Geophysical Research Abstracts
Vol. 17, EGU2015-4815-1, 2015
EGU General Assembly 2015

Timing of late Pleistocene glaciation in Mongolia: Surface exposure dating reveals a differentiated pattern of glacial forcing

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The focus of this study is on the geochronological and paleoclimatic characterization of Pleistocene glaciation in central (Khangai Mountains) and western (Turgen Mountains, Mongolian Altai) Mongolia. These two mountain ranges form a 700 km long SE-NW transect through Mongolia and allow assumptions of the temporal and causal dynamics of regional glaciation and their correlation to other mountain glacier records from Central and High Asia. In order to evaluate the Pleistocene glaciations in Mongolia we undertook geomorphological mapping and cosmogenic radionuclide (CRN) surface exposure dating (10Be) in four valley systems located in the Khangai Mountains and Turgen Mountains. In total 46 glacial boulders and roche moutonnées were sampled, prepared and AMS measured to determine their 10Be surface exposure ages. Of these, 26 samples were obtained from the Khangai Mountains (three separate moraine sequences) and 20 samples were taken from the Turgen Mountains (one moraine sequence). Our results give evidence of major ice advances during early MIS-4 (74−71 ka) and MIS-2 (25−20 and 18− 17 ka) in both mountain ranges. However, in the Khangai Mountains of central Mongolia very significant ice advances also occurred during MIS-3 (37−32 ka), which exceeded the ice limits set during the MIS-2 glaciation. These results show that climatic conditions during phases of insolation minima characterized by extremely cold and dry conditions (MIS-4 and MIS-2) produced a favorable setting for major ice expansion in Mongolia. Yet, glacial accumulation in the Khangai Mountains also increased substantially in response to the cool-wet conditions of MIS-3, associated with a possibly greater-than-today input from winter precipitation. These records indicate that in addition to the thermally induced glaciations of MIS-4 and MIS-2, variations in atmospheric moisture supply are also capable of triggering large ice advances as observed during MIS-3. Taken together, this suggests that the role of atmospheric circulation and its significance for controlling regional precipitation results in a more differentiated pattern of late Pleistocene glaciation in Mongolia than previously recognized. Compared to other glacial records from High Asia, the observed patterns of past glaciations in Mongolia show similar results (i.e. ice maxima during interstadial wet phases) compared to monsoon influenced regions in southern Central Asia and NE-Tibet, while major expansion during insolation minima (MIS-4 and MIS-2) are more in tune with glacier responses known from western Central Asia and Siberia.