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MONITORING SNOW COVER AREA IN SEMIARID REGIONS USING TERRESTRIAL PHOTOGRAPHY

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Terrestrial photography is a powerful alternative to remote sensing when scale issues arise (e.g. snow evolution in semiarid regions) since its spatiotemporal resolution can be adapted to the scale of the process. This work shows a graphic user interface (GUI) developed in MATLAB to facilitate the specific steps in those image analyses required to quantify the area covered by snow: (1) a georeferencing process, to provide spatial coordinates to the images, and (2) a snow detection process, to distinguish snow-no snow pixels. This tool has been evaluated over the Sierra Nevada Mountains (southern Spain), where in three different locations it was able to successfully capture the variability of snow behavior. The capability and versatility of terrestrial photography for easy and continuous monitoring of snow was shown from the results.

INTRODUCTION

The important role of snow in hydrologic mountain regimes increases in semiarid environments [1]. In these areas, due to the presence of recurrent drought stages, snowpack constitutes one of the main reservoirs of water during the dry season. However, measuring and monitoring snow evolution is hard work in these areas, where the extreme and highly variable climate conditions increase the heterogeneity of snow distribution. Snow cover area (SCA) is one of the best snow state variables to explain this snow spatial heterogeneous behavior [2] [3].

Currently, the most popular techniques employed for the detection of snow in medium-large areas include satellite remote sensing. Simple procedures, based on physical properties of the snow throughout the electromagnetic spectrum, are employed to distinguish between snow and non-snow areas [4] [5]. However, the efficiency of these techniques may be reduced when the representative scale of the study problem is lower than their fixed resolution (e.g. NOAA, daily images with 1 x 1 km cell size; MODIS, daily images with 250 x 250m cell size; Landsat, 16-day images with 30 x 30 m cell size). Snow in semiarid regions is subject to some of these limitations such as the persistence of small snow patches (O~1m) during many weeks in early summer and the rapid snow melt on sunny and warm days. Thus, the use of other monitoring methods is needed.

An economic alternative to the conventional satellite remote sensing techniques is the use of terrestrial photography. These images are taken from the Earth's surface and have the advantage of a flexible adaptation to temporal and spatial resolutions of the processes studied [6]. Terrestrial photography is not projected over a horizontal plane and does not possess any spatial reference, so that a georeferencing process has to be applied. Basic graphics design principles are employed to define the georeference algorithm [7]. The snow is detected by using a non-supervised clustering algorithm, in which case only the visible range of the spectrum is employed.

In accordance with previous considerations, this study proposes the implementation of the algorithm needed to obtain snow cover maps (georeferencing process and snow automatic detection), by means of a GUI developed in MATLAB. This implementation allows the obtainment of snow georeference maps by users in an easy way. The tool was tested over different locations in Sierra Nevada Mountain, southern Spain.

METHODS

A GUI to georeference terrestrial photography and detect snow, was developed by means of MATLAB's Graphical User Interface Design Editor (GUIDE). This section explains the methodology employed by both. Figure 1 shows the flux diagram of the process to obtain snow maps.

Georeferencing process

The aim of this process is to find a function to relate the two-dimensional pixels in the images to the three-dimensional points in a Digital Elevation Model (DEM). This function allows the projection over a horizontal plane of images also giving a correct spatial location. Standard procedures for viewing with computer graphics are employed to achieve this [8] [9]. A transformation matrix, which includes translation, rotation and projection, is applied to the DEM points. This mapping function translates the coordinate system of the DEM to the camera position and applies a transformation according to the focal length and view direction (Figure 1 b). The result is a virtual photograph of the DEM, that is, a representation of it as it would be seen from the point of view of the camera (Figure 1 c). The two-dimensional representation of the DEM is then scaled according to the resolution of the photograph [10]. In this way, the two representations can be superimposed thanks to some control points known in both; establishing the necessary correspondence between a pixel in the photograph and its projection coordinates in the DEM (Figure 1 e). The final result is a map in which all the pixels in the TP have been located over the terrain (Figure 1 f).

The final accuracy of the resulting map is closely related to the quality of the DEM together with the image quality (level of distortion induced by the lens during the acquisition process).

Snow detection process

To distinguish the snow-covered and non-covered pixels in each image, a clustering algorithm was applied. These unsupervised methods are generally used to group together data according to a certain notions of similarity. In this case, all the white points in the scene are linked to the presence of snow, so that two clusters can be easily defined: snow-covered and non-covered pixels. A K-mean clustering [11] was selected; this algorithm classifies the data into a given number of clusters, selecting a random center within each cluster and minimizing the distance between the data and these centers. This algorithm proved to be efficient enough to differentiate these two kinds of pixels since it was capable of detecting most of the snow area with no previous calibration or the use of fixed thresholds in the images, with a resulting low level of misclassifications, which were in turn related to the presence of strong shadows in the images (Pimentel et al. 2012). From this pixel classification, the SCF can be easily calculated (Figure 1 g).

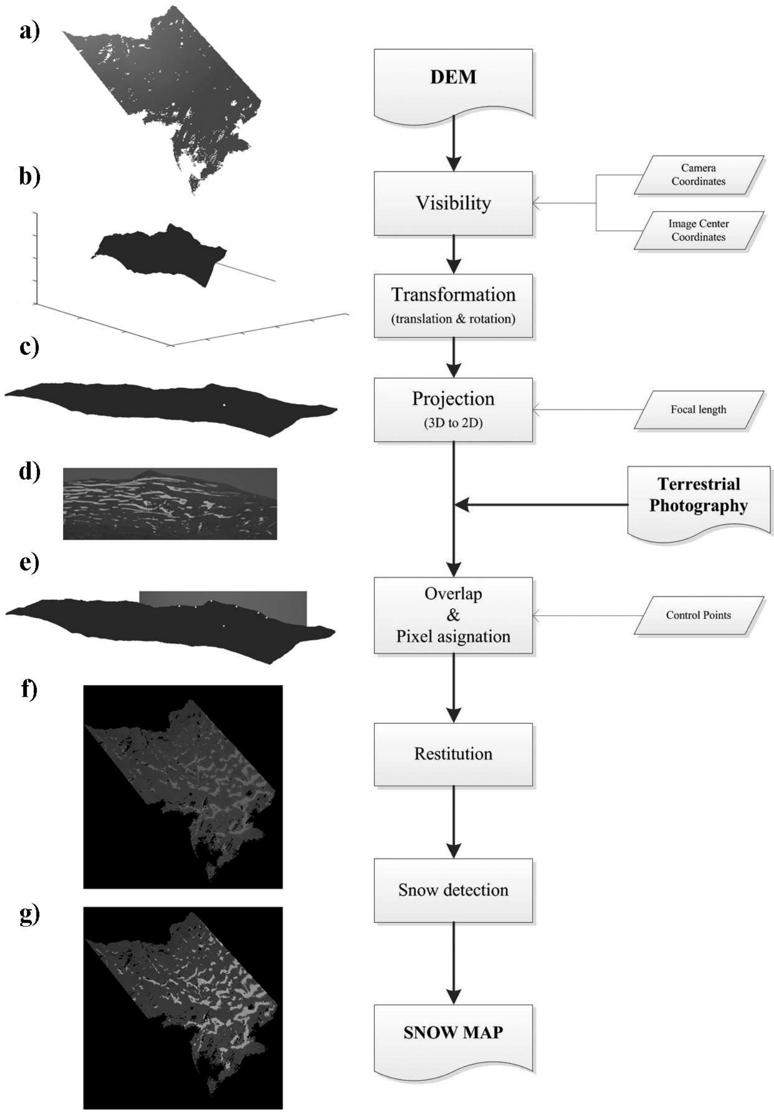

Figure 1. Diagram flux of the snow map obtaining process

Graphic User Interface

The GUI developed in MATLAB is shown in Figure 2. All the inputs required are specified in configuration file: 1) the camera location coordinates; 2) the coordinates of the central point of the image; 3) the location of some control points in both the DEM and the image; 4) the focal length of the camera; and 5) the paths of the DEM and terrestrial photography. This file is loaded in ZONE A (Figure 2), where, moreover, the information available is shown. In this area a pull-down menu to select between the different loaded images also appears. The georeference and snow detection processes are realized by means of two buttons located in the two different visualization areas in the GUI (Figure 2 ZONE C and ZONE B, respectively). Finally, in ZONE D the user can select, from different formats, how to save the snow maps.

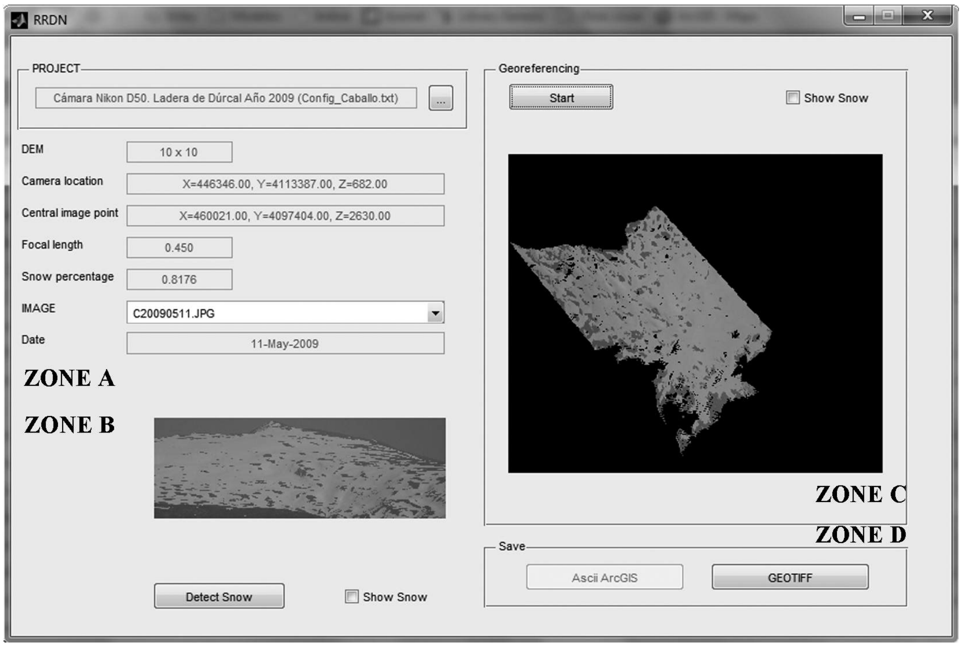

Figure 2. GUI tool for georeferencing terrestrial photography and detecting snow. Four areas can be distinguished: ZONE A, where the input file is loaded and information available on it is shown; ZONE B, where the original terrestrial photography is visualized and the button for snow detection is located; ZONE C, the second visualization area, where the georeferenced button appears; and ZONE D, where different output formats can be selected.

APPLICATION EXAMPLE

This tool has been applied over different locations in Sierra Nevada Mountains, southern Spain. They form a linear mountain range 60 km long, parallel to the coastline of the Mediterranean Sea. The mountain climate is modified by its proximity to the sea, which generates semi-arid Mediterranean and tropical conditions in the surrounding area. These conditions make the snow, which usually appears in altitudes of over 2000 m, be distributed irregularly. (Figure 3)

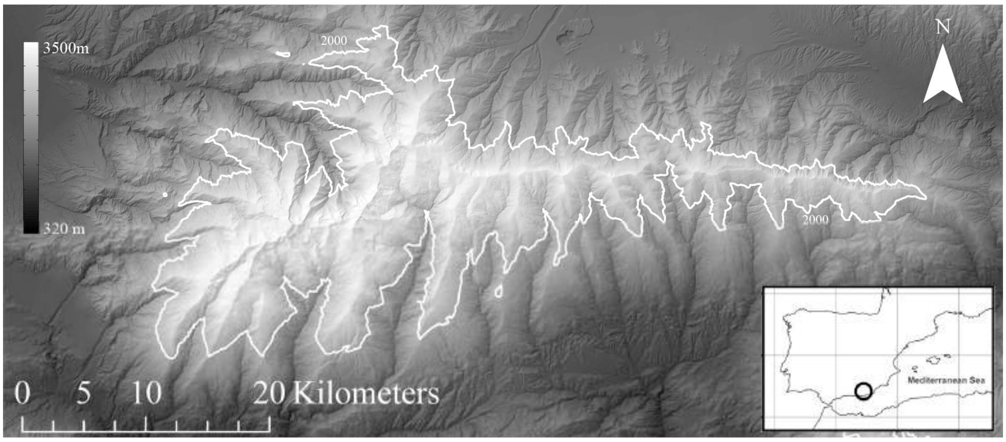

Figure 3. Location of Sierra Nevada Mointain, souther Spain

Several automatic cameras were installed over this area to capture different behavior in snow dynamics. Table 1 shows different technical information about the cameras installed and the images reordered.

Table 1. Technical information of each one of the cameras employed

Camera	Installation	Temporal resolution	Spatial scale	Photo resolution (pixels)
Sony IPELA SNC-RZ50P	2011/11/20-opperational	4 images per hour (4 different location, from 7 a.m. to 7 p.m.)	Hillside (O~10m)	640 x 480
Canon EOS Digital Rebel XS	2011/09/15-2013/09/15	8 images per day (from 8 a.m. to 19 p.m.)	Basin (O~100m)	3888 x 2592
CC640 Campel Scientific	2009/07/22-opperational	5 images per day (from 8 a.m. to 4 p.m.)	Detail (O~m)	640 x 504

Figure 4 shows different examples of some of the images processed. Those selected show the validity of the techniques at different scales, from right to left: hillside scale, basin scale and detail scale. In each case the spatial resolution of the final snow maps depends on the DEM employed (10 m x 10m; 30 m x 30 m and 0.1 x 0.1 m). Temporal resolution matches the resolution of the acquisition process.

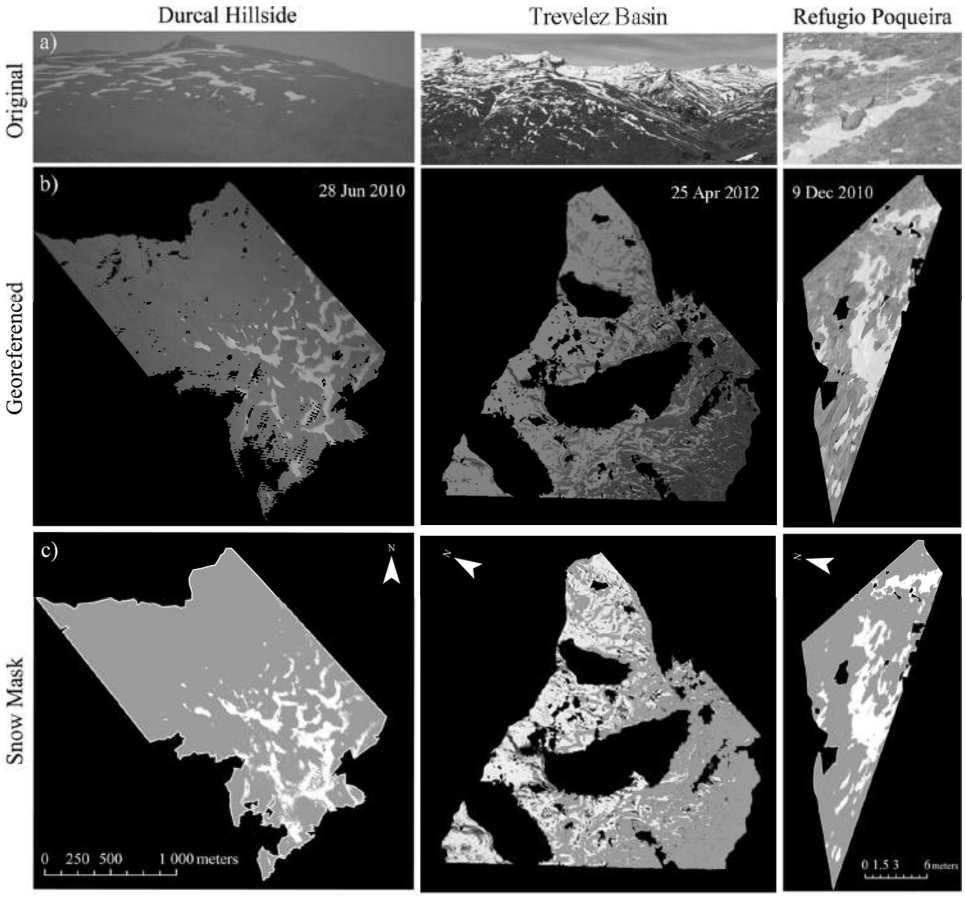

Figure 4. Selected examples of terrestrial photography processing: a) Original terrestrial images; b) Image Georeference; and c) Snow mask

CONCLUSION

The use of terrestrial photography greatly improves the quality of snow cover evolution measurement and provides us with a deeper insight into the seasonal, weekly, and daily variability exhibited by snow processes in semiarid climates. This results in a sounder knowledge of the dynamics of such processes and their better further modeling at the watershed scale. The implemented GUI facilitates the automation of the georeference process in an easy way. It has also been evaluated under different spatial scales, showing a good accuracy in all the cases. Thus, the capability and versatility of terrestrial photography for easy and continuous monitoring of snow has been demonstrated from the results. Additionally, the different formats of output snow maps allow its inclusion in other software like ENVI or ARCGIS, frequently used in GIS-based applications.

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