Geogr. Fis. Dinam. Quat.
24 (2001), 199-201, 2 figg.

Nota Breve
Short communication

GUGLIELMINA DIOLAIUTI (*), CARLO D'AGATA (*), MAURO PAVAN (**), GIORGIO VASSENA (***), CARLO LANZI (***), MARIO PINOLI (****), MANUELA PELFINI (*), MASSIMO PECCI (*****) & CLAUDIO SMIRAGLIA C. (*)

THE PHYSICAL EVOLUTION OF AND THE ANTHROPIC IMPACT ON A GLACIER SUBJECTED TO A HIGH INFLUX OF TOURISTS: VEDRETTA PIANA GLACIER (ITALIAN ALPS)

ABSTRACT: DIOLAIUTI G., D'AGATA C., PAVAN M., VASSENA G., LANZI C., PINOLI M., PELFINI M., PECCI M. & SMIRAGLIA C., *The physical evolution of and the anthropic impact on a glacier subjected to a high influx of tourists: Vedretta Piana Glacier (Italian Alps).* (IT ISSN 0391-9838, 2001).

Vedretta Piana Glacier is situated in Valle di Trafoi, near Stelvio Pass (Italian Alps). Summer skiing has been a popular sport on this glacier for over seventy years. On this glacier a study for determining its recent evolution was carried out by means of a quantitative, detailed analysis (GPS and GPR surveys) carried out in 1999 and in 2000. The data elaboration shows that the loss of ice and snow during the September 1999 - September 2000 period was equal to 938.920 m^3. The specific net mass balance for the 1999/2000 hydrological year thus amounts to –2.138 mm. The glacier's mean thickness proved to be equal to 71 m. The glacier volume proved to be equal to 72.500.000 m^3 over a surface area of about 1 km^2. The survival time of the glacier is valued of about 35 years (KEY WORDS: Glaciers, Tourism, Vedretta Piana, Alps).

RIASSUNTO: DIOLAIUTI G., D'AGATA C., PAVAN M., VASSENA G., LANZI C., PINOLI M., PELFINI M., PECCI M. & SMIRAGLIA C., *L'evoluzione fisica e l'impatto antropico di un ghiacciaio sottoposto ad intensa frequentazione turistica: la Vedretta Piana (Alpi Italiane).* (IT ISSN 0391-9838, 2001).

Il Ghiacciaio della Vedretta Piana è situato nella Valle di Trafoi vicino al Passo dello Stelvio (Alpi Italiane). Su questo ghiacciaio, dove da oltre 70 anni viene praticato lo sci estivo, sono stati effettuati nel 1999 e nel 2000 rilievi dettagliati per determinare la sua evoluzione in atto mediante GPS e GPR. L'elaborazione dei dati ha indicato che fra il Settembre 1999 ed il Settembre 2000 vi è stata una perdita di nevato e di ghiaccio pari a 938.920 m^3. Il bilancio di massa netto specifico calcolato per l'anno idrologico 1999/2000 ammonta a –2138 mm. Lo spessore medio del ghiacciaio è stato stimato pari a 71 m. Il volume calcolato è pari a 72.500.000 m^3 di ghiaccio su una superficie di circa 1 km^2. Il tempo di sopravvivenza dell'apparato glaciale è stato valutato pari a circa 35 anni (TERMINI CHIAVE: Ghiacciai, Turismo, Vedretta Piana, Alpi).

Vedretta Piana Glacier is situated in Valle di Trafoi, a valley incised by a torrent bearing the same name on the Adige side of the Ortles-Cevedale Massif (Italian Alps). This structure has a particular morphology that extends over the Punta degli Spiriti crest in a north-northwest direction and without well-defined boundaries. In fact, the upper sector is subdivided into differentiated flows, which in the eastern sector feed the Madaccio Glacier, while in the western sector, they flow into the Vitelli Glacier (Desio, 1967).

Summer skiing has been a popular sport on this glacier for over seventy years. The area utilized for this sport also includes part of the catchment area of the Vitelli Glacier, which flows towards Valtellina and of the Madaccio Glacier, which flows towards Val Venosta.

The use of the glacier for tourist activities and the construction of lifts and infrastructures serving for those activities have undoubtedly influenced the dynamics of the glacier, in addition to changing the natural landscape (Diolaiuti, Pelfini & Smiraglia, in press).

(*) *Dipartimento di Scienze della Terra, Università degli Studi di Milano.*
(**) *Dipartimento per lo Studio del Territorio e delle sue Risorse, Università degli Studi di Genova.*
(***) *Dipartimento di Ingegneria Civile, Università degli Studi di Brescia.*
(****) *Montana S.r.l.*
(*****) *ISPESL, Roma.*

Communication presented at the EGS (European Geophysical Society) Meeting in Nice (26 march 2001, Glaciology and Climatology poster session, Glaciers and Icesheets). This study was part of the research program «Alpine Glacier and Environmental variations», COFIN MURST 40% 1999 and of the program of Comitato di Gestione Lombardo del Parco Nazionale dello Stelvio «Vedretta Piana in the Stelvio National Park: geometric and volumetric variations». The authors thank the Centro Nivometeorologico Regione Lombardia in Bormio and the Laboratorio Alte Prestazioni at S. Caterina Valfurva for the logistic support.

The number of lifts and their size have varied over time, depending upon the changes in the glacier's extension and snow cover over which they stand. In fact, as in other areas where summer skiing is popular, several lifts at Stelvio Pass have been abandoned due to the complete disappearance of the underlying ice, which served to support the ski trails (this is the case of the ski lifts located on Platigliole Glacier) following the glacial recession in recent years caused by global warming. With the change in climate, the area available for tourist activities (summer skiing) on the glacier has also undergone changes. In conclusion, on the one hand, the presence of man has influenced the glacier system and its evolution over time, and on the other hand, the change in climate has brought about changes in the glacier (its volume and extension), which, in turn, have limited the influx of tourists and man's use of the glacier.

On this glacier a study for determining its recent evolution was carried out by means of a quantitative, detailed analysis carried out in 1999 and in 2000 (Smiraglia & Diolaiuti, 2000). The analysis was aimed at determining the glacier's main geometric features and those pertaining to its dynamics. More specifically, quantitative data were collected on its thickness and current volume, on the dynamic phase in progress and on the pace of its transformation and the response times to forcing phenomena of a climatic type (response, reaction and relaxation times). All of this is directed towards the construction of database with essential information serving for a more in-depth knowledge of this glacier as a natural resource, for the purpose of quantifying the impacts brought about by man and postulating possible measures for the preservation and compatible use of this natural asset.

This research was organized in stages, a fieldwork stage carried out during the summers of 1999 and 2000 and a later stage serving for data processing and analysis.

In the summer of 1999 the following fieldworks were carried out:

1) two topographic surveys using Real Time Kinematic (RTK) GPS in June and September for the acquisition of reference points and the subsequent calculation of two DEMs (Digital Elevation Model) on the glacier; 2) placement of measurement points to assess the entity of summer ablation using the traditional method with ablation stakes; 3) two radar surveys (GPR techniques) to determine the thicknesses of the ice. We used 35 and 50 Mhz antennas; 4) measurement on the variations in thickness and density at the stakes

In the Summer of 2000 the fieldworks were the following ones:

1) two topographic surveys (July-September) using RTK GPS for the acquisition of reference points and for the subsequent calculation of two DEMs on the glacier; 2) Post-Processing (PP) GPS monitoring of variations in the extension of the surface occupied by ski slopes and the number of crevasses present; 3) preparation of geomorphologic sketches and thematic maps using GIS, serving to represent the variations in area over time.

The data processing and analysis followed those steps:

1) comparison of four topographic DEMs in order to determine the variations in glacier thickness during the summer months and to evaluate the mass balance; 2) processing of the stake measurement variation data to determine the ablation rates; 3) filtering of the radar tracks surveyed and interpretation of GPR profiles to determine the thicknesses and to prepare an isopach map (fig. 1) showing the morphology of the bedrock; 4) seasonal evaluation of the variations in the extension of the ski-trails surface and in the evolution of the number of crevasses present; 5) comparison of the historical maps (1955-1981) by means of digitalization and the evaluation of the variations in thickness that took place; comparison of the 1981 map with the map prepared in 1999 using the GPS surveys.

The main results of the research especially deriving from the comparison of four DEMs led to an assessment of the thickness and volume variations of the glacier under examination.

The loss of ice and snow during the 1999 June-September period amounted to 441,890 m^3 corresponding to a mean thickness of 871 mm. The loss of ice and snow

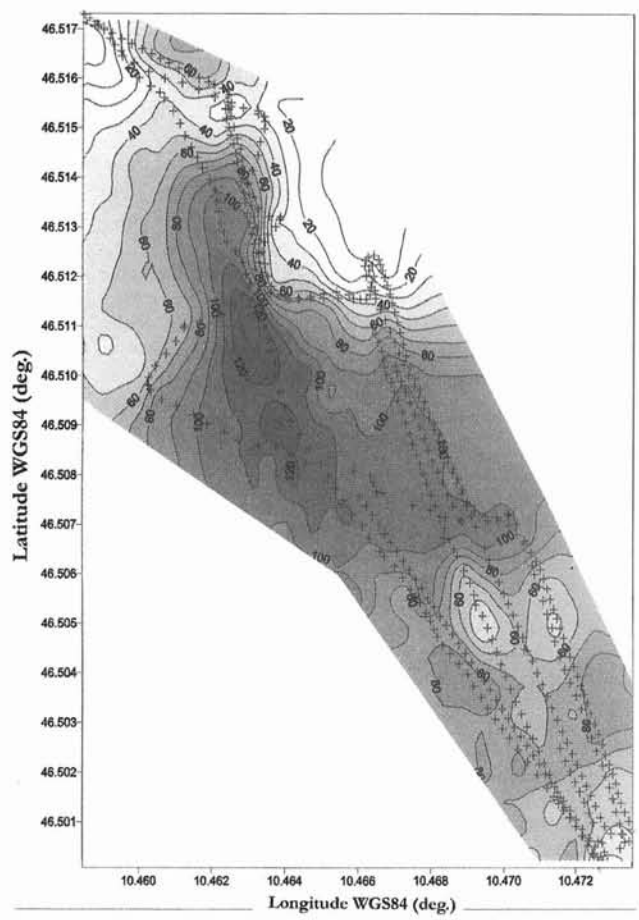

Fig. 1 - Isopach Map obtained from elaboration of GPR survey data.

Fig. 2 - Human impact on Vedretta Piana Glacier, snow pit at the beginning of the summer season in order to prepare the ski area for tourist activity.

in the 2000 July-September period amounted to 605,876 m^3 corresponding to a mean thickness of 1227 mm. The loss of ice and snow during the September 1999 - September 2000 period was equal to 938.920 m^3. The specific net mass balance for the 1999/2000 hydrological year thus amounts to –2.138 mm. The glacier's mean thickness was calculated from the isopach map derived from the radar survey and it proved to be equal to 71 m. The glacier volume proved to be equal to 72.500.000 m^3 over a surface area of about 1 km^2.

The GPR surveys reported only partial information about glacier's thickness because scattering and signal adsorption, due to crevasses and to liquid water that which is contained in them, have limited the response of the bedrock surface in the lateral part of the glacier. The maximum measured thickness is of about 100 m, but the central area of Vedretta Piana seems to be deeper.

The comparison between the historical maps dating from 1955 to 1981 revealed a slightly positive balance, with a mean increase of 2 m. The balance for the next twenty-year period (1981-1999) proved to be markedly negative with a mean decrease of slightly over 7 m in thickness.

Accumulation as detected by GPS monitoring proved to be influenced by snowcats bringing snow down from the upper sections, demonstrating the strong influence of anthropic activities on the dynamics and evolution of the glacier (fig. 2).

In conclusion what does the future hold in store for Vedretta Piana? How much longer will it still be possible to use it for summer skiing? Will this sport accelerate the current dynamics of the glacier? Is sustainable tourism a feasible option?

Finding answers to these questions is not an easy matter, for these answers are interconnected with the extreme complexity of a system in which natural dynamics and human behaviors are interrelated (Pinoli, 2000). If we utilize the current thickness of the glacier and the 1999-2000 balance figures, the glacier proves to have a survival time of 35 years. However, if we consider the longer-term data resulting from the comparison of the maps available (1955-1981-1999), the glacier's survival time (Haeberli & Hoeltze, 1995) increases to 70 years. Obviously, although the research results are highly reliable in terms of the volume and thickness measurements, they are less reliable as regards the calculation of the glacier's survival time. In fact, the estimates are based on the very likely, but not certain supposition that present-day climatic conditions will not change, except in the sense of a further rise in temperature. This will evidently have a clear-cut negative influence on the «glacier's health» and its «skiing potential», increasing the annual ablation rate. However, if an event like the Cold Event of the second half of 20th century (Pinna, 1996) were to occur, it would favour the continuation of summer skiing, for it increased glacier accumulation areas. If it were not to occur, Vedretta Piana, which could reach extinction as a glacier before the end of the 21st century, would no longer be usable for summer skiing already several decades before then due to the whole series of processes that generally accompany the extinction of a glacier (increase in debris cover, reduction of the accumulation area, rise in the altitude of the snow line, changes in its longitudinal profile and surface morphology). The consequence would be a possibility of glacier use for summer skiing for slightly over twenty years. Moreover, this period could be further reduced if the influence of man on its mass balance were to become of massive scope.

In any case, the supply of tourist-related offerings in the Stelvio Pass district will necessarily have to be diversified in order to contribute to the delicate balance between economic needs and the preservation of natural assets in the desired direction of Sustainable Development.

REFERENCES

DESIO A. (1967) - *I Ghiacciai dell'Ortles Cevedale*, Comitato Glaciologico Italiano, Torino, 874 pp.

DIOLAIUTI G., PELFINI M.& SMIRAGLIA C. (in press) - *Il turismo estivo al Passo dello Stelvio (Alpi Centrali): problemi e prospettive della fruizione antropica di un ghiacciaio alpino in un'area protetta.* Proceedings of the International Workshop on National Park and Protect Areas, Sharm el Sheik 28 Maj-2 June 2000.

HAEBERLI W. & HOELZLE M. (1995) - *Application of inventory data for estimating characteristics of and regional climate change effects on mountain glaciers: a pilot study with the European Alps.* Ann. Glaciol., 21, 206-212.

PINNA M. (1996) - *Le variazioni recenti del clima*, Angeli, Milano, 214 pp.

PINOLI M. (2000) - *Manuale di gestione ambientale per l'area ghiacciaio.* Montana, Milano, 16 pp.

SMIRAGLIA C. & DIOLAIUTI G. (a cura di) (2000) - *La Vedretta Piana nel Parco Nazionale dello Stelvio. Caratterizzazione geometrica e dinamica.* Relazione sui risultati delle ricerche svolte nell'ambito della convenzione con il Comitato di Gestione Lombardo del Parco Nazionale dello Stelvio. Milano, pp. 55.

(ms. received 1 September 2001; accepted 1 November 2001)