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Spatial debris-cover effect on the maritime glaciers of Mount Gongga, south-eastern Tibetan Plateau

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The Tibetan Plateau and surroundings contain a large number of debris-covered glaciers, on which debris cover affects glacier response to climate change by altering ice melting rates and spatial patterns of mass loss. Insufficient spatial distribution of debris thickness data makes it difficult to analyze regional debris-cover effects. Mount Gongga offers an opportunity to study a monsoonal maritime glacier system with debris-covered and debris-free glaciers in the south-eastern Tibetan Plateau, where specific, though incomplete, information is available for both the glaciology and meteorology. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)-derived thermal property of the debris layer reveals that 68% of Mount Gongga glaciers have extensive mantles of supraglacial debris in the ablation zones, where the debris-covered proportions of the total glacier area vary from 1.74% to 53.0%. These glaciers show a general downglacier increasing trend in debris thickness with significant spatial inhomogeneity at each site. High-resolution in situ measurements of debris thickness indicate that thin debris thicknesses of $<$ 0.03 m are widely distributed on the glaciers. Against the background of global warming, we find that although the presence of supraglacial debris has a significant insulating effect on the trend of greater negative mass balance on the debris-covered glaciers, especially on the glaciers with debris-covered proportions $>$ 20%, it accelerates the trend of faster ice melting on ˜ 10.2% of the total ablation area and produces a more negative mass balance, which is primarily caused by temperature rise, on ˜25% of the debris-covered glaciers on Mount Gongga, with the consequence that regionally averaged mass balance of debris-covered glaciers is not statistically different from that of debris-free glaciers, all showing an intensive negative mass balance trend on Mount Gongga. Also, the intensely inhomogeneous ice melting caused by widespread debris cover in association with high ice velocities and relatively steep surface leads to active terminus regions of the debris-covered glaciers, of which the terminus retreat rates are faster than those of the debris-free glaciers. In addition, regional differences in the debris-cover effect are apparent, highlighting the importance of debris cover for understanding glacier status and hydrology in both the Tibetan Plateau and other mountain ranges around the world.

Keywords: debris, melting, effect, Tibetan Plateau