Geophysical Research Abstracts
Vol. 14, EGU2012-14279, 2012
EGU General Assembly 2012

Combining thermal data, topography and texture analysis to analyze debris-covered glaciers: a case study from Kangchendzonga area, eastern Himalaya

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Accurate delineation of debris-covered glaciers in the Himalaya is needed for estimating rates of glacier area change, mass balance and the contribution of these glaciers to regional hydrology. The delineation of debris-covered glacial remains a challenge in glacier mapping from spaceborne imagery, particularly in optical remote sensing, due to the similarity of the spectral signature of debris-covered ice to surrounding moraines, which makes it difficult to apply standard semi-automated algorithms generally used for clean ice delineation. This paper exploits the potential of visible, infrared and thermal Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery combined with high-resolution Quickbird and Worldview2 imagery for mapping debris cover in the eastern part of the Himalaya. We combine band ratios, thresholds and normalized difference indices with topographic parameters derived from the ASTER digital elevation model in a decision tree algorithm to estimate potentially debris-covered area in the Sikkim Himalaya, with a focus on the Kangchendzonga area. We also evaluate the potential of texture analysis such as statistical techniques and filtering in spatial and frequency domain to characterize debris-covered surfaces and to improve the current classification schemes. Criteria and thresholds for each condition in the decision tree are chosen on the basis of a-priori knowledge extracted from an older topographic map and field observations. The predictive performance of the decision tree algorithm is evaluated using high-resolution Quickbird and Worldview2 data on several debris-covered glacier tongues in the study area. Results of the decision tree algorithm are promising, and show that most glacier tongues can be captures with the use of multi-spectral data combined with topographic variables. Texture analysis shows differences in surface roughness between debris-covered tongues and the surrounding non-ice moraine and clean ice, indicating its potential to improve the decision tree algorithm.