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Hydrology and Earth System Sciences Discussions

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Interactive Comment

Interactive comment on "Spatial variability in channel and slope morphology within the Ardennes Massif, and its link with tectonics" *by* N. Sougnez and V. Vanacker

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The comments that were made by referee #2 were very constructive and helped us to improve the presentation of our findings. We feel that we have implemented all of the suggestions, and include below a point-by-point response to the comments, and a summary of the corresponding modifications to the manuscript.

GENERAL COMMENTS

This work is based on morphometric variables that were derived from a DEM. The authors comment that the original DTM at 1:10000 scale is a regular grid with 20m resolution and that it contains interpolation artifacts, so the contour lines were reconstructed from the DTM and re-interpolated (probably with the same resolution, but there is no mention of it). First there is a conflict with DEM and DTM. If this is a model constructed from photogrammetric-derived contours, I would say it is a DTM, since it represents the ground surface. Second, if the original data contains artifacts, should't the reconstructed contours present these artifacts as well? What impact this could have in the resulting re-interpolated DTM?

REPLY: The elevation data provided by the Geographical Institute of Belgium (IGN) is called "DTM 1:10000", and different data sources has been used for the realization of this product : photogrammetric derived points and structure-lines, airborne laserscanning (points) and field observations (points). It actually represents the ground "real" surface (i.e. not the treetops or roofs). The DTM acronym is now used systematically throughout the manuscript. The artefacts present in the DTM 1:10000 are essentially due to the interpolation method that the IGN has applied, but not due to the quality of the original data. We have clarified this in the revised version of the manuscript. The IGN seem to have used a simple Spline method to interpolate between the contour lines and photogrammetric points, resulting in flat areas in the large valleys plains and staircase effects on steep hillslopes. Therefore, we reconstructed the initial contour lines; and then interpolated to a grid resolution of 20m. The details of the interpolation method are given in our reply to the comment of S. Grimaldi, and are also indicated in the revised version of the manuscript.

The reconstructed contour lines were interpolated using ArcGIS0 topo to raster. What about other interpolation methods? Could this step alter significantly the results? A discussion on DEM-creation methods and its relations with hydrological parameters is valid here (see the interactive comment by Salvatore Grimaldi on this subject as well).

REPLY: We discussed this briefly in our reply to the comments of S. Grimaldi. As we were mainly interested in large changes in morphometric parameters, we did not focus too much on the use of different interpolation techniques. The maximum RMS error of the altitude (Z) in the DTM is around one meter. Since our analyses are based on longitudinal profiles that have amplitude comprised between 100 and 600 meters, this RMS error could be neglected for our study. The knickpoints that we identified in the profiles typically have a horizontal extent of more than 100m and a vertical extent that exceed 10 meters. The use of alternative interpolation methods could have increased/diminished the overall altitude range over one or two meters maximum, but not affects the results that are presented in this paper.

In item 2.3, morphometric parameters, the indices of Gravelius, Schumm and Horton are cited, but not explained. Even if the authors feel that these indices are "classical", they still need to be properly addressed. At least on paragraph is needed to explain each index, how it is calculated and what it represents. Still in the first paragraph of this item, the authors mention that the local relief was calculated in a 100m moving window. In GIS, one can use moving-windows or roving-windows, which can lead to different results. Although it seems to me they used moving-windows, it is worth to check. There is a recent review on this subject by Grohmann & Riccomini (2009).

REPLY : We now added a separate paragraph where we explain the “classical” morphometric indices of Gravelius, Schumm and Horton, and now indicate clearly how they are calculated. We now also explained the type of moving-windows that we are using to calculate local relief (and included this reference in our bibliography). According to Grohmann and Riccomini (2009) we used the Roving-window technique.

The slope-area diagrams cited in page 6987 need to be explained. How are they constructed? Are there references or is this original?

REPLY : The slope-area diagrams of the different river basins were constructed by combining information from the flow accumulation raster, with information on the slope gradient of the river sections. In our reply to the comment of S. Grimaldi, we also give more information on the method that we used to derive the flow accumulation raster (ArcGis-Spatial Analyst function, which calculates a linear flux on the DTM, and uses

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the Deterministic-8 method)

For each river, we divided the streamline into several segments. The segments correspond to that part of the streamline that is encompassed between two following contour lines according to the original topographic dataset. The drainage area (x axis) was calculated at every intersection with the contour lines (every meters) using the flow accumulation raster, and the slope (y axis) was calculated as the river gradient to the next intersection (and corresponds to the interval of the contour lines (i.e. one meter) divided by the flow path distance of the river segment). The relations between A and S are typically following a negative power function, and are commonly represented on a log-log graph. Slope-area diagrams are commonly used to identify river knickzones, and to identify different river morphologies in tectonically active ranges (see Whipple, 2004).

One major issue in this work issue is that 10 catchments were selected. But some questions arise: How were they choosed? Why these and not others? This is not clear in the text and should be. Also the low number of catchments may pose difficulties for statistical comparison, for instance. This problem can be illustrated with the sentence (section 3, results): "The catchments in the western and southern part of the Ardennes Massif are more prone to have relatively smooth river and channel profiles, although various exceptions exist." With 10 catchments to compare, "various exceptions" may be too much to get a valid conclusion!

REPLY: We have selected only ten catchments for this analysis based on the following criteria. First, we selected catchments of the same order of size to avoid some unwanted scale-distortion of the results (between 150 and 250 km^2 as written in the paper). Second, we performed a selection of the catchments where a consistent and regular database of topographic and geological data was available. This is now clarified in the text. The “exceptions” we are talking about in the paper are essentially very specific cases were a river capture has occurred. In the Ardennes Massif, those river captures are very well documented (e.g. Demoulin, 1998), and the slope convexities

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they have induced in the longitudinal profile (following the base level drop) are limited in both horizontal and vertical extension. For obvious reasons, we did not include these catchments in our knickpoint analysis.

In section 4, discussion, the authors say that figure 3 "clearly" show "that the 20 knick zones in the tributaries of the Meuse River are located at different heights, with the highest knick zones located in the northeastern part of the Ardennes Massif." Here we have the problem of authors writing about an area which they know really well, but forgetting that others don't. I don't know what is supposed to be the print size of figure 1, but if this is your only location map, it must be better, the names of the rivers and catchments must be very clear to the reader that are not familiar with your area.

REPLY: We have provided a new figure that clearly shows the location of the rivers and the catchments. For an optimized visibility in the Figure 1, we displayed only the initials of the catchments on the maps. The figure caption now gives for each river its full name and its abbreviation as used in the figures.

Another thing I missed was a geological map, ideally encompassing the same area as the map of figure 1. This would facilitate the understanding of the local tectonic setting and how it may be influencing the catchments. Still on the third paragraph of section 4, it is said: "This suggests that the response of the fluvial system was strongly diachronous, and that a transient signal of adjustment is migrating from the Meuse valley towards the Ardennian headwaters." The response of the catchments, as indicated by knickpoints elevation and spatial distribution, could be diachronous, but why? Is there differential uplift? Are there active faults in the area that could be responsible for this?

REPLY: As requested by the Reviewer#2, the geologic map of the area has been added as a new figure to the paper. The uplift pattern of the studied area is dome-like, centred on the Eiffel region and with an amplitude varying strongly (from 0 to 175 m). The uplift has affected the eastern regions first, and then the "uplift wave" has propagated to the south-west. In our presentation of the study area, we specifically refer to Demoulin and Hallot (2009) for a detailed discussion on the uplift regime of the Ardennes Massif. Rivers are responding to this dome-like uplift pattern by incising, and a complex system of stair-cased terraces can be found in the major river systems (e.g. Meuse River) in the Ardennes Massif. Our catchments are draining to the Meuse River. Their river profiles will gradually adjust to the new local base level that is controlled by the topographic evolution of the Meuse River. Tributary rivers that are located far in the hydrological network are therefore expected to adapt later to the tectonic uplift, and we can see this as a “diachronous” response of rivers to tectonic activity. We now added a few sentences in the discussion to clarify this concept.

SPECIFIC COMMENTS

6894,3: replace "till" by "until" 6894,26: remove "even" 6989,3: remove "Obviously" 6993,6: change "equilibrium long" by "long equilibrium" 6994,16: replace "is an" by "are" ?

REPLY : These specific comments were all addressed, and corrections are made.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 6981, 2010.

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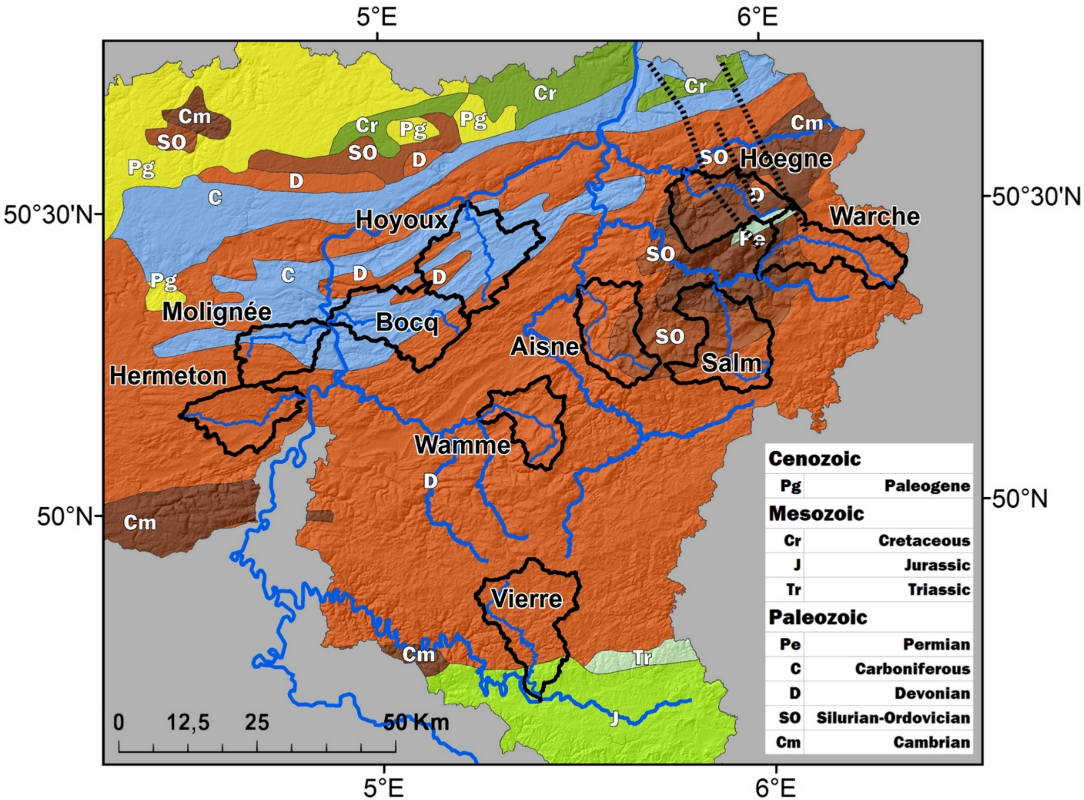

Fig. 1. Geologic map of the Belgian Ardennes Massif. Dotted lines on the North-East represents faults in the Hockaï area.

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