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Spatial and temporal patterns of thermal resistance and heat conduction on debris covered Miage Glacier, Italian Alps

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Thermal resistance, defined as material thickness divided by thermal conductivity, is the key determinant of the sub-debris ablation rate on debris-covered glaciers. An extensive glacial and meteorological study was conducted at Miage Glacier, Italian Alps, between June and September 2005, which enables spatial and temporal patterns in debris layer thermal resistance to be determined for the first time. Miage Glacier is the largest ice mass on the southern side of the Mont Blanc massif, and is covered by a continuous mantle of rock debris in its lowest 5 km. At 25 sites, with debris thicknesses between 4 and 41 cm and ranging in elevation from 1839 to 2417 m above sea level (a.s.l.), debris surface temperatures and sub-debris ablation were monitored, enabling estimates of debris thermal conductivity to be made. The % void space in the debris layer at each site was assessed by measuring the quantity of water needed to immerse a fixed volume of debris. At 4 sites, profiles of temperature and humidity were also monitored at 4 levels within the debris layer. Meteorological conditions were monitored continuously throughout at an automatic weather station located at 2030 m a.s.l. The main findings are: (1) thermal conductivity values ranged from 0.4 to 1.7 W m-1 K-1 in the June to July period and were strongly inversely dependent on % void space, but independent of debris thickness and elevation; (2) thermal conductivity had a smaller range but similar mean value in the August to September period, with deeper debris sites showing larger magnitude changes over time than shallower sites; (3) thermal resistance values increased downglacier from 0.1 to 0.8 m2 K W-1 in response to increasing debris thickness; (4) midday conductive heat flux values peaked at $>$ 400 W m-2 on well compacted medium thickness debris layers, but were more

typically between 100 and 300 W m-2; and (5) humidity values indicate that evaporation of melt water is an important energy sink in the debris layer. The implications of these findings for the melt modelling of debris covered glaciers will be discussed.