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This report is the **Final Pubishable Report** of GLORIA-Europe and at the same time the **Final Technical Report.** They are identical because the full content is non-confidential.

The following six annexes are appended to the Final Technical Report. These annexes are not referenced in the report to keep it publishable. Yet, the chapters to which the annexes relate are indicated below:

ANNEX 1: The *GLORIA Field Manual – Multi-Summit Approach*
English edition and Spanish edition
to chapter 4.1.1

ANNEX 2: Manual to the GLORIA DATA INPUT TOOLS
to chapter 4.1.3

ANNEX 3: Manual to the GLORIA Photodocumentation Management Tool
to chapter 4.1.4

ANNEX 4: Contributions from the GLORIA Target Regions
to chapter 4.3.3

ANNEX 5: Geographical arrangement of future GLORIA Target Regions on the global level and additional indicators
to chapter 4.3.5 and 4.5

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2. Executive Publishable Summary

GLORIA-EUROPE – (EVK2-2000-00056)
The European dimension of the *Global Observation Research Initiative in Alpine Environments* (*GLORIA*) – a contribution to *GTOS* *www.gloria.ac.at*

The project has established the first Europe-wide network for assessing and monitoring the effects of climate change on biodiversity (plant species composition and vegetation structure) in mountain environments. GLORIA-Europe was conducted as a pilot project for the establishment of a world-wide long-term observation network. The rationale for choosing high mountain ecosystems was that they are globally distributed and because they are determined by low-temperature conditions, they are particularly sensitive and vulnerable to the impacts of climate warming. In Europe, 25% of the vascular plants occur in alpine regions – thus climate change potentially threatens a significant part of the continent's natural heritage. The assessment of climate change impacts on mountain biota requires direct field-based observations.

The main outputs of GLORIA-Europe are:

An active Europe-wide monitoring and research network
In establishing GLORIA-Europe the essential requirements of a much-needed large-scale *in situ* observation network were fulfilled. An effective, standardised, user-friendly, and cost-efficient monitoring method was devised; an extensive network of field sites with permanent plots was established from southern Spain to the Russian Polar Urals; a central database including input and management tools was developed; and a broad basis of co-operation and information flow was established. This co-operation involves not only the academic community but also user groups being mediators to the public and to decision makers. User groups such as powerful NGOs (WWF, CIPRA) and research organisations linking to global change issues in a wider context, including socio-economic perspectives (the Mountain Research Initiative of IGBP, IHDP and GTOS; the Centre for Mountain Studies at Perth College), were directly involved in the project. The central platform for data and information exchange is the GLORIA website.

Patterns of alpine biodiversity, climate, and potential climate-induced risks across Europe
The extensive GLORIA-Europe dataset enabled a comparative study of the regional differentiation of high mountain plant diversity and the corresponding bioclimates across Europe's alpine life zone, at a spatial resolution never reached before. The data analysis allowed us to investigate large-scale scenarios on potential threats of climate-induced biodiversity losses. The most alarming signals come from the mediterranean mountains such as the Sierra Nevada in Spain, followed by sub-mediterranen and temperate mountains such as the Pyrenees, the Caucasus, and parts of the Alps.

High impact in the public medias
The project effectively contributed to raise public awareness of critical ecological consequences of climate warming in mountain regions. Numerous articles in newspapers and illustrated magazines (e.g., Spektrum der Wissenschaft; National Geographic, scheduled for 2004) were published and television reports were broadcast (e.g., in the Norwegian, Greek, and Austrian TV).

The foundations of a consolidated long-term operation on a large-scale level
The self-maintained operation of future long-term monitoring activities is a key concern of the GLORIA network. The use of simple methods and low maintenance cost of the permanent observation plots used are key to achieving this goal. A durable extensive observation network is accomplishable owing to the stimulating impact of GLORIA-Europe. The scientific community's interest in joining GLORIA has been high. Numerous researchers, using local or national funds (e.g., from Switzerland, Italy, Russia, New Zealand, Australia, USA), have joined the global GLORIA community since the start of GLORIA-Europe.
The comprehensive dataset compiled during the GLORIA-Europe project is the first standardised account of Europe's mountain plant diversity which will serve as a crucial baseline for model evaluations and future comparisons.

3. Objectives of the project

- **Scientific/Technological Objectives**

The ultimate objective of *GLORIA*, to be attained beyond the lifetime of this project, is to establish a durable world-wide observation network to assess the risks of biodiversity losses and the vulnerability of fragile alpine ecosystems under climate change pressures in the major mountain systems on Earth.

The observation network is a response to increasingly alarming climate change scenarios: the previous *IPCC* report (WATSON et al. 1998) predicted an increase in temperature of 1 to 3.5°C by the year 2100; this estimate was recently updated to 1.4 to 5.8°C (HOUGHTON et al. 2001). The recent *IPCC* report stated that climate warming is related to human activities and that warming will be more rapid than expected – with dramatic consequences on the Earth's environment and the human population.
This statement emphatically underlines the urgent need for a well-coordinated implementation of comparative observation networks to detect climate-induced ecological impacts on the continental and the global scales. The urgent demand for monitoring climate change impacts on the biodiversity of key ecosystems is also manifested by numerous work programmes, commitments and recommendations published in recent years (MESSERLI & IVES 1997; HEAL et al. 1998; EEA 1999; PRICE et al. 1999; BECKER & BUGMANN 2001; KÖRNER & SPEHN 2002; UNEP-WCMC 2002).
GLORIA ultimately aims to develop such a world-wide observation network in high mountain environments (GRABHERR et al. 2000; GRABHERR et al. 2001a; GOTTFRIED et al. 2002; PAULI et al. 2003b). High mountain ecosystems (i.e. the alpine life zone from the treeline upwards) offer ideal requirements for large-scale comparisons and are considered as a priority environment for climate impact research because they are:

→ highly sensitive to climate warming as they are controlled by low-temperature conditions;

→ less complex compared to most of the lowland ecosystems, and abiotic environmental factors are more pronounced compared to biotic factors such as competition among species;

→ particularly vulnerable to climate-induced effects;

→ showing a high degree of naturalness and less "direct anthropogenic noise" which can mask signals of climate change impacts;

→ distributed over all life zones on earth from polar to tropical latitudes.

Therefore, high mountain ecosystems are excellent indicators for climate change impacts.

The key scientific/technological objectives of GLORIA-Europe were:

(1) **the development and testing** of an effective, standardised and widely applicable **monitoring method and design**;
(2) **the building of a central database** with data input tools and cross-check routines for data consistency;
(3) **the establishment of a Europe-wide observation network** with monitoring sites in the major mountain systems from the mediterranean to the subarctic zone;
(4) **the comparative analysis** of biodiversity and vegetation patterns as well as of climatic indices in order to draw data-based **scenarios on potential warming-induced losses** of the natural diversity of mountain plant life;
(5) **an assessment of feasible options for an effective long-term operation** of the observation network.

The aims of *GLORIA-Europe* are in agreement with scientific needs: networks for monitoring species and species communities are still lacking, but are an essential component for ecological climate impact research. As such, this meets the objectives of the 5th Framework Programme in *Part A: Environment and Sustainable Development* under *Key action 2: Global Change, Climate and Biodiversity* (*2.4: European component of the global observing systems; 2.4.2: Development of new long-term observing capacity*).

- **Socio-economic objectives and strategic aspects including contribution to EU policy needs**

(1) *GLORIA-Europe* is concerned to enforce the co-operation with other global change networks to strengthen the interfaces with the wider scope of global change research with its physical, biotic, and socio-economic components; e.g., with *the Mountain Research Initiative* (*MRI*) a multidisciplinary scientific organisation endorsed by the *IGBP, IHDP, GTOS*; the *Global Mountain Biodiversity Assessment* (*GMBA*), a research network of *DIVERSITAS*; and the *Global Terrestrial Observing System* (*GTOS*), established by *FAO, ICSU, UNEP, UNESCO,* and *WMO*.

(2) The project aims to contribute to European environmental policies. For example, for upcoming adaptations of the *EU biodiversity strategy* (COM-42-FINAL 1998) through the *Convention of Biological Diversity* (http://www.biodiv.org; ANDERSON et al. 1999), and for the scientific backing of the *Kyoto Protocol* (UNFCCC 2003). The *European Centre for Nature Conservation* (*ECNC*) and the *European Environment Agency* (*EEA*) consider *GLORIA* as European site-based biodiversity monitoring network which may be used to support environmental policy needs (DELBAERE 2003).

(3) The long-term monitoring strategy of *GLORIA* aims to support community social objectives by:

- → contributing to reduce uncertainty in the complex climate change debate;
- → reading the state of alpine nature: are mountain environments in a healthy condition? – mountains are of increasing importance as recreation areas and for the direct and indirect tourism sector;
- → using alpine ecosystems for an early warning system of biodiversity losses and environmental change;
- → providing high-quality data from in-situ monitoring as an essential tool to realise international environmental commitments.

To attain these aims, user participants were part of the project consortium: powerful NGOs such as the *WWF* and *CIPRA*; and research organisations linking to global change issues in a wider context including socio-economic perspectives (*MRI*; *Centre for Mountain Studies* at *Perthcollege*).

4. Scientific and technical description of the results

4.1 Developed methods, protocols, tools, and structures

4.1.1 The GLORIA Field Manual – Multi-Summit approach

An effective, standardised and widely applicable monitoring method and design for high mountain environments

The method and the sampling design of the *Multi-Summit approach* was developed, tested and widely applied within the *GLORIA-Europe* project and by co-operating researchers in Europe and overseas. Its principles are explained in GOTTFRIED et al. 2002; PAULI et al. 2003b. A main result of the project is the *GLORIA Field Manual*, containing the detailed description of the *Multi-Summit approach* with exhaustive guidelines for its field application.

The first version of the *GLORIA Field Manual* was circulated before the kick-off meeting of the project in April 2001. The second version was thoroughly discussed and amended at the kick-off meeting, leading to the third version of the field manual which was used for the major field application in summer 2001 in 18 mountain regions of Europe. A further workshop in October 2002 (financed by the *Austrian Federal Ministry of Education, Science and Culture*) was devoted to produce the final *GLORIA Field Manual* (4th version (PAULI et al. 2003c) with justifications based on the broad experience from the continent-wide application. This final version is currently in press and will be published as report of the European

Commission. A Spanish version of the field manual is close to its finalisation (translated by L. Villar at the Instituto Pirenaico de Ecología in Jaca / Spain).

Comparability, simplicity and economy were the main considerations in designing the *Multi-Summit approach* for an effective large-scale network. The low-instrument and low-cost approach, together with the short time required in the field makes the method workable even under expedition conditions. Therefore, field experiments, extensive phenological observations, and costly sampling procedures have to be excluded from the basic approach. Randomised sampling strategies and large numbers of replicates would be useful from a statistical point of view, but they are not feasible in high mountain ecosystems in most cases. Over the longer term, and as a synergistic supplement to the *Multi-Summit approach*, more extensive methods and other indicators may be included at *GLORIA* master sites which are planned to be established at existing field stations; see subchapter 4.3.5 and compare also the *Single-Mountain approach* (PAULI et al. 1999). The main focus of the *Multi-Summit approach*, *GLORIA*'s basic approach, lies on biodiversity and on vegetation patterns. Changes in species richness may be detectable at time-scales of 5 to 20 years, whereas clear signals for changes of vegetation cover and structure may become obvious over a longer period (e.g. 20 to >50 years). The strength of the *Multi-Summit approach* is the large and growing number of reference sites, arranged along the fundamental climatic gradients in both the vertical and the biogeographical dimensions. The establishment of such a multi-site network is a challenge that can only be met by a world-wide community of committed ecologists. It wholly depends on researchers who are willing to establish the foundations for a long-term programme, which will yield results for future generations.

Summit habitats as reference sites

Mountain summits are considered as the most appropriate sites for comparing ecosystems along climatic gradients. Summit habitats are particularly amenable reference units for a large-scale comparison of climate change effects because they:

- are well-defined topographic units comprising habitats in all exposures within a small area;
- are not or almost not influenced by shading effects from neighbouring land features;
- show climatic conditions which are mostly defined by the altitude;
- usually show a species composition which is typical for the respective elevation;
- often show vegetation gradients over short distances (e.g., from N to S) with transition zones which enable a rapid recognition of climate-induced shifts of boundaries.
- may function as traps for upward-migrating species due to the absence of escape routes for cryophilic species with weak competitive abilities. This is particularly critical on isolated mountains with a high percentage of endemic species occurring only at the uppermost elevation levels (GOTTFRIED et al. 1994; THEURILLAT 1995; GRABHERR et al. 2001b; PAULI et al. 2003a).

The typical GLORIA target region with 4 observation summits in different altitude

A *GLORIA* target region should comprise a suite of at least four summits which represent an elevation gradient from the natural treeline ecotone (where applicable) up to the limits of (vascular) plant life, or in regions where these limits are not reached, up to the uppermost vegetation zone; a target region is the mountain area in which these four summits are located. All summits of a target region must be exposed to the same local climate, where climatic differences are caused only by altitude.

The selection of the summits will follow the criteria:

- low pressure from land use (to minimise masking effects from direct human influence);
- moderate geomorphological shape (for the adequate application of the method; compare Fig. 4.1a);
- and consistent substrate conditions (to optimise the comparability of the 4 summits).

For a description of the site selection criteria see the *GLORIA Field Manual*.

Method and sampling design

A detailed description of the sampling design, of the setup procedure and the recording methods is given in the *GLORIA Field Manual* (PAULI et al. 2003c) which is available at the *GLORIA* website: www.gloria.ac.at .

On each of the four summits per target region, three different types of ecological records plus temperature data will result from the application of the *Multi-Summit approach*:

- detailed vegetation samples with species cover in 1x1m quadrats to detect compositional changes;

- frequency counts in 1x1m quadrats to detect changes of vegetation patterns;
- samples of summit floras to detect species migration and changes of species richness;
- and continuous temperature measurements to compare changes of temperature and snow regimes.

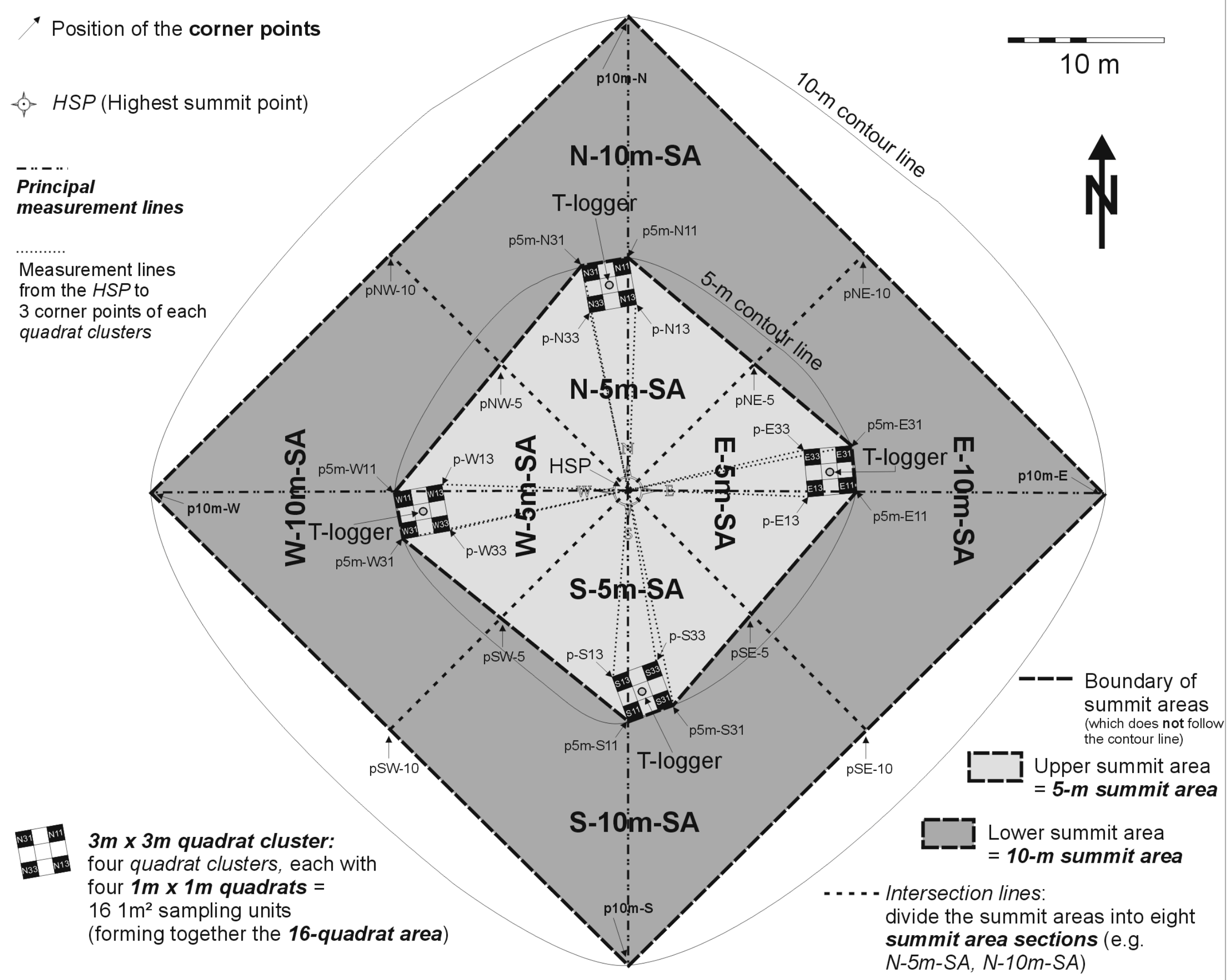
→ In the first part of the approach, permanent quadrat clusters, each with four 1x1m quadrats, were positioned in the four compass directions (see Fig. 4.1a). Within the resulting 16 permanent plots per summit
(1) a detailed vegetation recording will be conducted: i. e., %-cover of each plant species, and %-cover of vegetation (divided into vascular plants, bryophytes, lichens), of open soil, scree, and solid rock, and
(2) frequency counts for species by using a gridframe with 100 cells of 10x10cm were made.

→ The second part contains the species mapping of the entire summit site, divided into eight summit area sections reaching from the highest summit point downwards to the 10-m contour line (Fig. 4.1a). All plant species were mapped in each of the eight areas per summit with an estimation of their percentage cover.

→ The third part consists of continuous temperature measurements 10 cm below the soil surface at four locations per summit in the centres of the 3x3m quadrat clusters (see Fig. 4.1a): mini-dataloggers (StowAway Tidbits) were used with measurement intervals of 1 hour. The measuring position in the soil is preferred to enhance the comparability of data (compared to a surface position which is more susceptible for site specific errors) and to conduct a save and cost-effective measuring (compared to above ground measuring with a high risk of weather damage of equipment). Snow cover can be determined also at the position in 10 cm soil depth with a delay of only a few hours. Temperature time series were be retrieved after one year for its inclusion in the data analysis and a new set of loggers was installed. Therefore, each target region required 32 data loggers. The second set, i.e. 290 loggers are currently in the field and will yield temperature series in hourly intervals for the time period August 2002 to August 2006.

Methods for establishing the permanent plots: for the delimitation of summit areas, and for the positioning of the dataloggers, flexible measurement tapes, electronic spirit levels or a clinometer were used. Permanent plot-clusters were delimited by grids made of measurement tapes.
A detailed photo-documentation proved to be the most efficient method for an exact repositioning of the plots. For the future, repositioning and reinvestigation are due after 5 years and then will be continued at 10-year intervals. Appropriate future intervals will be evaluated on basis of the results of the first monitoring cycle at the *GLORIA-Europe* summits, planned for summer 2006.

Additional indicators: On an obligatory level, vascular plant species were recorded in all *GLORIA-Europe* target regions (TRs). On an optional level, in some TRs, bryophytes and lichens were recorded additionally. A further aim of the project was to explore other indicator organism groups which can be considered to respond sensitively to climatic changes and other indicator parameters which can be included in future protocols. This resulted not only in a list of suggested additional indicators, but also in the development and testing of field methods for selected organism groups (bryophytes, nematodes, mycorrhizal fungi) and in the formation of a task force group for the future establishing of master sites at existing field stations, where additional sensitive organisms and parameters should be used as indicators of climate impacts. See sub-chapter 4.3.5 for details.



The **corner points:**

***p5m-N11, p5m-E31, p5m-E11, p5m-S31, p5m-S11, p5m-W31, p5m-W11, p5m-N31*:**
the 8 lower corner points of the *3m x 3m quadrat clusters* at the **5-m level**;

they determine the position of the *quadrat clusters* and the lower limit of the *5-m summit area*

***p-N13, p-E13, p-S13, p-W13, p-N33, p-E33, p-S33, p-W33m* :**

the 8 upper corner points of the *quadrat clusters*

***p10m-N, p10m-E, p10m-S,p10m-W* :**
the 4 corner points at the **10-m level**; they determine the lower limit of the *10-m summit area;*

The *principal measurement line* for each main direction starts at the *HSP*, runs through one of the points at the 5-m level (e.g. *p5m-N11 or p5m-N31*) and ends at the points at the 10-m level;

***pNE-5, pNE-10, pSE-5, pSE-10 pSW-5, pSW-10, pNW-5,pNW-10* :**
the 8 corner points at the *intersection lines* (these points usually lie above the 5-m level and the 10-m level, respectively)
The *summit area sections* are delimited by these points, by the *HSP*, and the points at the 5-m and 10-m levels;

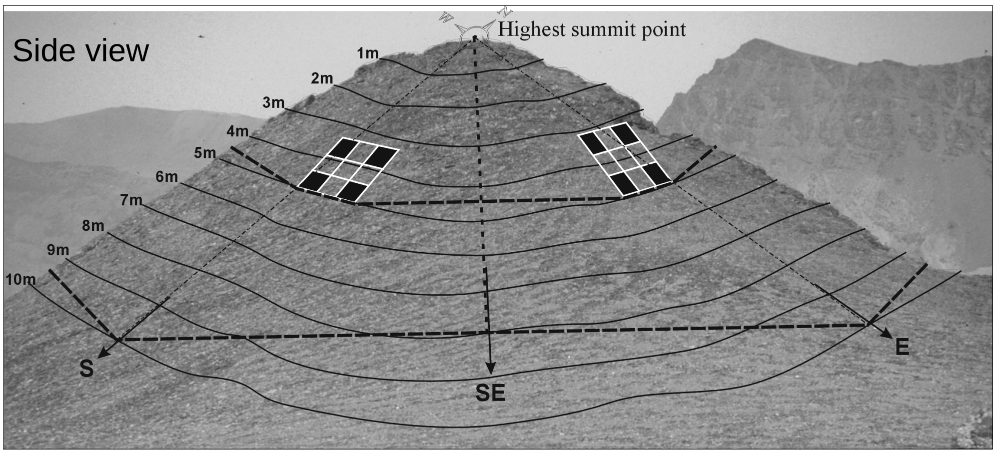


Fig. 4.1a: The *GLORIA Multi-Summit* sampling design (for details see the *GLORIA Field Manual*; PAULI et al. 2003c)

4.1.2 The Europe-wide site-based observation network

A first continent-wide monitoring network for the ecological implications of climate change in mountain environments

The *GLORIA-Europe* network consists of 18 target regions (TRs), distributed over the five major latitudinal vegetation zones of Europe (mediterranean; sub-mediterranean, temperate, boreal, subarctic; Fig. 4.1b). The target regions lie in typical parts of the respective mountain systems. Larger mountain systems are represented with several target regions (e.g. the Alps with four TRs, the Scandes with 2 TRs). Each target region consists of four observation summits in different elevation. In each case, the lowest summit lies within the potential natural treeline ecotone. The treeline ecotone is the transition zone between the line where closed forests end and the upper limit of tree species (adult tree species, including prostrate ones or scrub). The subsequent observation summits lie within the alpine and nival zones, or in transition zones in between, arranged in +/- even elevation intervals from each other. Some target regions only reach from the treeline to the alpine zone (e.g. Lefka Ori in Crete, the Northern Apennines, the East Carpathians, or the North-eastern Limestone Alps), while others reach the subnival or nival zone (e.g. the Sierra Nevada, the Central Pyrenees, the Central Western Alps, the Dolomites/S-Alps, the central Caucasus, the central and the northern Scandes, and the Polar Ural).

Fig. 4.1b shows the distribution of the target regions. In Table 1, target regions and their observation summits are listed.

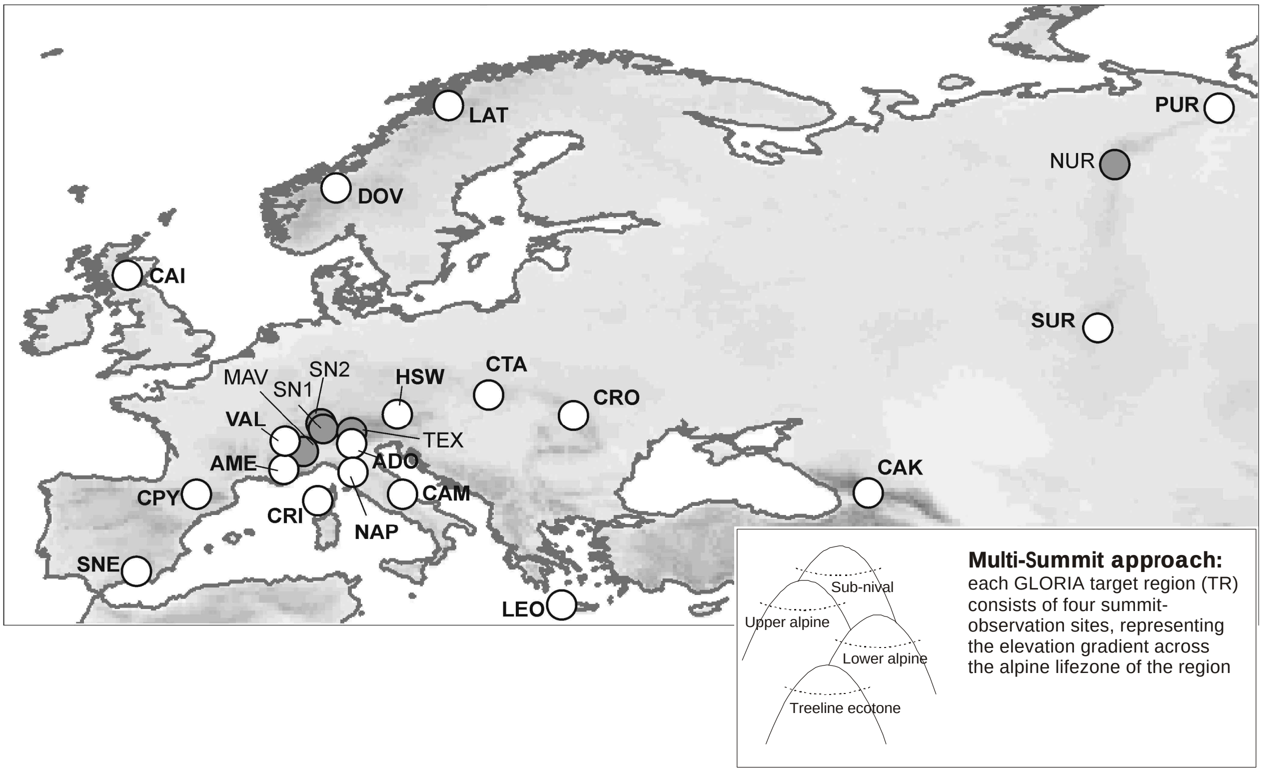


Fig. 4.1b: *GLORIA* target regions (TRs) in Europe; white circles: *GLORIA-Europe* TRs established in 2001 within this project; grey circles: established by local or national funds in 2002 or 2003. For details see Table 1 with corresponding target region codes.

All sites were established in summer 2001. This included the final selection of the four observation summits, the survey for fixing the positions of the permanent settings, a detailed photo documentation of each plot, the recording of biotic and abiotic data, and the positioning of temperature data loggers. In most of the target regions, fieldwork for site setup and recording was completed in summer 2001. In some TRs, fieldwork had to be made in the following summer 2002, because of bad weather conditions in 2001. In all target regions, however, temperature data loggers were retrieved in 2002 after a one-year measuring period (at interval of one hour), and were replaced by a second set of loggers for a subsequent measuring period of three years.

Table 1: The target regions of *GLORIA-Europe* and their observation summits. Data from additional target regions (see bottom of table) are not yet compiled in the central database; their establishment was financed by local or national funds.

Country code	Target region code	Target region name	Life zone (zonobiome)*	Summit code	Summit name	Elevation in metres	Altitudinal vegetation zone**
GR	**LEO**	Lefka Ori - Crete	Mediterranean (Zb. IV)	LOW	low summit	1664	tl-e
				CHO	Chorafas	1965	tl-e
				SEK	South-East of Kakovoli	2160	l-alp
				STR	Sternes	2339	l-u-alp
ES	**SNE**	Sierra Nevada - Baetic Cordillera	Mediterranean (Zb. IV)	PUL	Pulpitito	2778	l-u-alp
				CUP	Cúpula	2968	u-alp
				TCA	Pico del Tosal Cartujo	3150	an-e
				MAC	Cerro de los Machos	3327	niv
ES	**CPY**	Ordesa - Central Pyrenees	Mediterranean to temperate (transition between Zb. IV and VI)	ACU	Punta Acuta	2242	tl-e
				CUS	Punta Custodia	2519	l-alp
				TOB	Punta Tobacor	2779	an-e
				OLA	Punta de las Olas	3022	niv
FR	**CRI**	Monte Cinto region - Corsica	Mediterranean (Zb. IV)	COR	Monte Curona (Corona)	2144	tl-e
				BOR	Capu Borba	2305	l-alp
				EBO	Pointe des Eboulis	2607	u-alp
IT	**CAM**	Majella - Central Apennines	Mediterranean to temperate (transition between Zb. IV and VI)	FEM	Femmina Morta	2405	l-alp
				MAN	Manzini	2511	l-u-alp
				MAC	Monte Macellaro	2635	u-alp
				MAM	Monte Mammoccio	2737	u-alp
IT	**NAP**	Northern Apennines	Mediterranean to temperate (transition between Zb. IV and VI)	FOG	Cima di Foce a Giovo	1722	tl-e
				PCA	Cima di Pian Cavallaro	1815	l-alp
				MOM	Alpe di Mommio	1855	l-alp
				CAS	Monte Casarola	1978	l-u-alp
FR	**AME**	Mercantour - SW-Alps	Temperate (Zb. VI)	LAU	Butte des Laussets	2508	tl-e
				CFE	Cîme du Fer	2700	l-alp
				CBA	Cîme des Babarottes	2792	u-alp
				MTE	Mont Ténibre	3031	an-e
CH	**VAL**	Entremont/Valais - Central W-Alps	Temperate (Zb. VI)	LAL	La Ly	2360	tl-e
				BRU	Mont Brûlé	2550	l-u-alp
				PAR	Pointe du Parc	2989	an-e
				BOV	Pointe de Boveire	3212	niv
IT	**ADO**	Dolomites - S-Alps	Temperate (Zb. VI)	GRM	Grasmugl	2199	tl-e
				PNL	Do Peniola	2463	l-alp
				RNK	Ragnaroek	2757	u-alp
				MTS	Monte Schutto	2893	an-e
AT	**HSW**	Hochschwab - NE-Alps	Temperate (Zb. VI)	ZIK	Zinken-NW-summit	1910	tl-e
				WEK	Weihbrunnkogel	2065	l-alp
				GHK	G´hacktkogel	2214	l-u-alp
				ZAK	Zagelkogel-NW-summit	2255	l-u-alp
SK	**CTA**	High Tatra - W-Carpathians	Temperate (Zb. VI)	KRI	Krížna	1919	l-alp
				VEK	Vel'ká kopa	2052	l-u-alp
				SED	Sedielková kopa	2061	l-u-alp
				KRA	Krátka	2375	u-alp
RO	**CRO**	Rodna mountains - E-Carpathians	Temperate (Zb. VI)	GOL	Golgota	2010	l-alp
				GRO	Gropile	2063	l-alp
				BUH	Buhaiescu	2221	u-alp
				REB	Rebra	2268	u-alp
GE	**CAK**	Kazbegi - Central Caucasus	Temperate (Zb. VI)	CP1	Cross Pass 1	2240	tl-e
				CP2	Cross Pass 2	2477	l-alp
				CP3	Cross Pass 3	2815	u-alp
				CP4	Cross Pass 4- Kudebi	3024	an-e
UK	**CAI**	Cairngorms - Scotland	Boreal (Zb. VIII)	MIG	Creag Mhigeachaidh	742	tl-e
				CAM	Camp Cairn	904	l-alp
				UNK	Unknown Hillock	978	l-alp
				SGO	Sgoran Dubh Mor	1111	u-alp
NO	**DOV**	Dovrefjell - Central Scandes	Boreal (Zb. VIII)	VAR	Vesle Armodshokollen	1161	tl-e
				VKO	Veslekolla	1418	u-alp
				KOL	Kolla	1651	an-e
				SKI	Storkinn	1845	niv
SE	**LAT**	Latnjajaure - N-Scandes	Subarctic (transition between Zb. VIII and IX)	RVA	Rakkasvare	492	tl-e
				KVA	Kårasvagge	1000	l-u-alp
				LCH	Latnjachorru	1300	an-e
				KTJ	Kårsatjåkka	1560	niv
RU	**SUR**	South Urals	Temperate (Zb. VI)	TAG	Dalny Taganai	1109	tl-e
				NUR	Nurgush	1413	l-alp
				MIR	Maly Iremel	1437	l-alp
				BIR	Bolshoi Iremel	1565	u-alp
RU	**PUR**	Polar Urals	Subarctic (transition between Zb. VIII and IX)	SHL	Shlem	300	tl-e
				SLA	Slantsevaya	417	l-alp
				MPO	Maliy Pourkeu	641	u-alp
				POU	Pourkeu	839	niv
European GLORIA TRs funded by local or national grants							
IT	MAV	Mont Avic - S-Alps	Temperate (Zb. VI)		4 summits established in 2002		
CH	SN1	Swiss N.P./Calcareous - Central Alps	Temperate (Zb. VI)		4 summits established in 2002 and 2003		
CH	SN2	Swiss N.P./Siliceous - Central Alps	Temperate (Zb. VI)		4 summits established in 2002 and 2003		
IT	TEX	Texel - Central Alps	Temperate (Zb. VI)		4 summits established in 2003		
RU	NUR	North Ural	Boreal (Zb. VIII)		4 summits established in 2003		

* zonobiome (Zb) according to Walter 1985; ** tl-e: treeline ecotone; l-alp: lower alpine; l-u-alp: transition from lower to upper alpine; u-alp: upper alpine; an-e: alpine-nival ecotone; niv: nival.

4.1.3 Data input tools (GDIT)

As an inevitable prerequisite for standardised data handling, electronic input tools were produced to facilitate the process of data input of the *GLORIA* target region's field data in an uniformed manner. That means, on the one hand, to provide a way to make the data input quick and user-friendly and, on the other hand, to avoid any inconsistency in the data, within and between target regions, as much as possible. Any data which has to be inserted in the *Central GLORIA Database* has to be consistent according to the *GLORIA Field Manual*, not only for the purpose of performing meta analyses but also to provide clear and exact monitoring data for the future.

The tool was written under *Microsoft ACCESS* using *Visual Basic for Applications*. It includes forms which resemble the protocol sheets in the field manual (Fig. 4.1.c); definition lists for plant taxa and parameter definitions; reports for data output; and checking routines on data consistency. Each researcher responsible for a target region received his own software package. These packages contain taxa definition lists particular to the respective target region; all the other objects and codes are similar for all target regions.

The detailed procedure of data input:

1) Each researcher responsible for a target region (named *partner* hereunder) compiles a species list of all taxa in his regional dataset. This list is sent to the co-ordinator.
2) The co-ordinator checks the taxa list for nomenclature consistency through the whole *GLORIA* dataset. Following, the *GDIT* (*Gloria Data Input Tool*) is produced automatically for the respective target region.
3) The partner can download his personal package from the *GLORIA* website; he installs the software on a computer in his laboratory.
4) After finishing data input for the particular target region, the software checks the dataset for consistency. Warnings are displayed when certain properties of the dataset are weak but tolerable. Errors are displayed when certain properties are illogical, e.g., missing species in a *summit area section* which are present in a corresponding quadrat plot.
5) The partner refines his dataset to solve errors and warnings.
6) After the consistency check succeeded, the partner uploads his dataset to the central *GLORIA* server.
7) The co-ordinator compiles the regional dataset into the *Central GLORIA Database* (see below).

If a partner has to change some entries in his dataset afterwards, a new upload package is created and sent to the *GLORIA* server. There, the complete data of the particular target region are erased, and the new regional dataset is included.

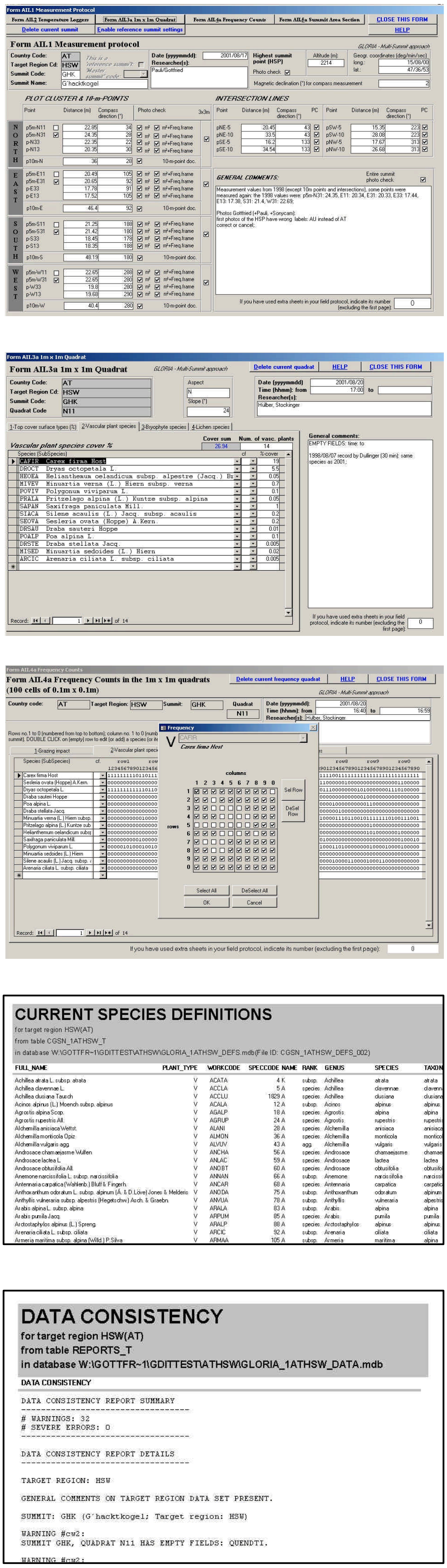


Fig. 4.1c: Some Screens, as examples, of the GLORIA Data Input Tools (GDIT).

This assures that at every time each dataset for a specific target region is identically represented at the *Central GLORIA Database* as well as in the lab of the respective partner.

The electronic tool was stable from the first release. 90% of the partners used it without problems from the beginning. After some debugging, the second release was stable at all machines used in the project.

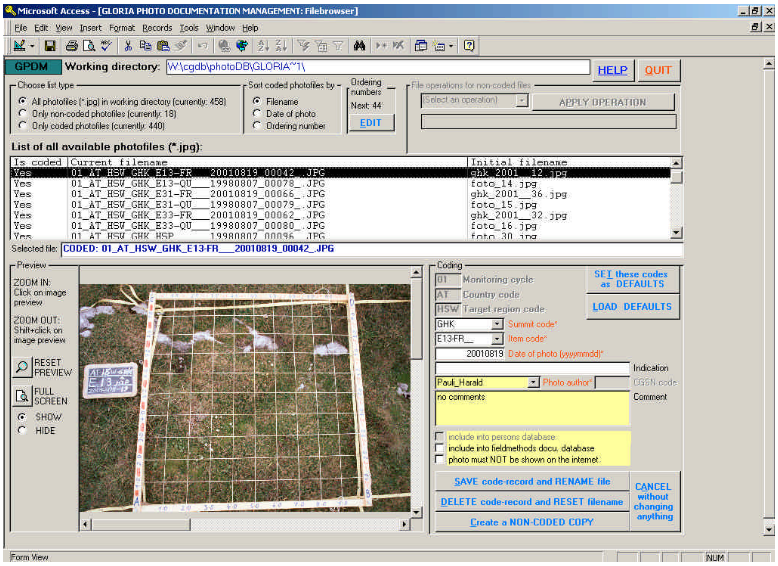
The tools are applicable for future use in the *GLORIA* network. A detailed manual and trial version of the software is obtainable from www.gloria.ac.at/res/downloads/GDIT/.

4.1.4 Photo documentation tool

An exhaustive photo documentation of plots, methods, plants, vegetation patterns, and landscapes plays a central role in the *GLORIA* monitoring philosophy. Sampling plots can be quickly, and precisely, re-installed using photos. Changes in vegetation patterns, when detected using monitoring protocols, can be validated.

Each sampling area, plots as well as summit area sections, positions of temperature loggers, and other motifs, have been photographed in each target region. This gave a current total of 5174 photos, on average 320 per target region.

The photo documentation material was digitally centralised at the *GLORIA* server (Fig. 4.1d). Similar to field data, this required a coherent scheme of coding and naming for images. This was supported by an electronic tool produced in the co-ordinators lab and delivered to each partner. The tool was written under Microsoft ACCESS, versions are available both for ACESS 97 and ACCESS 2000.



The tool allows for viewing and sorting of images, and for a standardised naming and coding. Each partner responsible for a target region scanned her/his photos, coded it using the tool, and sent it on CD to the co-ordinator. The several sets were compiled and are linked to several entries at the *GLORIA* website.

The tool and a manual are obtainable from: www.gloria.ac.at/res/downloads/GPDM_phototool/.

Fig. 4.1d: The GLORIA Photo Documentation Tool (GPDM).

4.1.5 The Central GLORIA database

The philosophy of data storage and maintaining in *GLORIA* is threefold. Firstly, it must be guaranteed that all the data, wherever obtained in the network, are fully compliant to the standards of methods and protocols in the network. This is supported by specific electronic tools, see 4.1.3 and 4.1.4. Secondly, each regional dataset has to be stored in the lab of the respective researches. Thirdly, all regional datasets have to be compiled into the *Central GLORIA Database*. This structure allows for a maximum of data security where each of the data containers, the central and the regional ones, can be replicated after any data damage.

The *Central GLORIA Database* resides on the *GLORIA* server in the co-ordinator's lab. It aims not only on a central data storage (see 4.2) but is also the basis for synoptic analyses (see 4.3) and for data presentation on the World Wide Web (see 4.1.6 and 4.4.2).

Currently, the Central *GLORIA* Dataset (excluding climatic data, see 4.2.4) consists of 15 tables, 401 fields, 51405 records, and about one million entries. The filesize is 10.3 MB. All data are thoroughly linked (Fig. 4.1e), and maintained by several Visual Basic routines.

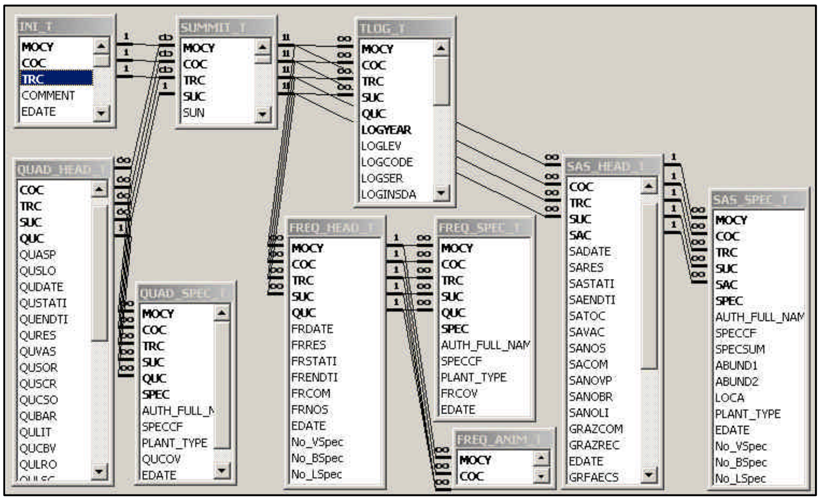


Fig. 4.1e: Relationships between the tables of the Central GLORIA Field Database.

4.1.6 The GLORIA website: the central platform for data and information exchange

From the start of the project, *GLORIA-Europe* was online on the internet. A website was created and maintained at the co-ordinator's server. This website has proofed to be vital for a feasible project management, in terms of data and information exchange between the consortium members, as well as for dissemination of scientific ideas and results (see also 4.4.2). Technically, the website was implemented under Microsoft Internet Information Server 5.0 in combination with Cold Fusion Server 4.5 to execute dynamical webpages. These dynamical pages extract information from several project databases online, which helps to keep the presented information up to date.

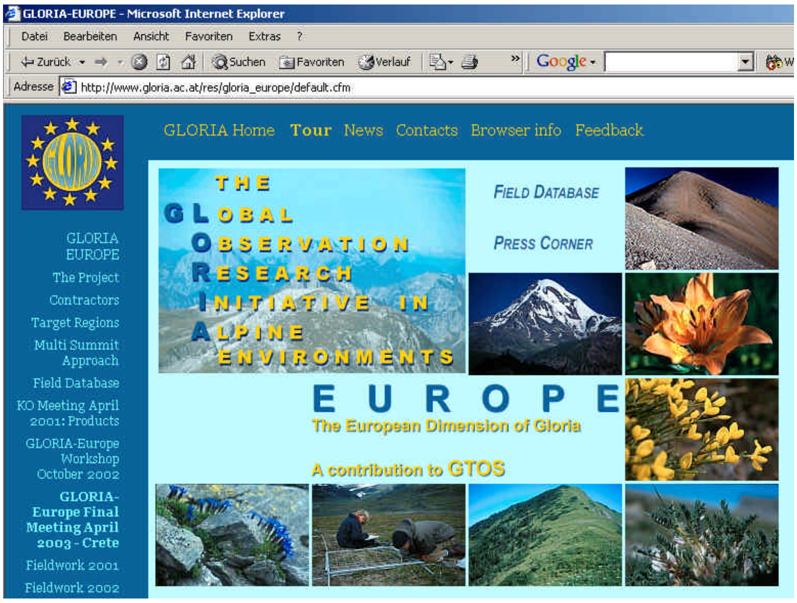
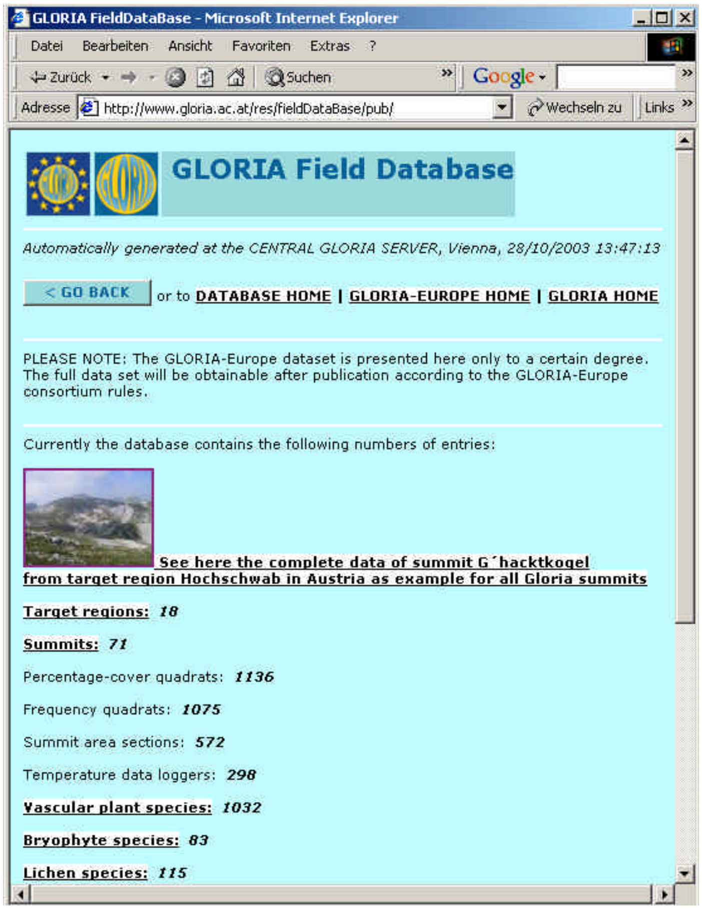


Fig. 4.1f: Start page of the project's website: www.gloria.ac.at/europe.

The website is structured along a number of general themes and aims (Fig. 4.1f): **(a) General project information**: scientific background, contract details. **(b) Administrative information**: addresses of persons involved, meeting announcements and schedules**. (c) Geographical information**: about the target regions. **(d) Data exchange**: via the website, the consortium members were able download various lists and tools for data preparation (see 4.1.3 and 4.1.4). After offline data input they uploaded their data to the website. A download centre was installed to support with various project oriented documents. **(e) Press corner**: various press releases about *GLORIA* are presented here. **(f) Data presentation**: The *central GLORIA database* can be browsed at the website including sampled field data (Fig. 4.1g) as well as the photo documentation. This is achieved by a user management including passwords. To which degree of detail a visitor can obtain field data depends on a hierarchy as stated in the consortium agreement. The concept behind says that any information is released to the public in a stepwise manner after scientific publication by the data owner. Currently, these levels are: (i) an 'anonymous' visitor can read general information about target regions and summits, like geographical position, number of sampled

plots, number of data loggers, etc. He can browse photos of the landscapes, the summits, and of plants of the respective target region.
(ii) Additionally, partner groups which are responsible for a particular target region can browse their own data set. (iii) The co-ordinator and the scientific officer of the EC can browse the full data set. The full dataset consists of information on target regions, summits, plots, plant species sampled in the plots, and any documentary photos on these objects.



To give the 'anonymous' visitor an impression of the structure and amount of data in the field database, one particular *GLORIA* summit was made freely accessible in full detail. This is AUSTRIA – Hochschwab/NE-Alps - G'hacktkogel (AT-HSW-GHK), a 'typical' *GLORIA* summit in the co-ordinators target region.
As stated above, visitors will gain more detailed data access in the future depending on the degree of scientific publication.
GLORIA is an open process, and new network members were and will be connected stepwise. As most of the website's pages are dynamically connected to the various project databases, the website content grows, and is updated, automatically. This constitutes it's valuable future impact for the network. See the website at:
www.gloria.ac.at and the field database at *www.gloria.ac.at/res/fielddatabase*.

Fig. 4.1g: The *GLORIA* field database.

4.1.7 Communication structures and links to other global change networks

GLORIA-Europe has strengthened the co-operation with related global change research networks, programmes, and projects in order to build, respectively to improve, interfaces and to integrate into the wider scope of global change research with its physical, biotic, and socio-economic components.

GLORIA-Europe has built up a close co-operation with the *MRI* (*Mountain Research Initiative*), a multidisciplinary scientific organisation endorsed by the *IGBP*, *IHDP*, *GTOS*. A *Specific Support Action* of the FP-6 of the European Community (*GLOCHAMORE*) is scheduled to start in autumn 2003. *GLOCHAMORE* is co-ordinated by the *GLORIA* team at the *University of Vienna* and will conduct a series of product-oriented scientific workshops and a major open science conference, where an interdisciplinary group of encouraged scientists will look forward to improving our understanding of the causes and impacts of global changes in mountain regions.

Since its start, *GLORIA-Europe* was in communication with the *GMBA* (*Global Mountain Biodiversity Assessment*; a research network of *DIVERSITAS*), a user of data and results for scientific assessments as well as papers for non-experts on the state of the world's mountain biodiversity. A joint conference is planned in the follow-up of the project.

Members of the project consortium are involved in *ITEX* (*International Tundra Experiment*) and have strong links to national and international terrestrial global change research networks, for example to the *UK ECN* (*Environmental Change Networks*) and to *SCANNET* (the FP-5 funded *Scandinavian/North European Network of Terrestrial Field Bases*). *GLORIA* will be directly involved in the FP-6 IP *ALARM* (*Assessing Large-scale Environmental Risks with Tested Methods*), scheduled to start at the end of 2003.

Further it will contribute with know-how to the FP-6 NoE *ALTER-Net* (*A Long-term Biodiversity, Ecosystem and Awareness Research Network*).

GTOS, the *Global Terrestrial Observing System*, established by *FAO*, *ICSU*, *UNEP*, *UNESCO*, and *WMO*, has identified mountain-related climate change research as a priority. *GLORIA-Europe* was endorsed by *GTOS* as one of three mountain-related activities (see: http://www.fao.org/gtos/gt-netMOU.html). *GTOS* is one of the major users of *GLORIA*'s outputs in its function to facilitate access to ecosystem information for researchers and policy makers so that they can detect and manage global and regional environmental change.

The *GLORIA* observation network intends to contribute to *GMES* (*Global Monitoring for Environment and Security*), an initiative under the auspices of the European Commission and the *European Space Agency* (GMES 2003). *GLORIA* actively seeks to support environmental policies by providing data-based scenarios on critical climate-induced biodiversity and habitat losses. For example, for upcoming adaptations of the *EU biodiversity strategy* (COM-42-FINAL 1998) through the *Convention of Biological Diversity* (http://www.biodiv.org; ANDERSON et al. 1999), and for the scientific backing of the *Kyoto Protocol* (UNFCCC 2003). The *DG-Environment* of the European Commission is a potential user of the projects results, as stated by officers responsible for the *EU Biodiversity Strategy*, and for the *FFH-Directive*. The *European Centre for Nature Conservation* (*ECNC*) and the *European Environment Agency* (*EEA*) consider *GLORIA* as European site-based biodiversity monitoring network which may be used to support environmental policy needs (DELBAERE 2003).

4.2 Datasets of GLORIA-Europe

4.2.1 Surveying data for plot repositioning

The principal measurement point for positioning the permanent plots is the *Highest Summit Point (HSP)* which was permanently marked and photographically documented (see 4.2.3).
The position of the permanent plots (four 3x3m quadrat clusters and 8 *summit area sections* per summit; compare Fig. 4.1a) were determined by the distance of each corner point from the *HSP* (in centimetres) and by the direction (points on the compass; 360scale) as seen from the *HSP*.
This yielded 24 distance values and 24 direction values obligatory measurement values per summit. In total, 3456# single surveying values are compiled in the central database.

These values are essential to
(1) draw a detailed outline of the particular sampling design of each summit; this is used for two purposes: the re-establishing of plots, and to calculate the area of the *summit area sections*;
(2) determine the directions and the exact plot locations for the future reassignment; this is of particular relevance in cases where it is not possible to re-establish the plots by using photographs (e.g., due to severe disturbance events or due to unexpectedly pronounced changes in vegetation cover).

4.2.2 Photo data

A careful photo documentation is crucial for the accurate and fast reassignment of the plots and for documenting the whole visual situation of the 1x1m quadrats. For the photo documentation it is vital to keep exactly on the *GLORIA* coding scheme (see the *GLORIA Field Manual*).

The following items are obligatory for the photo documentation:
- the highest summit point; all corner points of the 8 summit area sections;
- the four 3x3m quadrat clusters (overview photos); each of the 16 one-m² quadrats was photographed twice (one without, and one with the frequency grid frame mounted);
- the position of the temperature data loggers (open hole and buried 10cm below soil surface);
- overview photos of the summit site

This yielded around 80 photographs per summit and approximately obligatory 5000 photos in total. All photos are archived in digital versions in the central database (see under 4.1.4: photo documentation tool).

4.2.3 Data of biotic and abiotic parameters

Data from all 18 *GLORIA-Europe* target regions were compiled in the *Central GLORIA Database* (see 4.1.5). Data input was carried out by the partners of the particular region by using electronic input tools (see 4.1.3). On each of the 71 observation summits, the following data were recorded. The total numbers of entries currently available in the database, separately for each particular item, are indicated.

Summit area sections (572)

- **Complete list of plant taxa** on the species or sub-species level (vascular plants obligatory; bryophytes and lichens optional); vascular plants *(14568)*, bryophytes *(543)*, lichens *(1661)*;
- **Percentage cover of each taxon** *(16727)*;
- **Total percentage cover** of vegetation, and of vascular plant vegetation separately *(1054)*.

One-m² quadrats (1136), see Fig. 4.2a

Biotic parameters:

- **Complete list of plant taxa** on the species level or sub-species level (vascular plants obligatory; bryophytes and lichens optional); vascular plants *(10834)*, bryophytes *(716)*, lichens *(2712)*;
- **Percentage cover of each taxon** *(15398)*;
- **Total percentage cover** of vascular plants and of plant litter in the whole plot *(2272)*;
- **Total percentage cover** of cryptogams, recorded separately on different substrate types: below vascular plants, on soil not covered by vascular plants, on solid rock, and on scree *(4544)*;

Fig. 4.2a: A 1x1 m quadrat, with mounted frame for frequency sampling.

- **Total vegetation cover in the plot**: as sum of the different categories listed in the two rows above *(1136)*;
- **Frequency** of each taxon (by dividing the quadrat into 100 cells); *219580* presences of vascular plants, *14990* presences of bryophytes, *31287* presences of lichens;
- **Frequency of grazing-related features** (faeces, browsing damage, trampling). *4775* presences;

Abiotic parameters:

- **Aspect** (compass direction), averaged for the plot *(1136)*;
- **Slope**, averaged for the plot *(1136)*;
- **Percentage cover** of **solid rock** *(1136)*, **scree** *(1136)***,** and **bare ground** *(1136)***.**

The total number of entries in the dataset of biotic and abiotic parameters amounts currently to ***349568***. The sampled climatic data, which in fact are abiotic parameters as well but measured with a different protocol, are described in the following chapter.

4.2.4 Climatic data

Any climate impact monitoring of environmental units needs a fundament of direct climate observations. There are principally two options to perform these. Either one can do sophisticated measurements, sampling several climatic parameters on a technically high standard. This implies expensive equipment like automatic weather stations. Especially in a network consisting of many sites (in *GLORIA-Europe*, 71 summit sites were observed) this would be extremely costly; in consequence, climate sampling sites would have to be reduced.

Or the climate measure-ment network is based on a simple protocol with the advantage that many sampling devices at geographically widespread positions are affordable.

Fig. 4.2b: Temperature loggers used in GLORIA-Europe.

The climate measure-ment protocol of *GLORIA* is based on the latter scheme.

As sampling devices, miniature data loggers (Stowaway Tidbit -20+50) were used (Fig. 4.2b). These devices have the following properties: they measure temperature at an accuracy of +/- 0.2 K, they are small (coin-sized), sealed in epoxy and therefore extremely robust, and, last but not least, they are cheap.

In total, 292 loggers were installed in the first field season, four of these on each summit site. They were located at the centres of each 3x3 m quadrat cluster (see Fig 4.1a). In four target regions, an additional logger was installed at the Highest Summit Point (HSP), to draw comparisons between the distinct summit situation and the slopes.

The devices were programmed in the co-ordinator's lab for a sampling rate of one hour, then delivered to each partner. They were buried in the soil in 10 cm depth. The loggers have proved to be extremely robust; only four devices showed malfunctions.

After a one-year measurement period, data were read out and uploaded to the central *GLORIA* server. At the same time, a new set of loggers was installed in the same positions to measure the future climatic development at the study sites.

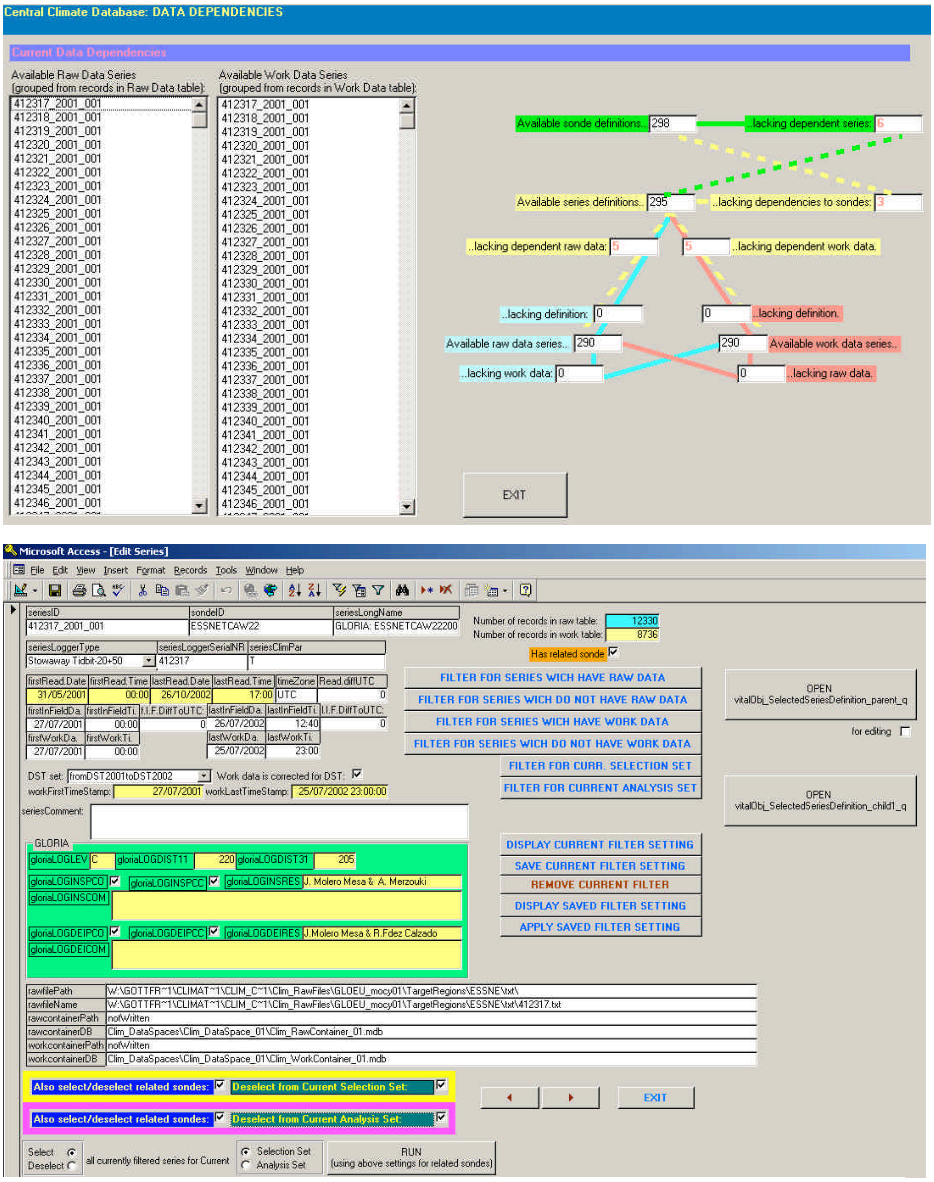


Fig. 4.2c: An administrative pages of the Climate Database.

The temperature series were compiled in a climate database written in the co-ordinator's lab to serve for the particular demands of analyses (Fig. 4.2c). This software includes several data correction routines, e.g., for daylight saving time which is tracked by the loggers in it's pre-settings of the manufacturer, and to cut counts prior and after installation period in the field. Secondly, a number of indirect climatic indices is calculated by the software, including: T means for years, months, and weeks; length of the snowy period which can be derived from the shape of the temperature series; length of the growing season, as a combination of several properties of the T series; T parameters during growing, and non-growing, season. These parameters serve as input for the several subsequent analyses of climate alone, and in combination with the observations of biotic units (see 4.3). Currently, the climate database comprises 2,746,460 T counts, on average 152,500 per target region and 9,470 per logger, as well as a number of tables with derived parameters (see above). With that, it is the spatially most detailed consistent dataset of Europe's alpine climate currently available. It is not only the basis for several analyses within the reported project itself but will be also input to other activities and projects, e.g., the FP-6 Integrated Project *ALARM*.

4.3 Scientific results

This chapter provides a brief overview about the data analysis for continent-wide and regional comparisons of biotic and climatic data. A number of publications to be submitted to peer reviewed scientific journals are in preparation.

4.3.1 Europe-wide comparison of mountain phytodiversity

Vascular plant richness in the target regions: In all 18 target regions together, 991 vascular plant species were found – around 1/3 of Europe's alpine flora (compare VÄRE et al. 2003). Striking differences of vascular plant species richness were observed across the main mountain systems of Europe (see Fig. 4.3a). The number of species per target region ranges from only 14 in the Scottish Cairngorms (UK-CAI) to 198 species in the Dolomites, Southern Alps (IT-ADO). There is no north-south gradient in species richness, but a maximum in the carbonate parts of the Alps (IT-ADO and AT-HSW), followed by the northern Apennines (IT-NAP). Surprisingly, the mediterranean target regions do no not show higher species richness than the boreal and subarctic regions. This contrasts with the overall species richness in mediterranean countries (Greece, Italy or Spain), which is 2.6 to 4.4 times higher than in the Scandinavian countries (Norway, Sweden); compare http://www.ecnc.nl/doc/data/species.html.

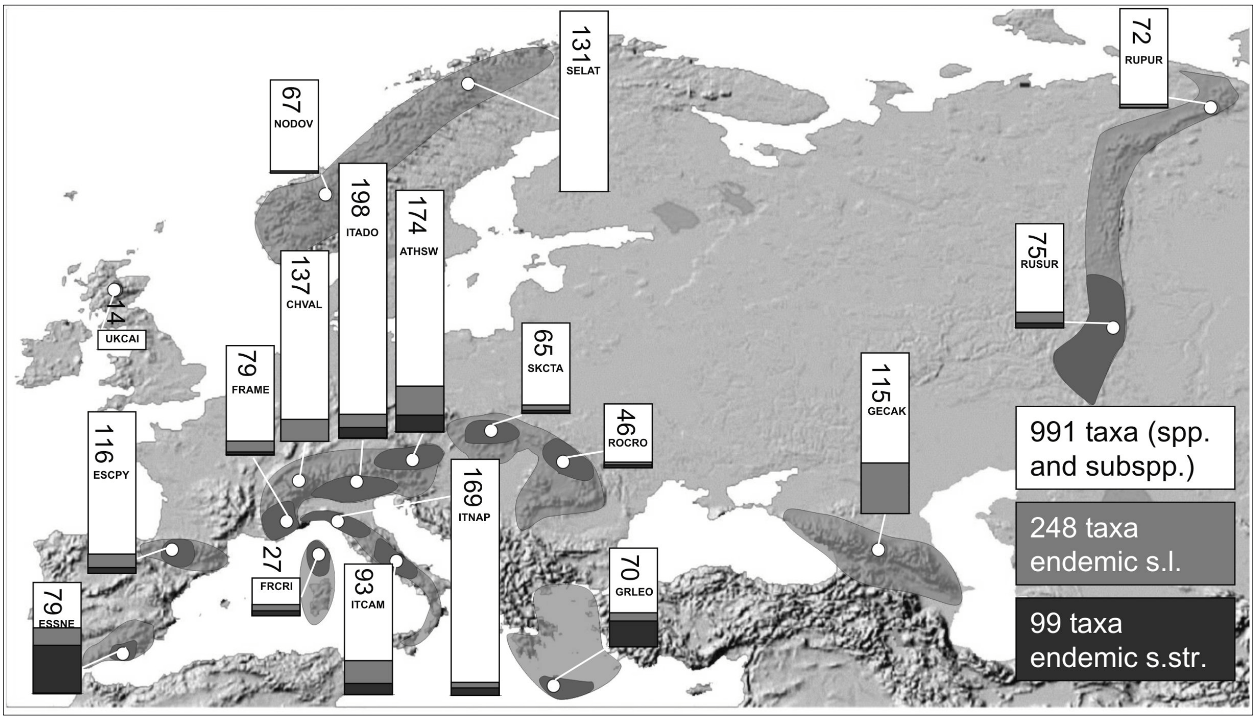


Fig. 4.3a: Vascular plant species richness and endemism in the 18 target regions. Columns show the number of taxa in each target region (taxa found on all four summit sites). The proportion of endemic taxa sensu lato is indicated in grey, of endemics sensu stricto in dark grey. The areas to which endemism is referring to are shown on the map in grey shades for sensu lato, and in dark grey for sensu stricto endemism.

Elevation gradients of vascular plant richness: In most target regions, species richness decreases with altitude (Fig. 4.3b). This is, of course, most pronounced in those target regions which show the large elevation differences between the summits and which extend from the treeline to the alpine-nival or the nival zone. Such a gradient is less pronounced or not obvious in the regions which only reach the alpine zone and are inverted in the northern Apennines where the highest summit lies in the lower alpine zone and the elevation difference from the lowest to the highest summit is only around 250m. Over all data, the number of species decreases discontinuously from the treeline ecotone to the nival zone (Fig. 4.3c). Species richness increases again at transition zones or ecotones where elevation zones overlap or remains stable until the transition zone is crossed. This is in consistence with regional studies and models from the Alps (GRABHERR et al. 1995; GOTTFRIED et al. 1998).

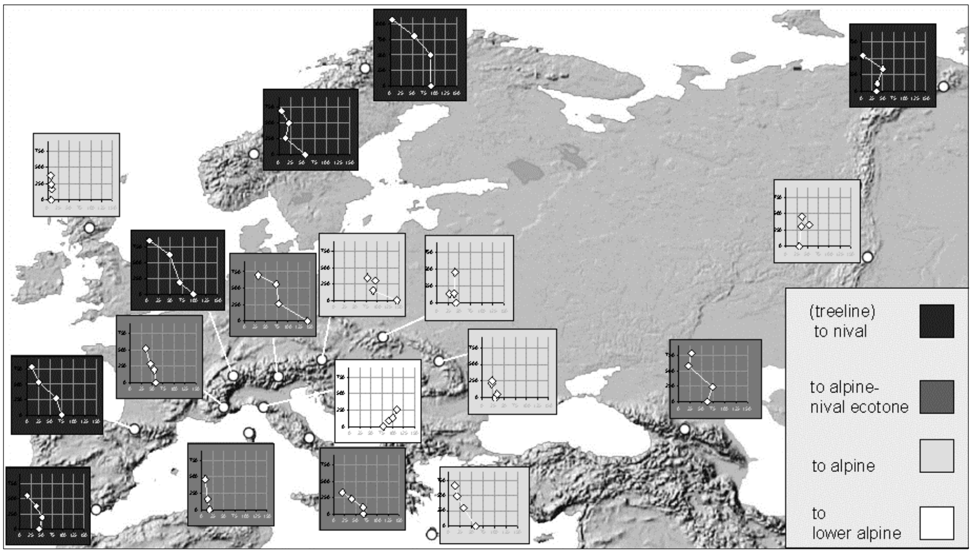


Fig. 4.3b: Vascular plant species richness along the elevation gradient in the 18 target regions (TRs). The diagrams show the number of species and the relative elevation of each observation summit per target region. X-axis: number of species 0-150 spp.; Y-axis: relative elevation 0-1000m (0 = the altitude of the lowest summit). Most TRs with a pronounced elevation range show a clear decrease of species richness with altitude. The opposite is the case in the TR with the narrowest elevation range.

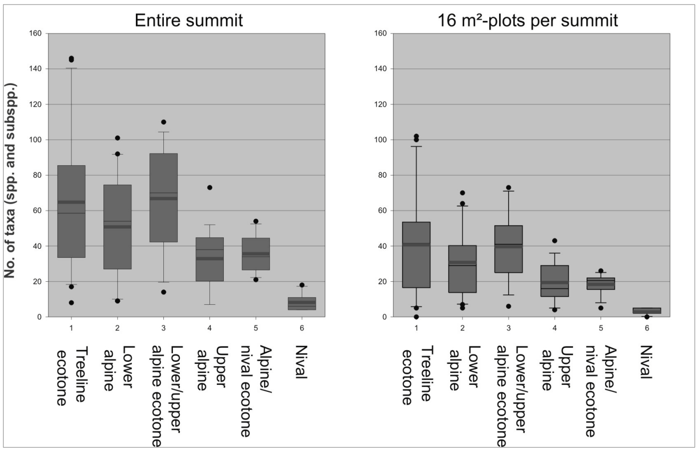


Fig. 4.3c: Species richness on summits of different altitudinal vegetation zones; left: number of species in the entire summit areas; right: number of species found in the 16 permanent 1x1m quadrats per summit. Box plots show the percentiles and means for each elevation zone (thick line: arithmetic mean, thin line: median, boxes: the upper and lower quartiles, whiskers: the 10th and 90th percentiles). Species richness does not decrease continuously, but shows peaks at ecotones between the zones.

Aspect gradients of species richness: a remarkable result yielded from the comparison of main compass directions of each of the 71 summit sites. Notwithstanding the assumption that the southern aspect (on the northern hemisphere) is the most favourable side of a mountain for species richness, it turned out that this is the case for the eastern aspect. This was significant by comparing the summit area sections as well as when comparing only the four 1 m² quadrats positioned in each direction (Fig. 3.4d). The eastern sides may be more favourable, because insolation is there from the beginning of the day. The daily active period for plants is therefore longer compared to south, west and, north. Thus not, or not only, the total supply of solar energy appears to be of particular relevance for plant life in temperature-limited environments, but the length of the period where threshold temperatures are exceeded.

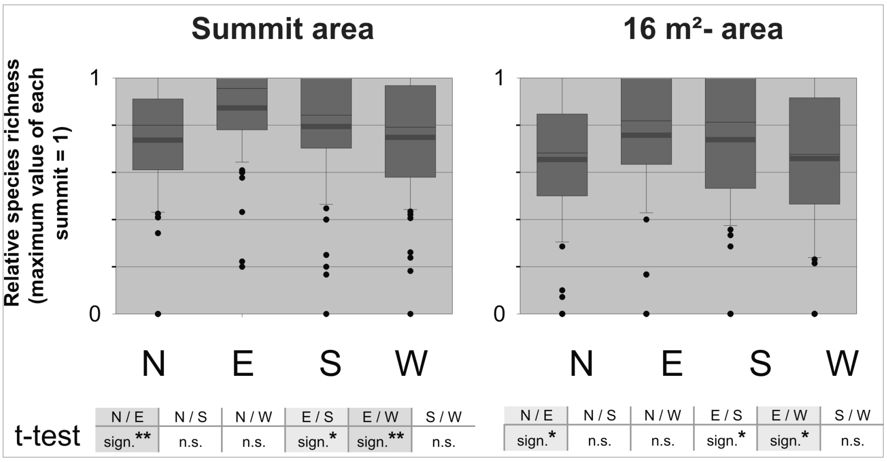
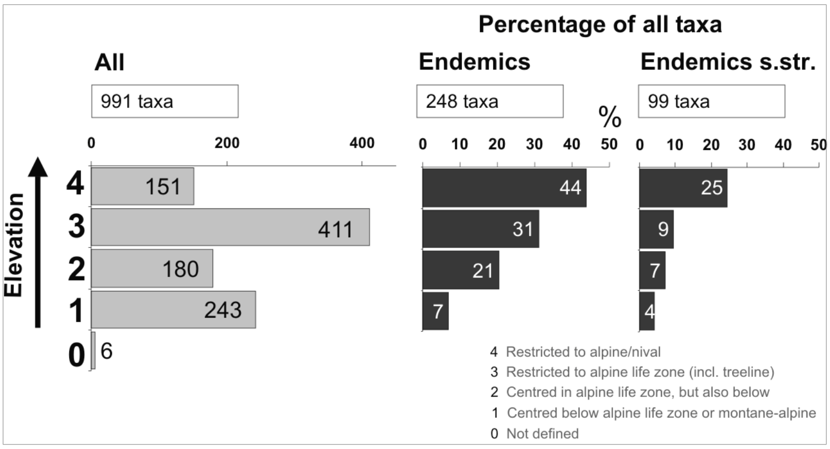


Fig. 4.3d: Comparison of species richness between the main direction of each of the 71 summits; left: number of species in the entire summit areas; right: number of species found in the 16 permanent 1x1m quadrats per summit. Box plots show the percentiles and means for each elevation zone (thick line: arithmetic mean, thin line: median, boxes: the upper and lower quartiles, whiskers: the 10th and 90th percentiles). In both cases, highest species richness was observed at the eastern sides of the summits.

Vascular plant endemism in Europe's mountains: From the 991 taxa, 248 are restricted to a single mountain system and 99 taxa only occur within parts of a mountain system (Fig. .4.3a). In contrast to the overall species richness of vascular plants, a clear gradient from low of even absent endemism in the north to high endemism in the south is indicated (Fig. 4.3a).

Elevation gradient of endemism: Endemic species are not only restricted to small areas but also to narrow elevation ranges. Moreover, most of these species have their centre of distribution in the uppermost elevation zones (Fig. 4.3e). This became obvious by comparing all *GLORIA-Europe* species by their altitudinal amplitudes as known from the literature; it is assumed to be a general trend throughout Europe's mountains. The increase of the proportion of locally distributed species was yet significant when comparing the distribution of vascular plants over the four summits in each target region (Fig. 4.3f). On the other hand, the elevational distribution patterns of endemics show pronounced differences as a consequence of their geographic and orographic isolation since the Pleistocene (compare PAULI et al. 2003a).

Fig. 4.3e: Altitudinal distribution ranges of the 991 taxa of the *GLORIA-Europe* target regions compared with the altitudinal ranges of endemic taxa. Elevation ranges of taxa were obtained from literature data. Endemics show a striking tendency towards a narrow distribution in the uppermost elevation zones.



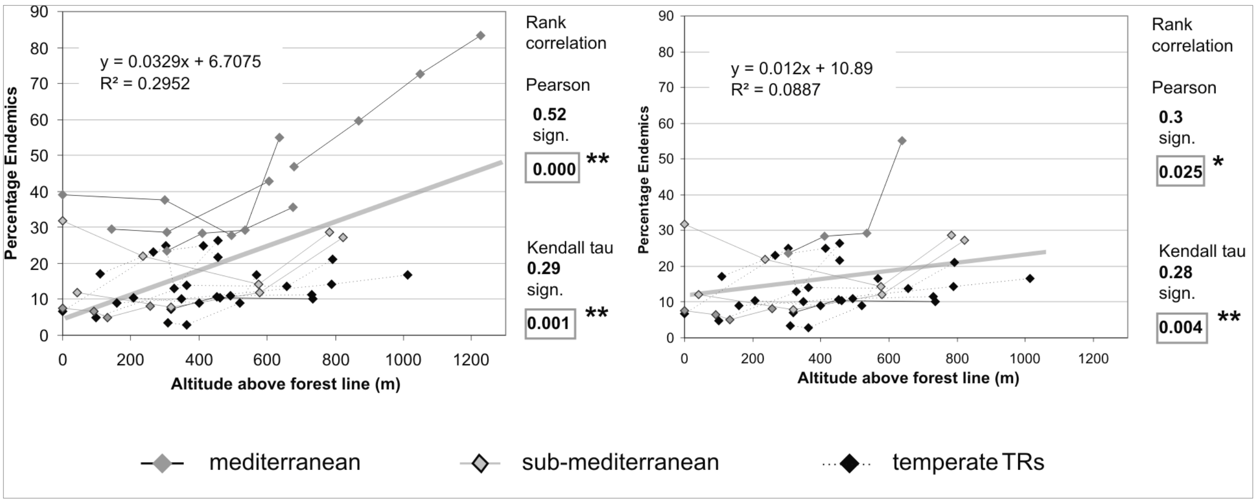


Fig. 4.3f: Percentage of endemism along the elevation gradient referring to the total vascular plant species richness on each summit site. Left: all target regions (TRs) where endemic taxa occur; right: excluding the orographically isolated TR Sierra Nevada and the geographically isolated TRs on islands (Lefka Ori and Corsica).

The regional differences in endemics's altitudinal distribution is shown along six examples (Fig. 4.3g). Target region NO-DOV in the central Scandes shows only one endemic species, but which is distributed over large parts of the Scandes. This reflects the almost complete ice-coverage of the nowadays alpine Scandinavia, where almost no plant was able to withstand the severe Pleistocene conditions in higher elevations. In the central Alps (TR CH-VAL in the Swiss western Alps), the situation during the ice age might have been similar, but refugia may have been in a distance that a few Alps'-wide endemics were able to re-colonise high elevations, while they disappeared in lower altitudes (compare STEHLIK et al. 2001; SCHÖNSWETTER et al. 2002). In the outer ranges of the Alps (e.g., in TR AT-HSW in the northeastern Limestone Alps), endemics, including species with narrow distribution areas, were found in higher percentages which increased with altitude – at least until the second highest summit. This target region lies in an area which was only partly ice-covered in the Pleistocene, and thus provided more extensive habitats for plant survival. The situation within mediterranean alpine regions shows differences due to historic and current isolation. The central Apennines (TR IT-CAM) and particularly the Sierra Nevada (TR ES-SNE) are not only currently small alpine patches in the large surrounding of montane and lowland regions, but are likely to have been isolated also during the ice age. Therefore, many of the mountain plants are endemics, particularly those of the high elevations. The high peaks of such regions function as "orographic islands" for mountain biota, isolated by low-temperature conditions. In mountain systems on actual islands (e.g., TR GR-LEO on Crete), the percentage of endemics is again high, but is mainly caused by the geographic isolation; no elevation gradient was observed.

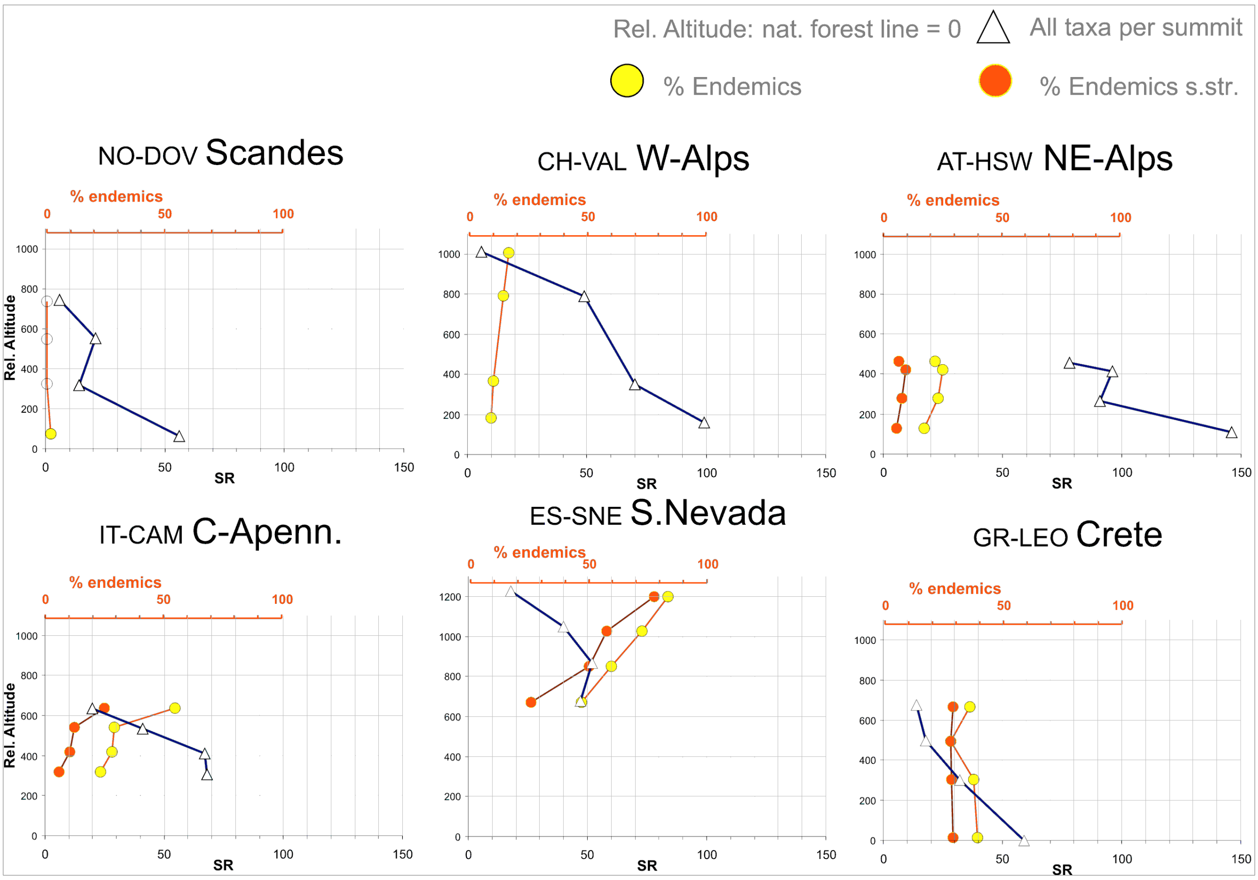
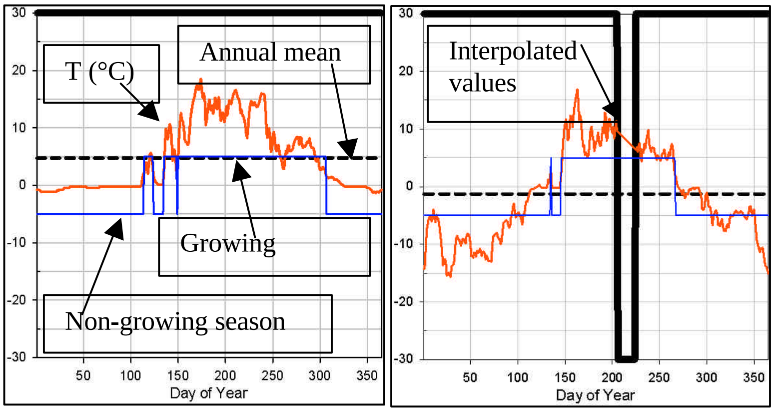


Fig. 4.3g: Examples of endemics/total vascular plant species richness along the elevation gradient. Y-axis: relative altitude (0 = the elevation of the potential natural forest line); bottom X-axis and triangles show the number of species per summit; top X-axis and circles show the percentage of endemics and separately of endemics sensu stricto.

4.3.2 The alpine climate across Europe

To date, only a few spatially detailed accounts on Europe's mountain climate are available, especially for the zone above treeline. KÖRNER et al. 2003 gave a comparison of the alpine bioclimate measured at 23 positions, each about 200m above the climatic treeline. Their results show that the alpine bioclimates of European alpine zones are highly comparable. In *GLORIA-Europe*, we present an analysis which defines bioclimatic envelopes for different levels of the full elevation range above treeline, i.e., the treeline ecotone, the lower and the upper alpine, and the nival zone, derived from 292 positions in total. This report gives an overview; detailed scientific publications are in preparation. The data serve not only for a bioclimatic description alone but for explaining observed species and vegetation distribution patterns, e.g., the differences in species richness in the elevation gradient, and it's peculiar differences between main compass directions, as reported under 4.3.1. They are crucial for any risk assessment for the development of biodiversity in Europe's high mountains (see 4.3.4).



The data were aggregated on different levels. The annual series of each logger position gives information of the temperature course and of the length of the growing season. Missing data (if a logger was excavated at an earlier day of 2002 than installed in 2001; only at a view sites) were interpolated. From the oscillation of the temperature series, one can infer whether the logger was below snow (Fig. 4.3h, left), or if soil was deep frozen during winter (Fig. 4.3h, right).

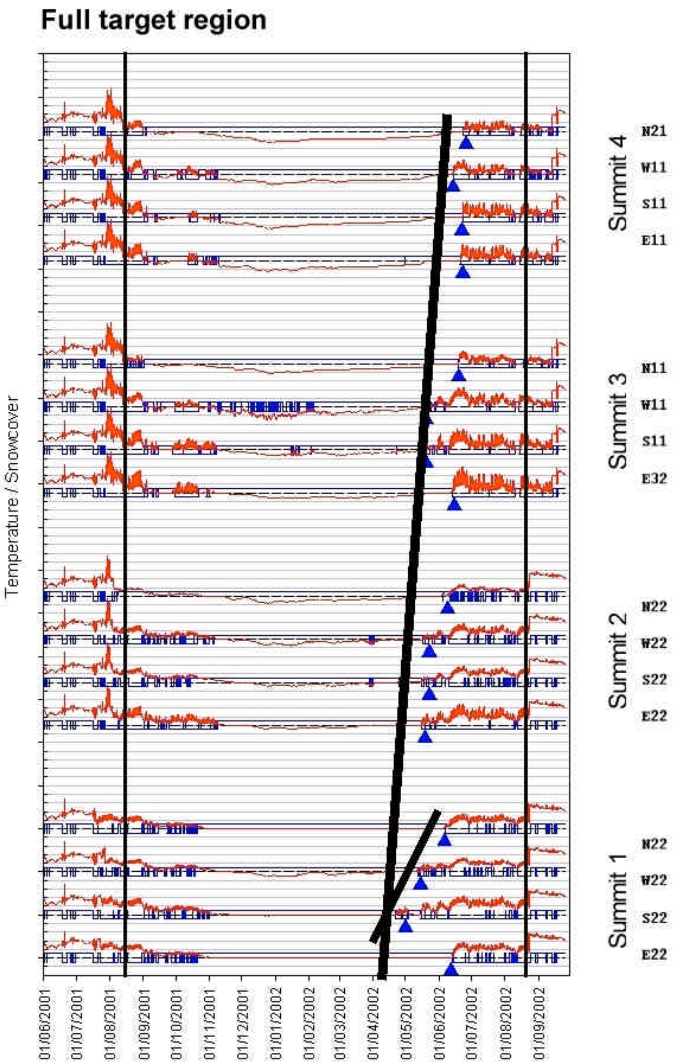


Fig. 4.3h: Time series of climatic parameters: temperature and growing season. Above: two examples of particular loggers; left: a plot where the soil was not deeply froozen in winter; right: a plot with heavy soil freezing in winter. Below: climate series from a full target region. Summit 1 is the lowest and summit 4 the highest one. On each summit, for loggers measured T in the four main wind directions. Short black line: the snowmelt gradient from S to W to N. Long black line: the snowmelt gradient from the lowest to the highest summit.

Target region overviews show climatic gradients, e.g. of snowmelt (Fig. 4.3h, below) along different aspects and along different summits of the region.

The highest level of aggregation, i.e., comparing data from all 18 target regions, gives insight in the climatic envelopes of the different vegetation belts of Europe's alpine zone (Fig. 4.3i). The original figure was presented at the *GLORIA* kick-out meeting in Crete 2003. The content in the graph shown here is reduced because the full data's publication is in preparation.

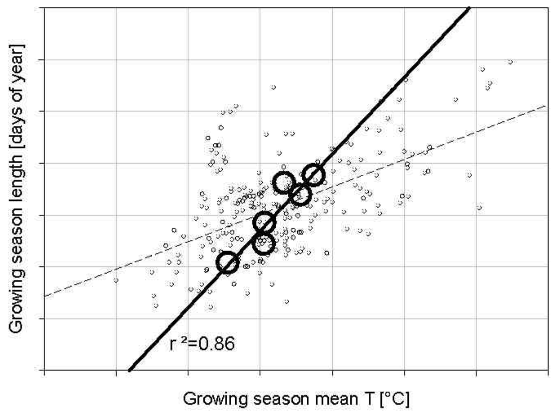


Fig. 4.3i: Bioclimatic characters through the full spatial range of GLORIA-Europe. Small dots: all loggers (71 summits, four loggers per summit). Wide circles: centroids of groups of summits after categorising them into vegetation belts (from treeline ecotone to the nival zone). Data not published, therefore axes scales and symbol descriptions of the graph are masked.

However, Fig. 4.3i shows the following: (a) the good correlation between the two most important climate indices of summits (small dots) which are the length of the growing season, and the mean temperature in this period. (b) When grouping the several summits into vegetation belts and calculating the centroids of these groups (wide circles), one can see the almost perfect correlation of these indices when averaged for each single vegetation belt. The bioclimatic envelopes from the treeline ecotone up to the nival belt can be precisely described from the data behind this figure.

4.3.3 Regional accounts on phytodiversity and the corresponding bioclimate

These analyses from the particular target regions provided valuable insights into the regional differences of biodiversity and climatic gradients. Although general trends were observed across the continent, striking regional peculiarities let assume differential climate-induced effects regarding their impact and the consequences for future high mountain biota. Some publications have already appeared, others are in submission or in preparation.

TR ES-SNE – Sierra Nevada (J. Molero-Mesa, A. Merzouki & R. Fernandez): This mountain region is a prime example for high mountain plant endemism and for alpine ecosystems at high risk of potentially severe impacts caused by climate warming. For details see PAULI et al. 2003a and subchapter 4.3.4; for endemism and species rarity see BLANCA et al. 1998; MOLERO MESA 1998; BLANCA et al. 2002.

TR ES-CPY – Ordesa / Central Pyrenees (L. Villar & J.L. Benito Alonso): Regional analysis focused on the impact of mountain pasturing and grazing impacts by wild ungulates. The lowest summit 2242m a.s.l. was heavily affected by sheep and goats grazing (67% of the 1600 frequency cells showed browsing damage; 31% had faeces); the mediate summit site (2519m) was much less impacted by sheep and chamois (10% browsing; 3% faeces), while the high summits (2779 and 3022m) showed only very occasional impacts by chamois (VILLAR & BENITO ALONSO 2003). Europe's high mountains are certainly less affected by land use than low elevations. Yet, pronounced local and regional differences became obvious as shown above. Grazing impacts can mask climate-induced impacts, but they can be quantified by the method used.

TR IT-CAM – Majella / Central Apennines (A. Stanisci, G. Pelino & C. Blasi): Annual mean temperature differences were between 3.11°C at the lowest and 0.03°C at the highest site. The treeline and lower alpine sites are expected to be more prone to invasion caused by climate warming through upward migration of thermophilous low-elevation plants; particularly at their warmer eastern sides. A critical situation is assumed for the low alpine zone, where treeline species are already present. A sustained temperature increase of only 1.5°C is expected to lead to drastic reductions of alpine habitats and consecutive species losses. The *GLORIA* observation sites at Majella are linked to regional gradient and phytodiversity studies (STANISCI et al. submitted).

TR IT-NAP – Northern Apennines (G. Rossi, M. Tomaselli, L. Bertin, R. Dellavedova & M. Gualmini): The region only shows a narrow alpine zone which does not exceed the lower alpine level. An uncommon increase of species richness with altitude was observed. This lower species richness at the treeline is explained by dominating Vaccinium species causing plant communities poor in species, while the highest elevations showed ecotonal situations supporting a higher plant diversity. Further, correlation between aspect, surface area and species richness was analysed, where W sides generally showed the highest richness; this was related to geomorpological peculiarities of the region (see also BERTIN et al. 2001).

TR GR-LEO – Lefka Ori / Crete (G. Kazakis & D. Ghosn): Diversity indices and vegetation cover decreased drastically with altitude, reflecting the extreme alpine condition in mediterranean calcareous environments with low winter temperatures and exceptionally dry conditions during summer. The percentage of endemic flora remained almost stable along the altitudinal gradient. A cluster analysis for species similarity showed high relationships among the higher sites contrasting with the treeline summit.

TR FR-CRI – Monte Cintu / Corsica (L. Nagy): The region is characterised by an extremely steep geomorphology with predominantly rocks and screes – thus it was exceptionally difficult to find appropriate summit sites for monitoring and therefore only three sites could be established. These summits show a pronounced decrease of species richness with altitude as well as of the mean annual temperature (5.6, 4.9, and 2.7 °C on the highest summit) and of the minimum temperatures (-8.3, -11.4, and –12.3, respectively). As optional activity and as alternative to the fourth summit, snowbed permanent plots were established along an altitudinal gradient (2200-2350m). In this mainly bare environment, snowbeds are the most densely populated patches and are considered to be sensitive to climate warming, particularly concerning changes of the date of snow melt.

TR FR-AME – Mercantour / SW-Alps (J.-L. Borel, M. Sintes & P. Ravanel): The four summits established show typically a decreasing species richness from the upper reaches of the treeline ecotone to the alpine-nival ecotone. The SW-Alps are known to be richest part of the Alps for endemic plants. Yet, this is not reflected in the summit data. In contrast to other mountains, e.g. the NE-Alps or the Sierra Nevada, many endemics of this region are centred at the treeline or below.

TR CH-VAL – Entremont / Central W-Alps (J.-P. Theurillat, P. Vittoz, M. Vust, J. Kissling, S. Marie): Besides vascular plants, bryophytes and lichens were recorded on the species level (VUST et al. 2001). A comparison of vascular species and lichens showed that the latter are less influenced by elevation. Lichens didn't show a pronounced difference in species richness and similarity along the elevation gradient. In contrast, vascular plants did, and thus are much more related to temperature, the main factor changing linearly with altitude. Lichens appear to be mostly determined by micromorphological processes, air humidity, and by competition with vascular plants – they can grow at all elevations as long as vascular plants are limited.

TR IT-ADO – Dolomites / S-Alps (B. Erschbamer, M. Mallaun, P. Unterluggauer): This region showed the highest vascular species diversity (198 species). It was compared with the petrologically similar TR AT-HSW (Hochschwab / NE-Alps; 174 species). Both showed a clear decrease of richness with elevation, but less pronounced at the latter due to the smaller altitudinal range. Species similarity between the two lowest sites of the two different TRs was higher than between all summits within a TRs. This shows the importance of elevational diversity gradients which are more pronounced than geographical gradients between the north and the south of the Eastern Alps. Further, a Detrended Correspondence Analysis (DCA) surprisingly showed that heterogeneity between the four main compass directions was considerable at the lowest summits, compared to the higher sites.

SK-CTA – High Tatra / W-Carpathians (P. Barancok, R. Kanka, J. Kollár, J. Oszlanyi & M. Varšavová): Species richness among the summits was not markedly different, although the altitudinal range from the lowest (upper treeline ecotone) and the highest summit (alpine-nival ecotone) was more than 450 m. A DCA showed, as expected, the greatest difference in species composition (in the m^2 quadrats) between the highest and the lowest summits; though, strikingly, the difference between the north and west sides among the altitudinally contrasting summits was particularly low. This suggests that exposition effects can override elevation effects even when comparing treeline and subnival habitats.

TR RO-CRO – Rodna Mountains / E-Carpathians (G. Coldea & A. Pop): The most important factor determining species richness was altitude; the number of species on the two lower summits (between treeline and lower alpine zone) was higher than those of the two high sites (alpine zone). Three endemic species were found at the high sites. Soil temperature were lowest in the northern sides, being 1-3°C lower than in the east, south and west; temperatures in 10 cm below surface dropped below zero (-3°C) on the highest peak even in summer. On the high summit's eastern and surprisingly also the northern slopes, the number of species was higher compared to west and south (see also COLDEA & POP 2003). As the colder north exposed habitats showed lower vegetation cover, they might be preferred sites of less competitive cryophilic species.

TR GE-CAK – Kasbegi / Central Caucasus (G. Nakhutsrishvili): Among the 115 vascular species found at the Caucasian *GLORIA* sites, 32% are endemic to the Caucasus. This high percentage is only exceeded by mediterranean mountains such as the Sierra Nevada or Crete. Endemic species are found from the alpine to the nival zone, but also at the treeline ecotone with narrow elevation amplitudes. Rare subalpine mesophyllous species are considered to be at high risk to get extinct in consequence of increasingly dry and cold winters and hot summers with low precipitation. Soil temperatures showed that particularly the lowest (subalpine) summit was unprotected by snow during winter at all four directions – thus all habitats were exposed to frost. Moreover, an increase of the annual temperature (by about 1°C) and a decrease of precipitation (by about 160mm) was detected by comparing 1960-1970 data with records from 1980-1990 and 1997-1999.

TR UK-CAI – Cairngorms / Scotland (N. Bayfield): The four granite summit sites range from 700 to 1100 m a.s.l. With only 14 vascular species, richness was lowest among all target regions and no pronounced species richness gradient was found along the altitudinal gradient. The summits are linked to the extensive UK Environmental Change Network which has a site in this catchment area. Additional activities focused on statistical power testing for future monitoring.

TR NO-DOV – Dovrefjell / Central Scandes (J. Holten, O. Michelsen & H. Hytteborn): Total vegetation cover, total cover of vascular plants, and vascular species richness were decreasing with altitude; this trend was most pronounced for vegetation cover. Shrubs and dwarf shrubs were the dominant growth forms at the lower elevations above podsolic soils extending to about 1400m a.s.l.; graminoides were increasingly important at the higher summits. Bryophytes and lichens, both were inventored on all summits, showed no difference in species richness along the altitudinal gradient. Their distributions appeared to be more dependent on humidity and snow cover (compare also TR CH-VAL, where lichens showed a similar trend), while vascular plant richness seems to be mainly controlled by thermic factors which are closely related to elevation (summer temperature, length of growing season).

TR SE-LAT – Latnjajaure / N-Scandes (U. Molau & P. Larsson): Despite the far north location, species richness was unusually high for the Scandes (131 species; in the central Scandes, TR NO-DOV above acidic gneiss bedrock, only 67 species were recorded) and is even high in a Europe-wide comparison (see Fig. 4.3.a#). This is most likely owing to the mica schists with prominent layers of dolomites, building the predominant bedrock. In spite of the high richness, non of the species is endemic to the Scandes. Vascular species numbers decreased markedly from the two low summits to the second highest and particular to the highest (nival) peak. Bryophytes and lichens were inventored at the two mid-altitude sites; they showed also a decrease in species richness, but less pronounced than the vasculars; the lichens in particular. The *GLORIA* summits at Latnjajaure are embedded in a major ecological field station which includes field experiments (ITEX open top chambers; exclosures), seed bank and propagation studies, vegetation mapping and studies on tundra landscape dynamics, among others.

TRs RU-SUR – South Urals and RU-PUR – Polar Urals (P. Moiseev, D. Moiseev, S. Shiyatov, O. Moiseeva): It was found that soil temperatures during the growing season are higher on the S and E sides, compared to W and N; this difference was more pronounced in the Polar Urals than in the South Urals. On wet soils, temperature was lower than on dry soils. In the Polar Urals, alpine to nival species predominated (61%), while in the S-Urals, montane to treeline species (56%) were more important. More than 1/4 of the species have both TRs in common. Among the differing species in the S-Urals are some endemics and Pleistocene relict species who were migrating from Europe to the southern part of the Urals and to southern Siberia, while many of the Polar Urals' species are representatives of the zonal arctic flora.

4.3.4 The regional differences of potential risks of climate-induced biodiversity losses

Any realistic scenarios and risk assessments on climate-induced biodiversity losses must include *in situ* data from ground-based observations and measurements. The required datasets on species, vegetation, and climate became available through this project on an Europe-wide scale. Scenario building is in progress and respective publications are in preparation. Yet, some regional examples are shown here in brief.

The following geo-ecological relationships and features are to be considered in particular when assessing potential risks of critical biodiversity losses in Europe's alpine zone: (1) the generally increasing proportion of endemic mountain plants with increasing altitude, as shown in Figs. 4.3e and 4.3f under 4.3.1. This means that the majority of endemic, and thus generally rare species are centred at the higher parts of the mountain systems. Mountains which remained isolated during and since the Pleistocene favoured endemism; today, the temperature component of orographic isolation is considered to be a crucial factor for the survival of endemic mountain plants. (2) the finding that particular species have a clear preference for low-temperature habitats (cryophilic species). (3) the relationship between the length of snow cover and the species distribution. Further, the altitudinal range of the zone above the treeline of a particular mountain region, the regional climatic situation during the past decades and regional predictions of climate change must be considered.

High mountain endemic plants in future warmer climates: The mediterranean mountain system Sierra Nevada in southern Spain is a prime example for a mountain region at high risk to loose a significant part of its flora in consequence of climate change-induced impacts. The majority of plants which can be found nowhere else but in this spatially limited mountain system, covering an area of only about 80 by 15 km, is centred to the uppermost elevation levels. The percentage of endemics increases with elevation up to the highest peaks (see Fig. 4.3j and PAULI et al. 2003a). Hence, it is assumed that most endemic species are cryophilic plants restricted to high elevations. Predicted warming can seriously threaten the survival of such species. A prolonged growing season caused by an earlier snowmelt could reduce the vitality of cryophilic species due to an extended dry season. In addition, their habitats are likely to be opened up for competitive species which already have a wider distribution; most of the more common and wide-spread species are at the same time distributed over larger altitudinal range, compared to the endemics. In Sierra Nevada, migration routes for potential invaders from lower elevations are more open compared to most of the European mountain systems, owing to the absence of a closed montane forest belt, acting as barrier against invasion.

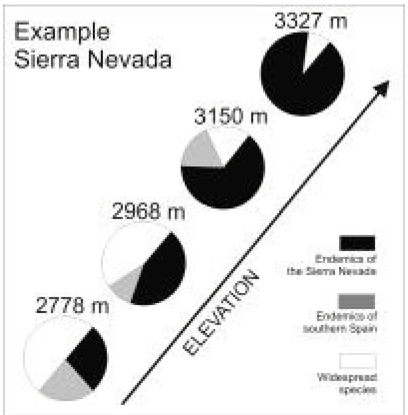


Fig. 4.3j: The Sierra Nevada GLORIA summits show a pronounced increase of the percentage of endemic species with altitude.

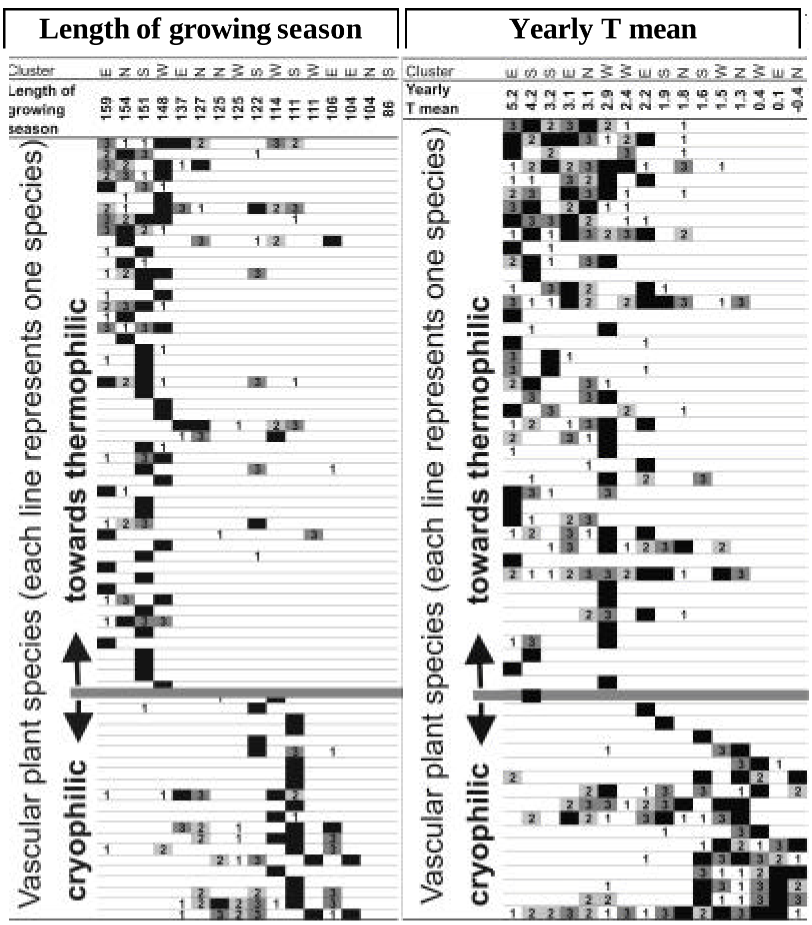


Fig. 4.3k: Species recorded in the 1x1m quadrats on the 4 summits per target region. **Left:** a subarctic target region. Species ranked along decreasing length of growing season (indicated in days) from top-left to bottom-right. **Right:** a submediterranean target region. Species ranked along decreasing yearly mean temperature from top-left to bottom-right. Rectangles in the species lines show the relative species cover for each quadrat cluster from white/1 (low) to black/4 (high relative cover).

Plant distribution compared with climatic parameters: For each target region, relations between plant species distributions and climatic parameters, derived from the measured temperature series, were analysed. The climatic parameters tested so far were: yearly mean temperature (T), mean T of the warmest month, mean T of the coldest month, length of the growing season, growing season mean T, non-growing season mean T. The growing season length was defined as the period between snowmelt in spring or early summer and the first day of a new continuous snow cover in autumn. In different European mountain regions, different climatic parameters best explained the species distribution patterns. Overall, cryophilic species were clearly distinguishable from more thermophilic mountain plants. In the subarctic example (Fig. 4.3k, left), the length of the growing season is of high relevance. About 70% of the species preferentially grow at sites being free of snow pack for > 150 days, while about 30% of the species mostly occur at sites with < 125 days free of snow. In the sub-

mediterranean example (Fig. 4.3k, right), ranking along the annual mean soil temperature, well explains the distribution patters of species. Here, about 70% of the species grow where is > 2°C, while about 30% of the species are centred at habitats where the annual mean soil T is < 1.6°C.
Similar trends as shown in the two examples above were found for the other target regions. A synoptic account on the risks for Europe's mountain plant diversity is under preparation.

4.3.5 Account on additional indicators

At the final *GLORIA-Europe* meeting in April 2003, a task force group for establishing *GLORIA* master sites emerged. This group consists of members of *GLORIA-Europe* and of partners of the world-wide *GLORIA* community. It is led by R. Brooker at the Centre for Ecology and Hydrology/ Banchory/ Scotland, a partner of *GLORIA-Europe*. The *GLORIA master sites approach* (*MAST approach*) aims to develop monitoring methods and explore experimental approaches for master sites by targeting key climatic and biotic variables which would be too detailed and expensive for an investigation via the full *Multi-Summit approach*, but which will support the interpretation of the summit observations and provide invaluable information for the future development of a more intensive terrestrial global monitoring network in alpine systems. Such master sites will be based on existing research capacities and infrastructures and will thus provide exceptional added value.
One of the key advantages of *GLORIA-Europe* and the envisaged and starting *GLORIA-WORLDwide* networks is their concentration on a limited number of low cost, well studied and rapidly assessed variables as part of the monitoring regime. However, additional power can be provided to the analysis of the extensive datasets that will be gathered by these networks, and to the future monitoring of climate change impacts in alpine environments, by monitoring a wider suite of variables. Broadening the scope of the monitoring regime obviously increases both the cost and complexity of the monitoring and network integration processes. The *GLORIA MAST approach* will address these problems by investigating the potential to broaden the future scope of *GLORIA* monitoring.

A questionnaire sent out by N. Bayfield, Banchory, was circulated to all site managers of *GLORIA-Europe* to gather opinion on priorities for additional indicators for monitoring at master sites. The questionnaire was hierarchically arranged along resources (e.g., climate, vegetation dynamics, soil), topics (e.g. meteorological data, snow, altitudinal vegetation transects, soil biota), and a total of 35 generic indicators. The highest scores were reached for climate with 1) temperature, 2) precipitation and snow; permafrost and wind appeared to be important in some sites; and for vegetation with 1) vascular species frequency, 2) cryptogam frequency.

The *Multi-Summit approach* focuses in the first instance on temperature and on vascular plants, being the most important organism group concerning biomass and, among the plants, the most diverse organism group. Other organism groups, however, hold other functions in an ecosystem and thus may be used as value additional indicators of climate change impacts. Non-rooted plants such as bryophytes and lichens were already included in the *Multi-Summit approach* on an optional basis.

The effective use of other organism groups require adequate recording methods which are usually more time-consuming and thus more expensive than those used for vascular plants. Yet, for three important groups: bryophytes, nematodes, and mycorrhizal fungi, methods were developed and tested by this project. To a certain extend, they could be included in the *Multi-Summit approach*, and they are recommended to be used at *GLORIA* master sites:

Bryophytes: The response of bryophytes to the date of snowmelt in the alpine life zone was investigated at Mount Schrankogel, Stubaier Alps, Austria – a proposed master site of *GLORIA*. A fine-scaled recording method using cross-pointing in a nested plot design was applied and a total of 10530 points were sampled. Temperature series derived from data loggers were analysed according to their date of snowmelt (HOHENWALLNER et al. submitted).
Four groups of bryophyte species (snowbed species, open ground species, open alpine grassland species, and solid rock species) were defined. A Generalised Linear Model was applied to explain the dependency of the abundance of the four groups of bryophytes on various abiotic and biotic factors.
The date of snowmelt explained 86% of the variance in the distribution of snowbed species, whereas the importance of this factor decreased for open ground species (63%) and alpine grassland species (31%). The main factor controlling the abundance of solid rock species was altitude. The value of alpine

bryophytes as climate change indicator is very high for snowbed bryophytes, high for open ground species, low for alpine grassland species and cannot be confirmed for solid rock species.

Nematodes: The structure of soil nematode communities and the implications of microclimatic differences on nematodes were studied at three *GLORIA* summits in the Austrian limestone Alps (TR AT-HSW; Styria); (HOSCHITZ & KAUFMANN in prep.). Abundance, diversity, maturity indices, and trophic structure of nematodes were used to detect differences between the three summits and between their four geographical main directions, respectively. Samples were taken from plots at a level 6 m below the highest summit point at each of the four compass directions (N, E, S, W) of Zinken (1910 m a.s.l.), G'hacktkogel (2214 m a.s.l.), and Zagelkogel (2255 m a.s.l.) in August 2001. For continuous soil temperature measurement data logger placed in soil (10 cm depth) at all sampling plots were used.
A total of 27 families with 18 to 23 families per summit were found. Mean nematode abundance at the summits ranged from 342 to 444 individuals per 100g dry soil. Shannon-Wiener diversity indices ranged between 3.1 and 3.4, mean evenness (0.8), maturity index (3.0-3.3), and plant parasite index (2.4-2.6) were nearly identical among summits but significant differences in nematode abundance and diversity were found between the plots of the four compass directions. Significant differences in the community composition (based on families and feeding types) were detected between summits as well as between the exposition directions. Additionally, nematode data and temperature data were correlated. Soil temperature explained only a part of the summit side differences and temperature relationships found within summits for nematode abundance did not apply across summits. Strong correlation was found between winter temperatures and the number of nematode families.

Soil and plant associated fungi: A mycological study was carried out in the Northern Apennines (Italy), as an optional activity within the frame of the *GLORIA-Europe* project (BURATTI et al. in prep.).
The objective in the present work is the taxonomical and eco-physiological characterisation of the soil and plant associated fungi in TR IT-NAP (Northern Apennines, Italy).
Soil and plant samples (*Vaccinium myrtillus*, *V. gaultherioides*, *Festuca riccerii*, *Juniperus nana*, *Juncus trifidus*) were collected in duplicate, in the four permanent quadrats, at the four cardinal points on Alpe di Mommio (1855 m). Moreover, samples of soil, plants, mammal faeces and hairs were also collected outside but close to the permanent quadrats. Samples were processed in the laboratory and fungal strains were isolated and taxonomically determined by means of specific keys and methods. Temperature range and optimum for the growth of the isolated species were determined by incubating fungal colonies at different growth temperatures (4, 15, 20, 25, 30, 37, 45°C).
Preliminary results are available about species composition and thermal preferences of the isolated species. More than 140 strains of filamentous fungi and yeast were isolated, belonging to 24 different fungal taxa. The most representative genera were *Acremonium, Alternaria, Aureobasidium, Botryotrichum, Botrytis, Cladosporium, Dinemasporium, Epicoccum, Mortierella, Phoma, Pinicillium, Podospora, Rhizopus, Trichocladium, Trichoderma*. Numerous species of white, pink and black yeast are also frequently observed. Results about the temperature influence on the fungal growth highlight that most of the analysed strains can be considered mesophile psychrotrophic; they grow at 4°C but cannot when temperature is over 30°C, with an optimum at 20-25 °C.

4.3.6 GLORIA-Europe's presence at scientific conferences and publications

Presentations, meetings and publications are listed in chronological order from year 2003 to 2001, and for each year in alphabetic order.

Project meetings

GLORIA-Europe kick-out meeting, attended by the entire consortium an by external partners and observers; jointly organised by the project co-ordinator and the Greek project partners at Maich in Crete (G. Kazakis and D. Ghosn), held from 9-13 April 2003 in Chania, Crete (Greece).

GLORIA-Europe workshop, attended by all "supplier partners" of the project and by external partners; organised by the co-ordinator and financed by the Austrian Federal Ministry of Education, Science and Culture, held from 25-27 October 2002 at Tulbinger Kogel (Austria).

GLORIA-Europe kick-off meeting, attended by the entire consortium; organised by the co-ordinator, held from 25-29 April 2001 in Vienna (Austria).

Presentations at scientific conferences and meetings

Bertin L, Dellavedova R, Gualmini M, Rossi G & Tomaselli M (2003) Monitoring plant diversity in the Northern Apennines, Italy (*GLORIA* project). *46th International Association of Vegetation Science Symposium*, 8-14 June 2003, Naples (Italy).

Borel JL (2003) Présentation du Programme Européen de Recherches *GLORIA-Europe*. *Commission "Diversité Biologique et Biologie de la Conservation" des Réserves Naturelles de Haute Savoie*, 25 February 2003, Samoens, Haute Savoie, (France).

Borel JL (2003) Présentation du bilan des deux premières campagnes de terrain en Haute Tinée (massif du Mercantour) dans le cadre du Programme Européen de Recherches *GLORIA-EUROPE*. *Direction du Parc National du Mercantour*, 15-16 May 2003, Nice, (France).

Grabherr G (2003) Observation of recent climatic trends and shifts in species distribution. *NCCR Climate Summer School,* 3 Sept 2003, Griendlwald (Switzerland).

Grabherr G (2003) *GLORIA* – the Global Observation Research Initiative in Alpine Environments – aims and perspectives. *Mountain Task Force of the IUCN*, 15 Jan. 2003, Gland (Switzerland).

Grabherr G (2003) Dynamik alpiner Ökosysteme. *Seminar Inst. für Geobotanik, University Hannover*, 21 Jan. 2003, Hannover (Germany).

Hohenwallner D, Gottfried M, Pauli H & Grabherr G (2003) Vascular plants as sensitive indicators of climate change impacts in the alpine life zone: the example *GLORIA-EUROPE*. *Conference of the Società Botanica Italiana, Gruppo di lavoro per l'Ecologia*, 8-9 May 2003, Bologna, (Italy).

Hohenwallner D (2003) Bio-monitoring of climate change in high mountains in Europe and in the World (The project *GLORIA* and *GLORIA-EUROPE*). What perspectives? *Conference at the University of Pavia,* May 2003, Pavia (Italy).

Molero Mesa J, Fernandez Calzado R & Merzouki A (2003) El Proyecto *GLORIA-Europe* en Sierra Nevada (España). *Congreso Internacional de fitosociología "Biodiversidad y Gestión del territorio"*. XIX Jornadas de Fitosociología, 16-19 September 2003, La Laguna Tenerife (Spain).

Nakhutsrishvili G (2003) Anthropogenic load on alpine plant communities. *Symposium "Plant interactions and effect of global warming on alpine plant diversity"*. 30 June-5 July 2003, Kazbegi (Georgia).

Nakhutsrishvili G (2003) High-mountain vegetation of the Caucasus: diversity and ecology. *Symposium "Biodiversity and Evolutionary Biology"*. 2003, Frankfurt/M. (Germany).

Nakhutsrishvili G (2003) Ecological situation in the mountains of the Caucasus. *Workshop "Plant Conservation in the Caucasus"*. 14-21 October, 2003, Tbilisi (Georgia).

Pauli H, Gottfried M, Hohenwallner D, Reiter K & Grabherr G (2003) *GLORIA* as a contribution to the IGBP Mountain Research Initiative. *Third IGBP Congress "Connectivities in the Earth System"*, 19-24 June 2003, Banff (Canada).

Pauli H, Gottfried M, Hohenwallner D, Reiter K & Grabherr G (2003) *GLORIA* (Global Observation Research Initiative in Alpine Environments) monitoring methods and first results. *State of the Art in Vegetation Monitoring Approaches*. 24-26 March, 2003, Swiss Federal Research Institute WSL, Birmensdorf (Switzerland).

Pelino G, Stanisci A, Giancola C & Carranza ML (2003) Alpine belt and global change in central Apennines (Italy). *Third International Balcan Botanical Congress*, 18-24 May, 2003, Sarajevo (Bosnia-Herzegovina).

Reiter K, Pauli H, Gottfried M, Hohenwallner D & Grabherr G (2003) *GLORIA* (Global Observation Research Initiative in Alpine Environments) – Zielsetzung und erste Ergebnisse aus dem Pilotprojekt *GLORIA-EUROPE*. *54. Deutscher Geographentag.* 28 September – 4 October, 2003, Bern (Switzerland).

Rossi G (2003) Plant biomonitoring by mean of *GLORIA* method. *Natural History Museum*. 28 October, 2003, Cremona (Italy).

Shiyatov S (2003) *GLORIA-Europe* project presentation. Meeting of the Ekaterinburg branch of the Russian Botanical Society. 28 May, 2003, Ekaterinburg (Russia).

Stanisci A (2003) Diversità di piante vascolari e cambiamenti climatici globali in Appennino. *Conference for Doctoral Students, Dep. Sciences and Technology of Environment and Territory, University of Molise*, 2003, Isernia (Italy).

Stanisci A, Pelino G, Riggio L & Blasi C (2003) The monitoring of alpine plant diversity and global change in central Apennines (Italy). *46th International Association of Vegetation Science Symposium*, 8-14 June 2003, Naples (Italy).

Stanisci A (2003) Il monitoraggio della fitodiversità altomontana in Appennino centrale in relazione ai cambiamenti climatici globali. *Workshop " Biological issues in mountain environment". Dep.to Biology, University of Rome Three*, 2003, Rome (Italy).

Villar L & Benito Alonso JL (2003) La flora alpina y el cambio climático: el caso del Pirineo central (Proyecto *GLORIA-Europe*). VII Congreso Nacional de la Asociación Española de Ecología Terrestre. 2-4 July 2003, Barcelona (Spain).

Villar L & Benito Alonso JL (2003) Pastoreo y excrementos en el piso alpino del Parque Nacional de Ordesa y Monte Perdido. *Junta de Andalucía*. 2003, Sevilla (Spain)

Borel JL (2002) Présentation du Programme Européen de Recherches *GLORIA-EUROPE*. *Commission Environnement du Conseil Général de l'Isère*, 26 November 2002, Grenoble, Isère, (France).

Barancok et al. (2002) Presentation about *GLORIA* in the Tatry Mountains. *Symposium on Ecological Research in High-mountain ecosystems of the Tatry Mountains*. May, 2003, Východná (Slovakia).

Coldea G & Pop A (2002) Presentation of regional results of the project: vegetation diversity in relation to climatic factors in the sub-alpine-alpine belt of Rodna Mountains. *National Symposiums: "Biological Diversity, Biotechnology, Socio-economic Development*. December, 2002, Cluj-Napoca (Romania).

Erschbamer B, Mallaun M & Unterluggauer P (2002) The Dolomites, hot spots of species diversity. *Conference on zoological and botanical research in South Tyrol*. September, 2002, Bozen (Italy).

Gottfried M, Hohenwallner D, Pauli H & Grabherr G (2002) The aims and the role of *GLORIA*. *Symposium on Ecological Research in High-mountain ecosystems of the Tatry Mountains*. May, 2003, Východná, Slovakia.

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Grabherr G (2002) Climate change effects in mountain environments. *University of Edinburgh*, November, 2002, Edinburgh (UK).

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Holten J (2002) Presentation of the *GLORIA* project at Dovrefjell. *Annual meeting of the foundation iNARDO*, March, 2003, Dombås (Norway).

Holten J (2002) Presentation on climate effects monitoring at Dovrefjell through a *GLORIA* Master Station – location alternatives for climatic stations. *Meeting with the Norwegian Army - the Hjerkinn Shooting Range (followed by a field survey)*. May, 2002, Hjerkinn (Norway).

Holten J (2002) Plans for and funding of a *GLORIA* Master Station at Dovrefjell. *Meeting with the Norwegian Parliament – the Committee for Energy and Environment*. May, 2002, Oslo (Norway).

Holten J (2002) Plans for and funding of a *GLORIA* Master Station at Dovrefjell. *Meeting with the Ministry of Environment.* May, 2002, Oslo (Norway).

Holten J (2002) Presentation on the establishment of a *GLORIA* Master Station at Dovrefjell. May, 2002, Dombås (Norway).

Holten J (2002) Presentation on establishing of a *GLORIA* Master Site at Dovrefjell. *Meeting with the state secretary of the Ministry of Environment*. August, 2002, Oslo (Norway).

Kazakis G, D. Ghosn D & Papanastasis VP (2002) Poster presentation about *GLORIA. 3rd Panhellenic Rangeland Congress.* September, 2002, Karpenisi (Greece).

Oszlányi J (2002) Presentation about *GLORIA. Annual ILTER Meeting.* March, 2002, Aylmer, Quebec, (Canada).

Oszlanyi J (2002) Presentation about *GLORIA. International workshop on Long-term Ecological Research*. August, 2002, Zvolen (Slovakia).

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Borel JL (2001) Présentation du Programme Européen de Recherches *GLORIA-EUROPE*. *Section des Alpes Maritimes du Club Alpin Français. Direction du Parc National du Mercantour*, 28-29 June, 2001, Nice (France).

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Coldea G & Pop A (2003) Floristic diversity in relation to geomorphological and climatic factors in the subalpine-alpine belt of the Rodna Mountains (Romanian Carpathians). *Pirineos*, **158**.

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Pauli H, Gottfried M, Hohenwallner D, Reiter K & Grabherr G (2003) Ecological Climate Impact Research in High Mountain Environments: *GLORIA* (Global Observation Research Initiative in Alpine Environments) – its Roots, Purpose and Long-term Perspectives. In: Huber U, Reasoner M & Bugmann H (eds.) *Global change and mountain regions: a state of knowledge overview.* Kluwer Academic Publisher (in press).

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Villar L & Benito Alonso JL (2003) Pastoreo y excrementos en el piso alpino del Parque Nacional de Ordesa y Monte Perdido. In: Robles AB et al. (eds.) *Pastos, Desarrollo y Conservación*. Junta de Andalucía. Sevilla, pp. 507-512.

Gottfried M, Pauli H, Hohenwallner D, Reiter K, Grabherr G (2002): *GLORIA* - the Global Observation Research Initiative in Alpine Environments: wo stehen wir? *Petermanns Geographische Mitteilungen* ***4****: 69-71.*

Gottfried M, Pauli H, Reiter K & Grabherr G (2002) Aktuelle Trends und Szenarien der Klimafolgenforschung im Hochgebirge. *Conference Proceedings 10. Österreichisches Botanikertreffen, 30.Mai–1.Juni 2002, Bundesanstalt für alpenländische Landwirtschaft Gumpenstein, Irdning*, pp. 11-15.

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Hohenwallner D, Zechmeister HG & Grabherr G (2002) Bryophyten und ihre Eignung als Indikatoren für den Klimawandel im Hochgebirge – erste Ergebnisse. *10. Österreichisches Botanikertreffen, 30.Mai–1.Juni 2002, Bundesanstalt für alpenländische Landwirtschaft Gumpenstein, Irdning*, pp 19-21.

Richter M (2002) Moderne Aspekte der Pflanzengeographie. *Praxis Geographie* **7-8**: 4-10.

Scheurer T & Camenisch M (2002) Leben in dünner Luft. *Cratschla* **2**: 8-9.

Bertin L, Dellavedova R, Gualmini M, Rossi G & Tomaselli M (2001) Monitoring plant diversity in the Northern Apennines, Italy. The *GLORIA* project. *Arch. Geobot*. **7**(1).

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Vust M, Vittoz P & Theurillat JP (2001) *GLORIA* CH pense aux lichens. *Meylania* **22**: 25-27.

Buratti C, Solari N & Tosi S (in prep) Caratterizzazione tassonomica ed ecofisiologica di funghi associati a piante e suolo di un area dell'Appennino Settentrionale monitorata per il cambiamento climatico.

Hohenwallner D, Zechmeister H, Gottfried M, Moser D, Pauli, Reiter K, & Grabherr G (submitted) Alpine bryophytes indicate climate change.

Hoschitz M & Kaufmann R (in prep) Soil nematode communities of Alpine summits - Nematode composition and distribution to the four geographical main directions.

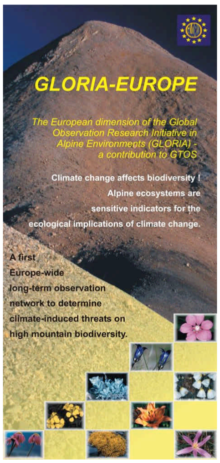
Moiseev PA & Moiseev DA (in prep) Target regions of the international monitoring network *GLORIA* in the Urals as a series of stations used for monitoring for climate changes influence on highlands vegetation.

Stanisci A, Pelino G & Blasi C (submitted) Vascular plant diversity and climate change in the alpine belt of central Apennines (Italy). Conservation and Biodiversity.

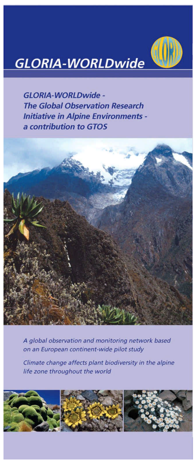
4.4 Outputs for and dissemination to the non-expert audience

4.4.1 Glossy project folders

The project has produced two glossy folders in high print runs, aiming to reach a wide audience from the scientific community to policy makers and the interested non-expert enduser (Fig 4.4a).



The first folder was printed in December 2001 at the end of the first project year. It contains information about the role, the aim, and the methods of *GLORIA-Europe* as well as a brief presentation of the observation sites in the 18 target distributed across Europe.



The second folder was produced in June 2003 close to the end of the project. It shows the Multi-Summit method, the European *GLORIA* sites and preliminary results of *GLORIA-Europe*. It further gives an outlook to the forthcoming major activities of the *GLORIA* network: the extension to the global level (*GLORIA-WORLDwide*) including the establishment of master sites based at existing field stations as well as the rationale behind a world-wide monitoring network for climate-induced impacts on alpine biota from the polar to the tropical regions. This folder can be obtained at www.gloria.ac.at

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Fig. 4.4a: The glossy brochures to promote the project.

4.4.2 The GLORIA website for public users

The project's website was not only vital for information and data exchange within the consortium but serves as one important dissemination tool of the project outputs. The public visitors can not only browse most of the general pages, they can use also a guest account to query the field database. Some overview information on target regions, summits, and lots of pictures are public available as well as the full dataset of one summit site (the others are restricted to the consortium until publication). For details on the field database, see 4.1.6.

A recent product is a guided tour through the website. It shall turn the visitor's attention on the most relevant pages of the site, and on details which are a bit complicated to find when browsing through the numerous pages by hand. See www.gloria.ac.at → Tour. The product is still under construction but will improve.

To introduce *GLORIA*'s *Multi-Summit approach* in a pleasing manner, an imagemap of the sampling design is available. Visitors can click any spatial element sampled in the field, e.g., quadrat plots or summit area sections, to linking photos which present the particular object. See www.gloria.ac.at → *Multi-Summit approach*.

Other websites of projects, networks, and organisations which are related to *GLORIA* can be found at the page www.gloria.ac.at → Related sites.

Probably the most important entry for the non-scientific visitor is the *GLORIA* press corner. This is an up-to-date area of press articles and web links dealing with the *GLORIA-Europe* project and the *GLORIA* network. See www.gloria.ac.at → Press corner; see

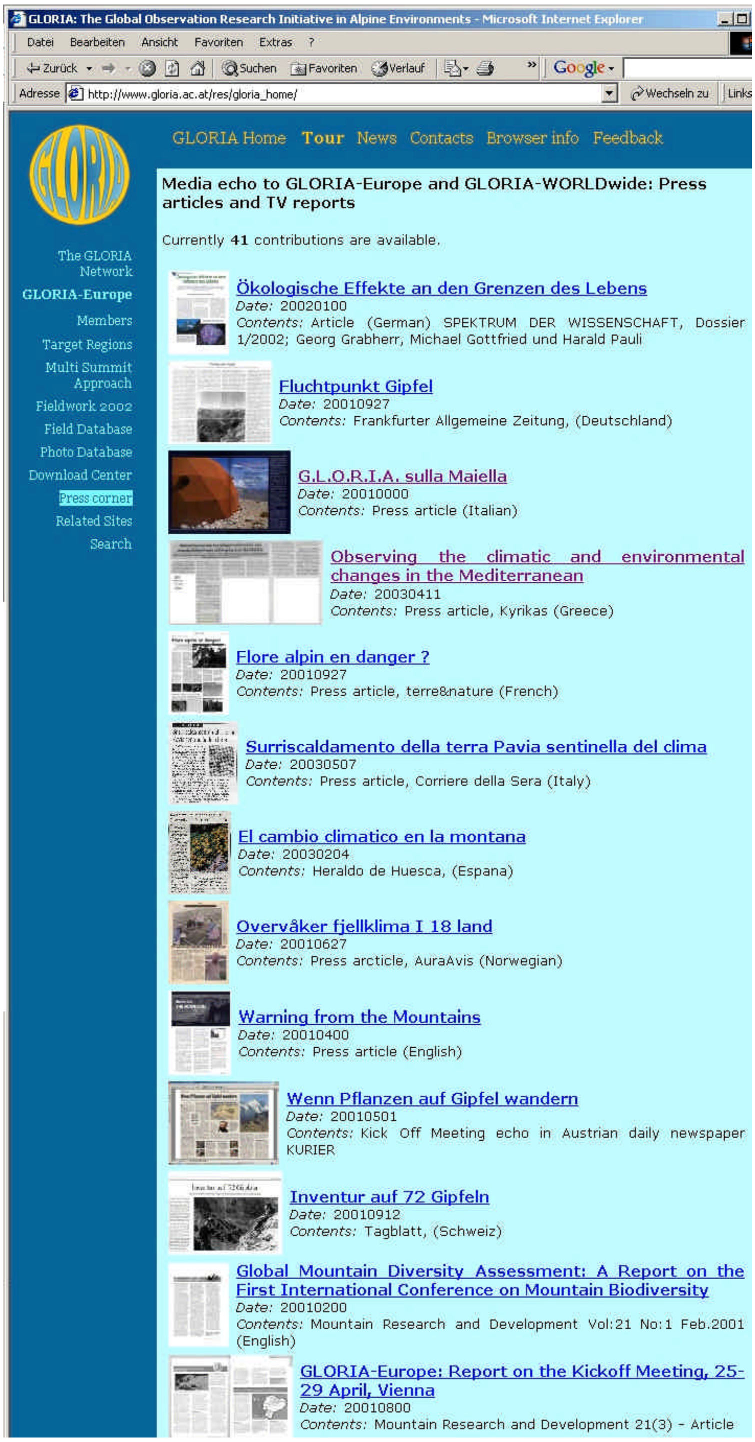

Fig. 4.4b: GLORIA's press corner on the web.

The website is well indexed on the World Wide Web. *GLORIA* can be found, for example, by using the the following terms at the search machine Google (search term/position of link on the search results page):

GLORIA-Europe/pos. **1**; *GLORIA*/pos. **23**; *GLORIA*+mountains/pos. **8**; Europe+mountains+monitoring/pos. **8**; "European mountains"+"climate change"/pos. **9.**

The website will be not closed at the end of the project but is the basis for the ongoing activities in the *GLORIA* network.

4.4.3 Impact in the public medias

The interest of the public medias in *GLORIA-Europe* was exceptionally high. This indicated that the European public is concerned about the fate of our mountain ecosystems in changing climates and is interested in the question on whether we are steering towards "safer" or towards "hazardous" decades.
The project effectively contributed to raise public awareness of critical ecological consequences of climate warming in mountain regions. Press conferences were organised at the main project meetings. Numerous articles in newspapers and illustrated magazines were published and television and radio reports were broadcast (e.g., in the Norwegian, Greek, and Austrian TV); see the list below.
For example, the widely distributed magazine "Spektrum der Wissenschaft" published an article about *GLORIA* in 2002 ("Folgen des Klimawandels – Ökologische Effekte an den Grenzen des Lebens"); an other detailed report is scheduled for publication in the "National Geographic" magazine in 2004.

List of reports in the public medias

Print media

Austria – Salzburger Nachrichten, 13 Oct. 2003 "Klima im Hochgebirge"
Austria – Tiroler Tageszeitung, 1 Oct 2003 "Hitze lässt Blumen Gipfel erstürmen"
Austria – Der Standard, 21 Aug. 2003 "WWF: Edelweiss in Gefahr"
Austria – ORF ON Science, 31 July 2003 "Hochgebirgspflanzen als Indikator der Klimaerwärmung"
Austria – Sonnen Zeitung, May 2003 "Ein Hoch auf *GLORIA*"
Italy – Il Ticino, 1 Feb. 2003 "Camiamenti climatici: lo studio die naturalisti"
Greece – Kyrikas, 11 April 2003 "Observing the climatic and environmental changes in the Mediterranean" (in Greek)
Greece – Chaniotica, 11 April 2003 "Observation sites for climate change" (in Greek)
Greece – Eleutherotypia, 11 April 2003 "Species will be lost" (in Greek)
Greece – Chaniotica, 9 April 2003 "The exact analysis of alpine ecosystems" (in Greek)
Italy – Corriere della Sera, 7 May 2003 "Surriscaldamento della terra Pavia sentinella del clima"
Italy – Lunedi, 5 May 2003 "Pavia studia la biodiversita sulle vette del mondo"
Italy – Il Ticino, 3 May 2003 "Monitorata la flora di alta montagna grazie a Gloria Europe"
Spain – Heraldo DeHuesco, 4 Feb 2003 "El cambio climatico en la montana"
Italy – Gardenia, January 2003 "La flora d'ALTA QUOTA ci dirá come cambia il clima"
Italy – L'Ente Parco Informa, 1 Dec. 2001 "Progetto UE: Majella e Global Change"
Germany – Spektrum der Wissenschaft, Jan. 2002 "Folgen des Klimawandels – Ökologische Effekte an den Grenzen des Lebens"
Russia – Nauka Urala, 28 Dec. 2001 "Plodotvornoe leto" ("Fruitful summer")
Germany – Frankfurter Allgemeine Zeitung, 27 Sept. 2001 "Fluchtpunkt Gipfel. Ein Projekt der EU erforscht ökologische Schäden durch die Klimaerwärmung"
Switzerland – Terre&Nature, 27 Sept 2001 "Flore alpine en danger?"
Switzerland – Tagblatt, 12 Sept. 2001 "Inventur auf 72 Gipfeln"
Switzerland – Der Bund, 24 Aug. 2001 "Angeheizter Kampf um die Berggipfel"
Liechtenstein – CIPRA-Info 61, Aug. 2001 "*GLORIA*: biodiversity and climate change" (in French, German, Italian, and Slovenian language)
Italy – D'Abruzzo, 2001 "G.L.O.R.I.A. sulla Majella"
Germany – Die Tageszeitung, 20. July 2001 "Klimamessungen im Hochgebirge"
Norway – Adresseavisen, 14. July 2001 "Dovre varsler nytt klima"
Norway – Vigga, 28. June 2001 "Internasjonalt klima-prosjekt pa Dovrefjell i tre ar framover"
Norway – AuraAvis, 27. June 2001 "Oyeryaker fjellklima I 18 land"
Switzerland – Der Tages-Anzeiger, 22. May 2001 "Konkurrenz für Pflanzen im Hochgebirge"
Austria – Kurier, 1. May 2001 "Wenn Pflanzen auf Gipfel wandern"
Austria – APA, 30. April 2001 "Österreich leitet Klimaprojekt"
Austria – Die Presse, 28. April 2001 "*GLORIA*: Mehr Daten vom Klimawandel"
Austria – Fact sheet B.I.T, 2001 "EU Projekt *GLORIA-Europe*"
Italy – La Provincia Pavese, 9. March 2001 "Passa da Pavio lo studio globale sul surriscaldamento della Terra"
Italy – Bolletino universita e ricerca, 26. April 2001 "Universita di Pavia"
Austria – InFoTeKo 5, Nov. 2000 "EU-Projekt "*GLORIA-Europe*" soll Umweltfrühwarnsystem aufbauen"

Broadcast media

Russia – Radio Echo Moskvi, 12 June 2003, Interview with Ural *GLORIA* partners (in Russian)
Greece – TV Kydon, News bulletin 10 April 2003, Report about the *GLORIA-Europe* final meeting
Greece – TV Creta Channel, News bulletin 10 April 2003, the *GLORIA-Europe* final meeting
Austria – TV ORF, Universum, 17 Oct. 2002 "Wetterküche Alpen"
Austria – Radio ORF channel Ö1, Radiokolleg, March 2002, "Klima - die Fieberkurve steigt"
Austria – TV ORF Modern Times, 11 Oct. 2001 "Klima im Wandel"
Austria – Radio ORF channel Ö1, Dimensionen, 3 Sept. 2001, "Das Projekt *GLORIA*"
Norway – TV NRK, 20 Sept. 2001"*GLORIA* in Schrødinger's Cat"
Austria – TV ORF Modern Times, 27 July 2001 "Klimawandel in Österreich"

4.4.4 Dissemination activities of the "user participants"

The project's four user participants attended the two main project meetings to contribute with presentations about the concerns of endusers and on how their organisations can effectively act as interface between the researchers and the public, policy makers and experts of other disciplines of global change research.
During the project, the user partners actively supported the dissemination of the project's outputs and contributed to raise public awareness of critical ecological consequences of climate warming in mountain regions.

The *Centre for Mountain Studies* at *Perthcollege*, Scotland, focuses on the socio-economic relevance of mountain ecology and climate change impacts. The project partner and director of the *Centre for Mountain Studies*, Prof. Dr. M. Price, plays a key role as advisor on mountain issues to international organisations such as *IUCN, UNEP, UNESCO.* He publishes widely in scientific, popular and policy-related publications and has used such activities to increase awareness of *GLORIA*; for example, he presented *GLORIA* at the *5th World Parks Congress* in Durban, South Africa, 9-17 September 2003 in "Designing strategies to increase the resilience of alpine/montane systems to climate change".
This presentation was published in a user's manual for building resistance and resilience to climate change in natural systems (PRICE & NEVILLE 2003; see also http://www.panda.org/news_facts/publications/climate_change/index.cfm).

Further, *GLORIA* is described and mentioned repeatedly at the website of the *Mountain Forum*, a global network for mountain communities, environments, and sustainable development with regional network in all continents. Its powerful electronic pathways will facilitate access to *GLORIA*. At the *GLORIA* kick-out meeting of *GLORIA-Europe,* the *European Mountain Forum* was represented by L. Soubrier who gave presentation on links between *GLORIA* and the *Mountain Forum*.

The international *Mountain Research Initiative (MRI)* with its coordination office located in Bern (Switzerland) performed the following dissemination activities of *GLORIA* results:
(1) Dr. Mel Reasoner (Executive Director of the *MRI*) and Prof. Dr. Harald Bugmann (Chair of the Scientific Advisory Board of the *MRI*) made a presentation in June 2002 that featured the *GLORIA* project results as a key component of the strategy towards implementing global change research activities world-wide. This took place at a liaison meeting with officials of the Leading House of the *International Year of Mountains (IYM)*, the *UN Food and Agriculture Organisation (FAO)* in Rome.
(2) At the *Third Congress* of the *International Geosphere-Biosphere Programme (IGBP)* in Banff, Canada, in June 2003, the *GLORIA* project results were again featured prominently as a successful example of Global Change research in mountain regions. This happened in the context of a Special Session devoted to Mountain Regions and their role in the future of the IGBP.
(3) *GLORIA-Europe*'s project results will also be highlighted at an upcoming international workshop co-sponsored by the *MRI* and *UNESCO's Mountain Biosphere Reserves*, to be held in November 2003 in Soerenberg, Switzerland.
(4) A link to the *GLORIA-Europe* project is also included in the web pages of the *MRI*, see http://www.mri.unibe.ch.

La Commission International pour la Protection des Alpes (CIPRA), a major mountain-related NGO with more than 100 member organisations in all seven Alpine countries was an active supporter of the project. On the occasion of the kick-off meeting in April 2001, *CIPRA* composed an article (in four languages) about *GLORIA* and its background, aims and methodical approach in the *"CIPRA-Info"* magazine (Nr. 61, August 2001). All articles of the *"CIPRA-Info"* magazines are also published on the *CIPRA* website (www.cipra.org). In the follow-up of the final project meeting in April 2003, *CIPRA* released a news item (again in four languages) in the *"alpMedia"* newsletter, which can also be found on the *alpMedia* website (www.alpmedia.net). Both meetings were attended by Mag. E. Haubner-Köll from *CIPRA.*

The World wide Fund for Nature (WWF) raised public awareness of *GLORIA* through a press conference at the project's kick-off meeting and through press releases in 2003. The *WWF* actively contributes to climate impact issues with publications and international campaigns; thus *WWF* is an important user of current and future results of *GLORIA* network.

4.5 Assessment of the long-term operation

The self-maintenance of the *GLORIA* network – i.e., not permanently EU-funded – is a crucial requirement for a successful long-term monitoring operation, and was a main concern of the observation network, since its initial structures were developed.

The important forthcoming step beyond *GLORIA-Europe* goes towards the extension of the network to the world-wide level. This is the level *GLORIA* was initially designed for.
For this major setup, establishing, and consolidation phase of *GLORIA*, further grants from the European Community were proposed for a three-year period. Within this period (*GLORIA-WORLDwide*), a globally active observation network, with 50 target regions (with 200 observation summits), distributed over all continents and life zones, should be established. The geographical arrangement of these target regions will follow a three-fold approach (according to M. Richter, T. Fickert & F. Grüninger from Erlangen, Germany) in order to balance their global distribution; it considers the patterns of mountain systems across the continents and across the major vegetation zones (compare WALTER 1985; RICHTER 2001) and accounts for global circulation models (ECHAM4 circulation model; ROECKNER et al. 1996). Moreover, a network of *GLORIA* master sites to complement the *Multi-Summit approach* and to support the interpretation of the summit observations, should be developed. Such master sites will be established at existing field stations with long experience in high mountain ecology.
This establishing and consolidation phase of *GLORIA-WORLDwide* is planned to be finalised by 2007. After this period, the *GLORIA* network aims to operate in a self-maintained basis by using local or national budgets. For the following reasons, this is feasible and accomplishable:

(1) An effective method with low maintenance costs
The use of simple methods and low maintenance costs of the permanent plots used are a key to achieving this goal. The sampling design is clearly focused on the fundamental climatic gradients (altitude and large-scale horizontal gradients across the major life zones) and thus will be highly effective in assessing the current and future large-scale patterns of plant diversity of the world's mountains.
Further, the re-investigation of *GLORIA* permanent plots does not require expensive equipment and is significantly less time-consuming than the first establishment of sites (approx. 50% of the time necessary for establishing and first recording). Further, monitoring intervals are 5 to 10 years. Thus, there is no need for an expensive high-frequency service of the sites.

(2) A global community of committed researchers
A durable extensive observation network is accomplishable owing to the stimulating impact of *GLORIA-Europe*. The interest in joining *GLORIA* has been and is high in the world-wide community of ecologists, geographers and climate impact researchers due to the effective communication and due to the networks unrivalled global design of comparable sites along the three fundamental climatic gradients.
Numerous researchers, using local or national funds (e.g., from Switzerland, Italy, Russia, New Zealand, Australia and the USA) have joined the global *GLORIA* community since the start of *GLORIA-Europe*, and have established or have started to establish *GLORIA* field sites. These sites are set up along the *GLORIA-Europe* guidelines.
Moreover, *GLORIA* meetings, such as the workshop for the final discussion of the *Multi-Summit approach*, attended by more than 50 participants, was financed from national funds (the *Austrian Federal Ministry of Education, Science and Culture*). Finally, the *GLORIA* co-ordination group was supported by the *Austrian Federal Ministry of Education, Science and Culture* throughout the lifetime of *GLORIA-Europe*. This exemplifies that national governments have a strong interest in promoting such long-term observation networks.

(3) Education and training for future re-investigators
A successful and durable long-term operation does not only require adequate research grants from local or national funds, but also an educated and encouraged young generation of researchers.
To many young researchers, the *GLORIA* network is already well known: some were involved in the *GLORIA-Europe* site setup, others learned from University courses, teaching the role, the aims and the methods of *GLORIA* (e.g. in Italy and Germany). The majority of the project participants were universities – these are the major scientific educational institutions. This will assure that an experienced

well-trained generation of researchers will be aware of the importance and the value of future long-term monitoring efforts.

(4) High-quality baseline data – an investment for the future
The comprehensive dataset complied during the *GLORIA-Europe* project is the first standardised account of Europe's mountain plant diversity which will serve as crucial baseline for model evaluations and future comparisons. Standardised in-situ data from a large-scale network of permanent plots are getting increasingly attractive for re-investigators with time. Such high-quality data from 5 to 10 years or even several decades old plots at sites undisturbed by direct human land-use will be invaluable for any future assessment or modelling evaluation of climate change-induced biodiversity and habitat losses. The network of precisely documented permanent plots combined with a successively updated database will provide an urgently required investment for future generations.

5. List of deliverables

Project duration: January 2001 (project month 1) to July 2003 (project month 31)

Deliverable No [1]	Deliverable title	Planned delivery date [2]	Actual delivery date and references	Nature [3]	Disse-mination level [4]
D0	Co-ordination and management	1-31	Successful administrative and scientific co-ordination and management throughout the project; this included the building of the *GLORIA* website as central platform of data and information exchange (see 4.1.6 and 4.4.2); see also the additional deliverables D0-a to D0-c;	**O**	**RE** **(partly CO)**
D0-a (mandatory addition 1)	User Requirement document	within the first 5 months	December 2001 (month 12);	**Re**	**RE**
D0-b (mandatory addition 2)	Short glossy brochure/folder to introduce the project to a non-specialist audience	within the first 12 months	December 2001 (month 12); see 4.4.1;	**Re**	**PU**
D0-c (mandatory addition 3)	Update of the glossy brochure/folder	at the end of the project	June 2003 (month 29); see 4.4.1 and www.gloria.ac.at;	**Re**	**PU**
D1	Draft versions of tools for the observation system: Field manual, field equipment and database structure	4	March 2001 (month 3): the drafts for discussion and justification;	**Me**	**PU**
D2	Evaluated and justified tools	6	June 2001 (month 6): third version of the *GLORIA Multi-summit* field manual ready for field application;	**Me**	**RE**
Mandatory addition 4	Short management report	10	October 2001 (month 10);	**Re**	**RE**
D3	Species and vegetation data sets and permanent plots data from 18 Target Regions (= D3.1 - D3.18)	11	October 2001 (month 10): data from the 18 target regions; additions from some target regions in September 2002 (month 21), because of bad-weather conditions in 2001;	**Da**	**RE**
D4.I	Compiled data in a central data base for comparative analysis	13	December 2001 (month 12): data input tools developed (see 4.1.4); October 2002 (month 22): all data compiled (deviation owing to delayed field recording);	**Da**	**RE**

D4.II	Compiled data in a central data base as reference for long-term monitoring (= same data as above + data for re-establishing permanent plots)	13	December 2001 (month 12): data input tools developed (see 4.1.4); October 2002 (month 22): all data compiled (deviation owing to delayed field recording);	**Da**	**RE**
Mandatory addition 5	Progress report No. 1 (for the year 2001)	14	February 2002 (month 14);	**Re**	**RE**
D5	Result of 1. meta analysis: theory on vertical and horizontal gradients of species and vegetation patterns	18	October 2002 (month 22): first results presented at an additional project meeting (Oct. 25-27), financed by the Austrian Federal Ministry of Education, Science and Culture;	**Th**	**RE**
Mandatory addition 6	Progress report No. 2 (for the year 2002)	26	February 2003 (month 26);	**Re**	**RE**
D6	Commented catalogue of additional indicators	26	April 2003 (month 28); see 4.3.5;	**Me**	**RE**
D7	Climatic characterisation and comparison of sites derived from temperature time series	23	April 2003 (month 28); see 4.3.2;	**Th**	**RE**
D8.I	Result of 2. meta analysis: theory on vertical and horizontal gradients of species and vegetation patterns linked to climatological parameters	26	April 2003 (month 28); see 4.3.1 and 4.3.3);	**Th**	**RE**
D8.II	Result of 2. meta analysis: risk assessment for biodiversity losses	26	July 2003 (month 31); see 4.3.4;	**Th**	**RE**
D9.I	Examined results of the analysis including discussion and concluding remarks	26	July 2003 (month 31); see 4.3 and chapter 8;	**Th**	**RE**
D9.II	First outline for options of the long-term operation	26	July 2003 (month 31); see 4.5;	**Me**	**RE**
D10.I	Publications in scientific journals	31	at the end of the project and its follow-up (September 2003); see 4.3.6; a number of publications in peer-reviewed journals are in preparation; the publication of the *GLORIA Field Manual* as report of the EC is scheduled for January 2004;	**Re**	**PU**
D10.II	Dissemination to a broad audience (INTERNET web site, summary reports)	31	throughout and at the end of the project and its follow-up (September 2003); see 4.4.2 and 4.4.3;	**Re**	**PU**
D11	Final report, assessment report on feasible options for the long-term operation, TIP	31	at the end of the project and its follow-up (September 2003); see this report and Technological Implementation Plan.	**Re**	**PU**

1 Deliverable number according to the contract

2 Project month in which the deliverable was planned to be available (according to the project contract); project month 1 = start month January 2001; project month 31 = end month July 2003;

3 The nature of the deliverable: Re = report; Da = dataset; Eq = equipment; Pr = prototype; Si = simulation; Th = theory; De = demonstrator; Me = methodology; O = other;

4 The dissemination level: PU = public; RE = restricted to a group specified by the consortium (including the Commission Services); CO = confidential, only for members of the consortium (including the Commission Services).

6. Comparison of initially planned activities and work actually accomplished

The only major deviation from the work content of *the Description of Work* in the contract was the delayed finalisation of the field work in some *GLORIA-Europe* target regions. This lead to a time displacement of the final data compilation and analysis of a few months.

Justification: The delay was caused by bad-weather conditions in some target regions (e.g., in AT-HSW, CH-CAP, FR-CRI, SE-LAT, SK-CTA) during the growing season 2001. The planned field programme, however, was not cancelled, but was shifted to summer 2002. Finally, all intended field work was completed.

Effects on the project: Despite of the delayed field work and the resulting time displacement of data analysis, no crucial part of the project was cancelled. This was accomplished by an earlier start of the final work packages as far as this was possible (see Fig. 6a) and by intensified action between October 2002 and the end of the project. First scientific outputs in form of publications already have appeared or are submitted (see 4.3.6). Papers on the Europe-wide comparisons of biota, climate and climate-induced risks are well in progress and will be submitted to peer reviewed international journals.

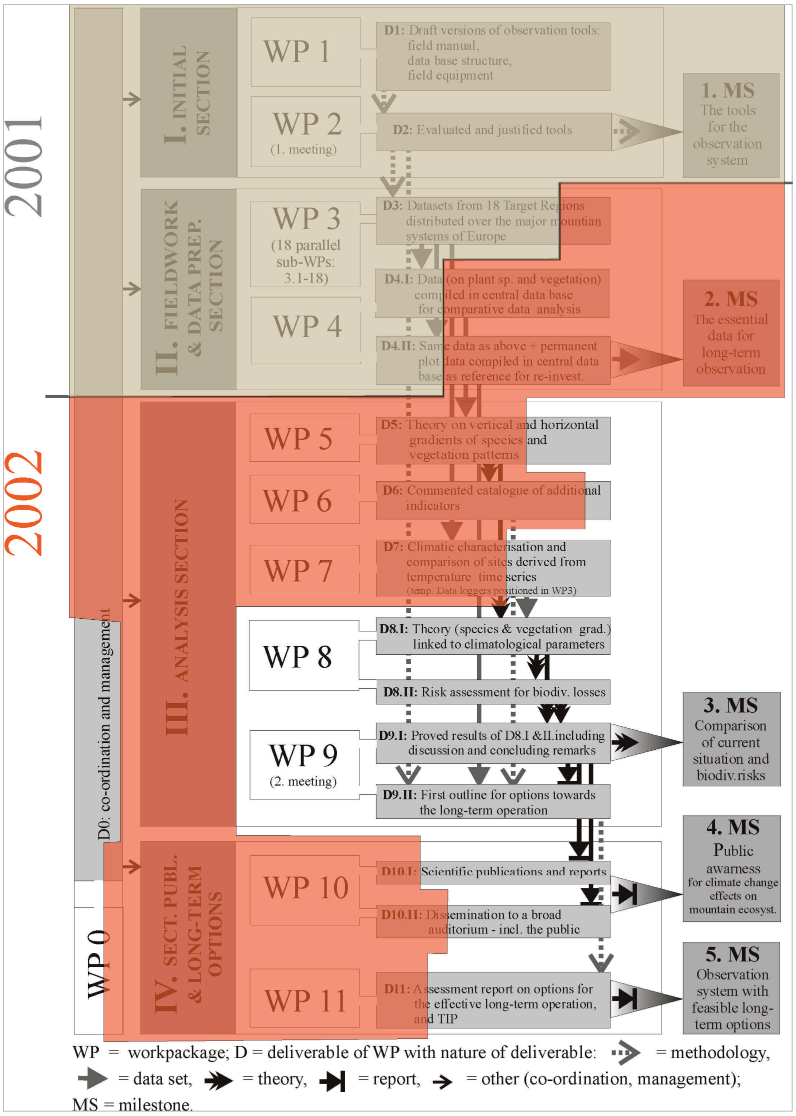

Fig. 6a: The project's components according to the *Description of Work* in the contract. Shaded: the work completed during the first two project year; unshaded: work completed in 2003.

7. Management and co-ordination aspects

The project consortium consisted of three types of contractors with different roles within the project:

- the co-ordination group, who was responsible for (1) the administrative and technical communication between the project partners and the European Commission including the handling of financial transactions; (2) the maintenance and further development of communication structures including a powerful website; (3) the organisation of the project meetings; (4) the scientific co-ordination an management of fieldwork and data handling; (5) the comparative data analysis; and (6) the management of the dissemination activities; and (7) it will be the key group for managing the long-term monitoring activities of *GLORIA*.
- the 18 supplier participant groups, who were site managers responsible for (1) the particular target regions, the fieldwork in this region and the data input; (2) regional data analysis; (3) they contributed

to the development of the field method and to the scientific discussion of the project's outputs, and (4) they will be the key persons for maintaining the long-term monitoring activities in their regions. Further, some of these partners initiated the formation of a task force group of *GLORIA* master sites for more extensive field protocols as future support for the interpretation of the summit monitoring results; others supported the careful editing of the final *GLORIA Field Manual* and its translation from English into Spanish in the view of the extension to the global level.
All 18 "supplier partners" with their encouraged and persevered field teams contributed significantly to establish the first Europe-wide site-based ecological monitoring network for climate impacts in alpine environments.

- the four user participants, who acted as interface between the researchers and the public, policy makers and experts of other disciplines of global change research (see also under 4.4.4). They attended the two main project meetings and focused on different topics relevant for endusers: the *Centre for Mountain Studies* at *Perthcollege*, Scotland, focuses on the socio-economic relevance of mountain ecology and climate change impacts; the *Mountain Research Initiative (ETHZ)*, Switzerland, represented the involvement of the international global change research programmes IGBP and GTOS; and two leading NGOs: the *CIPRA*, Liechtenstein and the *WWF* mediated to the public and to policy makers in environmental and nature conservation concerns.

The project's outputs, as presented in brief under chapter 4, was only possible through this well-assembled consortium, consisting of experienced and highly motivated ecologists, of interested user participants facilitating the outreach to a wide auditorium of endusers, and of an effective co-ordination, acting as central platform for the information flow and for data analysis.

Names of institutions and key persons who can be contacted concerning the follow-up of the project:

Project co-ordinator:

Universität Wien/Institute of Ecology and Conservation Biology/Vienna/Austria

(also responsible for the TR AT-HSW: Northeast Alps-Hochschwab/ Austria).

Project leader and chair of *GLORIA*: Prof. Dr. G. Grabherr (grab@pflaphy.pph.univie.ac.at);

Co-ordination office: Dr. M. Gottfried, Mag. D. Hohenwallner, C. Klettner, Dr. H. Pauli, Dr. K. Reiter (gloriaeurope.oekologie@univie.ac.at; gloria@pflaphy.pph.univie.ac.at).

Contacts for the target regions (TRs):

TR ES-SNE – Sierra Nevada, Spain: Universidad de Granada/Departamento de Botanica/Granada/Spain; Prof. Dr. J. Molero-Mesa (jmolero@ugr.es).

TR ES-CPY – Central Pyrenees-Ordesa, Spain: Consejo Superior de Investigaciones Científicas/Instituto Pirenaico de Ecología/Jaca/Spain; Dr. L. Villar (lvillar@ipe.csic.es).

TR IT-CAM – Central Apennines-Majella, Italy: Universita'del Molise/Dip. Scienze, Tecnologie dell'Ambiente & Territorio/Isernia/Italy; Prof. Dr. A. Stanisci (Angela.Stanisci@uniroma1.it).

TR IT-NAP – N-Apennines, Italy: Università degli Studi di Pavia/Dipartimento di Ecologia del Territorio e degli Ambienti Terrestri/Pavia/Italy; Prof. Dr. G. Rossi (grossi@et.unipv.it).

and Università degli Studi di Parma/Dipartimento di Biologia Evolutiva e Funzionale/Parma/Italy; Prof. Dr. M. Tomaselli (tomasell@unipr.it).

TR GR-LEO – Crete-Lefka Ori, Greece: Mediterranean Agronomic Institute of Chania/Department of Environmental Management/Chania/Greece; Dr. G. Kazakis (kazakis@maich.gr), D. Ghosn (dghosn@maich.gr).

TR FR-CRI –Corsica-Mt.Cinto region; France: University of Stirling/School of Biological and Environmental Sciences/Stirling/UK; Dr. L. Nagy (lnsc16324@blueyonder.co.uk).

TR FR-AME – Alps-Mercantour, France: Université Joseph Fourier, Grenoble, France; Dr. J.-L. Borel (borel@lamasig.ujf-grenoble.fr); and Parc National du Mercantour/Nice/France; Dr. B. Lequette (blequette@parc-mercantour.com).

TR CH-VAL – Western Central Alps-Entremont, Switzerland: Centre alpien de Phytogéographie/Fondation J.-M. Aubert/Campex/Switzerland; Dr. J.-P. Theurillat (jean-paul.theurillat@bioveg.unige.ch).

TR IT-ADO – Southern Alps-Dolomites, Italy: Universität Innsbruck/Institute of Botany, Department of Systematics, Palynology and Geobotany/Innsbruck/Austria; Prof. Dr. B. Erschbamer (brigitta.erschbamer@uibk.ac.at).

TR SK-CTA –High Tatra, Slovakia: Institute of Landscape Ecology of the Slovak Academy of Sciences/Bratislava/Slovakia; Dr. J. Oszlanyi (julius.oszlanyi@savba.sk) and Dr. P. Barancok (peter.barancok@savba.sk).

TR RO-CRO – Eastern Carpathians-Rodnei, Romania: Inst. of Biological Research/Dep. of Taxonomy & Ecology/Cluj-Napoca/Romania; Dr. G. Coldea (icb@mail.dntcj.ro).

TR GE-CAK – Central Caucasus-Kazbegi, Georgia: Institute of Botany of the Georgian Academy of Sciences/Tbilisi/Georgia; Prof. Dr. G. Nakhutsrishvili (nakhutsrishvili@yahoo.com).

TR UK-CAI – Cairngorms, Scotland: Centre for Ecology and Hydrology/Banchory Research Station/Banchory/UK: Dr. R. Brooker (robb@ceh.ac.uk) and Dr. N. Bayfield (nb@ceh.ac.uk).

TR NO-DOV – Central Scandes-Dovre, Norway: Norwegian University of Science and Technology/Department of Biology/Trondheim/Norway; Dr. J. Holten (jiholten@online.no) and Prof. Dr. H. Hytteborn (hakan.hytteborn@chembio.ntnu.no).

TR SE-LAT – Northern Scandes-Latnjajaure, Sweden: Goeteborg University/Botanical Institute/Goeteborg/Sweden; Prof. Dr. U. Molau (ulf.molau@systbot.gu.se).

TR RU-SUR – Southern Urals and TR RU-PUR – s Polar Urals, Russia: Inst. Plant & Animal Ecology, Ural Div. Russian Academy of Sciences/Lab. Dendrochronology/Ekaterinburg/Russia; Prof. Dr. S. Shiyatov (stepan@ipae.uran.ru) and Dr. P. Moiseev (moiseev@mail.ur.ru).

Contacts of the "user partners":

Perthcollege, Centre for Mountain Studies/Perth/Scotland, UK: Prof. Dr. M. Price (Martin.Price@perth.uhi.ac.uk).

ETH-Zürich, Mountain Research Initiative (MRI)/Zurich/Switzerland: Prof. Dr. H. Bugmann (bugmann@fowi.ethz.ch) and Dr. M. Reasoner (mel.reasoner@sanw.unibe.ch).

La Commission International pour la Protection des Alpes (CIPRA)/Schaan/Liechtenstein: Mag. E. Haubner-Köll (elke.haubner@aon.at).

Worldwide Fund for Nature (WWF)/Vienna/Austria: Dr. S. Moidl (stefan.moidl@wwf.at).

8. Results and Conclusions

The outputs and results of *GLORIA*-Europe can be grouped in four main categories. These were described in detail in chapter four and are summarised here.

Developed methods, protocols, tools, and structures

The *GLORIA Field Manual* served as the basis for all data sampling activities in the project. It was developed further during the project, and finalised and accepted at the workshop in October 2002. An English and a Spanish version are in print.

The protocols of this manual were applied in 18 target regions, distributed over the five major latitudinal vegetation zones of Europe, stretching from southern Spain to the Polar Urals in Russia. In each target region, four summits were selected as observation sites, aligned along the elevation gradient from the treeline ecotone to the nival zone. On each summit, eight summit area sections and 16 1x1 m quadrats were installed as long-term monitoring plots; their vegetation and abiotic features were sampled. Climate series for temperature and derived indices were obtained by four miniature dataloggers per summit. This continent-wide, and standardised, mountain observation network will be the basis for future monitoring of climate impacts on Europe’s high mountain flora and vegetation.

Electronic tools were developed to aid the data input process. These guaranteed full compliance of the several target region datasets. All data provided by the consortium members were compiled to the *Central GLORIA Database*, residing at the co-ordinators server. The database comprises about 3.5 million single entries.

From the start of the project, a website was implemented. It served not only as platform for information and data exchange between the consortium but was one of the project’s main interfaces to the public. Most of the tools and documents developed in the project can be downloaded. On highly structured dynamic webpages, the *GLORIA* dataset is presented online.

GLORIA-Europe has strengthened the co-operation with related global change research networks, programmes, and projects in order to build, respectively to improve, interfaces and to integrate into the wider scope of global change research with its physical, biotic, and socio-economic components. Among them are *GTOS (Global Terrestrial Observing System), GMES (Global Monitoring for Environment and Security), MRI (Mountain Research Initiative), GMBA (Global Mountain Biodiversity Assessment), ITEX (International Tundra Experiment), GLOCHAMORE (FP-6), ALARM (FP-6), ALTER-Net (FP-6).*

Datasets

GLORIA-Europe produced four main datasets:

(a) Surveying data for plot repositioning. These data are essential for drawing detailed outlines of the particular sampling designs on each summit, as well as for future reassignment of the sampling plots for monitoring.

(b) Photo data. Each sampling plot was photo documented. This will not only support the future plot re-installation but is vital for interpreting any scientific results, of the current analysis as well as of the future monitoring. Moreover, the photo database contains numerous pictures documenting fieldwork, landscapes, and plants. Currently, 5175 pictures are available.

(c) Data of biotic and abiotic parameters. For each sampling plot, complete lists of vascular plant species and optionally of bryophytes and lichens were recorded. The ground cover of each single species and the total vegetation cover was sampled. Estimates of abiotic parameters such as slope, compass direction, and substrate types complete the records. These data were obtained at three spatial levels: at the 50 to 5000 m² level, for summit area sections; at the 1 m² level for 1x1 m quadrats; and on the 0.01 m² level for frequency counts. These data sum up to about 350000 single entries.

(d) Climatic data. This set comprises 290 one-year series for temperature, and derived parameters such as length-of-growing-season. Each summit site was measured at four standard positions at the centres of 3x3 m plot clusters. The climate series are managed in a database constructed for the special needs of analyses. The dataset comprises about 2750000 single temperature counts. With that, it is the spatially most detailed consistent dataset of Europe's alpine climate currently available. It is not only the basis for several analyses within the reported project itself but will be also input to other activities and projects, e.g., the FP-6 Integrated Project *ALARM*.

Scientific results

In all 18 target regions together, 991 vascular plant species were found; this is about 30% of Europe's alpine flora. Striking differences in species richness were observed, ranging from only 14 in the Scottish Cairngorms to 198 species in the Dolomites, Southern Alps. No north-south gradient of vascular species richness was observed, but an elevation gradient with decreasing numbers towards the peaks, with few exceptions; e.g. n the Northern Apennines. Among the main compass directions, the eastern sides showed the highest number of species on average. Locally distributed species (endemics) showed increasing percentages of the total vascular flora with altitude. Analyses from the particular target regions provided valuable insights into the regional differences of biodiversity and temperature-related gradients.

A number of clearly defined climatic gradients were described at different spatial levels. Not surprising, on most of the summits temperature as well as the length of the growing season decrease from south to east/west to north. These parameters in general decrease with altitude in all target regions. However, surprising differences appeared both within and between target regions. For instance, some sites show a highly contradicting regime of soil freezing during winter, with sites of soil temperatures around 0 °C through almost the whole non-growing season while others show deep soil freezing. Pooling the Europe-wide data elucidated that the particular high mountain vegetation belts are continent-wide highly comparable in terms of climate features. Bioclimatic envelopes can be defined now for these vegetation belts. These are vital for scenario building on the consequences of the anticipated climate changes for the mountain flora and vegetation.

A synoptic account on the risks for Europe's mountain plant diversity and respective publications are in preparation. A high risk of critical climate-induced biodiversity losses is assumed for regions showing a high degree of endemic plants which are at the same time centred within the uppermost elevation levels; e.g., the Sierra Nevada, Central Apennines, Central Caucasus. In the latter region, rare mesophilic species restricted to the treeline ecotone are also considered to be at risk to suffer significant losses in consequence of reduced snow protection, and thus colder winters. A comparison of plant distribution patterns with climatic parameters, derived from the temperature time series measured during this project, showed that cryophilic species are distinguishable from more thermophilic plants; however, different temperature-related ecological factors such as yearly mean temperature, length of growing season, mean temperature of the growing season, are of differential relevance in the particular mountain regions. Climate change, a sustained warming in particular, are likely to affect most of the alpine regions, yet the impacts on their biological richness can be pronouncedly differ in their destructive effects. Future monitoring, building on the baseline established by this project, will be crucial to calibrate the currently developed and data-based scenarios and risk assessments.

The *Multi-Summit approach* focused in the first instance on temperature and on vascular plants, being the most important organism group concerning biomass and, among the plants, the most diverse organism group. Other organism groups, however, hold other functions in an ecosystem and thus may be used as value additional indicators of climate change impacts. Therefore, appropriate methods for using bryophytes, nematodes, and fungi associated to plants and soil were tested. Further, a task force group for establishing GLORIA master sites emerged from the project. Master sites will be established at existing field station to carry out more extensive monitoring, including other indicator organisms, and experimental studies as a synergistic approach to the *Multi-Summit* network.

Outputs for and dissemination to the expert and non-expert audience

While the synoptic analytical papers of the project's results are – as usual for scientific projects – still in preparation, GLORIA produced so far a number of scientific papers dealing mostly with regional results. Until the editing of this reports, 37 contributions were published or in press, and five more were submitted or in preparation.

The consortium members were active in promoting the project. Fifty-five papers were presented at scientific conferences and meetings.

Various types of materials and products for disseminating the ideas and outputs of GLORIA-Europe to the non-expert audience were released, on paper as well as electronically. Beside scientific information, the GLORIA websites presents a huge amount of materials which are of interest for the public. This includes the project’s two glossy brochures, the photo database, and, probably most attractive, the press corner where reports in newspapers or journal articles dealing with the project are posted. GLORIA-Europe organised two press conferences and stimulated 36 newspaper and popular journal articles as well as nine TV and radio reports. The user participants of the consortium played a key role in the dissemination process. They presented the background and results of GLORIA to various public audiences and were active in organising press releases.

The long-term operation of GLORIA

The self-maintained operation of the *GLORIA* network, after it is once established on the global scale, is a key concern and is accomplishable thanks to the stimulating pilot project *GLORIA-Europe*. Five additional target regions in Europe, each with 4 sites were recently established, and 5 in other continents are currently in the set-up phase; all these efforts were financed by local or national funds. Partners of the project were active in education and training through university courses teaching the young generation of future researchers. The standardised high-quality data of the network are getting increasingly attractive as baseline for re-investigations and model evaluations in the short- mid- and the longer-term future.

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11. Glossary of acronyms and terms used in this report

Alpine life zone: the area from the low-temperature determined *treeline ecotone* upwards. The term is applied to the *high mountain biome* world-wide and to any low stature vegetation between the climatic *treeline ecotone* and the highest tops of mountains (compare KÖRNER 1999).

Central GLORIA Database*:* This database is maintained at the *GLORIA* server in Vienna and holds all *GLORIA* data collected until now (www.gloria.ac.at/res/fieldDataBase/*).*

CIPRA: *La Commission International pour la Protection des Alpes*, (www.cipra.org).

DIVERSITAS: an international programme on biodiversity research, (www.icsu.org/DIVERSITAS/).

Frequency counts: this term is used here for presence/absence records of plant species (vascular plant species obligatory, cryptogam species optional) and of *grazing impacts* within the *16-quadrat area* by using a *1m x 1m grid frame*.

ECNC: European Centre for Nature Conservation, (www.ecnc.nl/).

EEA: European Environment Agency, (www.eea.eu.int/).

GCTE: *Global Change and Terrestrial Ecosystem,* a Core Project of *IGBP,* (www.gcte.org/index.htm).

GLORIA: *Global Observation Research Initiative in Alpine Environments,* (www.gloria.ac.at).

GLORIA data input tools (GDIT): Electronic tools for data input available at the *GLORIA* server (www.gloria.ac.at/res/downloads/GDIT/).

GLORIA master sites: existing field stations and institutions for high mountain ecology and climate impact research, where more extensive studies (including monitoring, experimental and modelling approaches) can be carried out; a set of such stations (the number much smaller than those of the target regions for the *Multi-Summit approach*) is planned to participate in the *GLORIA* network.

GMBA: *Global Mountain Biodiversity Assessment* – a new network of *DIVERSITAS,* (www.unibas.ch/gmba).

GMES: Global Monitoring for Environment and Security; an initiative of the European Commission and the European Space Agency; (www.GMES.info).

GTOS: *Global Terrestrial Observing System* established by *FAO, ICSU, UNEP, UNESCO, and WMO,* (www.fao.org/gtos/gt-netmou.html and www.gos.udel.edu/gtos/GTNet-M_data_access.htm)

High mountain environment: generally corresponds to the *alpine life zone.* According to TROLL 1966, high mountain areas are determined by 1) their position above the natural low-temperature treeline; 2) a landscape shaped by glaciers, which were present at least in the Pleistocene; 3) frost as an important factor for pedogenesis and substrate structure.

ICSU: International Council for Science, (www.icsu.org).

IGBP: *International Geosphere-Biosphere Programme,* (www.igbp.kva.se/cgi-bin/php/frameset.php).

IHDP: *International Human Dimension Programme on Global Environmental Change, (*http://www.uni-bonn.de/ihdp/*).*

IP: Integrated Project; a new instrument of the FP-6 of the European Community.

IPCC: *Intergovernmental Panel on Climate change, (*www.ipcc.ch/*).*

ITEX: International Tundra Experiment, (www.itex-science.net/default.cfm).

Mountain Forum: a global network for mountain communities, environments, and sustainable development, (http://www.mtnforum.org/index.html).

MRI: *Mountain Research Initiative* of *IGBP/GTOS,* (www.mri.unibe.ch/).

Multi-Summit approach: the basic approach of *GLORIA* for the comparison of climate-induced changes of high mountain biota along the vertical and horizontal climatic gradients. Summit sites arranged in different altitudes in a *target region* will be used as reference units. Such *target regions* should be distributed over all major life zones on Earth. The standardised sampling design, as described in this manual, should be applied on each summit site.

Quadrat: used here for permanent 1m² quadrats for detailed vegetation samples, at the 4 corner positions within the *3m x 3m plot clusters.*

Summit: culmination points in a mountain system. In the context of the *GLORIA* network, this can be even a small hump in a ridge which projects only 20 elevation metres above the surrounding land features.

Summit area: the entire sampling area of a summit site used for the *Multi-Summit approach*: i.e., 16-quadrat area, 5-m summit area (which includes the 16-quadrat area), and 10-m summit area.

Summit area section (SA-section): the 4 subdivisions of the *5-m summit area* and the 4 subdivisions of the 10-m summit area (8 sections per summit). These sections are used as sampling units to estimate the total vegetation cover, the cover of the common species (by using the *step-pointing* method) and the abundance of all vascular plant species (by using *abundance classes*) within the *summit area*.

Target region: the mountain area in which at least 4 summit sites, representing the regional elevation gradient, are located. The general climatic situation within this area should not show fundamental differences along a horizontal gradient.

TR: see target region.

Temperature data loggers: small instruments (StowAway Tidbit loggers are currently suggested) used for continuous temperature measurements on the *summits* at 10cm below soil surface. Aim is to compare the temperature regimes and to detect the length of the snow-cover period along the elevation gradient.

UK ECN: The UK Environmental Change Network, (www.ecn.ac.uk/).

UNEP: United Nations Environmental Programme, (www.unep.org/).

UNESCO MaB: The Man and Biosphere programme of the United Nations Educational, Scientific and Cultural Organization, (www.unesco.org/mab/).

WMO: World Meteorological Organisation – a United Nations Specialised Agency, (www.wmo.ch/index-en.html).