

Scientific Report

*Symposium on
Atmospheric Chemistry and Physics at Mountain Sites*

*June 8-10, 2010,
Interlaken, Switzerland*

Summary

The first International Symposium on "Atmospheric Chemistry and Physics at Mountain Sites" was held at Interlaken from June 8 to June 10, 2010. The Symposium was organized by the Commission of Atmospheric Chemistry and Physics (ACP) of the Swiss Academy of Sciences (scnat).

Almost 100 leading atmospheric scientists from 22 countries and four continents representing more than 30 elevated observatories shared their research results. From the data presented, it became clear that high elevation mountain atmospheric observatories provide a unique opportunity to study long range transport of air pollutants and dust, to investigate chemical reactions in the atmosphere and to get crucial information on background concentrations of trace gases and aerosols influencing ozone concentrations, and those that drive climate change.

Special emphasis was given to the fact that long-term time series represent an inestimable value for natural and human caused global change investigations. It was shown that these data can also provide critical data for extreme episodes (e.g. biomass burning, radionuclide releases, etc.). Such studies, together with satellite observations, are relevant for societal, ecological and economical issues as recently demonstrated by the ash cloud movement originating from the erupting volcano under the Eyjafjalla glacier in Iceland, and its implication on European air traffic.

A follow up meeting is offered to be organized by US scientists who contributed with their research results from elevated sites to the Interlaken meeting.

Introduction

During the second week in June (8-10, 2010), the first International Symposium on "Atmospheric Chemistry and Physics at Mountain Sites" was held at Interlaken, Switzerland. The Symposium was organized by the ACP-commission (Atmospheric Chemistry and Physics) of the Swiss Academy of Sciences.

One of the main goals was to intensify a closer cooperation of the "observing" and "modelling" community which was achieved successfully. Both communities were well represented and the targeted interdisciplinary discussions were successfully initiated as the meeting brought together scientists from all over the world (see also chapter participants) with expert knowledge in air constituent measurements and/or experience in modelling transport as well as in dynamic processes at mountain sites.

Scientific content and discussions

More than 100 contributions were submitted and the schedule allowed 46 of the participants to present their results by an oral presentation (see attached programme). All the others showed their results during two poster sessions, each 1.5 hours which allowed even more profound discussions. The numerous registrations documented the strong demand of the scientific community for such an opportunity, and this was reinforced by very lively contribution of the participants during the whole meeting. In addition, side meeting were held to discuss specific results and/or prepare new projects.

The **scientific programme** triggered by the shared scientific questions, in the particular circumstances and requirements of elevated sites, was organized in the following sessions (for the details, see attached final programme):

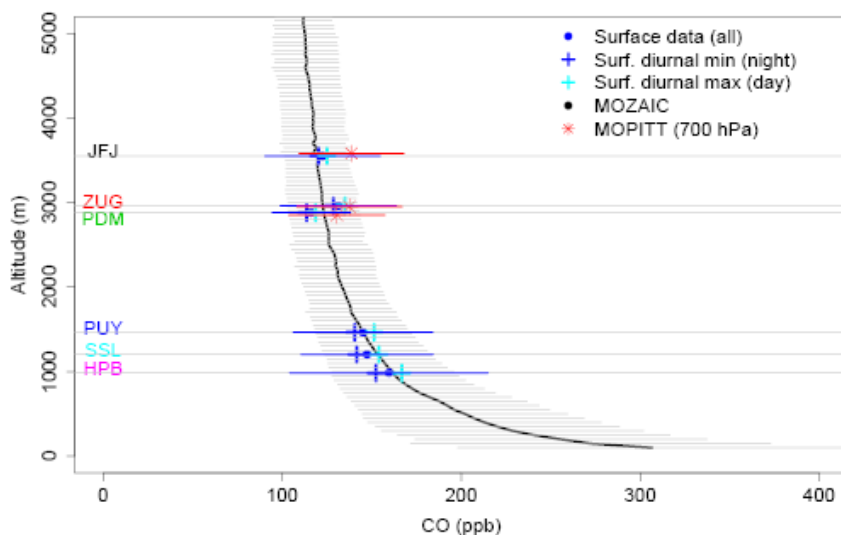
- Session 1: Effects of the planetary boundary layer on measurements at mountain sites and transport modelling
- Session 2: Background baseline observations at mountain sites
- Session 3: Carbon monoxide and carbon dioxide
- Session 4: NMHC, PAN, and ammonia
- Session 5: Long-term changes of ozone and its precursors
- Session 6: Aerosol optical depth and other aerosol properties
- Session 7: Aerosols at high-elevation sites in Asia
- Session 8: Nucleation and clouds
- Session 9: Aerosol chemical composition

From the data presented, it became clear that high elevation mountain atmospheric observatories provide a unique window on long range transport of air pollution and dust, chemical reactions in the atmosphere, and crucial information on background concentrations of trace gases and aerosols influencing ozone concentrations, and those that drive climate change. Special emphasis was given to the fact that long-term time series represent an inestimable value for natural and human caused global change investigations.

It was shown that these data can also provide critical information for extreme episodes (e.g. biomass burning, radionuclide releases, etc.). Such studies, together with satellite observations, are relevant for societal, ecological and economical issues as recently demonstrated by the ash cloud movement originating from the erupting volcano under the Eyjafjalla glacier in Iceland, and its implication on European air traffic.

Moreover, it became clear that high mountain observatories allow analyses of the radiation reflecting properties, the so called albedo effects associated with clouds in more detail. In particular, the mixed clouds, i.e. the clouds containing both water drops and ice crystals, are rather poorly understood and need dedicated attention. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change IPCC from 2007 is pointing out that the uncertainty in the knowledge about this cloud albedo feedback on the climate should be reduced.

In particular Session 1 (effects of the planetary boundary layer on measurements at mountain sites and transport modelling) illustrated that transport modelling has been strongly improved over the last decades due to better information in modern weather forecast models and developments in Lagrangian methods and higher spatial resolution. However, attribution to the free tropospheric and planetary boundary layer air is often a difficult task, particularly when convective transport is involved. Nevertheless, knowledge exchange during the symposium showed clearly that basic processes are often very similar among many mountain sites. This inspired participants to apply concepts presented at the symposium to their own sites. One aspect that is scientifically very attractive is the determination of source regions of anthropogenic species. Such methods can be applied to monitor emission source strengths of relevant compounds and can therefore be used to support and independently verify international regulations. Source attribution methods strongly depend on highly complex transport pathways of pollutants from emission sources to mountain sites because air pollutant transport in mountainous topography can be affected by many local processes, which themselves depend on the actual synoptic weather conditions. The following example shows clearly the benefit in combining model results with measurements from different platforms for cross validations purpose:



- Comparison of:
- MOZAIAC profiles above Frankfurt (black and grey)
 - surface stations data (blue)
 - 700 hPa MOPITT CO (JFJ, ZUG and PDM (red).

Averaging period: June 04–May 05

F. Gheusi at al.

Bold line and dots: 1-year averaged CO mixing ratio; bars: ± 1 standard deviation.

Session 2 (background baseline observations at mountain sites) revealed that monitoring of (anthropogenic) changes in atmospheric background composition with the required precision and accuracy is a great analytical challenge. It became evident that this often requires the most advanced techniques because of the very low concentrations of many of the important atmospheric constituents. In order to obtain valuable and reliable long-term measurements, fully automated techniques are often needed, which leads to additional challenges. Since mountain sites are usually remote locations, a suitable infrastructure is very helpful to support the work of the scientists. This issue was discussed following the scheduled programme.

The lack of support of long-term measurements makes it often impossible to investigate multi decadal time scales although this is often the basis of climate change research. An initiative to support observatories providing the required long term measurements drafted the relevant argumentation (see attached letter of support) for supporting these sites in general but in addition the scientist of this Symposium also provided a specific support letter for Mt. Fuji, which is suffering the required funding.

Session 3 (carbon monoxide and carbon dioxide), Session 4 (NMHC, PAN, and ammonia) and Session 5 (long-term changes of ozone and its precursors) presented results of different reactive compounds. Mountainous observations of ozone, peroxyacetylnitrate (PAN), aerosols, and ozone precursors allowed to study intercontinental transport, which has developed into an important research topic in the northern hemisphere due to changes in continental emissions.

Session 6 (aerosol optical depth and other aerosol properties), Session 7 (aerosols at high-elevation sites in Asia), Session 8 (nucleation and clouds) and Session 9 (aerosol chemical composition) clearly demonstrated that mountain sites offer suitable conditions to study aerosol-cloud interactions, a further challenging topic in present climate research.

On Friday, June 11, 2010, the symposium was followed by an excursion to Jungfraujoch and offered to the whole science community to visit of the High Altitude Research Station which is considered as one of the world leading high mountain observatories for environmental and climate research. This excursion complemented the theoretical part at the symposium with a practical deepening which was especially for the participants of the developing countries of additional educational value.

Benefits of the symposium

This symposium “Atmospheric Chemistry and Physics at Mountain Sites”, offered opportunities to exchange research experiences at elevated sites and fostered investigations of relevant topics in climate change research as well as process analysis in the free troposphere. Because of the high costs related to long term measurements, it is crucial to make best scientific use of such measurements. Thus it was very beneficial to bring together experts in measurements and models. Science benefit can even be improved by a more intensified encouragement of combined research projects in the future.

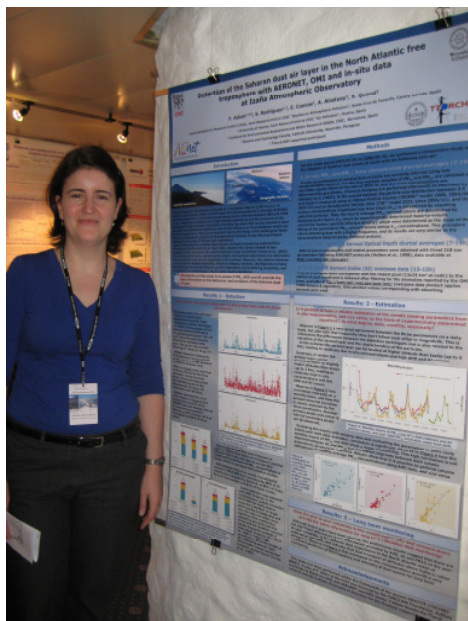
We achieved to include young scientists and were able to provide capacity building for scientist from developing countries. This was possible thanks to the support of TTORCH, MeteoSwiss and the strong involvement of the organizing institutions.

A comprehensive abstract book was published and gives a nice overview about all contributions.

Supported Scientists

The support of TTOCH, ESF made it possible for 9 young scientists (master students, PhD students or young scientist from developing countries) to participate in the meeting and present their results with a talk or a poster to experts who provided the expected feedback. During the meeting and the excursion on Friday, there were plenty of opportunities to discuss open questions and future collaborations.

Additional support was provided by MeteoSwiss to support five more experienced researchers from developing countries such as China, Egypt, Armenia, India and Russia to participate to the Symposium.



PhD student from Paraguay, supported by TTORCH, presenting her results about Aerosols investigations based on measurements at the high observatory at Izania combined with satellite data.



Young scientists from Indonesia (left) and from Kenya (right), supported by TTORCH, exchanging their experience of running measurement at sites contributing to the Global Atmosphere Watch programme of WMO. Both contributed with an oral presentation to the ACP-Symposium.

Participants

Almost 100 scientists from 22 countries representing more than 30 observatories in 4 continents (Europe, America, Africa and Asia) reflect a very good participation of elevated observatories in the ACP – Symposium which indicates the interest of researchers at elevated sites in discussing common scientific question as well as technical issues under the often challenging boundary condition at these remote and elevated sites.



- Mauna Loa, Mt. Whistler
- Mt. Bachelor Dessert Storm Peak
- Pico Espejo Pico Mountain
- Teiide Pyrenäen
- Puy du Dome Pic du Midi
- Schauinsland Monte Rosa
- Jungfrauoch Mt. Cimone
- Zugspitze Hohen Peissenberg
- Sonnblick Kasprowy Wierck
- Kislowosk Mt. Kenya
- Sinhagd Piton Maidon
- Mt. Waliuan NCO-Pyramide
- Mt. Everst Tibetan Plateau
- Mt. Lulin Bukkit Kototabang
- Mt. Jodo Mt. Happos
- Mt. Fuji

Organizing Committee

The organizing committee included representatives of the Swiss Federal Institute of Technology Zürich (ETHZ), the Paul Scherrer Institute (PSI), the Swiss Federal Laboratory for

Material Sciences and Technology (Empa), the International Foundation High Altitude Research Stations Jungfrauoch and Gornergrat (HFSJG), the Federal Office of Meteorology and Climatology (MeteoSwiss). Key persons involved have been Prof. Dr. Johannes Stähelin (ETHZ), Prof. Dr. Urs Baltensperger (PSI), Dr. Brigitte Buchmann (Empa), Dr. rer. nat. Dominique Ruffieux, MeteoSwiss, Prof. Dr. Erwin Flückiger and Prof. Markus Leuenberger both HFSJG.

Acknowledgement

The Organizing Committee especially thanks the staff members Doris Hirsch-Hoffmann, Louise Wilson, Carole Delémont, Daniel Oderbolz and April Siegwolf for the outstanding support in organizing and realizing the meeting. Besides financial support from Swiss scnat commission ACP, we are grateful to TTORCH, the European Science Foundation by providing travel support for young scientists (<http://www.ttorch.org/tiki-index.php>) and acknowledge additional support from MeteoSwiss (<http://www.meteoschweiz.admin.ch/web/en.html>) enabling co-funding the participation of colleagues from developing countries. The support of the High Altitude Research Stations Jungfrauoch and Gornergrat (<http://www.hfsjg.ch/>) and the Jungfrau Railway Company (<http://www.jungfrau.ch/en/DesktopDefault.aspx/tabid-1/>) enabled a trip for the whole group to the Swiss high altitude research station Jungfrauoch very well acknowledged.

Outlook

The attractive and comprehensive programme caused lively discussions and enabled splinter meeting to initiate new joint project activities (e.g. University of Krakow and Empa, a research institute in the ETH – domain, CH). An argumentation was put together to support the development of long term operations of atmospheric observatories at high elevated sites. Based on this stimulating atmosphere our American colleagues offered to organize a follow up meeting in a 2-3 year timeframe close to one of the high mountain observatories in the US covering a similar scientific programme.



Dübendorf, 08. 10. 2010

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Attachments:

Final Programme
List of participants
Support letter elevated sites
Abstract Book, submitted separately (15MB)

Program

Monday, June 7

16.00 - 21.00 Registration
19.00 - 21.00 Ice Breaker – Apéro [Please register first.](#)

Tuesday, June 8

08.30 - 08.40 **Welcome and introduction, Johannes Staehelin**

Talks - Session 1 **Effects of the planetary boundary layer on measurements at mountain sites and transport modelling**
Chair: Dominique Ruffieux

08.40 - 09.00 **Delia Arnold**
High-resolution backwards atmospheric transport modelling in mountainous regions applied to source identification

09.00 - 09.20 **François Gheusi**
High-resolution model studies of transport of surface pollutants to Pic du Midi, Piton Maïdo (Reunion Island) and Jungfraujoch

09.20 - 09.40 **Christoph Gerbig**
Mesoscale eulerian and lagrangian modeling of CO₂: The challenge of representing mountain sites

09.40 - 10.00 **Dominik Brunner**
Allocation and trends of halogenated hydrocarbon emissions in Europe as observed from Jungfraujoch

10.00 - 10.20 **Stephan Henne**
A global Lagrangian model to study trace gas variability and long range transport

10.20 - 10.50 Break

Talks - Session 2 **Background baseline observations at mountain sites**
Chair: Johannes Staehelin

10.50 - 11.10 **Daniel Jaffe**
Recent discoveries at the Mt. Bachelor Observatory in Oregon

11.10 - 11.30 **Neng-Huei (George) Lin**
Chemical and physical measurements at Lulin Atmospheric Background Station (LABS, 2,862m msl) in Taiwan since 2006

Program

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| 11.30 - 11.50 | Martine Collaud Coen Impact of synoptic weather types on the planetary boundary layer influence at the Jungfraujoch |
| 11.50 - 12.10 | René Stübi On the differences between ground based and balloon ozone measurements: Payerne sounding vs. Jungfraujoch |
| 12.10 - 12.30 | Christian Plass-Dülmer NMHC Climatology from Central European mountain observatories |
| 12.30 - 14.00 | Lunch |
| Posters - Session 1 | Chair: Markus Leuenberger |
| 14.00 - 15.30 | Poster session, related to sessions 1-5 |
| 15.30 - 16.00 | Break |
| Talks - Session 3 | Carbon monoxide and carbon dioxide <i>Chair: Brigitte Buchmann</i> |
| 16.00 - 16.20 | Markus Leuenberger Atmospheric O ₂ and CO ₂ at the High Alpine Station Jungfraujoch, Switzerland - a comparison between online and flask measurements |
| 16.20 - 16.40 | Silvia Ferrarese Study of a CO ₂ high concentration event at Plateau Rosa station (Italy) with WRF model |
| 16.40 - 17.00 | Edison Kurniawan The study of eddy correlation in carbon dioxide concentrations related to vertical wind velocity |
| 17.00 - 17.20 | Michal Galkowski Stable isotope composition of atmospheric CO ₂ at high mountain site (Kasprowy Wierch, Southern Poland) |
| 17.20 - 17.40 | Lukas Emmenegger Regional pollution events observed by continuous measurements of $\delta^{13}\text{C-CO}_2$ and $\delta^{18}\text{O-CO}_2$ at Jungfraujoch using quantum cascade laser spectroscopy |
| 17.40 - 18.00 | Urs Baltensperger Mountain sites as an important infrastructure for the impact assessment of volcanic ash |
| 19:00 | Dinner |

Program

Wednesday, June 9

Talks - Session 4 **NMHC, PAN, and ammonia**

Chair: Erwin Flückiger

- 08.30 - 08.50 **Michael Leuchner**
Source apportionment of NMHCs at the GAW background site
Environmental Research Station Schneefernerhaus, Germany
- 08.50 - 09.10 **Detlev Helmig**
Non-methane hydrocarbons as tracer for long-range transport studies
at Pico Mountain, Azores, Portugal
- 09.10 - 09.30 **Emily Fischer**
Measurements and importance of PAN in the free troposphere: Multi-
year springtime observations at the Mount Bachelor Observatory
- 09.30 - 09.50 **Shubha Pandey**
NO_y speciation and relationship with PAN in the troposphere from the
measurements at Jungfraujoch
- 09.50 - 10.10 **Meng Zhaoyang**
Ambient ammonia observed at a remote mountain site in the north-
eastern Qinghai-Tibetan Plateau, Western China

10.10 - 10.40 Break

Talks - Session 5 **Long-term changes of ozone and its precursors**

Chair: Daniel Jaffe

- 10.40 - 11.00 **Stefan Gilge**
Time series of reactive trace gases at the GAW-DACH-sites
Sonnblick, Jungfraujoch, Zugspitze and Hohenpeissenberg
- 11.00 - 11.20 **Yenny González Ramos**
Long term ozone observations at Izaña Atmospheric Observatory
(1988-2008)
- 11.20 - 11.40 **Kennedy Thiongo**
Trend of carbon monoxide and ozone at Mount Kenya GAW station
- 11.40 - 12.00 **Johannes Staehelin**
Ozone and ozone precursors at Jungfraujoch (Switzerland):
Data analysis and long-term changes
- 12.00 - 12.20 **Hiroshi Tanimoto**
Decadal trend in springtime tropospheric ozone at a mountainous site
in Japan: 1998-2007

Program

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| 12.30 - 14.00 | Lunch |
| Posters - Session 2 | <i>Chair: Andre Prévôt</i> |
| 14.00 - 15.30 | Poster session, related to sessions 6-9 |
| 15.30 - 16.00 | Break |
| Talks - Session 6 | Aerosol optical depth and other aerosol properties <i>Chair: Anna Gannet Haller</i> |
| 16.00 - 16.20 | Betsy Andrews Climatology of aerosol radiative properties in the free troposphere |
| 16.20 - 16.40 | Chrisoph Wehrli Long-term aerosol optical depth (AOD) measurements at the Jungfraujoch Global GAW station |
| 16.40 - 17.00 | Huizheng Che Aerosol optical properties measured by Cimel sunphotometer over six GAW stations in China |
| 17.00 - 17.20 | Sergio Rodríguez Gorzáles Origin, size distribution and chemical composition of the Saharan dust particles collected in the North Atlantic free troposphere at Izaña Atmospheric Observatory |
| 17.20 - 17.40 | Paolo Cristofanelli Atmospheric composition at the Italian climate observatory "O. Vittori" at Mt. Cimone (Italy, 2154 m a.s.l.) |
| 17.40 - 18.00 | Radovan Krejci Aerosol properties in tropical free troposphere at high altitude research station Pico Espejo (4775 MSL) in Venezuela |
| 19:00 | Dinner |

Program

Thursday June 10

- Talks - Session 7** **Aerosols at high-elevation sites in Asia**
Chair: Neng-Huei (George) Lin
- 08.30 - 08.50 **Paolo Laj**
 Aerosol optical properties and radiative forcing in the high Himalaya based on measurements at the Nepal Climate Observatory - Pyramid Site (5100 m a.s.l.)
- 08.50 - 09.10 **Niku Kivekäs**
 Aerosol size distribution measurements at Mt Waliguan, inland China
- 09.10 - 09.30 **Kazuo Osada**
 Impact of Chinese anthropogenic emissions on submicrometer aerosol concentration at Mt. Tateyama, Japan
- 09.30 - 09.50 **Kazuhiko Miura**
 Size distributions of aerosol particles measured at the summit and a base of Mt. Fuji
- 09.50 - 10.10 **Atsushi Matsuki**
 Size distribution measurement of air ions at the summit of Mt. Fuji during 2009 summer campaign
- 10.10 - 10.40 Break
- Talks - Session 8** **Nucleation and clouds**
Chair: Paolo Laj
- 10.40 - 11.00 **Julien Boulon**
 Vertical extension of nucleation events: Evidences for a favoured high altitude process
- 11.00 - 11.20 **Anna Gannet Hallar**
 Persistent daily aerosol nucleation events at mountain-top location
- 11.20 - 11.40 **Zsofia Juranyi**
 Long-term cloud condensation nucleus concentration measurement at Jungfrauoch
- 11.40 - 12.00 **Johanna Spiegel**
 Droplet number size distributions measured in mixed-phase clouds at the high-alpine research Station Jungfrauoch
- 12.00 - 12.20 **Ernest Weingartner**
 Influence of aerosol particles on cloud microphysical properties

Program

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| 12.30 - 14.00 | Lunch |
| Talks - Session 9 | Aerosol chemical composition <i>Chair: Urs Baltensperger</i> |
| 14.00 - 14.20 | Angela Marinoni 2-Years of measurements of the chemical composition of PM10 and PM1 at the high elevated Nepal Climate Observatory – Pyramid NCO-P (5079m a.s.l.) |
| 14.20 – 14.40 | Richard Leaitch Components of the carbonaceous aerosol at the peak of Whistler Mountain during the spring and summer of 2009 |
| 14.40 - 15.00 | Anne Marie Macdonald Multi year aerosol characterisation at the Whistler mountain site |
| 15.00 - 15.20 | Andre Prévôt Composition of particulate matter at Jungfraujoch compared to the boundary layer in Central Europe |
| 15.20-16.00 | Concluding remarks: all |
| 16.00 - 16.30 | Break |
| 16.30 -18.00 | Round-Table Discussion: High Mountain Observatories as a part of the UNESCO Initiative "Astronomy and World Heritage" <i>Chair: Martin Huber</i> |

Annex 2

List of participants, ACP Symposium 2010

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Annex 3:

Support for high elevated observatories

During the week of June 8-10, 2010, fifty leading atmospheric scientists from around the world shared their research results at the first international symposium on "Atmospheric Chemistry and Physics at Mountain Sites", Interlaken, Switzerland. From the data presented, it became clear that high elevation mountain atmospheric observatories provide a unique window on long range transport of air pollution and dust, chemical reactions in the atmosphere. These data also provide key information on background concentrations of trace gases and aerosols influencing ozone concentrations, and those that drive climate change. Due to the small number of high elevation atmospheric research stations around the globe, the conference participants agreed on the following statement.

Whereas high elevation atmospheric observatories provide critical data on weather, climate, air quality, and long-range transport of pollution that can only be observed by in-situ observations;

Whereas many critical processes for climate and air quality occur in the free troposphere;

Whereas observations of the volcanic ash cloud from Iceland at the Jungfrauoch station provided critical data on the volcanic ash properties, which was essential for understanding the risk to aircraft engines;

Whereas high altitude observatories can provide critical data for all types of extreme episodes including volcanic, dust, biomass burning and radionuclide releases;

Whereas long-term data records provide critical information on both natural and human caused global changes and there are very few atmospheric records longer than 10 years anywhere on the globe;

Whereas data from high elevation observatories have been used to evaluate and improve chemical transport models and satellite observations;

Whereas a recent report from the US National Academy of Sciences emphasized the need for strengthening existing background sites and adding new sites, especially those that can sample the free troposphere;

Whereas there is a relatively small number of these observatories world-wide able to monitor and conduct research in the free troposphere and neither models nor satellite observations can replace these in-situ observations;

Be it resolved that we the participants in the first ACP/Swiss Academy of Sciences "Symposium on Atmospheric Chemistry and Physics at Mountain Sites" urge our national science and environmental agencies to support the development and long-term operation of atmospheric observatories at high elevation.