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Preliminary assessment of active rock slope instabilities in the high Himalaya of Bhutan

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The small kingdom of Bhutan, nested between India and Tibet (between 88° and 92° east and 26° and 28° north), is characterised by markedly different landscapes and climatic zones. V-shaped, forest-covered valleys in the south, affected by the monsoonal rains, give gradually way to steep, barren slopes of U-shaped valleys in the drier north, host of the highest peaks, a large number of glaciers and glacial lakes. A transition zone of vegetated, elevated plateaus collects the towns in which most of the population lives. Landslides in the high Himalaya of Bhutan have not been extensively studied despite the primary and secondary hazards related to them. The regulations and restrictions to travel to and within Bhutan imposed by the government, as well as the extremely rugged terrain hinder the accessibility to remote slopes and valleys, both of which have resulted in lack of data and investigations. In this work, we aim at producing an inventory of large rock slope instabilities (> 1 million m3) across the high Himalaya of Bhutan, identifying types of failure, assessing the activity and analysing the distribution of landslides in combination with predisposing and preparatory factors, such as lithology, tectonic structures, hypsometry, deglaciation, fluvial erosive power and climate. At this stage, we rely on the information retrieved through satellite remote sensing data, i.e. medium and high resolution DEMs, optical images and space borne Synthetic Aperture Radar (SAR) data. An initial inventory was compiled based on the identification of geomorphological features associated with slope instabilities using the available Google Earth images. Moreover, we assessed the SAR data coverage and the expected geometrical distortions by assuming different sensors (ERS, Envisat, and ALOS Palsar-1). As we are mainly interested in detecting the surface deformation related to large unstable slopes by applying Differential SAR, we also computed the percentage of potentially detectable movement along the satellite line of sight by assuming that the dominant motion is along the line of maximum slope. Finally, we present the preliminary surface velocities and displacement time series obtained by applying the P-SBAS technique (implemented within the ESA Geohazard Exploitation Platform) on available SAR data (24 images, period 2007-2010, Envisat ASAR, track 176), where several anomalies identified have been interpreted as active rock slope instabilities previously unknown.