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Snow Avalanche Susceptibility Based Assessment of Release Zones over Complex Terrain of Siachen Glacier Applying Ramms and Dsr as Active Macroclimatic Factor

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Abstract

Glaciers are a critical component of the earth system and environment, both in Polar regions and high altitude terrains. At glaciated terrain, local physiographical and climatological variance causes natural hazard which can lead to local and regional consequences. However, focusing the local complex terrain, the snow avalanches are not easily predictable. RAMMS (Rapid mass movement) application has applied successfully to determine the release areas for snow avalanche dimensions, yet the local microclimatic parameters have not been considered. To assess and identify the susceptible zones on basis of snow avalanche susceptibility, we applied RAMMS-avalanche simulation for avalanche dimension and MTLCIM-XL (Mountain Microclimate) simulator to calculate downward shortwave radiation (DSR) integration as the active microclimatic factor, at target release areas over the Siachen glacier. We obtain high dimension values (above assume a maximum value of pressure 50-80 kPa) for the selected release areas from the resultant simulation of snow avalanche maximum dimension. Additional integrative approach base assessment of DSR calculation revealed high values (threshold of daily mean $\geq$ 350-400 W/m^2) specifically over three release zones for critical month of April (daily mean based). Prospectively, the conclusive susceptibility analysis depicts the target release areas as potential zones for snow avalanche. In conclusion, the combined approach of RAMMS avalanche simulation with the consideration of local microclimatic parameters show better results; and will need to be considered in future studies of snow avalanche susceptibility and preparedness.

Keywords: Snow avalanche; RAMMS; MCTLIM-XL; DSR; Siachen glacier; Susceptibility

1. Introduction

Glaciers are considered a critical component of the earth system and environment both in polar regions and high altitude mountains due to a unique source of freshwater for agricultural, industrial and domestic use, an important

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economic component of tourism and hydroelectric power production. However, on the basis of consequences, it can be the main source for devastating natural hazard at local and regional level (GCOS 2004)[1]. Focusing glaciers as a significant source for snow avalanche, there local scale consequences at high altitude represent the short and dynamic consequences. Snow avalanches are not easily predictable because its main triggering agents are gravitational parameters, as well as, Local meteorological and climatological factors that have spatiotemporal variations at high elevation and complex terrain.

Satellite-based datasets and methods enable the observation of land ice masses over large spatial scales and remain helpful in such terrain which may not be easily monitored on basis of access and financial limitations (Kääb 2005)[2]. It is critical to consider and determine the local topographic and climatic factors for the focused regional assessment of snow avalanche prediction and or potential zones. There is a need for integrative approach base study and process models that determine the local and focused potential sites (zones) for their avalanche hazard or risk susceptibility.

Successive advancement in software based simulation systems and computational capabilities have shown progressive approach in solving the problems in prediction and assessment of natural hazards. Applications developed specifically for snow avalanche analysis i.e., determination (prediction), such as AVAL-1D (Bartelt et al., 1999; Christen et al., 2002)[3, 4], are used as helpful engineering tools, However; such one-dimensional models require that the primary avalanche flow direction and flow width must be defined for simulation, which is difficult especially in open terrain, or in terrain consisting of several possible flow channels (Christen et al., 2010)[5]. Moreover, other such developed applications (during simulation) ignore correlative topographic parameters at local regional level.

In snow avalanche susceptibility Application, As an integrative approach to consider local topographic parameters simulation ,as well as, microclimatic (meteorological) parameters as an active factors in snow avalanche potential determination; the integrative application of RAMMS (Rapid Mass Movements Simulation) module developed for Avalanche simulation and MTCLIM-XL (Mountain micro-Climatic-Xl) simulations can be applied to determine susceptible release areas (zones) at the known zones for snow initiation (run-out) over glaciated surfaces.

Developed by the RAMMS program team at the WSL Institute for Snow and Avalanche Research SLF, 'RAMMS-avalanche' is a state-of-the-art numerical simulation model to calculate the dimension of the avalanche in a two-dimensional simulation from initiation area (zone) of a snow avalanche to its resultant run-out in a three-dimensional terrain. It allows an easy access to display and analyze simulation results, while its developed application can solve both large, extreme avalanche events, as well as, smaller mass movements (Bartelt, P et al (2013) User Manual v1.5 Avalanche) [6] .The important scientific studies (publications) about RAMMS and its updated applications can be found in; (Bartelt, P et al (2013) User Manual v1.5 Avalanche, and all references therein). The active microclimatic factor i.e., Downward (incoming) shortwave radiation (DSR) can be calculated with the advance extrapolation model MTCLIM-XL mountain microclimate simulation. MTCLIM extrapolates data from a pre-defined base station to a single focused site in the target region. Original code written by R.R. Nemani (MTCLIM: Running et al. 1987)[7], the developed MTCLIM-XL (William M. Jolly- US Forest Service) was applied for spatial assessment and estimation of DSR at complex terrain by Sardar et al. (2016)[8] (all the related important scientific publications about MTCLIM and its updated applications therein).

This study focus on the determination of susceptible zones (release areas) on basis of potential for snow-avalanche by integrating the RAMMS simulation based findings with the MTCLIM-XL extrapolation to calculate the focused zones (sites) DSR as an active microclimatic factor for snow avalanche triggering. Following this approach, the potential release areas selected at the defined and variable sites for focused analysis over Siachen glacier is presented. According to the authors (to date knowledge) no such integrative approach based study has found in the previous related studies. With anticipation, the present study will be an insightful approach focusing the snow avalanche susceptibility based potential (hotspot or susceptible) zones identification at such critical geopolitical conflict zone with harsh weather and a complex terrain.

Sections 2 of this paper include methodological approach as; a brief description of the study area, the basic data obtained and methodology (applied simulations), While in Section 3 the obtained results and discussion is presented. Finally, section 4 presents the main conclusions of the present study.