EGU2020-9153
https://doi.org/10.5194/egusphere-egu2020-9153
EGU General Assembly 2020

Multidecadal elevation changes from spy satellite images: application to glaciers and landslides

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Earth's surface has evolved dramatically over the last 50 years as a consequence of anthropogenic activities and climate change. The observation of such changes at decadal scales is often limited to sparse in-situ observations. The growth of satellite remote-sensing has enabled such monitoring at regional/global scales but generally over less than two decades.

More than 2 million images have been acquired by American reconnaissance ("spy") satellites on photographic film from the 1960s to the 1980s, and progressively declassified. With near-global coverage and meter to sub-meter resolution, these images have a large potential for many geoscience applications. However the photographic archive represents a unique set of challenges: pre-processing of the scans, correction of the image distortion caused during storing and scanning, poorly known camera positions and parameters. The vast majority of studies using these data rely on tedious manual processing of the data, hindering regional scale applications.

Here, we present the existing datasets and the development of an automated processing pipeline. We will focus in particular on images acquired by the Hexagon mapping camera (1973-1980, 12 missions) at 6-9 m ground resolution. A fully automated workflow has been developed to detect the 1081 fiducial markers present on the image, correct for distortion and stitch the different parts of the image, scanned in multiple sections. The pre-processed images are then used to generate Digital Elevation Models (DEMs) at 24 m resolution with the open-source NASA Ames Stereo Pipeline. The developed workflow is able to automatically solve for the unknown camera positions/orientations and optimally aligns the DEMs to an ancillary DEM for the determination of elevation changes. The application to ~600 images has revealed systematic biases in the retrieved elevation, up to 30 m error, linked to uncertainties in the camera parameters (focal length, lens distortion). We present a methodology to refine these parameters using an ancillary DEM only, without use of manual Ground Control Points. The KH-9 elevation is then validated against existing maps in Europe and Alaska and shows a vertical accuracy of ~5 m (68% interval) to 10-15 m (95% interval), sufficient for the study of large surface deformation (glaciers, landslides).

Finally, we conclude with several use of these data for the estimation of 40 years geodetic glacier mass balance in Europe and Alaska, and irrigation-triggered landslides in South Peru.