Earth Surf. Dynam. Discuss., 2, C609–C617, 2015
www.earth-surf-dynam-discuss.net/2/C609/2015/

Interactive comment on "The hydrological cycle in the high Pamir Mountains: how temperature and seasonal precipitation distribution influence stream flow in the Gunt catchment, Tajikistan" *by* E. Pohl et al.

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Received and published: 11 February 2015

Comments given in C594 are repeated for clarification purposes in italics.

Overall Comments:
1) The calibration period for the model is stated as the years 2002-2007 (page 1175, line 21). Are the results presented in figure 7 produced via cross validation or are they from the calibration procedure?

We agree with the reviewer this has not been very clear in our manuscript. Unfortunately we do not have sufficient data to run a long calibration period. The results presented in this manuscript represent the calibration period. We have only 7 years of observational data and the inter-annual variability in the hydrograph is very important (compare e.g. 2003 and 2005 in Fig.7). We justify this approach because it allows us to better address issues with the used datasets and to assess their quality. Choosing different calibration and validation periods would certainly have affected the resulting parameterisation and would have led to a hardly comprehensible assessment of our model results.

2) The study area is stated as being characterised by a long lasting snow cover (page 1161, lines 23-24). Available satellite images on google earth of the headwaters of the Gunt catchment are sparsely snow covered when the images were taken on the 10th April 2003. Furthermore, figure 1 in Lutz et al. (2012) depicts the headwaters of the Gunt catchment exhibiting a very small glacierised fraction. What data is available to highlight this long lasting snow cover?

The characterisation of the area having long lasting snow cover derives on the one hand from our own analyses of MODIS MOD10CM (Hall et al. 2006) monthly snow cover data (see attached Fig. 1) On the other hand, it has been widely discussed in the literature that this region is snow dominated e.g.Immerzeel et al. (2009, see their Fig. 4), Pu et al. (2007, see their Fig.4), Xiao et al. (2002, see their Fig.9), but also (should be implemented in the final version) by Dietz et al. (2014, see their Fig. 8). Immerzeel et al. (2009) and Pu et al. (2007) use MODIS snow cover data, Xiao et al. (2002) use AVHRR, and Dietz et al. (2014) use both data sources. In our work we state that there is subsequent melting, which depends on altitude. This results in a long lasting snow cover at high altitude areas (which provide the main input of water during the later snow melt period). This also results in the hysteresis loop in Fig.7F with a lower response of discharge to the same temperature later in the melting season. Hence the snow cover and its duration has a clearly characterising effect in

the hydrological cycle.
Figure 1 in Lutz et al. (2012) shows the glacierised regions in the Pamir. Compared to the Fedchenko glacier and its surrounding (in the North of our study site) the fraction in the Gunt catchment seems indeed small. We derive the glacierised area from MODIS MCD12Q1 land cover data. The dataset states permanent snow and ice, which bares the chance of over-predicting glacier areas if the snow line did not reach the glacier termini or if snow covered flanks surrounding the actual glaciers contribute to the area of the land cover class. On the other hand, debris covered glacier termini are not detected by MODIS but e.g. make up to 20% of glacier areas in the Hindu Kush and Karakoram (Scherler et al. 2011). Different scenes of MCD12Q1 for different years show a narrow range of glacier extent and hence we are confident that the exact glacier covered area is close to our value of approx. 7.5%.

3) It is stated that the Gunt catchment is considered representative for the central Pamirs (page 1160, lines 24-25). Figure 1 in Lutz et al. (2013) depicts the varied nature of glacierisation in the Pamirs, with greater glacierisation to the north of the Gunt catchment. In addition, figure 3 in Fuchs et al. (2013) depicts the variation in mean annual precipitation across the Pamirs, showing an order of magnitude increase in precipitation between the Gunt catchment and the areas north-west of the Gunt catchment. This information casts doubt on the representativeness of the Gunt catchment for the central Pamirs.

The Pamirs as a whole are very heterogenous in terms of geomorphology and climate (e.g. Fuchs et al. 2013, 2015). Figure 1 in Lutz et al. (2013) highlights this heterogeneity even more in terms of glaciation. Moisture supply certainly plays a key role here. The main distribution of moisture provided by the Westerlies are deflected at the western Pamir margins towards the North and to the South. This results in a strong precipitation gradient with lower values towards the eastern plateaus (Fig.A1). The Gunt catchment comprises also very different climatological,

and topographical settings as stated in the study area section. This includes a high precipitation gradient in W-E direction, accompanied with decreasing glaciation, and it also provides high relief areas in the West and low relief areas in the East. Because the Gunt catchment covers such different settings, which can be observed at larger scale for the grater Pamirs, we think it was the best choice for the intended study.

4) No reference is given to the possible effects of Lake Yashikul on the precipitation-discharge relationship. Could this lake possibly de-couple the headwaters of the Gunt catchment from the monitoring station downstream? Furthermore, could this play a role in the seemingly substantial amount of groundwater discharge that all models agreed on (page 1175, lines 24-25)?

There is no discharge data available for Lake Yashilkul, which makes the assessment difficult. A few years of isolated discharge data from the 1970s and 1980s for a downstream catchment at the Gunt River ($\approx$50km downstream) shows about 8m^3/s of discharge in winter, which is about 30% of what is observed at the Gunt outlet. The drainage area of this sub-catchment is about 900km2 draining three further sub-catchments. No data is available for these either. However, they have a drainage area and shape similar to a further downstream catchment (downstream of where the 8m^3/s were measured) showing about 1 to 2m^3/s discharge in winter. This lets us assume that at least a portion of the 8m^3/s measured downstream of the Yashilkul result from groundwater discharge. Hence, we assume the discharge effect of Lake Yashilkul is negligible for the found decoupling of precipitation and discharge.

5) It is stated that the ISM extension reaching the eastern part of the Pamirs (Murghab and Shaimak) in summer, is responsible for the increase in summer precipitation at these two gauge stations (page 1161, lines 21-22). Previous studies have found that the Hindu Kush and Karakoram mountain ranges are a barrier to the northward movement of the ISM, and therefore the ISM does not impact the *precipitation of the Pamirs (Syed et al., 2006; Schiemann et al., 2007). Is it possible that the summer precipitation observed at these sites is caused by north or north westerly intrusions of air masses resulting in showers and thunderstorms over the mountains as described in Schiemann et al. (2008)? An improved physically based justification for attributing this precipitation to the ISM would be beneficial, expanding on what is stated on page 1187, lines 24-25.*

It is indeed possible that intrusions other than the ISM are affecting the observed summer peak in precipitation in the eastern Pamirs. We basically followed literature references that the summer precipitation in the central Pamirs originates from the ISM (Zech et al. 2005, Mischke et al. 2011). We were not aware of the publication of Schiemann et al. (2007) but would like to include it into the final paper as it indicates the importance of temperature in the Pamir runoff regime. However, their statement that ISM spill-over over the southern Pamir margins is not the cause for increased runoff, does not contradict a possible intrusion of ISM precipitation into the eastern Pamirs. Due to the lack of precise knowledge we would change our statement that the observed peak in summer precipitation is ISM-induced to that it coincides with the ISM period. The importance for this study clearly lies in the differentiation between winter and summer precipitation. The variability of ISM intrusions into the pamirs is ongoing research which is in preparation for submission.

Short comments:
6) In the abstract and conclusions it is stated that around 80% of precipitation in the catchment is supplied as snow. A suitable reference or data would help to give weight to this statement.

This statement is based on the results of our results. Fig.A1 corroborates this statement with the available in situ data from meteorological stations. Since all the stations are located at river level but the surrounding relief might be 2km, a much

higher fraction of snow than suggested by these figures is expected. The main problem is the uncertain spatio-temporal precipitation distribution (this study, Palazzi et al. 2013, Schiemann et al. 2008). Schiemann et al. (2008), and the used HAR10 data agree on a well pronounced seasonality with a peak of precipitation in late winter/ early spring. Maussion et al. (2014) suggest even more than 80% of precipitation provided as snow for the Central Pamirs (see their Fig. 5d). Fig.8F (this work) shows that mean catchment temperature is below 0°C between October and late April. This consequently results in the bulk of precipitation provided as snow.

7) The addition of a time series plot of temperature to figure 7 could aid the conclusion that temperature is the dominant trigger of melt (page 1182, lines 18-19).

This is a good suggestion and shall be implemented in the final version.

8) A Summary of the study's findings regarding glaciology (from figure 5) could help comparisons to be drawn with other studies findings that are currently summarised in the text (page 1183, line 17).

This suggestion would certainly make it easier to directly see if the model results are in agreement with other studies. The difficulty is that some of the other results refer to a decrease in area, rather than in mass balance. Calculating according mass balances would be beyond the scope of this work. We therefore address glacier related studies with a separate paragraph in the discussion where we point out qualitative and quantitative agreements.

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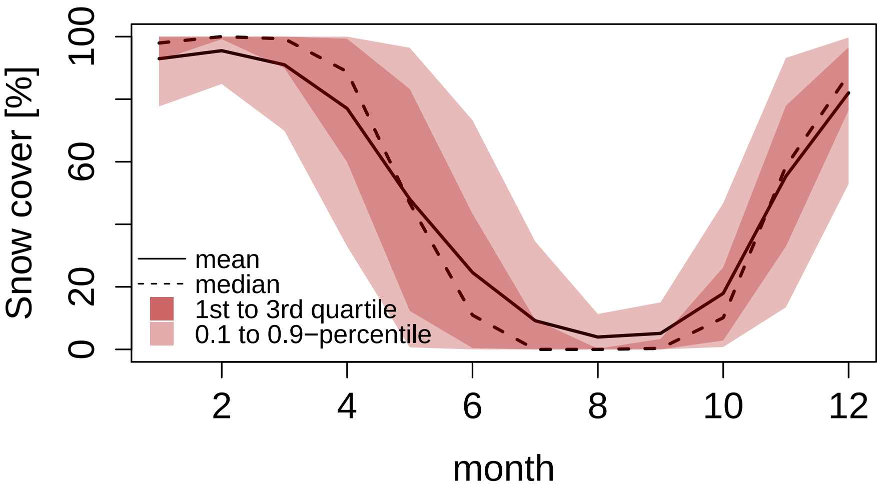

Fig. 1. Gunt catchment snow cover dynamics based on 12 years of MODIS MOD10CM monthly snow cover data. Mean, median and quantiles are given to highlight variability.