Assessment of the drainage network extracted by the TerraHidro system using the CCM2 drainage as reference data

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Abstract

The objective of this study is to compare the drainage networks extracted by the TerraHidro system, developed in the Image Processing Division (DPI) of the National Institute for Space Research (INPE), using SRTM data with resolutions of 30 and 90 meters, with the existing drainages in the pan-European drainage network database, called Catchment Characterization and Modelling version 2.1 (CCM2), river and catchment database developed at the Institute for Environment and Sustainability (IES) of the Joint Research Centre (JRC). In other words, CCM2 data set was used as reference data for qualitative analysis of the extracted drainages by TerraHidro. The SRTM 30m data contains altimetry points with value -32767, called *void* points, that must be substituted by some estimated altimetry data. TerraHidro automatically performs these corrections using any available altimetry data set grid as an alternative value grid. In this work we used the SRTM 90m as the alternative grid. To do so, TerraHidro uses a bilinear interpolator, which performs a linear interpolation weighting by the inverse of the distance using the four nearest values. A conversion process of these drainages, called *upscaling*, was executed in order to adapt them to lower resolutions, in this case 900m. Again, this new set of drainage was compared with the reference data. Finally, a procedure called HAND was executed and the result is displayed indicating areas with varying levels of flooding potential. The data used in this work are the SRTM 90m and SRTM 30m from the UK. The basic TerraHidro features have also been described.
Keywords: TerraHidro, drainage network, SRTM, HAND, upscaling.

1 Introduction

Digital elevation model (DEM) is useful and important. It is used in several applications such as: slope calculation for landslide occurrences, flood alerts, drainage network and watershed delimitation, hydrological models, agricultural studies, protected geographical areas, among others. High resolution altimetry data sets are expensive.

This data is obtained only for small regions. In countries like Brazil, with continental dimensions, it is time consuming to analyse large areas using high resolution data sets. The common solution is to use the datasets available as SRTM [1] with horizontal resolution of 90 meters (SRTM-90) and 30 meters (SRTM-30), and Aster GDEM [2] with 30 meter resolution. These data sets are freely available for the entire Earth surface for latitudes lower than 60^o.

The main limitation of using these data is that in a dense forest they represent the tree canopy surface, and not the terrain surface. If in a satellite collected image a forest parcel was cut, the altimetry values on the parcel are different from those in its neighbourhood, leading to some errors in the extracted drainage.

Another problem related to Aster GDEM data set images of different dates used for composing the stereoscopy mosaic, is that they don't usually have the same spectral response.

SRTM data set presents another problem: large aquatic areas, such as large rivers and lakes are represented by flat levels. Flat areas must be properly treated to assure a correct water flow path determination.

The SRTM-30 data was recently made available, but it does not have valid values at all grid positions. These positions, called *voids*, are marked with the value -32767, and it must be substituted by some estimated altimetry data. TerraHidro system [3], which is a software system for hydrological studies, was employed to perform this task. A linear interpolator was implemented in TerraHidro: it uses the four nearest values from the void position taken from a lower resolution grid of the same area, usually an SRTM-90 data grid.

This work shows qualitatively the precision of drainages extracted by the TerraHidro system, using SRTM-90 and SRTM-30 data sets, in comparison with the pan-European Catchment Characterization and Modelling version 2.1 (CCM2), river and catchment database [4] developed and generated by the JRC [5].

The paper is organized as follows: Section 2 briefly presents the TerraHidro system and the geographic region used in this work, and Section 3 shows the results and some comparison.

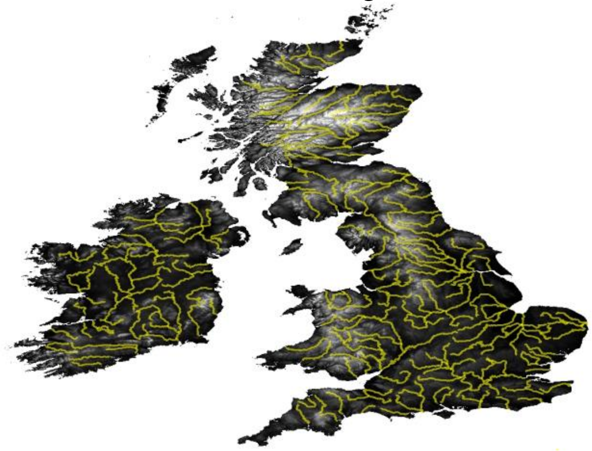
2 Materials and methods

The United Kingdom was the geographic region used in the development of this work. Although it is not a significantly large area, it is an isolated area, bordered only by the ocean. The SRTM-90 and SRTM-30 data of this region were used. Figure 1 shows in grey levels the SRTM-30 data set.

Figure 1: SRTM-30 data for the United Kingdom.

The drainage information of the CCM2 database was used as reference information in this work. The CCM2 database was designed, developed and implemented by the JRC in accordance with the European Water Framework Directive (WFD, 2000/60/EC). CCM2 used an Otto Pfafstetter [6] codification extension to code drainages and watersheds extracted from a digital elevation model at 100 meter spatial resolution, regarding a scale of at least 1:500,000. Figure 2 shows the SRTM-90 and the CCM2 drainages of United Kingdom.

Figure 2: SRTM-90 and CCM2 drainage (in yellow) for the United Kingdom.



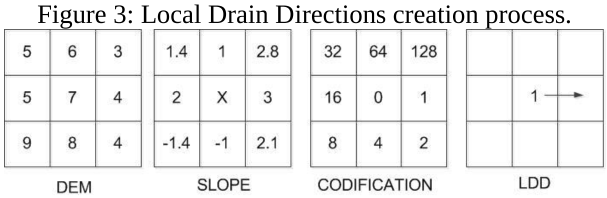
TerraHidro system was used to process these data sets. It has been developed at the Digital Image Processing Division of the National Institute for Space Research (DPI-INPE), situated in São José dos Campos, Brazil. It's free for download under the GNU (GPL) license, as published by Free Software Foundation. TerraHidro has functions to perform: local drain direction determination, contributing area grid calculation, drainage definition using an arbitrary threshold value, drainage segmentation, watershed delineation by segments and isolated points, vectorised drainage and watershed, drainage upscaling, Height Above the Nearest Drainage (HAND) [7] that computes the difference between the altimetry grid value of each point and the closest drainage value reached by following the local drain directions, among others.

TerraHidro is, in fact, a plugin of the geographic viewer TerraView that loads and stores data in a geographical library called TerraLib [8], an open source geographical library implemented in C++ language that has also been developed at DPI-INPE. TerraLib is an open source Geographical Information System (GIS) software library. TerraLib supports coding of geographical applications using spatial databases, and stores data in different database management system (DBMS) including MySQL, PostgreSQL and others. Some TerraHidro functions are described below.

2.1 Local Flow Determination

The Local Drain Direction (LDD) grid gives the local water flow [9]. For each DEM grid cell, the LDD was calculated considering the steepest downstream regarding the 8-neighbour grid cells. At the end of the task, a new grid was created with the same number of columns and rows as the original DEM. Each grid cell receives a code indicating the water flow direction from this cell. Figure 3 shows LDD construction.

Figure 3: Local Drain Directions creation process.

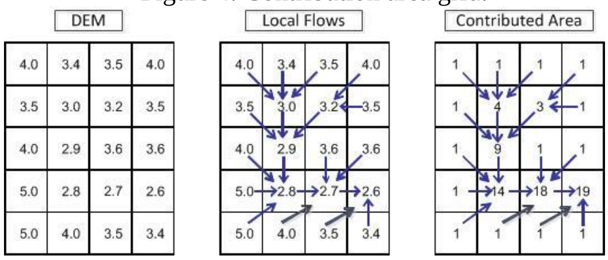


The drainage extracted from TerraHidro is unidirectional, but, the codification expressed in power of 2 will allow using multipath local flows.

2.2 Contribution Area Grid

It is usual to work only with representative drainage regarding an application, and not with all the LDD's drainage. Each cell of the contribution area grid receives a value that is the amount of the areas of all cells participating in the paths arriving at that cell. Figure 4 presents an example.

Figure 4: Contribution area grid.

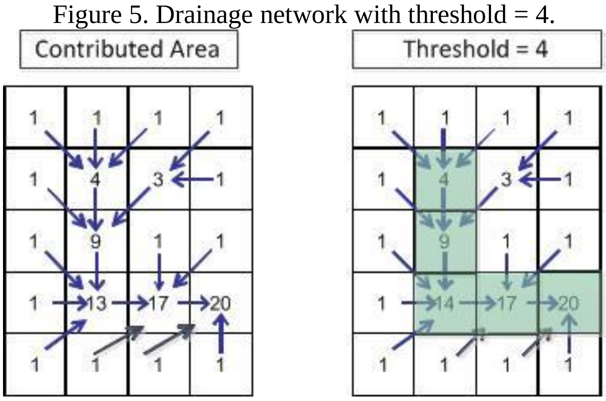


The contribution area grid is used to select a particular drainage network.

2.3 Drainage Network Definition

A particular drainage network is defined by choosing a threshold value. The value of each cell from the contribution area grid is compared with the threshold value. If the value of contribution area grid is equal to or greater than the threshold value, the cell is selected as a drainage network cell. At the end of this process a new grid is created, defining the drainage network. Figure 5 presents an example of drainage network creating process.

Figure 5. Drainage network with threshold = 4.



The threshold value controls the density of the drainage network; for instance, low threshold values produce denser networks.

2.4 Watershed Delineation

Watershed can be delimitated considering isolated watershed points or drainage segments. A watershed point is a location on the drainage defined by the user. A segment is a drainage path between water springs and junctions, between junctions, or between junctions and the mouth of the drainage. The watershed areas are calculated for each isolated point or for all drainage segments. Figure 6 and Figure 7 show an example of each watershed delimitation type.

Figure 6: Watershed delimitation for each segment.

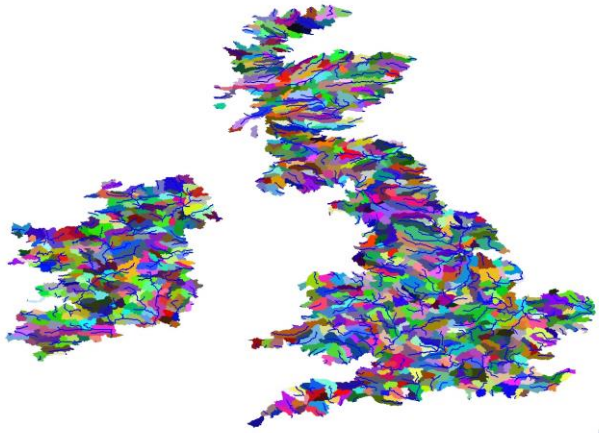
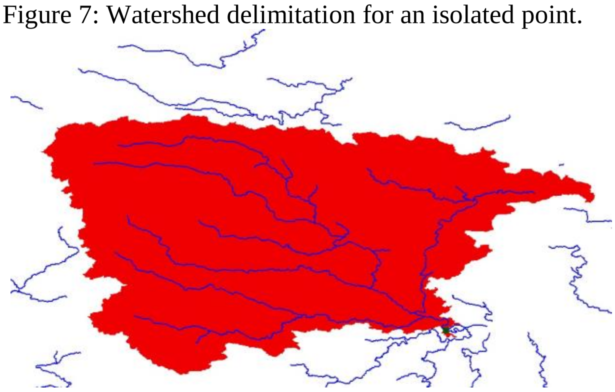


Figure 7: Watershed delimitation for an isolated point.



2.5 Upscaling - Drainage Conversion from High to Low Resolution

The determination of good quality drainage network, extracted from altimetry grids of high or at least medium resolution, is basic information for developing applications involving surface and underground water resources.

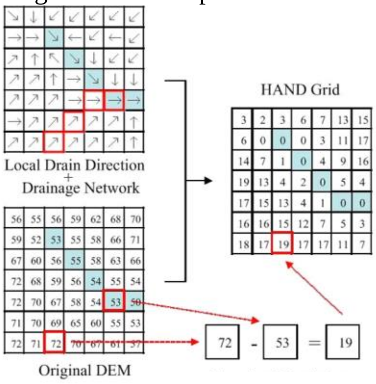
When the target is a large watershed, high and medium resolutions might not be adequate. The drainage network for a low resolution grid is better represented when obtained from a higher resolution drainage network than when obtained directly from a lower resolution grid. This process is called *upscaling* and it is also implemented in TerraHidro.

TerraHidro has an edition tool to change the local flow directions, whenever necessary.

2.6 HAND - Height Above the Nearest Drainage

TerraHidro uses the HAND procedure to identify potential flood areas. It calculates, for every DEM cell, the altimetry difference between this cell and the nearest cell belonging to the drainage network, following the local drain directions. Figure 8 shows a numeric example of HAND process.

Figure 8: HAND process.



HAND process can only identify areas with potential for flooding. This information allows the water resource manager to focus his efforts on the most susceptible areas regarding the occurrence of extreme events involving water. For a more precise study, hydrological models must be used.

3 Results and Comparison

The results of this work were generated by TerraHidro for the UK region using SRTM-90 and SRTM-30 data. A threshold value was used to provide a reasonable drainage density, considering the study area. Figure 9 shows the SRTM-90 and the SRTM-30 drainages over the CCM2 drainage.

Figure 9: CCM2, SRTM-90 and SRTM-30 drainage networks.

In the following pictures enlarged remarkable areas are shown from Figure 9 providing a more detailed analysis. Four remarkable areas were analysed: two areas that the drainages match well in large extensions (Figure 10 and Figure 11), and two areas that present important discrepancies (Figure 12 and Figure 13).

For each enlarged area, three scenes are presented: the first scene shows a combination of the drainages using SRTM-90 data (green), SRTM-30 data (blue), and CCM2 database (red); the second scene, SRTM-90 and CCM2; and the third scene, SRTM-30 and CCM2.

Figure 10: First area with good drainage representation.

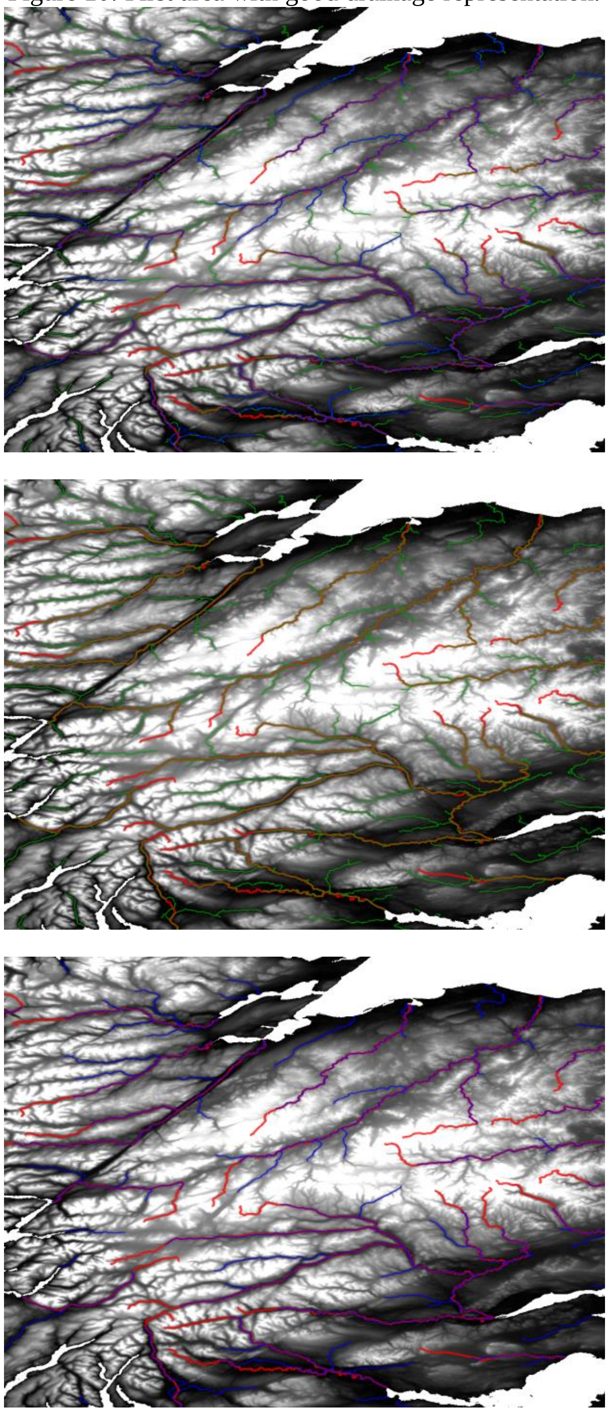
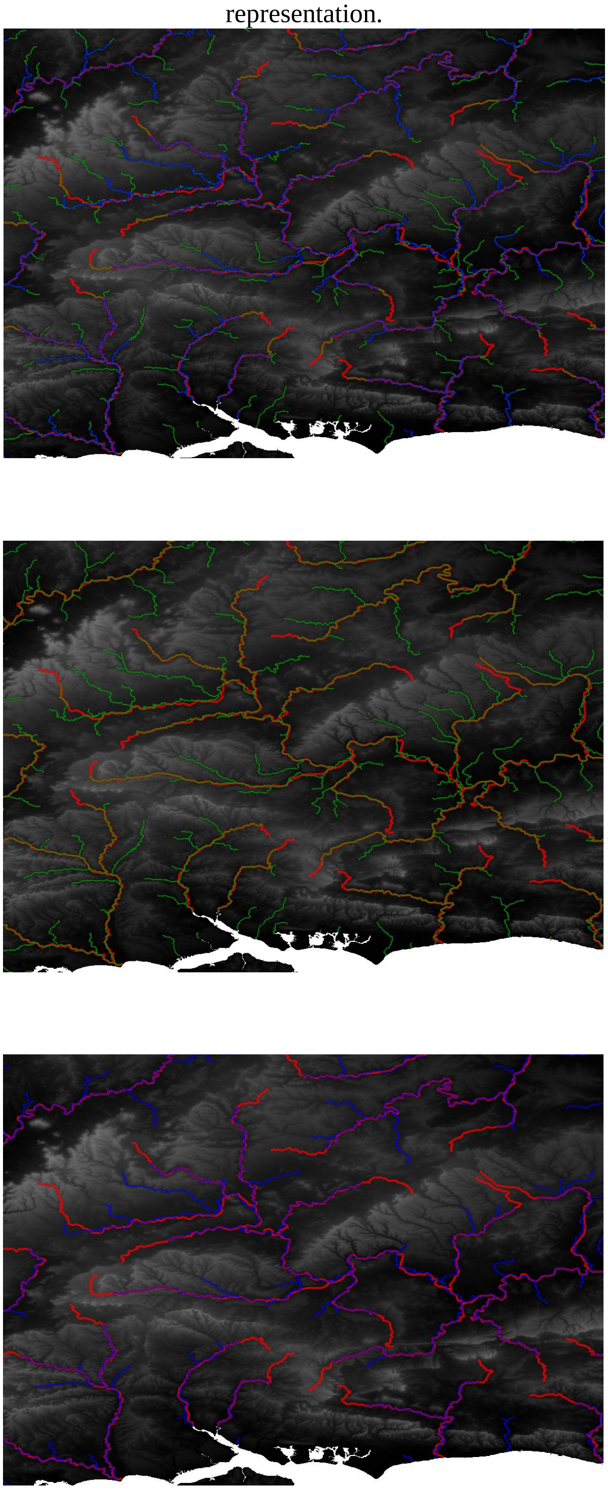


Figure 11: Second area with good drainage representation.



It is noted that in rugged areas TerraHidro, using SRTM data, extracts the drainage with good precision, largely agreeing with the CCM2 drainage.

Figure 12: First area with drainage discrepancies.

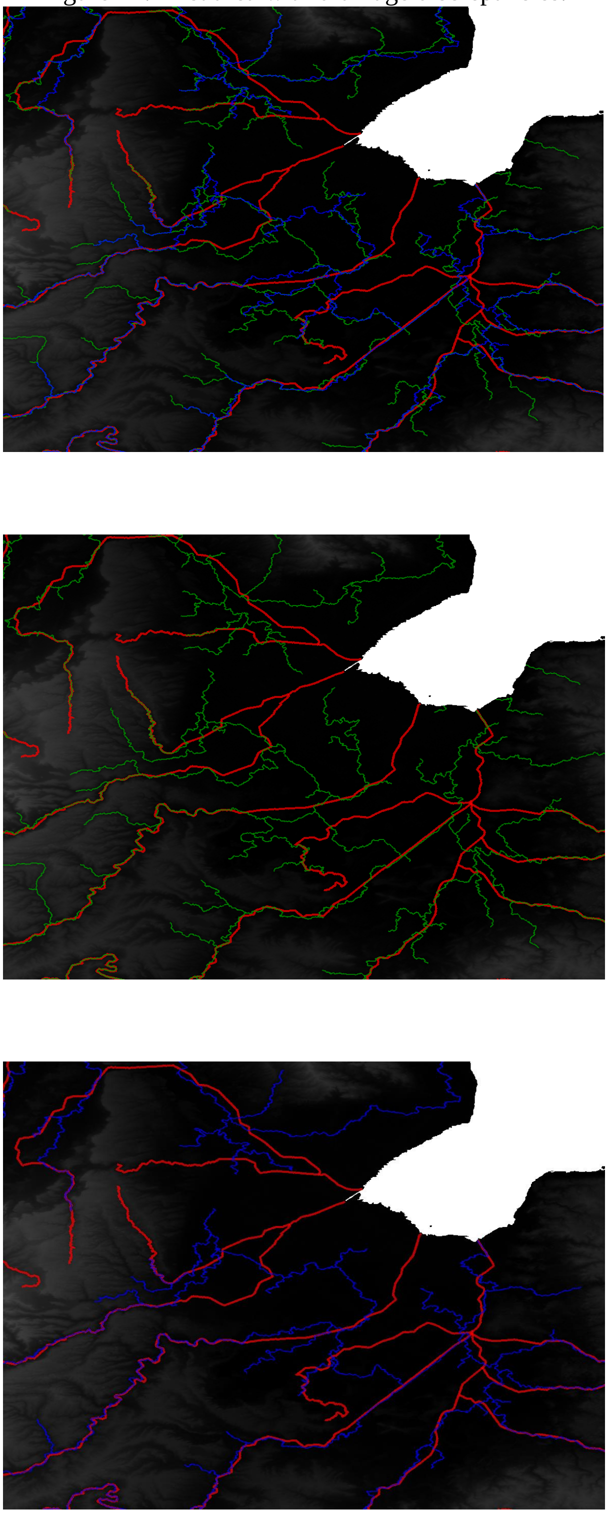
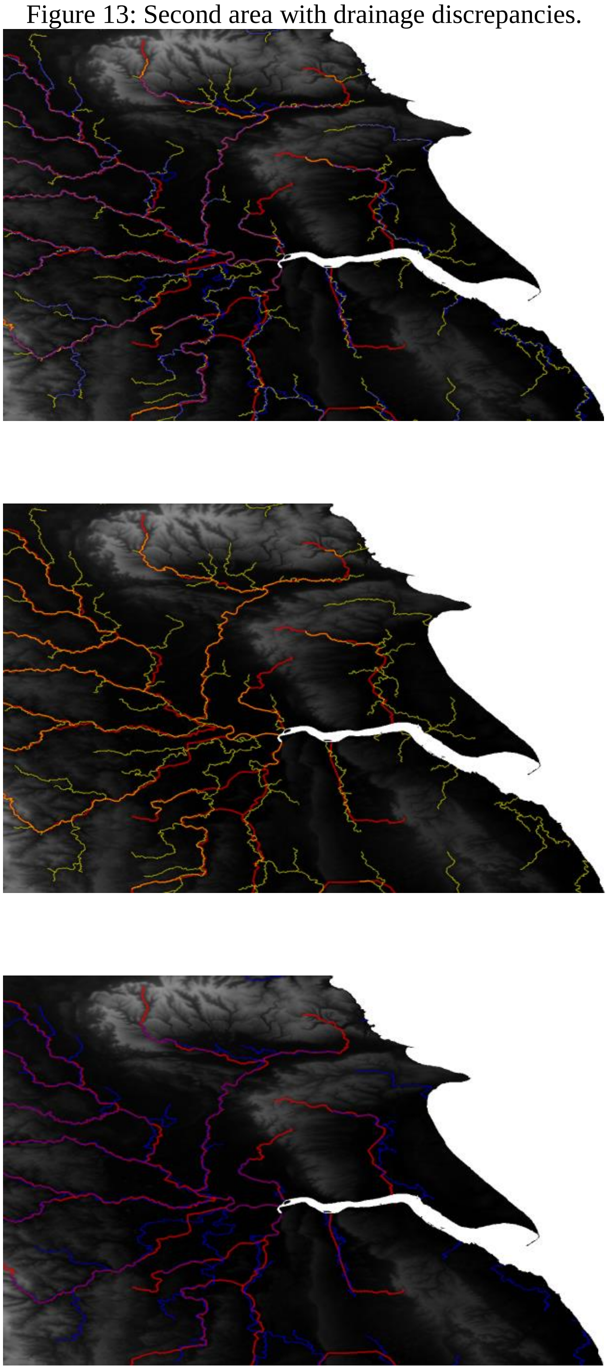


Figure 13: Second area with drainage discrepancies.



In other areas, such as flat areas, forest areas, or urban areas, the drainage obtained using SRTM data and TerraHidro are substantially different from the CCM2 drainage.

In very flat areas, cultivated areas or wetlands, it is very difficult to precise the exact drainage path, even because in these areas minor terrain modifications may lead to large changes in river beds.

In fact, some flat area rivers change their river beds seasonally. In forest areas, the SRTM data represents the top of the trees, given rise to discrepancies. If a road cuts through a forest, it is likely that this road is identified by TerraHidro as part of the drainage.

In some situations, as in studies related to climate changes, it is desirable to use a drainage defined in a lower resolution grid.

The result of this process to obtain lower resolution drainage, called upscaling, is presented in Figure 14 for a drainage obtained using a 900m of horizontal resolution grid, together with the CCM2 drainage, with different zoom levels.

Figure 14: Upscaling representation.

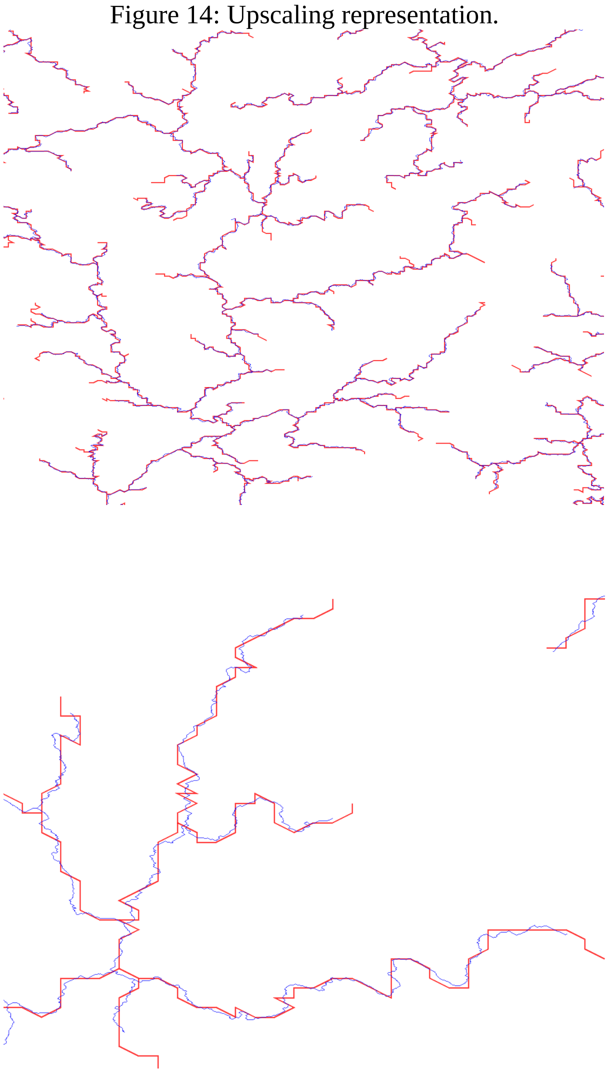
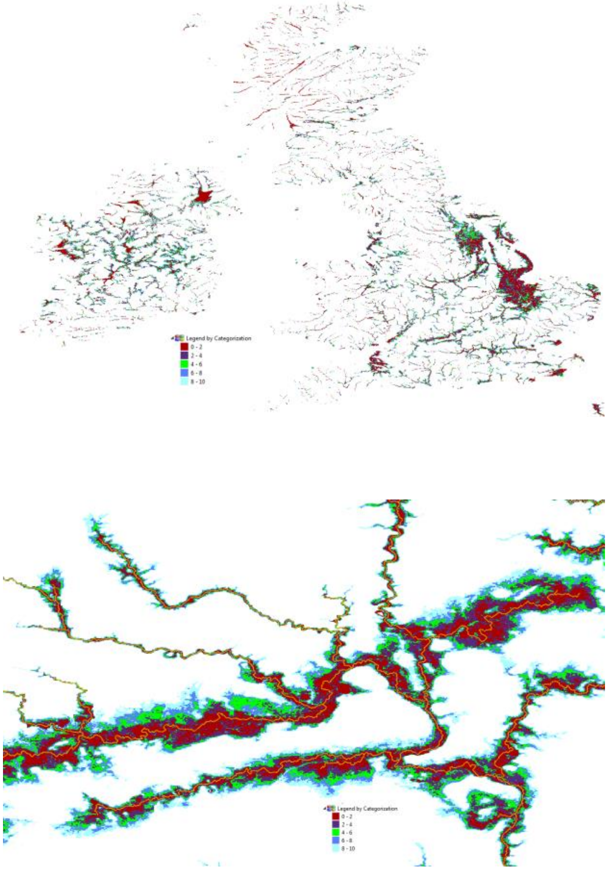


Figure 15 shows different levels of flooding potential through the use of the HAND tool of the TerraHidro system, very useful in analysing the most endangered areas for flooding, for the entire United Kingdom and for an enlarged area.

Figure 15: Flooding potential levels.



TerraHidro system showed good capability of representing the drainages in the studied area using SRTM-90 and SRTM-30 data, providing good results despite some few errors, which needed little processing time and few resources.

A more detailed study of the drainage discrepancies found in this work would be very interesting, possibly using satellite images or field work data, to better understand these results.

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