

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

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I wish to thank Mr. Shea for his review of our paper. I also wish to stress once again that the paper he reviewed is, as stated in the text, a summary of a more-detailed report describing methodologies and findings from a study of the glaciers and rivers of Nepal, undertaken for the World Bank. This summary was only intended to present the more-salient findings, and a very general description of the methodologies employed. This study was conducted at a time when the topic of glaciers and rivers in the mountains of Asia had been highly politicized by individuals with an apparent agenda, but little actual understanding of either the glaciers or rivers of the Himalaya. While the IPCC has conceded the error of "2035", there seem to be residual misconceptions from the rather unfortunate era of glaciers as icons of anthropogenic climate change

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that remain in the present conventional wisdom. Our paper is an attempt to deal with one of those apparent misconceptions (below)* - the importance of the glaciers of the eastern Himalaya in the volume of flow in the Ganges River.

* an extract from the original report:

"It is not possible to conduct an assessment of the role of glaciers in the Nepal Himalaya without becoming aware of the major role played by discussions of the impacts of climate change on glaciers and glacier-fed streamflow in both the technical and lay literature for at least the past decade. There is general agreement among earth scientists that a widespread retreat of the global ice cover has been occurring since at least the early 1800s. In recent years, evidence has been presented (IPCC, 2007) in support of the hypothesis that a major change in historical patterns of the global climate may be occurring. It has been suggested that glacier retreat is linked to climate change, as a result of anthropogenic causes related to the increase of CO₂ and other "greenhouse" gases in the atmosphere. However, an understanding of the significance of glacier retreat in terms of changes in glacier mass balance or the resulting water resource availability is extremely limited, and has generated a number of conflicting responses. Much of the debate over the significance of the IPCC findings has been conducted in the context of political, rather than scientific, concerns. This may be particularly true of mountain hydrometeorology and glaciology. The IPCC results contain few data from high mountain sites. To compensate for this lack, many have pointed to the general retreat of mountain glaciers as indicators of current climate trends at all mountain locations. Some opinions have verged on the apocalyptic. The following is from the World Wildlife Fund paper, "An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in Nepal, India and China" (2005, p.2):

"The New Scientist magazine carried the article "Flooded Out – Retreating glaciers spell disaster for valley communities" in their 5 June 1999 issue. It quoted Professor

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Syed Hasnain, then Chairman of the International Commission for Snow and Ice's (ICSI) Working Group on Himalayan Glaciology, who said most of the glaciers in the Himalayan region "will vanish within 40 years as a result of global warming". The article also predicted that freshwater flow in rivers across South Asia will "eventually diminish, resulting in widespread water shortages".

The Intergovernmental Panel on Climate Change (IPCC, Working Group II, Fourth Assessment Report 2007) cited the 2005 World Wildlife Fund paper as a source in stating: "The current trends of glacial melt suggest that the Ganga, Indus, Brahmaputra and other rivers that criss-cross the northern Indian plain could likely become seasonal rivers in the near future as a consequence of climate change and could likely affect the economies in the region".

Variations on this theme have been taken up by the popular press:

"There's a growing consensus, however, that one of the most severe effects will be on the glaciers of the Himalayas. Their meltwater currently supplies up to 85% of the flow of the Ganga, Brahmaputra and Indus rivers. Latest IPCC estimates suggest that they may shrink to one-fifth of their volume within a few decades. Initially this will cause floods as the waters melt – and then a water crisis of unprecedented proportions as the rivers dry" (Slavin and Mehra, 2008), with similar, if less extreme, forecasts in technical publications:

"Under the uniform warming scenario of $+0.06^{\circ}\text{C}$ per year, impacts of declining glacier area on river flow will be greater in small, more highly glaciated basins in both the western and eastern Himalayas. Flow for the most glaciated sub-catchments (glaciations $\geq 50\%$) will attain peaks of 150 and 170% of initial flow around 2050 and 2070 in the west and east respectively before declining until the respective glaciers disappear in 2086 and 2109". (Rees and Collins 2006, quoted in Xu, et.al, 2007).

Bennett, et.al, writing in Nature in 2005, stated that, "...the hydrological cycle of the region is complicated by the Asian Monsoon, but there is little doubt that that melting

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glaciers provide a key source of water for the region in the summer months, as much as 70% of the Ganges river and 50-60% of the flow in other major rivers" (Bennett, et.al, 2005). The authors provide no data to support this assertion.

It is probable that the movie, "An Inconvenient Truth" in which retreating and calving glaciers are used as an icon of "global warming", and for which Albert Gore and the Intergovernmental Panel on Climate Change (IPCC) received the Nobel Prize, was a factor in increasing the concerns that are expressed over the potential impact of glacier retreat.

Recently, the World Glacier Monitoring Service, WGMS, University of Zurich, Switzerland, circulated the following by e-mail: ... "The statement of Himalayan glaciers...disappearing with very high likelihood by the year 2035 as well as the one about the Himalayan glacier area...likely shrink from present 500,000 to 100,000 km² by the year 2035, as made in Chapter 10.6 (Case studies) of the IPCC report of the Working Group II (2007), is under present state-of-knowledge, not plausible. The sources given do not support the statement (Table 10.9, IPCC 2007) and are a non-reviewed report of an organisation without expertise in glaciology (WWF 2005). As a consequence this statement should not have been published in the IPCC report (2007). Future scientific studies are to pick up such statements and to provide a sound answer to it, which is to be summarized in the next IPCC report" (Michael Zemp, WGMS, michael.zemp@geo.uzh.ch, 2008)".

The entire report is now in press, and I am reluctant to rewrite it for these discussions, just to demonstrate that we did cross most of our t's, and dot most of our i's. If desired by the editors of Cryosphere Discussions, I will be happy to contact the World Bank to determine if they would object to the entire 90 page report being placed into the Discussions.

There seems to be an unfortunate tendency in some academic circles to feel that the

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list of references is more important than the findings and conclusions. In the case of Mr. Shea's review, there seems to be some concern that our findings and conclusions may be based mostly on a lack of understanding of the literature. For Mr. Shea, as well as all other potential readers in academia who may be interested, I include below a list of most of the materials we consulted while involved in the study. There are some we undoubtedly overlooked, and there were some we deemed irrelevant, repetitious, or in error. In general, however, I suspect most who have worked in the Nepal Himalaya will find themselves represented. One person overlooked in the literature review was Prof. V. Klemes, and I would like to recommend his papers to Mr. Shea, and any others who might be interest in mountain hydrology, the role of scale, and hydrological modeling. They are easy to find on Google Scholar.

In an invocation of the literature, one wants to make certain that most relevant materials are considered. I feel Mr Shea's use of the literature is somewhat selective. As an example, he refers to the letter by Cogley, et.al, 2010, in *Science*, but overlooks the note by Pallava Bagli in a earlier issue of the same journal (11/13/2009), as well as the report by the Indian glaciologist Raina, that played a role in inspiring the response by Cogley, et.al.

In passing - an earlier version of this summary was included in a paper prepared by Prof. Jack Ives as one in a lengthy series of papers and books he has written debunking Himalayan myths. While we ultimately requested that the paper not be submitted for publication, it is my understanding from Prof. Ives that it was reviewed by Prof. Cogley, and received generally good marks.

The following list of references represents a majority, but not all, of the materials that have been read in developing an understanding of the relationship between glaciers and streamflow in the Nepal Himalaya. Not all of these references appear in the text of this report, but are included here primarily to show the broad scope of the problem, of studies pertaining to aspects of the problem, and the widely scattered nature, and character of data and opinions on the subjects pertaining to this relationship.

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