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The Cryosphere Discussions

# *Interactive comment on* "Role of glaciers in watershed hydrology: Himalayan catchment perspective" *by* R. J. Thayyen and J. T. Gergan

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M. Pelto made fourteen comments on this paper. Twelve of them are specific to the data and method of analysis and two of them (comment No.7&10) general comments on the characteristics of the Alpine basins. We would like to respond to the comment No.7 & 10 first, as it is concerned with the most important conceptual issues discussed in this paper.

C-7(453-22) We completely agree with the view that the buffering capacity of glaciers during the period of low runoff in glacier fed rivers is a typical aspect of glaciated Alpine basins. What is atypical about the 'Himalayan catchment' is that this buffering occurs during the wet period of the annual runoff cycle in contrary to the Alpine basins, where this buffering occurs during the dry period. We feel it is very important to dispel the



notion that the glaciers world over are contributing to the dry period of the annual runoff cycle, because over the years this concept has become the corner stone of glacier research and management strategies of glacier fed streams in the Himalayan region. The views of Barnett et al., (2005), in a review article in the journal 'Nature' espoused the impact of glacier melt in the Hindu Khush -Himalayan region (HKH) under the concept of dry period contribution of glaciers to the stream flow. Which stated "But in the HKH region, there may (for the next several decades) appear to be normal, even increased, amounts of available melt water to satisfy dry season needs. The shortage when it comes, will likely arrive much more abruptly in time; with water systems going from plenty to want in perhaps a few decades or less. It appears that some areas of the most populated region on Earth are likely to 'run out of water' during the dry season if the current warming and glacial melting trends continue for several more decades". If we analyse the situation under the 'Himalayan catchment' perspective, as defined in this paper, we could see a completely different scenario emerging. Bhutiyani et al., (2008,pp 622) attributed the reduced runoff in the Sutlej River during 1991-2004 periods on reduced contribution from the glacier melt due to thinning of the glaciers. These kind of interpretational issues are also a manifestation of the concept of dry period dominance of glacier melt across the Himalayan arc. So we feel it is important to distinguish between dry period glacier contribution of Alpine catchment and wet period glacier contribution of Himalayan catchment to espouse the different role of glaciers in the watershed hydrology of different glacio-hydrological regimes.

C-10(455-18) M. Pelto suggested that the low runoff associated with high negative balance and high runoff associated with more positive balance on wetter years is typical for alpine glaciers. However, general view available in the literature suggests contrary. Rothlisberger and Lang (1987, pp 211) says that the "additional contribution of meltwater to the runoff in the period of strong glacier retreat is clearly reflected in the high average runoff, particularly between 1940 and 1950. The minimum runoff in the period n 1975-80 is connected with the significant storage of water into positive glacier mass balance" Also see the figure reproduced below. Benn and Evans, 1998 suggests that the" discharges will be highest when deglaciation is rapid" (pp.134). Most recently, in a preface to the abstract volume of the workshop on "Glaciers in Watershed and Global hydrology", Obergurgl, Austria,27-31 August 2007 says that "annual basin runoff is enhanced or decreased in years of negative or positive glacier mass balances, respectively". More over, we believe that the synthesis of IPCC, 2007, based on the many referenced work, summarized that "the enhanced melting of glaciers leads first to increased river runoff and discharge peakes and an increased melt season" is based on the present understanding that the negative mass balance regime will produce increased runoff in a glacier catchment. However, our suggestion of low runoff occurrence in association with negative mass balance regime and higher runoff occurrence associated with wetter periods and positive mass balance regime of the glaciers in strictly confined to the 'Himalayan catchment'.

C-1(446-20) This is the average rate of accumulation rate estimated by identifying the Chernobyl fall out layer by 137Cs activity and by the accumulation measurement as part of the mass balance studies by glaciological method. More details are available in the references cited.

C-2(448-13) In the Din Gad catchment we operated three hydrometric station and the snow line observation is required to estimate snow covered as well as snow free areas of the sub-catchments as this have direct bearing on the stream flow, even that of bulk glacier discharge as reflected in 1999. (Please see 455,5-20). We feel that the issue of summer accumulation is still debatable and remain as a main unresolved problem in Himalayan glaciology. A lot of work needs to be done to resolve this issue. During the course of this study, accumulation zone of the Dokriani glacier used to experience rainfall during the monsoon months of July and August, baring few instances of snowfall occurrence around the peaks and snow line during the summer was above 5200 m a.s.l.

C-3(448-15). By the glaciological method. Details are available in the references cited.



C-4(450-20) This statement is not regarding the glacier runoff, but for catchment and basin scale runoff. Data for Din Gad catchment showing dominant monsoon component in summer months is shown in (Fig 3b) and basin scale in Fig.10

C-5 (452-5) Refer C-3

C-6(452-15) – Please see 452(15-18).

C-8(454-4). Here we are comparing the highest specific runoff from non-glacierised lower catchment in 1998 to the highest specific runoff of glacier catchment in 2001 (See Table-1) to show that the productivity of non-glacierised part of the catchment during the years of good precipitation can equal that of the glacier catchment. Figure-7 summarises the data generated from Din Gad catchment during the study period.

C-9 (454-22) Data is presented in Table-1, Figure-3 &Figure-7. We agree that data is for a short period but this includes some extreme hydrological years like 1998, 1999 & 2004. Relationship between highest runoff and high precipitation is obvious for 'Himalayan catchment' as illustrated in Figure-3, Figure-10 & Table-1

C-12 Figure-6 This shows greater role of glacial system in regulating the flow regimes of headwater stream during the periods of reduced contributions from non- glacierised area of the catchment. This can be added in the text.

C-13 Figure-7. Data presented here is generated from Din gad catchment as explained in the section 2.2. Figure caption will be modified accordingly

C-14 Figure-11 Rainfall information is available in the data source; Kumar et al.(2007). This can be incorporated in the figure.

We completely agree with the view that there are more questions than answers are available today as far as Himalayan cryospheric system processes are concerned. Resolving those issues need great effort for persistent data collection and research under a robust research strategy. We believe that differentiating glacio-hydrological regimes of the Himalaya and characterizing them is the first step towards that goal, as process and response vary in each of these major glacio- hydrological regimes and we need to formulate the research and adaptation strategies accordingly. In a data and knowledge free regime like Himalayas, the views expressed by IPCC, 2001 & 2007 has great influence on planning and management of water resources, impacting the development of most populated region on Earth. Hence our limited objective is to dispel the notion of increased river runoff due to enhanced glacier melting in a 'Himalayan catchment' and suggest a conceptual foundation for future work in this region. We hope that the debate will progress around this focal theme.

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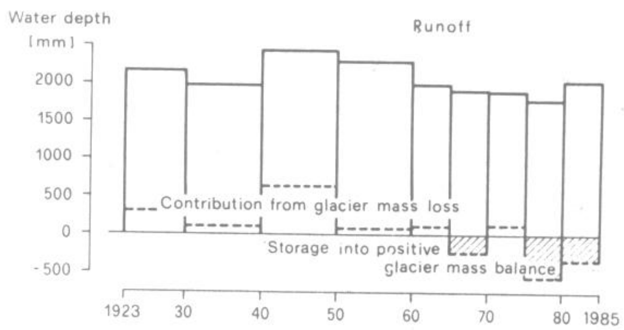


FIGURE 10.1 Mass balance and runoff in the Aletschgletscher river basin (Massa/Blatten, 195 km², 67% glacier area) for the period 1922–23 to 1984–85. The additional contribution of meltwater to the runoff in the period of strong glacier retreat is clearly reflected in the high average runoff, particularly between 1940 and 1950. The minimum runoff in the period 1975–80 is connected with the significant storage of water into positive glacier mass balance. [Data sources: Aellen (1985), and personal communication; Haeberli (1985); Kasser (1967, 1973a); Müller (1977).]

**Fig. 1.** (After Rothlisberger and Lang, 1987)