



State of glaciers in the Caucasus and southern Siberian mountains and their links with climate oscillations since the 1950s

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In this paper, we present changes in the extent of glaciers located in the Caucasus (Russia and Georgia), Altay, Sayan, and Kodar (Russia) mountain ranges that have occurred over the last 50 years. This is achieved through analysis of satellite imagery (Landsat TM, ETM+ and ASTER), aerial photographs, historical maps, and glacier mass balance records. The Caucasus and Altay accommodate approximately 1600 km² and 900 km² of ice, respectively, but the extent of glaciation in the Kodar and Sayans is much less and is largely restricted to cirque glaciation. In all regions, glaciers have been retreating throughout the 20th century. The rates of retreat are not uniform, however, and decline from west to east. The highest rates of retreat are observed in the westernmost Caucasus Mountains where glacial extent declined by 10% between 1985 and 2000. In the Siberian mountains the retreat rates are slower (7% of

ice was lost between 1952 and 1998 in the Altay) but appears to be accelerating (a further 4% of ice reduction occurred between 1998 and 2006 in the Altay). The observed glacier retreat is linked to rising summer temperatures which have been increasing in the Caucasus and the Altay at a rate of 0.4-0.6° per 10 years since the late 1960s between the altitudes of 1600 m and 2600 m. Mass balance records from individual glaciers (e.g. Djankuat in the Caucasus and Aktru in the Altay) confirm that increasing summer ablation is not compensated by winter accumulation. There are no long-term, continuous records of mass balance observations in the Sayans and Kodar. However, assessment of mass balance of the Azarova glacier in the Kodar, derived using the cartographic method, confirms that the formation of superimposed ice, enhanced by the rising summer temperatures, does not compensate for glacier melt and cold glaciers in the Kodar are retreating albeit slower than temperate glaciers in other regions.