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Interactive comment on "The role of glaciers in stream flow from the Nepal Himalaya" *by* D. Alford and R. Armstrong

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Alford and Armstrong (2010) provide a generalized examination of glacier runoff in Nepal, assessing the importance to the Ganges River in particular. Quantifying the role of Himalayan glaciers in regional runoff is an important topic. The glaciers in the region are unique and we cannot simply extrapolate from other alpine regions. The examination by Alford and Armstrong (2010) is too general to provide meaningful insight or accurate output. The general concept and conclusions may be valid, but this cannot be assessed from the paper, which seems to be a starting point not the end product for an important investigation of glacier runoff in the Himalaya. After many recent detailed contributions on the topic of Himalayan runoff and glaciers by Thayyen and Gergen (2010); Singh et al., (2008), Fujita (2008) and Kulkarni et al.(2010) to

name a few, this paper takes a step backward as if most of this research had not been completed. The following is not a complete evaluation of the paper, but a list of four key issues that render the results unreliable as presently presented and explained.

1) Debris Cover: Himalayan glaciers have received considerable attention, and there are numerous papers detailing the impact of debris cover on the melting of the Himalayan glacier in Nepal. The debris cover is recognized as a key component in controlling ablation and glacier runoff (Adhikari et al., 2000; Gades et al., 2000; Kayastha et al., 2000; Singh et al., 2000). In this paper the only mention of debris cover is in the references. Nakawo and Rana, (1999) noted the fundamental importance of determining ablation under the debris layer for understanding meltwater production form Himalayan glaciers. It is not possible to model the runoff reliably from Nepalese glaciers without consideration of debris cover. The terminus elevation of glaciers with debris cover typically extend several hundred meters below that of adjacent clean glaciers, another indication of the importance.

2) Summer Accumulation Glaciers: The fact that Nepal glaciers are summer accumulation type glacier's, is an important and unique characteristic of these glaciers, that has a profound effect on their seasonal runoff signal and the distribution of mass balance with elevation (Ageta and Fujita, 1996; Fujita and Ageta, 2000; Kulkarni et al., 2002; Fujita, 2008; Thayyen and Gergen, 2005; Thayyen and Gergen, 2010). This paper does not mention the critical import of these glaciers having the main accumulation season and ablation season during the summer monsoon. The paper never acknowledges the glaciers are summer accumulation type glaciers at all. Summer accumulation type glaciers have a very steep balance gradient in the lower accumulation zone. Gupta et al., (2005) observed that there are four zones in Himalayan glacier basins: dry snow zone, wet snow zone, exposed glacial ice and moraine-covered glacial ice, each possessing unique hydrological characteristics. Thayyen and Gergen (2010) in Figure 2 note the areal distribution of the summer monsoon glacio-hydrological regimes and in Figure 3 provide the contrast between hydrographs for glaciers in this summer accu-

mualation zone and typical alpine glaciers. That is why it is critical to consider each of the four glacier zones in constructing a realistic model of glacier runoff in the Himalaya.

3) ELA Assumptions: It is assumed that there is no ablation above the ELA. For the first several hundred meters above the equilibrium line it is observed that substantial melting does occur on Himalayan glaciers (Kulkarni, 1992; Fujita, 2008; Prasad et al., 2009; Adhikari and Huybrechts, 2010). This is the wet snow zone (Gupta et al. 2005). It has also been noted that black carbon could impact this ablation (Adhikary et al., 2000; Prasad et al., 2009). On the extensive Himalayan valley glaciers there is a high elevation dry snow zone where ablation is minimal, this zone is neither identified nor referred to in this paper. They note that as a first approximation it is assumed that the ELA is 5400 m. Bajracharya and Mool,(2009) note several glaciers with top elevations below 5400 m. Kulkarni et al. (2004) notes ranges for ELA from 5000 to 5500 meters in the Baspa Basin, India If ELA values are adjusted spatially or temporally in the model it is not made clear how or when. Considerable data exists that indicate the significant variation of the ELA in Nepal and Indian Himalaya, this data needs to be utilized. A key input to mass balance is the mass balance gradient. Fujita and Ageta (2000) mass balance gradient does not resemble that of Figure 7. Figure 7 has a small elevation range compared with the large Himalayan glaciers with a gradient for this zone that certainly cannot be applied to the glacier as a whole, 1.4 m/100 m. What is the point of Figure 1 a balance gradient that is not appropriate to the region, and has an upper elevation of 4000 m. The gradient derived provides an ablation gradient that simply cannot be supported and ignores the role of debris cover. It is assumed that ablation and accumulation are equal volumes this ignores the volume losses experienced by Nepal glaciers over the last decade and the expected loss in future decades (Fujita et al., 2000; Fujita, 2008, Bajracharya and Mool, 2009; Adhikari et al., 2009). There is no mention of how to deal with the extraordinary volume of avalanche redistribution from the high mountains slopes onto the ablation zone either. In fact the word avalanche does not appear in the paper. This is mechanism that increases glacier melt, and is the reason why some Himalayan glaciers have relatively low AAR values (Muller,

1980). An examination of the Dudh Khosi basin is provided, but no data on the ELA for the glaciers. Bajracharya and Mool (2009) note there are 278 glaciers in the Dudh Khosi basin, 40 of them valley glaciers, retreating at rates from 10-59 ma-1, with the creation of 24 new proglacial lakes, and 34 large expanding lakes. How has the ice volume loss and the lake volume gain been accounted for in the current study for this basin?

4) Previous Seasonal Melt Modeling: Kulkarni et al., (2010) found a considerable variation in response from basin to basin in the timing of snowmelt. What does the annual hydrograph look like for the various basins in this study? Does the generated hydrograph resemble reality? It is much easier to generate an annual volume of runoff for a model, than to determine the timing accurately. The contribution of glaciers to runoff is not that large in many rivers basins when averaged for the entire year, but does become seasonally important (Singh and Jain, 2002; Kumar et al., 2007; Kulkarni et al.,2010) . This is repeatedly emphasized for the Himalaya. There is no comparison of results to other study results such as the SNOWMOD used by Singh et al. (2008) and Singh and Bengston (2004); or Kumar et al., (2007) who used a water balance approach as well, or Rees and Collins (2006) who used a simple temperature-index-based hydro-glaciological model to assess the impact of climate warming on Himalayan glacier dimensions and downstream river flows. Without an examination of the seasonal impact of glaciers on river flow, the importance of glaciers cannot be assessed. The approach of Alford and Armstrong (2010) and the results have to be compared to the aforementioned methods, to illustrate potential advantages and relative differences in output.

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