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Annual and seasonal mass balances of Chhota Shigri Glacier (benchmark glacier, Western Himalaya), India

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Several studies on Himalayan glaciers have been recently initiated as they are of particular interest in terms of future water supply, regional climate change and sea-level rise. In 2002, a long-term monitoring program was initiated on Chhota Shigri Glacier (15.7 square km, 9 km long, 6263-4050 m a.s.l.) located in Lahaul and Spiti Valley, Himachal Pradesh, India. This glacier lies in the monsoon–arid transition zone (western Himalaya) and is a representative glacier in Lahaul and Spiti Valley. While annual mass balances have been measured continuously since 2002 using the glaciological method, seasonal scale observations began in 2009. The annual and seasonal mass balances were then analyzed along with meteorological conditions in order to understand the role of winter and summer balances on annual glacier-wide mass balance of Chhota Shigri glacier. During the period 2002–2013, the glacier experienced a negative glacier-wide mass balance of -0.59±0.40 m w.e. a-1 with a cumulative glaciological mass balance of –6.45 m w.e. Annual glacier-wide mass balances were negative except for four years (2004/05, 2008/09, 2009/10 and 2010/11) where it was generally close to balanced conditions. Equilibrium line altitude (ELA) for steady state condition is calculated as 4950 m a.s.l. corresponding to an accumulation area ratio (AAR) of 62% using annual glacier-wide mass balance, ELA and AAR data between 2002 and 2013. The winter glacier-wide mass balance between 2009 and 2013 ranges from a maximum value of 1.38 m w.e. in 2009/10 to a minimum value of 0.89 in 2012/13 year whereas the summer glacier-wide mass balance varies from the highest value of –0.95 m w.e. in 2010/11 to the lowest value of –1.72 m w.e. in 2011/12 year.
The mean vertical mass balance gradient between 2002 and 2013 was 0.66 m w.e. (100 m)-1 quite similar to Alps, Nepalese Himalayas etc. Over debris covered area, the gradients are highly variable with a negative mean value of -2.15 m w.e. (100 m)-1 over 2002-2013 observation period. The negative gradients can be explained by the thickness of debris cover that increases with decrease in altitude, thus protecting the glacier more efficiently at lower altitudes. Mass balance is strongly dependent on debris cover, exposure (solar radiation) and the shading effect of surrounding steep slopes.