

Taking the temperature of mountains

Future climate warming is expected to be especially marked in colder environments, such as mountains and northern climes. For the past two years, 350 scientists participating in the European Union-funded Global Change in Mountain Regions (GLOCHAMORE) project involving UNESCO and the Swiss-based Mountain Research Initiative have been developing a network of sites in selected mountain biosphere reserves to observe and study over time the signs of global change in nature and their impact on the people who inhabit these regions. The project was coordinated by the University of Vienna (Austria) and comprised 14 partners from eight European countries, plus India. By the time the project wound up last October, some 28 biosphere reserves around the world had been identified and the foundations had been laid for the long-term study of change in these alpine monitoring sites.



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One-quarter of our globe's terrestrial surface is covered by mountain regions, which provide goods and services – such as the provision of clean freshwater – to more than half of humanity. Though rugged in appearance, mountains

are actually highly susceptible to environmental degradation, as anyone knows who has seen the corrosive effects of strip-mining or clear-cut logging on mountain slopes. The main drivers of change in alpine environments are climate, land use and nitrogen deposits.



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Climate change to create water shortages for millions dependent on glaciers

For millions of people in Asia and Latin America who rely on melting snow and glaciers for freshwater supplies, climate change will cause major shortages, says a research team led by Tim Barnett of the US-based Scripps Institute of Oceanography, in a paper published in *Nature* on 17 November.

In many parts of the world, glaciers are melting at an unprecedented rate. The area of Peru covered by glaciers has shrunk by 25% in the past 30 years. However, 'perhaps the most critical region in which vanishing glaciers will negatively affect water supply in the next few decades', say the authors, 'will be China and parts of Asia, including India, which together form the Himalaya-Hindu Kush region' populated by about 50–60% of the world's population.

The Himalaya-Hindu Kush region contains more ice than anywhere else on Earth, apart from the polar regions. The authors write that 'there is little doubt that the glaciers of the Himalaya-Hindu Kush region are melting and that the melting is accompanied by a long-term increase of near-surface air temperature'. After 25 years of study, the recently released *China Glacier Inventory* shows 'substantial melting of virtually all glaciers, with one of the most marked retreats in the last 13 years (750 m) of the glacier that acts as one of the major sources of the Yangtze River, the largest river in China,...' The authors add that the rate of melting seems to be accelerating.

'The hydrological cycle of the region is complicated by the Asian monsoon but there is little doubt that melting glaciers provide a key source of water for the region in the summer months: as much as 70% of the summer flow in the Ganges and 50–60% of the flow in other major rivers. In China, 23% of the population lives in the western regions, where glacial melt provides the principal dry season water source'.

The authors conclude that 'it appears that some areas of the most populated region on Earth are likely to "run out of water" during the dry season if the current warming and glacial melting trends continue for several more decades. This may be enough time for long-term planning to see just how the region can cope with this problem'.

Source: *Nature* 438, 303 (2005) and M. Shanahan for *SciDev.net*



In the Cordillera Blanca mountain range in Latin America, the area covered by glaciers has shrunk markedly over the past 30 years. Seen here is rapidly retreating Yanamarey Glacier in the Huascarán Biosphere Reserve in Peru



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Scientists can reconstruct climate history from sediment layers and ice cores. These scientists are studying mountain snow pack to reconstruct climate history in Glacier National Park in the State of Montana in the USA

Mountain landscapes are among the most complex and fragile ecosystems on earth. Their mere verticality produces a huge range of habitats, whose composition varies dramatically with short changes in altitude. These differences can be obvious in the tropics or sub-tropics – such as the presence of palm trees at lower altitudes and glaciers at higher ones – or more subtle, such as the shifts in insect species as you move up a mountain slope.

Calculating and forecasting the effects of climate change on these environments encompasses a demanding range of scientific inquiry. This is why the scientists participating in the GLOCHAMORE project developed a research strategy encompassing such diverse areas as land-use changes, the cryosphere (permanent frozen landscapes, from the Greek word *Kruos* meaning cold) and snow-covered areas, hydrological systems, grasslands and tundra areas, forests and aquatic ecosystems, wildlife, alien plant and animal species and natural hazards (floods, fires, landslides, etc), to name but a few.

One of the recommendations made by scientists participating in GLOCHAMORE is for ‘early warning’ mechanisms to be developed to detect invaders and their environmental impact. As annual temperatures rise over the long-term due to global warming, for example, non-native plant, insect and animal species may more easily invade new ecosystems where there is often no check on their behaviour. This lack of “checks and balances” can play havoc with a mountain ecosystem’s structure and function. Hostile bugs might attack the plants and grasses that anchor a slope’s thin layer of topsoil, for example. Remove the anchor and you get severe erosion and landslides, with their cascading effect on local communities.

A network of alpine observation posts

The GLOCHAMORE project set up a network of observation posts to monitor the effects of changes on the natural world but also on the people living in these colder climes. In the space of two years, the project has developed a plan for environmental and social monitoring in mountain regions that is helping to implement global change research strategies in selected UNESCO Biosphere Reserves (see table overleaf). There is no reason why the GLOCHAMORE research strategy could not be applied to other mountain biosphere reserves – there are over 150 in total – or to world heritage sites, such as Mount Kilimanjaro in the United Republic of Tanzania. Some alpine sites have even been accorded dual status, as in the case of Uvs Nuur Basin (Mongolia) and Mount Kenya, which are both biosphere reserves and world heritage sites. It so happens that the impact of climate change on world heritage sites will be the subject of a meeting taking place at UNESCO just two months from now, on 16 and 17 March.

Tell-tale signs of climate change

In a survey conducted in 2004 within the GLOCHAMORE project, managers of mountain biosphere reserves reported on their experiences of global warming. High on the list of concerns was the economic impact of the changing natural environment. In the Kosciuszko Biosphere Reserve in Australia, for example, where four ski resorts bring the area an estimated A\$190 million annually, the winter season is becoming shorter. In Changbaishan Biosphere Reserve in China, lesser snow cover is responsible for a drop in the quantity of water available to farmers for agriculture. In Mount Kenya Biosphere Reserve, flash floods and other hydrological hazards are silting waterworks and canals used for irrigation. Local communities are also suffering from water shortages, as in the Kruger to Canyons Biosphere Reserve in South Africa.

The greatest impact of climate warming observed in nature can be seen in vegetation. The Changbaishan Biosphere Reserve reported that ‘the alpine *Betula ermannii* birch tree has moved upwards towards the tundra ecosystem over the past 20 years. Results show that, for other species, such as the *Larix olgensis* and *Abies nephrolepis*, there is an apparent increase in their biomass with climate warming’. In other words, these two plant species are proliferating as a result of the increase in temperature, a phenomenon which will eventually create an ecological imbalance.

The following is a non-exhaustive list of impacts associated with climate change in mountain biosphere reserves. Many of the signs of climate change below are interlinked, reflecting the fact that a single impact of climate change can set off chain reactions with both physical and social dimensions:

- Greater solar ultraviolet radiation
- Melting of glaciers (see box on facing page)
- Thawing of permafrost soils causing greater weathering (the breakdown of rocks and minerals on, or just below, the surface, caused by changes in temperature or humidity, etc.)
- As a result of greater weathering, dryer soils, subsidence, siltation, landslides caused by erosion, etc.
- More frequent storms, floods, landslides and avalanches of greater intensity
- Changes in the distribution and numbers of plant and animal species
- A longer growing period for vegetation, with the vegetation lines moving up the mountain
- Less rainfall and snowfall (precipitation)
- Drying out of the forest area due to the drop in precipitation
- A greater fire hazard due to the drying out of the forest area
- Greater competition for more limited natural resources among the human populations living in the lowlands.



Sky Lake Meteorological Station at an altitude of 2600 m in Changbaishan Biosphere Reserve in China. Other research stations study hydrological factors and seismic and volcanic activity

Over the past two years, GLOCHAMORE has defined indicators to detect and analyse signals of change in these high-altitude regions and to analyse direct cause–effect relationships in individual ecosystems using carefully chosen markers. These indicators have been ranked in terms of ease of application.

Disturbing evidence of climate change

Glaciers, permafrost and alpine regions are all sensitive to changes in atmospheric temperature, so act as an indicator of global climate change. Warming during the 20th century has already had a pronounced effect on glacial and



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Crossing a river in Katunsky Biosphere Reserve in Altai, Russian Federation

periglacial mountain belts. If this trend continues, experts predict smaller mountain glaciers could melt, areas of frozen ground (permafrost) could thaw and alpine regions could shrink.

Specifically, the network of selected biosphere reserves is observing cryospheric indicators, such as snow cover, glaciers, permafrost and solifluction (where freezing and thawing of the ground results in soil-surface slippage); high-mountain, freshwater ecosystems and watershed hydrology; and terrestrial ecosystems, especially mountain plant life and certain soil-dwelling animals. They have already uncovered disturbing evidence of climate change (see box on page 11).

Living laboratories for sustainable development

UNESCO’s mountain biosphere reserves were chosen as monitoring sites for the GLOCHAMORE project both because they offer a major advantage for global comparisons and because the ‘biosphere concept’ is particularly well adapted to integrated research observing change in both the natural and socio-economic environments.

This is because the biosphere concept acknowledges that people and nature cohabit and that conservation practices have to incorporate this reality. The biosphere reserve concept adopts a zoning approach: strictly protected core areas are surrounded by buffer zones where conservation is emphasized but where people also live and work; and the whole is encircled by a transition area promoting sustainable development.

It was the Brundtland Report, *Our Common Future*, which proposed a definition of sustainable development in 1987 that is now generally recognized as the standard:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The Brundtland report helped to trigger a wide range of initiatives by the United Nations, including the ‘Earth Summits’ in Rio (Brazil, 1992), which adopted *Agenda 21*, and in Johannesburg (South Africa, 2002), as well as the Framework Convention on Climate Change, to which the Kyoto Protocol was added in 1997 (see p. 29).

At the Earth Summit in Rio, the United Nations promoted UNESCO’s wide network of biosphere reserves as ‘living laboratories’ for conservation efforts. The Rio Summit was the start of a growing awareness of the importance of mountains. A decade later, the United Nations would designate 2002 as the International Year of Mountains. UNESCO’s main contribution to the Year would be the launch of the GLOCHAMORE project. Significantly, mountain-related research by the European Union has also gathered momentum in the past decade.

On the International Year of Mountains, see A World of Science 1(2), January 2003



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People in the Sierra Nevada Biosphere Reserve in southern Spain live in close proximity to the mountain. The mountain serves as a source of revenue via tourism and recreational activities. A ski resort is situated in the buffer zone on the lower slopes

Ensuring the long-term viability of mountain monitoring

The choice of monitoring sites was not a random one. Sites were chosen in countries in such a way as to provide representative geographic coverage and different socio-economic backgrounds and cultures. Another criterion for selection was whether or not the site had the necessary infrastructure in place to partake in the project.

The studies undertaken at the chosen locations needed to integrate natural and societal factors, and therefore various scientific disciplines. 'Through monitoring, one can design a scheme to target indicators that are driven by human action and managers of mountain biosphere reserves can set threshold values, such as for sustainability for example, which can be met by management,' suggests the report of the project's first thematic meeting in Vienna in 2004. But a fully integrated study of the so-called 'nature-society system' entails finding common denominators and even coining a new language which



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Glacier National Park in the USA

The Perth Declaration moves mountains

During its two years of activity, GLOCHAMORE organized no less than five specialized international workshops. In general, these scientific workshops focused on the drivers of global change and the impact of those changes on ecosystems, ecosystem goods and services, regional economies, health and institutional arrangements. The proceedings of these workshops are compiled in a series of publications.

Scientists examined the most pressing aspects of climate change observed in mountain landscapes, such as sustainable land use and natural resource management, the monitoring of human activity linked to environmental changes and modelling to project the future effects of global warming in mountains.

The project culminated in an Open Science Conference on Global Change in Mountain Regions in Perth (Scotland) from 2 to 6 October. This meeting built on successful gatherings in Vienna (Austria) and l'Aquila (Italy) in 2004, in Granada (Spain) and Samedan (Switzerland) in 2005 and the project's kick-off meeting at the Entlebuch Biosphere Reserve (Switzerland) in November 2003.

The Open Science Conference brought together 250 delegates from 47 countries to review the project's work and define the path ahead. At the conference, scientists issued a clarion call – the *Perth Declaration* – to governments, funding agencies and private sector to support further research into the effects of climate change on mountain ecosystems and the sustainable management of mountain environments and adjacent lowland communities.

Read the Perth Declaration: www.unesco.org/mab/mountains/news.htm; and the Proceedings of the GLOCHAMORE meetings: www.unesco.org/mab/mountains/publications.htm

<i>The selected mountain biosphere reserves</i>	<i>Altitudinal range (m.a.s.l.)</i>
Africa	
Tassili N'Ajjer (Algeria)	1 150 – 2 158
Mount Kenya	1 600 – 5 199
Oasis du Sud (Morocco)	680 – 4 071
Kruger to Canyons (South Africa)	200 – 2 050
Asia-Pacific	
Kosciuszko (Australia)	213 – 2 228
Changbaishan (China)	720 – 2 691
Issyk-Kul (Kyrgyzstan)	1 609 – 7 439
Nanda Devi (India)	1 800 – 7 817
Uvs Nuur Basin (Mongolia)	759 – 3 966
Katunskiy (Russian Federation)	765 – 4 506
Sikhote-Alin (Russian Federation)	0 – 1 600
Teberda (Russian Federation)	1 260 – 4 047
Europe	
Gossenköllesee (Austria)	2 413 – 2 828
Gurgler Kamm (Austria)	1 900 – 3 400
Berchtesgaden Alps (Germany)	471 – 2 713
Sierra Nevada (Spain)	400 – 3 482
Lake Torne (Sweden)	340 – 1 610
Entlebuch (Switzerland)	600 – 2 350
Swiss National Park	1 500 – 3 174
Latin America	
Araucarias (Chile)	800 – 3 124
Torres del Paine (Chile)	20 – 3 050
Cinturón Andino (Colombia)	1 700 – 5 750
Huascarán (Peru)	2 500 – 6 768
North America	
Mount Arrowsmith (Canada)	300 – 1 817
Glacier National Park (USA)	972 – 3 185
Niwot Ridge (USA)	2 866 – 3 780
Denali (USA)	122 – 6 194
Olympic (USA)	0 – 2 428

practitioners of both the natural and social sciences can understand, the report concludes.

Managers of mountain biosphere reserves will be crucial to the long-term viability of mountain monitoring. They will serve as the custodians of the information and data collected by the body of both national and visiting scientists who, themselves, will come and go over the coming decade. By definition, monitoring climate change is a long-term undertaking that calls for comprehensive and constant *in situ* observation. The involvement of other stakeholders, such as local communities, will also be crucial to maintaining a viable 'observation post' for climate change.

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