Shrinkage of the central Mediterranean cryosphere in a changing mountain environment
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The summit area of the Apennines is quickly changing and the mid latitude cryosphere is contemporarily shrinking and degrading due to global warming. In such an environmental framework suffering of the sole glacier in the Apennine belt, the Calderone glacier, and general reduction of the cryosphere is widely inducing permafrost degradation; variation in time and spatial distribution of snow cover; instability involving both ice/snow and rock/debris; changes in the rhythms of precipitation and of melting, as well as of runoff; concentration/dilution/distribution of chemical pollutant compounds.

Moreover, environmental changes seem to promote direct transition from the native and genuine glacial (periglacial to paraglacial) processes on a relatively reduced spatial and temporal scale.

This is a synthetic state of the art study and research is presented that takes into account three different cryospheric components in the Gran Sasso d'Italia massif.

Snow and snow cover
Snow cover assumes a central role in the assessment of the climate change effects on mid latitude mountain regions. Different amounts of precipitation and time dependant distribution produce effects both on tourist economic activities (namely ski resorts) and risks (snow avalanche risks and emerging snow cover risks). Until a few years ago, the risk due to snow was limited to mountainous areas and to the capability of eventual avalanches. Since the new millennium, emerging and new snow risks are directly linked to climate change. These consist of the huge amounts of low altitude snow precipitation and coverage, as well as related effects of intensity and spatial or time-dependant concentrations on vehicles circulation, mobility and lifelines (energy supply and distribution, telecommunications, water supply and its distribution).

It is important to highlight that the entire Italian peninsula was once familiar - at least from 1921 to 1960 - to constant and prolonged snow coverage, with the exception of the Tyrrhenian, Ionic and insular shores. This snow abundance also promoted development of new and vast ski resorts, which always brought on more increasing problems of mitigation for avalanche risks in the valleys as well on summits.

With global warming and different patterns of snow precipitation (concentration in premature or delayed periods of the winter season), the geography of well snow-covered ski resorts is quickly changing. Moreover, based on the International Panel on Climate Change (IPCC) scenarios, snow limits will move to higher altitudes for periods and permanence times will be shorter than now.

In the future in particular, we could face several factors such as an increase of the average air temperature between 1.5°C and 3°C; a rise of snow limit up to 500 m in altitude both in the Apennines and in Mediterranean massifs; a decline, during the spring season, of snow precipitation also in high altitude (up to 2500 m); an absence of snow precipitation beyond the winter season in the Apennines; a reduction of snow coverage up to 80 percent at an altitude of 1500 m in the Apennines.

Consequently, the mountains of the Mediterranean will begin to face substantially different winter seasons, having different patterns of snow-melted waters from springs and torrent water discharges. This will mean different territorial usage and different human presence in high altitudes. Finally, snow and even ice coverage have been caused by concentration and cold condensation (trapping) processes of inorganic, organic and radioactive pollutants.

During the winter season of 2005 – 2006, in several sample sites of the Italian territory a research program was promoted with focus on quick in situ control of chemical features for snow cover, in terms of pH, electrical conductivity and radioactivity. Activities were carried out within routine surveys of snow pack profile for avalanche risk mitigation. The quick surveys (Fig. 1) were performed by three initial operative units IMONT in Gran Sasso d'Italia, CVA-ARPA Veneto in the Dolomiti Bellunesi and Centro Nivometeo di Bormio at 3000 m, followed by two more carried out by MeteoSvizzera for the Basodino glacier area and by the Ufficio Neve e Valanghe, Università di Torino in the Valle d'Aosta site of Fontainemore.

The experimental goal for the first year was to verify the feasibility of new quick environmental snowpack profiles. Furthermore field sites, measure features, a standardised and shared methodology were experimented and chosen. The problems found during the fist year were discussed in order to perform an operative test in the winter season 2006 – 2007. The test aimed to standardise procedures and tools to introduce in routine surveys. In this way, a new tool for pre-monitoring of quality of water resources, coming directly from the cryosphere, could be proposed.

Fig. 1 - *Sampling snow layer for pH and conductivity determination in Arabba site, Dolomites, Italy.* Photo: M. Pecci

The ice

The Calderone glacier, located just behind the top of the Corno Grande d'Italia, has had strong reduction in volume (Fig. 2) between 2650 and 2830 m. During the 20th century, altitudinal development was estimated at about 2.000.000 m^3, which makes for an approximate total of 4.000.000 m^3 since the Little Ice Age. This also produces an estimated reduction of ice thickness for an average of about 30 m or an average of about 36 m since the end of Little Ice Age and is very evident during last ten years (Fig. 2). The principal effect of tensional release on the rocky edges and walls is the development of gravitational phenomena. A further feature of rapid evolution the glacier's area is evident in glacial debris coverage, which constitutes the left (hydrographical) arch of the frontal-lateral moraine and includes superficial movements and displacements. Both evidences highlight the hypothesised deglaciation phase and could suggest development of paraglacial environment and processes that are also linked to possible degradation of the rock and debris permafrost.

Fig. 2 - *The lower section of the Calderone glacier (central Apennines, Italy): a time-comparison showing reduction of ice thickness.* Photo: M. Pecci

The Calderone glacier shows characteristic behaviour with a substantially stationary mass balance over the last years (if the two ice aprons are considered as unique apparatus) although in reduction and subdivided actually into two small glaciers since 2000. Debris coverage, morpho-topographic and exceptional winter snow accumulation, of more than 10 metres, seem to be the principal causes for these actions, which are opposite to that of the general trend in most Alpine glaciers.

Permafrost

The activity of periglacial processes in relation to the presence of active permafrost in the area is only hypothesised. There is positive feedback from debris movements and evolutionary patterns, as well as from gravitational movements due to tensional release following ice reduction.

The most severe and recent phenomenon was the rock fall from the "paretone" (big wall) of the *Corno Grande d'Italia* (Fig 3). This occurred during the summer of 2006 on 22 August. Fortunately there were no victims, nor any grave damages. Since then, a detailed study and mountaineering monitoring of the area have been carried out in order to further evaluate the phenomena of rock instability. Monitoring of the permafrost presence and distribution of two thermal in situ stations also began in a comparable site at almost the same altitude in order to detect the hypothesised presence of permafrost and to survey its evolution.

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