## Web Resources on Natural Hazards

### http://www.colorado.edu/hazards/index.html

The Natural Hazards Center Web site at the University of Colorado, Boulder, USA, is a national and international clearinghouse for information on natural hazards and human adaptations to hazards and disasters. The center's prime goal is to increase communication among hazard/disaster researchers and those individuals, agencies, and organizations that are actively working to reduce disaster damage and suffering. Its mission includes four principal areas: information dissemination, an annual workshop, research, and library services.

### http://www.preparenow.org/

The community preparedness web site project from California is of particular interest because it has extensive information on earthquake preparedness for persons with disabilities. The site has specific sections for each of the categories of disabilities, along with a special links section devoted to vulnerable populations. This site would be of interest to persons with disabilities, emergency planners developing procedures for employees requiring assistance, caregivers, and for emergency social services organizations. This portal web site is multi-language with special emphasis in the Spanish language.

### http://www.sire.gov.co/index.htm

Information system for the management of risks and response to emergencies, SIRE from Bogotá, Colombia is an information system available for the public, with the aim of contributing and facilitating access to information related to the management of risks and attending to emergencies. The project is developed through several national agencies and the International Cooperation Agency of Japan (JICA).

Compiled by Ms. Victoria Mazo-Gray

## GeoSemantica: Expanding the Map Concept

On a daily basis, we travel through the terrain that shapes our lives, cities and rural areas. We have the awareness that the survival of explorers and early adventurers were directly tied to their understanding of the lay of the land. Ever conscious of the need to manage complexity, humans developed numerous techniques to enhance our understanding of the landscape, to discern patterns, and to navigate through this space. Maps play a unique role in supporting this understanding. Very often maps are created to situate and describe the physical features that exist on the landscape and to assist in navigation – getting from point A to point B will require that these routes be followed and take a certain amount of time. Along the way, the map reveals landmarks such as natural features or vegetation, to reinforce the correct path to the intended destination.

Maps, space and place are slightly different concepts. How we map space, topographically, is different from how a map might convey meaning through a thematic map of ethnicity or an historical map of literary icons, where they have lived or where they set their novels. Insofar as a map can represent a physical reality, thereby reflecting a shared and measured view of the known topographical world, it can also reflect how a person or a group of people understand the world: socially, environmentally and economically. In this way, a map is a way to represent a sense of place, to visually provide context and situate a cultural or social group within their relationship between each other and with their physical surroundings.

Mapping and navigation have a great and long tradition that has seen the evolution of the map from drawings in the dirt and sand to the sophisticated digital imagery that is produced today. Cartography, or the drawing of maps, is at once a science and an art form. Over time, and with the rapid increase of computerized technology during the latter portion of the 20th century, cartography expanded to a digital environment, where shortly after the visual map representation was partnered with database technology to create what is known as a geographic information system.

The first geographic information system (GIS) was developed in Canada as a land inventory system in the late 1960s. As a means to manage land parcels, the system was the first to fuse a map representation of the land type linked with a database to provide additional facts to characterize a particular section of land. Since then many countries throughout the world have further refined the technology and developed applications to advance the ability to query (ask questions of) maps and to document, record and maintain information on land management.

GeoSemantica is the next chapter of this evolution. It provides both a representation of landscape and the meanings that people attach to places that make them unique and interesting. GeoSemantica is building on developments in geographic information systems, database management systems, and the timeliness and ubiquity of information that is available on the internet. In so doing, it can provide increased and direct access to the spatial, or map, data that has been collected from aerial surveys, from field mapping, and satellite data. In addition, GeoSemantica provides a means of connecting the meaning that is infused in information to be communicated so that the human understanding of place might also be conveyed along with the physical features and defining elements of the landscape.

Ms. Sonia Talwar

## Upcoming Events

**January 27 – 29, 2003:**
Cordilleran Roundup Conference in Vancouver, Canada. MAP:GAC staff will represent the project at a booth.

**February 10 – 14, 2003:**
MAP:GAC Project Management visit to Peru/Ecuador binational project area.

**March 9 – 14, 2003:**
Executive Council Meeting and PDAC (Prospectors & Developers Association of Canada) in Toronto, Canada.
Required information for this meeting:

- Work Plans for 2003/04 fiscal year. Please send them to Mike Ellerbeck by **February 15**.
- Please forward names and travel dates of participants to the Executive Council Meetings.
- Please forward suggestions for agenda items for the Executive Council Meetings to Ellerbeck by February 28.

Complied by Mr. Mike Ellerbeck

## GeoSematica Update

Dr. Murray Journeay and Mr. Otto Krauth of GSC Pacific will be presenting a functional test version of GeoSemantica to the Executive Council during meetings in Toronto in March 2003.

It is planned that during the first quarter of the 2003/04 fiscal year, a short course/seminar of 3 to 4 days will be held at a venue to be announced in one of the member countries.

Each country will also receive a GeoSemantica server during this period and will be expected to begin populating the database.

It is hoped that each country will present a case study on their use of the system at the mid-year Executive Council Meetings (Sep./Oct. 2003).
Mr. Mike Ellerbeck

For further MAP:GAC information
please consult the project Web page at
http://www.pma-map.com/gac/

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# MAP GAC

Internal Newsletter of the Multinational Andean Project: Geoscience for Andean Communities
http://www.pma-map.com/gac/

*Vancouver, Canada, January 2003* *Vol. 2 - No. 6*

## *Geohazard Series No.2*

*This is the second article in the Geohazard Series. Readers may have noted that supplemental material for the first article has not yet appeared on the website. This is because the project team is currently revising much of the website, a process that will take another few weeks.*

*The technical demands for translating, editing and reviewing the Geohazard Series require special attention and we are in the process of developing an improved capability. Ms. Monica Jaramillo has just joined the MAP:GAC team in Vancouver and will help with translating and editing, and Dr. Fernando Munoz Carmona is the first member to be added to a small editorial review committee. Further additions to this committee will be made in coming months.*

*The first article gave an overview of issues to consider when selecting geophysical monitoring and measurement techniques, and the current approach taken by the project. This article describes the methods of creation and uses of digital elevation models.*

*The views stated in the Geohazard Series articles, unless specifically stated as such, are the views of the authors and may not represent the official views of the MAP:GAC project management team or the participating countries.*

## From the Manager's Desk - January 2003

Hopefully you are reading this after a joyous and relaxing holiday season. Our heartfelt wishes to you and yours for the very best in 2003. I spent most of my December on vacation, cruising the spectacular southern coast of Chile, rounding Cape Horn, and exploring south-eastern Argentina. We started in Valaparaiso, Chile and ended in Buenos Aires, Argentina. The cruise was a wonderful event and an exciting way to see the spectacular geology of this little traveled part of the world and to make the acquaintance with the thousands of penguins that inhabit the area.

While I was vacationing, the rest of the MAP:GAC team was hard at work making progress in a number of areas. Mr. Otto Krauth and the GeoSemantica group have been continuing to make steady progress in program development. They are aiming to have made significant advances by March's Executive Council meeting.

The MAP:GAC administrative system (MAPAS) is now working smoothly thanks to the efforts made in November. Financial information pertaining to expenditures made on behalf of each country can be requested at any time (via Mr. Mike Ellerbeck). The system ensures accountability, and financial records can now be retrieved in a fast and efficient way for all members of the Project. Henceforth, MAPAS will significantly reduce the amount of time spent on reporting. For those countries which have requested copies of the program, distribution will await final documentation of the system.

Ms. Monica Jaramillo has joined the MAP:GAC team for three months. Jaramillo will be assisting Dr. Mark Stasiuk in pursuing aspects of the hazard modelling software part of the Project. Jaramillo has a B.Sc. in geology from the National University of Colombia and has been working in hazards research for several years. The search continues for a Landslide Specialist. I am hopeful a suitable candidate will be found in January.

Dr. Catherine Hickson

## *Topography: The foundation of natural hazard assessment*

### Introduction

Geological hazards are profoundly influenced by topography. The steepness and detailed shape of slopes in large part determine their stability. The morphology of the landscape reveals areas of past or developing slope instability, as well as young fault movements and volcanic features. The three-dimensional shape of slopes determines how rain will run off and percolate through sediments, triggering debris evulsions and variations in pore pressure. The detailed form of valley floors controls the distribution of water and debris inundation that accompanies many natural hazard events. The shape and size of terraces and ridges will determine areas that can be considered relatively safe from the impact of debris flows, landslides, lava and pyroclastic flows, versus those areas that are likely to be devastated. The list goes on and on, and demonstrates that a hazard assessment cannot be done well without good topographic information.

Curiously, the importance of having topographic information stands in stark contrast to the lack of this kind of information, and the generally high cost of acquiring it. Topographic data has traditionally been created by government organizations responsible for cartography and surveying, but their priority is usually for national coverage rather than high resolution coverage of specific areas. This situation is changing rapidly as new methods are developed. Recently, we have been examining this situation for our hazards projects in Canada, and have developed a methodology that is working well and will be proposed for some of the MAP:GAC project areas. The method uses software to automatically extract topographic data from stereoscopic air photographs, constrained with precise ground control points obtained using differential GPS. In this article we describe various survey methods for obtaining topographic formation, their costs, advantages and limitations, and demonstrate the rationale for our proposed methodology.

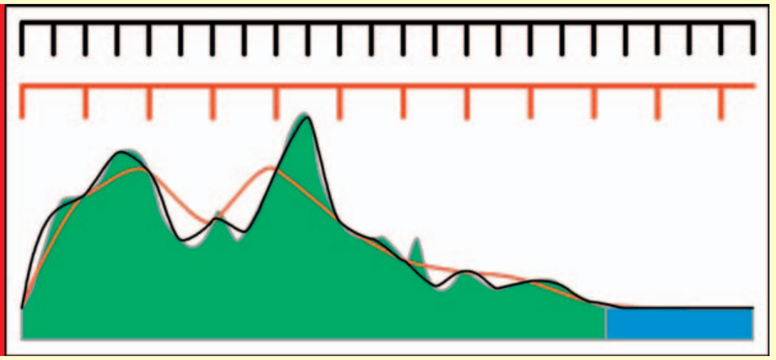
### Digital Elevation Models: Issues

Topographic data, as used by computers in GIS applications, must be in digital form. The most commonly-used term for a digital topographic map is Digital Elevation Model (DEM), although Digital Terrain Model (DTM) is often used as well. DTMs typically contain additional terrain information such as the location of sharp breaks such as lake edges, ridges and cliffs. A basic DEM, however, is simply a numerical expression of a surface. The most common format is a two-dimensional matrix of numbers, where each x-y position in the matrix is a horizontal position (e.g., latitude and longitude) and the number itself represents the elevation of the surface at that position. In addition to this information the DEM must be accompanied by data which references the matrix to the real world; for example, the latitude and longitude of the lower left corner of the matrix and the horizontal spacing of elevation values. The horizontal spacing is often called the resolution. A good DEM should also be accompanied by a description of how the data was obtained and an estimate of the horizontal and vertical errors. The quality of a DEM is measured by its resolution and errors.

DEMs are "models" because they are an approximation of the real surface. Typically, the approximating starts with data collection, when elevations are obtained at a series of locations which are not on a regular grid. Elevations are then interpolated to positions on a regular grid to produce the DEM. When a GIS program uses the DEM to create an image, the visualized surface may be very similar or very different from the real one, depending on the DEM resolution, errors, the method of the software's interpolation between DEM data points, and the original surface complexity. Particularly important is the balance between DEM resolution and the real surface complexity. Figure 1 shows an artificial cross-section of a mountain range with adjacent coastal plains and ocean. The red graduated line above the landscape shows locations of elevation points taken to form a cross-section, and the resulting interpolated section is shown by the red curve superimposed on the real cross-section. The red curve models the mountainous landscape poorly, cutting off major peaks, flying high over valleys, and smoothing areas where the topography is rapidly varying. Such coarsely-spaced DEMs also tend to displace sharp transitions, such as coastlines. By cutting the horizontal spacing in half, as shown by the black graduated line and resulting black curve, a model is created which is a far better representation of reality, particularly in areas of gentle topographic change. The mathematics of time-series analysis provides an important rule for appropriate sampling of continuous data: In order to accurately represent the data, the sampling rate (resolution) must be approximately half the characteristic wavelength or less, or detail will be missed. This means, for example, that if we wish to accurately visualize in our DEM features such as small channels 10 metres across, the DEM spatial resolution must be 5 metres or less. Figure 1 also illustrates the importance of the type of interpolation between data points. Simple linear interpolation will produce a jagged surface, whereas curved (e.g., quadratic) interpolation will produce smoother, more natural-looking surfaces. But then, any sudden topographic effects such as cliffs will tend to be smoothed.

For the purposes of geological hazards assessments, the DEM should be able to model features relevant to hazards, such as debris flow deposits, stream channels, stream terraces, lava flow deposits, rotational slump features in slopes, etc. These features can be very large, but they also commonly occur on small size scales of just a few metres wide and thick. Such small features are nevertheless hazardous and hence of interest, and should be resolvable in a suitable DEM. This means having a spatial resolution of a few metres or less, and errors in the elevation measurements of 1 m to 2 m. These specifications go considerably beyond free and inexpensive data sets.

**Figure 1:** Artificial cross-section of a mountain range, with two superimposed cross-sections constructed from different spatial sampling intervals, shown by the top graduated rules. The coarsely-sampled section models the landscape poorly except where it becomes smooth, and the finer-sampled section does far better.



## Data Sources and Methods

High resolution DEMs quickly start costing large amounts of money, despite the existence of much free data. The GTOPO30 data set is free and covers the entire Earth, but the resolution is approximately 1000 m and hence of little use. Moderately expensive remote sensing data sets, such as stereo ASTER and RADARSAT images, can be used to derive DEMs, but the spatial resolutions are no better than 10 to 20 metres and vertical elevations accurate only 5 to 10 metres (the resolution depends on the wavelength of light used). Remote sensing is a rapidly advancing field and we expect to see improvements in the next few years which will reach needed resolutions at an accessible cost. In the meantime, alternative methods are needed.

For high resolution DEMs it becomes necessary either to pay for some form of detailed surveying for each specific area as needed, or acquire the capability to generate the data with little direct cost after the initial investment in software, hardware and training. It's necessary to emphasize "direct" cost because generating data means indirect spending on staff time. The reality is that most geoscience agencies have insufficient funds for large direct costs such as service contracts, but can afford the indirect cost of staff time. A further strong advantage of being able to create DEMs in-house means that there is quality control and new data can be created whenever it is judged necessary, for example in the event of a major landslide in order to measure changes.

There are numerous surveying methods that can be used to generate DEMs, but what is needed is a balance between time, cost, resolution and accuracy. The premier method at present is LIDAR (Light Detection and Ranging), which is equivalent to SONAR depth sounding but uses a laser. This method can be airborne (helicopter, airplane or space vehicle) or ground-based. Current commercial systems can produce DEMs with spatial resolution and vertical errors of tens of centimetres, and can collect 10,000 elevation points per second. Perhaps most remarkable is that the laser generates reflections off vegetation and the underlying ground surface, so it is possible to measure the dimensions of vegetation as well as to remove its effects to produce a "bare earth" DEM. LIDAR is the only method with this capability. The main problem with this method is the cost. To produce a DEM for a modestly-sized area (25 km$^2$) costs tens of thousands of dollars (U.S.). Despite this, the quality of the data is causing a great deal of development activity and we can look forward to decreasing costs in the future. For the moment, LIDAR is not a realistic method for extensive use in MAP:GAC, but may be proposed for specific applications. In North America, it has been possible to make limited use of LIDAR by forming consortiums of institutions with a common need for the data, thus reducing costs to each organization. Such consortiums may be worth considering for certain areas in MAP:GAC, but would need careful consideration and significant time to organize.

A variety of other, less expensive and lower technology surveying methods can be used. For example, topographic data can be measured quite easily using a theodolite, total station or high-precision differential GPS system, but in all these cases each elevation point requires at least one specific measurement. The fastest of these methods is the GPS system, which can measure a single location with better than 1 m accuracy in seconds. However, obtaining the full DEM would mean transporting the equipment all over the area of interest, which is unrealistic and time consuming. For a DEM with 5 m spatial resolution and an area measuring 10 km by 10 km, approximately 4 million elevation points would have to be collected.

Photo: Dr. Kirstie Simpson

**Figure 2: Helicopter with attached differential GPS antenna hovers over a distinctive rock formation, used as a ground control point for creation of a DEM. Data collection at this point took about 10 seconds.**

Aerial photogrammetry is a known reliable method that can produce DEMs of the required resolution and accuracy from inexpensive stereoscopic air photographs, but it is rather slow and subjective. Instead, we propose a computer-automated version of this classical technique that achieves the same resolution and accuracy, but can obtain data over a significant area far more rapidly and objectively.

The concept of automatically extracting topographic data from photographs is not new and in fact is quite simple. The technique works on geometric principles. Two photographs of the same landscape are taken from different locations. Ground control points (that is points visible in both photographs whose locations are known) are used to provide a spatial frame of reference, and then the locations of other points visible in both photographs can be calculated. In principle this method does not require vertical air photographs. Oblique photographs taken from the ground can also be used. In addition, if three photographs are taken the same principles can be used to determine the topography without needing to know the location of the photographer. These principles have been applied to produce a free program for DEM creation for small areas, available from the website of researchers at Dartmouth University:
http://www.cs.dartmouth.edu/farid/research/phototop/

The 3-image photographic technique is a good choice if your area of interest is small as there is significant work involved in picking common points; for larger areas an automated method is needed. All such photographic techniques require visibility and recognizable features, and hence cannot produce data in bad weather, where there are deep shadows or featureless surfaces such as flat snow and ice. They also cannot see through dense vegetation, and hence tend to map the tops of forests as the land surface. Fortunately, many areas subject to geological hazards are sparsely vegetated.

All photographic surveying techniques require ground control points, and the accuracy and number of these will determine the accuracy of the final DEM. Ground control points must be points clearly visible in the photographs and have a precisely known location. They can be derived from points already surveyed by another organization, but in remote areas such points are not likely to exist. When we applied the method, we chose to survey our own ground control points using differential GPS. Differential GPS will be described in the next article in this series in some detail. To achieve an accuracy of 1 m, it is possible to obtain locations as rapidly as one point per second. For our work, we had a significant area to cover and so attached the GPS antenna to a helicopter, and then flew to and hovered over points that had been previously selected on air photographs (Figure 2). Additional points were collected using the same equipment and transporting it by truck and on foot. The entire process took 4 days. We then used the ground control points with precisely-scanned images of stereoscopic air photographs in software modules of PCI Geomatica Orthoengine (Airphoto Model), to produce a DEM of an area near Vancouver, Canada. A piece of the resulting DEM measuring about 10 km$^2$, and the corresponding air photograph, is shown in Figure 3.

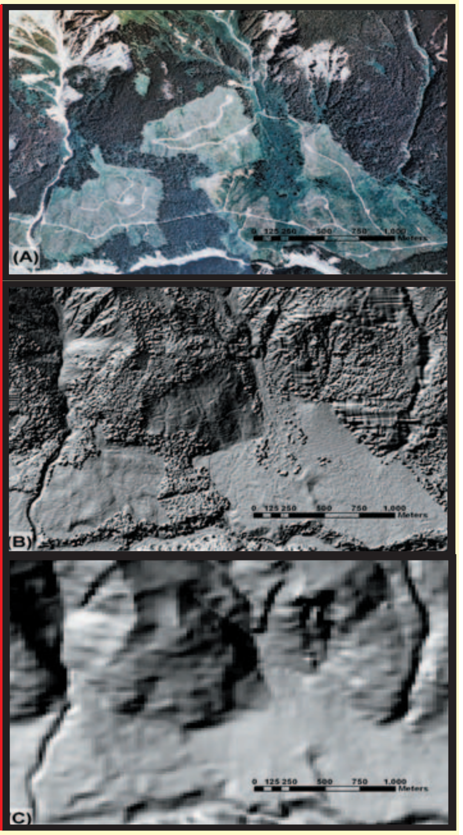
The high resolution DEM of Figure 3 demonstrates both the power and the limitations of our technique. As the method cannot see through dense vegetation, the top surface of the forest is incorporated as part of the modelled land surface, visible in the image because square blocks of the forest have been removed by logging. In addition, in areas where the software was unable to determine the elevation because of deep shadows or featureless snow surfaces, there are data gaps. These have been "filled in" by interpolation and show up as soft, almost blurred parts of the DEM surface. It's important to be aware of interpolated areas to avoid detailed morphological interpretations where there is no data. Despite the limitations, much of the land surface is modelled in useful detail. The slightly flattened path of the gravel road snaking up the ridge is clearly visible in the DEM, as well as subtle, high-frequency slope changes in the ground surface.

**Figure 3:**

**The first image (a) is an air photograph of an area for which a DEM was created.**

**The central image (b) is a 2.6 metre resolution DEM of the same area created using Orthoengine and ground control points.**

**The last image (c) is a 25 metre resolution DEM, similar to that which could be produced from remote sensing data such as RADARSAT.**



The cost of acquiring the DEM auto-extraction method is less than the cost of a single LIDAR survey. It requires purchasing software (PCI Geomatica Orthoengine, approximately Cdn$ 11,000), a precision scanner (approximately Cdn$2,500), a high-quality desktop computer (approx. Cdn$5,000), and training for a GIS technician (approx. Cdn$1000). For ground control points, differential GPS equipment can be rented when needed, or purchased and used for other applications such as ground deformation monitoring (this technique will be discussed in the next article). Once an institution acquires the methodology, the great advantage is that further DEM creation costs little as it requires only the purchase of air photographs, the cost of work to collect ground control points, and the time to scan the photographs and process the data. We estimate that, with experience, the time to collect ground control points and process the data (produce the DEM) from a mountainous area measuring 10 km by 10 km is 1 to 2 months of two people's time.

Dr. Mark Stasiuk and Mr. Kaz Shimamura