Climate change: a new software to study the variations of snow images shot by web cam

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ABSTRACT: The seasonal Snow cover and its extension play a relevant role for environmental studies in mountain areas especially considering its variation during time; the estimation of snow cover areal distribution is also particularly interesting to study evolution of climate and atmospheric dynamics. Recently, webcam images collected at daily or even hourly intervals are used as tools to observe the snow covered areas for touristic purposes; nevertheless those images, properly processed, can represent a very important environmental data source. This paper presents the Snow-noSnow software specifically designed to automatically detect the extension of snow cover from webcam images. The software was tested on images collected on Alps (ARPAV webcam network) and on Apennines in a pilot station properly equipped for this project by CNR-IIA.

KEYWORDS: snow cover monitoring, climate change, digital images, software, Alps, Apennines.

1 INTRODUCTION

Monitoring the snow cover state (extension) is one of the most important parameter to study climate evolution; it plays an important role for the sustainable management on the mountain territory and its resources. Snow monitoring is performed through traditional systems like the weather stations scattered on the territory (Cagnati, 2003) and automatic snow height sampling stations using probes (Cagnati, 1984); nowadays those equipments are also implemented with webcam systems that allow to observe the assessment of territory and ski slopes (Gook-Hwan et al., 2007). Considering webcam collect images at high temporal and spatial resolution and with a relatively low cost, it implies that these data sets become a useful tool for describing the territory at local scale (Hinkler et al. 2002). The use of webcam increases the potentialities highlighted by Hinkler et al. (2003) and Corripio et al. (2004), that used digital images acquired manually by an operator during one season. Therefore the availability of long time image-series provides an important innovation when dealing with the study of climatic variations (Buus-Hinkler et al. 2006). In this perspective the networks of cameras, especially those with a fixed long shot, started to play a relevant role in an environmental perspective. During the past 10 years, in the Alpine region many webcams have been installed and their images have been mainly used for touristic purposes and to a very limited extent for environmental monitoring or in order to provide support to snow field observations. When suitably processed these images can be used for scientific purposes, having a good resolution (at least 800x600x16 million colours) and a very good sampling frequency (hourly images taken through the whole year). Once stored in databases, these images represent therefore an important source of information for the study of recent climatic changes, to evaluate the available water resources and to analyse the daily surface evolution of the snow cover. This paper describes a project aiming at monitoring areas at different scales, particularly analysing areas close to the camera and with homogeneous land features in order to obtain information on the snow presence/absence, its persistence and distribution within the examined area (Salvatori et 2011). One of the first results of this project is the development of a dedicated software for the snow cover analysis through the processing of images taken from webcams and fixed or mobile digital cameras.

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2 IMAGES DATA SETS

To test the software two different image data sets have been used: the first one relate to Alpine region and the second one to Central Apennine.

The monitoring stations is provided by Sistemi Video Monitoraggio S.r.l. (Romito Magra-SP) and is equipped with a high resolution digital camera (Canon Powershot SX110 IS, 1/2.3" CCD, 3456x2592 pixel, 6mm objective - 35 mm equivalent focal length of 36mm), a specific hardware for data logging and transmission, placed into a waterproof case, a power supply unit using AC or photovoltaic panels with a buffer battery. Data are stored locally and automatically copied on a backup hard disk Data transfer is performed using an intranet connection with the receiving station. The system is controlled by the VM95 software, developed by SVM S.r.l. and Erdmann Video System (Valt, 2002).

First set of images is taken from the camera of the Cima Pradazzo station, (46°21'24"N, 11°49'20"E) located at 2200 m asl in the Belluno Dolomites (Valt, 2002). The choice of the field of view is related to the different kind of snow represented into the image that ranges from untrampled to groomed snow; the areas in the long shot remain covered by snow for a long time. The camera is installed close to the snow monitoring station of Cima Pradazzo, equipped with snow and weather sampling and monitoring instruments, between the others snow height, internal and surface temperature sensors.

In order to make available a series of images of an area in the Apennines, a brand new experimental station has been conceived and implemented by CNR-IIA in the territory of the Monti della Laga - Gran Sasso National Park in 2010. During the winter season 2013 the station has been moved close to CNR IIA headquarter in order to test the effectiveness of monitoring snow cover from a long distance. Mt. Terminillo was chosen as target area (42°28'25"N 12°59'51"E, 2217 m asl) due to seasonal abundance of snow and its importance for tourism and recreational activities

The station is equipped with the same digital camera, hardware and software of the ARPAV stations.

3 Snow-noSnow SOFTWARE

The Snow-noSnow software has been specifically designed to automatically detect the extension of snow cover collected from webcam images with a very limited human intervention.

The software starting point derive by the experience of the author in remote sensing image processing.

The core function of the software is based on a binary Snow-noSnow classification algorithm that allows the real identification of snow covered surfaces. The procedure consists in a statistical analysis of RGB values of all pixels inside the mask, *ad hoc* prepared, that allows, using mathematical criteria, to identify a threshold value to be linked to the snow cover thus allowing its detection. The classification procedure is based on statistical criteria and does not require human intervention other than the initial selection of the dataset.

The jpg image is separated into its RGB components; for each part of the image inside the predefined mask the Digital Number (DN) frequency histograms are calculated. A smoothing function is applied to the frequency histogram of blue component calculated as an average of the 5 nearest points. It is clear that The DN frequency distribution within the area inside the mask will be different according to the amount of snow-covered pixels.

Snow-noSnow operates in a semi-automatic way and has a reduced processing time. For these reason it is possible to analyze a series of images acquired in different years, thus following the seasonal evolution of the snow cover (Figure 1).

The software was tested on about 300 images collected on Alps and on Apennine: the images were processed with Snow-noSnow software and with a different image processing supervised classification algorithms; the results were compared with those achieved by photo-interpreter (Salvatori et al 2011).

Taking as true data coming out from photointerpretation, results show that using Snow-noSnow only 1% of pixels is misinterpreted.

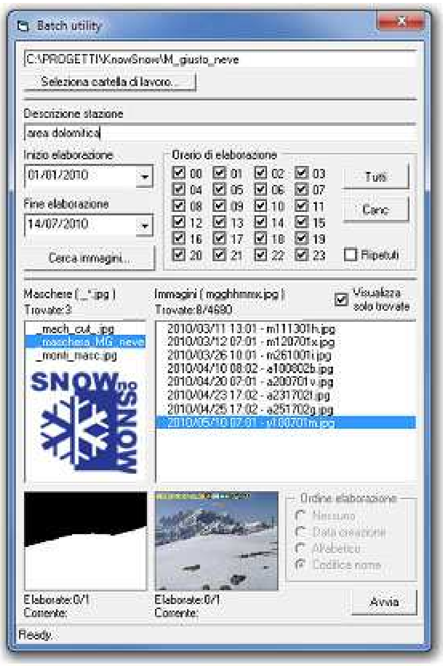

Figure 1. Screenshot of the Snow-noSnow input interface. On the bottom the image and its mask are shown.

4 CASE STUDIES

The analysis of images captured by monitoring stations during the past 10 years in the Alps and last 2-3 year in the Apennines shows the capabilities of the Snow-noSnow software to follow in detail the seasonal and daily evolution of the snow cover.

Considering as a meaningful example the images taken from Cima Pradazzo station it was possible to follow the snow cover evolution in the last 10 melting season.

The daily images were processed and the percentage of snow pixels in the mask were computed for each image. Resulting data were compared with the snow height measurements collected in the same place. As representative of the whole dataset, plots related to 2008 and 2013 are shown in figures 2a and 2b.

The melting trends measured by the snow-gauge in 2008 (Figure 2a) and 2013 (Figure 2b) are coherent with data derived by the images. The blue line describes the temperatures as recorded by the monitoring station installed with the snow gauge and can be a meaningful information to evaluate the data in prospective of climate change studies.

The Snow-noSnow multitemporal analysis shows how both the snow gauge and the webcam could be useful to describe the snow melting trend. However when the snow gauge records 0 cm of snow at the ground, the webcam continues to provide areal information about the snow cover until the melting is complete. all around.

In figure 2b it is evident the spotty snowfall at the end of June measured by both instruments.

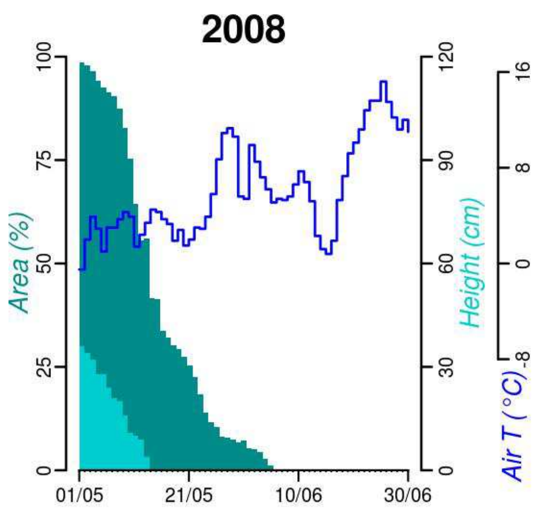

Figure 2a. Melting trend of snow covered area (% of pixels) for Cima Pradazzo in 2008.

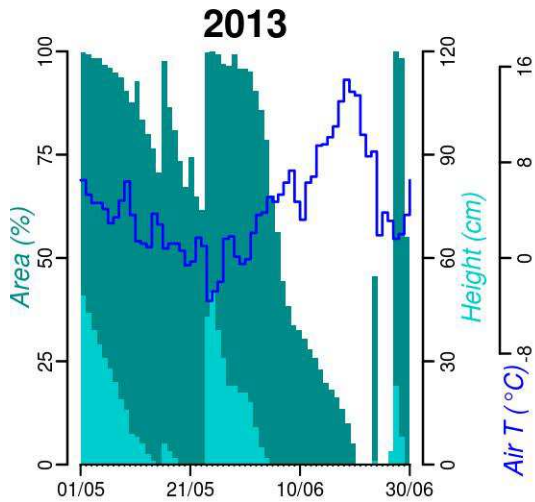

Figure 2b. Melting trend of snow covered area (% of pixels) for Cima Pradazzo in 2013.

In both figures the melting trend is clearly highlighted by the two instruments. Images recorded by the webcam seem to better identify the end of the melting phase since it is able to detect the presence/absence of snow on a wide area even if scattered on the surface.

In the Apennines area where snow cover variation could be sudden, the software was particularly effective because it allows to rapidly process a large amount of hourly images. The analysis of hourly images taken at Monti della Laga station in 2010 shows how in less than 24 hours snow cover could vary from 0% up to 85% and then back to 0%, especially during the spring time (Figure 3).

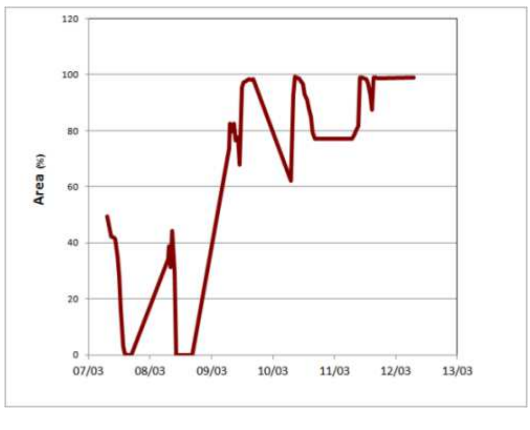

Figure 3. Snow cover variation (% of pixels) as recorded by hourly images at Monti della Laga station.

To better analyze daily variation of the snow cover also on images taken at long distance a linear stretch to minimize the haze effects was applied before using the Snow-noSnow. Results show how the use of this software makes possible to analyse also long shot images; the only prerequisite is to rely on images clear enough to make possible for Snow-noSnow to calculate the threshold value which is mandatory to process them.

It is foreseen to make available the stretching routine in the next versions of the software.

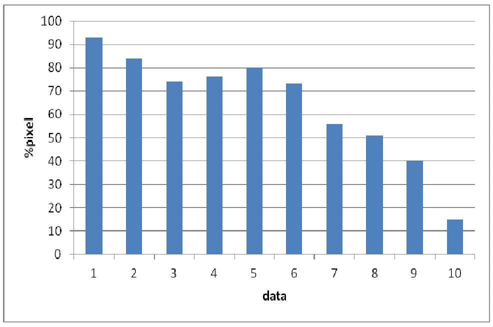

Figure 4. Melting trend of snow covered area (% of pixels) as recorded by long shot images of Mt.Terminillo.

5 CONCLUSIONS AND FURTHER DEVELOPMENTS

Snow cover data when used by studies on climate changes represent an important element to be used as an input for models.

The traditional way for evaluating the extension of snow cover and the persistence of snow at ground is the integration between data obtained from meteo stations equipped with snow gauges and processed satellite images. Snow gauges data could be considered punctual data since they sample snow thickness precisely but they do not allow to know at what extent the snow depth could be related to spatial distribution. Even if this is not a problem during the winter, it becomes much more important during the melting phase. During a melting period, in fact, snow can be discontinuously distributed on the surface and a snow gauge is only able to detect snow thickness at one point.

Even though the sensors devoted to monitoring operate in the visible range as well as in the microwave range, satellite images are affected by cloud cover and/or by weather conditions. Therefore it is sometimes difficult to automatically extract snow cover data. Data obtained from webcams automatically and hourly represent an important feature useful to follow in detail the seasonal evolution of snow cover. Both in Alpine and Apennine territory during the melting season the snow covered land extension could suddenly vary from 100% to 0% in a few days. Hourly images scan the transformation of the surface allowing also to visualize minor snow patches that overstay (preserved in shady areas).

Manually analyse those images could be wasteful in terms of time and resources, the adoption of an automatic procedure to process images and calculate the percentage of snow-covered area would therefore be an important tool to describe the trend of the melting phase even if lacking of data on the snow depth. This lack could be anyway compensated by using in an integrated way data from webcams and these provided by snow monitoring stations.

However, since Snow-noSnow allows to analyse different parts of an image, it is possible to take advantage of this feature applying it to a mask corresponding to areas that could be considered an infinite distance away. The images could be analysed to monitor the snow cover using different masks corresponding to different altitude belts.

Therefore data resulting by the use of Snow-noSnow represent a very good integration element between satellite data and data from snow monitoring stations. Webcam images are moderately affected by cloud cover since they are shot close to the surface and by haze effects. The latter can be minimized by using an image processing software.

Data derived by the image processed with Snow-noSnow in coming years could represent a meaningful element to support the climate studies at local level.

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