Proposal for the implementation of a regional GAW station at Chacaltaya (5320 m, Bolivia)

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1. Rationale for the project

Information on atmospheric composition and circulation and its evolution, from the local to the global scale, is of strategic value in particular for climate related studies. Despite important improvements in Earth observing approaches in the last decade, there is still a critical need for both the consolidation of existing observation infrastructure and the development of a more efficient observing system that would help fill major data and information gaps, and assist stakeholders in planning new investments.

Within the atmospheric science community, there is a growing consensus that both a surface and a satellite-based observing system should provide well documented, global observations of the atmosphere including: chemical composition; Green House Gas (GEG) concentration; isotopic composition of water; physical properties from pole to pole with temporal, horizontal and vertical resolution sufficient to satisfy and verify current legislation, validate and help to improve our understanding of atmospheric processes and permit accurate predictions of future atmospheric states by providing inputs for forecast models.

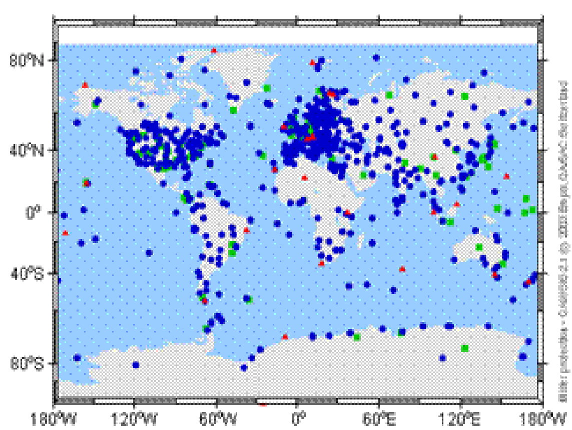

Figure 1: location of GAW atmospheric stations in 2006 (red: global stations, blue: regional stations, Green: Contributing stations)

Clearly, current gaps in the observing system for atmospheric composition changes are numerous, in particular its ground-based component. One of the drawbacks of ground-based networks relates to uneven global and regional coverage of atmospheric observations. A first conclusion from working groups on atmospheric observation strategies points to the need for additional information from the free troposphere.

Observations of the free troposphere are needed to understand long-range transport, climate change and trends in the oxidizing capacity of the atmosphere, as well as, to provide a 'baseline' for the characterization of atmospheric chemistry and physics (IGACO Theme Team, 2004; WMO, 2007). Further analysis of global networks also shows that the Southern

Hemisphere is clearly under-sampled in comparison to the Northern Hemisphere (see Figure 1). This is partly due to the predominance of oceanic surfaces but also the lack of monitoring stations on land and the restricted number of dedicated field campaigns in many parts of the Southern Hemisphere. The Global Atmosphere Watch network in South America consists of 24 fully operational stations across 9 countries (plus two stations operated by the United Kingdom in the Antarctic Peninsula and the Falkland Islands). Of the 24 stations, 22 are GAW regional stations and 2 are GAW global stations (Ushuaia in Argentina and Arembepe in Brazil); among them 6 are located at high altitude,. An analysis of the data from these stations, provided by the South American network, shows that information mostly concerns either the Ozone column, flask sampling for greenhouse gases, irradiance and/or a series of meteorological parameters. Exceptions are the NDACC station at Paramaribo (Suriname) where atmospheric profiling of atmospheric gases and the global GAW station at Ushuaia where measurements of some reactive gases are done on a monitoring basis. The GAW network is complemented by AERONET sun photometer measurements. In 2008, 10 stations provided information to the network. In addition, there are isolated stations that have been monitoring the isotopic composition of precipitation over the past ten years. Clearly, there is a lack of information on atmospheric composition from the South American subcontinent, especially concerning continuous series of aerosol, reactive gases and greenhouse measurements, in particular from the free troposphere.

Figure 2: A view of Mount Chacaltaya in Bolivia´s Cordillera Real.

The present proposed project for the implementation of a regional GAW station at Chacaltaya (5320 m, Bolivia) aims to fill existing gaps in the global observation network in South America and in particular for in-situ monitoring of reactive gases, aerosol properties and greenhouse gases. Use of the existing Chacaltaya atmospheric station, which was once a WMO station in the 60s[1], was recently proposed by the Atmospheric Physics Laboratory (part of Universidad Mayor de San Andrés, the largest university in Bolivia) as a potential base for implementing a regional GAW station. This would be part of an international effort by a core team of experts in the field of atmospheric observations in Bolivia, France, Italy and Switzerland. Additional resources in Germany and Sweden can also be found for the project..

The ultimate goal of this project is the implementation of a long-term station operated by the Atmospheric Physics Laboratory (‘Laboratorio de Física de la Atmósfera’, LFA-UMSA) with the potential to become the 3rd GAW global station in South America and the unique high altitude station over the Continent.

2. Description of the Chacaltaya site

The Cosmic Ray Laboratory (CRL) at Mount Chacaltaya is located at 5.200 m asl, 16.2ºS and 68.1ºW, and is easily reachable within 90 minutes from La Paz city by car. The CRL is operated by the Physics Research Institute of the Universidad Mayor de San Andrés, La Paz. Currently the Atmospheric Physics Laboratory (also part of the Physics Research Institute)

[1] http://gaw.empa.ch/gawsis/reports.asp?StationID=-739518975).

has some equipment and facilities at this site. The CRL is located approximately 25 km, in straight line, from the LFA-UMSA in downtown La Paz. Chacaltaya is a mountain with a horizon, open to the South and West and with high peaks at its North and East. The climate at Chacaltaya is generally dry and semi-desert, with annual precipitations of around 680 mm (50% of such rainfall occurs during the Austral summer).

The site is served by a little travelled stony road. Electric power is available at CRL through transmission wires from La Paz. Cell phones get a weak but continuous signal on site. There are permanent (or semi-permanent) personnel at the CRL. Scientists and technicians travel to the Laboratory regularly during work days. Although there are several buildings on site none of them have been specifically designed for housing instruments related to atmospheric sciences. There is, however, a plan to refurbish and/or build some infrastructure for such purpose. The LFA-UMSA has requested University funds to remodel some rooms for measuring gas concentrations and solar radiation. Different studies have shown that during El Niño years (warm phase of ENSO) the Altiplano climate tends to be dry, while during La Niña years (ENSO cold phase) conditions are wet. There is no marked seasonal variation in temperature. The monthly mean high and low temperatures average around 15 ºC and -5ºC, and the annual mean is around -1ºC. Pressure does not exhibit seasonal variation. The barometric pressure at the site is approximately 540 mbars. The area surrounding the CRL is stony, partly covered by snow (especially in summer), and with little vegetation. La Paz is one of the largest cities in Bolivia, with a metropolitan population of about 1.4 million inhabitants. The city is located in a valley surrounded by mountains with a relatively steep altitudinal gradient.

Figure 3: Map of the La Paz / Chacaltaya area.

Additional instruments, which measure other relevant atmospheric parameters, are located at the LFA-UMSA. The Laboratory is situated at UMSA´s Cota Cota University Campus in the southern outskirts of La Paz at 3420 m above sea level (asl) and at 68.1º W longitude and 16.5º S latitude. The campus is bounded by a river-bed and non-urbanized land on one side, and a main street on the other. Despite the latter, the vehicular circulation around the campus is not significant. LFA-UMSA has direct and exclusive access to the lab's rooftop where it operates atmospheric monitoring equipment and is currently building new infrastructure is being built to accommodate a Nd:YAG LIDAR donated by the European Space Agency and refurbished by the Goddard Space Flight Center, NASA. Due to its high altitude location in Bolivia´s Cordillera Real, the Chacaltaya station is ideally located to provide information on the free tropical troposphere.

Figure 4: A view of Chacaltaya station

Climate in the region around Chacaltaya exhibits tropical characteristics. The rainfall annual cycle is monomodal, i.e. there is one rainy season that runs from December to March during which

moist and dry conditions alternate at intraseasonal scale. Moisture is brought to this region by easterly winds coming from the Amazon (Falvey and Garreaud, 2005) and exhibits a marked diurnal cycle. Convection peaks around local noon time due to the surface heating of the Andean plateau (the Altiplano). Even though mean temperature shows a small annual variability, the daily amplitude is usually large (about 20ºC).
The main features that affect climate in the region around Chacaltaya (especially precipitation) are: El Nino Southern Oscillation (ENSO), the South AtlanticConvergence Zone (SACZ), Sea Surface Temperatures (SSTs) from the Pacific Ocean, the South American Low Level Jet (SALLJ), the Pacific High (PH) and the Bolivian High. Vuille et al. (2007) and Aceituno (1988) showed that typically during ENSO events precipitation is reduced over the Altiplano whereas during La Nina precipitation is typically enhanced over the region. Nogués-Paegle and Mo (1997) found that when SACZ intensifies, the Altiplano has a deficit in precipitation. On the other hand, when the SACZ weakens, precipitation increases abundantly. The Pacific SSTs plays a major role during ENSO events. Due to the positive anomalies of temperatures along the Southern Pacific´s Humboldt Current the Pacific High intensifies and migrates eastward inhibiting convection over the Altiplano. The SALLJ exhibits an annual cycle peaking during austral summer. The SALLJ is the major moisture transport mechanism in South America. Despite its low altitude (around 850 hPa), it enhances the moisture availability for convection on the Altiplano (Nogués-Paegle and Mo, 1997). The location of the proposed station is thus of considerable interest because it can be used to monitor the behaviour of several continental features

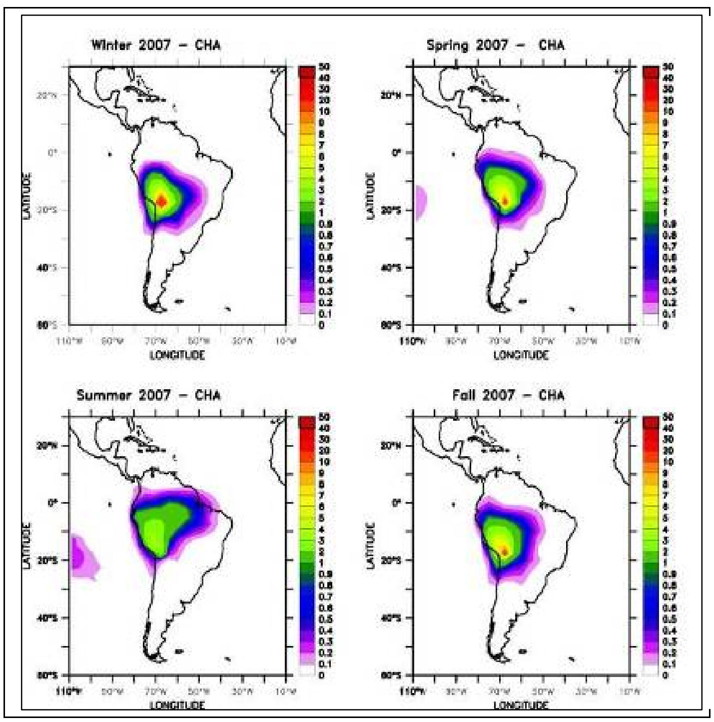

Figure 5: Air mass origin density plot

3. Description of the projected GAW station

3.1. Recommended GAW measurements

The recent development of satellite-based sensors for long- and short-lived atmospheric species and water stable isotopes may satisfy the need for global coverage for the next decade. However, in mountainous regions like Chacaltaya, ground validation of satellite measurements will still be needed. In addition, a full understanding of atmospheric cycles will still require continuous observations to characterize the diurnal variation of sources and sinks. The instrumental requirements for regional/global GAW stations are defined by the GAW expert groups and concern a suite of measurements relevant to both Air Quality and Climate. The list is given in Table 1. A process-level understanding of the physico-chemical behaviour of atmospheric particles requires continuous observations with hourly to daily resolution, depending on the variables.

		Context			
	Property or Chemical Variable	**Air Quality**	**Oxidation Efficiency**	**Climate**	**Strat. Ozone Depletion**
	Water stable isotopes (Vapor and Precip.)			■	
*	**O3 (ozone)**	■	■	■	■
*	**CO (carbon monoxide)**	■	■		
*	*j*(NO_2)	■	■		
*	***j*(O^1D)**	■	■		
*	H_2O (water vapor)	■	■	■	■
	HCHO (formaldehyde)	■	■		
*	**VOCs (volatile organic compounds)**	■	■		
	Active nitrogen: $NO_x = NO+NO_2$	■	■		■
	Reservoir species: HNO_3	■	■	■	■
	N_2O			■	
	SO_2	■		■	
	Active halogens: BrO, ClO, OClO				■
	Reservoir species: HCl, $ClONO_2$				■
	Sources: CH_3Br, CFC-12, HCFC-22, halons			■	■
*	**CO_2**			■	
	CH_4		■	■	■
	Multiwavelength optical depth	■		■	
*	**Mass in two size fractions**	■		■	
*	**Major chemical components in two size fractions**	■		■	
*	**Light absorption coefficient**			■	
*	**Light scattering coefficient at various wavelengths**			■	
	Hemispheric backscattering coefficient at various wavelengths			■	
	Aerosol number concentration	■		■	
*	**Cloud condensation nuclei at 0.5% supersaturation**			■	
*	**Aerosol size distribution**	■		■	
	Detailed size fractionated chemical composition	■		■	

	Dependence on relative humidity		■
	CCN spectra (various supersaturations)		■
*	**Vertical distribution of aerosol properties**	■	■

Table 1. List of comprehensive aerosol and gas measurements with a subset of core variables (printed in bold) recommended by the GAW Scientific Advisory Groups. The last column indicates the measurements to be deployed at Chacaltaya in the framework of the present project. Asterisks in the first column indicate the measurement the consortium is planning to perform at the site.

An international team from four different countries (Bolivia, France, Italy, and Switzerland) is now ready, under the umbrella of the Global Atmosphere Watch program, to implement the world´s highest atmospheric monitoring station for aerosol, reactive and greenhouse gases. This consortium, led by the Atmospheric Physics Laboratory of the University of San Andres will provide the expertise and the instruments to be implemented, during the course of the next 2 years (2010-2012).

3.2. Measurements to be deployed at Chacaltaya

The Chacaltaya Climate Observatory project will be launched with the installation of a weather station at the summit of Chacaltaya. This activity falls under the Bolivian component of a regional program on climate change called "Adaptación al Impacto de Retroceso Acelerado de Glaciares en los Andes Tropicales" (Adaptation to the Impact of the Accelerated Retreat of Tropical Andean Glaciers), partly funded by the World Bank. The installation will take place in 2010 and the new station will be located on a high site open to both Amazonian and the Altiplano sights.

The configuration of the station is based on the glacier monitoring program GLACIOCLIM (http://www-lgge.ujf-grenoble.fr/ServiceObs/), funded by IRD and CNRS in France and the SHARE (http://www.evk2cnr.org/cms/en/research/integrated_programs/share) project funded by Ev-K2-CNR. The weather station is equipped with sensors for temperature, humidity, atmospheric pressure, wind direction and intensity, large and short wavelength radiation, incident as well as reflected, and measurement of snow depth. This station will be jointly managed by the Institute of Hydrology and Hydraulic (IHH), LFA-UMSA, the National Weather Service (SENAMHI), IRD, Ev-K2-CNR and ISAC.

In a second phase, the station will be implemented with basic instrumentation for the in-situ determination of atmospheric composition. In that sense, instrumentation already available at La Paz will be complemented with instruments mainly devoted to 3D characterization (**PI LFA-UMSA**). This phase will include:

- Installation of aerosol High Volume PM10 samplers (Month 12) for night/day investigation of aerosol chemical composition. Filters will be weighted and subsequently analyzed for major ions, organic and elemental carbon and in-depth speciation of carbon for tracer identification (levoglucosan and 14C). **PI. LGGE/PSI**

- Installation of aerosol physical and optical properties including Scanning Mobility Particle sizers (Custom-made SMPS), nephelometer (ECOTECH 1 l type) and aethalometer or MAAP (Month 16). The information retrieved from the measurement of size, absorption and scattering coefficient provides the basic information for deriving the aerosol radiative impact in terms of W m-2. **PI. LGGE/IRD/PSI**

- Installation of a pluviometer and a laser technology (Month 12). **PI. LSCE** Water stables isotopes in Andean meteoric water are known to be a tracer of climate conditions (convective regime) affecting air masses along their trajectories from an oceanic source (the tropical Atlantic Ocean) to the Andes. For 1999, a network of pluviometers has been collecting precipitation both at a monthly and an event-based timescale in Bolivia, especially in the Zongo Valley at about 40 km from La Paz (30 km from the Chacaltaya site) which links the Amazon basin to the Altiplano. These measurements enable us to better understand the climate controls on water stable isotopes (and so this leads to a better interpretation of all climate archives preserving this proxy as ice cores or speleothems). It also enables us to improve our knowledge of precipitation regime and convective processes in this region. This latter point is of primary importance regarding future climate simulations in tropical regions because significant scattering still exists between coupled ocean-atmosphere climate models in terms of reproducing the precipitation regime at the correct site (not in magnitude of precipitation). Up until now, we have only been able to measure the isotopic composition of water in precipitation given the difficulty of isotopic measurements in water vapor. Important assumptions have been made regarding isotopic fractionation processes and our knowledge of water stable isotopes atmospheric cycles. New laser technology will enable us to obtain a unique set of water vapor isotopic composition and will greatly improve our representation of isotopic fractionation. At a larger scale, the understanding of tropical convection, not only in tropical South America but globally should be enhanced using this new methodology. It should bring new information about the parametrization of convection in climate models and thus should reduce uncertainties associated to cloud cover parametrization.

  We thus plan to set up:
  - several pluviometers to collect precipitation from intra-event to interannual timescales and to monitor the isotopic composition
  - a laser technology instrument to monitor water vapor isotopic composition with a time resolution that could vary from 1 minute to 1 day.
  - Installation of Aerodynamic Particle Sizer – APS (or Optical Particle Counters – OPC) for the determination of aerosol size distributions (Month 12). Even if the Chacaltaya region does not appear among the locations more systematically influenced by transport of mineral dust from main desert areas or Oceans (as suggested by Figure 5), the installation of an APS (or OPC) can easily provide useful information for the determination of the transport processes affecting the coarse mode of atmospheric aerosol due to regional and extra-regional crustal dust, in particular during dry season. **PI ISAC/EvK2CNR**
  - Installation of reactive gas analyzers (Month 12)**.** As being located in front to the Amazon basin (one of the most active world biomass burning area) and not far from an important urban areas (La Paz), it is mandatory to well evaluate at Chacaltaya the levels and the behaviour of atmospheric reactive gases, also with the aim to obtain long-term information about their trend and inter-annual and seasonal variability. In particular, in troposphere, O3 represents a major greenhouse gas and it contributes to determine the oxidation capacity of the troposphere. For this reason, a UV-absorption analyser (Tei 49C) will be installed at this station. This activity can also allow top better investigate the possible role played by air-mass transport processes in determining the low total column O_3

values observed over Andes. With the purpose of better characterize the processes affecting tropospheric composition at Chacaltaya, a CO analyser will be installed (Picarro or modified Thermo Electron 48CTL). In fact, as being an efficient tracer for anthropogenic pollution and biomass burning activity, CO contributes in influencing the abundance of the OH radical and initiates several important chemical reactions involving climate altering compounds and chemically active gases. Finally, also the installation of a NO_x analyzer (Thermo Electron 42iTLi) is foreseen to investigate the "O_3" regimes which characterize the measurement site as well as to correctly tag the air-mass origins. Moreover, with the purpose of tracing possible polluted air-mass transport, the installation of similar in the La Paz sub-urban area is suggested **PI ISAC/EVK2CNR**

- Installation of greenhouse gas analysers (Month 16): our plan is to install a new WS-CRDS based Analyzer for CO2 and H2O which provides the ppb sensitivity, precision and accuracy required by long-term measurement and trend detection. The analyzer is well suited for operation at remote, unattended monitoring stations **PI LSCE/ISAC**

Other activities include:

- Installation of Cloud Condensation Nuclei (CCN) measurements (Month 16). CCN concentration data are important for the validation of derived global aerosol climatologies, which form the basis for the derivation of the indirect climate effects of aerosol using global and other climate models. Past CCN measurements in the GAW programme have been made predominantly using static thermal-gradient chambers, which are well-suited to relatively low frequency sampling and low-resolution CCN spectrum determination. Instruments using continuous flow offer another approach, but have yet to be implemented in GAW for more than "process studies". The recommended standard operation is for continuous measurements at a fixed super saturation of 0.5%. The sampling frequency should be sufficient to allow derivation of hourly statistics. CCN super saturation spectra at super saturations between 0.1 and 1% should be determined. Taking into account all these recommendations, we propose to develop a purpose-built CCN counter dedicated to the monitoring of CCN in difficult environment. Calibration of counting efficiency and measures of supersaturation such as critical diameter will be carried out on a regular basis. Protocols at GAW stations that have experience in making long-term CCN measurements (e.g. Cape Grim, Australia; Mace Head, Ireland) will be adopted. **PI. CNRM**
- **Installation of radiometer for the determination of $J(O^1D)$ and $J(NO_2)$ behaviours.** As being located at an altitude above 5000 m asl, the measurement site should be characterised by high rate of solar radiation fluxes. Moreover, several studies indicated the presence of an "ozone valley" in the total ozone above Andes. Thus, in combination with O_3, CO and NOx measurements, $J(O^1D)$ and $J(NO_2)$ quantification can help in investigating the role of in-situ photochemistry in determining O_3 levels in this remote area **PI: ISAC-CNR/CNRS-LGGE**

4. Description of the consortium and main researchers involved

The project calls for the expertise of several research teams in Bolivia and Europe to develop suitable observational capacity and ensure long-term sustainability of the initiative. The joint international team is composed of 7 partners.

- **University Mayor de San Andres, La Paz, Bolivia**

University Mayor de San Andres will be the project coordinator. The Atmospheric Physics Laboratory (LFA-UMSA) was founded in 1995 as part of the Department of Physics and the Physics Research Institute at Universidad Mayor de San Andrés, La Paz, Bolivia. At the beginning LFA-UMSA worked measuring stratospheric ozone and ultraviolet radiation in close collaboration with the Brazilian National Institute for Space Research (INPE). Currently LFA-UMSA is a WHO Collaborating Center in UV radiation due to its experience in research and public campaigns on the subject. In the recent years the LFA-UMSA has put the climate change as an important issue. The LFA-UMSA is leading a joint effort of several research institutes in this subject. At present LFA-UMSA's research focuses both in climate modelling and atmospheric measurements at high altitude locations.

The main researchers at LFA-UMSA are:

Dr. Francesco Zaratti is founder and director of the LFA-UMSA. He is in charge of the Ozone and UV radiation group at LFA-UMSA and is author and co-author of several papers in this field.

Dr. Marcos Andrade, earned a PhD in Meteorology at the University of Maryland and is now in charge of the Climate Change group at LFA-UMSA. He is also involved in the AERONET Network in Bolivia.

Luis Blacutt, MSc in Meteorology at the University of Utah, is in charge of the Climate Modelling group at LFA-UMSA and has experience collaborating in UV and ozone research

Ricardo Forno, MSc has a wide experience in experimental optics and is now in charge of the new YAG Lidar at LFA-UMSA, in collaboration with GSFC-NASA and Howard University.

- **Centre National de la Recherche Scientifique (CNRS) Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE) in Grenoble, France and Institut de Recherche et Développement (IRD)**

The Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE), Grenoble, France is one of the leading laboratories dealing with the use of polar ice cores for environmental studies (past concentrations of gases and aerosols, climate records) and the vulnerability of high altitude regions. Over the last decade, the LGGE has been a leading partner in European atmospheric programmes dedicated to aerosol in Europe (CARBOSOL, MEGAPOLI).

The 'Institut de Recherche pour le Développement' (IRD) is a French scientific institute under the joint authority of the French Ministry of Higher Education and Research and of the Ministry of Foreign and European Affairs. The IRD has three main activity areas: research, consultancy and training. It conducts scientific programs contributing to the sustainable development of Southern hemisphere countries with an emphasis on the relationship between man and the environment.

IRD scientists in Grenoble are involved in the study of Andean glaciers in order to evaluate the water flows coming from the cryosphere (snow and ice), to characterize the climatic variability during the last 500 years and to simulate its impacts in the near future. IRD is responsible in the Andes for the observatory 'GlacioClim'. It combines instrumental measurements for the recent periods influenced by the global change (climatic and anthropogenic) and indirect indicators (historical documents and environmental proxies) for past periods. The main role of IRD/CNRS/LGGE in this project is to deal with aerosol measurements (chemical, physical and optical properties) at the station and derive primary information such as the levels of absorbing material in air. In addition LGGE will be involved in the identification of sources and the estimation of radioactive impacts of anthropogenic aerosols in the mountain regions. In addition, IRD/LGGE/CNRS

Dr. Patrick Ginot is a research engineer since 2003, and has been assigned to IRD glaciological programs in Bolivia since 2006. He has published 15 research articles in the field of ice coring techniques, ice cores and post-deposition studies. He has participated in ANR, ACI and ECLIPSE projects. Patrick is in charge of the IRD ice core program, and related chemical major ions analyzes. He is also involved in the the development of scientific relations between Andean partners and French institutions working within these topics.

Dr. Paolo Laj has published more than 50 research articles in the field of aerosols, clouds and their interaction. He has participated in 8 EU projects within FP4, FP5 and FP6 and produced more than 6 M€ in research income. He leads the aerosol group at CNRS-LaMP and is responsible for the French national aerosol programme. He is a member of the steering committee of the national programme for atmospheric research and of the national agency committee for environment and health. He is also the scientific coordinator of the EUSAAR I3 project and coordinator of the action access to infrastructures within the NoE ACCENT. Paolo Laj is involved in the MEGAPOLI project and he is in charge of a Workpackage on the transport and transformation of aerosols within the EUCAARI (EU-FP6) integrated program. He is a member of WMO expert group on aerosols.

- **Centre National de la Recherche Scientifique (CNRS), Laboratoire des Sciences du Climat et de l'Environnement (LSCE) in Gif/Yvette, France**

LSCE

Dr. Françoise Vimeux, is in charge of research at the Institut de Recherche pour le Développement (IRD). Since 2001 she has worked on past climate variability in South America using water stable isotopes in ice cores. Francoise combines observations and climate modelisation to refine the interpretation of water stables isotopes in Andean ice cores as tracers of past climate conditions. She has led an important project (grouping 15 laboratories) at INSU dealing with recent climate variations in South America and is now leading a project at ANR on Patagonia´s past climate variability through the analysis of a unique deep ice core drilled in 2007.

- **Météo-France, Centre National de la Recherche Scientifique (CNRM) in Toulouse, France**

Centre National de la Recherche Scientifique (CNRM) has a long trajectory and experience in measurements of aerosol physic-chemical properties. The study program of the Meteo-France team, involved in this project, is mainly focussed on hygroscopic properties of aerosol particles, particularly aerosols of anthropic origin, their capacity to form CCN, then cloud droplets, the growth of droplets in cloud or fog and the formation of precipitation. CNRM contributes to studies of the impact of aerosols on cloud radiative properties and the efficiency of precipitations, which lead to a better understanding of the indirect effect of aerosols on climate. Consequently, the activities of the team are triple: instrumental development, measurement campaigns, and the development of aerosol code for modelling. **Dr. Laurent Gomes** is experienced with CCN counters and aerosol/cloud interactions. He will be leading the CNRM team.

- **Consiglio Nazionale delle Ricerche, Istituto per lo Studio dell'Atmosfera e del Clima (ISAC-CNR) Bologna, Italy**

The Institute of Atmospheric Sciences and Climate - ISAC employs over 200 staff members, postdoctoral researchers, and students to conduct pure and applied research on atmospheric sciences and the climate system. The Institute is organized into four divisions: Dynamic Meteorology, Climate Change, Observations, Atmospheric Processes and a technical service structure: Field Facilities and Instrumentation. The ISAC mission is to improve our knowledge of the atmospheric and climate processes of the planet Earth and at the same time to produce results directly transferable to the society also beyond the national borders. Numerical modelling, laboratory and field experiments, remote sensing and development of novel instrumentation are the natural means to fulfil the institutional commitments.
The ISAC group involved in this project has great experience in high mountain observations devoted to climate change studies and atmospheric composition monitoring. This activity is particularly developed at the "O. Vittori" GAW Mt. Cimone station (Italian Apennines), and at the Nepal Climate Observatory – Pyramid in Himalaya (Nepal), where in the framework of SHARE-EvK2CNR and ABC-UNEP projects a monitoring station at 5079 m a.s.l. has been developed and realized together with CNRS- LGGE.
In this project ISAC-CNR promote the research activities concerning ozone and other climatic trace gas measurements, aerosol size distribution (> 0.3 micron) and in the station - shelter design and setup.

Dr. Paolo Bonasoni is in charge of the GAW CNR Station "O. Vittori" at Mt. Cimone, and GAW Ev-K2-CNR Nepal Climate Observatory - Pyramid in Himalaya, also involved in ABC-UNEP and SHARE/Ev-K2-CNR and EUSAAR- EC projects. PI in several national and international projects mainly concerning the study of tropospheric ozone and atmospheric background composition in remote areas, he was also involved in Antarctic atmospheric researches. He is author of more than 50 peer-reviewed papers, most of which concerns the study of the tropospheric ozone and atmospheric composition in high mountain areas.

Dr. Paolo Cristofanelli, PhD in environmental sciences, is researcher at the ISAC – CNR. He is in charge for surface ozone and meteorological observations at the GAW high-mountain stations of Mt. Cimone and NCO-P and for surface ozone at the Dome-C Antarctic station. His main research activity is devoted to the investigation of atmospheric transport processes able to influence the tropospheric background composition in high altitude remote areas.

Dr. Angela Marinoni, Environmental Sciences Degree and PhD has a long and wide experience in atmospheric sciences, sweeping from snow, cloud and aerosol chemistry to aerosol physics and investigation of processes leading to atmospheric composition changes in remote mountain sites. She's in charge of aerosol measurements (chemical, optical and physical properties) at Monte Cimone and NCO-P Stations.

- **Paul-Scherrer Institute, laboratory for atmospheric processes (PSI) in Villigen, Switzerland**

The Laboratory of Atmospheric Chemistry at PSI consists of about 35 researchers. It has in-depth experience with the design of experiments to characterize physical and chemical properties of aerosols and has a strong interest in the impact of aerosols on climate. The laboratory operates an aerosol program at the high Alpine research station Jungfraujoch (3580 m asl) within the Global Atmosphere watch programme and has published more than 30 peer-reviewed papers on aerosol research at the Jungfraujoch. In the project, PSI will be mainly involved with the measurements of aerosol optical properties and their radiative impact.

Dr. Urs Baltensperger is the head of the Laboratory of Atmospheric Chemistry at PSI. His main interest is in the formation and transformation of aerosols as well as the study of their impact. He is the Chairman of the Scientific Advisory Group for Aerosols of the Global Atmosphere Watch (GAW) program of WMO. He also is president of the Commission for Atmospheric Chemistry and Physics of the Swiss Academy of Natural Sciences. He is author and co-author of about 120 peer-reviewed papers. He is coordinator of the EC project POLYSOA.

- **Ev-K2-CNR Committee in Bergamo, Italy.**

The Ev-K2-CNR Committee is an autonomous, non-profit association, which promotes scientific and technological research in mountain areas. Particular emphasis is placed on the Hindu Kush – Karakorum – Himalaya region and on work in the countries of Nepal, Pakistan, China (Tibetan Autonomous Region) but the activity has recently expanded in Europe (Italian Alps and Apennines) other then in Africa (Mt. Ruwenzori-Uganda)). Ev-K2-CNR is probably best known for the Pyramid International Laboratory-Observatory, the high altitude scientific facility located in Nepal's Sagarmatha National Park at 5,050 m a.s.l., at the base of Mt. Everest, installed in 1990 in collaboration with the Nepal Academy of Science and Technology

(NAST) and more recently by Nepal Climate Observatory – Pyramid (5,079 m a.s.l.), the highest monitoring station of ABC – UNEP network. Ev-K2-CNR research has traditionally focused on the fields of Earth Sciences, Environmental Sciences, Medicine and Physiology, Anthropology, and development of new technologies. Today, Ev-K2-CNR's work is mainly organized via broad-scale integrated multi-disciplinary programs aimed at helping resolve urgent environmental and development issues.
Within the project, Ev-K2-CNR will act as an umbrella organization to support technological implementation, management, providing needed assistance for the operational functioning of Chacaltaya station.

Agostino da Polenza is the President of Ev-K2-CNR Committee. Mountain climber, he leads the Italian and international Ev-K2-CNR activities in cooperation with the Italian National Research Council, also in the framework of several UNEP projects.

Dr. Elisa Vuillermoz is Executive Coordinator of Ev-K2-CNR SHARE project. She has participated to several field campaign in Himalaya and Karakorum, starting from 2004 K2 Italian scientific expedition and more recently in the framework of SHARE Project. She is responsible for AWSs meteorological data validation within WCRP/GEWEX/CEOP Project.

Other partners from Germany (A. Wiedensohler – IFT-Leipzig) and Sweden (Radek Krejci, U. Stockholm) have expressed interest in participating in the project.

5. Capacity Building

A major objective of the project is to consolidate current observation efforts, ensure their continuation and promote the research activity proposed within the present project. This will be done very efficiently through the involvement of experienced university personnel from the University Mayor de San Andres. In addition, the participation of field personnel involved in the operation of GAW and EUSAAR specialized training courses and workshops will be ensured. Finally, in order to develop cooperation between Bolivian and European partners bilateral agreement supported by government institutions will be possible.

6. Data bases

Results of atmospheric measurements performed at the Chacaltaya Station will be periodically transferred to the GAW-WMO and AERONET databases. These data-bases include meteorological parameters (air temperature, atmospheric pressure, relative humidity, wind speed and direction, aerosol scattering and diffusion coefficients, aerosol number concentration and size distribution, aerosol optical depth (CIMEL-AERONET), surface ozone and CO concentrations, chemical composition of PM10, number of Cloud Condensation nuclei at a given supersaturation, and solar irradiance (200 - 3600 nm). Data will be provided on an annual basis to specific data centers after QA/QC process and formatting, and will be made available to the entire scientific community.

7. Provisional Agenda

Timing of activities within the project	Month	year 1 (2009)				year 2 (2010)				year 3 (2011)				year 4 (2012)				year 5 (2013)			
		I	II	III	III	IV	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
WP1	**Institutional preparation**																				
	1.1. Endorsement of the project by WMO and																				
	1.2. Finalization of the project with Bolivian partners																				
	1.3. Application to international funding agencies																				
	1.4. Application for national funding in France / Italy and Switzerland																				
	1.5 Visits to Chacaltaya																				
WP2.	**Installation of scientific instruments**																				
	2.1. Shelter design and preparation (power, battery back-up, remote control and NRT data transmission included)																				
	2.2. preparation and Installation of High Vol. sampler																				
	2.3. Development of aerosol spectrometers and Aerosol column instruments																				
	2.3 Installation of a specific pluviometer for isotopic composition of precipitation																				
	2.4. Acquisition / preparation of GHG and O3 instrumentation																				
	2.4. Acquisition / preparation of atmospheric isotope sampling																				
	2.4. Acquisition / preparation of CO instrumentation																				
	2.5 Acquisition / preparation of aerosol optical instruments																				
	2.6 Acquisition/validation of a laser system for water vapor isotopic measurement																				
WP3	**Measurements**																				
	3.1. Installation of weather station and measurements																				
	3.2. Aerosol chemistry sampling and analysis and Ozone measurements																				
	3.3. GHG installation and measurements																				
	3.4. Aerosol spectrometer and optical properties installation and measurements																				
	3.5. Aerosol column installation and measurements (LIDAR, AOD)																				
	3.6 Isotopic composition of precipitation																				
	3.7. Isotopic composition of water vapor																				
	3.8. Data transmission/ data storage/Shelter control																				
	3.9. Delivery to WDC data bases																				
WP4	**Data analysis**																				
	4.1. Analysis of atmospheric variability																				
	4.2. Chemical transport modelling																				
	4.3. Inverse modelling and identification of sources																				
	4.4. Evaluation of future changes and vulnerability studies .																				
	4.5: Links to past atmospheric variability seen from ice core records.																				
	4.6 Isotopic modelling with atmospheric model																				
WP5	**Project Management**																				
	5.1. Post-doctoral fellow and PhD student hired																				
	5.2. Training sessions within GAW																				
	5.3. Publication of first results																				
	5.3. Definition of station operation beyond the project																				
	5.4. Application to GAW global station																				

8. Financial issues / Personnel involved

The overall cost of the infrastructure will be approximately 200k€ (including all scientific equipment described above). In addition, the operational costs of the infrastructure will be approximately 30 k€/year, including chemical analysis. The project will require the expertise of the researchers involved representing approximately 12 persons-month/year. The plan is to hire a post-doctoral fellow for a 2-year period (possibly extended) from month 12 to month 36 of the project to supervise the installation of the station and analyse the first set of measurements. In addition, one or two PhD students shared by several groups in the consortium and funded under bilateral programs could be involved from month 16^{th} of the project with the task of specific data set analysis. To ensure the sustainability of the project activities opportunities will be given to both post-doctorates and students from South America.

Funding opportunities will be sought at both national and international levels. The World Bank has generously contributed to the acquisition of weather monitoring stations however it is hoped that once the project is endorsed by the international community through WMO other funding agencies will contribute to the project. In France, the project will be presented to the National Agency for Research in October 2009. Following the invited talk of Prof. Zaratti during the SHARE workshop held in Milan (May 2009) the Italian support at this Project is foreseen in the framework of the SHARE Project.

9. Potential impacts

Facing the consequences of global climate changes will require implementing sustainable adaptation strategies derived from the sound scientific assessment of trends in atmospheric composition. In this respect, an atmospheric monitoring station at Chacaltaya will help filling in the existing gap in South America. In addition, links with glaciological studies will contribute to the study of the water resources and vulnerability of the mountain areas. There is, in fact, a general consensus that high mountain environments are extremely vulnerable to global changes and that without action plans and risk assessments, the likelihood of deteriorating water availability, quality and use efficiency is high. A scientifically-sound assessment of the causes and consequences of changes in the water availability in the Andes is of fundamental importance for orienting the environmental and economical development of the nations of these regions. Understanding past climate changes and their links to current observations will be extremely valuable. In 1999, a deep ice core was extracted from the summit glacier of Illimani (6432m) located 50km South–East of Chacaltaya, along the Andean ridge. This record is covering at least the 20th century with a seasonal resolution and is updated with a shallow core extracted in 2009. Another shallow core (about 10 years) is available from the Huayna Potosi glacier located 10km North-West. From these ice cores, major ions, dust concentration and distribution, traces elements and stables isotopes profiles were reconstructed at high resolution. The interpretation of ice core recorded as an environmental archive was highly demonstrated for polar and alpine sites, but not really explored along such a bimodal Andean site, influenced by the wet Amazon basin and dry Altiplano. In order to validate the ice core record in terms of aerosol deposition reconstruction, taking in account the dust scavenging and post-deposition perturbation, a comparison with direct aerosol studies is be crucial. New ice core updates are also possible after a few years' aerosol records to consolidate the calibration.