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On the impact of the extreme summer 2003 on glacier mass balance in the Alps: Results from modelling and satellite data

F. Paul (1), H. Machguth (1), M. Hoelzle (1), A. Kaeaeb (1)
(1) Department of Geography, University of Zurich, Switzerland

Glacier changes are among the best natural indicators for ongoing climate change. Analysis of recent satellite data has revealed an accelerated glacier shrinkage during the past two decades in the Alps with an increasing tendency for down-wasting (stationary thinning) and disintegration rather than an active dynamic response. Under such conditions of general decline, the extraordinary hot summer of 2003 has caused record breaking negative glacier mass balances of about -2.5 m w.e. in the Alps, which is 5 to 10% of the remaining ice masses. This is also ten times the long-term average and three times the decadal mean of the "hot" 1990s.

Measurements and modelling of glacier energy balance components have shown that direct radiation is the most important factor for glacier melt in the Alps and, thus, glacier albedo is the most sensitive variable. In this study we use Landsat Thematic Mapper (TM) data from the end of the ablation period in three different years to determine glacier albedo as well as a distributed mass balance model for calculation of the corresponding glacier melt rates. A comparison of 1992, 1998 and 2003 glacier albedo reveals about two-times lower albedo values in 2003. The enhanced accumulation of soot and dust due to the persisting dry conditions in the summer 2003 plays a major role for the observed albedo lowering. A forcing of the mass balance model with identical meteorological conditions as for 2003, but using the three different albedo maps, yields more than doubled melt rates for 2003.

Additional effects related to the special characteristics of the summer 2003 have caused the extremely negative 2003 mass balances: The first heat wave in June melted the highly reflective snow cover, during the mostly clear conditions in July the bare glacier surfaces absorbed highest amounts of direct radiation, and during August the

lowered glacier albedo has compensated for the decreased solar elevation. Further amplification of glacier melt was caused by the second heat wave in August. The predicted future temperature increase together with the related increase of extreme climate conditions will result in a fast disappearance of most Alpine glaciers. This process will be further enhanced by positive feedbacks.