

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

Project leader and team:

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Observatoire Royal de Belgique:
Jacques Sauval, Ronnie Blomme, Joan Vandekerckhove.

Project description:

The main activity of the Liège group at the Jungfraujoch was the continuation of the long-term monitoring of the Earth atmosphere. The two high-performance infrared spectrometers allowed to routinely derive total abundances of more than 20 constituents: gases related to the erosion of the ozone layer in the stratosphere (HCl, ClONO₂, HNO₃, NO, NO₂, HF, COF₂, O₃, ...), greenhouse gases monitored in the frame of the Kyoto protocol (N₂O, CH₄, CO₂, SF₆, CCl₂F₂, CHClF₂, ...) and gases affecting the oxidization processes in the troposphere (CO, C₂H₂, C₂H₆, OCS, HCN, H₂CO, ...)

During 2002, 294 days were spent at the Jungfraujoch by observers from Liège and from the Observatoire Royal de Belgique. Good weather conditions enabled observations on 138 days.

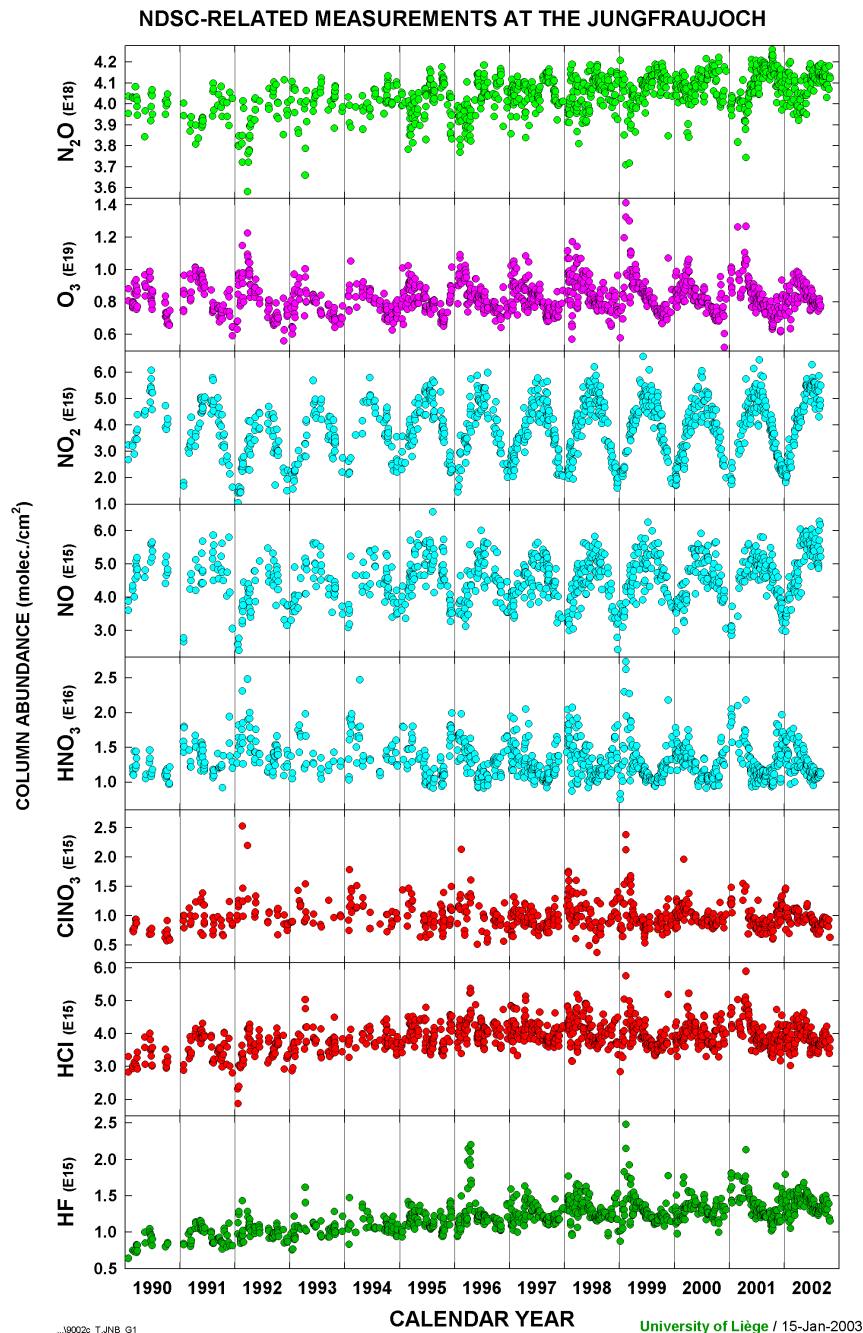
The figure on next page reproduces an excerpt of the databases derived from the analysis of observations carried out at the station; it shows, for the period 1990-2002, daily averaged vertical column abundances of seven stratospheric species (HF, HCl, ClONO₂, HNO₃, NO, NO₂ and O₃), as well as those of the long-lived source gas N₂O which is used as a tracer of atmospheric circulation and dynamics. These databases allow to determine short-term variability, seasonal modulations (easily seen on the graph for ozone, NO and NO₂), as well as long-term changes affecting most of these species. Short-term variability, which occurs mainly during the winter-spring-time period, is also noticeable in the figure: for example, during the first part of 1999, we have observed intrusions of Arctic polar air over the station, characterized by record-high values for O₃, HNO₃, ClONO₂, HCl and HF, anti-correlated with low N₂O columns.

We continued to evaluate the budget of chlorine- fluorine- and nitrogen-containing species. The analysis confirms, for example, that the chlorine content of the atmosphere has leveled off during the late 1990s and starts to decrease, as a result of the restrictions imposed by the Montreal Protocol and its successive amendments on the production of chlorine-bearing source gases.

For a number of the species listed above, a complete re-analysis of the archived spectra is currently under way, with a new retrieval algorithm that provides some

information on the distribution of the molecules versus altitude. This new tool will provide partial abundances as well as more accurate column densities.

The software has also been modified to accept much wider spectral intervals (up to 50 cm^{-1}), in order to analyze heavy molecules like CFCs, HCFCs and other new substitutes. Tests performed in the case of CFC-11 (CCl_3F) are in progress. The spectral region where CCl_4 absorbs is strongly affected by the "line-mixing" effect in an interfering CO_2 band. The implementation of this effect in the software will now allow us to study CCl_4 .



From July to December 2002, we participated to the calibration/validation campaign of 3 instruments (MIPAS, SCIAMACHY and GOMOS) aboard the European satellite Envisat. During this period, we provided to the calibration team, in quasi real time, 3426 total abundances measured at the Jungfraujoch, distributed over 69 days. For this purpose, we had to automate some tasks, such as the transfer of the spectra from

the station to Liège, the analysis of the data, while ensuring the reliability of the results.

The solar spectrum reveals spectral features interfering with the atmospheric absorption signatures of interest. It is thus desirable to take the solar spectral features into account in the modeling of atmospheric transmission spectra. To this end, high-resolution measurements pointing at the center and at the limb of the solar disk have been recorded at the Jungfraujoch with the homemade FTS. These observations have then been used to validate a model of the solar lines in the mid-infrared developed by F. Hase (IMK Karlsruhe) and G. Toon (JPL Pasadena). The model estimates center-to-limb variations of the area and width of each line.

A camera has been fixed on the sun tracker: the status of the sky around the sun can now be checked from any computer on the Jungfraujoch network.

Key words:

Earth atmosphere, ozone layer, greenhouse gases, long-term monitoring, infrared spectrometry

Internet data bases:

<http://www.nilu.no/nadir/>, <ftp://ozone.wwb.noaa.gov/pub/ndsc/jungfrau/>

Collaborating partners/networks:

Main collaborations: IASB (Institut d'Aéronomie Spatiale de Belgique) / NDSC (Network for the Detection of Stratospheric Change) / SOGE partners (e.g. EMPA) [<http://www.nilu.no/niluweb/services/soge>] / NASA Langley Research Center / NASA JPL / University of Oslo / IMK (Forschungszentrum Karlsruhe) / satellites: MOPITT, ENVISAT and ACE validation

Scientific publications and public outreach 2002:

Refereed journal articles

Barret, B., M. De Mazière, and P. Demoulin, Retrieval and characterisation of ozone profiles from solar infrared spectra at the Jungfraujoch, *J. Geophys. Res.*, **107**, D24, 4788, doi:10.1029/2001JD001298, 2002.

Rinsland, C. P., Goldman, A., E. Mahieu, R. Zander, J. Notholt, N. Jones, D. W. T. Griffith, T. M. Stephen, L. S. Chiou, ground-based infrared spectroscopic measurements of carbonyl sulfide: free tropospheric trends from a 24-year time series of solar absorption measurements, *J. Geophys. Res.*, 10.1029/2002JD002522, 2002.

Rinsland, C. P., N. B. Jones, B. J. Connor, S. W. Wood, A. Goldman, T. M. Stephen, F. J. Murcray, L. S. Chiou, R. Zander, and E. Mahieu, Multiyear infrared solar spectroscopic measurements of HCN, CO, C₂H₆ and C₂H₂ tropospheric columns above Lauder, New Zealand (45°S Latitude), *J. Geophys. Res.*, **107**, D14, 10.1029/2001JD001150, 2002.

Rinsland, C. P., R. Zander, E. Mahieu, L. S. Chiou, A. Goldman, and N. B. Jones, Stratospheric HF column abundances above Kitt Peak (31.9°N latitude): trends from 1977 to 2001 and correlations with stratospheric HCl columns, *J. Quant. Spectrosc. Radiat. Transfer*, **74**, 205-216, 2002.

Book sections

Zander, R., E. Mahieu, C. Servais, G. Roland, P. Duchatelet, P. Demoulin, L. Delbouille, C. P. Rinsland, M. De Mazière, and R. Blomme, Potential of the NDSC in

support of the Kyoto Protocol: Examples from the station Jungfraujoch, Switzerland, in *Proceedings of "The Third International Symposium on Non-CO₂ Greenhouse Gases: Scientific Understanding, Control Options and Policy Aspects"*, Maastricht, The Netherlands, January 21-23, 2002, J. Van Ham et al. Eds., Millpress-Rotterdam Publishers, ISBN 90 77017-70-4, 305-310, 2002.

Conference papers

De Mazière, M., M. Van Roozendael, B. R. Bojkov, J. de La Noë, E. Mahieu, and R. Neuber, Archiving of atmospheric data: data formats and database, in *Proceedings of the "International Radiation Symposium 2000"*, St. Petersburg, 24-29 July 2000, W. L. Smith and Y. M. Timofeyev Eds., A. Deepack Publishing, Hampton, Virginia USA, 1019-1022, 2001.

Duchatelet, P., E. Mahieu, R. Zander, P. Demoulin, B. Barret, and C.P. Rinsland; Updating the Jungfraujoch database: current status, in *Proceedings of the "Sixth European Symposium on Stratospheric Ozone"*, Göteborg, Sweden, September 2-6, 2002, in press, 2002.

Mahieu, E., C. P. Rinsland, R. Zander, P. Duchatelet, C. Servais, and M. De Mazière, Tropospheric and stratospheric carbonyl sulfide (OCS): long-term trends and seasonal cycles above the Jungfraujoch station, in *Proceedings of the "Sixth European Symposium on Stratospheric Ozone"*, Göteborg, Sweden, September 2-6, 2002, in press, 2002.

Thesis

Mahieu, E., L'évolution du chlore inorganique au-dessus du Jungfraujoch et le Protocole de Montréal, PhD Thesis, University of Liège, 17 Allée du 6 Août, 4000-Liège, Belgium, pp. 1-172, December 2001.

Data books and reports

De Mazière, M., R. Colin, D. De Muer, and R. Zander, The Earth Observing System: synergy between ground-based and satellite observations, and model experiments, in *Space Science Research in Belgium, Vol. III - Part 3*, Federal Office for Scientific, Technical and Cultural Affairs, Brussels, Ref. D/2001/1191/68 (2001), 9-31, 2001.

Montzka, S. A., P. J. Fraser, J. H. Butler, D. Cunnold, J. Daniel, D. Derwent, P. S. Connell, S. Lal, A. McCulloch, D. E. Oram, C. E. Reeves, E. Sanhueza, P. Steele, G. J. M. Velders, and R. Zander, Controlled substances and other source gases, Chapter 1 of *WMO Scientific Assessment of Ozone Depletion: 2002*. WMO-Geneva, in press, 2002.

Van Roozendael, M., G. Vaughan, A. Engel, S. Godin, H. Jäger, E. Kyrö, B. Naujokat, C. Schiller, A. Weiss, and R. Zander, Long-term changes, in *"European Research in the Stratosphere 1996-2000"*, Ch.1, pp. 29-67, European Commission EUR 19867 – ISBN 92-894-1398-0, 2001.

Zander, R., E. Mahieu, P. Demoulin, F. Mélen, C. Servais, and P. Duchatelet, Monitoring of the variability and long-term evolution of tropospheric constituents by infrared solar absorption spectrometry at the Jungfraujoch, Switzerland, in *Annual Report 2001- TROPOSAT: The Use and Usability of Satellite Data for Tropospheric Research*, EUROTRAC-2 International Scientific Secretariat, Munich, Germany, pp. 192-196, 2002.

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