Research at Jungfraujoch – "Top of Science"

Abstract Book

September 11-14, 2006
Interlaken, Switzerland

International Foundation
High Altitude Research Stations
Jungfraujoch and Gornergrat
Sidlerstrasse 5
CH-3012 Bern
Switzerland

September 2006

Abstracts Poster Presentations

1. Aerosols

2. Water vapour

3. Freons

75th Anniversary of the High Altitude Research Station Jungfraujoch

Welcome !

Dear Participants, dear Ladies and Gentlemen,

It is our pleasure to welcome you to Interlaken – in the heart of the Swiss alps, situated between the Lakes of Thun and Brienz, and at the foot the famous trio of peaks, the Eiger, the Mönch and the Jungfrau. The focal point of our conference is located among these peaks: the High Altitude Research Station at Jungfraujoch.

Now at the grand age of 75, the station has steadfastly harboured many researchers over the decades and still keeps pace with the constantly evolving fields of scientific work. Some of this rich diversity will be presented in the historical overview, in the presentations on present day research, and in the outlook for the coming years. But the diversity will also be shown in the interdisciplinary research and by the collaboration among institutions.

This book of abstracts is the work of participating researchers at high altitude research stations from various countries. We are grateful for your response to our invitation and for your contribution to the success of this conference.

We wish you an enjoyable stay in Interlaken and hope that this conference will motivate and challenge us all.

Prof. Erwin Flückiger | Prof. Heinz Hugo Loosli

Local Organizers

Railway and infrastructure development in the last 75 years

Walter Steuri

CEO Jungfraubahn Holding AG

At the end of the 19th century, the Jungfrau Railway project was extremely controversial. A wide circle of people wanted to keep the Alpine summits for mountaineers. People spoke of the ‘desecration of the Alps’. A German publicist and mountaineer wrote: “This project will drag the proud Jungfrau down to the level of a market woman.” In view of the enormous opposition, initiator Adolf Guyer-Zeller looked for ways to persuade the Federal Parliament to grant a concession. He succeeded above all by accepting the following conditions in Art. 9a of the concessionary deed:

“The company pledges, after partial or whole completion of the line, to construct and equip a permanent observatory, in particular for meteorological and other telluric-physical observation purposes, at the Mönch station or on the Jungfrau, or possibly both, to use a minimum amount of CHF 100,000 and, during respective observation periods, to contribute a monthly sum of CHF 1000 towards operating costs. However, this sum shall not exceed CHF 6000 in one year.”

Today’s cooperation is ultimately based on a Swiss Federal Assembly decision of 21 December, 1894. Since then, research and Jungfrau Railways have been linked together.

When the High-Alpine Research Station on the Jungfraujoch was opened in 1931, visitors to the Jungfraujoch numbered around 30,000. The first signs of the world economic crisis were making themselves apparent. So it is all the more astonishing that construction of the Sphinx Observatory was taken in hand in 1937.

After the Second World War, the development of Jungfrau Railway traffic was very satisfactory. Visitor numbers increased in stages from some 30,000 per year in the crisis and war years of 1931 to 1945, to over 300,000 in the first half of the 1970s. One major inroad was caused by the burning down of the Berghaus and Tourist Lodge in October 1972. It was feared that this might herald the economic collapse of the company. But what happened is almost exactly the opposite. As early as January 1975, the Jungfrau Railway opened a new building with two restaurants on the site of the old Tourist Lodge. The new Berghaus was opened on 1 August 1987, the 75th anniversary of the Jungfrau Railway. Building costs amounted to CHF 50 million. The tourist flow showed very positive development and so the Jungfrau Railway soon tackled further modifications. The opening of the second railway hall in 1991 was followed by the completion of the new Sphinx building and new lift installation in 1996, and the new link between the Ice Palace and plateau, the Ice-Gateway, in 2002. Another good CHF 50 million was invested in these three projects. The extension of the Sphinx terrace, which also benefited the research station, was down to the fortunate circumstance that the first project to build a Berghaus, called “Crystal”, on the snow ridge met with growing opposition from worldwide environmental circles.

The admission of the Jungfrau-Aletsch-Bietschhorn region to the prestigious list of UNESCO World Heritage sites in 2001 was a significant milestone for both the Jungfrau Railway and the Research Station. The natural landscape thus received international recognition as a global asset. The Jungfraujoch lies in the heart of this World Heritage. In this respect, research work has been given a new podium and tourists made more aware of a special feature of this attraction. Sustainable development in the World Heritage also provides an opportunity for future generations.

Since the year 2000, visitor numbers have more or less regularly exceeded the previous dream ceiling of 500,000. In 2005, we welcomed 560,766 visitors. Around a quarter of visitors come from Japan. Some 20% come from south-east Asia and Europe (without Switzerland) and around 15 - 20% from inside Switzerland. With around 10% from India, we have more Indian visitors to the Jungfraujoch than Americans, who make up 7%. As 85% of our guests are first-time visitors, we have to win almost half- a-million new customers worldwide every year - a mighty challenge for our marketing people.

The Jungfrau Railway has also undergone great organizational changes. On 1 January 1994, the company was integrated into the Jungfrau Railways Group under the umbrella of the newly-founded Jungfraubahn Holding AG. In addition to the Jungfrau Railway, the group comprises: the Wengernalp Railway, which runs from Lauterbrunnen to Kleine Scheidegg and Grindelwald and also operates ski lifts and chairlifts in winter; the First Aerial Cableway, an aerial gondola in Grindelwald also with ski lifts and chairlifts; the Lauterbrunnen-Mürren Mountain Railway and the Harder Railway, a funicular travelling up Interlaken’s own mountain.

In 2005, the Group achieved a turnover of CHF 120 million, of which CHF 90 million was operating revenue. We earn 60% of operating revenue in summer and 40% in winter. Earnings from ski passes make up around 25% of our operating revenue. EBITDA is CHF 40 million and declared annual profit CHF 17.5 million. We are the largest mountain railway group in Switzerland. Our shares are quoted on the Zurich Stock Exchange. Our major shareholder is the American Investment Company with a 22% participation. The Bernese Cantonal Bank holds 11%, the Bernese Power Plants BKW 10% and the Bernese Building Insurance Company 6%. The remaining 51% is held by over 11,000 minor shareholders, who for the most part have domicile in Switzerland.

In closing, a few thoughts on the cooperation between the High-Alpine Research Station and our railways. I must first stress that both partners are very much aware of the mutual benefits. Alone the fact that a detailed, daily report of weather on the Jungfraujoch is published in the Swiss media boosts recognition of our Jungfraujoch – Top of Europe brand. The many reports on the Jungfraujoch research projects are obviously very important from an international point of view. The Jungfraujoch is seen - and I am convinced quite rightly so - as a top location in the Alps. But visitors to the Jungfraujoch also feel that they are experiencing something extraordinary, a feeling which is reinforced by features including information on the Research Station. On the other hand the Research Station profits form the infrastructure of Jungfrau Railways.

My wish for the future is that the association between the Research Station and Jungfrau Railway continues to be marked by mutual respect, mutual benefit and friendship. The Jungfrau Railway team is proud of your performance and wishes you many more valuable research findings.

Climate and Environmental Information from Extreme Locations

Thomas Stocker

Physics Institute, University of Bern, Bern, Switzerland

The global network of meteorological stations produces measurements which demonstrate that 10 of the 11 warmest decades of the past 150 years have occurred since 1995, and that the warmest year was 2005. How can we put such a result into a longer term perspective?

The longterm perspective of environmental information on the global scale can only be achieved by a combined strategy of performing sustained monitoring in minimally disturbed locations and of reconstructing climate and environmental conditions deciphering natural archives. This strategy is often put in peril by short-sighted funding constraints and frequently expressed views that persistent and consistent sampling and measurement of environmental data is unable to provide new insight.

In this overview the focus will be on one specific of many contributions from three extreme locations: (i) **Mauna Loa on Hawai'i** (19° 32' N, 155°35' W, 3396 m.a.s.l.), (ii) **Dome Concordia in Antarctica** (75° 06' S, 123° 21' E, 3233 m.a.s.l.), and (iii) **Jungfraujoch in Switzerland** (46° 33' N, 7° 59' E, 3580 m.a.s.l.). Data from these three extreme locations have provided unique information and enabled scientific insight into one of the grand global challenges of mankind.

Since 1958, the atmospheric CO_2 concentration has been measured at NOAA's research station on Mauna Loa and has produced the most important time series in the debate on anthropogenic climate change. Since the beginning of the measurements, performed by the late *Charles Keeling*, CO_2 concentration has increased from 313 ppm to over 384 ppm in 2006. The measurements are so accurate that the "breathing" of the vegetation cover of the northern hemisphere can be recognized. While clear to the scientists right from the beginning, public opinion was hard to convince that this increase is not part of a natural cycle.

It was only through the measurements of minute samples of air, extracted from Antarctic ice cores, that the Mauna Loa CO_2 time series could be extended into the past. The experimental development of this technique was done by *Hans Oeschger* and colleagues at the University of Bern in the early 1980s. They could show that the CO_2 concentration was nearly constant at a value of about 278 ppm before the latter part of the 18th century. We have recently measured the oldest ice from Antarctica which was obtained in the framework of the European Project for Ice Coring in Antarctica (EPICA). The ice core drilled at Dome Concordia is 3270 meters long, and the age of the deepest ice is estimated at about 900,000 years. Our analyses of the CO_2 concentrations in the air bubbles trapped in the Antarctic ice show that the CO_2 concentrations in the atmosphere over at least the last six ice ages, i.e. the last 650,000 years, vary naturally between 180 and 300 ppm. Low values are measured during ice ages, high values are achieved in the shorter warm phases. These measurements demonstrate (i), that the atmospheric CO_2 concentration today is 28% higher, and (ii), that the rate of increase is over

100 times faster now, than any time during the past 650'000 years and before the Industrial Revolution.

The increase of CO_2 in the atmosphere since about 1800 is caused primarily by the burning of fossil fuels, and by changes in land use. Among the many lines of evidence for this fact are the very precise measurements of the oxygen concentration in the atmosphere. When fossil fuels are combusted, oxygen is consumed in a fixed proportion leading to a very small but measurable decrease of the O_2/N_2 ratio in the atmosphere. This technique, conbined with extensive model simulations, also permits the attribution of sources and sinks of CO_2 and thus has a special role in future allocations of CO_2 reductions to different regions on the global scale. Recent online measurements of the O_2/N_2 ratio at the High-Altitude Research Station of Jungfraujoch contribute important data to a European Network with the ambitious goal to quantify and attribute such carbon emissions.

In summary, monitoring in remote locations such as the Jungfraujoch, in conjunction with research and innovation, have and continue to provide crucial and unique environmental data. These data are indispensable to recognize and quantify trends of dangerous developments and provide the basis of any policy decision addressing such problems.

Scientific highlights of the last 75 years

Erwin Flückiger

Director, High Altitude Research Stations Jungfraujoch and Gornergrat

Doing research in a high alpine environment has been and remains to be a challenging experience. It took courage and a big portion of foresight, 75 years ago, to establish a research station at 3500 meters. Jungfraujoch is the highest research station in Europe that is accessible all year round by rail. It was the intention of the founders to provide to the scientists an infrastructure that allowed world-class research at high altitude, alpine environment. The kind of research that is performed has to be designed by the scientists. Due to this „bottom-up“ policy, the character of the scientific projects has changed appreciably over these 75 years. The station started out hosting mainly physiologists and astronomers. Today Jungfraujoch is much more a user lab for environmental science, being on top of the pollution layer.

The success of the High Altitude Research Station Jungfraujoch is measured by the quality of the scientific results and by the extent to which the infrastructure is used. In the past, the research work at Jungfraujoch was marked by several milestones:

- As early as 1925/26, before the founding of the Research Station Jungfraujoch, Kolhörster and von Salis did pioneer work in cosmic ray research.
- Shortly thereafter, Chalonge, the French pioneer in astrophysics and one of the founders of the "Institut d’Astrophysique de Paris", carried out the first ozone measurements.
- In 1950 the Université de Liège began spectrometry measurements of sunlight. These results appeared in the first atlas of the Sun’s spectrum of the frequencies between 2.8 – 23.7 μm. This atlas was produced by Migeotte, Neven, and Swensson and was the basis for the later additions in the frequencies 0.3 – 1 μm by Delbouille, Roland, and Neven. This document is still a recognized reference worldwide on the spectrum of sunlight and is fundamental in the field of astronomy and theoretical spectroscopy.
- The research on cosmic rays done by Blackett and Wilson provided basic results closely related to two Nobel prizes in physics (Blackett, 1948; Powell, 1950). The large Wilson chamber that was built up by the two Britons in 1951 in the Sphinx observatory was later used by CERN, where it ushered in the era of modern high-energy experiments.
- The excellent transparency of the atmosphere above Jungfraujoch made it possible in 1962 for the German physicists Labs and Neckel to make the first absolute measurements of the solar energy output (i.e. ‘solar constant’).
- The Genevan astronomer Golay developed the 7-color photometry for the classification of stars. This means of classification was the basis for a unique catalog that up to now includes over 40’000 stars.

- After the solar flare on June 3, 1982, the cosmic ray detector of the Physikalisches Institut of Bern was able to prove for the first time the presence of high energy solar neutrons in the Earth's atmosphere.
- In 1990 the Austrian researchers Blumthaler and Ambach gained worldwide attention with the first direct measurements of the increase in the UV-intensity at the Earth.
- Long and short-term measurements now being carried out by various research groups of around 25 air pollutants are of eminent importance and will have a long lasting effect on the understanding of our environment.
- In recognition of the global significance of the environmental measurements made at this station, Jungfraujoch became part of the global measurement network of the GAW program in 2005.

This overview shows that during the past, several changes of emphasis of research at the Research Station Jungfraujoch have occurred: glaciology-/medicine ∏ cosmic rays/astrophysics ∏ astronomy. At the present time environmental sciences make up more than 50% of all experiments done at Jungfraujoch. An overview of the present research activity at the High Altitude Research Station Jungfraujoch can be found in the annual activity reports of the Foundation (http://www.hfsjg.ch/). In 2005, researchers from 36 teams with 41 projects spent 1432 person-working days at Jungfraujoch. By country, the major part of the scientists originates from Switzerland, Belgium, Germany, and the UK. About 20 automatic measuring installations are operated around the clock. In 1999, the astronomical observations were stopped because of the existence of other observatories that enjoy better weather conditions (astrophysical work has almost entirely been moved to Gornergrat). The 76cm telescope at Jungfraujoch is now used by the 'Air Pollution Laboratory' of the Swiss Federal Institute of Technology in Lausanne (EPFL), for the operation of a LIDAR (LIght Detection And Ranging), and by the 'Laboratoire de Physique Solaire de l'Université de Liège', for the operation of an infrared spectrometer. Most of the research groups working at Jungfraujoch participate in national, European, and global measurement networks, e.g. the 'Network for the Detection of Stratospheric Change' (NDSC), the 'Global Atmosphere Watch' (GAW), and the 'European Aerosol Research Lidar Network' (EARLINET). Recent measurement campaigns included e.g. the 'Cloud and Aerosol Characterization Experiments' CLACE-3, -4, and -5 (Paul Scherrer Institute, PSI). Today more than ever, long-term experiments are being carried out whose importance cannot be evaluated on a short-term basis. It can be assumed that in the future, materials research will also gain importance at the Research Station at Jungfraujoch.

Within a long-term strategy for the future of the Foundation HFSJG the following high priority challenges have been identified:

Environment: Preservation of the natural environment at the research stations in the face of the often controversial needs of research and tourism is a constant challenge. The intact environment is a prerequisite for the success of research projects within worldwide networks on "System Earth", such as "Global Atmosphere Watch (GAW)". A continuous dialog is needed between the Foundation HFSJG and other institutions present at the two research sites (e.g. railways, restaurants). Furthermore, at Jungfraujoch, research activity will be embedded at least partially in the management plan of the UNESCO World Heritage Jungfrau-Aletsch-Bietschhorn.

Flexibility of infrastructure: The adaptability of the infrastructure in the research stations must be carefully maintained. In the past, research emphasis has changed several times. With the present research tempo, rapid changes in the future must be expected. For example, it is already evident that materials research will continue to make more demands. The research stations must be in a position to meet these changing requirements (space, information technology, support for long-term measurements).

Evaluation of scientific results: Scientific results must be compiled, distributed, and evaluated on a regular schedule. The annual reports of the HFSJG contain a bibliography of all publications based on observations from the research stations. Outside experts evaluate different research areas from time to time (such as the external evaluation of the long-term experiments in environmental sciences at Jungfraujoch in 1999). Periodic workshops with international participation place the research done at Jungfraujoch and Gornergrat into a competitive framework (workshop ‘Atmospheric Research at Jungfraujoch and in the Alps’, Davos, September 20, 2002; and this conference).

Public outreach, Support for young scientists: The web-site of the Foundation must be adapted continuously to help publicize and popularize research results. Information to the general public about the research conducted at Jungfraujoch and Gornergrat has to be promoted. Early career scientists are encouraged to take part in the research work at the research stations and at scientific meetings held by the Foundation HFSJG.

Networks of European Research Infrastructure: The Foundation has to define and strengthen its role and cooperation within the increasing networking of European research infrastructure.

Past performance is no guarantee or indication of future results. However, thanks to its truly unique location, the easy access, and the continuing endeavor of mankind to explore the unknown, we are confident that the High Altitude Research Station Jungfraujoch faces a bright future.

Long-Term Monitoring of Greenhouse and Ozone-Depleting Gases at Jungfraujoch

Rodolphe Zander[1] and Stefan Reimann[2]

[1]Institute of Astrophysics and Geophysics, University of Liège, Belgium
[2]EMPA, Laboratory for Air Pollution/Environmental Technology, Switzerland

Long-term measurements of greenhouse- and ozone-depleting gases are essential for characterising and understanding the present state of our atmosphere (troposphere and stratosphere combined) and for predicting its evolution with respect to scenario-based natural and anthropogenic changes. Without such early monitoring activities, the connection of the chloro-fluorocarbons (CFCs) and the observed springtime stratospheric ozone depletion over most of the globe would hardly have been detected in time to react and put the Montreal Protocol into force as early as 1987. They also have provided evidences in support of the United Nations Convention on Climate Change (UNFCCC), which has recently gone into force with the formal implementation of the Kyoto Protocol.

Related findings resulting from the spectrometric analysis of infrared solar observations and by local *in situ* samplings at the International scientific station of the Jungfraujoch will be summarized in this combined presentation.

The first column measurements resulting from the analysis of **infrared solar spectra** recorded with grating spectrometers were undertaken as early as 1950-51. They allowed to show that a few atmospheric gases, namely CO_2, CH_4, N_2O and CO were present, worldwide, and apparently constant, thus supporting the general belief in the geophysical research community that the mean state of the earth's atmosphere was sufficiently stable, on a geological time scale, for anthropogenic perturbations not to be worried about.

This latter belief had drastically changed by the mid-1970s, when it was shown that new anthropogenic source gases such as CFCs, hydro-chlorofluorocarbons (HCFCs) and Halons (bromine-containing gases) were quickly accumulating in the troposphere and efficiently transported in the stratosphere. There, their photodissociation products initiate catalytic cycles involving inorganic chlorinated and brominated trace species that efficiently add to the nitrogen cycle to deplete the protective ozone layer.

Within this context, the Liège group progressively reframed its solar observation activities as well as operation of new instruments, in particular Fourier transform infrared (FTIR) spectrometers, to increase the number of targeted telluric gases (over two dozen now) to be observed quasi simultaneously. Instrumentation specifics and related performances will be discussed elsewhere (see presentation by L. Delbouille).

Original findings resulting from the spectrometric analysis of solar spectra performed consistently with FTIRs since 1985 will be presented, namely:

- the temporal evolution of most observed individual target gases, including short-term variability and long-term trends;

- the investigation of the inorganic nitrogen-, chlorine- and fluorine- loadings in the stratosphere, which have primarily been conducted within the frame of the Network for the Detection of Stratospheric Change (NDSC);

- the overall good agreement found between the trends resulting from IR-derived columns and *in situ* concentrations for the important long-lived greenhouse gases mostly present in the troposphere;

- specific data contributions for the validation/intercomparison of numerous space-based sensors and the testing of model simulations (see also presentation by M. De Mazière);

- regular contributions to the confection/content of National, EC and International WMO-UNEP Assessments, and data releases to the scientific community via data archiving Centres and publications in peer-reviewed scientific journals.

Since January 2000, ***in-situ* measurements** of halogenated greenhouse gases (CFCs, HCFCs, hydrofluorocarbons (HFCs) and Halons) have also been performed quasi-continuously at the Jungfraujoch by gas chromatography-mass spectrometry (GC-MS). These halocarbons are important industrial substances with a wide variety of applications such as refrigeration, foam blowing, and fire extinction. In addition, methane (CH_4) and nitrous oxide (N_2O) have been analysed since the beginning of 2005 by gas chromatography with flame ionization/electron capture detection (GC-FID/ECD). CH_4 and N_2O have both natural and anthropogenic sources and their concentrations have considerably increased after 1750, the beginning of industrialization. Jungfraujoch is the highest site worldwide to host this kind of measurements. The strength of these new measurements is their potential to be used as a tool for the independent source allocation for these trace compounds.

For the halocarbons, the banned CFCs have reached a stable level for the very long-lived compounds or have begun to decline at a rate dependent on their atmospheric lifetime and the amounts of on-going emissions from delayed releases in modern countries or temporary authorized consumptions in developing countries. The HCFCs, being the first generation substitutes for the banned CFCs, have to be phased out in the industrialized counties within the next years. The HFCs, as second-generation substitutes, do not deplete the stratospheric ozone, but are still greenhouse gases; their background concentrations exhibit high growth rates of 20-50% per year. For CH_4 a preliminary analysis of the new measurements in 2005 shows that its growth has recently stopped, which is in accordance with data from other background sites and the Jungfraujoch column measurements. N_2O exhibits a small but steady growth rate of about 0.25%/y, caused primarily by emissions from agricultural activities.

Periods when boundary layer air is transported to the Jungfraujoch are used to estimate emissions from the European continent. In combination with the other European background sites, these measurements can potentially be used as a tool for independent validation of emission figures submitted as national communications to the UNFCCC. For the localisation of potential

European source regions, a trajectory model was used, based on the Swiss Alpine Model. The results should be regarded as indicative. European sources of CFCs have been declining, after they have been banned from usage. On the other hand, considerable increase of non-regulated HFCs could be seen, which are mostly used for refrigeration and foam blowing.

The operation of both remote- and *in situ* measurement systems, as is presently the case at Jungfraujoch (FTIR, GC, UV-Vis, LIDAR, …) provides an excellent combination for the detection of changes in the troposphere as well as in the stratosphere. Ongoing improvements in analytical approaches and related ancillary parameters, combined with ground- and space-based data and with model assimilations should further help increasing the accuracy of the measurements and better assessing species’ origins and global distributions, especially with regard to contributions associated with major Asian and African countries’ developments.

Remote sensing of atmospheric water vapor at Jungfraujoch and Bern

Niklaus Kämpfer

Institute of Applied Physics, University of Bern, Sidlerstr. 5, CH-3012 Bern, Switzerland

Atmospheric water vapor plays a multiple role. It is involved in chemical, radiative and physical processes. In the troposphere it is mainly involved in the hydrological cycle, in the upper troposphere and lower stratosphere it contributes to the greenhouse warming as the most important green house gas. In the stratosphere H_2O is the primary source of the OH radical and thus is involved in a large number of chemical processes, including ozone depletion. Polar Stratospheric Clouds, PSC, can be produced at sufficiently low temperatures depending on the amount of water vapour. Finally H_2O determines the temperature and hence the circulation of the middle atmosphere, the stratosphere and mesosphere, by contributing to their long wave cooling. As a consequence any change in the abundance of water vapor may have different impacts.

Despite the fact of the importance of water vapour for atmospheric chemistry and physics the available data sets are relatively sparse. The total amount of water vapor, the column density, can be determined by different remote sensing techniques, e.g. precision filter radiometers, GPS-receivers, Fourier-Transform Interferometers and by microwave radiometry. The vertical distribution in the lower troposphere is measured on a regular basis by radio soundings. However above approx. 7 km data get unreliable. More recently the profile in the troposphere has also been measured by lidar techniques. Measurements from the ground in the middle atmosphere are thus far only possible by microwave remote sensing techniques. This technique detects pressure broadened rotational transitions of atmospheric molecules. Due to the exceptionally high spectral resolution capability of a heterodyne receiver, it is possible to infer altitude profiles from approx. 20 km up to 75 km depending on atmospheric opacity. As the technique is passive and independent from a background source, such as the sun or the moon, it is possible to obtain measurements during the day and at night. Moreover observations are only weakly affected by clouds in most cases.

Several of the remote sensing techniques to infer atmospheric water vapor are in use at the high alpine research station Jungfraujoch. Jungfraujoch together with Bern acts as a primary station of NDACC, the "Network for the Detection of Atmospheric Composition Change". Since autumn 2005 the "Middle Atmospheric Water Vapor Radiometer", MIAWARA, of the University of Bern is operated in the frame of NDACC and produces profiles since 2003. Data about atmospheric water as measured from Jungfraujoch by different techniques is also investigated in the frame of the Swiss National Center of Competence and Research, NCCR-climate, within project STARTWAVE.

We report about research in the field of atmospheric water as performed at the NDACC stations Jungfraujoch and Bern.

High Resolution Spectrometry

L. Delbouille

Institut d’Astrophysique et de Géophysique, Université de Liège

At the very beginning of the talk, its scope will be clearly delimited: no attempt will be done to treat the very broad subject perhaps suggested by its title. Only high resolution solar spectrometry in the optical domain will be considered, in relation with the research activities developed at the Jungfraujoch over the past fifty-five years.

A discussion will follow about how to express spectral resolution and the definition of the “instrumental profile”, a way to describe how the spectrometer is perturbing the results. A brief review of the general uses of spectrometry at increasing resolution will be presented, showing that the information contents of a spectrum do not increase regularly, but by steps, when that resolution progresses linearly.

Working at low or even medium resolutions is always easier, faster and less expensive, but cannot give answers to a majority of the questions raised when one tries to improve the accuracy in the determination of either the abundances of the elements in the solar photosphere or the varying earth’s atmosphere composition. The progresses in the instrumental techniques used over years at the Jungfraujoch will be illustrated, and what new information came out of each increasing resolution step briefly exposed.

The actual “state of the art” in the way to obtain the primary observational results needed to finely understand the physics and chemistry of the upper atmosphere (the subject of R.Zander’s talk) will then be reviewed with more attention. It will be explained how “Fourier Transform Spectrometry” (FTS in short) is without any doubt the best choice to get as close as possible to the real physical profiles of many lines of different origins recorded simultaneously in a broad spectral domain, or to detect the presence of new molecules in the upper atmosphere. Advocated early at the Jungfraujoch, that approach is now widely used in many laboratories collaborating to study the atmospheric composition and follow closely its temporal changes.

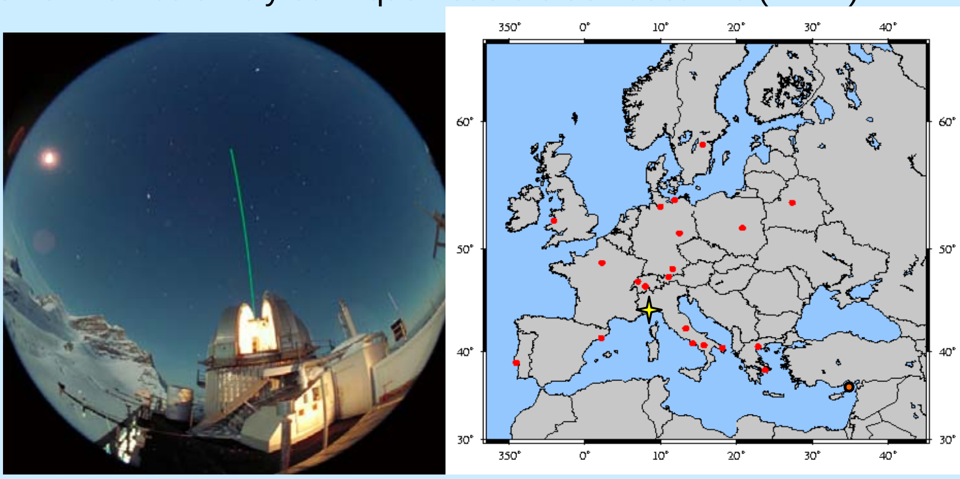
Some suggestions about how to increase further the efficiency of FTS will finally be presented, as a possible glimpse towards the future.

Lidar and QCL measurements from Jungfraujoch

Valentin Simeonov, Marian Taslakov, Marcel Bartlome and
Hubert Van den Bergh

Air and Soil Pollution Laboratory, Swiss Federal Institute of Technology, EPFL, Lausanne, Switzerland

The research lidar deployed at the Jungfraujoch High Alpine research station was designed to measure aerosol optical properties at three wavelengths, water vapor, and temperature. The lidar was built in the Laboratory of Air pollution of the Ecole Polytéchnique Fédérale de Lausanne (EPFL).



The EPFL lidar at Jungfraujoch *left* and its position on the map of the EARLINET stations *right* (see text below)

The lidar was installed and operates on a regular basis as part of the European Aerosol Lidar Network- EARLINET since May 2000. The main objective of the EARLINET project is to establish a comprehensive database for aerosol spatial and temporal distribution and aerosol optical properties over Europe. The database is used for calibration of satellite measurements and to study the aerosol influence on the Earth radiative balance. The network consists of 23, spread all over Europe, lidar stations that carry out co-ordinated measurements. Because of its high altitude location, 3550 m above sea level, the Jungfraujoch lidar is the only lidar in the network that is situated almost all the time in the “free troposphere”, above the atmospheric boundary layer (ABL). The implementation of a multi functional lidar at the Jungfraujoch station has contributed to the European Lidar Network by supplying regular aerosol, water vapor and temperature data with high temporal and spatial resolution.

A number of gases are involved in the human caused enhancement of the greenhouse effect the most important them being CO_2, CH_4, N_2O, chloro-fluorocarbons (CFC); and O_3. The continuing increase of GHGs and their influence on Global climate explains the need for accurate measurements and modeling.

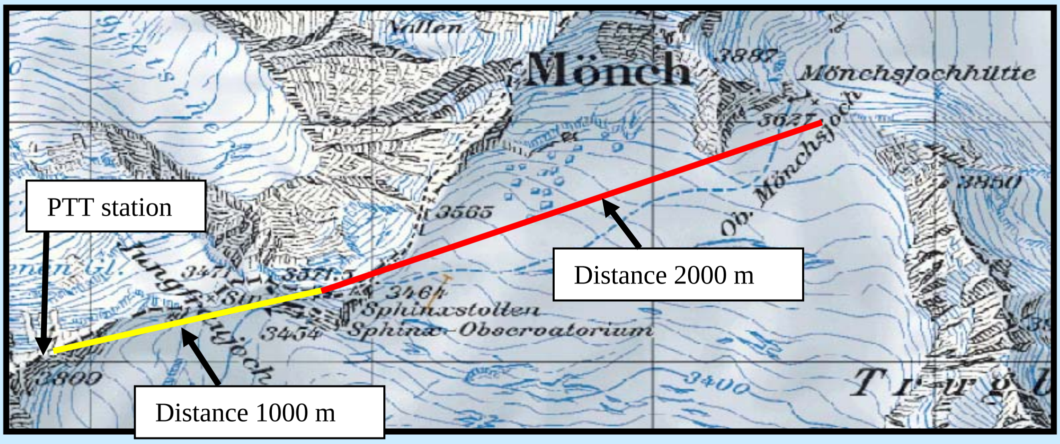
At present, ground-based GHGs measurements are most often taken with point sampling instruments. Point measurements have several drawbacks;

they can be easily altered by sample taking and affected by local sources, sinks or transport; they lack the spatial representativeness needed for modeling purposes.

The detection of various GHGs over long trajectory open paths can help solve all these problems. This technique employs the absorption spectroscopy principle to obtain species concentration. The concentration is derived from the light transmittance measured over an optical trajectory in the open atmosphere.

During the last years, the Laboratory of Air Pollution at EPFL has performed the first (to our knowledge) open-path mid IR quantitative measurements of O_3 and detection of CO_2 and water vapor over distances of up to 5800 m by employing the recently available Quantum cascade Lasers (QCL). The main features of the open-path QCL method, which make it a valuable technique for atmospheric measurements are: immunity to interferences by other species; the possibility to make measurements that are averaged over an extended path, and therefore are much less affected by local fluctuations than point sensors.

We plan to deploy a QCL based open-path instrument at the Jungfraujoch station. The most suitable optical trajectories we envisage are: from the Sphinx to the PTT station, or to the surroundings of Mönchsjohhütte hut (see the figure below).



The comparison with various O_3, N_2O and CH_4 point measurements taken at the Jungfraujoch station will be used to verify the QCL data. Since the QCL spectrometer will supply data averaged over one (two) kilometers it could be possible to study the correlation between the difference of the point and QCL data, and the visitor's statistics and the meteorological data and from there to determine the influence the Jungfraujoch station on GHGs measurements

Alpine Permafrost in a Changing Climate (and a Changing Perspective)

Stephan Gruber

Glaciology and Geomorphodynamics Group, Department of Geography
University of Zurich, Switzerland

Permafrost is invisible at the ground surface and only 40 years ago, neither researchers nor engineers considered its existence in the Alps. Today, it is rather common knowledge (and a popular topic for the media) in Switzerland that warming or thawing permafrost can cause rock fall and problems to infrastructure as a consequence of climate change. What has happened in the mean time? How has the importance of permafrost changed? How has our perception changed? What do we know now about Alpine permafrost and what are the pressing questions? In a brief response to these questions, this presentation will be focused on permafrost in bedrock and in steep bedrock slopes because on one hand this is at present one of the most dynamic areas of research and on the other hand, the Research Station Jungfraujoch and the Jungfraubahn AG have played an important role here for nearly 35 years, now.

In recent years – and especially during the hot and dry summer of 2003 – an increased number of large rock fall events from permafrost as well as stability problems in the direct vicinity of a large number of high-altitude installations such as cable car stations has been reported. Permafrost in steep bedrock slopes is wide spread and possibly makes up the largest proportion of permafrost in Switzerland despite the little attention it has received previously. Additionally, it is in steep slopes where we find the most rapid reaction of subsurface temperatures to climatic signals as well as the highest potential energy available for mass movements. Little surprising, the number of researchers investigating permafrost in steep bedrock has increased manifold during the last three years. However, basic understanding as well as available observations and experience are extremely limited. Currently, we are faced with three main types of questions: A) Temperature: Where do permafrost conditions exist and how will the corresponding 3-dimensional temperature field evolve? B) Ice: Where can we expect ice in the perennially frozen bedrock, how was it formed and what properties does it have? C) Temperature and stability: How does a temperature rise affect rock slope stability? This set of questions that are intimately related as well as some preliminary insights will be discussed.

Advancing the answers to these questions is important if we aim to assess the possible impacts that climate change might have on natural hazard potentials or if we wish to contribute to well-adapted and cost-effective construction and management of high-altitude infrastructure. Besides these applied goals, also our understanding of climate control of cold-mountain landscape evolution will be advanced.

This changing perspective in permafrost research that gives more focus to steep bedrock slopes will also mean a changed perspective for the High-Altitude Research Station Jungfraujoch in this respect: it will likely become one focal point of alpine permafrost research during coming years.

On the predictability of ice avalanches

Martin Funk

Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie (VAW), ETH Zürich

Following the 1965 tragic event at Allalingletscher in Valais, Switzerland, interest in the stability of so called hanging glaciers grew in the Alpine glaciological community. It was understood that an early recognition and an accurate prediction of large ice falls from hanging glaciers can effectively reduce the loss of lives and damages to settlements.

In 1973, a method to predict the time of failure of large unstable ice masses from hanging glaciers was proposed by A. Flotron and H. Röthlisberger. The method is based on the regular acceleration observed on large unstable ice masses prior to their collapse. Recently, investigations performed on the hanging glacier at Mönch showed the possibilities and the limits in predicting ice avalanches. Due to positive feedback mechanisms the velocity of the unstable ice mass approaches a finite time singularity; that is, theoretically the velocity increases to infinity at a finite time. This characteristic acceleration is used for forecasting icefalls. Using advanced statistical methods of non-linear regression analysis, it could be shown that the accuracy of the prediction is strongly sensitive to the time when the measurements are started and stopped. The residuals of the data set show log-periodic oscillations. It could be shown that these oscillations may lead to inaccurate predictions if a respective term is not included in the model.

Aerosols and Climate

Ulrike Lohmann

Institute for Atmospheric and Climate Science, ETH Zurich, 8092 Zurich, Switzerland

Aerosols are an integral part of the atmospheric hydrological cycle and the atmosphere’s radiation budget, with many possible feedback mechanisms that are not fully understood yet. First, they scatter and can absorb solar radiation. Second, they can scatter, absorb and emit thermal radiation. Third, aerosol particles act as cloud condensation nuclei and ice nuclei, they may inhibit freezing and they could have an influence on the hydrological cycle. The first two mechanisms are referred to as direct aerosol effects and the last one is referred to as an indirect aerosol effect.

The indirect aerosol effect itself consists of a several mechanics. An increase in aerosols due to industrial activity leads to more cloud droplets. If the cloud liquid water content remains the same, then these cloud droplets will be smaller, which increases the cross-sectional area of the clouds and causes enhanced reflection of solar radiation back to space. This negative forcing can partly offset the greenhouse gas warming and is referred to as the cloud albedo effect. In addition to the cloud albedo effect, the more and smaller cloud droplets in polluted stratiform clouds may decrease the precipitation formation, which would have an influence on the cloud lifetime (cloud lifetime effect). In climate models both of these mechanism are important and caused a negative radiative perturbation at the top-of-the-atmosphere between -0.9 and -2.9 W/m^2 since pre-industrial times (Figure 1). Which of these two effects is more important is not known yet.

In addition to an aerosol effect on water clouds, aerosols could also perturb ice clouds. If, for instance, a fraction of the soot aerosols acts as ice nuclei, this could cause a rapid freezing of cloud droplets at temperatures below 0° C. Unlike cloud droplets, these ice crystals grow in an environment of high supersaturation with respect to ice, quickly reaching precipitation size, and with that can turn a non-precipitating cloud into a precipitating cloud (glaciation effect). In this talk, I will discuss the multitude of aerosol effects on clouds, climate and the hydrological cycle.

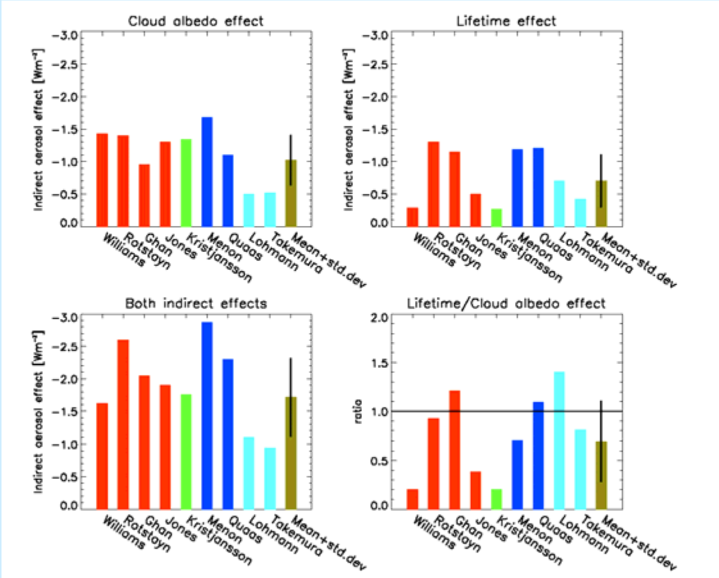


Figure 1: Global annual mean radiative flux changes at the top-of-the-atmosphere due to the cloud albedo and lifetime effect of anthropogenic aerosols from different climate model simulations. The flux changes are obtained from multi-year simulations for the present-day climate minus multi-year simulations for pre-industrial conditions in which the anthropogenic emissions were set to zero. The colours refer to the different aerosol compounds that were considered in these studies (adapted from Lohmann and Feichter, 2005).

Reference: Lohmann, U. and J. Feichter, 2005: Global indirect aerosol effects: A review. *Atmos. Chem. Phys.*, **5,** 715-737.

Climate Relevant Aerosol Research at the High Altitude Research Station Jungfraujoch, Switzerland

Urs Baltensperger and Ernest Weingartner

Laboratory of Atmospheric Chemistry
Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

Aerosols influence the atmospheric energy budget through direct and indirect effects. Direct effects refer to the scattering and absorption of radiation and their subsequent influence on the planetary albedo and the climate system. Indirect effects refer to the increase in available cloud condensation nuclei (CCN) due to an increase in anthropogenic aerosol concentration. This is believed to change the cloud droplet number concentration for a constant cloud liquid water content (LWC), and the resulting increase in cloud albedo influences the Earth's radiation budget. We started continuous aerosol measurements at the Jungfraujoch high Alpine site in 1988. In 1995, these measurements were substantially augmented and embedded into the Global Atmosphere Watch (GAW) program of the World Meteorological Organization (WMO). The stations participating in GAW aim at contributing to a greater understanding of both the direct and indirect effect of aerosols on climate by continuous measurements of aerosol parameters. The Jungfraujoch aerosol program is among the most complete ones worldwide. The following GAW parameters are currently measured continuously by PSI:

- Particle number density (particle diameter $D_p>10$ nm), using a condensation particle counter
- Scattering coefficient at various wavelengths (nephelometer, TSI 3563)
- Absorption coefficient at various wavelengths and black carbon (BC) concentration (aethalometer, AE-31)
- Absorption coefficient and black carbon (BC) concentration (MAAP)
- Aerosol major ionic composition (for $D_p<1$ m and total aerosol) using filter packs and off-line chemical analysis
- Aerosol mass concentration ($D_p<1$ m) using a betameter

As more than 10 years are now available for some aerosol parameters, it has become possible to calculated trends. As an example, Figure 1 shows the temporal evolution of the light scattering coefficient.

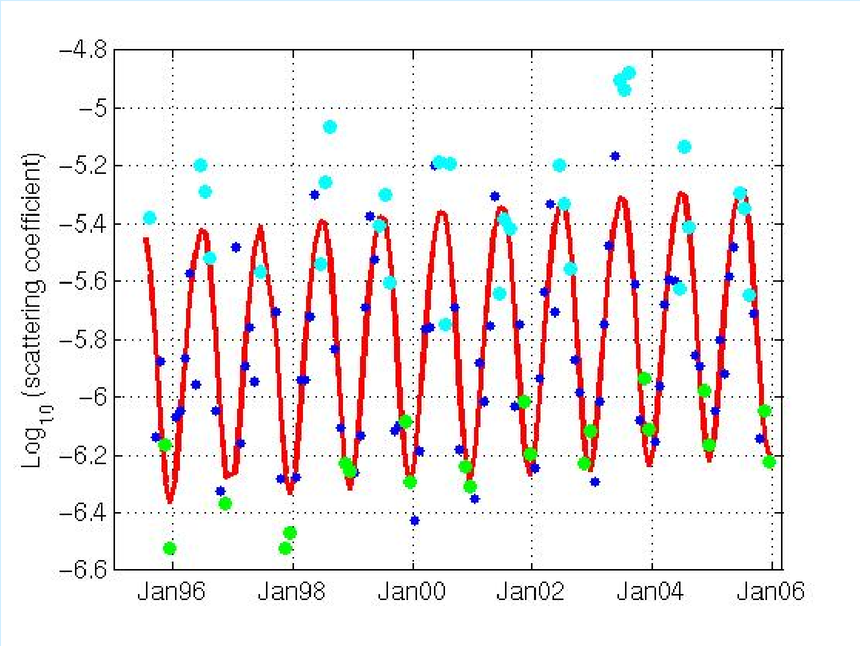


Figure 1. Temporal evolution of the light scattering coefficient at 700 nm (from Collaud et al., in preparation).

A strong seasonal variation is seen, with high values in summer and low values in winter. This is due to stronger vertical transport due to thermal convection in summer. A detailed analysis (Collaud et al., in preparation) shows that the summer values (turquoise points in Figure 1) do not exhibit a significant trend, while there is a significant positive trend for the winter values (green points). Possible reasons for this are currently investigated.

In addition to the long-term program, several intensive field studies, named CLACE (Cloud and Aerosol Characterization Experiment), were performed in both summer and winter within international collaborations. The goals of these intensive campaigns were:

- A full physical, chemical, and optical characterization of the aerosol at the Jungfraujoch in order to better quantify the direct aerosol effect.
- An investigation of the interaction of aerosol with clouds, for a better quantification of the indirect effect.

As an example, Figure 2 shows the size distributions of the total aerosol particles (i.e., after evaporation of the cloud water) and the so-called interstitial (non-activated) aerosol particles for a liquid cloud (consisting only of water droplets). The area between the two lines represents those particles that were activated to cloud droplets. It can be seen that for small particles the two lines are identical, which means that these particles are not activated. With increasing diameter the fraction of activated particles increases.

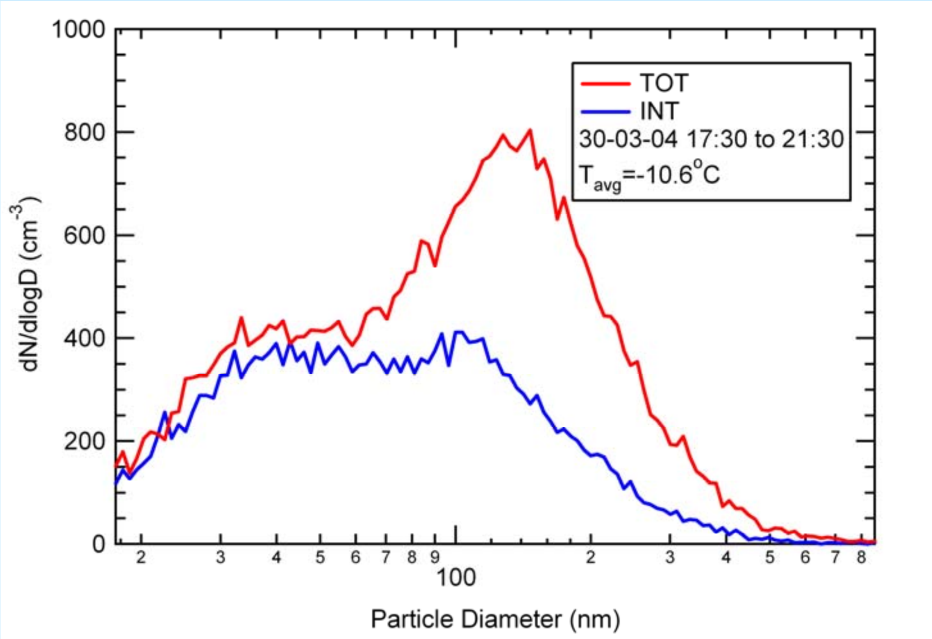


Figure 2. Size distributions of the total aerosol (TOT, red line) and the interstitial (non-activated, INT, blue line) aerosol during a cloud event.

In mixed phase clouds (clouds that contain a certain fraction of ice) the activated fraction of aerosol particles is strongly dependent on this ice fraction. This is explained by the Bergeron-Findeisen process, which describes the effect of a water vapor flux from liquid droplets to ice crystals. The lower the ambient temperature, the more liquid droplets evaporate and a higher fraction of CCN is released back to the interstitial aerosol phase.

Acknowledgment: This work was supported by MeteoSwiss within the Swiss GAW program.

Radiation Measurements Manifest Increasing Greenhouse Warming

Rolf Philipona

Physikalisch-Meteorologisches Observatorium Davos
and MeteoSwiss Payerne

The global annual mean temperature measured at Earth's surface increased by about 0.8 degree Celsius over the past 150 years. On the Northern Hemisphere sea- surface and land-surface air temperature measurements show similar increases up until the 1980s, but from that time on greater warming is measured over land. From 1980 to 2005 surface temperature in Europe increased about twice as much as the northern hemisphere average. In Switzerland and in the Alps records show rapid temperature increases of about 1.2 degrees since 1981.

Hence, surface temperature does increase - but why does it increase? From the radiation point of view, possible reasons for a rise of surface temperature are either increasing solar radiation, a change of radiative transmission in the atomsphere or a decrease of surface albedo followed by increasing solar absorption. Solar irradiance measurements from space show no or very little increase since the early 1980's. Surface albedo changes are poorly recorded in Europe, but possible changes would predominantly occur during fall or spring season, hence during rather short time periods and limited solar elevation. The rapid temperature increase observed in the Alps and large parts of Europe is therefore likely related to atmospheric radiative transmission by changes of clouds, aerosols or greenhouse gases, and a complex interplay between solar shortwave transmission and terrestrial longwave absorption and emission, which is often referred to as the natural greenhouse effect of the atmosphere.

Surface radiation measurements on the Jungfraujoch, on the Gornergrat and on eight additional CHARM (Swiss Atmospheric Radiation Measurement program) and ASRB (Alpine Surface Radiation Budget network) stations distributed over an area of about 200 by 200 km square in the Alps have been installed in the 1990s in collaboration between MeteoSwiss, the World Radiation Center at Davos and the High Altitude Research Station Jungfraujoch. The main goals are to investigate the altitude dependence and possible changes of the atmospheric transmission, the surface radiation budget and the greenhouse effect. Aerosol optical depth, downward and upward shortwave and longwave components for the radiation budget as well as UV radiation is accurately measured from the lowest Station Locarno-Monti at 370 m a.s.l. up to the Jungfraujoch at 3580 m a.s.l..

Aerosol Optical Depth (AOD) measurements show a sharp increase with the eruption of mount Pinatubo in 1991, which is followed by a congruent decrease in the following three years. From 1995 on AOD still shows a slight decrease at low altitude, suggesting a minor increase of atmospheric transmission for visible solar radiation over the last decade, whereas at high altitude changes are very small and insignificant.

First attempts to look for changes of the alpine radiation budget and possible relations to climate change were made in 2003. While shortwave downward radiation was found to decrease from 1995 to 2002, a strong increase was observed on the longwave downward radiation, concurrent with rapid temperature and humidity increases. The sum of the two fluxes shortwave net plus longwave downward, which represents the total surface absorbed radiation, in fact, showed good correlation (r=0.85) with the increasing temperature.

Clouds are expected to play an important role on the radiation budget and hence on surface temperature. Our observations however, showed increasing cloud amount north but decreasing south, whereas both sides of the Alps experienced clear warming over the investigated time period. This fact of cloud changes having apparently little net radiative effect was previously observed with ASRB cloud investigations showing that for midlatitudes, annual mean cloud cooling by reflection of solar shortwave radiation is roughly canceled by cloud warming caused by emitted longwave radiation from clouds.

More insight on the relation between radiation and temperature was found by investigating radiative fluxes under cloud-free skies. Very high correlation (r=0.98) was observed between strong increasing longwave downward radiation and the rising temperature. This goes in line with a strong dependence of longwave downward radiation with the surface temperature. However, after subtractting the longwave change that is due to surface temperature increase, the remaining longwave downward radiation still increases and furthermore shows good correlation (r=0.89) with the increasing humidity.

These observations combine to suggest that the region is experiencing an increasing greenhouse effect with positive water vapor feedback, where carbon dioxide emissions warm the Earth’s surface and cause more surface water to evaporate. This water vapor accumulates in the atmosphere and further increases surface temperature.

Investigations over larger parts of Europe showed that temperature increases from 1995 to 2002 are tightly connected to increasing water vapor in the atmosphere. Same investigations also revealed that large-scale weather patterns uniformly but weakly influence annual mean temperature by advection, whereas radiative forcings in conjunction with regional strong atmospheric water vapor build-up clearly dominate the longterm temperature increase.

Solar radiation as well as temperature and humidity measurements from Jungfraujoch and other MeteoSwiss stations, allowed investigations back to 1981. From 1981 to 2002 solar shortwave radiation decreases in the Alps, and only if the time period is extended to 2005 shortwave radiation shows a slight increase, which is mainly due to a reduced cloud amount during summer 2003. Nevertheless, by using surface absolute humidity as a proxy for longwave downward radiation it can be clearly shown that the rapid temperature increase in central Europe over the last two and a half decades is not due to increased solar radiation but due to an increased greenhouse effect.

The strong rise of longwave downward radiation can be shown to be due to increasing cloudiness, rising temperature, rising water vapor and due to the driving cause: the long-lived anthropogenic greenhouse gases. The Swiss radiation measurements therefore show for the first time that anthropogenic greenhouse warming is measurable at Earth's surface and that strong water vapor feedback additionally warms the Alps and Central Europe, where sufficient surface water is available for evaporation.

References:
Philipona, R., B. Dürr, A. Ohmura, and C. Ruckstuhl, 2005: Anthropogenic greenhouse forcing and strong water vapor feedback increase temperature in Europe, Geophys. Res. Lett., 32, L19809, doi:10.1029/2005GL023624.
(For this paper the authors have been nominated for the 2007 WMO"Norbert Gerbier – MUMM International Award").

Medical implications of O_3 variations in stratosphere and troposphere

Mario Blumthaler

Division for Biomedical Physics, Innsbruck Medical University, Austria

In the Earth's atmosphere ozone is distributed in a very specific vertical profile. More than 90% are concentrated in the stratosphere with a marked peak of ozone concentration at an altitude of about 20 to 25 km, slightly depending on season and on geographical latitude. In the troposphere ozone is distributed with only slight vertical variations. The total amount of ozone in the atmosphere is measured as the height of a layer of pure ozone under conditions at the Earth's surface; on the average this layer is about 3 mm thick, which is expressed as 300 Dobson Units (DU). The world-wide longest uninterrupted record of ozone measurements is carried out in Arosa (Switzerland) since 1926. Nowadays total ozone is measured routinely at many stations around the world and from instruments on board of satellites, which show the global distribution and its variation.

The reason for the specific vertical profile of ozone in the atmosphere is the process of production and destruction of ozone, which gives rise to a dynamic equilibrium in dependence on temperature and pressure. Besides these natural parameters, in the last decades also anthropogenic effects have influenced global ozone concentrations, namely the release of the chlorofluorocarbons (CFCs), which leaded to a decrease of stratospheric ozone levels. This decrease is especially pronounced during Austral spring over Antarctica, where every year for about two months the total ozone concentrations is dramatically reduced to less than half of the normal value, which is called the 'ozone hole'. In mid-latitudes of the Northern hemisphere, the total ozone amount decreased only slightly, showing about 3-4% lower values in the period 1997-2001 compared to pre-1980 values. In contrast to the stratosphere, the ozone levels in the troposphere were mostly rising in the last decades due to increased local air pollution. Volatile organic compounds, CO and NO_x react together under the influence of sunlight leading to the generation of ozone and other photo oxidants during daylight.

Ozone in the atmosphere acts twofold. On the one hand, ozone is a very efficient absorber of short wavelengths of UV radiation. The absorption coefficient increases strongly with decreasing wavelengths below 320 nm. This leads in the atmosphere to complete absorption of solar UVC (wavelengths below 280 nm) and at the Earth's surface to a steep increase of radiation levels by more than 4 orders of magnitude in the UVB range (280 nm to 315 nm). Thus, atmospheric ozone protects life at the Earth's surface from the harmful UVC radiation and partly from UVB radiation. Therefore, a reduction of the amount of ozone in the atmosphere leads to an increase in UVB radiation. For small changes, a linear amplification factor of about 1.2 can be assumed, which means that 1% decrease of ozone will increase erythemally weighted UV radiation by 1.2%. The erythema action (sunburn) is often taken as a general measure for biological consequences of UV radiation, because it is well investigated and its spectral dependence is standardised. However, the individual reaction of humans can differ significantly from the standardised values, as skin type and skin sensitivity are greatly different. Whereas erythema is an acute reaction of the skin to UV radiation, the long term consequence of overexposure is the development of skin cancer. Like the skin, also the eyes are affected by UV radiation. Inflammation of the cornea (photokeratitis, snowblindness) is an acute effect, whereas darkening of the lens (cataract) follows after long-term exposure. However, it is also important to mention that a certain amount of UVB radiation is absolutely necessary for human health for production of vitamin D in the human skin; otherwise a vitamin D deficiency would result. This would have a negative effect on the strength of the bones, but possibly it is also favouring different kinds of cancer diseases. The level of UVB radiation necessary to produce enough vitamin D in the human skin is far below the level producing erythema; therefore overexposure should be avoided without completely blocking all UVB radiation reaching the skin. A decrease of atmospheric ozone will increase the negative health effects of enlarged UVB radiation; therefore it is important that the behaviour of the population is adequately adapted.

In addition to the effect of absorbance, ozone is also a poison gas. This becomes significant for ozone near the Earth's surface, because there ozone is inhaled while breathing and it adversely affects plants. In humans, high levels of ozone can reduce lung capacity and it causes chest pains, throat irritation, and coughing. Furthermore, it can worsen pre-existing health conditions related to the heart and lungs. Continuous monitoring of ozone levels at the Earth's surface will allow to asses the health hazards and to control the necessary improvement of air quality by reduction of the precursors for ozone formation.

In order to investigate the effect of atmospheric ozone on UV radiation, measurements of UV at high altitude are especially important. There the amount of aerosols is very low and therefore they do not effect UV radiation significantly. Long-term measurements of UV radiation at the High mountain station Jungfraujoch (3576 m above sea level, Switzerland) have shown that in the 80's and beginning of the 90's a slight but statistically increase of erythemally weighted UV radiation by several percent occurred. However, analysing the whole time series from 1981 up to 2002 does not show any significant long-term trend, which is in agreement with the observed long-term variation of total atmospheric ozone.

For the future it will be important to continue monitoring solar UV radiation in order to verify if the trend of decreasing ozone levels will really be changing, as model calculations predict for the next decades as a consequence of the world-wide banning of the CFC's. Furthermore, monitoring of solar UV radiation will give quantitative information for the public for a reasonable behaviour to avoid overexposure from the harmful UV radiation.

Integrated use of ground-based and satellite measurements of atmospheric composition.

M. De Mazière, J.C. Lambert and M. Van Roozendael.

Belgian Institute for Space Aeronomy, Ringlaan 3, B-1180 Brussels, Belgium

The study of the chemical composition of the atmosphere requires information about a large number of atmospheric variables including the abundances of many species and their distribution in space and time, as well as additional parameters of more physical nature like temperature and winds that affect the chemistry and dynamics happening in the atmosphere. No single observing system is able to provide this information. One path to overcome the problem, at least partially, is to operate various ground-based sounders in a coordinated way. This option has been successfully realised in the Network for the Detection of Atmospheric Composition Change (NDACC, formerly called Network for the Detection of Stratospheric Change or NDSC, http://www.ndacc.org). The High Altitude Research Station of the Jungfraujoch is one of the primary stations in this network, equipped with a variety of in-situ and remote sounding instruments. Another way to increase the available observational information is to make an integrated use of satellite- and ground-based measurements.

This talk will show various applications of the integrated use of ground-based and satellite measurements of the atmospheric composition, including examples that involve data from NDACC observatories and from the Jungfraujoch Station in particular. The ground-based observing systems that we will address include the SAOZ (Système d’Analyse par Observation Zénithale) and MAXDOAS (Multi-Axis Differential Absorption Spectroscopy) UV-visible instruments, and the Fourier transform infrared spectrometers of NDACC. Regarding the satellite experiments we will mainly deal with the MIPAS and SCIAMACHY spectrometers onboard the Envisat satellite, as well as with the latter’s precursor named GOME onboard ERS-2.

One of the applications that will be discussed is the cross-validation of data from ground and space, and the verification and improvement of satellite data retrieval algorithms and numerical models of the atmosphere. Another application concerns the investigation of the budget, trend and photochemistry of the bromine species, from the lower troposphere to the stratosphere. Third, we will show how a climatology of the NO_2 vertical profile was derived from an ensemble of ground-based, balloon- and space-borne observations.

In all applications, one must take into account the specificities in terms of accuracy and precision, as well as spatial and temporal resolution and smoothing of each of the observing systems. The particularities of the satellite and ground-based systems mentioned above, and the complementarities that are exploited in the applications, will be highlighted during the talk.

Palaeo- and Present Day Atmosphere

Margit Schwikowski

Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

Reconstruction of long-term regional variability of temperature, precipitation and atmospheric composition is of great interest in climate research. In the Alpine region, much progress has been made in reconstructing climate history using long instrumental records (e.g. Böhm et al. 2001), documentary evidence (e.g. Pfister 1999; Luterbacher et al., 2004) and tree-ring series (e.g. Büntgen et al. 2005). Nevertheless, climate proxies covering more than a few centuries with a sufficiently high time resolution are rare in Central Europe, but may be found in cold glacier archives.

However, important for an improved understanding of the characteristics of a natural archive is the calibration of the proxy records with instrumental data. For this purpose the high-altitude research station Jungfraujoch offers a worldwide unique setting: high-quality instrumental meteorological and air quality records exist in the proximity of glaciers suitable for climate reconstruction (Schwikowski et al., 1999). Within the NCCR climate project VITA a 150 m ice core recovered from the Fiescherhorn glacier (46°33’3.2”N, 8°4’0.4”E, 3900 m a.s.l.) in December 2002 is investigated, which covers the time period 1680-2002 AD in high-resolution. This site is located in 6 km horizontal and 300 m vertical distance from the Jungfraujoch. The aerosol-sulphur record from Jungfraujoch and the sulphate concentration in the ice core for the time period 1973-2002 show the same trend, but the latter one is slightly influenced by melt water percolation. The stable isotope ratio δD in the ice core compares well with temperatures registered at Jungfraujoch since 1939, revealing a strong warming of about 0.9°C.

Böhm R., Auer I., Brunetti M., Maugeri M., Nanni T., Schöner, W., *Int. J. Clim.*, **21** (14), 1779-1801, 2001.
Büntgen U., Esper J., Frank D.C., Nicolussi K., Schmidhalter M., *Climate Dynamics* 25 (2-3) 141-153, 2005.
Luterbacher J., Dietrich D., Xoplaki E., Grosjean M., Wanner H., *Science* 303 (5663) 1499-1503, 2004.
Pfister C., Brazdil R., Glaser R., Barriendos M., Camuffo D., Deutsch M., Dobrovolny P., Enzi S., Guidoboni E., Kotyza O., Militzer S., Racz L., Rodrigo F.S., *Climatic Change* 43 (1) 55-110, 1999.
Schwikowski M., Brütsch S., Gäggeler H.W., Schotterer U., *J. Geophys. Res*., 104, 13'709-13'720, 1999.

High mountain observatories

J.N. Stamenov and B.I. Vachev

Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences

High mountain observatories (HMOs) are placed in height between 2000 and 5500 m a.s.l. all over the world. The research area of these observatories could contain: atmospheric physics and chemistry, Climate variability and Climate effects, UV radiation, remote sensing, material research, solar technologies, sensor development, high altitude biology and medicine, astrophysics and astronomy.

The research in high mountains was started at the end of 19th century combining the sporting and scientific interests of the people.

The most of European HMO are developed as complex research institutions, covering in their activities the most of the branches of the existing research area. Starting with the well defined and instrumented measurements according to the Global Atmospheric Watch (GAW) programme and extending Climate studies, Aerospace weather studies and Astronomical and astrophysical investigations in extremely large energy interval: 10^{9}eV-10^{19}eV. Special attention is paid to the processes, which affect climate change as: solar radiation, clouds, ocean currents and atmospheric circulation. The solar activity with its 11 year cycle and the solar magnetic field with its 22 year cycle play extremely important role in the atmosphere.

The dynamics of stratosphere – troposphere exchanges is very important for the energetic balance of the atmosphere, where the anthropogenic products, greenhouse effect, stratospheric ozone reduction and clouds formation play essential roles, moreover the interactions of cosmic rays (CR) are from fundamental importance. Taking into account the connections between CR flux variation and climate changes, CR intensity and cloud coverage, solar cycle variability and mesosphere – troposphere ozone dynamics, the connections between lighting formation and the CR flux, it becomes clear that there are extensive interdisciplinary studies needed towards to reach success by the investigation of the interactions between CR, climate changes and aerospace weather.

The HMO give good basis for astronomical observations in very large energy (wave) interval. Of course, the optical and Cerenkov light astronomy are in very advanced position in the case of a site with good astroclimate and good atmosphere transparency.

The big astrophysical complex installations devoted to registration of extensive air showers (EAS), generated in the atmosphere by primary cosmic particles with high energies as information carriers about astrophysical objects in the energy range 10^{14}eV-1019eV have better mass and energy resolution by given detector displacement because the smaller difference between observation level and the height of the shower development maximum.

The necessity of the HMO becomes quite clear performing interdisciplinary research activities, carrying out physical and chemical studies of the atmosphere, CR-measurements towards to solve present problems of the aerospace weather and the astrophysics, avoiding anthropogenic pollutants of all types as much as possible. Moreover the high mountain ecosystems are very sensitive and their recover time is relative long, what gives good opportunities for carefully complex studies of the environment.

The future development of the HMOs is mainly connected with the improvement of the measuring devices, elaboration of measuring methods and algorithms for statistical data treatment, with the real time measurements and high speed data transmission, assuring optimal level of the physical security and information safety of each HMO. The main possible research activities will remain more or less the same as now: meteorology and hydrology, climate variability and climate effects, space weather forecast, remote sensing, pollution monitoring and ecological risks, radiation monitoring and early warning, cosmic ray studies in extended energy interval 10^9eV-10^{19}eV, high altitude medicine and dosimetry, instrumental tests. Possible development of new methods for atmosphere studies has to be expected based on registration of different characteristics of secondary CR components. HMOs are the places were the human satisfaction from beauty of the nature and the active efforts to know and to understand it are in perfect agreement, improving the human discovery willingness to passion.

Jungfraujoch, A Global GAW Station

Bertrand Calpini

Meteoswiss - Aerological Station, Payerne, Switzerland

The Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO) was established in 1989. It is focused upon the role of atmospheric chemistry in global change (http://www.wmo.ch/web/arep/gaw/gaw_home.html), and consists of a partnership from 80 countries worldwide coordinated by the WMO Secretariat in Geneva and the Working Group on Environmental Pollution and Atmospheric Chemistry (WG-EPAC) of the Commission for Atmospheric Science (CAS).

GAW has taken the lead in a scientific assessment of the past, present and future state of *global air composition observations, the measurement requirements and priorities* in the next 15 years for Integrated Global Atmospheric Chemistry Observations (IGACO, 2004). The latter recommends an approach for integration of ground-based, aircraft and satellite observations of 13 chemical species in the atmosphere using atmospheric forecast models that assimilate not only meteorological observations but also chemical constituents. Socio-economic issues related to climate change, ozone depletion/ UV increase and air quality benefit by having such a system in place.

The GAW target variables are the greenhouse gases, UV radiation, ozone, aerosols, major reactive gases (CO, VOCs, NO_y and SO_2), and precipitation chemistry. The Swiss GAW programme is a contributor to GAW with a large research effort within the country on data management, quality assurance, training and network infrastructure support for global activities. Switzerland has recently added Jungfraujoch as the 23rd Global station to the GAW global network: the Jungfraujoch station fills all requirements and is an important high altitude station in Europe. Examples of its scientific contributions into the GAW programme will be presented. Further description can be found in the GAW Station Information System (GAWSIS): (http://www.empa.ch/gaw/gawsis).

As another example of the importance of the Jungfraujoch research station into GAW, the **DACH** joint co-operation programme between Germany (DWD), Austria (ZAMG) and Switzerland (MeteoSwiss) will be presented, with a focus on the alpine GAW sites Zugspitze/Hohenpeissenberg (**D**, 2650m/ 985m asl), Sonnblick (**A**, 3106 m asl) and Jungfraujoch (**CH**, 3580m asl). The goal of DACH was to investigate the trace gas background concentrations of GAW data series over Central Europe, and to determine and detect the related potential changes/trends of the atmosphere composition.

(1.1)

Variability and long-term trends of aerosol parameters at the Jungfraujoch

Martine Collaud Coen[1], Ernest Weingartner[2], Stephan Nyeki[2] and Urs Baltensperger[2]

[1] MeteoSwiss, Aerological Station, Les Invuardes, CH-1530 Payerne, Switzerland
[2] Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, CH-5232 Villigen, Switzerland

Introduction

Continuous measurements of aerosol parameters have been performed since 1995 at the high alpine research station Jungfraujoch (JFJ) situated at 3580 m asl, enabling a 10-year long-term trend analysis to be performed. The JFJ is prevalently situated in the free troposphere, but is often influenced by thermal convection of planetary boundary layer (PBL) air during warmer months [Baltensperger et al., 1997, Lugauer et al., 1998]. Consequently all measured aerosol parameters show a clear annual cycle with maximum values between June and August and minimum values in December-January.

Methods

Since the aerosol parameters are approximately lognormally distributed, a non-parametric test, the seasonal Kendall test, and a non-parametric slope estimator, the Sen's slope estimator, were applied to detect the long-term trends and their magnitudes for each month [Gilbert, 1987]. With this method, an annual trend can be estimated only if the monthly trends are homogeneous in direction and magnitude, which is seldom the case in our study. The global trend was estimated by a least-mean square (LMS) fit of the data (or on the data logarithms if they are lognormally distributed) and the number of years necessary to detect the estimated trend was also calculated [Weatherhead et al., 2000]. With these statistical tools, a global picture of the aerosol long-term variability can be obtained for the lower free troposphere.

Results

Figure 1 shows that an increase of the scattering coefficient is clearly visible in the LMS fit of the data logarithms. This yearly positive trend is detected at a 95% confidence level for all wavelengths. The same procedure applied to the scattering coefficient itself (rather than the logarithm) allows for estimating a positive trend magnitude of 3 to 4% yr^{-1}. Careful examination of Figure 1 shows that no visible increase of the scattering coefficient is found for the warmest months (June to August monthly medians, shown as dark grey squares) while a strong increase can be observed for November and December (light grey circles). A more detailed analysis of the long-term trend was therefore performed with the seasonal Kendall test.

The most significant trend detected with the seasonal Kendall test is the increase (2-4% per year) of the aerosol light scattering coefficients at 450, 550 and 700 nm during the September to December period. The back-scattering and absorption coefficients, and to a lesser extent the condensation nuclei concentration, also have significant positive trends in autumn. This increase of most of the aerosol parameters in the September-December period does not directly depend on the aerosol loading in nearby valleys, but probably relates to a European-wide increase in injection of PBL airmasses into the lower FT coupled with large-scale transport. In this sense the positive trend of the extensive aerosol properties in autumn can be described as an increase of the background aerosol concentration in the lower free troposphere.

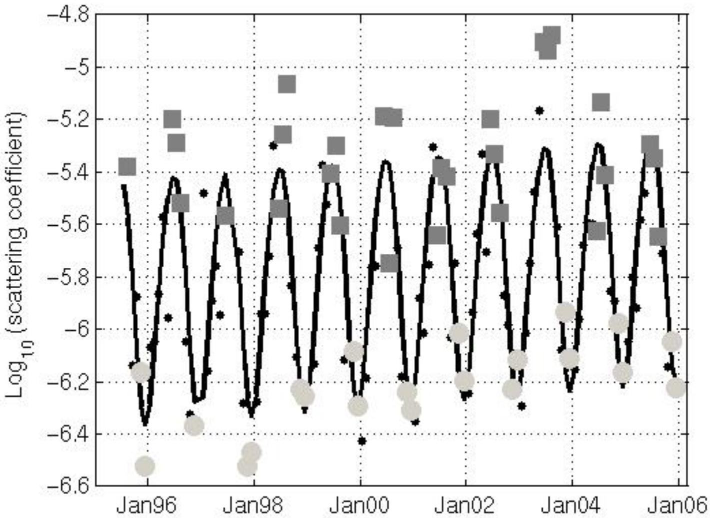


Figure 1: Scattering coefficient logarithm as a function of time, with June, July and August represented by dark grey squares and November and December by hell grey circles. The black line is the LMS fit of the data.

In general, the summer months, which are strongly influenced by the PBL, do not show any significant long-term trend. It seems therefore that the measured decrease of anthropogenic aerosol emissions in Europe is not reflected in the summer mixed air masses found at the JFJ in summer.
The hemispheric backscattering fractions (backscattering coefficient /scattering coefficient) and the scattering exponent show an increase in size of small particles during the whole year, except during summer, with the size of large particle remaining constant. This size increase is possibly related to a simultaneous decrease of SO_2, with a corresponding decrease in new particle formation by homogeneous nucleation.
Most of the described trends are significant at the 95% confidence level for both statistical methods. The number of years necessary to detect the estimated trend is usually found to be as long as or smaller than the measurement periods (i.e 10 years). We can therefore conclude that, due to the large magnitude of the detected long-term trends, our dataset is long enough to estimate the aerosol variability in the lower free troposphere.

References

Baltensperger, U., Gäggeler, H.W., Jost, D.T., Lugauer, M., Schwikowski, M., Weingartner, E., and Seibert, P., J. Geophys. Res., 102,19707-19715, 1997.

Gilbert, R. O., Van Nostrand Reinhold Company, New York, 1987.

Lugauer, M., Baltensperger, U., Furger, M., Gäggeler, H.W., Jost D.T., Schwikowski, M., and Wanner, H., Tellus Series B, Chemical and Physical Meteorology, 50B, 76-92, 1998.

Weatherhead E.C., Reinsel G.C., Tiao, J.C.H., Bishop L., Hollandsworth, F. S.M., DeLuisi J., Keller T., Oltmans S.J., Flemming E.L., Wuebbles D.J., Kerr J.B., Miller A.J., Herman J., McPeters R., Nagatani R.M., and Frederick J.E., J. Geophys. Res. 105, 22201-22210, 2000.

(1.2)
Saharan dust events at the Jungfraujoch: a new detection method and a five-year climatology

Martine Collaud Coen[1], Ernest Weingartner[2], Daniel Schaub[3], Christoph Hueglin[3] and Urs Baltensperger[2]

[1] MeteoSwiss, Aerological Station, Les Invuardes, CH-1530 Payerne, Switzerland
[2] Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, CH-5232 Villigen, Switzerland
[3] Air Pollution/Environmental Technology Department, Swiss Federal Laboratories for Materials Testing and Research (EMPA), CH-8600 Dübendorf, Switzerland

Introduction
Mineral dust is a major constituent of the atmospheric aerosol. The Saharan desert is the strongest source of mineral aerosol. Its contribution to European aerosol loading has been previously evaluated by red rain, or dust content of snow and ice. With such methods, the importance of mineral dust in ambient air cannot reliably be estimated. We developed a new operational detection method allowing for detecting the occurrence of Saharan dust events (SDE) at the JFJ with an hourly time resolution.

Methods
The single scattering albedo (ω_0) and its wavelength dependence are one of the key parameters for the calculation of the direct aerosol radiative forcing. It is the ratio between the scattering coefficient and the sum of the scattering and absorption coefficients. Since March 2001, both coefficients have been measured at several wavelengths at the high-alpine research station of the Jungfraujoch, so that all coefficients can be fitted with a power law dependence on the wavelength, e.g. $\omega_0 = \beta\ e^{-\alpha}$, and the exponent α can be estimated. Usually ω_0 decreases with increasing wavelengths so that its exponent $\alpha(\omega_0)$ is positive. During SDE, the ω_0 wavelength dependence is however inversed such that $\alpha(\omega_0)$ becomes negative [Collaud Coen et al., 2004]. Such a wavelength dependence inversion can be explained by two reasons. First, mineral dust is greater in size than the 'normal' JFJ aerosol. For coarse particles, scattering is dominated by geometric processes, such that a wavelength independence of the scattering coefficient is predicted, and a clear decrease of the scattering exponent occurs during SDE (Fig. 1). Second, a greater wavelength dependence of the absorption coefficient is observed. This increase can be explained by a difference in aerosol chemical composition. The simultaneous decrease

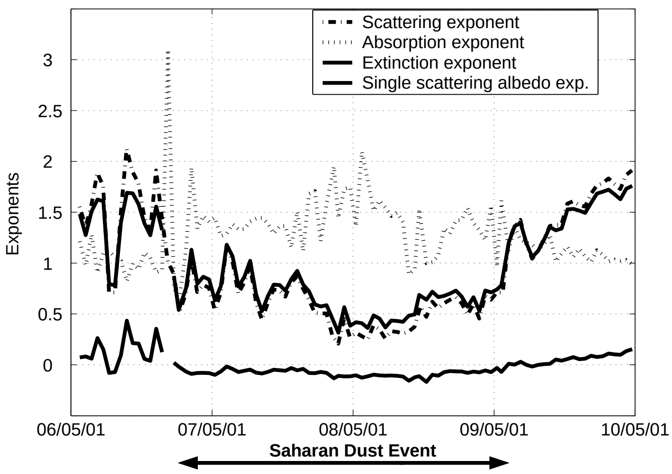


Fig. 1: Scattering, absorption, extinction, and single scattering albedo exponents during a Saharan dust event.

of α_{sc} and the increase of α_{abs} lead to the observed negative $\alpha(\omega_0)$. Therefore, the sign of $\alpha(\omega_0)$ allows for determining the occurrence of SDE at the JFJ (Fig. 1). Only inversions lasting longer than 3 hours were considered as SDE. When several SDE were separated by a few hours, they were assimilated to one single event. This new detection method has been corroborated by filter coloration, back-trajectory analysis and/or satellite observations (Collaud Coen et al., 2004).

Five-year climatology

Generally, SDE strongly contribute to the aerosol loading at the JFJ during the spring time (March to June) as well as in October and November (Fig. 2). The summer time has only sparse events and the winter time very short ones. Most of the SDE last only a few hours: 47% are shorter than 10 h, 29% last between 10h and 24h, and 24% are longer than a day. Trajectory analysis shows that mineral dust traveling times are typically between 2 days and one week. The main sources of Saharan dust reaching the JFJ are the north-west part of the Saharan.

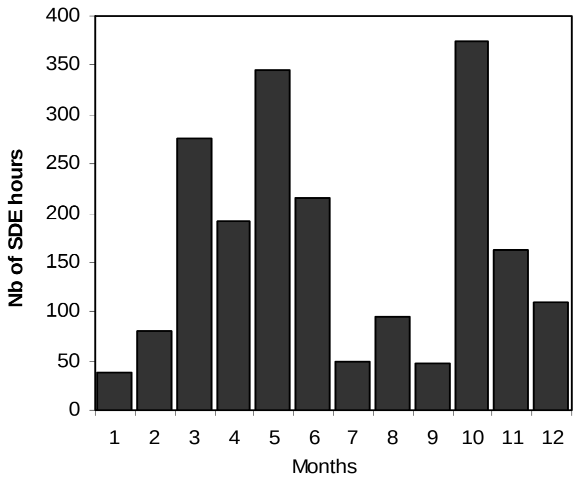


Figure 2: Number of SDE hours for all months.

10 to 34 SDE were detected each year, which corresponds to 200-500 hours with mineral dust at the JFJ. On average, the hourly contribution of Saharan dust has been evaluated to 0.8 $\mu g/m^3$, which corresponds to 24% of the total aerosol mass concentration.

2003 shows the largest number of events (see Table), probably due to the particular weather conditions from May to October characterized by very high temperature and no precipitation. 2005 presents the smallest number of events and of number of hours with SDE. These abnormally rare SDE can perhaps be related to a greater sunshine duration in spring and fall (Bulletin Météorologique, http://www.meteosuisse.ch/web/fr/climat/bulletins_actuels/bulletins_mensuels_et_annuels.html), which are probably related to stable weather conditions (which is for example the case in October 2005, due to a blocking anticyclone over south-east Europe) and unfavorable long-range transport of Saharan air masses. A more detailed meteorological analysis has however to be performed to understand this year-to-year variation.

	2001	2002	2003	2004	2005
Number of SDE	18	27	34	32	10
Hours with SDE	495	379	432	471	206

Reference

Collaud Coen M., E. Weingartner, D. Schaub, C. Hueglin, C. Corrigan, S. Henning, M. Schikowski, and U. Baltensperger, Atmospheric Chemistry and Physics, 4, 2465-2480, 2004.

(1.3)

Source apportionment of carbonaceous aerosols with ^{14}C: I. Results from Jungfraujoch

S. Szidat[1,2], T.M. Jenk[1,2], L. Wacker[3], H.-A. Synal[4], S. Reimann[5], J. Cozic[2], E. Weingartner[2], A.S.H. Prévôt[2], U. Baltensperger[2]

[1] Department of Chemistry and Biochemistry, University of Berne, CH-3012 Bern, Switzerland
[2] Paul Scherrer Institut (PSI), CH-5232 Villigen, Switzerland
[3] Institute for Particle Physics, ETH Hönggerberg, CH-8093 Zürich, Switzerland
[4] PSI, c/o Institute for Particle Physics, ETH Hönggerberg, CH-8093 Zürich, Switzerland
[5] Swiss Federal Laboratories for Materials Testing and Research (EMPA), CH-8600 Dübendorf, Switzerland

Carbonaceous particles (total carbon, TC) are a major component of the fine atmospheric aerosol. TC is classified into the sub-fractions elemental carbon (EC) and organic carbon (OC). EC is optically absorptive and often also designated as “soot”. OC comprises light organic molecules, which scatter sunlight without absorption. Carbonaceous particles originate from anthropogenic (mainly from fossil fuel combustion and biomass burning) and biogenic emissions. For the identification and quantification of these sources, many elemental and organic molecular tracers have been employed, but their reliability often suffers from limited atmospheric lifetimes due to their chemical reactivity and highly variable emission factors. Thus, there is a large uncertainty about the importance of anthropogenic emissions for the total carbonaceous aerosol burden of the atmosphere. In contrast to these tracers, radiocarbon (^{14}C) determinations enable a direct distinction of contemporary and fossil carbon in ambient aerosols, because ^{14}C has decayed in fossil material.

In this work, we present ^{14}C measurements in OC and EC from Jungfraujoch during summer 2004, winter 2004/2005, and summer 2005. For winter, we observed at Jungfraujoch a similar pattern of contributions from fossil, biogenic and biomass-burning sources as for an urban background station in Zurich[1,2], whereas concentration levels are more than an order of magnitude lower at the High-Alpine station. For summer, on the other hand, measurements indicate that aerosols from Jungfraujoch show higher percentages from biomass burning compared to Zurich, which suggest long-range transport of aerosols from forest fires, e.g. from Portugal and Spain in 2005.

[1] Szidat et al., J. Geophys. Res. 111, D07206 (2006).
[2] Wehrli et al., these proceedings (2006).

(1.4)

Source apportionment of carbonaceous aerosols with ^{14}C II. Results from the Swiss Plateau

M. Wehrli[1], S. Szidat[1,2], H.W. Gäggeler[1,2], M. Ruff[1,2], L. Wacker[3], H.-A. Synal[4], J. Sandradewi[2], A.S.H. Prévôt[2], U. Baltensperger[2]

[1] Department of Chemistry and Biochemistry, University of Berne, CH-3012 Bern, Switzerland
[2] Paul Scherrer Institut (PSI), CH-5232 Villigen, Switzerland
[3] Institute for Particle Physics, ETH Hönggerberg, CH-8093 Zürich, Switzerland
[4] PSI, c/o Institute for Particle Physics, ETH Hönggerberg, CH-8093 Zürich, Switzerland

Major components of the ambient aerosol are carbonaceous particles, which originate from biogenic or anthropogenic sources. A large amount of anthropogenic emissions are caused by fossil fuel combustion and biomass burning. In order to identify these different sources radiocarbon (^{14}C) is an important tracer. Since ^{14}C is already extinct in fossil fuels and biogenic sources emit aerosols on the present $^{14}C/^{12}C$ level, a direct determination of contemporary and fossil carbon in ambient aerosol is possible and enables, furthermore, an apportionment of biogenic and anthropogenic sources[1,2].

During an episode of high PM10 (particular matter with aerodynamic diameter <10 µm) concentrations, caused by the long-standing inversion weather conditions in January and February 2006, aerosol samples were collected on quartz fiber filters from an urban background site in Zurich, a heavily traffic-influenced site in Reiden and a rural site at Sedel, both in the Canton Lucerne. Preliminary the total carbon (TC) was subdivided into organic carbon (OC) and elemental carbon (EC). The origin of OC and EC can either be natural, thus from biogenic emissions (whereas the EC fraction can be neglected), or anthropogenic from biomass burning or fossil fuel combustion. The different major emission sources for the three sites Zurich, Reiden and Sedel will be shown.

[1] Szidat et al., Radiocarbon 46, 475 (2004).
[2] Szidat et al., these proceedings (2006).

(1.5)

Black carbon contribution to the aerosol phase and its scavenged fraction in mixed phase clouds at the high alpine site Jungfraujoch (3580m asl)

J. Cozic[1], B. Verheggen[1], S. Mertes[2], P. Connolly[3], K. Bower[3], A. Petzold[4], U. Baltensperger[1] and E. Weingartner[1]

[1] Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, CH-5232, Villigen PSI, Switzerland
[2] Leibniz-Institute for Tropospheric Research, D-04318, Leipzig, Germany
[3] University of Manchester, M60 1QD, Manchester, United Kingdom
[4] German Aerospace Centre, D-82234, Wessling, Germany

The mass fraction of black carbon (BC) and its mixing state are important for the direct aerosol climate effect. These properties also determine if BC is incorporated into cloud hydrometeors (i.e. droplets and ice crystals) and are important because the microphysical and optical properties of the cloud are altered (indirect aerosol effect). Measurements were performed during several Cloud and Aerosol Characterization Experiments, in winter 2004 (CLACE 3), summer 2004 (CLACE 3.5), winter 2005 (CLACE 4) and summer 2005 (CLACE 4.5) at the high Alpine research station Jungfraujoch (3580 m asl).

The aerosol was sampled by three well characterized inlets, discriminating between the total aerosol particles (including the residuals of the evaporated hydrometeors) using a heated inlet, the interstitial (unactivated) particles within a cloud using a PM2 cyclone, and the ice crystal residuals using a counterflow virtual impactor (CVI). A wide variety of physical and chemical parameters was determined downstream of these inlets. The BC concentration behind the inlets was measured by two Multi-Angle Absorption Photometers and two Particle Soot Absorption Photometers. These measurements were complemented by ion determination on filters (TSP and PM1) on the total inlet, EC/OC concentrations (thermo-optical analyzer) and submicron aerosol size distribution (SMPS) (from which a mass concentration was derived). In-situ measurements of cloud microphysical parameters (Particulate Volume Monitors and Cloud Particle Imager) allowed for the determination of the cloud liquid water content (LWC) and ice water content (IWC).

A mass closure of the Jungfraujoch aerosol was performed in winter and summer 2005 for total suspended particles (TSP) and PM1. The major aerosol mass was found to be quasi-internally mixed and present in the submicrometer size range except during Sahara dust events. OC is an important component with a larger contribution in summer (~55%) compared to winter (~26%). Black carbon represents ~7% of the PM1 aerosol mass in winter and ~3% in summer.

The scavenged fraction of BC ($F_{Scav, BC}$) is defined as the fraction of BC that has been incorporated into cloud droplets and ice crystals. BC was found to be scavenged into the cloud phase to the same extent as the bulk aerosol. Measurements show a continuous decrease of the scavenged fraction with increasing cloud ice mass fraction (IMF) from $F_{Scav, BC}$ = 60% in summer liquid phase clouds (IMF ~ 0) to $F_{Scav, BC}$ < 10% in mixed-phase clouds in winter (IMF > 0.8). This is explained by the evaporation of liquid droplets in the presence of ice crystals (Bergeron-Findeisen process) releasing the formerly activated cloud condensation nuclei (CCN), containing BC, back into the interstitial phase. In liquid clouds, the scavenged BC fraction is found to decrease with decreasing cloud liquid water content most likely resulting from a smaller amount of water vapour available for condensation which in turn might induce a lower supersaturation and thus less activated aerosol particles. The scavenged BC fraction is also found to decrease with increasing BC mass concentration since there is an increased competition for the water vapour available. The BC fraction was found to be enriched in small ice particles in comparison to the total aerosol phase (~20%), indicating that a high BC content renders a particle more likely to act as an ice nucleus and thus initiate droplet freezing. This result indicates that particles with an above average BC content serve as ice nuclei implying an anthropogenic influence of ice formation in Tropospheric clouds. Since ice formation affects the microphysical and radiative cloud properties this might have significant consequence for the indirect effect of aerosols on climate.

(1.6)

Four-year measurements of aerosol size distribution at the Mt. Cimone Station (Italy- 2165 m a.s.l)

A. Marinoni, P. Cristofanelli, F. Calzolari, F. Roccato, U. Bonafè and P. Bonasoni

CNR - Institute for Atmospheric Sciences and Climate, Via Gobetti, 101 Bologna, Italy

Atmospheric aerosols are important components of the earth-atmosphere system, which play a major role both in driving global climate and many biogeochemical cycles. Dust particles degraded visibility by solar attenuation (Kim et al, 2001), aerosols also help control the concentration, lifetime and the physical and chemical behavior of many important tracer gases by providing reaction sites and serving as carrier and/or sink for many atmospheric species (Zhang and Carmichael, 1999). In particular they can adsorb sulfur and nitrogen during the transport of polluted air masses (Kim and Park, 2001; Ma et al., 2001) influencing the (and thus pose a major uncertainty in) radiative forcing (Boucher and Anderson, 1996; Koloustou-Vakakis et al., 1999). In addition, the dust events has been reported to induce an inflammation effect on pulmonary intensive rats (Lei et al., 2004) and might thus increase the health risk on vulnerable people.

Mt. Cimone "O.Vittori" Station (2165 m asl) provides information on South European free troposphere aerosol number size distribution, in a site exposed to 360° air mass origin and over standing the polluted Po Valley. Since June 2002 at Mt. Cimone "O.Vittori" Station, accumulation and coarse particle concentration (in 15 size distribution channels) is continuously recorded with an optical particle counter for 0.30 m ≤ Dp < 20 m. At this site, coarse fraction of aerosol population is indicative of Saharan dust transport events that were identified and correlated with other meteorological and chemical parameters.

Moreover, since November 2005, a Differential Mobility Particle Sizer permits to extend the number size distribution to smaller particles until Aitken and Nucleation modes (lower diameter at 10 nm). The complete aerosol size distribution allows to reach good information on different contributions (sources and transformations) to the aerosol total mass and also to estimate the effectiveness at scattering incoming solar radiation, back to space.

The goals of this study are:

i. identify long range and regional transport of air masses rich in aerosol particles,
ii. study the relationship between aerosol size distribution and meteorological parameters, ozone and other atmospheric compounds,
iii. provide data to model results about the influence of aerosol on climate change.

References

Kim, B-G. and S-U. Park. 2001. Transport and evolution of a winter-time Yellow sand observed in Korea. Atmospheric Environment 35, 3191-3201.

Zhang, Y. and G.R. Carmichael. 1999. The role of mineral aerosol in tropospheric chem.istry in East Asia – a model study. Journal of Applied Meteorology 38, 353-366.

Kim, K.W., Y.J. Kim and S.J. Oh. 2001. Visibility impairment during Yellow Sand periods in the urban atmosphere of Kwangju, Korea. Atmospheric Enviroment 35, 5157-5167.

Ma, C.J, M. Kasahara, S. Tohno and K.C. Hwang. 2001. Charactherisation of atmospheric aerosol in Kyoto and Seoul using PIXE, EAS and IC, Atmospheric Environment 35, 747-752.

Boucher, O. and Anderson T.L. 1996. GCM assessment of the sensitivity od direct climate forcing by anthropogenic sulphate aerosol to aerosol size and chemistry. Journal of Geophysical Research 100, 26117-26134.

Koloustou-Vakakis, S., C.M. Carrico, Z. Li, M.J. Rood and J.A. Ogren. 1999. Characterisation of aerosol properties and radiative forcing at an anthropogenically perturbed continental site. Physics Chemistry Earth (C), 24 (5), 541-546.

(1.7)

Continuous aerosol and ozone measurements at 5079 m in Himalaya: the ABC-Pyramid Atmospheric Research Laboratory

P. Bonasoni[1], P. Laj[2], U. Bonafè[1], F. Calzolari[1], P. Cristofanelli[1], S. Decesari[1], L. Emblico[1], MC. Facchini[1], S. Fuzzi[1], GP. Gobbi[1], A. Marinoni[1], F. Roccato[1], JM. Pichon[2], K. Sellegri[2], H. Venzac[2], P. Villani[2], J. Arduini[3], M. Maione[3], A. Petzold[4], M. Sprenger[5], G. Tartari[6], GP. Verza[6] and E. Vuillermoz[6]

[1] CNR - Institute for Atmospheric Sciences and Climate, Bologna, Italy
[2] CNRS - Université Blaise Pascal, Aubière Cedex, France
[3] Urbino University, Department of Environmental Science, Urbino, Italy
[4] DLR – Institute of Atmospheric Physics, Wessling, Germany
[5] ETHZ - Swiss Federal Institute of Technology, Zurich, Switzerland
[6] EV-K2-CNR Committee, Bergamo, Italy

The monitoring of atmospheric composition at high altitudes can play a relevant role in the climate change studies and (in order) to evaluate the environmental influences of the development of very densely populated regions. The South Asia continent is one of these regions which spread in the area and worldwide high pollutant emissions. For these reasons and in order to make up for a lack of background information in this region, in the framework of the Ev-K^2-CNR SHARE ASIA (Stations at High Altitude for Research on the Environment) and ABC (Atmospheric Brown Clouds) projects the remote monitoring station ABC-Pyramid has been installed in Nepal, at 5079 m asl. This monitoring station, starting the activity in February 2006, was projected to perform continuous measurements of chemical, physical and optical properties of aerosol and tropospheric ozone, as well as halocarbons and other greenhouse gases. Thus, this station, controlled by a remote satellite connection and designed to operate for long-term in extremely adverse weather conditions, represents a unique source of data for evaluating the conditions of the free troposphere, for quantifying the pollution levels at high altitudes of the Himalayan ridges, between India and China, and for studying regional and long-range air mass transport of natural and anthropogenic compounds.

The goal of this project is to increase the knowledge on: i) how the physical, chemical, and optical properties of aerosol change at high Himalayan altitude, with season and air mass origin; ii) how aerosol size and light scattering change during pollution and dust transport episodes; iii) establish how much stratospheric intrusions, polluted long-range transport and regional episodes contribute to background ozone concentrations; iv) determine the concentrations of greenhouse active and ozone-destroying halocarbons. Preliminary results will be presented.

(2.1)
Water vapour measurements from ground-based remote sensing instruments situated between the Swiss plains and Jungfraujoch (3584 m)

June Morland, Christian Mätzler

Institute of Applied Physics, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland

Water vapour is a natural greenhouse gas, and the amount of water vapour in the atmosphere increases with increasing temperature. If the atmosphere warms as a consequence of increased greenhouse gas concentrations, increased water vapour amounts will lead to further atmospheric warming. It is therefore important to understand the role played by water vapour in the climate system and to carry out long term water vapour monitoring.

Until recently, atmospheric water vapour could only be measured directly through radiosonde ascents. Passive microwave sensors on satellites can provide measurements of Integrated Water Vapour (IWV) or water vapour profiles over the ocean. Over the land, however; these measurements are not possible due to the high background emission. Infrared sensors, such as that on the Meteosat Second Generation satellite, can provide measurements of water vapour in the higher atmospheric layers (500 hPa upwards) over both land and water. Infrared spectrometers, such as the GOME and SCHIAMACHY instruments, can provide water vapour profiles down to the surface, but the revisit time is several days.

In this context, water vapour measurements from ground-based remote sensing can be extremely useful, both for understanding water vapour variations and for long term monitoring. In the context of the NCCR (National Centre for Competence in Research) Climate STARTWAVE (Studies in Atmospheric Radiation and Water Vapour Effects) project, we have created a database of IWV measurements made in Switzerland by radiosonde (Payerne), microwave radiometers (Bern), sun photometers (five locations between 366 and 3580 m) and fixed Global Positioning System (GPS) receivers (31 locations between 330 and 3584 m). `

The dense network of fixed GPS receivers operated by the Federal Swiss Office of Topography provide hourly IWV measurements arid allow us to observe spatial changes in IWV associated with weather phenomena. Muttenz (330 m) in the Swiss plains has a mean annual pressure of 980 mb and the mean annual IWV is 16.8 mm. Jungfraujoch (3584 m), on the other hand, is located on a high Alpine pass and has a mean annual pressure of 660 mb and a mean annual IWV of just 3.6 mm. At Jungfraujoch, IWV values as low as 0.2 mm have been recorded by the sun photometer. In these conditions, the noise in the GPS measurement is larger than the quantity being measured. When the GPS records less than 1 mm water vapour, we combine the GPS data with sun photometer data or an IWV estimate based on temperature, humidity and radiation measurements.

The Alps present both an opportunity and a challenge for the exploitation of these data. The opportunity lies in the fact that we can use the GPS network to provide hourly vertical profiles of IWV for the Swiss region and the challenge in the fact that we must correct the measurements to a standard altitude in order to observe horizontal variations in IWV. We fit an exponential relationship to the change in IWV with altitude observed by the Swiss GPS network and this is used to correct the measurements made by each station to a standard altitude of 500 m. The IWV scale height is calculated from the difference between the IWV measured at Payerne (498 m) and that measured at Jungfraujoch (3584 m). The average annual value of the scale height is 2:1 km, although the hourly value can vary between 0.8 and 5.8 km.

(2.2)

Water vapor/aerosol profiling using a Raman lidar: The Jungfraujoch EPFL lidar station as a kick-off platform for an operational instrument within MeteoSwiss

Bertrand Calpini[1], Todor Dinoev[2], Pablo Ristori[2], Yuri Arshinov[3], Sergey Bobrovnikov[3], Yves-Alain Roulet[1], lya Serikov[2], Valentin Simeonov[2], and Hubert van den Bergh[2]

[1] MeteoSwiss - Aerological station Payerne
[2] EPFL - Air Pollution Laboratory
[3] Institute of Atmospheric Optics -Tomsk, Russia

Initial R&D work for the setup of a water vapor/aerosol Raman lidar demonstrator was performed by the Swiss Federal Institute of Technology in Lausanne EPFL using the Jungfraujoch research station. In 2004 MeteoSwiss and EPFL signed a contract for the development and deployment of an operational water vapor/aerosol Raman lidar. This poster will highlight the different steps between an instrument developed as a research tool for atmospheric studies and a system of observation designed for füll time (day and night) continuous operational use over years. The specifications of this lidar unit will be presented, and a special emphasis will be given on the different original and custom design elements used in the instrument. The target of this project is the longest lifetime of the entire lidar unit with minimum human resources for maintenance and repair. The lidar should fulfill the following requirements: Continuous automated operation, without operator on site, Manual re-calibration activated when separate calibrated data are available, Generation of automatic products (water vapor and attenuated backscatter profiles). A series of results obtained from the lidar currently in development at EPFL will be demonstrated.

(3.1)

Trends of new F-Gases derived from measurements at the high-altitude observatory at Jungfraujoch

Martin K. Vollmer, Stefan Reimann and Doris Folini

EMPA, Swiss Federal Institute for Environmental Technology and Research, Air Pollution and Environmental Technology, Uberlandstrasse 129, 8600 Dubendorf

International regulations on the use of ozone-depleting substances are leading to the global phase-out of chlorofluorocarbons (CFCs) and hydro-chlorofluorocarbons (HCFCs) over the next decades. Substitutes are the non-ozone depleting hydrofluorocarbons (HFCs) or F-Gases. Among these are some compounds which have been on the market for less than a decade, and the focus of this presentation is on these substances. We present the first observations world-wide of atmospheric HFC-365mfc (CF3CH2CF2CH3) and HFC-245fa (CHF2CH2CF3) from measurements at the high-altitude obser-vatory at Jungfraujoch, Switzerland. Our measurements capture the recent appearance of these substances in the clean background air. These 2 sub-stances have entered the foam blowing market less than 5 years ago and are mainly replacements for HCFC-141b which is in the phase-out process under the Montreal Protocol. HFC-365mfc, with an atmospheric lifetime of 10 yrs, has increased in the northern hemisphere troposphere from 0.1 ppt in early 2003 to 0.4 ppt in early 2006. This compound is currently used and emitted exclusively in Europe and consequently frequent pollution events are monitored at Jungfraujoch. HFC-245fa on the other hand, is predominantly marketed and emitted in North America and is currently growing at an overall rate of nearly 90% per year in the northern hemisphere. Pollution events of this substance at Jungfraujoch are rare. In the southern hemisphere, where most developing countries’ phase-out of CFCs and HCFCs is delayed, the use and emissions of HFC-365mfc and HFC-245fa are negligible compared to the northern hemisphere. The absence of southern hemispheric emissions of these compounds simplifies the modeling of the atmospheric fate of these gases. This suggests that they may be excellent tracers of interhemispheric exchange, or they may be valuable tools to study southern hemisphere OH, since reaction with OH is the only significant sink of these compounds in the atmosphere.

(3.2)
BEO Moussala – a new site for complex environmental studies

Ivo Angelov, Christo Angelov, Luben Barnekov, Georgy Bonchev, Dimiter Belokapov, Alexander Bojukliisky, Bojidar Damianov, Anna Damianova, Kostadin Georgiev, Metody Guelev, Petar Ivanov, Ivo Kalapov, Ivan Kirov, Elisaveta Malamova, Alexander Mishev, Alexei Nishev, Nina Nikolova, Ilia Penev, Ivan Sivriev, Jordan Stamenov, Boyko Vachev

Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences
72, Tzarigradsko chaussee Blvd., 1784 Sofia, Bulgaria

The basic directions of studies and activities of Basic Environmental Observatory (BEO) Moussala have been presented: Global change; Space weather; Sustainable development; Measurement devices and systems development and enhancement; Improvement of technical infrastructure of research infrastructure; Science communication.

The recent reconstruction and renovation of BEO Moussala is the result of the EUSAAR I3 FP6 project "European Super-sites for Atmospheric Aerosol Research" and BEOBAL FP6 Project "BEO Centre of Excellence Research Capacity Improvement for Sustainable Environment and Advanced Integration into ERA" *(INCO-CT-2005-016663).*

In fact, now more of the 95% of all measurement systems and devices and basic infrastructure systems of the BEO Moussala are in stage of full replacement or principle reconstruction and modernization.

The recent results and achievements of BEO Moussala in the framework of BEOBAL and EUSAAR projects are presented.

The relative contents of gases as: CO, NO, NO_2, NO_x, SO_2 and O_3 in the atmosphere were obtained in real time.

The radioactive aerosol content is measured and analysed in quasi real time. Special attention is paid to BE_7.

The gamma background, muon and neutron flux of cosmic radiation were measured and their fluctuation in real time analysed, taking into account the meteorological parameters obtained with the Vaisala automatic device.

All this data are stored in data base towards to perform complex data analysis in frame of global change and aerospace weather.

The live data and detail information about BEO Moussala activities are available on the BEO web sites http://www.beo.inrne.bas.bg and http://beo-db.inrne.bas.bg .

(3.3)

OVOCs at the high alpine station Jungfraujoch: In-situ measurements and estimation of anthropogenic sources

G. Legreid[1], S. Reimann[1], M. Steinbacher[1], J. Balzani-Lööv[2] and J. Staehelin[2]

[1]Swiss Federal Laboratories for Material Testing and Research (EMPA)
CH-8600 Duebendorf, Switzerland
[2]Institute for Atmospheric and Climate Science, Swiss Federal Institute of Technology,
CH-8092 Zurich, Switzerland

A double adsorbent sampling system for the Oxygenated Volatile Organic Compounds (OVOCs) coupled to a GC-MS was used to analyse air during both winter and summer conditions at the high Alpine station at Jungfraujoch. The OVOCs measured are not only emitted from anthropogenic and biogenic sources, but also produced by oxidation processes in the atmosphere [1]. The compounds of main interest have been C1-C5 alcohols, C2-C6 carbonyls and selected VOCs. Figure 1 shows the time series for selected OVOCs during the two campaigns in 2005. Primary source regions for these compounds have been identified from back-trajectory analysis, and their source strength was calculated from average ratio of the OVOCs versus carbon monoxide (CO) concentrations during pollution events [2]. Characteristic ratios of the OVOCs with more stable compounds (CO, benzene etc.) are compared with ratios from comparable measurements from an urban station in Zürich (Figure 2). Results from this analysis give an indication on the secondary production and destruction rate during transport to the remote troposphere. The POCP values of the compounds are used to estimate their importance in the ozone production in the Swiss boundary layer.

References:

[1]: Singh, H. B., L. J. Salas, et al. (2004). *Journal of Geophysical Research-Atmospheres* **109**(D15): art. no.-D15S07.
[2]: Reimann, S., D. Schaub, et al. (2004). *Journal of Geophysical Research-Atmospheres* **109**(D5): art. No. –D05307.

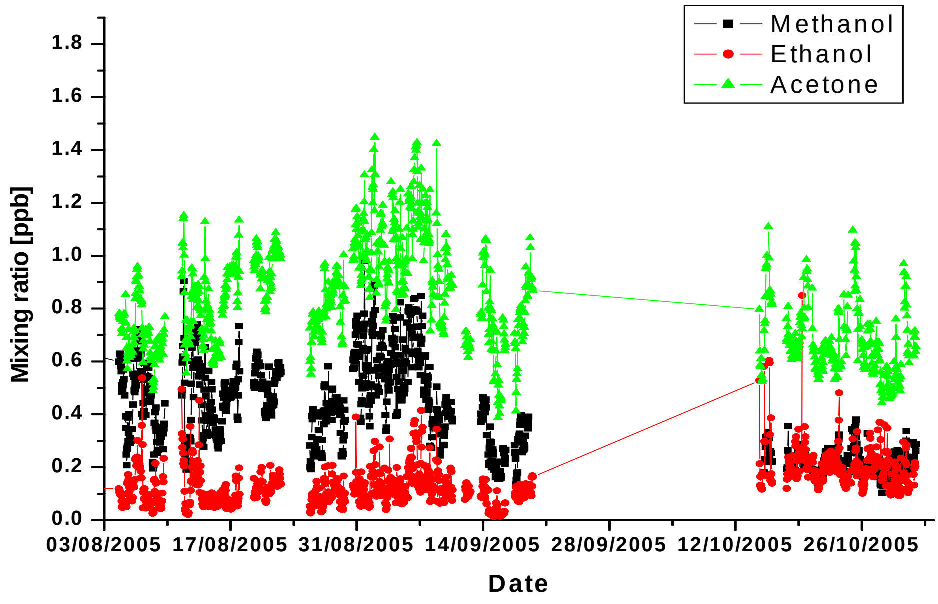


Figure.1. Continuous measurements of 3 OVOCs at the high alpine site Jungfraujoch during the measurement campaigns in August/September and October 2005.

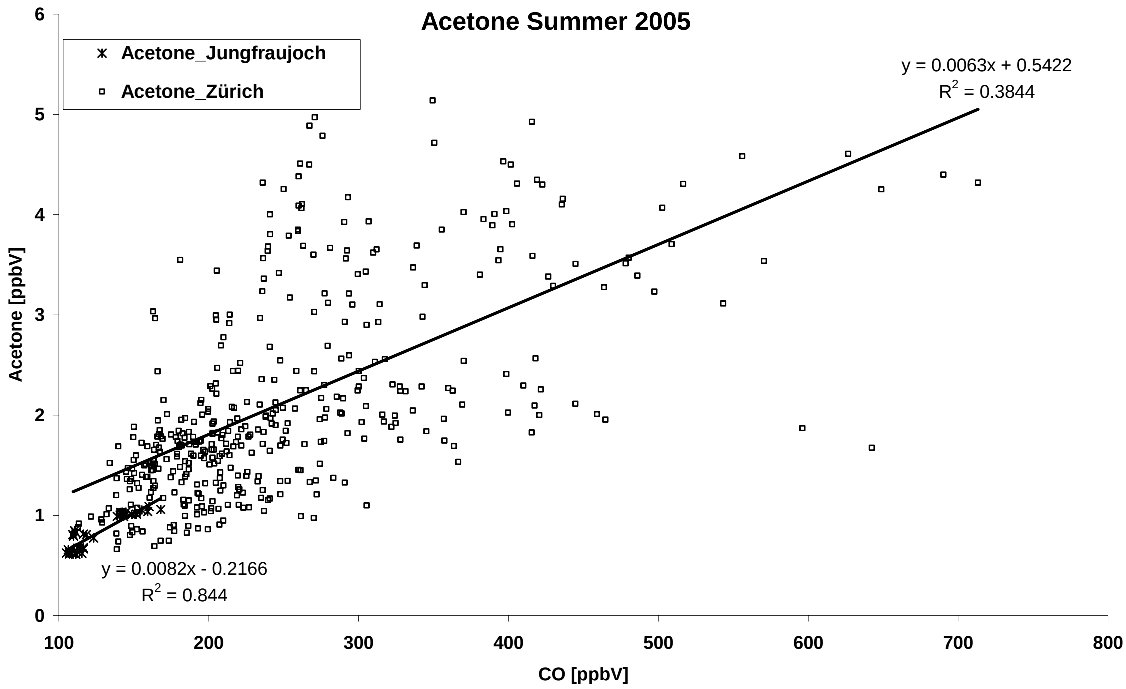


Figure 2. Acetone versus CO from measurements in Zürich and at Jungfraujoch during summer conditions in 2005. Data from Jungfraujoch are only for periods where air arrived from the northern boundary layer.

(3.4)

Volatile organic compounds (VOC) in air at high alpine research station Jungfraujoch during CLACE 4 and CLACE 5

K. Sieg, E. Fries, E. Starokozhev, B. Heurich, W. Püttmann, W. Jaeschke

Institut für Atmosphäre und Umwelt, J.W. Goethe Universität, D-60325 Frankfurt am Main, Germany

Naturally occurring emissions and continuously rising levels of anthropogenic emissions are responsible for the presence of volatile organic compounds (VOC) in the atmosphere. Due to vertical transport processes chlorinated and aromatic hydrocarbons were detected at higher altitudes (Prévot et al., 2000, Reimann et al., 2004). Secondary aerosols are formed from biogenic and anthropogenic VOC (Barthelmie & Pryor, 1997). An important process affecting the fate of VOC in the atmosphere is their removal by wet deposition (Czuczwa et al., 1988). Most of the precipitation falling to the surface at mid-latitudines originates as ice in mixed phase clouds at higher altitudes. One possible uptake mechanism for VOC by ice crystals could be the uptake of gaseous VOC during crystal growth by vapour deposition (Huffmann & Snider, 2004).

During the Cloud and Aerosol Characterization Experiments CLACE 4 in February-March 2005 and CLACE 5 in February-March 2006 quasi-continuous measurements of VOC in air, snow, ice crystals and super-cooled droplets were carried out at the Sphinx laboratory at the alpine research station Jungfraujoch (3580 m asl). The measurements were focused on C_2-C_{12} nonmethane hydrocarbons (NMHC). The following poster focuses on the presentation of the air measurements.

During the CLACE – experiments VOC in air were measured primary with a method based on an online-gas chromatographic system (AirmoVOC 2010) with a time resolution of 240 min (CLACE 4) respectively 60 min (CLACE 5). The VOC were collected on adsorption tubes filled with activated charcoal. The equipment was calibrated by a parent gas standard (National Physical Laboratory, UK) containing 28 VOC (alkenes, alkanes, aromatics) at a concentration of approximately 5 ppb.

Preliminary results show that alkenes, alkanes and aromatic hydrocarbons are present in the gas phase at the Jungfraujoch area at high altitudes. The results of both campaigns show good agreement to each other. The results of our measurements are a contribution to the continuous gas phase measurements of the EMPA group at Jungfraujoch. A sustainable monitoring allows us to evaluate the impact of anthropogenic emissions on the free troposphere.

The results obtained from Jungfraujoch are compared to the results from the BERLIOZ field campaign in summer 1998. During the BERLIOZ experiment VOC were measured on selected ground level stations to get an image of the VOC distribution in air in and around Berlin (Winkler, 2002). Changes of concentration levels during one day at Jungfraujoch and in Berlin are presented exemplary for single compounds.

At Jungfraujoch the maximum daily concentration was detected mainly in the early afternoon. The minimum concentration was measured during the night time. In Berlin, the maximum daily concentration was measured in the night. The minimum concentration was measured during first hours of afternoon.

A possible explanation for these results could be polluted air masses from the Valley arising at higher altitudes at Jungfraujoch due to thermal uphill lifting during the day. In the night, the influence of the free atmosphere could result in a dilution of the VOC concentrations due to the absence of vertical mixing. However, during the BERLIOZ campaign, the maximum daily concentrations of VOC in the night are explained by a strong photochemical degradation of those compounds during the day. This can lead to a concentration minimum during the day although car traffic is an important source of VOC at that time. In the night photochemical degradation of VOC is low. Those compounds accumulate at night and reach a concentration maximum.

Barthelmie, R.J., Pryor, S.C (1997). Sci. Total Environ. 205, 167-178.
Czuczwa, J, Leuenberger, C. and Giger, W. (1988). Atmos. Environ. 22, 907-916.

Huffman, W.A. and Snider, J.R. (2004). J. Geophys. Res, 109, D01302.

Prévot, A.S.H., Dommen, J., Bäumle, M. (2000). Atmos. Environ., 34, 4719-4726.

Reimann, S., Schaub, D., Stemmler, K., Folini, D., Hill, M. Hofer, P., Buchmann, B. J. (2004). Geophys. Res. 109, D05307.

Winkler, J., Blank, P., Glaser, K., Gomes, J.A.G., Habram, M, . Jambert, C., Jaeschke, W.,

Konrad, S., Kurtenbach, R., Lenschow, P., Lörzer, J.C., Perros, P.E., Pesch, M., Prümke, H.J., Rappenglück, B., Schmitz, Th., Slemr, F., Volz-Thomas, A., Wickert, B. (2002) Ground-based and airbonre measuremnts of nonmethane hydrocarbons in BERLIOZ: Analysis and selected results. Journal of Atmospheric Chemistry 42, 465-492.

(3.5)
Significant enhancement of CO_2 and O_2 trends at the High Alpine Research Station Jungfraujoch

M. Leuenberger, C. Uglietti, F. L. Valentino, P. Nyfeler, H.P. Moret, P. Sturm

Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland

Atmospheric oxygen measurement, together with carbon dioxide, is a useful tool to deduce and separate carbon fluxes due to surface exchange and atmospheric transport processes. A powerful approach, developed by (Keeling & Shertz, 1992), is based on measurements of atmospheric oxygen to constrain the partitioning of anthropogenic CO_2 between the ocean and the terrestrial biosphere. O_2 and CO_2 are exchanged in relatively fixed stoichiometric ratios during the burning of fossil fuels as well as during photosynthesis and respiration by plant, animals, and bacteria. By contrast, dissolution of CO_2 in the ocean has no effect on atmospheric O_2 which is also less soluble than CO_2 in water. Hence mainly the uptake or release of CO_2 by the biosphere will leave an imprint on atmospheric O_2. By knowing the fossil fuel emissions and the exact values of the stoichiometric ratios, one can separate on timescales of a few years the total CO_2 uptake into land and ocean components.

Here we present a study done on coupled CO_2 and O_2 measurements performed at the High Alpine Research Station Jungfraujoch. Atmospheric Potential Oxygen ($APO = O_2/N_2 - 1.1 \cdot CO_2$) is a helpful tracer since the scaled terrestrial signal is subtracted and it should essentially be dominated by ocean exchange and/or fossil fuel emissions (Stephens et al., 1998). A recent analysis done by (Sturm et al., 2005), by means of computed oxidation ratios and APO derived from flasks measurements, indicates a strong oceanic component contributing to the oxygen seasonal cycle even at the continental site Jungfraujoch. The last updated flasks measurements confirms these findings while the new continuous on-line measurements provide us new results with a daily to weekly variability in the oxidation ratios of -1.31 to -2.47 mol O_2/mol CO_2.

References:

Keeling RF, Shertz SR. 1992. Seasonal and interannual variations in atmospheric oxygen and implications for the global carbon cycle. Nature 358:723-727.

Stephens BB, Keeling RF, Heiman M, Six KD, Murnane R, Caldeira K. 1998. Testing global ocean carbon cycle models using measurements of atmospheric O_2 and CO_2 concentration. Glob. Biogeochem. Cycles 12(2):213-230.

Sturm P, Leuenberger M, Schmidt M. 2005. Atmospheric O_2, CO_2 and $d^{13}C$ observations from the remote sites Jungfraujoch, Switzerland, and Puy de Dôme, France. Geophysical Research Letters 32:L17811.

(3.6)

Atmospheric CO_2 and $\delta^{13}C$ flask measurements combined with a continuous on line CO_2 record at the High Alpine Research Station Jungfraujoch

F.L. Valentino[1], M. Leuenberger[1], C. Uglietti[1], P. Nyfeler[1], H.P. Moret[1], P.Sturm[1], M. Fischer[2], K. Hemund[2]

[1]Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
[2] Hochalpine Forschungsstation CH-3801 Jungfraujoch, Switzerland

Since the year 2000 the Climate and Environmental Physics Institute of Bern is monitoring carbon dioxide at the High Alpine Research Station Jungfraujoch. Every two weeks two air samples are collected at the Jungfraujoch station into glass flasks and analyzed in Bern to determine the CO_2 and the $\delta^{13}C$ concentration. The CO_2 mixing ratio is measured using a mass spectrometric method (Leuenberger et al., 2000) with an estimated accuracy of about ±0.5ppm. $\delta^{13}C$ is determined with a technique developed in our laboratory (Leuenberger et al., 2003) using a GC/MS and a syringe method. These measurements provide us interesting information on seasonal cycles and long-term trends as documented by (Sturm et al., 2005). Additionally they can be compared to other flasks measurements from aircraft sampling above Griffin Forest, UK, and from Puy de Dôme, France.

To learn more about short term variations of atmospheric CO_2 and to get a higher time resolution of the measurements a new on line system for continuous recording the carbon dioxide and oxygen concentrations has been installed in December 2004. Carbon dioxide is measured with a resolution of 1 second by a commercially available infrared analyzer (Sick Maihak S700). The system controls the gas path thanks to a setup of Clippard valves switching between sample air and three different calibration gases. The measurement precision is better than 0.1 ppm. The results of the continuous measurements agree nicely with the CO_2 data of the flasks samples but revealing additional short-tem (hourly to daily) variations. This suggests us to reconsider our restrictive outlier criteria for the flasks measurements.

References:

Leuenberger M, Nyfeler P, Moret HP, Sturm P, Indermühle A, Schwander J. 2000. CO_2-concentration measurements on air samples by mass spectrometry. Rapid Communications in Mass Spectrometry 14:1552-1557.

Leuenberger MC, Eyer M, Nyffeler P, Stauffer B, Stocker TF. 2003. High-resolution $d^{13}C$ measurements on ancient air extracted from less than 10 cm^3 of ice. Tellus 55B:138--144.

Sturm P, Leuenberger M, Schmidt M. 2005. Atmospheric O_2, CO_2 and $d^{13}C$ observations from the remote sites Jungfraujoch, Switzerland, and Puy de Dôme, France. Geophysical Research Letters 32:L17811.

(3.7)

Measurement of Formaldehyde and PAN at the high alpine Jungfraujoch research station: Seasonal differences and Background Concentrations.

Jacob Marcus Balzani Lööv[1], Johannes Staehelin[1], Geir Legreid[2], Stefan Reimann[2], Martin Steinbacher[2], André Prévôt[3].

[1]ETH Institute of Atmospheric and Climate Science, Schaftmattstr. 30, CH 8093 Zürich, Switzerland;
[2]EMPA Abteilung Luftfremdtstoffe / Umwelttechnik, Überlandstr. 128, CH 8600 Dübendorf, Switzerland;
[3]Paul Scherrer Institut Labor für Atmosphärenchemie, CH 5232 Villingen PSI.

The high alpine station at Jungfraujoch located at 3580 m a.s.l. in the Swiss Alps is a very suitable site to study intercontinental transport events of air masses polluted by primary emissions of the planetary boundary layer of North America and to study in-situ photochemistry of the lower free troposphere over the European continent as documented by earlier studies. In the 2005, 4 different campaigns, one for every season, took place at the research station. During those campaigns Formaldehyde and Oxygenated Volatile Organic Compunds (OVOCs) have been measured. Peroxyacetylnitrate (PAN) has been measured thorough all 2005 until August 2006.

Those field measurements extend and complement the continuous measurements performed in the Global Atmosphere Watch (GAW) project of the World Meteorological Station (WMO) performed by EMPA (NO, NO_2, NO_x, CO, O_3 and selected volatile hydrocarbons).

One hour resolution LAGRANTO trajectories have been used as a main tool to define an air mass with a particular signature: Stratospheric, North American P.B.L. or European P.B.L. Furthermore they help to define background concentrations, a critical step for compounds which are primary and secondary air pollutants. The measurement results will be shown including statistics of Formaldehyde and PAN in the different seasons.

(3.8)
Monitoring of non-CO_2 Greenhouse Gases at the High Mountain Station of Mt. Cimone (2165 m a.s.l.), Northern Apennines, Italy

Jgor Arduini, Luca Belfiore, Francesco Furlani, Annalisa Geniali, Umberto Giostra, Giovanna Mangani and Michela Maione

University of Urbino, Faculty of Environmental Sciences, 61029 Urbino (Italy)

Halogenated greenhouse gases are continuously monitored at the Italian high mountain station of Monte Cimone (Northern Apennines, 2165 m a.s.l.), whose location is crucial both for assessing baseline concentrations and for identifying transport events from the polluted areas located in the nearby valleys. The activity is carried out in the frame of the EU funded project SOGE (System for Observation of halogenated Greenhouse gases in Europe) aimed at four European back-ground sites in the frame of the SOGE (System for Observation of halogenated Greenhouse gases in Europe) network. The network includes four stations Mace Head (IE), Ny-Ålesund (Spitsbergen, NO), Jungfraujoch (CH) and Monte Cimone (IT), two of which (Jungfraujoch and Monte Cimone) are mountain sites, whose location is crucial in assessing the role of specific potential source regions in Europe. Capillary gas chromatography-quadrupole mass spectrometry preceded by on-line sampling/adsorption is used. The four stations are fully inter-calibrated among themselves thanks to the use of “working secondary standards” linked to two absolute calibration scales for halocarbons which reside at the Scripps Institution of Oceanography (SIO98 scale-SIO, La Jolla, Ca, USA) and at Bristol University (UB98 scale, University of Bristol, Bristol, UK), for 7 and 14 compounds, respectively.

Extended time series are available for the halogenated greenhouse gases object of the study as well as data analysis using a back-trajectories approach.

(4.1)

A 1000-year climate history from an Alpine ice core?

Michael Sigl [1,2], David Bolius[1], Theo Jenk[1,2], Margit Schwikowski[1], Heinz W. Gäggeler[1,2]

1 Paul Scherrer Institut, Laboratory for Radio- und Environmental Chemistry, 5232 Villigen PSI, Switzerland
2 Department of Chemistry and Biochemistry, University of Bern, Freiestr.3, 3012 Bern, Switzerland

Reconstruction of long-term regional temperature variability is of great interest in climate research. In the Alpine region, much progress has been made in reconstructing climate history using long instrumental records (e.g. Böhm et al. 2001), documentary evidence (e.g. Pfister 1999; Luterbacher et al., 2004) and tree-ring series (e.g. Büntgen et al. 2005). However, climate proxies covering more than a few centuries with a sufficiently high time resolution are rare in Central Europe, but may be found in cold glacier archives.

Here, we present the first results from a 82 m long ice core drilled in 2003 on Colle Gnifetti (4450 m), a glacier saddle in the Monte Rosa Massif, Swiss Alps. The location has been the focus of climate researchers for a long time (Oeschger et al. 1978; Schotterer et al. 1985; Döscher et al. 1996). Cold temperatures as well as the saddle position promise a low influence on the quality of the record by melting and ice flow.

For dating the ice core different methods have been applied. Annual layer counting based on parameters with a pronounced seasonality, such as concentration of NH_4^+ or $\delta^{18}O$, has been used in the upper part of the core. More dating points could be added by identifying well known stratigraphic time markers like Saharan dust events, volcanic eruptions or the maximum of superficial nuclear weapon tests in the early 1960ies. Those events can easily be detected in the ice core by their chemical or isotopic fingerprints. For the deepest part of the core, ages have been determined by analysing ^{14}C in carbonaceous particles extracted from the ice (Jenk et al. submitted). Within the last 2.5 m of this ice-core the ^{14}C ages are continuously increasing from 1’500 to more than 16’000 yrs BP.

The record of stable isotopes in water ($\delta^{18}O$, δD) is assumed to provide a proxy for past temperatures. Most of the core has already been analyzed. The $\delta^{18}O$ signal shows an intriguing depletion of 6‰ at 2.5 m above bedrock. A similar dip was observed in ice cores from Greenland at the Glacial-Holocene transition (Grootes et al. 1993). Together with the presented ^{14}C ages, it is likely that this Alpine ice core covers the entire Holocene, however with extreme thinning of annual layers in the last couple of meters.

Before a detailed climatic interpretation of this record can be done, analyses have to be completed. Besides that, our future work will concentrate on a refinement of the depth-age relationship and the calibration of the stable isotope records with instrumental data series.

References

Böhm, R., Auer, I., Brunetti, M., Maugeri, M., Nanni, T., Schöner, W. 2001: Regional temperature variability in the European Alps: 1760-1998 from homogenized instrumental time series. International Journal of Climatology 21, 1779-1801.

Büntgen, U., Esper, J., Frank, D.C., Nicolussi, K., Schmidhalter, M. (2005): A 1052-year tree-ring proxy for Alpine summer temperatures. Climate Dynamics 25, 141-153.

Döscher, A., Gäggeler, H.W., Schotterer, U., Schwikowski, M. (1996): A historical record of ammonium concentrations from a glacier in the Alps. Geophysical Research Letters 23, 2741-2744.

Grootes, P.M., Stuiver, M., White J.W.C., Johnsen, S., Jouzel, J. (1993): Comparison of oxygen isotope records from the GISP2 and GRIP Greenland ice cores. Nature 366, 552-554.

Jenk, T., Szidat, S., Schwikowski, M., Gäggeler, H.W., Bolius, D., Wacker, L., Synal, H.A., Saurer, M. (submitted): Microgram level radiocarbon (^{14}C) determination on carbonaceous particles in ice. Proceedings of AMS-10 Conference, Berkley, Sept 05-10, 2005. Nuclear Instruments and Methods in Physics Research B.

Luterbacher, J., Dietrich, D., Xoplaki, E., Grosjean, M., Wanner, H. (2004): European seasonal and annual temperature variability, trends and extremes since 1500. Science 303, 1499-1503.

Oeschger, H., Schotterer, U., Stauffer, B., Haeberli, W., Röthlisberger, H. (1978): First results from Alpine core drilling projects. Zeitschrift für Gletscherkunde und Glazialgeologie 13, 193-208.

Pfister, C. (1999): Wetternachhersage. 500 Jahre Klimavariationen und Naturkatastrophen 1496-1995. Bern, Stuttgart, Wien.

Schotterer, U., Oeschger, H., Wagenbach, D., Münnich, K.O. (1985): Information on paleo-precipitation on a high-altitude glacier, Monte Rosa, Switzerland. Zeitschrift für Gletscherkunde und Glazialgeologie 21, 379-388.

(4.2)

An ice core record of ENSO related climate variability from Mercedario (32°S) in the Central Argentinean Andes

Anita Ciric[1, 2], Margit Schwikowski[1], Heinz W. Gäggeler[1,2]

[1] Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[2] Department of Chemistry and Biochemistry, University of Berne, Freiestrasse 3, CH-3012 Bern, Switzerland

Ice cores from high altitude glaciers have proved to contain valuable archives recording regional climate fluctuations and atmospheric pollution history. The El Niño-Southern Oscillation (ENSO), which describes a complex coupled circulation system between the atmosphere and the ocean, influences precipitation over the entire coast of South America. Its impact on Andean glaciers is most direct between 28°S and 35°S where the Pacific acts as the moisture source. The amount of winter precipitation in this semi-arid area is significantly correlated to the Southern Oscillation Index (SOI) (Aceituno, 1988), with higher values during El Niño years. South of 35°S, it is generally more humid and the influence of ENSO on precipitation declines. Between 45°S and 55°S precipitation even decreases by about 15% during strong El Niño years (Schneider and Gies, 2004).

Hence, glaciers between 28°S and 35°S are expected to record a strong ENSO signal and are therefore potential paleoclimatic archives containing information about ENSO in the past.

In February 2005, a 104 m long ice core was recovered from La Ollada glacier on Mercedario (31°58'S, 70°07'W, 6100 m a.s.l.) in Argentina. Assuming that in El Niño years the $\delta^{18}O$ signal is more depleted when strong precipitation causes a "rainout effect", as was interpreted for Cerro Tapado (Ginot and others, 2002), more negative $\delta^{18}O$ values in the Mercedario core were attributed to known El Niño events (years 1993, 1991, 1986, 1982, Fig 1). Generally high MSA (methane sulfonic acid) concentrations (up to 56 ppb) indicate that the Pacific is major source for precipitation (Fig 2).

References

Aceituno, P. 1988. On the Functioning of the Southern Oscillation in the South American Sector. *Monthly Weather Review,* **116** (505-525).

Ginot, P., M. Schwikowski, U. Schotterer, W. Stichler, H. W. Gäggeler, B. Francou, R. Gallair and B. Pouyaud. 2002. Potential for climate variability reconstruction from Andean glaciochemical records. *Ann. Glaciology,* **35**, 443-450.

Schneider, C. and D. Gies. 2004. Effects of El Nino-southern oscillation on southernmost South America precipitation at 53 degrees S revealed from NCEP-NCAR reanalyses and weather station data. *Int. J. Clim.,* **24** (9), 1057-1076.

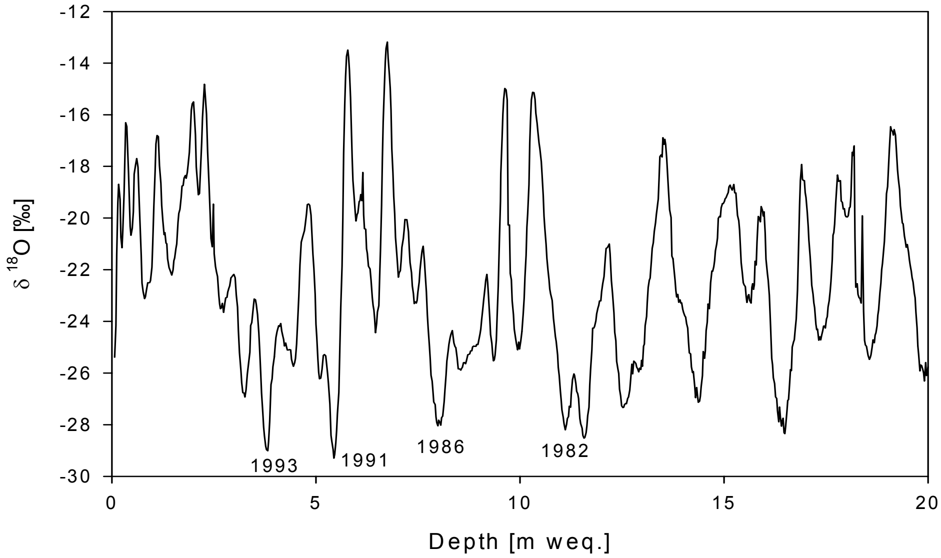


Fig 1: $\delta^{18}O$ record of Mercedario with the El Niño events 1993, 1991, 1986 and 1982.

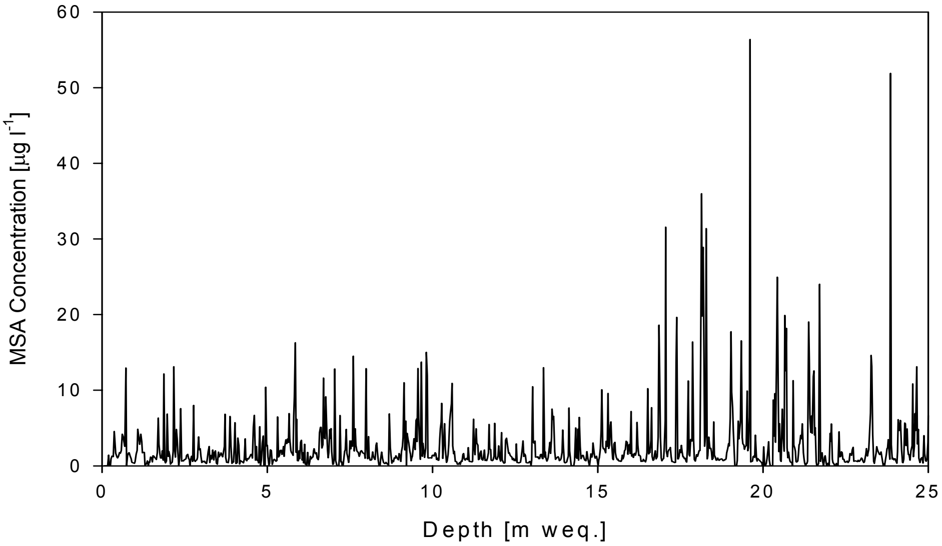


Fig 2: MSA profile in the Mercedario ice core.

(4.3)

Mass spectrometric analysis of residuals from small ice particles and from supercooled cloud droplets during the Cloud and Aerosol Characterization Experiments (CLACE)

S. Walter[1], J. Schneider[1], J. Curtius[2], S. Borrmann[1,2], S. Mertes[3], E. Weingartner[4], B. Verheggen[4], J. Cozic[4] and U. Baltensperger[4]

[1] Particle Chemistry Department, Max Planck Institute for Chemistry, D-55128 Mainz, Germany
[2] Institute for Atmospheric Physics, Johannes Gutenberg University, D-55099 Mainz, Germany
[3] Leibniz-Institute for Tropospheric Research, D-04318 Leipzig, Germany
[4] Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, CH-5232 Villigen, Switzerland

Introduction

The identification of ice nuclei is crucial for the understanding of heterogeneous ice nucleation in supercooled clouds, which is an important initiation process of precipitation in mid-latitudes (e. g. Chen and Lamb, 1999). Until today it is not well understood which chemical components contained inside or on the surface of aerosol particles enable a particle to act as an ice nucleus.

Experimental

During the 3rd and the 4th Cloud and Aerosol Characterization Experiment (CLACE-3, CLACE-4) in winter 2004 and 2005, mass spectrometric measurements of residuals of supercooled cloud droplets and ice crystals were performed at the High Alpine Research Station Jungfraujoch (Switzerland), located on a mountain col at 3580 m asl. An Aerodyne Quadrupole Aerosol Mass Spectrometer (Q-AMS, Jayne et al., 2000) was used for measuring chemically resolved mass concentrations and size distributions of various non-refractory aerosol components (sulfate, nitrate, ammonium, organics) in the size range of 20 – 1500 nm.

The Q-AMS was coupled to a novel sampling system for freshly formed ice particles (Ice-CVI, Mertes et al., in prep.). By pre-segregation of other mixed-phase cloud constituents and evaporation of small ice particles and/or supercooled drops, the residual particles, which are expected to be the original ice nuclei and/or the original cloud condensation nuclei, were made available for analysis with the Q-AMS, depending on cloud type and Ice-CVI operation mode. Alternatively, the interstitial and out-of-cloud aerosol was sampled downstream of an interstitial inlet and compared to the residual particles. Size distribution measurements were made with scanning mobility particle sizers (SMPS) behind both inlets. A multi-angle absorption photometer (MAAP) and a particle soot absorption photometer (PSAP) were used to measure black carbon concentration.

Several cloud events were encountered, both mixed-phase and pure supercooled clouds, as well as long episodes of free tropospheric aerosol.

Results

The comparison of integrated mass concentrations for the transmission range of the AMS inlet system (vacuum aerodynamic diameter < 1 µm) from both AMS and SMPS indicates that the out-of-cloud aerosol was composed to about 80% of non-refractory material. The interstitial aerosol was found to contain a larger fraction of refractory compounds than the out-of-cloud aerosol. The ice cloud residuals sampled by the CVI show very low mass concentrations detected by the AMS, although the total mass below 1 µm, as inferred from the SMPS, was well above the AMS detection limit. This implies that a large fraction of the ice residual mass could not be detected by the AMS. Since the amount of black carbon only partially accounts for this difference, this finding implies that preferably refractory particles like mineral dust act as ice nuclei. This agrees with the findings reported by Cziczo et al. (2004).

Results from measurements carried out with a similar setup using additionally two single particle laser ablation mass spectrometers during a follow-up experiment (CLACE-5) in February/March 2006 confirmed these results and will be included in the discussion.

References

Cziczo, D. J., D. M. Murphy, P. K. Hudson, and D. S. Thomson (2004), Single particle measurements of the chemical composition of cirrus ice residue during CRYSTAL-FACE, *J. Geophys. Res*., *109*, D04201, doi:10.1029/2003JD004032.

Jayne, J. T., D. C. Leard, X. Zhang, P. Davidovits, K. A. Smith, C. E. Kolb, and D. R. Worsnop (2000), Development of an aerosol mass spectrometer for size and composition analysis of submicron particles*, Aerosol Sci. Technol., 33*, 49-70.

Chen, J.-P. and D. Lamb (1999), Simulation of cloud microphysical and chemical processes using a multicomponent framework: Part II: Microphysical evolution of a wintertime orographic cloud, *J. Atmos. Sci.*, *56*, 2293-2312.

Mertes, S., B. Verheggen, S. Walter, M. Ebert, P. Conolly, E. Weingartner, J. Schneider, K. Bower, M. Inerle-Hof, J. Cozic and J. Heintzenberg (2006), Counterflow virtual impactor based collection of small ice particles in mixed-phase clouds for the physico-chemical characterisation of tropospheric ice nuclei: sampler description and first case study, *in preparation*.

Acknowledgements

We acknowledge that the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat (HFSJG), Switzerland, made it possible for us to carry out our experiments at the High Altitude Research Station at Jungfraujoch. Part of this work has been supported by ACCENT and the International Max Planck Research School (IMPRS) on Atmospheric Chemistry and Physics.

(4.4)
The environmental research station Schneefernerhaus: overview and potential for climate research

Crewell, S.[1,2], G. Enders[2], L. Kins[2], W. Fricke[3], L. Ries[4]

[1] Institut für Geophysik und Meteorologie, Universität zu Köln,
[2] Betriebsgesellschaft UFS Schneefernerhaus mbH
[3] Deutscher Wetterdienst, Meteorologisches Observatorium Hohenpeissenberg
[4] Umweltbundesamt, GAW-Global Station Schneefernerhaus

The environmental research station Schneefernerhaus (UFS) located at 2650 m height just below the summit of Germany’s highest mountain Zugspitze was established in 1998 by the state of Bavaria as its centre for Altitude and Climate Research. It offers well-equipped laboratories, observation and experimental decks, offices, overnight accommodation, conference and meeting facilities to the national and international scientific community. Year-around access is provided by cable cars and – for cargo transport and special events – by a directly linked cogwheel train. Under the umbrella of an observatory (GAW Global Station) UFS combines the long-term continuous characterization of the atmospheres physical and chemical properties with basic research (alternating scientific users and field campaigns) and applied studies (SME's, industry).

Together with the Observatory Hohenpeissenberg of the German Weather Service (DWD) the UFS forms one of the 24 global stations in the world-wide network of the "Global Atmosphere Watch"-Programme (GAW) of the World Meteorological Organisation (WMO). The data set gathered by DWD and the Federal Environment Agency (UBA) since the setup of the UFS allows a first site characterization in terms of meteorology and trace gas distributions. For example, clear sky conditions and overcast situations both exist about 40 % of the time while during the rest (~20 %) of the time the station is within clouds. Information on mean yearly and diurnal cycles can be found on the UFS web site http://www.schneefernerhaus.de.

The basic instrumentation of the UFS is increasingly extended with automated remote sensing instrumentation. An example is a 14 channel microwave radiometer for the continuous monitoring of the liquid water path, humidity and temperature profiles. This information supports dedicated field campaigns with active (micro rain radar) and passive (polarized millimetre wavelength) instruments for the investigation of snow crystal properties.

(4.5)
Numerical modeling of glacier flow

Andy Aschwanden and Heinz Blatter

Institute for Atmospheric and Climate Science, ETH Zurich, 8092 Zurich, Switzerland

Rising global mean sea level will have a strong impact on society and the environment. Contribution of glaciers and small ice caps to a sea level rise is assumed to play an important role in the near future. Assessing this contribution requires accurate and well-validated numerical glacier models. Glacier ice is treated as an incompressible, heat-conducting non-Newtonian fluid with a temperature-dependent viscosity. The ice of Storglaciären, a small valley glacier in northern Sweden, is mostly at the melting point, except for a small layer, where temperatures reach -5°C. Flow fields are calculated along a longitudinal section of Storglaciären with both a temperature-dependent and a temperature-independent viscosity. To this end, non-Newtonian fluid flow is coupled with the heat transfer equation. It is shown that, in the case of Storglaciären, neglecting the temperature-dependence of the viscosity does not change the general flow field significantly and, therefore, negligence of the temperature-dependence is well justified.

(5.1)
Cosmic Ray measurements at Lomnický Štít

Karel Kudela, Vladimír Kollár, Ronald Langer, Igor Strhárský

Institute of Experimental Physics, Slovak Academy of Sciences,
Watsonova 47, 04001 Košice, Slovakia

Selected results based on the measurements of neutron monitor at high mountain station Lomnický Štít (2634 m above sea level in High Tatras mountain, 49.40 N, 20.22 E, vertical geomagnetic cut-off rigidity ~ 4 GV) are presented.

Cosmic ray research in High Tatras started around the IGY in 1957 – 1958. Since 1958 the neutron monitor data from that position are available. The experimental device was several times reconstructed. Average counting rate was increased and time resolution was improved. From 1982 the neutron monitor with 8 tubes in 4 sections is in operation with 5 min resolution and from 1984 with 1 min resolution. Preliminary data in real time are available at http://neutronmonitor.ta3.sk. In addition, neutron multiplicity measurements are running for the past three years.

Relatively high statistical acurracy due to high altitude (average counting rate ~ 440 s^{-1}) allows to study the details of the variability of primary cosmic ray flux. Acceleration of ions in solar flares and/or in interplanetary space to rigidity > 4 GV is illustrated for several ground level events, both isotropic and anisotropic as observed on Earth. Power spectrum density of cosmic ray time series in wide interval of frequencies was obtained.

At high mountains the local effects, mainly the variable wind and snow fall may strongly affect the measurements by neutron monitor. For correct interpretation of the data a comparison with another not very distant (in terms of cut-off rigidity and asymptotic directions) high mountain neutron monitor is important. We illustrate the value of simultaneous measurements at Lomnický Štít with that by neutron monitor at Jungfraujoch (a) in confirmation of the first ground-based response from solar neutrons in the flare of June 3, 1982; (b) in the description of fractal/multifractal structure of cosmic ray time series at high frequencies; (c) in estimates of the slope of power spectrum density of cosmic rays in the frequency range where IMF with field lines frozen in the solar wind can influence primary cosmic ray intensity in the energy interval to which neutron monitors are sensitive.

There are two types of relations between cosmic ray variability and space weather effects. First, the direct one, is connected with the interaction of high energy cosmic ray particles with the materials (atmosphere, technological systems on spacecraft, on airplanes, on the ground). While increase of the dose was observed in an airplane flight during the solar flare on April 15, 2001 in time coincidence with the increase of > 4 GV particles observed by neutron monitors, a clear decrease of the dose in airplane flight in central – south Europe was observed during one of the largests Forbush decreases on October 29, 2003. Dosimetric measurements with the same/similar equipment on the airplanes and on the high mountains where simultaneous data from

neutron monitors are available, are important for checking the models of radiation dose on airplanes.

The second, indirect relation of cosmic rays to space weather effects, is connected with checking possible precursors of e.g. geomagnetic storms using signatures of cosmic ray anisotropy/variability from ground-based networks. In addition to Spaceship Earth and Muon telescope network, the neutron monitor measurements at middle latitudes provide relevant information too. The magnetospheric transmissivity changes have to be taken into acount. Results and limitations of using middle and high latitude neutron monitor data (including that of Lomnický Štít) for space weather predictions are discussed.

Existing infrastructure of the Department of Space Physics of IEP SAS Košice at Lomnický Štít connected with continuous neutron monitor measurements can be used for other types of high mountain studies.

Neutron Monitor measurements at Lomnický štít are supported by Slovak Grant Agency APVV, project no. 51-053805.

(5.2)
Cosmogenic radionucleides as tracers of stratospheric air mass exchange

Thomas Flury, Hansruedi Völkle

SUER, Bundesamt für Gesundheit, Switzerland

We use a Digitel DHA-80 high-volume air sampler with an air sampling rate of up to 1m^3 per minute. Aerosol particles are collected on circular glass fiber filters (150 mm in diameter). Filters are then sent every two weeks to the laboratory in Fribourg and a gamma-ray spectrum of the air sample is measured with a germanium gamma-ray spectrometer. The spectrometer consists of a high purity coaxial germanium detector.

Our main interest lies in Beryllium: ^{7}Be (Half life 53.3 days) and ^{10}Be (Half life 1.5x10^6 years) are both radioactive spallation products of the interaction of cosmic rays, which consist mainly in protons, with atmospheric oxygen and nitrogen. Beryllium rapidly attaches to aerosol particles. Scavenging by precipitation is the main process bringing Be to earth’s surface. The Be production rate depends on the 11-year cycle of solar activity because there is an anti-correlation between the galactic cosmic ray flux and the solar activity (Forbush effect). Approximately 70 % of the whole production takes place in the stratosphere and only 30 % in the troposphere due to decreasing cosmic ray intensity with increasing atmospheric depth. The mean residence time of aerosols in troposphere is 10-30 days while it is 1-2 years in the stratosphere. The global average production ratio of ^{10}Be/^{7}Be was calculated to be approximately 0.6(Nagai [2000]) and due to the long residence time in the stratosphere compared to the short half life of ^{7}Be this ratio increases in stratospheric air samples (up to 8) while the residence time in the troposphere is not long enough to let the ratio getting bigger than 1. If we now measure both activities we can estimate whether there was stratospheric air mixing down to the troposphere or not. ^{10}Be has to be measured in collaboration with EAWAG in Dübendorf by accelerator mass spectrometry at the ETH Zurich.

Else we measure seasonal variations in ^{7}Be, its activity always peaks in summer and is lowest in winter. This effect is due to the lability of the troposphere in summer. The sun is heating the surface and an upward transport of air is generated and for reason of equilibrium tropospheric air of high altitude with higher ^{7}Be concentrations has to be pushed downwards for the same reason stratosphere-troposphere air mass exchange is more frequent in summer. Further we observe a good correlation between ^{7}Be and ^{210}Pb although they do not have the same origin. ^{210}Pb is a radioactive daughter nuclide of the radioactive noble gas Radon-222. Naturally occurring ^{222}Rn with a half life of 3.8 days ascends from the surface to the atmosphere and can reach high tropospheric altitudes where it decays in several steps into ^{210}Pb with a half life of 20 years. As Beryllium the lead isotope attaches to aerosol particles and comes down by air mixing mechanisms.

Taken together ^{7}Be and ^{210}Pb yield information on vertical motions in the atmosphere and the scavenging of aerosols.

(5.3)
Decadal scale signals in stratospheric ozone as derived from ground-based NDACC measurements

Y. Calisesi

International Space Science Institute, Bern, Switzerland

We used time-domain digital filtering to extract stratospheric variability signals from long-term ground- and balloon-based ozone datasets. In contrast to the more commonly used multiple regression analysis (MRA) method, time-domain bandpass filtering does not imply least-squares fitting of a prescribed periodic or proxy data function into the considered timeseries, thus allowing the extraction of relevant signal information while avoiding aliasing problems.

Our results show that decadal-scale signals are observed in mid-latitude ozone both in the troposphere and in the stratosphere. The origins of the tropospheric signal are unclear and could be related to major volcanic eruptions as well as to indirect solar-cycle influences. A clearer response to the 11-year solar activity cycle appears, however, in the middle stratosphere between 20 and 30 km, where ozone varies in phase with the solar cycle.

In addition, digital bandpass filtering reveals consistent features of the quasi-biennial oscillation signal extracted from the midlatitude datasets, thus allowing the comparison of the ozone features to the equatorial winds proxy data commonly used in MRA.

Finally, the employed data analysis method allows to extract, from the longest available data sets, information as to the actual shape of the long-term trend observed in lower stratospheric ozone since the 1970's, and in particular as to the onset of the ozone recovery expected as a result of the implementation of the Montreal Protocol and its amendments.

(5.4)

Influence of the Lift-Off and Transport on the Activity Level of ^{137}Cs in Altitude

L. Bourcier[1], O. Masson[2], K. Sellegri[1], P. Paulat[2], J. M. Pichon[1], P. Chausse[1], G. Aymoz[1], P. Laj[1] and G. Cautenet[1]

[1] Laboratoire de Météorologie Physique, Observatoire de Physique du Globe de Clermont-Ferrand, 24 avenue des Landais 63177 Aubière, France
[2] Institut de Radioprotection et de Sûreté Nucléaire, BP 3, 13 115 Saint-Paul lez Durance, France

The activity of ^{137}Cs has been measured at the Puy de Dôme (45° 46' 20'' N, 2° 57' 57'' E, 1465 m a.s.l.) research station since October 2005. This site is mainly in the free troposphere during winter. A high volume sampler (600-700 m3/h) was installed and the filters analyzed with low-level gamma spectrometry to determine the activity of different radionuclides. Aerosols were also sampled on a Teflon filter and chromatographically analyzed for inorganic ions and on a quartz fibber filter for the organic fraction, in order to relate the radionuclide level with the inorganic and organic content of particles at the site. First results will be presented on the relationship between activity level and particulate content.

On another hand, the activity level at the top of the puy de Dôme was compared with the activity level on another site situated in the boundary layer in the vicinity of the puy de Dôme (Opme, 45° 43' 00'' N, 3° 5' 30'' E, 660 m a.s.l.). First, the results surprisingly show a relatively high activity in altitude compared to the boundary layer. A higher activity can be attributed to higher concentrations of resuspended particulate material, because of the absence of a source term of ^{137}Cs in the atmosphere since the end of atmospheric nuclear tests in 1980. During the sampling period, no local re-suspension was expected to contribute to the local activity level due to the snow cover or soil humidity during winter. The back-trajectories calculated for the sampling periods show that the maximum ^{137}Cs activity level at the puy de Dôme came in some cases from North Africa during eolian dust events and in the other cases from Eastern Europe, these last regions being well known for their high level of activity in the soil due to the fallout from Tchernobyl. This work shows the high impact of the long range transport on radionuclides concentrations in the free Troposphere.

(5.5)
Radiocarbon Observations in Atmospheric CO_2: Determining Fossil Fuel CO_2 over Europe

Ingeborg Levin and Bernd Kromer

Institut für Umweltphysik, University of Heidelberg, and Heidelberger Akademie der Wissenschaften, INF 229, 69120 Heidelberg

Anthropogenic CO_2 emissions from burning of fossil fuels play an important role in the European carbon budget. Only a quantitative knowledge of the fossil fuel component allows estimates of biogenic CO_2 fluxes from atmospheric observations and transport model simulations. Measurements of the radioactive carbon isotope ^{14}C in CO_2 are the only means to quantitatively decipher the fossil fuel CO_2 component, because fossil fuel CO_2 is free of Radiocarbon, and therewith clearly distinguishable from biogenic CO_2. Here we present monthly mean $^{14}CO_2$ observations at two regional European stations in comparison to free tropospheric background measurements at the High Alpine Research Station Jungfraujoch and calculate the regional fossil fuel CO_2 surplus. Parallel ^{222}Radon observations are further applied to estimate fossil fuel CO_2 fluxes in the respective catchment areas of the stations. Depending on the distance from ground level emissions, at the regional sites Schauinsland in the Black Forest and Heidelberg in the upper Rhine valley the mean fossil fuel CO_2 surplus lies between 2 and 10 ppm in summer and between 5 and 20 ppm in winter. The ^{222}Radon-derived fossil fuel CO_2 fluxes show systematic seasonal variations but only small long-term trends.

(5.6)
Snow vole (*Chionomys nivalis*) an appropriate environmental bioindicator in alpine ecosystems

Roumiana Metcheva, Michela Beltcheva and Tzenka Tchassovnikarova

Institute of Zoology, Bulgarian Academy of Science,
1, Tzar Osvoboditel, 1000 Sofia

The snow vole (*Chionomys nivalis Martins, 1842*) is a common species in Bulgarian high mountains. Its populations are distributed in different altitudes and regions and keep high population density. That is the reason that it was tested as bioindicator for environmental quality in alpine ecosystems.

The cumulative environmental impacts in snow vole's populations were evaluated using qualitative (citogenetic and hematology) and quantitative (ecotoxicology, total β-activity-radionuclids, ecophysiology and morphophysiology) indices.

The standard karyotype, the distribution and pattern of heterochromatic blocks of different populations from Vitosha and Rila were observed. Chromosomal aberrations and other diversions from the standard karyotype were not found.

These complex investigations in the framework of the project "Complex monitoring on Rila Mountain" reveal that the snow vole is one of the most appropriate biomonitor species for environmental assessment in mountains.

(5.7)
Forbush Decreases and Cloud Cover

J. Calogovic[1,2], J. Beer[1], L. Desorgher[2], and E. Flueckiger[2]

[1]EAWAG, PO Box 611, CH-8600 Duebendorf, Switzerland
[2]Physikalisches Institut, University of Bern, CH-3012 Bern, Switzerland

According to the cosmic ray - cloud hypothesis, changes in the cosmic ray intensity over the past two and a half solar cycles caused significant changes in the Earth\u2019s cloud cover with important consequences for the climate. To test this hypothesis we investigated on a global scale the atmospheric cloud cover and the variation of the atmospheric ionization induced by galactic cosmic rays during the seven largest Forbush decreases from 1989 to 2003. A Forbush decrease is a solar induced sudden decrease in the cosmic ray intensity that occurs within about a day, followed by subsequent recovery within 4-7 days. The reduction in the cosmic ray intensity for the selected events is of the order of 10-20% and therefore comparable with the changes during an 11-year solar cycle. For each event neutron monitor data were used to determine the changes in the primary differential energy spectrum of the galactic cosmic rays for a period of 20 days starting about 5 days prior to the onset of the Forbush decrease. Using this spectral information the Monte Carlo PLANETOCOSMICS code based on Geant4 was applied to calculate the ion production rate in the atmosphere during each event period as a function of latitude, longitude, and altitude, taking into account the geomagnetic field prevailing at that time. In this way the changes in the atmospheric ionization rate were obtained for a global grid with a resolution of 5 x 5 degrees and a temporal resolution of 3 hours. After calculating daily averages these data were compared with the corresponding cloud data (ISCCP D1) allowing for lags ranging from 0 to 10 days. The results of these comparisons for different cloud heights, latitudes, and areas (ocean-land) will be presented and discussed.

(5.8)

The Extreme Solar Cosmic Ray Particle Event on January 20, 2005

E.O. Flückiger, R. Bütikofer, M.R. Moser, and L. Desorgher

Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern

Introduction

Although the sunspot activity cycle 23 is on its decreasing phase approaching minimum, the Sun had a phase of very high activity between January 15 and 20, 2005. The solar NOAA active region (AR) 10720 produced five powerful solar flares. In association with this major solar activity several pronounced variations in the cosmic ray intensity near Earth were observed. On January 20, 2005, the solar active region NOAA AR 10720 produced its fifth flare, an X7.1 solar burst with onset time at 0636 UT and peak time at 0952 UT. The flare position on the Sun was at 14ºN, 67ºW, i.e. near the west limb, and therefore the Earth was well connected to the flare site along the interplanetary magnetic field lines. Less than 15 minutes after the observation of the flare onset, the first relativistic solar particles arrived near Earth and a solar cosmic ray ground level enhancement (GLE) was recorded by the worldwide network of neutron monitor (NM) stations. This GLE is ranked the second largest in fifty years with gigantic count rate increases at the south polar NM stations McMurdo (almost 3000%), Terre Adelie (over 4500%), and South Pole (more than 5000%). The onset time of the GLE at the south polar NM stations was at ~0648 UT. This is 2-7 minutes before the onset times of the other NM stations of the worldwide network. This implies a very anisotropic solar cosmic ray flux near Earth during the initial phase of the event. In the Jungfraujoch NM 1-minute data the onset time of the GLE was at 0654 UT and reached a maximum amplitude of 11.4%. From the recordings of the Swiss cosmic ray detectors and of the worldwide network of neutron monitors, we determined the characteristics of the solar particle flux near Earth.

Measurements

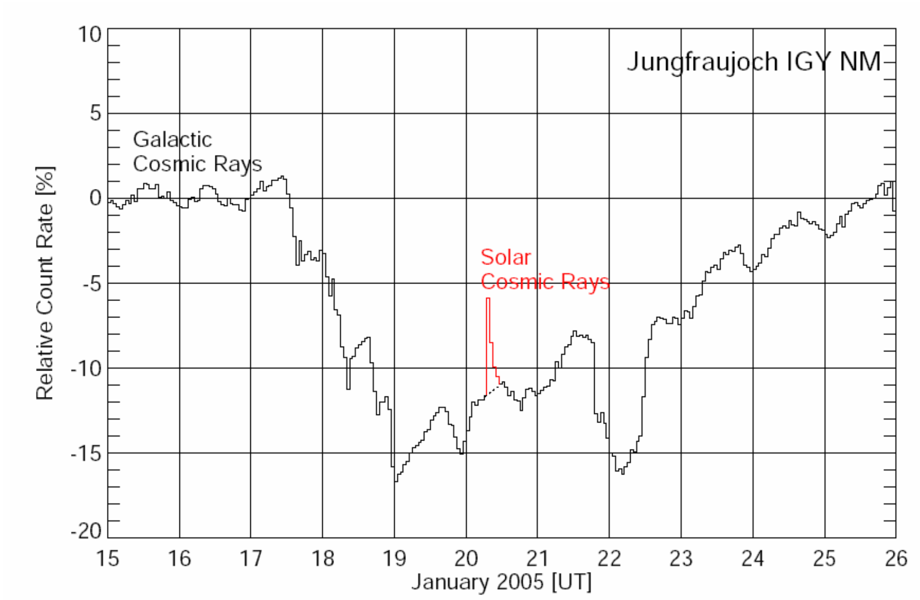


Figure 1: Relative pressure corrected hourly counting rate of the IGY NM at Jungfraujoch for the time interval 15-25 January 2005.

Method

Measurements of solar protons by NMs during solar flares are useful in understanding the acceleration of protons at or near the Sun and the transport processes of the solar cosmic rays in the heliosphere as well as in the Earth’s magnetosphere. From the recordings of the cosmic ray detectors at Jungfraujoch and of the worldwide network of NMs, we determined the characteristics of the solar particle flux near Earth (spectral form, amplitude, pitch angle distribution). Using a trial and error procedure the directional solar proton flux in the presumed source direction, $J_{\|}(P,t)$, the pitch angle distribution, $F(\delta(P),t)$, and the apparent source position can be determined by minimizing the difference between the calculated and the observed NM increases, $\Delta N(t)$. It can be assumed that the solar cosmic rays follow the heliospheric magnetic field (HMF) lines; therefore the apparent source position outside the Earth's magnetosphere is expected to correspond to the direction of the HMF near Earth.

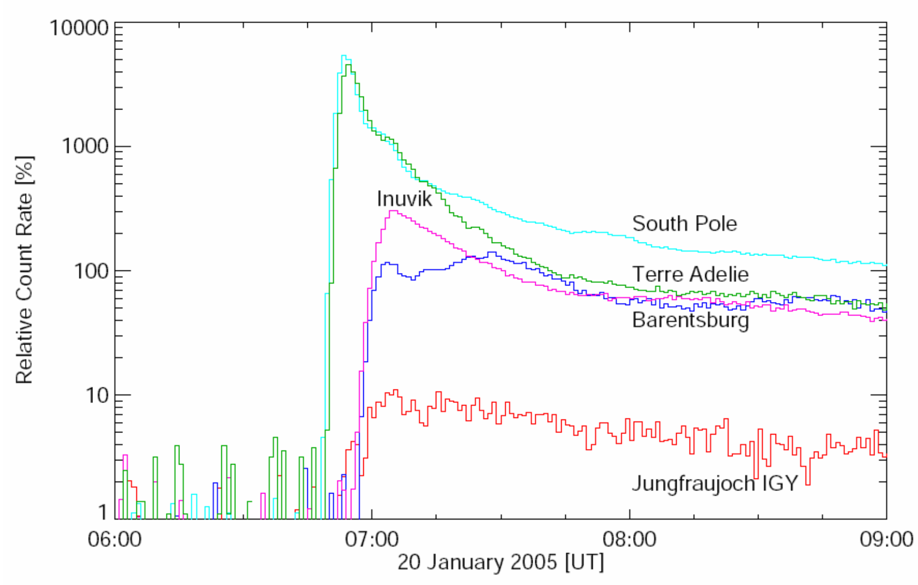


Figure 2: Relative pressure corrected 1-minute counting rates of the NM stations South Pole, Terre Adelie, Inuvik, Barentsburg and Jungfraujoch (IGY and NM64 combinded) for 20 January 2005, 0600-0900 UT,

Results

This GLE was characterized by a very narrow pitch angle distribution (pencil beam) during the first minutes of the event, but already some minutes later the anisotropy decreased clearly. The rigidity spectrum changed from very hard at the start of the GLE to a very soft spectrum within ~10 minutes. However, it seems that after 0700 UT the spectrum was again somewhat harder. This may indicate a possible second population of solar cosmic rays that was accelerated during a second phase of the event.

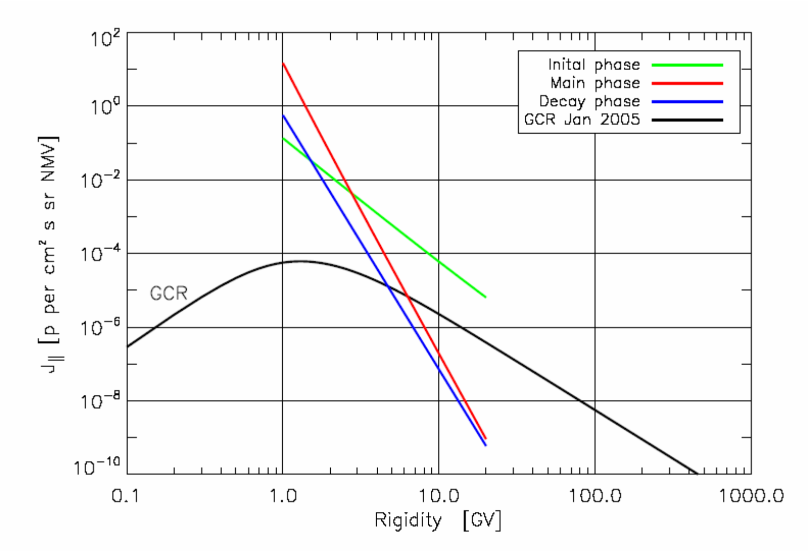


Figure 3: Directional solar proton flux, $J_{\parallel}$, for the initial, main, and decay phases during the giant solar particle event on 20 January 2005, and galactic cosmic ray (GCR) spectrum near Earth for January 2005.

(6.1)
Radiative forcing budget of non-CO2 trace gases at the high-Alpine site Jungfraujoch

Martin Steinbacher, Martin K. Vollmer, Stefan Reimann

EMPA, Swiss Federal Laboratories for Materials Testing and Research, Laboratory for Air Pollution / Environmental Technology, Ueberlandstrasse 129, CH - 8600 Duebendorf, Switzerland

In-situ measurements of the complete dataset of non-CO_2 greenhouse gases are continuously running at the Jungfraujoch since 2000 for halocarbons and since February 2005 for methane, nitrous oxide and sulphur hexafluoride. When combining these data with other long-term time series of greenhouse gases, our long-term measurements allow to evaluate the current radiative forcing of the species and to assess the effect of the replacement of ozone-depleting substances due to their restriction within the Montreal Protocol.

Besides water vapour, a large number of gases that are at least partly emitted by human activities do change the Earth’s radiation balance. The concentrations of these gases remained nearly constant in pre-industrial time and since then increased considerably potentially resulting in an upward trend of regional and global surface temperatures (IPCC, 2001). Due to its high abundance in the atmosphere, carbon dioxide (CO_2) is by far the most important greenhouse gas (GHG). Besides other major GHGs like methane (CH_4), nitrous oxide (N_2O), and sulphur hexafluoride (SF_6), halocarbons also have a considerable potential to alter the Earth’s radiation balance. Whereas the chlorinated species such as chlorofluorocarbons (CFCs), hydro-chlorofluorocarbons (HCFCs) also contribute to the stratospheric ozone-depletion, chlorine-free species like hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) do only affect the surface climate.

Since these chlorinated species were identified as the major players in the stratospheric ozone depletion, regulations were negotiated to regulate the use and the emissions of these species. As a result, the Montreal Protocol on substances that deplete the ozone layer became legally binding in 1987. It regulated the phase out of halons (bromine-containing halocarbons) for developed countries by the end of 1993 and CFCs, carbon tetrachloride and methyl chloroform by the end of 1995, respectively. The CFCs were replaced by either HCFCs or HFCs, i.e. compounds with only minor (HCFCs) or even no ozone depletion potential (HFCs). Thus, negative trends are measured in the last years for methyl chloroform (Reimann *et al.*, 2005) and CFC-11 (Reimann *et al.*, 2004), and at least a change from increasing to stagnant concentrations is detected for CFC-12, CFC-113 (decreases world-wide) and CCl_4 (decreases world-wide). At the same time, positive trends in the background concentrations were observed for the CFC-substitutes (HCFCs, HFCs) (Reimann *et al.*, 2004).

As the Montreal Protocol-regulated species as well as their replacement products are greenhouse gases but with different radiative efficiencies, their regulation influences climate change, too. We tried to identify and quantify these effects by means of continuous measurements at the Jungfraujoch in comparison with long-term datasets from known databases.

Our long-term measurements show that ozone-depleting substances were partly replaced by chlorine-free species (i.e. HFCs), which do not only reduce the atmospheric ozone depletion but also do improve the situation in terms of global warming. We extrapolate the observed trends of CFCs before the Montreal Protocol became legally binding, assuming a business-as-usual scenario and compare the extrapolated concentrations with the observed values. The recent difference between the extrapolated and the observed concentration is defined as the prevented increase for each species.

We multiply the observed trends of the major GHGs and the replacements products as well as the prevented increases with the radiative efficiencies of the respective gases. We rather consider the radiative efficiencies rather than their global warming potentials (GWPs) since we investigate the changes on the current situation. The radiative efficiencies denote the instantaneous change of the radiative forcing due to the increase of a specific compound whereas the GWPs represent the integral of the radiative efficiency for a chosen time horizon. Subsequently, the GWPs imply a decision regarding the climate processes and impacts of interest (IPCC, 2001).

The presented approach using the unique comprehensive dataset of Montreal and Kyoto regulated species measured at the Jungfraujoch results in a prevented yearly increase of the radiative forcing of $8.25 \cdot 10^{-3}$ W m^{-2} due to the phase-out of CFCs and the chlorinated solvents. It is to approximately 18.5% compensated by the increase of CFC-replacement compounds (HCFCs and HFCs). The net effect due to the Montreal regulations counterbalances around 23% of the rising greenhouse effect related to the major greenhouse gases CO_2, CH_4, N_2O, and also SF_6 that are part of the Kyoto Protocol.

Long-term measurements of halocarbons can be used to assess the consequences of international treaties regulating their emissions. The Montreal Protocol did not only succeed to reduce the ozone depletion but also contributed to lower the increasing atmospheric greenhouse effect already before the Kyoto Protocol came into force.

IPCC, 2001. Climate Change 2001: The Scientific Basis, pp. 881. Cambridge University Press, New York.
Reimann S., Manning A. J., Simmonds P. G., Cunnold D. M., Wang R. H. J., Li J., McCulloch A., Prinn R. G., Huang J., Weiss R. F., Fraser P. J., O'Doherty S., Greally B. R., Stemmler K., Hill M., Folini D., 2005. Low European methyl chloroform emissions inferred from long-term atmospheric measurements. Nature 433, 506-508.
Reimann S., Schaub D., Stemmler K., Folini D., Hill M., Hofer P., Buchmann B., Simmonds P. G., Greally B. R., O'Doherty S., 2004. Halogenated greenhouse gases at the Swiss High Alpine Site of Jungfraujoch (3580m asl): Continuous measurements and their use for regional European source allocation. Journal of Geophysical Research 109, D05307, 10.1029/2003JD003923.

(6.2)

GAW-CH Radiation Measurements at Jungfraujoch

L. Vuilleumier, A. Vernez and S. Nyeki

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss CH-1530 Payerne, Switzerland

Introduction

Beside its conventional meteorological measurements, MeteoSwiss has an active program at Jungfraujoch (JFJ) for monitoring solar and atmospheric radiation. Radiation is the driving force in energy exchanges between the atmosphere, the oceans and the ground; furthermore, the most direct effect of global warming is expected to be an increase of the infrared radiation emitted from the atmosphere to the ground. Long-term observation of surface radiation fluxes is consequently a prominent component of climate change monitoring in which MeteoSwiss actively participate in the framework of the Global Atmosphere Watch program of the World Meteorological Organization. Parameters routinely monitored in the framework of this program include solar (short-wave) and infrared thermal (long-wave) radiation flux, ultraviolet radiation at the ground, and a program of solar photometry monitoring the direct irradiance at narrowband spectral lines, that allows deducing the amount of different atmospheric components such as aerosol or water vapor. This presentation focuses on the solar photometry and the monitoring of ultraviolet surface radiation at JFJ.

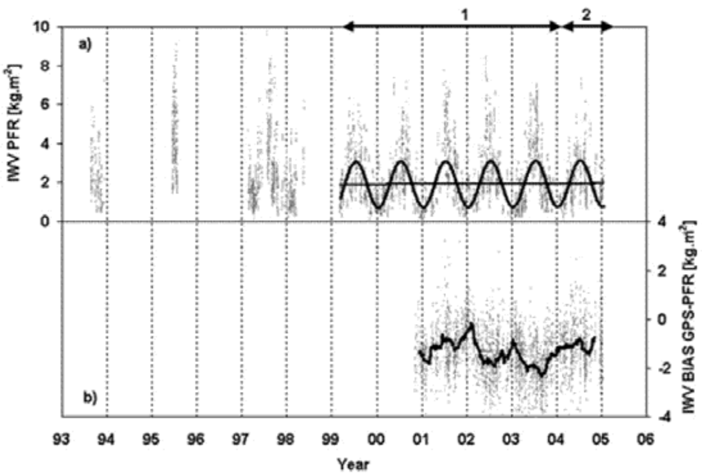


Figure 1. Time-series of 1-hr IWV averages at Jungfraujoch: (a) PFR-derived values with superposed seasonal and linear trend analyses, and (b) GPS – PFR IWV bias with superposed 60-day running mean. Periods 1–2 correspond to use of different sun photometers. (From [Nyeki et al., 2005])

Solar photometry

Sun photometers have the capabilities to measure water vapor transmittance at wavelengths where water vapor absorption is strong. From this quantity, vertically integrated water vapor (IWV) concentration can be derived [e.g. Schmid et al., 2001].

Such analysis was performed on data measured continuously from 1995 to 2005 at Davos and from 1999 to 2005 at JFJ (although sporadic JFJ data available for the period 1993–1999 were also included in some analyses), and is reported by Nyeki et al. [2005]. The IWV time series exhibited clear annual cycles at both Davos and Jungfraujoch with a maximum in summer and minimum in winter (see Figure 1). They also showed a decrease in absolute values with increasing station altitude. The annual mean IWV at Davos is 6.7 (±3.9; 1 std) kg m^{-2}, and 2.2 (±1.5) kg m^{-2} at JFJ. Respective monthly averages range from ~13.3 (Davos) and 3.9 kg m^{-2} (JFJ) in August to ~3.5 (Davos) and 1.0 kg m^{-2} (JFJ) in January, representing a factor 3.8 and 3.9 variation in maximum to minimum. Low and stable IWV values from January to April are observed at both stations, which are then followed by a large increase in May (by a factor ~2).

An IWV trend analysis was conducted for both Davos and JFJ, and the JFJ linear trend and sinusoidal fits of the seasonal cycle, based on monthly values, are shown in Figure 1a. The resulting linear trends were found to be -3.6 x 10^{-4} and 3.4 x 10^{-4} kg m^{-2} per year for Davos and Jungfraujoch (95% confidence limits: -0.003 to 0.004 kg m^{-2} and -0.002 to 0.003 kg m^{-2}). As such, both trends are compatible with zero. IWV is strongly correlated with atmospheric temperature (T) and specific humidity (q). In a study of the trends in ground temperature T2 (at 2 m) and q, Philipona et al. [2004] found increases of 1.32°C and 0.51 g m^{-3} for the 1980–2002 period over Switzerland. Part of the reason for such difference with our results may lie in our analysis giving a higher weight to periods of the year when clear-sky period are more frequent, but statistical analysis disproved this idea. The other restriction to the data set is clearly its limitation to clear-sky periods. Restricting the analysis of Philipona et al. [2004] to the same periods gave much smaller increases (R. Philipona, personal communication, 2005). This observation is therefore a likely explanation for the absence of discernible trends in our analysis. The question of interest is whether IWV is increasing as a consequence of increasing ground temperature during all-weather conditions, which may be resolved when long GPS IWV time series at Davos and JFJ will be available.

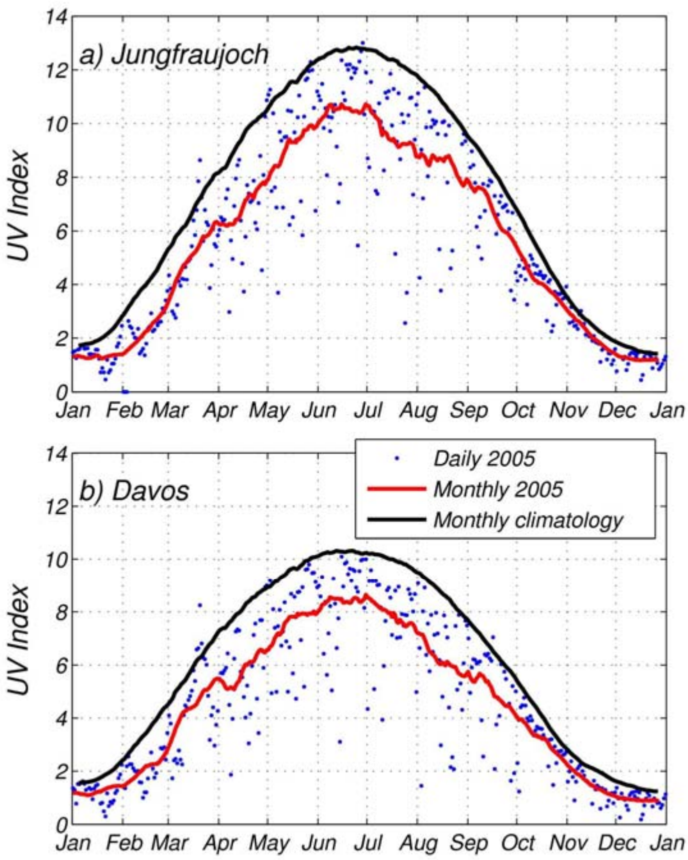


Figure 2: 2005 annual cycle of UV index daily maxima as a function of time of year.

UV radiation

MeteoSwiss monitors the amount of erythemally-weighted UV radiation at the CHARM stations. These data provide a measured UV index, which is available online at the MeteoSwiss web site (www.meteoswiss.ch → Health → UV index). Because of its high elevation, and the high albedo of the surroundings, JFJ is often submitted to high UV radiation at the ground. UV index value in excess of 11, which is considered as extreme are relatively often reached in summer.

On Figure 2, the 2005 annual cycle of the UV index daily maxima is shown for Jungfraujoch and Davos. The importance of the midday sun elevation is obvious in the large difference between summer and winter values. Similarly, the importance of elevation and snow can be seen in the difference between UV indices at Jungfraujoch and Davos. The blue dots are the individual daily maxima whose large variability is due to meteorological conditions. The red lines represent a moving average for year 2005, while the black lines are moving average of daily maxima considering all years on record. This means that for a given day of the year (e.g., June 16), the daily maxima for June 16 is searched for all years on record (1997-2005 for Jungfraujoch). Since it is more likely to find a sunny day for a given day of the year over several years, the black curves are higher and smoother than the red ones. They show what UV-index can be expected on sunny days at a given time of year.

Nyeki, S., L. Vuilleumier, J. Morland, A. Bokoye, P. Viatte, C. Mätzler, and N. Kämpfer (2005), A 10-year integrated atmospheric water vapor record using precision filter radiometers at two high-alpine sites, Geophys. Res. Lett., 32, L23803, doi:10.1029/2005GL024079.

Philipona, R., B. Du¨ rr, C. Marty, A. Ohmura, and M. Wild (2004), Radiative forcing, measured at Earth's surface, corroborate the increasing greenhouse effect, Geophys. Res. Lett., 31, L03202.

Schmid, B., et al. (2001), Comparison of columnar water-vapor measurements from solar transmittance methods, Appl. Opt., 40, 1886–1896.

(6.3)
Solar dimming and brightening in Switzerland – global irradiance from Magadino to Jungfraujoch measured since 1981

C. Ruckstuhl[1] and R. Philipona[2]

[1]Institute for atmospheric and climate science, ETH, Zurich
[2]Physikalisch-Meteorologisches Observatorium Davos

Analyses of shortwave global irradiance measured at Earth's surface in various regions of the globe generally show decreasing solar radiation from about 1960 on, but an increasing tendency since the 1990s (*1*). These dimming and brightening of solar radiation is thought to have strong influence on the climate system and is often related to cloud or aerosol effects.

Within the MeteoSwiss automatic meteorological network ANETZ solar radiation has been measured at 54 stations since 1981, ranging from Magadino (197 m a.s.l.) up to Jungfraujoch (3580 m a.s.l.). In addition to these ANETZ measurements, the Baseline Surface Radiation Budget Network (BSRN) station at Payerne and the Alpine Surface Radiation Budget Network (ASRB) offer additional high quality solar irradiance measurements since the mid 1990s. A detailed homogenization of ANETZ dataset has been done at MeteoSwiss using ASRB and BSRN measurements (*2*). ANETZ measurements show a constant offset of about 5% with respect to the ASRB measurements. The uncertainty on monthly means of the ANETZ measurements is of about 2-3% (*2*).

First analyses of the 54 ANETZ stations show no changes of the shortwave global irradiance from 1981 to 2002. However, if the analysis is extended to the year 2005 a slight increase of 2.3 Wm^{-2}/decade is observed, even though this decadal change is not on a statistical significant level. The observed increase from 1981 to 2005 is related to the extreme summer 2003 and its strongly reduced cloud amount. With respect to the altitude, lowland stations (elevations < 900 m a.s.l) show slightly larger increases than stations at higher elevations. This likely refers to an aerosol effect. Further investigations will focus on the determination of the clear-sky irradiance, which will help to answer the questions of the cause of possible changes of solar radiation at Earth's surface in Central Europe.

1. M. Wild *et al., Nature*, **308**, (2005)
2. M. Moesch and A. Zelenka, *Arbeitsbericht MeteoSchweiz,* **207**, (2004)

(7.1)
Variability of snow height at Sonnblick and its importance for the cryosphere

Wolfgang Schöner, Ingeborg Auer, Reinhard Böhm

Central Institute of Meteorology and Geodynamics, Vienna, Austria

Snow height and duration of snow cover at higher elevated sites are important for both Alpine economics as well as Alpine ecology. Generally detailed measurements of snow cover properties at higher elevated sites of the Alps are only available since about the last 50 years and related trends are therefore hard to derive from measurements. Moreover statistical evaluation of snow cover measurements are influenced by several measurement errors which increases with elevation. At high mountain observatory Sonnblick (Eastern Alps, Austria) snow-height has been measured not only at the observatory but also at a stake-network at nearby glaciers Goldbergkees and Kleinfleißkees back to 1927. The interest in glacier behaviour and its relation to climate initialised the snow height measurements at Sonnblick. Maximum values of snow height were measured in the 1940ies and 1950ies (1944: more than 10m). Since the last 25 to 30 years maximum snow height values are quite stable. Information about snow cover at Sonnblick previous to 1927 is available from measurements of precipitation and fraction of solid precipitation. This data are however influenced from errors of precipitation measurements.

Comparison of stake network available since 1927 with a dense snow probing (approx. 100m distance) available from glacier mass balance measurements shows that individual stakes of the long term network have different spatial representativity. Some of the stakes can explain up to 75% of variance of entire glacier area. One stake describes only local snow accumulation hardly affected from snow drift processes.

A statistical relationship between air temperature and fraction of solid precipitation was used to compute snow precipitation not only for the mountain top of Sonnblick but also for lower elevated sites. This non-linear relationship shows elevation zones with highest sensitivity of snow precipitation on air temperature for individual months. Comparison of amount of snow precipitation with snow height measurements shows some common variability but also discrepancies which results from the importance of redistribution process of snow by the wind.

In the final part the paper summarises the effects of snow cover variability on the Alpine cryosphere, glaciers and permafrost respectively.

(7.2)
Variations of the Grosser Aletschgletscher

Andreas Bauder

Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie (VAW), ETH Zürich

Temporal glacier variations are among the clearest natural indicators of ongoing climate change. The state (length, area, volume, flow velocity) and the temporal evolution of glaciers are mainly determined by the mass balance and the glacier flow dynamics. As the mass balance of glaciers results from the mass gain through accumulation and mass loss through ablation, it is closely related to precipitation and air temperature. Long-term glacier observations have been carried out to document glacier variations of the Grosser Aletschgletscher, the largest glacier in the Alps.

Long time-series of length variation, mass balance and volume change of glaciers have been achieved. Important observations include: (1) variations of front position recorded annually since the 1890's, (2) the firn accumulation and mass balance measured on Jungfraufirn starting in September 1918, and (3) the hydrological water balance of the whole catchment evaluated based on runoff measurements since 1922. In addition, repeated survey of the glacier surface topography has been conducted. Two special high precision topographic maps covering the whole catchment area of the branched glacier system have been produced for the states of 1926/27 and 1957. These maps are complemented by an earlier map from 1880 and two photogrammetrical analyses of recent sets of aerial photographs dating 1980 and 1999.

Net volume changes of high spatial resolution were calculated by comparing two consecutive surveys of the surface topography. The mass change for four decadal periods is the result. In order to increase to seasonal (winter and summer) temporal resolution of the mass change, a distributed temperature-index model is used. The model calculates the snow accumulation and ice melt with air-temperature and precipitation data from a nearby weather station and potential clear sky radiation. The model results are validated with the independently evaluated net volume changes and the direct point-observations of the accumulation and melt.

A retreat in length of 2.6 km and a net mass loss of about 50 meters of water equivalent in mean thickness has been observed on the Grosser Aletschgletscher since 1880. The length variation is characterized by a continuous retreat with a slight tendency of an increased rate in the second half of the twentieth century. A more detailed insight is given by the mass change: periods of higher mass losses are interrupted by two periods of reduced losses and even shorter decadal phases of mass gain. While in the accumulation area thickness change is small, large changes occur at the glacier snout.

(7.3)
Stable isotopes in precipitation at Jungfraujoch and in surrounding glaciers

Ulrich Schotterer[1] and Markus Leuenberger[1]
Willibald Stichler[2]
Ronald Kozel[3] and Marc Schürch[3]

[1]Div. of Climate and Environmental Physics, Physics Institute, University Bern, Switzerland
[2]GSF-Institute for Groundwater Ecology, Neuherberg, Germany
[3]Federal Office for the Environment, Switzerland

The variability of the stable isotopes deuterium (δD) and oxygen -18 ($\delta^{18}O$) in precipitation is related to the rainout history of air masses. Especially the close relation of the δ-values to ground level temperature or precipitation amount and distribution is widely used in hydrologic or palaeo-climatic applications. The relation has been proved world wide on data from the IAEA-WMO global network for isotopes in precipitation (1). In Switzerland isotopes are measured regularly since 1970 in a network that covers today the principal hydro-meteorological regions at different altitudes. The official Swiss network (NISOT) is operated by the Federal Office for Environment and includes also rivers and shallow groundwater (2).

At the research station Jungfraujoch (today the highest and best-equipped meteorological station in Europe at 3580 m) precipitation sampling started in 1983 regardless the fact that no data are reported on the amount of precipitation from that altitude. This is due to the exposed situation with strong winds, snow throughout the year (except occasional rain during summer) and the resulting difficulties to distinguish between drifting snow, actual precipitation and wind-blown loss from the sampling device. However, the isotope data of the monthly totals of daily precipitation are well correlated to data from stations with regular amount measurements (for example Grimsel at 1950 m). Moreover, the data follow also the altitude effect of stable isotopes in precipitation (depletion of heavier isotopes with increasing altitude). Both, winter and summer values fit into the linear relationship established by other stations at lower altitudes. Missing precipitation or irregular monthly composites would otherwise course a distinct offset. Therefore these findings indicate that the samples correctly characterize the isotopic signature of precipitating air masses around Jungfraujoch.

For climate and environmental studies in alpine ice cores the comparison with direct data is crucial. The accumulated information is not archived in the same way as in stacked monthly composites of precipitation that are safely stored. For a rigorous evaluation of post-depositional changes the glaciers in the vicinity of Jungfraujoch are ideal laboratories. Although in the temperate Jungfraufirn many isotopic features of the precipitation record are preserved, especially summer layer are disturbed or removed by melt. On the cold Fiescherhorn Plateau snow drifting removes or re-distributes mainly the light winter snow (3). These discrepancies remind us that alpine glaciers are dynamic open systems for precipitation, and that due caution is required in attempting to decipher their isotopic records.

(1) Rozanski, K., Araguas-Araguas, L.,Gonfiantini, R., 1993: Isotope patterns in modern global prcipitation, in Climate Change in Continental Isotopic Records, AGU, Washington DC 1-37.
(2) Schürch, M., Kozel, R., Schotterer, U., Tripet, J.P. 2003: Observations of isotopes in the water cycle – the Swiss National Network (NISOT), Environmental Geology, 45-1-11, DOI 10.1007/s00254-003-0843-9.
(3) Schotterer, U. Stichler, W., Ginot P., 2004: The influence of post-depositional effects on ice core studies. In: Earth Paleoenvironments: Records Preserved in Mid- and Low Latitude glaciers. Vol. 9, 39-60, Kluwert Academic Publishers.

(8.1)
Continuous in-situ air quality measurements at the Jungfraujoch as part of the Swiss National Air Pollution Monitoring Network (NABEL)

Martin Steinbacher, Beat Schwarzenbach, Brigitte Buchmann, Christoph Hueglin

EMPA, Swiss Federal Laboratories for Materials Testing and Research, Laboratory for Air Pollution / Environmental Technology, Ueberlandstrasse 129, CH - 8600 Duebendorf, Switzerland

The high-Alpine site at Jungfraujoch is one of the sixteen sites of the Swiss national air pollution monitoring network (NABEL) which is jointly run by the Federal Office for the Environment (FOEN) and Empa. The Jungfraujoch represents a very low polluted background site, providing information on the long-term trend of air pollution levels of the lower free troposphere in central Europe. The NABEL network was established in 1978. However, measurements at Jungfraujoch already started in 1973 with emphasis on sulphur dioxide (SO_2), particulate sulphur, and total suspended particulate matter (TSP). Today, the NABEL measurement programme at Jungfraujoch additionally includes the mass concentration of fine particulate matter with aerodynamic diameter less than 10 micrometer (PM10), as well as the mixing ratios of following trace gases: ozone (O_3), carbon monoxide (CO), SO_2, nitrogen monoxide (NO), nitrogen dioxide (NO_2), and the sum of nitrogen oxides (NO_y), nitrous oxide (N_2O), methane (CH_4), sulphur hexafluouride (SF_6), a selection of VOCs (alkanes, aromatics), and a variety of halogenated hydrocarbons.

Due to the year-round accessibility and the good infrastructure, the Jungfraujoch research station is well suited for long-term ground-based monitoring of trace gas concentrations. The site is frequently representative for the free troposphere and measurements therefore allow to investigate chemical processes and changes in the composition of the unpolluted atmosphere as well as to detect long-term trends in the background atmosphere (e.g. Zanis et al., 1999; Brönnimann et al., 2000; Henne et al., 2005; Zanis et al., 2006). On the other hand, the Jungfraujoch is temporarily influenced by polluted air masses that are transported from the boundary layer to the Jungfraujoch. These features enable the study of local scale transport phenomena in the Alpine region (Forrer et al., 2000; Zellweger et al., 2003) as well as the investigation of intercontinental transport processes (Li et al., 2005). Due to its location in Cental Europe, continuous measurements of air pollutants during pollution eposides are also combined with transport models to identify regional European emission sources (Collaud Coen et al., 2004; Reimann et al., 2004; Reimann et al., 2005). Our presentation will give a comprehensive overview about the NABEL activities and the analyses related to their results.

Brönnimann S., Schuepbach E., Zanis P., Buchmann B., Wanner H., 2000. A climatology of regional background ozone at different elevations in Switzerland (1992 - 1998). Atmospheric Environment 34, 5191-5198.

Collaud Coen M., Weingartner E., Schaub D., Hueglin C., Corrigan C., Henning S., Schwikowski M., Baltensperger U., 2004. Saharan dust events at the Jungfraujoch: detection by wavelength dependence of the single scattering albedo and first climatology analysis. Atmospheric Chemistry and Physics 4, 2465-2480.

Forrer J., Rüttimann R., Schneiter D., Fischer A., Buchmann B., Hofer P., 2000. Variability of trace gases at the high-Alpine site Jungfraujoch caused by meteorological transport processes. Journal of Geophysical Research 105, 12241-12251.

Henne S., Dommen J., Neininger B., Reimann S., Staehelin J., Prevot A. S. H., 2005. Influence of mountain venting in the Alps on the ozone chemistry of the lower free troposphere and the European pollution export. Journal of Geophysical Research 110, D22307, doi: 10.1029/2005JD005936.

Li Y., Campana M., Reimann S., Schaub D., Stemmler K., Staehelin J., Peter T., 2005. Hydrocarbon concentrations at the Alpine mountain sites Jungfraujoch and Arosa. Atmospheric Environment 39, 1113-1127.

Reimann S., Manning A. J., Simmonds P. G., Cunnold D. M., Wang R. H. J., Li J., McCulloch A., Prinn R. G., Huang J., Weiss R. F., Fraser P. J., O'Doherty S., Greally B. R., Stemmler K., Hill M., Folini D., 2005. Low European methyl chloroform emissions inferred from long-term atmospheric measurements. Nature 433, 506-508.

Reimann S., Schaub D., Stemmler K., Folini D., Hill M., Hofer P., Buchmann B., Simmonds P. G., Greally B. R., O'Doherty S., 2004. Halogenated greenhouse gases at the Swiss High Alpine Site of Jungfraujoch (3580m asl): Continuous measurements and their use for regional European source allocation. Journal of Geophysical Research 109, D05307, 10.1029/2003JD003923.

Zanis P., Ganser A., Zellweger C., Henne S., Steinbacher M., Staehelin J., 2006. Seasonal variability of measured Ozone Production Efficiencies in the lower free troposphere of Central Europe. Atmospheric Chemistry and Physics Discussions, accepted.

Zanis P., Schuepbach E., Scheel H. E., Baudenbacher M., Buchmann B., 1999. Inhomogenities and trends in the surface ozone record (1998-1996) at Jungfraujoch in the Swiss Alps. Atmospheric Environment 33, 3777-3786.

Zellweger C., Forrer J., Hofer P., Nyeki S., Schwarzenbach B., Weingartner E., Ammann M., Baltensperger U., 2003. Partitioning of reactive nitrogen (NO_y) and dependence on meteorological conditions in the lower free troposphere. Atmospheric Chemistry and Physics 3, 779-796.

(8.2)
Digital Holography of Ice Particles on the Jungfraujoch during CLACE 5

S.M.F. Raupach[1], J. Curtius[1], H.J. Voessing[1], and S. Borrmann[1,2]

[1]Johannes Gutenberg Universität Mainz, Institut für Physik der Atmosphäre, Joh.-Joachim-Becher-Weg 21, D-55099 Mainz, Germany
[2]Max-Planck-Institut für Chemie, Joh.-Joachim-Becher-Weg 27, D-55020 Mainz, Germany

Holography is a versatile tool among the optical techniques in atmospheric sciences, as it opens up the prospect of imaging particles in a deep volume without being restricted by a typically small depth of focus. At the same time it offers the possibility to gain information on the relative 3D-position of particles within that volume as well as on their shape. In *digital* holography, the holograms are digitally recorded and are reconstructed on a computer.

At Johannes Gutenberg-University Mainz, a digital-holographic camera system is being developed within a PhD-project. The system is intended for *in situ*-imaging of atmospheric particles in the micron to millimetre range. A first, ground-based prototype was built and was successfully tested for several weeks on the High Altitude Research Station Jungfraujoch in February and March 2006 during the “Cloud and Aerosol Characterization Experiment (CLACE) 5”.

The basic ideas of digital inline holography will be presented as well as the general setup of the instrument used during CLACE 5; additionally, digital holograms from ice particles obtained during that experiment and their reconstructions will be shown.

(8.3)

Results of on-line and flasks measurements of O_2 at the High Alpine Research Station Jungfraujoch

C. Uglietti[1], M. Leuenberger[1], F.L. Valentino[1], P. Nyfeler[1], H.P. Moret[1], P Sturm[1], M. Fischer[2], K. Hemund[2]

[1] Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
[2] Hochalpine Forschungsstation, CH-3801 Jungfraujoch, Switzerland

Measurements of atmospheric oxygen are getting more and more relevant as an indicator of natural carbon fluxes. O_2 and CO_2 are inversely linked to the photosynthesis, respiration and combustion. In addition O_2 is less soluble than CO_2 in water and therefore we can use O_2 inventory changes to determine the land-ocean partitioning of carbon storage (Battle et al., 2000).

This work is part of the CarboEurope IP project that aims to understand and quantify the terrestrial carbon balance of Europe at local, regional and continental scale in a multidisciplinary and integrated way.

Here we present the results of glass flasks measurements which are collected every two weeks at the High Alpine Research Station Jungfraujoch and sent back to University of Bern where they are analysed by mass spectrometry.

The Jungfraujoch glass flasks measurements are compared with analyses from two other CarboEurope IP sites, Puy de Dôme (France) and vertical profile over Griffin Forest (UK).

We also present results of the last two years of continuous O_2 measurements at the High Alpine Research Station Jungfraujoch by an on-line system based on fuels cells and a paramagnetic sensor. We found a good relationship between the paramagnetic sensor and the fuels cells signals when smoothing the fuel cell signals. There is a strong dependence of the fuel cells signal on small temperature variations (Leuenberger et al., 2006).

A good correlation between the flasks and the online measurements is observed; both records show the seasonal pattern of O_2 in the atmosphere, with maximum values in summertime due to photosynthesis and lowest levels in winter due to respiration and the ocean exchange.

Further studies should be done to better understand variations of O_2 and CO_2 and assigning those to fossil fuel emission, biological processes and ocean exchange.

Reference:

Battle M, Bender ML, Tans PP, White JWC, Ellis JT, Conway T, Francey RJ. 2000. Global carbon sinks and their variability inferred from atmospheric O_2 and $d^{13}C$. Science 287:2467-2470.

Leuenberger M, Nyfeler P, Moret HP, Sturm P, Valentino FL, Uglietti C. 13th WMO-IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurements Techniques, Boulder US, 2006.

(8.4)
Upgrade of the EPFL multiwavelength lidar with an ozone channel

Marcel Bartlome, Valentin Simeonov, Hubert Van den Bergh

Air and Soil Pollution Laboratory, Swiss Federal Institute of Technology, EPFL, Lausanne, Switzerland

The research multi-wavelength elastic-Raman lidar deployed at the Jungfraujoch High Alpine research station was built in the Laboratory of Air pollution of the École Polytechnique Fédérale de Lausanne (EPFL). The lidar was designed to measure: aerosol optical properties at three wavelengths; water vapor; and temperature. It has been operated on a regular basis, as a part of the European Aerosol Lidar Network- EARLINET, since May 2000.

Responding to the importance of monitoring ozone content and vertical distribution we are upgrading the Jungfraujoch lidar with a new channel for vertical measurements of ozone in the troposphere and the low stratosphere. The ozone measurements will be carried out employing a UV DIAL method. The work started in 2005 and was interrupted because of a serious damage to the laser. This damage was caused by frozen cooling water due to below zero temperatures in the Coudé room. Because of difficulties with repairing the original laser (discontinued from production by the producer) a new laser was installed. The new laser is Continuum 8000 Powerlite with 1.2 J energy per pulse and repetition rate of 10 Hz. To allow ozone and aerosol measurements, the laser was modified at the EPFL so as to produce four wavelengths simultaneously (1064, 532, 355 and 266 nm). To achieve this goal, to the original configuration producing fundamental (1064 nm), second (532 nm) and fourth (266 nm) harmonics, a third harmonic (355 nm) converter was added. The third harmonic is produced from the residual (after the fourth harmonic) fundamental and the second harmonics radiation. The additional converter uses a KDP crystal. To attain maximum conversion efficiency, a special phase-adjusting device was designed and built at the EPFL.

The laser could not be operated at high altitudes because of the high-voltage arching caused by the low atmospheric pressure and needed additional upgrade. The producer could not assist us in any way because of lack of experience and we had to redesign the laser heads.

To complete the transmission part of the lidar system, a special Raman converter for producing two additional DIAL wavelengths (284 and 304 nm) from the 266 nm radiation was designed and built. In its final configuration the new transmission part of the lidar consists of two separate lines (see Fig. 1). In the first line, as in the original configuration, the three wavelengths (1064, 532, and 355 nm) are transmitted coaxially to the 20 cm (short range) receiving telescope after passing through a five-times multi-wavelength beam expander. These wavelengths are used in the aerosol, temperature and water vapor observations. The new UV wavelengths used for ozone measurements are transmitted into the atmosphere off-axis to the short range and the long range (astronomical) receiving telescopes directly after the Raman converter. A spectral separation unit was designed for the new ozone channel of the lidar receiver. The unit has a resolution of 1 nm/mm and is based on a

UV enhanced flat field imaging grating (Zeiss GmbH). The spectral separation unit will be installed together with the multi-wavelength aerosol and water vapor polychromator on the 76 cm astronomical telescope. We plan to complete the work in the end of August 2006.

The ozone data together with the results from the water vapor and temperature channels will be used to study troposphere-stratosphere exchange.

Keywords:
High Altitude Research Station Jungfraujoch, multi-wavelength lidar, Raman lidar, DIAL, pure rotational Raman scattering, backscatter and extinction coefficients, vertical profiles, aerosols, water-vapor mixing ratio, temperature channel, ozone channel, stratosphere-troposphere exchange

(8.5)
Investigating heat and moisture fluxes in high-Alpine rock walls around the Jungfraujoch with a wireless sensor field

Andreas Hasler[1,2], Hansueli Gubler[3], Igor Talzi[1], Stephan Gruber[2], Daniel VonderMühll[4] und Christian Tschudin[1]

1 Computer Science Departement, University of Basel, Switzerland.
2 Glaciology and Geomorphodynamics Group, Department of Geography, University of Zurich, Switzerland.
3 ALPUG GmbH, Davos, Switzerland
4 Rektorat, University of Basel, Switzerland.

Warming and thawing permafrost in steep alpine bedrock can affect slope stability, leading to natural hazards and complicating the operation of man-made infrastructure in the Alps. Corresponding heat flux and phase change processes in porous fractured rock are currently poorly understood, especially their boundary conditions. In order to develop theoretical models for hazard assessment, we need continuous and reliable measurements of physical parameters in natural and diverse slope areas. At present, limited measurement data exist for selected locations, but large scale measurement series do not exist which is in part due to the lack of inexpensive and easy to deploy measurement systems.

The project PERMASENSE[I] aims at developing and demonstrating a flexible, distributed and self-organizing wireless network adapted to geophysical sensors. The first generation of such a sensor field will be installed in autumn 2006. It will monitor in near real-time the temperature as well as rock moisture content and gradients in the near surface layer. The PERMASENSE data chain consists of several wireless nodes to which multiple sensors are attached, a GPRS gateway node for data uplink as well as a database server in the Internet with a web based front-end for data retrieval and network monitoring. The sensors are mouthed in a fiberglass rod and measure temperature and electrical conductivity between electrodes with high accuracy at four

depths inside the 1 meter drill hole. Measurement electronics are kept inside the rod to minimize the effect of temperature fluctuations. On the wireless node side, measurement data are stored in non-volatile flash memory but are also transmitted through the network and then via GPRS for immediate inspection on the Web. Network protocols permit the wireless nodes to form a self-organizing synchronized network with a common 30 minutes sleep- and wake cycle that minimizes power consumption.

On August 29 a first reconnaissance and test setup will be done on Jungfraujoch. The whole system with 15 nodes and sensors rods will be installed mid September 2006 on the Jungfrau east ridge and Sphinx. The system will then be operated through the winter and spring. The data generated with this first generation is expected to provide valuable insight into the advective component of the near-surface heat transfer as well as freeze-

[I] Permasens is funded by the SNF through the NCCR MICS (Mobile Information and Communication Systems) as well as FOEN (Federal Office for the Environment)

thaw processes. We plan to build a second generation of sensors for summer 2007 that can also measure crack dilatation, moisture/ice content and possibly acoustic events. This will permit to further deepen our understanding of permafrost and rock weathering in steep slopes.

Supporting Institutions for the Research Station Jungfraujoch

Schweizerischer Nationalfonds (SNF), Bern

Fonds National de la Recherche Scientifique FNRS, Bruxelles*

Max-Planck Gesellschaft, München*

The Royal Society, London*

Istituto Nazionale di Astrofisica (INAF), Rom*

Österreichische Akademie der Wissenschaften, Wien*

Akademie der Naturwissenschaften Schweiz (scnat), Bern*

Jungfraubahn AG, Interlaken*

Gornergrat Bahn AG, Brig*

Burgergemeinde Zermatt, Zermatt*

Kanton Bern

Universität Bern

Mammut Sports Group AG, Seon

***** Members of the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat

Supporting Institutions Sponsors for the scientific conference in celebration of the 75th anniversary of the High Altitude Research Station Jungfraujoch:

Akademie der Naturwissenschaften Schweiz (scnat)

Lotteriefonds des Kantons Bern

Berner Kantonalbank BEKB | BCBE

Universität Bern

Max und Elsa Beer-Brawand-Fonds

Jungfraubahnen

Gletscherrestaurants Top of Europe

MeteoSchweiz

Helvetia Patria Versicherungen

Notebox GmbH, Basel

European Science Foundation (INTROP, Interdisciplinary Tropospheric Research: from the Laboratory to Global Change)

ACCENT (Atmospheric Composition Change, The European Network of Excellence)