

## ***Interactive comment on “Sustainability of water resources management in the Indus Basin under changing climatic and socio economic conditions” by D. R. Archer et al.***

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My present comment deals only with section “5.2 The glacial regime”

(1) Because of the shortage in mass balance measurements, the discussion by Archer et al. about glacier change is mainly based on observations of glacier length (or area) changes. The authors should better stressed that this a very indirect indicator of the glacier health (Oerlemans, 2001) and that we severely lack measurements of glacier mass change in this area of the world. The occurrence of numerous surges in the Karakorum as reported by (Hewitt, 2007) is certainly not a proof itself that the glaciers are healthy. Glaciers in Iceland (Björnsson and Pálsson, 2008), in Alaska (Muskett

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et al., 2003) or in Svalbard (Nuth et al., 2010) have experienced some rapid ice loss recently but still some of these glaciers are continuing to surge.

(2) "the lack in the Karakoram of widespread retreat of glaciers reported in mountain regions elsewhere (Greenwood et al., 2010)." The reference to Greenwood et al., 2010 (the editorial to the special issue) is obviously not the relevant glaciological reference. See e.g., (Cogley, 2009) for a better overview of glacier change.

(2) "in line with experience in the central Himalaya (Hasnain, 1999)" A "dangerous" reference to gray literature. Evidence of recent ice loss in the central part of the Himalaya can be found in (Berthier et al., 2007; Dobhal et al., 2008; Kulkarni, 1992; Kulkarni et al., 2004; Wagnon et al., 2007) and I may have forgotten some other references. Note however that in the above list, Dokriani glacier, studied by Dobhal et al. (2008), is not contributing to the Indus river flow (but it is still in central Himalaya).

(3) You could improve your discussion of the glacier loss by discussing contrasted response within the UIB. There seems to be widespread ice loss in the Spiti/Lahul (cf. Chotta Shigri glacier) compared to reduced ice loss in the Karakorum. In this respect, you should also read and cite a recent paper using GRACE gravimetry data (Matsuo and Heki, 2010) that seems to confirm your statement that glacier loss are reduced in the Karakorum area compared to the central Himalaya. Grace data have their own issues but still they can help to understand the large scale pattern of ice mass loss.

(4) Fig. 1. The Indus Basin The "Glacier and Permanent snow area" is not complete and lack many glaciers and icefields. It is a poor representation of ice masses for a paper that deals with water resources in a highly glaciated area. What is the source of the glacier outlines that you used? Some better data may be available from the GLIMS glacier database (<http://glims.colorado.edu/glacierdata/>)

Reference for my Short Comment:

Berthier, E. et al., 2007. Remote sensing estimates of glacier mass balances in the Hi-

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machal Pradesh (Western Himalaya, India). *Remote Sensing of Environment*, 108(3): 327-338. Björnsson, H. and Pálsson, F., 2008. Icelandic glaciers. *Jökull*, 58: 365-386. Cogley, J.G., 2009. Geodetic and direct mass-balance measurements: comparison and joint analysis. *Annals of Glaciology*, 50(50): 96-100. Dobhal, D.P., Gergan, J.T. and Thayyen, R.J., 2008. Mass balance studies of the Dokriani Glacier from 1992 to 2000, Garhwal Himalaya, India. *Bulletin of Glaciological Research*, 25: 9-17. Hewitt, K., 2007. Tributary glacier surges: an exceptional concentration at Panmah Glacier, Karakoram Himalaya. *Journal of Glaciology*, 53(181): 181-188. Kulkarni, A.V., 1992. Mass balance of Himalayan glaciers using AAR and ELA methods. *Journal of Glaciology*, 38: 101-104. Kulkarni, A.V., Rathore, B.P. and Alex, S., 2004. Monitoring of glacial mass balance in the Baspa basin using accumulation area ratio method. *Current Science*, 86(1): 185-190. Matsuo, K. and Heki, K., 2010. Time-variable ice loss in Asian high mountains from satellite gravimetry. *Earth and Planetary Science Letters*, 290: 30–36. Muskett, R.R., Lingle, C.S., Tangborn, W.V. and Rabus, B.T., 2003. Multi-decadal elevation changes on Bagley Ice Valley and Malaspina Glacier, Alaska. *Geophys Res Lett*, 30(16). Nuth, C., Moholdt, G., Kohler, J., Hagen, J.O. and Kaab, A., 2010. Svalbard glacier elevation changes and contribution to sea level rise. *Journal of Geophysical Research-Earth Surface*, 115: F01008. Oerlemans, J., 2001. *Glaciers and climate change*. A. A. Balkema Publishers, Rotterdam. Wagnon, P. et al., 2007. Four years of mass balance on Chhota Shigri Glacier, Himachal Pradesh, India, a new benchmark glacier in the western Himalaya. *Journal of Glaciology*, 53(183): 603-611.

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