SOUNDING ROCKET AND BALLOON ACTIVITIES AND RELATED RESEARCH IN SWITZERLAND 2009 - 2011

Marcel Egli

Swiss Federal Institute of Technology Zurich (ETH Zurich), Space Biology Group, CH-8005 Zürich, Switzerland
Email: marcel.egli@spacebiol.ethz.ch

ABSTRACT

There have been miscellaneous activities performed by Swiss-based research groups in relation to high altitude research during the past few years. Research platforms used involve, in addition to sounding rockets and stratospheric balloons also high altitude stations in the Swiss Alps. The research topics are spread across various disciplines of science, including physics, astrophysics, meteorology and biology/medicine. A typical example would be a balloon experiment of the University of Bern testing a new generation of neutral gas mass spectrometer designed for a Mars mission. Another balloon experiment carried out by the École Polytechnique Fédérale de Lausanne (EPFL) is designed to measure protons, helium, electrons, positrons and anti-protons in cosmic rays. In contrast, the Zero-g LifeTec Company is engaged in a biomedical study investigating the activation behavior of human immune cells under microgravity condition during a sounding rocket flight.

Space Research has been made accessible not only to distinguished research-institutes but also to students of Swiss universities. A project from EPFL has been selected by ESA recently for a participation in the REXUS/BEXUS program.

Switzerland offers researchers high altitude research stations which allow the investigation of the upper atmosphere without using balloons or sounding rockets. The two research facilities at Jungfraujoch and Gornergrat are frequently used by research teams from all over Europe and overseas.

A very short summery of a few Swiss projects under the framework of sounding rocket and balloon activities and related research carried out between 2009 and 2011 is provided in the following paragraphs.

1. INTRODUCTION

During the many years that Switzerland has participated in the Esrange Andoya Special Projects (EASP) program, numerous Swiss researchers have conducted high altitude balloons or sounding rocket campaigns. Among these is the research group of the Physics Institute at the University of Bern, which has conducted a Polar Balloon Atmospheric Composition Experiment testing a new generation of neutral gas mass spectrometer designed for Mars missions. The stratospheric flight at an altitude of 35 – 40 km enabled a thorough performance test of the installed instruments under remarkably similar condition to those on Mars.

The Swiss Zero-g LifeTec Company is coordinating a sounding rocket project which is focused on the effects of microgravity on immune cells. This experiment is one of a series of experiments in the field of life sciences led by the Swiss team.

The high altitude research stations Jungfraujoch and Gornergrat, located in the heart of the Swiss Alps offers researchers additional platforms for high altitude investigations. These stations provide infrastructure and support for scientific research that has to be carried out at an altitude of 3’000 – 3’500 meters above sea level. Scientists from universities, schools of technology, and research institutes of the member countries, as well as from other countries, can carry out research concerning radiation measurements, aerosol monitoring, atmospheric gas composition observation, air pollution sensing, and surveillance of general meteorological phenomenon or investigations in the bio-medical field. Even commercial companies are using the harsh environment of these high altitude research stations to test their outdoor products.

A short description of selected Swiss experiments carried out in the framework of the “Sounding rocket and balloon activities and related research” during the years 2009 - 2011 is provided below. Conclusive information on Swiss activities in high altitude or space can be found under the following web links: http://www.sbf.admin.ch/htm/themen/weltraum_de.htm or http://www.scnat.ch/. Particular information regarding the high altitude research platforms Jungfraujoch and Gornergrat are summarized in the yearly reports of the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat published at the web site: http://www.hfsjg.ch/.

2. STRATOSPHERIC BALLOON EXPERIMENT “MEAP” (MARS ENVIRONMENT ANALOGUE PLATFORM)

Circumpolar balloon flights in the northern hemisphere starting from Swedish Space Corporation’s Esrange Space Center have been performed during wintertime

Proc. ‘20th ESA Symposium on European Rocket and Balloon Programmes and Related Research’
Hyère, France, 22–26 May 2011 (ESA SP-700, October 2011)

when the nights are dark and sensitive optical equipment is protected from the sunlight. When instruments are not sensitive to light, it can be advantageous to fly during summer time when the midnight sun helps the charging of on board batteries from solar arrays around the clock.
The MEAP mission was a technology test for future long duration balloon flights around the North Pole during summer time. The flight was conducted by the Swedish Space Corporation's Esrange Space Center.
The conditions in the stratosphere at a typical float altitude between 30 and 40 km altitude are somewhat similar to the conditions on the Mars surface, although bulk atmospheric composition differs. Nevertheless, the balloon flight has opened up the opportunity to verify instrumentation and equipment for Mars landers under real and, not laboratory, flight conditions.
The scientific payload consisted of the high-resolution neutral gas mass spectrometer P-BACE (Polar Balloon Atmospheric Composition Experiment), a neutral gas mass spectrometer of the time-of flight type for the analysis of ambient atmospheric gas with a mass resolution m/Dm of about 1000 and 6–7 orders of magnitude dynamic range for 1-min measurements (Fig. 1). A full mass spectrum from 1 to 1000 amu is obtained once every minute. P-BACE was built by University of Bern, Switzerland and Swedish Institute of Space Physics (IRF), Kiruna, Sweden. It was originally developed to study the Martian atmosphere from a landed spacecraft.

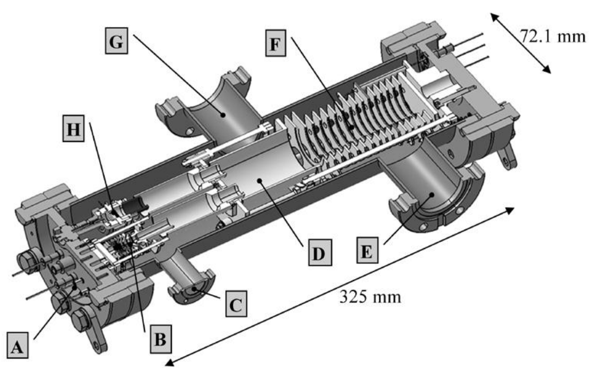

Figure 1. Engineering drawing of the mass spectrometer. A) Flange with ion source and detector and corresponding electrical feed-throughs, B) ion source with acceleration electrodes, C) sampling gas inlet, D) drift region, E) flange for external turbo-pump, F) ion reflectron region, G) flange for ion getter pump, H) ion detector.

The primary mission objective for MEAP was balloon platform technology validation. This included a new power distribution system for the balloon platform with solar arrays, the thermal design of the gondola and satellite based communication and tracking systems for both platform and payload. The primary mission objective for P-BACE was to verify instrument design and operations under flight conditions. The secondary objective for P-BACE were atmospheric science questions: at an altitude of 40 km one gets close to the upper end of the ozone layer. This is a region in the atmosphere where photochemical reactions are favored by the absorption of solar UV photons. Additional chemical processes occur because of frequent ion-neutral reactions. Thus, a large variety of complex molecules are expected. Possible in-fall and decomposition of meteorites delivers Si, Mg, Ca, Fe, and other atoms that serve as catalysts for chemical reaction in the middle atmosphere or may be incorporated in chemical compounds. The high mass and time resolution and the high dynamic range made P-BACE ideally suited to investigate these processes.

Several launch attempts were made after the opening of the launch window on June 9, 2008. An 11 Million cft (3'340'700 m^3) Helium balloon, type Aerostar 11.82-1E-38, was used for the MEAP mission. The system carried a 452 m^2 Aerostar parachute in the flight train for descent. Including the gondola mass of 450 kg and 272 kg ballast, the total system had a mass of 1644 kg. This resulted in a predicted float altitude of 36.5 km.
The balloon was successfully launched June 28, 2008, 05:07 UTC from Esrange Space Center, Sweden (67.89° N / 21.08° E). MEAP operations were conducted from Esrange flight control center, throughout the flight P-BACE operations were initially located at Esrange until shortly after launch and then transferred to the Swedish Institute of Space Physics, Kiruna for the remainder of the flight. MEAP reached a float altitude of 38 km within 2 h and 22 min. The flight lasted for 116 h at an altitude between 33 km and 38 km over a distance of more than 5'800 km.

The Polar Balloon Atmospheric Composition Experiment (P-BACE), led by Peter Wurz (Physics Institute, University of Bern) and Stas Barabash (Swedish Institute of Space Physics, Kiruna, Sweden) is a new generation of neutral gas mass spectrometer based on the time-of-flight principle. P-BACE is the scientific experiment on the Mars Environment Analogue Platform (MEAP) flown successfully on a balloon mission in summer 2008. The MEAP mission was flown with a 334,000 m3 helium balloon in the stratosphere on a semicircular trajectory from northern Sweden around the North Pole to Canada using the summer northern hemispheric wind current. The atmospheric conditions at an atmospheric altitude of 35 – 40 km are remarkably similar to those on the surface of Mars and thus the balloon mission was an ideal test bed for our mass spectrometer P-BACE. Originally this instrument was designed for in situ measurements of the chemical composition of the Martian atmosphere.

P-BACE has a unique mass range from 0 to 1,000 amu / q with a mass resolution m/Δm (FWHM) > 1,000, and the dynamic range is at least six orders of magnitude. During this experiment, the acquisition of one mass spectrum is a sum of 65,535 single spectra, recorded in a time frame of 66 seconds.
The balloon mission lasted five days and had successfully demonstrated the functionality of the P-BACE instrument during flight conditions. We had recorded more than 4,500 mass spectra. With little modifications, P-BACE can be used on a planetary mission for Mars, but for example also for Venus or Mercury, if placed on a satellite.

3. STRATOSPHERIC BALLOON EXPERIMENT "PEBS" (POSITRON ELECTRON BALLOON SPECTROMETER)

The goal of the project is to establish a new suborbital device aimed at providing essentially background-free measurements of cosmic-ray electrons and positrons from energies below 1 GeV to about 1 TeV, with excellent separation between positive and negative particles up to about 600 GeV. There is great interest in such measurements within the scientific community at present because of apparent "features" or unexpected behaviors seen in recently-reported electron and positron spectra.
One such feature, an anomalous rise in the positron fraction, ($e^+ / (e^+ + e^-)$) above 10 GeV, has been reported by the PAMELA collaboration. This rise seems to be in conflict with our understanding of cosmic-ray positron physics and has been attributed to a wide variety of phenomena, including particle production in nearby astrophysical sources or to even more exotic processes including the annihilation of dark matter particles. It is however also possible, that unidentified instrumental backgrounds are affecting the results. Such a background could arise from limitations in the instrument's ability to uniquely discriminate between positrons and protons at high energy.
Excitement has also been generated by several new measurements of the all-electron energy spectrum ($e^+ + e^-$) above a few hundred GeV. The reported data may exhibit a spectral feature ("bump"); the spectrum could be unexpectedly hard or curved, and could exhibit a sharp cut-off above 1 TeV. Some of these results are in mutual disagreement and, as with the positron measurements, background contamination or efficiency problems may need to be resolved.

To directly address the lingering questions surrounding these measurements, we have developed a new long-duration balloon detector system called PEBS (Positron Electron Balloon Spectrometer). PEBS is a large magnet spectrometer surrounded by a suite of sophisticated particle detectors designed to make measurements of positrons and electrons - essentially free of hadronic background. The heart of the PEBS spectrometer is a powerful permanent magnet which makes use of modern ferromagnetic alloys. This magnet is an evolution of the successful AMS-1 design, and when combined with a novel high-precision scintillating-fiber (SciFi) hodoscope, it will enable electron-positron separation possible up to 600 GeV, while also achieving a large sensitive detector area, as required for high statistics measurements up to these energies.
The PEBS Collaboration comprises a US team with a long history of successful cosmic ray balloon payloads - including several magnet spectrometers- and a European team from forefront institutions in particle physics. The European collaborators are also part of the team developing the AMS-2 instrument.

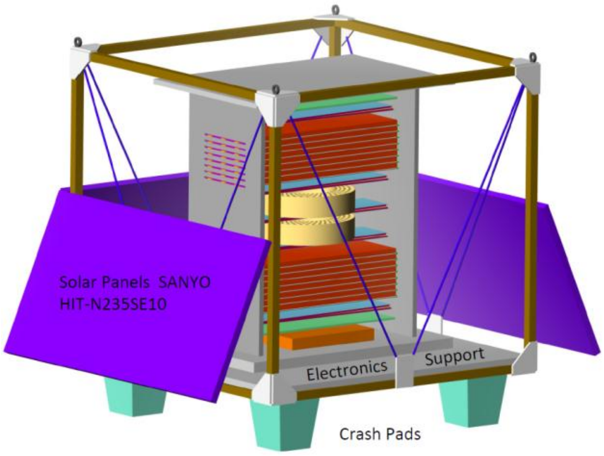

Figure 2. PEBSino integrated into the gondola

The experiment is foreseen for a balloon flight in the near future.

4. SOUNDING ROCKET EXPERIMENT "STIM" (SIGNAL TRANSDUCTION IN MICRO-GRAVITY)

The STIM experiment is focused on T cell activation in vitro under microgravity conditions. In particular early events are of interest which can be observed within minutes, even seconds after the cells have been exposed to an effective stimulus. The early response of the T cells is divided in several consecutive steps which will be analyzed separately. When specific activator molecules are recognized by the cell (the cell membrane is studded with receptor molecules and acts as a sensory surface), an intracellular signal is generated which is transferred via a complex network of molecular pathways to the nucleus. The ensuing response from the nucleus consists of commands submitted to the protein machinery of the cell.

T cell activation can easily be demonstrated in vitro by applying standard laboratory methods on fresh blood cells. T cells have been investigated many times in microgravity and it is well known that in vitro activation is severely hampered under such condition [1]. Although certain aspects of the signaling pathways have gradually been clarified, the picture is far from complete. In the STIM experiment, T cells will be activated in micro-g and two groups of cells will be analyzed afterwards. Cells that experience micro-g continuously and cells which have been placed on a 1g centrifuge (serving as control). By analyzing and comparing the results of the two groups, the signal transduction (intact at 1g and defect in micro-g) can be further explored and possibly, more light can be shed on the particular T cells response in micro-g. The sounding rocket experiment is focused on the following specific objectives:

a) To investigate the association and modification of signal transducing proteins of the lipid draft-associated signalosome complex during T cell receptor stimulation and membrane proximal signal transduction.

b) To investigate membrane-proximal-cytoplasmatic signal transduction by the ras/raf/MAPKpathway during T cell receptor or protein kinase C stimulation.

c.) To elucidate the molecular targets of gravisensitive signal transduction downstream from T cell receptor and upstream from cytoplasmatic signal transduction pathways.

d.) To investigate histone modifications and binding to underlying DNA sequences in stimulated and non-stimulated T cells.

e.) To elucidate the epigenetic ‘histone code’ of microgravity in T cells.

Experiment concept: At Esrange, T cells will be isolated from voluntary healthy donors. Upon isolation, T cells will be suspended in a culture medium. The cell suspension will be loaded into the experiment cassettes together with (in separate compartments) a stimulating agent and a fixative. One set of cassettes will be exposed to micro-g, with a duplicate set at 1g on the reference centrifuge. A third set, the ground control, is operated at 1g in the Esrange laboratory in synchrony with the sounding rocket flight. At the start of the 6-minutes micro-g window the activator (a suspension of immobilized anti-CD3 and anti-CD28 antibodies) is added to the T cells. At the end of the micro-g window the fixative is added to the T-cell/antibody mixture. In addition, a subset of the T cell cultures will be fixed at the start of the micro-g window to provide a zero-time control series.

The experiment is scheduled to fly on the MASER 12 sounding rocket, November, 2011

5. SOUNDING ROCKET EXPERIMENT “GGES” (GRAVITY GRADIENT EARTH SENSOR)

The GGES experiment proposed by a team of 8 students from the École polytechnique fédérale de Lausanne (EPFL) has been selected for participation in the REXUS (Rocket-borne Experiments for University Students) program. This program is designed to allow students from universities and higher education colleges across Europe to carry out scientific and technological experiments on research rockets.

The GGES experiment is an instrument aimed at testing a prototype of Earth Sensor that has been designed and fabricated by the EPFL laboratory LMTS (Micro-systems for Space Technologies Laboratory). The Earth Sensor uses the principle of gravity gradient sensing, which is apparent in the very slight change of gravity as you move away from the center of the earth. When an elongated mass is placed in this environment, it will tend to align itself with this field, since one part of the mass is pulled more strongly than the other. By measuring this displacement, of the mass trying to align itself, it is possible to calculate the exact position of the Earth (Fig. 1).

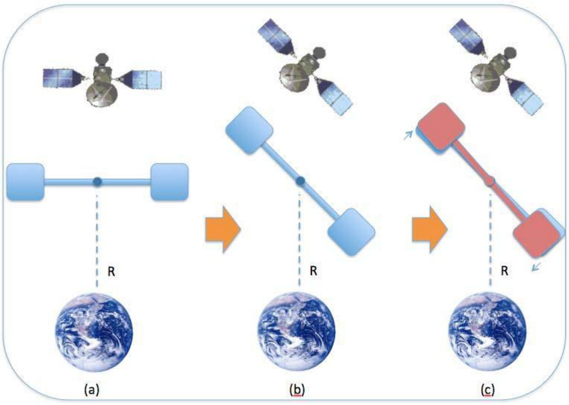

Figure 3. Diagram showing the effect of gravity gradient on a proof mass. (a) The proof mass (blue) inside the satellite is orientated perpendicular to the Earth. Both sides of the mass being the same distance from Earth thus there is no detectable effect. (b) If the satellite rotates a few degrees, the proof mass inside the satellite follows. As one side of the mass is closer to the Earth a slightly higher force is pulling on that side. As a consequence, an additional rotation (torque) will occur as shown in (c, red).

The principle is based on the use of a MEMS (Micro Electro Mechanical System) device that can measure the Gravity Gradient Vector, which always points to the center of the Earth. The goal of the sounding rocket experiment is to measure the rotation of a silicon proof mass under free-fall conditions due to gravity gradient

torque, and from the data, to determine the accuracy of the attitude measurement for a Low Earth Orbit (LEO) satellite. Gravity gradient torque (GGT) has been used to stabilize small satellites after launch, but never as an attitude determination device. Instead of sensing the Earth's infrared radiation emission for determining the attitude, the EPFL's system tries to apply a much lighter and more compact MEMSbased technique for doing the same.
The MEMS Earth Sensor represents a novel development in inertial sensors. Apart from a low mass and lower power solution for attitude determination on low Earth orbit satellites, it is an example of added capability for space missions using MEMS technology. The sensor fits on a chip which is about 3 cm by 6 cm and only 5mm thick. However, the designed experiment includes several other components. Among other things, control electronics as well as boards to handle the voltage levels and power fed to the sensors are needed. In addition, microprocessors are used to communicate with the sensors and storage of the data received for the duration of the flight, which is about 4 minutes. Finally, the boards and sensors must be installed in a frame of 10 cm x 10 cm x 10 cm, resistant to vibration and acceleration (Fig. 2).

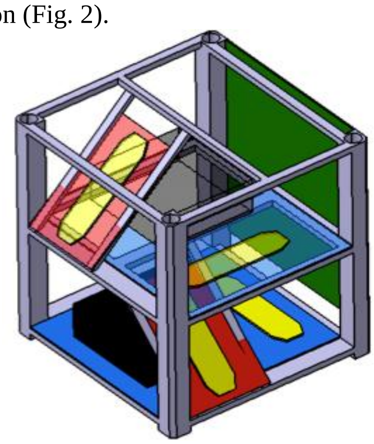

Figure 4. 3D model of a mechanical frame with two redundant electronic boards (green), each having two earth sensors (red) placed with a 90 deg. offset. The offset is necessary to make sure that two axis are measured and that the sensor will be able to point to the Earth at all times.

The experience is planned for a flight in March 2012.

6. ASSESSMENT OF HIGH ALTITUDE CLOUD CHARACTERISTICS, CLACE 2010 CAMPAIGN

A mobile elastic backscatter lidar (Leosphere type ALS 450) was employed for the first time in the field to monitor cirrus clouds and atmospheric aerosol from a high alpine site. It worked in a stable and reliable manner without any need for in-situ maintenance.

The lidar measures aerosols and clouds with a wavelength of 355 nm at a laser repetition rate of 20 Hz. It retrieves attenuated backscatter polarized parallel and perpendicular to the laser emission allowing determination of the depolarization ratio. The depolarization ratio depends on particle sphericity and increases with increasing asphericity. This channel thus provides information whether liquid or ice clouds are being observed. As the aim of the measurements is to monitor ice clouds and boundary layer aerosols, this is information of great value.
An example of measurements is given in Fig. 3 showing Saharan dust transported to the Jungfraujoch. The dust is barely visible in the parallel channel while in the perpendicular channel it is clearly discernable, starting at a height of approximately 4.5 km.

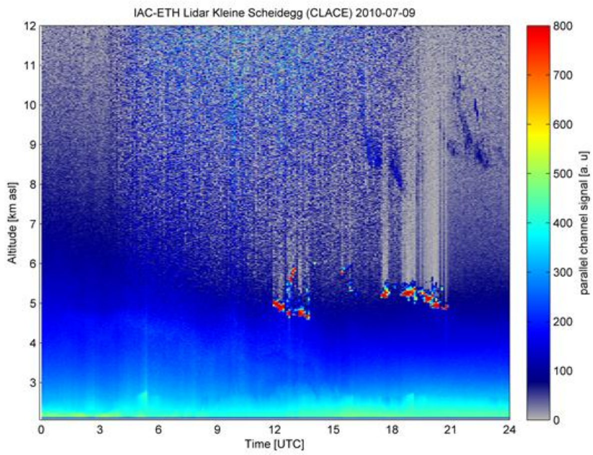

Figure 5. Example of the lidar measurements (parallel channel) showing Saharan dust starting at an altitude of approximately 4.5 km.

The measurements conducted on Jungfraujoch in 2010 were an excellent opportunity for the characterization of lidar properties. Since Jungfraujoch was often covered by clouds during the second phase when the instrument was installed on the Sphinx terrace, further measurements on Jungfraujoch are desirable.

7. THE GLOBAL ATMOSPHERE WATCH (GAW) AEROSOL PROGRAM AT THE JUNGFRAUJOCH

Airborne aerosols affect our climate primarily by influencing the atmospheric energy budget through direct and indirect effects. Direct effects refer to the scattering and absorption of radiation as well as their 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 could lead to an increase in cloud droplet number concentration and a decrease in cloud droplet effective radius, when the cloud liquid water content (LWC) remains constant. The resulting cloud droplet spectrum could lead to reduced precipitation and increased cloud lifetime. The overall result would be an increase in cloud albedo which cools the Earth's climate. Despite the uncertainty, it is believed that in regions with high anthropogenic aerosol concentrations, aerosol forcing may be of the same magnitude, but opposite in significance compared to the combined effect of all greenhouse gases.

The Global Atmosphere Watch (GAW) program is an activity overseen by the World Meteorological Organization (WMO). The goal of GAW is to ensure long-term measurements in order to detect trends and to develop an understanding of these trends. With respect to aerosols, the objective of GAW is to determine the spatiotemporal distribution of aerosol properties related to climate forcing and air quality up to multi-decadal time scales. Since the atmospheric residence time of aerosol particles is relatively short, a large number of measuring stations are needed. The GAW monitoring network consists of 27 global (including the Jungfraujoch) and about 300 regional stations. While global stations are expected to measure as many of the key variables as possible, the regional stations generally carry out a smaller set of observations.

The Jungfraujoch aerosol program is among the most complete worldwide. At the end of 2010 it had carried out 16 years of continuous measurements. The permanent GAW monitoring activities include measurements of the total concentration of particles with diameters larger than 10 nm. However, the number size distribution of aerosol particles, which plays a key role for direct and indirect aerosol climate interactions, was not yet monitored on a permanent basis. Therefore, a scanning particle mobility sizer (SMPS) and an optical particle counter (OPC) were installed at the JFJ in January 2008. These instruments have been fully operational since then and provide a complete size distribution from 20 nm to 20 µm.

The eruption of the volcano Eyjafjallajökull, Iceland in April and May 2010 strongly impaired the flight traffic in large regions of Europe. In central Europe, it caused an almost complete closure of the airspace during several days in mid-April 2010. Since the lead time for actions to be taken in the predicted areas of concern was very short after the initial eruption, data from existing and operational monitoring networks was highly valuable considering the urgency of the situation.

In Switzerland, the volcanic ash plume was clearly detected at the High Altitude Research Station Jungfraujoch. Figure 6 shows the clear presence of volcanic aerosol at the Jungfraujoch on several days in April and May 2010, indicated by a strong simultaneous increase in mass concentration (PM10), sulfur dioxide (SO2) and coarse mode ash particles.

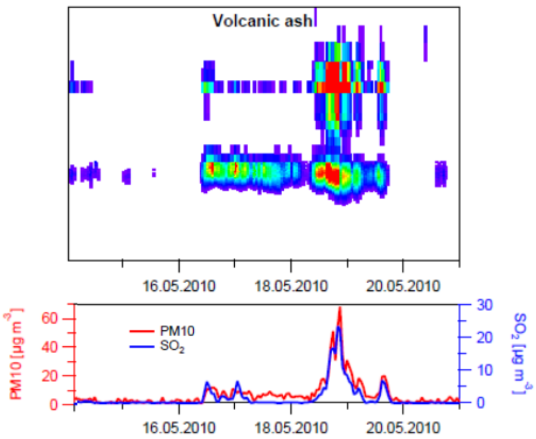

Figure 6. Volcanic aerosol was detected at the Jungfraujoch by a simultaneous increase in mass concentration (PM10), sulfur dioxide (SO_2) and by the presence of ash particles with a diameter of 3 µm in the aerosol. Volume size distribution (upper panel). (PM10 and SO_2 data: Courtesy of Empa/NABEL).

8. REFERENCES

1. Cogoli, A.C.-G., M., ed. *Cells of the Immune System in Space (Lymphocytes)*. Biology in Space and Life on Earth ed. E. Brinckmann. 2007, Wiley. 193-219.

9. ACKNOWLEDGEMENT

We would like to thank all the contributors from the different institutions for providing the input necessary to write this report. Furthermore, we gratefully acknowledge the support of the Swiss Space Office SSO, Federal Department of Home Affairs FDHA, State Secretariat for Education and Research SER.