

**Response to interactive comment ESurfD 3, C35-39, 2015 -
Anonymous Referee #2**

MS title: *Millennial erosion rates across the Pamir based on ^{10}Be concentrations in fluvial sediments: Dominance of topographic over climatic factors*
by: Fuchs et al.
June 16, 2015

We thank the reviewer for the critical comments and recommendations to improve the manuscript. In the revised version, we follow the major and minor points raised as stated in detail in our responses below. Major changes include:

- erosion rates are changed to denudation rates
- amended title: Denudation rates across the Pamir ...
- we expanded the sections on glaciated / snow and ice covered areas of our basins
- expanded the explanation on our linear regression analyses
- shortened the introduction chapter focussing on the Pamir
- shortened the material and methods chapter
- new supplementary material file including parts from material and methods which present standard procedures and two result figures (former numbers 3 and 4)

Few minor recommendations became irrelevant during editing as a consequence of addressing the comments of both reviewers.

General comments:

The manuscript in its present form is quite tedious to read, and the extended developments of many technical parts makes it difficult to extract the key ideas. A significant amount of the material in the present ms should be moved to supplementary datasets with only a brief and synthetic presentation left in the main text. This is for example clearly an issue for large parts

of sections 3 and 4.

REPLY: *Ok, thank you for this critical comment. We carefully edited the manuscript and shifted those part from the Material and methods chapter to the new supplementary material file that we consider to be standard procedures as also suggested by the other reviewer.*

There are also two main problems with the present analysis of the dataset by the authors, which need to be addressed:

(1) The dataset is mostly composed of very large basins, that average processes over very contrasted domains, from low relief areas to very dissected landscapes. This is clearly not an ideal situation to analyze the influence of topographic or climatic parameters on denudation, as such long-wavelength averaging will blur the geomorphic signal you are interested in. This is an important issue that should be acknowledged and discussed more thoroughly in the manuscript.

REPLY: *We agree with the reviewer that most basins are quite large and average over very different domains. In this first study on erosion variability in the entire Pamir with extremely difficult samples (very low quartz content) we focussed on basins that represent the main geomorphic areas of the Pamir Plateau and its margins described by very low relief versus dissected landscapes. We consider our basin-wide erosion rates to deliver first insights into the major factors driving erosion. We intend to better discriminate between respective major domains by slope-weighted erosion rates for marginal sub-basins and now expanded the discussion of the influence from sediment yield of the glacial domain within basins. For a more detailed differentiation, more small-scale data are needed. On the other hand while it is true that large basin tend to smooth out some effects we selected basins with outstanding differences. Even at this scale the basins display large variations in geometry and climate*

(2) The assumption that glaciated areas are not contributing sediments is clearly a very significant limitation of this study, as pointed by the previous reviewer. Providing more insights into the impact of glacial processes on the derived denudation rates is mandatory before any kind of parametric analysis of the data. Simple mixing calculations could deliver first-order ideas

about the importance of these glaciated part of the landscape on the measured CRN concentrations.

REPLY: *We agree with the reviewer. As already replied to the other reviewer, we expanded the discussion of the effects of glaciated areas on our calculated erosion rates in the discussion chapter on spatial variations to account for the important points raised by the reviewer. We included that glacial contribution to sediment yield is still under debate (e.g., Norton:2010go, Gardardetal2012) and consider possible effects on CN concentrations and production rates. We note that*

- retreating glaciers suggest low efficiency of erosion (overall since the last 100 kyrs (e.g., Abramovski et al. 2006, Roehringer et al. 2012), since the Little Ice Age 15 % in the western Pamir and 3-5 %) in the central and eastern Pamir (Aizen 2011), while also no or slight gain is reported as Karakorum-Pamir anomalie for 1999-2011 (Gardelle et al. 2013)

- the glacial extend based on MODIS satellite data do not account for any possible millennial-scale retreat, but integrate permanent snow and ice covered areas - further data is needed to quantify the sediment contribution from the glaciers and refine the absolute magnitudes of the presented rates.

- moraines and glacial deposits exist in the catchments. Nonetheless they are much older than the time span evaluated in the present study. These remnants are mainly on the plateau where erosion is minimal. Contribution to river sediments is thus marginal.

- other meteorological factors, such as temperature and glaciated area do not show any significant relationship with suspended sediment yields on an annual basis, which would therefore suggest subordinate relevance of climate (Pohl E., and Gloaguen Richard, per. comm.)

We argue that is not any systematic influence because glaciated areas and erosion rates do not correlate.

More specific comments:

P86-L11 : The peculiar tectonic and climatic setting of the Pamir : this is a rather vague statement

REPLY: *Ok, we deleted "peculiar".*

P86-L21 : inferred roughly 0.5 mm yr⁻¹ : of what, exhumation?

REPLY: *Ok, we inserted "erosion during the Miocene".*

P87-L23 : cosmogenic nuclide (CN) techniques : you are talking specifically of CN concentration measurements in detrital sediments here

REPLY: *Yes, we agree. We deleted the relevant section according to the recommendation of the other reviewer to focus the introduction more on the Pamir and our research question.*

P87-L27 : scales : is inversely proportional

REPLY: *We deleted the relevant section (see reply above)*

P88 : a large part of this is too detailed at the introduction stage and is redundant with section 3

REPLY: *Ok, we shortened this section, but prefer to keep especially the last part that was requested before online acceptance as a discussion paper*

P89-L5 : could you be more specific about these equivalences?

REPLY: *This is a rather complex question and still focus of ongoing research. We prefer to not extend or open a discussion on that and refer to the cited literature.*

P89-L9 : the bulk of the Pamir : unclear (and repetition of Pamir in the sentence)

REPLY: *Ok, we re-phrased the sentence.*

P90-L19 : these are references about the specific problem of glacial influence on CRN derived denudation rates, for the more general problem of the influence of glacial processes on erosion you should use other references.

REPLY: *We agree. Here, we now focus on the climatic setting and shifted the rather methodological statement to the discussion section on effects of glaciated areas in a basin.*

P91-L6 : **scales** : same comment as above

REPLY: *Ok, changed accordingly.*

P91-L7 : it may be convenient to use both terms interchangeably in the

following : I disagree, stick to the clear, usual and widely accepted definitions.

REPLY: *Ok, we changed to denudation throughout the manuscript.*

P91-L21 : Niemi et al. 2005 and Yanites et al. 2009 are appropriate references here

REPLY: *We assume the reviewer refers to page 92, we sediment mixing is addressed and both references refer to mass wasting processes. We thank for the suggestion and included the references in the supplementary material, because the section is now shifted there according to the other reviewer.*

P95-L10 : Assuming total shielding by permanent ice and snow cover, we excluded respective areas from further calculations of ^{10}Be production rates : this clearly a weak point of your analysis. Nearly half of your catchments have >25% ice cover, you need to discuss the influence of the likely addition of glacially derived sediments. Simple mixing calculations can provide significant insights into that problem.

REPLY: *We agree and expanded the relevant section (see reply to the 2nd general point above).*

P96- L6 : these are interesting and informative plots but they clearly belong to the supplementary materials

REPLY: *We assume the reviewer refers to figures in of the result section (page numbers seem different in our downloaded files). As also the other reviewer recommended also a shift, we transferred figures 3 and 4 to the supplementary material. Figure 1 presents the study area and figure two the basic geometric properties (plus precipitation) of the sampled basins.*

P96-L20 : The median, 0.25 and 0.75 quartiles of each parameter serve for (multiple-) linear regression analyses to infer the importance of individual parameters for explaining the variations in erosion : As a context for such statistical analysis you should provide more information about the actual underlying physical processes you want to test.

REPLY: *We re-phrased the text, because be performed the linear regression analyses to find predictors that explain the variance in denudation rates. We included information why we used the quartiles to describe the basin parameters.*

P97-L7 : The basins of the southern Panj and of the major Panj tributaries show strong east west elongations (Fig. 1b). The basin elongation allow

to integrate gradients from the Pamir Plateau to its western margin, while their parallel configuration enables to resolve southnorth changes in controlling factors : Most of your basins have very large areas and are averaging denudation over contrasting domains in terms of elevation, regional slope, vegetation, climate : : : This is a significant limitation for your ability to discuss the influence of these factors on denudation based on your dataset.

REPLY: *We agree that the lengthened basins average the over contrasting domains. We amended the text to outline that with this first results of denudation rates for the Pamir we focus on the major basins and clarify which basins enable to discriminate the conditions at the plateau from the margins.*

P99-2nd paragraph : this is typically the kind of information that could be moved to supplementary materials

REPLY: *We agree and shifted large parts of the paragraph to the supplementary material, but expanded to section on snow and ice covered areas.*

P102-L4 The area factor a can be replaced by a slope factor s to account for morphometric differences in basin portions. The factor s describes the ratio of the sub-basin slope scaled the slope of the entire basin and normalized to 1 : : : the relationship between hillslopes angles and denudation can be strongly non-linear, how do you account for that in this calculation?

REPLY: *We added information to the text that we use a robust linear model because of our small data set and intend to discriminate possible predictors for the denudation rates. Results show that from this first data the additive multiple linear regression allows to explain more than 90% of the variance.*

P103-L6 We performed a multiple linear regression analysis with two components as predictors for erosion. Including more components result in multicollinearity and insignificant effects on the goodness of correlation : Based on the available information in the paper it is difficult to assess how your best correlation results with slope and precipitation stand out with respect to other possible combinations of predictors.

REPLY: *Ok, we inserted the information that the other, independent predictor combinations yielded lower R^2 values than using only slope in a standard linear regression.*

P104-L25 : The low abundance of such events in the study area (e.g. Lake Yashilkul) indicates their minor relevance : what would be the most exposed

basin to such events? Did you perform a systematic inventory of landslide related landforms along the main rivers for these basins?

REPLY: *We deleted the sentence because the mentioned landslide is likely older than 3kyr and we already excluded the area upstream of the Yashilkul landslide that restricts downstream sediment transfer to the sampled Gunt River basin (TA31B).*

P106-L15... : Overall, the 10 Be-based basin-wide erosion rates are 10 times lower than OSL-based incision rates. : : : this paragraph would be more relevant to the previous section (5.1) dealing with time-scales of integration.

REPLY: *Ok, we have been unclear on the indication of the OSL based incision rates and added information to the text that fluvial incision does not change over time but indicates consistent rates over the last 23kyr.*

P110-L10 : In the much drier Pamir, this adjustment is not reached. Incision clearly exceeds uplift. Basin-wide erosion rates do not balance the up to 10 times faster OSLbased incision rates measured along the Panj river. From Fuchs et al. (2014, Geomorphology) it seems that most of these terraces are fills (but I could be wrong about that). If this is the case it is not surprising to find strong discrepancies between the landscape-averaged denudation and the local rates of incision into usually poorly consolidated sediments. Incision rates into fill material does not provide much information about long-term bedrock incision and its relationship with uplift rates.

REPLY: *No, the terraces are no fill terraces and their only local, short-term formation and preservation under overall incising conditions is addressed in detail in the cited paper.*