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Processes of mass loss on a debris covered glacier determined by high resolution DEM differencing

Sarah Thompson (1), Doug I Benn (1,2), Jordan Mertes (3,1)

(1) UNIS, Longyearbyen, Norway (sarah.thompson@unis.no), (2) University of St. Andrews, St. Andrews, Scotland, UK (doug.benn@unis.no), (3) Michigan Technological University, Houghton, USA (jrmertes@mtu.edu)

In recent years the response of debris-covered glaciers to climatic warming has seen significant disscussion. The insulating properties of a debris layer (> 5-6 cm) are well established however, in the Himalayas regionally averaged thinning rates, based on satellite laser altimetry, were found to be very similar on both debris-covered, and clean ice glaciers in the Himalayas. Overall mass loss rates on large debris covered glaciers have been discussed in conjunction with supraglacial lake development and growth but the processes involved in downwasting are often numerous and complex. Here we report on mass loss measurements, from a combination of in situ lake surveys and remote sensing, on large debris covered glacier in the Khumbu Himal Nepal. Lake bathymetry sonar surveys were conducted in the winter of 2009 and 2012, and GeoEye-1 stereo imagery was acquired in 2010 and 2012. The temporal data sets were combined and differencd to allow detailed investigation of glacial surface change over the 2 year period. Ngozumpa Glacier has a stagnant ice tongue extending down to ∼4650 m asl, the lower 15 km of which is debris covered. This debris covered region is highly irregular with many hollows occupied by studded with numerous supraglacial ponds and lakes. In the early 1990s a base level lake was identified ∼1 km from the glacier terminus. Our results show a highly complex pattern of glacial downwasting and lake change. Numerous examples of rapid supra glacial growth and drainage are evident, including the formation and enlargement of lakes along preexisting structures such as relic englacial drainage conduits. However, also in evidence are areas of significant lake shrinkage due to sedimentation and lake shore debris collapse. In addition to lake induced mass loss a background downwasting rate of ∼ 0.5 m a-1 is evident in the lower ablation area where debris thicknesses are known to be between 1-3 m thick. The results illustrate the highly complex nature of debris covered glacier evolution and the myriad processes involved.