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Nourishment conditions and main features of ablation were analyzed using a model of mass exchange for some glaciers in the Tien Shan, Pamir, Southeast Tibet, and north slope of Himalaya. We used expeditionary data and long-term records on the Golubin, Tuyuksu, Inylchek, Fedchenko, Gonga, and Shishapangma glaciers and standard meteorological data from 36 stations in the region. Glaciation in these areas is less balanced and responds strongly to climatic changes. At the same time, each of these areas has its own specific features of glacioclimatic conditions depending on the orography, latitude, and relative location in the Central Asian mountain system. The primary glacioclimatic factors controlling the current state of glaciation in these systems were identified and quantified.

Most of the glaciers studied in this work have a negative mass balance, which illustrates the general trend towards degradation of glaciation in Central Asia. The greatest values of negative balance were found for glaciers with a monsoon-type alimentation, as well as for glaciers of the Central Pamir, whose glaciation conditions are determined to a considerable extent by the influence of Atlantic air masses. Variability of mass balance and firn-line position are greatest for these areas. These characteristics are typically stable for the Central Tien Shan. Progressing from north to south, average summer values of air temperature grow simultaneously with increase of total annual precipitation. Based on reconstructed meteorological information and dendrochronological materials, we estimated that over the past 150 to 200 years mean air temperature in North Tien Shan has risen 0.9°C in summer and annual precipitation has decreased 100 to 150 mm.

H22A-6 1400h POSTER

How many ablation stakes are enough?

A G Fountain and A V Vecchia, U S Geological Survey, P O Box 25046, MS 412, Denver, CO 80225

The most common method of determining the mass change of a glacier is to calculate it from changes in density and thickness of the near surface layers measured at stakes planted in the glacier surface. A practical problem is determining how many ablation stakes are necessary to adequately represent the glacier surface. The problem has three facets: 1) How many stakes are required to achieve a certain accuracy? 2) Given a limited number of stakes, how large is the incurred error? 3) Given a limited number of stakes, where should they be placed in order to achieve maximum accuracy? The solution to this problem will not only benefit the operation of field programs but also provide an objective estimate of the error in the mass change, which will aid in assessing the significance of the change. Together with data from other glaciers, such an error estimate will help determine the significance of glacier mass changes to regional water supplies and to sea level changes.

Alpine glaciers generally show a strong dependence of mass change on elevation and this dependence can be often described by a quadratic equation. For one case investigated, using a universal kriging approach, no significant spatial correlation was found in the deviations from the quadratic equation. This indicates that standard statistical regression methods can be used to determine the error in the calculated mass change. The stake location becomes important when the number of stakes are reduced as one attempts to define the relation between mass change and elevation.

H22A-7 1400h POSTER

Mass Balance of Griesgletscher 1961-1984: different methods of determination

M. Funk, W. Stahel and R. Morelli (Eidgenösische Technische Hochschule Zürich)

Mass balance measurements started on Griesgletscher in 1961. The number of stakes used was 20 in the first 8 years and has been increased up to 78 ($\approx 13 \frac{stakes}{km^2}$) and kept constant until 1984. From 1984 until now, the measurements were continued with 8 stakes. Until 1984, the mass balance for the whole glacier was determined with the traditional method, where contour lines of equal mass balances were drawn by hand, then calculated for elevetion intervalls and finally for the entire glacier. For that period (1961-1984), 73% of the 23×78 data are available. With this important data set, different statistic methods to determine the mass balance of the whole glacier were tested to assess their accuracy and to consider a reduction of the number of stakes. It could be shown that the linear model of Lliboutry is not valid for the whole glacier, but gives satisfying results if the accumulation and the ablation areas are treated separately.

H22A-8 1400h POSTER

Determining Glacier Mass Balance Using Digital Elevation Models and Geographic Information Systems

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D YANG (Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou 730000, People's Republic of China) (currently at Canadian Climate Centre, Environment Canada, Downsview, Ontario)

Mass balance measurements were carried out in May of 1990 on Glacier No. 1 in the Ürümqi River basin, Xinjiang Uygur Autonomous Region, northwestern China, in an effort to examine differences in mass balance calculations resulting from sampling and estimation procedures. Three different snow-depth data sets were collected consisting of: (1) high-resolution depth transects covering the glacier, (2) depths taken from the permanent stake network, and (3) an intermediate data set constructed using the stake network and supplementary depth data from locations not covered by the stake network. The glacier was divided into ten elevation zones and the data were registered to a digital elevation model for analysis. Analysis was completed using IPW (Image Processing Workbench) and the GIS package GRASS.

Results show that the permanent stake network provides an accurate estimate of total mass balance if certain techniques are used for extrapolation to higher elevations, although estimates of mass balance for particular regions of the glacier are not accurate. Some regions were overestimated while others were underestimated, leading to a good overall estimate. The intermediate resolution data set provided better within-zone estimates of mass balance, but was less accurate than the stake network for total mass balance. We found that digital elevation models coupled with analytical capabilities common to a typical GIS provide a powerful tool for determining glacial mass balance.

H22A-9 1400h POSTER

Internal Ablation--An Overlooked Component of Glacier Mass Balance

L R Mayo (US Geological Survey, 800 Yukon Drive, Fairbanks, AK 99775; 907-479-5645)

Glacier surface measurements of snow, old firn, and glacier icemelt are made at numerous glaciers but estimates of internal ablation are not. Therefore, the glaciers' total ablations are underestimated. Internal melting is caused by heat from geothermal sources and by potential energy losses due to flowing glacier ice and liquid runoff.

Assuming that geothermal heat and all potential energy losses in the temperate part of a glacier cause melting, the annual internal ablation averaged over the total glacier area and the percentage of the traditional assessment of old firn and ice ablation for five glaciers in North America are approximately

Glacier	Ablation (meters)	Percentage
Black Rapids	0.06	7
Wolverine	.10	12
Columbia	.17	11
Hubbard	.18	35
South Cascade	.09	11

At all glaciers except Hubbard, the potential energy loss from liquid runoff is the primary heat source causing internal ablation. Hubbard Glacier is unusual because the potential energy loss due to ice flow causes more than half of the internal ablation. Furthermore, that melting is a relatively large part of glacier ice ablation because only 5 percent of the glacier's surface is below its equilibrium line. Estimation of both internal accumulation and ablation are required if long-term mass balance series are checked against measured ice volume changes.

H22A-10 1400h POSTER

Mass Balance and Cold Air Ponding, an Analysis of Conness Glacier, Sierra Nevada, California

F B Chambers (Department of Geography and Center for Environmental Sciences, University of Colorado, Denver, Denver, CO, 80217; ph. 303-556-2619; fax. 303-556-4822 (Sponsor: Andrew G. Fountain)

Conness Glacier, like many of the small glaciers in the Sierra Nevada and central Rockies, exists at the southernmost limit of glacierization in the northern hemisphere in what might be described as a "marginal" glacier environment. These are areas confined to high elevations and susceptible to small changes in atmospheric energy and moisture regimes. The location of Conness Glacier is no exception. The current six-year California drought has resulted in a series of extremely negative balance years for the glacier. Approximately five percent of the ice surface area melted away during the summer of 1991. It now appears that an even larger portion of the glacier may melt away within the next few years.

An exception to this trend is found, however, at the base of the glacier in what is characteristically considered the "ablation zone". Here, cold air ponding behind a massive terminal moraine/bedrock complex seems to be inhibiting melt and may be promoting accumulation, while upper reaches of the glacier show extreme ice wastage. Temperature measurements taken during several summer ablation seasons indicate that the lower glacier experiences more frequent and harder freezes than do higher regions on the glacier. Thus, Conness Glacier appears to be an example of an "inverse glacier".

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