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Hydrology and Earth System Sciences Discussions

## *Interactive comment on* "

# Snow cover dynamics and hydrological regime of the Hunza River basin, Karakoram Range, Northern Pakistan" *by* A. A. Tahir et al.

**A. A. Tahir et al.**

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We already replied for referee#1 but the answers are a bit modified according to changes in the revised manuscript.

RC: As an additional (very interesting) analysis, the authors could separate the snow-cover data into elevation slices and then compare the fit. My prediction is that low-elevation, high-relief areas have a larger mismatch than lower slope, higher elevations.



AR: We have compared the zonewise and total snow cover area for each of 4 images and the results will be presented in the table 4 of the revised submission. The referee prediction seems true for the low-elevation areas where the mismatch is larger than the high elevation areas.

RC: There have been recent reports that underline the importance of snowmelt processes in this part of the Himalaya [Bookhagen and Burbank, 2010] and indicate growing cryospheric reservoirs through advancing glaciers [Scherler et al., 2010].

AR: We will add these references in the revised manuscript. Some references are already added as Hewitt (2003, 2007) etc.

RC: I am somewhat uncertain about performing a trend analysis on a 9-year long precipitation record (Figure 8). There are several monsoonal oscillations and large-scale atmospheric circulation systems that have longer periodicities. If the authors want to retain this analysis, it should be justified with either published, longer records or other arguments.

AR: We have just 9 years precipitation records of these high altitude climate stations within the basin. Monsoonal rain system does not influence the hydrological regime of Hunza River because the high mountain ranges of Karakoram resist the monsoon system to enter in the Hunza catchment. Moreover, the maximum precipitation in Hunza basin is brought by westerly circulations in winter in the form of snow as cited by other authors like Hewitt, 2005. The comment about performing the trend analysis on 9 years data is made by almost all the referees. We will discuss this issue with more precaution and results based on this time-series analysis will be stated as an assumption.

RC: Table 1: No need to mention ArcMap. If you mention a software package, the correct reference is ESRI ArcGIS (ArcMap is just a subset of ArcGIS). Please correct subsequent reference in tables and text, too.

AR: We agree and we will modify it in the revised manuscript.

RC: Table 5: This contains a lot of information, but is not easy to read. It would be really instructive to have a figure showing these correlations in graph form (chose only the most important ones). This table can be retained. AR: One graph may not be sufficient for this data. Actually, we wanted to control the length of the manuscript. So we will rather keep this table.

RC: Figure 5: It is hard to distinguish between the colors of Ziarat and Gilgit.

AR: We will change the colors. We will present the figures in color in revised manuscript.

RC: Figure 7: In the caption, you have to list the data source for the snowcover data (MODIS). It may be instructive to add it on the Y axis. Change label Lineaire and increase size and width of line.

AR: We have modified the figure according to referee suggestion and it will be presented in the revised manuscript.

RC: Figure 8: Change label Lineaire (also in all other figures, too). In the caption, briefly indicate how snowmelt or snow-water-equivalents were included in precipitation records.

AR: We have changed the labels in all the figures. We presented the precipitation data as it was observed at the automatic climate stations of WAPDA.

RC: Figure 9: This graph contains too much information and needs to be simplified. First, add a moving average line for all years. Second, choose the max and min snowcover years and show their moving average to give a sense of the inter-annual variability.

AR: We modified the figure according to the referee suggestion but the moving average lines for each year made the graph very congested. We have added three moving average lines on the same figure. One line for average snow cover area during 10 years and the two other average lines for maximum and minimum snow years (2000



and 2004, respectively).

RC: Figure 11: Show uncertainties for fit. Is this a weighted fit line? It is likely that large snow cover difference has a larger impact on discharges, because larger snowcover may also results in higher snowdepths (at least in low-slope areas).

AR: It is a linear fit. We have replaced the figure with a colored figure presenting a weighted fit (with 95% confidence interval).

RC: Figure 12: Again, what is the uncertainty of the Runoff trend? There appears to be a decreasing trend, but how certain can you be? Change label rain to precipitation, as I assume you is merging rainfall and snowfall, right?

AR: We have added the uncertainty for this trend in the revised manuscript. It is the precipitation data observed at Gilgit situated outside the Hunza basin at lower valley elevation and was used by many authors to relate it with Hunza discharge. I will change the label from rainfall to precipitation.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/8/C1483/2011/hessd-8-C1483-2011-supplement.pdf

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 2821, 2011.

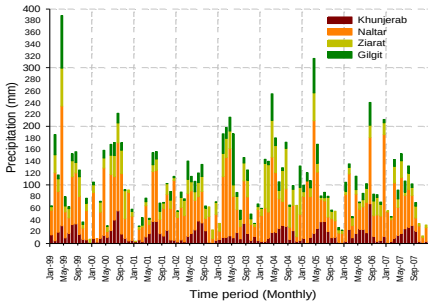


Fig. 5 Monthly variations of precipitation at the Hunza River basin climate stations and Gilgit climate station.

**Fig. 1.** Fig. 5 Precipitation variation



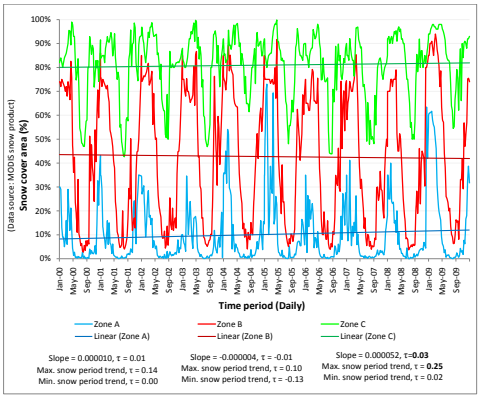


Fig. 7 Snow cover distribution in three different altitudinal zones of the Hunza River basin. Significant expansion can be noted in zone C. Temporal trend is also presented for maximum and minimum snow cover periods. (Kendall's tau (**τ**) coefficient values presented in bold figures indicate a significant trend with $p<0.05$).

**Fig. 2.** Fig. 7 Zonal snow cover area

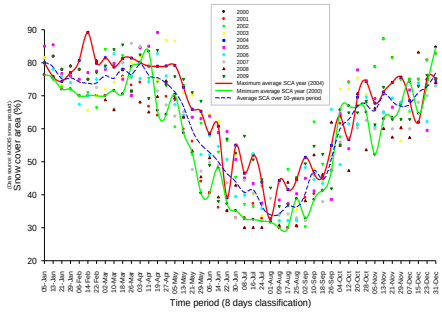


Fig. 9 Percentage snow cover area (SCA) in the Hunza River basin calculated by analysing 450 MODIS images.

**Fig. 3.** Fig. 9 Snow cover area in the Hunza basin



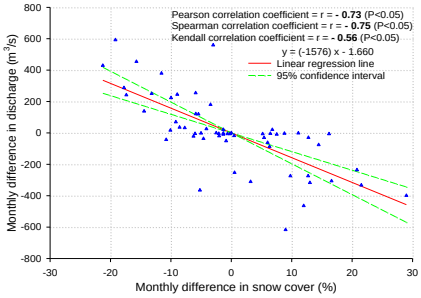


Fig. 11 Correlation between monthly difference in snow cover and monthly difference in discharge at Dainyor in the Hunza River basin. (Correlation coefficient values presented in bold figures are significant with a significance level, $p$<0.05).

**Fig. 4.** Fig. 11 Monthly difference in snow cover vs monthly difference in discharge

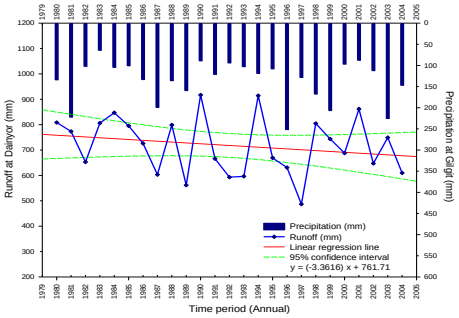


Fig. 12 Annual flow trend in Hunza River at Dainyor Bridge and total annual precipitation at Gilgit over 25 years (1980–2004).

**Fig. 5.** Fig. 12 Runoff trend in the Hunza River