsin, and a Doctorate of Humane Letters (honoris causa) from North Carolina State University.

Recent Increases in Global HFC-23 Emissions and the Contribution of HFCs and HCFCs to Radiative Forcing

S. Montzka[1], L. Kuijpers[2], M. Battle[3], M. Aydin[4], K. Verhulst[4], E. Saltzman[4], D. Fahey[1], B. Miller[5], L. Miller[6], C. Siso[5] and B. Hall[1]

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[2]Eindhoven Centre for Sustainability, Technical University Eindhoven, Eindhoven, Netherlands
[3]Department of Physics and Astronomy, Bowdoin College, Brunswick, ME 04011
[4]Department of Earth System Science, University of California, Irvine, CA 92697
[5]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309
[6]Science and Technology Corporation, Boulder, CO 80305

Trifluoromethane (HFC-23) is an unintended by-product of chlorodifluoromethane (HCFC-22) production and has a 100-yr global warming potential of 14,800. Firn-air and ambient air measurements of HFC-23 from three firn sampling excursions to Antarctica between 2001 and 2009 have been used to construct a consistent atmospheric history for this chemical in the Southern Hemisphere. The results show continued increases in the atmospheric abundance of HFC-23 and they imply substantial increases in HFC-23 global emissions since 2003. These emission increases are coincident with rapidly increasing HCFC-22 production in developing countries and are observed despite efforts in recent years to limit emissions of HFC-23 through the Kyoto Protocol's Clean Development Mechanism. These results will be considered along with new NOAA measurements of additional hydrofluorocarbons (HFCs) from archived air, firn air, and ongoing flask-air measurements. Summed together, hydrochlorofluorocarbons (HCFCs) and HFCs accounted for 2.2% of the direct radiative forcing from all anthropogenic, long-lived gases in 2008, but they accounted for ~9% of the increase in total forcing from trace gases during 2003-2008. The increase in radiative forcing from HCFCs and HFCs was slightly larger than attributable to N_2O global mixing ratio increases over this same period.

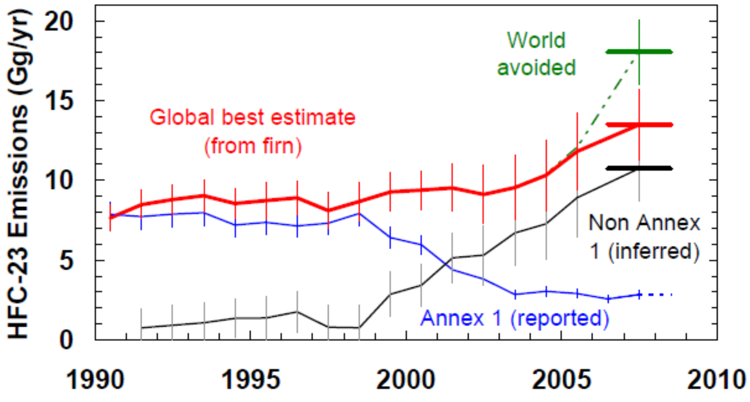

Figure 1. Global HFC-23 emissions derived from Antarctic firn air and ambient air measurements compared to augmented emissions reported to the UNFCCC by developed countries (blue line). The difference is attributed to developing countries (black line). HFC-23 emissions avoided through Clean Development Mechanism (CDM) projects of the Kyoto Protocol have been added to global emissions (green dashed line) to provide a picture of the 'world avoided' by these activities.

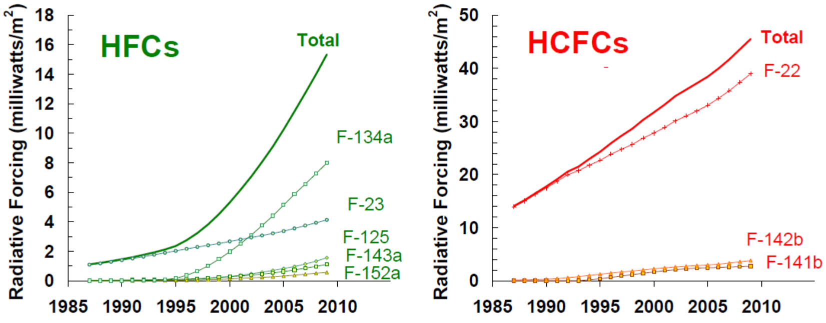

Figure 2. Radiative forcing from HFCs and HCFCs in recent years based on samples regularly collected at remote sites throughout the globe, archived samples from the Northern Hemisphere, and firn-air collected in Antarctica.

Top-Down Validation of European Halocarbon Emission Inventories

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[3]Met Office, Exeter, United Kingdom

Continuous measurements of halocarbons at continental background sites have the potential to be used to estimate regional and global sources. Whereas global emissions of specific substances can be estimated by straightforward accounting for their trends and atmospheric lifetimes, assessing regional sources requires a more sophisticated approach. In Europe emissions of halocarbons are regularly estimated by continuous measurements at Jungfraujoch (high-alpine site, Switzerland) and at Mace Head (coastal site, Ireland). These estimations are derived by combining measurements during pollution events with independent tracers (e.g. CO, Rn-222), concurrent meteorological information, or statistical methods. The derived emissions down to the level of individual countries have the potential to be used as an independent tool for verification of the yearly inventories submitted to the United Nations Framework Convention on Climate Change. Examples of the different methods in use and case studies of the divergence between the inventories and measurement-based estimates will be shown (Figure 1).

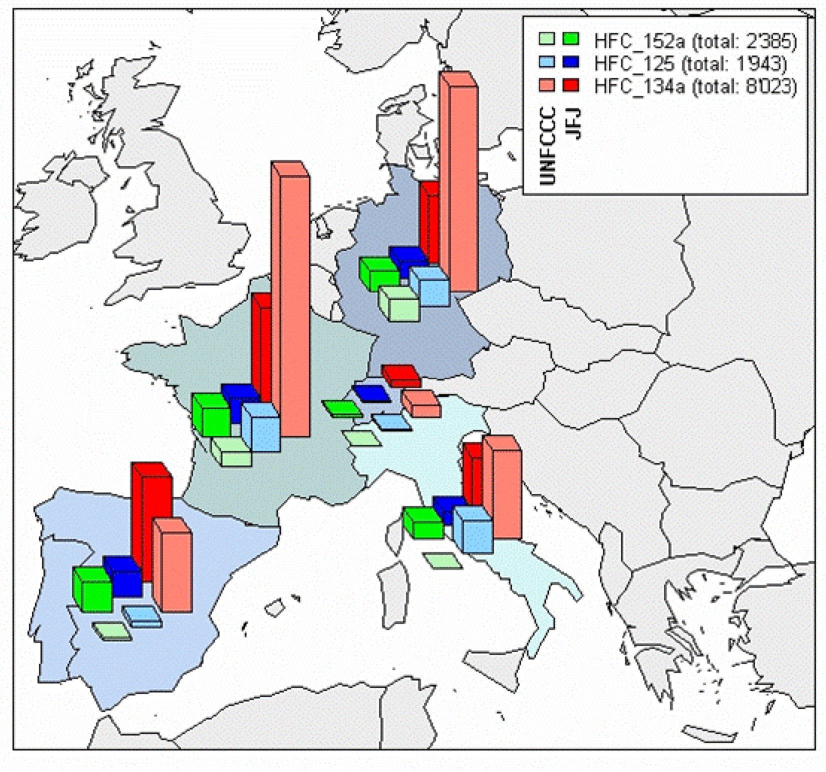

Figure 1. Estimation of emissions of different Hydrofluorocarbons (HFCs) divided into individual European countries, using measurements of HFCs and Rn-222 at Jungfraujoch in combination with a Lagrangian Particle Dispersion Model (FLEXPART).

Integrating Observations and Inventories to Improve Emission Estimates: A Framework for Global Synthesis

R. Duren

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Currently, accounting for greenhouse gas emissions is accomplished by two distinct methods: bottom-up inventories and top-down inverse modeling of fluxes based on observed airborne fractions. The degree of intercomparison and reconciliation between the two methods is currently limited to periodic research-driven campaigns in well-surveyed regions such as the United States and the European Union. This talk will describe a notional framework for a global synthesis of top-down and bottom-up methods with a goal of consistency testing to improve constraints on the underpinning models for both methods as well the complementary roles of the two methods in verifying specific policy actions and validating the efficacy of those actions. the 3 principal barriers to practical implementation: flux uncertainties, relative scope, and the attribution challenge, will be discussed, along with suggestions on how existing and planned assets might be leveraged over the coming years to address these issues.

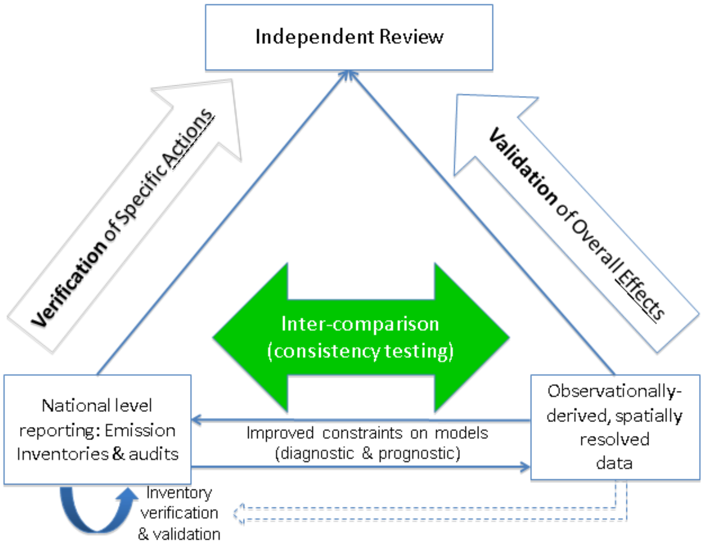

Figure 1. Complementary roles of inventories & observations (and different levels of "V&V").

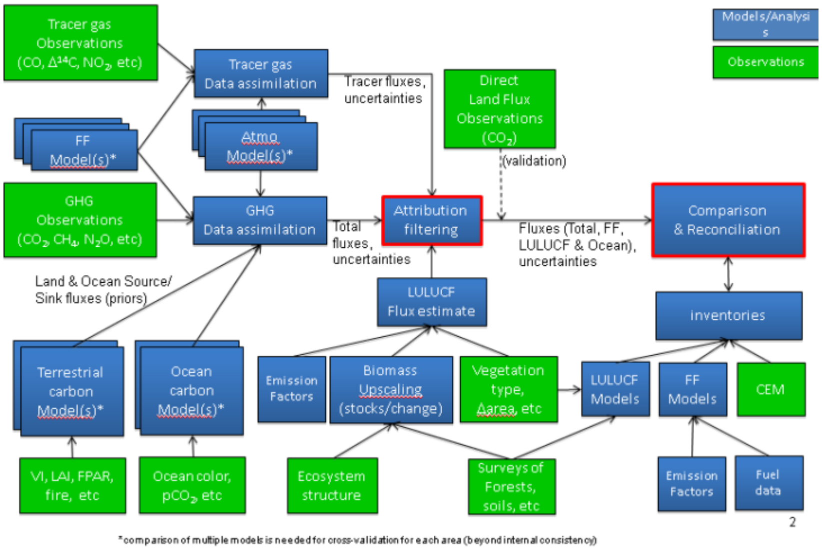

Figure 2. Putting it all together: a **notional** synthesis framework.

Radiance Calibrated Night Lights Products that Reveal Unsaturated Urban Cores and Gas Flares

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[2]NOAA National Geophysical Data Center, Boulder, CO 80305

One of the most obvious characteristics of the human-built environment is lighting at night. It is so prominent that cities can be confidently mapped by the light they emit to space at night (see Figure 1). The Defense Meteorological Satellite Program, run by the United States Air Force, has been monitoring the Earth at night and producing digital data for almost two decades. These data are archived at the National Oceanic & Atmospheric Administration/National Geophysical Data Center. The useful data record stretches back to 1992 and is ongoing. One limitation of the data is that it typically saturates over urban cores and other bright sources such as gas flares. There is a relatively small collection of data where the gain of the instrument is significantly reduced which allows resolution of bright sources. The goal is to blend the limited low-gain data with the operational data to optimize the value in each product (see Figure 2).

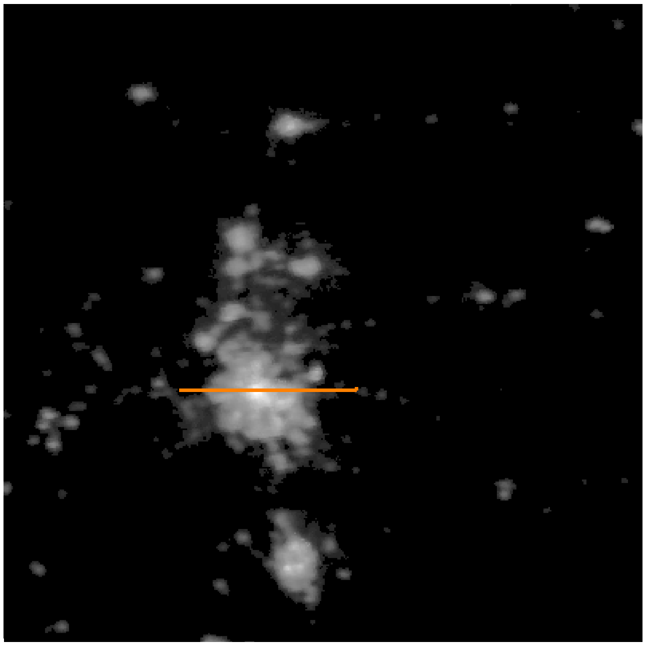

Figure 1. The Front Range of Colorado. Denver is in the center with Colorado Springs to the south and Fort Collins to the north. The orange line indicates a transect through the center of Denver.

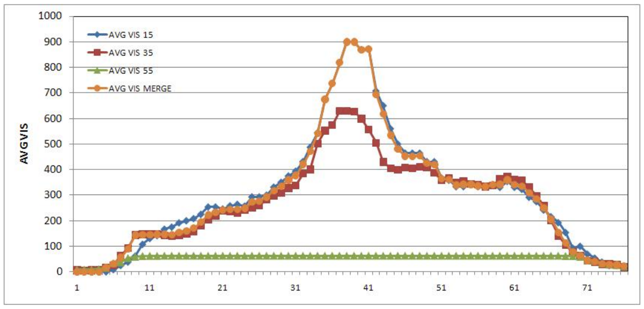

Figure 2. The Transect Data. The transect Digital Numbers are presented for each fixed gain setting. The green line (Gain = 55) is saturated at its maximum value for the entire urban portion of the transect. The red (Gain = 35) is less sensitive than the Gain 55 data by a factor of 10. It saturates in the urban core. The blue line is lower in gain by another factor of 10 (Gain = 15). That channel is able to resolve the lights from the brightest pixels in Denver. The Orange line is the merged product when a synthesis of these fixed gain products are combined.

Downscaling of Advanced Microwave Scanning Radiometer (AMSR-E) Soil Moisture Using Thermal Sensors and a Physically-Based Model

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[3]University of Colorado in Denver, Denver, CO 80202

A deterministic approach for downscaling 25 km resolution AMSR-E daily soil moisture data was developed from 1 km resolution Moderate Resolution Imaging Spectroradiometer (MODIS) data. The downscaling relationship was built on creating an association between soil evaporative efficiency and near surface soil moisture through a physically-based scaling function. This function was created by bringing together soil properties, a Von Karman wind turbulence model, and aerodynamic resistance to form a semi-empirical parameter. For the soil property, percent clay and bulk density was extracted from Soil Survey Geographic (SSURGO) data to infer published lab findings for application. Aerodynamic resistance was calculated from wind speed measurements at wind gage height given soil roughness. A vegetation index and surface temperature data derived from MODIS was used to estimate soil temperature and, subsequently, to calculate soil evaporative efficiency. In this process, MODIS was used to downscale low resolution microwave derived soil moisture to the 1-km resolution. To account for the lower soil moisture sensitivity of the MODIS surface temperature and the poor capability of AMSR-E to differentiate soil and vegetation signals, saturated hydraulic conductivity values extracted from the SSURGO database were used to explore its association with soil moisture dynamics in the drying phase.

The research site encompasses the Babocomari River and Walnut Gulch River watersheds in Arizona. The soil moisture data from the NOAA Hydrometeorology Testbed soil moisture network and from the USDA Walnut Gulch Experiment Watershed are being used for model validation.

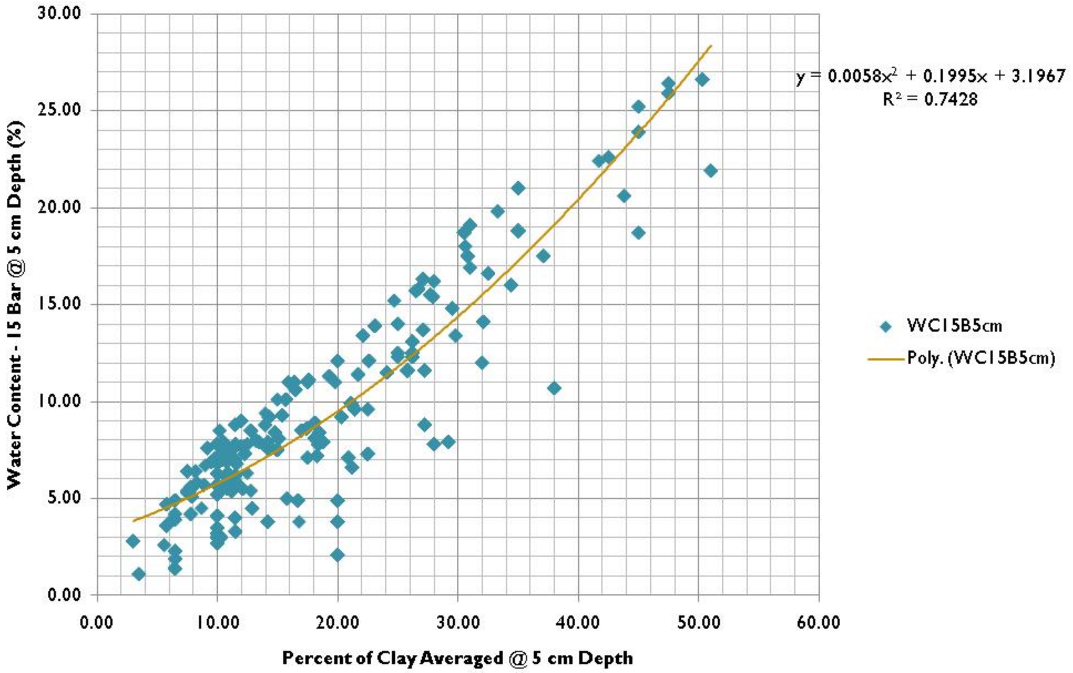

Figure 1. Percent Clay is found to be strongly related to water content averaged at 5-cm depth. Published laboratory experimental data for soils having different Bulk Density and Percent Clay were used to support the downscaling procedure.

Decadal Variations in Surface Radiation Budget Observations: An Unexpected Trend for the U.S.

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For the past 35 years, NOAA ESRL Global Monitoring Division (GMD) and its predecessor organizations have been monitoring components of the Earth's surface radiation budget with the knowledge that changing atmospheric composition and state would impact those components, which in turn contribute to variations in the surface energy budget. Although the surface energy budget's primary roles in driving the Earth's atmospheric and oceanic circulations are well known, details of the various interactions of the energy components with: (1) The many elements of individual surface types, (2) The turbulent boundary layers, and especially (3) Changes over time, are much less understood. The intent of the surface radiation monitoring effort is to contribute a highly accurate observational record for diagnostic and predictive development purposes on climatological temporal and spatial scales. The observational methods are *in situ* surface-based, thereby providing the highest possible accuracy, but such that global coverage is not feasible, although these measurements have contributed extensively to development of satellite-based retrievals intended to provide reasonable worldwide coverage. We have established two small networks of remote, climatically diverse and representative observing sites on different spatial scales, global and continental U.S., to continuously sub-sample long-term variations of upward and downward flowing solar and terrestrial (or thermal infrared) broadband radiation. The summed radiation components, taking the downwelling as positive and upwelling as negative, constitute the net surface radiation, which is the energy available for heat gain or loss at the surface, resulting in changes to; surface temperature, convection, storage in the subsurface, surface water state (e.g., evaporation or melting), and/or photosynthesis. Interesting variations and suggestive trend tendencies exist in several of the GMD surface radiation records. Of particular note and highlighted here is the highly significant (at least statistically) upward trend in net surface radiation for one of those networks (SURFRAD, continental U.S.), as shown in the figure below. Contributions to the upward trend come from both the net solar and net infrared components. Unfortunately, longer or more extensive records to either evaluate this trend's prevalence, or to completely explain it do not exist, although it would be important for weather and climate models to include or replicate this change. Further investigations are underway as well as an effort to extend and expand the observational networks.

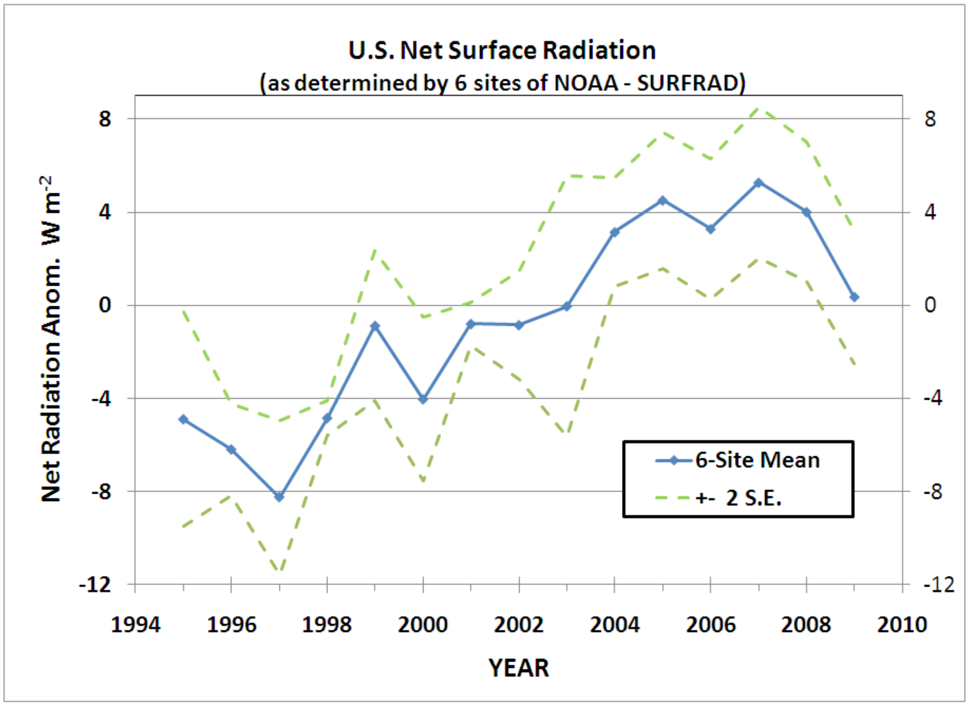

Figure 1. Net surface radiation annual anomalies, means and ± 2 Std. Err. for U.S. SURFRAD.

A Ten-Month Comparison of All-Weather Pyrheliometers

J. Michalsky[1], S. Wilcox[2], E. Dutton[1], T. Stoffel[2], D. Nelson[1], A. Andreas[2], D. Myers[2], I. Reda[2] and P. Gotseff[2]

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Thirty-three, commercially-available pyrheliometers were compared over more than nine months at the National Renewable Energy Laboratory (NREL) Solar Radiation Research Laboratory near Golden, Colorado. Included among the 33 instruments were four all-weather absolute cavity radiometers, which proved to be as stable as the open cavities that were used to periodically calibrate all pyrheliometers during the study. The average of the four all-weather cavities was chosen as the standard irradiance to which the other 29 pyrheliometers were compared. The two standard deviation precision of the cavity standard was ±1.2 W/m^2. In addition to the four all-weather cavities, there were seven sets of three pyrheliometers of the same make and model plus an additional eight prototypes in the study. These test instruments include those most widely used by the international community along with these new production models. Instruments were cleaned every workday. Analysis was performed by a non-participant in the experiment who had no knowledge of the identification of the instruments except for the cavity radiometers; the analyst also knew which three pyrheliometers formed a set. If the manufacturer provided temperature corrections, they were applied. The early analysis suggests four groupings of pyrheliometers: windowed cavity radiometers are the most accurate; followed by pryheliometers that have 95% uncertainties around ±5 W/m^2; followed by pyrheliometers with uncertainties between ±10 - 15 W/m^2; and then two prototypes that were clear outliers. The results will be illustrated; the identity of the instruments is pending completion of the analysis. The comparison was organized under the auspices of the Baseline Surface Radiation Network with instruments donated from many sources. NREL staff members were responsible for most of the observational activity.

Figure 1. All 33 instruments tracking the sun during the pyrheliometer comparison.

A Characterization of Arctic Aerosols as Derived from Airborne Observations and Their Influence on the Surface Radiation Budget

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The Arctic climate is influenced by aerosols that affect the radiation balance at the surface and within the atmosphere. Impacts depend on the composition and concentration of aerosols that determine opacity, which is quantified by the measure of aerosol optical depth (AOD). During winter and spring aerosols are transported into the Arctic from lower latitude industrial regions. During April 2009, a trans-Arctic flight of the German Polar-5 provided an opportunity to collect a comprehensive data set from which properties of the aerosol were derived, including AOD. Measurements were made from near the surface to over 4 km in altitude during a flight from Svalbard, Norway to Pt. Barrow, Alaska, passing near the North Pole (Figure 1). These measurements, along with ancillary measurements of particle size and black carbon content (BC), provide a three-dimensional characterization of the aerosols encountered along track. The horizontal and vertical distribution of Arctic haze, in particular, was evaluated. During April 2009, the Arctic atmosphere was variably turbid with total column AOD (at 500 nm) ranging from ~ 0.12 to > 0.35, where clean background values are typically < 0.06. The haze was concentrated within and just above the surface-based temperature inversion layer. BC was observed at all levels at moderately low concentrations compared with historical records. Few distinct elevated aerosol layers were observed, although lidar observations revealed evidence of volcanic aerosol at upper levels. Enhanced values of AOD above 4 km are attributed to an accumulation of industrial pollutants, in combination with volcanic aerosol from the March/April 2009 eruptions of Mount Redoubt in Alaska. The presence of aerosols in the Arctic atmosphere during April 2009 reduced the diurnally-averaged net shortwave irradiance, which can cause cooling of the surface, depending on its Albedo (reflectivity). An overview of the campaign will be given with results presented in the context of historical observations and current thinking about the impact aerosols have on the Arctic climate.

Figure 1. On 10 April, 2009 the German Research aircraft, Polar-5, landed on an ice runway prepared by the crew of the Russian ice station, North Pole-35. Along the route from Svalbard, Norway to Pt. Barrow, Alaska, a comprehensive set of data was collected to evaluate Arctic aerosol characteristics.

Assessing the ‘Full Spectral’ Potential Radiative Impact of Arctic Aerosols: Dust, Smoke, Haze

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Measurements of aerosol overburden at the NOAA ESRL Barrow site are part of the suite of ongoing long-term records. Typically, the particle size distribution is derived from measurements of local shortwave spectral Aerosol Optical Depth (AOD), along with Surface Net Flux Measurements. The fundamental inferred values of Extinction, Absorption, and Asymmetry Parameters can then be inserted into a ‘single column’ Radiative Transfer (RT) code (e.g. such as Moderate Resolution Transmittance radiative transfer model, MODTRAN®5) to predict radiance at all altitudes, along with fluxes and cooling rates. The agreement (or lack thereof) between measured surface fluxes and RT-code predictions attests to the closure within this system. This methodology has already been applied to the shortwave Direct Aerosol Radiative Forcing (DARF), the change in net shortwave irradiance per unit of AOD, associated with an incursion of Asian dust observed at Barrow during spring, 2002, and boreal smoke during summer, 2004; both analyses reproduced the measurements to within 5%. These studies are now being extended into the longwave, where a spectral cooling response is expected. Initial results (cooling rate plots) for a light dust layer over snow are depicted below. Smoke, over snow or tundra, shows a similar result, but the Longwave spectral response of haze has yet to be established.

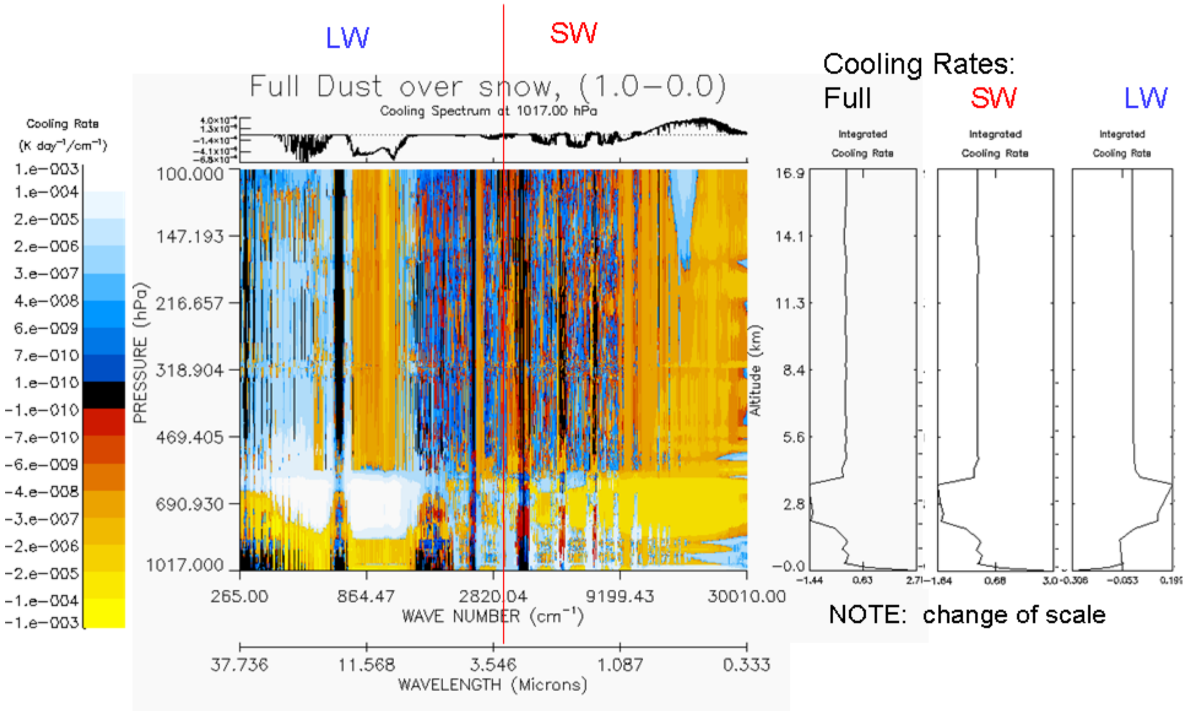

Figure 1. Full spectral (~0.3- 40 μm) cooling rate ‘difference’ plot of calculation employing a ‘dust aerosol layer’ – ‘clean background’; NOTE: The sign reversal: negative cooling = positive heating. The dust aerosol resides between 2-4 km, has an AOD (550nm) ~ 0.4, and provides a net heating within the layer: -1.64K cooling rate °K/day. It also provides a net cooling at the surface, ~2.7°K/day. The cooling profiles for Shortwave (SW) and Longwave (LW) allocate the contributions from each spectral range. The LW cools in the layer and heats at the surface.

Detection of Aerosol Growth Rate Using a Mass Balance Model Constrained by Water Isotopes Measurements at Mauna Loa

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[2]Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO 80309

While the chemistry that governs the formation of sulfate aerosols is well known, point measurements of aerosol abundance cannot be easily used to quantify new particle formation because of transport processes. In this study, we use a novel approach to distinguish between changes in aerosol distributions due to advection from those due to *in situ* nucleation and growth. We isolate advective changes by strictly defining periods of atmospheric mixing using high-frequency stable water isotope measurements of vapor. Vapor isotopologues were measured at the Mauna Loa Observatory (MLO) in the Fall of 2008. During periods of air mass mixing, the ratio of deuterated (HDO) to normal water (H_2O) follows very clear mixing lines (identified in our record when the linear slope between the HDO/H_2O ratio and the inverse of water exhibits an R^2 greater than or equal to 0.95). During these periods, distinct air masses, such as the marine boundary layer (Figure 1 a-b, green curve) and the free troposphere (Figure 1 a-b, blue curve), mix without undergoing condensation or evaporation. The evolution of aerosol size spectra, measured with an Ultra-High Sensitivity Aerosol Spectrometer, during these events is modeled through a mass balance approach (Figure 1b), in which the mixing term is constrained by the water isotopologue data at each 5-minute time step. Chemical or physical aerosol growth that is independent of the mixing signature can then be evaluated in terms of the differences between observed and modeled distributions, with aerosol source appearing as a residual (Figure 1c). The resulting difference distributions are analyzed to discriminate amongst new particle formation, accumulation growth, and ablation.

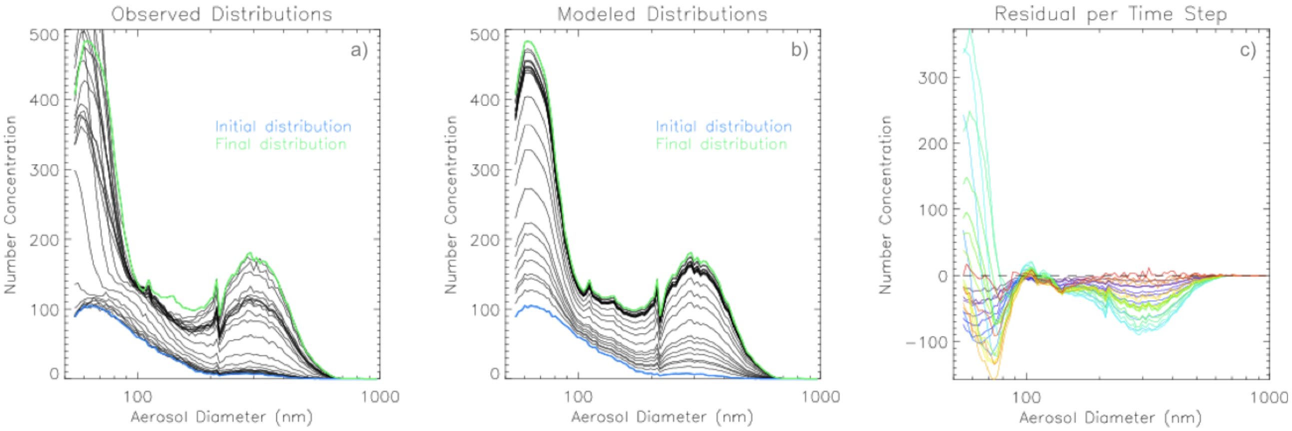

Figure 1. Evolution of a) aerosol number spectra measured on October 21, 2008 at MLO, b) a mass balance box model, which accounts for air mass mixing, and c) differences between the observed and modeled spectra, which describe the chemical source, for every 5-minute time step.

Inclusion of Aerosol Impacts on Medium-Range Forecasts of Weather and Air Quality in the Flow-Following Finite Volume Icosahedral Model (FIM) Global Model

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[2]Brazilian National Space Institute (INPE), Center for Numerical Weather Forecast and Climate Studies (CPTEC), Cachoeira Paulista, Brazil
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Development of the FIM, the NOAA ESRL's new global model for medium-range weather forecasting, is now being extended to include aerosols, trace gases, and the impact of wild fires on air quality and weather. 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). Inclusion of simple chemistry, aerosols and wildfire effects requires development of a numerical tool to generate emission data for several types of grid projection for global and regional models. Sources emission for anthropogenic (industrial, urban, transportation, biomass burning, charcoal production, waste burning, etc) and biogenic processes uses a set of published data and methodologies (e.g., RETRO, EDGAR, GEIA-POET, 3BEM, GFEDv2). In particular, the Brazilian biomass burning emission model (3BEM) uses remote sensing fire count data together with global carbon density to determine the timing, location, and intensity of fire emissions as well as information to initiate the plume rise module. Emissions of dust are included using the method from the Goddard Chemistry, Aerosol, Radiation and Transport model. Aerosol interaction with atmospheric radiation is included using the GFS physics. We will show results from runs with and without the aerosol direct effect, and focus on tropical regions that exhibit large areas with emissions from wild fires and dust.

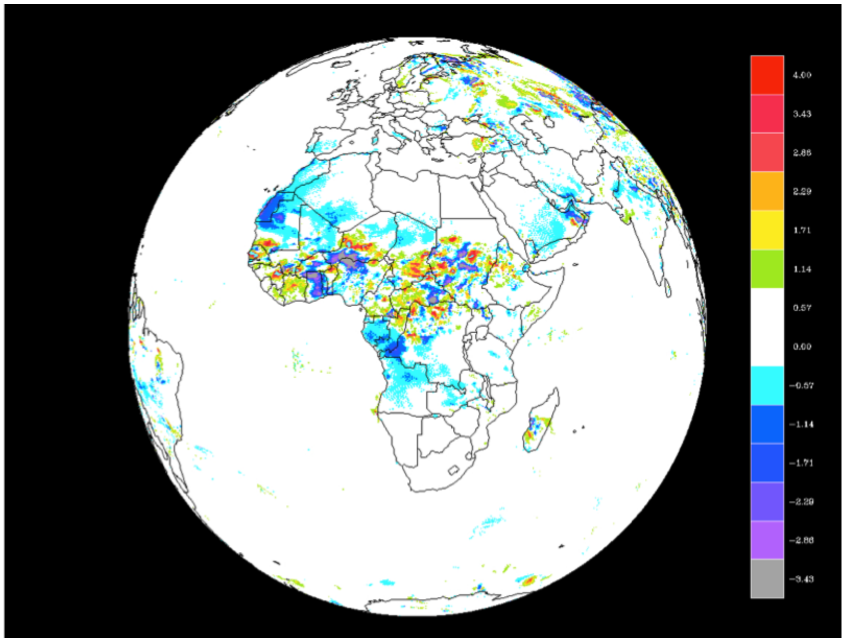

Figure 1. Surface temperature difference caused by aerosol direct effect for a 120 hr forecast using the FIM-Chem.

Results from Initial-Year Aerosol Optical Property Measurements at the New NOAA ESRL Collaborative Aerosol Monitoring Station in Boone, North Carolina

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[3]NOAA Earth System Research Laboratory, Boulder, CO 80305

A NOAA ESRL collaborative aerosol monitoring station was established at Appalachian State University, located in Boone, NC (36.22ºN, 81.67ºW), in May 2009. Boone's mountain location (1000m above sea level) is a region devoid of major local industrial pollution sources and is home to a variety of meteorological regimes and air mass sources, facilitating regionally-representative measurements of aerosol properties originating from a variety of natural and anthropogenic sources. Initial-year measurements of size-segregated (submicron and sub-10µm) aerosol light scattering and absorption coefficients at three visible wavelengths and aerosol number concentrations will be presented, along with derived quantities such as angstrom exponent, single-scattering albedo, and backscatter fraction. The median scattering coefficient of $28Mm^{-1}$ at 550nm is comparable to that measured with similar instruments at the Southern Great Plains (SGP), OK station and a little lower than that measured at the Bondville (BND), IL station. The median absorption coefficient of ~2.9 Mm^{-1} at 550nm is slightly higher than that measured at the SGP and BND sites, leading to lower single-scattering albedos. These values show strong seasonal dependence, with summer months possessing much higher scattering and higher single-scattering albedo and fall and winter months possessing lower single-scattering albedo. Sub-micron particles represent approximately 90% of the total particulate light scattering and 94% of the light absorption, although strong seasonal variations were observed (markedly lower submicron fractions during winter months). The values depend significantly on aerosol source region and source-apportioned aerosol optical properties will also be presented. The above-mentioned measurements are supplemented by a co-located meteorological station and chemical composition measurements. Several new instruments will be brought online in 2010, providing an expanded suite of aerosol and radiation measurements that will facilitate calculations of direct aerosol radiative forcing and initial studies of the indirect aerosol radiative effect.

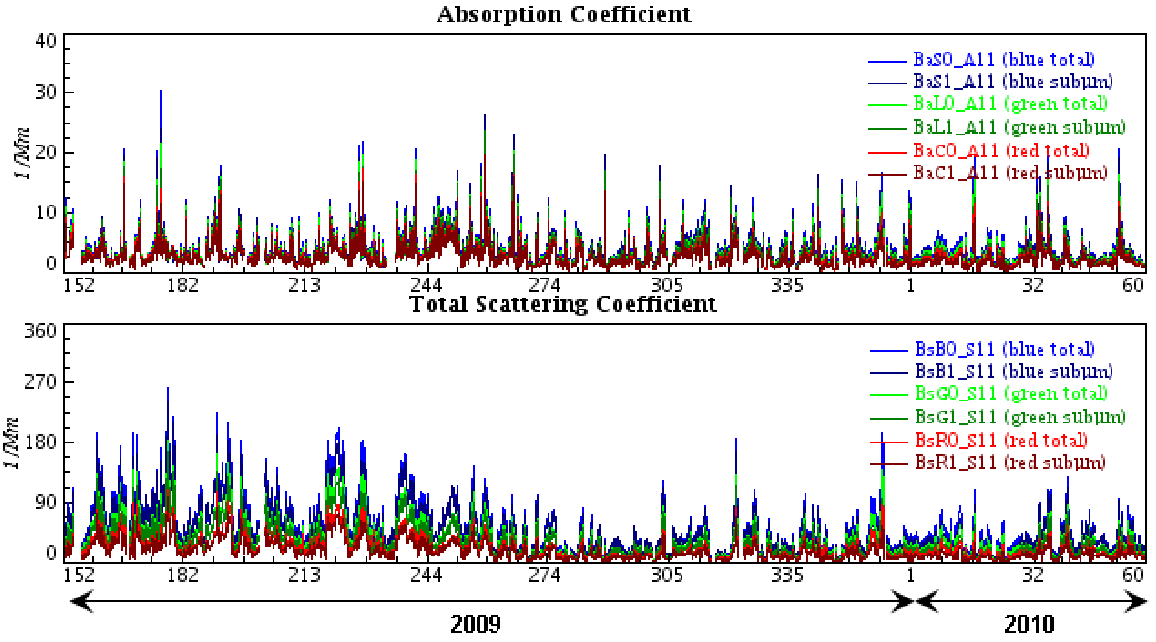

Figure 1. Time series plots of the aerosol light absorption and scattering coefficients for two size fractions at three wavelengths measured at the Appalachian Station.

Updated Aerosol Climatology for Cape Point, South Africa

C. Labuschagne[1], E. Brunke[1], E. Andrews[2], J.A. Ogren[3] and P.J. Sheridan[3]

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[3]NOAA Earth System Research Laboratory, Boulder, CO 80305

The Cape Point cooperative aerosol sampling program is currently in its 5th year of existence. The data set has grown significantly to the point where seasonal and annual patterns can be discerned using statistical distributions with an ever increasing amount of confidence. The aerosol optical data displays typical features of a site that is strongly influenced by oceanic emissions (sea salt as well as marine organic particles), combined with episodes of urban impacted air masses as well as the occasional biomass burning episode. A strong seasonal component is evident for many of the aerosol parameters being measured. Figure 1 show that light scattering remains relatively constant throughout the year, while single scattering albedo is lowest during austral winter. The Ångström exponent (not shown) is quite low (annual median <0.02) throughout the year, thus indicating that the sampling site is dominated by sea salt aerosols. However, the observed wintertime incursions of pollution and biomass aerosols do result in seasonal increases in the Ångström exponent (indicated by elevated 75th – 95th percentiles). This finding is consistent with a significant increase in the amount of sub-micrometer aerosol. Generally, the observed seasonal variability in the aerosol parameters is well correlated with the overall circulation experienced at the site – continental outflow and inversion trapping of pollutants during the austral winter and strong oceanic winds from October to March bringing clean marine air to the sampling site. The aerosol single scattering albedo (ω_o), which is an indicator of the relative amount of aerosol light absorption, shows a dominance of dark, absorbing particles during May – Aug, whilst Nov – Feb is characterized by whiter and predominately scattering aerosol particles. These variations are useful when identifying urban / biomass burning smoke plumes; continental outflow and oceanic aerosol emissions which all need to be considered in terms of their respective radiative forcing efficacies.

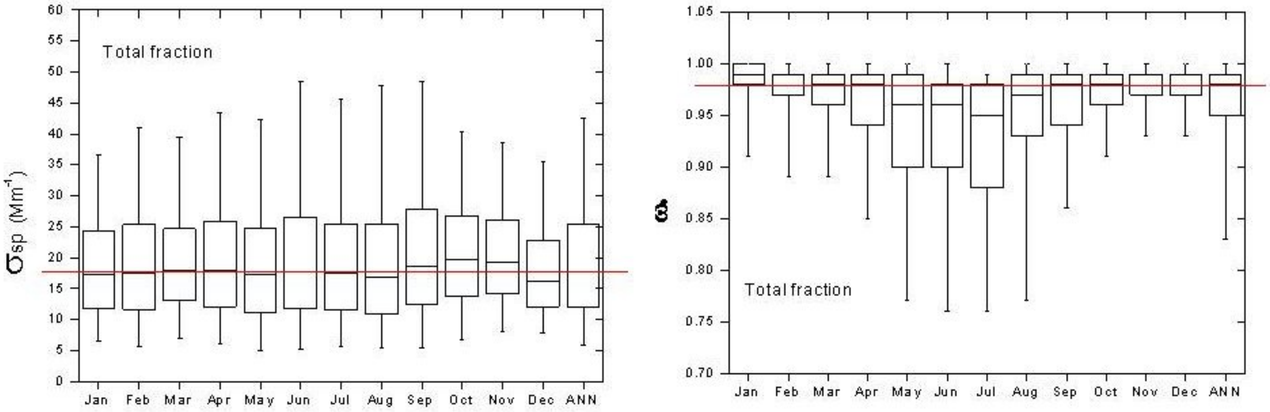

Figure 1. Annual climatology of aerosol optical parameters. The data is represented as monthly percentile values (2006 - 2009). Center line = median, top and bottom of box are 25th and 75th percentiles respectively and top and bottom whiskers correspond to 5th and 95th percentiles. The red line represents the annual median for the entire data set. Left: aerosol light scattering coefficient. Right: aerosol single scattering albedo.

The NOAA ESRL Airborne Aerosol Observatory: Climatology and Seasonal Variation of Aerosol Properties Over Central Illinois

P. Sheridan[1], E. Andrews[2], A. Jefferson[2], D. Hageman[2], R. Albee[3], J. Wendell[1] and J. Ogren[1]

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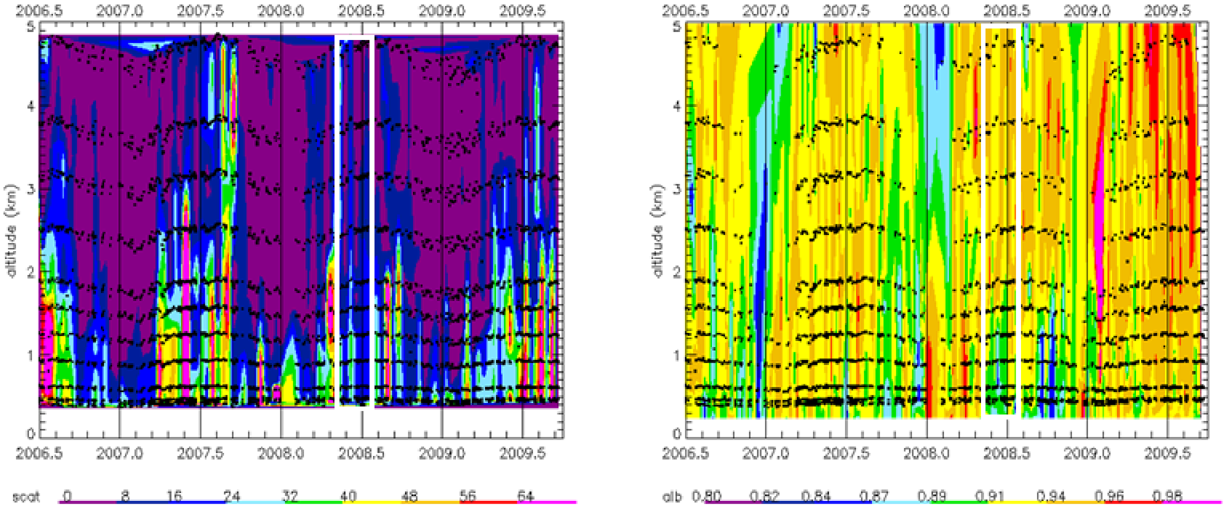
In June of 2006, ESRL began conducting regular (2-3 times per week) light aircraft measurements over central Illinois. The platform of the Airborne Aerosol Observatory (AAO) was a Cessna T206H aircraft. The primary objective of this program was to obtain a climatology of aerosol properties aloft for evaluating aerosol radiative forcing and testing chemical transport models. Through the end of the program in September 2009 (~40 months), 401 research flights and over 4000 level flight segments have been conducted, most of these over the Bondville surface monitoring 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 3+ years of data permit us to begin to understand seasonal variation of the aerosols over central Illinois. Seasonal variation in the scattering data is evident (Fig. 1), 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 buildup and removal by meteorological events. An extended rainy period over the months of May through July 2008 (indicated on the plots by white boxes) is also evident in the aerosol data. Scattering coefficients are low during this period, consistent with hygroscopic aerosols being removed by water absorption, growth and subsequent cloud processing and/or rainout. The same period shows lower single-scattering albedos, suggesting preferential removal of hygroscopic aerosols by the wetter conditions. Low altitude fly-bys of the Bondville Station show that surface measurements of aerosol extinction are representative of aerosols in the lowest 1-2 km of the column. Although individual profiles can be quite variable, the climatological profile of single-scattering albedo shows relatively little variation in the vertical. Comparisons of AAO measurements with Aeronet Sunphotometer and the Cloud-Aerosol Lidar & Infrared Pathfinder Satellite Observation satellite-borne lidar data will also be discussed.



Scattering, 550nm (Mm^{-1})

Single-scattering Albedo (550nm)

Figure 1. Contour plots of dry aerosol light scattering coefficient (550 nm) and single-scattering albedo in time-altitude space measured by the AAO over central Illinois. Black dots represent individual level flight segments. White boxes represent a three month rain-dominated period in summer 2008.

Climate Services, World Meteorological Organization (WMO) and Global Atmosphere Watch (GAW) Observations

L. Jalkanen

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The World Climate Conference-3, that was held 31 Aug – 4 Sept 2009 in Geneva Switzerland, and organized by the WMO, resulted in the establishment of the Global Framework for Climate Services (GFCS) to strengthen the production, availability, delivery and application of science-based climate prediction and services. The components of the GFCS that are being proposed are: (1) Observations; (2) Climate Research, Modeling and Prediction; (3) the Climate Services Information System (CSIS); (4) the Climate User Interface Programme (CUIP); and (5) Capacity Building. The WMO/GAW Programme will be providing input to the components 1, 3 and 5.

GAW provides quality assured and controlled global data on ozone, greenhouse gases, reactive gases, aerosols, atmospheric wet deposition and UV radiation. GAW CO_2, CH_4 and ozone measurements form a comprehensive baseline network of the Global Climate Observing System (GCOS) with discussions on the way for the inclusion of aerosol observations. GAW is encouraging for enhanced use of the data in environmental assessments related to climate, air quality, ozone depletion and the long-range transport of pollution between regions.

In regard to atmospheric chemistry observations related to climate change, it is vital to continue these as they provide the only way of telling whether mitigation is working. There are indications that there can be substantial air-quality co-benefits to mitigating climate change and it is therefore important to integrate air-quality and climate-stabilization goals in the design of environmental policy to realize potential synergistic benefits. Because of the potential role of greenhouse gases in the future of emissions control and emissions trading, these measurements will be seriously scrutinized. The need for traceable, accurate measurements will be critical for defensible results and therefore the role of the National Metrology Institutes in the GAW greenhouse gas measurements has been carefully considered and an agreement between WMO and Bureau International des Poids et Mesures (BIPM) has been signed.

WMO/GAW, with support of its Members publishes annually the Greenhouse Gas Bulletin, in time for the annual sessions of the Conference of the Parties to the United Nations Framework Convention on Climate Change. GAW recognizes the important support of the participating agencies, institutes, services and experts for its activities. NOAA ESRL is a major GAW partner, for instance hosting the WMO primary standards for CO_2, CH_4, and N_2O. Many other WMO GAW participants contribute to the network following WMO GAW measurement guidelines, data quality objectives, and submission of data to the appropriate World Data Centre.

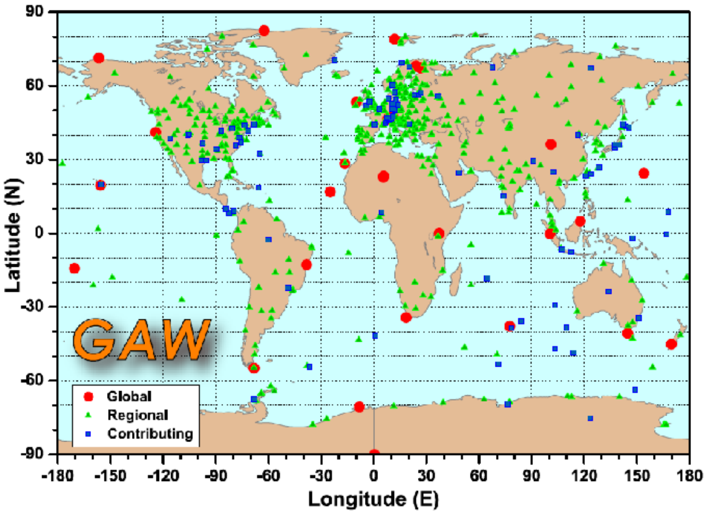

Figure 1. The GAW station networks.

Enhanced Ozone Over Western North America from Biomass Burning in Eurasia During April 2008 as Seen in Surface and Profile Observations

S.J. Oltmans[1], A.S. Lefohn[2], J.M. Harris[1], D.W. Tarasick[3], A.M. Thompson[4], H. Wernli[5], B.J. Johnson[1], J. Davies[3], P.C. Novelli[1], S.A. Montzka[1], C. Sweeney[6], L. Patrick[6], A. Jefferson[6], T. Dann[3], B. Holben[7] and M. Shapiro[8]

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During April 2008, as part of the International Polar Year, several ground-based and aircraft campaigns were carried out in the North American Arctic region. The ubiquitous presence during this period of biomass burning effluent, both gaseous and particulate, has been reported. Unusually high ozone readings for this time of year were recorded at surface ozone monitoring sites from northern Alaska to northern California. At Barrow, Alaska the highest April ozone readings recorded at the surface (hourly average values >55 ppbv) in 36 years of observation were measured on April 19, 2008. At Denali National Park (NP) in central Alaska an hourly average of 79 ppbv was recorded during an 8 hour period in which the average was over 75 ppb. These averages exceeded the ozone ambient air standard threshold value in the U.S.. Elevated ozone (>60 ppbv) persisted almost continuously from April 19-23 at the monitoring site during this event. At a coastal site in northern California (Trinidad Head) hourly ozone readings were ≥50 ppb nearly continuously for a 35-hour period from April 18-20. At several sites in northern California, located to the east of the Trinidad Head coastal site, extensive occurrences of ozone readings exceeding 60 ppbv were recorded during April 2008. During the first three weeks of April 2008, near daily ozone soundings were performed at several sites in western North America as part of the Arctic Intensive Ozonesonde Network Study in conjunction with Arctic Research of the Composition of the Troposphere from Aircraft & Satellites. These soundings showed lower tropospheric features at ~1-4 km with enhanced ozone during the times of elevated ozone amounts at the surface sites noted above. Ancillary information, such as aerosol optical thickness and back trajectories, are employed to diagnose the potential air masses that may have contributed to these elevated ozone readings. The back trajectories appear to be matched with known burning source regions in the Eurasian region during April 2008. At a few surface sites, atmospheric trace constituents in addition to ozone were measured that help identify biomass burning as a likely source of the enhanced ozone readings.

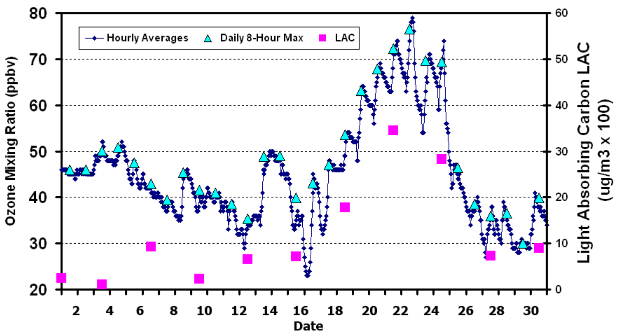

Figure 1. Surface ozone mixing ratio and light absorbing carbon at Denali NP, Alaska during April 2008.

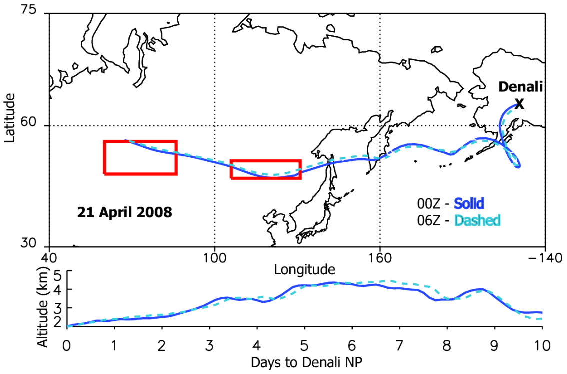

Figure 2. Back trajectories from Denali on 21 April 2008 during high ozone episode. Red boxes denote biomass burning regions.

Ozone Profile Trends from Ground-Based and Satellite Data

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In view of the upcoming World Meteorological Organization (WMO) Ozone Assessment, and with four more years in the ozone record, evaluation of the current state of the ozone layer is of interest to the scientific community. The 2006 Ozone Assessment suggested that the long-term ozone decline over the mid-latitudes had stopped and that ozone had stabilized since 1996. When extended to 2008, the ground-based and satellite data in the middle and upper stratosphere continue to show no significant changes to the ozone layer beyond its natural variability. Moreover, over the northern mid-latitudes, the recent increase in the observed total ozone column is not caused by the expected recovery of upper stratospheric ozone, but rather by changes in the lowermost stratosphere. We will present analyses of upper and low stratospheric ozone changes at northern mid-latitudes with respect to the stratospheric abundance of Ozone Depleted Substances (ODS). We will use the time series of well-established and calibrated ground based Dobson Umkehr instruments, several quality assured European ozone-sounding data, and the Solar Backscatter Ultraviolet Radiometer (SBUV/2) Merged Ozone Dataset. We will also discuss the impact of the recent years on the mid-latitude ozone recovery. Analysis will be done by using the Effective Equivalent Stratospheric Chlorine (EESC, A1_2010A WMO scenario) curve fit to the long-term ozone data. A second approach involves the use of the Piece-Wise Linear Trend (PWLT) model. Results from both approaches are compared for the slopes before and after the turning point in the EESC curve. Comparisons of the PWLT-determined ozone recovery rates and those predicted by the EESC curve help to identify changes unrelated to declining ODS concentrations.

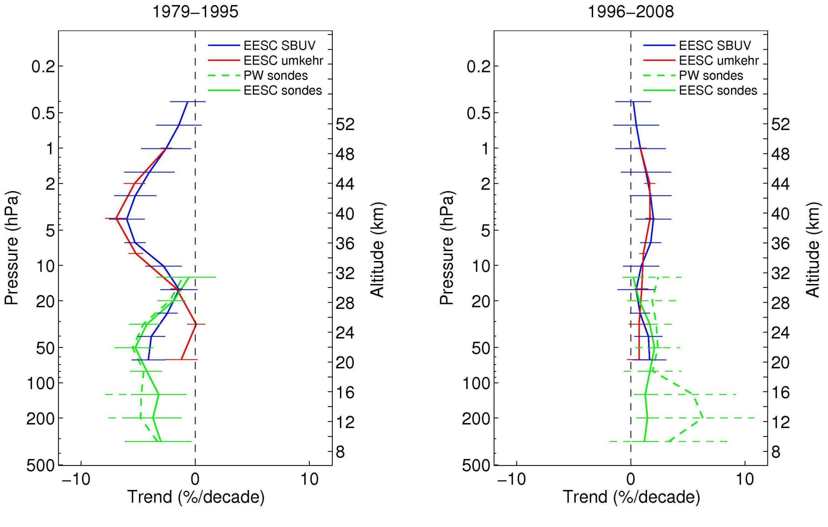

Figure 1. Vertical profile of ozone trends over northern middle-latitudes estimated from ozone sondes, Umkehr, and SBUV(/2) from 1979-2008. The trends were estimated using regression to an EESC curve and converted to %/decade using the variation of EESC with time from 1979 to 1995 (left panel) and from 1996 to 2008 (right panel). PWLTs with inflexion point in January 1996 derived from ozone sonde data is also shown. The altitude scale is from the standard atmosphere. The error bars correspond to 95% confidence interval.

Using the Relationship Between Mean 500-Millibar (Mb) Heights and Mean Surface Ozone Concentrations in Colorado to Decompose Ozone Times Series and Evaluate the Impacts of Changes in Precursor Emissions

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Since 1995, variations in summer weather have had more impact on year-to-year changes in ozone concentrations along Colorado's Front Range than changes in emissions. Correcting the ozone record for the effects of weather provides us with a better tool for understanding local trends as they are affected by emissions. July monthly mean daily maximum 8-hour surface ozone concentrations are more strongly correlated with July mean 500-mb heights than a host of other logical choices for predictors of ozone, including mean surface temperatures, mean temperatures aloft, winds aloft, cloud cover, solar radiation, and number of days with temperatures above 90 degrees. While annual fourth maximum 8-hour ozone concentrations, benchmarks for attainment of health standards, can occur in any month in summer, it turns out that the mean July 500-mb height over Denver is also one of the single best predictors for this value. The R-squared values for the correlation between July mean ozone and heights ranges from about 0.60 to 0.86, suggesting that 60% to 86% of the year-to-year variation at these sites can be explained by changes in weather. This strong relationship is also evident at sites in Utah, Arizona, New Mexico, and Wyoming. Removing the effects of heights from the ozone time series may reveal the impacts of the recession in 2009, changes in tropospheric NO_2, and changes in various source categories, including power plants and the oil and gas industry in northern Colorado. While heights may be a surrogate for many factors that influence ground level ozone, the strong correspondence discussed here may also be related to the increased accumulation of ozone and its precursors in the troposphere under the influence of persistent upper level high-pressure systems.

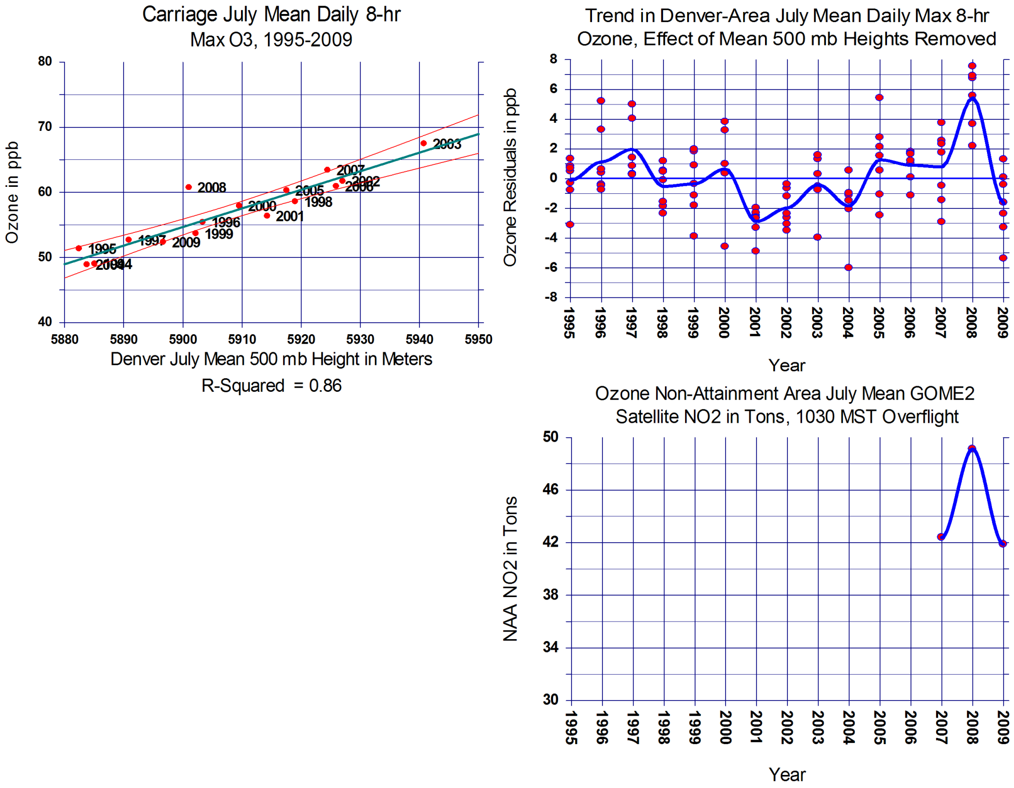

Figure 1. (Top Left): Denver monitor July mean daily max O_3 and heights, (Top Right): Denver area ozone time series after correcting for heights, and (Bottom) Global Ozone Monitoring Experiment 2, July mean NO_2 in tons for Denver Non-attainment area.

Profiles of the Water Vapor Isotope Composition for Determining Regional Water Sources and Trace Gas Exchange in the Boundary Layer

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The exchange of water and carbon between the atmosphere and the land surface remains poorly understood, particularly in regions of complex terrain and in the case of stable nighttime boundary layers. While limitations in knowledge of transport of carbon dioxide in the boundary layer is the leading source of error in estimate of CO_2 fluxes from global models, understanding the transport of water is critical to resolving regional water recycling and the surface energy balance. The stable isotope chemistry of water is invaluable for evaluating hydrological exchanges and has proven to be a clear tracer of air mass transport. In this regard the isotopic composition can be used for identifying surface water sources and tracking the fate of that water as it moves though the boundary layer. High resolution profile measurement of water, the isotopic composition of water and CO_2 concentration were made at the NOAA Boulder Atmospheric Observatory (BAO) tall tower facility in Erie, CO in February of 2010. Measurements were made by placing instruments on the elevator, and manually controlling the ascent and decent every 15 minutes, leading to a total of 311 profiles. The 4-day observation period followed a storm that left about 1 inch of snow. The recently fallen snow sublimated over the 4 days and our analysis (Figure 1) shows the isotopic composition unambiguously tracks the sublimated water from the surface though the surface layer during the daytime and that there is a significant advective sink. Snow began falling on the final day, and seemed to be associated with an isotopically distinct (enriched) air mass. Nighttime conditions were very stable leading to strong surface trapping of water vapor and that also restricted transport of near surface (respired or anthropogenic) CO_2. The experimental results are of particular interest because of the extremely weak transport during times of the very stable nighttime boundary layer, which is poorly modeled. Our analysis shows that this is associated with a board failure of simple turbulence theory which is of the type typically found in global and regional scale models. To this end, they are improving the representation of the evolution of our observed water isotope and CO_2 profiles provides a clear way to improved models. The results thereby reinforce the call for detailed water, energy and trace gas exchange studies at tower sites in complex terrain to better constrain surface exchange and allow baseline trace gas measurements to better constrain surface flux estimates with atmospheric inverse calculations.

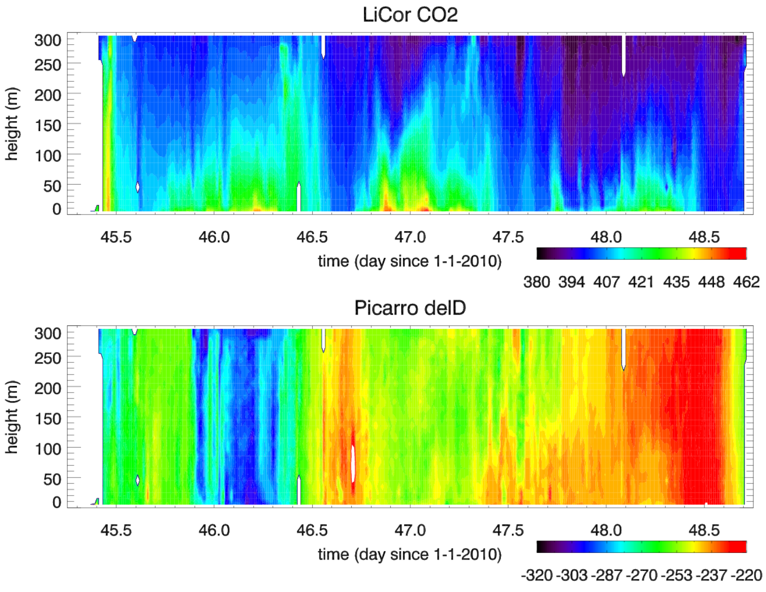

Figure 1. Profile measurements of a) HDO/H_2O water isotopologue ratio (as dD) and b) CO_2 during a 4-day period February 15-18, 2010 at the NOAA/BAO. Daytime sublimation is seen in the dD of water and the restriction of trace gas transport is seen at nighttime in the CO_2.

The Complementarities of NDACC and GRUAN in Establishing Measurement Requirements for Water Vapor Trends Detection

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The international Network Detection of Atmospheric Composition Change (NDACC) provides a consistent standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed research stations. While the NDACC remains committed to its initial objective of monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer (its decay, likely stabilization and expected recovery). NDACC measurement and analysis priorities have broadened considerably to encompass both the stratosphere and free troposphere as well as to explore the interface between changing atmospheric composition and climate. Although NDACC is neither designed nor operated as a climate monitoring network per se, its measurement thrusts and associated activities are highly complementary to networks such as the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN), the reference network for upper-air climate observations.

Various models agree that, during the current century, water vapor will increase throughout the troposphere and into the stratosphere as a result of anticipated increases in temperature. NDACC and GRUAN have tasked themselves with measuring atmospheric water vapor with sufficient accuracy to monitor these trends. But how long and with what accuracy will these networks have to conduct such measurements to reveal the trends with statistical confidence? This presentation will illustrate how estimates of anticipated trends in water vapor based on coupled climate models can be used to estimate the time required to measure trends in water vapor with statistical robustness. The results have additional implications in terms of measurement technology, the location of measurement sites, and the calibration requirements of the instruments.

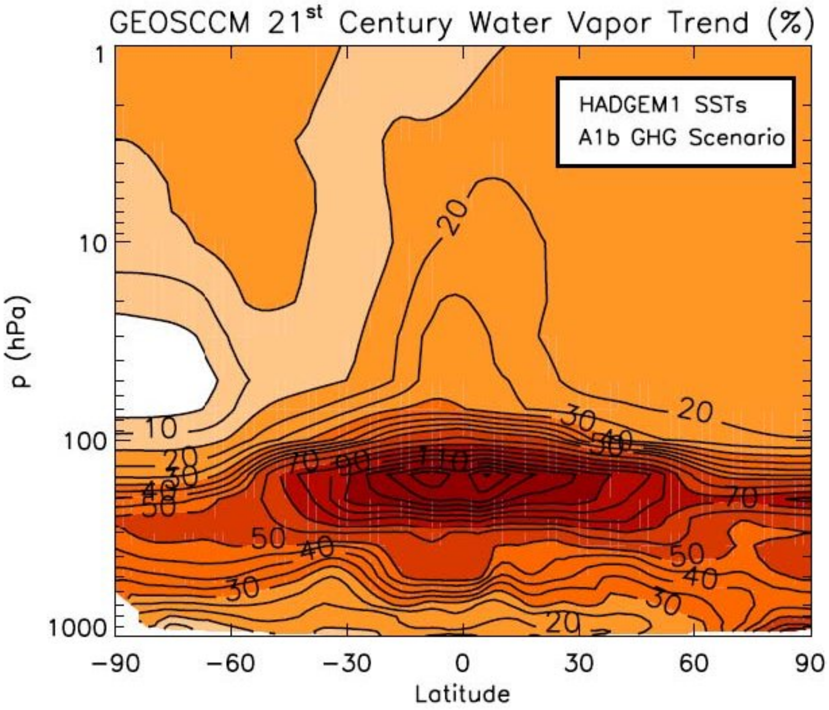

Figure 1. Simulated increases in atmospheric water vapor during the 21st Century from the Goddard Earth Observing System Chemistry Climate Model.

The “Boulder Record”: 30 Years of Water Vapor Vertical Profiles Over Boulder, Colorado

D. Hurst[1], E. Hall[1], A. Jordan[1], S. Davis[1], K. Rosenlof[2] and S. Oltmans[2]

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[2]NOAA Earth System Research Laboratory, Boulder, CO 80305

The balloon-borne NOAA frost point hygrometer (FPH) has been providing *in situ* measurements of water vapor from the surface to 30 km above Boulder (40°N, 105°W) since April 1980. The resultant “Boulder record” is now comprised of 330 vertical profiles of water vapor mixing ratios that span 30 years. Though the FPH has undergone numerous improvements since its inception, the long-term measurement record has remained self-consistent because the fundamental measurement technique and its calibration have not changed. Stringent assessments of data quality, including evaluations of frost point temperature stability and ascent-descent differences for each stratospheric water vapor profile, have recently been performed to provide statistical weights for use in trend analyses. The newly calculated trends for stratospheric water vapor during 1980-2000 are only 75-90% of those originally published [Oltmans et al., 2000]. It will be shown that 20-40% of the 1980-2000 increase in water vapor above 20 km is attributable to the growth of atmospheric methane.

The 30-year time series can be divided into four distinct periods based on multi-year trends in stratospheric water vapor abundance: a period of mixed increases and decreases (1980-1988), a net increase (1989-2000), a rapid decline (2001-2005) and a short but significant increase in recent years (2005-present). The “Boulder record” is unique and has proven useful in connecting changes in mid-latitude stratospheric water vapor abundance to changes in climate. The rapid and significant decline in stratospheric water vapor during 2001-2005 has been linked to a reduction in tropical tropopause temperatures thought to be driven by increased tropical upwelling [Randel et al., 2006], and to a change in the Earth’s radiation budget that slowed the rate of increase in global surface temperatures during the last decade [Solomon et al, 2010].

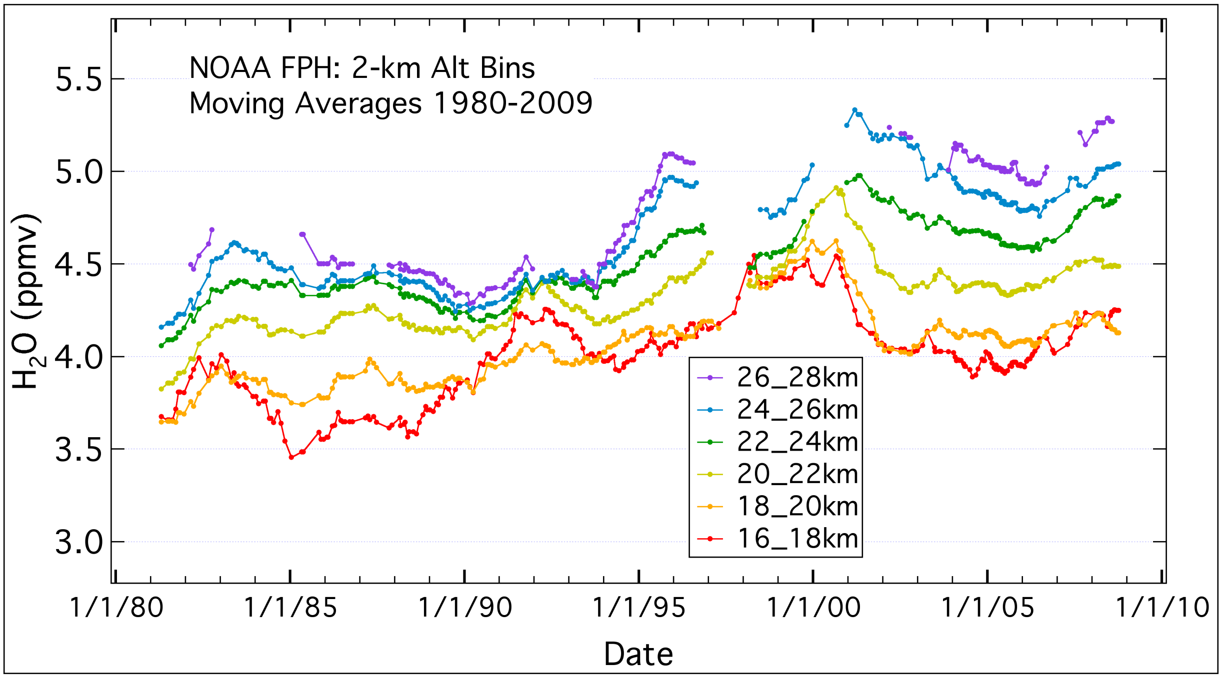

Figure 1. Moving averages of mean water vapor mixing ratios in 2-km altitude bins as measured during 330 flights of the NOAA FPH. Stratospheric water vapor gradually increased during 1980-2000, rapidly declined during 2001-2005, and is now increasing again.

Laboratory Evaluation of the Effect of Nitric Acid on Chilled Mirror Hygrometer Measurements in the Upper Troposphere (UT)/Lower Stratosphere (LS)

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[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Meteorologisches Observatorium Lindenberg, German Weather Service, Lindenberg 15848, Germany

Chilled mirror hygrometers (CMH) are widely used to measure water vapor in the UT/LS from balloon-borne sondes. CMH instruments operate by determining the temperature required to maintain a condensate layer with constant optical scattering on a chilled mirror in contact with ambient air. The dependence of the scattering on condensation and evaporation of water from the mirror surface allows the mirror temperature to be used to calculate the partial pressure of water vapor in the ambient air from a formulation of the Clausius-Clapeyron relation. Systematic discrepancies among *in situ* water vapor instruments have been observed at low water vapor mixing ratios (< 5 ppm) in the UT/LS, and understanding these measurement discrepancies is important for accurate determination of water vapor values and trends in this region. We have conducted a laboratory study to investigate the potential interference of gas-phase nitric acid (HNO_3) with the measurement of frost point temperature, and consequently the water vapor mixing ratio, by CMH. The CMH instruments used in these experiments are a reconfiguration of the Cryogenic Frostpoint Hygrometer (CFH) to include a hermetically sealed flow path and a modified optical arrangement allowing direct imaging of the mirror surface as an additional measurement diagnostic. A HNO_3 permeation source and a reactive nitrogen (NOy) instrument were used to add and measure HNO_3 to the flow system. A water vapor permeation source was used to produce stable H_2O mixing ratios of a few ppm in the flow system at pressures of 90-140 hPa and flows of 2-4 slpm, representative of conditions for CFH operation in the UT/LS. No detectable change in the measured frost point temperature was found for HNO_3 mixing ratios up to 4 ppb for exposure times up to 150 minutes. HNO_3 was observed to co-condense on the mirror frost layer with the mass increasing linearly with time at constant exposure levels. During a typical CFH ascent period (90-120 min), the maximum condensed HNO_3 amounts were comparable to monolayer coverage of the geometric mirror surface area.

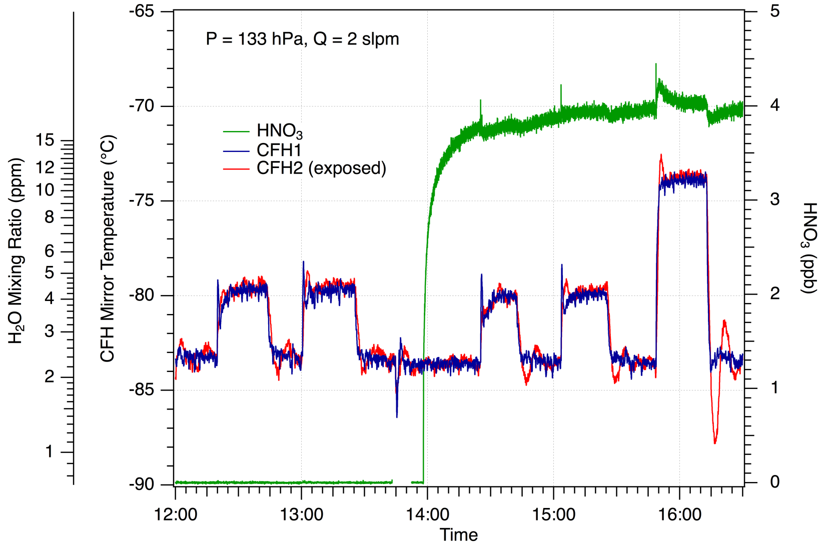

Figure 1. Time series showing the measured frost point temperatures from exposed and unexposed CFH instruments prior and subsequent to the addition of HNO_3 to the sample flow and the HNO_3 abundance in the flow system as measured with the NO_y instrument. Increases in observed frost point temperature were due to addition of small flows of room air to the sample flow.

NOTES:

2010 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)

Tuesday, May 18th, 2010: 17:00-20:00

- ***Carbon Cycle***

P-1 Empirical Estimates of Interannual Changes in Air-Sea CO_2 Fluxes
G. Park (NOAA/Atlantic Oceanographic and Meteorological Laboratory)

P-2 AirCore: An Innovative Atmospheric Sampling System
A. Karion (University of Colorado/CIRES)

P-3 Comparison of Simulated and Observed $^{13}CO_2$ at North American Sites
C. Alden (University of Colorado/INSTAAR)

P-4 The Influence of Hydrological Changes on the ^{18}O Content of Atmospheric CO_2
N. Buenning (University of Colorado/CIRES)

P-5 Modeling the Synoptic Atmospheric Interaction with Anthropogenic and Biospheric CO_2 Emissions
D. Chan (Environment Canada)

P-6 A Simplified Estimate of Contribution to Change of CO_2 Concentration by the Statistical Method
H.-C. Lim (Korean Meteorological Administration, South Korea)

P-7 Novel Analyzer for Real-Time N_2O and CO Measurements in Air
R. Provencal (Los Gatos Research)

P-8 Quantifying Canada's Natural and Anthropogenic Methane Budgets Using Atmospheric Observations & Modeling: Progress and Limitations
D. Worthy (Environment Canada)

P-9 Diagnosing the Bayesian Balance in Atmospheric Inversions
A.R. Jacobson (University of Colorado/CIRES)

P-10 Evaluating CarbonTracker (CT) Performance During the North American Carbon Program Mid-Continent Intensive Campaign
G. Petron (NOAA/ESRL)

P-11 Aura TES Measurements Related to the Carbon, Nitrogen and Water Cycles and Their Impact on Air Quality and Climate
J. Worden (JPL, California Institute of Technology)

P-12 How Well Could Satellite Data Constrain Degree-Resolution Carbon Fluxes?
D. Baker (Colorado State University/CIRA)

P-13 Application of Extractive Fourier Transform Infrared Spectroscopy with Cryogenic Preconcentration: Preliminary Laboratory Results
P.I. Buckley (University of Alabama)

P-14 Spatial and Temporal Variations of Atmospheric Methane and Carbon Dioxide Observed in Environment Canada, Canada's Greenhouse Gas (GHG) Measurement Network
E. Chan (Environment Canada)

P-15 Seasonal Variations in CH_4 and N_2O Emissions from Central California
M.L. Fischer (Lawrence Berkeley National Laboratory)

P-16 Temporal variations in CO_2 in Air in Pasadena, California
S. Newman (California Institute of Technology)

P-17 Records of Northern Hemisphere Atmospheric Carbon Monoxide Back to ~1950 AD from Greenland Firn Air
V.V. Petrenko (University of Colorado/INSTAAR)

P-18 Using Tropospheric Emission Spectrometer CO_2 Observations for Inverse Modeling Estimates of Carbon Fluxes
S. Kulawik (JPL, California Institute of Technology)

POSTER SESSION AGENDA (continued)

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

• *Carbon Cycle (continued)*

P-19 Potential New Methods for Examining Regional Sources and Sinks of Carbon
E. Weatherhead (University of Colorado/CIRES)
P-20 Creating a Global CO_2 Grid from Nighttime Lights Imagery
T. Ghosh (University of Colorado/CIRES)
P-21 Boundary Resolution of CO_2 Using Infrared (IR) and Near Infrared (NIR) Measurements
D. Lafont (JPL, California Institute of Technology)
P-22 The Atmospheric and Terrestrial Mobile Laboratory (ATML)
B. Zak (Sandia National Laboratories)

• *Ozone*

P-23 Instantaneous Radiative Kernels for Tropospheric Ozone: Satellite Observations and Model Evaluation
H.M. Worden (National Center for Atmospheric Research)
P-24 The Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE) 2009 Campaign
M. Kurylo (University of Maryland/Goddard Earth Science and Technology Center)
P-25 Determination of Dobson Spectral Characteristics, a New Method
G. McConville (University of Colorado/CIRES)
P-26 The Radiative Heating in Underexplored Bands Campaign (RHUBC): Evaluating Water Vapor Spectroscopy
J. Delamere (Atmospheric and Environmental Research, Inc.)
P-27 On the Reproducibility and Stability of Water Vapor in Stainless Steel Gas Cylinders
B. Hall (NOAA/ESRL)
P-28 Balloon-borne Ozonesonde Measurements at South Pole in 2009: Ozone Hole 7th lowest in 24-year record
B.J. Johnson (NOAA/ESRL)
P-29 Some Results of Surface and Tropospheric Ozone Measurements in Mongolia
D. Oyunchimeg (Climate Change and Environmental Research Center, Institute of Meteorology and Hydrology, Mongolia)
P-30 Trace Gases Measurement Results of Russian-Mongolian Expedition in the Arid and Semi-Arid Region of Mongolia
D. Oyunchimeg (Climate Change and Environmental Research Center, Institute of Meteorology and Hydrology, Mongolia)
P-31 Influence of Transport by the Nocturnal Jet on Ozone Levels in Central Texas
L.C. Patrick (University of Colorado/CIRES)
P-32 Ozone Depleting Substances, Emissions and Trends Derived by Long-Term Continuous Measurements at a European Site
M. Maione (University of Urbino, Italy)

POSTER SESSION AGENDA (continued)

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

• *Halocarbons and Other Trace Species*

P-33 Long-Lived Halocarbons and Other Atmospheric Trace Species Trends
G. Dutton (University of Colorado/CIRES)

P-34 HOCl and Cl_2 in the Remote Marine Atmosphere
M. Lawler (University of California, Irvine/Department of Earth Science)

P-35 Abiotic and Biogeochemical Signals in the Seasonal Cycles of Atmospheric Nitrous Oxide
C. Nevison (University of Colorado/INSTAAR)

P-36 Hydrocarbon and Terpene Gas Standards Research and Development to Assist in Atmospheric Measurements
J. Rhoderick (National Institute of Standards and Technology)

• *Solar Radiation*

P-37 Hyperspectral Infrared Imager (HyspIRI) - A Sensor Optimized for Tracking Earth Surface Processes for Climate Analysis
C. Elvidge (NOAA/National Geophysical Data Center)

P-38 Variability of Spectral Albedo at Table Mountain, Colorado
G. Hodges (University of Colorado/CIRES)

P-39 Explaining the Seasonal Variation of MultiFilter Rotating Shadowband Radiometer (MFRSR) *in situ* Calibrations and Effects on Aerosol Optical Depth (AOD)
J.A. Augustine (NOAA/ESRL)

P-40 The Role of Ultraviolet (UV) Solar Radiation in Erythema and Vitamin D Synthesis Central Illinois
K. Lantz (University of Colorado/CIRES)

P-41 The Current Configuration of An Automated Cleaning System Coupled With Modified Ventilation Design at the Kwajalein BSRN Site in the Republic of the Marshall Islands
D. Nelson (NOAA/ESRL)

P-42 Photosynthetically Active Radiation (PAR) Attenuation in the Atmosphere in North China
J. Bai (Laboratory for Middle Atmosphere & Global Environmental Observation/Institute of Atmospheric Physics, China)

P-43 The Antarctic Ultraviolet (UV) Monitoring Program: A New NOAA ESRL Effort
P. Disterhoft (University of Colorado/CIRES)

• *Aerosols*

P-44 Climatology of Aerosol Radiative Properties in the Free Troposphere
E. Andrews (University of Colorado/CIRES)

P-45 Lidar Observations of Aerosols Above American Samoa
J.E. Barnes (NOAA/ESRL)

P-46 Nighttime Aerosol Optical Properties Obtained From Lunar Photometry
T.A. Berkoff (University of Maryland/Goddard Earth Science and Technology Center)

P-47 Overview of the Physical and Radiative Properties of Atmospheric Particles at Cape San Juan, Puerto Rico (CPR) Station
O.L. Mayol-Bracero (Institute for Tropical Ecosystems Studies, University of Puerto Rico)

P-48 Impact of Ocean Ice Extent and Atmospheric Transport on Biogenic Aerosol Sulfur in the Arctic
S. Sharma (Environment Canada)

POSTER SESSION AGENDA (continued)

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

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

P-49 Development of Greenhouse Gas Observations Network within Integrated Carbon Observing System (ICOS) - Finland
Y. Viisanen (Finnish Meteorological Institute, Finland)

P-50 Measurement System for Aerosol, Methane and Carbon Dioxide Concentrations and Fluxes at Tiksi Observatory in Northeast Siberia
T. Laurila (Finnish Meteorological Institute, Finland)

P-51 Year-Round Major Ion Measurements at Greenland Environmental Observatory, Summit (GEOSummit)
R. Bales (University of California, Merced)

P-52 The Global Ocean Observing System for Climate Studies
R. Lumpkin (NOAA/Atlantic Oceanographic and Meteorological Laboratory)

P-53 Characterizing the Atlantic Meridional Overturning Circulation
R. Lumpkin (NOAA/Atlantic Oceanographic and Meteorological Laboratory)

P-54 Recovery Act-Funded Additions to the U.S. Department of Energy's Atmospheric Radiation Measurement Climate Research Facilities on the North Slope of Alaska
M. Ivey (DOE/Sandia National Laboratories)

P-55 The Global Atmosphere Watch (GAW) Station Information System – GAWSIS
J. Klausen (Empa/Materials Science and Technology, Switzerland)

P-56 The Development of the Sir Crispin Tickell High-Altitude Global Climate Observatory in Mexico (MEX)
L.R. Acosta (Climate Institute, Mexico)

Empirical Estimates of Interannual Changes in Air-Sea CO_2 Fluxes

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The ocean is the primary long-term sink for taking up anthropogenic CO_2, on average, 1.5-2 Pg C per yr, or about 20-30% of the current annual release of anthropogenic CO_2. However, the oceanic uptake of CO_2 is highly variable in time and space, and the interannual variability is not well constrained. Here we present updated estimates of interannual variability, based on correlations of partial pressure of CO_2 in surface water (pCO_2SW) with temperature (Park et al., 2006), which yields a net uptake of 1.44 Pg C per yr. The interannual variability, expressed as a standard deviation, is ±0.12 Pg C per yr over the past 26 years (Figure 1). The results are based on the new climatology of Takahashi et al. (2009), updated algorithms between sea surface temperature (SST) and pCO_2SW in the Equatorial Pacific accounting for the temporal changes in the El Nino/Southern Oscillation (Feely et al., 2006), and new wind speed (6-hour National Center for Environmental Prediction/Department of Energy Reanalysis II) and Sea Surface Temperature (SST) (NOAA/Optimum Interpolation SST V2) records. The relationship of gas transfer velocities with wind has been adjusted to be consistent with the global uptake of bomb ^{14}C (Sweeney et al., 2007).

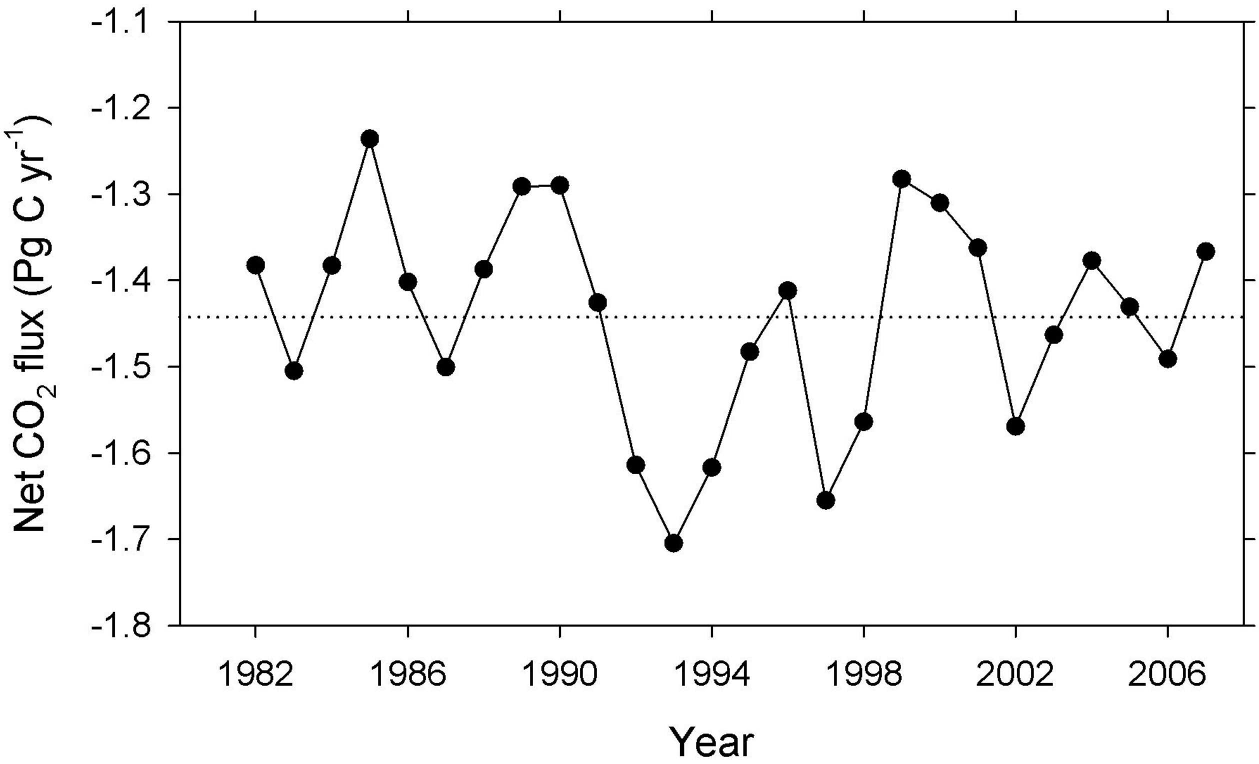

Figure 1. Interannual variability of air-sea CO_2 flux deduced from the empirical estimates based on SST. Negative values correspond to net oceanic CO_2 uptake.

AirCore: An Innovative Atmospheric Sampling System

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This work describes the AirCore, a simple and innovative atmospheric sampling system. The AirCore used in this study is a 150m long stainless steel tube, open at one end and closed at the other, that relies on positive changes in ambient pressure for passive sampling of the atmosphere. The AirCore evacuates while ascending to a high altitude and collects a sample of the ambient air as it descends. It is sealed upon recovery and measured with a continuous analyzer for trace gas mole fraction. The AirCore tubing can be shaped into a variety of configurations to accommodate any sampling platform; for the testing done in this work it was shaped into a 0.75m diameter coil. Measurements of CO_2 and CH_4 mole fractions in laboratory tests indicate a repeatability and accuracy of better than 0.05ppm for CO_2 and 0.4ppb for CH_4 under a variety of conditions. Comparisons of AirCore data with continuous *in situ* and flask data in aircraft field tests indicate average absolute differences of 0.3ppm and 5ppb for CO_2 and CH_4, respectively, with no apparent bias. Accounting for molecular diffusion and flow-induced mixing, the expected measurement resolution for CO_2 and CH_4 is 110m at sea level and 260m at 8000m above sea level after three hours of storage, decreasing to 170m and 400m, respectively, after nine hours. Validation tests confirm that the AirCore is a robust sampling device for many species on a variety of platforms including balloons, unmanned aerial vehicles, and aircraft.

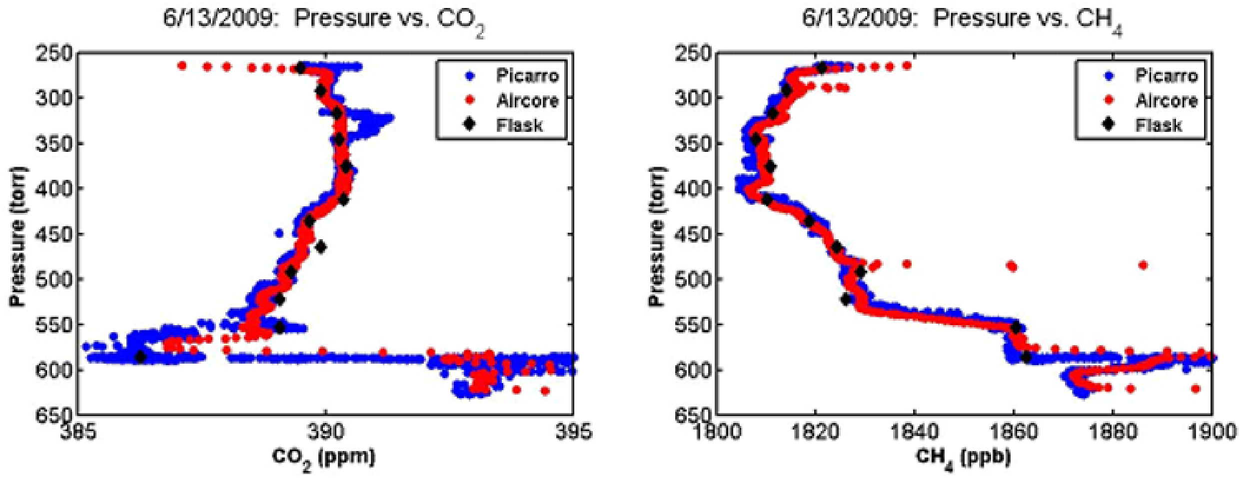

Figure 1. Pressure profiles for CO_2 (left) and CH_4 (right) by three different methods from a profile Cessna flight on 13 June 2009.

Comparison of Simulated and Observed $^{13}CO_2$ at North American Sites

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The rare stable carbon isotope, ^{13}C, has been used previously to partition CO_2 fluxes into land and ocean components. The major fluxes of this gas (fossil fuel, ocean, and land) impose distinctive and predictable fractionation patterns upon the stable isotope ratio, making it an excellent tool for distinguishing between them. Historically, isotope constrained inverse methods for calculating CO_2 surface fluxes (the "double deconvolution") have disagreed with bottom-up flux estimates. By using the double deconvolution technique, with independent estimates of time histories of ocean fluxes and atmospheric observations of CO_2 and $^{13}CO_2$, it is possible to derive the disequilibrium flux. We hypothesize that estimating disequilibrium flux in this way can not only reconcile previous disagreements between global scale atmospheric observations and bottom-up ocean flux estimates, but can also be a valuable tool for understanding variability in terrestrial biosphere exchange mechanisms, and the implications of these processes for carbon cycling. Calculated time series of the global land flux, disequilibrium flux, and terrestrial discrimination from 1991 through 2008 that are consistent with bottom-up net ocean fluxes suggest high interannual variability in terrestrial disequilibrium flux. The primary contributors to this variability likely include discrimination due to plant stomatal opening and the relative contributions of C3 and C4 vegetation to net ecosystem exchange. Identification of the mechanisms driving variability in the terrestrial exchange of $^{13}CO_2$ necessitates higher spatial resolution of terrestrial disequilibrium flux variability. As a first step towards creating spatially resolved estimations of terrestrial disequilibrium flux and its drivers, we predict the CO_2 and $^{13}CO_2$ concentrations at several North American NOAA ESRL Global Monitoring Division tower sites, using a Lagrangian transport model, and compare our simulated values to those observed at the monitoring sites. Preliminary results will be presented.

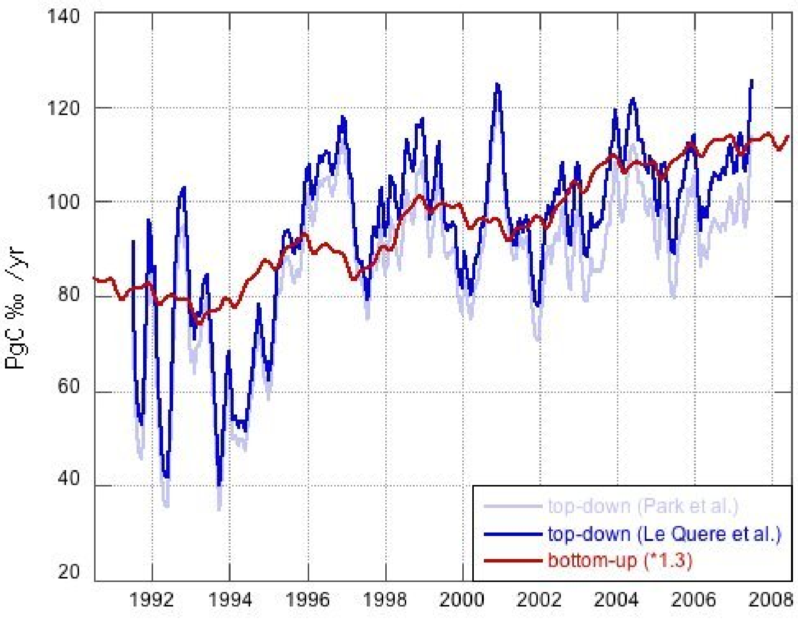

Figure 1. Global 12-month mean disequilibrium flux, calculated using the ocean fluxes of Park et al. (in prep.) (light blue) and Le Quéré et al. (2007) (dark blue). Red line is bottom-up global 12-month mean disequilibrium flux, scaled by 30%. The scaling factor was chosen because it produces land and ocean flux magnitudes similar to that of the single deconvolution approach, which eases comparison. The choice of 1.3 does not impact our conclusions, because we focus on the issue of interannual variability. Of note is the difference in interannual variability between the bottom-up and top-down global disequilibrium flux calculations.

The Influence of Hydrological Changes on the ^{18}O Content of Atmospheric CO_2

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Observations show no long-term trend in the ^{18}O content of atmospheric CO_2 (denoted as δCa), though stations around the world observe similar interannual variations in δCa values. Modeling studies have shown evidence that the seasonal cycle and spatial structure of δCa values result from land ecosystem fluxes. This study evaluates the δCa budget to identify meteorological variables that could potentially cause the observed variations. It is found that observed δCa values negatively correlate with relative humidity in certain regions of the tropics and mid to high latitudes, and it is estimated that the variations in relative humidity would drive a 0.25‰ decrease in δCa values during the 1990s. It is also shown that there are similar variations in precipitation totals within the tropics that would suggest positive correlations between δWP and δCa values consistent with an amount effect (δWP values typically decreasing as precipitation amounts increase). The decrease in δWP values would act to decrease δCa values by as much as 0.56‰. A global model is constructed to simulate the atmospheric concentrations of both CO_2 and $CO^{18}O$. Model results agree well with observations in the global mean and zonal mean (Figure 1). Sensitivity experiments were conducted with the model, and the results confirm that δCa values respond to changes in relative humidity and δWP values. This study suggests that interannual δCa variations are driven primarily by isotope hydrology and relative humidity. In contrast to previous work, we find little evidence of changes to photosynthesis or respiration driving the observed δCa variations.

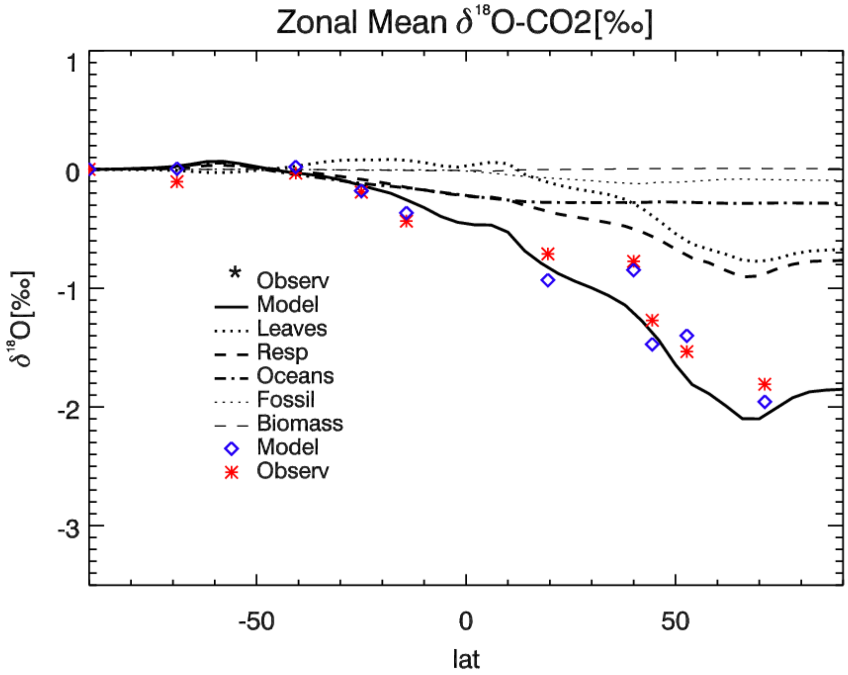

Figure 1. Simulated north-south gradient in δCa values (‰) (solid line) and the contributions from leaves (dark dotted), respiration (dark dashed), oceans (dash-dot), fossil fuel consumption (light dotted), and biomass burning (light dashed). Asterisks are values from an observed mean value, and the squares are from the closest grid-cell to each observation.

Modeling the Synoptic Atmospheric Interaction with Anthropogenic and Biospheric CO_2 Emissions

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CO_2 concentration measurements at continental sites typically show strong synoptic variability. Figure 1 shows the CO_2 concentration time series at the various sites in Canada. There are significant differences in the synoptic variability at these sites. In this study we used a dynamic atmospheric model Global Environmental Multiscale (GEM) with variable horizontal resolution (with minimum delta x of ~15 km) to examine the atmospheric synoptic interaction with the regional anthropogenic and biospheric CO_2 fluxes. The results (Figure 2) show the atmospheric transport varies at these sites and the interaction of atmospheric transport and surface CO_2 emissions (all sources) leads to different synoptic variability at different sites. Furthermore, the atmospheric interaction with anthropogenic emissions is distinct from the interaction with biospheric emissions, leading to different synoptic characteristics in the CO_2 concentrations. Thus the synoptic CO_2 concentration characteristics at a site contain information on the regional emission. The model and observations can be used to evaluate different emission estimates.

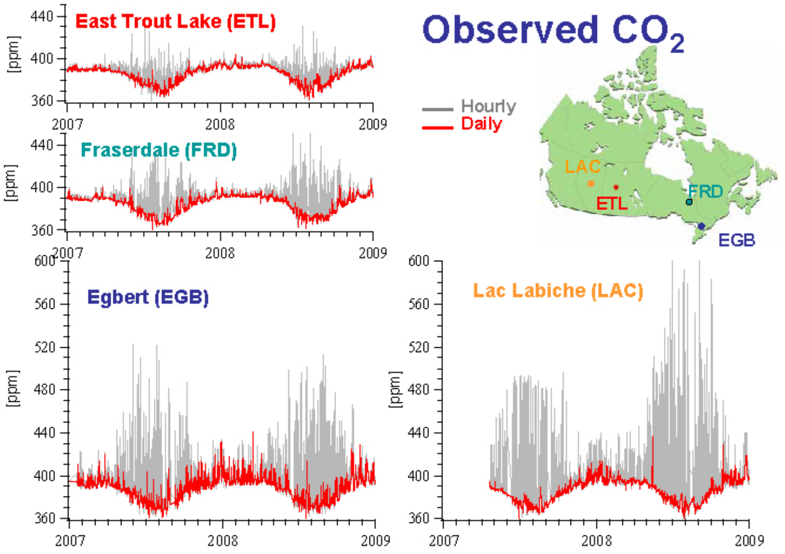

Figure 1. The Observed CO_2 concentration time series at the different continental sites on the map, the gray curve is the hourly concentration, and the red curve is the afternoon (3-6 pm local time) concentration. The synoptic variability varies with locations, indicating different atmosphere and source emission interaction.

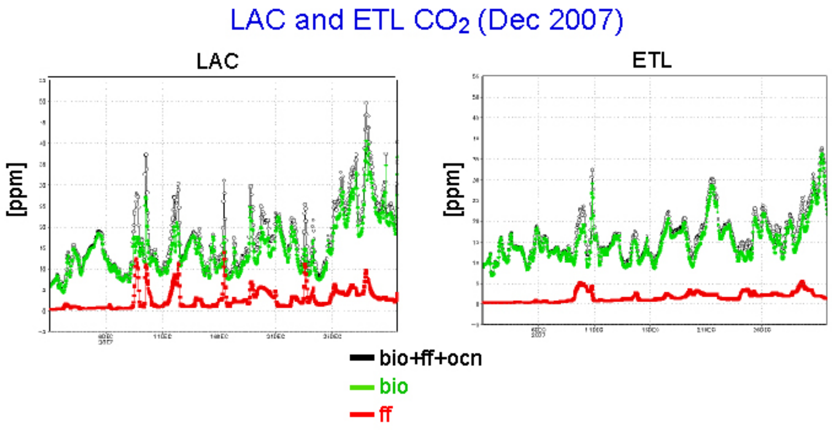

Figure 2. Time series from GEM model for December 2007 at the Lac Labiche and East Trout Lake sites. Black curve includes all sources bio+ff+ocn (biosphere + fossil fuel + ocean), green curve is for bio only, and red curve is for ff only. Bio CO_2 concentration shows more variability than ff concentration. GEM was initialized with 0ppm CO_2 concentration at the initial model integration time, November 1, 2007.

A Simplified Estimate of Contribution to Change of CO_2 Concentration by the Statistical Method

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The atmospheric CO_2 concentration has been continuously observed at Anmyeon Island, Korea (36° 32’N, 126° 19’E) since 1999. The raw data of CO_2 concentration measured at Anmyeon Island have gone through the quality assurance and quality control procedures, which are the same methodology advised by the World Data Center of Green House Gases. In the last outputs, three components of CO_2 concentration variation remain and this timeseries of CO_2 concentration is called the ‘keeling curve’. The dominant components of variations of CO_2 concentration are the seasonal variation, the long-term trend, and interannual variation. Figure 1 shows the three components of CO_2 concentration measured at the Korea Global Atmosphere Watch Center from 1999 to 2009. Each component of CO_2 variations is separated by a low-cut pass filter and a single liner regression analysis. If it is assumed that total variance of CO_2 concentration has three components: the long-term trend forced by combustion of fossil fuels, seasonal variation by biosphere and atmospheric transport, and interannual variation related with oceanic sink and release, we can comfortably estimate the contribution of change of CO_2 concentration from ratios of each variance against total variance. Our results are that over 72% by combustion of fossil fuels, ~27% by biosphere and transport, and ~1% by ocean has contributed to total change of CO_2 concentration in Anmyeon Island, Korea from 1999 to 2009.

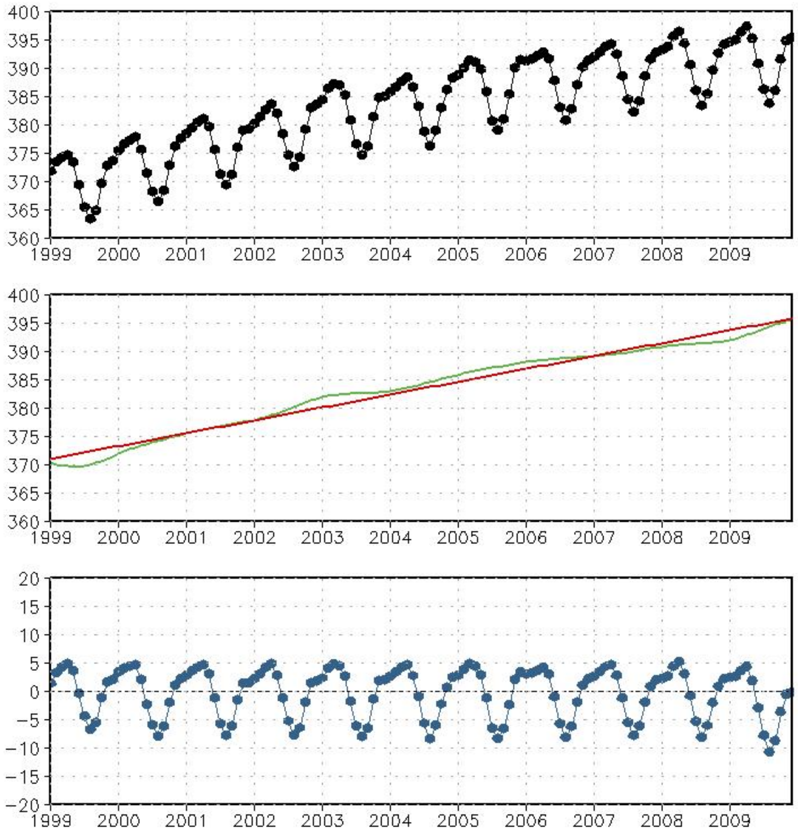

Figure 1. Timeseries of CO_2 concentration measured at Anmyeon Island, Korea from 1999 to 2009, and three dominant components of CO_2 variation. Long-term trend (red line), interannual variation (green line), and seasonal variation (blue line).

Novel Analyzer for Real-Time N_2O and CO Measurements in Air

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Accurate and precise measurements of both nitrous oxide and carbon monoxide concentrations are important in understanding global atmospheric chemistry. Because atmospheric mixing ratios of these species are relatively small (generally < 0.5 ppmv), an analyzer designed to probe these species must have high sensitivity and high precision to make meaningful measurements. We report the development and performance characterization of a commercial analyzer (Los Gatos Research, Model 908-0014) based on a patented cavity enhanced laser absorption spectroscopy technique which measures both CO and N_2O simultaneously in air with a precision of better than 0.3 ppbv in a 1-second measurement time. Higher precision may be obtained with further averaging. Data rates of up to 20 Hz may be achieved to allow for eddy flux correlation measurements. The instrument requires low power (200 watts) and does not require liquid nitrogen, allowing for measurements in the field.

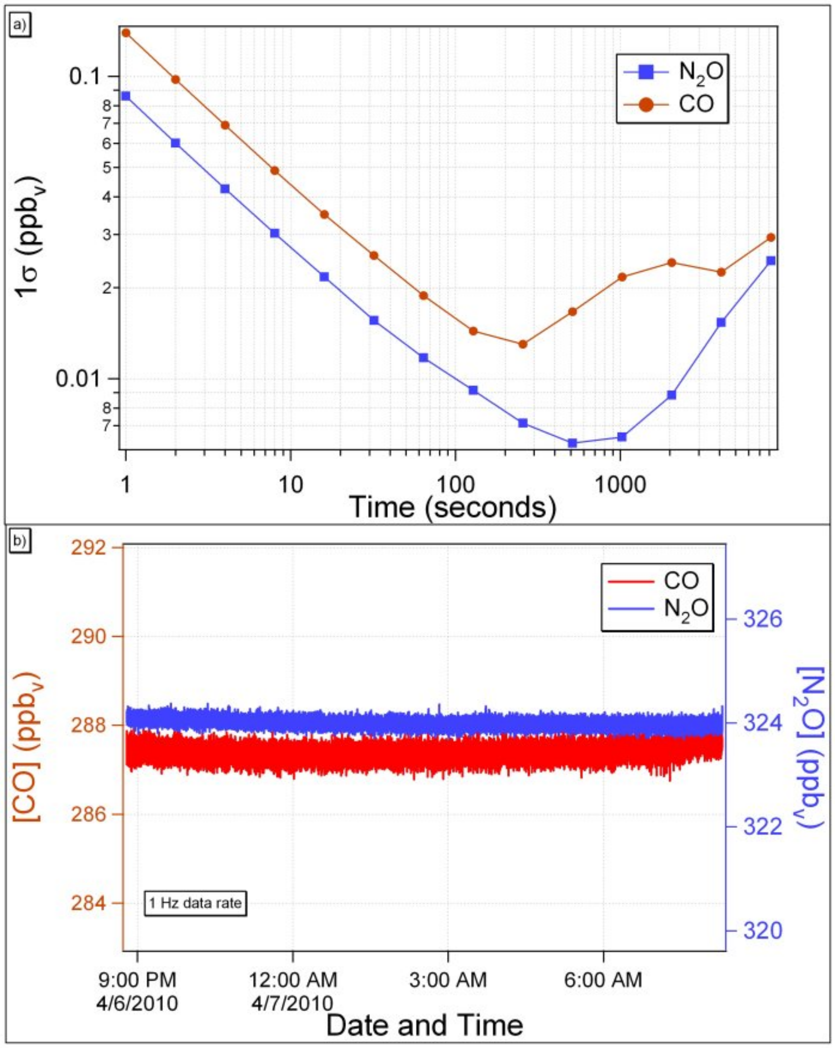

Figure 1. Long term performance of the Los Gatos Research (LGR) N_2O/CO Analyzer. (a) Allan deviation plot of the LGR analyzer measuring dry bottled air. A precision (1-sigma) of 0.09 ppbv for N_2O and 0.14 ppbv for CO was obtained in a 1-second measurement time. Long term precision of better than 0.040 ppbv is obtained for both N_2O and CO without any calibration. (b) Time trace of the data used to obtain the Allan variances in (a).

Quantifying Canada's Natural and Anthropogenic Methane Budgets Using Atmospheric Observations & Modeling: Progress and Limitations

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The long lifetime and rapid mixing of CH_4 in the atmosphere provides a large scale integration of surface fluxes. With sufficient measurement precision and surface coverage (measurement sites), a signature of individual surface source or sink regions can be detected and quantified. For example, below are preliminary results from a study to quantify Canada's wetland CH_4 budget using atmospheric CH_4 measurements and Four-Dimensional Variational Analysis modelling [applying prior gridded source patterns, an atmospheric transport model (TM5) and analyzed wind fields (The European Center for Medium-Range Weather Forecasts)] . The global analysis was done using CH_4 data from the NOAA ESRL's global air sampling network in addition to continuous CH_4 measurements from 4 of Environment Canada's observational sites. The figures show gridded wetland fluxes for 2004 (~ 7.5 Tg) and 2006 (~12Tg). Anthropogenic emission estimates for these same years will be reported as well. The poster demonstrates the potential of using atmospheric methane observations along with modelling to track and estimate methane emissions for Canada. Limitations in the analyses will be addressed as well.

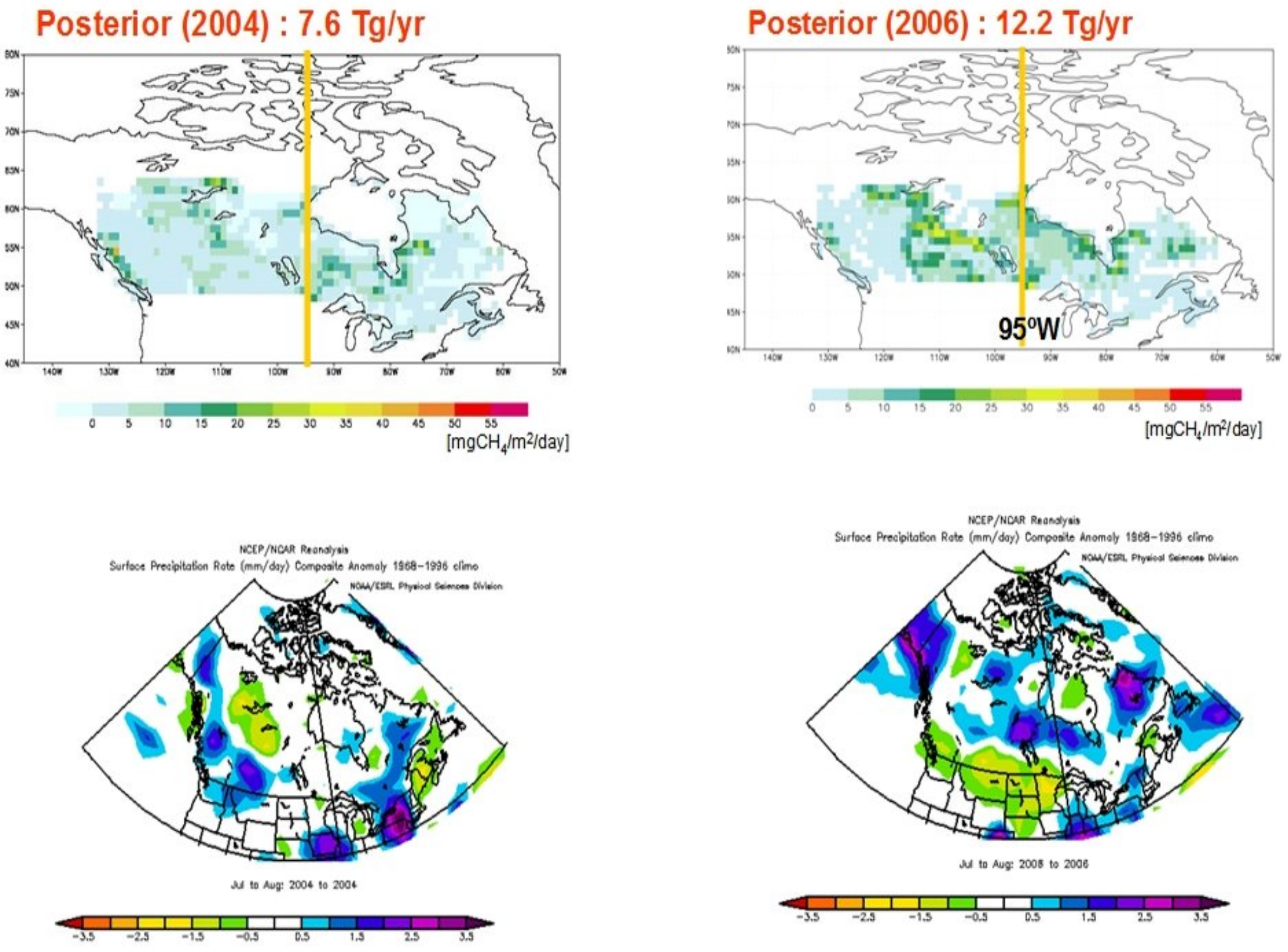

Figure 1. Annual gridded modelled wetland methane fluxes for 2004 and 2006 (top 2 figures) shown along with observed summer precipitation anomalies for the same 2 years. The lower flux estimated for western Canada in 2004 appears to be correlated with an unusual dry summer period.

Diagnosing the Bayesian Balance in Atmospheric Inversions

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Atmospheric inversions are challenged by a strongly underdetermined mathematical problem characterized by highly variable surface fluxes and an undersampled atmospheric CO_2 field. In the face of this problem, modelers must somehow set a balance between extracting as much signal as possible from observations and maintaining a stable inversion, one free of obvious artifacts. In the face of these competing requirements, Bayesian, geostatistical, and variational inverse schemes must choose a strength of extrinsic information, supplied in the form of prior flux estimates, flux covariance length scales, and other configuration choices. Setting this "Bayesian balance" requires careful consideration by the researcher, but the optimal level of prior constraint is made evident when plotting flux variance against observational residuals for varying levels of prior error covariance. Underdetermined problems tend to reveal an "L-curve" structure (Fig. 1), for which the optimal balance is represented by a sharp corner towards the origin. In this presentation, we discuss the Bayesian balance for recent inversions, including CarbonTracker and the Transcom3 interannual inversions. This analysis yields insights into the performance of transport models and flux inversion schemes.

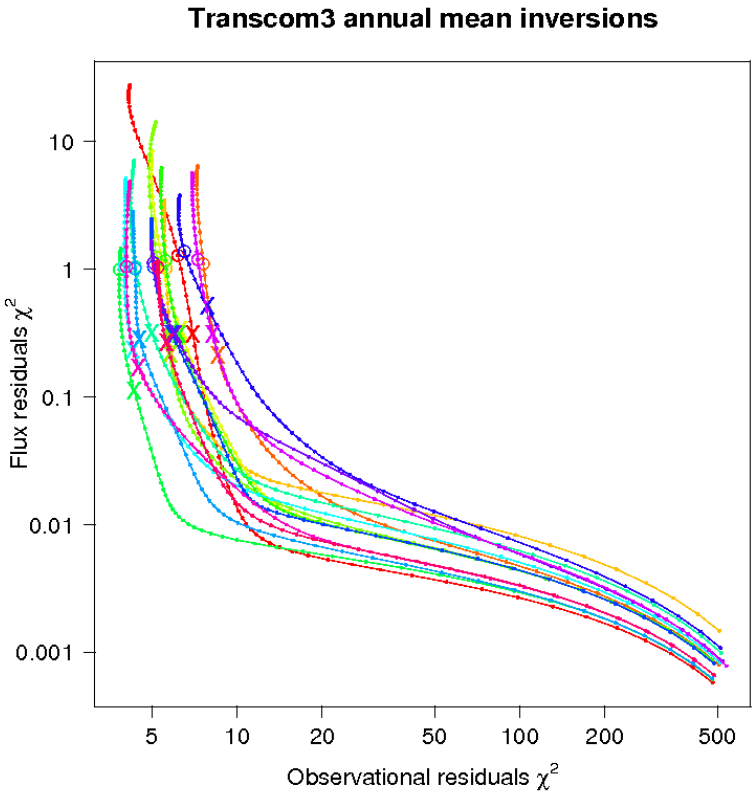

Figure 1. The Bayesian balance chosen by the Transcom3 annual mean inversions of Gurney et al. (2002), as revealed by each model's characteristic L-curve. Models are shown in different colors, with the balance between prior and observations as published shown with X symbols. The curves show that all models are challenged to agree with measurements (observations χ^2 values are relatively large), and that some models are significantly more successful than others. While this particular Bayesian balance resides away from the optimum (at the elbow of each curve), the Transcom3 researchers chose their prior constraints wisely. This balance favors aggressive fitting of measurements at the risk of allowing some flux artifacts, which would presumably be attenuated by considering the across-model average.

Evaluating CarbonTracker (CT) Performance During the North American Carbon Program Mid-Continent Intensive Campaign

G. Petron[1], A. Andrews[2], A. Jacobson[2], C. Sweeney[2], M. Trudeau[2], K. Masarie[2], P. Tans[2], J. Eluszkiewicz[3], T. Nehrkorn[3], J. Henderson[3], S. Ogle[4], A. Schuh[5], K. Davis[6], T. Lauvaux[6], T. Miles[6], S. Richardson[6], T. West[7], L. Olsen[7], B. Cook[7], V.Y. Chow[8], A. Michalak[9], S. Gourdji[9], K. Mueller[9], P. Shepson[10], D. Martins[11] and K. Gurney[10]

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[4]Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523
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[8]Biosphere-Atmosphere Exchange Group, Harvard University, Cambridge, MA 02138
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[10]Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907
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The Mid-Continent Intensive (MCI) took place in Iowa and its border states from May 2007 to November 2009. The objective of the MCI was to provide dense atmospheric CO_2 monitoring in the region and to bring together experts from the “bottom-up” inventory and eco-system modeling community and “top-down” atmospheric modelers to estimate the region’s CO_2 budget. To alleviate the under-constrained nature of the inverse problem, researchers from Pennsylvania State University instrumented five transmitter towers in the upper Midwest to measure well-calibrated atmospheric CO_2 mole fractions at 110/120m above ground level (Ring 2 data set). The Global Monitoring Division (GMD) instrumented the West Branch Iowa (WBI) tall tower in July 2007 with quasi-continuous CO_2 and CO analyzers and daily air sample collection. GMD also conducted regular (~ bimonthly) aircraft profiles with discrete air sampling at 6 locations within the MCI region. Researchers from Purdue University collaborated with the GMD aircraft group for several flights in May-June 2007 with continuous CO_2 measurements.

Mid-afternoon averages from the Iowa tall tower WBI have been assimilated in the most recent version of CarbonTracker (CT2009). It showed a substantial impact on the optimized North America Temperate Crop Net Ecosystem Exchange. A branch inversion was done with the Ring 2 data being assimilated as well. Results from the branch inversion did not differ significantly from the CT2009 run. Furthermore the summertime positive biases of the modeled CO_2 at most North American site including WBI remain in both inversions. The inability of CT to match the observations better during the growing season in the MCI region and its more general summer time positive bias are being investigated. Here we will report on recent findings based on analyses with the Stochastic Time-Inverted Lagrangian Transport Lagrangian Particle Disperson Model. We will also present some work done in collaboration with the other top-down working groups at Penn State University and Colorado State University.

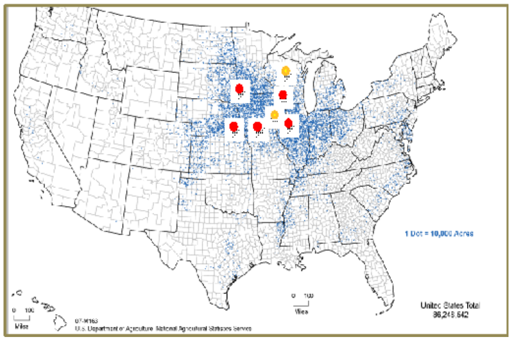

Figure 1. U.S. Corn Belt (corn for grain, harvested acres, U.S. Department of Agriculture 2007). Over-plotted are the two NOAA Tall Towers in the region (Park Falls, Wisconsin and WBI, yellow dots) and the five Ring 2 short towers (red dots).

Aura Tropospheric Emission Spectrometer (TES) Measurements Related to the Carbon, Nitrogen and Water Cycles and Their Impact on Air Quality and Climate

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The Aura satellite, launched in 2004 provides a comprehensive set of measurements of stratospheric and tropospheric composition. In particular, the TES instrument provides measurements of many species important for understanding the carbon, nitrogen, and water cycles and the relationships between them. This poster provides an overview of TES measurements of ozone, water vapor and its isotopes, CO, CO_2, ammonia, methane, and N_2O and shows examples of how these measurements are used to constrain budgets related to these natural cycles, the linkages between them, and their impact on air quality and climate. These measurements, mostly in the free troposphere, point towards the need for co-measurements of multiple species, with the capability to estimate concentrations in the planetary boundary layer in order to provide improved constraints on surface fluxes and emissions, sinks, and transport of carbon, nitrogen, and water and how their corresponding cycles interact. Next generation satellite concepts with these capabilities are presented

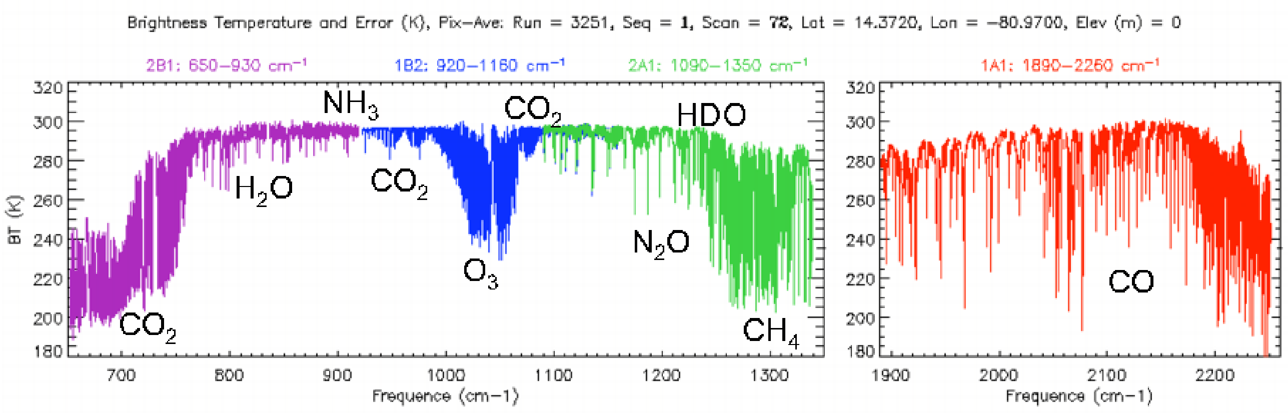

Figure 1. TES observes co-located CO_2, CH_4, N_2O, CO, O_3, H_2O, HDO, NH_3, temperature and optical cloud properties.

How Well Could Satellite Data Constrain Degree-Resolution Carbon Fluxes?

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With the launch of the Greenhouse-Gases Satellite, CO_2 concentrations recently affected by surface fluxes may now be measured well from space; satellites with greater accuracy and ability to avoid clouds and aerosols should follow in the next several years. From a policy standpoint, it is reasonable to ask how well a fleet of such satellites could estimate natural carbon fluxes and/or fossil fuel emissions from individual countries. Here we use simulated measurements from multiple Orbiting Carbon Observatory (OCO)-like satellites in a variational data assimilation scheme to estimate weekly CO_2 fluxes (and uncertainties) at 1.0°x2.5° resolution: for regions roughly the size (~30,000 km^2) of Belgium, Albania, or the State of Maryland. We use OCO column CO_2 measurement uncertainities as a function of surface type, aerosol optical depth, solar zenith angle (SZA), and viewing mode (nadir or glint) obtained from a linear analysis of the OCO "full-physics" retrieval scheme. The availability of cloud-free scenes, and the impact of aerosols, is calculated as a function of SZA using Moderate Resolution Imaging Spectroradiometer data. Measurements are obtained using realistic vertical weighting and viewing geometries. Fleets of up to four OCO satellites, with orbital ascending nodes centered about 13:30 local time, are considered, viewing in both nadir and glint modes. Over the land, we find that a fleet of four OCO-like satellites could constrain weekly fluxes at 1.0°x2.5° to within ~100 gG m^{-2} a^{-1}, or ~0.004 GtC/yr per box, either in glint or nadir modes. This is adequate for identifying most non-diffuse fossil fuel emission sources, and represents an error reduction of ≥ 60% in the natural biospheric fluxes, compared to our prior (Fig. 1). Since this analysis considers random retrieval errors only, these are “best case” results obtainable only after systematic errors are removed.

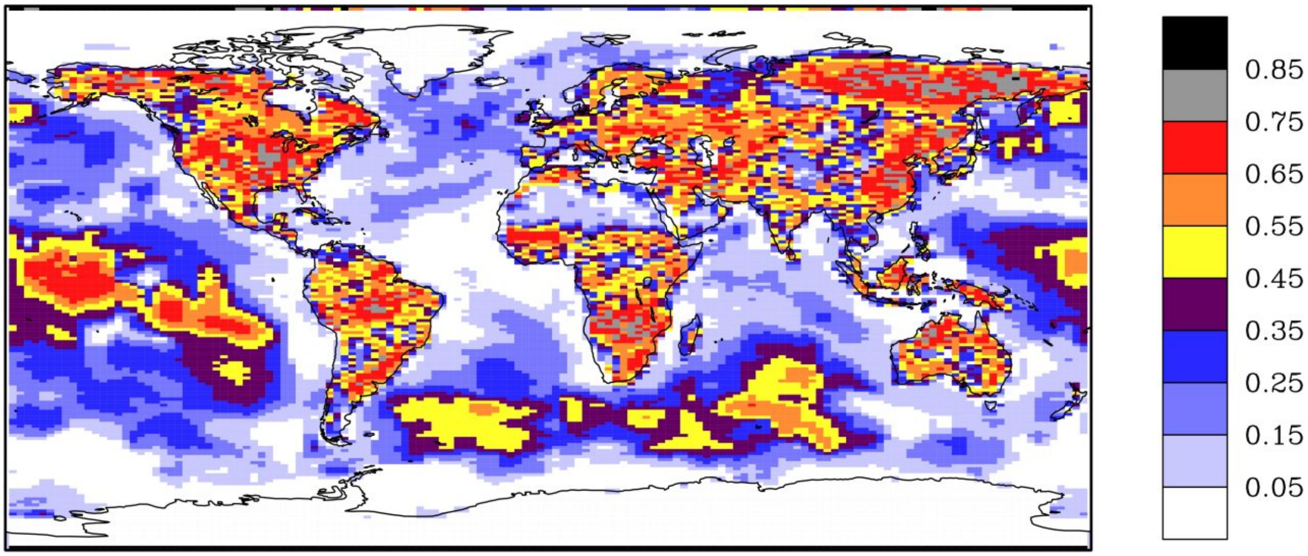

Figure 1. The constraint provided by a fleet of four OCO-like satellites, on weekly fluxes at 1.0°x2.5° resolution (lat/lon), in terms of the fractional reduction in the uncertainty of the natural fluxes (ocean and land biosphere).

Application of Extractive Fourier Transform Infrared Spectroscopy with Cryogenic Preconcentration: Preliminary Laboratory Results

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In collaboration with the Jefferson County Department of Health and the Environmental Protection Agency (EPA) Region IV, the University of Alabama in Huntsville recently developed a near-real-time trace gas monitor using extractive Fourier Transform Infrared Spectroscopy (FTIR) in concert with Extractive Cryocooled Inert Preconcentration (ECIP). The ECIP-FTIR uses a commercial FTIR spectrometer, a commercial long-path Infrared (IR) gas cell, a commercial acoustic Stirling cyrocooler, and two custom parallel cryogen-free cryotraps to autonomously monitor an evolving multi-pollutant suite of volatile organic compounds. Every 15 minutes, the system records a trace gas absorption spectrum and the derived trace gas concentrations, using continuous non-preconcentrated sample flow through the gas cell, to achieve detection limits of ~10 parts per billion volume and a signal-to-noise ratio of ~10^5. Every 4 hours, the FTIR and gas cell obtain similar data on preconcentrated batch samples that have been thermally desorbed from the cryotrap, to improve detection limits to ~5 parts per trillion volume and improving the signal-to-noise ratio.

We present preliminary laboratory data collected at the National Space Science and Technology Center in Huntsville. These laboratory results show the ECIP-FTIR methodology is well suited for a wide range of trace gas research and monitoring applications, including EPA National Air Toxics Trends Stations and National Core monitoring network.

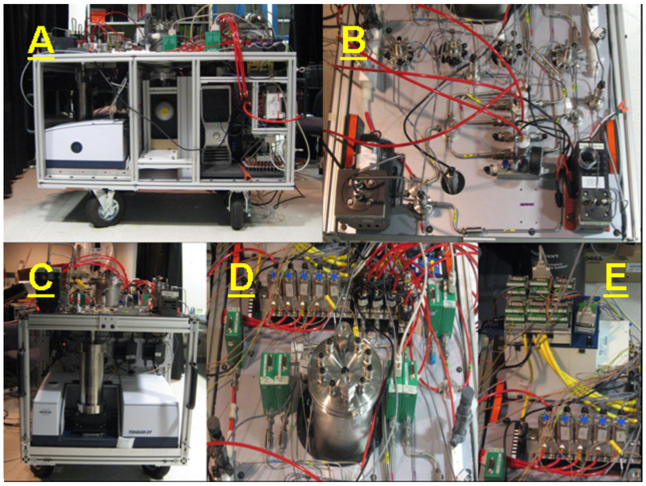

Figure 1. The ECIP-FTIR Instrument Layout. Panel A shows the entire instrument layout. From left to right, the FTIR, cryocooler, and electronics compartment with operations personal computer can be seen. Panel B shows the fluid subsystem including flow passages, inlet pumps, and shut off and flow selection valves. Panel C shows the optical subsystem with emphasis on the FTIR and gas cell. Panel D show the cryogenic subsystem and Quality Assurance/Quality Control manifold along with mass flow controllers (green boxes). Panel E shows the data acquisition system and mass flow junction boxes.

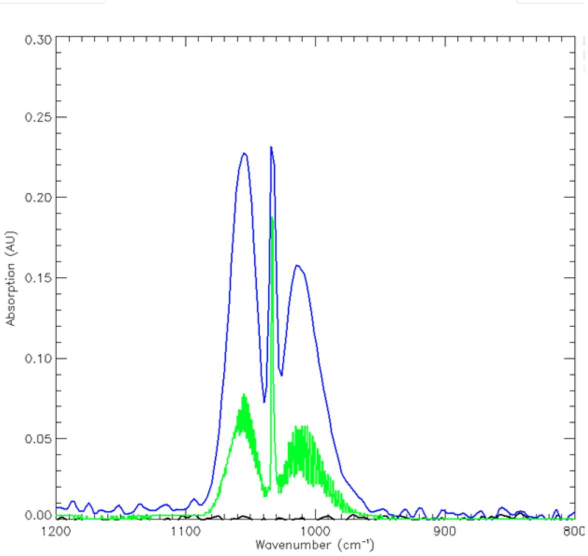

Figure 2. IR Spectrum of trace methanol in air taken at 1cm-1 resolution and 15 minute co-addition. The blue trace is the measured methanol spectrum. The green trace is the deresolved library spectrum.

Spatial and Temporal Variations of Atmospheric Methane and Carbon Dioxide Observed in Environment Canada's Greenhouse Gas (GHG) Measurement Network

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Environment Canada conducts high quality ground-based atmospheric measurements of GHGs from coastal, interior and Arctic regions in Canada. The current network of 12 stations is strategically located to catch the regional atmospheric signals of carbon fluxes from major ecosystems over Canada and reflect the long-range transport of GHGs into and out of Canada. These measurements document the spatial and temporal distributions of GHGs in Canada, providing essential constraints to our understanding of Canada's natural and anthropogenic sources and sinks of GHGs. An analysis of the spatial distribution of atmospheric CO_2 and CH_4 extent utilizing backward trajectory calculations is demonstrated. The results show that methane and carbon dioxide sources have the potential to affect regions covering several hundred kilometers. Temporally (synoptic, seasonal and inter-annual variations), atmospheric observations of CO_2 and CH_4 clearly provide information on controlling processes in important ecosystems such as the boreal forest and wetland regions in Canada and their possible response to changes in climate.

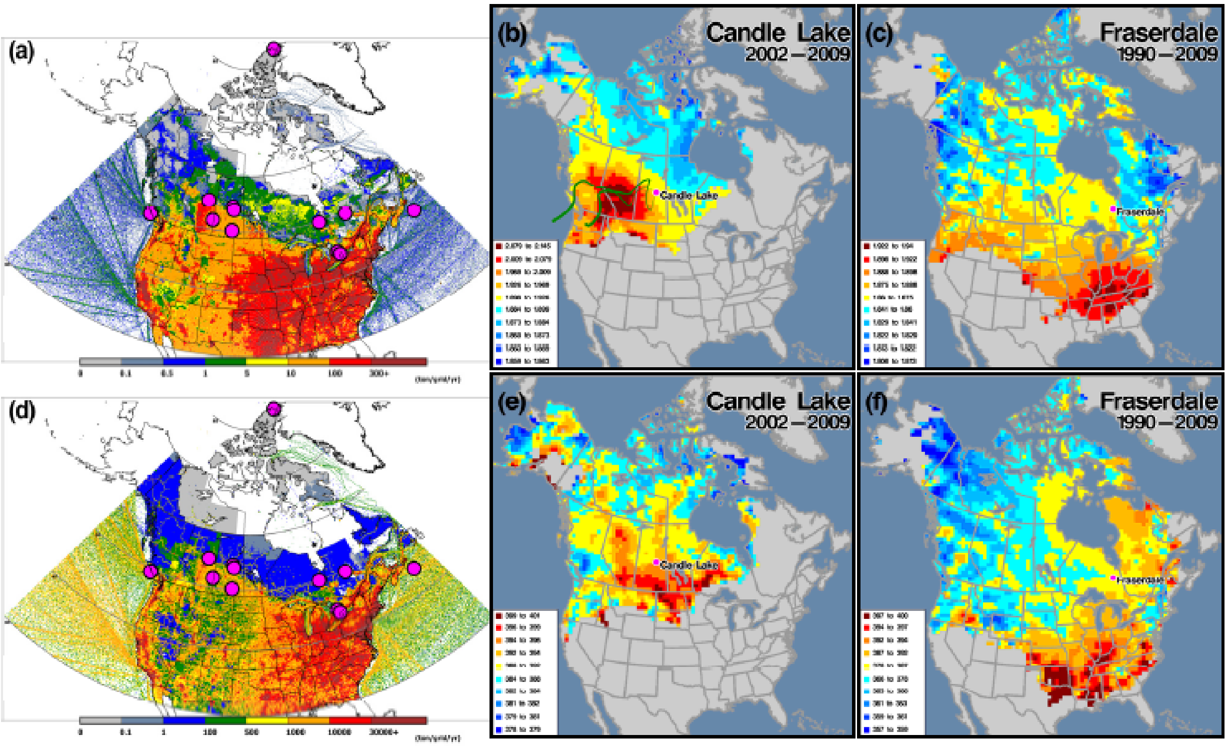

Figure 1. Receptor analysis (Seibert et al., 1994) using measurements of surface GHGs (CH_4 and CO_2) mixing ratios during Nov-Feb from Environment Canada, Climate Chemistry Research Section. Figures 1a and 1d show the year 2005 annual total emissions of CH_4 and CO_2 respectively, from Edgar v4.0 (0.1 x 0.1 degree). The circles show the current site locations. Figure 1b, 1c, 1e, 1f show the receptor modeling results using 5-day backward trajectories for CH_4 at Candle Lake, CH_4 at Fraserdale, CO_2 at Candle Lake, and CO_2 at Fraserdale respectively. NOTE: The scales are independent. Reference: Seibert, P., Kromp-Kolb, H., Baltensperger, U. et al. (1994), Academic Publishing, 689–693.

Seasonal Variations in CH_4 and N_2O Emissions from Central California

M.L. Fischer[1], C. Zhao[1], A.E. Andrews[2], L. Bianco[2], E. Dlugokencky[2], J. Eluszkiewicz[3], K. Masarie[2], T. Nehrkorn[3] and J. Wilczak[2]

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Methane and nitrous oxide mixing ratios measured at two tall-towers (Mt Sutro and Walnut Grove) in Central California are compared with model predictions to estimate surface emissions of CH_4 and N_2O from December, 2007 to November, 2008. Predicted mixing ratios are calculated based on spatially resolved *a priori* CH_4 and N_2O emissions and simulated atmospheric trajectories. Meteological fields are computed using the Weather Research and Forecast (WRF2.2) with a parameterization developed at the NOAA for simulations in California. Surface influence functions (footprints) are then calculated using the Stochastic Time-Inverted Lagrangian Transport model driven by the WRF output. Predicted winds and boundary layer heights compare favorably with measurements from radar wind profilers in the Central Valley. Footprints calculated for well-mixed periods at 91m on the Walnut Grove, California (WGC) tower vary with seasonal meteorology; broader footprints are obtained in winter due to more north-south winds, while narrower footprints oriented in the west direction area obtained in spring, fall, and particularly summer. Coupled with *a priori* emission models, predicted CH_4 and N_2O signals are computed and compared with measured mixing ratios. Predicted CH_4 is found to be statistically consistent with the measurements in winter but significantly under-predicted during the summer. Examination of the summer footprints reveals channeling from the Bay Area through the Sacramento delta to the WGC tower. This suggests that emissions from the Bay Area and the Delta region are likely stronger in summer or more concentrated on the footprint than in the inventory map. For N_2O, predicted mixing ratios are consistently lower than measured, suggesting that N_2O emissions are significantly underestimated. Further analysis will provide an update on predicted emissions from the Bay Area and Central Valley.

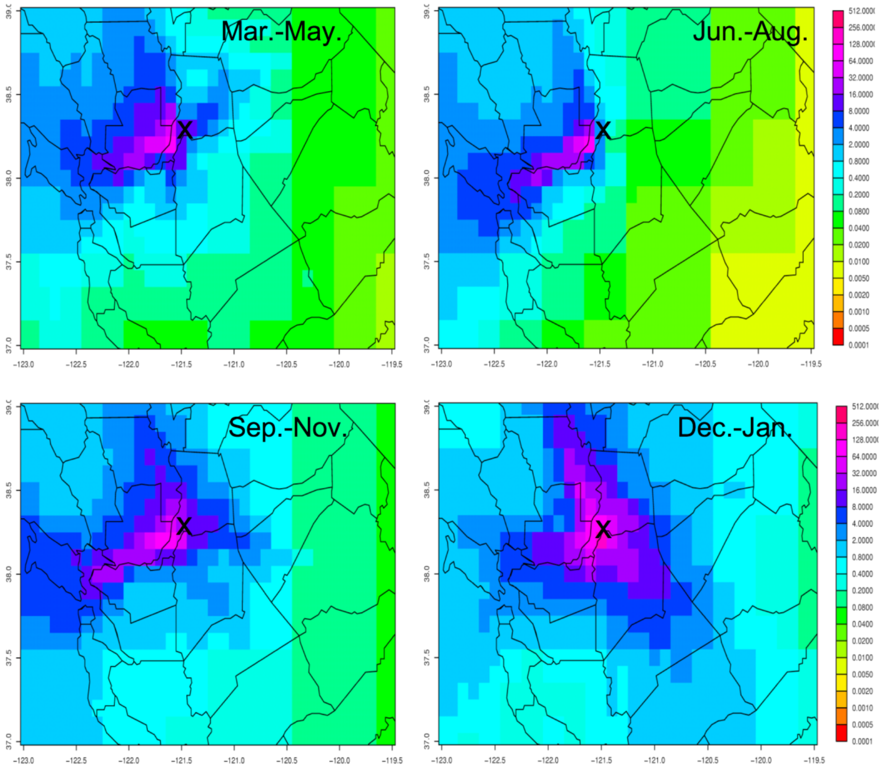

Figure 1. Seasonal well-mixed period footprints for 91m sample height on Walnut Grove Tower (marked with x) for December, 2007 to November, 2008.

Temporal Variations in CO_2 in Air in Pasadena, California

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How does an urban environment modify the global cycle of observed atmospheric CO_2? To address this question, we have studied CO_2 since 1998 on the Caltech campus and compared the observed temporal variations with relatively local clean air data from La Jolla (http://scrippsco2.ucsd.edu/data/ljo.html). Time series analysis of daily [CO_2] and isotopic composition Caltech data reveal periodicities at 1 and 0.5 year and 7 days. This last period is not observed in La Jolla. In addition, the $\delta^{13}C$ pattern is inverted in Pasadena relative to that at La Jolla, and there is no well-defined seasonal variation in CO_2 mixing ratio in Pasadena, in contrast to the La Jolla pattern (Figure 1). The seasonal variations in Pasadena reflect the superposition of local contributions of CO_2 in Pasadena on global clean air temporal variations. The local contributions are significant: e.g., the total CO_2 concentration in Pasadena is ~25 ppm higher than in clean air. Although the typical diurnal variation in CO_2 mixing ratio consists of a low [CO_2] plateau at about ~10 AM-4 PM PST and a high [CO_2] plateau at ~9 PM-3 AM, there are significant variations with season and day of the week (Figure 2). The amplitude of the diurnal variation in Pasadena varies from ~20 ppm in June to ~80 ppm in December. We typically observe a maximum in [CO_2] at ~5-9 AM on weekday mornings, which is smaller on weekends and coincides with increased traffic on surface streets in Los Angeles due to weekday morning rush hour. There is no corresponding peak that can be associated with afternoon rush hour.

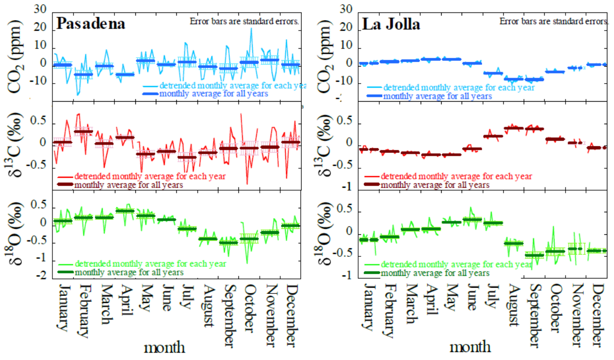

Figure 1. Annual cycles of [CO_2], $\delta^{13}C$, and $\delta^{18}O$ for mid-day flask samples for Pasadena and La Jolla from 2001-2008. Long-term linear trends have been subtracted from all analyses. The darker line segments indicate the averages for each month for all years, whereas the lighter time series indicate the averages for each month for individual years.

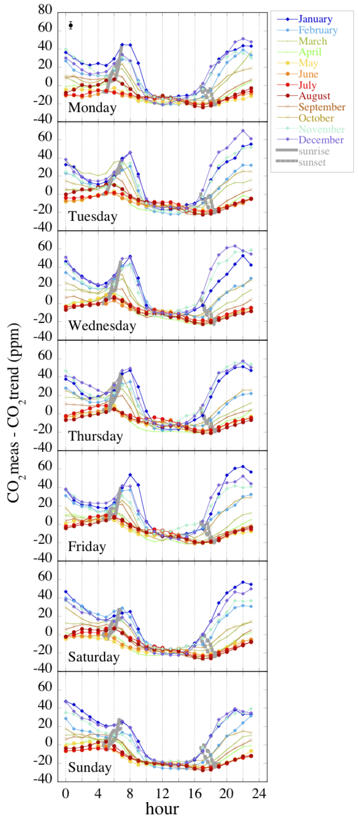

Figure 2. Changes in diurnal variations in [CO_2] with day of the week and month of the year. Summer months are in red and winter months in blue. [CO_2] is given as the difference from the long-term linear trend. The error bar in the Monday panel indicates the average standard error.

Records of Northern Hemisphere Atmospheric Carbon Monoxide Back to ~1950 AD from Greenland Firn Air

V.V. Petrenko[1], P. Martinerie[2], P. Novelli[3], D.M. Etheridge[4], I. Levin[5], Z. Wang[6], T. Blunier[7], J. Chappellaz[2], J. Kaiser[8], P. Lang[3], L.P. Steele[4], F. Vogel[5], M.A. Leist[4], J. Mak[6], R.L. Langenfelds[4], J. Schwander[9], J.P. Severinghaus[10], G. Forster[8], W. Sturges[8], G. Petron[3], M. Rubino[4] and J.W.C. White[1]

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[7]Centre for Ice and Climate, Niels Bohr Institute, University of Copenhagen, København DK-2100, Denmark
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Carbon monoxide (CO) plays a key role in global atmospheric chemistry by being the main sink of atmospheric hydroxyl radicals (OH). Records of past [CO] from both hemispheres are essential for understanding past changes in atmospheric [OH] because the atmospheric lifetime of CO is less than the interhemispheric mixing time. Earlier attempts at reconstruction of northern hemisphere (NH) [CO] suffered from apparent *in situ* CO production in ice and firn. We present a record of high-latitude NH [CO] to ~1950 AD, from measurements by four different laboratories of firn air collected from three different boreholes at the North EEMian (NEEM) ice core site in Greenland. Procedural blanks indicate no detectable [CO] contamination from sampling. Excellent agreement with a firn air record from another cold Greenland site North Greenland Ice Core Project is consistent with the NEEM firn CO record being unaltered. A preliminary analysis of our measurements, interpreted using two different firn air diffusion models, suggests that high-latitude NH [CO]: 1) was ~150 ppb in the year 1950, 2) increased from 1950 to the 1970s, 3) peaked above 160 ppb in the 1970s and 4) gradually declined after the 1970s. Work is in progress to finalize the [CO] reconstruction and interpret the record in the context of historical CO emissions estimates as well as changes in other relevant trace atmospheric constituents.

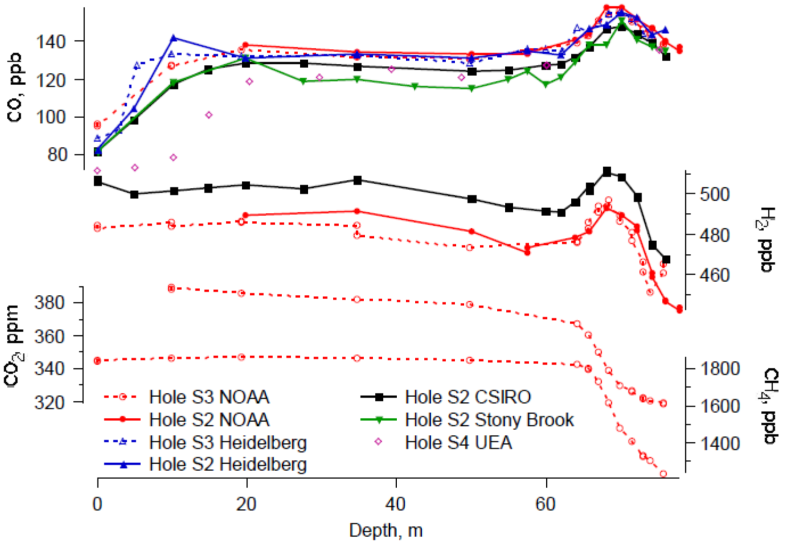

Figure 1. Depth – mixing ratio data for CO from the NEEM 2008 firn air campaign. H_2, CO_2 and CH_4 depth profiles are also shown for reference.

Using Tropospheric Emission Spectrometer CO_2 Observations for Inverse Modeling Estimates of Carbon Fluxes

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[2]University of Toronto, Department of Physics, Toronto, Ontario, Canada
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We present carbon dioxide estimates and characterization from the Tropospheric Emission Spectrometer (TES) aboard the NASA Aura spacecraft, launched in 2004, with comparisons to aircraft and surface *in situ* data. TES CO_2 is sensitive between about 200 and 800 hPa, with peak sensitivity in the mid-troposphere (511 hPa) and ~1.5 ppm accuracy for regional monthly averages. We compute terrestrial and ocean flux estimates with TES data and the GEOS-Chem chemical transport model, using a Bayesian inversion approach, and find that TES satellite observations of CO_2 provide important constraints on flux estimates, particularly in the tropics.

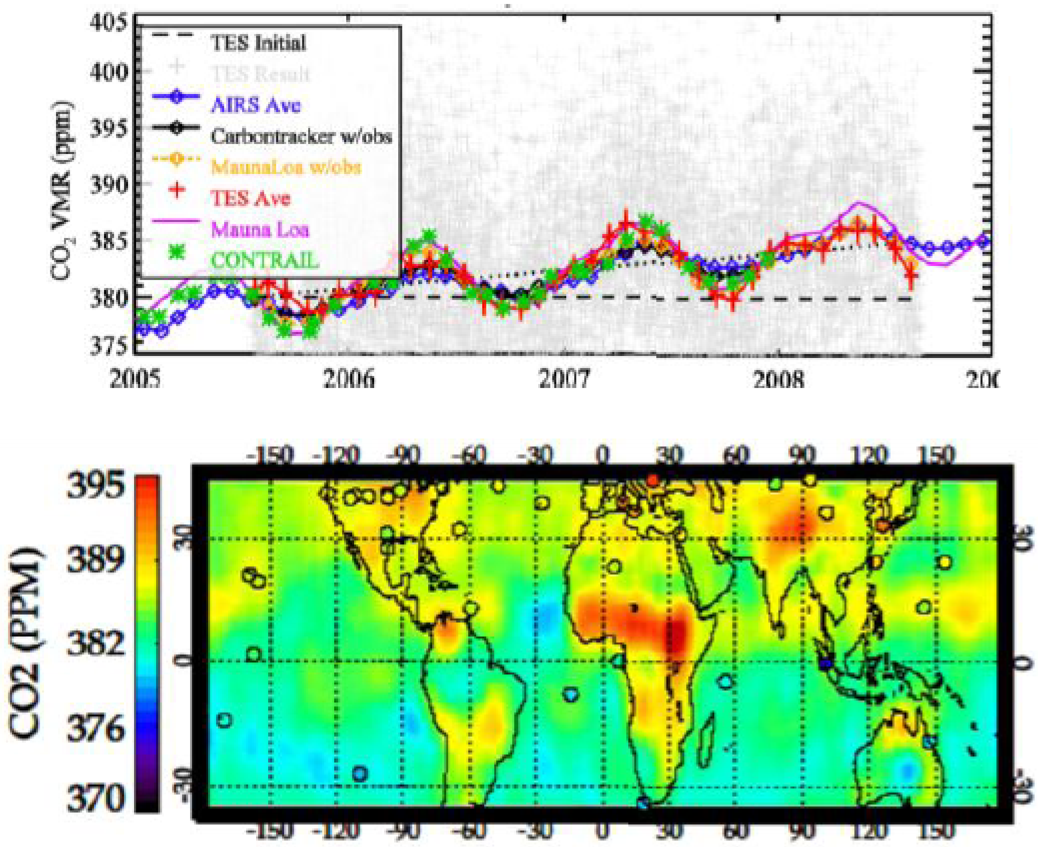

Figure 1. TES comparison to validation data and versus GLOBALVIEW (circles) for March – May, 2006-2007. TES data monthly averaged over 15x15 degrees shows similar patterns to surface data and has about 1.5 ppm error.

Potential New Methods for Examining Regional Sources and Sinks of Carbon

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Unmanned Aircraft Systems (UAS) offer unique capabilities for measuring carbon fluxes over regions critical for carbon cycle research. In a pre-programmed mode, the vehicles can fly repeat patterns over varying time periods to measure diurnal, seasonal and annual variability in fluxes. Four specific science objectives that UAS could address would include: 1) Quantify ecosystem fluxes and variability; 2) Distinguish locally produced sub-grid variability of CO_2, CH_4 mole fraction from patterns advected from outside control region; 3) Scale-up ecosystem flux measurements to 10,000 km^2 and 4) Compare flux estimates from models and satellite retrievals with *in situ* observations. The ability to address these questions would provide an important link between the current satellite, modeling and measurement communities and could offer results to clarify the discrepancies in estimates of regional fluxes.

Aircraft have been used to estimate carbon fluxes, but questions remain as to the amount of disturbance introduced by the airplane and the ability to distinguish between ambient vertical air motion from that induced by the vehicle. UASs preserve the flexibility of manned aircraft and offer two distinct advantages: they can fly lower and with less disturbance to ambient air movement. Using a combination of LICOR and Picarro gas analyzing instrumentation, we could resolve typical fluxes to an uncertainty of +/- 10%: CO_2 0.2 $\mu mol\ m^{-2}\ s^{-1}$ (200 $mg\ C\ m^{-2}\ day^{-1}$) and CH_4 2 $nmol\ m^{-2}\ s^{-1}$ (2.8 $mg\ CH_4\ m^{-2}\ day^{-1}$). Combined with global positioning system-assisted location and attitude sensors we should be able to detect 1 km average fluxes every 100m and georectify these fluxes to surface conditions and spatial variabilities.

Uncertainty in fluxes due to advection could be quantified with transecting flights, both upwind and downwind of flux towers, to measure the amount of advected carbon not accounted for. Both the magnitude and sign of the flux varies through a 24-hr period resulting in large uncertainties on diurnal behavior of fluxes from tall towers and Eddy Covariance. Flux measurements over regions with existing flux towers will allow for identification of sub-grid variability that can influence existing flux algorithms. The primary test will be to determine if sub-grid flux characteristics can be approximated as linear.

Six locations stand out as particularly appropriate: Park Falls, WI and Lamont, OK are Total Carbon Column Observing Network primary validation sites, Fort Hunter Liggett, CA is a controlled burn site, Larimore, ND is in agricultural and Atqasuk and Tanana Valley are in separate parts of Alaska.

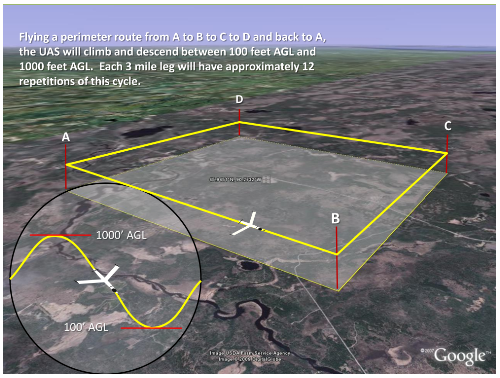

Figure 1. Regularly repeated flight plans will allow for a time series of carbon flux estimates across time scales that has previously not been possible.

Figure 2. Unmanned aircraft are serving a variety of societal and scientific roles--filling gaps that could not be filled with manned aircraft.

Creating a Global CO_2 Grid from Nighttime Lights Imagery

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The potential use of satellite observed nighttime lights for estimating CO_2 emissions has been demonstrated in several previous studies. However, the procedures for fine resolution global map of fossil fuel CO_2 emissions based on nighttime lights are still in the developmental phase. We report on progress of developing a method for mapping distributed (excluding major point sources) fossil fuel CO_2 emissions at 30 arc-second resolution using nighttime lights data collected by the Defense Meteorological Satellite Program's Operational Linescan System along with population count data from the U.S. Department of Energy's LandScan grid. The Vulcan sectoral carbon emissions data for the continental United States (U.S.), for the year 2002, produced by the Purdue University are being used for modeling CO_2 emissions from nighttime lights imagery. A statistical analysis of the Vulcan sectors indicated that lights and population count are well correlated to the emissions from the mobile, commercial, residential, industrial, and aircraft sectors, which together account for more than 50 percent of non-point sources of carbon emissions in the continental U.S. We are testing the model by aggregating the input data to different resolutions. The regression coefficients derived through the models developed for the U.S. will be applied to the nighttime lights data for the whole world to create a 30 arc-second or 1 km^2 resolution global grid of estimated CO_2 emissions for the year 2000. The estimated CO_2 emissions from the nighttime lights imagery will be aggregated to the national level and compared with the published CO_2 emission estimates derived from the Carbon Dioxide Information Analysis Center. The resulting CO_2 emission grid may be a useful input to CO_2 flux models.

Figure 1. Nighttime lights of the U.S. (2000). Source: Earth Observation Group, the NOAA, National Geophysical Data Center.

Figure 2. Sum of carbon emissions data of the mobile, commercial, industrial, residential, and aircraft sectors in the U.S. (2002). Source: Project Vulcan, Purdue University, Department of Earth and Atmospheric Sciences.

Boundary Resolution of CO_2 Using Infrared (IR) and Near Infrared (NIR) Measurements

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Since CO_2 concentrations in the boundary layer (BL) are primarily sensitive to surface fluxes mixing within the BL, closing the global carbon budget is best achieved by discriminating between CO_2 in the BL from CO_2 in the free troposphere. From previous studies showing that adding CO_2 laser band increases sensitivity to lower troposphere and that NIR measurements can be used to obtain “column” CO_2 measurements with sufficient precision to obtain CO_2 sources and sinks, we used simulated retrieval approach using IR, NIR and combined radiances. In this method, joint estimates of the atmospheric temperature, water, surface temperature, emissivity and CO_2 using optimal estimation provided a fully characterization of errors and sensitivity of the estimate to a simulated “true” CO_2 distribution. A linear retrieval is used to examine the impact of using different spectral bands on a CO_2 estimate. The results show that combined radiance retrieval i.e. using NIR and IR have the potential to resolve the boundary layer CO_2 from free tropospheric CO_2 and therefore to increase sensitivity to surface fluxes and to reduce transport error in inverse estimates of global carbon budget.

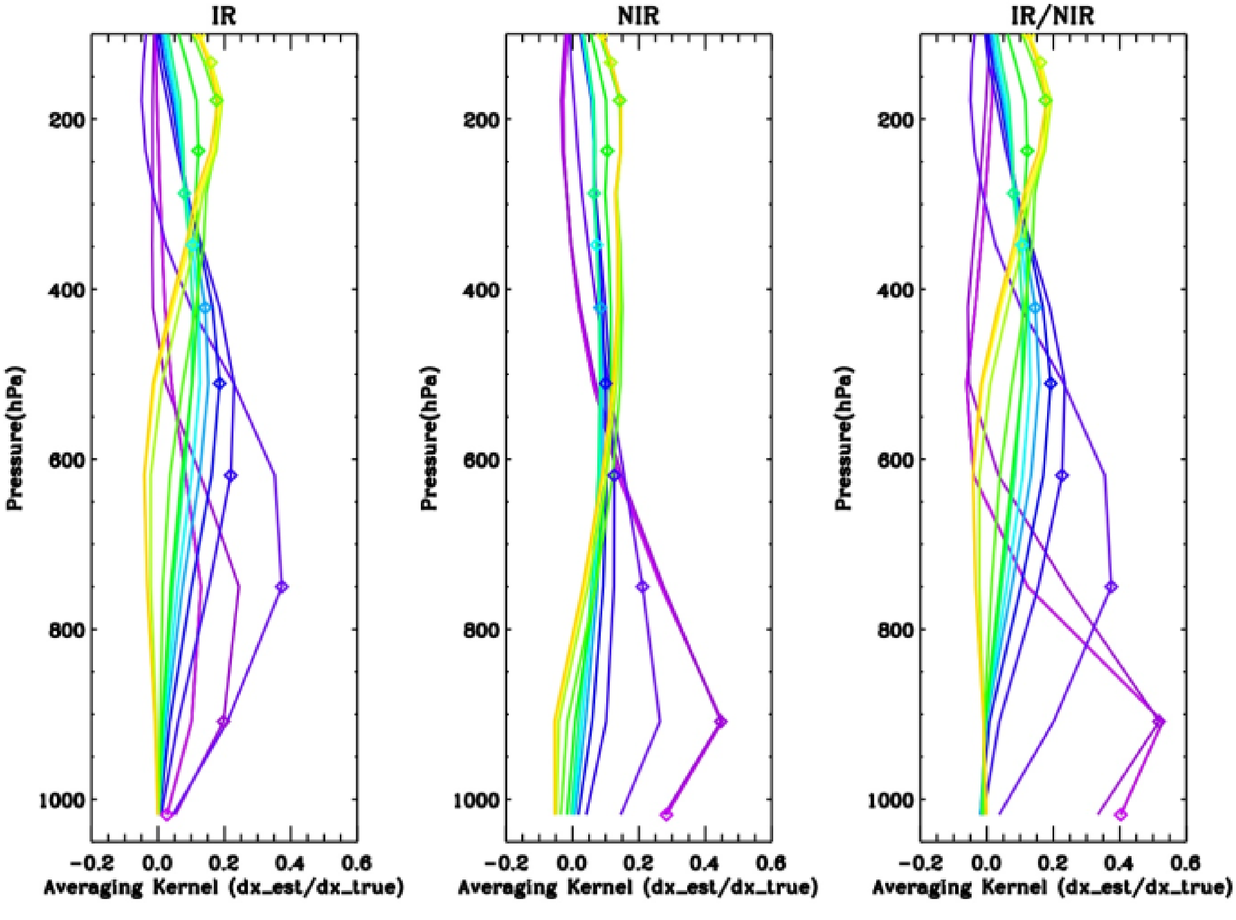

Figure 1. Averaging kernels representing the sensitivity of estimate to “true state” used in the “linear retrieval”: $x_{retrieved} = x_a + A (x_{true} – x_a)$ and used to examine the impact of using different spectral bands on a CO_2 estimate. Combined radiances (IR/NIR) retrievals can resolve the boundary layer from lower troposphere.

The Atmospheric and Terrestrial Mobile Laboratory (ATML)

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A new truck-mounted mobile laboratory for greenhouse gas (GHG) measurement and source attribution is under development in support of a three-laboratory (Los Alamos National Lab, Lawrence Livermore National Lab and Sandia National Labs) Department of Energy program. The ATML will provide measurement capabilities to aid in attribution of ambient carbon dioxide concentrations to their diverse source types, to quantify fluxes of CO_2, and to improve our ability to integrate ground- and satellite-based GHG measurements. Here we describe the suite of instruments on the ATML, including a proton transfer mass spectrometer and laser-based analyzers for field measurement of CO_2, CH_4 and water vapor isotopolog concentrations. The ATML is outfitted with a 10 m pneumatically-operated sampling mast, a balloon-supported air sampling system for sampling at higher elevations, flask samplers for collection of air samples for C14 analyses, an eddy correlation flux system, photoacoustic and trace element aerosol samplers and standard air quality and meteorological instrumentation, as well as a Vaisala ceilometer, a CIMEL Sunphotometer, and a Yankee total sky imager (the latter three instruments to aid in interpretation of satellite GHG data). A separate, transportable high resolution solar tracking Fourier Transform Spectrometer (FTS) that operates in the Ultraviolet-Visible and near Infrared is also being acquired for retrievals of columnar concentrations of CO_2, CH_4, N_2O, CO and other absorbing species. We plan to deploy the ATML and transportable FTS for three short field experiments in late FY10 focused on GHG measurement and attribution, emphasizing intercomparison and cross-validation of new analytical approaches. This project benefits from collaboration with several elements of the NOAA ESRL. It is anticipated that in FY11 and beyond, the ATML will be available for additional collaborative field experiments.

Figure 1. The existing mobile lab being outfitted as the ATML.

Figure 2. Note the fold-down railings deployed around the top, and the 10 m pneumatic mast.

Instantaneous Radiative Kernels for Tropospheric Ozone: Satellite Observations and Model Evaluation

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Radiative kernels representing the Top of Atmosphere flux response to a change in an atmospheric state variable are essential to understanding radiative feedbacks in climate change predictions. Using infrared spectra for the 10 micron ozone band and corresponding Jacobian calculations from the Tropospheric Emission Spectrometer (TES) on the NASA Earth Observing System-Aura, we can compute Instantaneous Radiative Kernels (IRK) for the vertical distribution of ozone. By storing TES radiance Jacobians for the final converged retrieval iteration and estimating anisotropy we derive ozone IRK profiles (in W/m^2/ppb) for all observation types: ocean, land, cloudy and cloud-free conditions. Along with ozone IRKs for August 2006, we will show comparisons of climate model ozone distributions to TES measurements with corresponding radiative implications of ozone differences.

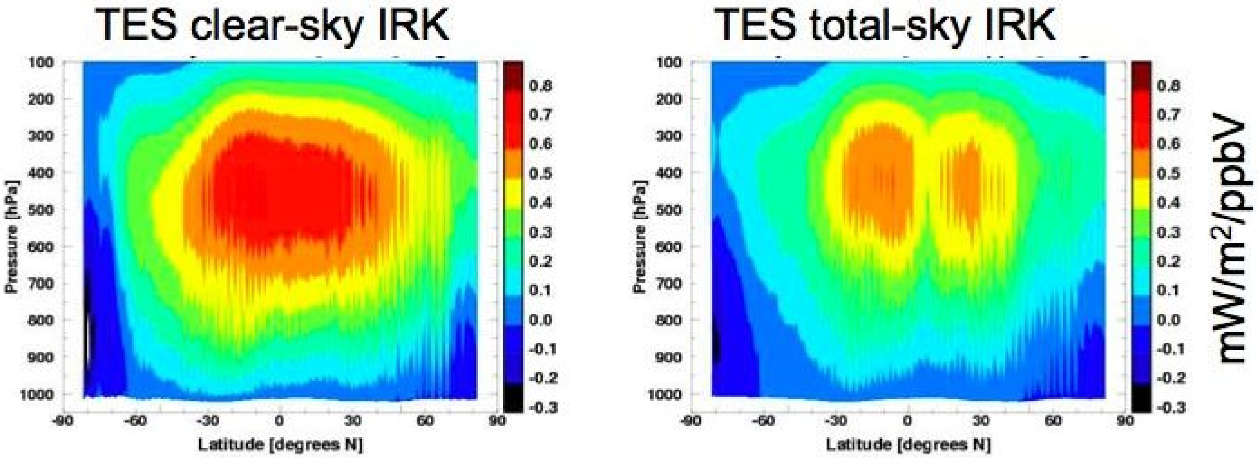

Figure 1. The zonal mean distribution of TES clear (left) and total sky (right) Instantaneous Radiative Forcing Kernels (IRFK, in milli-Watts/m^2/ppbv) in August 2006. [Aghedo et al, submitted to JGR-Atmos. 2010].

The Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE) 2009 Campaign

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The MOHAVE 2009 campaign took place at the Jet Propulsion Laboratory (JPL) Table Mountain Facility from October 11-27, 2009. This campaign allowed a thorough evaluation of Raman Lidar measurements throughout the troposphere by comparing them to RS92 radiosonde, NOAA-Frost Point, and Cryogenic Frost-Point Hygrometer (CFH) profiles. The campaign also hosted three other instruments/techniques, leading to the correlative measurement of temperature and water vapor from the ground to the mesopause, and ozone from the ground to the stratopause. The primary goals of the campaign were: 1) to identify and quantify Upper-Troposphere Humidity (UTH) changes associated with transport processes in the vicinity of the Sub-Tropical Jet, 2) to estimate the capability of the Raman lidar in detecting such UTH changes, and 3) to provide continuous water vapor profiles from the ground to the mesosphere by combining the measurements of the various participating instruments and techniques, including sonde, lidar, and microwave.

In order to achieve these goals, simultaneous and co-located measurements included: 3 water vapor Raman lidars (JPL and Goddard Space Flight Center (GSFC)) [0-20 km]; 16 CFH launches (JPL and GSFC) [0-30 km and total column]; 4 Frost-point Hygrometer launches (NOAA) [0-30 km and total column]; 58 RS92 launches (JPL and GSFC) [0-12 km and total column]; 2 improved microwave radiometers (Naval Research Laboratory and Univsity Bern) [20-80 km and total column]; 1 Fourier Transform Infrared Spectrophotometer (JPL) [total column]; 2 Global Positioning System receivers (JPL/NOAA and GSFC) [total column].

Additional high priority nights (i.e., selected timing and increased density of the measurements and balloon launches) corresponded to best coincidences with various satellite instruments.

Comparisons between the CFH and the JPL Raman lidar at Table Mountain show excellent agreement, with a systematic bias less than 2% up to 20 km altitude. Comparisons between the NOAA frost-point, Cryogenic Frost-Point, and Vaisala RS92 revealed systematic biases at various altitudes and relative humidity values already reported in the past. Comparisons of pressure/temperature profiles between RS92 and a new InterMet sensor revealed non-negligible systematic differences that critically impact the derivation of the Frost-Point water vapor mixing ratio. Comparisons of simultaneous and co-located Total Precipitable Water retrieved from at least six different instruments/techniques show general agreement within 10%.

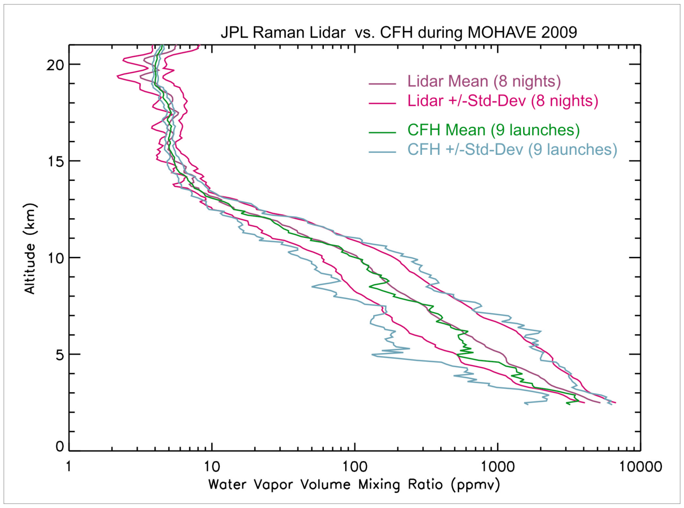

Figure 1. Comparisons between the CFH and the JPL Raman lidar at Table Mountain.

Determination of Dobson Spectral Characteristics, a New Method

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The Dobson instrument has been used for the determination of total ozone column (TOC) since the mid-1920s. A complete description of the instrument operation, principles of measurement, and use is available elsewhere; briefly, the instrument measures the difference between the intensity of selected wavelength pairs in the 300-340 nm spectral range. The ESRL Global Monitoring Division (GMD) operates 16 of these instruments throughout the world, and serves as the Central Calibration Laboratory for measurements with this instrument. The record of TOC starts in the early part of the 1900s, and the part of the record prior to 1979 is almost exclusively from measurements with the Dobson instrument. As newer measurement techniques are developed to measure TOC, the relationship with the existing record must be established. As the requirements for accuracy increase, a better understanding of the instrument characteristics is needed. In the past, only one Dobson instrument (D083, the World Primary Standard held at ESRL GMD) has had the slit functions measured. This is a time-consuming process that required the instrument be taken to a special facility specializing in this characterization. All other instruments have then been optically aligned mechanically to resemble that reference instrument. The data processing algorithms were developed based on the characteristics of the reference instrument, and consistently applied to the world network. There are differences in the TOC results of the individual Dobson instruments and stations, especially when compared to other measurement systems, ground-based and satellite-borne. To understand these differences, a method is being developed for quick characterization of the individual Dobson instruments while at the instrument's normal operational site. NASA provided several Avantes AvaSpec-2048x14 Fiber Optic Spectrometers (specifications are compatible with the Dobson instrument spectral characteristics) to ESRL for investigation. We present the first results of measurements inside the photomultiplier box of several Dobson instruments, and a method for determining the slit functions. In addition, investigation of other optical and spectral characteristics of Dobson, such as internal stray light levels, is ongoing.

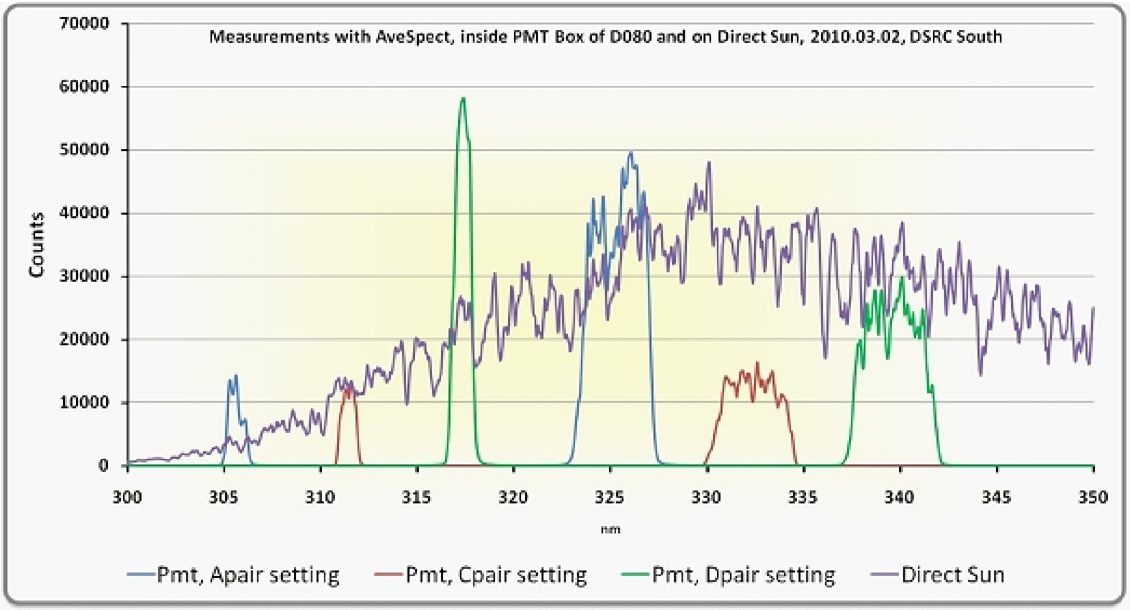

Figure 1. Unprocessed measurements on the direct sun and inside Dobson D080.

The Radiative Heating in Underexplored Bands Campaign (RHUBC): Evaluating Water Vapor Spectroscopy

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Radiative heating and cooling are important drivers of Earth's climate. In the mid-to-upper troposphere, the dominant radiative processes in both the solar and thermal regimes are due to water vapor. These processes are imperceptible from the ground in typical conditions due to absorption by water vapor in the intervening lower atmosphere. We will present the motivation and initial results from the RHUBC, a series of ground-based campaigns conducted under the auspices of the Atmospheric Radiation Measurement (ARM) program. The primary objective of RHUBC is to deploy state-of-the-art radiometers and spectrometers in dry environmental conditions so that the strong water vapor absorption bands remain semi-transparent. Radiosondes are also launched frequently to provide atmospheric state measurements. The first phase of the campaign, RHUBC-I, was conducted in February-March 2007 in Barrow, Alaska, with minimum observed precipitable water vapor (PWV) of 0.9 mm. The second phase, RHUBC-II, was conducted from August to October 2009 at an altitude of 5.3 km in the Atacama Desert, Chile; PWV values as low as 0.2 mm were observed. The RHUBC measurements span the microwave to the near-infrared, comprising a robust and complete dataset for evaluating water vapor line parameters and the water vapor continuum and providing a unique opportunity to assess the consistency of water vapor spectroscopy between the different spectral regions. In this presentation, we will focus on model/measurement comparisons in the microwave and sub-millimeter regions. Instrumentation deployed during RHUBC-II included a spectrally resolved sub-millimeter instrument - the Smithsonian Astrophysical Observatory Fourier Transform Spectrometer. Measurements from this instrument bridge the spectral gap between the regions covered by microwave radiometers and infrared spectrometers, allowing valuable ground-based validation of radiative transfer models from 300 GHz to beyond 1 THz.

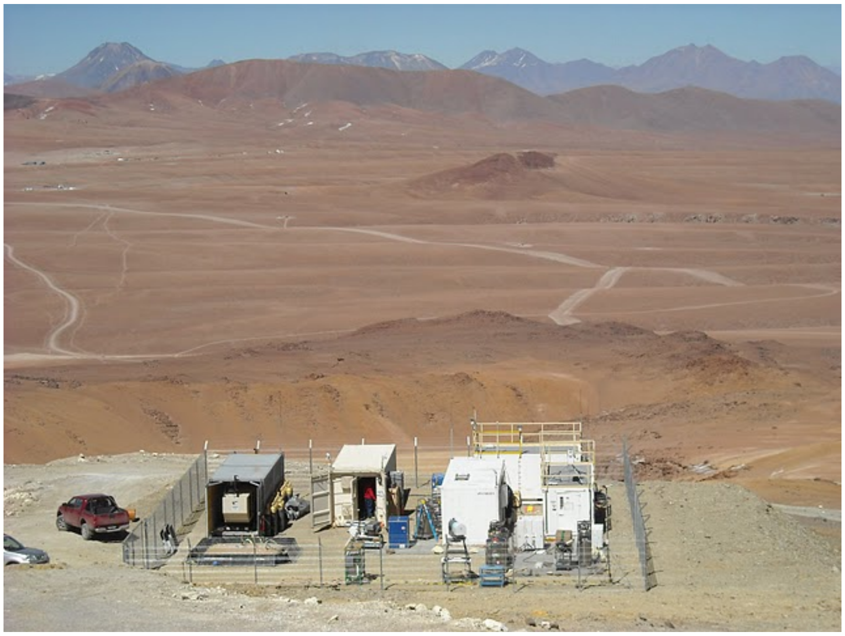

Figure 1. RHUBC-II was conducted from August to October 2009 at an altitude of 5.3 km in the Atacama Desert, Chile.

On the Reproducibility and Stability of Water Vapor in Stainless Steel Gas Cylinders

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Recent work by Solomon et al (2010) has sparked interest in the link between changes in stratospheric water vapor and changes in tropospheric temperature. There is a growing need to reliably measure trends and distributions of water vapor in the upper troposphere and lower stratosphere (UTLS). Measurement of water vapor in the UTLS region is difficult, and there has been some disagreement among measurement methods. The issue is complicated by the fact that accurate, stable sources of water vapor for calibration are difficult to obtain, particularly for use in field projects. We have explored the preparation of water vapor/air mixtures in electropolished stainless steel cylinders. Stable mixtures of humidified air at high pressure might be very useful as a tool to test water vapor instruments over long periods. They might also be used to link the calibrations of multiple instruments together, as long as the air taken out of the cylinder can be shown to provide a constant water vapor mixing ratio. We will present work performed to evaluate the stability and reproducibility of water vapor mixtures in electro-polished stainless steel cylinders.

Solomon, S., K. Rosenlof, R. Portman, J. Daniel, S. Davis, T. Sanford, G-K. Plattner, Contributions of stratospheric water vapor to decadal changes in the rate of global warming, Science, 10.1126/science.1182488, (2010).

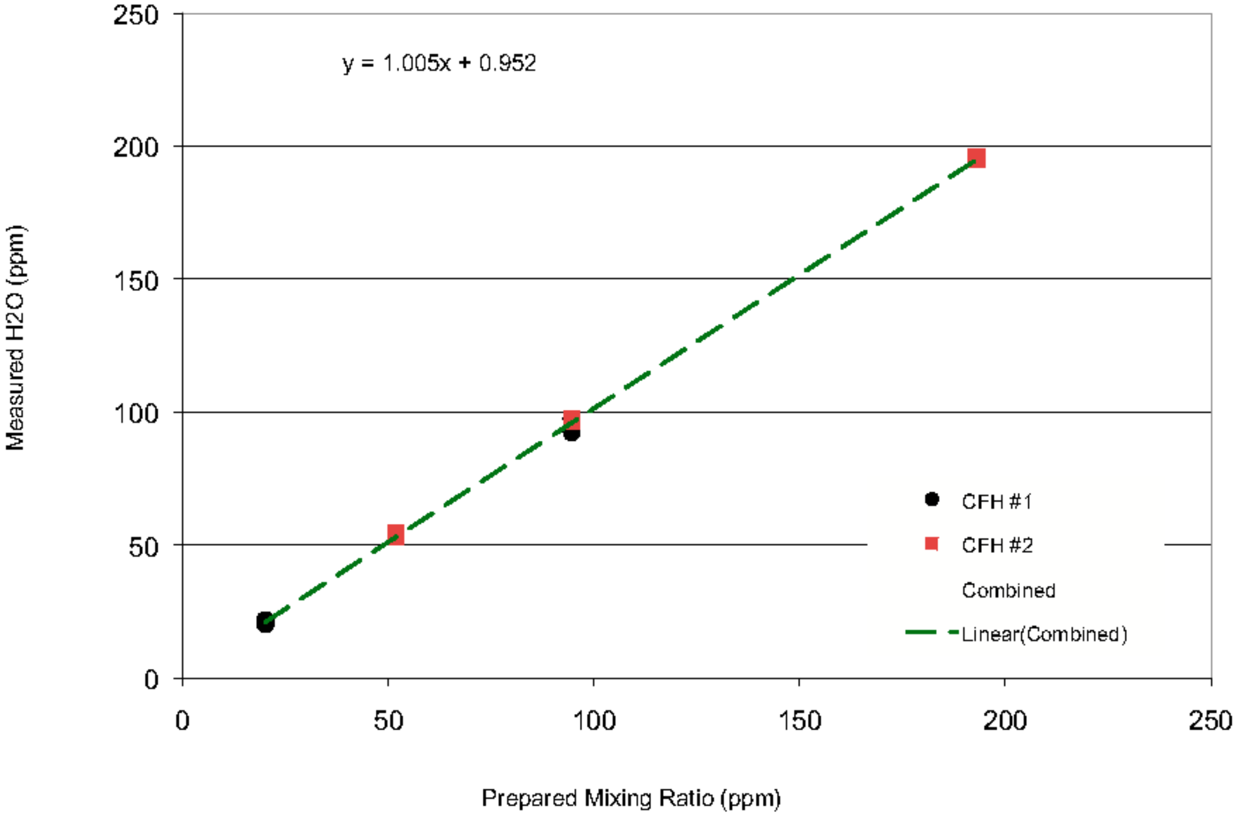

Figure 1. Analysis of water vapor mixtures prepared in stainless steel cylinders was performed using two cryogenic frost-point hygrometers.

Balloon-Borne Ozonesonde Measurements at South Pole in 2009: Ozone Hole 7th Lowest in 24-Year Record

B.J. Johnson and S.J. Oltmans

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Total column ozone at South Pole dropped from 241 Dobson Units (DU) in August to 98 DU measured on September 25, 2009 (Figure 1). This minimum places 2009 as the 7th lowest ozone hole in the 24-year ozonesonde record from Amundsen Scott South Pole Station. The NOAA ESRL has measured vertical profiles of ozone and temperature at South Pole using balloon-borne electrochemical concentration cell ozonesondes since 1986. Balloon flights are done weekly, then increase to 2-3 per week during the ozone hole period in September and October. Typically, the lowest amount of ozone over South Pole is observed between September 26 and October 11, and can fluctuate each year depending on the position and stability of the polar vortex and stratospheric temperatures. The 24-year average minimum is 112 DU, with the record low at 89 DU measured on October 6, 1993. NOAA and the NASA Ozone Monitoring Instrument satellite observations showed that the 2009 ozone hole area (regions with <220 DU) was about average, reaching a maximum of 23.7 million sq. km (9.2 million square miles), just under the size of North America. Longer-term ozone hole conditions are determined by chlorine and bromine concentrations in the stratosphere. Chlorine levels are on a slow decline since 1995 (Global Monitoring Division/Halocarbons & other Atmospheric Trace Species Group), but this year’s low ozone indicates the halogen levels remain high enough for severe ozone depletion each spring over South Pole Station, Antarctica.

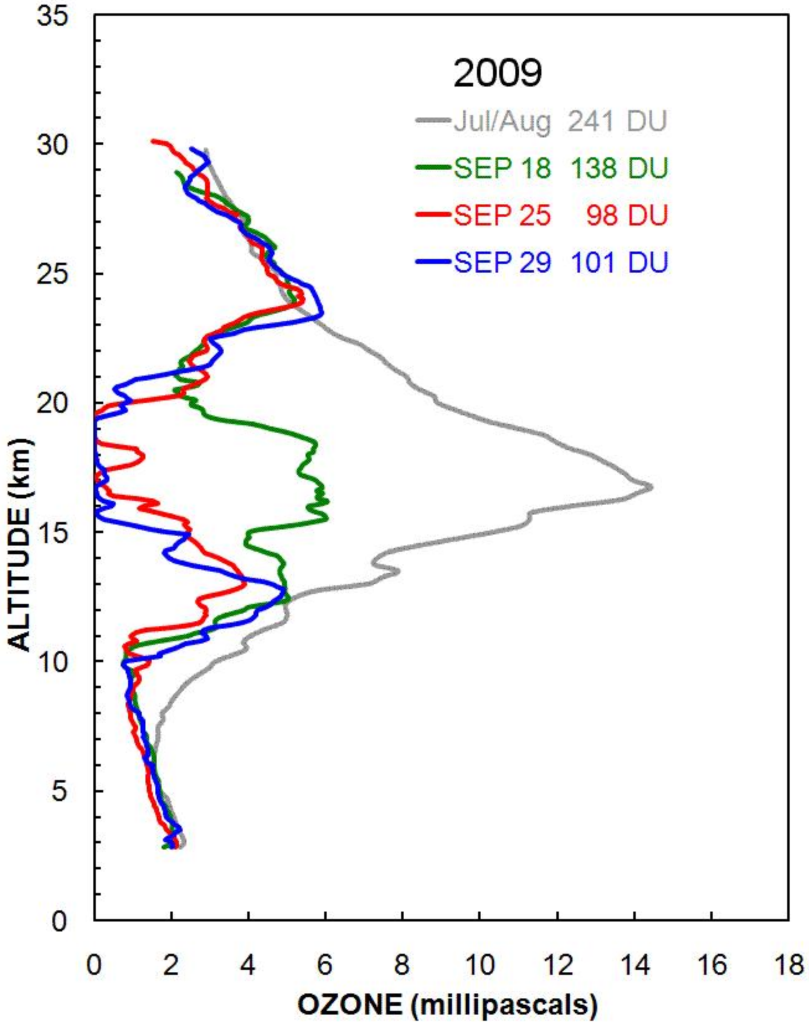

Figure 1. Four selected profiles of altitude vs ozone partial pressure (millipascals) measured by ozonesondes at South Pole Station. The profiles show the pre-ozone hole average in July and August (241 Dobson Units), a mid-September profile and the minimum values of 98 and 101 DU measured at the end of September.

Some Results of Surface and Tropospheric Ozone Measurements in Mongolia

D. Oyunchimeg

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The results of measurements of the Buryat Science Centre of the Russian Academy of Science and the Institute of Meteorology and Hydrology of Mongolia show there are diurnal and weekly variations of trace gases transported from Russian industrial regions south east to Mongolia. Occasionaly this air contains high concentrations of surface ozone. Also, general circulation and weather conditions affect the concentrations of trace gases. [G.S. Zhamsueva, A.S. Zayakhanov, V.V. Tsydypov, A.A. Ayurzhanaev, D. Oyunchimeg.D. Azzaya 2009]. Figure 1 shows that the same annual variation of surface ozone in Ulaanbaatar is similar to European stations with relatively high concentrations in Mongolia. [Data from the NOAA ESRL Global Monitoring Division and the Global Atmosphere Watch Training & Education Center].

References:

1. G.S. Zhamsueva, A.S. Zayakhanov, V.V. Tsydypov, A.A. Ayurzhanaev, D. Oyunchimeg.D. Azzaya. Some results of trace gases measurement of Russian Mongolian expedition in Mongolia Govian region, Papers in Meteorology and Hydrology, Mongolia 2009.

2. D. Oyunchimeg, GHG measurement results in Mongolian gobi, presentation for workshop for Mongolian southern regional climate change 16-18 Sep 2009, Sainshand Mongolia.

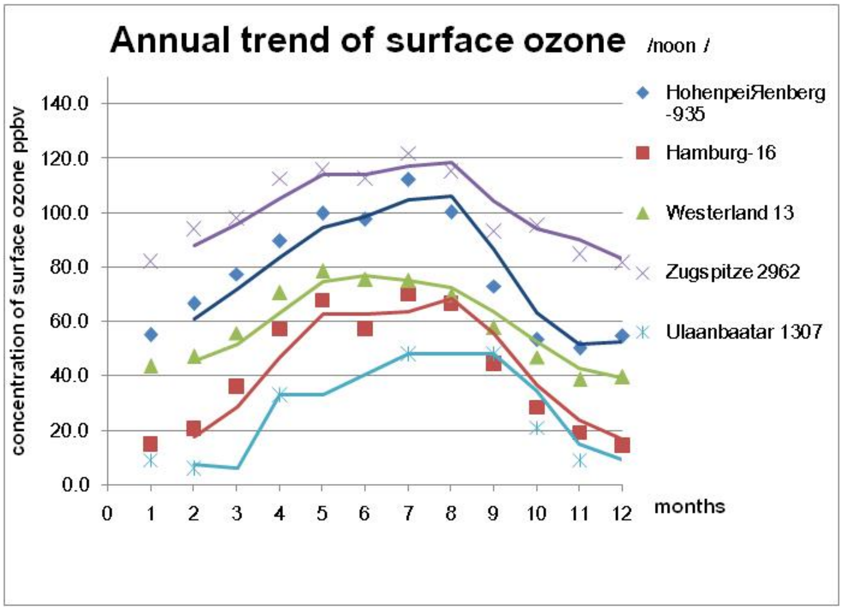

Figure 1. Annual trend of surface ozone in Ulaanbaatar compared with European stations.

Trace Gases Measurement Results of Russian-Mongolian Expedition in the Arid and Semi-Arid Region of Mongolia

G.S. Zhamsueva[1], A.S. Zayakhanov[1], V.V. Tsydypov[1], A.A. Ayurzhanaev[1], D. Oyunchimeg[2] and D.Azzaya[2]

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[2]Climate Change and Environmental Research Center, Institute of Meteorology and Hydrology, Ulaanbaatar, Mongolia

The scientific expedition of the Buryat Science Centre of the Russian Academy of Science and the Institute of Meteorology and Hydrology of Mongolia has worked in the Mongolian arid and semi-arid desert region (Sainshand) during summers from 2005-2008. We have measured surface ozone, NO_2, CO_2, aerosol optical depth and meteorological parameters in this region which is free of anthropogenic influence. The results show that there has been a lot of diurnal and weekly variation of trace gases and sometimes high concentrations of surface ozone and NO_2 (Figure 1) during the period. We have used the NOAA-HYSPLIT model and found that there was long-range trace gases transport from Russian industrial regions to the South East region of Mongolia. It was also noted that general circulation and weather conditions affect the concentration of the trace gases.

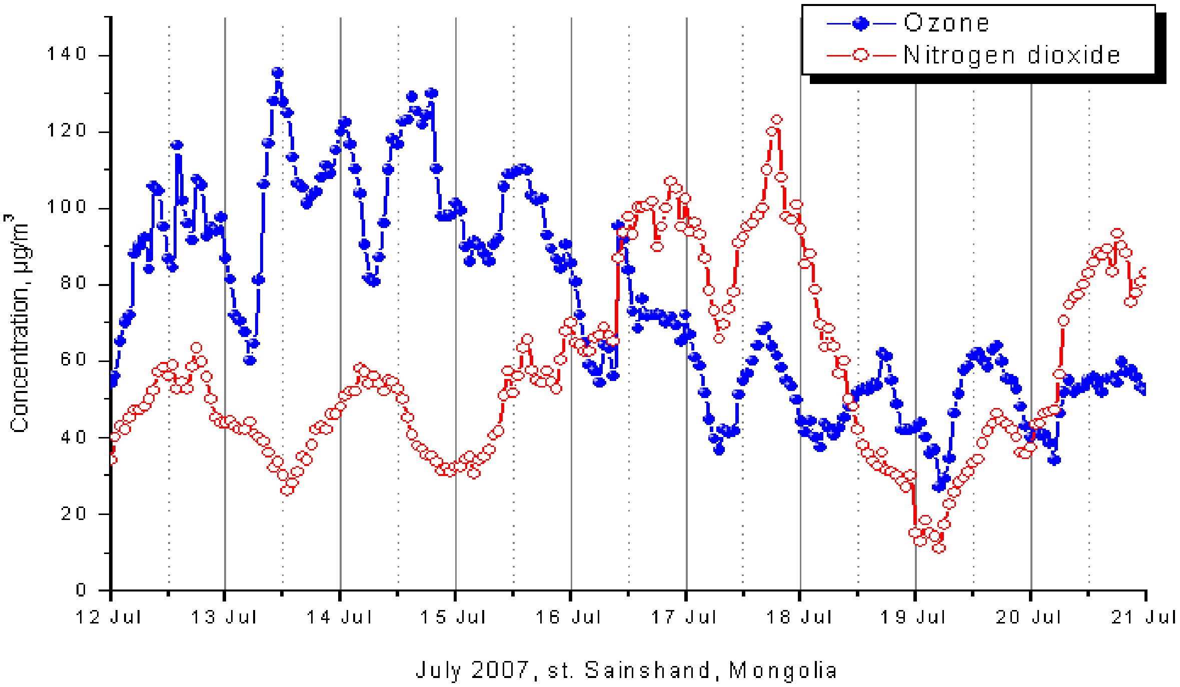

Figure 1. Surface ozone and nitrogen dioxide concentration at Sainshand from 12-21 July 2007 .

Influence of Transport by the Nocturnal Jet on Ozone Levels in Central Texas

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

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KWKT tower in Moody, Texas has been the home to NOAA ESRL's CO, CO_2, and meteorological continuous-monitoring equipment since 2006. Additional instrumentation was installed in April 2009 and the tower now hosts a number of continuous-sampling instruments at multiple levels (6m, 30m, 122m and 457m above ground level) that measure ozone, carbon dioxide, carbon monoxide, and meteorological components (temperature, relative humidity, wind direction and wind speed) every 30 seconds. The primary purpose for this ongoing study is to determine whether ozone levels in central Texas are influenced by the nocturnal transport of air that carries ozone and precursors from upwind sources. In addition to continuous tower measurements, an ozonesonde campaign was conducted at the tower site during late August and September, 2009, which is a time of year with many high ozone (O_3 > 80 ppb) days. Newly installed and already existing instrumentation at the site is discussed. General seasonal trends and findings are presented, including quantification of diurnal and seasonal nighttime median wind, ozone, CO and CO_2 values. Evidence suggests that a low-level nighttime continental jet exists and generally influences the region by transport of low ozone "clean" air from the Gulf of Mexico. Occasionally, the low-level nocturnal jet carries high ozone to the vicinity, but does not appear to have a strong affect on surface ozone levels. However, high ozone levels were often found to be a result of non-jet North/Northeast winds that have travelled from the vicinity of Dallas before reaching the tower. Study conclusions, recommendations for further study are also discussed.

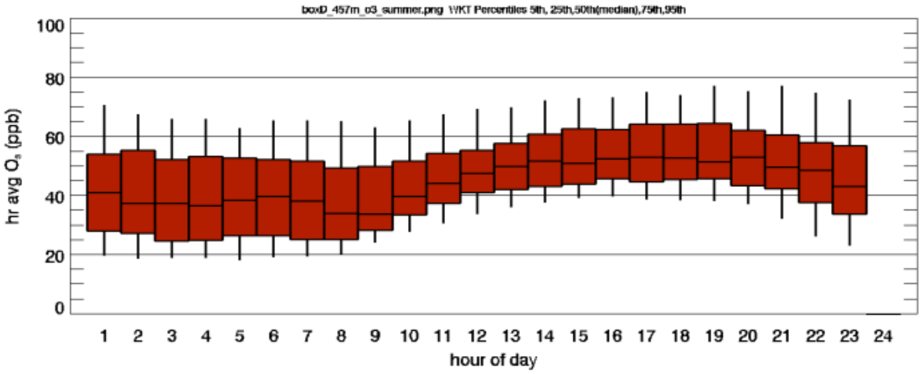

Figure 1. KWKT nighttime O_3 percentiles (5th, 25th, 50th (median), 75th, 95th) at the 457m tower level in summer (Jul, Aug, and Sep).

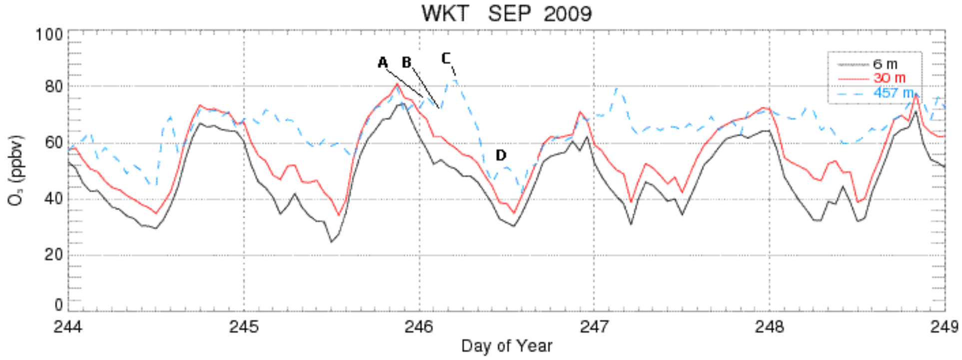

Figure 2. September 2009 hourly-ozone averages at times marked A, B, C, D were found to originate in various locations through the use of HYbrid Single-Particle Lagrangian Integrated Trajectory back trajectories.

Ozone Depleting Substances, Emissions and Trends Derived by Long-Term Continuous Measurements at a European Site

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Chlorofluorocarbons, methyl chloroform, carbon tetrachloride, methyl bromide and halons are the principal ozone depleting substances. In response to the United Nations Environmental Programme Montreal Protocol on Substances That Deplete the Ozone Layer and subsequent amendments, production and consumption of these gases have been prohibited in developed (non-A5) countries since 1996, with the exception of methyl bromide, for which the Protocol asked for a complete phase-out in 2005. The Protocol also regulates the hydrochlorofluorocarbons (HCFCs), i.e. low-ozone-depletion potential substitutes classified under the Protocol as "‘transitional substitutes," to be used during the time it took to commercialize new ozone-safe alternatives and replacements. HCFCs are being progressively phased out in non-A5 countries, meanwhile in A5 countries they will not be regulated before 2016. In the absence of regulations in developing countries, the demand for HCFCs in many applications is expected to increase (Montzka et al., 2009; Velders et al, 2009).

Continuous high-frequency measurements of a wide range of ozone depleting substances (ODSs) have been made at the Consiglio Nazionale delle Ricerche Atmospheric Research Station of Monte Cimone, on the highest peak of the Italian Northern Apennines, since 2001, using an automated gas chromatographic-mass spectrometric system. The activity has been carried out within the European Union funded project "System for Observation of Halogenated Greenhouse Gases in Europe." Long time series are therefore available, showing different trends according to their different lifetimes.

However, for methyl chloroform and halons differently than expected in a phase out regime, elevations from the baseline are recorded, indicating that ODSs are still being released even if not reported. Elevations above the baseline, together with air mass back trajectories analysis, allow the identification of source regions. For the HCFCs, high values of acceleration in the growth rate have been found, reflecting the increase in global emissions resulting from the increase of demand in Asian countries.

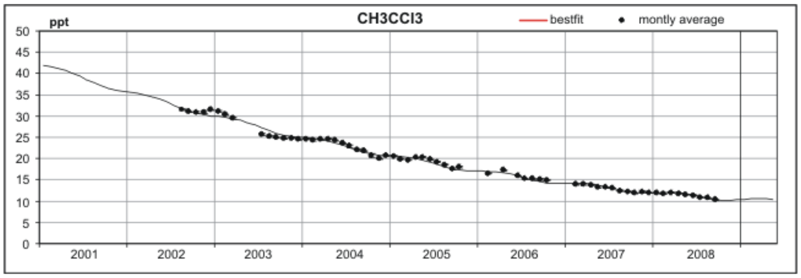

Figure 1. Long term trend of methyl chloroform recorded at the mountain site of Monte Cimone, Italy.

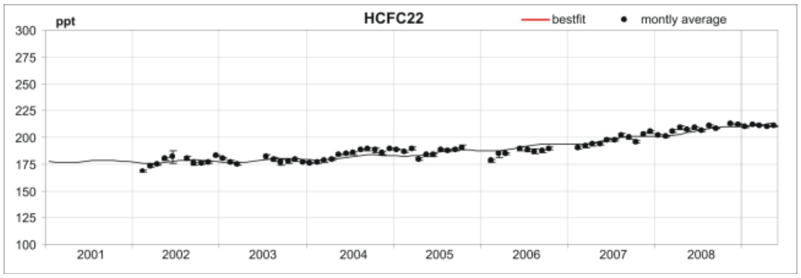

Figure 2. Long term trend of HCFC-22 recorded at the mountain site of Monte Cimone, Italy.

Long-Lived Halocarbons and Other Atmospheric Trace Species Trends

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In the mid-1970s, the NOAA Geophysical Monitoring for Climate Change (GMCC) program started. Among many obligations, GMCC focused on long-term trace gas measurements. As GMCC grew into a division and then a premier laboratory (NOAA ESRL), the trace gas measurement program evolved into groups with separate programs. Today's Halocarbons and other Atmospheric Trace Species Group measures 40+ atmospheric trace gases via flasks or *in situ* methods at surface sites and aboard airborne platforms. NOAA halocarbon measurements in the 1970s and 80s demonstrated the rapid increase due to unregulated anthropogenic uses. Throughout the 1990s, global growth rates of all major chlorofluorocarbons (CFCs), excluding CFC-12, steadily declined as a result of commitments to the Montreal Protocol. By the mid-2000s, CFC-12s growth rate had reached zero and continues to decline. Current and past global tropospheric trends of halocarbons and nitrous oxide (N_2O) will be shown in this presentation.

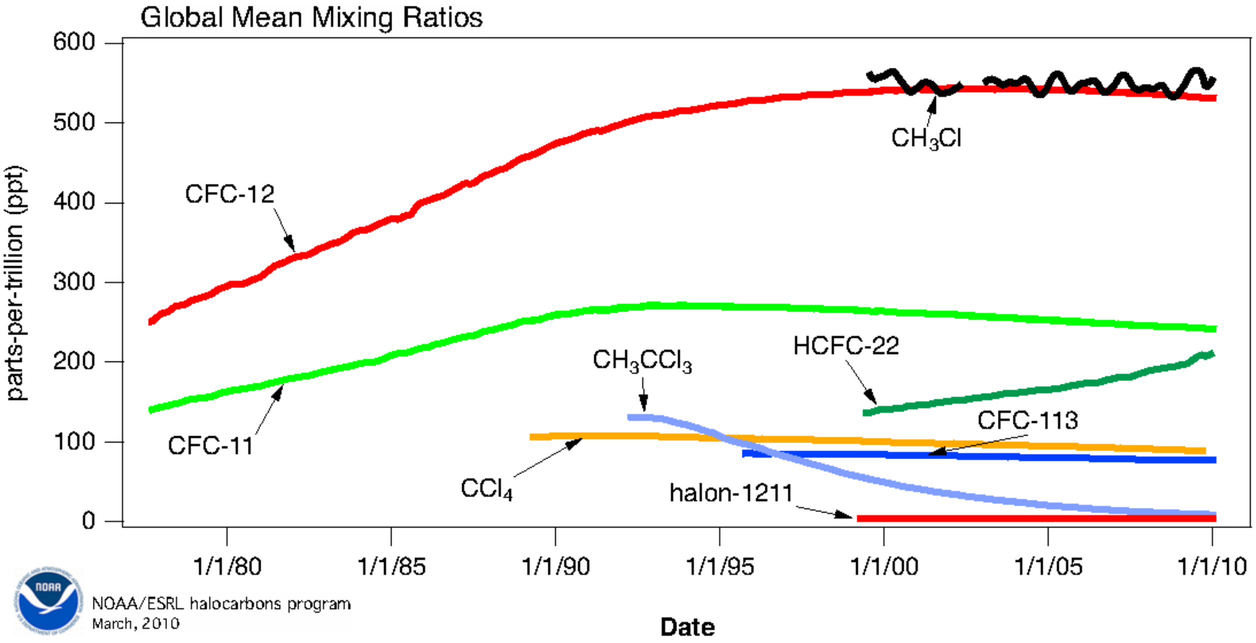

Figure 1. Global atmospheric trends of halocarbons measured by ESRL Global Monitoring Division show the dramatic rise (CFC-11 and CFC-12) and decline (CH_3CCl_3) of ozone depleting gases.

HOCl and Cl_2 in the Remote Marine Atmosphere

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The chlorine (Cl) atom may be an important sink for methane, ozone, and non-methane hydrocarbons in the marine atmosphere. However, the processes giving rise to Cl remain poorly understood, and estimates of Cl concentration vary widely. Cl atom concentrations have been inferred using the hydrocarbon clock technique, methane and methane isotope budgets, and gas/aerosol photochemical models. To date, there have been very few measurements of Cl atom precursors in marine air. We measured HOCl and Cl_2 at the Cape Verde Atmospheric Observatory (CVAO) in the remote tropical Atlantic (17 °N, 25 °W) during May-June 2010. HOCl ranged from <10-103 ppt and was primarily present during the daytime. Cl_2 ranged from <1-35 ppt and was primarily present at night. The levels of these Cl atom precursors were elevated in air masses originating over southwestern Europe, and lower in air masses originating over the remote Atlantic. The photolysis rates of HOCl and Cl_2 provide a lower bound on Cl atom production. Based on this estimate for Cl production alone, Cl accounted for up to ~8% of local daily methane destruction during the campaign. However, multiphase photochemical box model simulations show that the total Cl production rate was significantly larger than this estimate. Observed HOCl levels during the campaign were higher than predicted by the model, suggesting the existence of an unidentified mechanism for the production of reactive chlorine in marine air.

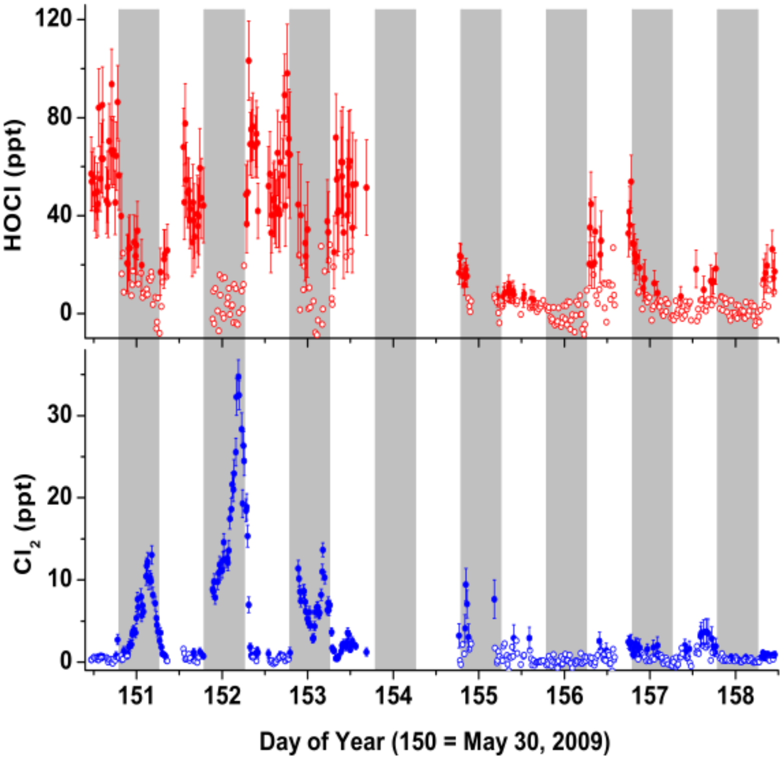

Figure 1. HOCl and Cl_2 mixing ratios at CVAO during May 30 - June 7, 2009. Closed circles are data points above the detection limit, and open circle points are below detection. Gray shading indicates nighttime. Error bars are +/- 1 standard error.

Abiotic and Biogeochemical Signals in the Seasonal Cycles of Atmospheric Nitrous Oxide

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The seasonal cycle of atmospheric nitrous oxide (N_2O) is difficult to quantify due to the small signal to noise ratio and large interannual variability in the data. Differences among four monitoring networks (Advanced Global Atmospheric Gases Experiment (AGAGE), Commonweath Scientific & Industrial Research Organization, NOAA Carbon Cycle Greenhouse Gases, and Halocarbons & Other Atmospheric Trace Species (HATS) also influence the interpretation of the N_2O seasonal cycle. In the northern hemisphere, correlations between N_2O seasonal minimum anomalies and polar winter stratospheric temperature provide compelling evidence for a stratospheric influence, which may dominate the N_2O seasonal cycle at many stations. In the southern hemisphere, oceanic signals are comparable in magnitude to stratospheric signals. The oceanic signals include both thermal in/outgassing and ventilation components and are easier to distinguish in N_2O data than in other atmospheric species, e.g. CO_2 or O_2/N_2. As a result, N_2O seasonal cycles can provide insight into these important oceanic processes.

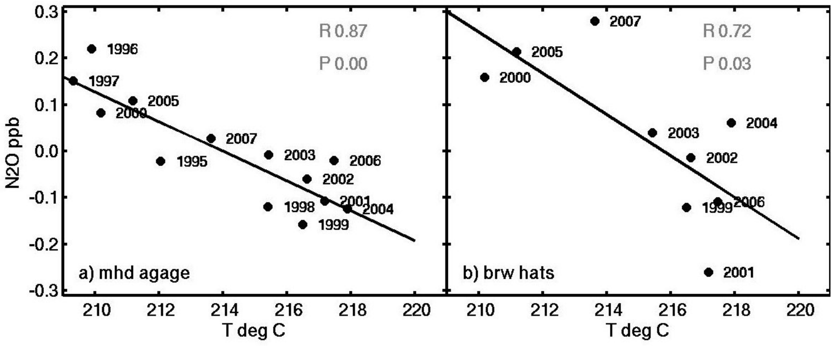

Figure 1. N_2O seasonal minimum anomaly plotted against mean January-March 100 hPa 60-90N lower stratospheric temperature: a) AGAGE data at Mace Head, Ireland, b) NOAA HATS data at Barrow, Alaska. Wintertime lower stratospheric temperature is a proxy for the strength of the seasonal descent of N_2O-depleted air from the middle and upper stratosphere, with greater descent occurring in warm years.

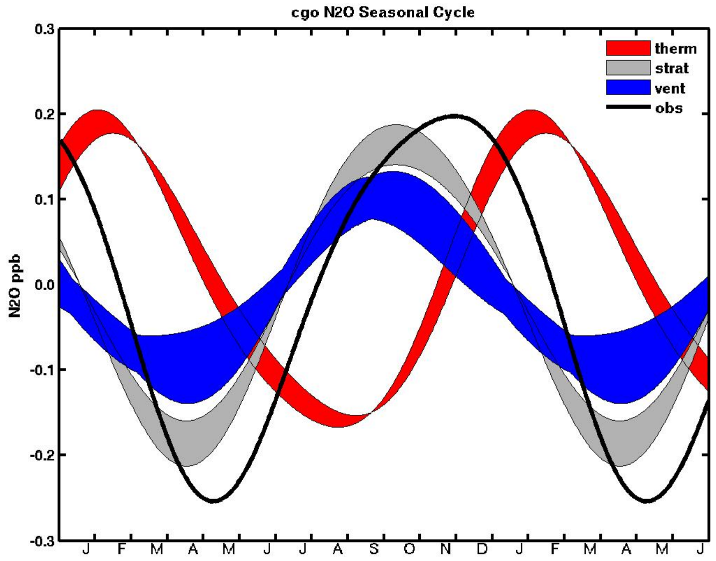

Figure 2. Partitioning of the observed mean N_2O seasonal cycle at Cape Grim, Tasmania into ventilation, thermal in/outgassing and stratospheric components, estimated based on AGAGE N_2O and CFC-12 data and National Centers for Environmental Prediction heatfluxes.

Hydrocarbon and Terpene Gas Standards Research and Development to Assist in Atmospheric Measurements

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The World Metrological Organizations (WMO) Global Atmospheric Watch (GAW) group responsible for Volatile Organic Compounds (VOC) has been measuring hydrocarbons and terpenes for many years but has seen large discrepancies in available calibration standards. In 2006 the WMO/GAW-VOC group approached the National Metrology Institutes (NMIs) worldwide to collaborate together and develop calibration gas standards for key hydrocarbons and terpenes. The NMIs, working through the Consultative Committee on the Quality of Material/Gas Analysis Working Group, have individually researched and developed gas mixture standards. The Gas Metrology Group (GMG) of the Analytical Chemistry Division at the National Institute of Standards and Technology (NIST) has successfully developed a suite of standards containing 18 alkane, alkene and aromatic hydrocarbons (in nitrogen) ranging in concentrations from 50 to 250 ppt. International comparisons between participating NMIs are currently ongoing with some preliminary results indicating good agreement. The GMG of NIST is currently researching stability of terpenes and monterpenes in treated aluminum gas cylinders at low ppb concentrations. Four of 11 terpenes studied have demonstrated 7 month stability, while others indicate that chemical reactions may be taking place within the gas mixture. Limited comparisons between NMIs have been undertaken with preliminary results indicating mixed agreement. Agreement between the suite of ppt hydrocarbon standards and the terpene stability issues will be illustrated and discussed.

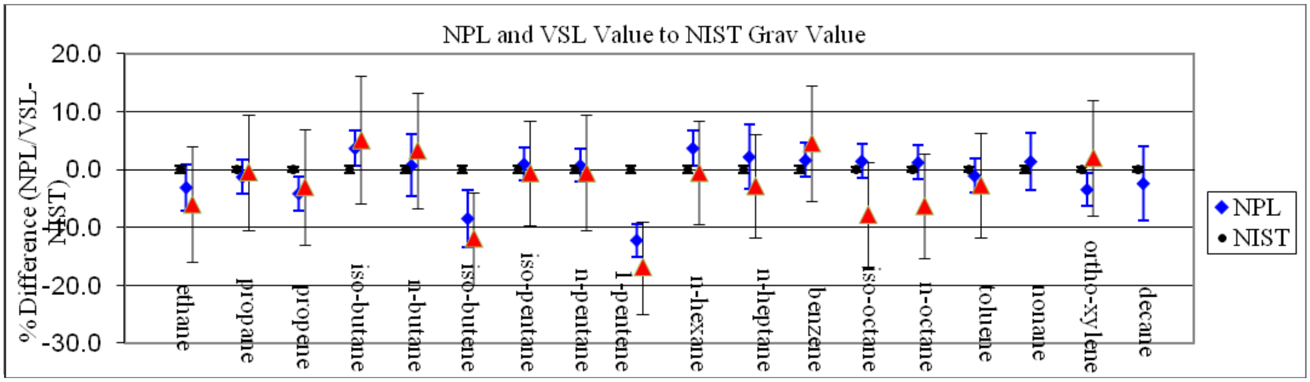

Figure 1. Preliminary results between National Physical Laboratory (NPL), Van Swinden Laboratoruim (VSL) and NIST at nominal 200 ppt hydrocarbon standard. Agreement is in general better than 4.0 % but iso-butene and 1-pentene may be degrading.

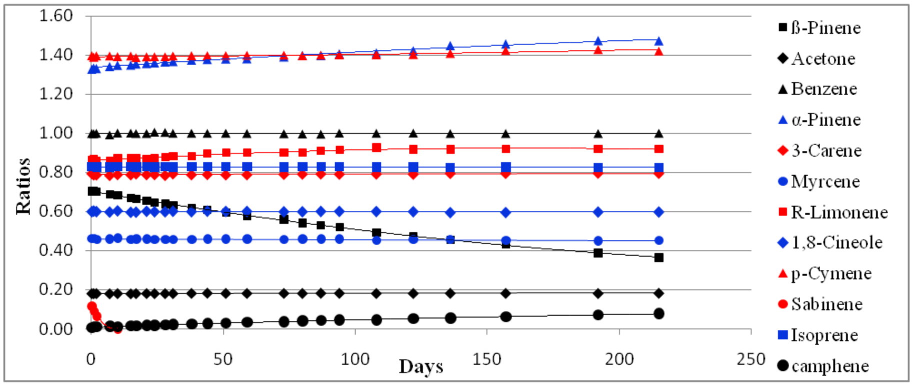

Figure 2. Stability of terpene gas mixture at nominal 5 ppb in aluminum cylinder over days.

Hyperspectral Infrared Imager (HyspIRI) - A Sensor Optimized for Tracking Earth Surface Processes for Climate Analysis

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Among the sensors recommended in the 2007 National Research Council Decadal Survey for Earth science is a moderate resolution hyperspectral sensor with a repeat cycle sufficient to track seasonal processes in the biosphere and cryosphere. This recommendation led to the development of the HyspIRI mission concept, which is now being considered for flight in the ~2015 time period. The HyspIRI mission includes two instruments mounted on a satellite to be flown in low Earth orbit. There is an imaging spectrometer measuring from the visible to short wave infrared (VSWIR) and a multispectral thermal infrared (TIR) imager. The VSWIR and TIR instruments will both have a spatial resolution of 60 m at nadir. The VSWIR will have a temporal revisit of approximately 3 weeks and the TIR will have a temporal revisit of approximately 1 week. These data will be used for studies of terrestrial and coastal ecosystem composition, function, and condition; carbon cycle science; biomass burning (fuels, severity, recovery); water resource; volcanoes; cryospheric processes; and climate change impacts assessment and prediction. The presentation will focus on the support HyspIRI will provide to the climate sciences.

Figure 1. NASA has an extensive array of observing systems in 2010, though many are at or past their design life.

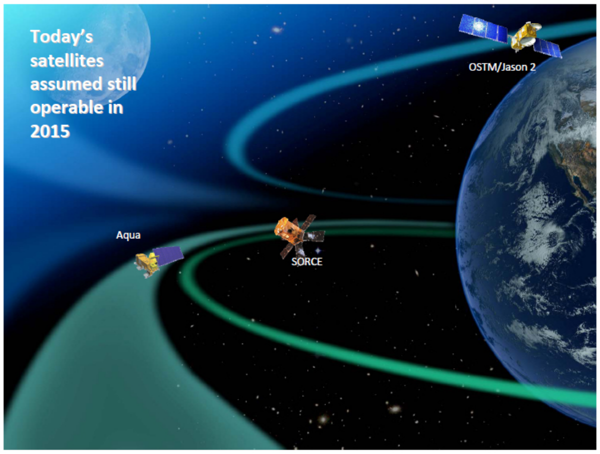

Figure 2. NASA's observing capabilities could be substantially thinned by 2015 unless new systems are deployed.

Variability of Spectral Albedo at Table Mountain, Colorado

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We explore the variability of spectral albedo, including the breakdown of the white- and black-sky components, using data collected at the ESRL Global Monitoring Division's Table Mountain Surface Radiation station. The instrumentation used for this study are lamp calibrated Multi-Filter Rotating Shadowband Radiometers. These instruments measure at six narrowband channels: 415, 500, 615, 673, 870, and 940 nm. White-sky albedo is the reflectance of the surface under diffuse-sky conditions. Black-sky albedo, also known as directional hemispherical reflectance, is the reflectance of the surface from direct-beam illumination only. Using the surface albedo measured under overcast conditions, the components of the upwelling signal can be separated under black-sky conditions. The primary assumption for this analysis is that diffuse albedo is comparable under both cloudy and clear-sky conditions.

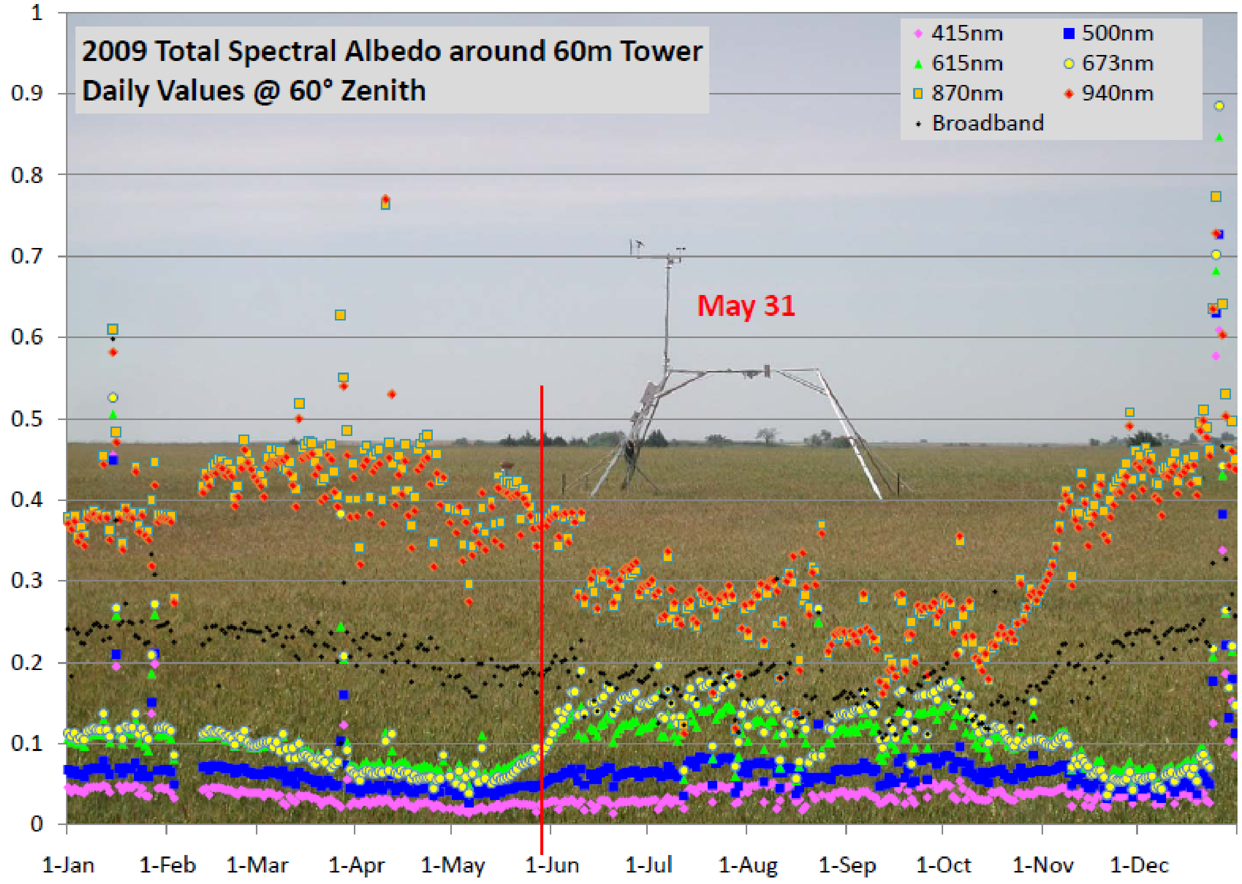

Figure 1. Shown is a plot of spectral albedo vs time. Location is an agricultural field at the Atmospheric System Research (ASR, formally ARM) facility in north-central Oklahoma. The narrowband data are collected with Multi-Filter Rotating Shadowband Radiometers. The down-pointing unit is located at the 25m level of the ASR 60m tower. The broadband data, shown for reference, are measured with separate instruments. The background image is from May 31, 2009, and is indicated by the red vertical line.

Explaining the Seasonal Variation of MultiFilter Rotating Shadowband Radiometer (MFRSR) *in situ* Calibrations and Effects on Aerosol Optical Depth (AOD)

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Long-term visible MFRSR *in situ* top-of-atmosphere (TOA) spectral channel calibration (V_o) time series show a repeatable seasonal periodicity that, if not treated properly, could adversely impact AOD climatologies. Relatively high calibrations in summer, low values in winter, and an orderly transition through the equinoxes are observed. The average amplitude is ±4%, which translates to an AOD error of 0.04, if interpolation of the calibrations to individual days for AOD analysis is not treated properly. This seasonal behavior is reproducible for all MFRSRs and is superimposed on sensor drift. The nature of the observed periodicity suggests a temperature dependence. Although the MFRSR head is designed to be stabilized at 40°C operational data show that the temperature of the head electronics varies in the same direction as the outside temperature but to a lesser degree, while the temperature of the filters and detectors, which are better exposed to the heater, remains stable. Possible sources of the periodicity were narrowed to changes in the transmission of the diffuser with temperature and the thermal response of the head electronics. A laboratory experiment was designed to test these effects. Several MFRSR heads were placed in an environmental chamber and exposed to ambient air temperatures that were systematically stepped from -5°C to 45°C, and back (light blue ramps in Figure 1). The head electronics temperature responded by varying from 34°C and 45°C. Because the MFRSR has no cooling capacity, when the air temperature surpassed 40°C the electronics' temperature matched the outside temperature. A sample response of the MFRSRs spectral channel output for a constant light source is shown in Figure 1 as a function of the chamber air temperature (light blue ramps). Channel response to the constant light source departed from the initial value (measured at -5°C) by a maximum of 9% to 58% as the chamber temperature approached 40°C. When measurements without a light source (dark signal) were removed, those amplitudes reduced to 2% - 7%, strongly indicating that the response of the head electronics to changes in temperature is a likely source of the observed seasonal variation of *in situ* calibrations. The experiment also revealed that the MFRSR diffuser transmission changes by 1% as its temperature passes through 19°C. That effect is caused by molecular structural changes to Spectralon (a form of Teflon that the diffuser is made of) that occur around 19°C. The maximum effect of this change in diffuser transmission on V_o was found to be 0.22%, which is negligible compared to the ±4% seasonal variation of V_o, most of which is attributable to the thermal response of the head electronics. This experiment proved that the seasonal variation of MFRSR *in situ* TOA calibrations is real and must be accounted for when interpolating those calibrations to individual days for AOD analysis.

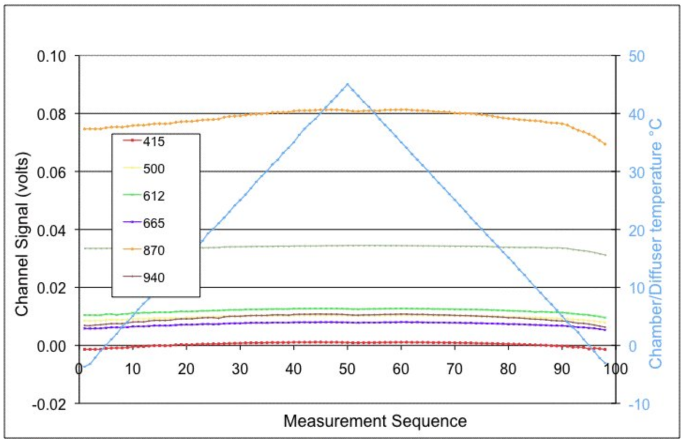

Figure 1. MFRSR channel voltage (left y-axis) output time series for a constant light source as the air temperature changes from -5°C to 45°C and back (light blue ramps, right y-axis).

The Role of Ultraviolet (UV) Solar Radiation in Erythema and Vitamin D Synthesis

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A smart-phone application has been developed for calculating time to sunburn and solar vitamin D production. UV exposure is directly related to squamous cell carcinoma and basal cell carcinoma and is a factor in malignant melanoma. UV from the sun is needed for the production of vitamin D, whether in plants or in human bodies. Severe vitamin D deficiency results in rickets in children, a deforming bone disease, and osteomalacia in adults. The health benefits of vitamin D include the strengthening of bones and muscles, and a lowered risk for some types of autoimmune diseases and cancers such as colon and breast cancer. The smart phone application is to provide a tool for sensible sun exposure that avoids erythema while optimizing vitamin D production. This tool utilizes a cloud-based and a cloud-free UV Index forecast from the NOAA's Climate Prediction Center. Several methods are proposed for applying cloud modification factors to the clear-sky UV Index forecast. Vitamin D production from sunlight is calculated from the UV Index using calibration and correction factors to convert from erythemally weighted solar irradiance to solar irradiance weighted with the Commission internationale de L'Eclairage vitamin D action spectrum and with an earlier version of the vitamin D action spectrum. The correction factors from UV Index to vitamin D weighted solar irradiance were calculated using the tropospheric UV and visible radiative transfer code. Results for vitamin D production are presented as a function of latitude and season.

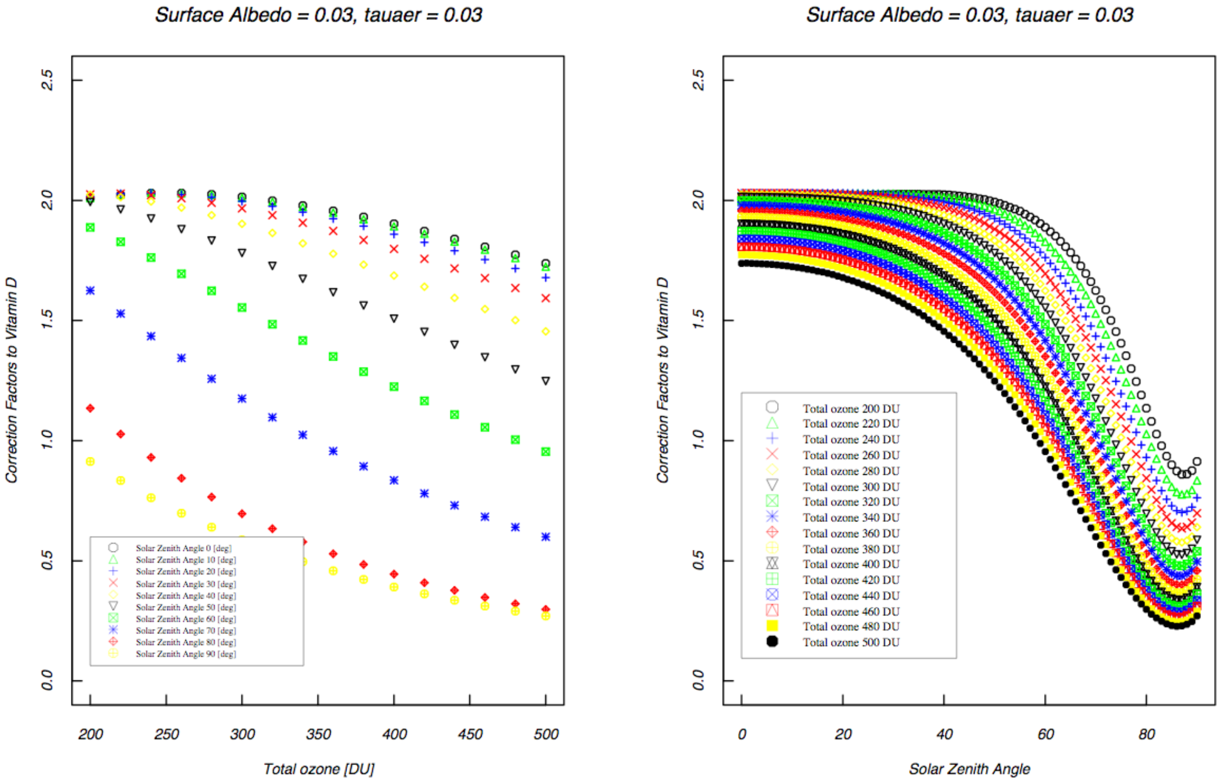

Figure 1. Correction factors for the conversion of UV Index to Vitamin D weighted solar irradiance.

The Current Configuration of an Automated Cleaning System Coupled With Modified Ventilation Design at the Kwajalein Baseline Surface Radiation Network (BSRN) Site in the Republic of the Marshall Islands

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Broadband shortwave and longwave surface radiation measurements were initiatied at the weather station located on Kwajalein atoll in 1989. The site was modified in April 1996 and became one of the NOAA ESRL BSRN sites. Modifications included installation of an automated solar tracker configured for solar direct beam, diffuse sky shortwave and downwelling longwave radiation measurement using a shaded pyranometer and shaded pyrgeometer plus meteorological measurements of temperature, humidity, windspeed and direction plus pressure. The current installation consists of redundant measurements of direct beam, diffuse sky irradiance plus total solar irradiance (unshaded pyranometer), optical depth using a four channel sun photometer. The site is located on the roof of a building and is continuously exposed to surf zone air containing fine sea salt laden water droplets which fog over the optical surfaces of solar sensors. In spite of the frequent rain showers which flush the sensor windows, the clear periods with no showers pose the most challenging measurement environment since a typical daily cleaning by station personnel is not adequate to keep the sensors acceptably clean for the whole day. Multiple daily cleanings under persistent clear conditions proved necessary to avoid measurement degradation due to salt spray fogged sensor optics. In 2004 an initial version of an automated washing system and modified ventilation system was installed and activated as needed via modified data logger software. This poster describes the current configuration and design of the automated system as it has evolved over the past five years. The basic components (air blowers and washing fluid pump) of the system have proved reliable but the maritime tropical environment of Kwajalein has been challenging for plumbing components used for water and ventilation. Currently, the most sustainable system design to date is described but still requires refurbishment and replacement every twelve to eighteen months due to material degradation in the Kwajalein environment.

Figure 1. A view of the sensor wash cycle in operation at the Kwajalein BSRN site. The sensor domes are sprayed with water obtained from a fresh water line inside the building on which the tracker is mounted. Each cycle lasts about 15 seconds and is turned on and off via software in the data logger program. The sensors are ventilated using conditioned air pumped continuously by regenerative blowers located inside the building. Two blowers are used to add redundancy.

Photosynthetically Active Radiation (PAR) Attenuation in the Atmosphere in North China

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Integrated observations of solar radiation and meteorological parameters at 4 stations in North China from September 2004 to October 2006 show that PAR and global radiation (Q) were influenced by water vapor and aerosol scattering factors. From these measurements, an empirical model of hourly PAR under all sky conditions for North China was developed. The annual average PAR at the Earth's surface in North China attenuated by the water vapor factor and its ratio to PAR were 7.99 Wm^{-2} and 4.24%, and PAR at the Earth's surface attenuated by the scattering factor and its ratio to PAR at the Earth's surface were 172.36 Wm^{-2} and 95.76%. PAR losses influenced by water vapor and scattering in the atmosphere are 15.33, 309.30 Wm^{-2} in North China, respectively. This energy loss displayed seasonal variations and regional differences. Sensitivity tests shows that PAR displayed different responses to different changing rates of the water vapor factor and the scattering factor; PAR is more sensitive to the change of the scattering factor than that of the water vapor factor. The relation of the water vapor factor and PAR indicated a close relation with water, the sum of direct absorption and indirect consumption (in the reactions of chemistry and photochemistry through hydroxyl radicals, including homogeneous and heterogeneous processes) and by various substances (including gases, liquid and solids) in the atmosphere. PAR at the top of the atmosphere was calculated by an empirical model, its error was -3.5%. The consumed energy in the atmosphere is related to water or water vapor and is not fully recognized at present, but, it influences almost all basic processes in the atmosphere, such as radiation transmission, atmospheric chemistry and photochemistry, biological process on the earth, local climate and global climate change. As such, it should be paid more attention in future studies, including laboratory, field experiments and models.

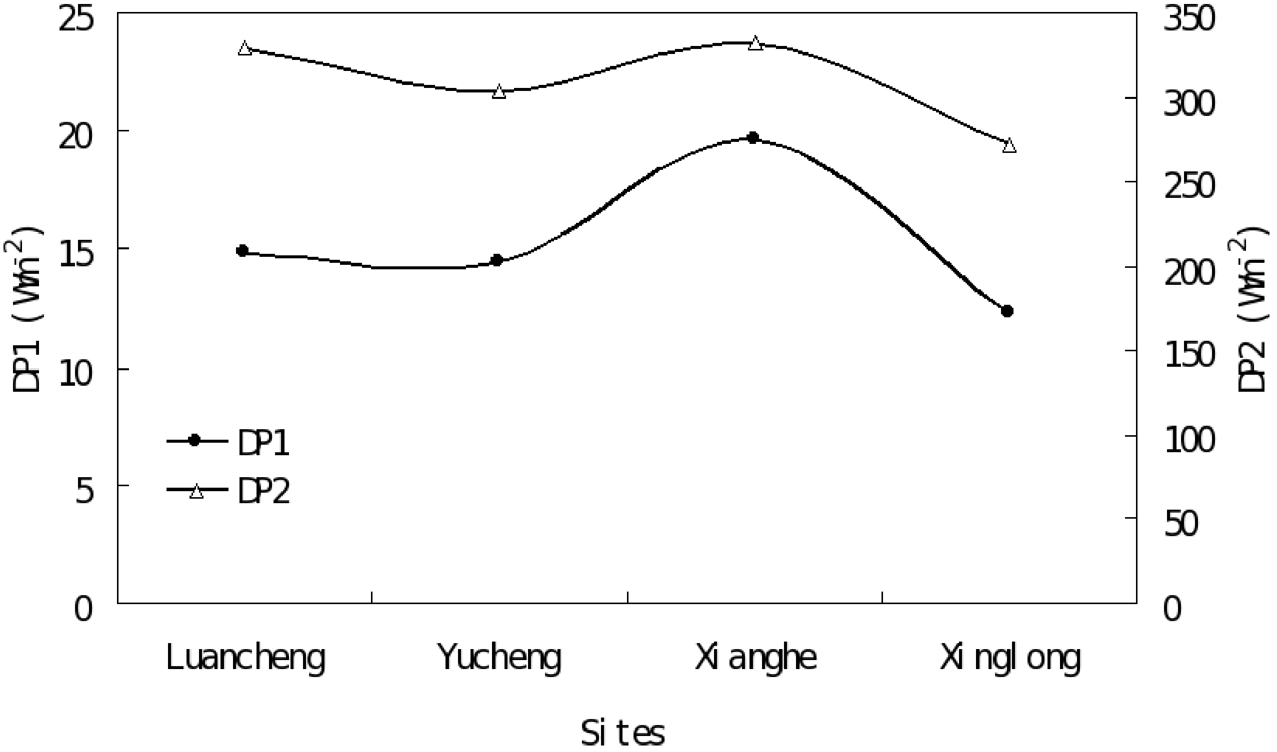

Figure 1. PAR losses in the atmosphere caused by the water vapor factor (DP1) and the scattering factor (DP2), respectively.

The Antarctic Ultraviolet (UV) Monitoring Program: A New NOAA ESRL Global Monitoring Division (GMD) Effort

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Since the discovery of the Antarctic ozone hole the National Science Foundation (NSF) has supported a polar (Arctic and Antarctic) UV monitoring program. There is a continuous dataset for more than 20 years at several polar sites. Recently, the NSF requested that NOAA continue the Antarctic portion of this program. The Global Radiation Group of NOAA ESRL's GMD is moving forward to assimilate this program into current UV radiation monitoring efforts. The measurement of the biologically effective portion of the UV spectrum, UV-B is environmentally important. There are potentially UV-sensitive ecosystems within the boundaries of the Antarctic circumpolar current and also within the areas influenced by the dynamic processes of the polar vortex that push ozone-depleted air into lower latitude regions that cross southern South America. As an example, the current through the Drake Passage into the Shackleton fracture zone acts to lift iron-rich nutrients from the ocean floor. This process feeds the seasonal phytoplankton bloom that occurs in the Scotia Sea, a base component of the food change that is affected by UV dose. Other various species that could be affected by much higher than normal UV exposure that inhabit the areas in and around the Antarctic waters are seals, penguins, birds, fish, krill, etc.

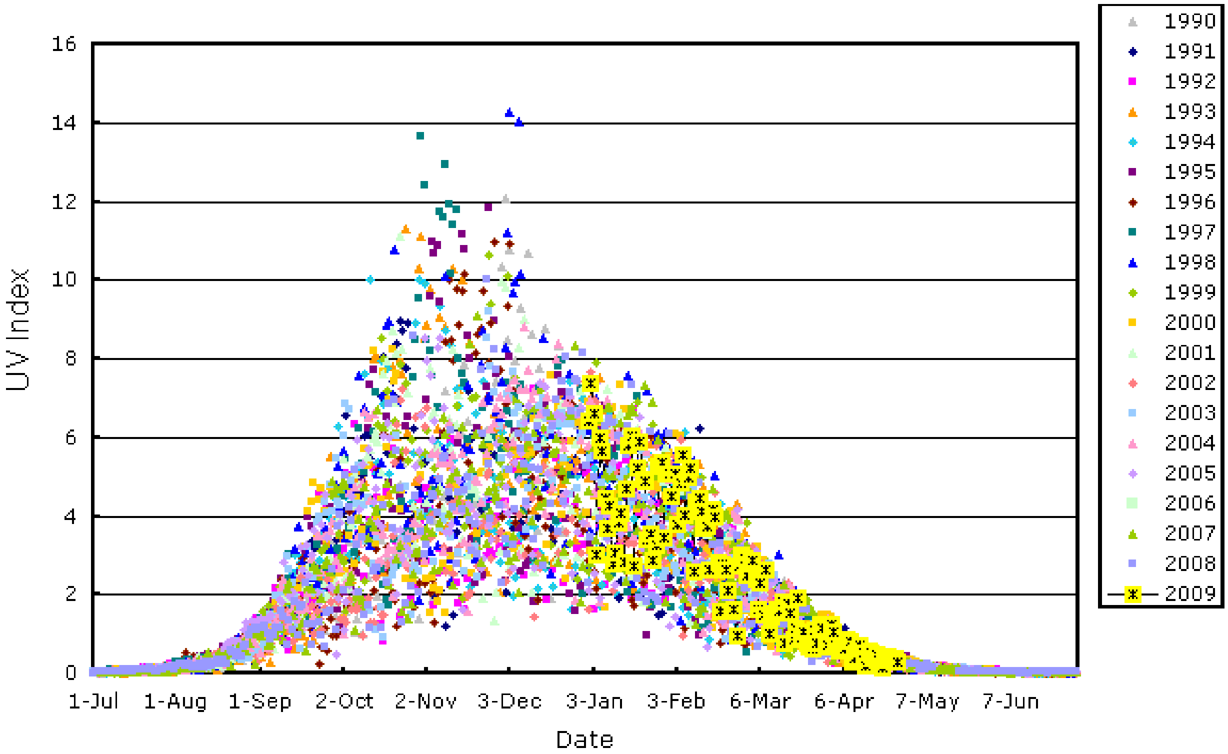

Figure 1. The daily maximum UV index values for the Antarctic peninsula site at Palmer Station are shown for the ozone hole seasons 1990 through 2008. The graph is provided by Biospherical Instruments Inc. Notice the large increase in dose rates that coincide with the ozone hole event, Sept-Dec. These are extremely large values for latitude 64 degrees south. Table Mountain, Colorado (40 degrees north and elevation of 1,689 masl) typically sees its highest UV index values around 10. Rapidly changing irradiance levels have been shown to be more biologically damaging than long continuous elevated exposures.

Climatology of Aerosol Radiative Properties in the Free Troposphere

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[11]Laboratoire de Glaciologie et Géophysique de lEnvironement, University of Grenoble, Grenoble, France
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High-altitude mountaintop observatories provide the opportunity to study aerosol properties in the free troposphere without the added expense and difficulty of making airborne measurements. Here we present statistics of means, variability, and trends of aerosol radiative properties, including light scattering, light absorption, light extinction, single scattering albedo, Ångström exponent, hemispheric backscatter fraction and radiative forcing efficiency, from various high altitude measurements. These climatologies utilize data from ten mountaintop observatories in the 20-50ºN latitude band: Mauna Loa, USA; Lulin Mountain, Taiwan; Pyramid, Nepal; Izaña, Spain; Mount Waliguan, China; Beo Moussala, Bulgaria; Mount Bachelor, USA; Monte Cimone, Italy; Jungfraujoch, Switzerland; Whistler Mountain, Canada. Results are also included from two multi-year, *in-situ* aerosol vertical profiling programs: Southern Great Plains, USA and Bondville, USA. Figure 1 shows the monthly climatology of free troposphere aerosol scattering at Mauna Loa Observatory, and demonstrates the well-documented effect of long range transport from Asia in the springtime months. By taking this data set as a whole and developing a self-consistent climatology, the combined observatory measurements of free tropospheric aerosol radiative properties have the potential to contribute to aerosol-climate research in a way that far exceeds the contribution from individual observatories. For example, this type of analysis may help constrain chemical transport models and validate satellite measurements.

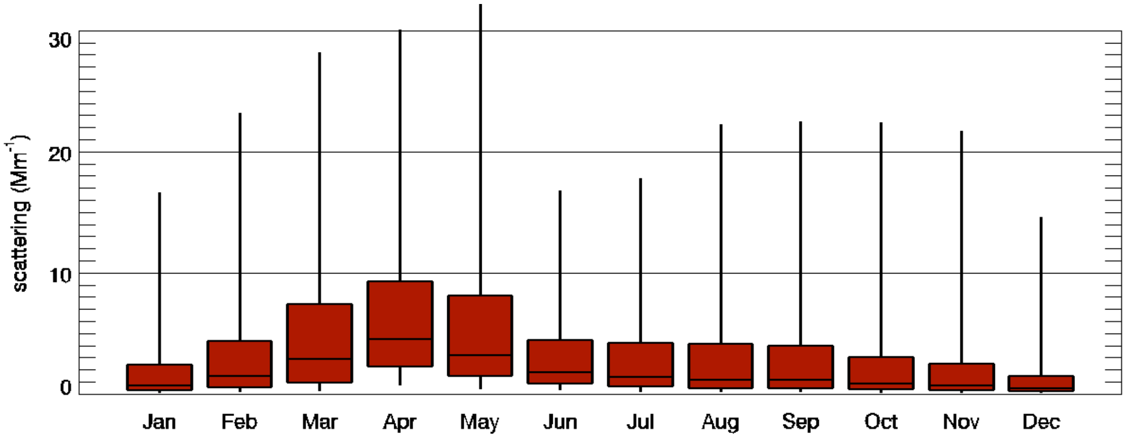

Figure 1. Monthly climatology of aerosol scattering at Mauna Loa (1974-2009), USA.

Lidar Observations of Aerosols Above American Samoa

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An aerosol lidar was installed as part of the ESRL Global Monitoring Division (GMD) American Samoa baseline observatory (14.232 deg S, 170.563 deg W) in April, 2005. There are very few lidar records of stratospheric aerosol in tropical regions and this instrument complements the records at Mauna Loa Observatory (19.539 deg N) and Boulder (40.0 deg N). The instrument measures backscattered light at 532 nm with high and low altitude channels, and is very much like the GMD lidar in Boulder. Over one hundred nighttime observations have been analyzed to date. There is substantially more scatter in the boundary layer than observed at Mauna Loa Observatory (MLO) and Boulder. The sensitivity of the detectors to the high scatter has required a lower laser power which has decreased the accuracy. In addition, frequent clouds over the site has necessitated shorter integration times (one minute) so the cloud-free data can be selected. The aerosol scatter in the boundary layer reaches the free tropospheric level at about 2.5 km. The instrument is located near the living quarters of the staff and is operated when there is at least some clear sky. So there is a bias toward clearer weather, but typically there are a few measurements for every month. Cirrus clouds can easily be seen in the data and the backscattered light is usually much stronger than the stratospheric layer. Cirrus clouds are seen in 70%+/-9% of the Samoa observations, compared with MLO, 34%+/-11%, but again there may be a bias to clearer weather. The stratospheric backscatter at Samoa is 24% higher than MLO in the 20-25 km altitude range, but this difference is affected by the absolute accuracy of both lidars which has not been well quantified. An increase in the stratospheric aerosol, possibly due to increased coal-burning in Asia, has been seen at MLO and Boulder, and is also seen in Samoa. At MLO a 4.8% per year increase was seen for 20-25 km altitude range and in Samoa it is higher, 11%. The higher rate of increase at Samoa may be due to its proximity to the western pacific upwelling region. An eruption or smoke layer was detected on 2009/03/19 and was seen until 2009/06/15. At the peak (2009/04/06) the backscattered light doubled the stratospheric layer.

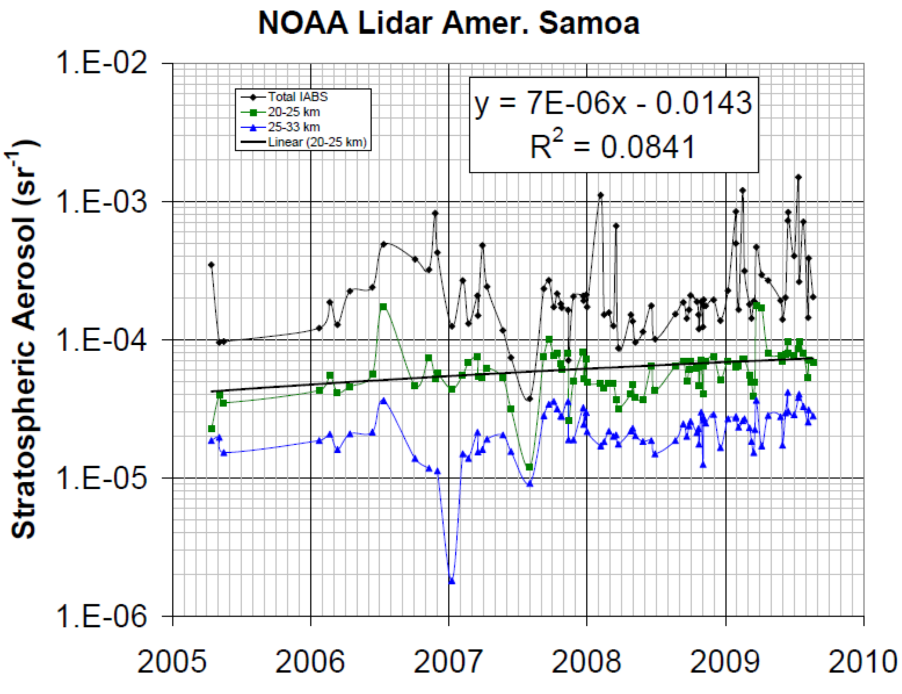

Figure 1. Integrated stratospheric aerosol backscatter (IABS) for different altitude intervals. A linear curve fit is shown for the 20-25 km interval showing the increasing trend.

Nighttime Aerosol Optical Properties Obtained from Lunar Photometry

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Ground-based measurements of multi-wavelength atmospheric transmission are important for understanding both regional and global scales of aerosol properties. The NASA-Goddard Space Flight Center Aerosol Robotic Network (AERONET) project provides such measurements from a network of sun photometers at partner locations around the globe, including several sites from NOAA/ESRL baseline and regional stations. These collaborative efforts enable long-term, continuous monitoring of aerosol optical, micro-physical, and radiative effects that provide important benefits to satellite validation and transport modeling studies. However, the photometers rely on the sun as a radiation source to obtain measurements, thus no nighttime aerosol data are currently available within the network. To further expand capabilities, nighttime measurements have been pursued using the moon as a light source. Although this approach poses some challenges, the moon is by far the brightest object in the nighttime sky enabling the use of small-aperture automated photometers. Lunar photometry has yet to be implemented within the AERONET framework due to a lack of automation, limited detector gain, and ability to track the moon with existing network hardware. Recently, an AERONET-style sun-photometer was mounted to a programmable 2-axis motor stage and configured to automatically track the moon and sun to obtain irradiance values over six spectral bands from 440-1246 nm. This enabled observations starting in late 2009, from University of Maryland Baltimore County's air quality testbed facility in Baltimore, MD. In this presentation, the approach used for nighttime aerosols will be described and initial results from recent automated measurements will be presented, including example nighttime aerosol optical depth retrievals.

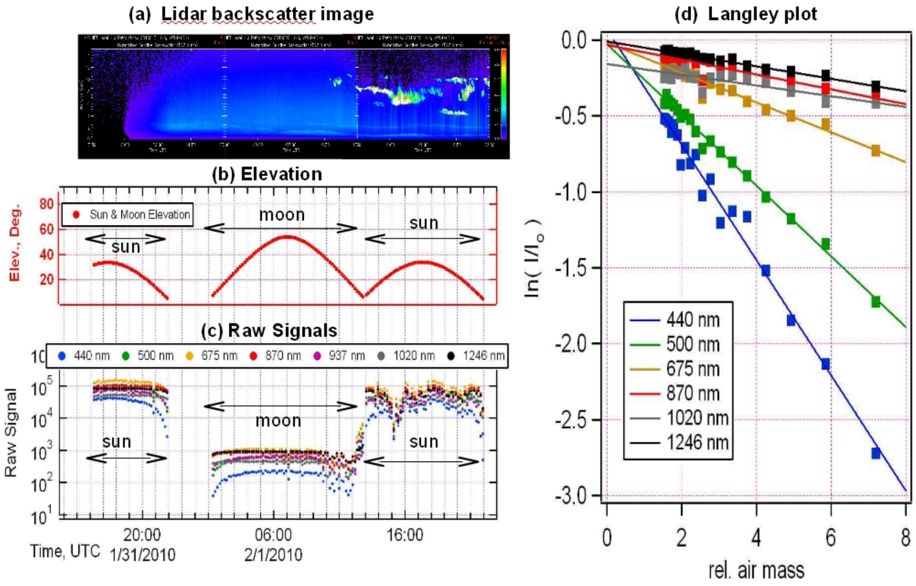

Figure 1. Example observations over a multi-day period from Jan 31 to Feb 1, 2010. (a): lidar backscatter profiles during measurements of initial clear sky conditions that turn cloudy on Feb 1; (b): sun and moon elevation above horizon; (c): Multi-wavelength uncalibrated signal magnitudes obtained from sun & moon; (d): Langley calibration-validation analysis using Feb 1 lunar observations (1:00 to 3:00 UTC) and USGS Robotic Lunar Observation model top-of-atmosphere irradiances to determine atmosphere attenuation, I/Io.

Overview of the Physical and Radiative Properties of Atmospheric Particles at Cape San Juan, Puerto Rico (CPR) Station

O.L. Mayol-Bracero[1], H. Rivera[1], J.A. Ogren[2], E. Andrews[3] and P. Sheridan[2]

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[2]NOAA Earth System Research Laboratory, Boulder, CO 80305
[3]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309

Cape San Juan Observatory (CPR, 18° 23' N, 65° 37' W), located in the Caribbean region on the island of Puerto Rico, is supported by the NOAA ESRL Global Monitoring Division, is part of the NASA's AErosol RObotic NETwork (http://aeronet.gsfc.nasa.gov), and is one of the contributing stations to the Global Atmosphere Watch (http://www.empa.ch/gaw/). Physical and radiative properties of atmospheric particles have been measured since 2005 at CPR. Here we present an overview of the results for year 2007. Three types of air masses predominated in this study, (1) those of marine origin or "clean" (C), (2) those bringing African Dust (AD), and (3) those with the influence of volcanic ash (VA) from the Soufriere Hills in the island of Montserrat. Preliminary results show that the average values for the total σ_{sp} (Fig. 1) were higher for AD (83 Mm^{-1}) and VA (34 Mm^{-1}) compared to C (17 Mm^{-1}). The same happened for the Aerosol Optical Thickness (AOT) maximum values at 500 nm with 0.92, 0.30, and 0.06 for AD, VA, and C, respectively. The observed increase in the values of the Angstrom exponent (å) (Fig. 2) is indicative of a decrease in the size of the particles associated to VA (å= 0.27) and AD (å =0.89) when compared to C (å =0.24). The volume size distributions and thus the mass were dominated by the coarse mode (> 1.0 µm) especially for the AD case. Results have shown that AD as well as VA has a significant impact on the physical and radiative properties across Puerto Rico and the Caribbean. Additional discussions together with results on the AOT wavelength dependence and on the annual variability of the properties under study will be presented.

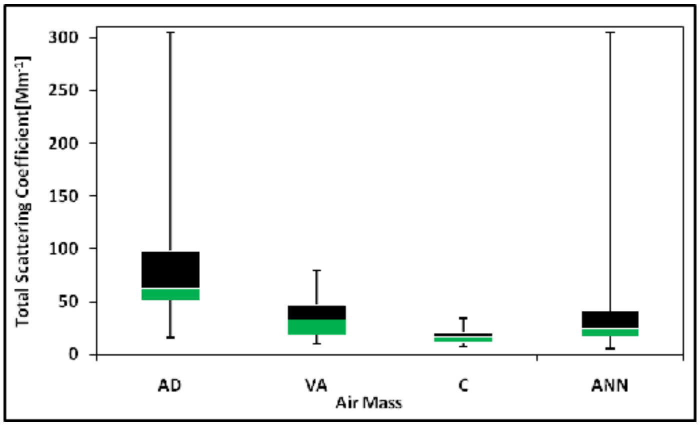

Figure 1. For the total scattering, σsp, AD shows the larger values and the larger variability, and C shows the lowest. σ_{sp} average values were 83, 34 and 17 Mm^{-1} for AD, VA, and C, respectively.

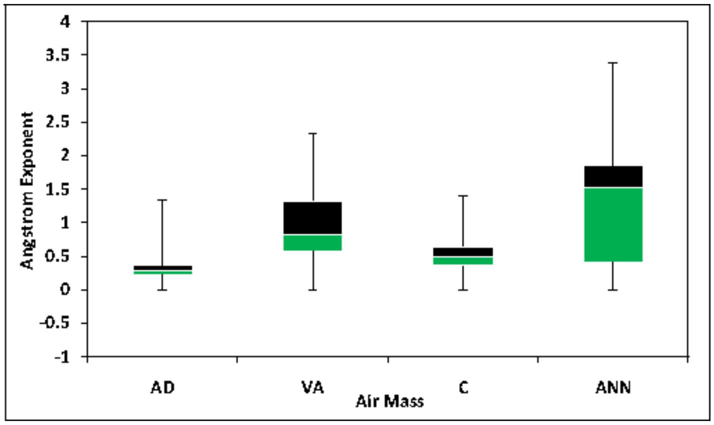

Figure 2. The lowest angstrom exponent (å) median values are for AD because coarse dust particles, indeed, reach the island. The highest median values were observed for VA.

Impact of Ocean Ice Extent and Atmospheric Transport on Biogenic Aerosol Sulfur in the Arctic

S. Sharma[1], E. Chan[1], M. Ishizawa[1], D. Toom-Sauntry[1], A. Norman[2], S. Gong[1], T. Agnew[1], S.M. Li[1], R. Leaitch[1], P.K. Quinn[3], T. Bates[3], M. Levasseur[4] and L.A. Barrie[5]

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[5]World Meteorological Organization, Geneva, Switzerland

Biogenic aerosols formed from the oxidation of dimethyl sulfide (DMS) can impact Arctic clouds and radiative forcing. The recent decline in ice cover over the Arctic Ocean, particularly over the western Arctic Ocean affects the sea-ice-atmosphere exchange of DMS and the biogenic aerosol products formed from its atmospheric oxidation, such as methanesulfonic acid (MSA). Measurements of MSA from 1980 to 2009 at Alert (82°N, 62.5°W), Nunavut, Canada and from 1997 to 2008 at Point Barrow (71°N, 156.6°W), Alaska, USA are used to look for evidence that changes in ice cover have influenced changes in MSA. At Alert, there is declining tendencies in MSA concentrations in the 1980s (April-May & July-Aug), MSA remained relatively low during the 1990s and showed increasing tendencies during the springtime (April, May & June; Figure 1). Increasing trends during the springtime and summertime MSA are also apparent at Barrow since 2000. The decadal changes in MSA at Alert may be related to the changes in the source strengths in the MSA source regions (Figure 2) and to a lesser extent to the atmospheric transport. Increase in MSA at both sites since 2000 coincides with the northward migration of the marginal ice-edge zone, which is known to be enriched in DMS. The relationship between MSA and sea-ice extent will be discussed.

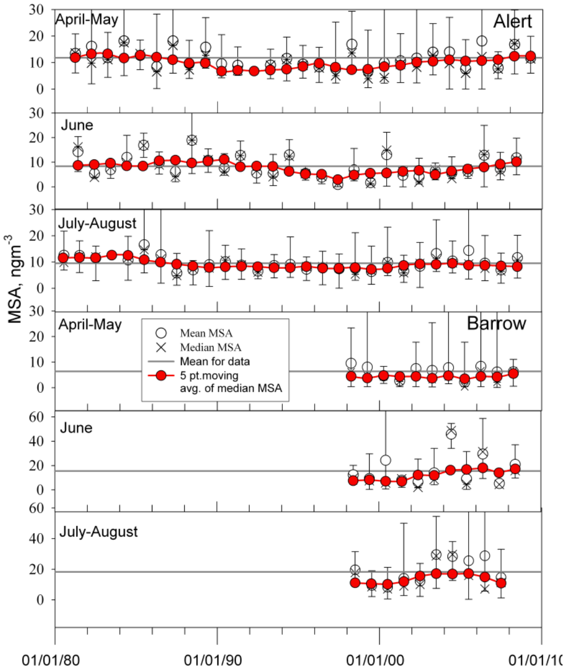

Figure 1. Monthly mean (open circle), median (x) and 5 point moving average (red circles) of MSA concentrations for April-May, June and July-August for Alert from 1980-2009 and for Barrow from 1997-2008. Increasing MSA concentrations are evident at both sites since 2000. The bars represent the maximum and minimum range.

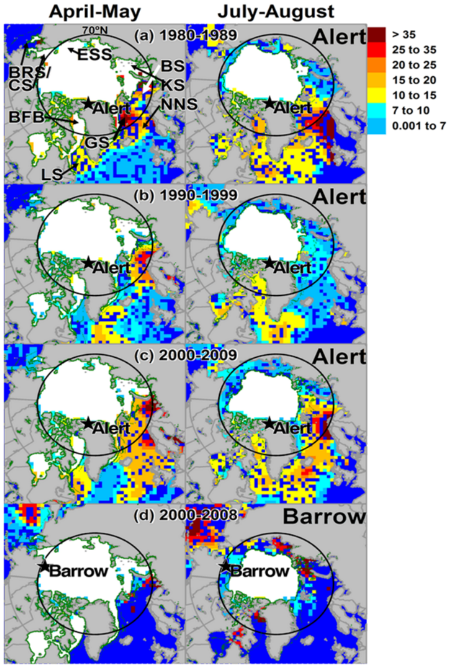

Figure 2. Seven-day back trajectory weighted MSA concentrations (weighted Seibert et al. 1994 analysis plots) for April-May & July-August.

Development of Greenhouse Gas Observations Network Within Integrated Carbon Observing System (ICOS) - Finland

Y. Viisanen, T. Laurila and T. Vesala

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ICOS is a new European Research Infrastructure for quantifying and understanding the greenhouse balance of the European continent and of adjacent regions (http://www.icos-infrastructure.eu/). The aim is to provide the long-term atmospheric and flux observations required to understand the present state and predict future behaviour of the global carbon cycle and greenhouse gas emissions. This poster presents the ICOS contribution by Finland (http://www.icos-infrastructure.fi/). The atmospheric concentration network will be upgraded and expanded to cover all parts of Finland. Atmospheric observations are supported by relevant ecosystem scale micrometeorological flux measurements. The special focus of flux measurements are coniferous forests, wetlands and the Baltic Sea. The studies are closely linked with other trace gases and atmospheric aerosols. The poster presents future measurement network and methods to be used.

Figure 1. The Finnish ICOS sites (dark green) and complementary ecosystem flux sites (light green).

Measurement System for Aerosol, Methane and Carbon Dioxide Concentrations and Fluxes at Tiksi Observatory in Northeast Siberia

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Tiksi meteorological observatory, on the coast of the Laptev Sea, has been operating since the 1930s. As part of the International Polar Year project "The International Arctic Systems for Observing the Atmosphere", Russian, U.S. and Finnish participants have been upgrading the observatory. The project is run in collaboration with partners from the United States in NOAA with the support of the National Science Foundation, Russian Roshydromet (Arctic & Antacrtic Research Institute and Main Geophysical Observatory units, Yakutian hydromet), the government of the Republic of Sakha (Yakutia) and the Finnish Meteorological Institute (FMI). FMI has contributed to the observations of aerosol size distribution, methane and carbon dioxide concentrations and micrometeorological flux observations of carbon dioxide and methane fluxes above the tundra landscape. The installations were successfully implemented in autumn 2009 by delivering the instrumentation to Tiksi observatory and performing preliminary tests. First data are expected in the summer of 2010. The poster will present the measurement system.

Figure 1. Micrometeorological eddy-covariance fluxes of carbon dioxide and methane are measured on the close-by tundra. Atmospheric concentrations of trace gases and aerosols are measured at the Clean Air Facility on an elevated location behind.

Year-Round Major Ion Measurements at Greenland Environmental Observatory, Summit (GEOSummit)

R. Banta[1], R. Bales[2], J. McConnell[1], L. Zhao[2] and C. Moon[2]

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[2]University of California at Merced, Merced, CA 95343

Long-term, year-round surface snow and snow pit sampling at remote high latitude locations is essential to better understanding arctic geophysical processes. Research at the GEOSummit from 2003 to present includes high temporal resolution year-round ion chromatography (IC) measurements of surface snow and snow pit samples for Na, NH_4, K^+, Mg_2^+, Ca_2^+, Cl^-, NO_3, SO_4^{2-}, oxalate, MSA, acetate and formate. Many of these species exhibit annual cycles corresponding to source emissions. For example, Ca_2^+ exhibits a spring peak attributed to dust deposition, and formate exhibits a summer/fall peak associated with biomass burning. Monthly snow-pit major-ion sample measurements at 3-cm resolution indicate concentration variability of many species within the snow pack. Concentrations are generally consistent with prior ice-core concentrations. Concurrently measured snow-accumulation rates exhibited relatively uniform intra-annual accumulation (5.9 cm/month +/- 4.3 cm, 1 sigma) with significant inter-annual variability. Snow-pit density values also show consistent trends with time as snow accumulates. These baseline measurements at GEOSummit will continue through another 5-year period to better characterize major ion concentrations preserved in snow on annual to decadal scales, and connections with source apportionment and atmospheric transport pathways.

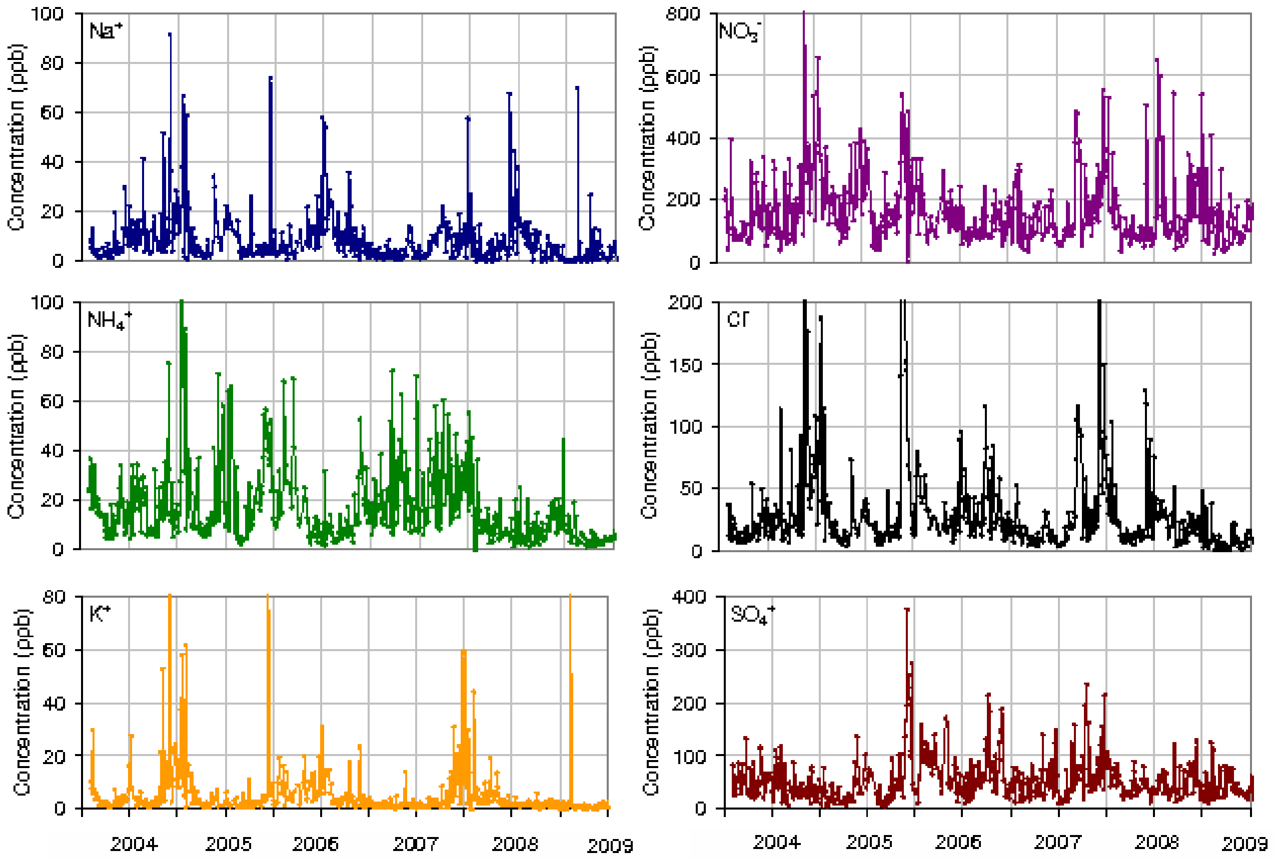

Figure 1. High resolution surface snow IC data. Many of these species exhibit seasonal cycles corresponding to source emissions.

The Global Ocean Observing System for Climate Studies

G. Goni, R. Lumpkin, M. Baringer, S.L. Garzoli, S. Dong, D. Enfield, G. Halliwell, E. Johns, C. Meinen, R. Molinari, R. Perez, C. Schmid, C. Thacker and C. Wang

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NOAA maintains a Global Ocean Observing System (GOOS), a component of the global climate observing system, consisting of moored and drifting instruments and sensor-bearing vessels. Components of the GOOS include the Ship of Opportunity Program, Argo profiling floats, the Global Drifter Program, the Tropical Moored Array programs, Expendable Bathythermograph transects, the Western Boundary Time Series program, the Meridional Overturning Circulation and Heat-flux Array, and the Climate Variability and Predictability Repeat Hydrography and CO_2 inventory program. The components of the GOOS are summarized in this poster.

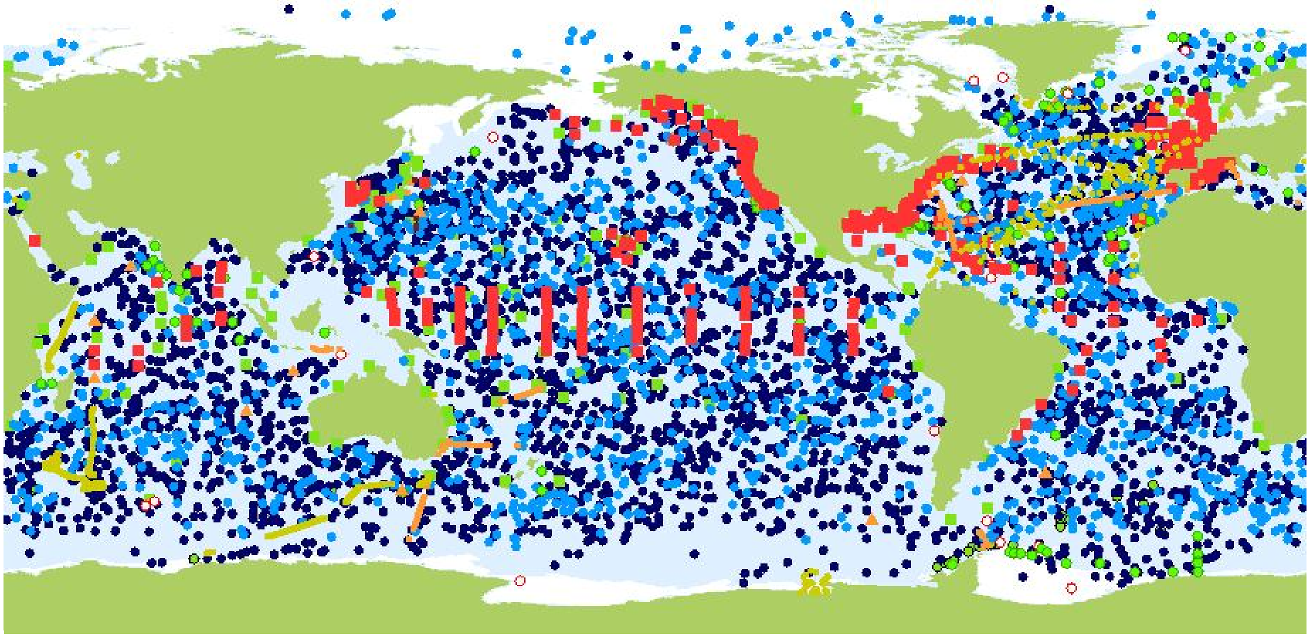

Figure 1. Observations reported from the GOOS in February 2010 (Joint World Meteorological Organization-Intergovernmental Oceanographic Commission Technical Commission for Oceanography and Marine Meteorology-Operations, http://wo.jcommops.org). Red: moored buoys. Light blue: drifting buoys. Dark blue: profiling floats. Green and orange: shipboard ocean observations.

Characterizing the Atlantic Meridional Overturning Circulation

M. Baringer, R. Lumpkin, S.L. Garzoli, S. Dong, D. Enfield, G. Goni, G. Halliwell, E. Johns, C. Meinen, R. Molinari, R. Perez, C. Schmid, C. Thacker and C. Wang

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The Atlantic Meridional Overturning Circulation (AMOC) consists of northward flow at surface and intermediate depths, and southward flow of North Atlantic Deep Water. The AMOC is a major component of northern hemisphere meridional heat transport, and may fluctuate on a broad range of time scales with significant climate implications. In this poster, we describe efforts to characterize and observe the AMOC and its variability. These include Argo float and Expendable Bathythermograph profiles, measurements of the Florida Current transport and the Deep Western Boundary Current off the Bahama Plateau (the Western Boundary Time Series program), several new programs to measure the AMOC in the South Atlantic, and the Meridional Overturning Circulation Heat-flux Array (MOCHA) at 26.5°N across the Atlantic. The MOCHA system is part of the joint U.K./U.S. RAPID-MOCHA program, and has been continuously observing the AMOC since March 2004.

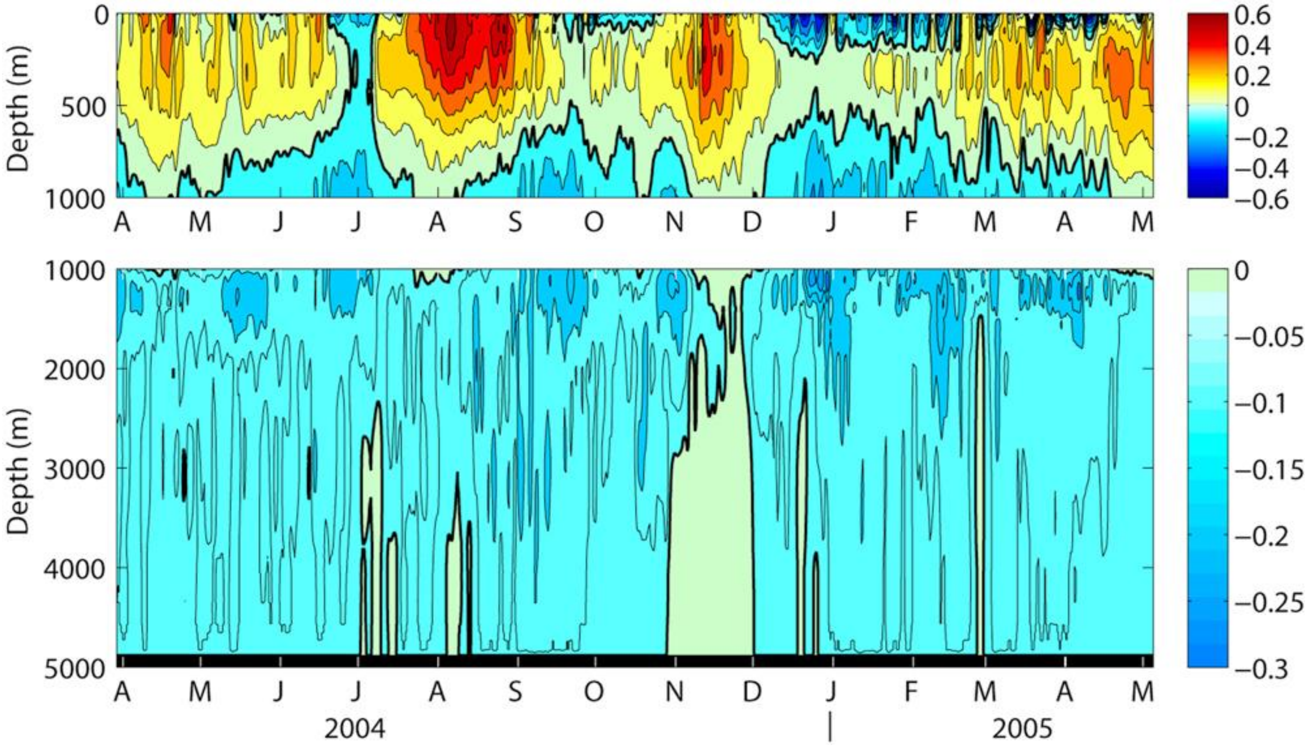

Figure 1. Time series of the transport-per-unit-depth profile (10^5 m^2/s) measured by the MOCHA array. The contour interval is decreased in the lower panel to better illustrate the deep variability. A notable reversal in the deep flow occurs during November 2004 (from Johns et al., 2008).

Recovery Act-Funded Additions to the U.S. Department of Energy's Atmospheric Radiation Measurement Climate Research Facilities on the North Slope of Alaska

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Sandia National Laboratories, Albuquerque, NM 87185; 505-284-9092, E-mail: mdivey@sandia.gov

The U.S. Department of Energy (DOE) provides scientific infrastructure and data archives to the international Arctic research community through a national user facility, the Atmospheric Radiation Measurement (ARM) Climate Research Facilities (ACRF), located on the North Slope of Alaska. The ACRF installations at Barrow and Atqasuk, Alaska have been collecting and archiving atmospheric data for more than ten years. These data have been used for investigations of clouds, cloud processes, and radiative transfer as well as for remote sensing validations. Funding from the Recovery Act (American Recovery and Reinvestment Act of 2009) will be used to install new instruments and upgrade existing instruments at the North Slope ACRF. These instruments include:

- Scanning Precipitation Radar;
- Scanning Cloud Radar;
- Automatic Balloon Launcher;
- High Spectral Resolution Lidar;
- Eddy Correlation Flux Systems;
- Upgraded Ceilometer, Atmospheric Emitted Radiance Interferometer, Micropulse Lidar, and Millimeter Cloud Radar.

Information on these planned additions and upgrades will be provided in our poster. An update on experimental and unmanned aerial vehicle activities planned at Oliktok Point, Alaska will also be provided.

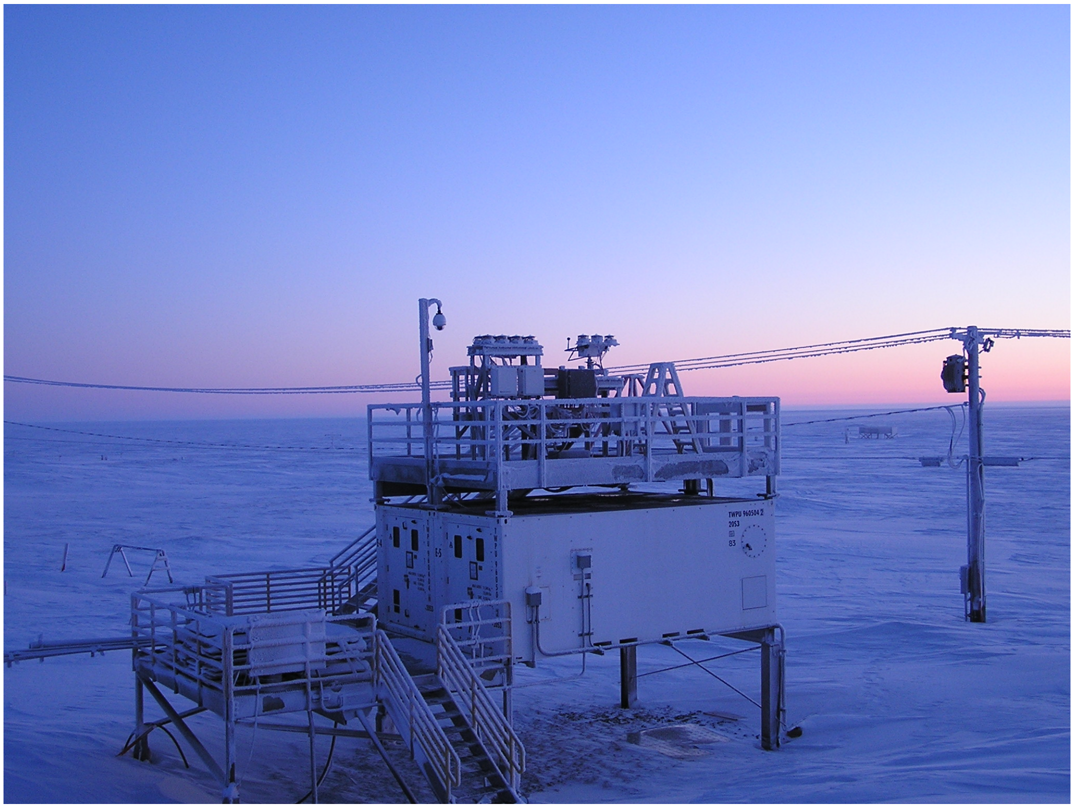

Figure 1. Instrument Shelters at ARM Climate Research Facility in Barrow.

The Global Atmosphere Watch (GAW) Station Information System - GAWSIS

J. Klausen and S. Henne

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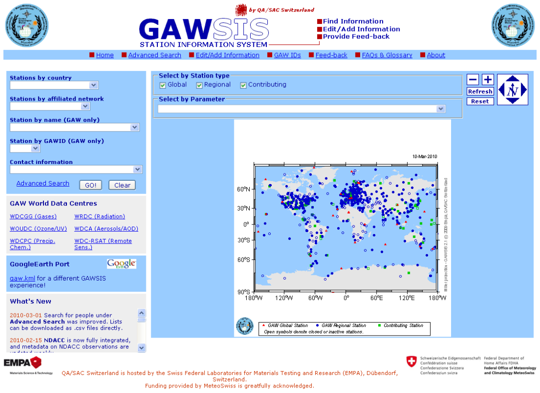
GAWSIS is an interactive web application and the official catalogue of the observational base of the World Meteorological Organization (WMO)/GAW programme. It was designed with a hierarchical log-in system to allow registered users to change and amend information. On top, it uses automated machine-to-machine processes using metadata obtained from a number of data centers regularly update information on the measurement programs of stations. The GAWSIS development effort has been guided by the objectives to:

- Document the ground-based observational network of GAW (& partner programs) and help keep this information up-to-date
- Facilitate data discovery and data retrieval of atmospheric data
- Increase the visibility of GAW (& partner programs)
- Promote scientific exchange and collaboration between stations and
- provide an entry point for researchers interested in placing an experiment.

GAWSIS is available on-line at http://gaw.empa.ch/gawsis. The web interface and functionalities have been steadily improved over the years. GAWSIS serves as a structuring element in the increasingly complex landscape of atmospheric monitoring programs and data archives. At present, GAWSIS provides:

- station reports for a total of 788 stations world-wide (of which 180 stations are reported closed) including
- site characterization,
- contact people,
- measurement program with links to data sources, and access to trajectories
- bibliographic references
- simple search interfaces to produce lists of stations and people based on geographical criteria or measurements of interest
- vocabularies for variables, methods
- a collocation table for identification of stations in various programs
- International Organization for Standardization-compliant metadata representations in Extensible Markup Language for use in WMO Information System (WIS) or Global Earth Observation System of Systems
- A GoogleEarth™ port and GoogleMaps™ visualizations, as well as a custom-built mapping system.

WMO/Commission for Atmospheric Sciences-XV recommended to establish GAWSIS as a World Data Centre for Metadata and a Data Collection and Production Centre for WIS. It is believed that the present design concepts used in GAWSIS are very well suited to support such a development.



gaw.kml for a different GAWSIS experience!

2010-03-01 Search for people under **Advanced Search** was improved. Lists can be downloaded as .csv files directly.

2010-02-15 **NDACC** is now fully integrated, and metadata on NDACC observations are

QA/SAC Switzerland is hosted by the Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland.
Funding provided by MeteoSwiss is greatfully acknowledged.

Figure 1. Entry page of GAWSIS at http://gaw.empa.ch/gawsis

The Development of the Sir Crispin Tickell High-Altitude Global Climate Observatory in Mexico (MEX)

L.R. Acosta[1], C.J.D. Leal[1], M. MacCracken[1], J.C. Topping[1], F. Menendez[1], M. Rosengaus[2] and B. Hernández[3]

[1]Climate Institute, 900 17th Street NW, Washington, DC 20006; 202-536-5276, E-mail: acosta@climate.org
[2]National Meteorological Service, México
[3]Fundación Pedro y Elena Hernandez, México

The High-Altitude Global Climate Observatory, named after Sir Crispin Tickell, a United Kingdom diplomat and global issues visionary, has under development since 2005 in Mexico's highlands to fill a “crucial-gap” of the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) and other Global Climate Observation networks. At an altitude of 4,550 meters above sea level (m.a.s.l.) the new High Altitude Global Climate Observation Center is located on Sierra Negra Volcano at Longitude 97°w10' and Latitude 19°n59'. This is at similar latitude to the Mauna Loa (MLO) baseline climate observatory (3,397 m.a.s.l.), that has been in operation since 1958. The extra-dry, high-altitude tropical location above the boundary region, near the Gulf of México, added to the lack of near-by vegetation or pollution sources, makes of the MEX observatory a prime location for conducting Green House Gases (GHG) monitoring, Aerosols, Radiation and other essential climate variables observation and research programs. In close Latitudinal alignment with MLO, the MEX high-altitude station enjoys easy accessibility from major international research centers. Preliminary GHG data is presented from the NOAA ESRL Global Monitoring Division’s flask-based network. Data is compared between MEX and MLO observatory for the 2009 period. The status of the high altitude observatory development, operation and outreach programs are discussed.

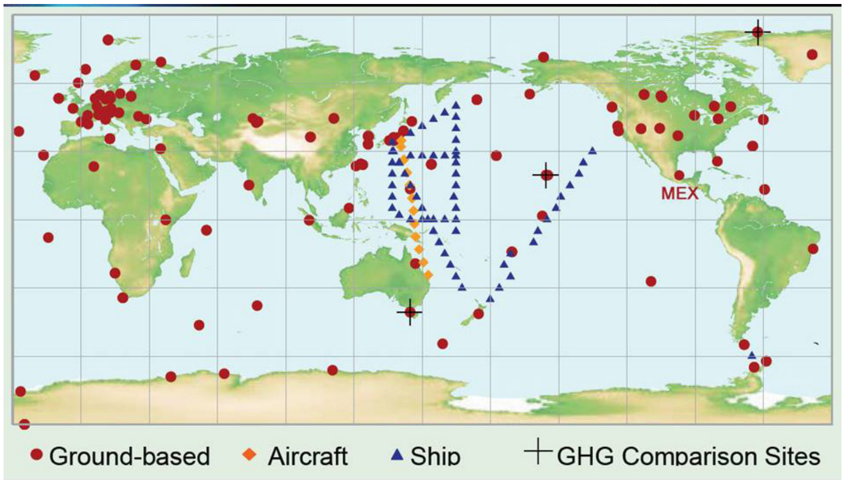


Figure 1. Location of the High Altitude Global Climate Observatory above 4,500 m.a.s.l. in Sierra Negra Volcano in Mexico. Since 2009 the observatory contributes to the WMO-GAW global network for carbon dioxide (CO_2) and NOAA ESRL Carbon Cycle global network.

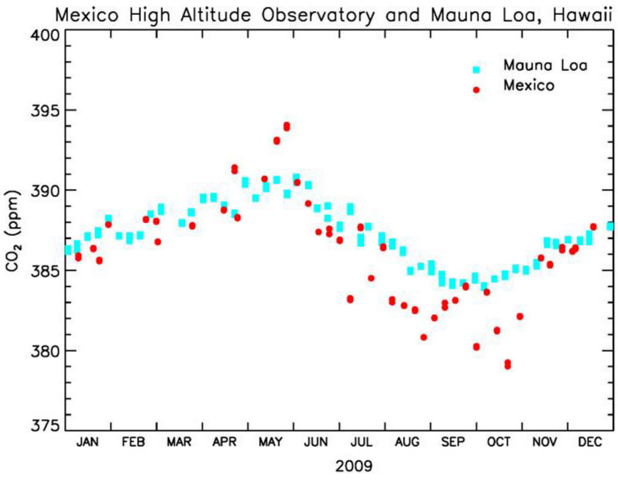
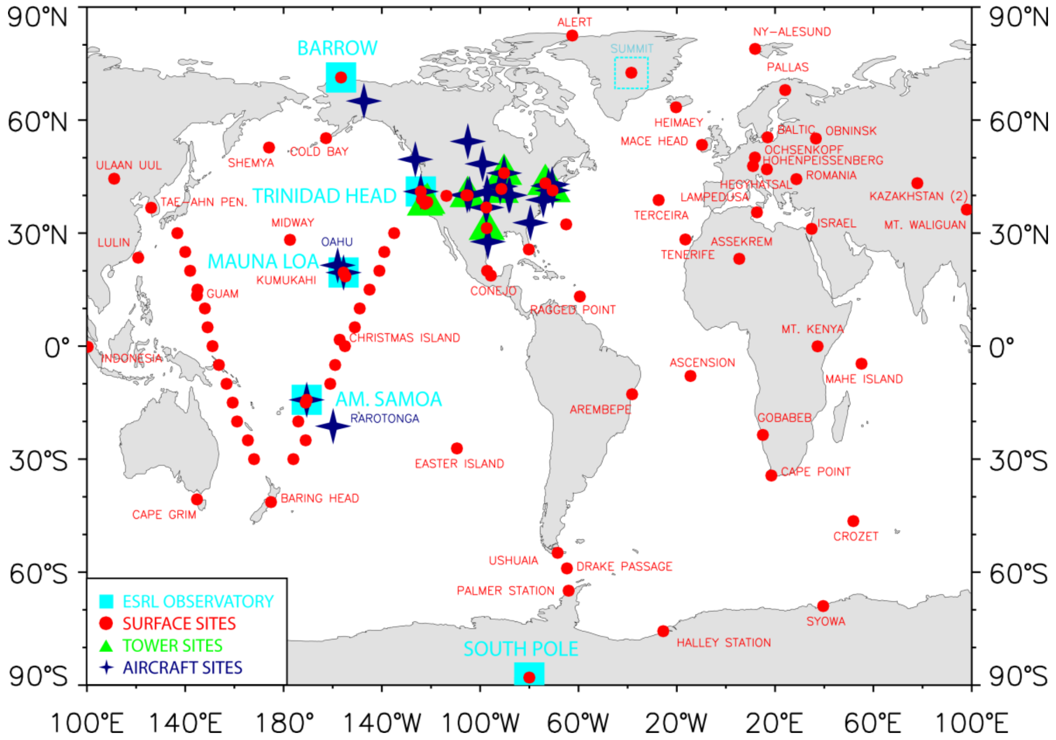
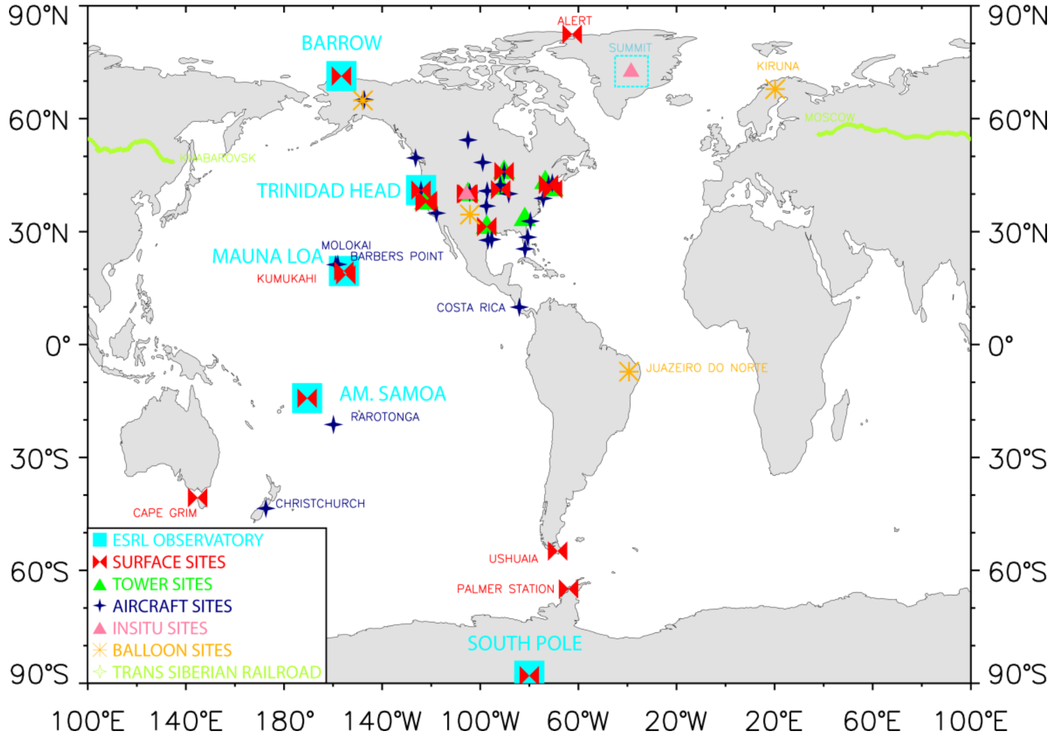


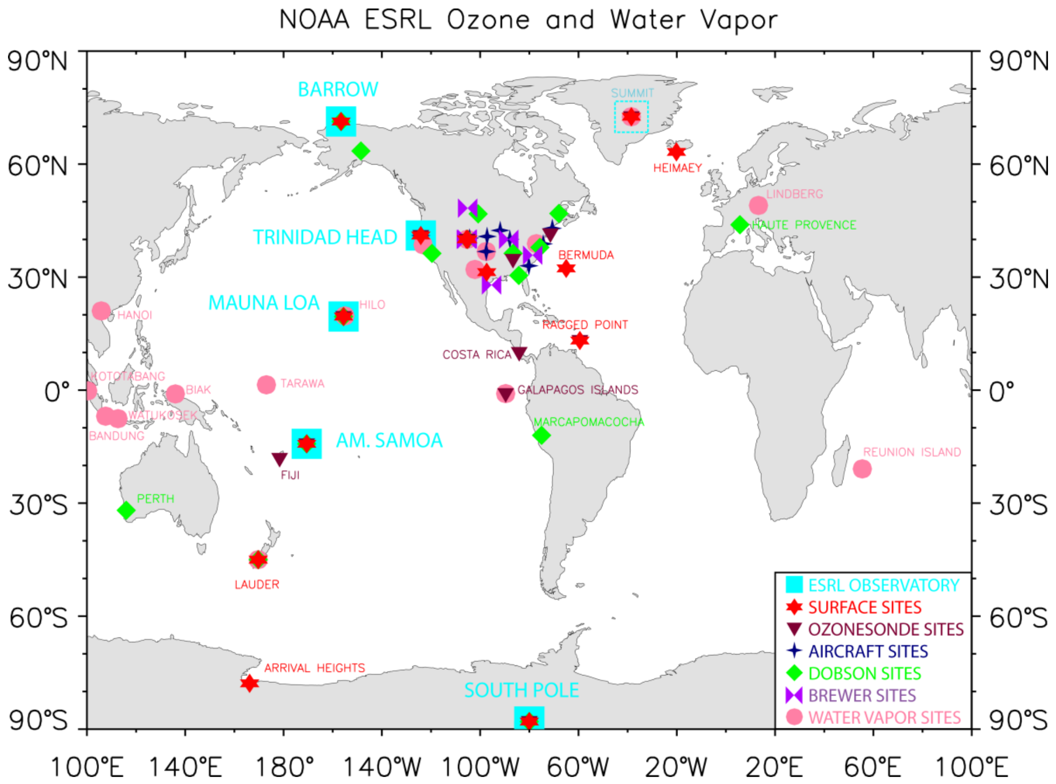
Figure 2. The chart shows CO_2 concentration levels comparison between Mexico High Altitude Climate Observatory and MLO, Hawaii in 2009.

NOAA ESRL Carbon Cycle Greenhouse Gases

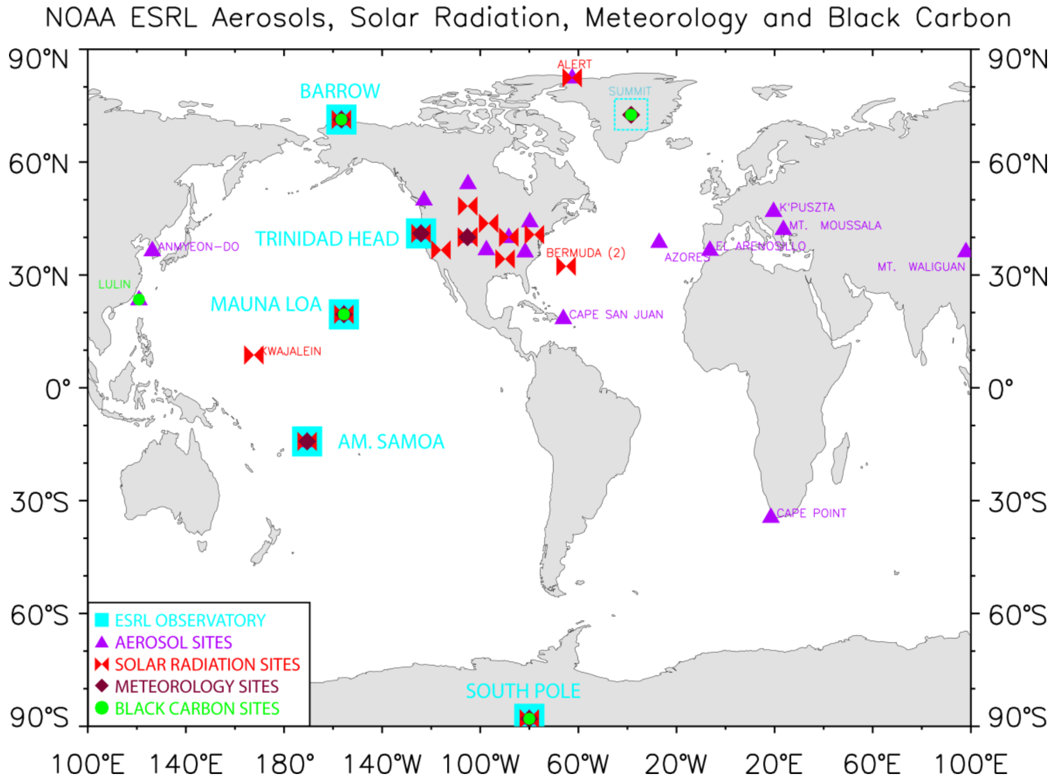


NOAA ESRL Halocarbons and Atmospheric Trace Species





NOAA ESRL Ozone and Water Vapor



NOAA ESRL Aerosols, Solar Radiation, Meteorology and Black Carbon