Geophysical Research Abstracts,
Vol. 10, EGU2008-A-01406, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-01406
EGU General Assembly 2008
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Glaciers and climate change (Louis Agassiz Medal Lecture)

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A model describing the response of a glacier to climate change has two distinct components: (i) a mass-balance module, generating the surface balance rate from meteorological input data, and (ii) a glacier flow module, describing how glacier geometry changes in time as a response to mass balance forcing. In the context of dynamical systems theory, most glaciers are strongly damped systems with a large mass throughput. Therefore, the response of glaciers to climate change is first of all dictated by conservation of mass. Glacier mechanics determine the response time and the feedback on the surface mass balance (because the balance rate is to a large extent determined by the mean surface elevation).

Over the past 20 years the Institute for Marine and Atmospheric Research, Utrecht University, has made a large effort to collect long-term meteorological data from weather stations on glaciers. This has resulted in a much better understanding of the processes that regulate the exchange of mass and energy between glacier surface and atmosphere. The meteorological datasets have made it possible to calibrate mass balance models and to determine the sensitivity of the balance rate to a changing climate with much greater confidence. Studying the dynamics of individual glaciers is best done with numerical models. Yet the possibilities of analytical models to gain basic insights have been underestimated. Notably, the first order-effects of bed slope and elevation-mass balance feedback on the sensitivity of glaciers can be estimated from simple models.

In this lecture I will tell about the use of automatic weather stations on glaciers. I will give a flavour of the problems involved, and of the rewards obtained. Then I will try to

demonstrate the power of simple glacier models. I will put the bits and pieces together in an attempt to obtain a global picture of what glaciers have done in the past few centuries. In the end I will discuss how a climate signal can be extracted from glacier fluctuations, and how the contribution of glaciers to sea-level rise can be estimated.