Assessing positional accuracy of drainage networks extracted from ASTER, SRTM and OpenStreetMap

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Abstract

This study intends to evaluate the positional accuracy and compare the completeness of the drainage networks extracted from three sources of free geographic data, namely from the Digital Elevation Models ASTER and SRTM and the collaborative project OpenStreetMap (OSM), in an area included in the basin of Mondego river, located in the centre of continental Portugal. The drainage networks extracted from ASTER and SRTM are generated considering several values of flow accumulation as the critical level to identify the water courses and the feature "waterway" was extracted from OSM. To assess the completeness and positional accuracy of these water courses the drainage network of the 1/25000 topographic map of the Portuguese Army Geographical Institute was used as reference. The distance between the ASTER, SRTM and OSM derived water courses to the reference data was computed as well as the length of the water courses and the results compared.

Keywords: drainage networks, waterways, OpenStreetMap, SRTM, ASTER, DEM.

1 Introduction

Drainage networks are fundamental for many types of studies and applications, namely in the field of hydrological modelling. These can however be obtained from different sources and have different characteristics and quality, which may influence their usability for certain applications. Additionally, official data have frequently restricted access, which may involve considerable costs and therefore alternative sources of data may have to be used.

In this study we intend to analyse and compare the positional accuracy of the drainage networks extracted from three sources of free data, namely the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM), the Shuttle Radar Topography Mission (SRTM) DEM and the data available in the collaborative project OpenStreetMap (OSM).

The DEM derived from the SRTM and ASTER data are used in a wide range of applications, due to their close-to-global coverage [8]. However, DEM are subject to errors, which depend on several factors, such as the DEM resolution [13], and the terrain characteristics [12].

The global DEM SRTM and ASTER are constructed with data acquired by satellite, using different technologies and represent the altimetry of the terrain. To obtain the drainage networks from the ASTER and SRTM DEM it is necessary to extract them from the DEM using analysis operations available in GIS software.

Another type of free geographic data may be obtained from OSM (http://www.openstreetmap.org/), which is a collaborative project where geographical information of the world is created by volunteers. Goodchild [9] has coined a term to describe this type of data as "Volunteered Geographic Information" (VGI). There are many VGI initiatives that provide many types of data, such as photographs, descriptions of locations, classification of land cover and vector data (e.g. [11]), which correspond to a large quantity of data available for free use. OSM is one of the most known VGI initiatives, created with the main motivation of providing free access to digital geographical information [10]. The volunteers create vector data using a large diversity of available feature types (http://wiki.openstreetmap.org/wiki/Map_Features), which can be downloaded by the public. In OSM data there is a feature named "waterway" that correspond to water courses, which was used in this study.

A key issue related to VGI is the quality of the data produced (e.g. [5], [1], [2]). Some authors have evaluated the accuracy of VGI against reference data sources (e.g. [10], [5]) and other non-authoritative maps, such as Google Maps and Bing Maps [1]. As other crowdsourced data, the quality and completeness of OSM data varies greatly with the region of the world.

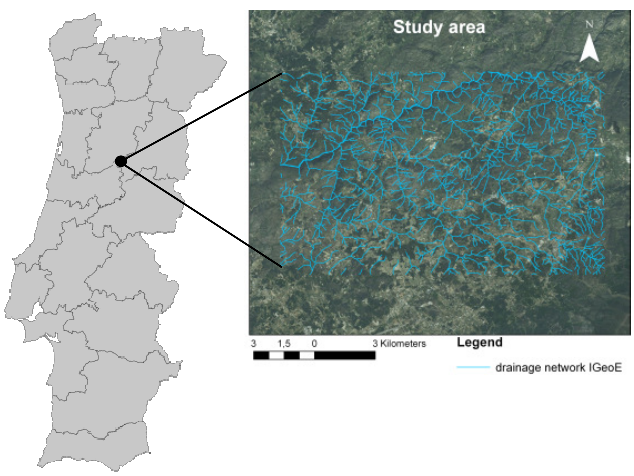
To assess the positional accuracy and completeness of the drainage networks mentioned above, the drainage network of the Portuguese Army Geographical Institute (IGeoE - Instituto Geográfico do Exército) topographic map at 1/25000 scale was used as reference data, which is obtained using photogrammetric methods and aerial photography.

The study was applied in an area for which the reference data was available, corresponding to a region in central Portugal with an area of 160 km^2.

2 Study Area and Data

The study area is a region corresponding to the sheet 201 of the M888 series of the 1/25000 IGeoE topographic map, located in Guarda municipality in continental Portugal. This region is part of the Mondego river basin and is characterized by steep relief, with deep valleys and rough mountains. Figure 1 shows the location of study area with the IGeoE 1/25000 topographic map drainage network overlaying the satellite image.

Figure 1: Location of study area (Gouveia – Guarda).



The global and free DEM ASTER and SRTM were used in this study for the area under analysis. These DEM have spatial resolutions of 30 m and 90 m, respectively and are in the WGS84 (World Geodetic System 1984) reference system.

Water courses (features waterways) were extracted from OSM on the 25th November 2014, using Geofabrick.

3 Methodology

In this section the methodology used to create the drainage networks from the ASTER and SRTM DEM is explained, as well as the methodology used to assess the positional accuracy of the drainage networks.

3.1 Extraction of drainage networks from SRTM and ASTER

The extraction of the drainage networks from the DEM ASTER and SRTM was performed using the D8 algorithm (e.g. [4] and [7]). A critical level of the flow accumulation was used to identify the water courses. The selection of different critical levels of flow accumulation, take into account the spatial resolution of both DEM. As the SRTM DEM has a spatial resolution of 90m and the ASTER DEM 30 m, one pixel of SRTM DEM includes 9 pixels of ASTER DEM. Therefore, the corresponding critical levels of flow accumulation in each DEM were identified multiplying the value used for SRTM by 9 to generate a correspondent value for ASTER DEM. The critical levels of flow accumulation tested were: 10, 7 and 5 cells for SRTM DEM and 90, 63 and 45 cells for ASTER DEM.

3.2 Assessing the positional accuracy of the drainage networks

To assess the positional accuracy of the water courses the distance between these lines to the reference was computed. For that, it was necessary to convert the lines in points corresponding to the ends of the segments that form the lines. The determination of the distance from each of these points to the reference line was done. The distance between each point and the reference line is the shortest distance from the point to each of the line segments forming the line, which may be the length of the segment defined by the point and the line segment, perpendicularly to the line segment, or the distance between the point and one of the line segment ends. With this approach, for each point of the lines to be evaluated, a distance to the reference line is obtained.

To assess the distance between the lines, the mean error (ME) of the distance between each point and the reference line was computed, as well as the root mean squared error (RMSE) using respectively formulas (1) and (2), where d_i is the horizontal distance of point i of the ASTER, SRTM or OSM water course to the IGeoE reference drainage network, n is the total number of points, and $\overline{D}$ is the mean value of the distances of ASTER, SRTM and OSM lines to IGeoE drainage network.

$$ME = \overline{D} = \frac{\sum_{i=1}^{n} d_i}{n} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (d_i - \overline{D})^2}{n-1}} \quad (2)$$

4 Results

4.1 Waterlines completeness

Figures 2, 3 and 4 show the OSM, SRTM and ASTER derived drainage networks overlaid with the reference drainage network (IGeoE). It can be seen in Figure 2 that OSM water courses just cover the main rivers of the region, and therefore can only be used when only the main water courses are of interest. A more detailed analysis also shows that some water courses are disconnected from the drainage network. This just happened in one place of the study area, as shown in Figure 2, in the location with the red circumference. In the entire area of basin Mondego we can observe this situation in several locations.

In Figure 3 and 4 we can observe that the drainage networks extracted from the SRTM and ASTER DEM using the critical levels of flow accumulation with values 5 and 63 respectively, have a coverage and completeness that approximates the reference data.

However they both have less water courses than the reference data, showing that even lower values of the critical level of flow accumulation might not produce the same water courses than the reference. For the critical level of flow accumulation illustrated in Figures 3 and 4, we can observe that the drainage network extracted from ASTER DEM is smoother than the drainage network extracted from SRTM DEM.

Figure 2: Drainage network extracted from OSM overlaying the reference drainage network.

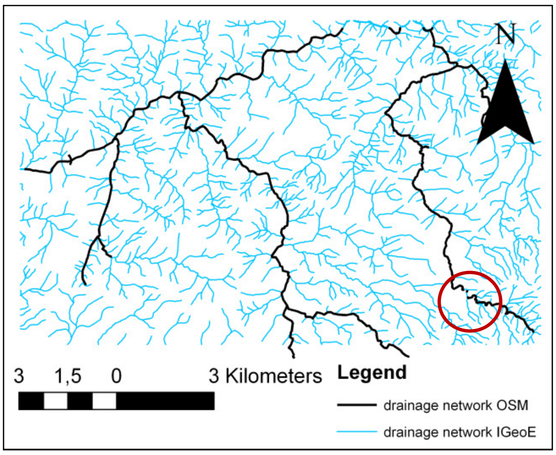


Figure 3: Drainage network derived from SRTM considering a critical level of flow accumulation of 5 cells.

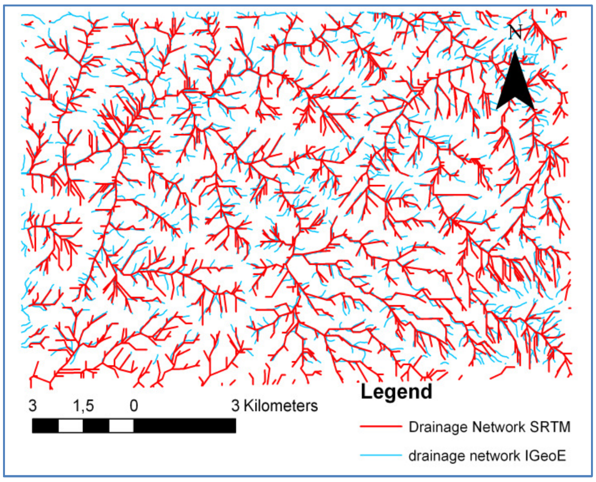
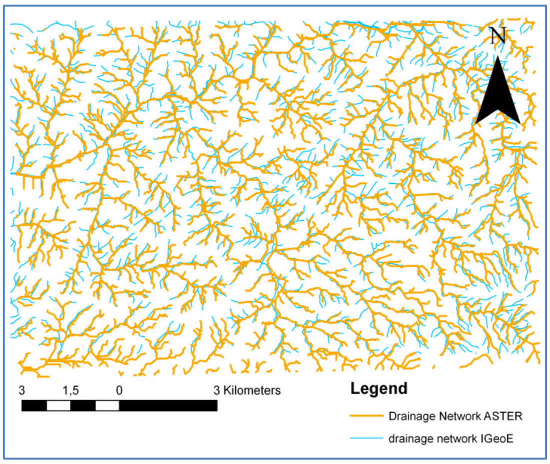


Figure 4: Drainage network derived from ASTER considering a critical level of flow accumulation of 63 cells.



4.2 Water courses positional accuracy

The horizontal distance between the three drainage networks under analysis and the IGeoE reference drainage network was computed as indicated in section 3.2. Table 1 shows the obtained results for the mean error (ME) and the root mean squared error (RMSE).

Table 1: Positional accuracy of the OSM, SRTM and ASTER derived drainage networks.

Distance	*ME* [m]	*RMSE*[m]
OSM - IGeoE	7	15
SRTM - IGeoE	26	27
ASTER - IGeoE	40	36

The results show that the water courses extracted from OSM in this study area have higher positional accuracy (with a ME of 7m to the reference lines and a RMSE of 15m) than the ones derived from SRTM and ASTER. The comparison of the results obtained for the ASTER and SRTM derived water courses show that, even though SRTM has lower spatial resolution, the water courses have a higher positional accuracy (ME to the reference line of 26m and RMSE of 27m) than the ones extracted from ASTER (ME of 40m and RMSE of 36m). These values are in agreement with the conclusions obtained in [3] and [6].

The topographic parameter total length of the drainage networks derived from the ASTER and SRTM DEM was also computed. As mentioned above the drainage network reference has a detail correspondent to a scale of 1/25000. Thus, the critical levels of flow accumulation that produce drainage networks more comparable with this reference were tested, namely the values of 10, 7 and 5 cells for SRTM and 90, 63 and 45 cells for ASTER. Table 2 shows the results obtained.

Table 2: Total length of drainage networks derived from ASTER and SRTM for the critical levels (CL) of flow accumulation of 90, 63 and 45 cells for ASTER and 10, 7 and 5 cells for SRTM.

CL	Length [m]	CL	Length [m]
ASTER		**SRTM**	
90	462498	10	403299
63	**562179**	7	491088
45	666412	5	**591929**

The total length of the IGeoE reference drainage network is 555661m. The critical levels that produces drainage networks with a total length closer to the reference is the critical level 5 for SRTM and critical level 63 for ASTER. The variations of total length obtained are present in Table 3.

Table 3: Difference between the total length of the drainage networks ASTER and SRTM and the IGeoE reference drainage network.

CL	Difference to IGeoE [m]	CL	Difference to IGeoE [m]
ASTER		**SRTM**	
90	93163	10	152362
63	**-6518**	7	64573
45	-110751	5	**-36268**

Observing the variation of the topographic parameter total length (Table 3), for ASTER, the drainage network obtained with the critical level 63 is the one closer to the total length of the IGeoE drainage network.

5 Conclusions

The three types of geographical data used in this work, ASTER and SRTM DEM and the feature waterways available in OSM constitute an important source of free geographic information that can be applied in the study of several problems. In the study area that was considered, and in terms of the horizontal positional accuracy of the drainage networks, we may conclude that OSM water courses presents better results when compared with the considered reference drainage network. In terms of completeness the situation is very different, because the only water courses represented are the major rivers and some water courses are disconnected from the main drainage network. In the study area, in the data downloaded from OSM there are some water courses that are not connected with the main network, so there is not a real network of drainage lines. The drainage networks derived from SRTM and ASTER are effectively networks with all segments linked and cover water courses of lower lengths. With critical levels of flow accumulation of 5 and 63 cells for SRTM and ASTER the drainage networks stay more closely to reference. We conclude also the drainage network SRTM (according the results presented in Table1), has a higher performance in terms of positional accuracy than drainage networks ASTER in spite of its lower resolution (90 m).

Since the waterways extracted from OSM showed to have high positional accuracy, it will be tested if they may be used to generate DEM with more accuracy, complementing with other available data, such us the ASTER and SRTM DEM.

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