Name of research institute or organization:

Empa - Materials Science and Technology

Title of project:

Hydrogen observations at Jungfraujoch, Switzerland

Project leader and team:

Steven W. Bond, Martin K. Vollmer (project leader), Martin Steinbacher, Stephan Henne, Stefan Reimann, Brigitte Buchmann

Project description:

Molecular hydrogen (H_2) is one of the most abundant atmospheric trace gases. Yet despite its classification as a trace constituent of the atmosphere, H_2 is widely regarded as a potential key component in the future energy chain. For this reason, measurements of molecular H_2 have recently gained broader scientific appeal, as a more complete understanding of atmospheric H_2 is essential as we move towards an increasingly hydrogen-intensive economy. To better ascertain the impacts of enhanced H_2 emissions to the atmosphere, however, the current H_2 budget must be better understood. In order to ameliorate our understanding of H_2 in the atmosphere, along with its various sources and sinks, continuous H_2 measurements have been conducted at Jungfraujoch since 2005. The goal of these observations is to evalutate various trends (diurnal, seasonal, annual), in addition to identifying European sources.

The instrument used to measure H_2 is a modified reduction gas analyzer (RGA3, Trace Analytical), which uses a technique based on chromatographic separation followed by the reduction of mercuric oxide (HgO):

$$X + HgO\ (solid) \rightarrow XO + Hg\ (vapor)$$

where X represents an appropriate reducing gas. The resultant mercury vapor is quantitatively determined through ultraviolet light absorption detection. Mercury vapor is easily measured in minute concentrations, which provides this method significant sensitivity and very low detection limits.

H_2 is not a direct greenhouse gas, although its behavior in the atmosphere has the ability to indirectly influence weather and climate patterns. An increase in atmospheric H_2 concentrations could have effects on chemistry in both the troposphere and stratosphere. An increase in tropospheric H_2, for example, could lead to a reduction in the hydroxyl radical (OH), which could consequently push methane (CH_4) concentrations upwards (H_2 and CH_4 similarly compete for the oxidizing OH radical), increasing the radiative forcing of CH_4, a potent greenhouse gas. An increase in tropospheric H_2 could also lead to an augmentation in stratospheric H_2. Greater concentrations of H_2 in the stratosphere could lead to a rise in stratospheric water vapor and the formation of polar stratospheric clouds, which in turn could accelerate ozone (O_3) depletion and exacerbate the development of the O_3 hole, particularly in the Antarctic due to the delayed breakdown of the polar vortex.

Source identification is an important function of the continuous measurements at Jungfraujoch. Figure 1 illustrates an example of the influence imposed by the southern hemisphere on northern mid-latitudes. On October 1, 2005, advection of clean maritime air masses from low northern latitudes led to depressed CH_4, carbon

monoxide (CO), and chlorofrom ($CHCl_3$) concentrations at Jungfraujoch. On the other hand, molecular H_2 concentrations were simultaneously elevated. Figure 2 below depicts the 10-day backward trajectories of the maritime air masses that produced the results observed in Figure 1. The trajectories are based on 3-D wind analysis from the European Centre for Medium-Range Weather Forecasts (ECMWF).

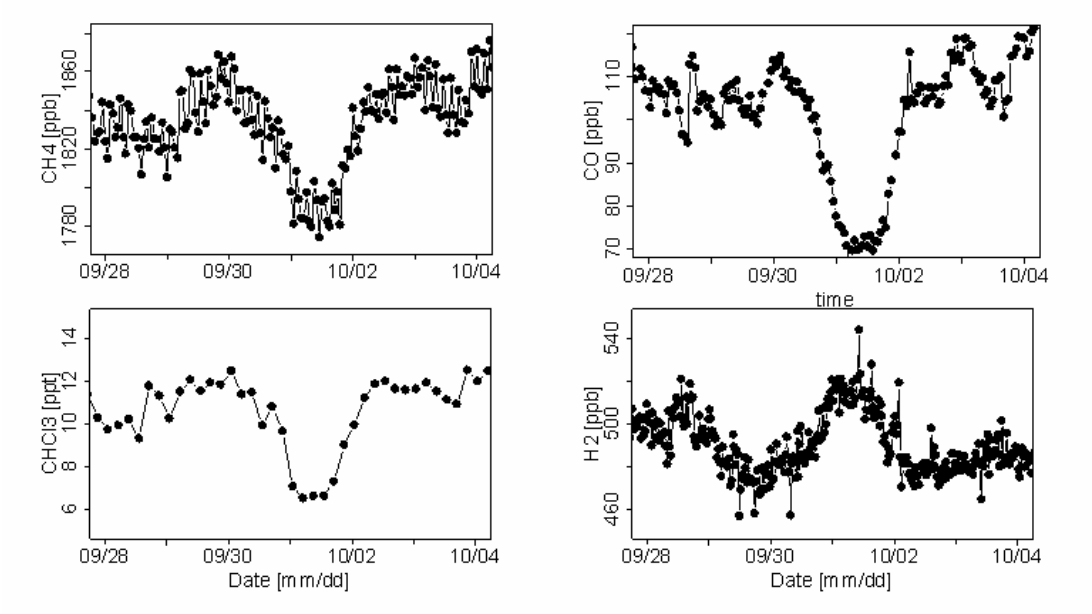

Figure 1. Concentrations of various substances depicting influence of southern hemisphere on northern mid-latitudes.

Anthropogenic activities are major sources of CH_4, CO, and $CHCl_3$, and are a significant factor in the global budget of each of these substances. As a result of human activities, concentrations of these pollutants are higher in the northern hemisphere. As air masses from low northern latitudes (which are influenced by the lower concentrations of these compounds in the southern hemisphere) are carried north, measured concentrations of these pollutants are reduced at the Jungfraujoch station. Alternatively, the soil sink is the major factor in the global H_2 budget. With the greater soil surface area in the northern hemisphere, H_2 concentrations are lower north of the equator, despite correspondingly

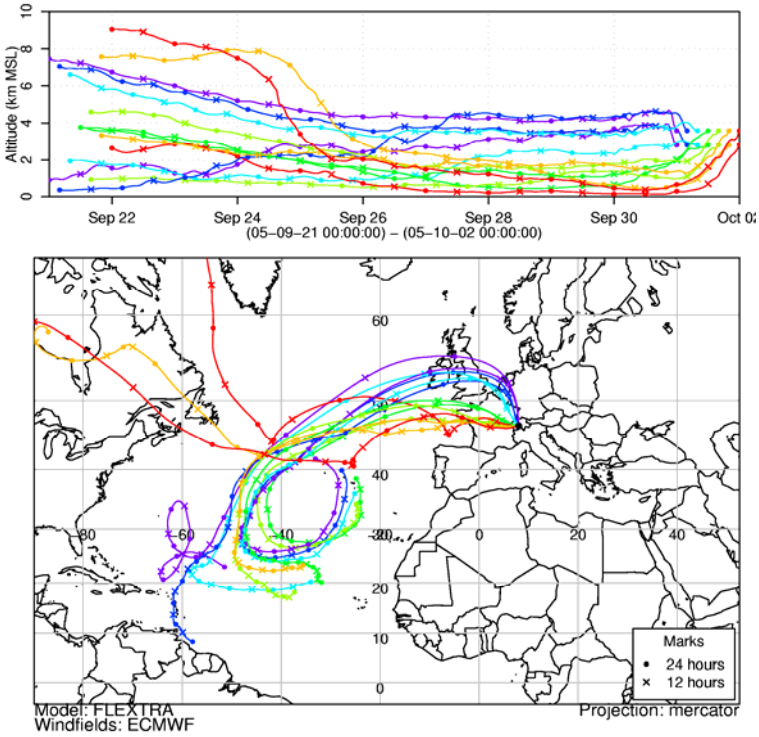

Figure 2. 10-day backward air mass trajectories leading to measurements at Jungfraujoch on October 1, 2005.

higher anthropogenic emissions. As such, as air from low northern latitudes (with high H_2 concentrations from the influence of the southern hemisphere, e.g. from biomass burning) are carried north, measurements at Jungfraujoch reveal elevated H_2 concentrations, as ambient alpine air is displaced by air from the south.

The continuously measured H_2 at Jungfraujoch will be further analysed for trends and for emissions from European sources. This activity is part of the EUROHYDROS project, where data from several European measurement stations are integrated. Furthermore, measurements are also used within the Competence Centre for Energy and Mobility (CCEM-CH), an activity within the ETH domain.

Key words:

Hydrogen, H_2, Jungfraujoch, Atmosphere

Collaborating partners/networks:

- EUROHYDROS – A European Network for Atmospheric Hydrogen Observations and Studies
- Competence Centre for Energy and Mobility (CCEM-CH)

Scientific publications and public outreach 2007:

Refereed journal articles

Steinbacher, M., A. Fischer, M.K. Vollmer, B. Buchmann, S. Reimann, C. Hueglin, 2007. Perennial observations of molecular hydrogen (H_2) at a suburban site in Switzerland. *Atmospheric Environment*, 41, 2111-2124.

Vollmer, M. K., N. Juergens, M. Steinbacher, S. Reimann, M. Weilenmann, B. Buchmann, 2007. Road vehicle emissions of molecular hydrogen (H_2) from a tunnel study. *Atmosperic Environment*, 41, 8355-8369, doi:10.1016/j.atmosenv.2007.06.037.

Conference contributions

Vollmer, M. K., Steinbacher, M., Reimann, S., Buchmann, B., Weilenmann, M., Fischer, A., Hill, M., Juergens, N. Atmospheric molecular hydrogen (H_2): sources, sinks, and Empa's links, TECAT seminar, Empa Dubendorf, May 5, 2007.

Steinbacher, M., Vollmer, M.K., Henne, S., Brunner, D., Buchmann, B., Reimann, S. Non-CO_2 Greenhouse Gas Mixing Ratios at Jungfraujoch, Switzerland - Influence of Air Mass Origin, 14th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases, and Related Tracer Measurement Techniques, Helsinki, Finland, September 10-13, 2007.

Steinbacher, M., Continuous H_2 observations and H_2 road tunnel studies in Switzerland, EUROHYDROS 1st annual meeting, Norwich, September 18-19, 2007.

Bond, S., Vollmer, M. K., Sources and Sinks of Atmospheric H_2 during the Transition to Hydrogen-based Transportation, CONCAWE, Brussels, November 5-6, 2007.

Poster presentations

Bond, S., Reimann, S., Vollmer, M. K., Steinbacher, Hill, M., Buchmann, B., Weilenmann, M., Sources and Sinks of Atmospheric H_2 during the Transition to Hydrogen-based Transportation, Empa PhD Symposium 2007, Empa Akademie, Dübendorf, November 21, 2007.

Address:

Empa
Laboratory for Air Pollution/Environmental Technology
Überlandstrasse 129
CH-8600 Dübendorf

Contacts:

Stefan Reimann
Tel.: +41 44 823 4638
Fax: +41 44 821 6244
e-mail: stefan.reimann@empa.ch