

## **GLORIA: A Global Observation Research Initiative in Alpine Environments**

Authors: Grabherr, Georg, Gottfried, Michael, and Pauli, Harald

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## GLORIA:

### A Global Observation Research Initiative in Alpine Environments

The first internationally coordinated initiatives to observe the environment in Alpine regions date back to the 19th century. Around 1880, the first mountain observatories were established on European mountains. Today, the record of their activities provides a meteorological time series covering more than a century. Continuous meteorological measurements on high mountains in other continents started in the 1930s (Barry 1992). Worldwide glacier monitoring began in 1894 with the establishment of the International Glacier Commission in Zurich, Switzerland. The aim of this worldwide monitoring program has been to record glacier variations over time and to understand the mechanisms leading to change (Haeberli 1996). Thanks to observations performed under this program, glacier dynamics, in particular dramatic recent glacial retreats, have been documented over the last 100 years. The observed retreats are the clearest evidence for the ongoing process of global warming (Beniston and Fox 1996).

No such long-term observations exist for detecting the impacts of climate on high mountain ecosystems. Among the few exceptions are old records (from 1835 to 1953) on the dynamics of the flora of high mountain summits in the European Alps. A recent reinvestigation of these historic summit sites revealed that vascular plants have been migrating upward to higher altitudes (Gottfried et al 1994; Grabherr et al 1994, 1999; Pauli et al 1996). The most likely cause of this migration process is global warming since the 19th century. Lively responses to our presentation of this phenomenon from international audiences, including nonscientif-

ic audiences, have made clear the importance of ongoing and even simple direct observation of ecosystems as a source of informed knowledge about environmental change, which in turn can become a sound basis for decision-making.

The Global Observation Research Initiative in Alpine environments (GLORIA) was initiated to satisfy the demand for such knowledge. In this context, alpine refers to areas from the timberline to the top of high mountains. High areas on desert or arctic mountains with no timberline but that meet other criteria are included. GLORIA, therefore, aims to establish an internationally coordinated network monitoring global warming on a global scale. It takes advantage of the high sensitivity of alpine ecosystems to climate change in order to detect how these changes might affect life throughout the world. We plan to establish GLORIA as part of international ecological monitoring efforts such as the Mountain Work Plan of the International Geosphere-Biosphere Program, IGBP (Becker and Bugmann 1997), the Mountain Biodiversity Assessment initiative (Körner and Spehn 1999) organized by DIVERSITAS (DIVERSITAS 1996), and the planned Global Terrestrial Observation System (GTOS). The present announcement aims to encourage researchers in the field of alpine ecology to become involved in a detailed discussion of proposed research activities and to cooperate within the planned global monitoring network.

#### Why focus on high mountains?

There are several good reasons why alpine ecosystems should be used as indicators of climate change in a worldwide monitoring network:

1. Being exposed to low temperature conditions, they are generally considered particularly sensitive to climate warming (Beniston 1994; Price and Barry 1997).
2. Their ecological complexity is comparatively low, and abiotic factors, particularly climatic factors, are more important than biotic factors such as competition. Hence, the impacts of climate change on alpine biota are expected to be more pronounced than on biota at lower altitudes.
3. In addition, the impacts of human land use, which could mask climate-related signals, are negligible or of little significance in many alpine regions. This is particularly true for national parks and other protected areas.
4. Compared with the latitudinal sequence of thermal life zones from the equator to the poles, the altitudinal sequence of thermal life zones on high mountains is compressed; small ecotones constitute the only separations between these zones. Alpine environments are therefore a kind of microcosm where environmental gradients occur along short distances. Invaders from lower down might appear earlier than along latitudinal gradients since they do not have to migrate over long distances.
5. Finally, alpine environments can be found in virtually all major life zones (ie, zoniobiomes) from the tropics to the far north. No other biome type on earth is distributed as evenly over the whole globe as alpine biomes, thus allowing for comparative ecological observation.

The principal objective of GLORIA is thus to establish a network of permanent plots at observation sites

in alpine environments in all major life zones (zonobiomes according to Walter 1985), from polar to tropical latitudes. For the first time, this would provide standardized reference data for global long-term monitoring of impacts of climate change on natural ecosystems. GLORIA aims to define target regions in all major mountain systems with natural environments (ie, with little or no pressure from local human land use). The distribution of regions should be geographically balanced both in terms of latitude and longitude.

#### GLORIA's basic approach

A pragmatic approach will be chosen to establish the global network of monitoring sites; designing standardized observation manuals will be a matter for future discussion. The basic network will consist of sites where only simple surveys, for example, sampling floristic vegetation structure, will be carried out. Such sites could even be visited by an expedition, providing that the position of the site and the sampling plots are recorded with great precision. Where long-term ecological research sites already exist, these could be defined as master stations where more sophisticated research methods will be applied, including experimentation. A sequence of several observation plots should follow the altitudinal gradient in master stations as well as at other sites.

Selection of sites should be done either according to the multisummit strategy or the single-mountain strategy.

1. The multisummit strategy takes advantage of the fact that most target regions will have summits of different heights, thus providing an altitudinal gradient. Establishing plots at the top of the different summits might be the most feasible and cost-efficient strategy to compare alpine biota along the two fundamental climatic gradients, that is, the altitudinal sequence within a target

region and the latitudinal sequence resulting from comparison between different target regions. Summits are good indicator sites, representing the average local climate at a distinct altitudinal level (shading effects are minimized). They include many kinds of habitats within a small area. Furthermore, summits may act as traps for upwardly migrating species; they are also pronounced landmarks that can easily be found again for subsequent visits. The time needed for simple standardized vegetation sampling of 16 1 × 1 m plots in 2 target regions has already been tested in the northeasternmost Alps (Austria) and the Sierra Nevada (Spain). It took 2 weeks to collect the vegetation samples (ie, floristic composition, abundance and/or density) and determine the precise position of sampling sites on a set of 4 summits in a target region and to establish the 16 plots on each of them.

2. The single-mountain strategy considers one mountain or one slope system per target region. The plots can be selected in the different altitudinal zones (eg, lower alpine, upper alpine, nival zone) or, preferably, within the ecotones between the zones where alterations of species composition induced by climate change might become most obvious. Studies conducted at Mt Schrankogel, Tyrol (Gottfried et al 1998; Pauli et al 1999), are examples of the single-mountain strategy.

#### Where does GLORIA stand now?

A first outline of the research initiative was presented in December 1997 at the European Conference on Environmental and Societal Change in Mountain Regions in Oxford (Price et al 1999), where it was recommended as a contribution toward the realization of the IGBP Mountain Work Plan. GLORIA is also linked to the newly emerging Global Mountain Biodiversity Assess-

ment (MBA) included in DIVERSITAS (DIVERSITAS 1996). MBA is supported by the Swiss Academy of Sciences as an initiative to create an international mountain biodiversity network (Körner and Spehn 1999).

Generation and testing of appropriate field methods for GLORIA's basic approach have been conducted so far at the Department of Vegetation Ecology and Conservation Biology, University of Vienna, and have been supported by the Austrian Academy of Sciences.

In the summer of 1999, we began a feasibility study for GLORIA (financed by the Austrian Federal Ministry of Science and Transport with a 6-month contract). The study contains a call for potential contributors (principal investigators, institutions) and also asks the latter to suggest potential target regions. About 200 calls for proposals have been sent out so far. The response has been very encouraging. Proposals for target regions range from Tierra del Fuego to Svalbard. The call is still open, and anyone interested is welcome to contribute. Please contact us by e-mail or visit our web site—where the list of references cited here is available—at [www.pph.univie.ac.at/gloria/gloria.html](http://www.pph.univie.ac.at/gloria/gloria.html). The next step will be a GLORIA workshop where a work plan, standardized observation manuals, organizational issues, and funding will be discussed. This workshop is planned as part of the first Conference for Global Mountain Biodiversity Assessment scheduled to take place from 7–10 September 2000. Hopefully, GLORIA will become a globally active network in 2002, the International Year of Mountains.

**Georg Grabherr, Michael Gottfried, and Harald Pauli**

GLORIA, Institute of Ecology and Conservation Biology, University of Vienna, Althanstr. 15, A-1090 Vienna, Austria. Web site: [www.pph.univie.ac.at/gloria/gloria.html](http://www.pph.univie.ac.at/gloria/gloria.html); E-mail: [gloria@pflaphy.pph.univie.ac.at](mailto:gloria@pflaphy.pph.univie.ac.at)