**Name of research institute or organization:**

Institut d’Astrophysique et de Géophysique, Université de Liège

**Title of project:**

High resolution, solar infrared Fourier Transform spectrometry. Application to the study of the Earth atmosphere

**Part of this programme:**

NDACC (Network for the Detection of Atmospheric Composition Change)
GAW (Global Atmospheric Watch)

**Project leader and team:**

Christian Servais (project leader), Whitney Bader, Olivier Flock, Emmanuel Mahieu, Maxime Prignon, Ginette Roland (em.), Vincent Van De Weerdt, Diane Zander

**Project description:**

The team’s objectives are essentially twofold: (i) improve the performance of the instrumentation and perform the observations, (ii) analyse the spectra in order to produce high-level geophysical parameters and valorize them.

In 2017, observations have been performed on site or recorded through a remote-control web interface. Altogether, a little less than 1500 high resolution infrared solar spectra have been collected on 72 days. The significant decrease in the recording frequency mainly results from the reduction in available manpower.

<table>
<thead>
<tr>
<th>Greenhouse gases</th>
<th>H₂O, CO₂, CH₄, N₂O, CF₄, SF₆</th>
<th>Support to the Paris Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone-related</td>
<td>O₃, NO, NO₂, HNO₃, ClONO₂, HCl, HF, COF₂, CFC-11, CFC-12, HCFC-22, HCFC-142b, CCl₃, CH₂Cl</td>
<td>Support to the Montreal Protocol</td>
</tr>
<tr>
<td>Air quality</td>
<td>CO, CH₃OH, C₂H₆, C₂H₂, C₂H₄, HCN, HCHO, HCOOH, NH₃</td>
<td>Support to the EU-Copernicus programme</td>
</tr>
<tr>
<td>Other</td>
<td>OCS, N₂, various isotopologues</td>
<td></td>
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</tbody>
</table>

*Table 1. List of atmospheric species currently retrieved from the Jungfraujoch observational database.*

Analysis of our spectra allows us to determine the abundance of an increasing number of constituents of the Earth atmosphere (currently more than 30; see Table 1), playing a role in ozone depletion, climate change or affecting air quality. Numerous target species are therefore relevant to the Montreal Protocol on substances that deplete stratospheric ozone (e.g. CFCs, HCFCs, HCl) and/or to the Paris Agreement (COP21) to combat climate change (e.g. CO₂, CH₄, N₂O). In 2017, the team notably published a study on the recent evolution of methane at 10 ground-based FTIR sites. It is briefly presented in the next section. For a complete view of the team’s scientific output in 2017, the reader is invited to consult the literature (see the “Refereed journal articles” section).

**Recent evolution of atmospheric methane from FTIR observations and GEOS-Chem simulations at 10 NDACC stations**

Methane is the second most abundant anthropogenic greenhouse gas after carbon dioxide, with a total radiative forcing of 0.97±0.23 W/m². Approximately one-fifth of the increase in radiative forcing by human-related greenhouse gases since 1750 is due to methane. Numerous natural and anthropogenic emission sources have been identified, contributing to a rising
abundance of atmospheric methane. The long-term trend of methane has been characterized by a plateau over 2000-2004, followed by an increase since then, both features still unexplained.

Our objective was to characterize the recent methane trend and compare FTIR (Fourier Transform InfraRed) observations with synthetic time series produced by the GEOS-Chem 3-D Chemistry Transport model (version 9-02) on a 2° x 2.5° horizontal grid, using a tagged offline simulation. This simulation accounts for the respective contribution of each emission source (biomass burning, biofuels, coal, livestock, gas & oil, rice cultures…) and one sink (soil absorption) in the total methane, on the basis of the most representative emissions inventories currently available (e.g., EDGAR v4.2, GFED3) and implements assimilated
meteorological fields from the Goddard Earth Observing System version 5 (GEOS-5) of the NASA Global Modeling Assimilation Office (GMAO). Finally, monthly OH 3-D fields from an independent full-chemistry run of GEOS-Chem are assumed.

Ground-based FTIR observations collected at 10 sites of the NDACC (Network for the Detection of Atmospheric Composition Change) from 80ºN to 77.8ºS have been used, to get a global view of the evolution of methane over the 2005-2014 time period. Relative annual growth rates ranging from 0.26 (±0.02; 2-σ) to 0.39 (±0.08) %/yr have been determined, with a global mean increase of 0.31 (±0.03) %/yr. These values are in good agreement with the mean annual change of 0.31 (±0.01) %/yr from the surface in situ sampling networks.

Trends have also been derived from the GEOS-Chem time series, accounting for the vertical resolution and sensitivity of the FTIR measurements characterized for each site by their averaging kernel matrices. A very good agreement is generally observed between the modeled and observed trends. The tagged simulation provides the contribution of each category/tracer to the recent CH₄ accumulation (see Fig. 1). A detailed analysis indicates that natural emissions from wetlands and biomass burning are the main drivers of the inter-annual variability of methane surface emissions. Another finding is that the coal and the gas & oil emissions both rank as the most important anthropogenic contributors to methane changes for all stations. In fact, the coal and the gas & oil tracers contributed a third (32 %) and almost a fifth (18 %) of the cumulative increase of methane over the 2005-2012 time period while their respective emissions are responsible for only 7.5 and 12.5 % of the methane budget.

Although we showed that GEOS-Chem agrees with our observations, we cannot rule out that some compensations between the various emission categories as implemented in the best available inventories we used could be at play. Given the emission source shared by both ethane and methane and several recent ethane studies, it is clear that anthropogenic methane inventories associated with fossil fuel and natural gas production are subject to improvement. More details are available in Bader et al. (2017).

Key words: Earth atmosphere, climate change, greenhouse gases, ozone layer, air quality, long-term monitoring, infrared spectroscopy, atmospheric circulation

Internet data bases:
Consolidated geophysical data are available from NDACC: ftp://ftp.cpc.ncep.noaa.gov/ndacc/station/jungfrau/hdf/ftir/

Collaborating partners/networks:
Main collaborations: BIRA-IASB (Institut d’Aéronomie Spatiale de Belgique) / NDACC (Network for the Detection of Atmospheric Composition Change; http://www.ndacc.org) / GAW-CH / ACE science team / NASA JPL / Empa / University of Leeds / IMK (Forschungszentrum Karlsruhe) / satellite experiments: IASI, OMI, ENVISAT / …

Scientific publications 2017:
The complete list of the GIRPAS peer-reviewed publications can be found at http://labos.ulg.ac.be/girpas/en/publications

Refered journal articles and their internet access


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