

## UP 2: Atmosphere - trace gases, Methods - remote sensing

Time: Monday 10:45–12:30

Location: G 1.011

**Invited Talk**

UP 2.1 Mon 10:45 G 1.011

**Remote Sensing of Greenhouse Gases from Ground and Space** — ●ANDRÉ BUTZ — Institut für Physik der Atmosphäre, Deutsches Zentrum für Luft- und Raumfahrt e.V., Oberpfaffenhofen — Insitut für Umweltphysik, Universität Heidelberg

Understanding the sources and sinks of the greenhouse gases carbon dioxide and methane is key to projecting future climate. It is the respective man-made emissions that drive climate change and, it is the climate-carbon feedbacks that are among the largest uncertainties.

Here, I will review recent progress in ground-based and space-based remote sensing of carbon dioxide and methane. A particular focus will be on ground-based spectroscopic techniques that we deployed on mobile platforms at source regions such as the Mt. Etna volcano, Italy, and the Upper Silesian Coal Basin, Poland. Volcanic carbon dioxide emissions could be reliably detected at distance of 5-10 km from the crater at detection levels of about 1/1000 of the background concentration showcasing the excellent accuracy achievable in the field. Methane emissions from coal mining in Poland were found to be among the largest localized methane sources in Europe. Another focus will be on current and next-generation greenhouse gas satellite sounders and the challenges for reliable concentration retrievals. Current satellites such as GOSAT have been shown to provide robust information on climatically driven carbon cycle anomalies on sub-continental scales. Next-generation satellites will aim at improved sampling density and resolution to constrain regional-scale sources and sinks.

UP 2.2 Mon 11:15 G 1.011

**Quantitative analysis of complex CH<sub>4</sub> sources using airborne remote sensing and in-situ observations** — ●SVEN KRAUTWURST, KONSTANTIN GERIŁOWSKI, THOMAS KRINGS, JAKOB BORCHARDT, MICHAEL BUCHWITZ, JOHN P. BURROWS, and HEINRICH BOVENS-MANN — Institute of Environmental Physics, University of Bremen, Germany

Methane (CH<sub>4</sub>) is the second most important anthropogenic greenhouse gas. However, its anthropogenic emissions, largely originating from localized sources such as fossil fuel exploitation and extraction sites or landfills, are often not readily assessed by current measurement systems and networks. A tool used to better understand and constrain emissions from these sources is the optical remote sensing instrument MAMAP (Methane Airborne MAPper), operated from aircraft. MAMAP delivers the background normalized column averaged dry air mole fractions for methane XCH<sub>4</sub> derived from absorption spectroscopic measurements in the short-wave infrared with a precision of about 0.3%.

This talk presents MAMAP observations accompanied by airborne in-situ measurements by a Picarro greenhouse gas in-situ analyser aboard the same aircraft over oil fields and landfills in California in 2014. Based on the two data sets, independent emission rate estimates for an oil field complex in the San Joaquin Valley and a landfill in the Los Angeles Basin were derived and compared to inventory values.

UP 2.3 Mon 11:30 G 1.011

**Methane retrieval and interpretation using high spatial resolution hyperspectral radiances obtained by aircraft measurements** — ●JAKOB BORCHARDT, KONSTANTIN GERIŁOWSKI, SVEN KRAUTWURST, MICHAEL BUCHWITZ, THOMAS KRINGS, HEINRICH BOVENS-MANN, and JOHN P. BURROWS — Institute of Environmental Physics, University of Bremen, P.O. 330440, 28334 Bremen, Germany

Methane (CH<sub>4</sub>) is an important greenhouse gas whose sources and sinks on regional scale are not well quantified. Science grade hyperspectral imaging spectrometers allow for source attribution with high spatial resolution ( $\lesssim 4 \times 4 \text{ m}^2$ ). The quantitative retrieval of methane (CH<sub>4</sub>) total column variations with the "Weighting Function Modified - DOAS" algorithm (WFM-DOAS) originally developed for medium to high spectral resolution instruments ( $\lesssim 1 \text{ nm}$ ) was successfully applied to the lower spectral resolution ( $\geq 5.5 \text{ nm}$ ) hyperspectral data. One source under investigation was a coal mine ventilation shaft located in the Four Corners region, which is known for its high CH<sub>4</sub> emissions. In this talk, the adaptation of the WFM-DOAS algorithm to imaging spectroscopy measurements and the flux inversion using a mass balance approach for that source will be presented. Also a qualitative comparison with measurements taken with a commercial off-the-shelf

hyperspectral sensor over coal mine ventilation shafts in silesia will be shown.

UP 2.4 Mon 11:45 G 1.011

**Precise, direct, simultaneous spectroscopic measurements of CO<sub>2</sub> singly- and doubly-substituted isotopologues** — ●IVAN PROKHOROV<sup>1,2</sup>, TOBIAS KLUGE<sup>1</sup>, and CHRISTOF JANSSEN<sup>1,2</sup> — <sup>1</sup>Institute of Environmental Physics, Heidelberg University, Heidelberg, Germany — <sup>2</sup>LERMA-IPSL, Sorbonne University, UPMC Univ. Paris 06, CNRS, Observatoire de Paris, PSL Research University, Paris, France

The <sup>17</sup>O/<sup>18</sup>O anomaly ( $\Delta^{17}\text{O}$ ) and the "clumped isotope" composition  $\Delta_{16\text{O}13\text{C}18\text{O}}$  in CO<sub>2</sub> are new tools for quantification of temperature dependent equilibrium and non-equilibrium processes in a variety of environmental systems, requiring the analysis of multiple carbon dioxide isotopologues. Here, we present a laser-based measurement technique for precise, direct and simultaneous measurements of the six most abundant CO<sub>2</sub> isotopologues, including the two rare and doubly-substituted species <sup>16</sup>O<sup>13</sup>C<sup>18</sup>O and <sup>16</sup>O<sup>13</sup>C<sup>17</sup>O. The prototype absorption spectrometer uses two intra-band cascade lasers (ICL) at 4.3 and 4.4  $\mu\text{m}$  to detect CO<sub>2</sub> absorption lines in the fundamental  $\nu_3$  band. Dry pure carbon dioxide samples ( $\leq 100 \mu\text{mol}$ ) are analysed in a custom built multipass Herriot cell equipped with two optical path lengths of 9 cm and 9 m. A full operation cycle consists of several comparisons of the sample gas with the working reference (6–10 minutes per one comparison). Within one hour of measurements, a reproducibility at the level of 50 ppm (1SEM) is obtained. The performance of the instrument is comparable with the state of the art mass-spectrometers, but void of isobaric interferences.

UP 2.5 Mon 12:00 G 1.011

**Retrieval advances of BrO/SO<sub>2</sub> molar ratios from NOVAC** — ●ELSA WILKEN<sup>1</sup>, FLORIAN DINGER<sup>1,2</sup>, NICOLE BOBROWSKI<sup>1,2</sup>, SIMON WARNACH<sup>1,2</sup>, and ULRICH PLATT<sup>1,2</sup> — <sup>1</sup>IUP, University of Heidelberg — <sup>2</sup>Max-Planck Institute for Chemistry, Germany

Measurements of magnitude and composition of volcanic gas emissions allow insights in magmatic processes. Within the Network for Observation of Volcanic and Atmospheric Change (NOVAC) automatically scanning UV-spectrometers are monitoring gas emission at volcanoes. The emissions of BrO and SO<sub>2</sub> can be retrieved from the recorded spectra by applying Differential Optical Absorption Spectroscopy (DOAS) and comparing the optical absorption of the volcanic plume to the background. Therefore, the background spectrum must not be affected by volcanic influence. Classically, the background spectrum is taken from the same scan but from an elevation angle which has been identified to be outside of the volcanic plume. However, experience shows those background spectra can still be contaminated by volcanic gases. Alternatively reference spectra can be derived from 1) a theoretical solar atlas spectrum or 2) a volcanic-gas-free reference spectrum recorded by the same instrument. 1) comes with a drawback of reduced precision, as the instrumental effects have to be modeled and added to the retrieval. For 2), the alternative reference spectrum should be recorded at similar conditions with respect to meteorology and radiation. We use 1) to check for contamination and 2) to evaluate the spectra to maintain a good fit quality. We present our approach and its results when applied on NOVAC data from Tungurahua and Nevado Del Ruiz.

UP 2.6 Mon 12:15 G 1.011

**BrO/SO<sub>2</sub> variations in the volcanic gas plumes of Cotopaxi and Tungurahua** — ●FLORIAN DINGER<sup>1,2</sup>, NICOLE BOBROWSKI<sup>1,2</sup>, SIMON WARNACH<sup>1,2</sup>, STEFAN BREDEMAYER<sup>3</sup>, SILVANA HIDALGO<sup>4</sup>, SANTIAGO ARELLANO<sup>5</sup>, BO GALLE<sup>5</sup>, ULRICH PLATT<sup>1,2</sup>, and THOMAS WAGNER<sup>1</sup> — <sup>1</sup>MPIC, Mainz, Germany — <sup>2</sup>IUP, Heidelberg, Germany — <sup>3</sup>GEOMAR, Kiel, Germany — <sup>4</sup>IGEPN, Quito, Ecuador — <sup>5</sup>CTH, Gothenburg, Sweden

Variations of the BrO/SO<sub>2</sub> ratio in volcanic gas plumes have been proposed as a proxy for volcanic activities. We present and discuss BrO/SO<sub>2</sub> data measured via remote sensing at Tungurahua and Cotopaxi. At Tungurahua, BrO/SO<sub>2</sub> ratios varied from  $< 1 \cdot 10^{-5}$  to  $16 \cdot 10^{-5}$  between 2007 and 2017. Lower ratios have been predominantly observed at periods when the seismic activity elevated as it

has been observed at other volcanoes, such as Nevado del Ruiz and Etna. In 2015, Cotopaxi awoke from a 72-years period of relative quiescence. The BrO/SO<sub>2</sub> ratios in Cotopaxi's gas plume were  $< 1 \cdot 10^{-5}$  from May 2015 until the week after the phreatomagmatic explosions in August 2015 and increased to a mean value of  $4 \cdot 10^{-5}$  in the period from September to December 2015. This change partially correlates

with the evaporation of the hydrothermal system prior to October 2015. Further, during the period from September to December 2015 the BrO/SO<sub>2</sub> ratios oscillated between  $2$  and  $8 \cdot 10^{-5}$  with a conspicuous periodic pattern of a period of 13.7 days. We found a partial correlation between BrO/SO<sub>2</sub> and the tide-induced surface displacement in North-South direction with a correlation coefficient of 47%.