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Interactive Comment

Interactive comment on "Erosion rates deduced from Seasonal mass balance along an active braided river in Tianshan" *by* Y. Liu et al.

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1 General comments:

Dr. Jolivet is acknowledged for his very positive comments and his insightful review.. In the following sections we will try to bring a complete answer to his comments in order to clarify what are mostly misunderstandings and show how the text has been modified accordingly.

2 Specific comments:

1. *In your introduction (page 543), when dealing with the problem of partitioning between solid and solute loads, you do not address the possible influence of lithology on the amount of chemical weathering. Even if the area you are working in is nearly free of plants I suggest you also put a general sentence on the influence of plant cover on mechanical erosion and chemical weathering. This would make your introduction more complete.*

   We agree and have changed the corresponding paragraph in the introduction. It now reads " The partitioning between solid and solute loads remains an issue in mountainous areas (West et al, 2002). In the Haut Glacier d'Arolla in the Swiss Alps mechanical erosion seems more important then chemical denudation by orders of magnitude (Sharp et al., 1995). The exact contrary has been shown for the Green Lakes catchment in the Colorado Front Range by Caine (1992). There chemical denudation rates, although low, are an order of magnitude larger mechanical denudation rates. In the Canadian Rockies, Smith (1992) also found that chemical denudation rates could be much more important than other mechanisms such as solifluction on the slopes. These large variations are often related to lithological or biologic controls (Millot et al., 2002; Oliva et al., 1999), tectonic control (Riebe et al., 2001), agricultural land use (West et al., 2002), and glacial cover (Anderson et al., 2003). "

2. *On page 544, line 18 you use the term "weathering rates" applied to both chemical and mechanical denudation. To my opinion "weathering" refers to chemical disruption of rocks. But I might be wrong on that.*

   We changed this to avoid confusions.

3. *Page 545, lines 20-22 : The Junggar is also filled with aeolian sediments, especially during the Late Tertiary - Quaternary periods. Altay is N and E of Tianshan.*

More importantly, water also flows into the Junggar basin from the Zhayier mountains to the west. Page 545, line 24: tectonic deformation in the Piedmont is not restricted to the Cenozoic and also occurred during Triassic, Jurassic and probably, to a smaller scale, during the Cretaceous (see for example Chen et al., 2011; Hendrix, 1992; Jolivet et al., 2010).

This is exact, we have changed the paragraph to be more complete on the geological setting. it reads:

"The Dzunggar Basin covers an area of 130 000 km^2. The sedimentary infill is of alluvial, lacustrine and aeolian type. Water comes from the adjacent mountain ranges: Tianshan to the south, Altai to the north and east and Zhayier to the west. The Dzunggar Basin records approximately 250 million years of sedimentary history. Deposits in front of the Tianshan range have experienced folding during Mesozoic and Cenozoic times (Chen et al., 2011; Hendrix, 1992; Jolivet et al., 2010). Folding was reactivated during the late Tertiary and Quaternary due to the northward propagation of deformation in the Tianshan. Deformation in the Piedmont is still active."

4. *Page 549, first paragraph: I am not a specialist but variations in the width of the Urumqi river can be quite large from place to place. Does that have an influence on the point-to-point amount of sediment in the bed load and suspended fractions?*

Yes of course this is the reason why the reproducibility of the measurements is not as good as suspended and dissolved loads as quoted in figure 5 and discussed in section 3.4. In the Urumqi drainage, these variations are mostly related to changes of the bed from bedrock type to and alluvial bed. They therefore can not be used to infer changes in sediment transport. Besides all our local measurements were integrated over the width to take the entire channel into account in the mass balance. We added a mention to this issue in the last paragraph of section 3.4 which now reads

"Bed load, as discussed above, is the least reproducible quantity measured. Most rates are consistent within a factor of 5 and a little more than half within a factor of 2. Again, this is perhaps due to the sampling procedure, bed composition or local topography (width, depth and slope), and the fact that bed load is by essence a local phenomenon that is difficult to sample and integrate over a section."

5. *Page 553, line 20: You also have a number of minerals in your rock series (gneiss and volcanics) that contain Cl-. For example micas, feldspars or some phosphates are very sensitive to weathering and may deliver Cl. Is that really negligible? You have the same sort of discussion with Ca2+ which represents an important contribution to your dissolved fraction. Ca2+ can also be mobilized by etching of minerals like feldspars that are quite frequent in granitoids.*

   Yes you are right. However, Cl in plutonic or metamorphic rocks is present as a trace element. Unrealistic levels of weathering rates would be necessary to explain the Cl concentration in the river dissolved load by chemical weathering of Cl-bearing minerals. In addition the amount of Cl in the rain is such that lithogenic Cl is not significant. A rough back-to-the-enveloppe calculation supports this. The typical Cl concentration of a granitic-metamorphic rock is $100 - 1000\mu \mathrm{g\,g^{-1}}$ (1000ppm is for shales, thus metamorphic rocks assuming that Cl is not mobilized). The total erosion (chemical+physical) is on order of $50 \mathrm{t\,km^{-2}\,yr^{-1}}$ over an area of less than $50\mathrm{km}^2$. If all Cl is mobilized this should lead to an amount of $2.5\,10^5 - 10^6 \mathrm{g\,yr^{-1}}$ of Cl to be compared to the $1.4\,10^{10} \mathrm{g\,yr^{-1}}$ observed in the river load (obtained by the product of the volume weighted average of Cl concentration in the river by the yearly volume of water flowing in the river). Therefore The contribution of lithogenic Cl can be neglected in the balance. Without going into the detail of the calculation we mention this in the corrected version of the manuscript in section 4.2. It now reads "The assessment of rain contribution to the river is important and can be estimated based on the Cl concentration. Chloride occurs in plutonic rocks as a trace element in a couple minerals. Yet compared to the amount of chloride delivered by rainwater, the input of lithogenic chloride is not significant. Furthermore the geology of the basin does not indicate the occurrence of evaporite rocks. Therefore, it is reasonable to assume that the Cl in the dissolved load is derived entirely from the atmosphere. "

6. *Page 554, line 24: similar comment: you seldom find calcite as a native mineral in granites. What you can get is calcite veins deposited by fluid circulation during metamorphic events. As I already said Ca can also be etched from other minerals in granitoids.*

   Yes we agree. In the paper, no attempt is made to separate the silicate weathering source from the carbonate weathering source. We think that significant carbonate dissolution occurs within the basin. This carbonate weathering has been included in the weathering budget. We added a mention to the potential importance of veins in the corresponding paragraph section 5.4 which now reads "It is therefore possible that the weathering of carbonates comes from the weathering of trace amounts of bedrock carbonates as shown by Blum et al. (1998) for the Raikhot catchment in the Himalayas. It is also possible that a significant Ca source can be found in the calcite veins deposited by fluid circulation during metamorphic events."

7. *Page 555: sulfurs are very common in the metamorphic arc series of northern Tianshan. For example the fault gouge corresponding to the surface expression of the basement thrust fault in the Kuitun area to the west has a very high sulfur content that can be easily mobilized by water.*

   Yes we agree and in the manuscript sulfur was included in the weathering mass balance because sulfide can be a significant source of sulfuric acide.

8. *Page 561: same comment as on page 553 and 554 about the source of Ca.*

   Yes we agree see our response above at point 6.

9. *Page 563- 564: I really appreciated this discussion on the present day erosion rates. Although I am a co-author of Charreau et al. (2011) I agree that sediment storage and recycling can introduce a significant bia in present day erosion rate calculations based on 10Be cosmogenic isotopes. Sediment storage is effectively occurring in the Kuitun river but also in several other rivers between the Kuitun and the Urumqi (the Manas river for example). However, the present study was conducted in a catchment area where catastrophic events like landslides for example are less frequent than in the deeply incised Kuitun canyon investigated by Charreau et al. (2011). I regret that in their manuscript, the authors do not take into account the fact that their measurements have been made in an area with a very different morphology compared to the other river catchments further west which show much steeper slopes. I think the representativity of the sampled area should be discussed further to allow the readers that are not familiar with the Tianshan piedmont to fully appreciate the results.*

To our knowledge, there is no published data analysis to demonstrate that the morphology of the rivers west of the Urumqi are different. Piedmont morphologies of the rivers are similar and therefore suggest the contrary (Poisson and Avouac 2004, Guerit 2011 unpublished Master thesis). All rivers entrench into deep canyons before leaving the range. The Urumqi as others is subject to frequent landsliding during the summer season. The road is often closed and blocked by landslides and maintenance crews are constantly working along the river during the summer season. Our measurements were levelled upstream of the canyons to address erosion in the high, glacially dominated, range. The comparison to downstream measurements made by Charreau et al. (2011) are there to raise two issues. The first issue relates to the common observation, you seem to agree with, that high downstream rates are often related to storage inside the range. The second issue relates to dynamic equilibrium as, depending on whether the rates are high or low, the balance between erosion and uplift may be radically different.

We will rephrase section 6.2 to clarify the purpose of the comparison accordingly:

"Thus, the mean denudation rate we estimate here is modest for a mountain range with peaks above 6000 m. It is also much smaller than the “present day” denudation rate of ~ 500 m Myr^{-1} obtained from river sand by Charreau et. (2011) in the Kuitun River, a river that runs parallel and to the west of the Urumqi River.

The Kuitun River has more discharge than the Urumqi River and stands in a region where the amount of shortening is probably higher (Avouac et al., 1993; Charreau et al., 2011; Metivier and Gaudemer, 1997; Poisson and Avouac, 2004; Yang et al., 2008). Yet the difference between the present day denudation rates of the upper drainage of the Urumqi River and the rates obtained from the analysis of river sands on the Kuitun River is very large and remains to be explained.

One probable reason the rates found in the Piedmont are higher is the reworking of glacial sediments stored in the floodplain. Sand samples dated by Charreau et al. (2011) where sampled downstream of the Kuitun river in its alluvial fan. They are supposed to integrate erosion on the entire catchment. Within this catchment some regions may have low rates or erosion whereas others may have much higher rates. Our measurements where made along the headwaters stream in the high range above an elevation of 3000m. they are representative of erosion processes in the high range.

Therefore, if both measurements are correct and comparable from one drainage to the other, there must be a large increase of sediment flux down the rivers. It has been shown by Church and Slaymaker (1989) that the increase of sediment fluxes with the drainage area within a glaciated catchment could be attributed to the reworking of sediments accumulated during the Holocene in the river network. In northern Tianshan there is evidence attesting to a recent reworking of the sediment. The rivers (both Urumqi and Kuitun) are deeply entrenched in their Quaternary fans. This entrenchment goes back inside the drainage, as attested by fill-cut terraces in gorges upstream from the outlet of the range in the case of the Urumqi. Thus, although a proper mass balance remains to be performed, downstream of the Urumqi River or upstream of the Kuitun river, it is probable that the supposed higher rates of denudation found elsewhere at the front of the northern Tianshan are not representative of the present-day catchment scale denudation but of the reworking of past deposits stored in canyons and small sedimentary basins inside the range (Church and Slaymaker, 1989) . The Houxia basin is an example of a small sedimentary braid plain along the Urumqi river that can serve as a temporary storage place."

3 Copy editing

All the editing errors noted at the end of the review will be taken care of in the corrected manuscript. Suggestions concerning the figures are sound will also be taken into account. Our only concern is Figure 11. We would prefer to keep it that way. We agree that the data points are numerous but they are not the key issue here. Binned averages are most important as they clearly disclose the trends associated with each type of sediment transport. To our knowledge this is the first time such a comparison is shown. It is therefore very instructive to have both bed, suspended and dissolved load concentration on the same graph to see how they co evolve as a function of discharge. All published references can be found in the discussion paper and the comment of Dr. Jolivet

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