The Cryosphere Discuss., 4, C263–C272, 2010
www.the-cryosphere-discuss.net/4/C263/2010/

The Cryosphere Discussions

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

M. Pelto

mauri.pelto@nichols.edu

Received and published: 24 May 2010

Alford and Armstrong (2010) and associated responses contend that it was the conventional wisdom that Himalayan glaciers would disappear by 2035 that prompted them to write this paper. Not one of the 30 papers on Himalayan glaciers referenced in my first comment mentioned this date, so it is not conventional wisdom. They further note that conventional wisdom indicates that major rivers fed by these glaciers would become intermittent. Again, not one of the 30 papers referenced many, with detailed hydrologic models and/or specific Himalayan runoff records, arrived at this conclusion. Alford and Armstrong (2010) main purpose seems to be dismantling this incorrect version of conventional wisdom.

As noted in the previous comments by Pelto (1010) and Shea (2010) the authors have

ignored almost all of the detailed hydrologic research in the region. The paper is on Nepal Himalaya glacier runoff; and there is limited data and published material on runoff from these glaciers. However, there is considerable information from the adjacent areas of the Himalaya in India that must be consulted if a serious attempt at accurately modeling glacier runoff is made, including many feeding the same watershed the Ganges River. Below two key issues are further explored seasonal runoff timing and the balance gradient.

Alford and Armstrong (2010) do not consider the issue of timing of glacier runoff, which makes the following conclusion indefensible. "...neither streamflow timing nor volume of the rivers flowing into the Ganges Basin from Nepal will be affected materially by a continued retreat of the glaciers of the Nepal Himalaya". This is not to say the statement is incorrect. Many authors have noted that the loss of glacier area does not impact annual discharge greatly, only seasonal discharge. Other papers examining the Himalaya have quantified the changes using detailed climate-snowmelt models the contribution of glaciers to the Ganges River and arrived at 9% on an annual basis summarized in ICIMOD (2007). These studies are not referenced by Alford and Armstrong (2010). Further the same studies identified an increased glacier melt would increase discharge by 1-2% in next few decades over the three main drainages from the Himalaya in South Asia, with a decrease of several percent occurring thereafter (ICIMOD, 2007). Jain (2008) finds a 4% contribution of glaciers overall also, but is not cited here. These results do not indicate that the conventional wisdom was that the rivers would become intermittent streams. These detailed studies also do not offer a vastly different answer than one provided by Alford and Armstrong (2010) for the role of glaciers in streamflow.

What is the evidence that timing and annual variations are key? Thayyen et al. (2007) indicated that only 29% of the annual flow in a Himalayan watershed comes from snowmelt, but up to 70% in specific months. Examining the runoff in the Bhagirathi River they found a 45% change in summer discharge from 1998 to 2000, which doubled the glacier contribution. The change resulted from changing winter precipitation characteristics. They noted a doubling for the bulk glacier runoff from 1994 and 1998 versus 1999 and 2000 due to an increase in rainfall component from an increase in rainfall area. The increase in rainfall area resulted from a lower temperature lapse (Thayyen et al., 2005). This change in lapse rate coincided with an observed rise in the snowline of close to two hundred meters in the Baspa Basin that has persisted (Kulkarni, 2005). Rai et al., (2009) observing flow in the Bhagirathi River at a station where half of the basin was glacier covered noted an increase in flow from 10 to 180 m3/sec from May into July as glacier melt increased, this is a large increase indeed. Thayyen et al, (2007) note that uncertainties in precipitation characteristics, especially winter snowfall have a greater effect on headwater run-off variability than receding glacier. They further point out glaciers are critical in sustaining river flows during low summer runoff years. Rathore et al., (2009) report that areal extent of glaciers will decline 59% by 2040, affecting stream runoff. The consequence was less loss in stream runoff estimated between April and June when contribution of glacier melt into runoff is not high and most of the runoff is generated from seasonal snow melt. Autumn shows 20% loss in stream runoff due to change in glacial extent in this basin. They further observe that in Wanger Gad Basin no major change in seasonal snow extent is expected between 2004 and 2040 due to the high elevation. This conclusion is supported by observation that snow and ice melt contribute about 70% of the summer flow of the main Ganges, Indus, and Kabul rivers in the periods before and after the summer monsoon (Singh and Bengtsson 2004). Thayyen et al., (2007) explain that enhanced melting of the glacier does not increase the river run-off, where winter snow and monsoon precipitation determine the regional hydrology. On the contrary, changing precipitation characteristics, mainly lowering of winter snow-cover extent and duration could reduce the headwater river flow drastically, while the glacier component sustains the low flow as explained in this study. The results of Thayyen et al, (2007) suggest that the lower reaches of the Himalayan headwater river's could in the future have larger annual and seasonal run-off variations, as buffering of shrinking glacier is reduced.

The annual snow and glacier melt contribution has been observed in a number of Himalayan headwater basins ranging from 60% in Satluj River, Bhakra dam (Singh and Jain, 2002), 49% in Chenab river at Akhnoor (Singh et al., 1997) and 35% Beas River at Pandoh Dam (Kumar et al., 2007). Each has been observed with detailed climate and hydrologic modeling and analysis. Of importance is the seasonal and annual variations observed, such as the dramatic change in the hydrographs and glacier contribution in the Gad watershed from 1998-2004 seen in Fig. 8 of Thayyen and Gergan (2010). Alford (1992) comments on seasonal differences, the Himalayan river's of Nepal contribute about 40% of the average annual flow in the Ganges Basin. More importantly, they contribute about 70% of the flow in the dry season (Alford, 1992).

In another recent detailed modeling studies Gosain et al., (2006) completed a detailed big picture water balance study of Indian rivers including the Ganges and its sub-basins for both current and climate change conditions. The conclusion was that the Ganges River basin shall experience seasonal or regular water-stressed conditions. Singh et al., (2008) used a detailed climate-snow melt model to examine Himalayan runoff in a glacier fed basin. The overall model efficiency R2 was 0.96. A difference in volume of computed and observed streamflow of -2.5%, suggests a model that is capturing the hydrologic processes well. The model clearly indicated that almost all streamflow high peaks are attributed to glacier melt. Taken together these studies demonstrate that it is at a seasonal level and in the higher reaches of the streams that Himalayan glacier runoff changes will be felt most significantly.

Alford and Armstrong (2010) provide a calculated balance gradient in Table 3 for Marsyangdi glaciers that is critical to their determination of glacier runoff, but does not resemble any reasonable balance gradient. The peak summer balance loss is -30.1 m. Given the nearly stagnant nature of many debris covered glacier tongues 30 m of annual melt would quickly eliminate the lower section of many of these glaciers, this has not happened. The noted ablation exceeds the peak observed ablation from any glacier reporting to the WGMS by a factor of two. Further the only glacier area at the lowest elevations in this basin is heavily debris covered, which greatly reduces ablation. Numerous papers quantify ablation beneath the debris cover on glaciers in Nepal. The winter balance in Table 3 is fixed above the ELA at 2.6 m which belies the balance gradient referenced in the paper and field measurements in the region. The balance gradient also does not consider avalanche redistribution which is key on many of the glaciers. Given these three flaws reliable glacier runoff volumes cannot be expected. Satellite imagers of three glaciers (Fig. 1-3) in the Marsyangdi Basin from Google Earth are used to illustrate the extent of debris cover and the potential of avalanche redistribution. The approximate 4500 meter and 5400 m contour are indicated. Below 4500 meters all three glaciers are entirely debris covered.

References: Gosain, A.K., Sandhya, R and Basuray, D.: Climate change impact assessment on hydrology of Indian river basins. Current Science, V. 90(3), 346-353, 2006.

ICIMOD Xu Jianchu, Arun Shrestha, Rameshananda Vaidya, Mats Eriksson, and Kenneth Hewitt): The Melting Himalayas Regional Challenges and Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods ICIMOD Technical Paper, 2007.

Jain, S.K.: Impact of retreat of Gangotri glacier on the flow of Ganga River. Current Science, 95(8), 1012-1014, 2008.

Kulkarni, A. V., Rathore, B. P., Mahajan, S. and Mathur, P.,: Alarming retreat of Parbati glacier, Beas basin, Himachal Pradesh. Curr. Sci., 88, 1844–1850, 2005.

Kulkarni, A. V., Bahuguna, I. M., Rathore, B. P., Singh, S. K., Randhawa, S. S., Sood, R. K., and Dhar, S.: Glacial retreat in Himalaya using Indian remote sensing satellite data, Curr. Sci. India, 92(1), 69–74, 2007.

Kumar, V., Singh, P., and Singh, V.: Snow and glacier melt contribution in the Beas River at Pandoh Dam, Himachal Pradesh, India Hydrolog. Sci. J., 52(2), 376–388.,

2007.

Rai, S.P., Kumar, B. and Singh, P.: Estimation of contribution ofsouthwest monsoon rain to Bhagirathi River near Gaumukh, western Himalayas, India, using oxygen-18 isotope Current Science, 97,(2) 240-245, 2009.

Rathore B.P., A.V. Kulkarni, and N. K. Sherasia.: Understanding future changes in snow and glacier melt runoff due to global warming in Wangar Gad basin, India Current Science, V. 97(7), 1077-1080, 2009.

Singh, P., Haritashya, U. K., and Kumar, N.: Modelling and estimation of different components of streamflow for Gangotri basin, Himalayas, Hydrolog. Sci. J., 53(2), 309–322, 2008.

Singh, P. and Bengtsson, L.: Hydrological sensitivity of a large Himalayan basin to climate change, Hydrol. Process., 18, 2363–2385, 2004.

Singh, P., Jain, S. K. and Kumar, N.,: Estimation of snow and glacier contribution to the Chenab river, western Himalaya. Mount.Res. Dev., 17, 49–55, 1997.

Singh, P. and Jain, S. K., : Snow and glacier melt in the Satluj river at Bhakra Dam in the western Himalayan region. Hydrol. Sci. J., 47, 93–106, 2002.

Thayyen, R. J., Gergan, J. T. and Dobhal, D. P.,: Monsoonal control on glacier discharge and hydrograph characteristics, a case study of Dokriani glacier, Garhwal Himalaya, India. J. Hydrol., 306, 37–49, 2005.

Thayyen, R. J., Gergan, J. T., and Dobhal, D. P.: Role of glaciers and snow cover on headwater river hydrology in monsoon regime: Micro scale study of Din Gad catchment (Dokriani Glacier), Garhwal Himalaya, India, Curr. Sci. India, 92(3), 376–382, 2007.

Thayyen, R. J., and Gergan, J. T.: Role of glaciers in watershed hydrology: a preliminary study of a "Himalayan catchment". The Cryosphere, 4, 115-128, doi:10.5194/tc-4-115-2010, 2010

Interactive comment on The Cryosphere Discuss., 4, 469, 2010.

Fig. 1. Thuleg Glacier on Manaslu, the entire glacier below 4500 meters is debris covered, though new snowfall covers some of this.

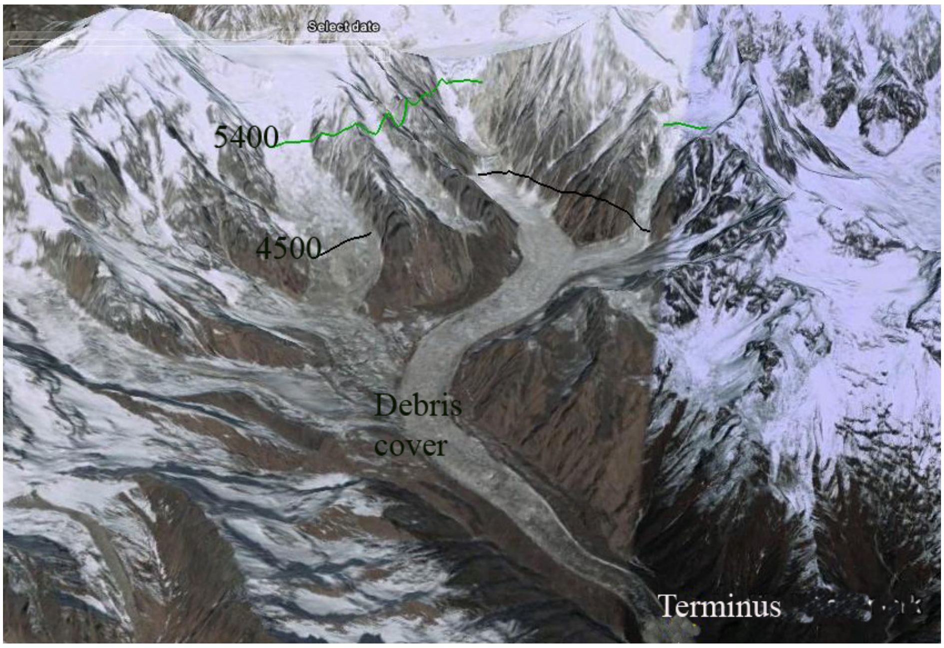

Fig. 2. Glacier draining south from Tilje Peak, Nepal.

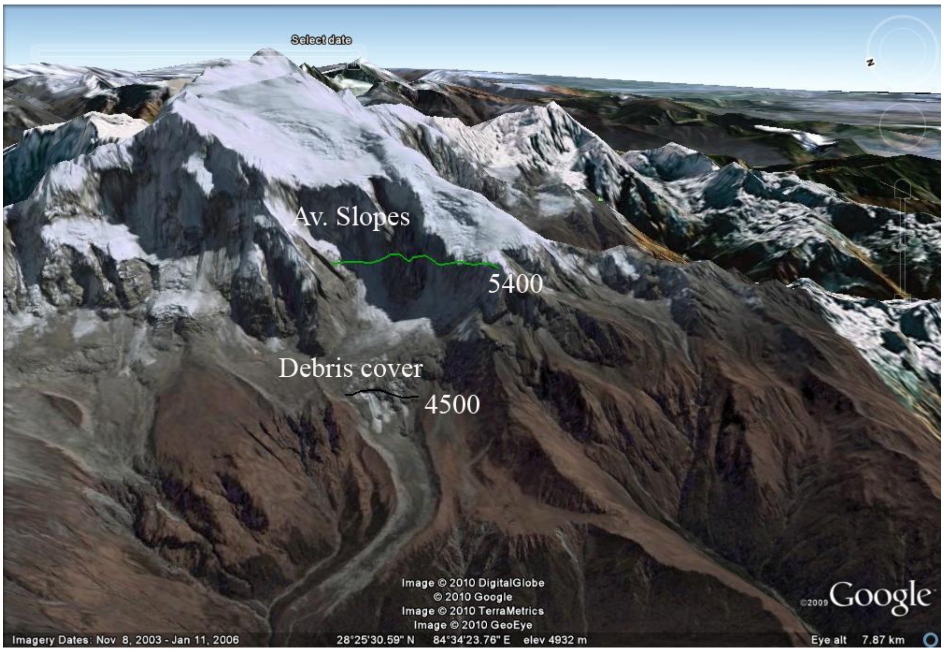

Fig. 3. Glacier draining the east flank of Manaslu Peak, Nepal. Complete debris cover beneath the avalanche slopes of the east face.