Observing the Stratosphere in an Era of Rapid Change: Part II

Monday, July 20, 2020, *8:30 am MDT*

Register for the eGMAC at https://www.esrl.noaa.gov/gmd/annualconference/
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Session Overview: GML maintains long-term UTLS and stratospheric records of water vapor, ozone, and ozone depleting substances, and since 2012, regular records of greenhouse and other trace gases using the AirCore. This session will be focused on all aspects of long-term UTLS and stratospheric observations and change on all timescales, as related to the anthropogenic drivers and associated climate feedbacks in both hemispheres. Attribution of observed and modeled long-term change will be discussed in this session as well as the need for strong and reliable observational constraints. We also emphasize the importance of maintaining long-term atmospheric composition observations in the UTLS and stratosphere with current and future ground-based and spaceborne platforms.

Session Chair: Bianca Baier
Chat Moderator: Arlyn Andrews

All times below are in Mountain Daylight Time (UTC -6).

Time	Title / Abstract	Presenter & Affiliation
08:30-08:35	**Introduction**	**Bianca Baier**
08:35-08:50	Determining the Strength of the Stratospheric Circulation from Satellite Observations of Trace Gases	**Marianna Linz** Harvard University
08:50-09:05	Vertical Profile Observations of Greenhouse Gases and Their Isotopic Compositions Using AirCore & LISA	**Huilin Chen** University of Groningen
09:05-09:20	Investigating Stratospheric Changes Between 2009 and 2018 with Aircraft, AirCores, and a Global Model Focusing on CFC-11	**Johannes Laube** Institute of Energy and Climate Research
09:20-09:35	NOAA/GML Stratospheric Sampling Using AirCores: Routine Measurements, Satellite Validation and Model Evaluation	**Bianca Baier** NOAA Global Monitoring Laboratory and CIRES
09:35-09:45	**Break**	

09:45-10:00	Recent Advances in Stratospheric Monitoring Using Balloon-borne Sondes	**Dale Hurst** NOAA Global Monitoring Laboratory and CIRES
10:00-10:15	The Portable Optical Particle Spectrometer and the Value for Stratospheric Aerosol Research	**Lizzy Asher** NOAA Chemical Sciences Laboratory and CIRES
10:15-10:30	From the Upper Troposphere Through the Stratosphere: How Satellite Measurements Help Us Decode the Past to Better Project the Future	**Luke Oman** NASA Goddard Space Flight Center
10:30-10:45	Discussion and Wrap up	**Bianca Baier**

SESSION ABSTRACTS

Observing the Stratosphere in an Era of Rapid Change: Part II

08:35-08:50 Marianna Linz, Harvard University, Cambridge, MA, USA

Title: Determining the Strength of the Stratospheric Circulation from Satellite Observations of Trace Gases

Abstract: Transport in the stratosphere is critical for shaping the distributions of water vapor and ozone, which impact radiation and human health. Quantifying the transport from observations is very difficult, however. I will show a simplified framework that allows quantification of both the slow meridional overturning and the horizontal mixing using the idealized tracer "age of air". Age is the time since an air parcel entered the stratosphere at the tropical tropopause. Although this is an idealized tracer, we can calculate it from observations from three satellite instruments (Microwave Limb Sounder, the Atmospheric Chemistry Experiment Fourier Transform Spectrometer, and the Michelson Interferometer for Passive Atmospheric Sounding) and in situ aircraft and balloon data. The strength of the overturning circulation at 460 K is 6.3-7.6 $x10^9$ kg/s, and the mixing efficiency is ~0.75, though the mixing efficiency is far less certain. I will also show a preliminary time series of the overturning strength and a comparison with the WACCM model.

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08:50-09:05 Huilin Chen, University of Groningen, Groningen, Netherlands

Title: Vertical Profile Observations of Greenhouse Gases and Their Isotopic Compositions Using AirCore & LISA

Abstract: AirCore is a useful tool to sample the atmosphere from the surface up to the balloon burst altitude of ~30 km for profile measurements of greenhouse gases. Due to its large vertical coverage, the profile measurements are suitable for evaluating the total column measurements from the ground-based Total Carbon Column Observing Network (TCCON) Fourier-transform infrared spectrometers (FTIRs) and satellite retrievals. Within the EU-funded Readiness of Integrated carbon observation system (ICOS) for Necessities of integrated Global Observations (RINGO) project, vertical profile measurements have been explored using both AirCores and the TCCON FTIRs to enhance

the link between ICOS ground-based stations, TCCON, and satellite measurements. Furthermore, valuable AirCore stratospheric air samples have been used for the analyses of isotopic compositions. Moreover, a lightweight stratospheric air (LISA) sampler has been developed and used for isotopic composition measurements of carbon monoxide, and demonstrated to be useful in characterizing the 2017 wildfire smoke in the stratosphere.

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09:05-09:20 Johannes Laube, Institute of Energy and Climate Research: Stratosphere, Jülich Research Centre, Jülich, Germany

Title: Investigating Stratospheric Changes Between 2009 and 2018 with Aircraft, AirCores, and a Global Model Focusing on CFC-11

Abstract: We present new observations of trace gases in the stratosphere based on the NOAA AirCore technique. The further development of this method now provides detection of species with abundances in the parts per trillion (ppt) range and less. We focus on mixing ratios for the ozone-depleting substances CFC-11, CFC-12, H1211 and HCFC-22 which can also be used for understanding stratospheric circulation. After demonstrating the quality of the data through comparisons with ground-based records and aircraft-based observations we combine them with the latter to demonstrate their potential. We first compare them with results from a global model driven by three widely used meteorological reanalyses (ERA-Interim, JRA-55, MERRA-2). Secondly, we focus on CFC-11 as recent evidence has indicated renewed atmospheric emissions of that species relevant on a global scale. Because the stratosphere represents the main sink region for CFC-11, potential changes in stratospheric circulation and troposphere-stratosphere exchange fluxes have been identified as the largest source of uncertainty for the accurate quantification of such emissions. Our observations span over a decade (up until 2018) and therefore cover the period of the slowdown of CFC-11 global mixing ratio decreases measured at the Earth's surface. The spatial and temporal coverage of the observations is insufficient for a global quantitative analysis, but we do find some trends that are in contrast with expectations; indicating that the stratosphere may have contributed to tropospheric changes, and not just in the case of CFC-11. Further investigating the model data we find that the required dynamical changes in the stratosphere required to explain the apparent change in tropospheric CFC-11 emissions after 2013 are possible, but with a very high uncertainty range in the change of stratosphere-to-troposphere flux of CFC-11. This is partly caused by the high variability of mass flux estimates from the stratosphere to the troposphere, especially at time scales of a few years, and partly by large differences between runs driven by different reanalysis products, none of which agree with our observations well enough for such a quantitative analysis.

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09:20-09:35 Bianca Baier, NOAA Global Monitoring Laboratory and Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, CO, USA

<u>Title</u>: NOAA/GML Stratospheric Sampling Using AirCores: Routine Measurements, Satellite Validation and Model Comparisons

<u>Abstract</u>: For over a decade, NOAA/GML has been sampling over 98% of the atmospheric column using the AirCore, a patented, balloon-borne sampling system, which collects whole air samples from the surface to the lower stratosphere (~30km) at better than 10 mb. To-date, over 100 profiles of carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO) have been measured by NOAA/GML researchers from select profiling locations worldwide. The AirCore also provides an important linkage between ground- and satellite-based greenhouse gas retrievals and long-term, ground-based observational networks through calibrated profiles that are traceable to World Meteorological Organization (WMO) scales. In this talk, we detail recent NASA Orbiting Carbon Observatory (OCO-2) column CO_2 retrieval evaluation efforts to improve the compatibility of these spaceborne retrievals to ground-based observing networks using the AirCore. Because these samples provide unique routine in situ measurements of CO_2 and CH_4 in the stratosphere, we also discuss ongoing AirCore-based evaluation of stratospheric trace gas species in models such as NOAA's CarbonTracker system and other stratospheric models. Finally, with an eye towards future sampling, we highlight several new developments in NOAA/GML AirCore sampling during the past decade – and measurements of these whole-air samples – as well as new atmospheric profiling platforms that offer strategies for significant expansion of profiling locations around the world.

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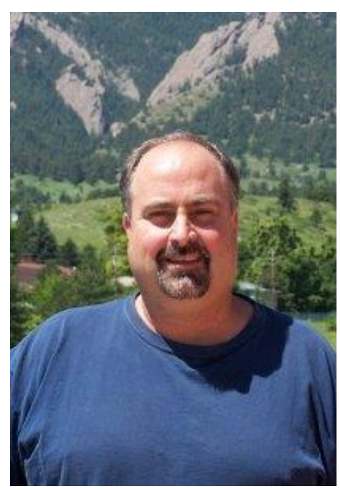
09:45-10:00 Dale Hurst, NOAA Global Monitoring Laboratory and Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, CO, USA

<u>Title:</u> Recent Advances in Stratospheric Monitoring Using Balloon-borne Sondes



<u>Abstract:</u> Over the past decade there has been a significant expansion in both the number and capabilities of programs designed to monitor the global stratosphere. Many of these recent advances are built upon the inception, development and sophistication of lightweight, compact instruments (sondes) that can be carried by small meteorological balloons. For example, the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) was conceived more than 10 years ago to provide long-term, climate-quality measurement records of atmospheric state variables and composition in the UTLS. The network now includes 28 sites on 5 continents that observe GRUAN-recommended best measurement practices and submit their raw and meta data to centralized processing facilities. More mature networks (e.g., NDACC, SHADOZ) have developed a strong reliance on

balloon-borne in situ measurements that consistently produce high-resolution vertical profiles of stratospheric ozone and water vapor. Now, more than ever before, instrumented balloons are being launched in coordination with satellite overpasses to validate stratospheric composition measurements by space-based remote sensing instruments. One of the initial steps in NOAA's new Earth Radiation Budget program is to compile climatologies of stratospheric aerosol number and size distributions along with ozone and water vapor profiles, via twice monthly balloon soundings at Boulder.

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10:00-10:15 Elizabeth (Lizzy) Asher, NOAA Chemical Sciences Laboratory and Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, CO, USA

Title: The Portable Optical Particle Spectrometer and the Value for Stratospheric Aerosol Research

Abstract: The potential for future anthropogenic perturbations to stratospheric aerosol from increased rocket emissions or intentional climate intervention, and reoccurring natural perturbations from volcanic eruptions and extremely large fires requires that we better characterize stratospheric aerosol microphysics to accurately predict the atmospheric and climate impacts. To achieve this goal, frequent observations of aerosol size distributions in the stratosphere over a range of latitudes are required. Here, we discuss a new, robust instrument ideally suited to monitor aerosol size distributions in the stratosphere, the Portable Optical Particle Spectrometer (POPS). This small, lightweight, semi-disposable instrument has low power consumption and measures the number concentration and sizes of particles between 140 – 2500 nm in diameter (Gao et al. 2016). In January 2019, POPS became a regular addition to NOAA's Global Monitoring Laboratory payloads on meteorological balloons launched from Boulder, CO and Lauder, NZ as part of the SAGE III/ISS satellite validation project. We present preliminary data from both the northern and southern Hemispheres in 2019 - 2020 related to the perturbations to stratospheric aerosol following volcanic eruptions and stratospheric injections from extremely large fires. Finally, we note a few of the anticipated advantages of the increased measurements as part of the Balloon Baseline Stratospheric Aerosol Profiles (B^2SAP) project, which will extend this measurement program in support of support of NOAA Earth Radiation Budget science goals.

Gao, R. S., et al., A light-weight, high-sensitivity particle spectrometer for PM2.5 aerosol measurements, Aerosol Science and Technology, 50, 88-99, 2016.

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10:15-10:30 Luke D. Oman, NASA Goddard Space Flight Center, Greenbelt, MD, USA

<u>Title:</u> **From the Upper Troposphere Through the Stratosphere: How Satellite Measurements Help Us Decode the Past to Better Project the Future**

<u>Abstract:</u> Decades of observations of key chemical species are allowing us to more fully understand processes important to transport and composition from the upper troposphere through the stratosphere. This talk will focus on a few examples and how they are informing our understanding of variability, trends, and future projections. The growth of the Antarctic ozone hole (late 1970s – mid 1990s) caused a dynamical perturbation to the Southern Hemisphere stratospheric circulation visible in ozone, one of our longest and best observed chemical constituents, and illustrates the connection between chemical change and the coupled radiative and dynamical response that challenges chemistry-climate models (CCMs). The quasi-biennial oscillation (QBO) is the dominant mode of interannual variability in the tropical stratosphere, however its impacts on stratospheric circulation and composition can be traced globally. The QBOs timing with respect to the seasonal cycle in each hemisphere is significant in understanding its impact on up to decadal scale variability. The El Nino Southern Oscillation (ENSO), which dominates tropical tropospheric interannual variability, also affects the stratosphere and its influence is visible in our growing record of tropospheric and stratospheric composition measurements. I will discuss how our knowledge of response has grown and how representation of these observed responses in CCMs is key both to understanding recent trends and to reducing uncertainty in future changes of composition.

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