# Implementation planning template of the High Elevation project in CEOP II

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**1. Title: High-Elevation**
Acronym: HE
Starting date: March 2007
Expected end date: December 2010
e-mail: ceop-he@evk2cnr.org
URL: http://www.ceop-he.org *(available soon)*

**Chairs and term dates**
**Dr. Gianni Tartari**, begin in March 2007

**Representative(s) to CEOP:**
- Raffaele Salerno, Epson Meteo Center, Milan, Italy
- Alessandro Perotto, Epson Meteo Center, Milan, Italy
- Laura Bertolani, Epson Meteo Center, Milan, Italy
- Andrea Lami, Ev-K²-CNR Committee, Bergamo & National Research Council-Institute for Ecosystems Study, Verbania-Pallanza, Italy
- Paolo Bonasoni, National Research Council-Institute of Atmospheric Sciences and Climate, Bologna, Italy
- Elisa Vuillermoz, Ev-K²-CNR Committee, Bergamo, Italy
- Kenichi Ueno, Tsukuba University, Japan
- Toshio Koike, University of Tokyo, Japan
- Yaoming Ma, Institute of the Tibetan Plateau Research, Chinese Academy of Sciences, Bejing, China)
- Sam Benedict, CEOP International Coordinator, USA

*TBD: Additional members, manager of high altitude monitoring sites and modelling centres from Europe, Africa, Asia, North and South America*

**2. Overall objectives and scientific agenda and background (page)**

**Goal of CEOP High Elevation (CEOP-HE)**
CEOP-HE is a new working group of CEOP II "project of projects". It will be a concerted, international and interdisciplinary effort to further the knowledge of the physical and dynamical processes in high altitude areas.

The main purposes of this working group are to:
1. establish a coordinated activity between the high altitude climatic stations with aims at building a network within CEOP Phase II reference stations;

2. contribute to the understanding of water and energy cycles in high elevation regions and study their role within the climate system by means of globally integrated analysis of CEOP reference sites data, remote sensing observations and models analysis and application;
3. build synergies between meteorological-climate and hydrological studies in order to improve the management of water resources;
4. provide QA/QC protocols for high altitude sites installation and for data representativeness;
5. create an electronic archive of high altitude monitoring stations;
6. improve the forecast capabilities of extreme weather events in high altitudes that influence not only mountain regions but also a much wider environment and an elevated number of people, with important social consequences depending on the interaction between the three major components: environment, economics and society.

**Research agenda**

- study of climatic characteristic at high altitude;
- link climatic change with energy and water budget and study their effects on glacial areas, hydrological regime, etc;
- development of high resolution modeling of atmosphere physics and dynamics in complex topography;
- global and regional climate modeling;
- evaluate the influence of aerosol on the hydro-geological cycle and climate.

**Implementation strategy**

- collect information on data availability in existing high altitude sites;
- analysis of available CEOP reference sites' data in high elevation regions;
- initiating inter-comparison studies by analysing at the same time different climate areas, to better understand any interaction among global, continental-regional and meso-local scales. The starting point of this study will be the Himalayas area where data availability and quality and modelling infrastructures are established, and due to its importance for global dynamics and climate. ;
- development of physical/chemical models specifically for high altitude environments.

**Background**

Mountains represent unique areas for the detection of climate change and the assessment of climate related impacts (Barry, 1981) at a global level. One reason for this is that, as climate changes rapidly with height in relatively short horizontal distances, so does vegetation and hydrology (Whiteman, 2000). 25% of continental surfaces (Kapos *et al.*, 2000) and about 26% of the world's people resides within mountains or in the foothills of the mountains (Meybeck *et al.*, 2001). Moreover, 40% of global population lives in the watersheds of rivers originating in the planet's different mountain ranges.
The geography controls mountain climates by four major factors (Barry, 1994): continentality, latitude, altitude and topography. As reported in Beniston (2003; 2006):

- <u>Continentality</u> refers to the proximity of a particular region to an ocean. Due to the large thermal capacity of the sea, the diurnal and annual ranges of temperatures in a maritime climate are markedly less than in regions far from the oceans. There is also more precipitation in a maritime climate than in a continental one, provided the dominant wind direction is onshore. At the contrary the mountains in continental regions experience more sunshine, less precipitation, and a larger range of temperatures.

- Latitude determines a large extent the amplitude of the annual cycle of temperature and a lesser extent the amount of precipitation. Mountains tend to amplify some of the characteristics of tropical, mid-latitude and boreal climates for reasons related to topography.
- Altitude is the most distinguishing and fundamental characteristic of mountain climates, because atmospheric density, pressure and temperature decrease with height in the troposphere. Diurnal and annual range of temperature tends to decrease with altitude because of the lower heat capacity of the atmosphere at height. The altitudinal controls on mountain climates also exert a significant influence on the distribution of ecosystems. Mountain systems generate their own climates as a function of the size of the landmass at a particular elevation.
- Topography play key role in determining local climates, in particular due to the slope, aspect, and exposure of the surface to climatic elements. These factors tend to govern the redistribution of solar energy as it is intercepted at the surface. The complexity of environmental topography. determines a rapid and systematic changes in temperature and precipitation, over very short distances (Barry, 1981; Becker & Bugmann, 1997); greatly enhanced direct runoff and erosion; systematic variation of other climatic and environmental factors. In some mountainous regions, it has been showed that there is an elevation dependency on temperature and anomalies.

Mountains in many parts of the world are susceptible to the impacts of rapidly changing climate and provide interesting locations for the early detection and study of the signals of climatic change and impacts on hydrogeological, ecological and societal systems (Beniston, 2003). Environmental deterioration in mountains can be driven by numerous factors that include deforestation, over-grazing by livestock and cultivation of marginal soils. Mountain ecosystems are susceptible to soil erosion, landslides and the rapid loss of habitat and genetic diversity. In many developing countries, in part because of degradation of the natural environment, there is a widespread unemployment, poverty, poor health and bad sanitation (Price *et al.*, 2000).

Mountain meteorology has generated a wide variety of interest and research since the beginning of modern meteorology. A lot of effort has been put in trying to simulate weather phenomena in complex terrain. Only in the latest years numerical weather prediction models have been able to reach resolutions adequate to realistically resolve complex topography and represent the circulation in mountain areas. The evolution of data assimilation techniques in conjunction with the availability of high resolution data sets can produce forecasts with great accuracy.

A combination of accurate meteorological short or medium-range forecasting by means of numerical weather prediction models, combined with sensors (rain gauges, radars, satellites) real-time monitoring of precipitation and river state, and with hydrological forecasting models might provide useful information and assistance for peoples and the public authorities.

**3. Major results so far (bullets). Please include key publications when possible**

Data collection

- Comparison of long-time series of meteo-climatic records in different part of the world;
- climatic characterization in the Himalayan area (determination of monsoon onset and decay, study on TBO);
- starting of data collection in the Karakorum area (Pakistan) and Rwenzori (Africa);
- to favorite the increasing of the HE atmospheric wheater stations in critical areas.

Modeling activities

- For the Himalayan range: set up of RSM (Regional Spectral Model) at different resolutions (60 km, 40 km, 15 km);
- for the Andes: set up of hydrostatic and non-hydrostatic RSM and MSM (Mesoscale Spectral Model) at different resolutions (20km, 5 km) and with different physical and numerical characteristics;
- for the Alps:
  - set up of hydrostatic and non-hydrostatic MSM at different resolutions (20km, 16 km, 10 km, 5 km) and with different physical and numerical characteristics;
  - set up of MESONH (Mesoscale Non Hydrostatic model) at different resolutions (20 km,10km);
  - set up of WRF (Weather Research and Forecasting) model at different resolutions (32 km, 10 km, 8 km, 4 km);
  - data assimilation technique (3DVAR) tested for WRF;
  - nesting techniques tested for WRF;
- verification and intercomparison of NWP global models against CEOP I Himalaya reference site data;
- global climate model ensembles and sensitivity tests.

Key publications

Barker, D.M., W. Huang, Y. R. Guo, and Q. N. Xiao., 2004: A Three-Dimensional (3DVAR)Data Assimilation System For Use With MM5: Implementation and Initial Results. *Mon. Wea. Rev.*, 132, 897-914.

Barry, R.G. 1981. Mountain weather and climate. Metheuen, London and New York. 308 pp

Barry, R.G. 1994. Past and potential future changes in mountain environments: a review. In Beniston, M. (ed.), Mountain Environments in Changing Climates. Routledge Publishing Company, London and New York, 3–33.

Becker, A. & H. Bugmann (eds), 1997. Predicting Global Change Impacts on Mountain Hydrology and Ecology: Integrated Catchment Hydrology/Altitudinal Gradient Studies. International Geosphere–Biosphere Programme (IGBP) Report 43, Stockholm. 61 pp.

Beniston M. 2006. Mountain weather and climate: a general overview and focus on climatic changes in the Alps. Hydrobiologia., 562: 3-16.

Beniston, M. 2003. Climatic change in mountain regions: a review of possible impacts. Climatic Change, 59:5-13.

Bertolani, L., M. Bollasina & G. Tartari. 2000. Recent biennial variability of meteorological features in the Eastern Highland Himalayas. Geophysical Research Letters, 27: 2185-2188.

Bertolani, L., R. Salerno. In press. Verification of numerical model forecasts of precipitation and satellite-derived rainfall estimates over the Indian region: monsoon 2004. In. Baudo, G. Tartari, E. Vuillermoz (Eds.) Mountains: Witnesses of Global Changes – Research in the Himalaya and Karakoram. Deveolpment in earth surface processes, 10.

Bollasina, M., L. Bertolani & G. Tartari. 1999. Recent Interannual Variability of local Climate in Eastern Highland Himalayas. UCLA Tropical Meteorology Newsletter, No. 31.

Bollasina, M., L. Bertolani & G. Tartari. 2002. Meteorological observations at high altitude in the Khumbu Valley, Nepal Himalayas, 1994-1999. Bulletin of Glaciological Research, 19: 1-11.

Kapos, V., J. Rhind, M. Edwards, C. Ravilious & M. Price, 2000. Developing a map of the world’s mountain forests. In Price, M. F. & N. Butt (Eds), Forests in a Sustainable Mountain Environment. CAB International, Wallingford.

Meybeck, M., P. Green & C. Vo¨ ro¨ smarty, 2001. A new typology for mountains and other relief classes: an application to global continental water resources and population distribution. Mountain Research and Development 21: 34–45.

Price, M., T. Kohler and T. Wachs (Eds). 2000. Mountain of the world: mountain forests and sustainable development. CDE, University of Bern, Switzerland. 42 pp.

Salerno, R., M. Giuliacci, L. Bertolani. In press. Climate change in Italy: an assessment of data and reanalysis models. In. Baudo, G. Tartari, E. Vuillermoz (Eds.) Mountains: Witnesses of Global Changes – Research in the Himalaya and Karakoram. Deveolpment in earth surface processes, 10.

Tartari, G., G.P. Verza & L. Bertolani. 1998. Meteorological data at the Pyramid Observatory Laboratory (Khumbu Valley, Sagarmatha National Park, Nepal). In: Lami, A. & G. Giussani (Eds). Limnology of high Altitude lakes in the Mt Everest regions (Himalaya, Nepal). Mem. Ist. Ital. Idrobiol., 57: 23-40.

Ueno, K, K. Toyotsu, L. Bertolani, G. Tartari. Submitted. Stepwise onset of monsoon weather observed in the Nepal Himalayas. J. Am. Met. Soc..

Vuillermoz, E., L. Bertolani, C. Smiraglia, G.P. Verza, G. Tartari, A. Marinoni & P. Bonasoni. In press. SHARE-Asia Automatic Weather Station Network: an integral component for climate research in the Karakorum – Himalayas region. Proceedings of the International Workshop on Energy and Water Cycle over the Tibetan Plateau, Chinese Academy of Sciences, Lhasa, Tibet, China, 3-12 September, 2006.

Whiteman, D., 2000. Mountain Meteorology. Oxford University Press, 355 pp.

## 4. Status in 2007

(Please include key meetings held, new results, etc.)

**Planning activities**

- Collection of information on high altitude monitoring sites;
- contacts with national and international institutions;
- staring to built a database of HE station in world;
- first Working Group High Elevation meeting indicatively at the end of 2007.

**Research activities**

- Definition of high elevation;
- individuation of high altitude mountain sites significant for the understanding of the climate system (e.g. monsoon and other circulation mechanisms, sensitivity to periodic changes like ENSO, NAO, TBO and other oscillations, sensitivity to global changes) and of some environmental issues (e.g. ecosystem fragility, pollution and hydrogeological risk exposure);
- QA/QC protocols for high altitude installations and for data representativeness;
- high resolution remote sensing data collection for upscaling and downscaling techniques related to HE areas;
- model set up and preliminary testing starting from the Himalayan range;
- comparison of the last 10-15 years temperature trend between different climate areas.

## 5. Plans for next 2-3 years

(more general plans)

- Analysis of CEOP Phase II data of high elevation reference sites.
- Development of coordinated enhanced observational study in high elevation sites by integrating all observation networks in these areas in addition to CEOP reference sites.
- High-resolution state of the art modelling in high elevation regions. Different resolutions will be used, downscaling from regional to local scale through nesting techniques. Simulations up to 4 km with output every hour will be performed. Particular attention will be given to precipitation and physical processes related to the water cycle. Different parameterizations and different data assimilation techniques will be tested. Experiments with coupled hydrological models in selected catchment, important for hydrological disease and population risk assessment will be performed.
- Comparison between model output and observational data collected.

## 6. Interactions with other Groups

(Desired and actual with other RHPs, models, crosscuts, DM, global projects, GEWEX groups, WCRP groups, etc.)

- Development of potential mechanisms to work with RHPs, particularly those projects where high altitudes regions are present.
- Development of potential mechanisms to work with cross-cutting working groups and other regional foci.
- Collaboration with aerosol groups in the study of natural and anthropic aerosol impacts on climate and the hydro-geological cycle.

## 7. Planned and potential contributions to the GEWEX roadmap

(include accomplished contributions (2007) as well as future contributions)

- High altitude observatories operate with mainly commercial available instrumentation, generally not dedicated to extreme condition at low pressure (air density) and temperature. These extreme characteristics could affects data quality. (GEWEX obj. #1);
- Due to inhomogeneous landscape in the high altitude areas, the morphology of mountain ranges could deeply influence data representativeness. This aspect should be considered in the collection of CEOP high altitude reference stations data.(GEWEX obj. #1);
- Importance of the connection between high altitude reference stations and regional monsoons (Africa, South America, North America, Asian/Australian) (GEWEX obj. #1);
- Since there are few monitoring sites in high-altitude areas and data quality and density is generally quite poor, an high-quality observational database, with instruments suitable in high-altitude environment, will be implemented (GEWEX obj. #1).
- A limited ability to simulate orographic circulation and its interaction with larger-scale flow will produce a failure in the forecast on mountain regions. An increase of knowledge in high resolution simulations of weather events in mountain areas may also give a benefit to climate studies and regional climate prediction (GEWEX obj. #2, 3);
- In high altitude remote areas (Himalayas, Karakorum, Andes, etc.) the monitoring strategies requires high technological approach and a good experience to guarantee continuous measurements with low percentage of data lost (GEWEX obj. #4);
- High altitudes are often located in developing countries where the carrying out of capacity buildings activities is very important for local populations (GEWEX obj. #4);
- At high altitude extreme conditions, the carrying out of interdisciplinary scientific programs is very important: high altitude observatories can provide fundamental contributions to understand upper troposphere behaviour in relation to global changes (GEWEX obj. #4);

- High altitude reference stations can play an important role in the management of local environment: early warning information; contribution to long time forecast, etc. (GEWEX obj. #4);
- Demonstrate the benefits of hydrometeorological predictions in water resources management (GEWEX obj. #4).

**8. Planned interactions with other research, application and user communities**
(Include planned meetings, sponsored special sessions at national and international meetings)

Undertake joint activities with other operational projects in high altitude sites like:
GAW (Global Atmosphere Watch),
ABC (Atmospheric Brown Clouds),
Map (Mesoscale Alpine Project).