Reviewer comment 2: Interactive comment on "Short communication: Multiscalar drag decomposition in fluvial systems using a transform-roughness correlation (TRC) approach" by David L. Adams and Andrea Zampiron

David L. Adams and Andrea Zampiron, August 2020

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General comments

We would like to thank the reviewer for suggesting where communication could be enhanced, and for encouraging us to consider the broader implications and applications of our research. First, general comments are presented and then followed by specific comments we feel appropriate to address at this time.

Reviewer: In the present study, only one single longitudinal profile is analysed. Although it is mentioned that "multiple streamlines (parallel or even intersecting) could be employed", I think that this aspect should be discussed in more detail. For example, how much would the results be affected by selecting different streamlines? How representative is a single streamline for the flow conditions averaged over the cross-section?

Author: There are two parts to this comment: (1) highlighting the limitations of the TRC approach in three-dimensional channel beds, and (2) the sensitivity of the TRC results to the position of the streamline.

We agree that a single streamline cannot be fully representative of the entire cross-section because it does not consider other resistance elements (e.g. banks, emergent bars), nor three-dimensional interactions between flow and channel topography. We suggest that, especially in simplified channels such as the ones of interest in this investigation, the thalweg elevation profile may still capture the important interactions between the channel topography and hydraulics. We would like to provide some evidence to demonstrate this.

Upon recommendation by another reviewer, we calculated the ks value using the hydraulic data and the rough-flow form of the Colebrook-White equation (which we can treat as a 'measured' ks value), using coefficients for open-channel flow from Keulegan (1938). We then compared this estimate of ks (k*s,CW) to the roughness correlation estimate (now termed [k*s,rc] rather than [k*s,pred]) (Figure 1). The experiments conducted for this study (PBR pool-bar-riffle, and PB plane-bed) have values of k*s,rc that are consistently within a factor-of-two of the Colebrook-White ks values, centering around the 1:1 line. On the other hand, for the published step-pool data, there is significant under-prediction of ks by the roughness correlation of around an order-of-magnitude, which may be explained by the lower relative submergence (median h/d84 = 1.5, rather than 3.9).

The relatively close relationship between the two independent estimates of k (estimates from either topography or hydraulics), suggests that for the experiments we conducted, the thalweg elevation profile is representative of in-channel processes. We have included this analysis and discussion in the revised manuscript.

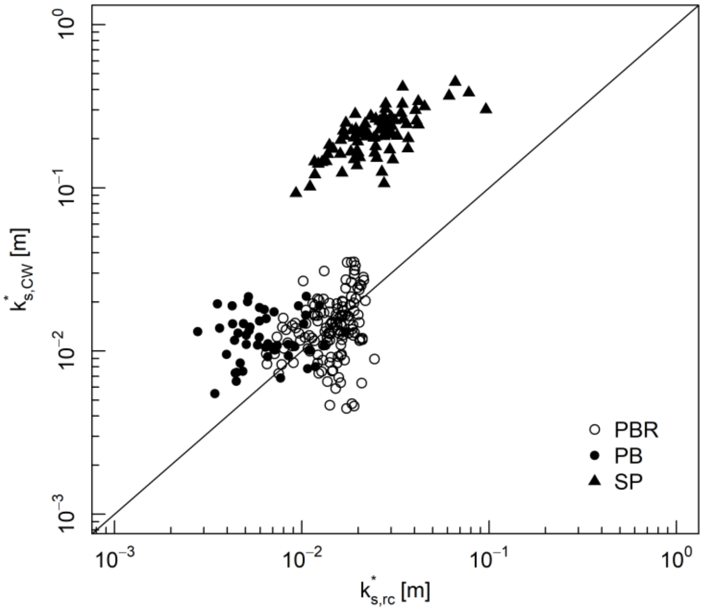

Figure 1. Comparison of ks calculated using the Colebrook-White formula and the roughness correlation. Data has been categorized based on the morphology: PBR = pool-bar-riffle (30cm expriments), PB = plane-bed (8cm experiments), SP = step-pool (Hohermuth experiments). Note the alteration of ks,pred to ks,rc in the new figure.

Now we will discuss the sensitivity of results to the streamline position. When we were testing the analyses, we initially used a series of parallel profiles positioned from one side of the wetted area to the other. There was a significant difference in results (FSD and DSD) between the profiles, given that some were aligned with the thalweg and the pool-riffle undulations, and others captured a set of different features such as emergent bars. For the profiles positioned near the centerline, the only discernible variation in was in the amplitude of the large-scale variations, due to some profiles intersecting with the deepest parts of pools. Moreover, for these near-thalweg profiles, the estimated values of ks showed almost the same pattern (e.g. the proportion of grain- and form-scale ks values, general drag size distribution DSD shape). It was clear that the general results were the same if the profile intersected with the deep part of the channel cross-section.

We have included a figure showing the profiles used for Experiment 1a (Figure 2), which have been extracted using the technique detailed in the methods. There is some variation between the profiles, particularly in the depth of the pools, which may represent an actual change in morphology, or it may be due to the elevation profiles taking slightly different paths. There are even a couple of cases where the profile intersects with a bar at the very downstream end, which is an error that occurs in the profile extraction process when the topography is more complicated. However, despite these variations in profile shape, the DSD remains relatively similar once the pool-bar-riffle sequence has been formed (Figure 3a). The only changes in the ks decomposition are at the largest spatial scales, but these contribute almost no ks and are therefore insignificant. Even if we remove the final 1m of either end of the profiles (thus removing edge effects and potential errors), the DSD is still the same (Figure 3b).

In summary, the decomposition of ks is not very sensitive to the precise position or shape of the profile. It is for this reason that we are currently exploring the DSD as an index of channel character, given that different broad types of channel morphology (pool-riffle, plane-bed, step-pool, dune-ripple, etc.) seem to manifest as distinctive distributions of ks as a function of scale.

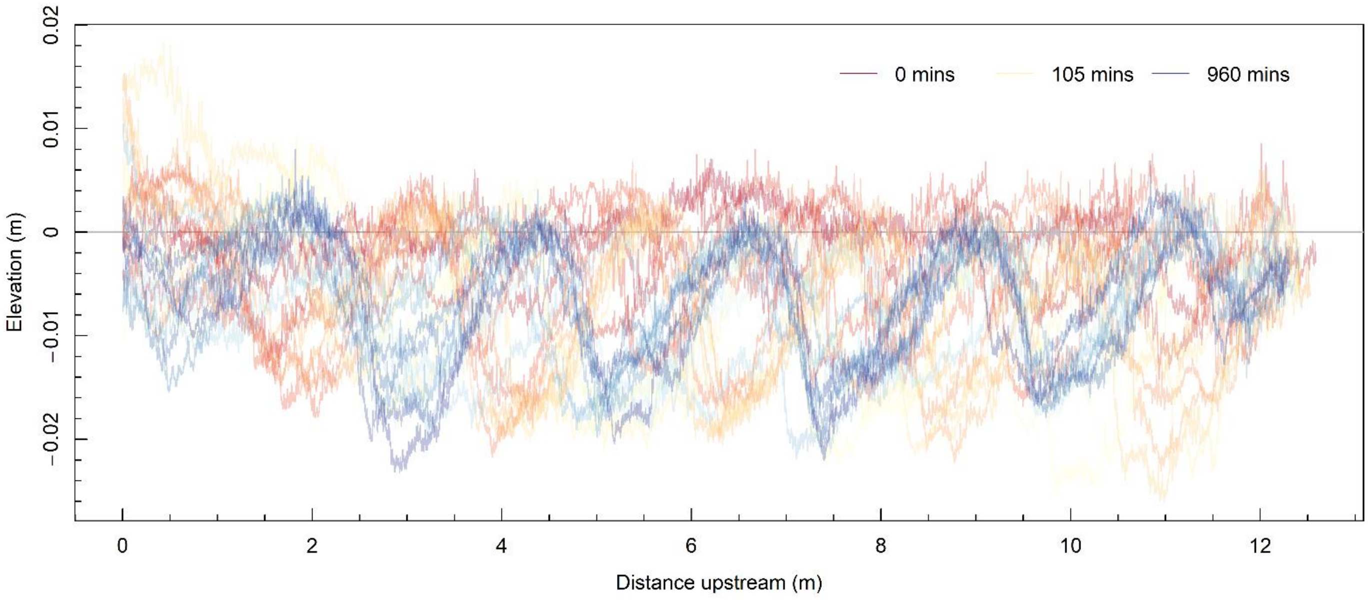

Figure 2. Thalweg elevation profiles (based on estimated position) throughout Experiment 1a. Zero represents the mean elevation of the screeded bed.

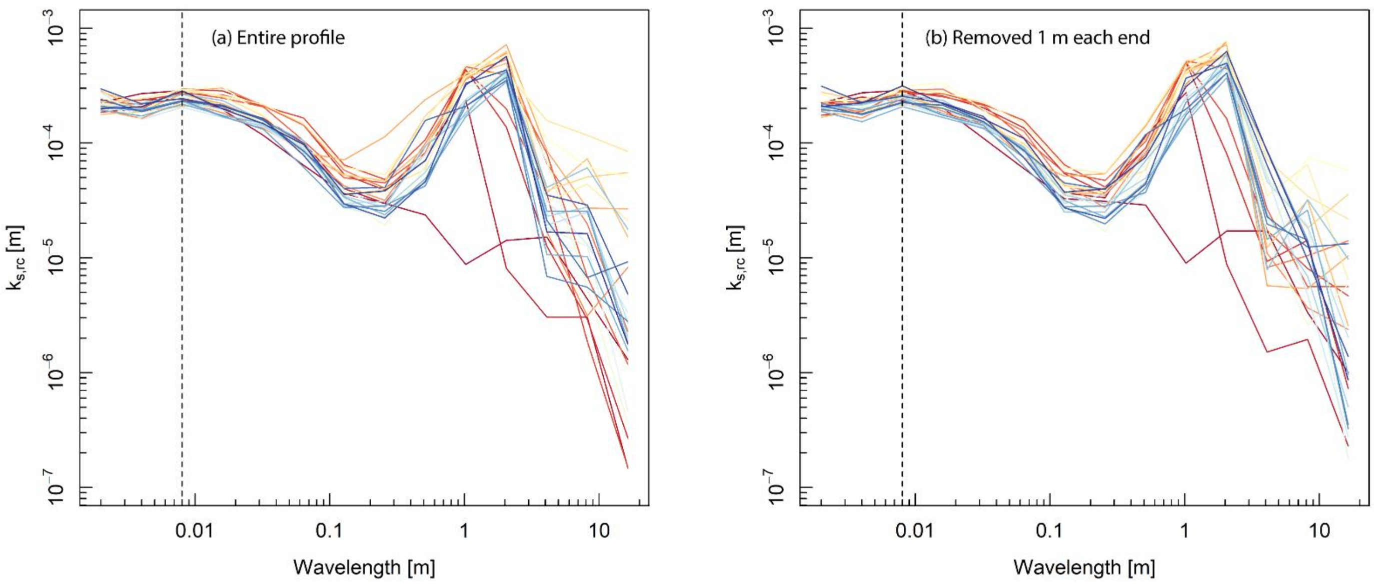

Figure 3. Drag size distribution when (a) entire profile is used, and (b) 1 m is removed off the end of each profile.

Reviewer: Frequent reference is made to the study of Forooghi et al. (2017), but for readers unfamiliar with this study it is not always clear what is meant exactly or what meaning, for example, the term "effective slope" had in this cited study (see also my specific comment below to L160-178). Therefore I suggest providing some more information on this important background study.

Author: We agree that more information regarding the initial study and effective slope parameter may be important. For example, we will explain in more detail the development of the roughness correlation in Forooghi et al. (2017), such as the general approach (i.e. relating different metrics of surface geometry to the total ks), and the surfaces that were used (e.g. their general characteristics). The effective slope is potentially a source of confusion given that surfaces with a high effective slope (i.e. steep roughness elements) do not necessarily have a large range of elevations. We have taken steps to explain this by improving word-choice and using examples.

*Reviewer: The application of the TRC approach to the two different sets of flume experiments as illustrated in Figure 9 appears to result in a somewhat better flow resistance prediction than more traditional approaches (reduced root-mean-square error when using the k*_s,pred roughness measure as compared to using the sigma_z measure), if the measure k*_s,pred really refers to the application of the new TRC approach. However, it is not clear how k*_s,pred was calculated, this needs to be clarified.*

Author: The k*s,pred parameter is calculated by applying the roughness correlation in the way Forooghi et al. (2017) originally intended, that is, the relation is applied directly to the profile without any use of the wavelet transform. We have clarified this in more detail in the methods section of the revised manuscript.

Reviewer: The presence of large wood on the streambed can substantially alter the total resistance, and that particularly in such a situation using sigma_z as compared to using e.g. a characteristic grain size such as D84 improves flow resistance calculations. Can you speculate if and how using the TRC approach could further improve flow resistance calculations in such settings?

Author: We agree that this is an important consideration. Given that the TRC approach uses surface geometry alone, any features on the channel bed surface (live or dead vegetation, large immobile grains, human structures) are incorporated within the estimates of ks. Isolating the role of large wood could be achieved with some creative thinking. For example, using structure-from-motion datasets of mountain channels, one could classify areas of large wood, remove them, and then re-interpolate to create a seamless bed without any wood. The TRC analysis could be applied to both the original DEM and the wood-less DEM (using perhaps a set of parallel profiles). The difference in ks could be attributed to the influence of large wood.

One could also perform the reverse by adding roughness elements to a profile to estimate the corresponding increase in flow resistance. This technique has applications in engineering (stabilization, flood-risk analysis) and re-naturalisation (geomorphic and biological), of rivers. We will be providing a brief discussion of these potential applications in the revised manuscript.

Reviewer: I see one potentially interesting further application of the TRC approach with regard to the question of stress partitioning in gravel-bed streams which is one important approach to improve bedload transport predictions in these channels (e.g. Ancey, 2020, JHR, part 2, https://doi.org/10.1080/00221686.2019.1702595). Some discussion of this aspect would be welcome.

Author: We are familiar with the concept of shear-stress partitioning but have yet to directly consider the application of the TRC to this problem. From our understanding, stress-partitioning is necessary to make accurate predictions of sediment transport because only grain drag acts to move sediment, and form drag dominates the momentum budget. A common approach to determining form drag is to subtract grain drag from the total stress, where grain drag is calculated using empirical relations (usually sourced from flume experiments with flat, planar beds, and using some representative roughness value). The TRC approach provides a more direct means of partitioning drag across different scales. However, one of the key limitations here is that the TRC approach, in its current form, does not incorporate the effects of slope or relative roughness (it assumes a flat surface as well as fully-developed flow), which are especially important in bedload transport processes. We will include a discussion of this topic in the revised manuscript.

Specific comments

Reviewer: Figure 1b): indicate which line refers to grain and form wavelength.

Author: We will now use a dashed line for the form wavelength.

L160-178: In the process of selecting an appropriate correlation between roughness measures and elements of the wavelet analysis, the authors refer to the study of Forooghi et al. (2017) who used a variable called "delta" (a measure of the diversity of roughness peak heights), and report that "effective slope is approximately proportional to drag in the range 0 < ES < 0.35". It is not clear whether the authors also determined "delta" or not. Furthermore, in eq. (2) a critical value of delta = 0.35 is used to separate the two ranges, whereas later in the text a (critical) value of 0.35 is associated with ES. (L172). This is all somewhat confusing and requires clarification.

Author: We agree that this is important to explain. We will first clarify that the delta parameter is the vertical range of peak heights divided by the mean. By identifying peaks in each wavelength, we found that delta was generally over 1 for our experiments and was as high as 4 (over the 0.35 threshold identified by Forooghi et al. 2017). The longest 3-4 wavelengths do not contain enough peaks for delta to be calculated. We will provide some statistics on delta values in the revised manuscript.

A critical value of ES has been identified to be 0.35, which separates two regimes, termed 'waviness' and 'roughness' (Schultz & Flack, 2009, "Turbulent boundary layers on a systematically varied rough wall"). In the waviness regime, where ES < 0.35, there is a positive correlation between ES and the roughness length (that is if the height range of the roughness remains the same and the aspect ratio changes). In the roughness regime, ES has far less effect on the roughness length. The 0.35 thresholds for both ES and Delta appear to be a coincidence. This can be clarified in the manuscript.

Reviewer: Figure 4: If the vertical dashed line is meant to indicate Dmax, it should plot at 0.008 m (L102).

Author: We picked this up after submission and have corrected.