

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.

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Cover info:

A “word cloud” generated from the titles on the 2014 GMAC Agenda superimposed over the CO₂ record from Mauna Loa Observatory, HI. The word cloud gives greater prominence to words that appear more frequently in the source text.



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 42nd Global Monitoring Annual Conference

May 20-21, 2014
Boulder, Colorado

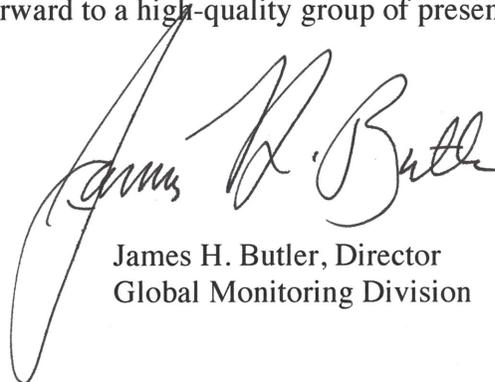
We at the Global Monitoring Division of NOAA's Earth System Research Laboratory welcome you to our 2014 Global Monitoring Annual Conference. Hosting this annual gathering is a privilege for GMD and a long-term commitment to the global community to bring researchers together to improve our knowledge base and our practices. The goal of the conference is to create a forum for thoughtful and lively discussion on the research that comes from sustained measurement records and what it takes to understand them.

The previous years' conference themes have changed from year to year, but the bottom line is always the same, long-term records are critical for understanding complex climate system variables. How we, as a global community, can learn from and leverage long-term records and sites to advance scientific understanding and complement one another's partnering networks remains central to GMD's mission and the goals of the conference.

We anticipate that conference discussions and topics will highlight long-term data sets, advances in technology, expansion of global monitoring networks, cooperation among agencies and nations, challenges that confront us, and opportunities within them.

The conference agenda and abstracts from all presentations and posters at the conference are available at <http://www.esrl.noaa.gov/gmd/annual/conference/>.

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



James H. Butler, Director
Global Monitoring Division



NOAA Atmospheric Baseline Observatories

Trinidad Head, California



Barrow, Alaska



Summit, Greenland



Mauna Loa, Hawaii



American Samoa



South Pole

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

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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

Tuesday Morning, May 20, 2014 AGENDA

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

- **07:00** **Registration Opens in GC-402 - lunch orders and posters collected at registration table**
- **07:30 - 08:30** **Morning Snacks - Coffee, tea, fruit, bagels and donuts served**
- Page No.
- **Session 1** **Welcome, Keynote Address & Highlights** — Chaired by James Butler
- 08:30 - 08:45 Welcome and Conference Overview -
 James H. Butler (NOAA Earth System Research Laboratory, Boulder, CO)
- 08:45 - 09:15 Atmospheric Signatures of Changing Global Biogeochemistry 1
 Ralph Keeling (Scripps Institution of Oceanography, La Jolla, CA)
- 09:15 - 09:30 The Earth Is Round: Some Elements of a Sustainable Society 2
 Pieter Tans (NOAA Earth System Research Laboratory, Boulder, CO)
- 09:30 - 09:45 Continued Permafrost Warming on the Arctic Slope of Alaska, 2014 Update 3
 Gary Clow (United States Geological Survey (USGS), Boulder, CO)
- 09:45 - 10:00 International Arctic Systems for Observing the Atmosphere (IASOA) – A Portal for Discovery, a Platform for
Pan-Arctic Collaboration 4
 *Sandra Starkweather (Cooperative Institute for Research in Environmental Sciences (CIRES), University of
Colorado, Boulder, CO)*
- **10:00 - 10:30** **Morning Break**
- **Session 2** **Carbon Cycle & Greenhouse Gases - Measurements** — Chaired by Arlyn Andrews
- 10:30 - 10:45 Detection and Quantification of Urban Greenhouse Gas Emissions: Ground-based Results of the 5
INDianapolis FLUX (INFLUX) Experiment
 Natasha Miles (The Pennsylvania State University, University Park, PA)
- 10:45 - 11:00 Partitioning of Urban Fossil Fuel CO₂ Emissions by Source Sector: Results from the INdianapolis FLUX 6
(INFLUX) Experiment
 *Jocelyn Turnbull (GNS Science, New Zealand, and Cooperative Institute for Reseach in Environmental
Sciences (CIRES), University of Colorado, Boulder, CO)*
- 11:00 - 11:15 Amazon Basin-wide Fluxes of CO₂ and CH₄ from Aircraft Vertical Profiles 7
 *John B. Miller (Cooperative Institute for Research in Environmental Sciences (CIRES), University of
Colorado, Boulder, CO)*
- 11:15 - 11:30 Seasonality and Trends of Atmospheric Transport Events to Summit, Greenland Derived from Long-term 8
Non-methane Hydrocarbon Observations
 Chelsea Thompson (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO)
- 11:30 - 11:45 Historic European Non-CO₂ Atmospheric Greenhouse Gas Records: Harmonization and Uncertainty Assessment 9
 Samuel Hammer (University of Heidelberg, Institut für Umweltphysik, Heidelberg, Germany)
- 11:45 - 12:00 A Half-century Record of State-by-State Changes in Fossil Fuel Carbon Emissions and Corresponding Isotope 10
Ratios in the United States
 T.J. Blasing (Independent Scholar, Knoxville, TN)
- **12:00 - 13:00** **Catered Lunch - Outreach Classroom GB-124 (pre-payment of \$12.00 at registration)**

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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

Tuesday Afternoon, May 20, 2014 AGENDA

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

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- **Session 3** **Carbon Cycle & Greenhouse Gases - Satellites & Modeling** — Chaired by Ed Dlugokencky
 - 13:00 - 13:15 The Ability of Satellite-based CO₂ Measurements to Constrain Carbon Cycle Science: From Greenhouse Gases (GHG) Observing SATellite (GOSAT) to Orbiting Carbon Observatory (OCO-2) 11
Christopher O'Dell (Colorado State University, Department of Atmospheric Science, Fort Collins, CO)
 - 13:15 - 13:30 Launch and Early Operations of the National Aeronautics & Space Administration (NASA) Orbiting Carbon Observatory-2 12
David Crisp (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, CA)
 - 13:30 - 13:45 Validation of Total Carbon Column Observing Network (TCCON) Observations of CO₂/CH₄/CO at Sodankylä Using AirCore 13
Huilin Chen (Centre for Isotope Research, University of Groningen, Groningen, Netherlands)
 - 13:45 - 14:00 Constraining Fossil Fuel CO₂ Emissions with Joint Assimilation of Atmospheric CO₂ and ¹⁴CO₂ Measurements 14
Sourish Basu (NRC Post-Doc & NOAA Earth System Research Laboratory, Boulder, CO)
 - 14:00 - 14:15 CarbonTracker-Lagrange: A New Tool for Regional- to Continental-scale Flux Estimation 15
Arlyn E. Andrews (NOAA Earth System Research Laboratory, Boulder, CO)
 - 14:15 - 14:30 Estimation of the Permafrost Carbon Feedback Using The SiBCASA Terrestrial Carbon Cycle Model 16
Elchin Jafarov (National Snow and Ice Data Center (NSIDC), Boulder, CO)
 - 14:30 - 14:45 Evaluating Models of Wetland CH₄ Emissions: How Believable Are Simulations of Future Emissions? 17
Lori Bruhwiler (NOAA Earth System Research Laboratory, Boulder, CO)
- **14:45 - 15:15 Afternoon Break**
- **Session 4** **Aerosols** — Chaired by Elisabeth Andrews
 - 15:15 - 15:30 Comparison of Aerosol Absorption Optical Depth from Remote-sensing and *In Situ* Measurements 18
John A. Ogren (NOAA Earth System Research Laboratory, Boulder, CO)
 - 15:30 - 15:45 Constraining Global Models of Black Carbon (BC) Aerosol with Pole-to-Pole Observations 19
Joshua Schwarz (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
 - 15:45 - 16:00 Can We Characterize Aerosol Type Using Aerosol Optical Properties? 20
Lauren Schmeisser (Universiteit van Amsterdam & NOAA Earth System Research Laboratory, Boulder, CO)
 - 16:00 - 16:15 A Small, Sensitive, Light-weight, and Disposable Aerosol Spectrometer for Balloon and Unmanned Aerial Vehicle Applications 21
Hagen Telg (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
 - 16:15 - 16:30 Biomass Burning at Cape Grim: Using Modeling to Explore a Possible Urban Influence on Plume Photochemistry and Composition 22
Sarah J. Lawson (Commonwealth Scientific Industrial Research Organization (CSIRO), Marine and Atmospheric Research, Aspendale, Australia)
 - 16:30 - 16:45 Aerosols at Mauna Loa Observatory (MLO) – Spring 2001, Versus Spring and Fall, 2011 23
Thomas A. Cahill (University of California at Davis, Davis, CA)
- **17:00 - 20:00 Poster Session (DSRC Cafeteria) with appetizers and refreshments**

Atmospheric Signatures of Changing Global Biogeochemistry

R. Keeling, L. Resplandy and Y. Eddebbar

Scripps Institution of Oceanography, La Jolla, CA 92037; 858-534-7582, E-mail: rkeeling@ucsd.edu

In 1957, Roger Revelle called attention to humanities "great geophysical experiment", i.e. release of billions of tons of CO_2 from fossil-fuel burning. As this "experiment" now slowly plays out, a major need is to track the fate of the excess CO_2 and to understand impacts on land and ocean ecosystems. Measurements of greenhouse gases by NOAA and other programs now constitute the core of an observing system to satisfy this need. The Scripps Inst. of Oceanography also plays a key role by tracking changes in the atmospheric O_2 abundance and maintaining links to early measurements.

One surprise coming from these observations is evidence that land ecosystems are serving as a sink for a significant fraction the excess carbon dioxide from fossil-fuel burning. Ecosystems remote from direct human influences have evidently been thrown out of steady state by a range of processes and are accumulating carbon unusually. Evidence for this sink is compelling found from a variety of methods, including from measurements of atmospheric O_2 abundance. Additional compelling evidence for large changes in land ecosystem comes from measurements of the seasonal cycle in atmospheric CO_2 .

In contrast, there is little evidence that marine ecosystems - at least those remote from coastal influences - have undergone such large changes. While the oceans are absorbing excess CO_2 , this is mostly a physical, not a biological, process. But just as the absence of evidence is not evidence for absence, it could just be that we lack strong long-term atmospheric constraints on marine ecosystems. Whereas atmospheric CO_2 data provides a wealth of information on land processes, they do a poor job of resolving ocean biological processes because the buffering chemistry of CO_2 in seawater slows the response of atmospheric CO_2 to processes originating from within the ocean.

This talk will highlight evidence for changes in land ecosystems from measurements and CO_2 and its isotopes, and will illustrate a path forward to resolving changes in marine ecosystems and related impacts on the ocean carbon sink via measurements in atmospheric O_2 concentration, particularly via the tracer "atmospheric potential oxygen" APO, which is effectively the sum of the O_2 and CO_2 concentrations, which shows rich variability of marine origin.

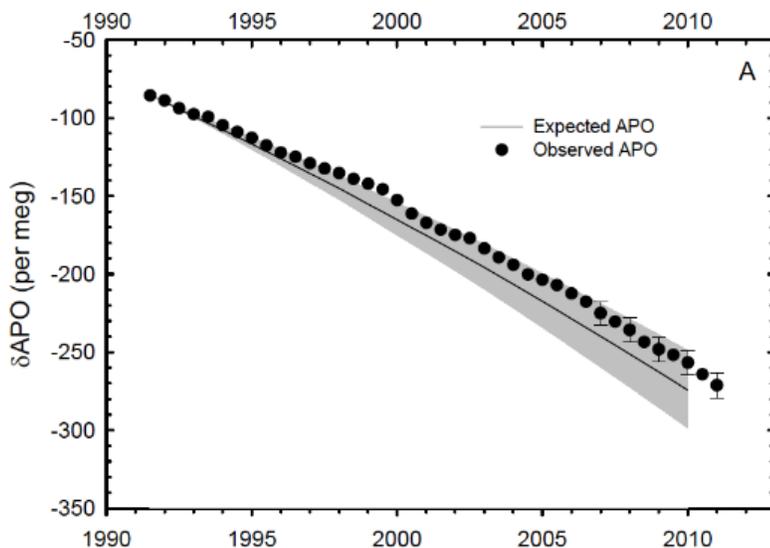


Figure 1. Global average APO derived (black circles) compared to trend computed from a model calculation (line) which accounts for fossil-fuel burning (which depletes APO because burning fossil-fuel consumes more O_2 per carbon than normal respiration) and ocean uptake of anthropogenic CO_2 . The APO decrease may also be influenced by air-sea O_2 and CO_2 fluxes driven by processes internal to the ocean, which are neglected in the model.

The Earth Is Round: Some Elements of a Sustainable Society

P. Tans

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

Global climate change demonstrates clearly that our current social economic system is running into physical limits. The economic growth we have experienced in the past has been beneficial in many ways. Most economists and politicians still argue for its perpetual continuation, perhaps at 2% per year or so in developed countries, and more rapidly in developing countries. However, our collective impact on the Earth system has now become so large that further continuation of growth would likely be disastrous. Our real challenge is very different, namely to develop a society that provides enough food, shelter, jobs, and services while protecting the Earth's resources and shrinking our throughput of materials. In addition, we have an aging population and a large fraction of current jobs will be replaced by robots. We have to rethink our system of money, developing new ways to match unmet needs with new jobs. Gross Domestic Product (GDP) has to be replaced as a measure of success, the rights and obligations of corporations redefined, and the vast accumulation of wealth and power in very few hands reversed.

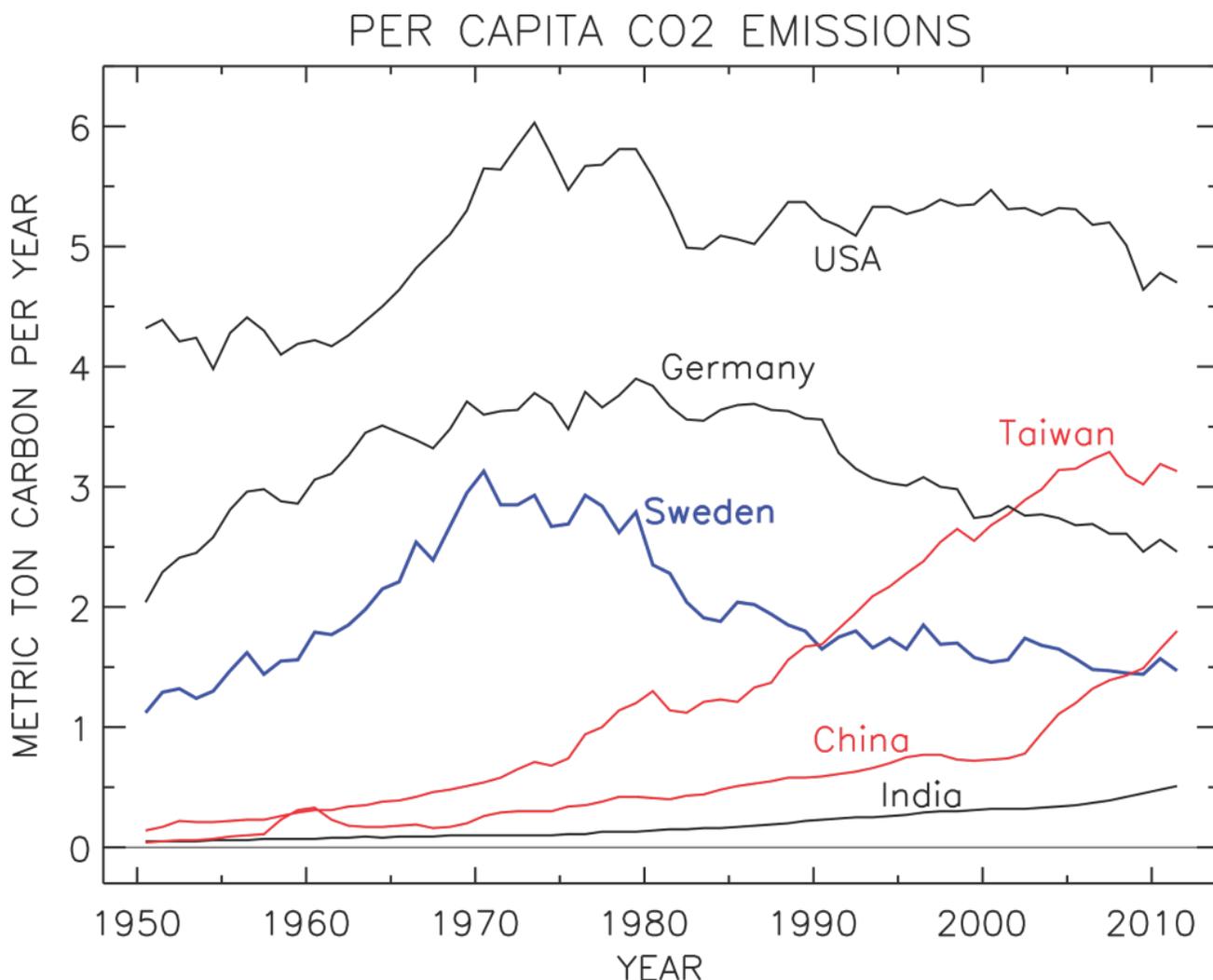


Figure 1. Vast emissions reductions can be accomplished with existing technology. Sweden's GDP per capita is almost the same as in the U.S., and it is much more equitably distributed.

Continued Permafrost Warming on the Arctic Slope of Alaska, 2014 Update

G. Clow

United States Geological Survey (USGS), Boulder, CO 80309; 303-735-7806, E-mail: clow@usgs.gov

USGS maintains a permafrost monitoring network on federal lands in northern Alaska as part of the Global Terrestrial Network for Permafrost (GTN-P). This network consists of two arrays: 1) An array of 16 automated meteorological/active-layer stations, and 2) an array of 19 deep boreholes, the majority of which are located on the Arctic Coastal Plain (a few are located in the northern foothills of the Brooks Range). Both arrays are sensitive to conditions in the nearby Beaufort and Chukchi Seas. Temperature measurements are made in the deep borehole array once every 5 years to monitor the thermal state of permafrost from the surface down to 125+ meters.

During the summer of 2012, permafrost temperatures were again obtained across the deep borehole array as part of an international effort to monitor the thermal state of permafrost. Previous measurements made in the USGS/GTN-P borehole array had shown little trend in permafrost temperatures during the 1980s, followed by a significant warming beginning ~1990. The 2012 measurements demonstrate that shallow permafrost temperatures are continuing to warm in this region; temperatures 20 m below the surface are now 2-3 K warmer than they were during the 1980s. Data from the co-located USGS/GTN-P meteorological array show that air temperatures have been warming significantly during the summer and autumn seasons (~ 1 K/decade mean-annual warming rate), 1-m ground temperatures have been warming during all seasons (~ 1 K/decade mean-annual warming rate), and that the winter freezeback of the active layer is occurring about 1 month later than it did a decade ago.

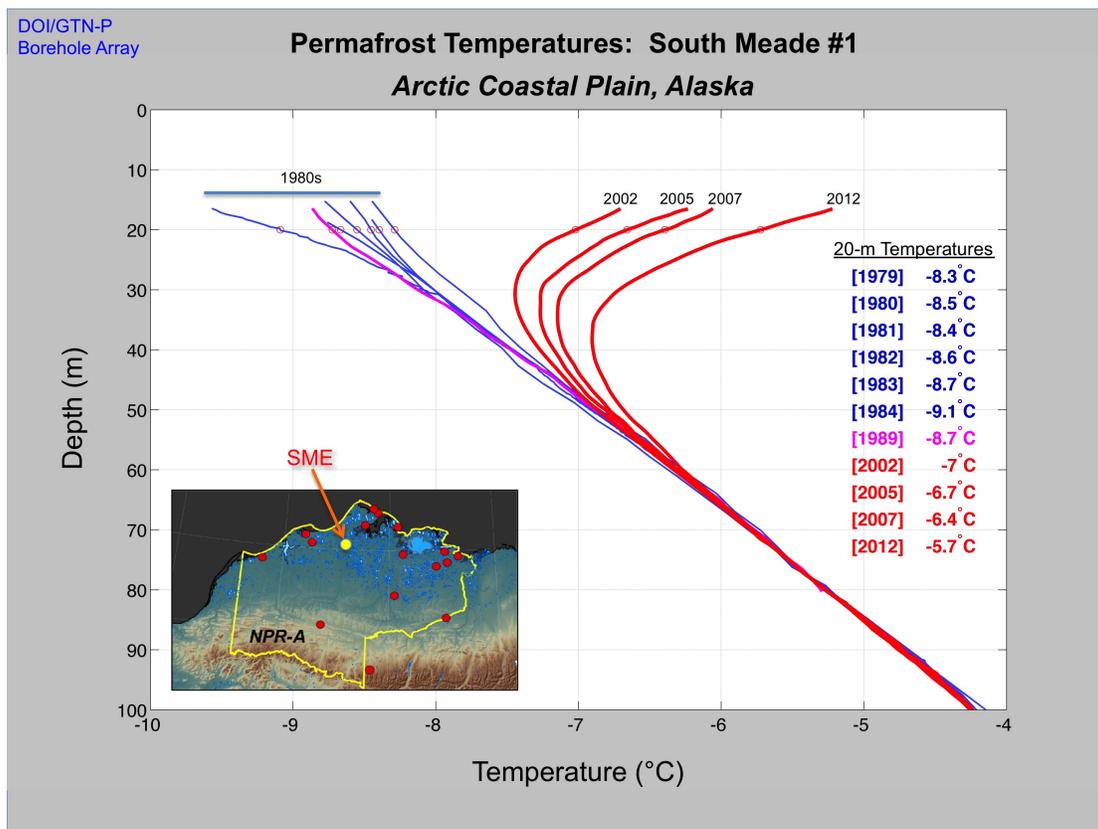


Figure 1. Permafrost temperatures measured in the South Meade #1 borehole on the Arctic Coastal Plain of Alaska since 1979. Temperatures 20 m below the surface have warmed about 2.8 K at this site since the early 1980s. South Meade is one of 19 deep boreholes currently monitored by the U.S. Geological Survey in Arctic Alaska.

International Arctic Systems for Observing the Atmosphere (IASOA) – A Portal for Discovery, a Platform for Pan-Arctic Collaboration

S. Starkweather

Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO 80309; 303-497-5247, E-mail: sandy.starkweather@noaa.gov

Long-term atmospheric and cryospheric observations underpin our understanding of the current state of the Arctic climate and provide a means for monitoring change, gaining insight into the causes of change and supporting decisions to manage change. IASOA (<http://iasoa.org>) was initiated in 2005 to mobilize the considerable long-term observing assets at ten, independently-funded international Arctic observatories towards coordinated pan-Arctic science to understand Arctic change.

This presentation will report on the progress we have made since 2012 on developing IASOA’s data sharing capabilities, including the creation of structured metadata for 182 datasets from NOAA’s Global Monitoring Division. The guiding design principles for the IASOA data portal were to leverage existing efforts and to listen closely to the IASOA community about what motivated them to visit and contribute to data portals.

Synthesis science is the ultimate realization of IASOA’s mission. In 2013, IASOA facilitated the development of a science working group structure including experts from NOAA’s Global Monitoring and Physical Science Divisions. The accomplishments-to-date of these groups includes: 1) facilitating the installation of a new radiation suite at Summit Station; 2) spearheading consistent processing routines for IASOA aethalometer and radiation datasets; and 3) two chapter contributions to the 2013 Arctic Report Card (Sharma et al., 2013; Key et al., 2013).

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■ Data Access Portal											About Help
Category	▼▲	Abisko	Alert	Barrow	Cherskii	Eureka	Ny-Alesund	Pallas-Sodankyla	Station Nord	Summit	Tiksi
Aerosol	▲	●	●	●		●	●	●		●	●
Physical, Optical		●	●	●		●	●	●		●	●
Physical, Primary			●	●							
Atmospheric State	▼	●	●	●	●	●	●	●	●	●	●
Cloud Properties	▲		●	●		●	●	●		●	●
Macrophysical			●	●		●	●	●		●	●
Microphysical				●		●				●	
Microphysical and Chemical Properties				●							
Optical and Radiative Properties				●						●	
Cryosphere	▼				●	●					●
Greenhouse Gas	▼		●	●	●	●	●	●		●	●
Ozone	▼		●	●		●	●	●		●	●
POPs	▼						●	●			
Precipitation Chem	▼						●	●			
Radiometric	▼		●	●	●	●	●	●		●	●
Reactive Gas	▼		●	●		●	●	●		●	●
Surface Properties	▼			●	●	●					●

Figure 1. Dataset entries in the new IASOA data portal are organized by site and nested geophysical parameters derived from widely used sources like the World Meteorological Organization. Each “dot” represents one or more dataset entries in our catalog. There are currently over 800 entries.

Detection and Quantification of Urban Greenhouse Gas Emissions: Ground-based Results of the INdianapolis FLUX (INFLUX) Experiment

N. Miles¹, T. Lauvaux¹, K. Davis¹, S. Richardson¹, D. Sarmiento¹, K. Wu¹, A. Karion², C. Sweeney², I. Vimont³, J. Turnbull⁴, M. Hardesty², A. Brewer⁵, K. Gurney⁶, I. Razlivanov⁶, L. Iraci⁷, P. Hillyard⁷, P. Shepson⁸, M. Cambaliza⁸ and J. Whetstone⁹

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⁸Purdue University, West Lafayette, IN 47907

⁹National Institute of Standards and Technology (NIST), Boulder, CO 80305

The INdianapolis FLUX (INFLUX) Experiment was designed to develop and evaluate methods for detection and attribution of greenhouse gas fluxes from urban environments. In addition to aircraft and flask measurements, the current INFLUX observation network includes twelve *in situ* towers instrumented for continuous measurements of CO₂/CO/CH₄, four eddy covariance flux towers, and a Doppler lidar. A Total Carbon Column Observing Network column remote sensing station was deployed for approximately four months. Results from the Hestia project provide high spatial/temporal resolution "bottom-up" emissions estimates. The modeling system includes the Weather Research and Forecast model and Lagrangian Particle Dispersion Model, combined with a Bayesian matrix inversion. Here we will present results from the *in situ* tower measurements and preliminary missions results from the inversion system. As shown in Figure 1, the model captures the overall ordering of the sites in terms of increase above background average CO₂ mole fraction, but the observations are 25% higher than the modeled values, on average. The discrepancy suggests an underestimate in the bottom up emissions estimate. The spatial structure of the difference between the posterior (inverse) and the prior emissions (Hestia) fluxes is shown in Figure 2. We investigate the sensitivity of the modeled results to the assumptions.

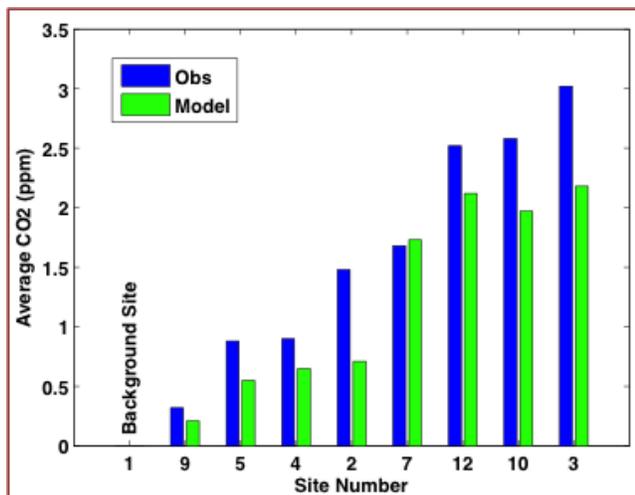


Figure 1. Shown in green is the observed averaged CO₂ mole fraction above background for INFLUX tower sites (1 Jan – 1 Apr 2013). Shown in blue are model results (prior to inversion) using a mesoscale atmospheric model and Hestia 2002.

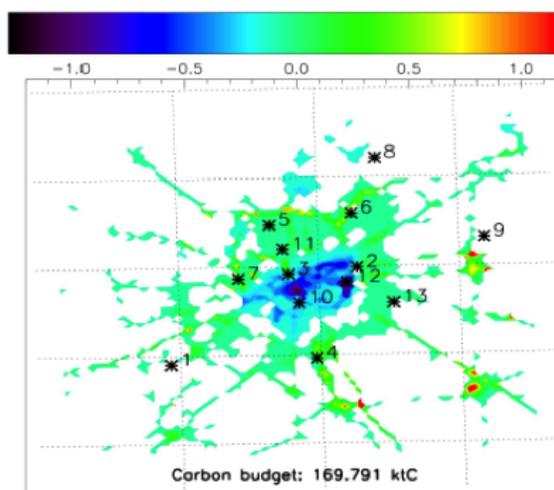


Figure 2. The spatial structure of the difference between the posterior (inverse) and the prior emissions (Hestia) fluxes for the period 6 Oct – 30 Nov 2012.

Partitioning of Urban Fossil Fuel CO₂ Emissions by Source Sector: Results from the Indianapolis FLUX (INFLUX) Experiment

J. Turnbull¹, A. Karion², C. Sweeney², M. Hardesty², S. Lehman³, T. Newberger², I. Vimont³, K. Davis⁴, T. Lauvaux⁴, N. Miles⁴, S. Richardson⁴, P. Shepson⁵, M. Cambaliza⁵, K. Gurney⁶, L. Iraci⁷ and J. Whetstone⁸

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Most fossil fuel CO₂ (CO₂ff) is emitted from urban areas, and cities are often leading the way in efforts to reduce GreenHouse Gas (GHG) emissions. In addition to information on total CO₂ff emissions, mitigation efforts will require details on the contributions from the various source sectors (electricity production, industry, vehicles, etc.). The Indianapolis FLUX (INFLUX) experiment aims to develop and evaluate methods for detection and attribution of urban GHG fluxes, including a large suite of measurements, a bottom-up CO₂ff data product and meso-scale modeling. We use multi-species flask and *in situ* observations from the INFLUX towers to separate CO₂ff by source sector. $\Delta^{14}\text{CO}_2$ measurements have shown that in winter, the total CO₂ enhancement over Indianapolis approximates the CO₂ff added. This somewhat surprising result allows us to use the wintertime *in situ* total CO₂ and CO measurements to determine the observed CO:CO₂ff ratio (RCO) at high resolution. Electricity production (~28% of CO₂ff) produces almost no CO, whereas other urban CO₂ff sources have RCO of up to ~15 ppb/ppm. Thus RCO can potentially be used to partition CO₂ff by source sector. We will present results examining spatial and temporal variability in RCO in Indianapolis to understand how this method might be applied.

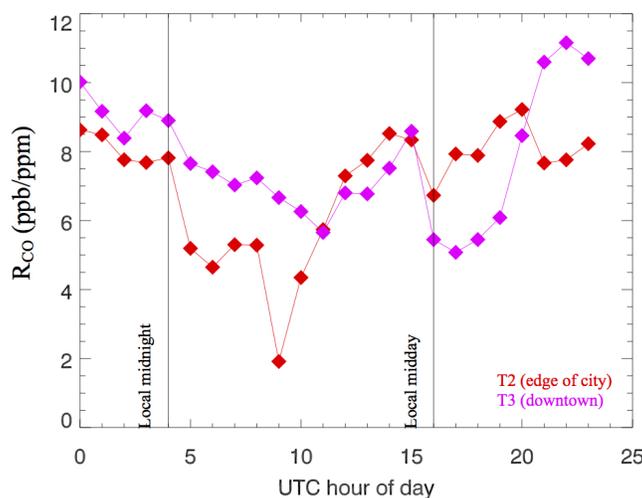


Figure 1. The typical Towers 2 and 3 RCO is 8 ppb/ppm, roughly consistent with expectations of the averaged urban RCO estimated from bottom-up data products. During late afternoon, RCO at Tower 3 increases, suggesting that vehicle emissions are more dominant in the signal. At other times of day (early morning at Tower 2 and early afternoon at Tower 3), RCO drops to much lower values, suggesting a stronger influence from electricity production in the tower footprints at these times.

Amazon Basin-wide Fluxes of CO₂ and CH₄ from Aircraft Vertical Profiles

J.B. Miller¹, L. Gatti², M. Gloor³ and L. Basso²

¹Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO 80309; 303-497-7739, E-mail: john.b.miller@noaa.gov

²Instituto de Pesquisas Energeticas e Nucleares (IPEN), Sao Paulo, Brazil

³University of Leeds, Leeds, United Kingdom

Potential feedbacks between land carbon pools and climate are one of the largest sources of uncertainty for predicting future global climate, but estimates of their sensitivity to climate anomalies in the tropics and determination of underlying mechanisms are either incomplete or strongly model-based. The Amazon Basin alone stores ~150-200 Pg (1015 g) of labile carbon, and has experienced an increasing trend in temperature and extreme floods and droughts over the last two decades. Here we report the first Amazon Basin-wide seasonal and annual carbon balances based on tropospheric greenhouse gas sampling, which is the product of a unique collaboration between scientists from NOAA, Brazil and the United Kingdom. Results presented here focus on an anomalously dry and a wet year, 2010 and 2011, providing the first Basin-wide assessment of sensitivity to such conditions. During 2010, the Amazon Basin lost 0.5 ± 0.2 PgCyr⁻¹ while in 2011 it was approximately carbon neutral (0.06 ± 0.1 PgCyr⁻¹). Carbon loss via fire was 0.5 ± 0.1 PgCyr⁻¹ in 2010 and 0.3 ± 0.1 PgCyr⁻¹ in 2011, as derived from Basin-wide carbon monoxide (CO) enhancements. Subtracting fire emissions from total carbon flux to derive Basin net biome exchange reveals that in 2010 the non-fire regions of the Basin were carbon neutral; in 2011, however, they were a net carbon sink of -0.3 ± 0.1 PgC yr⁻¹, roughly consistent with a three-decade long intact-forest biomass sink of $\sim -0.4 \pm 0.3$ PgCyr⁻¹ estimated from forest censuses. In contrast to CO₂, fluxes of methane (CH₄) from the Amazon Basin are smaller in 2011 than in 2010. In both years, by far the largest fluxes were seen in the eastern part of the basin, a result that process-based models have been unable to reproduce. And also unlike CO₂, fire is a relatively small component of CH₄ fluxes with wetland emissions likely dominating.

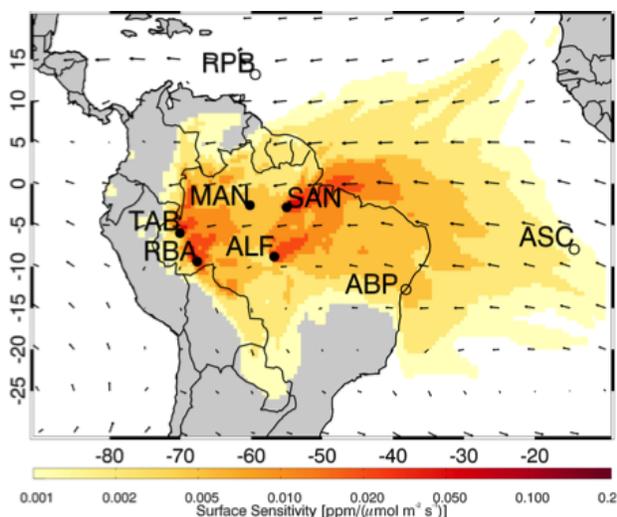


Figure 1. Map of IPEN (ALF, SAN, TAB, RBA) and NOAA (ABP, RPB, ASC) sites along with the soon to be implemented MAN site. Also shown are average surface influence functions for the four IPEN vertical profile sites during 2010 as calculated with the FLEXPART Lagrangian Particle Dispersion Model; annual average wind vectors below 600 mb also show the dominant influence of the trade winds in the lower troposphere.

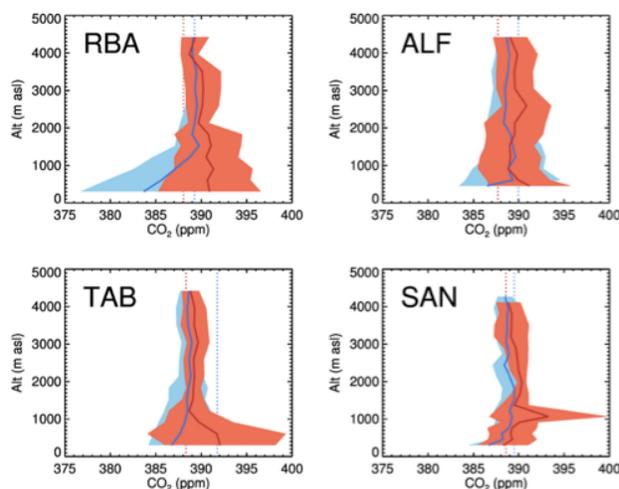


Figure 2. Examples of dry and wet season CO₂ light aircraft-based vertical profiles at the four IPEN sites from Fig 1. Red and blue lines are mean 2010 profiles for dry and wet seasons, respectively (n~10 per season), and background shading shows the one sigma standard deviation of variability at each altitude. Dashed vertical lines show the dry and wet season averages for the tropical Atlantic background CO₂ calculated as a weighted average of ASC and RPB.

Seasonality and Trends of Atmospheric Transport Events to Summit, Greenland Derived from Long-term Non-methane Hydrocarbon Observations

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Due to large-scale atmospheric circulation patterns, the Arctic is a large receptor for pollution from across the Northern Hemisphere. Transport efficiency varies seasonally depending on circulation changes and photochemical removal rates. Non-methane hydrocarbons exhibit a distinct seasonal cycle, with maxima in the winter and minima in the summer, that has been well-studied and is captured sufficiently from flask sampling performed by the NOAA Cooperative Air Sampling Network. There is, however, little knowledge regarding the frequency and seasonal or inter-annual trends of individual pollution transport events impacting the Arctic region, as elucidation of these behaviors requires higher time-resolution data. The non-methane hydrocarbons in particular, are valuable tracers for pollution events as specific compounds or ratios can be used to identify periods of anthropogenic pollution (e.g., light alkanes, chlorofluorocarbons/hydrochlorofluorocarbons), biomass burning (e.g., acetylene, benzene), or stratospheric intrusions (e.g., low alkane, high ozone events). Here, we utilize long-term observations of methane and non-methane hydrocarbons conducted at Summit Greenland from 2008 – 2010 and 2012 – 2014, in conjunction with flask data from the NOAA Cooperative Air Sampling Network and FLEXible PARTicle Dispersion Model (FLEXPART) back-trajectory analysis, to investigate the frequency, seasonality, and source distribution of atmospheric transport events impacting the Arctic.

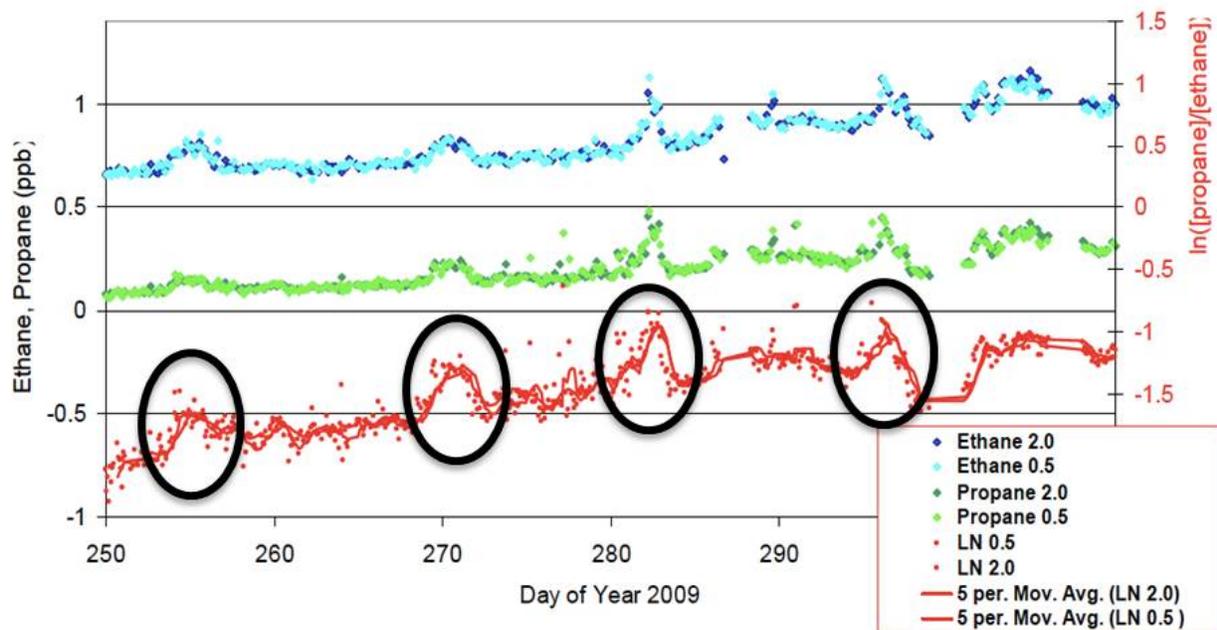


Figure 1. Record of *in situ* measurements of propane (green) and ethane (blue) at Summit for Fall 2009. The $\ln([\text{propane}]/[\text{ethane}])$ is shown as the red trace. Four pollution transport events are indicated by the circled periods.

Historic European Non-CO₂ Atmospheric Greenhouse Gas Records: Harmonization and Uncertainty Assessment

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One important aim of the European project InGOS ("Integrated non-CO₂ Greenhouse gas Observation System") is harmonizing historic greenhouse gas (GHG) observations. The project brings together the PIs of 20 European atmospheric monitoring stations to jointly revisit, reevaluate and quality control their historic datasets (i.e. starting from 2000) for CH₄, N₂O and H₂. The need for consolidating European in situ data has become necessary since in the last decades European GHG monitoring has been conducted by a multitude of national organizations and institutions, each with its own measurement procedures, quality control system and link to the international calibration scales.

Furthermore, for the first time, uniform and comprehensive uncertainty estimates are calculated for all sites to provide additional, valuable information to data users. The InGOS uncertainty assessment presented here makes use of all historically available quality measures at the monitoring sites such as surveillance cylinders and/or co-located flask sample measurements. The InGOS uncertainty assessment consists of different uncertainty categories, namely repeatability, reproducibility, lab internal scale consistency, flask comparison uncertainty and scale transfer uncertainty. In Figure 1 an example for the uncertainty estimates of the Heidelberg N₂O measurements is given. Although designed for gas chromatographic data, the InGOS uncertainty estimates may be universally applied for different GHG measurement techniques. In addition to the uncertainty methodology we present a section of the revisited European data sets including their uncertainties.

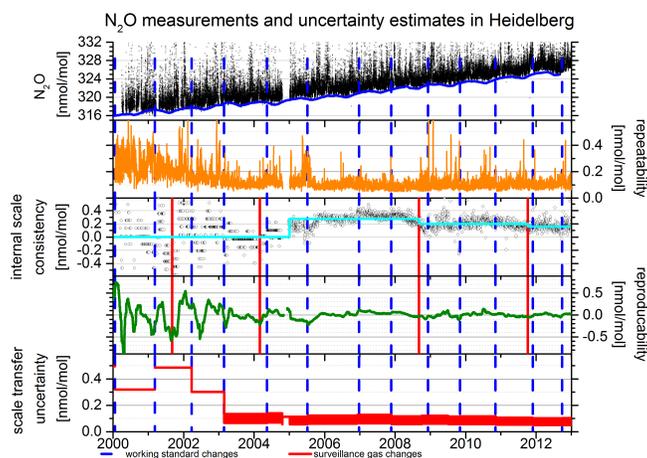


Figure 1. N₂O measurements in Heidelberg and the respective uncertainty estimates.

A Half-century Record of State-by-State Changes in Fossil Fuel Carbon Emissions and Corresponding Isotope Ratios in the United States

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A record of annual state-by-state fossil fuel carbon emissions from solid, liquid and gaseous fuels in the United States (US) since 1960 is now available for analysis. We focus on the period from 1960-2010. The spatial pattern of emissions, and of the ^{13}C signature of the emitted carbon, changes with events such as the peaking of oil/gas production in certain states, discovery of the Prudhoe Bay Oil Field and subsequent construction of the Alaskan Pipeline, and large-scale switching from heating oil to natural gas in the northeastern US as oil becomes more expensive and new gas pipelines are installed. From 1960-2010 the northeastern states were generally characterized by decreases in ^{13}C ratios and in per-capita carbon emissions. Largest increases in ^{13}C ratios were between the Rocky Mountains and the Mississippi River, and in Arizona and New Mexico. Largest increases in per-capita emissions were in coal-rich low-population states that export much electricity to other states. From 2000-2010 per-capita carbon emissions increased in only 5 states; new coal fired power plants were partly responsible for some of these increases, although a large increase in natural gas consumption was sometimes a strong influence. Per-capita emissions in other states declined from 2000-2010, while ^{13}C ratios also declined in 36 states plus the District of Columbia; these changes reflect decreased use of coal, increased use of natural gas, and increasing motor fuel economy.

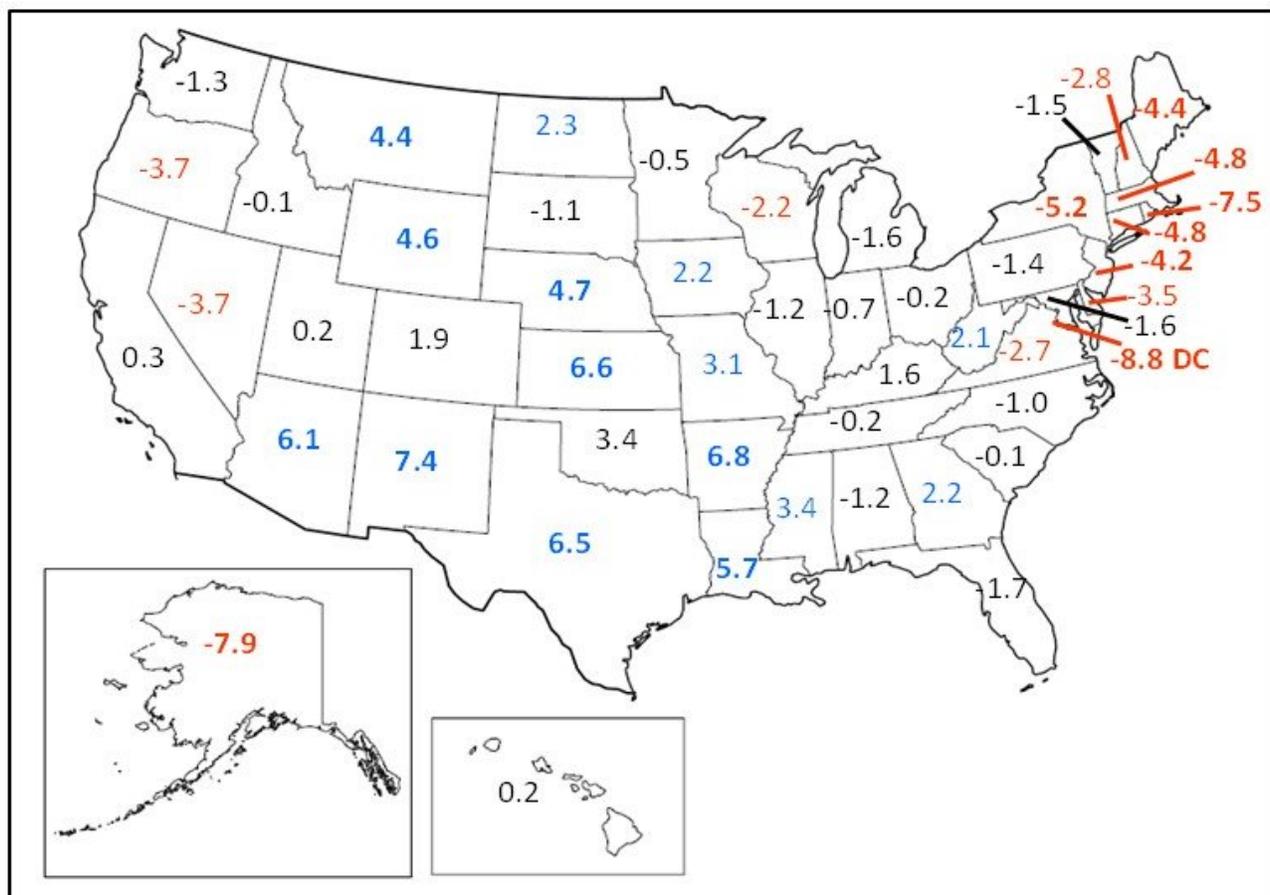


Figure 1. 1960-2010 change in the pattern of ^{13}C isotope ratio in fossil fuel carbon emissions in the United States. Changes of greater than 2.0 are colored red if negative, blue if positive. Values greater than 4.0 in either direction are in bold.

The Ability of Satellite-based CO₂ Measurements to Constrain Carbon Cycle Science: From Greenhouse Gases (GHG) Observing SATellite (GOSAT) to Orbiting Carbon Observatory (OCO-2)

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Since the launch of GOSAT in 2009, the holy grail of the satellite-GHG community has been to constrain sources and sinks of CO₂ by direct assimilation of satellite-measured column-averaged dry air mole fraction of CO₂ (XCO₂) into carbon inversion systems. However, this effort has been hampered by a number of factors. On the GOSAT side, the observations have regional-scale biases of the order of 1 ppm which can differ for different surface types, solar zenith angles, and other factors, which can induce false fluxes in the inversion results. Models have their own shortcomings including uncertain transport, incorrect or unfairly-constrained prior fluxes, and issues related to the inversion scheme itself (such as temporal window length or poorly-estimated posterior uncertainty). Building on the latest Atmospheric CO₂ Observations from Space (ACOS)/GOSAT XCO₂ results, we give an overview of the errors of the satellite measurements, discuss data/model comparisons, and argue for a parallel research effort to complement the direct inversion approach. We finish with an overview of what OCO-2 (scheduled to launch on July 1, 2014) may bring to the table above and beyond GOSAT measurements.

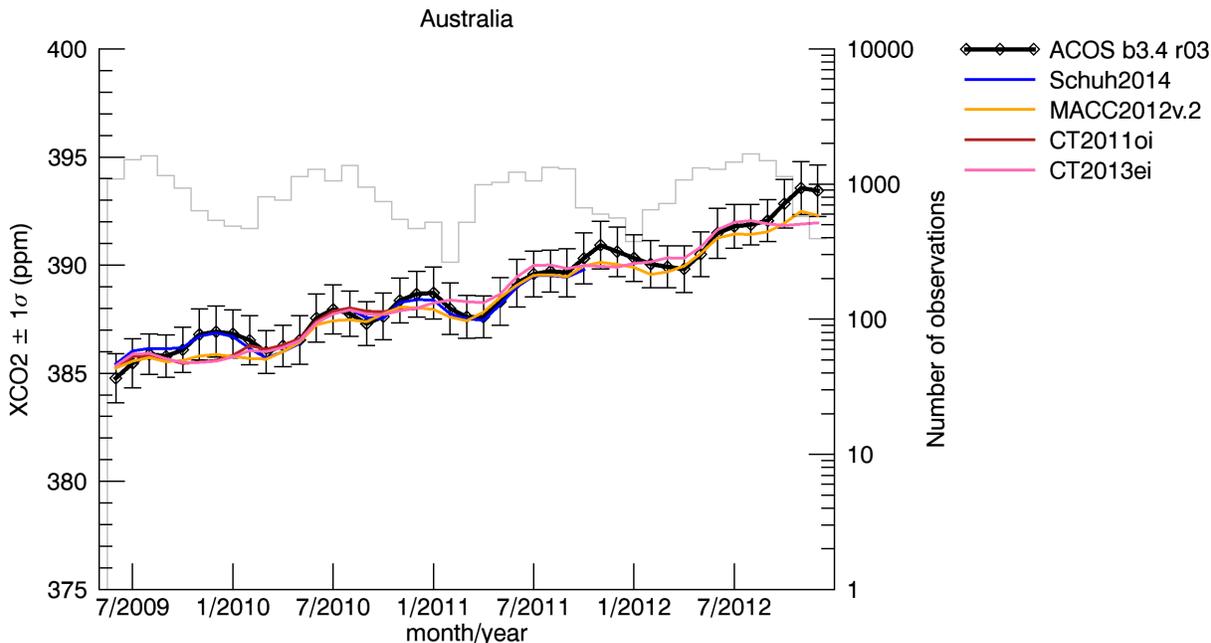


Figure 1. Monthly mean values of ACOS/GOSAT B3.4 XCO₂ values, averaged over the Australia Transcom-3 region (black). Corresponding values of model-averaged XCO₂, matched to the data and similarly averaged, are also shown: CarbonTracker 2011oi (red), CarbonTracker 2013ei (pink), Monitoring Atmospheric Composition & Climate 2012v2 (yellow). These models all were optimized against surface *in situ* and aircraft data. A model optimized against an earlier version of ACOS/GOSAT XCO₂ measurements (Schuh 2014), is also shown (blue). While there is good agreement, the satellite measurements suggest a larger CO₂ source in austral summer for certain years, especially 2009-10 and 2012-13.

Launch and Early Operations of the National Aeronautics & Space Administration (NASA) Orbiting Carbon Observatory-2

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The Orbiting Carbon Observatory – 2 (OCO-2) is scheduled to launch from Vandenberg Air Force Base in California on a Delta-II 7320-10 launch vehicle at 02:56:44 AM PDT (12:56:44 GMT) on 1 July 2014. OCO-2 will separate from the 2nd stage about 56.25 minutes after lift-off and begin a 10-day spacecraft checkout period. A 20-day series of orbit raising maneuvers will then be executed to insert OCO-2 at the front of the 705-km Afternoon Constellation (A-Train; Fig. 1). It will follow an orbit track that shares the same nadir ground track as the CloudSat radar and the Cloud-Aerosol Lidar & Infrared Pathfinder Satellite Observation lidar (Fig. 2). This 98.8-minute sun synchronous orbit has a 1:36:30 PM mean local time and a 16-day (233-orbit) ground track repeat cycle. The instrument optical bench and detectors will then be cooled to their operating temperatures and a ~7-day observatory check-out period will commence. OCO-2 will then start routinely collecting about 1 million soundings each day over the sunlit hemisphere. Within 90 days, calibrated, geo-located spectral radiances will start being delivered to the NASA Goddard Earth Sciences Data & information Services Center. Initial estimates of the column averaged CO₂ dry air mole fraction, XCO₂, will start being delivered 90 days after that.

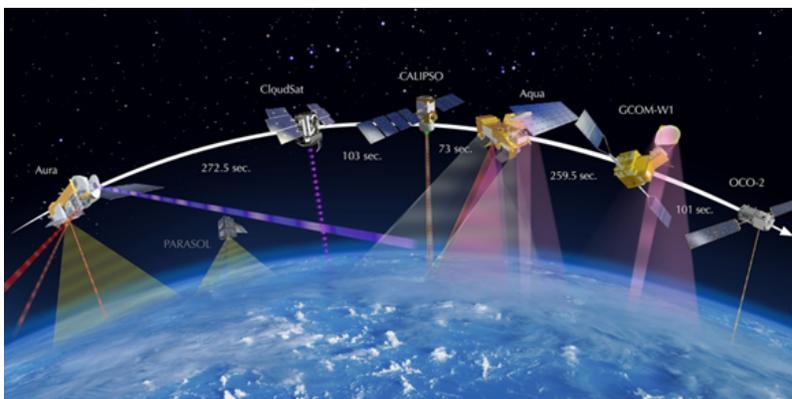


Figure 1. 705-km afternoon constellation, showing the positions and separations (in seconds) between the spacecraft.

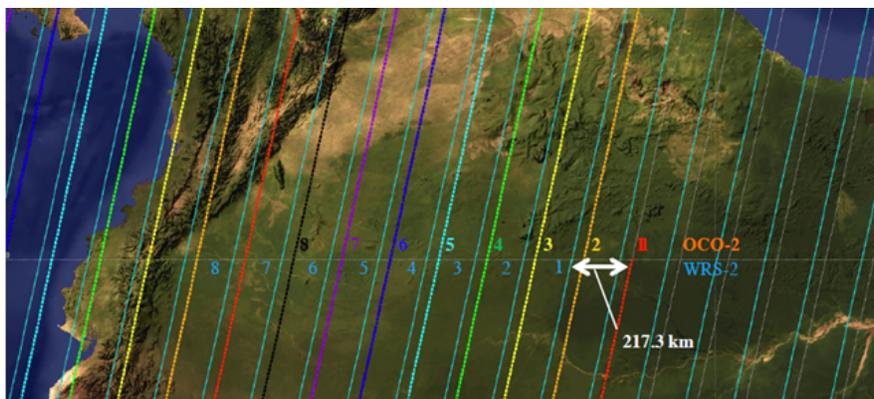


Figure 2. Map showing relationship of OCO-2 ground tracks and the Worldwide Reference System -2 paths followed by the Aqua satellite. The OCO-2 tracks are displaced eastward by 217.3 km at the equator.

Validation of Total Carbon Column Observing Network (TCCON) Observations of CO₂/CH₄/CO at Sodankylä Using AirCore

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As an essential network to validate satellite observations, TCCON observations of CO₂/CH₄/CO need to be tightly linked to ground-based observations, (i.e. on the World Meteorological Organization reference scale). AirCore, a long tube descending from a high altitude with one end open and the other closed, has been demonstrated to be a reliable, cost-effective sampling system for high-altitude profile measurements of CO₂ and CH₄, and an ideal tool to validate TCCON observations. We will present newly available AirCore profiles of CO₂/CH₄/CO over Sodankylä since September 2013 near the TCCON site at Sodankylä (67.368N, 26.633E, 179 m.a.s.l), and compare the integrated AirCore column averages with TCCON retrievals (preliminary results shown in Fig.1). Different from previous studies, this effort is to validate total column measurements at relatively high latitude. These activities are becoming important as active satellite sensors, which are currently under development and planned for launch in the near future (e.g. Merlin and ASCENDS), and will allow year around measurements at high latitudes. Furthermore, we compare the AirCore profiles of CH₄ at two TCCON stations of Sodankylä and Lamont with climatological profiles from the four-dimensional variational (4D-Var) data assimilation system based on the TM5 atmospheric transport model and the NOAA Earth System Research Laboratory observational data, and validate the model performance.

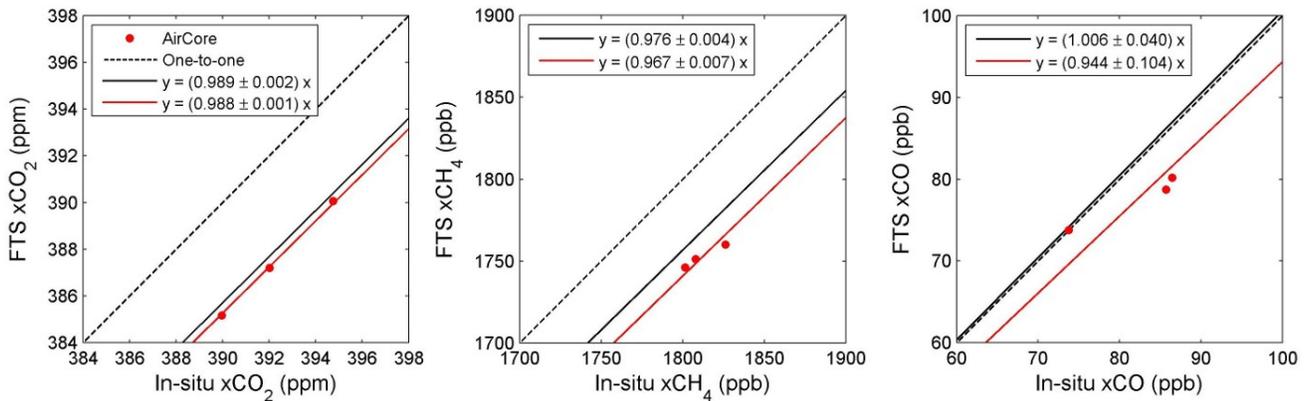


Figure 1. Comparisons of integrated AirCore averages of CO₂, CH₄, and CO with TCCON retrievals at Sodankylä (black lines show the calibration used by the current version of the TCCON retrievals and red lines are for the AirCore comparisons).

Constraining Fossil Fuel CO₂ Emissions with Joint Assimilation of Atmospheric CO₂ and ¹⁴CO₂ Measurements

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Atmospheric source-sink inversions can be used to estimate surface fluxes of a trace gas (such as CO₂ or CH₄) from observed atmospheric gradients. Present day inversion products reporting surface fluxes of CO₂, such as NOAA's CarbonTracker (<http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/>), solve for natural fluxes of CO₂ assuming that the fossil fuel flux of CO₂ is perfectly known. Since the CO₂ observing network is primarily sensitive to the sum of the natural and fossil fuel fluxes, any error made in calculating the 'fixed' fossil fuel CO₂ flux will lead directly to bias in the retrieved natural CO₂ flux. This is especially important at the regional scale. While the global total fossil fuel CO₂ flux is known to about 5% accuracy, regional estimates can be far less accurate. Over the past decade, the Carbon Cycle Greenhouse Gases Group at the Global Monitoring Division, in collaboration with the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado (Boulder), have been measuring atmospheric ¹⁴CO₂/¹²CO₂ at selected sites, mostly over North America. Fossil fuel carbon, which is millions of years old, is devoid of this radioisotope, which has a half life of 5730 years. As a result, fossil fuel CO₂ emissions have a very different isotopic signature than all other sources. Here, we present the first results from a joint inversion of atmospheric CO₂ and ¹⁴CO₂ measurements, in order to estimate the natural and fossil fuel fluxes of CO₂, as well as so-called "disequilibrium fluxes", which also influence atmospheric radiocarbon gradients.

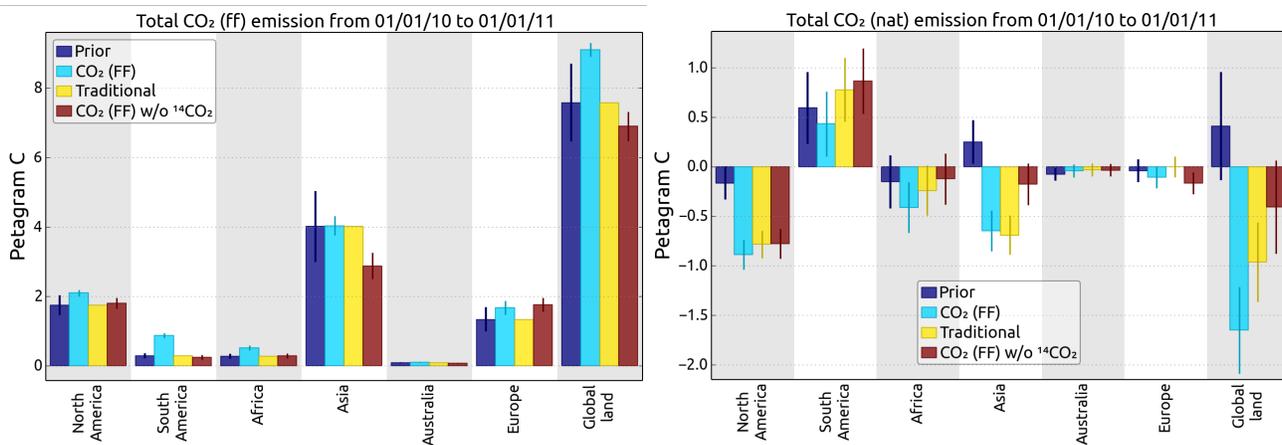


Figure 1. Optimized surface fluxes from three different source-sink inversions, and the first guess ("Prior"). The "Traditional" inversion uses fixed fossil-fuel fluxes, and adjusts natural CO₂ fluxes to fit atmospheric CO₂ measurements. The "CO₂ (FF) w/o ¹⁴CO₂" adjusts both natural and fossil fuel sources of CO₂, again using only CO₂ measurements. The "CO₂ (FF)" adjusts both natural and fossil fuel fluxes of CO₂ by assimilating both atmospheric CO₂ and ¹⁴CO₂ measurements.

CarbonTracker-Lagrange: A New Tool for Regional- to Continental-scale Flux Estimation

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CarbonTracker-Lagrange (CT-L) is a prototype inverse modeling framework for regional quantification of greenhouse gas fluxes, including anthropogenic emissions and biological uptake. CT-L uses sampling footprints, also known as influence functions, to relate atmospheric measurements to upwind fluxes and boundary values. First-guess or prior fluxes are adjusted using Bayesian methods to provide optimal agreement with available observations. Alternatively, geostatistical inverse modeling techniques may be used to estimate fluxes without relying on prior flux estimates. Footprints are pre-computed and the optimization algorithms are efficient, so many variants of the calculation can be performed. For example, we can test alternate prior flux estimates, data weighting scenarios and assignment of flux error covariance parameters.

To date, a library of footprints has been generated for measurements made during 2007 - 2010 using the Stochastic Time-Inverted Lagrangian Transport model driven by meteorological output from the Weather Research Forecast (WRF) model. WRF was run with 30-40 km resolution for an outer domain that covers nearly all of North America and with 10 km resolution over the continental U.S. Footprints are species independent and can be used to simulate any long-lived constituent. CT-L can also use footprints from the FLEXPART and HYSPLIT models and a variety of meteorological driver datasets. Planned applications for CT-L include developing objective methods for combining surface and airborne *in situ* observations with ground-based and satellite-borne column CO₂ sensors, with particular emphasis on evaluating the extent to which column and *in situ* measurements enable separate estimation of surface fluxes and boundary inflow for North America. We will also conduct realistic Observing System Simulation Experiments to consider how the density and uncertainty of the measurements impact flux estimates, and we plan to eventually use multiple models to investigate the impact of errors in simulated atmospheric transport.

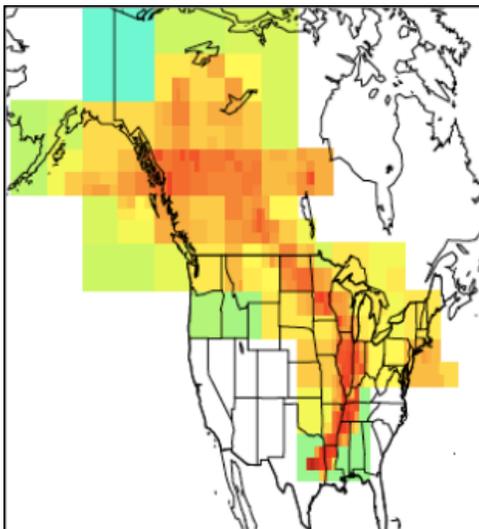


Figure 1. Sampling footprint for a mid-afternoon measurement from the WKT tall tower site near Moody, TX, showing the sensitivity to surface fluxes on a logarithmic scale.

Estimation of the Permafrost Carbon Feedback Using The SiBCASA Terrestrial Carbon Cycle Model

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The Permafrost Carbon Feedback (PCF) is an amplification of surface warming due to the release of carbon and methane from thawing permafrost. Studies show that the extensive northern wetlands contribute up to 25% of global methane emission, whereas 2.3% of methane emissions occurs from thawing permafrost in these regions. To improve estimates of the PCF we added prognostic organic layer to the Simple Biosphere/Carnegie-Ames-Stanford (SiBCASA) Terrestrial Carbon Cycle Model and quantified carbon and methane fluxes resulting from changes in terrestrial carbon storage in permafrost affected soils. Model simulations spanning from 1901 to 2010 were driven using Climatic Research Unit-National Centers for Environmental Prediction (CRUNCEP) reanalysis, atmospheric CO₂, and land use change information as modified by the Multi-Scale Terrestrial Model Intercomparison Project. From 2011 to 2300, multiple projections of CO₂ and methane emissions and changes in PCF were evaluated by scaling the CRUNCEP data using trends in weather data derived from the Fifth Coupled Model Intercomparison Project for 4.5 and 8.5 Representative Concentration Pathway (RCP) scenarios (Figure 1,2). Implementation of the dynamic organic layer into the model lowered the effective thermal conductivity between the soil and the atmosphere and increased the resilience of permafrost to climate warming and decreased permafrost seasonal thawing depth. The ensemble mean for each RCP is our best estimate of CO₂ and methane emissions from degrading permafrost and the standard deviation is a measure of uncertainty.

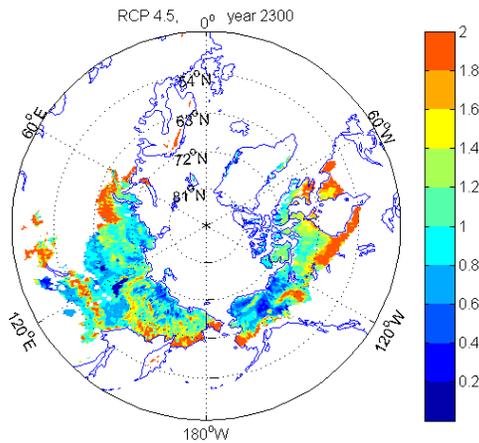


Figure 1. An average active-layer thickness for the periods 2290–99 for RCP 4.5. The colorbar is in meters.

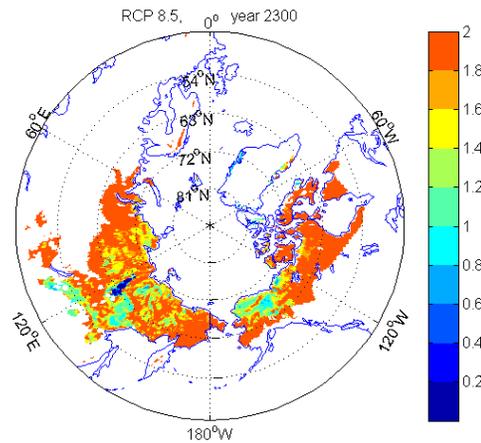


Figure 2. An average active-layer thickness for the periods 2290–99 for RCP 8.5. The colorbar is in meters.

Evaluating Models of Wetland CH₄ Emissions: How Believable Are Simulations of Future Emissions?

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An important challenge for predicting the future evolution of the global climate is representing feedback processes. One such feedback involves methane emissions from wetlands. Vast stores of carbon in the Arctic may thaw over the next centuries, and it is important to understand how wetlands will evolve over time; will the warmer temperatures lead to more CH₄ emissions, or will the wetlands drain as permafrost thaws? Changes in precipitation and land use in the tropics and mid-latitudes may also lead to significant changes in emissions, shifting the balance between respiration of CH₄ and CO₂.

Modeling CH₄ emissions from wetlands is a complicated problem since even the distribution of wetlands is subject to much uncertainty and is treated in a variety of ways in current CH₄ emission models. Nutrient cycling and small-scale processes must also be represented at scales that are large enough to be interpreted at global scales. Ultimately, confidence in models that couple greenhouse gas emissions with climate models should be dependent on the ability of the emission models to reproduce the current observed spatial distribution and variability. Global network and campaign data are critical to evaluation of bottom-up emission models. Multiple decades of surface network observations exist and provide metrics that wetland models should be able to reproduce such as the seasonal cycle, trends, gradients and inter-annual variability. Although models are commonly tested and even calibrated to flux tower data, the atmospheric observations provide an important check on how modeled emissions are represented regionally and globally. Ultimately, if models are unable to reproduce observed variability, it is unlikely that they can be expected to reliably reproduce future variability in CH₄ emissions.

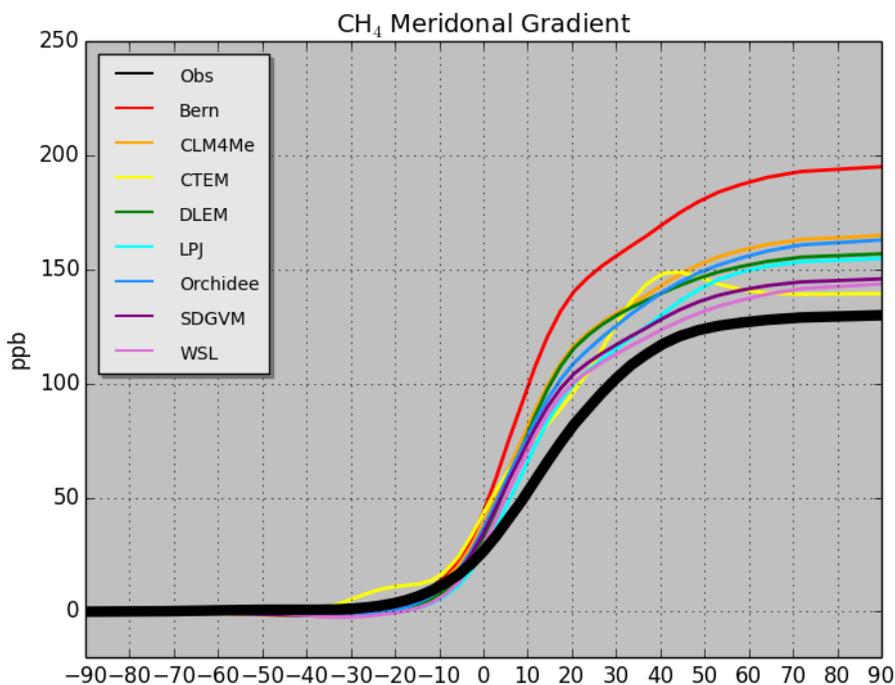


Figure 1. The observed and simulated North-South gradient of CH₄ relative to the South Pole. The thick black curve shows the zonal average marine boundary layer sites, and the colored curves show simulations sampled identically to the observations for a suite of wetland models.

Comparison of Aerosol Absorption Optical Depth from Remote-sensing and *In Situ* Measurements

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The aerosol absorption optical depth (AAOD) product derived from AERONET sun/sky radiometer measurements has been widely used to evaluate model predictions of black carbon (BC) and its radiative forcing. Most recently, the Bounding BC assessment (Bond et al., 2013) used the AERONET AAOD retrievals to justify adjusting modelled BC column burdens upwards by a globally-averaged factor of 2.6, leading to the conclusion that BC is the #2 most important climate-warming agent (behind CO₂), with an average forcing of +1.1 W m⁻² (90% uncertainty bounds +0.17 to 2.1 W m⁻²). However, the verification of the AERONET AAOD retrievals relies primarily on short-term aircraft studies done under conditions of very high aerosol loadings (biomass burning, dust), and the retrievals have not been evaluated under the low optical depth conditions that prevail over most of the globe. In this paper, we report comparisons of AERONET AAOD with *in situ* measurements of aerosol light absorption coefficient obtained over sites in Oklahoma (SGP) and Illinois (BND) in the US. The comparisons, illustrated in the figure for SGP, show that the *in situ* measurements do not support the up-scaling of modelled BC column burdens.

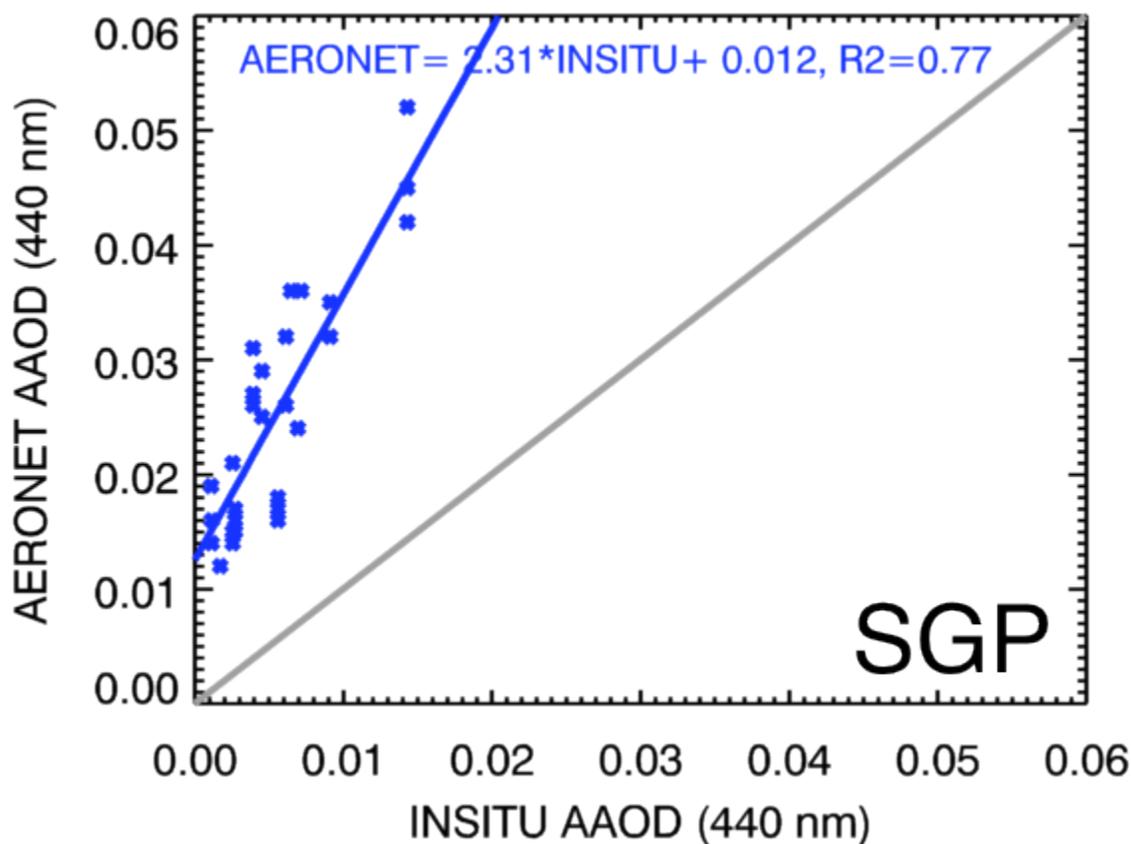


Figure 1. Comparison of aerosol absorption optical depth at Southern Great Plains, Oklahoma, USA.

Constraining Global Models of Black Carbon (BC) Aerosol with Pole-to-Pole Observations

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We have completed a comparison of the full HIAPER Pole-to-Pole Observations (HIPPO) mission data set to AeroCom Phase II model fields. Over 700 vertical profiles of BC Mass Mixing Ratio (MMR) obtained from 85N to 67S in five seasons and three years reveal climatological features of the BC distribution of particular significance for evaluating model performance. These include low variability in BC MMR in the lower stratosphere, and minima in tropical BC MMR near 200 hPa altitude pressure, consistent with convective outflow. The comparison expands earlier results focused on only the first of five deployments, and more clearly and robustly identifies systematic model biases in the remote regions. Individual and ensemble model skill will be presented by both season and geographic location as a function of altitude. Work tying these results, and those of other field missions, to BC direct Radiative Forcing (RF) identify BC lifetime as a critical parameter for reproducing remote and high altitude observations, and suggest significant biases in global BC RF due to far-field biases.

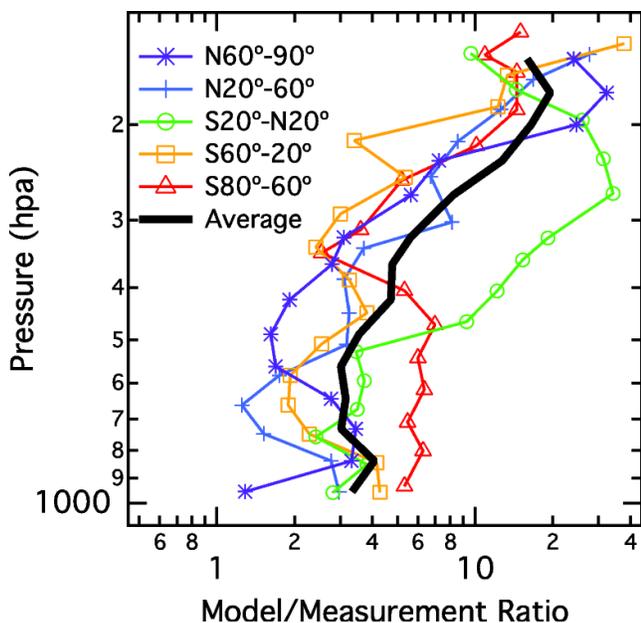


Figure 1. The ratio of modeled to measured vertical BC profiles for individual latitude bands (colored lines) and averaged over all latitudes (black line). These results are averaged over all seasons/HIPPO series and show consistent large biases at high altitude at all latitudes.

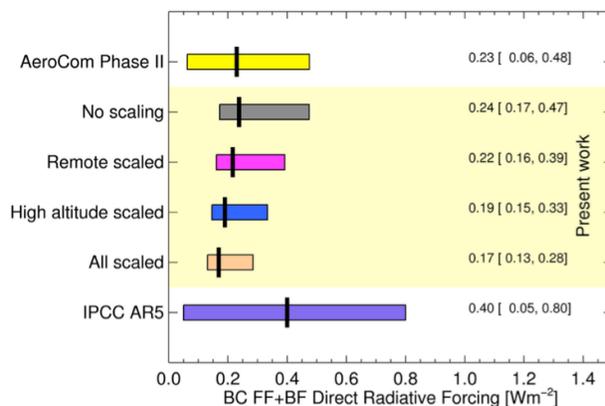


Figure 2. Model median and 5%-95% range for BC FF+BF forcing, for 1750-2010, with various scalings applied. The yellow bar shows the AeroCom Phase II result (Myhre, 2013). The grey bar shows unscaled values from the present work, then with remote scaling (pink) and high altitude scaling (blue) applied. The All scaled bar shows the lower limit on BC FF+BF forcing from the present work, with both scalings applied. In the bottom IPCC AR5 bar we compare with the recent estimate in IPCC WG1's AR5.

Can We Characterize Aerosol Type Using Aerosol Optical Properties?

L. Schmeisser¹, E. Andrews², J.A. Ogren³ and P. Sheridan³

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Several studies have used the relationships between aerosol optical properties to identify types of atmospheric aerosols or chemical characteristics of the aerosols. Two of these papers (Giles *et al.*, 2012; Cazorla *et al.*, 2013) utilized AEROSOL ROBOTIC NETWORK (AERONET) data, while another (Costabile *et al.*, 2013) used *in situ* measurements from the same type of instruments operated at NOAA's federated aerosol network. The wavelength dependence of the light absorption coefficient, as expressed by the Absorption Ångström Exponent (AAE), was found to be useful in discrimination of dominant aerosol type. Giles *et al.* (2012) evaluated the different relationships between AAE and Extinction Ångström Exponent among sites characterized *a priori* as having one of four characteristic aerosol types (dust, urban/industrial, biomass burning, and mixed). Similarly, Cazorla *et al.* (2013) utilized AERONET retrievals to parse fossil fuel, biomass burning and dust aerosol into categories such as 'Organic Compound dominated', 'Elemental Compound (EC) dominated', 'Dust/EC mix', etc. AERONET measurements are made at ambient conditions and the retrievals are limited to high Aerosol Optical Depth (AOD) conditions (AOD₄₄₀>0.4) so utilizing *in situ* aerosol data at controlled Relative Humidity may provide more information about the intrinsic relationships amongst different aerosol properties. Costabile *et al.* (2013) showed how *in situ* aerosol data from multiple field campaigns fit into categories similar to those used by Cazorla *et al.* (2013) by plotting Scattering Ångström Exponent (SAE) vs. AAE*dSSA, where dSSA indicates the wavelength dependence of single scattering albedo. Costabile *et al.* (2013) was somewhat limited, however, in that they only included short-term measurements at a narrow range of location types (e.g., they did not include arctic, clean marine, etc.).

Here we investigate the relationships between AAE and other simultaneously measured aerosol optical properties based on long-term measurements (>6 months) made at locations in NOAA's federated aerosol network. Some sites are relatively pristine while others have a strong anthropogenic influence and exhibit high aerosol loading. Aerosol properties at many of the sites exhibit seasonal and diurnal cycles due to large-scale air mass changes and/or source variability. Air mass trajectory clustering is used to explore the relationships between aerosol optical properties and air mass source.

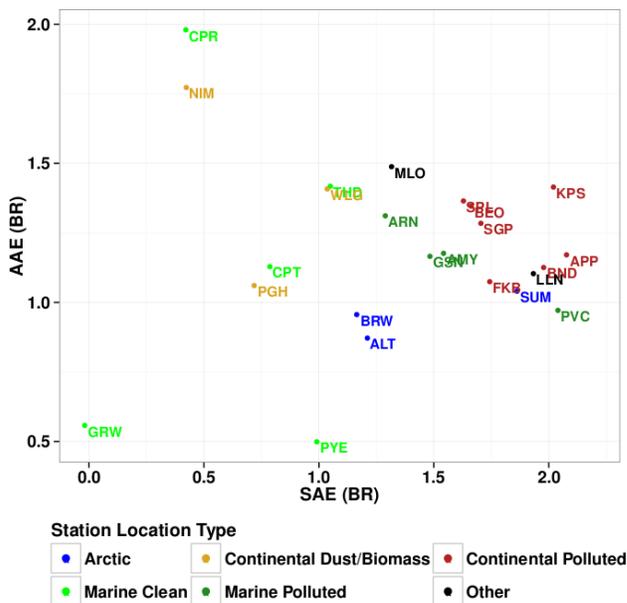


Figure 1. Median values of AAE and SAE at 24 sites in the NOAA network.

A Small, Sensitive, Light-weight, and Disposable Aerosol Spectrometer for Balloon and Unmanned Aerial Vehicle Applications

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In situ sampling with particle size spectrometers is an important method to provide detailed size spectra for atmospheric aerosol in the troposphere and stratosphere. The spectra are essential for understanding aerosol sources and aerosol chemical evolution and removal, and for aerosol remote sensing validation. These spectrometers are usually bulky, heavy, and expensive, thereby limiting their application to specific airborne platforms. Here we report a new type of small and light-weight optical aerosol particle size spectrometer that is sensitive enough for many aerosol applications yet is inexpensive enough to be disposable. 3D printing is used for producing structural components for simplicity and low cost. Weighing less than 1 kg individually, we expect these spectrometers can be deployed successfully on small unmanned aircraft systems (UASs) and up to 25 km on weather balloons. Immediate applications include the study of Arctic haze using the Manta UAS, detection of the Asian Tropopause Aerosol Layer in the Asian monsoon system and SAGE III validation onboard weather balloons. Results from recent test flights onboard the Manta UAS will be presented.

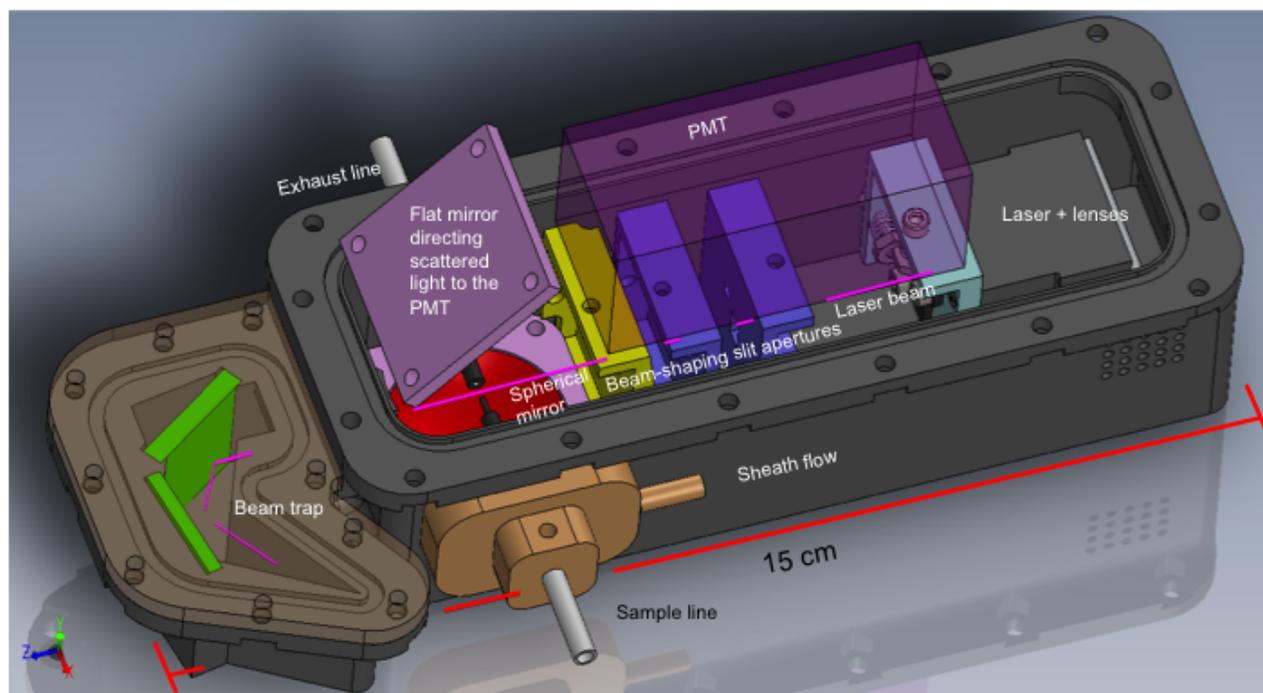


Figure 1. Computer-aided Design model of the small and light-weight optical aerosol particle size spectrometer.

Biomass Burning at Cape Grim: Using Modeling to Explore a Possible Urban Influence on Plume Photochemistry and Composition

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Biomass Burning (BB) emissions were opportunistically measured at Cape Grim during the 2006 Precursors to Particles Campaign, when a fire burned through coastal vegetation on nearby Robbins Island. The plume was at times advected directly over the station (fresh plume) and at times was diluted and re-circulated over the ocean and mainland Australia (aged plume). When compared to the fresh plume, the aged plume contained enhanced Normalised Excess Mixing Ratios (NEMR) of ozone and Oxygenated Volatile Organic Compounds (OVOC) (see Figure 1), an increase in the ratio of cloud condensation nuclei to particles > 80nm (indicating enhanced particle hygroscopicity) and a particle growth event.

We used Chemical Transport Modeling to determine the relative contribution of both BB and urban mainland emissions to the observed changes in plume composition and to determine the age of the re-circulated plume. To achieve robust model data we undertook a modeling sensitivity study in which the key modeling uncertainties (fire emission factors, spatial uncertainty and meteorology) were systematically explored. Both primary and secondary species of BB origin were highly sensitive to the explored model uncertainties. Therefore, a synthesis of all model data from this sensitivity study will be used to determine the likely contributions from different sources.

This work demonstrates the value of model-observation synergy in resolving complex interactions between multiple sources and meteorology, and the importance of assessing model uncertainties to achieve robust model outcomes.

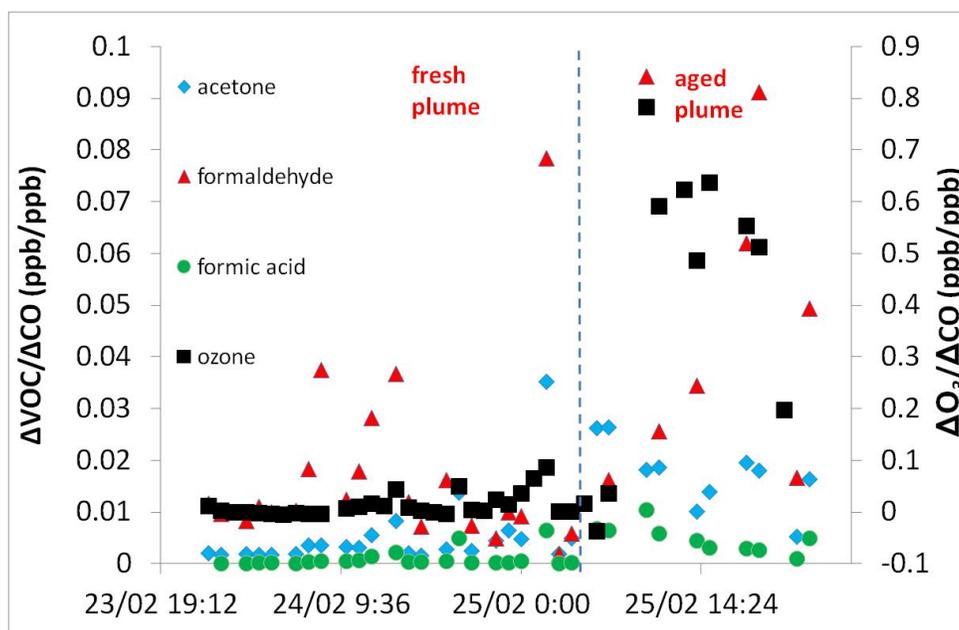


Figure 1. NEMR of oxygenated VOCs and ozone in the fresh plume, and in the aged re-circulated plume.

Aerosols at Mauna Loa Observatory (MLO) – Spring 2001, Versus Spring and Fall, 2011

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University of California at Davis, Davis, CA 95616; 530-297-4435, E-mail: tomandginny12@gmail.com

The rapid development in the Chinese industry has raised concerns about aerosol impacts and climate in the Pacific basin. In the Aerosol Characterization Experiment (ACE)-study of March – May, 2001, we measured Chinese aerosols at 3 sites, sampled by DRUM impactors in 3 hr. increments, in 8 size modes. These were compositionally analyzed for 32 elements using Synchrotron-induced X-Ray Fluorescence, including toxic metals like lead and mercury. To establish the downwind impacts in the 2001 work, we deployed at 19 aerosol sampling sites from Taiwan, Korea, and Japan to the United States, including MLO. We have duplicated the sampling and analysis of ACE-Asia at MLO in spring, 2011, and added data from fall, 2011. Several modern transport models and satellite data were used to identify the transport paths to MLO; 1) Fast Asian aerosols often arrive at MLO from the east during spring, with circulating clockwise around the Pacific high, carrying dust and several industrial metals, and 2) Slow transport west to east during the rest of the year, especially from mid-latitudes in China, with little dust but high organic matter highly correlated to sulfates. Since 2001, sulfates rose by a factor of 1.40, close to the rise in total Chinese SO₂ emissions, 1.32.

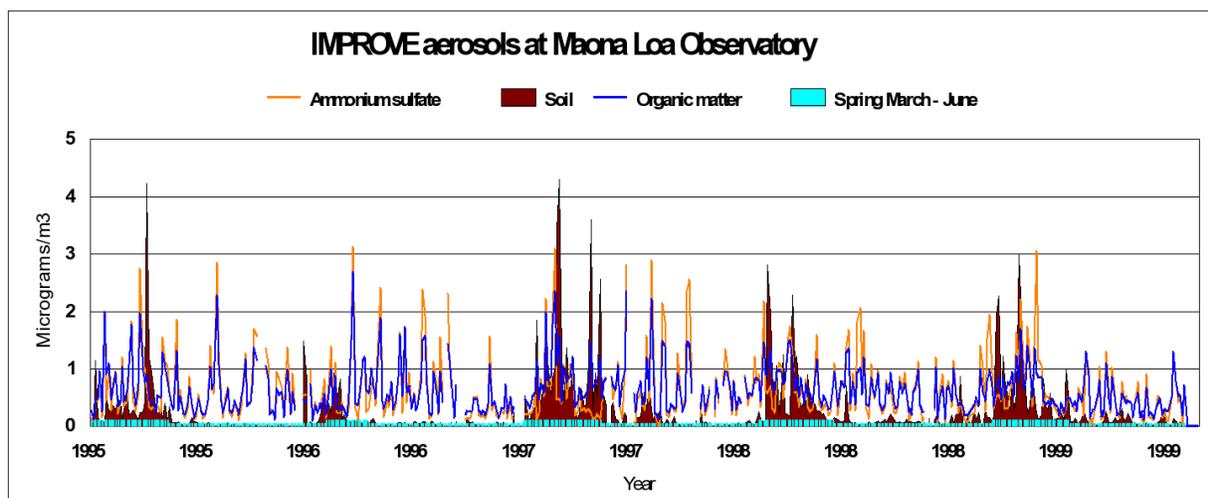


Figure 1. IMPROVE aerosols at Mauna Loa Observatory.

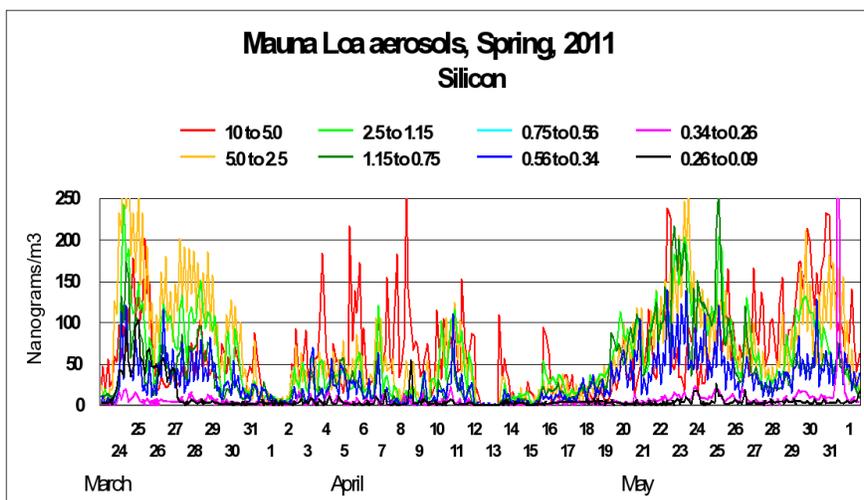


Figure 2. Size and time resolved silicon aerosols (a soil tracer) at Mauna Loa Observatory, spring 2011.

Notes:

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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

Wednesday Morning, May 21, 2014 AGENDA

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

- **07:00 - 08:30** **Registration & Morning Snacks - Coffee, tea, fruit, bagels and donuts served**
- Page No.
- **Session 5** **Ozone & Water Vapor** — Chaired by Samuel Oltmans
 - 08:30 - 08:45 The Alpha Jet Atmospheric EXperiment (AJAX): Three Years of Airborne Ozone and Greenhouse Gas Measurements Over California and Nevada 24
Emma L. Yates (National Aeronautics & Space Administration (NASA) Ames Research Center, Atmospheric Science Branch, Moffett Field, CA)
 - 08:45 - 09:00 An Overview of the 2013 Las Vegas Ozone Study (LVOS) 25
Andrew Langford (NOAA Earth System Research Laboratory, Boulder, CO)
 - 09:00 - 09:15 Source Distribution of Elevated Ozone in the Northern Colorado Front Range 26
Detlev Helmig (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO)
 - 09:15 - 09:30 Past Changes in the Vertical Distribution of Ozone: The SPN Activity and Its Outcome 27
Karen H. Rosenlof (NOAA Earth System Research Laboratory, Boulder, CO)
 - 09:30 - 09:45 The Pandora Spectrometer System: O₃ and Multiple Other Species Measured Using a Small, Inexpensive Package 28
Irina Petropavlovskikh (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
 - 09:45 - 10:00 Observed Global and Regional Variation in Earth's Water Vapor: Focus on the Weather-climate Interface 29
John Forsythe (Colorado State University, Cooperative Institute for Research in the Atmosphere, Fort Collins, CO)
 - 10:00 - 10:15 Validation of Aura Microwave Limb Sounder Stratospheric Water Vapor Measurements by the NOAA Frost Point Hygrometer 30
Dale Hurst (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- **10:15 - 10:45** **Morning Break**
- **Session 6** **Radiation** — Chaired by Kathleen Lantz
 - 10:45 - 11:00 The National Ecological Observatory Network (NEON): Overview and Strategies for Radiation Measurements Across the Continent 31
Jeffrey Taylor (National Ecological Observatory Network (NEON), Boulder, CO)
 - 11:00 - 11:15 Evidence for the Long-term Stability of the Eppley Model PIR for Measurements of Broadband Infrared Measurements 32
Joseph Michalsky (NOAA Earth System Research Laboratory, Boulder, CO)
 - 11:15 - 11:30 Results of Second Outdoor Comparison Between Absolute Cavity Pyrgeometer (ACP) and Infrared Integrating Sphere (IRIS) Radiometer at Physikalisch-Meteorologisches Observatorium Davos (PMOD) 33
Ibrahim Reda (National Renewable Energy Laboratory (NREL), Golden, CO)
 - 11:30 - 11:45 Radiative Forcing of a Small-scale Wildfire Smoke Plume at the Surface, Atmosphere, and Top of Atmosphere (TOA) from Surface and Satellite Observations 34
John A. Augustine (NOAA Earth System Research Laboratory, Boulder, CO)
- **11:45 - 13:00** **Catered Lunch - Outreach Classroom GB-124 (pre-payment of \$12.00 at registration)**

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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

Wednesday Afternoon, May 21, 2014 AGENDA

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

		Page No.
• Session 7	Halocarbons & Non-Methane Hydrocarbons — Chaired by James Elkins	
13:00 - 13:15	Recent Trends in Global Concentrations and Emissions of Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs) <i>Steve Montzka (NOAA Earth System Research Laboratory, Boulder, CO)</i>	35
13:15 - 13:30	Atmosphere-based “Top-down” Emission Estimates of 1,1,1,2-Tetrafluoroethane (HFC-134a) and Chlorodifluoromethane (HCFC-22) for the United States (U.S.) Over Multiple Years <i>Lei Hu (NRC Post-Doc & NOAA Earth System Research Laboratory, Boulder, CO)</i>	36
13:30 - 13:45	European Emissions of Chlorodifluoromethane (HCFC-22) Based on High Frequency Atmospheric Measurements and a Bayesian Inversion Method <i>Michela Maione (University of Urbino, Department of Basic Sciences and Foundations, Urbino, Italy)</i>	37
13:45 - 14:00	Measurements of Bromine Oxide, Iodine Oxide and Oxygenated Hydrocarbons in the Tropical Free Troposphere from Research Aircraft and Mountaintops <i>Rainer Volkamer (Cooperative Institute for Research in Environmental Sciences (CIRES), Department of Chemistry and Biochemistry, University of Colorado, Boulder, CO)</i>	38
14:00 - 14:15	A Seven-year (2006-2013) Record of NonMethane HydroCarbons (NMHC) in the Subtropical Marine Boundary Layer at the Cape Verde Atmospheric Observatory <i>Shalini Punjabi (The University of York, Department of Chemistry, Heslington, York, United Kingdom)</i>	39
14:15 - 14:30	Real-time Quantification and Geo-spatial Mapping of Volatile Organic Compounds (VOC) and SemiVolatile Organic Compounds (SVOC) by Tandem Mass Spectrometry <i>Ryan Bell (Applied Environmental Research Laboratories, Nanaimo, British Columbia, Canada)</i>	40
• 14:30 - 15:00	Afternoon Break	
• Session 8	Oil & Gas Fields — Chaired by Gabrielle Petron	
15:00 - 15:15	Development of a Calibration for Estimating Flared Gas Volume for Gas Flaring from Nighttime Visible Infrared Imaging Radiometer Suite (VIIRS) Data <i>Chris Elvidge (NOAA National Geophysical Data Center, Earth Observation Group, Boulder, CO)</i>	41
15:15 - 15:30	Methane Emissions Estimates from Oil and Natural Gas Production Using Atmospheric Measurements <i>Anna Karion (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)</i>	42
15:30 - 15:45	Quantifying Relative Contribution of Natural Gas Fugitive Emissions to Total Methane Emissions in CO, UT, and TX Using Mobile Isotopic Methane Analysis Based on Cavity RingDown Spectroscopy (CRDS) <i>Chris W. Rella (Picarro Inc., Santa Clara, CA)</i>	43
15:45 - 16:00	Mapping Sources of Methane Emissions Over the Barnett Shale in Texas <i>Bill Hirst (Shell Global Solutions International BV, The Hague, The Netherlands)</i>	44
16:00 - 16:15	Measurements and Modeling of Greenhouse Gases and the Planetary Boundary Layer (PBL) for the Boston Metro Area and the Northeastern Megalopolis <i>Philip DeCola (Sigma Space Corporation, Lanham, MD)</i>	45
16:15 - 16:30	Modeling of Atmospheric Methane and Ozone in the Uintah Basin, UT: The Role of Oil and Gas Emissions, Chemistry and Transport <i>Ravan Ahmadov (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)</i>	46
16:30 - 16:45	Anatomy of Wintertime Photochemical Ozone Production: Uintah Basin, UT, 2013 <i>Russ C. Schnell (NOAA Earth System Research Laboratory, Boulder, CO)</i>	47
• 16:45	Closing Remarks - Dr. James Butler, Director (NOAA/ESRL Global Monitoring Division)	

The Alpha Jet Atmospheric EXperiment (AJAX): Three Years of Airborne Ozone and Greenhouse Gas Measurements Over California and Nevada

E.L. Yates¹, L.T. Iraci¹, R.B. Pierce², M.Gustin³, R. Fine³, M. Roby⁴, D. Austerberry⁵, T. Tanaka¹ and W. Gore¹

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²NOAA/National Environmental Satellite, Data, and Information Service (NESDIS) Advanced Satellite Products Branch, Madison, Wisconsin 53706

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The AJAX is an on-going project that has been measuring ozone, carbon dioxide and methane up to 8000 m since January 2011. The project goals are to study photochemical ozone production and investigate the impact of extreme events on western U.S. air quality. Regular missions include flights to Railroad Valley (RRV) in Nevada, onshore-offshore flights in California, and flights to investigate local emissions.

Monthly RRV flights sample vertical ozone profiles over RRV for comparison with Nevada Rural Ozone Initiative surface ozone sites. Airborne measurements aid identification of local and long-range pollution, and correlations between the RRV ozone profile and surface ozone sites highlight the effects of vertical transport within Nevada's complex terrain. Onshore-offshore flights provide a direct assessment of photochemical ozone production and vertical transport above the San Joaquin Valley (SJV), while correlations between the offshore profile and SJV ozone surface sites gives information on transport mechanisms. These flights have identified stratospheric ozone laminae and with modeling efforts have been used to identify ozone standard exceedances resulting from stratosphere-to-troposphere transport (see Figure 1 (right)). The AJAX project is uniquely flexible to incorporate specialized flights with limited planning notice (e.g. sampling emissions from the Yosemite Rim fire). Elevated ozone was observed within the fire plume, yet data from surface sites show no ozone exceedances, shedding light on the plume chemistry which would otherwise not be identified. Future plans include expanding the altitude capability of AJAX through the addition of AirCore for enhanced satellite and model validation.

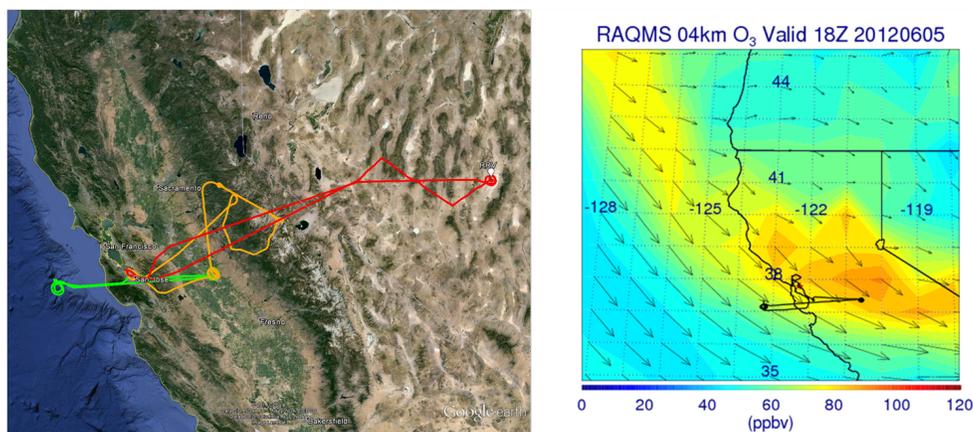


Figure 1. AJAX flight tracks on GoogleTM Earth: Railroad Valley, NV (red), onshore-offshore (green), Yosemite Rim Fire (yellow) (left plot). 4 km O₃ and wind vector map on 5 June 2012 at 1800 UTC from the Realtime Air Quality Modelling System (RAQMS) analyses; the aircraft flight track is shown in black (right plot).

An Overview of the 2013 Las Vegas Ozone Study (LVOS)

A. Langford¹, C. Senff², R. Alvarez II¹, J. Brioude², O. Cooper², J. Holloway², R. Marchbanks², B. Pierce³, S. Sandberg¹, A. Weickmann² and E. Williams¹

¹NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-3115, E-mail: andrew.o.langford@noaa.gov

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³NOAA National Environmental Satellite, Data, and Information Service, Camp Springs, MD 20746

The NOAA ESRL Chemical Sciences Division deployed the TOPAZ O₃ and aerosol lidar together with instruments for the *in situ* measurement of O₃, CO, and meteorological parameters to Angel Peak, NV (2.7 km above sea level) as part of the LVOS in the late spring of 2013. The primary purpose of this study, which ran from May 19 to June 28, was to investigate the influence of long-range transport on springtime surface ozone concentrations in Las Vegas and surrounding Clark County, with emphasis on the role of stratosphere-to-troposphere transport. The influences of Asian pollution plumes, wildland fires, and urban pollution from southern California were also examined. The Angel Peak measurements are compared with other measurements made within Clark County and surrounding areas, satellite observations, and O₃ and CO distributions predicted by the FLEXPART dispersion model. In this presentation, I will give an overview of the LVOS campaign, and show examples of how these sources influenced surface ozone, and in some cases contributed to exceedances of the current National Ambient Air Quality Standard.

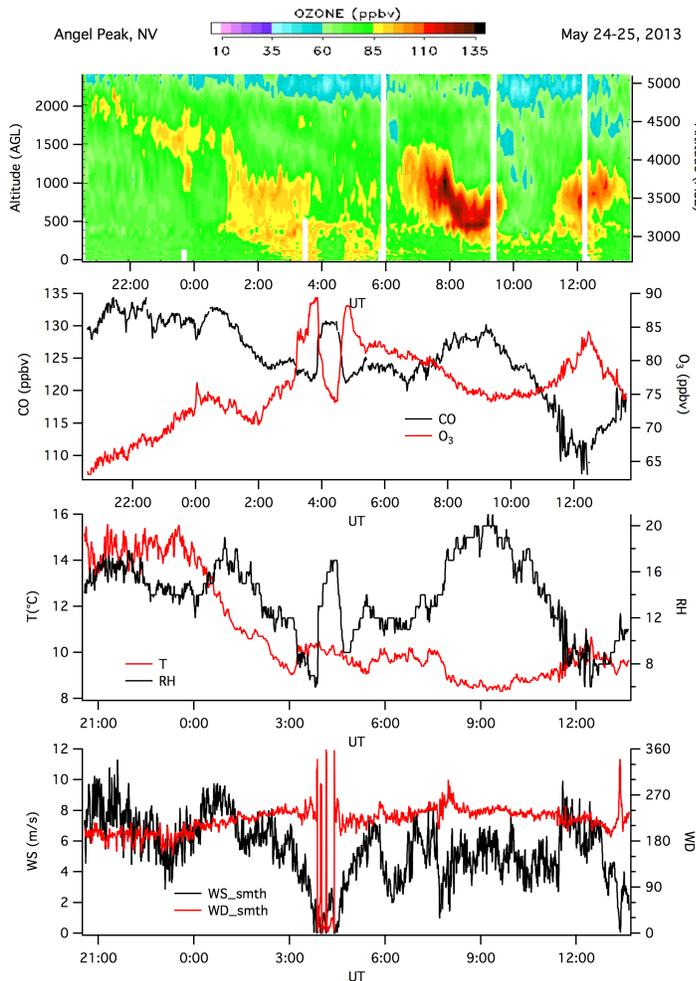


Figure 1. Time-height ozone curtain plot and *in situ* measurements from Angel Peak, NV showing the approach of a stratospheric intrusion to the surface on the night of May 24-25, 2013.

Source Distribution of Elevated Ozone in the Northern Colorado Front Range

J. Evans and D. Helmig

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The Northern Front Range region of Colorado has struggled with poor air quality in recent years, primarily in summer months, and since 2007 has been a non-attainment area for 8-hr ozone exceeding the Environmental Protection Agency National Ambient Air Quality Standard (NAAQS). A recent study by Gilman et al. (1) suggested that emissions from the oil and gas development area in Weld County constitute a major source of ozone precursors along the Front Range. Spatial Volatile Organic Compound (VOC) measurements and comparison with historic VOC data records further exemplify the rise and dominance of oil and gas VOC emissions in the Colorado Front Range (2). Here we use ozone data from the NOAA Boulder Atmospheric Observatory site in Erie, CO, and the Boulder County/Colorado Department of Public Health & Environment South Boulder monitoring site for an analysis of ozone climatology, transport, and source regions. While the winter data show a slight tendency of higher ozone being transported from the Rocky Mountains to the west, the summer data show a preponderance of high ozone events originating from the north to southeast sectors, in the direction of the oil and gas producing Wattenberg Field in the Denver-Julesburg Basin. This correlation suggests a significant contribution of emissions from the oil and gas operations to the summer ozone NAAQS exceedences in the Colorado Front Range.

- (1) Gilman, J.; Lerner, B.; Kuster, W.; de Gouw J. Source Signature of Volatile Organic Compounds from Oil and Natural Gas Operations in Northeastern Colorado, *Environ. Sci. Technol.* **2013**, 47, (3), 1297-1305.
- (2) Thompson C., Hueber J., and Helmig D. Regional impact of fugitive emissions from oil and gas operations on atmospheric non-methane hydrocarbons in Northeastern Colorado. *Submitted for publication.*

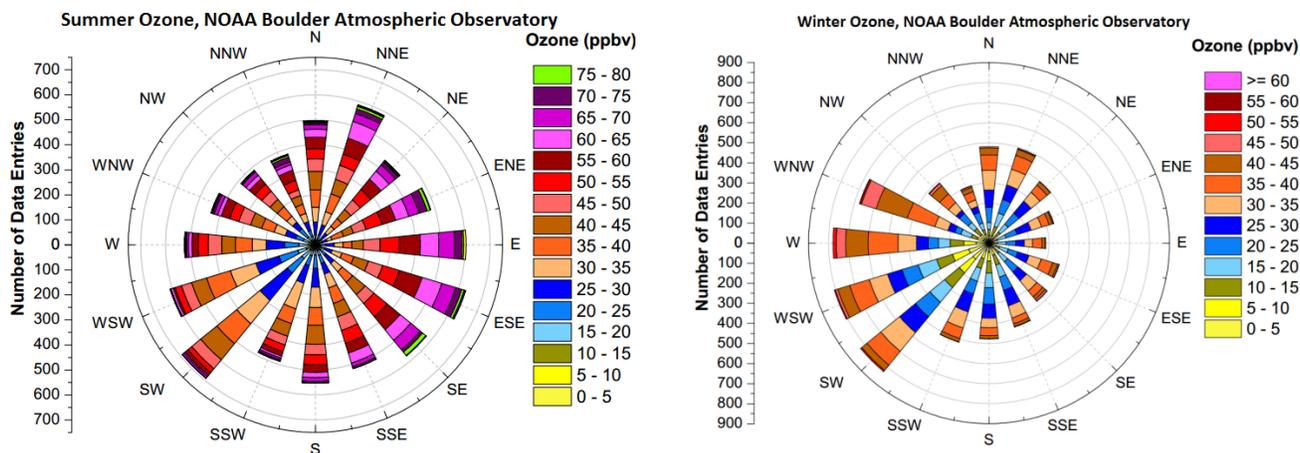


Figure 1. Ozone as a function of wind direction at NOAA's Boulder Atmospheric Observatory during the winter months (left: Dec 1 – Feb 28) compared to the summer (right: Jun 1 – Aug 30).

Past Changes in the Vertical Distribution of Ozone: The SP²N Activity and its Outcome

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⁵Johns Hopkins University, Baltimore, Baltimore, MD

Peak stratospheric chlorofluorocarbon and other Ozone Depleting Substance (ODS) concentrations were reached in the mid to late 1990s. Detection and attribution of the expected recovery of the stratospheric ozone layer in an atmosphere with reduced ODSs as well as efforts to understand the evolution of stratospheric ozone in the presence of increasing greenhouse gases are key current research topics.

In preparation for the 2014 United Nations Environment Programme (UNEP)/World Meteorological Organization (WMO) Scientific Assessment of Ozone Depletion, the SPARC/IO3C/IGACO-O3/NDACC (SPARC - Stratosphere-troposphere Processes And their Role in Climate; IO3C - International Ozone Commission; IGACO-O3 - Integrated Global Atmospheric Chemistry Observations - Ozone and ultra-violet radiation; NDACC - Network for the Detection of Atmospheric Composition Change), abbreviated as SP²N, initiative was designed to study and document changes in the global ozone profile distribution. This required assessing long-term ozone profile data sets in regards to measurement stability and uncertainty characteristics. Some of the data sets have been improved as part of this initiative with updated versions now available.

We will present a short overview of the different available stratospheric ozone profile data sets, noting drifts and biases between those data sets, and finally showing trend analyses for the ozone depletion period (1979/1984 to 1997), and the ozone recovery period (1998-2011). We found that ozone trends in the 1980s and early 1990s are well understood and consistent between different measurement systems. However, the multitude of stratospheric ozone profiling systems in the 2000s during a time period with quite small ozone changes result in an inconsistent trend picture during the ozone recovery period.

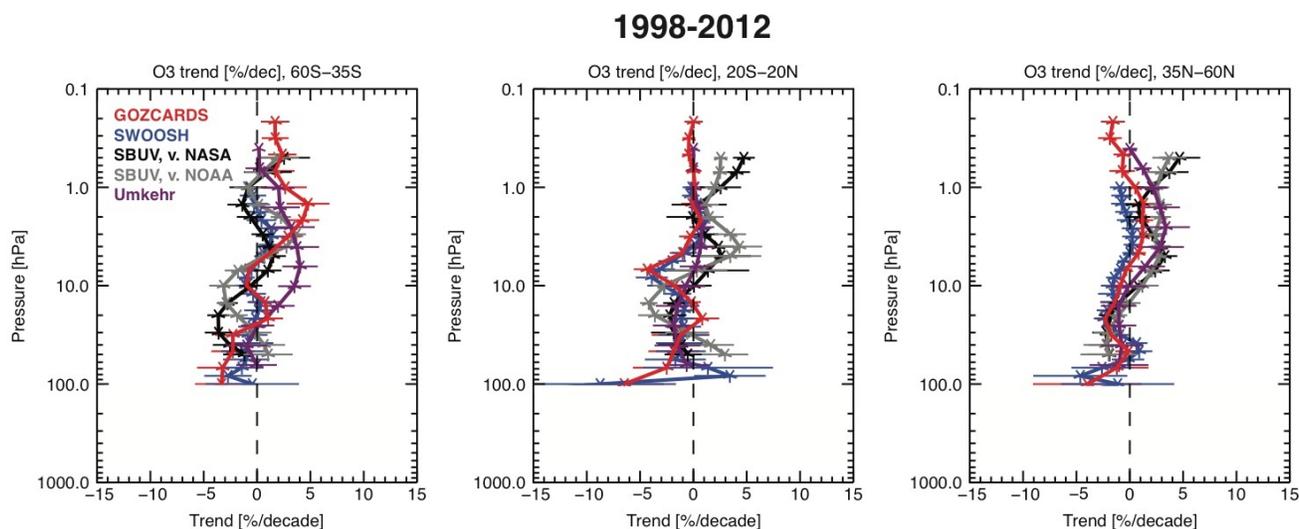


Figure 1. Ozone trends from 1998-2012 in percent per decade for three latitude bands: Northern Hemisphere mid-latitudes (35°N-60°N, left), the tropics (20°N-20°S, middle), and Southern Hemisphere mid-latitudes (35°S-60°S, right). Different colored lines denote trend profiles for different measurement systems.

The Pandora Spectrometer System: O₃ and Multiple Other Species Measured Using a Small, Inexpensive Package

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The measurement of the radiatively important gas ozone in the Earth's Atmosphere has been a part of the Global Monitoring Division mission since its inception in 1972. The primary instrument in NOAA's network to determine total column content (Thickness of the Ozone Layer) is the Dobson Ozone Spectrophotometer, which provides the historic baseline for this measurement. Recent improvements in commercial optical detectors have allowed for the development of small devices that measure surface solar spectra to the detail required to determine the amounts of many atmospheric components, especially Total Ozone Column. One such small spectrometer system (Pandora) was developed at NASA's Goddard Space Flight Center during the last six years. The almost autonomous Pandora system consists of a small commercially available symmetric Czerny-Turner spectrometer optimized for detection of trace gases in the 280 – 525 nm spectral range (0.5 nm resolution, 4.5x oversampling) with a 2048 x 64 Hamamatsu Charge Coupled Device detector. The optimized Avantes spectrometer is connected by a 400 micron fiber optic cable to an optical head (1.6° field of view) mounted on a high precision (0.01°) sun-sky tracker. The laboratory calibrated Pandora O₃ retrieval algorithm uses an external solar reference spectrum derived from the Atlas-3 SUSIM instrument, whereas Dobson and Brewer instruments are calibrated by the means of Langley plots. Recently, the Pandora spectrometer system has been used in three extensive field campaigns (Discover-AQ) in Maryland (2011), California (2013), and Texas (2013). The project involved 12 to 15 Pandoras distributed over a large area for comparison with aircraft and satellite NO₂ and O₃ data. This summer (2014) 15 Pandoras will be deployed in the Denver/Boulder area as part of the final Discover-AQ campaign. One of these Pandoras is currently operating from the NOAA building in Boulder Colorado to both obtain a longer data record and for total column O₃ comparison with NOAA's Dobson instruments. Initial results indicate that total ozone values from the Pandora are well correlated and close in value with the Boulder station Dobson instrument. Pandora's highly resolved spectral measurement allows further processing of the data to determine atmospheric pollutants such as SO₂.

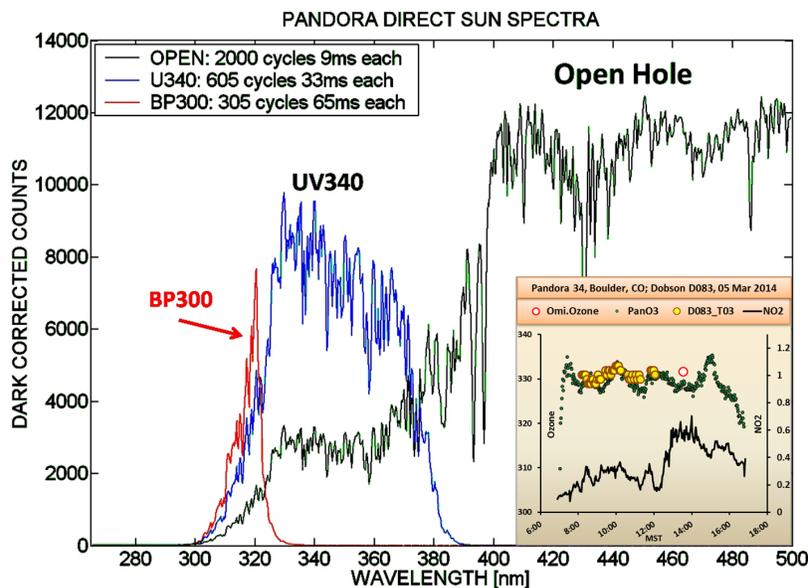


Figure 1. Representative spectra as measured by the Pandora instrument displayed with 5 March 2014 measurement results for the Pandora 34, Dobson D083, and Ozone Monitoring Instrument overpass.

Observed Global and Regional Variation in Earth's Water Vapor: Focus on the Weather-climate Interface

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The principal greenhouse gas water vapor variations are a key factor in any climate change. Their role in both the Earth's energy budget and water cycle is not well known. A new, observational dataset is now available for many science studies.

The NASA Making Earth Science Data Records for Research Environments (MEaSUREs) program supported the 4-year development and public release of the National Aeronautics & Space Administration (NASA) Water Vapor Project (NVAP-M) dataset. The dataset was released to the science community in 2013 via the NASA Langley Atmospheric Science Data Center. NVAP-M is a robust global (land and ocean) water vapor dataset created by merging multiple satellite and surface sources of atmospheric water vapor to form global gridded fields of total and layered precipitable water vapor. NVAP-M spans 22 years (1988-2009) of data, over 8000 daily fields.

NVAP-M is available globally at either daily, 1 degree or 6-hourly, or ½ degree resolution. It is observationally driven, with minimal dependence on numerical model fields, making it useful for comparison to models. Different processing paths are available with a global climate, an ocean-only and a weather event focus.

In this paper, we will present new science results from NVAP-M, including studies of extreme events, water vapor transport in data-sparse regions and trends in total precipitable water vapor. We will demonstrate a new approach for understanding sampling effects on long-term climate records developed from satellite observations. Special emphasis will be given to time-dependent sampling changes with respect to land / ocean and clear / cloudy regions. Biases in sampling can lead to misleading trends and spurious regional variations. The challenges – both from an observing system and data fusion standpoint - in creating a consistent, multi-decadal climate record of water vapor will be discussed .

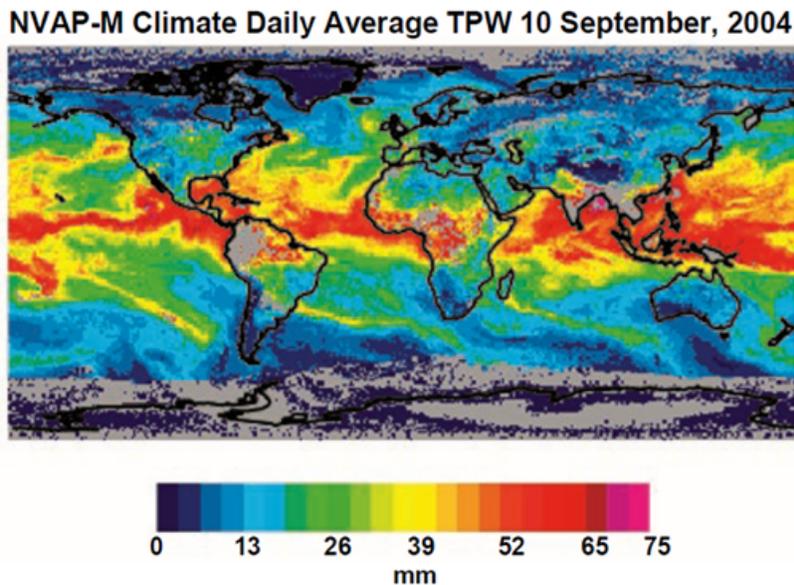


Figure 1. NVAP-M Climate daily average total precipitable water (mm) for September 10, 2004.

The National Ecological Observatory Network (NEON): Overview and Strategies for Radiation Measurements Across the Continent

J. Taylor, E. Ayres, H. Luo, S. Metzger, N. Pingingtha-Durden, J. Roberti, M. SanClements, D. Smith, S. Streett and R. Zulueta

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NEON is responsible for making observations of terrestrial, aquatic, and organismal ecology in 20 different eco-climatic domains across the continent. NEON will provide localized data on key physical, climate, and chemical forcing, as well as their associated biotic responses, in an effort to inform climate change, land-use change, invasive species, and other impact studies. The sheer volume of data is expected to exceed hundreds of Terabytes per year and will present challenges for data management on an unprecedented scale.

This talk will provide an overview of NEON as a whole, while specifically focusing on the numerous radiation measurements that will be made across the network. This consists of broad-band measurements in the Ultraviolet, Visible Spectroscopy, and Infrared throughout all NEON sites as well as planned observations with sunphoto spectrometers. Highlights will include preliminary first results hosted on the NEON data portal and look toward first article science results.

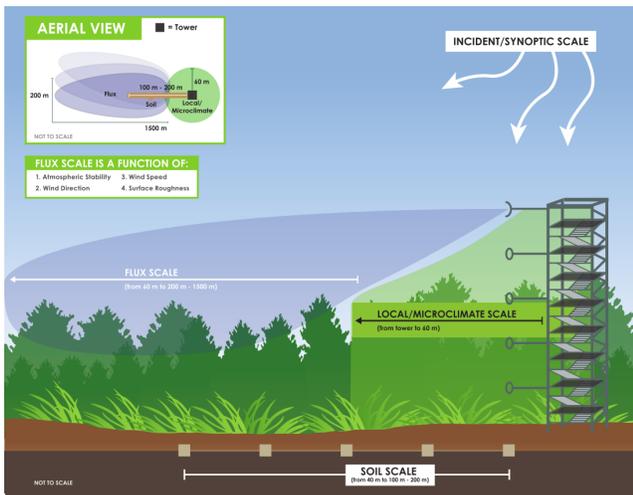


Figure 1. NEON's Tower-based Observations.

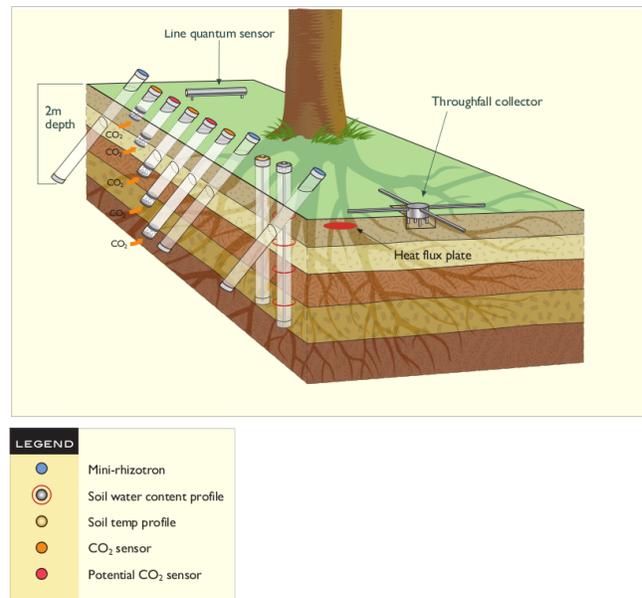


Figure 2. NEON's Soil-based Observations.

Evidence for the Long-term Stability of the Eppley Model PIR for Measurements of Broadband Infrared Measurements

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The Eppley Model PIR infrared radiometer has been the workhorse for measurements of upwelling and downwelling terrestrial radiation measured at the surface in many international programs including those in NOAA. Based on a consistent calibration methodology over the last 15 years we demonstrate just how stable the instrument has been with two of many examples. In one case the PIR had limited outdoor exposure and in the other the instrument was deployed most of the time in a wide range of conditions from tropical to polar. The results indicate that this instrument is suitable for detecting long-term trends in infrared radiation that may be associated with climate change.

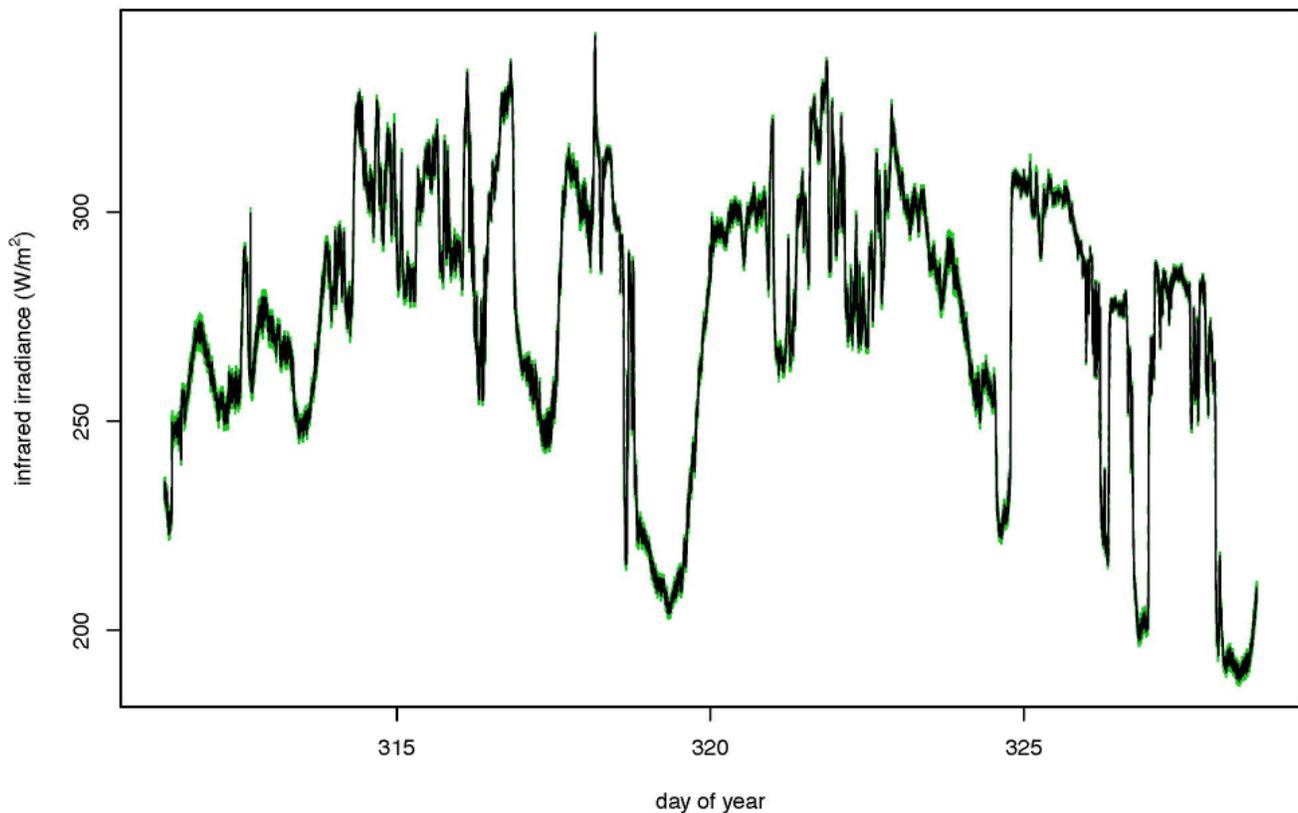


Figure 1. Multiple determinations of downwelling infrared irradiance over 17 days in November near Boulder, Colorado, using all 92 determinations of the calibration constants determined in the GMD blackbody.

Results of Second Outdoor Comparison Between Absolute Cavity Pyrgeometer (ACP) and Infrared Integrating Sphere (IRIS) Radiometer at Physikalisch-Meteorologisches Observatorium Davos (PMOD)

I. Reda

National Renewable Energy Laboratory (NREL), Golden, CO 80401; 303-384-6385, E-mail: Ibrahim.Red@nrel.gov

The Absolute Cavity Pyrgeometer (ACP) and InfraRed Integrating Sphere radiometer (IRIS) are developed to establish a world reference for calibrating pyrgeometers with traceability to International System of Units (SI). The two radiometers are un-windowed with negligible spectral dependence, and traceable to SI units through the temperature scale (ITS-90). The second outdoor comparison between the two designs was held from September 30 to October 11, 2013 at the Physikalisch-Meteorologisches Observatorium Davos (PMOD). The difference between the irradiance measured by ACP and that of the IRIS was within 1 W/m^2 (3 IRISs: PMOD + Australia + Germany). From the first and second comparisons, a difference of $4\text{-}6 \text{ W/m}^2$ was observed between the irradiance measured by ACP and IRIS and that of the interim World Infrared Standard Group. This presentation includes results from the first and second comparison in an effort to establish the world reference for pyrgeometer calibrations, a key deliverable for the World Meteorological Organization, NOAA, and the Department of Energy-Atmospheric System Research.

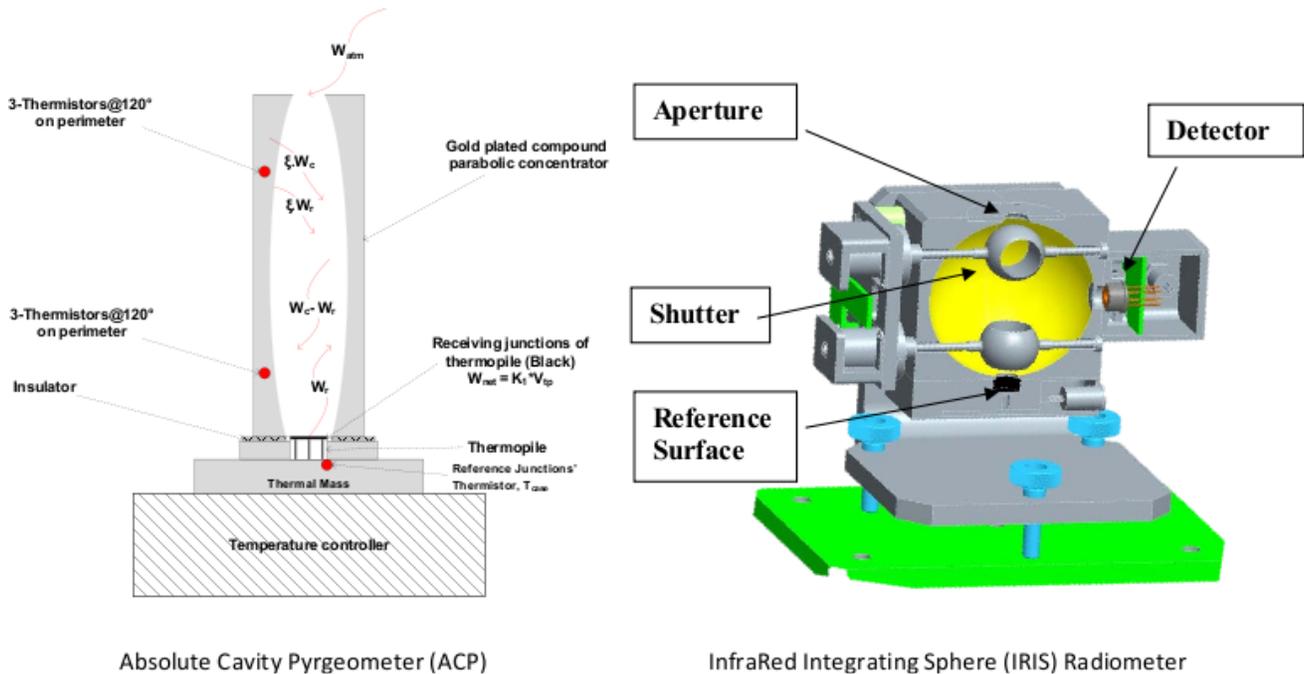


Figure 1. Left: ACP. Right: IRIS Radiometer.

Radiative Forcing of a Small-scale Wildfire Smoke Plume at the Surface, Atmosphere, and Top of Atmosphere (TOA) from Surface and Satellite Observations

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Circumstances converged on 6 Sep 2010 over northeastern Colorado that permitted documentation of the radiative impact of a small-scale forest fire smoke plume at the surface, TOA, and within the atmosphere. The plume drifted over two surface radiation budget sites where the radiative forcing of the smoke was computed throughout the day. For TOA, narrow-to-broadband conversion methods, one for ShortWave (SW) (see below), and one for LongWave (LW), were applied to high spatial resolution spectral MODIS data for two satellite passes that were an hour and 40 minutes apart. Results showed negative SW forcing by the smoke at both TOA and the surface, indicating cooling, but the magnitude of the cooling was two to four times greater at the surface. LW forcing warmed both TOA and the surface, but the magnitude of the LW warming was 4 to 10 times less than the SW cooling at both levels. Thus, the net effect of the plume was to cool the surface and TOA, but with a greater impact at the surface. This differential cooling resulted in instantaneous atmospheric warming rates of 2° to 9° C per day. These heating rates were a third to a half less than those computed from SW forcing alone, indicating the importance of including LW in calculations of smoke induced atmospheric heating. MODIS water vapor imagery clearly demonstrated that the burning biomass injected measureable water vapor into the atmosphere. Integrated water vapor within the plume area increased by 20 to 40% due to combustion alone during the period between the two satellite passes, and absolute increases were on the order of 0.1 to 0.2 cm.

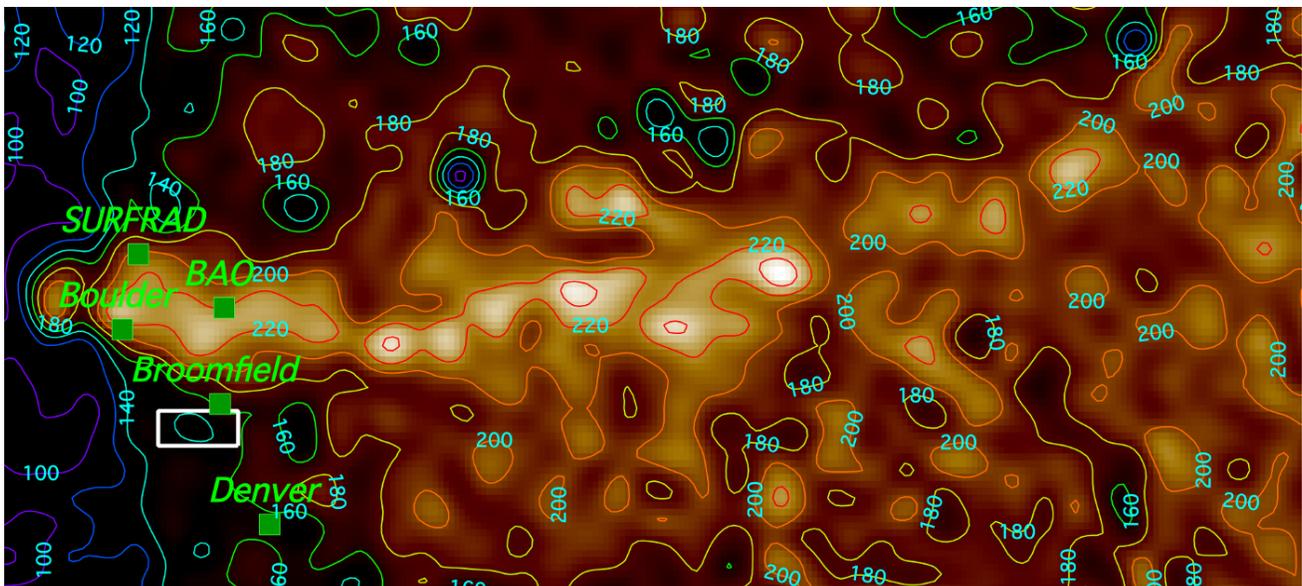


Figure 1. Upwelling broadband shortwave flux at TOA in Wm⁻² computed from MODIS spectral imagery for 2000 UTC on 6 Sep 2010. Greater fluxes reflected from the smoke plume show up as white and lighter shades of brown. CERES data was too coarse to resolve the plume.

Recent Trends in Global Concentrations and Emissions of Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs)

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Atmospheric observations allow an objective and independent assessment of policy control measures related to ozone-depleting substances and greenhouse gases. Currently there are uncertainties regarding use and emission of HCFCs and HFCs and how these chemicals will affect future stratospheric ozone depletion and climate. Here we resolve some of this uncertainty with updated measurements of these compounds from NOAA's cooperative flask sampling network. The results suggest that summed global HCFC emissions were increasing at ~8%/y in the mid-2000s. This increase did not continue after 2007 in part because of the 2007 Adjustments to the Montreal Protocol that accelerated the HCFC phase-out in developed countries and set caps beginning in 2013 on global HCFC production and consumption. The observations indicate that global HCFC emissions were stable at approximately 775 MtCO₂-eq/yr during 2007-2012, well in advance of the 2013 cap on global HCFC production. These measurements also allow climate impacts associated with current uses of HFCs to be estimated and the future climate benefits of potential controls to be assessed. Summed global emissions of HFCs used as ODS substitutes totaled approximately 500 MtCO₂-eq/yr in 2012 and had increased at an average rate of ~7%/yr from 2007 through 2012. These HFC emissions amount to approximately 1.5% of fossil-fuel-related emissions of CO₂ in recent years and are estimated to arise in approximately equal amounts from mobile air conditioning, commercial refrigeration, and all other applications.

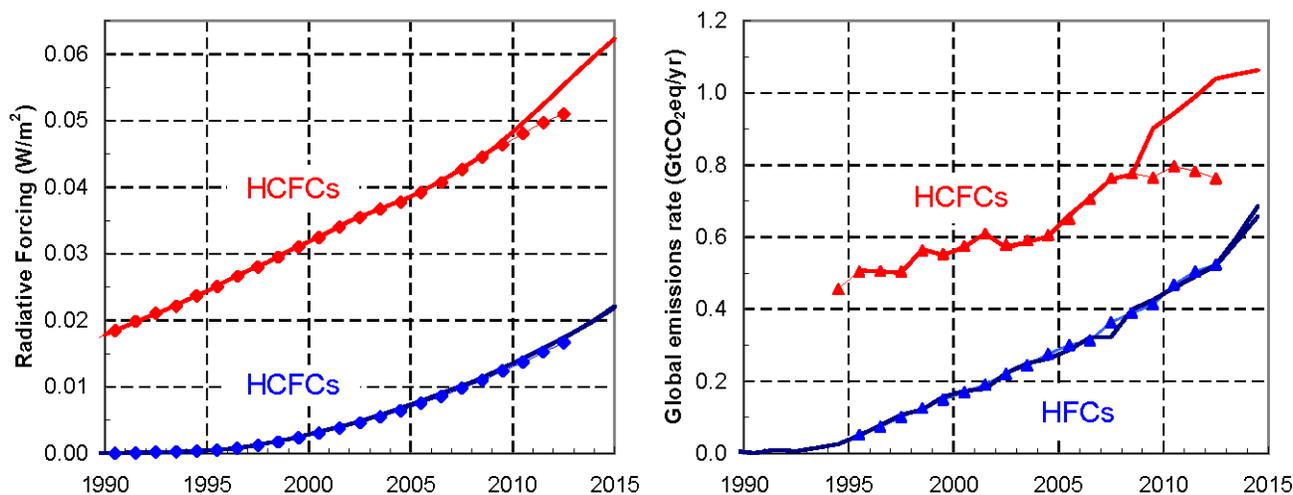


Figure 1. Direct radiative forcing (left panel) and global CO₂-eq emissions (right panel) derived from the sum of HCFCs (observations as red points, scenarios as lines; HCFC-22, -142b, -141b) and HFCs used as substitutes for ozone-depleting substances (observations as blue points, scenarios as lines; HFC-134a, -152a, -143a, -125, -227ea, -365mfc, -32). Measurement-derived values are compared to scenarios developed elsewhere (for HCFCs from the WMO Ozone Assessment report, Daniel *et al.*, 2011; for HFCs from Velders *et al.*, 2009). CO₂-eq emissions are derived by weighting mass emissions by 100-yr Global Warming Potentials (Daniel *et al.* (2011)).

Atmosphere-based “Top-down” Emission Estimates of 1,1,1,2-Tetrafluoroethane (HFC-134a) and Chlorodifluoromethane (HCFC-22) for the United States (U.S.) over Multiple Years

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⁹Atmospheric and Environmental Research, Inc., Lexington, MA 02421

HFC-134a and HCFC-22 are potent greenhouse gases; HCFC-22 is also an ozone-depleting gas. Uncertainty in their national emissions reported from inventory-based “bottom-up” estimates is not well determined due to incomplete understanding of the emissive processes and the size of their existing stocks and reserves. This study uses our atmospheric measurements from multiple surface and aircraft sites across the U.S. continent and in the Pacific Basin from 2008 - 2012, along with a newly-developed regional inverse model, to constrain U.S. national emissions of HFC-134a and HCFC-22 over this period. A suite of synthetic-data experiments were conducted to optimize the model design, assess model-data mismatch errors and a prior flux error covariance matrix given by the maximum likelihood estimation method, and test the sensitivity of derived national fluxes to a range of priors that have different emission magnitudes and distributions than the “synthetic-true” emission. Limitations in synthetic-data experiments led us to explore the influence of background and transport uncertainties on derived national emissions in real-data inversions. With multiple backgrounds, multiple priors, and multiple transport models driven by three different meteorological fields, derived national emissions of HFC-134a and HCFC-22 using actual observations agree within 20% on an annual basis. Results also consistently show seasonal variations with summer emissions higher than winter by 20 – 50 % (Figure 1). The HFC-134a emission estimated for the entire U.S. from our work is comparable to that reported by US Environmental Protection Agency (EPA) whereas HCFC-22 emission derived from our work is lower and shows a more rapid decline than that reported by U.S. EPA.

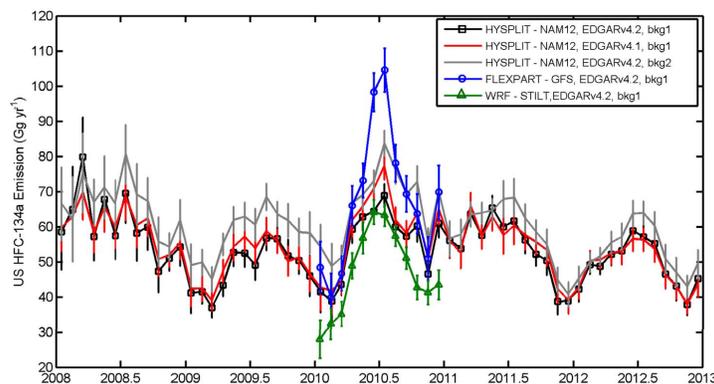


Figure 1. U.S. national emissions of HFC-134a estimated from this study using multiple transport models and meteorological data (HYSPLIT-NAM12, FLEXPART-GFS, and WRF-STILT), multiple priors (EDGARv4.2 and EDGARv4.1) and multiple backgrounds (bkg 1: the lowest 10th percentile at the surface sites and average mixing ratios between 3000 – 7000 masl at aircraft sites; bkg 2: average background mixing ratios from 500 particles that transported backward in time and intersected with an empirical “curtain” which represents North American HFC-134a background concentrations as a function of time, latitude and altitude).

European Emissions of Chlorodifluoromethane (HCFC-22) Based on High Frequency Atmospheric Measurements and a Bayesian Inversion Method

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HCFC-22 (CHClF_2) is a stratospheric ozone depleting substance and a powerful greenhouse gas primarily used in refrigeration and air conditioning systems as interim replacement for Chlorofluorocarbons. Combining atmospheric observations conducted at two European sites (Mace Head and Monte Cimone) with a Bayesian inversion technique, we estimated fluxes of HCFC-22 from the European geographic domain and from eight macro-areas within it, over an 11-year period from January 2002 to December 2012. We estimated that the maximum in European emissions was in 2003 ($37.8 \pm 4.1 \text{ Gg yr}^{-1}$), and the minimum in 2012 ($12.2 \pm 1.9 \text{ Gg yr}^{-1}$), with some years in between (2008 and 2010) in which the steady decreasing trend was interrupted. Background values of HCFC-22 as measured by the two European stations are still increasing with an overall trend of ca 7.0 ppt yr^{-1} . However, within such an increasing trend, changes in the growth rate acceleration are observed after 2008, when a slow-down in the acceleration occurred. The high spatial-temporal resolution of our estimates allowed us to identify a possible seasonal cycle in HCFC-22 emissions, when regions facing the Mediterranean basin were considered separately from the rest of Europe, with emissions in the warmer months ca 25% higher than those occurring in the colder months. Finally, we estimated the extent to which banks will contribute to the total European emissions of HCFC-22.

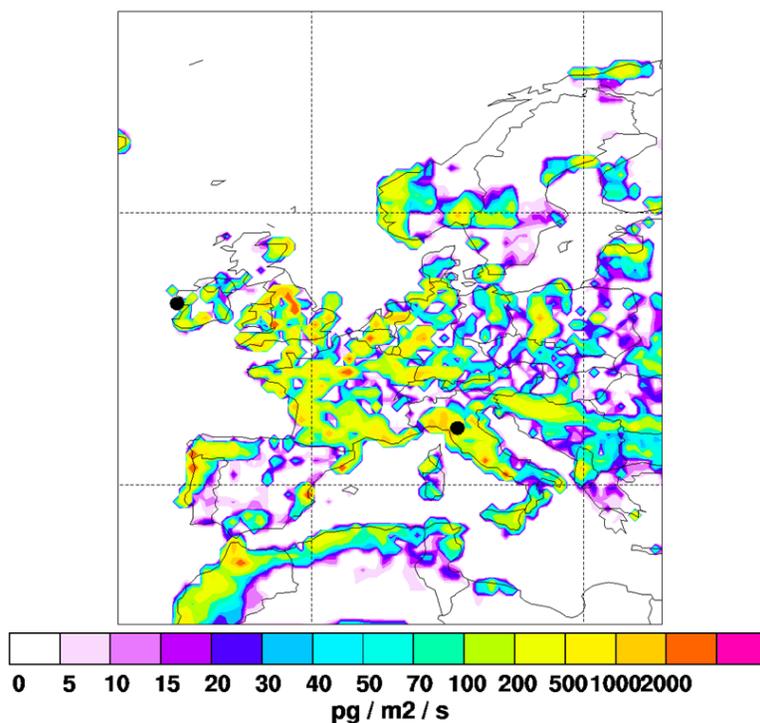


Figure 1. A posteriori emissions of HCFC-22 from the European geographic domain in 2007. The two measurement stations are marked with a black dot.

Measurements of Bromine Oxide, Iodine Oxide and Oxygenated Hydrocarbons in the Tropical Free Troposphere from Research Aircraft and Mountaintops

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⁵University of Colorado, Boulder, CO 80309

The Tropical Ocean Troposphere Exchange of Reactive halogen species and Oxygenated voc (TORERO) field experiment deployed an innovative payload of optical spectroscopic-, mass spectrometric-, and remote sensing instruments aboard the National Science Foundation (NSF)/NCAR Gulfstream V (GV) aircraft (HIAPER). 17 research flights were conducted, 6 above NOAA RV Ka'imimoana cruise KA-12-01 from Hawaii to Costa Rica (TAO program). We have measured small oxygenated hydrocarbons (glyoxal, methyl ethyl ketone, propanal, butanal etc), volatile organic compounds (some 50+ species), bromine oxide and iodine oxide radicals, methyl iodide, bromoform, dibromomethane, and other organohalogen precursors, aerosol size distributions, photolysis frequencies and other parameters from the sea surface to 15km altitude between 40N to 40S latitude over the eastern tropical Pacific Ocean. The project was motivated by our recent observations of very short-lived and very water soluble oxygenated hydrocarbons, like glyoxal, in the remote marine boundary layer (Sinreich et al., 2010, ACP) that remain as of yet unexplained by atmospheric models. Further, the project extended first measurements of iodine oxide radicals in the tropical free troposphere over the Central Pacific Ocean in the Northern Hemisphere (Dix et al., 2013, PNAS) towards measurements of iodine oxide and bromine oxide in the Southern Hemisphere. Organic carbon and halogens are relevant in the atmosphere because they influence the reactive chemical removal pathways of climate active gases (i.e., ozone, methane, dimethyl-sulfide), and can modify aerosols (e.g., secondary organic aerosol, secondary organic aerosol). This presentation provides a comprehensive field evidence of vertical distributions of small oxygenated molecules and halogen oxide radicals that are found to be widespread in the tropical free troposphere, where 75% of the global tropospheric ozone and methane destruction occurs, and mercury oxidation rates are accelerated at low temperatures. A mountaintop Multi AXis Differential Optical Absorption Spectroscopy (MAX-DOAS) instrument to measure tropospheric bromine oxide and iodine oxide vertical profiles was recently installed at Mauna Loa Observatory (MLO), and the capabilities of this instrument to observe the composition of the upper tropical free troposphere from the ground are discussed.

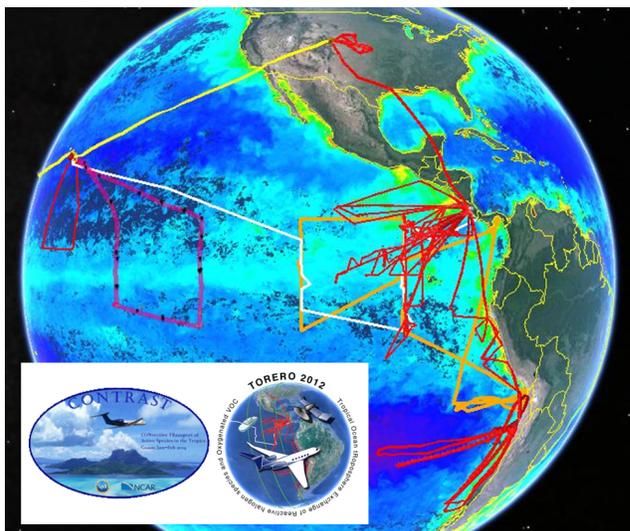


Figure 1. Flight tracks of the NSF/NCAR GV aircraft (red) and ship tracks of RV Ka'imimonana cruise KA-12-01 (white) during the TORERO Project (Jan/Feb 2012). Two flights were further conducted above the mountaintop MAX-DOAS setup at MLO as part of the CONvective TRansport of Active Species in the Tropics (CONTRAST) Project (Jan/Feb 2014).

A Seven-year (2006-2013) Record of NonMethane HydroCarbons (NMHC) in the Subtropical Marine Boundary Layer at the Cape Verde Atmospheric Observatory

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We report observations of light NonMethane HydroCarbons (NMHC), methane (CH_4) and carbon monoxide (CO) measured in the subtropical marine boundary layer at the Cape Verde Atmospheric Observatory ($16^\circ 51'$ N, $24^\circ 52'$ W) in the east Atlantic Ocean. Presented in Figure 1 is a time series of ethane, propane and CO measured during Oct 2006 - Dec 2013, showing well-defined seasonal cycles with spring maxima and summer minima, consistent with the seasonal variation of the OH radical. Simulations of NMHCs using the Community Atmosphere Model with Chemistry (CAM-chem) model show good agreement with the observations and allow an investigation of source attribution over the time series record. The major sources of ethane are shared with those of methane, and we investigate the relationship between ethane mixing ratios and the methane atmospheric growth rate over the past 7 years. The potential impact of Cl-atom reactions on the atmospheric removal of selected hydrocarbons in the marine atmosphere is also investigated. Oceanic emissions of alkanes may perturb such ratios, obscuring the discrimination of OH from Cl chemistry. Using hydrocarbon variability-OH lifetime relationships, we also show evidence for oceanic emissions of reactive alkenes (ethene and propene).

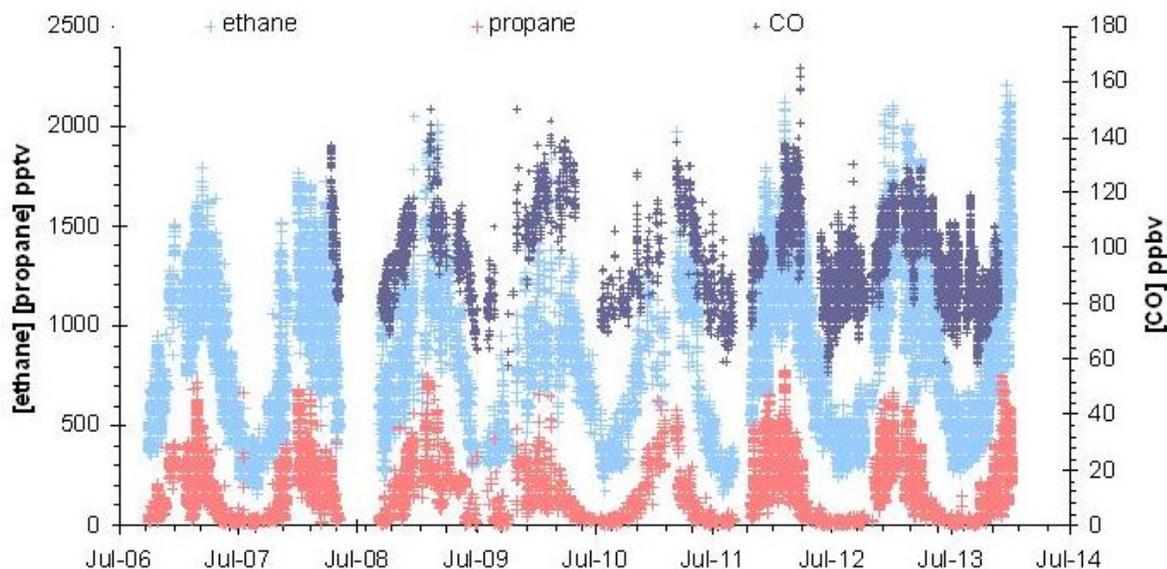


Figure 1. Time series of ethane, propane and CO during Oct 2006 - Dec 2013.

Real-time Quantification and Geo-spatial Mapping of Volatile Organic Compounds (VOC) and SemiVolatile Organic Compounds (SVOC) by Tandem Mass Spectrometry

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²Norwegian University of Science and Technology (NTNU) Chemistry Department, Trondheim, Norway

A miniature cylindrical ion trap mass spectrometer was modified to include a membrane inlet with atmospheric and aqueous sampling capabilities. The membrane inlet allowed for continuous online sampling on mobile platforms. To aid quantification of multiple VOC and SVOC analytes, several modifications were developed: 1) the inclusion of an internal standard delivery system, 2) the addition of mu-metal to shield the instrument from varying magnetic field vectors, and 3) the addition of multiple interlaced MSMS/Fullscan spectra. Continuous data collection enables the capture of transient events that may be missed or under represented by grab sampling strategies, provide improved data density for on-site assessments and real-time information to support decision making. Significant efforts were directed at developing the technical infrastructure necessary to enable adaptive sampling in a user-friendly manner. For example, Labview was used to integrate GPS data, mass spectrometer spectra, meteorological data, and meta-data. To take advantage of a hierarchical and network-friendly data structure, Google Earth was used to present color-based map trackpoints. Sample data sets presented were collected in western Canada in 2010-2012 and compared to discrete whole-air samples analyzed by state-of-the-art laboratory techniques.

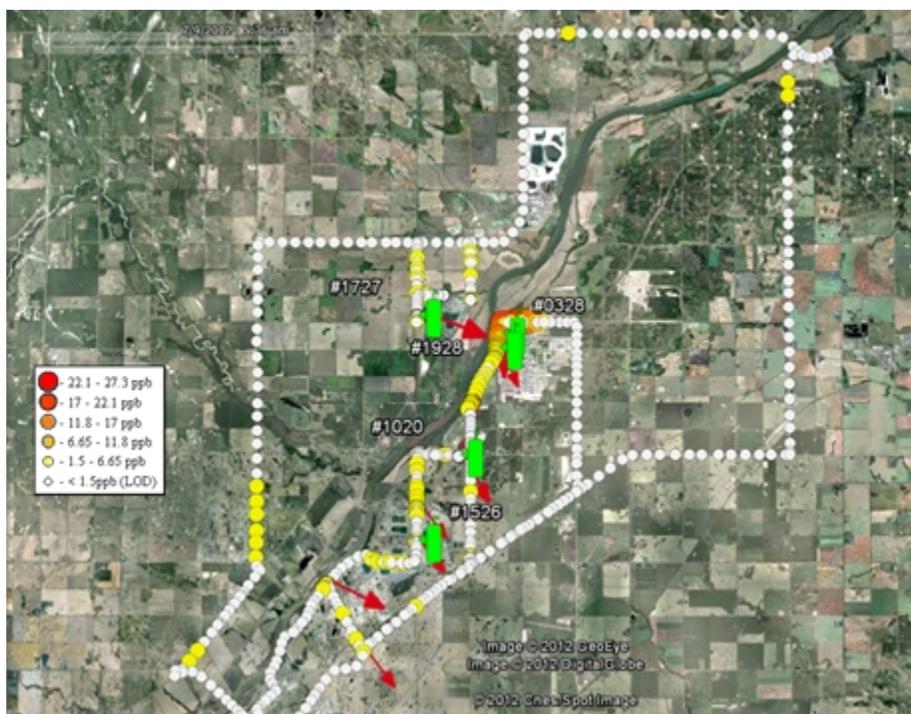


Figure 1. Benzene MS data collected in Fort Saskatchewan, AB. Fugitive emissions from heavy industry resulted in detections significantly above the detection limit (~1 ppb).

Development of a Calibration for Estimating Flared Gas Volume for Gas Flaring from Nighttime Visible Infrared Imaging Radiometer Suite (VIIRS) Data

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²Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO 80309

Gas flaring is a widely used practice for disposing of natural gas during the petroleum production process. The National Aeronautics & Space Administration/NOAA VIIRS has a unique capability to detect and quantify the radiant emissions from gas flares worldwide on a nightly basis. Gas flares are about twice as hot as biomass burning, with a typical temperature of 1800 K. As per Wein's Displacement Law, the radiant emission peak near 1.6 μm . This is the wavelength position of the VIIRS M10 spectral band. M10 is designed as a daytime imaging band. Most similar instruments forego the collection of daytime bands at nights. VIIRS collects M10 plus two additional near infrared spectral bands both day and night. With sunlight eliminated these spectral bands collect the peak radiant emission from gas flares. In this paper we present a calibration for estimating flared gas volumes from VIIRS data.

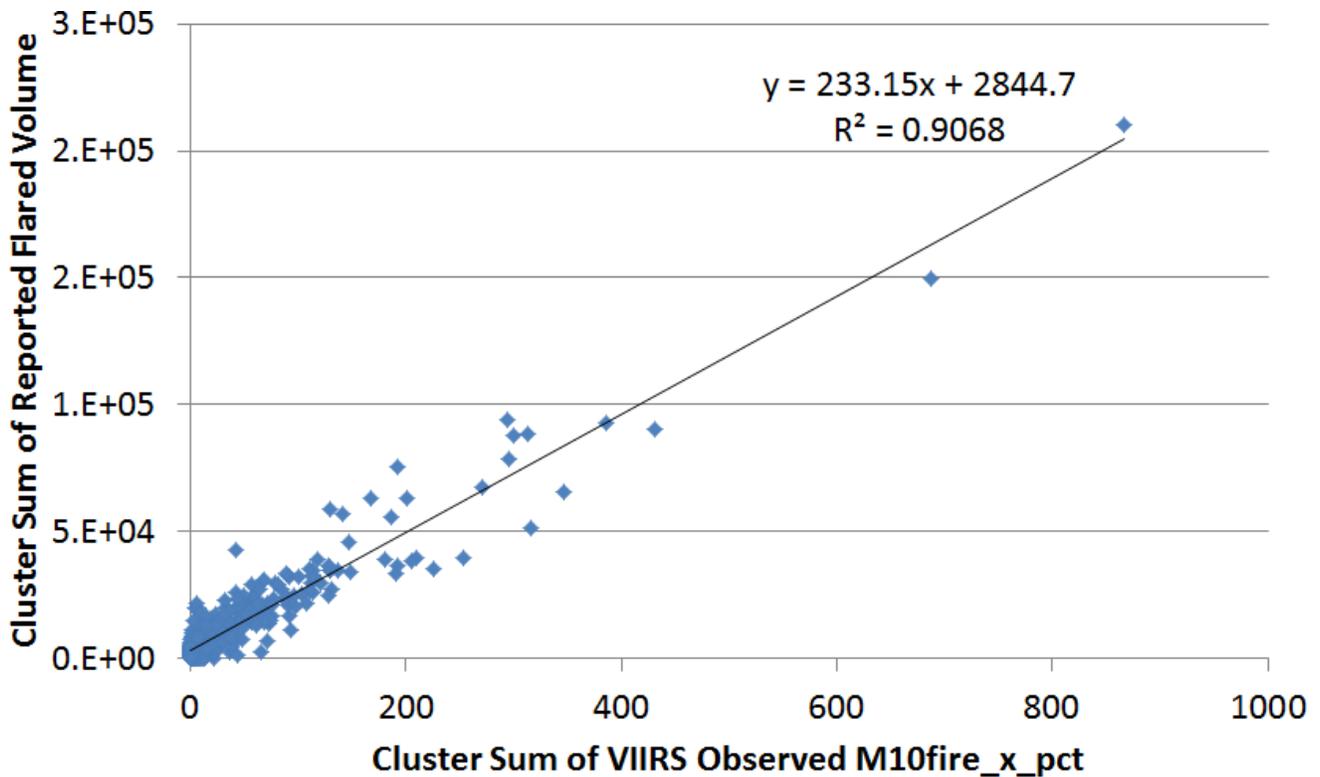


Figure 1. Calibration for estimating flared gas volumes based on monthly reported flare locations and flared gas volumes from the State of North Dakota.

Methane Emissions Estimates from Oil and Natural Gas Production Using Atmospheric Measurements

A. Karion¹, C. Sweeney¹, G. Petron¹, E. Kort², C. Rella³, P. Shepson⁴, S. Conley⁵, S. Wolter¹, T. Newberger¹, M. Trainer⁶, T. Lavoie⁴, M. Cambaliza⁴, T. Yacovitch⁷ and S. Herndon⁷

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⁷Aerodyne Research Inc., Billerica, MA 01821

The recent development of horizontal drilling technology has fueled a production boom in domestic oil and natural gas, which has led to widespread interest from the policy and scientific communities in quantifying the climate impact of the use of natural gas as an energy source. Quantifying this climate impact requires an understanding of methane emissions from natural gas and oil operations, because methane, the primary component of natural gas, is also a powerful greenhouse gas.

Several recent scientific field studies have focused on using atmospheric measurements to estimate natural gas methane emissions in different production basins. Ethane and carbon isotope measurements can be used to differentiate natural gas emissions from methane emissions that do not contain any non-methane hydrocarbons and have a different isotopic signature. We will present estimates of methane emissions from natural gas and oil production in two different unconventional basins in the U.S.: the Uintah (in Utah) and the Denver-Julesburg (in Colorado), along with preliminary results from a more recent measurement campaign in the Barnett Shale (in Texas). We find that current emissions inventories for the first two regions may be underestimated by a factor of two, indicating that further study is needed to identify the sources of the discrepancies between inventories and top-down estimates based on atmospheric measurements.

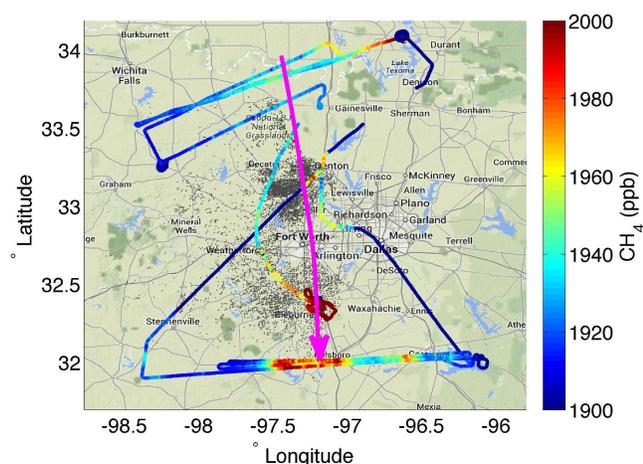


Figure 1. Map of aircraft flight path over the Barnett region gas wells (dark gray dots) colored by methane mole fraction. Map combines flight paths from two different aircraft on October 19, 2013. Magenta arrow indicates mean wind speed and direction.

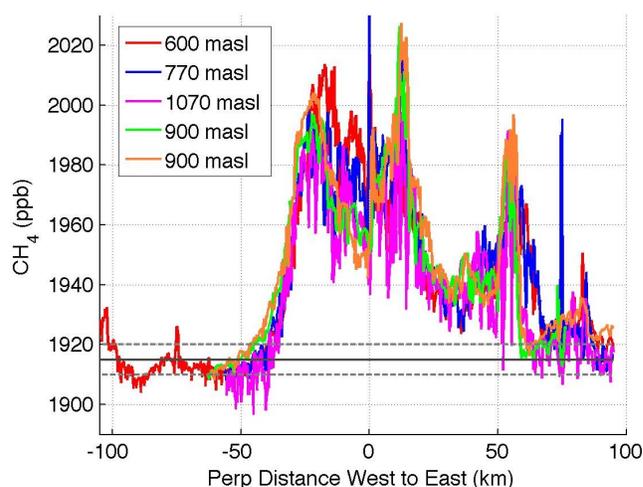


Figure 2. Methane mole fraction as a function of distance perpendicular to the average wind direction on October 19, 2013. Five passes were made in the downwind plume from the gas field at different aircraft altitudes (each differently colored in the figure). The average background condition is shown by the black line.

Quantifying Relative Contribution of Natural Gas Fugitive Emissions to Total Methane Emissions in CO, UT, and TX Using Mobile Isotopic Methane Analysis Based on Cavity RingDown Spectroscopy (CRDS)

C.W. Rella¹, E. Crosson¹, G. Jacobson¹, A. Nottrott¹, A. Karion², G. Petron² and C. Sweeney²

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Fugitive emissions of methane into the atmosphere are a major concern facing the natural gas production industry. Because methane is more energy-rich than coal per kg of carbon dioxide emitted into the atmosphere, it represents an attractive alternative to coal for electricity generation, provided that the fugitive emissions of methane are kept under control. A key step in assessing these emissions in a given region is partitioning the observed methane emissions between natural gas fugitive emissions and other sources of methane, such as from landfills or agricultural activities. One effective method for assessing the contribution of these different sources is stable isotope analysis, using the isotopic carbon signature to distinguish between natural gas and landfills or ruminants. We present measurements of methane using a mobile spectroscopic stable isotope analyzer based on cavity ringdown spectroscopy, in three intense natural gas producing regions of the United States: the Denver-Julesburg Basin in Colorado, the Uintah Basin in Utah, and the Barnett Shale in Texas. Performance of the CRDS isotope analyzer is presented, including precision, calibration, stability, and the potential for measurement bias due to other atmospheric constituents. Mobile isotope measurements of individual sources and in the nocturnal boundary layer have been combined to establish the fraction of the observed methane emissions that can be attributed to natural gas activities. The fraction of total methane emissions in the Denver-Julesburg Basin attributed to natural gas emissions is 78 +/- 13%. In the Uintah Basin, which has no other significant sources of methane, the fraction is 96% +/- 15%. In addition, results from the Barnett Shale are presented, which includes a major urban center (Dallas / Ft. Worth). Methane emissions in this region are spatially highly heterogeneous. Spatially-resolved isotope and concentration measurements are interpreted using a simple emissions model to arrive at an overall isotope ratio for the region.

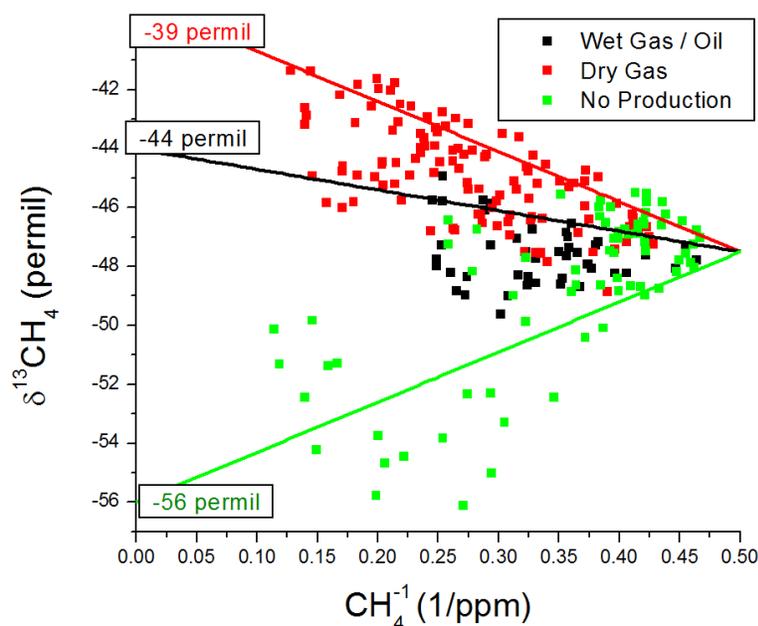


Figure 1. Keeling Plot of mobile isotope data in the Barnett Shale region, in dry gas production areas (red), wet gas production areas (black), and areas with little or no production (green).

Mapping Sources of Methane Emissions Over the Barnett Shale in Texas

B. Hirst, D. Randell, B. King and P. Jonathan

Shell Global Solutions International BV, The Hague, The Netherlands; +3170 447 7331, E-mail: bill.hirst@shell.com

We have developed and used a novel airborne survey technique to estimate the mass release rates and locations of numerous major sources of methane emissions to the atmosphere within the Barnett Shale in Texas, USA. This is one of the largest and longest established shale gas production areas in North America, producing 14% of U.S. shale gas. The survey area covers 3600km² of the densest production area; which includes 5,828 producing wells (mostly gas) and associated infrastructure. Many of the inferred source locations show a clear correlation to gas processing plants and compressor stations visible in Google Earth. The distribution of inferred source emission rates supports the “heavy tail” hypothesis of relatively few sources emitting a disproportionately large fraction of total emissions.

Combining individual source emission rates we have produced a lower bound estimate for total emissions of 12,595 kg/hr from the survey area, which would constitute 0.96% of the area's average gas production (with an estimated one standard deviation range of 0.78% to 1.13%). This is a lower bound estimate because of our method's detection threshold, but includes all emission categories: not just those related to oil and gas. Our survey technique was developed for mapping naturally occurring gas seeps as an aid to hydrocarbon exploration and is called “LightTouch™”. It uses a reversible jump Markov chain Monte-Carlo approach to analyse gas concentration and meteorological data from sixteen 4-hour flights. Atmospheric background methane concentrations are treated as a spatio-temporal Markov random field with anomalous concentrations attributed to local sources via a Gaussian plume atmospheric eddy dispersion model. Flights are at a height of 165m and multiply traverse areas at 2.5km line spacing, revealing local gas plumes aligned with the wind (see figure below). Our experimental design provided multiple coverage of the survey area during the 9-day campaign, with 24 data sets covering a central 900km² area; these provided consistency checks and revealed numerous transient emission events. For survey areas containing a greater variety of methane emitters, our location information could be used to help attribute emissions across source categories: e.g. oil and gas, landfills, electrical power generation, coal production, animal feed lots, etc. The heavy-tail distribution of source emission rates naturally assists mitigation efforts by focusing attention and resources on the most significant sources.

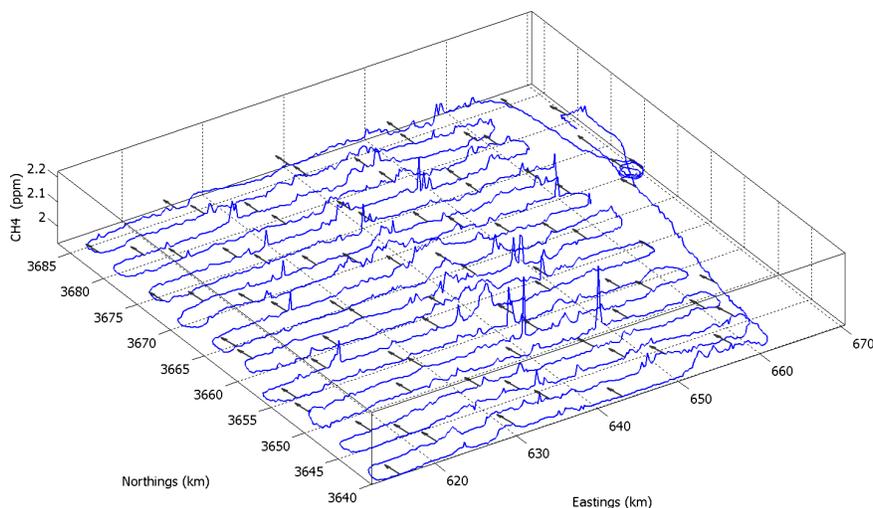


Figure 1. Raw methane concentration data from Flight 1007, showing correlation of local concentration anomalies with air movement vectors (black arrows). The flight area is 45x45km and aircraft flew at 165m altitude.

Measurements and Modeling of Greenhouse Gases and the Planetary Boundary Layer (PBL) for the Boston Metro Area and the Northeastern Megalopolis

P. DeCola¹, T. Jones¹, S. Wofsy², K. McKain², J. Chen², Y. Bererra², E. Gottlieb², T. Nehrkorn³, J. Hegarty³, J. Eluszkiewicz³, J. Henderson³, M. Mountain³, L. Hutyrá⁴, C. Sweeney⁵, A. Andrews⁶, J. Lewis⁷, J. Welton⁸ and W. Callahan⁹

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³Atmospheric and Environmental Research, Inc., Lexington, MA 02421

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⁷University of Maryland/Baltimore County (UMBC) Joint Center for Earth Systems Technology (JCET) and NASA/GSFC, Baltimore, MD 21250

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⁹Earth Networks, Inc., Germantown, MD 20876

The accuracy of GreenHouse Gas (GHG) emission and air quality simulations reflects the fidelity of the atmospheric transport model employed that in turn is highly dependent on the accuracy of the meteorological input data. We describe a multi-scale measurement network and model-data analysis framework for the Boston Metro region, with extension to the mid-Atlantic urban corridor. Observations include a network of automated concentrations of CO₂ and CH₄ inside and outside the urban domain, near the surface, on towers and tall buildings, total column measurements using the sun as a source, aerosol LiDAR data defining atmospheric structure, and meteorological data. The model-data analysis framework includes a Lagrangian Particle Dispersion Model, the Stochastic Time-Inverted Lagrangian Transport, driven by meteorological fields from the North American Regional Reanalysis and Weather Research and Forecasting (WRF) model, and an inversion framework. We show examples of data and discuss the observational network's sampling design and a plan for extension to the northeast urban corridor of the United States. These urban studies are demonstrating the feasibility and value of incorporating advanced instrumentation such as the Mini Micro Pulse LiDAR to evaluate and improve the fidelity of the WRF simulations of atmospheric transport and structure in the planetary boundary layer, thereby reducing the uncertainty of top-down inverse model estimates of GHG emission fluxes.

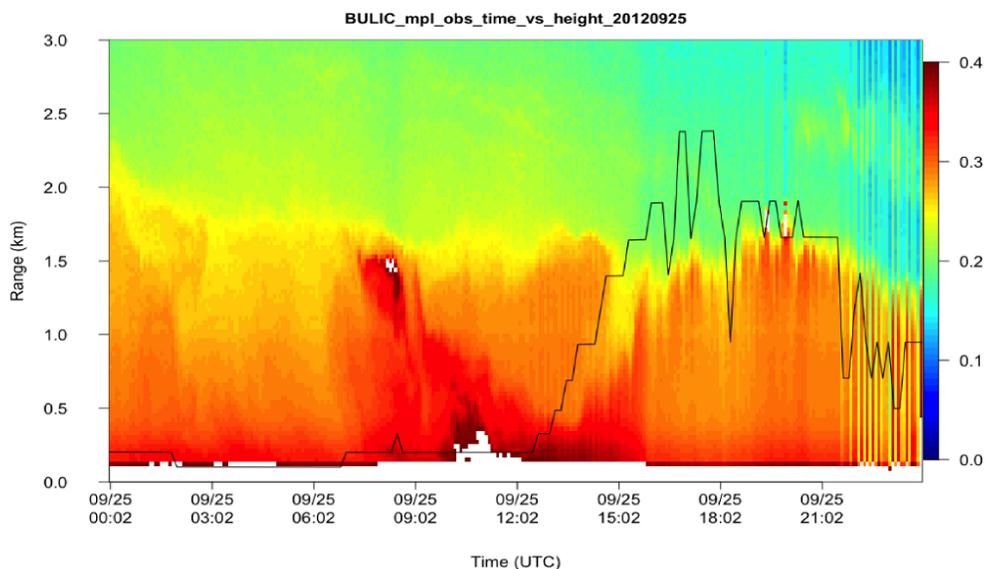


Figure 1. WRF Model PBL Height (black line) versus Mini Micro Pulse LiDAR Aerosol Backscatter Data.

Modeling of Atmospheric Methane and Ozone in the Uintah Basin, UT: The Role of Oil and Gas Emissions, Chemistry and Transport

R. Ahmadov¹, S. McKeen¹, M. Trainer², G.J. Frost¹, J.M. Roberts², J.D. Gouw¹, C. Warneke¹, J. Peischl¹, J. Gilman¹, S. Brown², P. Edwards¹, R. Wild¹, Y. Pichugina¹, A. Langford², R. Banta¹, A. Brewer¹, C. Senff¹, A. Karion¹, C. Sweeney¹, S.J. Oltmans¹, G. Petron¹, R.C. Schnell², B. Johnson² and D. Helmig³

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There is a growing concern about increasing methane and other Volatile Organic Compound (VOC) emissions due to rapid development of the oil and gas production across the United States. The Uintah Basin Winter Ozone Study (UBWOS) field campaigns took place in the winters of 2011-12 and 2012-13 in the Uintah Basin in Utah, which has a large number of oil and gas wells. Intensive measurements conducted by the NOAA/ESRL researchers were designed to characterize the meteorology and chemistry over the basin.

In this study, we present methane and ozone simulations for the UBWOS at high spatial resolution using the Weather Research & Forecasting-Chemistry model that uses two anthropogenic emissions inventory datasets. The first emission data set (bottom-up) is based on the U.S. Environmental Protection Agency National Emissions Inventory-2011 (version 1) emission inventory's gas and oil sector for the basin. Emissions of nitrogen oxides and VOCs in the second inventory (top-down) are constructed using the UBWOS measurements. The aircraft and tethered sonde measurements conducted by Global Monitoring Division during the UBWOS are extensively used in this study to evaluate the 3D distribution of modeled meteorological and chemical variables. Comparisons of the model results with the surface and aircraft measurements show greater underestimates of mixing ratios of methane and other VOCs in the simulation with the bottom-up inventory than the case when the top-down inventory is used. The photochemistry modeling using the emission datasets reveals that the top-down emissions allow the model to capture the high ozone episodes quite well. In contrast, the simulation case using the bottom-up inventory is not able to reproduce any of the observed high ozone concentrations in the basin.

We show the role of photochemical and deposition processes in driving the high ozone concentrations in the basin. In addition, the role of advection and vertical mixing of gas species within and out of the basin focusing the winter of 2013 will be discussed.

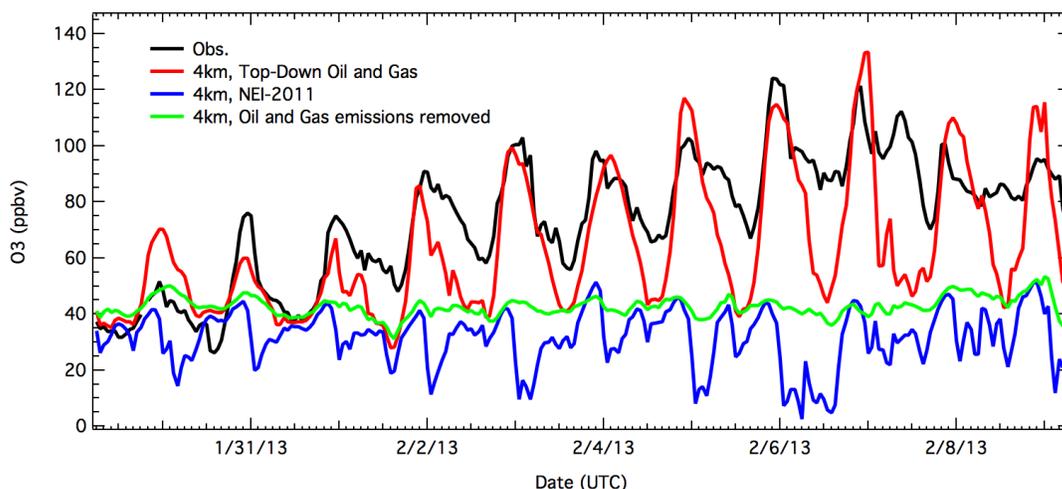


Figure 1. Time series of the observed and modeled ozone mixing ratios at the Horse Pool surface site during winter of 2013. Three modeled cases with different anthropogenic emission cases are shown.

Anatomy of Wintertime Photochemical Ozone Production: Uintah Basin, UT, 2013

R.C. Schnell¹, S.J. Oltmans², B. Johnson¹, E. Hall², P. Cullis², A. Jordan², C. Sterling³, R. Albee³ and T. Mefford²

¹NOAA Earth System Research Laboratory, 325 Broadway, Boulder, CO 80305; 303-497-6733, E-mail: russell.c.schnell@noaa.gov

²Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO 80309

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The Uintah Basin, Utah with lower elevations of ~1400 m asl is ringed by mountains rising to ~3,000 m. Within this basin are ~6,000 gas wells that produced 10 billion m³ of natural gas and ~4,000 oil wells that produced ~22 million barrels of oil in 2012. In winter, the confined geography in the basin traps effluents from these fossil fuel extraction activities into a shallow layer (a few 100 meters deep) beneath strong temperature inversions when ample snow cover is present. The reflective snow provides for enhanced photolysis rates that in February are comparable to those in June. In 2013, snowfall in the Uintah Basin persisted from December until early March with elevated ozone production occurring in 10-day periods separated by 2-3 days of near background values following frontal induced washouts of the basins. In one ozone event, background ozone levels of 55 ppb were measured from the surface to the lower troposphere on January 30, 2013. By February 1, ozone concentrations from the surface to the top of the 180 m deep temperature inversion averaged 100 ppb. By February 6 ozone concentrations were 165 ppb throughout the same layer. Cleanout of ozone and ozone precursors in the Uintah Basin was observed to occur within 4 hours or less as basin air was replaced with clean air from the west mixing to the surface.

**Contour Plot of Ozone Over Ouray, Uintah Basin, Utah,
February 6, 2013**

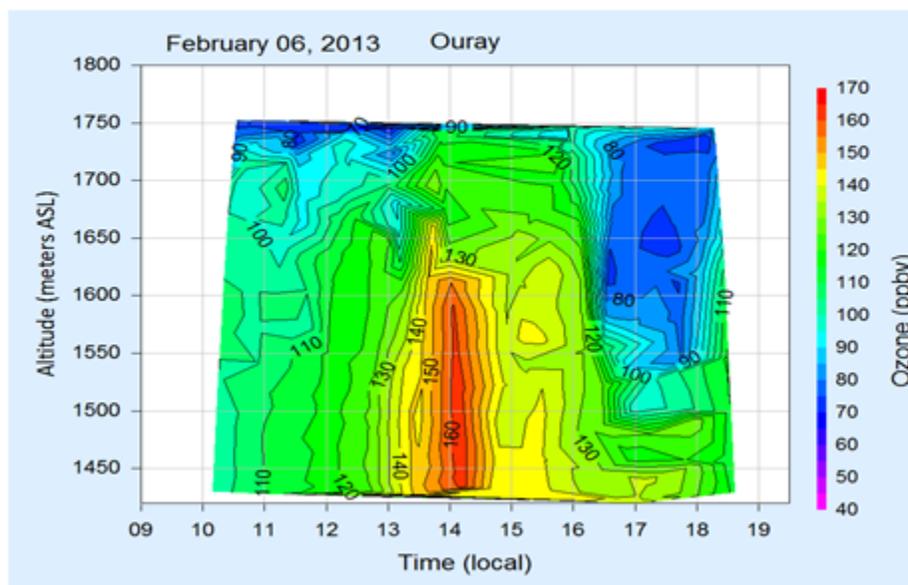


Figure 1. Contour plot of ozone in the Uintah Basin at the peak of an event. Later in the day air from the west began a partial basin cleanout as may be seen in the low ozone air entering the basin beginning around 1600 mst (blue area) descending down to 1550 m.

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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

Tuesday, May 20, 2014 17:00 - 20:00 POSTER SESSION AGENDA

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

• **International Stations & Partners**

- P-1 Halley – A Recently Established Global Atmospheric Watch (GAW) Global Atmospheric Research Station in Antarctica - Preliminary Results from Greenhouse Gas Measurements
Neil Brough (British Antarctic Survey, Cambridge, United Kingdom)
- P-2 Experimental Studies of Carbon Monoxide Based on Measurements in the Antarctic (Novolazarevskaya Station)
Felix Kashin (Federal State Budgetary Institution Research and Production Association “Typhoon”, Obninsk, Russia)
- P-3 The Dr. Neil Trivett Global Atmosphere Watch (GAW) Observatory at Alert, Nunavut: Program Highlights from a Decade of Collaborative Atmospheric Research
Andrew Platt (Environment Canada, Climate Research Division, Atmospheric Science Technology Directorate, Science Technology Branch, Toronto, Ontario, Canada)
- P-4 Comparison of NOAA Near-surface Temperatures and MODerate-resolution Imaging Spectroradiometer (MODIS) Ice-Surface Temperatures (IST) at Summit, Greenland
Thomas Mefford (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-5 Recent Measurements from the Cape Verde Atmospheric Observatory (CVAO)
Shalini Punjabi (University of York, York, United Kingdom)
- P-6 Long-term Measurements of Solar Radiation and Aerosol Optical Depth at Mt. Lulin (2,862m) in East Asia
Sheng-Hsiang Wang (National Central University, Department of Atmospheric Sciences, Chung-Li, Taiwan)
- P-7 CO₂, CH₄, and Stable Isotopes at Lulin and Dongsha Island, Taiwan
Chang-Feng Ou-Yang (National Central University, Department of Atmospheric Sciences, Chung-Li, Taiwan)

• **Radiation**

- P-8 A Miniature Upward-looking Radiometer for Balloon and Unmanned Aerial Vehicle (UAV) Use
Ru-Shan Gao (NOAA Earth System Research Laboratory, Boulder, CO)
- P-9 Update of the Mauna Loa Clear-sky Atmospheric Solar Transmission 1958 – 2013
Kathleen Lantz (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-10 Brewer 131 Calibration at 4-corners New Mexico Environment Department Site: Measurement and Calibration Issues
Patrick Disterhoft (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-11 Improved Quality Assurance Procedures for the Antarctic and U.S. Ultraviolet Monitoring Program
Patrick Disterhoft (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)

• **Halocarbons**

- P-12 NOAA Global Monitoring Division SkyWisp
Fred L. Moore (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-13 Recent Results from the Airborne Tropical Tropopause EXperiment (ATTREX) Over the Western Tropical Pacific
Eric Hintsa (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-14 How Much Can We Learn About Nitrous Oxide Emissions from Background Sites and Simple Box Models?
James W. Elkins (NOAA Earth System Research Laboratory, Boulder, CO)
- P-15 Global Measurement of Nitrous Oxide and Its Stable Isotopes Using Cavity Ring-down Spectroscopy
Amy Steiker (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO)
- P-16 Improvement and Additions to the Halocarbons & Other Atmospheric Trace Species Group (HATS) Combined Data Sets
Geoff Dutton (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-17 Atmosphere-based Estimates of Non-CO₂ Greenhouse Gas Emissions for the U.S. Derived from ¹⁴CO₂
Steve Montzka (NOAA Earth System Research Laboratory, Boulder, CO)

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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Tuesday, May 20, 2014 17:00 - 20:00 POSTER SESSION AGENDA (Continued)

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

• Carbon Cycle & Greenhouse Gases

- P-18 What We Learn from Updates of NOAA'S Annual Greenhouse Gas Index (AGGI)
James H. Butler (NOAA Earth System Research Laboratory, Boulder, CO)
- P-19 Environment Canada's Greenhouse Gases Measurement Program - Summary of Progress to 2014
Doug Worthy (Environment Canada, Toronto, Ontario, Canada)
- P-20 A New Reference Scale for Measurements of Carbon Monoxide in the Atmosphere
Paul C. Novelli (NOAA Earth System Research Laboratory, Boulder, CO)
- P-21 Meteorological Controls on the Diurnal Variability of Carbon Monoxide at Pinnacles, an East Coast Mountaintop Site in the CarbonTracker Observational Network
Stephan F. J. De Wekker (University of Virginia, Charlottesville, VA)
- P-22 A Central Facility for Greenhouse Gas Analyses Within the Integrated Carbon Observation System (ICOS) Research Infrastructure
Daniel Rzesanke (Max Planck Institute (MPI) for Biogeochemistry, ICOS Flask & Calibration Laboratory (FCL), Jena, Germany)
- P-23 Regional Carbon Cycle and Atmospheric Inversions in the Southeastern United States (U.S.) – Optimizing an Observational Network
Scott Richardson (The Pennsylvania State University, University Park, PA)
- P-24 Bayesian Optimization of the Net Ecosystem Exchange (NEE) in Oregon Using a New CO₂ Observation Tower Network, Transport Modeling, and the Community Land Model
Andres Schmidt (Oregon State University, Corvallis, OR)
- P-25 Quantification of Transport Errors in Regional CO₂ Inversions Using a Physics-based Ensemble of Weather Research & Forecast (WRF)-Chem Simulations
Liza I. Diaz Isaac (The Pennsylvania State University, Department of Meteorology, University Park, PA)
- P-26 Comparing Modeled Column-average CO₂ to Greenhouse Gases Observing SATellite (GOSAT) Atmospheric CO₂ Observations from Space (ACOS) 3.4 X_{CO₂} Product
Andrew Schuh (Colorado State University, Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins, CO)
- P-27 Improving CO₂ Air-sea Fluxes by Combining O₂ and CO₂ Data
Laure Resplandy (Scripps Institution of Oceanography, La Jolla, CA)
- P-28 Estimating Fire Emissions Using Visible Infrared Imaging Radiometer Suite (VIIRS) Nightfire Data and the Fire INventory from NCAR (FINN)
Tom Oda (Colorado State University, Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins, CO)
- P-29 Evidence of Causality Between the Atmospheric Concentration Levels of Carbon Dioxide and Temperature
Kevin F. Forbes (The Catholic University of America, Washington, DC)
- P-30 As Methane Concentration Goes Up, Stable Isotopes of Methane Go Down: ¹³C Implicates a Microbial Source Across Latitudinal Gradients
Sylvia Englund Michel (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO)
- P-31 Comparison of *In Situ* and Discrete Sample Methane Monitoring at Summit, Greenland
Reed M. Terrell (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO)

• Oil & Gas Fields

- P-32 Top-down Constraint on Hydrocarbon Emissions in the Denver-Julesburg Oil and Natural Gas Basin
Gabrielle Petron (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-33 Initial Results of a Natural Gas Methane Emissions Survey in California's Southern San Joaquin Valley
Marc L. Fischer (Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division, Berkeley, CA)
- P-34 Effect of Oil and Gas Development on Atmospheric Levels of Hydrocarbons and Tropospheric Ozone
So-Yun Kim (Fairview High School, Boulder, CO)

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2014

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Tuesday, May 20, 2014 17:00 - 20:00 POSTER SESSION AGENDA (Continued)

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

• Networks & Data Management

- P-35 Bridging the Work of Field Scientists and the Needs of Data Re-users
Antonia Rosati (National Snow and Ice Data Center (NSIDC), Boulder, CO)
- P-36 The National Ecological Observatory Network (NEON): Overview and Strategies for Managing Thousands of Simultaneous Measurements Across the Continent
Jeffrey Taylor (National Ecological Observatory Network (NEON), Boulder, CO)
- P-37 The National Ecological Observatory Network (NEON) Mobile Deployment Platform (MDP): A Flexible Community Resource for Ecological Research
Michael SanClements (National Ecological Observatory Network (NEON), Boulder, CO)
- P-38 Global Emissions Initiative's (GEIA) Vision for Improved Emissions Information
Gregory J. Frost (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)

• Aerosols

- P-39 Monitoring Aerosol Optical Depth During the Arctic Night: Development of a Lunar Photometer for Use at the NOAA Barrow Observatory
James Wendell (NOAA Earth System Research Laboratory, Boulder, CO)
- P-40 Results of Aerosol Hygroscopicity During The Two-Column Aerosol Project (TCAP) Campaign in the Frame of the NOAA Network
John A. Ogren (NOAA Earth System Research Laboratory, Boulder, CO)
- P-41 Black Carbon in the Arctic: In the Arctic Report Card
Sangeeta Sharma (Environment Canada, Climate Research Division, Atmospheric Science Technology Directorate/Science & Technology Branch, Toronto, Ontario, Canada)

• Ozone & Water Vapor

- P-42 Observational Evidence for Incomplete Dehydration in the Tropical Tropopause Layer
Andrew Rollins (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-43 The Stratospheric Water and OzOne Satellite Homogenized (SWOOSH) Data Set
Sean Davis (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-44 Towards a Combined Infrared Atmospheric Sounding Instrument (IASI)/Tropospheric Emission Spectrometer (TES) Record of Ozone: Validation and First Results
Hilke Oetjen (Joint Institute for Regional Earth System Science and Engineering (JIFRESSE) UCLA/Jet Propulsion Laboratory (JPL), Los Angeles, CA)
- P-45 South Pole Ozonesonde Measurements During the 2013 Ozone Hole
Bryan Johnson (NOAA Earth System Research Laboratory, Boulder, CO)
- P-46 The Implications of Background O₃ Affecting the Setting and Attainment of the National Ambient Air Quality Standards (NAAQS) for Surface O₃
Samuel J. Oltmans (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)
- P-47 Colorado Front Range Surface Ozone Characterization
Audra McClure-Begley (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO)

Notes:

Halley – A Recently Established Global Atmospheric Watch (GAW) Global Atmospheric Research Station in Antarctica - Preliminary Results from Greenhouse Gas Measurements

N. Brough, A. Jones and S. Colwell

British Antarctic Survey, Cambridge, United Kingdom; 44 01223 221208, E-mail: nbro@bas.ac.uk

Halley is an Antarctic coastal research station operated by the British Antarctic Survey. The Clean Air Sector Laboratory (CASlab) is situated about 1.2 km south of the main base and in a sector that is rarely affected by vehicles or base pollution. More details about the CASlab can be found at http://www.antarctica.ac.uk/bas_research/support/labs/caslab. The CASlab was opened in 2003, closed in early 2009 to facilitate the new build project (Halley VI), and re-commissioned in early 2011. It has almost continuous measurements of trace gas, O₃, CO, CPC, halogens and black carbon as well as filter sampling and snow sampling capabilities. NOAA flask sampling measurements have been continuously taken since 1982. Other instruments recently introduced include high temporal resolution CH₄ and CO₂ measurements (2013) and oxygen flask sampling (2014).

As well as continuous gas measurements the laboratory has hosted a number of field campaigns including collaborations involving many UK national and international universities, both to access the the chemical environment and to carry out process studies. Although the prevailing wind direction throughout the year is easterly, traversing hundreds of kilometers of undisturbed snow, strong directional changes to westerlies often occur, especially in the spring and summer months. Halley is therefore well placed to observe air masses with a variety of origins including the continental snowpack, the sea-ice zone and the southern ocean. In 2013 we incorporated a Picarro G2301 to provide high temporal resolution data of greenhouse gases CO₂, CH₄ and water vapour. Here we provide some measurement data and include an interesting synopsis of a local event that occurred. We also provide information on a network of continuous monitoring stations linking the northern and southern hemispheres ranging from Ny-Alesund, Svalbard in the north to Halley, Antarctica in the south and named Equianos (<http://equianos.com/news-feed/>). The Halley Research Station has recently achieved GAW global status by committing to long-term measurements of reactive trace gases (O₃, CO, NMVOC's, greenhouse gases and total column ozone) as well as providing other meteorological and atmospheric parameters.

Jones, A. E., et al.: Chemistry of the Antarctic Boundary Layer and the Interface with Snow: an overview of the CHABLIS campaign, *Atmos. Chem. Phys.*, 8, 3789–3803, doi:10.5194/acp-8-3789-2008, 2008.

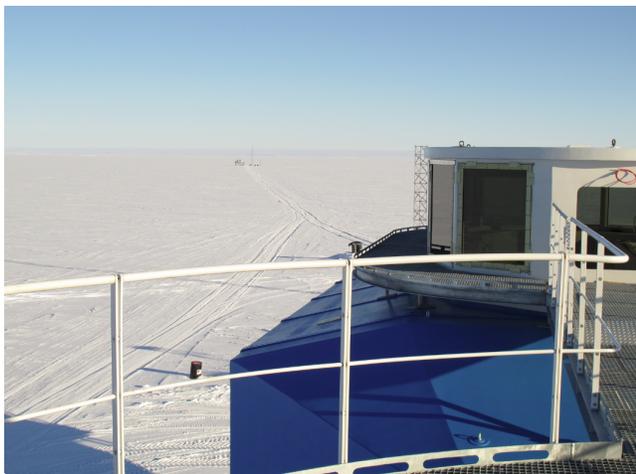


Figure 1. View of the CASlab from the Halley VI Station.



Figure 2. The CASlab above is situated 1.2 km south of the new Halley VI Station.

Experimental Studies of Carbon Monoxide Based on Measurements in the Antarctic (Novolazarevskaya Station)

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The measurement results of Carbon Monoxide (CO) obtained in the atmospheric optical depth with the use of solar radiation absorption spectroscopy. The observations were made in 2003 – 2012 at the Novolazarevskaya Station (the Antarctic, 70°46'S, 11°50'E, 120 m above the sea level). The measurement complex consists of a system following the Sun and a diffraction spectrometer. The spectral resolution is 0.2 cm⁻¹. The measurements were made with the account for direct solar radiation at the Sun's altitudes over 150. The gas content was determined from the transmission function within the ranges including CO absorption band rotation lines of about 4.6 micrometers. The relationship of the CO transmission function and its content is calculated with the use of the spectrum fine structure parameters, the data on vertical profiles of pressure, temperature, humidity and CO mixing ratios.

The contents of CO are given in atm.-cm (the gas thickness is in cm reduced to normal conditions, 1 atm.-cm = 2.69 x 10¹⁹ mole/cm²). The instrumentation random error in determining CO content obtained from the repetition frequency of measurement results during a day makes no more than ±4%. The measurement results are given in Fig. 1(1). They present average daily CO contents. The gaps in the data are connected with the absence of measurements during a polar night. For a correct analysis of the temporal trend, a method of CO atmospheric content reconstruction was developed. It is based on the application of moving average values in short time periods and a spectral analysis for reconstruction of data for a polar night. The reconstructed data are given in Fig. 1(2).

A statistical analysis of the data obtained and a comparison with the CO measurement data obtained at the Syowa Station are presented.

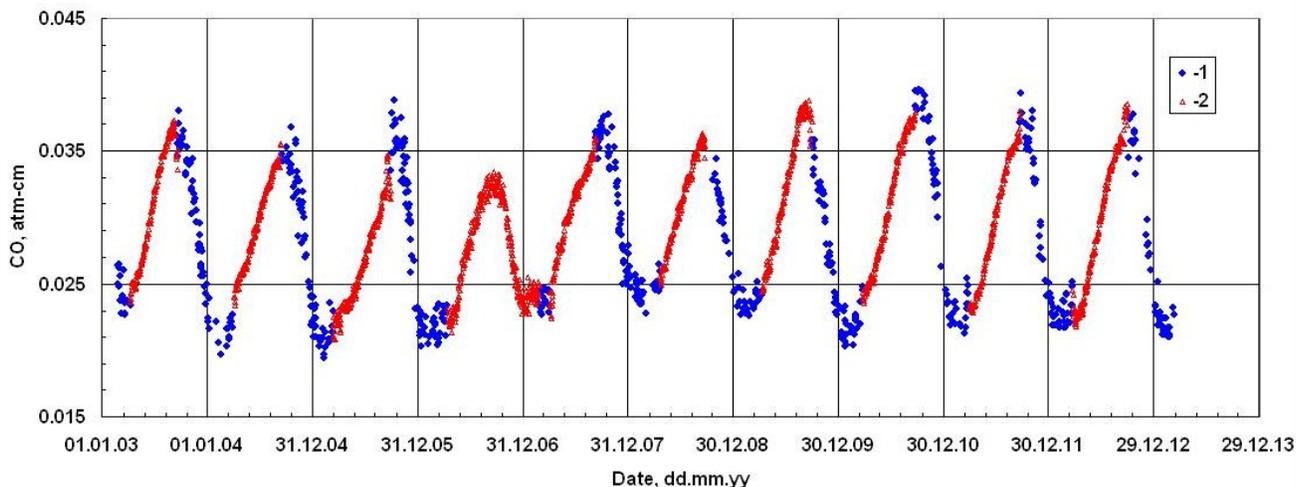


Figure 1. The contents of CO in the atmosphere. (1) measurement data, (2) reconstructed data.

The Dr. Neil Trivett Global Atmosphere Watch (GAW) Observatory at Alert, Nunavut: Program Highlights from a Decade of Collaborative Atmospheric Research

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The Dr. Neil Trivett Global Atmosphere Watch Observatory is located at 82°28'N, 62°30'W on the North-Eastern tip of Ellesmere Island, Canada. The observatory opened in 1986, as Canada's first research station for the continuous monitoring of background concentrations of trace gases and aerosols. The Alert Observatory is the most northern station in the GAW program of the World Meteorological Organization and its' isolated location is ideally situated for the monitoring of global atmospheric pollutants. It has expanded into an international collaboration with over a dozen science partners and is designated as one of three global greenhouse gas inter-comparison sites. With over two and a half decades of measurement history, Alert has compiled many unique and valuable data sets used by Canadian and international researchers in order to further studies of the complex physical and chemical changes occurring in the atmosphere. This poster will highlight some of the more recent collaborative research efforts involving our international partners.



Figure 1. Dr. Neil Trivett Global Atmosphere Watch Observatory at Alert, Nunavut.

Comparison of NOAA Near-surface Temperatures and MODerate-resolution Imaging Spectroradiometer (MODIS) Ice-Surface Temperatures (IST) at Summit, Greenland

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The availability of climate-quality data from NOAA/Earth System Research Laboratory Global Monitoring Division's (GMD) air temperature sensors at Greenland's Summit Station has enabled a multi-year comparison with MODerate-resolution Imaging Spectroradiometer (MODIS) infrared-derived Ice-Surface Temperatures (IST) from NASA's Terra satellite. Over 2008-2013, 2536 IST values were compared with ± 3 -minute average temperatures (TA) derived from NOAA's primary 2-m air temperature sensor. These data capture overall temperature variability and allowed investigation of an expected offset between air and surface temperatures (IST < TA) over multiple annual cycles.

Our findings are compatible with previous research but also suggest the cause of the 'cold bias'. We find that: 1) IST values are colder than the ± 3 -minute average TA values and that this difference increases as temperatures decrease; 2) IST-TA differences vary slightly with distance near the *in situ* data; 3) there is a small but detectable decrease in IST-TA as the sensor's zenith angle increases relative to the site; and 4) there is a pattern in IST-TA differences as the solar zenith angle increases especially during the polar night. This result explains the progressive offset from the TA data at colder temperatures but also indicates that the MODIS cloud mask is less effective in periods of low solar zenith angle.

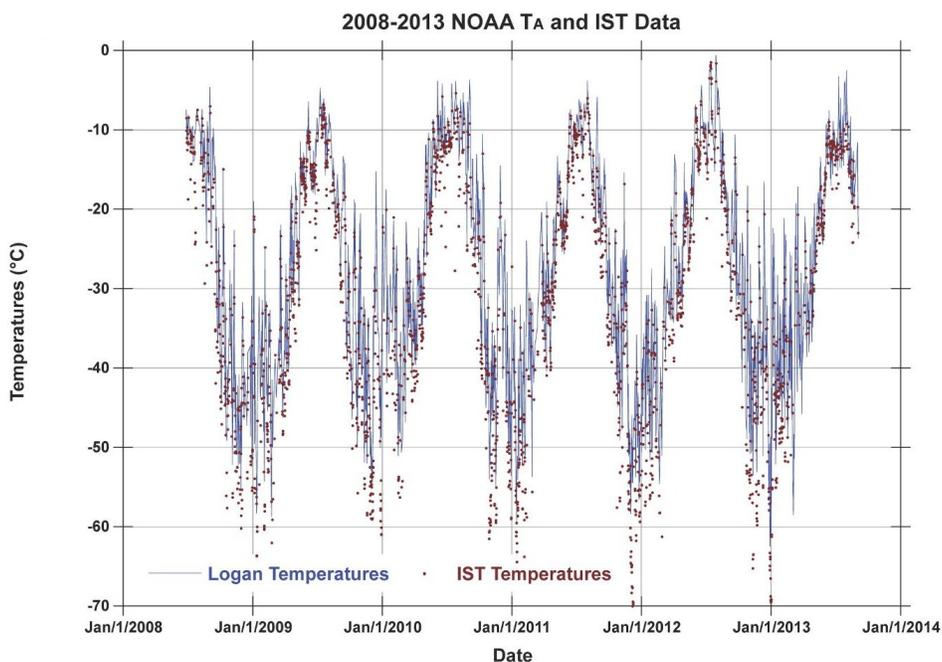


Figure 1. Comparison of NOAA/ESRL/GMD 2 meter temperature at the Temporary Atmospheric Watch Observatory and MODIS infrared-derived ice surface temperatures from 2008 - 2013.

Recent Measurements from the Cape Verde Atmospheric Observatory (CVAO)

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The Cape Verde Atmospheric Observatory (16,848°N, 24.871°W), a subtropical marine boundary layer atmospheric monitoring station situated on the island of São Vicente, has been in operation since October 2006. Almost continuous measurements of the trace gases O₃, CO, Non-Methane Volatile Organic Compound, NO, and NO₂ have been obtained. Other data from the CVAO, for example of greenhouse gases, aerosol, halocarbons, halogen oxides, total gaseous mercury (Global Mercury Observation System) are also available over various timescales. The observatory continues to host field campaigns with two more planned for the Oceanic Reactive Carbon project this year, which aims to better understand oceanic emissions of reactive organic compounds such as glyoxal and monoterpenes and how they might modify marine aerosol.

Measurements from the last seven years will be shown along with analysis of observed delta ozone (9am until 5pm [O₃] (ppbV)) and some investigation into NO_x emissions from shipping. We will also present some early interpretation of our three years of total gaseous mercury measurements.

The CVAO is a Global Atmosphere Watch station and so data is submitted regularly to the World Centre for the Greenhouse Gases in addition to the British Atmospheric Data Centre along with associated instrument metadata. The observatory has recently been audited by EMPA (Swiss Federal Laboratories for Materials Science and Technology) who are the World Calibration Centre for O₃, CO and the greenhouse gas species.

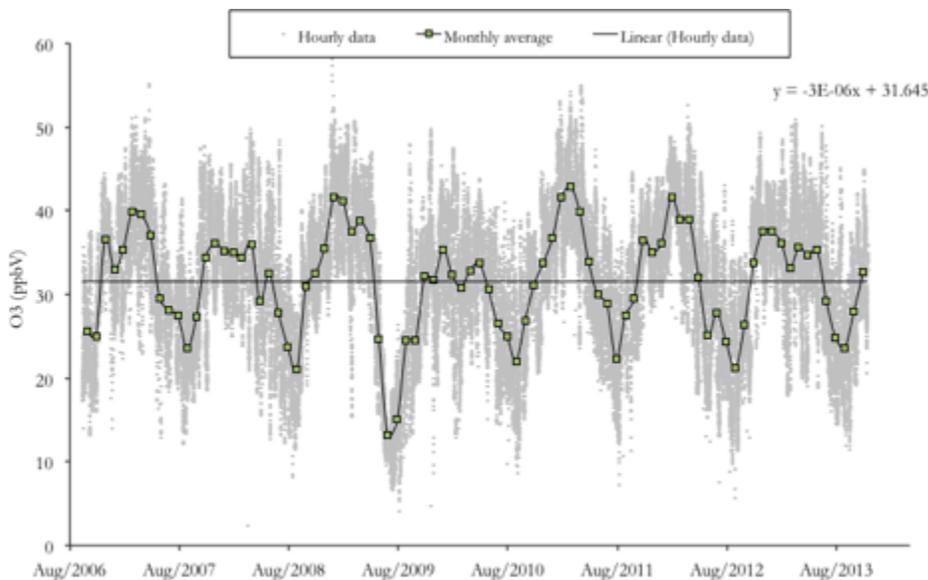


Figure 1. Time-series of surface ozone from the CVAO.

Long-term Measurements of Solar Radiation and Aerosol Optical Depth at Mt. Lulin (2,862m) in East Asia

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The Lulin Atmospheric Background Station (LABS) located at Mt. Lulin in central Taiwan was established to monitor the atmospheric compositions and radiation in the lower free troposphere of East Asia since 2006. Our radiation measurement suite, including Cimel sun-photometry, Multi-Filter Rotating Shadowband Radiometer, broad-band Shortwave/Longwave/Ultraviolet/Photosynthetically Active Radiation radiometers, and sky imager, has been operated based on National Aeronautics & Space Administration/Aerosol Robotic Network (AERONET), NOAA/Global Monitoring Division, and World Meteorological Organization/Global Atmosphere Watch protocols. In this presentation, we will focus on the overall climatology of solar radiation and Aerosol Optical Depth (AOD) at LABS during the period of 2006-2013. The annual mean AOD is 0.07 with the maximum value of 0.2 observed in March. The higher AOD is associated with high loading of biomass-burning aerosols transported from Indochina in spring. In comparison with other AERONET high-elevation sites, the Lulin site shows a significant seasonal variation and is relatively sensitive to influences of continental outflows. In a clear-sky condition, the downward solar radiation flux at surface decreases as AOD increases. A 1-D radiative transfer model is applied to enclosure measurement results and further to estimate the direct Aerosol Radiative Forcing (ARF). As a result, the mean downward shortwave ARFs at the surface are -14.6 ~ -6.5 W m⁻² (Global), 11.0 ~ 14.1 W m⁻² (Diffuse), and -23.2 ~ -17.1 W m⁻² (Direct), respectively.

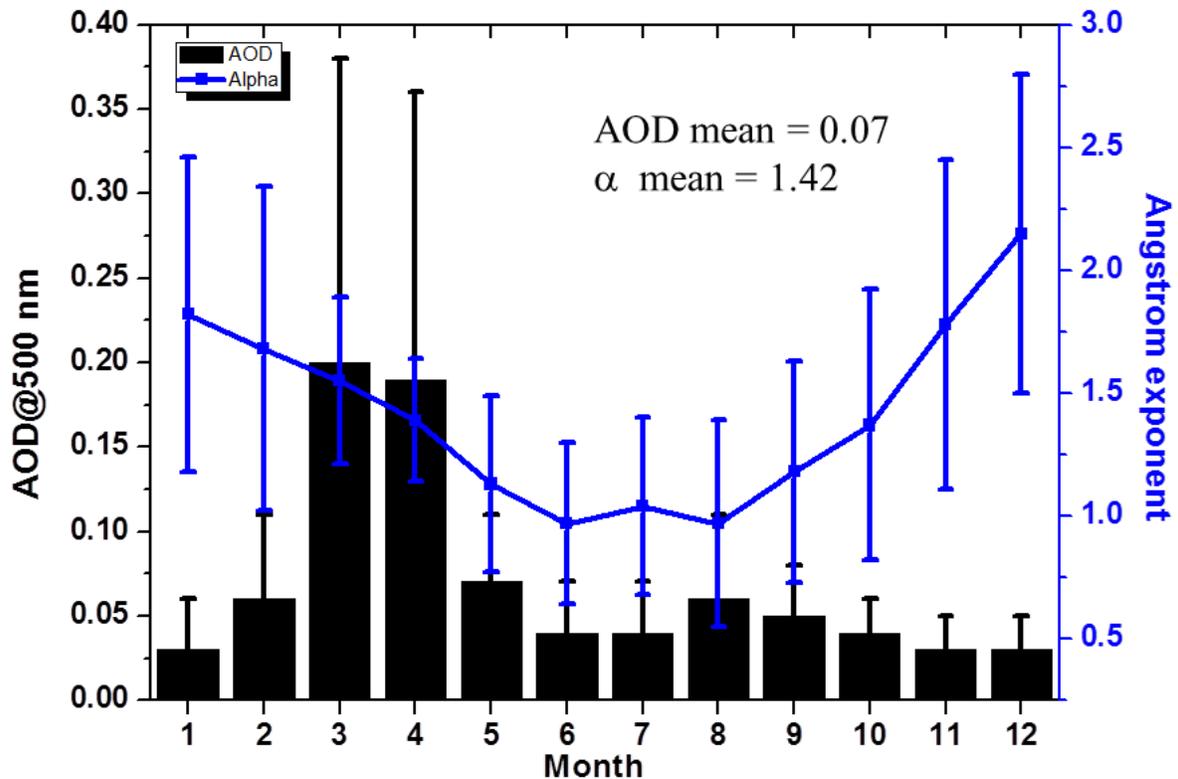


Figure 1. Monthly variations of AOD and angstrom exponent at Mt. Lulin.

CO₂, CH₄, and Stable Isotopes at Lulin and Dongsha Island, Taiwan

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The Taiwan Lulin Atmospheric Background Station (LABS; 23.47°N, 120.87°E; 2,862 m a.s.l., begun in 2006) monitors Asian dust, biomass burning and acidic pollutants originating in Southeast Asia. As part of the Global Monitoring Division's (GMD) Cooperative Air Sampling Network, flask sampling at Dongsha Island (DS; 20.70°N, 116.73°E; 3 m a.s.l.) began in 2010 to characterize sea level greenhouse gases in the South China Sea. The annual maxima and minima of CH₄, CO and O₃ at LABS and DS occur in March and July, respectively. At LABS, springtime maxima were related to long-range northeasterly monsoon transport from Southeast Asia moving polluted air masses into the South China Sea as indicated by elevated CO₂ levels at DS. Vegetation growth in spring drew down CO₂ concentration at LABS and DS in summer. At LABS, a daily minimum of CO₂ with a larger standard deviation was observed during daytime when photosynthesis was active. The diurnal patterns of CH₄, CO and PM₁₀ were similar, which was induced by the mountain-valley circulations. The stable isotope ($\delta^{13}\text{C}$) of CO₂ decreased at an annual rate of -0.056 ‰ per yr at LABS over the past 7.5 years with annual means of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ of CO₂ in 2013 of -8.494±0.167 ‰ and +0.282±0.478 ‰, and at DS -8.452±0.212 ‰ and +0.014±0.374 ‰, respectively.

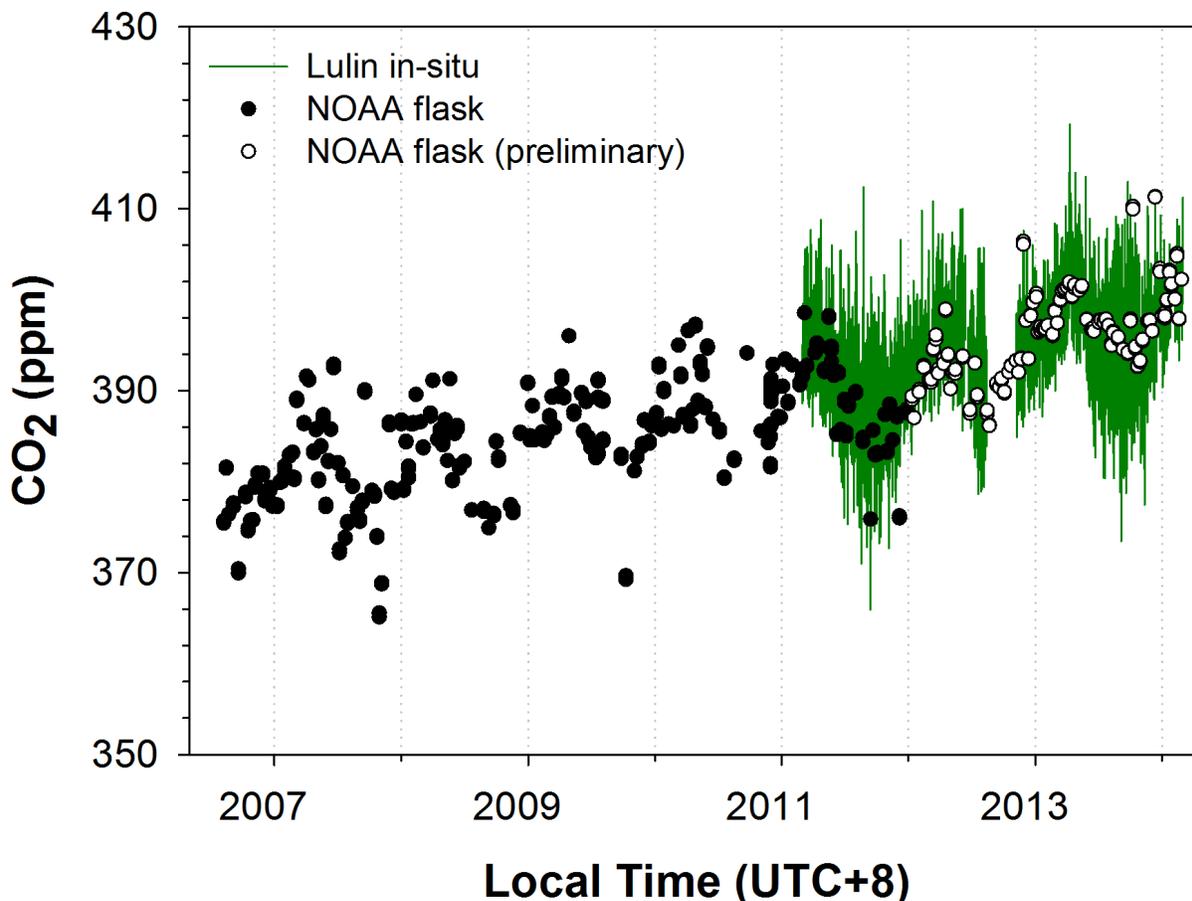


Figure 1. Time-series of CO₂ observed at LABS. Open circles are from GMD flask air samples and green continuous CO₂ data measured with a Cavity Ring-down Spectroscopy.

A Miniature Upward-looking Radiometer for Balloon and Unmanned Aerial Vehicle (UAV) Use

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A miniature radiometer has been developed for use on balloons, UAVs, and other light platforms. The radiometer scans continuously at the elevation angle of the sun (almucantar scans) and measures red, green, and blue light simultaneously about every half degree of rotation. It has the dynamic range to measure both the direct sun and scattered light in the sky. It can compensate in real time for a tilting platform. The instrument with a data system weighs about 300 grams. Doing vertical profiles will allow one to find the altitude of aerosol or cloud layers. A significant advantage of a vertical profile is that the sensitivity can be normalized to the sunlight at the top of the profile and this reduces the need for absolute calibration.

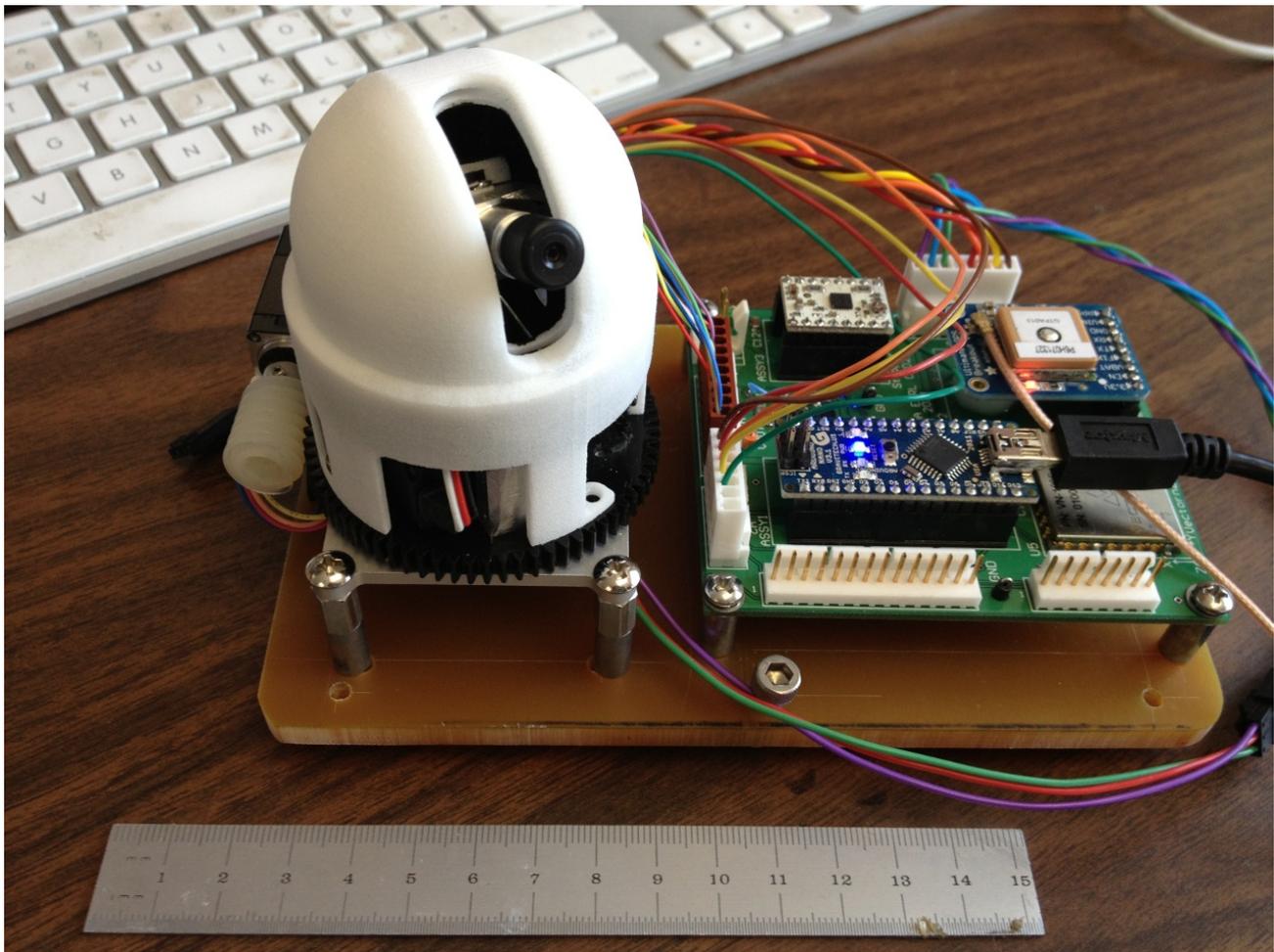


Figure 1. A radiometer.

Update of the Mauna Loa Clear-sky Atmospheric Solar Transmission 1958 – 2013

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Atmospheric apparent solar transmission has been measured for five and a half decades by the NOAA Global Monitoring Division at the Mauna Loa Observatory (MLO). MLO's remote location and high altitude makes it well suited for studying atmospheric changes in the free troposphere with limited local influences. A clear-sky "Apparent" solar Transmission (AT) is calculated using the ratio of direct-beam broadband pyrheliometer measurements at fixed atmospheric paths (airmass) [Ellis and Pueschel, 1971]. The MLO AT is particularly sensitive to changes in background stratospheric aerosols and the influence of volcanic eruptions. The updated clear-sky AT from 1958 to 2013 monthly record is computed from daily morning values to remove boundary layer influences due to upslope winds (Figure 1). The aerosol signal from the eruptions of Agung, El Chichon, and Mt Pinatubo in 1964, 1982, and 1991, respectively are clearly visible in the record. The 6-month running smoothed fit to the monthly values highlights the seasonal trends in the data that have been attributed primarily to Asian aerosol transport in the spring [Bodhaine et al., 1981]. This seasonal variability of the clear-sky AT has an amplitude of ~ 0.007 . A 24-month running smoothed fit highlights the longer term changes. The gray dashed line reflects the cleanest background observed from 1958 – 1962 in the record except for a brief period in 1978. After the eruption of Mount Pinatubo in 1991, the clear-sky AT reached a maximum in 1998 with a subsequent slow decrease through 2010 that was attributed to smaller volcanic eruptions [Vernier et al., 2011; Solomon et al., 2011]. The last few years show the AT has begun to show a slight increase. The AT results are compared with aerosol optical measurements at the site. Changes in the background aerosol have implications for climate change and surface temperature and their prediction from climate models.

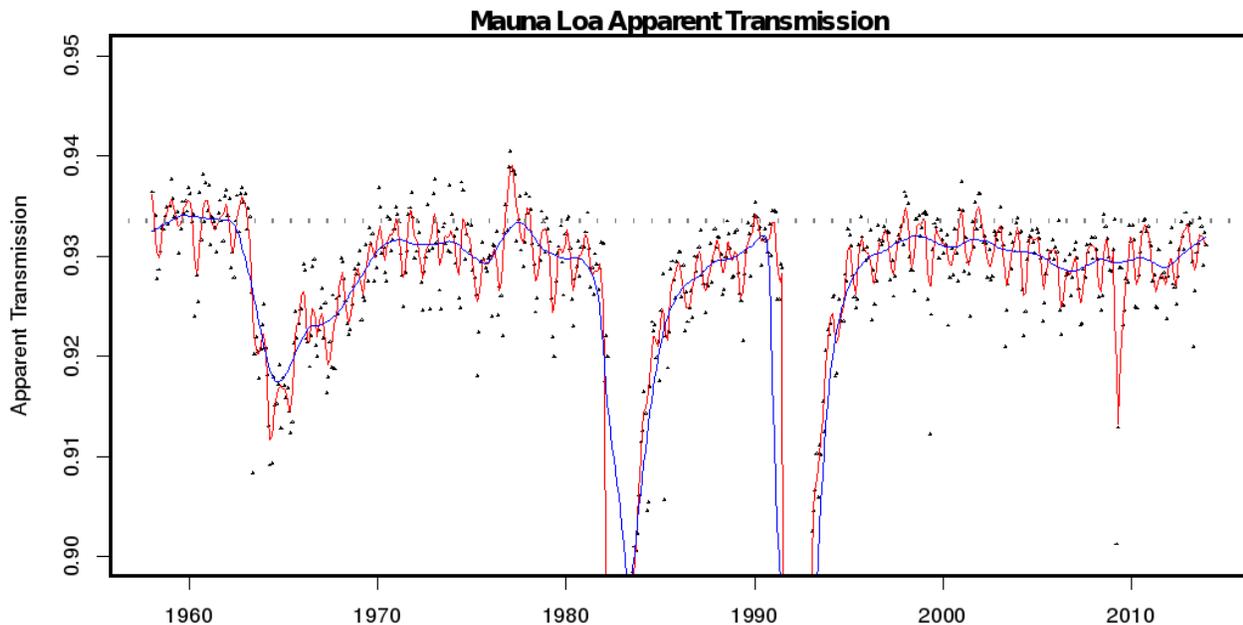


Figure 1. Monthly mean of the clear-sky AT at MLO. Means are determined from the morning values. The red line is the 6-month running smoothed fit, and the blue line is the 24-month smoothed fit using only monthly means that include at least 10 days. The dashed line is the background level from 1958 – 1972.

Brewer 131 Calibration at 4-corners New Mexico Environment Department Site: Measurement and Calibration Issues

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The GMD NEUBrew Brewer #131 has been operating at the New Mexico Environmental Department's (NMED) San Juan power station monitoring site since July 2013. Large diurnal variations in retrieved total column ozone have been observed since the deployment of the Brewer. Validation of the World Meteorological Organization-traceable ozone calibration by comparing it to the derived extra-terrestrial calibration constant (ETC) by the Langley regression technique has uncovered an interesting daily pollution-dependent atmospheric condition. The pollution condition is most likely caused by two coal-fired electrical generating stations in the area. Preliminary Langleys show a considerable difference between the AM and PM ETCs, more than what might have been expected due to normal daytime evolution of the atmosphere. Large diel changes in surface ozone measurements are strongly correlated to surface wind direction. We study how changes in surface ozone might contribute to the large diurnal variation in the total column ozone measured by the Brewer.

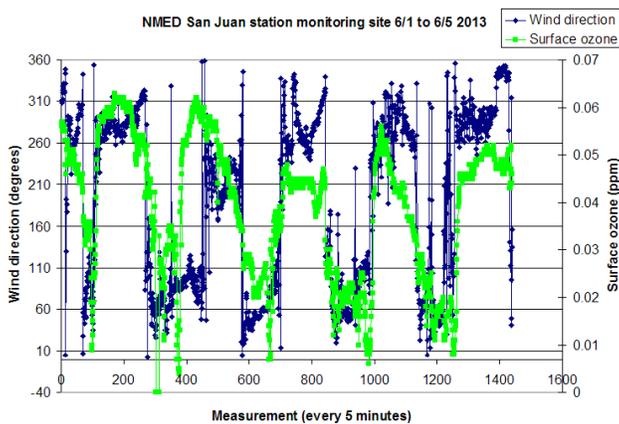


Figure 1. The surface ozone exhibits a strong dependence on the diurnal wind direction at the 4-corners monitoring site.

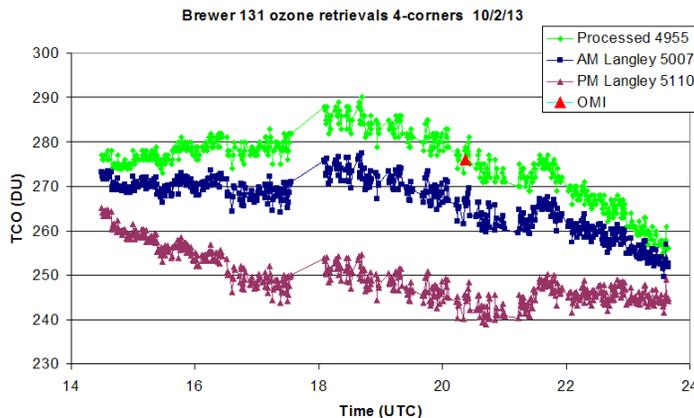


Figure 2. The total column ozone measured with Brewer 131 for the normal processing ETC, the AM Langley ETC, and the PM Langley ETC. Note the decrease in total column ozone in the late afternoon. Total column ozone measured by Ozone Measuring Instrument during its overpass is denoted by the red triangle.

Improved Quality Assurance Procedures for the Antarctic and U.S. Ultraviolet Monitoring Program

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To improve long-term data quality, new software based tools have been implemented to quickly analyze and track instrument operation and calibration. Small changes in the instrument adversely affect data quality that might not be detected until the data are being analyzed. These instrumental or calibration errors could result in a large loss of unrecoverable data. In conjunction with the new software tools, there has also been new calibration tracking standards developed for each station. The implementation of the tracking standards will provide a method to more accurately assess the stability of the irradiance scale at each station. The methods applied to the Antarctic and U.S. high-resolution spectroradiometers are similar to those that have been successfully employed by the NEUBrew network.

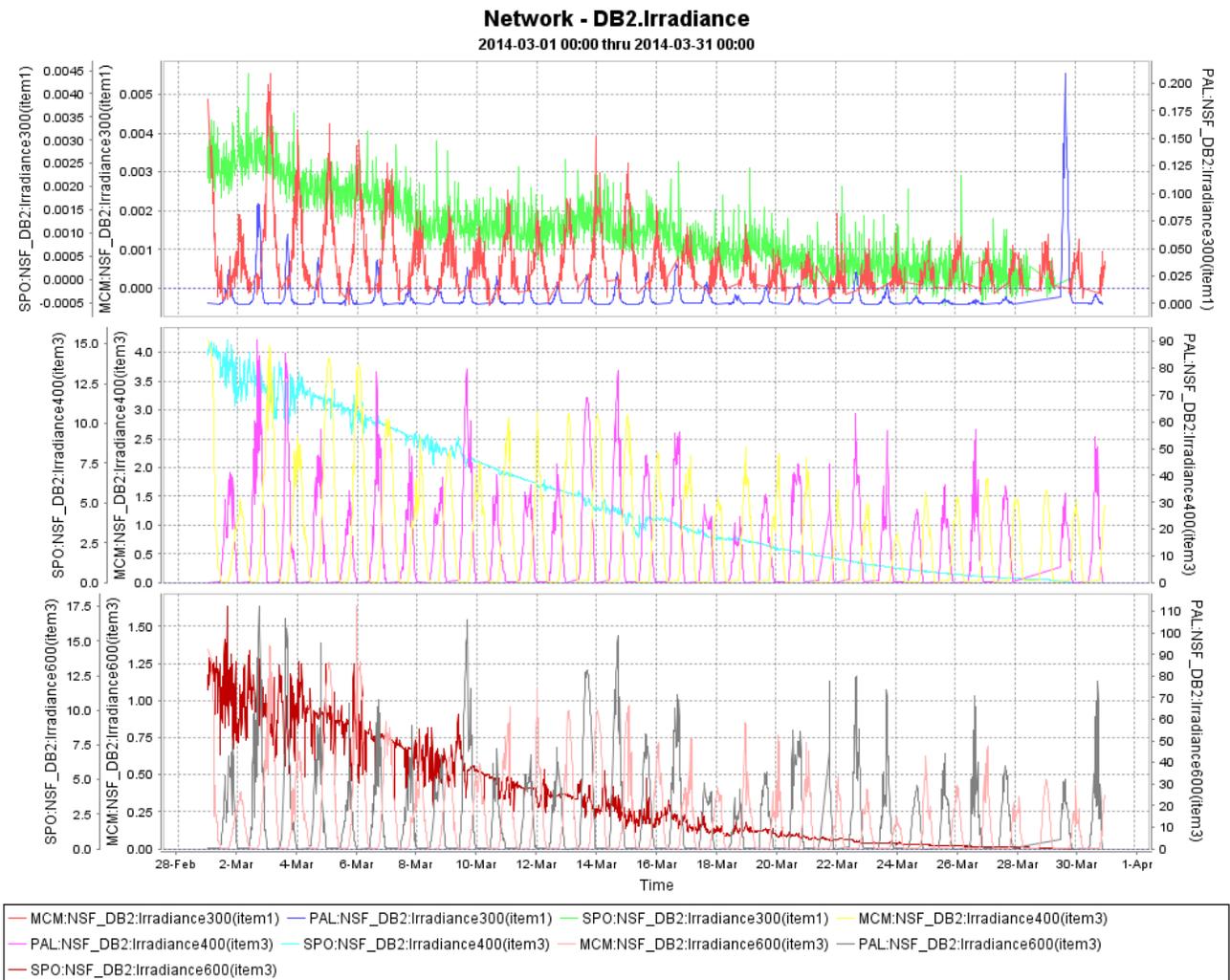


Figure 1. Changes in instrument operation can clearly and quickly be identified as shown in the daily irradiance from Palmer Station (top panel, blue plot). The event on March 30 was caused by a power failure at the station, which then caused the wavelength registration to shift by more than 4 nanometers. The problem was quickly identified and rectified before a large loss of data occurred.

NOAA Global Monitoring Division SkyWisp

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The training phase of the NOAA SkyWisp Unmanned Aerial Vehicle program has been completed. We outline in this presentation what was accomplished, what was recognized as a strength or limitation, and what modifications have been, and are being, put into place to bring the platform into use as a recovery vehicle for an up coming stratospheric air-core sample. We describe the laboratory instrumentation that is being put into place to make Gas Chromatograph measurements from this stratospheric sample for the trace gases SF₆, N₂O, CFC-11, CFC-12, CFC-113, and halon-1211. Finally, we present a short overview describing how measurements of these specific stratospheric trace gases can contribute to improvements of our understanding of climate and its changes.



Figure 1. Fred with one of three operational SkyWisp Unmanned Aircraft System, shown in front of the Flatirons, Boulder CO.

Recent Results from the Airborne Tropical Tropopause EXperiment (ATTREX) Over the Western Tropical Pacific

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The tropopause over the western tropical Pacific Ocean is thought to be one of the primary entry points of air from the troposphere into the stratosphere. In this area, temperatures are low enough in the tropical tropopause layer (TTL) to dehydrate air to the low values observed in the stratosphere. The NASA ATTREX mission was designed to study the transport of water vapor and other trace gases in the TTL over the Pacific Ocean, in order to understand how dehydration occurs in this region and how trace gases involved in ozone depletion and climate reach the lower stratosphere. The field campaign phase of this mission recently concluded with flights of the Global Hawk aircraft over the western tropical Pacific from Guam in January-March 2014. The plane carried a suite of in situ and remote sensing instruments for gases, aerosols, radiation, and meteorology. Two deployments occurred previously from NASA/Dryden (now Armstrong) Flight Research Center, with flights to the eastern and central tropical Pacific.

Nearly 100 vertical profiles in the TTL from about 14 to 18 km were obtained over the western tropical Pacific, as well as a few long sections at nearly constant altitude. Results are shown here from the UAS Chromatograph for Atmospheric Trace Species (UCATS) instrument and other sensors. UCATS was configured to measure N₂O, SF₆, H₂, CH₄, CO, water vapor, and ozone. In contrast to previous deployments over the eastern and central Pacific, ozone values were extremely low over the western tropical Pacific. The long-lived tracers N₂O, methane, and SF₆ were at near-tropospheric values for long stretches of the flight tracks, indicating little or no in-mixing of older stratospheric air. CO was often at elevated levels (50-80 ppb) compared to what might be expected in the clean upper troposphere/lower stratosphere for this region. Water vapor showed large variations and condensed water (ice) was often observed, along with high concentrations of ice particles.

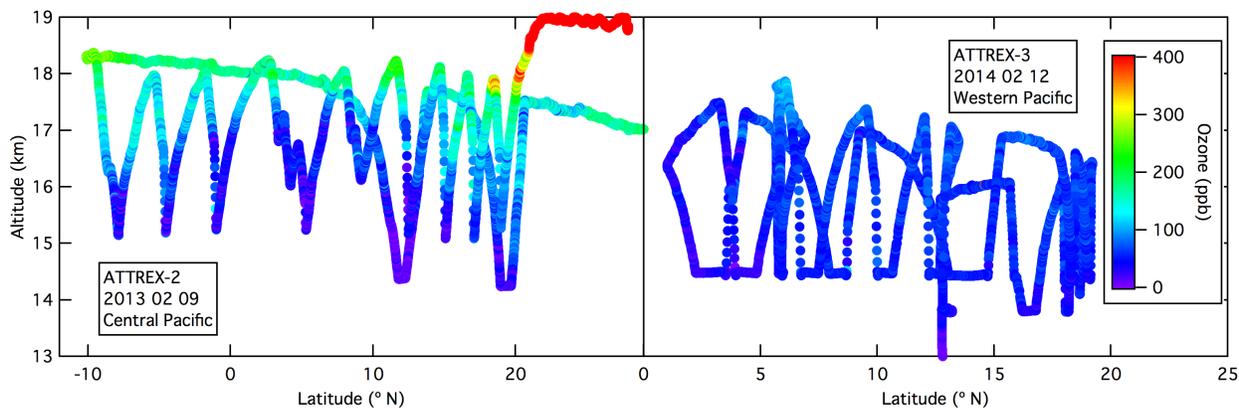


Figure 1. (Left) Flight track of the Global Hawk, February 9, 2013 over the central tropical Pacific, color-coded by UCATS ozone data. (Right) Flight track of the Global Hawk, February 12, 2014 over the western Pacific, color-coded by UCATS ozone data. Some of the difference in ozone mixing ratio is due to the lower altitudes sampled by the aircraft in 2014, but ozone was clearly lower on the flight from Guam even at the same altitude and latitude.

How Much Can We Learn About Nitrous Oxide Emissions from Background Sites and Simple Box Models?

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Atmospheric Nitrous Oxide (N₂O) is an important ozone-depleting gas that continues to rise in concentration even as chlorofluorocarbon emissions have virtually ceased. It is also a potent greenhouse gas with a global warming potential of 298 times per molecule that of carbon dioxide with 100 years time horizon. NOAA has been monitoring background concentrations of N₂O from weekly flask sampling since 1977, starting with five remote stations over a broad latitudinal coverage from Pt. Barrow, Alaska to South Pole, Antarctica. This network has expanded to thirteen flask sites and six *in situ* instrument sites. We have combined data from the collocated, ground-based sites using three different independent instruments all linked to the World Meteorological Organization N₂O calibration scale, primarily to assist in quantifying the global burden of atmospheric N₂O for international assessments of the state of the science in climate and stratospheric ozone depletion. The growth rate of atmospheric N₂O has been constant at 0.78±0.01(3σ) parts per billion (ppb) per year over the period (see figure), but with important deviations related to El Niño Southern Oscillation, transport, and changes in patterns of emissions. Recent studies used a combination of multiple atmospheric networks and different Global Climate Models to calculate emissions, even down to emission values for individual countries and sources. Slight calibration differences between networks of a few tenths of a ppb can have significant effects on the emissions calculated by these methods. Our approach is to use one calibration scale for our flask and *in situ* networks within different Global Monitoring Division (GMD) groups with simple box models to examine the locations of the emissions.

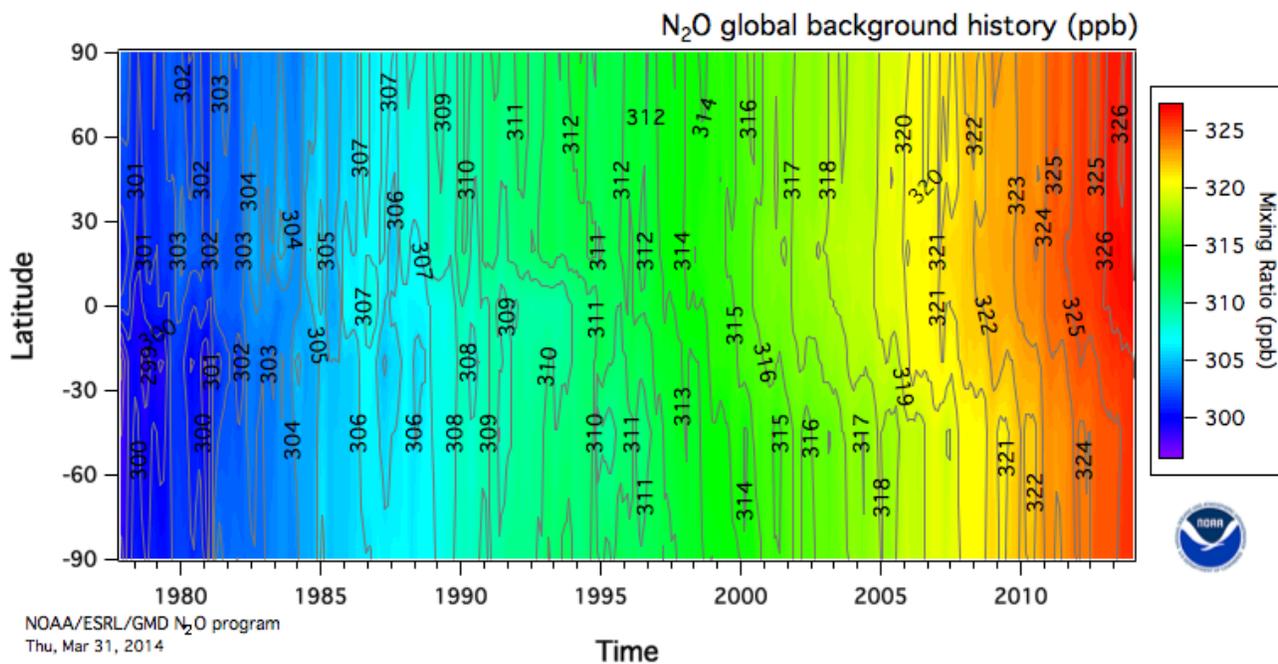


Figure 1. Global history of atmospheric N₂O (in ppb) from the NOAA GMD background observatories.

Global Measurement of Nitrous Oxide and its Stable Isotopes Using Cavity Ring-down Spectroscopy

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Nitrous oxide (N_2O), a greenhouse gas ~ 300 times the 100 year global warming potential of CO_2 , is currently increasing at a rate of $0.77 \text{ ppbv yr}^{-1}$ (World Meteorological Organization 2010) mainly due to increased microbial production from fertilized agricultural systems (Intergovernmental Panel on Climate Change 2007). Due to the complexity of microorganism processes within soil, the spatiotemporal effects of fertilizer on N_2O production at a high resolution remain largely unconstrained. Advances in the use of intramolecular, or position-specific, stable isotope techniques (β position $^{15}\text{N}^{14}\text{N}^{16}\text{O}$ versus α position $^{14}\text{N}^{15}\text{N}^{16}\text{O}$) can be a robust tool in order to determine the biological and physical controls over N_2O emission. Picarro Instruments recently developed a wavelength-scanned cavity ring-down spectrometer coupled with a quantum cascade laser capable of the mid-infrared wavelength detection needed for N_2O . This technique allows for streamlined simultaneous and continuous measurement of N_2O concentration, $\delta^{15}\text{N}\alpha\text{-N}_2\text{O}$, and $\delta^{15}\text{N}\beta\text{-N}_2\text{O}$ with measurement uncertainties of $< 0.5 \text{ ppb}$ and 1.5% for mole-fractions and isotopic delta values, respectively. A subset of sites from the NOAA Global Monitoring Division Cooperative Sampling Network is being measured in order to describe the global distribution of N_2O and its isotopes on a seasonal level. We expect to see a seasonal cycle in N_2O isotopomers due to stratospheric mixing in the spring of each hemisphere and heightened ocean and soil microbial activity in the summer and fall of each hemisphere.

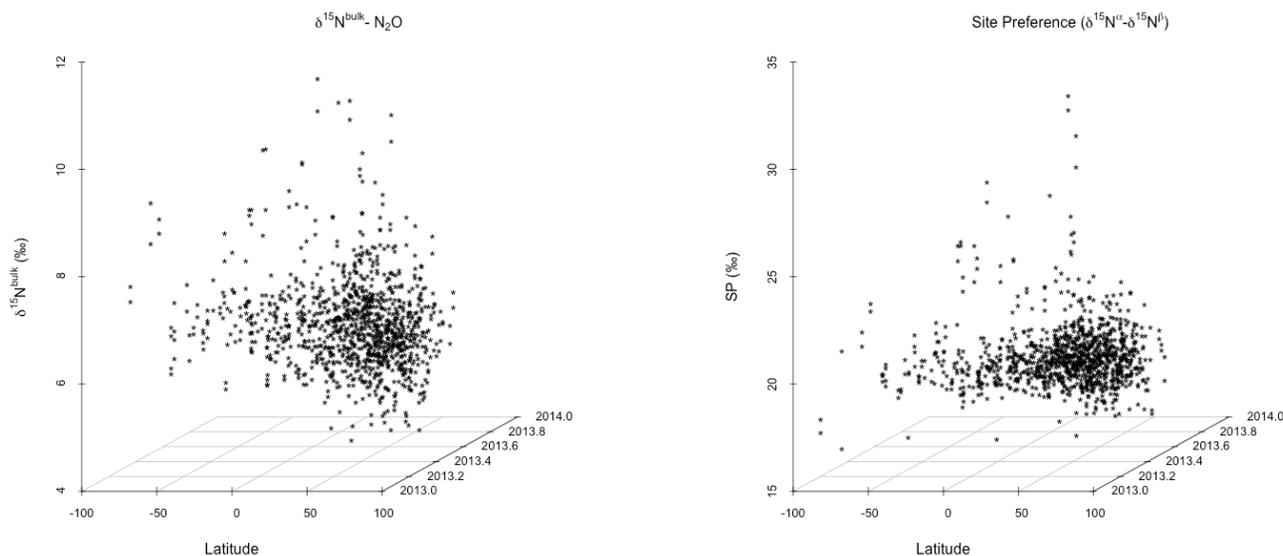


Figure 1. NOAA Cooperative Air Sampling Network N_2O isotopic measurements in 2013. Left: bulk $\delta^{15}\text{N}\text{-N}_2\text{O}$. Right: Site preference ($\delta^{15}\text{N}\alpha\text{-N}_2\text{O} - \delta^{15}\text{N}\beta\text{-N}_2\text{O}$).

Improvement and Additions to the Halocarbons & Other Atmospheric Trace Species Group (HATS) Combined Data Sets

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The HATS combined data sets for nitrous oxide (N₂O), sulfur hexafluoride (SF

), CFC-11, and CFC-12 were developed and introduced in 2011. A key motivation was to create a consistent, continuous, long-term record of trace gases measured by the Global Monitoring Division ((GMD) and preceding NOAA laboratories such as CMDL and GMCC); and to combine these publicly available data without being subjective, with the idea that the sum of many data sources is better than any individual measurement program. The combined data sets are a compilation of multiple instruments and measurement programs with care that all data are on the same calibration scale. For some gases, measurements prior to 1990 have been adjusted to match current NOAA calibration scales due to difficulties in determining calibration lineages. Recently, combined CFC-113 and carbon tetrachloride (CCl₄) data sets have been developed and added to the GMD ftp site and, newly revamped website.

The combining technique uses monthly mean or median data for co-located measurements; where the measurements are weighted by instrumental precision and sampling frequency. To provide a continuous long-term record, missing data due to instrumental or sampling problems are gap-filled. The previous gap-filling method relied on linear interpolation, which would ignore non-linear trends and seasonality. A new least-squares spectral regression technique has been developed that also estimates uncertainties for gap-filled data; thus providing more realistic trends and errors where data is missing.

There are many benefits in developing the framework to combine GMD measurement programs into a single data set. Long-term records are developed and can be traced to original data sets; and are used in national and international assessments, as well as the NOAA GMD's AGGI and ODGI indices. Likewise, we have used these methods for quick comparisons of multiple data sets for quality control and verification of internal consistency. We will present updated combined data sets and highlight recent improvements.

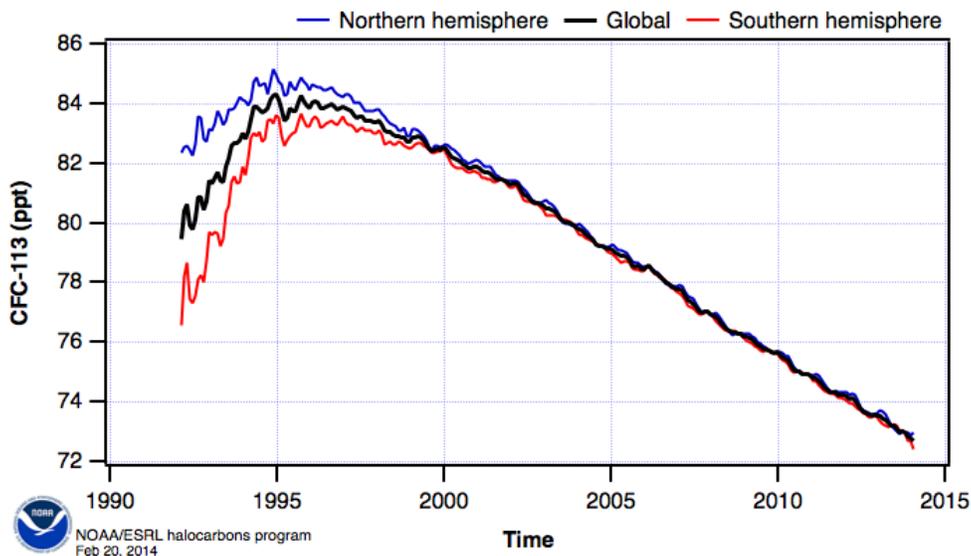


Figure 1. Hemispheric and global means calculated from the combined CFC-113 data set. Fewer and less precise measurements contribute to the variability in the early part of this record.

Atmosphere-based Estimates of Non-CO₂ Greenhouse Gas Emissions for the U.S. Derived from ¹⁴CO₂

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The small radiocarbon fraction of atmospheric CO₂ (~1:10¹² ¹⁴C:C) has proven to be an ideal tracer for the fossil fuel derived component of observed CO₂ (Cff) over large industrialized land areas. High-precision ¹⁴CO₂ measurements are being made in air sampled from a network of tall towers and airborne profiling sites around the U.S. together with measurements of more than 20 other anthropogenic trace gases including CO, CH₄, N₂O, SF₆, and halo- and hydro-carbons. Pairing Cff with boundary-layer concentration enhancements of these gases allows us to determine apparent emissions ratios for each gas with respect to Cff. When combined with model-derived spatial footprints and inventory-based fossil fuel emissions, absolute emission rates for the correlate gases can be derived, following simple scaling methods we have outlined previously [Miller et al. 2012, *J. Geophys. Res.*, doi:10.1029/2011JD017048]. Here we present emission magnitudes derived for select gases in regions of significant urban and industrial activity around the U.S. based on measurements in California, Texas, the mid-west, south-east and north-east. Statistically significant and coherent spatial and seasonal patterns in emissions ratios and absolute emissions are determined for many gases based on measurements over multiple years. We believe this approach provides reliable 'top down', observationally-based emissions estimates for these gases, many of which influence climate, air quality and stratospheric ozone.

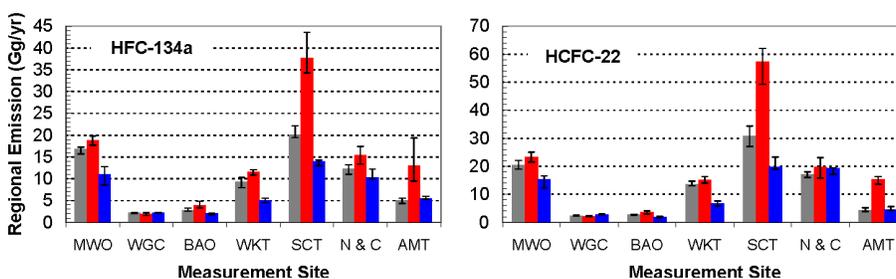


Figure 1. Regional emissions of HFC-134a and HCFC-22 derived at different locations in the U.S. during 2010 based on measured covariations in these halocarbons and the fossil-fuel component of CO₂ (Cff). Absolute emission magnitudes are derived from the measured halocarbon-to-Cff covariations and site-specific fossil-fuel emissions derived from computed sensitivities (over space and time) of collected samples to the VULCAN fossil-fuel emission inventory (Gurney et al., 2009). Measurement locations are listed west to east: MWO = Southern California; WGC = mid-California; BAO = Front range, Colorado; LEF = Wisconsin; WKT = Texas; SCT = South Carolina; N&C = average of results from New Jersey and New Hampshire; AMT = Maine. Estimates are derived for summer (May through September; red bars), winter (November through February; blue bars), and year-round (gray bars).

What We Learn from Updates of NOAA's Annual Greenhouse Gas Index (AGGI)

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Several years ago, NOAA introduced a unique index for expressing the influence of human-emitted, long-lived greenhouse gases in the atmosphere (DJ Hofmann et al., *Tellus*, 2006, S8B 614-619). Being a condensation and normalization of radiative forcing from long-lived gases, the NOAA Annual Greenhouse Gas Index (AGGI) was designed to enhance the connection between scientists and society by providing a standard that could be easily understood and followed. The index each year is calculated from high quality, long-term observations by NOAA's Global Monitoring Division, which includes real-time measurements extending over the past five decades, as well as published ice core records that go back to 1750. The AGGI is radiative forcing from these long-lived gases, normalized to 1.00 in 1990, the Kyoto Climate Protocol baseline year. For 2012, the AGGI was 1.34, indicating that global radiative forcing by long-lived greenhouse gases had increased 34% since 1990. During the 1980s CO₂ accounted for about 50-60% of the annual increase in radiative forcing (and the AGGI) by long-lived greenhouse gases, whereas, since 2000 it has accounted for 80-90% of this increase each year. After a decade of virtually level concentrations in the atmosphere, methane (CH₄) has increased measurably over the past 6 years, as did its contribution to radiative forcing (and the AGGI). This year, in addition to updating the AGGI for 2013, increases in radiative forcing will be evaluated and discussed with respect to time-dependent changes in the contributions from CO₂, CH₄, nitrous oxide (N₂O), chlorofluorocarbons, and other emerging greenhouse gases.

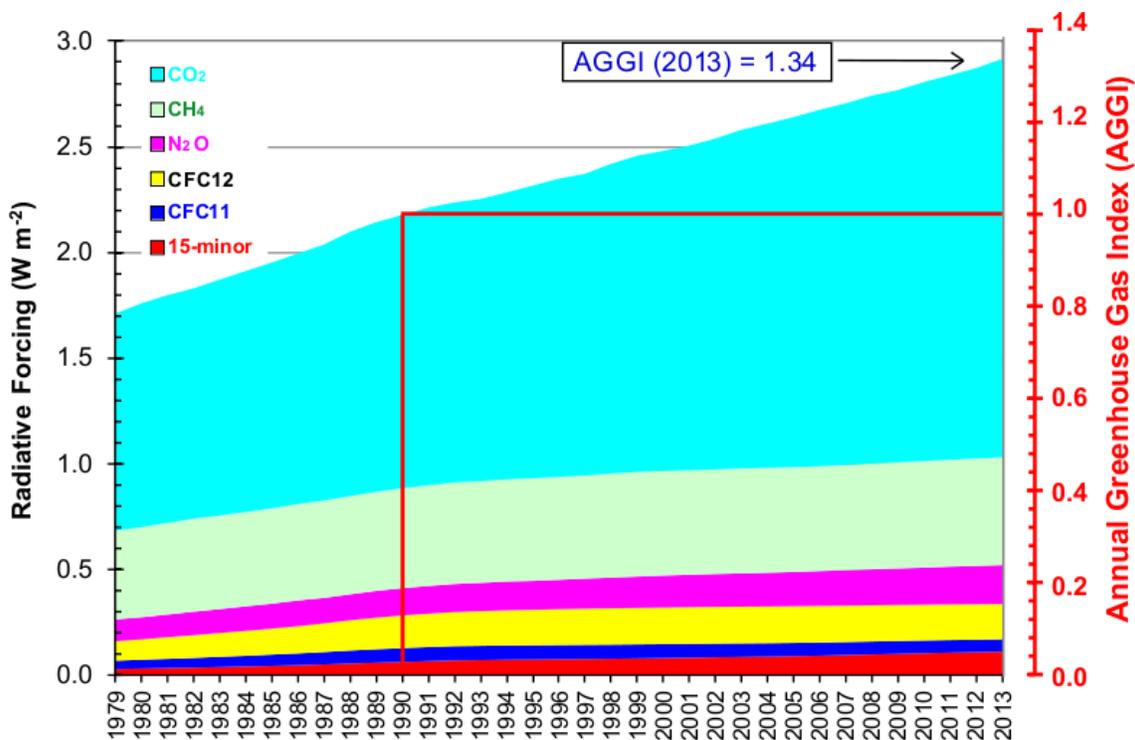


Figure 1. NOAA's Annual Greenhouse Index through 2013 shows that radiative forcing from virtually all long-lived greenhouse gases has been rising 1.3% +/- 0.3% per year since 1990, the target year for the Kyoto Protocol.

Environment Canada's Greenhouse Gases Measurement Program - Summary of Progress to 2014

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Environment Canada's (EC) atmospheric GreenHouse Gas (GHG) measurement program currently conducts on-going accurate atmospheric measurements of CO₂, CH₄ and other GHGs from coastal, interior and high Arctic regions in Canada (Figure 1). The primary aim of the program is to use measurements, along with modeling to independently estimate anthropogenic (man-made - such as fossil fuels) and natural GHG sources (i.e. wetland/arctic emissions) and sinks (i.e. uptake of CO₂ in forests) in Canada. With the recent site expansions to the sub-arctic regions, sites located in discontinuous permafrost regions and near the boggy tree-lined transitional zone, EC's atmospheric observational program has positioned itself to detect/observe changes in natural emissions of CH₄ and CO₂ but also emissions of CH₄ and CO₂ from planned fossil fuel exploration, including natural gas fracking, in the foreseeable future.

In this presentation, a number of examples will be shown on how these measurements, along with modeling, are currently being used to evaluate anthropogenic methane and carbon dioxide emissions from the largest emissions areas in Alberta and Ontario as well on preliminary arctic methane emission estimates for the north western subarctic region in Canada.

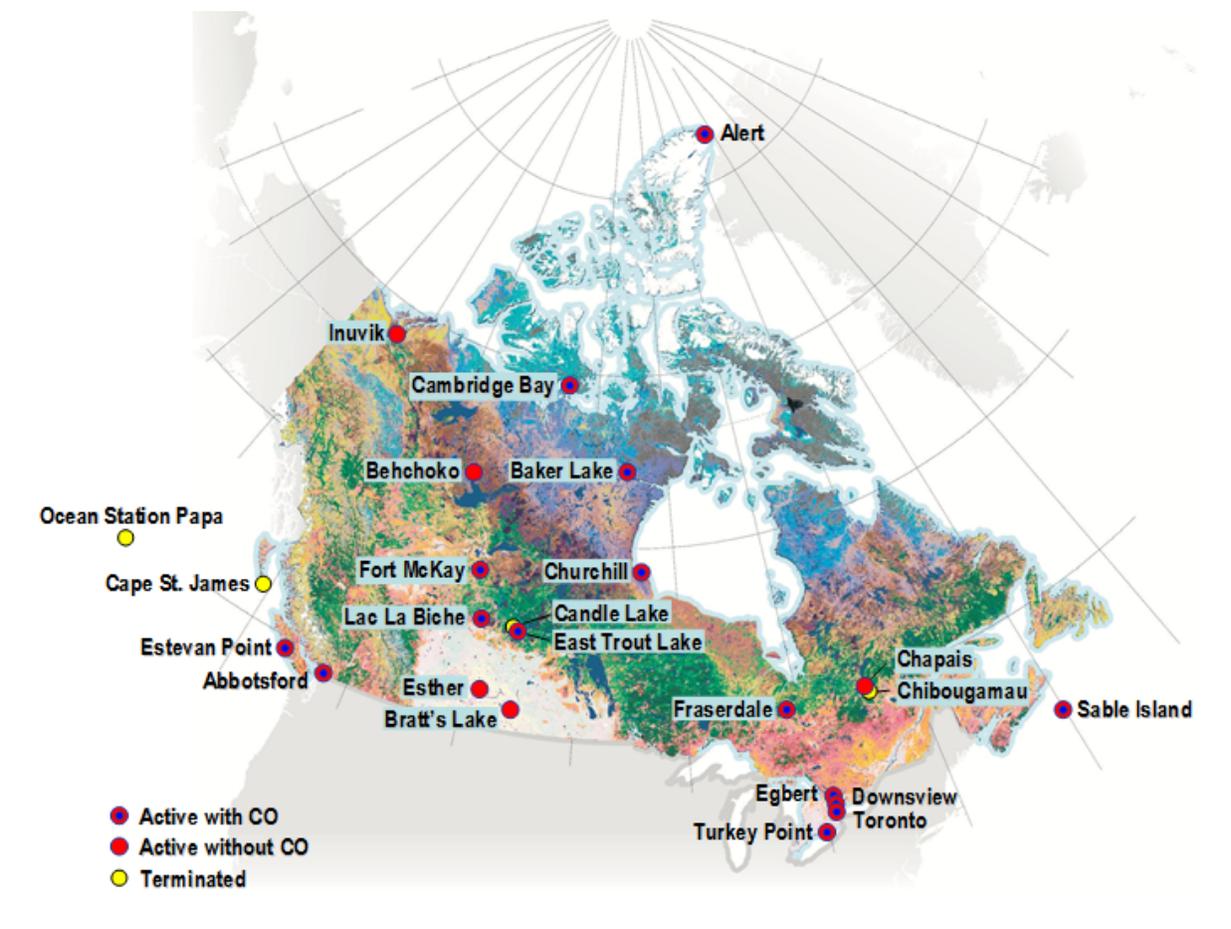


Figure 1. A map showing the location of the 20 *in situ* CO₂ and CH₄ observational stations in Canada, superimposed on a map of the vegetation eco-region distribution coverage in Canada. The 15 sites with blue dots have *in situ* CO₂, CH₄ and CO. Note sites shown in yellow were closed. Flask sampling for CO₂, CH₄, CO and N₂O and SF₆ is conducted at 14 sites.

A New Reference Scale for Measurements of Carbon Monoxide in the Atmosphere

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The Global Monitoring Division Carbon Cycle Group serves as the World Meteorological Organization (WMO)/Global Atmosphere Watch Central Calibration Laboratory for measurements of Carbon Monoxide (CO) and several other trace gases. Here we describe a new reference scale (denoted as WMO X2014) which builds upon the previous X2004 scale (WMO, 2010). WMO X2014 is based upon three sets of primary reference gases prepared in 2000, 2006 and 2011 using a common gravimetric method (Novelli et al., 1992; Hall et al., 2007). Several analytical methods were used to measure the primary standards and produce secondary and working standards. These include: 1) Gas chromatography with hot mercuric oxide reduction (GC-HgO, 2000-2005), 2) Resonance fluorescence in the Vacuum UltraViolet (VUV, 2004-2010), and 3) Off-axis Integrated Cavity Output Spectroscopy (ICOS, 2010 to present). Development and evaluation of the X2014 scale was aided by measurements of eight surveillance standards relative to different primary standards and calibration schemes between 2001 and 2014. A preliminary estimate of the scale uncertainty is mole fraction dependent: 1.2 nmol mol⁻¹ or 0.6% at k=2, whichever is greater. Calibration results determined prior to 2000 will be revised to X2014.

The figure below shows preliminary estimates of the uncertainties in mean mole fractions assigned surveillance cylinders using three sets of primary standards as reference. GC-HgO used the 2000 primary standards with mole fractions revised by their calibration by VURF_2000. The VURF_2000 results are based on two 2000 primary standards with CO > 300 nmol mol⁻¹; VURF_2006 results were referenced to primary standards prepared in 2006. The ICOS results are based on primary standards made in 2011. The table compares preliminary mean CO mole fractions assigned surveillance cylinders against the X2014 scale by ICOS to calibration results using VURF and reference gases on X2004. N = 10-12 for 2004, 4 for 2011, the error (2 sigma) includes estimates of both scale and measurement errors.

Tank ID	2004 scale	2014 scale
ND15747	57.6 (1.2)	58.7 (1.3)
ND17435	153.3 (1.6)	153.7 (1.4)
ND16416	301.5 (3.3)	302.6 (2.1)

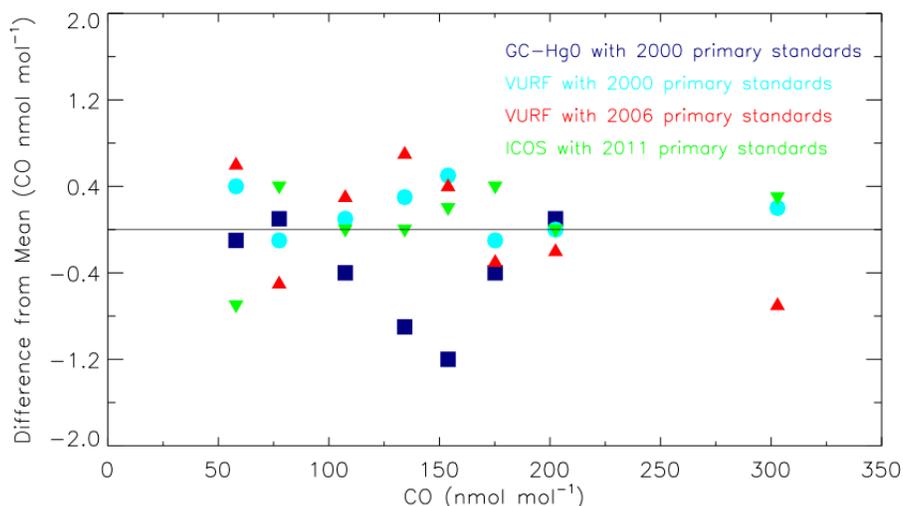


Figure 1. Differences between mean mole fractions assigned surveillance cylinders over 2000-2012 and CO assigned using different sets of primary standards and different analytical methods.

Meteorological Controls on the Diurnal Variability of Carbon Monoxide at Pinnacles, an East Coast Mountaintop Site in the CarbonTracker Observational Network

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Trace gases such as Carbon Monoxide (CO) are affected by site-specific meteorological conditions that are particularly complicated in mountainous terrain. Knowledge of these site-specific meteorological conditions and their effect on trace gas variability is required to know how best to assimilate mountaintop trace gas measurements in applications requiring regionally-representative measurements. In the present study, we investigate the meteorological and CO characteristics at Pinnacles, a mountaintop monitoring site in the Appalachian Mountains and part of the CarbonTracker Observational Network, over the period 1 January 2009 to 31 December 2012. CO increases from a minimum at 0800 Local Sidereal Time (LST) minimum to a maximum around 1900 LST. There is large day-to-day variability, although the smallest amplitudes typically occur on fair weather days which we investigated further in this study. On fair weather days, many of the day-to-day differences in the diurnal CO cycle are explained by the presence or absence of a wind shift (Figure 1). On fair weather days with steady northwesterly winds, there is a daytime CO decrease which is in contrast to the mean diurnal CO cycle at Pinnacles, but is consistent with findings at tall towers in flat terrain. On fair weather days with a wind shift from the northwest to the south, the CO cycle is more typical of the mean CO cycle at Pinnacles and at other mountaintops worldwide and caused by the vertical transport of polluted air from adjacent valleys.

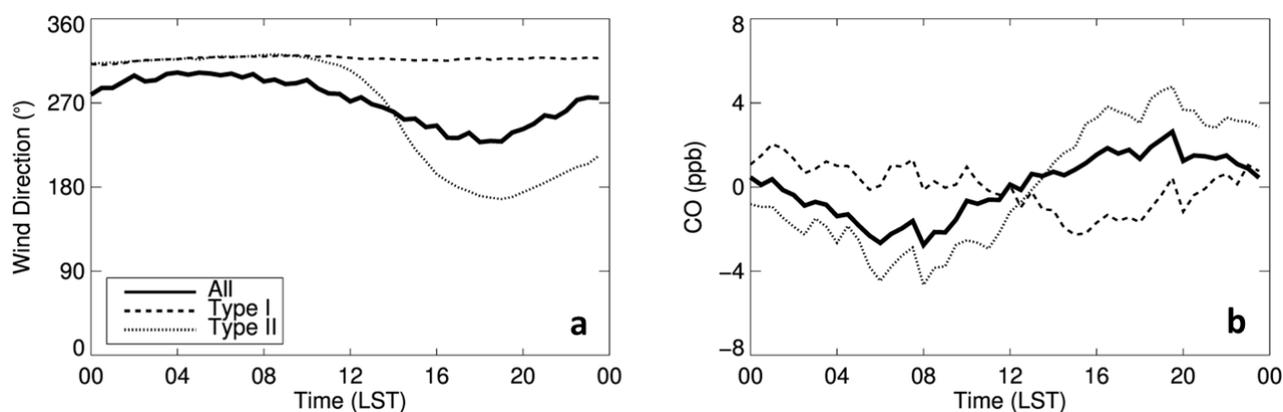


Figure 1. (a) Mean wind direction on all days (1 Jan 2009 – 31 Dec 2012) (black line, N=1126), fair weather days without a wind shift (Type I, dashed line, N=187), and fair weather days with a wind shift from northwesterly to southerly (Type II, dotted line, N=126) (panel a). Same for panel (b) but for CO measured 17 m above ground level with daily means removed.

A Central Facility for Greenhouse Gas Analyses Within the Integrated Carbon Observation System (ICOS) Research Infrastructure

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The ICOS RI is a European research infrastructure that aims at providing long-term, high quality observational data for the study of the European greenhouse gases balance. The accuracy and compatibility of these measurements shall be supported by Central Analytical Laboratories (CALs). The CALs comprise the CRL at Heidelberg University and the FCL related to the MPI for Biogeochemistry (BGC) in Jena. The FCL will provide measurements of CO₂, CH₄, N₂O, CO, H₂, SF₆ and O₂/N₂ ratios as well as stable isotope analyses of flask air samples collected at the ICOS observatories (see Gas Chromatograph (GC)-System schematics, Fig 1). These samples will be taken using an automated air sampling system, which is currently being developed at the MPI-BGC. The second major task of the FCL is the provision of real air reference standards to the monitoring stations calibrated relative to the respective World Meteorological Organization calibration scales. These reference air mixtures can be adjusted in their tracer composition using a scrubbing and spiking system. At the CRL the majority of the ICOS radiocarbon samples will be analysed using accelerator mass spectrometry, however the CRL will in addition continue the conventional low level counting to assure a solid comparison and overlap period between these two analysis techniques. The ICOS radiocarbon sampling strategy includes network-wide two-weekly integrated samples to monitor the European long-term trends of fossil fuel CO₂. In addition, tracer and event-based flask sampling will be implemented at stations of special interest to monitor local/regional fossil fuel budgets and to ease model comparison. We will present an overview of the laboratory facilities and the first results from performance tests of the new instrumentation and comparisons with the MPI-BGC laboratories.

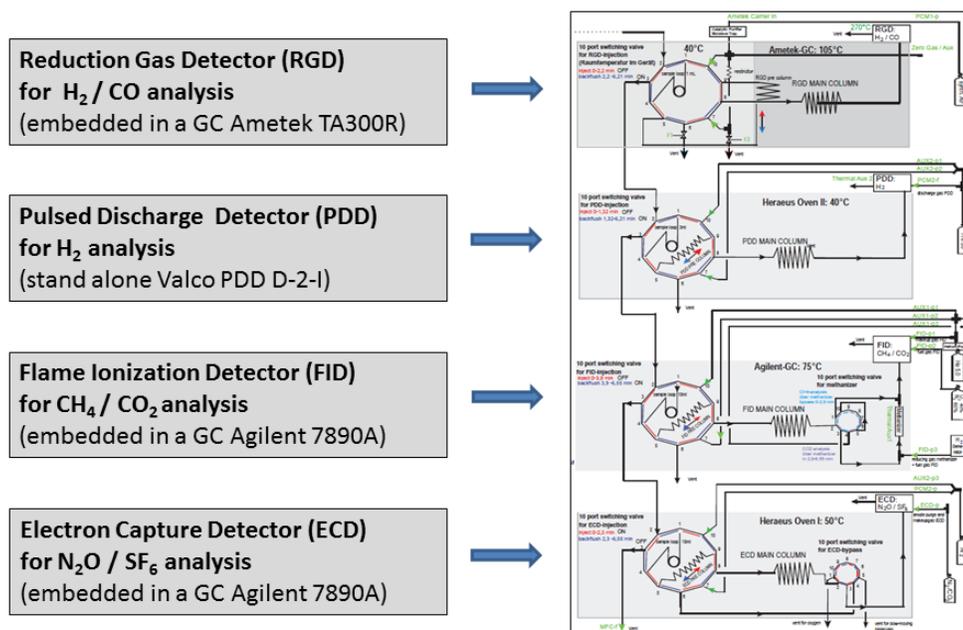


Figure 1. Setup and parallel operation of the GC trace gas analysis line.

Regional Carbon Cycle and Atmospheric Inversions in the Southeastern United States (U.S.) – Optimizing an Observational Network

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The earth's terrestrial biosphere has been a strong net sink of atmospheric CO₂ for roughly three decades, substantially slowing the rate of accumulation of CO₂ in the atmosphere due to combustion of fossil fuels. The causes of this net sink and its likely evolution in the future, however, both remain quite uncertain, yielding substantial uncertainty in our projections of future climate. Understanding the terrestrial carbon cycle remains a high priority for understanding climate change and is of great importance in the Southeastern (SE) U.S. in part because terrestrial biosphere models have shown that the largest uncertainty in simulated Net Ecosystem Productivity (NEP) of CO₂ in North America to be in the SE U.S. The region is a dynamic and relatively poorly constrained contributor to the terrestrial carbon balance of North America. Furthermore, the forests of the SE U.S. are important for the North American carbon balance because they are one of the most productive biomes on the continent, have large biological fluxes, and are sensitive to climate change.

The Gulf Coast Intensive (GCI) Project seeks to apply recent advances in atmospheric inversion methodology and observational technology to study the carbon balance of North America as a whole with special emphasis, including new terrestrial inventory assessments, on the dynamic and relatively understudied SE U.S. This poster focuses on designing an optimal observation strategy that minimizes anthropogenic influences (e.g., power plants) while maximizing the data impact of each site. Factors that were taken into consideration were existing observations, land coverage, NEP, fossil fuel emission estimates from Vulcan, and large emission sources such as power plants. In addition, we will present an analysis of seasonal and synoptic gradients in CO₂ mixing ratios across North America using the existing relatively dense CO₂ measurement network. Five different regions were identified (East, Southeast, Mid-Centiment, Northwest, and West) based on similarities in CO₂ seasonal cycle and differences will be discussed.

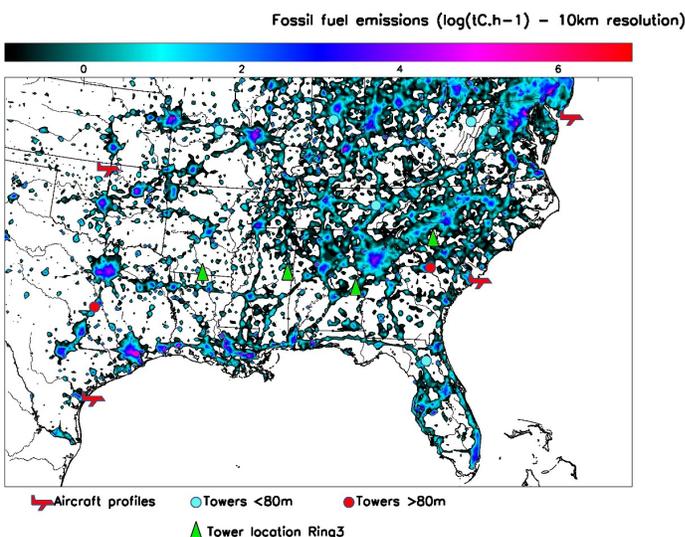


Figure 1. Vulcan fossil fuel emissions for the SE U.S. Existing towers are shown as aqua and red circles, and potential tower locations for the GCI are shown as green triangles.

Bayesian Optimization of the Net Ecosystem Exchange (NEE) in Oregon Using a New CO₂ Observation Tower Network, Transport Modeling, and the Community Land Model

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The high precision CO₂ observation tower network in Oregon comprises 4 towers equipped with PICARRO Cavity Ring-Down Spectrometers and 2 towers that are equipped with eddy flux systems. These towers provide very accurate CO and CO₂ measurements used for our inverse modeling setup. In addition to towers representing a variety of typical ecoregions in the Pacific Northwest (Coast Range, East Cascades, Northern Great Basin), the tallest tower in the network is located in Silverton in the Willamette Valley, which is the urban-suburban-forested-agriculture corridor of Oregon.

Obtaining the regional NEE in this area is challenging due to the land cover heterogeneity and anthropogenic influences on CO₂, which affect inverse modeling of the land surface sources. To account for traffic emissions, we used a mobile campaign during which the CO:CO₂ emission ratios were measured for the types of roads that can be found in the footprint area of the tall tower in Silverton (Fig. 1) so that we could remove anthropogenic sources from the vegetation CO₂ signal.

A spatial matrix containing the type of road, traffic amount, its abundance in the grid cell, and the associated emission ratios was derived. We corrected CO₂ mixing ratios measured at the Silverton tower using the Weather Research & Forecasting-Stochastic Time-Inverted Lagrangian Transport model. Three-hourly fluxes calculated with Community Land Model (CLM)4.5 were optimized using a classical Bayesian approach and CO₂ observations from the tower network all over Oregon. This enabled us to adjust the model to carbon processes within the various ecoregions and reduce uncertainties of the modeled fluxes and derived values such as annual Gross Primary Production. We will present the results for the optimized modelled fluxes using this framework that can be applied in other regions that exhibit a similar variety in land use and land cover.

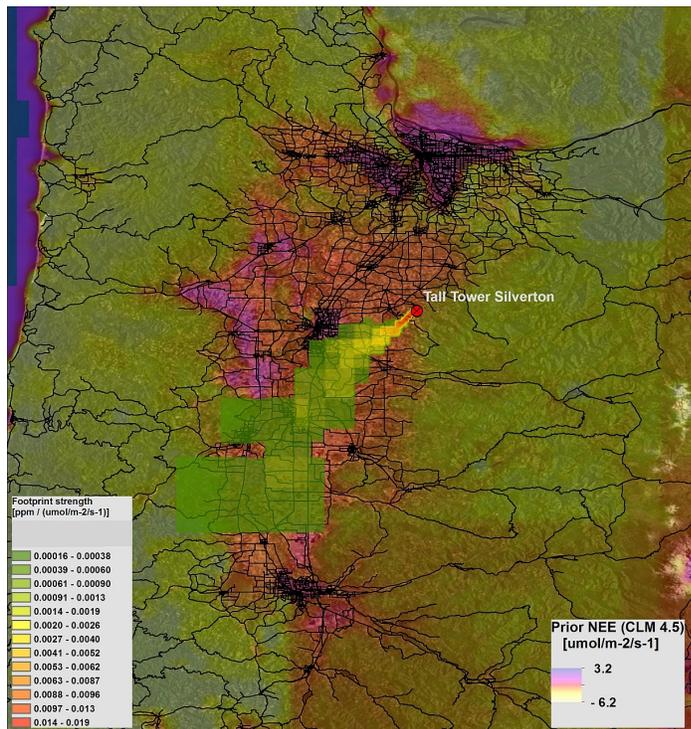


Figure 1. Prior NEE, modeled with CLM 4.5, in the highly inhomogeneous landscape of the Willamette Valley, Oregon for July 5, 2012. The corresponding footprint area at the tall tower in Silverton indicates the influences of urban areas and roads on the CO₂ mixing ratios measured at the tall tower in Silverton, OR and used for the inverse model optimization.

Quantification of Transport Errors in Regional CO₂ Inversions Using a Physics-based Ensemble of Weather Research & Forecast (WRF)-Chem Simulations

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Atmospheric transport model errors are one of the main contributors to the uncertainty affecting CO₂ inverse flux estimates, but have not been quantified thoroughly. This study aims to assess the transport errors over the Mid-Continental Intensive domain with an ensemble of simulations created with the WRF mesoscale model using different physical parameterizations (e.g., atmospheric boundary layer (ABL) schemes and land surface models (LSMs)). Modeled meteorological variables and atmospheric CO₂ concentrations were compared to observations during the summer of 2008. The model-data mismatch for several meteorological variables was used to examine the spread of the ensemble and identify the model configurations that were systematically biased. Preliminary results show that the spread of the ensemble is too small for the wind speed (Figure 1a), but large enough for the ABL height (Figure 1b). Across the domain, the bias in wind speed, mainly influenced by the LSM, is within a range of ± 2 m/s, whereas the ABL height, highly influenced by the choice of the ABL scheme, is within ± 500 m. Finally, we evaluated the impact of transport errors in atmospheric CO₂ concentrations and found that transport errors represent about 55% of the CO₂ model-data mismatch, potentially impacting our inverse flux estimate unless carefully addressed.

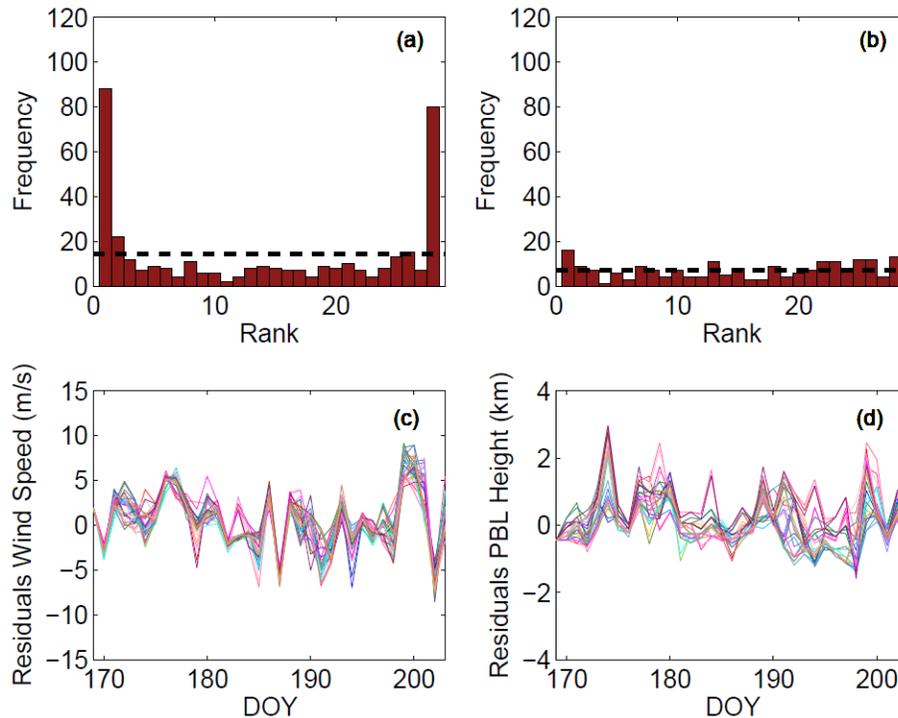


Figure 1. Rank histograms of all the sites for wind speed (a) and ABL height (b). The so-called "U-shape" rank histogram (a) implies that the ensemble under-estimates the model-data mismatch for the wind speed, whereas the flat rank histogram (b) implies that the ensemble represents the model-data mismatch in ABL height at the various observation locations. Wind speed (c) and ABL height (d) residuals (model-data mismatch) for 0000 UTC rawinsonde observations at Omaha, NE from 17 June to 21 July 2008. Colored lines represent each model configuration.

Comparing Modeled Column-average CO₂ to Greenhouse Gases Observing SATellite (GOSAT) Atmospheric CO₂ Observations from Space (ACOS) 3.4 X_{CO₂} Product

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In this poster, we'll compare a variety of atmospherically modeled CO₂ products, based upon both best guess surface flux products and atmospherically optimized (inversion) products, relative to the latest GOSAT ACOS X_{CO₂} product. Results are summarized over large Transcom regions from the period of 2009 - 2012. We'll include products from CIRA as well as European products (Monitoring Atmospheric Composition & Climate) and two different CarbonTracker products, all of which optimize CO₂ fluxes based upon surface observations of CO₂. Initial comparisons are promising with large scale space/time agreement between the models and the satellite data, although certain residual features require more investigation and research.

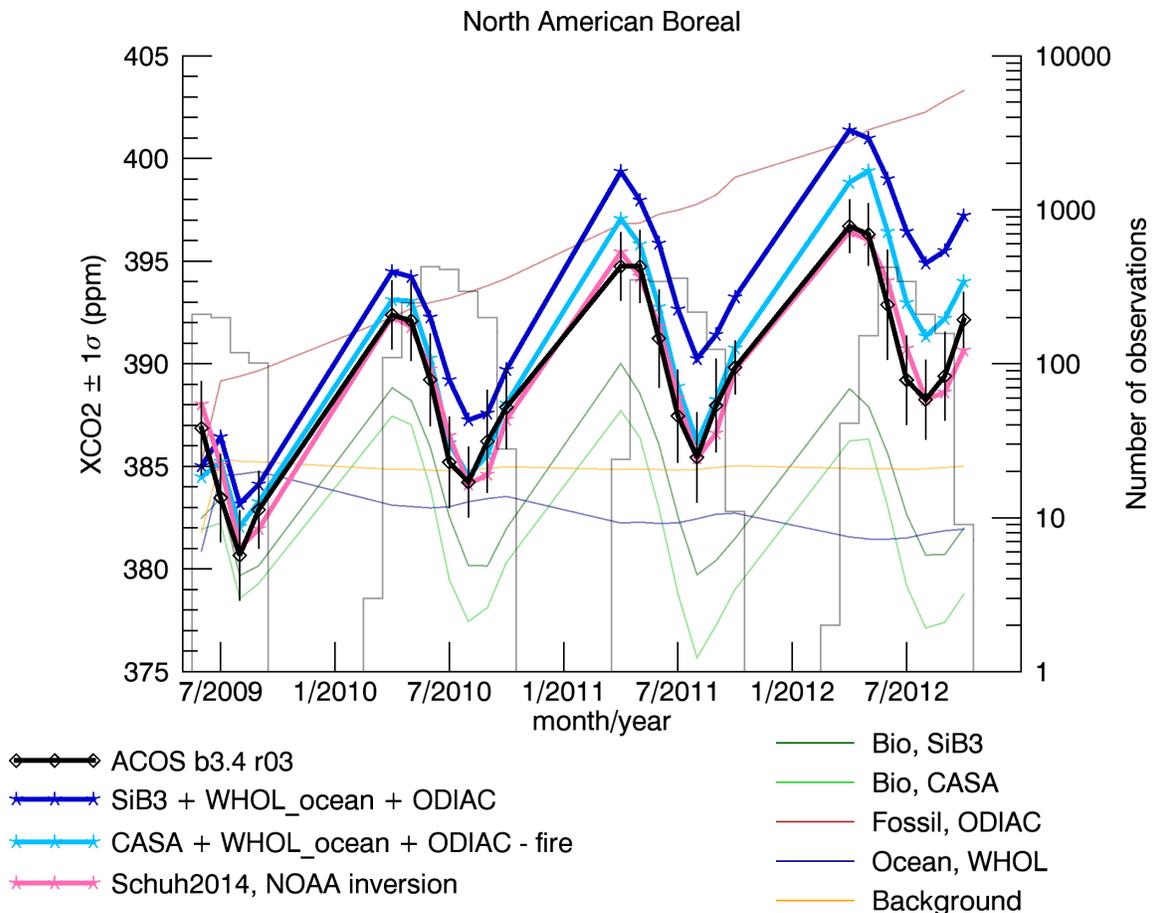


Figure 1. Time series of ACOS b3.4 r3 data against tracers and inversion results. Carbon dioxide tracers (right side of legend) form the fixed and a priori components of the inversion results (left side of legend). Total a priori carbon dioxide time series for the SiB3 and Carnegie-Ames-Stanford Approach (CASA) models are also shown on left side of legend as well. Note that the ocean tracer forms an inherent temporal sink, fossil tracer forms an inherent source and biosphere models are close to being balanced (zero flux) annually. Inversion results are based upon NOAA surface data.

Improving CO₂ Air-sea Fluxes by Combining O₂ and CO₂ Data

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The evolution of CO₂ and O₂ in the atmosphere is strongly coupled by the processes controlling their exchange with the land and the ocean. Combining O₂ and CO₂ data thus provide additional constraints on CO₂ fluxes and key insights into the processes at play. In particular, estimates of CO₂ fluxes based on atmospheric data assimilation such as Carbon Tracker are heavily tied to the ocean “prior” they use (i.e. the first guess of air-sea CO₂ fluxes obtained independently from atmospheric CO₂ data).

In this study, we exploit the strong link between O₂ and CO₂ data in the ocean and the atmosphere to constrain the estimate of air-sea CO₂ fluxes. This also provides insight into the process controlling the strong variability of oceanic origin that depends on the rate of ocean uptake of CO₂, ocean production/respiration, warming/cooling and mixing, all processes which impact both air-sea CO₂ and O₂ fluxes. Ultimately, this estimate will improve our estimate of ocean “priors”.

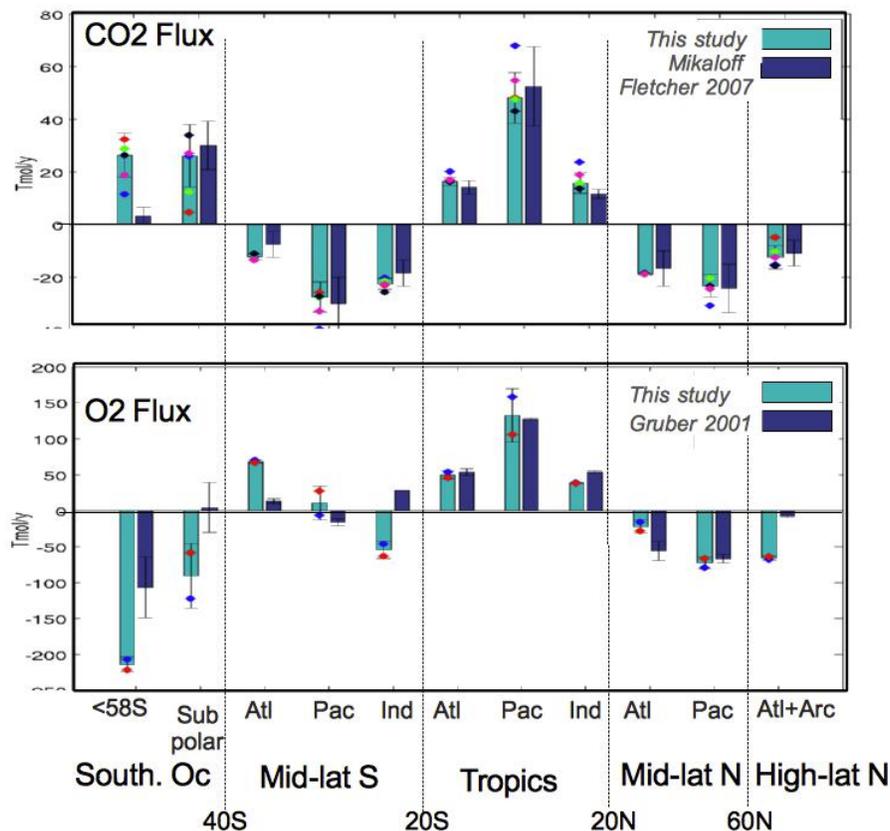


Figure 1. Estimates of regional CO₂ and O₂ fluxes obtained by an oceanic inversion in this study and in previous estimates. This illustrates the links between CO₂ and O₂. For example, in the Southern Ocean, deep convection brings carbon-rich/oxygen-poor waters to the surface, leading to strongly coupled CO₂ out-gas and O₂ in-gas. *Positive fluxes towards the atmosphere and symbols indicate estimates based on different ocean model parametrization.*

Estimating Fire Emissions Using Visible Infrared Imaging Radiometer Suite (VIIRS) Nightfire Data and the Fire INventory from NCAR (FINN)

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We are developing a new method to estimate fire emissions using nighttime data collected by the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi-National Polar-orbiting Partnership satellite, in conjunction with the Fire INventory from NCAR (FINN). The VIIRS NightFire (VNF) system is designed to detect and characterize sub-pixel combustion sources at night. VNF was originally developed for detecting gas flares and estimating their emissions. VNF employs a multispectral approach to detect hot sources and uses Plank curve fitting to derive combustion parameters such as temperature, source size, and radiant heat. We have noticed that it also detects other combustion events with relatively low combustion temperature that could be attributable to wildfires. In this work, we leverage combustion source size reported for each combustion event to estimate burnt areas and then calculate wildfire emissions using FINN. Although VNF data is limited to nighttime, we expect that VNF will help us to identify small fires, which we often have difficulty detecting, which will improve our overall fire emission estimates.

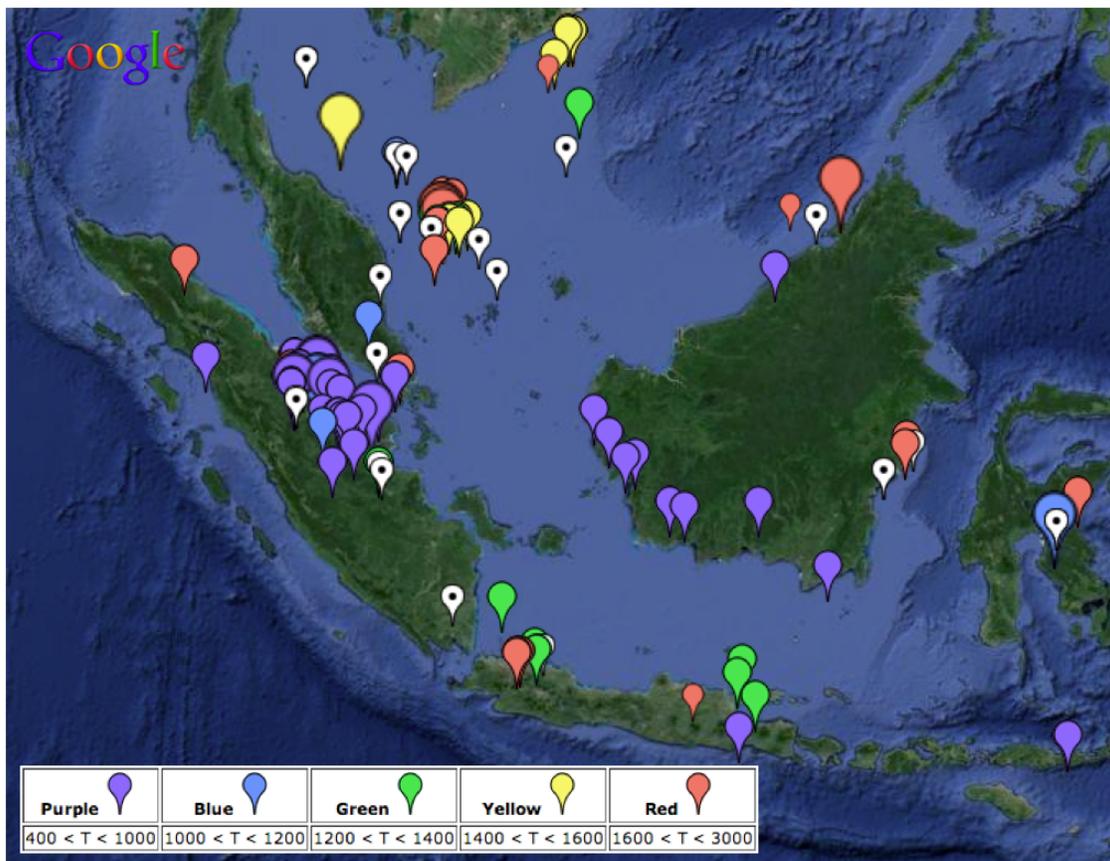


Figure 1. Combustion events detected by VNF over South East Asia (27 June, 2013). Note white placemarks indicate non-conforming detections.

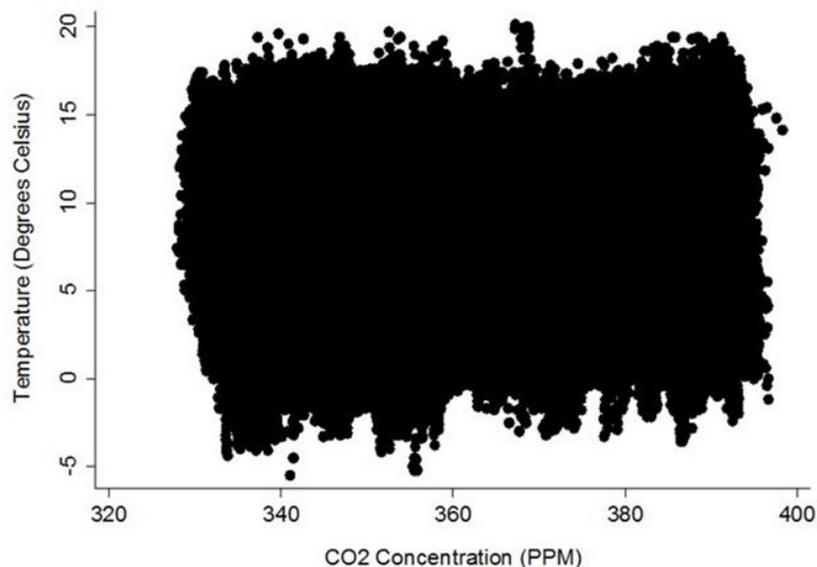
Evidence of Causality Between the Atmospheric Concentration Levels of Carbon Dioxide and Temperature

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This paper explores the relationship between the atmospheric concentration of Carbon Dioxide (CO₂) and the dry-bulb temperature using hourly CO₂ atmospheric concentration data from the Mauna Loa Observatory (MLO) in Hawaii. The starting point is that traditional correlation analysis does not yield evidence in support of a causal relationship between the CO₂ concentration level and temperature. This is readily apparent if one inspects a simple scatter diagram of the hourly CO₂ and temperatures levels at the MLO in Hawaii over the period 1 Jan 1977 through 31 Dec 2010 (Figure 1). More fundamentally, traditional correlation analysis is not capable of addressing whether there is a causal relationship between CO₂ and temperature because statistical methods alone cannot render results that establish or reject causality between two variables that are contemporaneously correlated. Nevertheless, advanced statistical methods can address the issue of causality.

The approach adopted in this paper addresses the issue of causality between CO₂ and temperature by following *Granger* [1969], who defined causality in terms of whether lagged values of a variable lead to more accurate predictions of some other variable. This study embraces this view of causality by examining whether lagged values of CO₂ lead to more accurate forecasts of temperature. The analysis makes use of lagged hourly CO₂ atmospheric concentration data from MLO, data on the hourly temperature at the nearby Hilo International Airport, and day-ahead hourly forecast data for the Hilo location. The estimated equation is used to make hourly out-of-sample forecasts. Consistent with the existence of a causal relationship, the inclusion of the CO₂ level as an explanatory variable improves the accuracy of the forecast. The improved forecast is also more accurate than conventional temperature forecasts for the same location.



Source: <http://www.esrl.noaa.gov/gmd/dv/data/> and <ftp://ftp.cmdl.noaa.gov/data/meteorology/in-situ/>

Figure 1. A Scatter Diagram of Hourly CO₂ and Temperature Levels at the Mauna Loa Observatory in Hawaii, 1 Jan 1977 through 31 Dec 2010.

As Methane Concentration Goes Up, Stable Isotopes of Methane Go Down: ^{13}C Implicates a Microbial Source Across Latitudinal Gradients

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The mixing ratio of methane in the atmosphere has increased in recent years for reasons that are not completely understood. It is important to better understand this greenhouse gas in regard to our changing climate and its role in atmospheric chemistry. Stable isotopes allow us to elucidate sources of methane due to the relatively distinct isotopic signatures from fossil fuels, biomass burning, and biological sources. Here we examine a 15-year record of atmospheric methane to show that since 2007, atmospheric methane isotopes have decreased by an average of 0.15 permil. This decrease is evident at Arctic sites as well as in the mid-latitudes and the Southern Hemisphere. There has been no change in the inter-hemispheric difference of atmospheric methane isotopes, suggesting that the changes are occurring in both northern and southern regions. Likewise, Miller-Tans plots, which examine regional deviations from the background signal, show that sources of methane have become isotopically more depleted since 2007 across latitudes. This suggests stronger microbial emissions (such as wetlands) from tropical, temperate, and Arctic environments. We use a 2-box model to test the plausibility of increased sources of microbial methane across a latitudinal gradient, and to constrain possible additional contributions of fossil fuel and biomass burning sources to the observed variability.

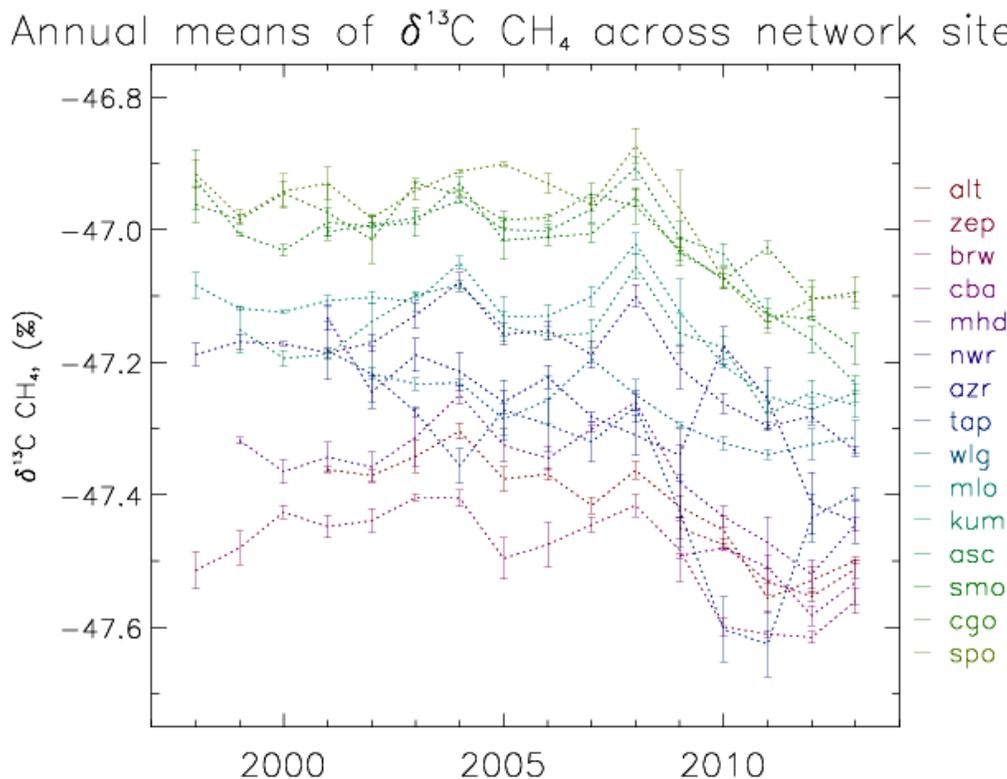


Figure 1. Annual means of $\delta^{13}\text{C}$ of CH_4 across sampling sites. Error bars represent the standard deviation in the data trend; seasons have been removed.

Comparison of *In Situ* and Discrete Sample Methane Monitoring at Summit, Greenland

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Observations of atmospheric methane mole fractions in the Arctic serve as an important benchmark for the study of global trends and levels. Due to the isolation from most anthropogenic sources, methane measurements in the Arctic are also a sensitive tool for investigating climate feedbacks and the potential methane release from permafrost and hydrates. In this study, two methods for observing atmospheric methane at the GEO Summit Facility in Greenland are compared for the purpose of evaluating the two distinct sets of data. The two methods are: 1) High resolution *in situ* sampling with analysis by Gas Chromatography-Flame Ionization Detection (GC-FID) with 2-3 hour time resolution in the Temporary Atmospheric Watch Observatory facility at the site, and 2) Bi-weekly whole air sample collection with GC-FID analysis at NOAA Global Monitoring Division after shipment of the discrete air samples to Boulder. Averaging all data from the period of overlapping discrete and *in situ* measurements gave a mean value of 1880.7 nmol mol⁻¹ for the *in situ*, and 1881.8 nmol mol⁻¹ for the discrete measurements, respectively, demonstrating good agreement with a relative difference of 0.06%. These data were aligned on common scales to further investigate their agreement. The discrete samples gave higher values for 33 comparisons, and lower values 32. The paired discrete samples showed an absolute standard deviation of 0.4 nmol mol⁻¹. Comparison of the two *in situ* measurements taken before and after the discrete sample yielded a mean standard deviation of 2.7 nmol mol⁻¹. Both data sets agree very well in defining the methane seasonal trends. In addition, the fine scale temporal changes in the *in situ* data allow for deciphering atmospheric transport events for studies of upwind methane source regions.

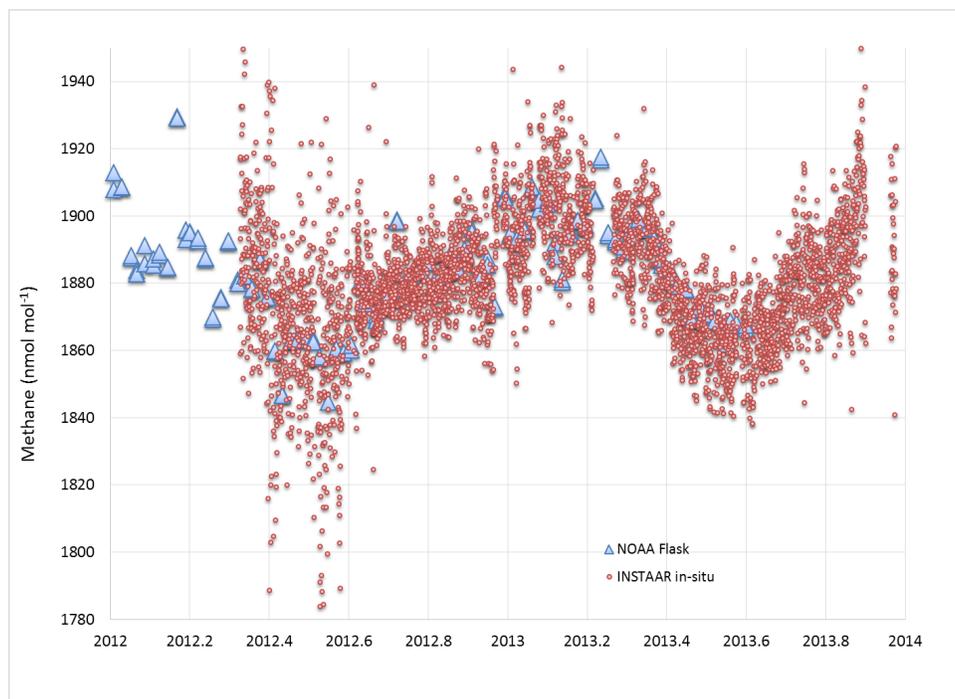


Figure 1. Results of graphing NOAA's flask methane mole fraction data against INSTAAR's *in situ* methane data. The two sets can be seen to agree on seasonal trends and levels very closely. The significantly larger amount of samples gathered by INSTAAR's *in situ* sampling process is also made apparent.

Top-down Constraint on Hydrocarbon Emissions in the Denver-Julesburg Oil and Natural Gas Basin

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NOAA Earth System Research Laboratory conducted an intensive measurement campaign in Colorado's NE Front Range in May 2012 to investigate hydrocarbon emissions from oil and gas operations. The study region was centered on the most densely drilled region (> 24,000 active wells) of the Denver-Julesburg Basin. Total methane (CH₄) emissions for the region were estimated using a mass-balance approach with *in situ* CH₄ data from flights conducted on two different days and ground-based measurements of wind direction and speed. CH₄ and over 40 different species were also analyzed in a total of 118 discrete air samples collected by the airplane on 12 flights. Here we present data for CH₄, propane, n-butane, i-pentane, n-pentane, benzene, acetylene and carbon monoxide. Top-down emission estimates were calculated for the non-methane hydrocarbon measured based on the total CH₄ emission top-down estimate and hydrocarbon correlation slopes for the airborne discrete air samples. The aircraft data are compared with the NOAA Global Monitoring Division long-term measurements of air samples collected since 2007 at the Boulder Atmospheric Observatory tower, north of Denver. We also compare the atmospheric measurements with raw natural gas and flashing tower emissions from oil tanks composition data provided by the Colorado Oil and Gas Conservation Commission (COGCC) and the Colorado Department of Public Health and the Environment (CDPHE).

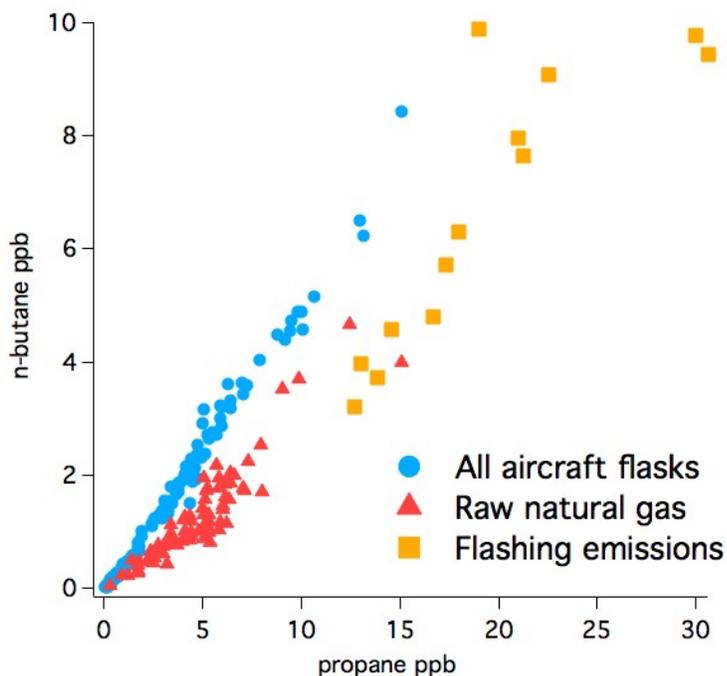


Figure 1. n-butane versus propane in aircraft samples collected in the Denver-Julesburg Basin in May 2012 (blue circles) and in composition profiles for natural gas produced in the region (source: COGCC, red triangles) and for flashing emissions from oil and liquid condensate storage tanks (source: CDPHE, yellow squares).

Initial Results of a Natural Gas Methane Emissions Survey in California's Southern San Joaquin Valley

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Methane emissions from natural infrastructure and associated with petroleum production are estimated to account for a small but uncertain fraction (~ 10%) of California's total methane emissions. In an effort to provide quantitative emissions estimates that might guide future mitigation efforts, we report initial results of measurements that survey emissions from natural gas infrastructure as part of the CALifornia Greenhouse Gas Emissions Measurement (CALGEM) project. In November 2013, we conducted a field campaign to measure CH₄ emissions from the Southern San Joaquin Valley. Measurements included the combination of continuous CH₄, Volatile Organic Compound (VOC) flask sampling and inflight meteorology on a small aircraft, surface and boundary layer winds and mixing depth with a ground-based Doppler Lidar, continuous multi-height CH₄ and meteorology measurements and ¹³CH₄ stable isotope sampling, and periodic VOC flask sampling from a roadway vehicle. Airborne CH₄ enhancements were clearly measurable above background mixing ratios for the Bakersfield urban area and two oil-gas fields. While initial results suggest CH₄, VOC, and isotopes measured on the south side of the Bakersfield urban area are dominated by nearby and interspersed livestock facilities, the north side of Bakersfield exhibited CH₄, light alkane, and isotope signals associated with oil and gas activities. Methane measurements from the roadway vehicles suggest that localized methane plumes were captured in several areas of urban Bakersfield. Ongoing analysis is expected to improve the specificity to petroleum and natural emission activities to provide quantitative emission estimates from natural activities.

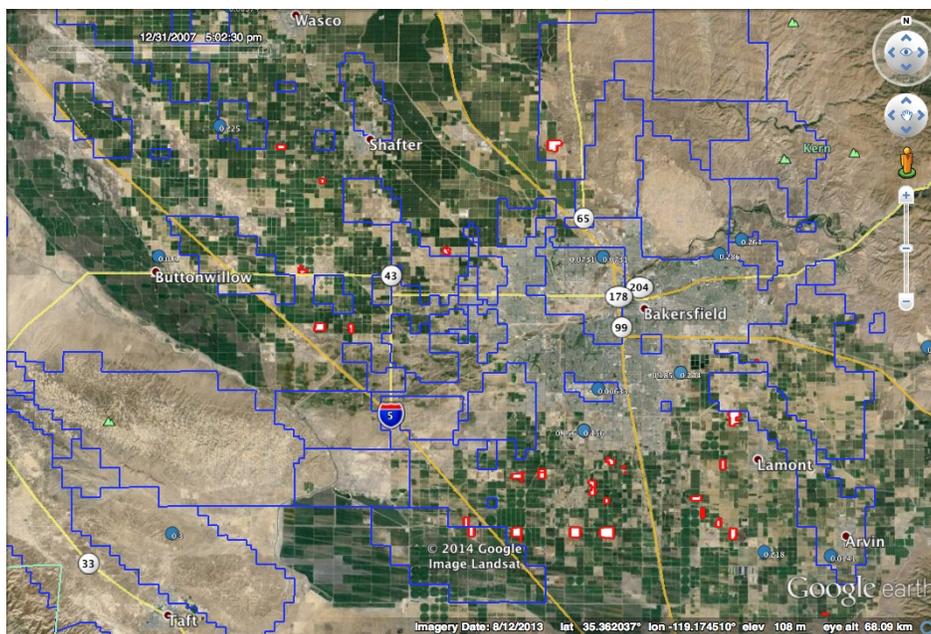


Figure 1. Image of Southern San Joaquin Valley showing locations of potential methane sources including urban Bakersfield, oil and gas field boundaries (blue lines), landfills and waste water treatment (blue dots), and dairies (red outlines).

Effect of Oil and Gas Development on Atmospheric Levels of Hydrocarbons and Tropospheric Ozone

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Unconventional oil and natural gas have been an increasingly significant source of energy in the United States due to modern technology such as hydraulic fracturing. The consequences of the production and processing of oil and gas development to climate and air quality are imperative to understand, especially in prevalent oil and gas sites like Colorado, Wyoming, and Utah. In this study, the data from a tower observatory in Colorado from 2008 to 2012 are utilized to characterize chemical composition of oil and gas emissions and investigate the impact of these emissions on tropospheric ozone. Alkane and benzene are significantly enhanced in the air originated from oil and gas development region in Denver-Julesburg Basin, which confirms the results in previous researches for different time periods. This study is the first to examine direct relationship between hydrocarbons and concurrently measured ozone in summer in Colorado. Under the conditions of high hydrocarbons concentrations, ozone concentration is high and tends to increase as hydrocarbon accumulates. Chemical analysis suggests large contribution of propane and butane from oil and gas development to ozone. Additional studies on a national level are beneficial to fully understand the relationship between hydrocarbons from oil and gas explorations and tropospheric ozone.

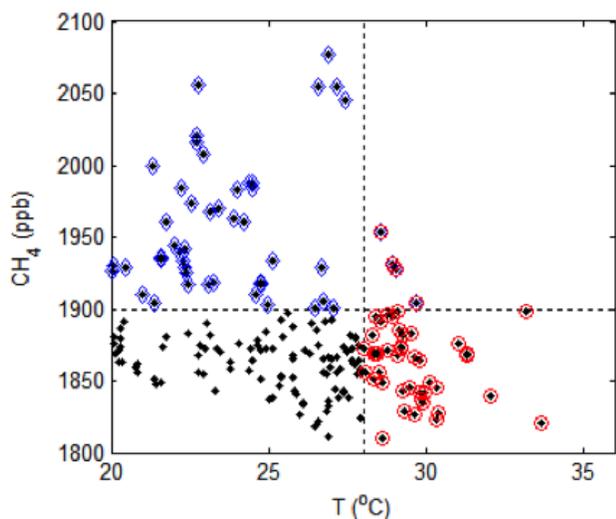


Figure 1. A graph comparing methane to temperature for the Boulder Atmospheric Observatory NE wind over summer 2008-2012. The data is highlighted for two conditions: high methane (blue, above 1900 ppb of methane) and high temperature (red, above, 28°C)

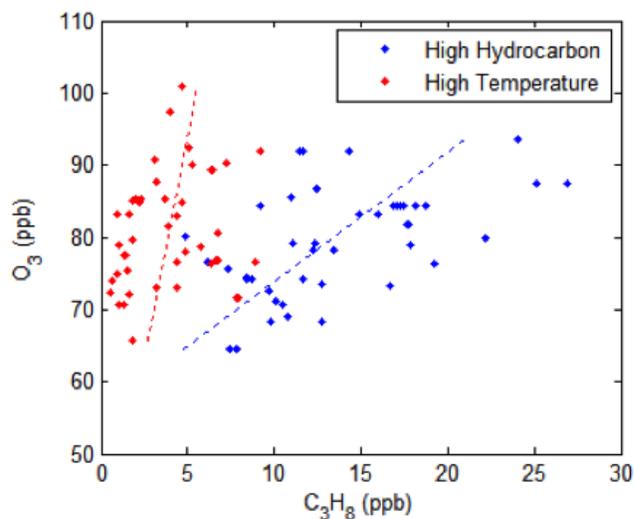


Figure 2. This graph is segregated into the same two conditions high temperature (red) and high methane/hydrocarbon (blue). Dashed lines denote orthogonal fit.

Bridging the Work of Field Scientists and the Needs of Data Re-users

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The National Science Foundation (NSF) requires Principal Investigators (PI) to make the data they collect and create publically available. To assist PIs with this requirement, NSF funded the Advanced Cooperative Arctic Data and Information Service (ACADIS). ACADIS houses data from the Division of Polar Programs, provides data management assistance to PIs, and advances search and data discovery tools. In short, ACADIS exists for NSF Arctic researchers by providing a safe home for data and encouraging data reuse.

ACADIS is a group of specialist organizations comprised to create a repository of Arctic data that encompasses spatial, temporal, and attribute granularity of data so that "big science" and "small science" may better integrate. The ACADIS project fosters scientific synthesis and discovery by providing services that make data from multiple disciplines freely available for access and analysis. ACADIS provides the arctic research community with data archival and data management services as well as value-added products to make the data more useful to more people. Essentially, the goal is to improve the usability and interdisciplinary re-use of arctic data. Many researchers and data providers understand their own data so intimately that it may seem that all the necessary information is contained in the file structure itself. This is clearly not the case with re-use. Placing the data and research in the greater scientific context is vital. ACADIS is a far-reaching program that provides assistance with data submission, data preservation and data sharing services. This poster discusses the various tools and services available through ACADIS. These include pieces from each step of the research process from proposal writing to meeting NSF requirements to maximizing citations.

ACADIS is a joint effort by the National Center for Atmospheric Research, University Corporation for Atmospheric Research, and the National Snow and Ice Data Center. For more information about ACADIS; to send feedback; or to submit, retrieve and search data; please visit their website, contact support@acnacadis.org, or call 720-443-1409.

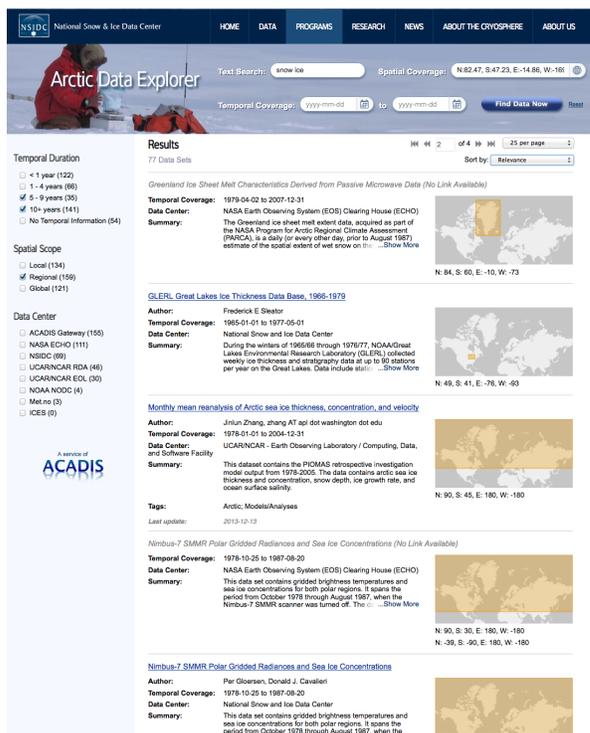


Figure 1. Example of results from the federated search tool, Arctic Data Explorer (ADE). The ADE simultaneously searches 8 data repositories with over 12,000 datasets.

The National Ecological Observatory Network (NEON): Overview and Strategies for Managing Thousands of Simultaneous Measurements Across the Continent

J. Taylor, E. Ayres, H. Luo, S. Metzger, N. Pingingtha-Durden, J. Roberti, M. SanClements, D. Smith, S. Streett and R. Zulueta

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NEON is responsible for making observations of terrestrial, aquatic, and organismal ecology in 20 different eco-climatic domains across the continent. NEON will provide localized data on key physical, climate, and chemical forcing, as well as their associated biotic responses, in an effort to inform climate change, land-use change, invasive species, and other impact studies. The sheer volume of data is expected to exceed hundreds of Terabytes per year and will present challenges for data management on an unprecedented scale. This poster will provide an overview of NEON as a whole, while specifically focusing on how to develop and implement a standardized ecological observatory that must accommodate such a large volume of data without sacrificing quality. Highlights will include preliminary first results hosted on the NEON data portal and look toward first article science results.



Figure 1. The National Ecological Observatory Network

The National Ecological Observatory Network (NEON) Mobile Deployment Platform (MDP): A Flexible Community Resource for Ecological Research

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The NEON Mobile Deployment Platforms (MDP) are the Principal Investigator and agency requestable infrastructure designed to observe stochastic or spatially important events, gradients, or quantities that cannot be reliably observed using fixed location sampling (e.g. fires and floods). Due to the transient temporal and spatial nature of such events, the MDPs will be designed to accommodate rapid deployment for time periods up to ~ 1 year. Broadly, the MDPs will be comprised of infrastructure and instrumentation capable of functioning individually or in conjunction with one another to support observations of ecological change, as well as education, training and outreach. This presentation will provide a detailed summary of that infrastructure and instrumentation, as well as providing information about protocols for requesting and deploying the NEON MDP.



Figure 1. Existing mobile infrastrucure as currently deployed by other agencies.

Global Emissions Initiative's (GEIA) Vision for Improved Emissions Information

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Accurate, timely, and accessible emissions information is critical for understanding and making predictions about the atmosphere. We will present recent progress of the Global Emissions Initiative (GEIA, <http://www.geiacenter.org/>), a community-driven joint activity of the International Global Atmospheric Chemistry, Integrated Land Ecosystem-Atmosphere Processes Study, and the Analysis, Integration, and Modeling of the Earth System within the International Geosphere-Biosphere Programme. Since 1990, GEIA has served as a forum for the exchange of expertise and information on anthropogenic and natural emissions of trace gases and aerosols. GEIA supports a worldwide network of emissions data developers and users, providing a solid scientific foundation for atmospheric chemistry research. By the year 2020, GEIA envisions being a bridge between the environmental science, regulatory, assessment, policy, and operational communities. GEIA's core activities include: 1) facilitating analysis that improves the scientific basis for emissions data, 2) enhancing access to emissions information, and 3) strengthening linkages within the international emissions community. We will highlight GEIA's current work distributing emissions data, organizing the development of new emissions datasets, facilitating regional emissions studies, and initiating analyses aimed at improving emissions information. GEIA welcomes new partnerships that advance emissions knowledge for the future.

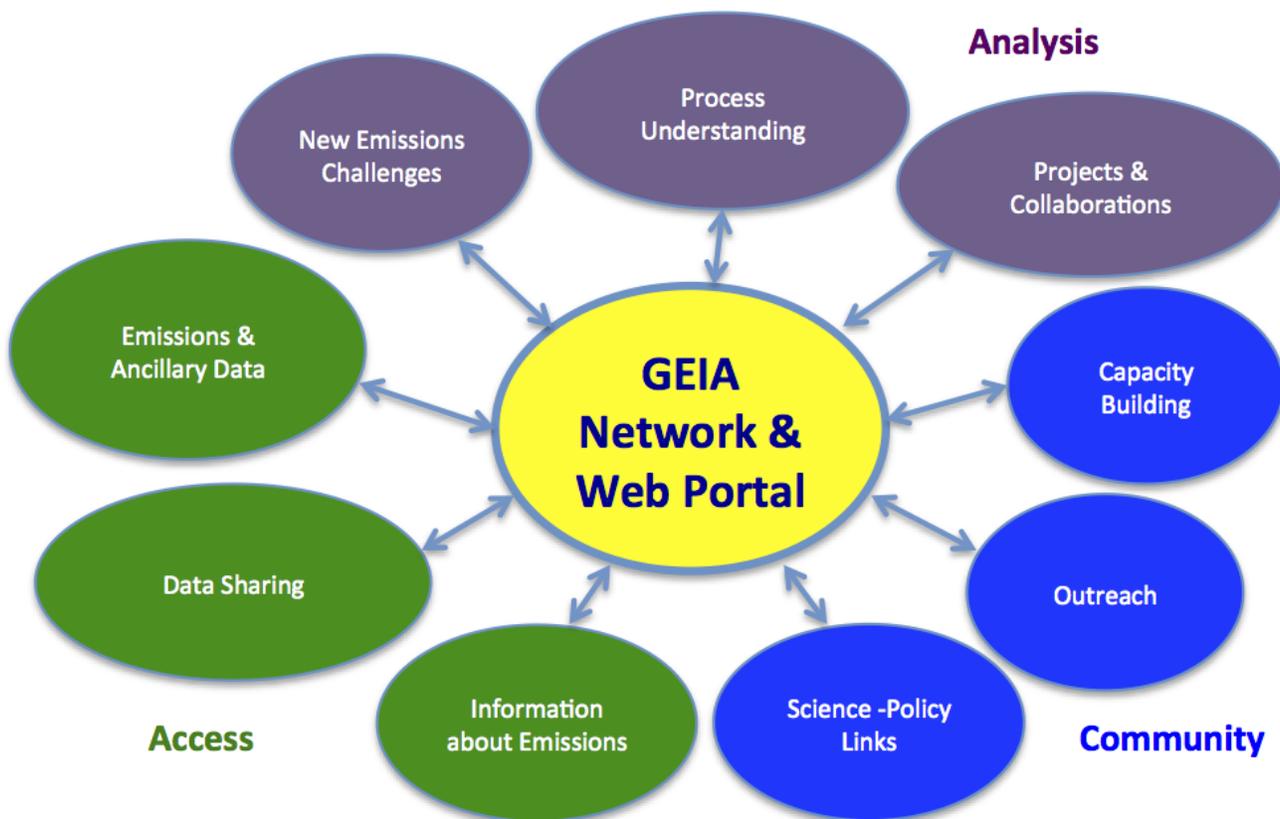


Figure 1. Schematic showing GEIA's core activities.

Monitoring Aerosol Optical Depth During the Arctic Night: Development of a Lunar Photometer for Use at the NOAA Barrow Observatory

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The objectives of the Polar-Aerosol Optical Depth (AOD) community are to characterize aerosol properties and gain an understanding of factors that control their distribution and climate impacts. NOAA has played a major role in this effort by establishing Sun Photometer Programs at a number of high-latitude sites, including Barrow, AK (BRW), where the surface radiation budget is influenced by airborne pollutants and natural aerosols transported from lower latitudes. Arctic aerosols are chemically and optically inhomogeneous over space and time. Of special interest is the burden of black carbon, which during sunlit periods warms the atmosphere and accelerates snow/ice melt if deposited on the surface. A mixture of aerosol tends to accumulate within the Arctic vortex during winter, when it is most difficult to observe, so their role in forcing climate is poorly understood. Polar orbiting satellites (e.g., CALIPSO) are used to derive properties of the aerosol at night, but validating retrievals have been limited due to the lack of ground-truth data. AOD measurements made at Arctic sites during periods of darkness would aid this effort, begin to fill gaps in our time series and contribute to the understanding of aerosol transport and chemistry in the context of global climate change.

Nighttime photometry using star and moon light is not new. However, star systems are very costly and sophisticated to operate, and the variation in lunar irradiance with phase has been a major deterrent to using the moon as a light source. A simple, cost-effective approach is needed. Although the Moon's luminosity is variable, it is periodic and predictable and its photometric properties are virtually invariant. In recent years, lunar brightness variations, librations, spatial non-uniformity, and non-Lambertian reflectance properties have been well-characterized and modeled by the USGS Robotic Lunar Observatory Project. Taking advantage of these advances, GMD has successfully modified a sun photometer to measure lunar irradiance and derive spectral AOD throughout the Arctic winter.

Here, we give an overview of the prototype lunar system developed by GMD, calibrated at the Mauna Loa Observatory and then deployed to BRW during winter 2012/2013. The feasibility of monitoring AOD through the Arctic is demonstrated. Efforts are underway to improve the system for future operational use, enabling year-round monitoring of AOD at BRW. In conjunction with surface radiation measurements, we will be able to evaluate the longwave radiative forcing by the aerosol and gain insights about nocturnal cloud-aerosol interactions. The data will also be used to validate satellite retrievals of AOD.



Figure 1. A layer of Arctic haze settles off the north coast of Greenland as the sun sets, April 2009;



Figure 2. A 4-channel SP02 Sun Photometer was modified for monitoring AOD at BRW during winter 2012/2013.

Results of Aerosol Hygroscopicity During The Two-Column Aerosol Project (TCAP) Campaign in the Frame of the NOAA Network

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Aerosol optical and microphysical properties have a strong dependence on the Relative Humidity (RH). Knowledge of this RH effect is of great importance for climate forcing calculations and for comparison of *in situ* measurements with satellite and remote sensing retrievals. The scattering enhancement factor, $f(\text{RH})$, is defined as the ratio of the scattering coefficient at a high and reference RH. In this study, aerosol optical properties were measured by the DOE/Atmospheric Radiation Measurement Program Mobile Facility in the framework of the TCAP deployed at Cape Cod. Over the study period, higher $f(\text{RH}=80\%)$ values were observed for wind directions from the marine sector together with high Single Scattering Albedo (SSA) and low Scattering Ångström Exponent (SAE) values. The anthropogenically-influenced sector was characterized by smaller, darker and less hygroscopic aerosols. The relationship between aerosol hygroscopicity and other aerosol parameters like SSA and SAE has been explored and we propose an exponential equation that successfully estimates aerosol hygroscopicity as a function of SSA at Cape Cod. In order to check the validity of this estimation at other sites, we selected a number of measurement sites where different aerosol types predominate (pristine marine, polluted marine, dust dominated, agricultural and forest environments). As can be seen in Figure 1, higher aerosol hygroscopicity was observed in marine environments, slightly lower for marine sites with anthropogenic influence and even lower for continental sites. The lowest value was obtained for dust dominated aerosols. In most cases, the scattering enhancement decreases as the SSA decreases, that is, as the contribution of absorbing particles increases. On the other hand, for marine influenced environments the scattering enhancement clearly increases as the contribution of coarse particles increases (SAE decreases), evidence of the influence of hygroscopic coarse sea salt particles.

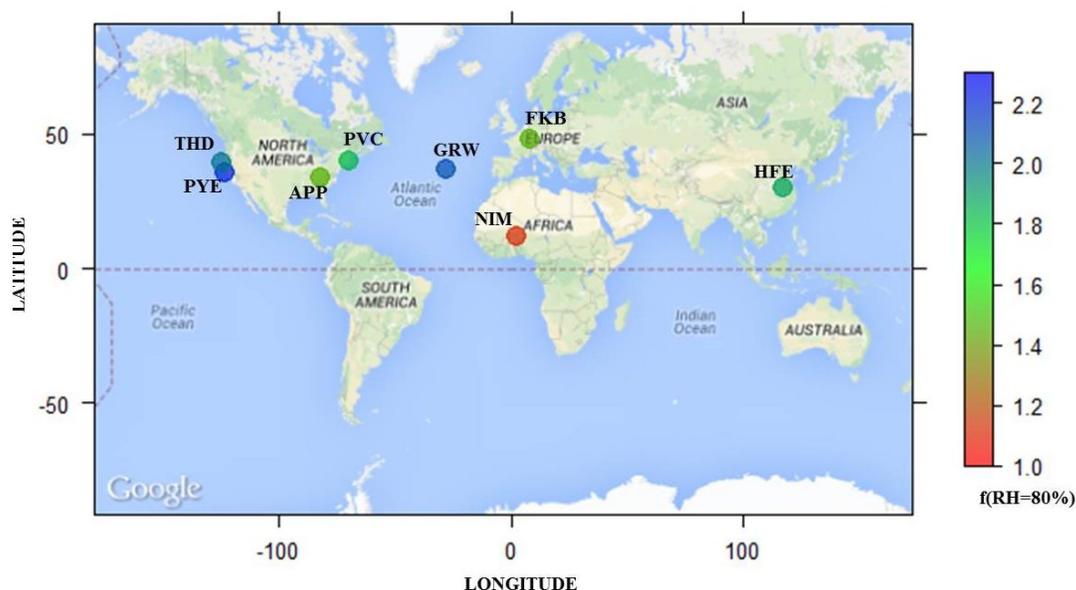


Figure 1. Location of the measurement sites. The color code represents the magnitude of the scattering enhancement (larger values of $f(\text{RH}=80\%)$ indicate a higher hygroscopicity of the aerosol particles).

Black Carbon in the Arctic: In the Arctic Report Card

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Long-term monitoring of black carbon in the Arctic is critical to understanding sources, transport pathways and environmental impacts in the Arctic, and to provide essential information for the development and implementation of mitigation options. Here we report long-term black carbon observations at three high Arctic locations: Alert (Canada), Barrow (United States) and Ny-Ålesund (Norway). A decline in Equivalent Black Carbon (EBC) concentrations of up to 55% was observed at Alert and Barrow (Figure 1a-c) since the early nineties, and has been related to changes in emissions sources in the Former Soviet Union region. Seasonally, all surface sites show the highest EBC concentrations when influenced by Arctic haze transported from mid-latitude source regions (Figure 1d). Minimal EBC is measured during the summer at these locations due to Arctic front confined to higher latitudes and more frequent wet deposition.

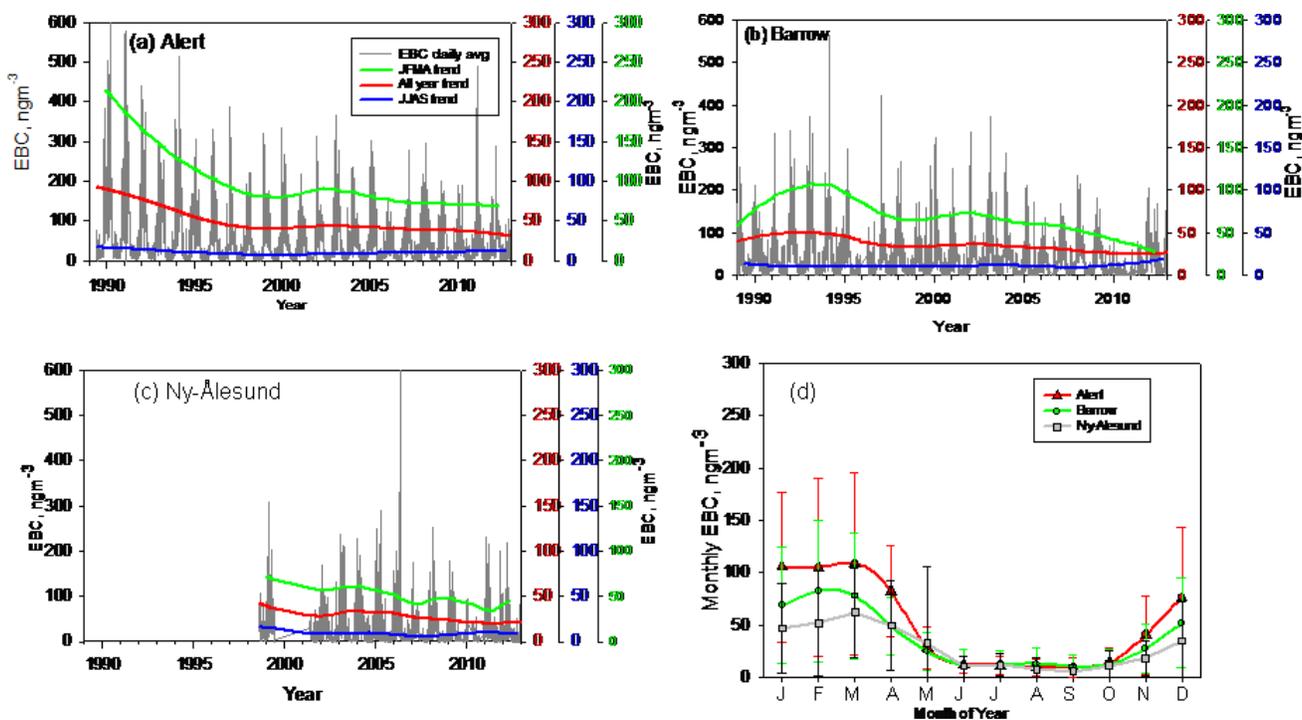


Figure 1. (a-c) Daily average EBC at Alert, Barrow and Ny-Ålesund. Trend lines (green, red, blue) were determined using the LOWESS technique (LOcally Weighed Exponentially Scatterplot Smoothing). The red line includes all EBC data, the green line is the average for January to April (JFMA), and the blue line is the average for June to September (JJAS). The % change in EBC between 1990-1993 and 2009-2012 is given for each trend line for Alert and Barrow. No significant (NS) change occurred in summer at those locations. (d) Seasonal variation at the three locations.

Observational Evidence for Incomplete Dehydration in the Tropical Tropopause Layer

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The Tropical Tropopause Layer (TTL), especially above the western Pacific, is the primary gateway for entry of air into the stratosphere from the troposphere. Dehydration of stratosphere-bound air parcels by deposition of water vapor to ice particles in the TTL is therefore a key process controlling the humidity of the stratospheric overworld. Strong correlations between large-scale stratospheric humidity and TTL temperatures on intra-annual and interannual timescales have demonstrated that this mechanism is largely correct. What remains uncertain is how efficiently air is dehydrated on its passage through the TTL and therefore the absolute value of water vapor entering the stratosphere. In the absence of appropriate particles to act as nuclei for ice crystal formation, relative humidity with respect to ice (RHi) exceeding 160% at TTL temperatures is required for clouds to form and remove water from the gas phase. If ice crystal concentrations are low (~100 / liter or less), the time for thermodynamic gas-particle equilibrium to be achieved can be on the order of hours following the formation of ice crystals. It is also possible that ice crystals, once formed, may evaporate before they are removed from the TTL by sedimentation. These mechanisms suggest the likelihood that air parcels with RHi exceeding 100% may frequently pass through the cold point and enter the stratosphere.

Here we present measurements made from the NASA Global Hawk Unmanned Aircraft System during the Airborne Tropical Tropopause EXperiment (ATTREX) of relative humidity, ice water content, and ice crystal concentrations in the central and eastern Pacific TTL in winter 2013 (ATTREX-2) and in the western Pacific TTL in winter 2014 (ATTREX-3). This dataset provides unprecedented high-quality observations of the key parameters required to test theoretical descriptions of dehydration in the TTL. During ATTREX, the cirrus clouds encountered most frequently had low ice crystal concentrations. While those clouds encountered with high ice crystal concentrations exhibited RHi very close to 100%, the more common thin clouds exhibited higher average and more variable RHi. A number of observations show supersaturated air or air with residual ice crystals at the potential temperature of the cold-point tropopause. ATTREX achieved a significant number of flight hours sampling air in this key region of the atmosphere. These observations provide evidence that suggest that the average entry value of water into the stratosphere is somewhat supersaturated due to incomplete dehydration to 100% RHi at the cold point.

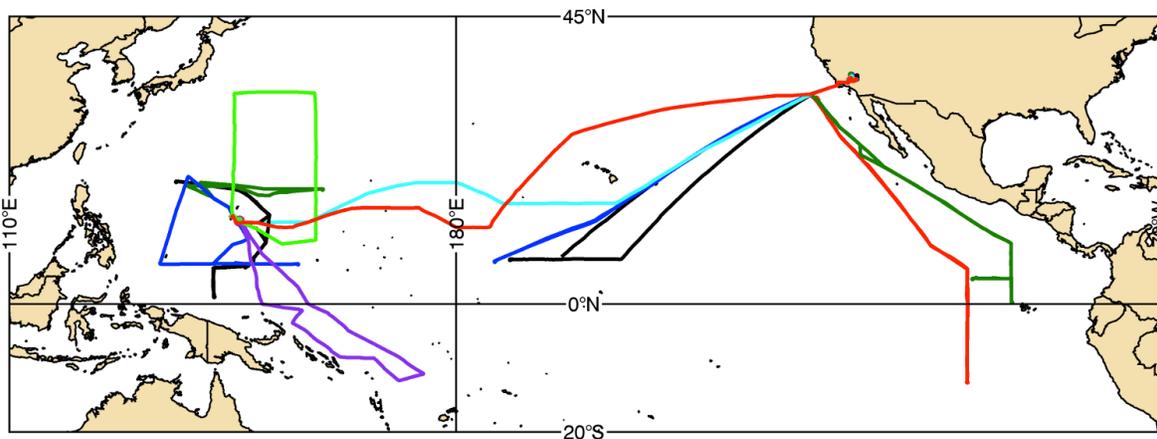


Figure 1. Flight tracks showing the regions covered by the ATTREX-2 and ATTREX-3 missions.

The Stratospheric Water and OzOne Satellite Homogenized (SWOOSH) Data Set

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Vertical profiles of ozone and humidity from the upper troposphere to stratosphere have been retrieved from several different limb sounding and solar occultation satellite instruments since the 1980s. Instruments include the Stratospheric Aerosol & Gas Experiment (SAGE) and the Polar Ozone & Aerosol Measurement instruments, Upper Atmosphere Research Satellite (UARS) Microwave Limb Sounder (MLS), UARS HALogen Occultation Experiment (HALOE), and most recently, Atmospheric Chemistry Experiment-Fourier Transform Spectrometer and Aura MLS, among others. Here, we present ongoing work aimed at combining these measurements into a geographically gridded data set that can be used for quantifying variability and long-term changes in water vapor and ozone, and can be used for assessing the radiative impact of these changes. In this poster, we describe the process of merging the various data sets, which are gridded into a monthly mean product using both geographic and Photo Voltaic-based equivalent latitude in the horizontal, and pressure and isentropic levels in the vertical. Coincident observations during overlap periods in the satellite record are used to construct bias corrections for each instrument that can be allowed to vary in both the horizontal and vertical.

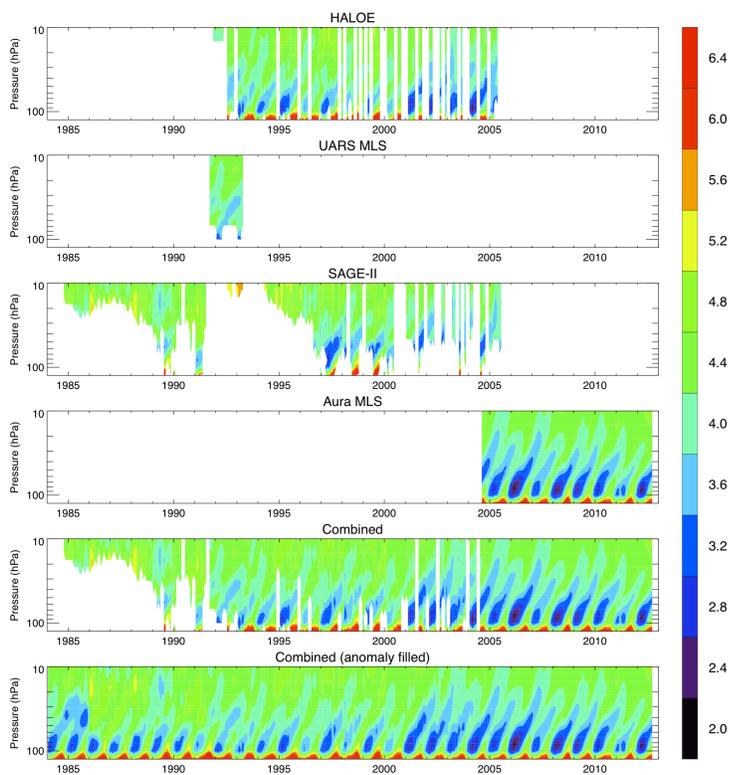


Figure 1. The tropical tape recorder from SWOOSH.

Towards a Combined Infrared Atmospheric Sounding Instrument (IASI)/Tropospheric Emission Spectrometer (TES) Record of Ozone: Validation and First Results

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Ozone is the third most important anthropogenic greenhouse gas and a significant pollutant at the surface affecting human and plant health. Rapidly increasing Asian emissions of ozone precursors, land-surface changes from burning, and decreasing surface emissions in Europe and North America have resulted in unknown changes to the distribution of tropospheric ozone. Satellite-borne instruments provide the means for global and continuous monitoring of this important trace gas. High spectral resolution infrared radiance measurements, such as those from the Tropospheric Emission Spectrometer (TES) on the NASA Aura satellite (launched in 2004), and the Infrared Atmospheric Sounding Instruments (IASI), on the MetOp-A and MetOp-B satellites (launched in 2006 and 2012 respectively) can be used to derive vertical information of tropospheric ozone. Together, these instruments now present a record spanning more than nine years. As part of efforts to assess consistency between the TES and IASI data records, a retrieval for ozone from IASI radiances, building on the data processor for TES, is under development as a collaboration between NASA JPL and NCAR. Using a priori information consistent with TES retrievals, the optimal estimation approach is applied to IASI radiances in order to obtain vertical distributions of ozone. This presentation shows the characterisation of these IASI ozone retrievals with respect to the vertical distribution of the uncertainties and sensitivities as well as validation with coincident ozonesonde profiles. Further comparisons with TES are presented and observed trends in ozone over Asia, North America, and Europe described.

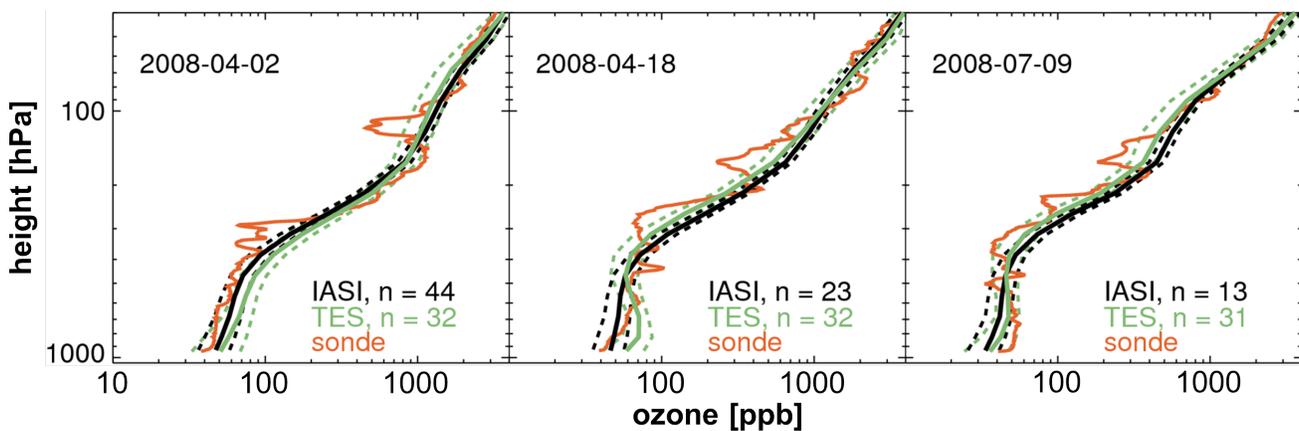


Figure 1. IASI and TES mean ozone profiles for Bratt's Lake Observatory (Canada). The maximum time difference between IASI and TES is 3:26 hr.

South Pole Ozonesonde Measurements During the 2013 Ozone Hole

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The South Pole balloon-borne ozonesondes showed an above average minimum during the 2013 Antarctic ozone hole. The August total column pre-ozone average of 242 Dobson Units (DU) dropped to a minimum of 124 DU on September 29, which ranked as the 20th lowest minimum measured in the 28 year record at South Pole Station. Even though the minimum was well above average, a typical rapid decline in ozone (> 3 dobson units per day) in early to mid September within the ozone layer region from 12-20 kilometers was observed. By September 20th the stratospheric temperatures shifted warmer by about 3 degrees C above average, which was accompanied by an abrupt end to ozone depletion several days earlier than average over South Pole. The 12-20 km layer dropped to 25 DU (80% depletion). This ranked 2013 as the 25th lowest minimum within the 12-20 km layer measured in the 28 year record. The October 22nd ozonesonde profile showed high ozone levels pouring in above 23 km altitude over South Pole after the vortex breakup. The 2014 profiles are currently showing above average column ozone amounts within the 12-20 km main ozone layer. However, the main indicators of ozone recovery will be the rate of ozone decline in September and the minimum column value reached by October 1, which will depend on how cold and stable the polar vortex remains this season.

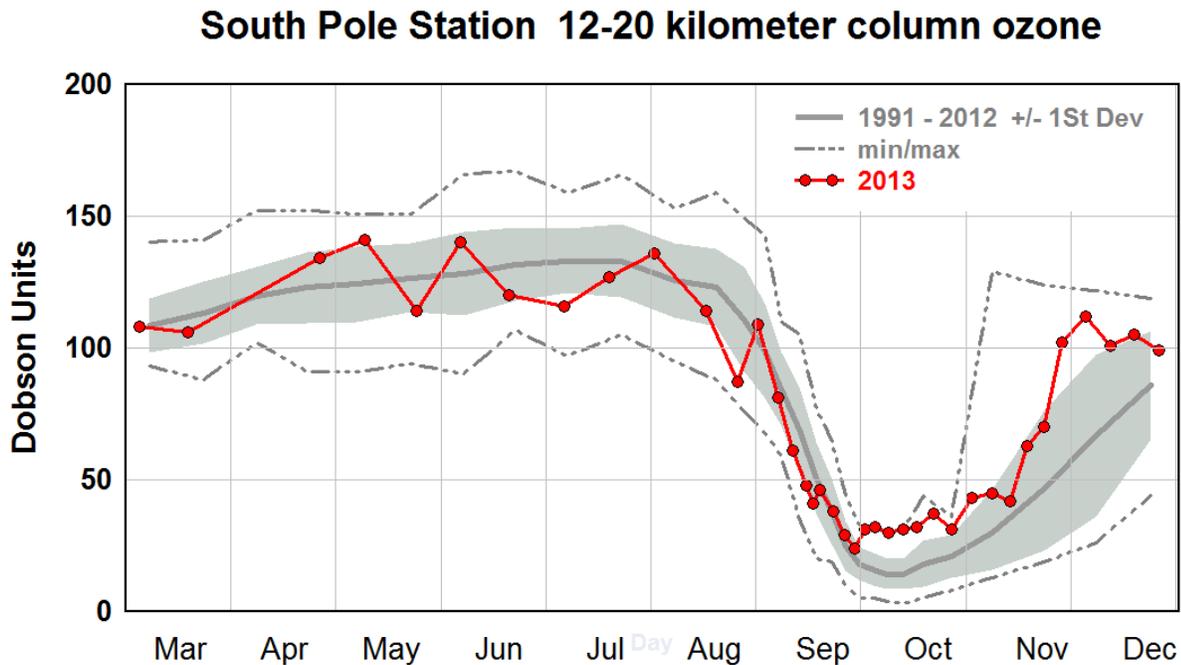


Figure 1. South Pole 12-20 km layer column ozone with min/max and 21-year average ranges.

The Implications of Background O₃ Affecting the Setting and Attainment of the National Ambient Air Quality Standards (NAAQS) for Surface O₃

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Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) periodically reviews National Ambient Air Quality Standards (NAAQS) for pollutants identified as criteria pollutants. Among the criteria pollutants is surface O₃, for which the current standard is under review to determine if the level should be maintained or modified. The Clean Air Act requires that the primary NAAQS be set on the basis of protection of human health with an adequate margin of safety. The current standard is that the 3-year average of the annual 4th highest maximum daily 8-hour average O₃ (MDA8) not exceed 75 parts per billion (ppb). Recent EPA staff recommendations and deliberations by the EPA Clean Air Scientific Advisory Committee Ozone Panel suggest that the standard should be in the range 60-70 ppb. Recent work (Lefohn et al., 2014a; 2014b) has shown that during the spring and early summer U.S. background O₃ (O₃ not contributed by U.S. pollutant emissions) over the western U.S. is a large fraction of measured ambient O₃ at levels <70 ppb. In addition much of the health risk associated with surface O₃ estimated by the EPA is associated with O₃ in the 25-55 ppb range and background O₃ contributes a large percentage in this range. Because of the large contribution of background O₃ to measured O₃ at a number of locations, the ability to meet a standard with a threshold <70 ppb by controlling local or regional emissions will be severely limited.

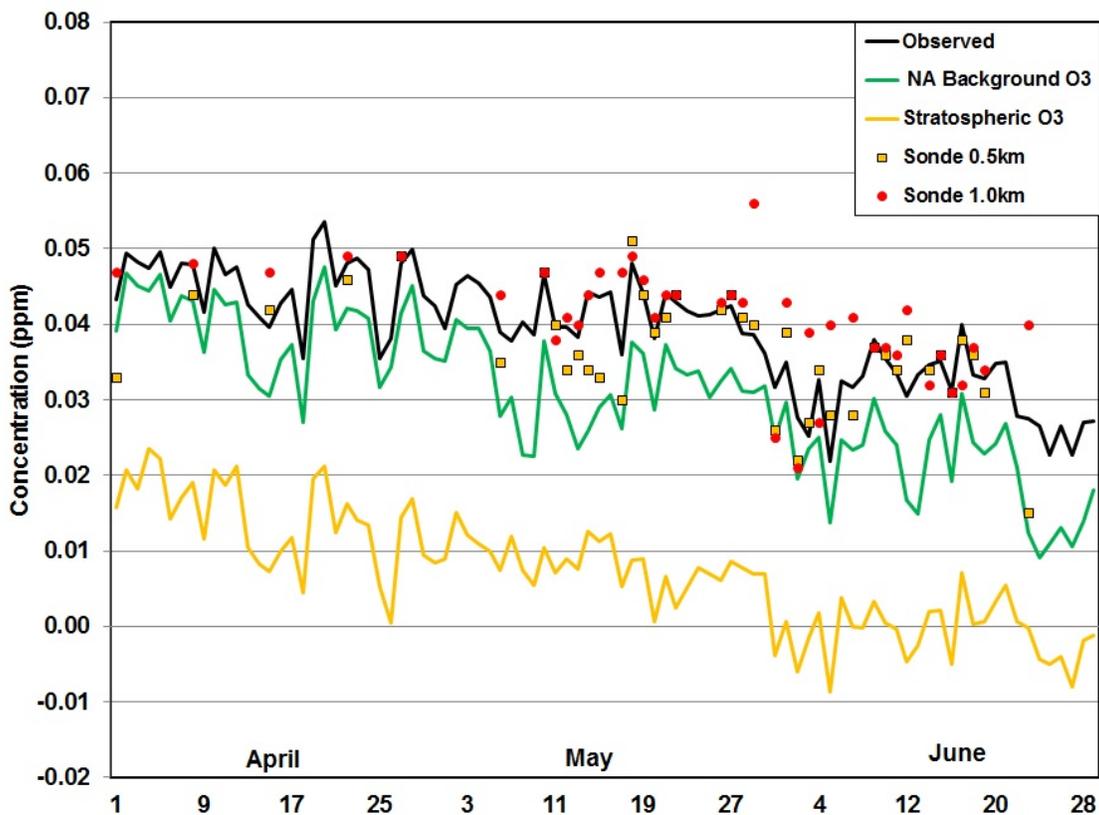


Figure 1. Model derived North American (NA) Background O₃ and stratospheric contribution compared to the observed MDA8 surface O₃ and ozonesondes at Trinidad Head, CA, in April - June 2010. (Lefohn et al., 2014b)

Colorado Front Range Surface Ozone Characterization

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The Colorado Front Range is a unique geographical region for air quality studies, including research of surface level ozone. Surface level ozone is not only a primary contributor to local smog, but leads to public health complications and altered ecosystem functioning. This region of Colorado is currently in a nonattainment status for surface level ozone, due to a variety of contributing factors. The Front Range is undergoing expansion of population, industrial production, and oil and gas extraction as well as enduring dramatic change in the annual wildfire frequency and size. Each of these processes contributes nitrogen oxides (NO_x) and Volatile Organic Carbons to the atmosphere. In the presence of sunlight, these compounds react and create surface level ozone. With the high frequency of sunny days in the Front Range region and increasing rates of pollution, the atmosphere has conditions suitable for production and accumulation of ozone at ground level. In order to understand the dynamics of Front Range ozone accumulation, Thermo Scientific ozone monitors have been continuously sampling from 3 different altitudes since the early 2000s. Analysis of ozone data in relation to NO_x, PAN, CO₂, and back-trajectory air mass origins help to address local pollution sources. With NOAA Hysplit back-trajectory modeling, tropospheric ozone aircraft measurements and complementary *in situ* data sets, increased ozone episodes are scrutinized to determine main sources of precursor emissions that lead to elevated ozone and variability in the long-term trends. Highlighting episodes of high ozone allows for further understanding of Colorado ozone dynamics and can assist in the future regulations on this important pollutant. Colorado ozone climatology and variability is addressed with emphasis on local pollution sources and precursor emissions which lead to elevated ozone episodes.

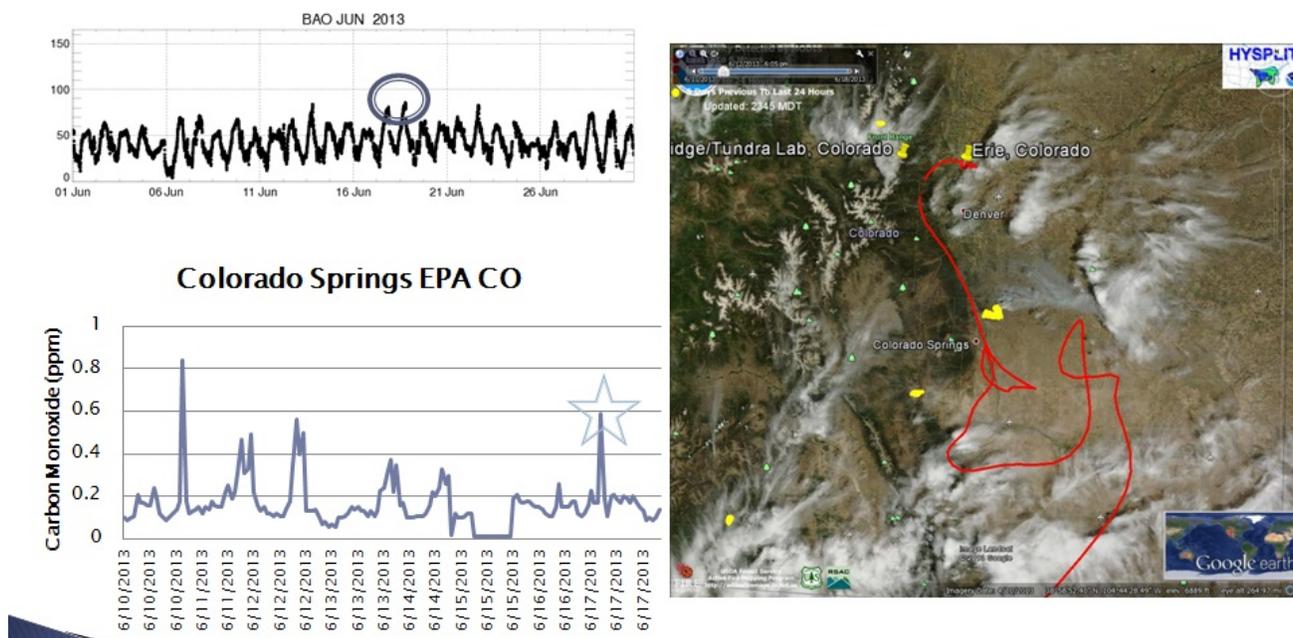
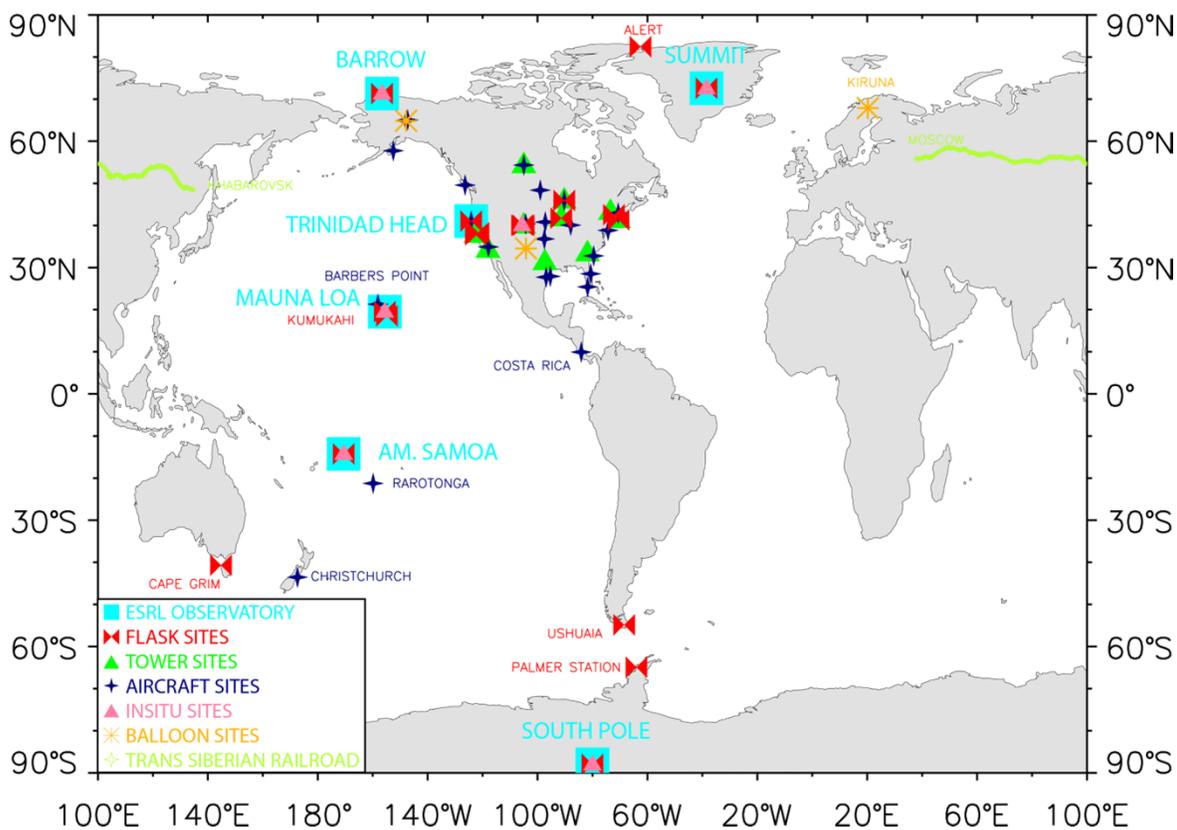
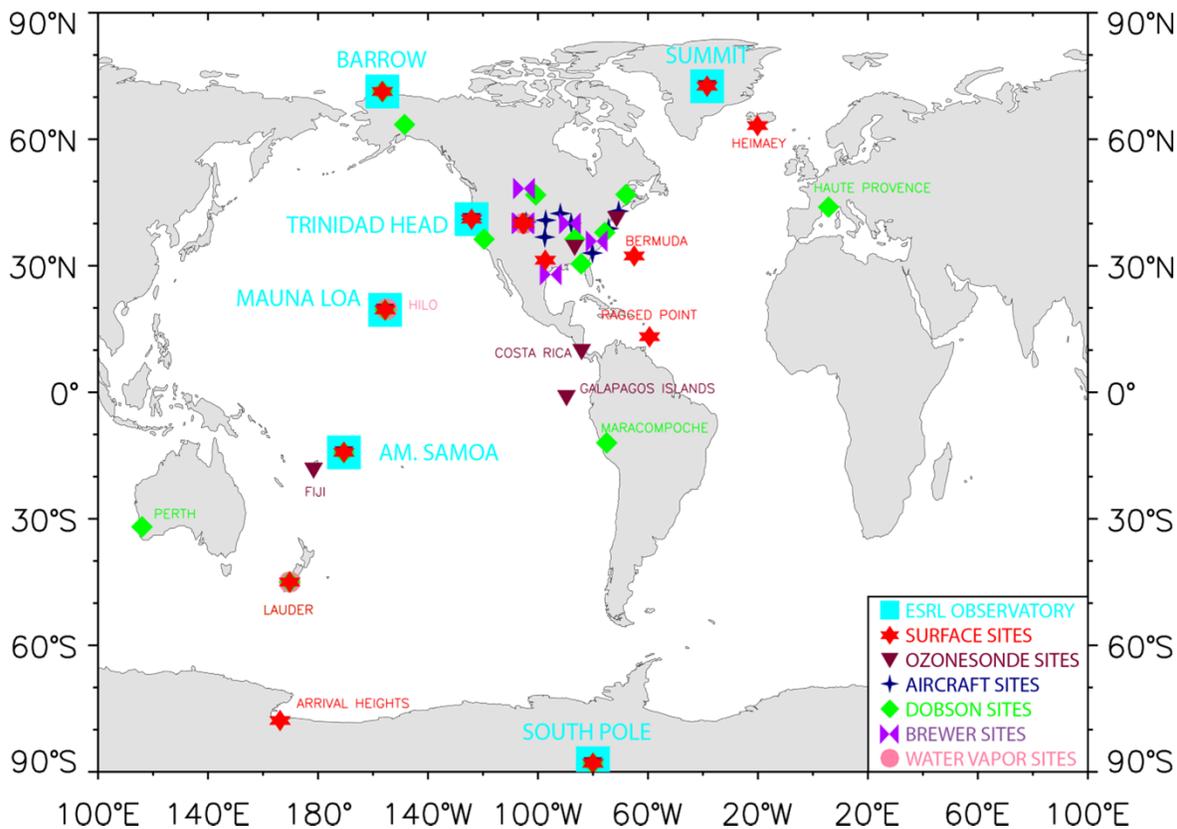


Figure 1. Data from Erie, Colorado shows elevated ozone June 18th and 19th, 2013. NOAA Hysplit back trajectory shows the path of the air mass to the measurement station. The air mass crosses through two major fire plumes 36 hours before entering the measurement site. The EPA Carbon Monoxide data from the Colorado Springs fire area demonstrates how this elevated ozone can be attributed to local forest fire.

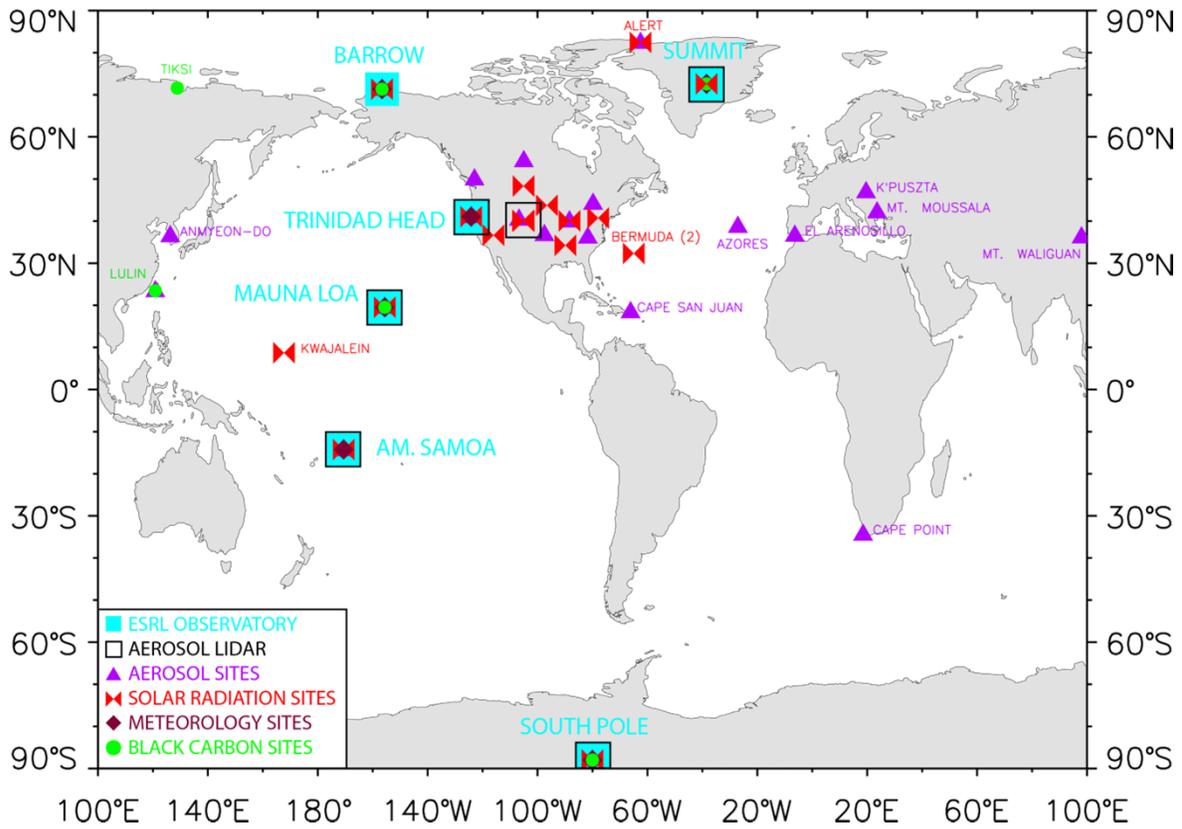
NOAA ESRL Halocarbons and Atmospheric Trace Species



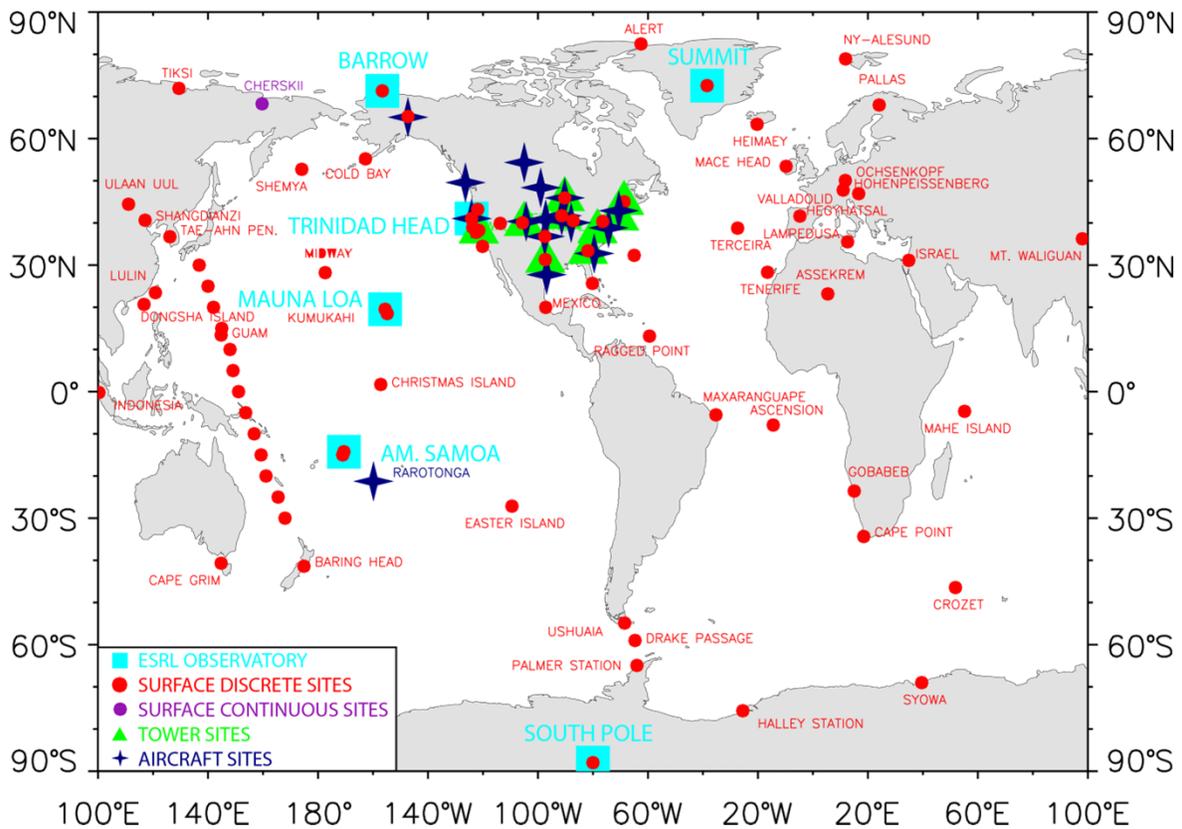
NOAA ESRL Ozone and Water Vapor



NOAA ESRL Aerosols, Solar Radiation, Meteorology and Black Carbon



NOAA ESRL Carbon Cycle Greenhouse Gases





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