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Interactive comment on "Top-kriging – geostatistics on stream networks" *by* J. O. Skøien et al.

J. O. Skøien et al.

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Author response to the comments of Referee 2

We would like to thank Referee 2 for his/her very helpful comments on the manuscript. We have addressed the comments as follows:

Referee comment: "In my point of view, we do not know if some parts of the results and some parts of the conclusions are an inductive reasoning or a deductive reasoning. I mean that it is not specified if they are induced from comparative results or deduced from the theory and confirmed by illustrative results."

It is the latter. From theory one would expect Top-kriging to be superior to Ordinary Kriging and the examples are used to illustrate what are the main advantages. The reason for selecting two regions from the entire data set was to understand the characteristics of Top-kriging which can be best done by examining individual catchments in a

regional context. To clarify this issue we have changed the first sentence of section 3.1 to "... the concept of Top-kriging is applied to an Austrian data set ..." and the beginning of the first paragraph of section 3.3 to "To understand and illustrate the characteristics of Top-kriging this paper focuses on two sub-regions of the entire data set. We will discuss the estimates for individual catchments in a regional context for both regions. The first region ..."

Referee comment: "Are the two examples representative and demonstrative or just exemplifying? Why not use all the dataset results to confirm the results from the two presented regions ?"

They are representative of the entire data set and are used to illustrate the characteristics of Top-kriging in detail as suggested above.

Referee comment: "P2266 L4 Here 'significantly' has an ambiguous meaning".

The wording has been changed to 'substantially' to avoid the ambiguity.

Referee comment: "P2266 L14-25 would be more pertinent if one incorporates cross validation results from all the dataset (or with all data also focusing on the tributaries), for example in order to perform a paired t-test between uncertainties from the two methods. Thus Fig. 8 should be changed or eliminated."

As indicated above, we believe that a focus on the results of individual catchments is more conducive to understanding why Top-kriging is superior to Ordinary Kriging, for example, and in what way. A 'black-box' comparison of all the data by statistical tests, as suggested by the Referee, would not allow us to understand and discuss why one method is better than the other. We have therefore chosen to retain Fig. 8.

Referee comment: "P2265 L22-28 same comment than the previous one. Fig 12 should also be different or eliminated."

Same response as above.

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Referee comment: "P2269 L10-14 'Overall, the Ordinary Kriging ... In contrast, Top-kriging captures exactly this information' I don't know if it is a deduction from for the methods and confirmed by results or an induction from results."

It is deduced from the methods and confirmed by the results. We have extended the last sentence to read: "In contrast, Top-kriging captures exactly this information, as expected." to clarify that this does not come as a surprise.

Referee comment: "P2269 L26 'In general, both ... will depend on the location of the gauges'. In general means from the two examples together or from all the dataset? Again I think this is not clear."

'In general' means 'in most instances' as deduced from theory and illustrated by the examples shown here. There will also be individual catchments where Ordinary Kriging happens to give better estimates if two errors cancel each other. We believe that the original wording is clear and hence have left it unaltered.

Referee comment: "P2270 L4-8 'In addition ... to the longer records' Is this ability induced from all results or only from the two examples?"

This is related to the way the method is formulated. To clarify this issue we have changed the wording to "... contained in short records (Eqs. 2 and 10)."

Referee comment: "P2270 L14-21 'On the main stream, ... where most of the uncertainty resides.' still the same remark. Are those results and conclusions formulated from the two illustrative examples or more basins?"

We have added "Figs. 9 and 13 are typical of the way Top-kriging estimates interpolation uncertainty. On the main stream, ..."

Referee comment: "P2270-2271 L1 We still ignore if the demonstration is based upon the 18 gauges, as an illustration of the theory or not, or upon the whole dataset."

This has been addressed above, we believe.

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Referee comment: "P2254 L6 'The concepts builds on ...' use passive form."

This has been changed to "The concept is built on ..."

Referee comment: "P2254 L9-10 'Top-kriging also provides estimates OF the uncertainty OF the variables OF interest' please reformulate."

This has been changed to: "For the variable of interest, Top-kriging also provides estimates of the uncertainty."

Referee comment: "P2254-2255 L1 'The main advantage ... unbiased meaning that the mean expected error is zero' nice summary for the BLUE definition, but more information or a reference would be perfect."

We have added Journel and Huijbregts (1978, p. 304) as a reference.

Referee comment: "P2255 L1-6 'Geostatistical methods ... from the point example.' Could you provide some references (e.g. D.G. Krige, G. Matheron (1962) and L. Gandin)."

We have added Journel and Huijbregts (1978) as a reference.

Referee comment: "P2255-2256 L1 '..., in an approximate way,...' why ?"

This is because the assumptions of standard geostatistics and Top-kriging imply that the variable of interest aggregates linearly as detailed in Eq. 3.

Referee comment: "P2256 L4 'This allows us to deal with variables that are non-stationary' why? explain."

The co-variance of a variable that is non-stationary in terms of its expectation does not exist but the variogram does as pointed out in standard text books (e.g. Journel and Huijbregts, 1978).

Referee comment: "P2256 L22 'In a similar way, ... as a point process' vague sentence"

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The sentence has been changed to: "In a similar way, other streamflow-related variables can be conceptualised as point processes on the local scale."

Referee comment: "P2257 L15 '... (such as Ordinary Kriging) ...' as you will use this particular Kriging method, present it, even succinctly (e.g. differences in respect to Simple Kriging or Universal Kriging)."

We do not think it is the purpose of this paper to explain these variants of kriging.

Referee comment: "P2258 L17 '...(Cressie, 1991 p.66)' the last version of this reference is now Statistics for Spatial Data, revised edition, by N. Cressie. Wiley, NY, 1993 (900pp.)."

Thank you for this information. No change is needed here.

Referee comment: "P2259 Eq.(4) ... I think that a discussion about hierarchical relationships between two catchments should be addressed. Actually, the influence of tributaries over the main streams is not the same as the influence of main streams over the tributaries. That fact seems to be an intrinsic part of Top-kriging, but this is not discussed. Thus, I suggest to add a part about that topic in discussion."

We have added the following sentences at the end of the paragraph on P2270, L3: "Typically, the effect of nesting will differ for upstream and downstream catchments. Larger catchments are generally given larger weights than smaller catchments (Fig. 3) and they are also likely to be well correlated with other large neighbours. It is therefore more likely that the nesting will have more impact on the weights of an upstream catchment than on those of a downstream catchment."

Referee comment: "P2259 L16 'In most cases ... analytically.' Explain".

The sentence has been changed to: "The integration in Eq (4) will, in most cases, be either very complex or impossible to carry out analytically."

Referee comment: "P2261 L10 '... the de-clustering effect of kriging' could you pro-

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vide a reference."

The sentence has been changed to: "This is because kriging reduces the weights of clustered samples in contrast to, e.g., inverse distance methods (Isaaks and Srivastava, 1989, pp. 318-321)."

Referee comment: "P2262 L2 'From these data, ... using Gumbel distribution' I suppose you did that in order to eliminate any temporal variability problem. Explain it."

We think this is clear in the original text.

Referee comment: "P2263 L16 '..., A1 was always chosen as the smallest area of the two pairs.' I don't understand. Do you mean the smaller area of the RESPECTIVE pairs?"

To clarify this, we have changed the sentence to: "To reduce the number of bins and to increase the number of pairs in each bin, A1 was always chosen as the smaller area of the two catchments in a pair."

Referee comment: "All Fig. 'To display' is a nice synonym for 'to show'."

We prefer to use 'show'.

Referee comment: "Fig. 6,7,9,10,11,13 legends should be named (with units)."

The units are given in the figure captions of Figs. 6, 7, 10 and 11. Figs. 9 and 13 display dimensionless numbers.

Isaaks, E. H., and Srivastava, R. M.: An introduction to applied geostatistics, Oxford University Press, New York, 1989.

Journel, A. G. and Huijbregts, C. J.: Mining geostatistics, Academic Press, London, UK, 1978.

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