METEOMONT SERVICE'S METEO-NIVOLOGICAL INFORMATIVE SYSTEM: A WEB-GIS APPROACH

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ABSTRACT:

Avalanches endanger natural and human systems and also military activities. In order to asses avalanche risk Italian Alpini Corps are provided with the Meteomont Service. In the past avalanches were surveyed and then plotted on paper maps, at 1:25000 scale, called "Monografia Militare delle Valanghe" and described on an attached book where historical and descriptive data of each event are recorded.
Nowadays the avalanche recording/displaying system has evolved to a web-GIS based application. The system integrates avalanche data with other sources as meteorological stations and other map layers. Layers are divided into two main groups: base layers and thematic layers. The first group includes both vector and raster data in order to represent the Alps sector with a multiscale approach. Thematic data represent the locations of meteorological stations, drilling pathways or area of interest as natural reserves.
The system has a web interface that allows every authorized user to access the described data and moreover perform simple processing such as querying data.
Avalanche data have been digitized from georeferenced maps and the associated records have been contemporarily inputted, both processes have been performed on a customized interface that interacts with an ArcSDE database where all data are stored. Than the database is interfaced with an ArcIMS map server that serves data to the authorized users' browsers.
The aim of the system is to provide Army Officers with an interactive geographical tool in order to improve their capability of managing and planning troops activities and contemporarily preventing avalanche and meteorological risks.

1. INTRODUCTION

Avalanches are a natural phenomenon, sometimes having tragic consequences, by which man, whether professional operator or tourist, has to compete with, on the basis of a deepened knowledge of this phenomenon characteristics and environmental conditions in which it could potentially take place.
These characteristics and conditions are also highly variable in space and time and depend on many factors, e.g. environmental and weather related, so a constant monitoring is a prerequisite for effective prevention activities and forecasting.
Operational and training tasks of Alpini Corps and the natural scenario in which they usually operate have, therefore, made essential the presence of a technical body capable of providing an informative support to units, necessary to provide a maximum security frame during activities carried out in snowy mountain areas.
In this context, the Meteomont service operates, whose main task is to provide its users with the informative support through the study of territory characteristics and the constant monitoring of meteo nivological parameters involved in avalanche phenomenology.
The monitoring system consists of the "Centro Raccolta Dati" (Data Collection Center), dislocated at "Centro Meteorologico dell'Aeronautica Militare" (Air Force Meteorological Centre) in Milano – Linate Airport, appointed to collect, compile and issue weather bulletins on the basis of data provided by "Servizio Meteorologico dell'Aeronautica Militare" (Air Force Meteorological Service), and a stations network, active throughout the whole Alpine area, composed of automatic and manual stations and of mobile squads.

Figure 1. Nivological surveys (Photo Courtesy Lieutenant E. Annis)

The surveys are carried out daily by the "Centri Settore Meteomont", squads located in different Alpini Corps bases, and concerns the key parameters for weather and snow conditions and those related to the avalanche phenomena observation (Figure 1), those analysis and evaluation allows, on the basis of Air Force bulletins, the release of "Bollettino della Neve e delle Valanghe" (Snow and Avalanche Bulletin),

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available also on the website www.meteomont.org, which therefore constitutes a major tool in the field of information in mountain security.
This instrument is not, in itself, sufficient to ensure an adequate framework of security for the users but it must necessarily be accompanied by an informative tool about the environmental characteristics in which they operate and this tool is the "Sistema Informativo Meteonivologico Territoriale" (Meteo Nivological Territorial Information System) or S.I.M.T.
The original framework of S.I.M.T. has been developed in ArcInfo environment on a Digital Open VMS platform (Goldenberg, 2002; Goldenberg et al., 1997) and now upgraded to the ArcGis environment running on MS Windows platforms.

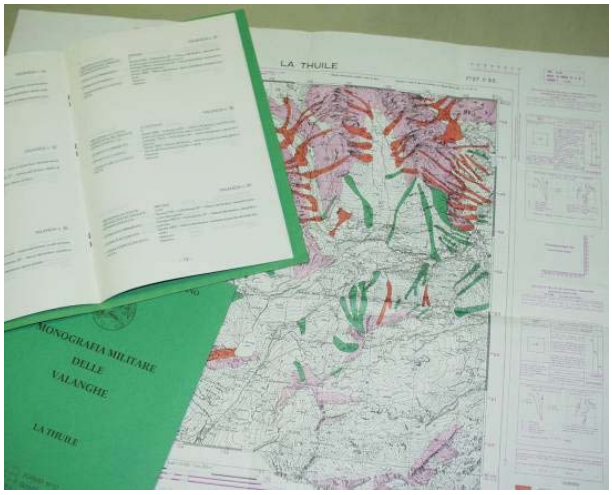

Figure 2. Elements of the "Monografia militare delle Valanghe", 1:25000 map (in background) and the attached book.

2. S.I.M.T. COMPONENTS AND STRUCTURE

2.1 Monografia Militare delle Valanghe

Avalanche phenomena observed during survey campaigns are recorded on a documentary support called "Monografia Militare delle Valanghe" (Military Avalanche Monograph). The main purpose of this support, coupled with the consultation of the Snow and Avalanche Bulletin, is to assure the safe accomplishment of drills and, generally, troop activities. The base map is a topographical map at 1:25000 scale produced by "Istituto Geografico Militare" (Geographic Military Institute) or I.G.M. Avalanche data are plotted on the map according to a four phases, multidisciplinary, methodology (Tecilla, 2007) as it involves several expertise areas as forestry, geology and photogrammetry.
In the first phase an historical research is carried out in order to point out the main phenomena of the study area and, then, a photo-interpretation is performed with the purpose of locating physical and geomorphological evidences of avalanche terrains. After these operations a first draft map is produced with the plotting of the detected avalanches. The second phase is a validation procedure and a study of the phenomena during wintertime. By airborne reconnaissance the whole studied territory is carefully checked in comparison with nivological features too. During survey a photographical documentation is built up, too. Then, in the following spring and summer seasons, field survey are carried out with the aim of defining release, track and deposit zones (Mc Lung and Schaerer, 1993) for each detected avalanche. Moreover, for every phenomenon, local witnesses are collected in order to complete the informative framework. At the end of these phases the map is ready to be printed and distributed.

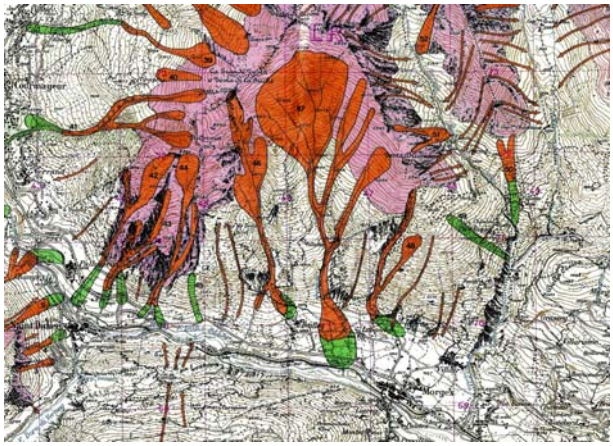
Figure 3. Graphical representation of avalanches in "Monografia militare delle Valanghe"

Avalanches are represented in different way in relation to their dimension and frequency:

- "Valanga Abituale" (habitual avalanche) : red polygons – the avalanche occurs one or more time during the year;
- "Valanga Periodica" (periodical avalanche): green polygon – the avalanche occurs with a frequency lower than 10 years
- "Valanga Eccezionale" (exceptional avalanche): the avalanche occurs with a frequency higher than 10 years or due to exceptional snowfall;
- "Zone pericolose" (risk prone areas): pink polygons with a dashed outline – areas where every point is prone to even partial releases risk, with various dimensions;
- "Valanga localizzata di piccola mole" (small proportions localised avalanche): red arrows – deposit width lower than 25 metres. The high event frequency may origin large deposit volumes.

The final document is constituted by the described paper map with avalanches numbered progressively inside any 1:25000 element. This number links the avalanche to a monographic form containing the description of every single phenomenon (Figure 4). Morphological features and historical data are displayed in order to provide a exhaustive site explanation.
The "Monografia Militare delle Valanghe" is therefore a statistical based document without forecasting aims, its main purpose is to provide additional decisional element to Officers when planning troops activities in mountain areas, by comparing map data with other , current or forecast, variables such as meteorological or snowpack conditions.
Avalanche polygons does not represent permanently avalanche events nor risk level while, on the other hand, areas where avalanche have not been plotted, due to lacking data or information, could be equally prone to similar risks.

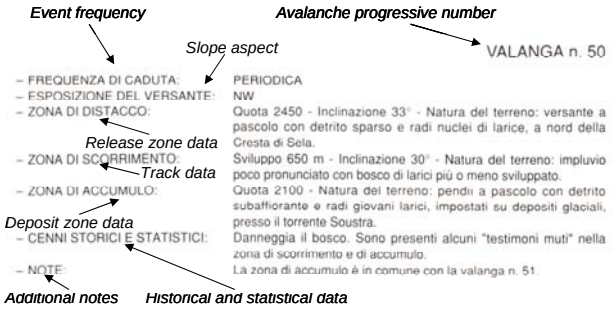

Figure 4. Avalanche descriptive form in the Monograph

2.2 Meteorological stations

The monitoring system of Meteomont Service is based on the activity of a monitoring network consisting of 99 stations:

- 51 manual stations entirely managed by military personnel;
- 48 automatic supported by 21 radio repeaters for data transmission.

The network is subdivided into 6 Alpine Areas and 1 Apennine Subsector concerning the Abruzzo Region.

The territorial distribution of the network has been defined, in order to ensure a comprehensive coverage of nivological monitoring and surveys areas and to allow the integration with other, civilian, networks; however, the service presence is emphasized in areas of military interest.

The Meteomont Service's information system is complemented by mobile survey squad operating in training, drills or generally of military interest, where the monitoring network is insufficient, or for other special needs. These squads, formed by specialized personnel, carry out detailed patrols and surveys in order to define in a more detailed and localized way the degree of avalanche risk.

2.3 Base layers

This first group includes both vector and raster data with the aim of representing the Alps sector with a multiscale approach, as the visualization may display the entire mountain range or can be focused on a single avalanche polygon or geographical zone. Data are obtained by "Istituto Geografico Militare" maps layers or by different sources as Regions or Provinces that issues their data to the Meteomont Service or from free web databases. The task of this data collection has been to provide a complete coverage of base maps of the Alpine region. These data have been processed in order to perform the necessary generalization or other geo-processing operations in order to merge correctly with other layers.

The Provincia Autonoma di Bolzano has been chosen as a test area because of the availability of high detail geographical datasets. The described processing has concerned the elevation layers (Appendix B. Multiscale Elevation Representation), considered a key factor among the S.I.M.T. purposes; the SRTM Digital Elevation Database (Farr et al., 2007; Jarvis et al., 2008; Rabus et al., 2003) has been chosen as the first one, thank to its resolution, approximately 90 m, and free availability it has been selected as a background layer in the full extent visualization of the study area. In order to obtain a full cover SRTM tiles have been merged into an unique raster layer. The output raster has then been projected according to the reference system employed in the system, UTM – ED 50, Zone 33N. The data has been further processed to obtain an hillshade map, to better represent the region morphology (Figure B1). Currently investigation have been carried out about the employment of an other free elevation database, the ASTER GDEM (Hirano et al., 2003; Huggel et al., 2008) due to its higher resolution and consequent employment at higher detail levels.

This first elevation layer disappears automatically at 1:250000 scale in order to allow the visualization of a second, more detailed, elevation map. The layer is the Digital Elevation Model of the Provincia Autonoma di Bolzano obtained from an Airborne Laser Scanner survey. The resolution varies according to three different areas (http://www.provinz.bz.it/raumordnung/kartografie/):

1. Zones included in 1:5000 technical maps (2594 km²): 0.64 laser point per square meter;
2. Zone not included in previous maps at altitude lower than 2000 m a.s.l. (2149 km²): 0.32 laser point per square meter;
3. Zone not included in previous maps at altitude higher than 2000 m a.s.l. (2668 km²): 0.12 laser point per square meter.

The accuracy varies, too, ranging respectively from ±25 to ±55 cm.

Data available in ASCII raster, with a 2.5 m cell size have been converted in ESRI GRID format and then merged together. As the previous one, the final raster has been projected into the desired system. The layer has been employed twice in the visualization, in the 1:250000 to 1:50000 scale interval it has been shown as an elevation layer representing different altitude intervals with certain colours (Figure B2), as defined by "Ordine Permanente OA 32" (1999); then at an higher detail, i.e. under 1:50000, the digital elevation model has been processed and thus visualized as an hillshade (Figure B3), the same layer has also been employed to produce a slope and aspect map (with intervals and colours defined according to the previously cited source) in order to help the user to point out areas with high or light avalanche release risk according to morphological parameters (United States Army Alaska's Northern Warfare Training Center, 2008).

The laser scanner campaign have also provided high resolution orthoimages (50 cm pixel size), which have been processed into a raster catalogue and included in the system at high level detail scales.

Vector base layer have also been managed according to the previously explained method, administrative borders, contour lines, etc. are visible according to the following table. Features are obtained from the I.G.M. vector database

2.4 Thematic layers

The previously described base layers are a support to other layers employed in the system main tasks (Figure A1). They are inputted in the final database according different methodologies in relation to the original data source. Layers characteristics are described in the following paragraphs while descriptive images are inserted in Appendix A "S.I.M.T. Screenshots"

"Monografia Militare delle Valanghe" maps have been scannned and georeferenced and then digitised in order to obtain a vector representation of each avalanche polygon. The attached descriptive and historical data are recorded (Figure A2), too, with the purpose of transferring the complete archive into the GIS. This phase is accomplished trough a customised interface (Figure 5) directly linked to the geodatabase which stores both kind of data, map or alphanumeric.

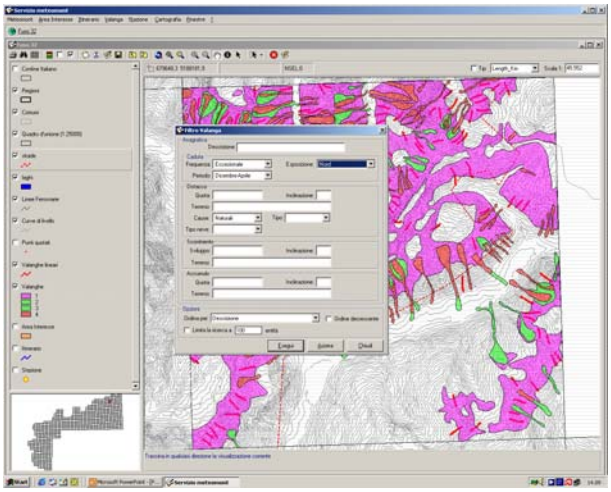

Figure 5. Data input interface

Meteorological station are represented as points showing their position; these features have different kind of data linked (Figure A3), first a descriptive from with information about the station location, radio repeaters etc. then an hyperlink connects the user with the station webpage in order to show real time data collected by the mounted instruments.
The system includes also drilling pathways (Figure A4), represented as linear features. This layers is highly useful in training activity planning as the appointed Officer may immediately check critical pathway sectors intersecting dangerous areas.
The last thematic layer is the polygonal representation of interest areas (Figure A5), as natural reserves or parks, that have to be avoided when planning new drill pathways in order to prevent the endangering of such areas during training activities.
Every area, according to their "Centro Settore", is also linked to the bulletin (Figure A6).
Raster layers are only employed to show scanned and georeferenced "Monografia Militare delle Valanghe"

2.5 System architecture

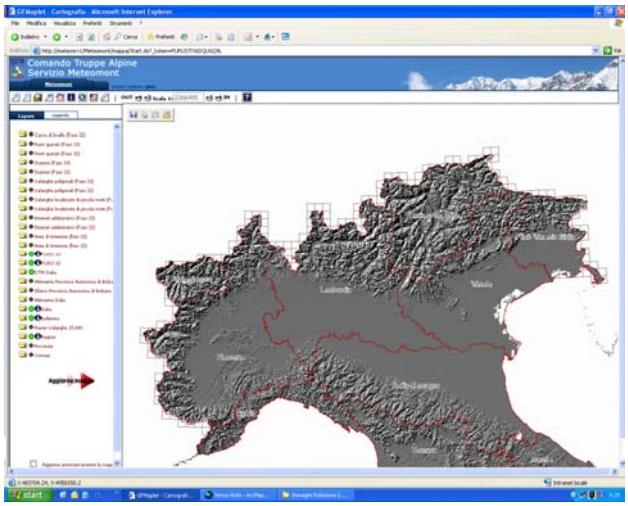

Figure 6. Client GIS interface (full extent initial visualisation)

The whole dataset is stored and managed by an ArcSDE database (ESRI Press, 2004) containing the described layers. The GIS project is accessible directly, for data input and maintenance purposes, or remotely, thank to an ArcIMS package (ESRI Press, 2002) that serves the system into the Army's Intranet (EINET). Only authorized user may access due to military classification of data.
The client has a customized interface which allows the querying of the map (Figure 6) or the database (Figure 7) concerning the thematic layers and the consequently visualization of the selected geometrical features or alphanumeric data sheets. On the other hand the user may opt to load directly the map and search on it the desired area.
The purpose is to provide terrain and avalanche data to every Army unit, whether located in Italy or in abroad operative areas, so Officers may plan activities, assuring the highest level of security to their troops.

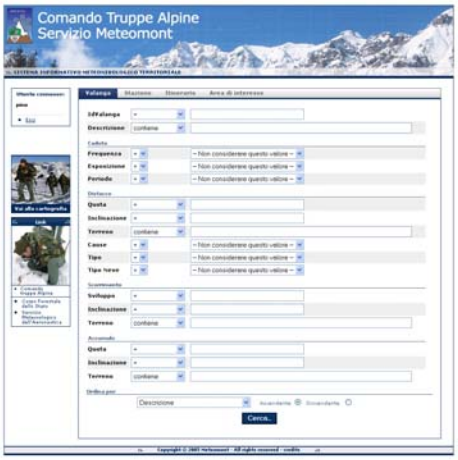

Figure 7. Alphanumeric query interface

3. CONCLUSIONS

The management of territorial, snow and meteorological data is a strategic issue for Army activities planning. Paper maps and reports are not suitable for a fast and reliable querying and the storing of such amount of data is hard to handle.
A digital approach is recommendable as data are stored in a safer way and the system may be updated or corrected with new data entries. For such reasons the GIS environment is the best solution for this task. Moreover the need to issue these data to remote users is assured by web based applications serving GIS data or complete projects in web browser. The approach adopted in this work has confirmed the feasibility and reliability of the method and of its results.
The GIS environment is user friendly so data entry and processing is easily performed. On the other hand, the user is provided with generic data to understand the territory and contemporarily can deepen the investigation level to higher detail in order to acquire specific data necessary to the planned activity.
Due to these qualities the project has been awarded in 2006 by 9th "Conferenza Italiana Utenti ESRI", where it has been firstly presented.
A future goal is to build up a system capable of providing such data remotely to each unit by palm top devices. Due to the public interest another future project is the extension of the access to Internet users, allowing the visualization of, obviously, non classified data to general public.

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The GIS interfaces have been developed by GLOBO srl.
The Airborne Laser Scanner elevation dataset has been provided by "Provincia Autonoma di Bolzano – Ufficio Coordinamento Territoriale"

APPENDIX A. S.I.M.T. SCREENSHOTS

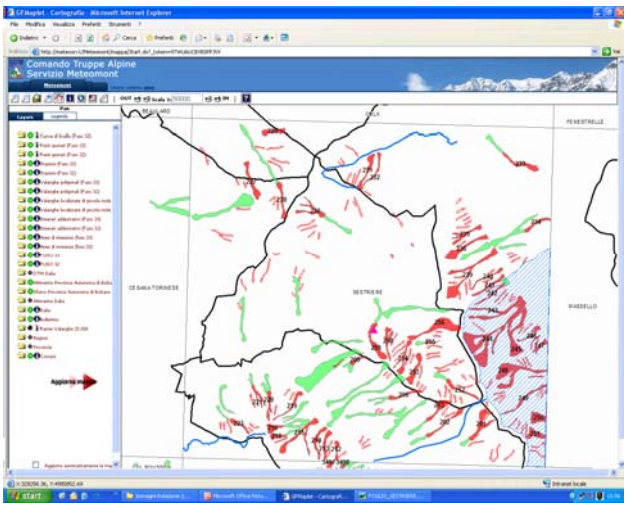

Figure A1. GIS interface showing the main S.I.M.T. features: red and green polygons – avalanches; red arrows: minor avalanches; pink triangles: meteorological stations; blue lines: drilling pathways; blue dashed polygons: areas of interest.

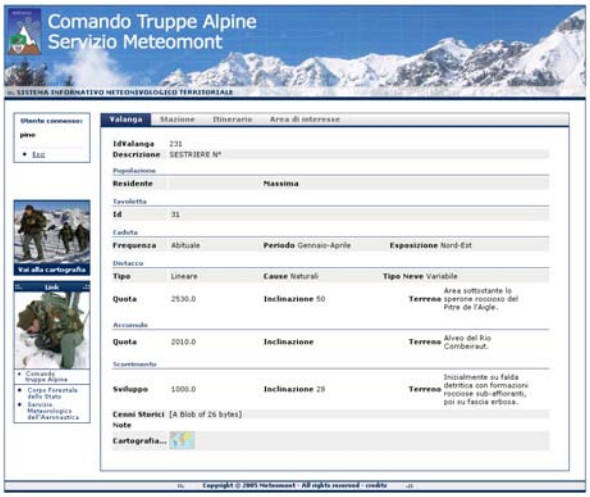

Figure A2. Database interface showing avalanche data.

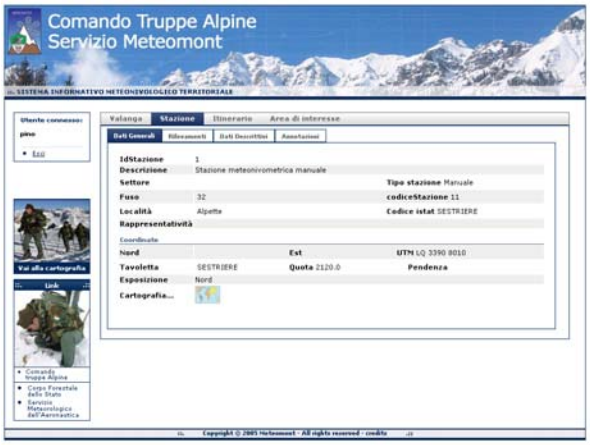

Figure A3. Database interface showing the meteorological station characteristics.

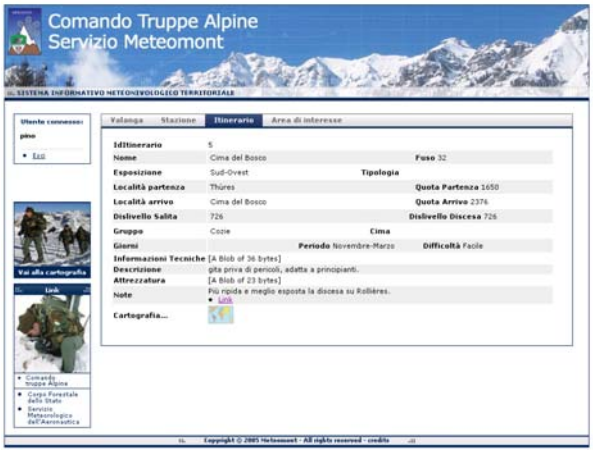

Figure A4. Database interface showing drilling pathway descriptive form and external web link.

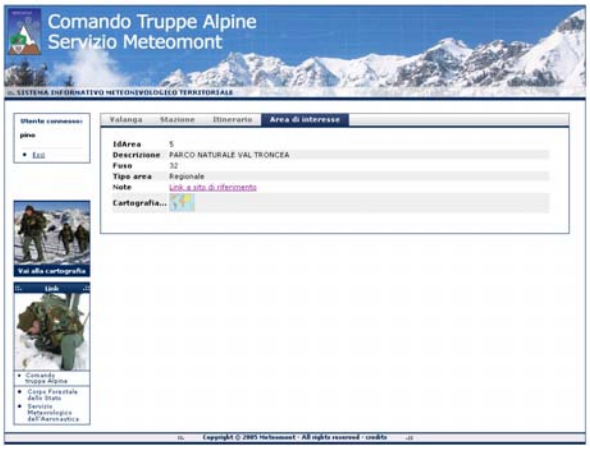

Figure A5. Database interface showing the description and external web link of the selected area of interest

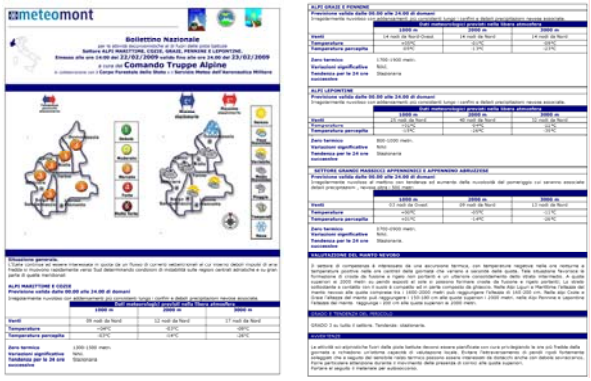

Figure A6. “Bollettino della Neve e delle Valanghe” linked to the GIS interface

APPENDIX B. MULTISCALE ELEVATION REPRESENTATION

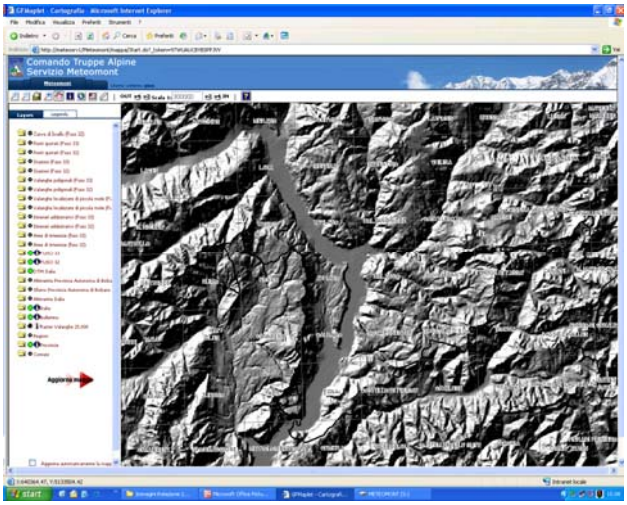

Figure B1. Hillshade computed from the SRTM elevation model

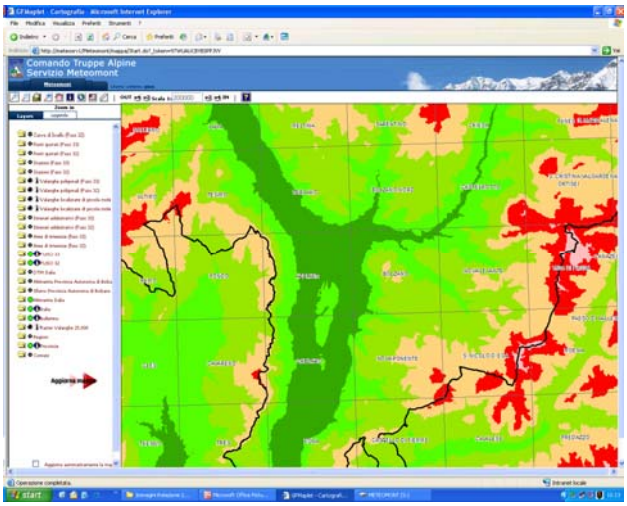

Figure B2. Elevation layer represented according to official colour definition

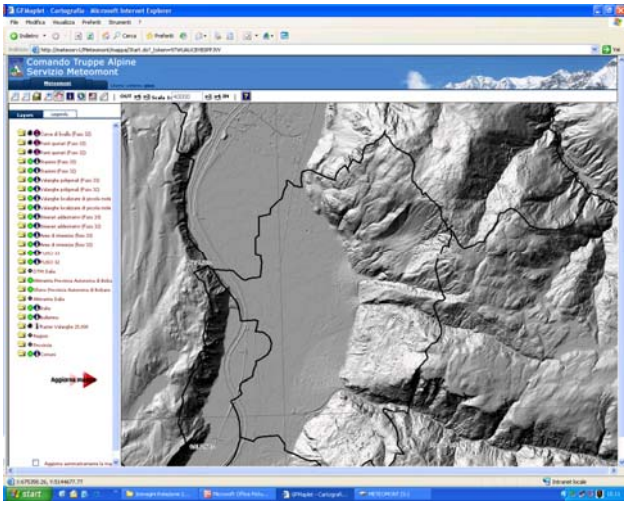

Figure B3. Hillshade computed from the Provincia Autonoma di Bolzano Airborne Laser Scanner survey