2D and 3D digital photogrammetry for assessing the rock glacier kinematics: Case studies from the Southern Swiss Alps

temps symposium
4–5 February 2015

Scuola universitaria professionale della Svizzera italiana
SUPSI
Dipartimento ambiente costruzioni e design
Istituto scienze della Terra

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Introduction

Despite the power of GIS tools for digital mapping, it is often difficult to correctly recognize the nature and the boundaries of geomorphological landforms on two-dimensional (2D) plane images (fig. 1). This applies particularly in the periglacial belt, which is characterized by steep zones (i.e. rock walls and talus slopes), and present often a very complex topography (for example, in periglacial sedimentary landscapes or in glacier forefields).

Figure 1 – *Comparison between the Sosto (2220.6 m asl) on an aerial orthophotograph (© swisstopo), the Swiss National Map 1:25,000 (© swisstopo) and a classical terrestrial oblique photograph (© C. Scapozza). The mountain symbol of the Blenio Valley (Canton Ticino), with its typical pyramidal form, is directly perceivable only from the terrestrial perspective.*

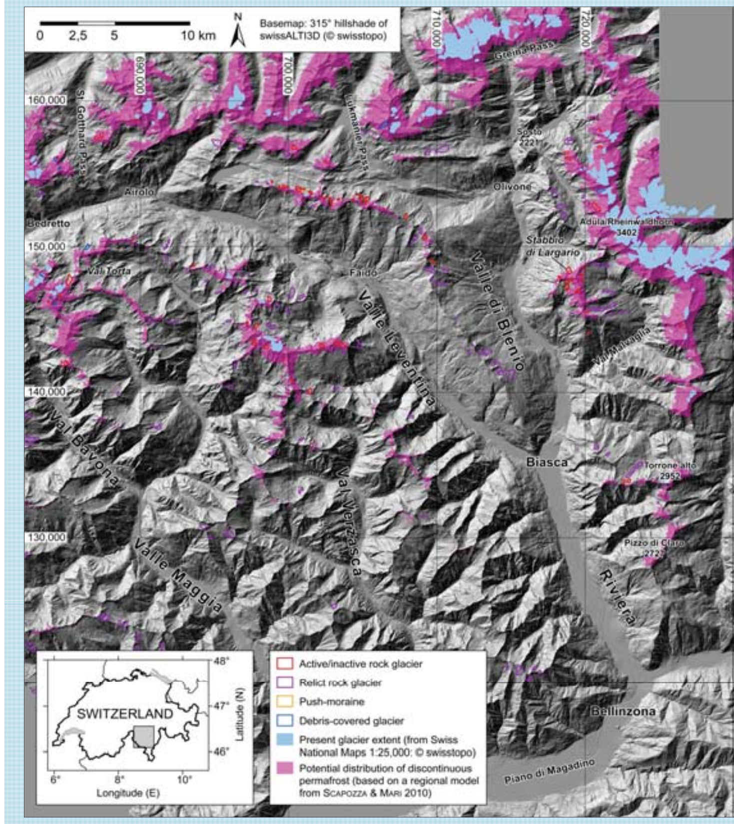

Figure 2 – *Characteristics of the cryosphere of the upper Ticino valleys.*

From Regional to Local scale

The former rock glacier inventory for the Ticino Alps by Scapozza & Mari (2010), based exclusively on 2D plane images, was improved by the use of **3D digital photogrammetry**. Finally, 285 periglacial landforms were mapped, including 100 active/inactive rock glaciers, 161 relict rock glaciers, 20 debris-covered glaciers, and 4 push-moraines (fig. 2). Compared to the previous inventory, this new mapping performed by 3D imaging, allowed 82 new landforms to be inventoried!

At the local scale, georeferentiation and ortho-rectification of six historical photographs of the Stabbio di Largario rock glacier taken between 1910 and today were analyzed using **digital monophotogrammetry** to detect the rock glacier displacement on the decennial scale from the end of the Little Ice Age (fig. 5). For recent decades, high monophotogrammetry-derived velocities since the 1990s are in the same order of magnitude as the maximal dGPS velocities range measured between 2009 and 2012 (Scapozza *et al*., 2014).

In September 2014, the quantification of movements and deformation process of two rock glaciers in the Southern Swiss Alps monitored for PERMOS was improved by the realization of very-high resolution digital elevation models thanks to the use of **drones** (fig. 6).

3D Digital Photogrammetry

The 3D digital mapping was performed thanks to an extension of the software ESRI® ArcGIS™ called ArcGDS™ (fig. 3). The stereoscopic vision allows obtaining precise results and collect a large amount of data such as perimeters, surfaces and volumes of rock glaciers, talus slopes and other quaternary formations and/or landforms (Ambrosi & Scapozza, 2015).

The ArcGDS™ tool allows the direct exploitation, visualization and digitization of stereoscopic digital linear scanned images (e.g. Digital Image Strips; fig. 4). Combined with high-resolution digital elevation models (as, for example, the new swissALTI3D), ArcGDS™ is a powerful tool, particularly over large areas, as well as under forest cover and on very steep slopes.

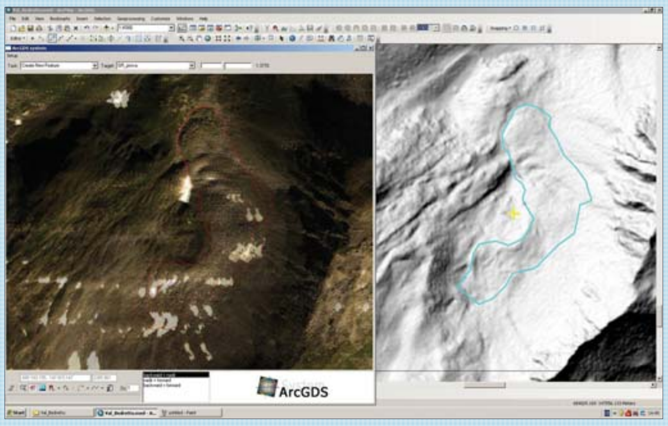

Figure 3 – *Example of 3D cartography on the ArcGDS™ extension. On the left, 3D cartography window with a stereoscopic visualization of a digital image strip of the Val Torta rock glacier (© swisstopo, 2008); on the right, the final result mapped in 2D on a 315° hillshade of the swissALTI3D DEM (© swisstopo, 2013).*

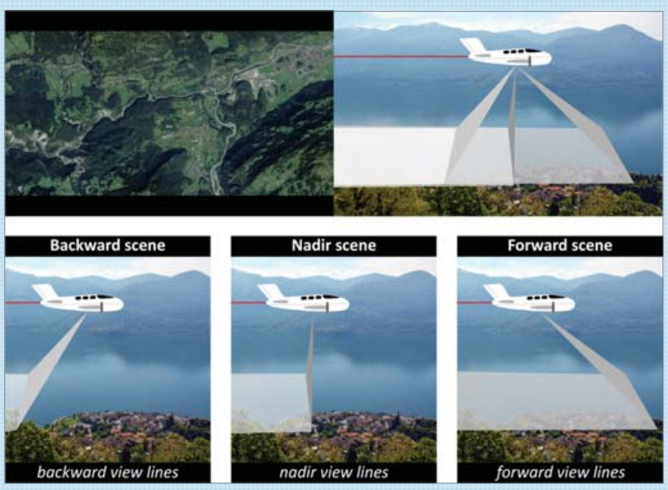

Figure 4 – *Realization of the digital image of 6 km wide strips collected by digital airborne pushbroom imagery by the Airborne Digital Sensor ADS80 of the Swiss Federal Office of Topography swisstopo. The acquisition of the three different available scenes (backward, nadir and forward scene) in accordance with the camera angle is also shown. From Ambrosi & Scapozza (2015).*

Digital Monophotogrammetry

The monophotogrammetry (or monoplotting) is the technique of photogrammetrical georeferentiation of single oblique unrectified photographs, which are related to a Digital Elevation Model (DEM). In other words, the monoplotting allows relating each pixel of the photograph to the corresponding real world pixel on the DEM (Bozzini *et al*., 2012; Conedera *et al*., 2013).

Thanks to this technique, it was possible to recuperate in a digital format in a GIS environment, spatial data obtained by the georeferentiation and orthorectification of photographs of the first half of the 20th century. This allows to drive in the past the diachronically mapping of the evolution of the Stabbio di Largario rock glacier from 1910 to 2010 (fig. 5; Scapozza *et al*., 2014).

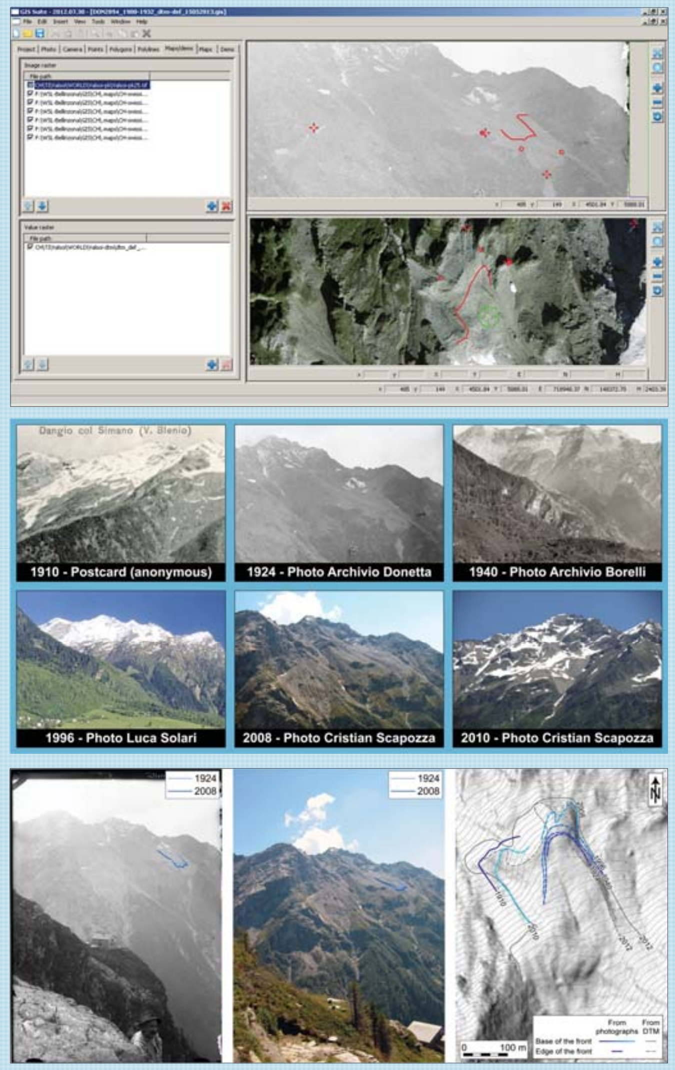

Figure 5 – *Georeferentiation and orthorectification of a non-metric oblique photograph with the WSL-Monoplotting-Tool; (Detail of) the six historical oblique terrestrial photographs analyzed by Scapozza* et al. *(2014); Comparison between the front position between 1924 and 2008 photographs and synthesis of the front positions determined by monoplotting.*

Drones digital images

In recent years, the miniaturization and useful utilization of Unmanned Aerial Vehicles (UAS), best known as drones, allowed the exploitation of these remotely piloted aircrafts for the self-production of very-high resolution aerial photographs, DEMs and orthophotos. From 2014, we carry out repeated very-high resolution ortophotos (fig. 6) and DEMs of two rock glaciers.

The aim is to monitor changes in surface structure and the debris volume exportation between the rooting zones to the front of the studied rock glaciers. dGPS measured ground control points (annual data are available since 2009) will make it possible a correct georeferentiation of drones images and then a spatialisation of dGPS punctual measurements.

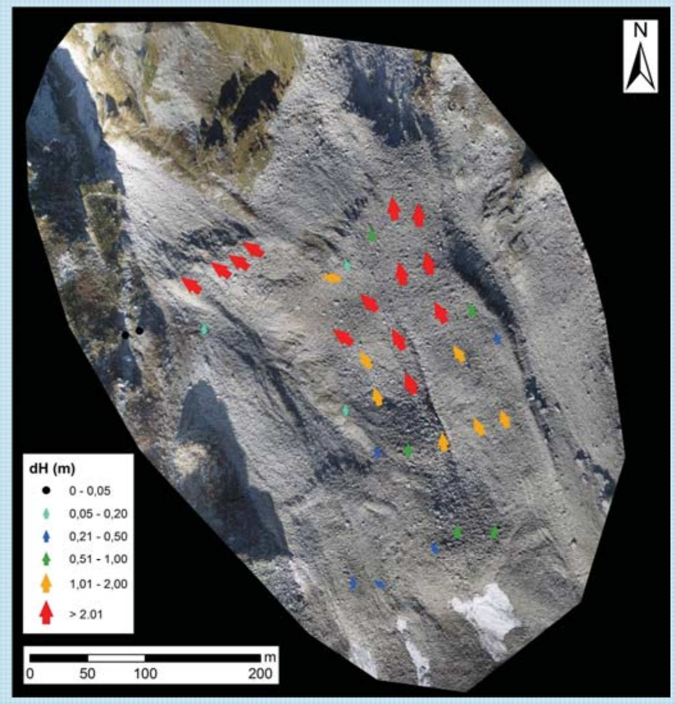

Figure 6 – *Horizontal displacements (2009–2013) measured by dGPS on a drone ortophoto of the Stabbio di Largario rock glacier.*

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