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The comparison between ASTER Data and the maps sources in Hydrological Researches (Study case from northern Morocco)

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ABSTRACT: Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) delivered a digital terrain model of a better spatial resolution and accuracy than the traditional free global DEM datasets at near-global coverage and made a wide range of detailed hydrologic applications feasible. In this study, the ASTER data is compared with the digitalized topographic contour DEM in hydrological analysis over the Loukkos catchment in Larache province, Morocco. Extracted stream network and flow directions were compared with the ones derived from the digitalized topographic maps. The result shows, for the stream network, more similarity in average altitude and large differences in lowlands as well as high elevations. For flow directions, the results are almost identical.

KEYWORDS: ASTER, DEM, Flow directions, Stream network, Hydrology.

1 INTRODUCTION

The digital elevation model (DEM) data has been used to derive hydrological features that serve as inputs to various models. Currently, elevation data are available from several major sources and at different spatial resolutions especially ASTER data.

Therefore, the primary objective of this study is to examine the roles of DEM sources and implicitly their associated accuracy characteristics in affecting hydrological modeling.

To demonstrate this influence, we chose an extracted drainage networks and flow direction statistic from topographic maps of Larache area. ASTER data downloaded from http://earthexplorer.usgs.gov/. The study examines the horizontal and vertical differences observed. The differences were attributed to many factors such as the errors generated during the process of digitalization, spatial resolutions of data source, and the adopted algorithms in analyzing the data.

The test site is located in the Northwestern Morocco, within the coordinates: 35°28.7’N-5°58’W to 35°1.2’N-6°20’W (fig. 1). The Loukkos river estuary, which is one of the major estuaries of Morocco.Its tributaries are extremely dense and draw a strictly hierarchical river network [1].

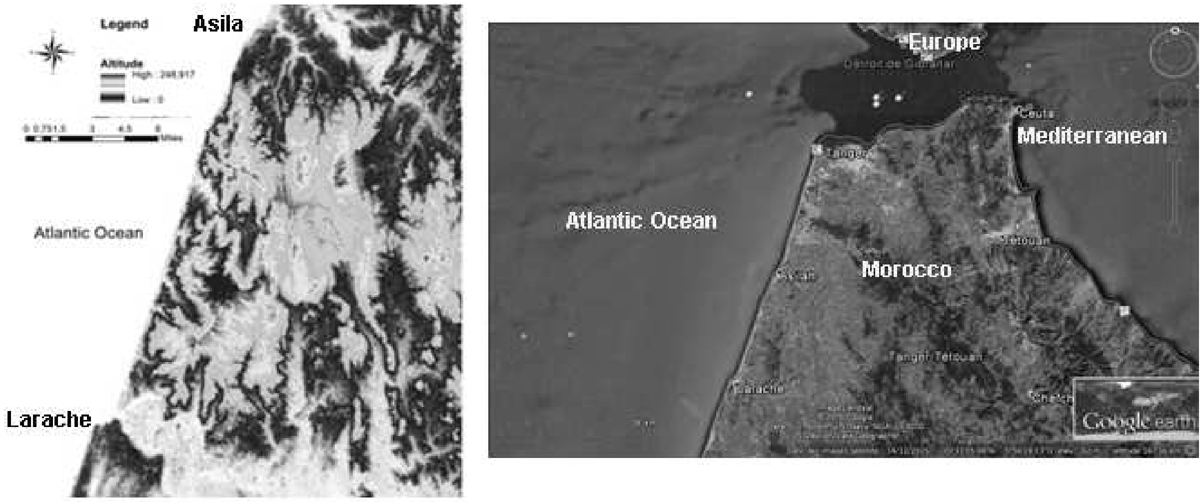


Figure 1. Studied area location superimposed on the ASTER digital elevation model (DEM)

The study of the distribution of river drains is a privileged means of access sedimentary and / or structural anisotropy. Indeed the study of the network Hydrographic allows highlighting the main anomalies drainage, and therefore to determine the main disturbing factors, flows (fracturing and geological structure) [2].

The ASTER Digital Elevation Model (DEM) product is generated by using bands 3N (Nadir Viewing) and 3B (Backward Viewing) of an ASTER Level-1A image acquired by the Visible and Near Infrared (VNIR) sensor. The VNIR subsystem includes two independent telescope assemblies that facilitate the generation of stereoscopic data. The DSM generation (On request) is based on an automated stereo-correlation method that generates a relative DEM without any ground control points (GCPs) [3].

The ASTER DEM is a single-band product with 30-meters horizontal postings. Larger water bodies are detected and typically have a single value, but they are no longer manually edited. Any failed areas, while infrequent, remain as they occur. Cloudy areas typically appear as bright regions, rather than as manually edited dark areas. The declared accuracy is better than 25 meters RMSExyz, [4].

ASTER GDEM (GDEM1) “Version 1” release on 2009, was compiled from over 1.2 million scene based DEMs covering land surfaces between 83°N and 83°S latitudes. A joint US-Japan validation team assessed the accuracy of the GDEM1, augmented by a team of 20 cooperators. The GDEM1 was found to have an overall accuracy of around 20 meters at the 95% confidence level. The team also noted several artifacts associated with poor stereo coverage at high latitudes, cloud contamination, water masking issues and the stacking process used to produce the GDEM1 from individual scene-based DEMs.

NASA and METI schedule a second version of the ASTER GDEM (GDEM2) for release in mid-October 2011. Improvements in the GDEM2 result from acquiring 260,000 additional scenes to improve coverage, a smaller correlation kernel to yield higher spatial resolution, and improved water masking [5].

2 THE METHODOLOGY

As the aim of this study is to compare drainages, networks derived from ASTER data and topographic maps respectively. We processed in two different ways to extract drainage network depending on data used as follows

2.1 EXTRACTION OF FLOW DIRECTION AND STREAM NETWORK FROM TOPOGRAPHIC MAPS

First, we determine the direction of the regional slope to identify the main drainage anomalies, [6, 7, 8].

Extraction of a stream network from a topographic map requires that the entire river system should be converted to vector file. This was done using a multi step process.

To generate the stream network, we used seven topographical sheets at 1 / 25000th, [9]. The topographic map had scanned and geo-referenced the river system was digitalized and converted to digital vectors. Each vector contour had tagged with their corresponding elevation value. The figure (fig.2) show the result of the digitalization process.

Following the digitization of the entire river system, we proceed to eliminate the so-called normal drains (Drains following the steepest slope of the line) and take into account all other types of drains are few their directions (Oblique or perpendicular to slope).

Then there are different groups of drains in the same direction, to finally, determine account the percentage of each group (Frequency drain groups). The treatment performed and allows highlighting all anomalous directions.All these data should be compared to data obtained by fieldwork.

2.2 EXTRACTION OF FLOW DIRECTION AND STREAM NETWORK FROM ASTER DEM

The extraction of stream network practiced in this study is based on the D8 algorithm [10]. It has been the most commonly used method of approximating flow direction on a topographic surface.

Extraction Procedure Filling of Voids: At the beginning of each hydrological analysis, the correction and the accuracy of digital terrain model must be guaranteed. This is necessary because the calculation of DEMs often involves creating artifacts elevation during the interpolation, some of which will lead to depression and other to flat areas. Depressions and flat areas can be accidental or represent a topographic reality in nature. They disrupt the continuity of flows and need to be redressed [11].

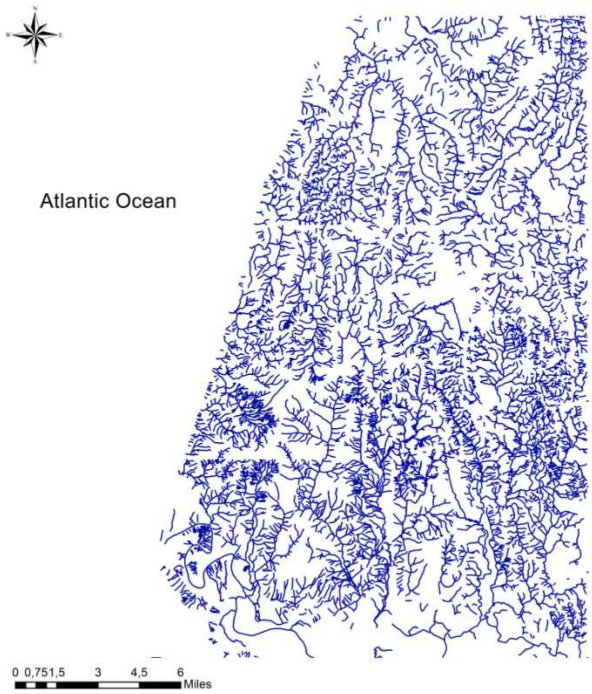
Creation of Flow Direction Raster: The direction of a stream is calculated by finding the direction of the steepest descent or the maximum slope of each cell (raster). It is calculated as follows equation (1) (http://resources.arcgis.com/fr/help/).

$$maximum\_drop = change\_in\_z\text{-}value / distance * 100 \quad (1)$$

The distance is calculated between the cell centers. Therefore, if the cell size is 1, the distance between the two orthogonal cells is 1 and the distance between two diagonal cells is 1.414, or the square root of two. If the maximum slope to several cells is the same, the neighborhood is enlarged until the steepest descent is found, [12]. When the direction of the steepest descent is found, the output cell is coded with the value representing that direction.

Creation of Flow Accumulation Raster: The accumulated flow is based on the number of cells flowing into each cell in the output raster. The current processing cell is not considered in this accumulation.

Flow Limitation and Creation of Stream Network : A limiting threshold value is to be given to limit the flow accumulation raster to the required limit of drainage density, and then the limits are converted to vector files to create Stream Network as shown in figure (fig.3).



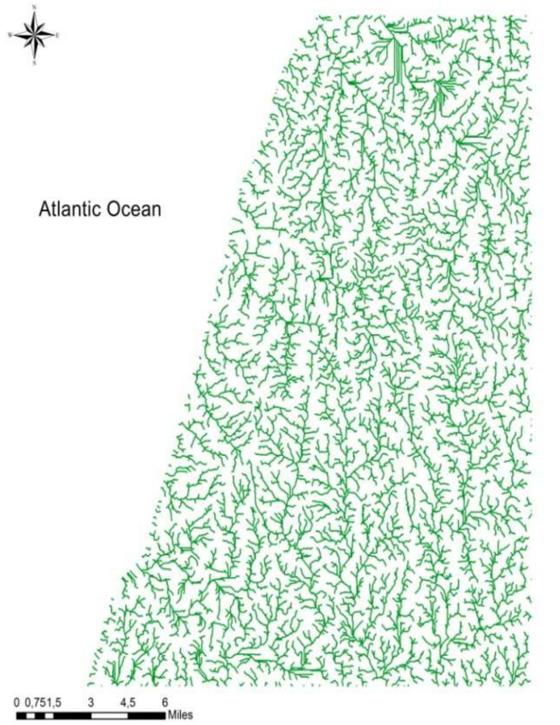


Figure 2. Digital River Network from Topographic map

Figure 3. Digital River Network from ASTER Data

3 RESULTS AND DISCUSSIONS

3.1 FLOW DIRECTION

3.1.1 FLOW DIRECTION ANALYSIS OBTAINED FROM CARTOGRAPHIC MAPS

The regional slope is defined by a sense direction and inclination. The slope be a key factor in guiding and organizing streams. Indeed, if the system was only controlled by the topography, all drains would follow the line of the greatest slope [13]. The slope map (Fig.4) shows a predominance of low slopes less than or equal to 5%, usually characterizing low-lying areas (0 to 110 m). However the highest slopes greater than 5%, characterize enclosures of high altitudes (110 to 220) and the area around the shoreline. The comparison of these two maps shows that the line of greatest slope is generally NNE – SSW.

Therefore, by the elimination of the normal drain (Fig.5), we find that the E-W and N-S direction present the majority in the sector with, respectively 40.75% and 31.25%. However, the NW-SE and NE- SW are minority where its proportion are respectively 13.88 % and 14.22%.

3.1.2 FLOW DIRECTION OBTAINED FROM ASTER DEM

The result of this method (fig.6) show some differences in values, we note that the major directions (E-W and N-S) are respectively 33.05% and 30.29%. However, the minors direction (NW-SE and NE-SW) are respectively 17.82% and 18.23%.

3.1.3 FIELDWORK VALIDATION

The in situ measurements of tectonic discontinuities and alignments, performed in the same location in the study area, principally in the third caps near continent (Ras Aswad, Koudiat Sidi BouQsiba and Lmedyar) confirmed that the majorities direction are E-W and N-S, and the minorities are the NW-SE and the NE-SW.

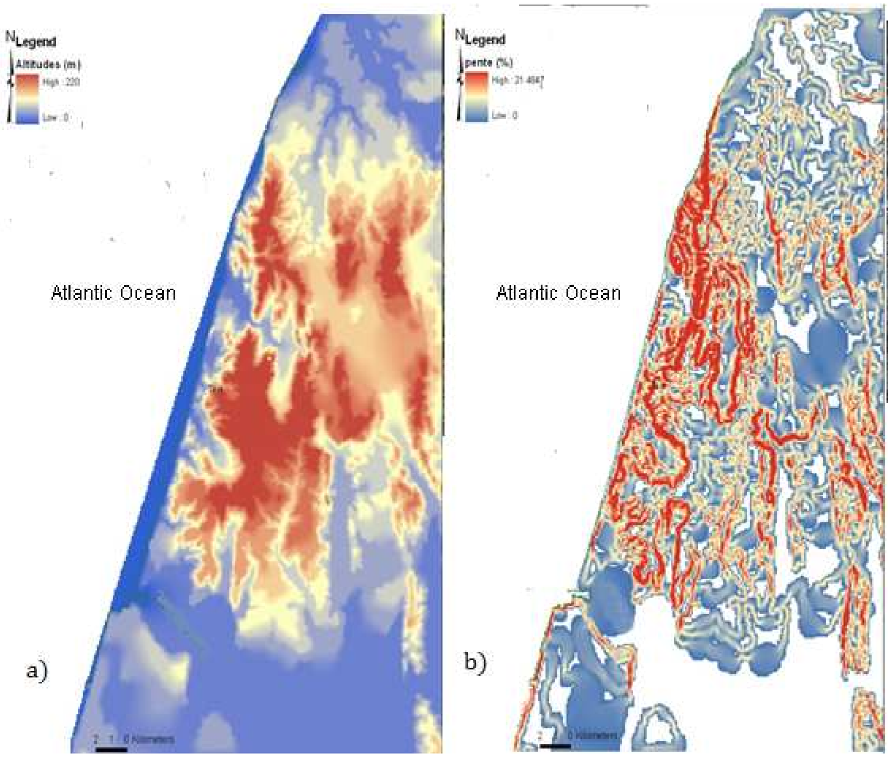


Figure 4. a. Elevations and b. Slopes Maps of Larache area.

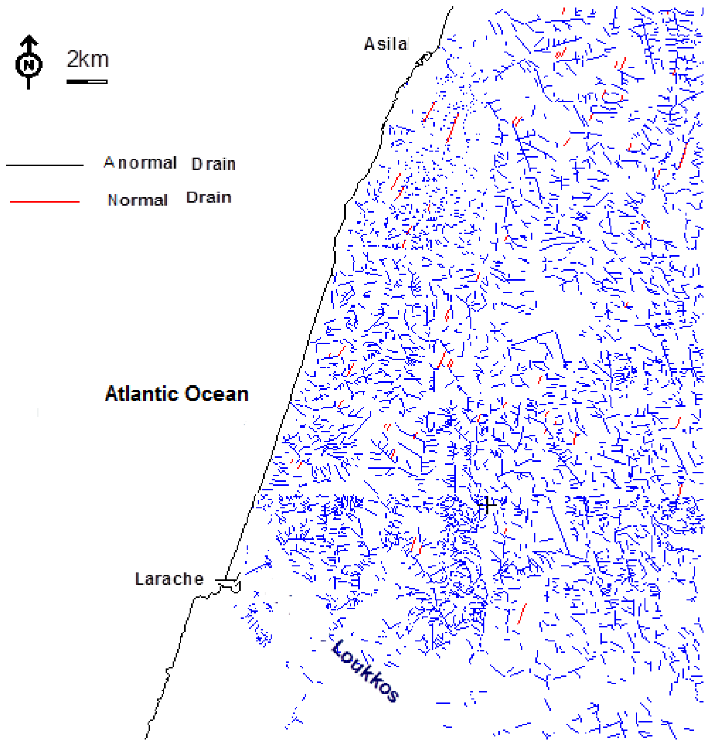


Figure 5.flow direction from topographic maps.

The following table (Table 1) resumes the results obtained, through different approach.

Table 1. Directions River system drains

		Topographic maps result	ASTER DEM Result	Fieldwork result
Directions	E- W	40,65%	33,05%	35%
	NW- SE	13,88%	17,82%	15%
	N-S	31,25%	30,29%	32%
	NE- SW	14,22%	18,23%	18%
Approach problem		Hard to extract	Easy to extract	Lot of time. hard work
Approach advantage		Hight precision	Precision dependent of data quality and extraction process	Real data

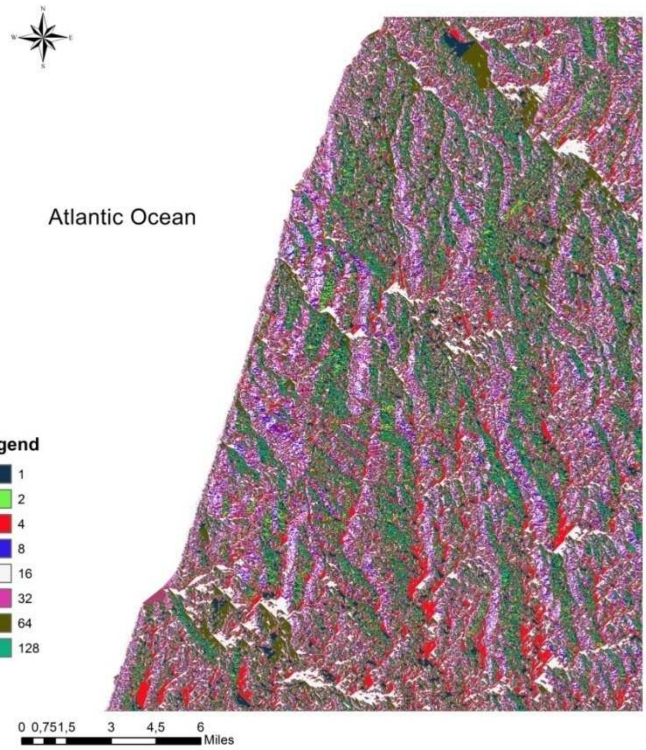


Figure 6. Flow direction map from ASTER DEM

The comparison of these three approaches shows very low differences in the flow direction results. However, the choice of the approach technique depend on the accuracy of the results expected and the resources variables

3.2 Analyst of stream network

3.2.1 Visual analyst

The superposition of drainage network generated from topographic maps and ASTER data are shown in (Fig. 7). Due to higher relief variation in the central and northern part of the study area, a number of small channels originate. Hence, drainage line having specific catchment area (>0.03 km 2) is considered in the drainage network.

Topographic maps DEM delineated streams are seen as very smoot in character compared to ASTER derived streamlines. The higher order stream (mainstream having fourth or fifth order) delineated from ASTER shows more similarity with drainage network derived from topographic maps. The major variation is found in the first and second order stream.

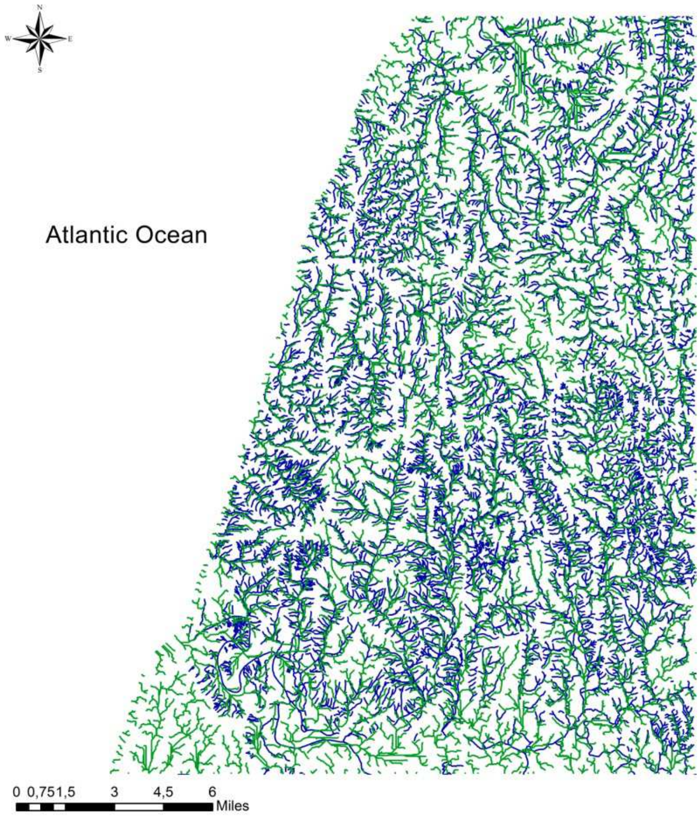


Figure 7. Drainage network extracted from topographic map (in blue) and ASTER data (in green)

3.2.2 GRAPHICAL ANALYST

Profiles are effective ways to illustrate differences between two Models of drainage network; it allows us to study the precision of the extracted drainage network compared to the digitalized one. For this reason, three profiles are used to assess data quality. They were produced from two segments along with two of the most representing rivers in terms of area covered and rate of flow.

Therefore, the result obtained can give us ideas about the different kinds of error due to digitalization.

The first graph (Fig. 8), compares a subset of an elevation profile for the two of drainage network. It is clear from the profile that while over most of the curve the elevations values does not by more than approximately 10 m. In high elevations, up to 80m the curve shows much more severe deviations from the reference.

In fact, the quality of derived attributes of DEMs such as flow direction and drainage network is closely linked to accuracy of DEMs. The vertical accuracy of the DEMs is affected by the terrain morphological characteristics and terrain roughness negatively influences vertical accuracy. In the higher altitude where the variance of elevation is high, the error of elevation is also increased, [14].

The second one (Fig. 9) compares the x coordinates values of the streams networks. Its show a high difference specially in low lands; this can be explained by the errors committed during the digitalization process. Therefore, the georeferencing is influenced by the quality of many elements; generally, the vertical and planimetric accuracy of control point used to georefence the topographic map, can distorted the quality of digitalization. Furthermore, in lowlands and in high altitude the process of digitalization is very difficult.

The last graph (Fig. 10) examines the y coordinate differences and it is clear that there are no significant differences between the two drainage networks.

We can conclude that if the elevations values of ASTER data are revised and the process of digitalization is executed carefully; the drainage network extracted from ASTER data can be closer to the digitalized one.

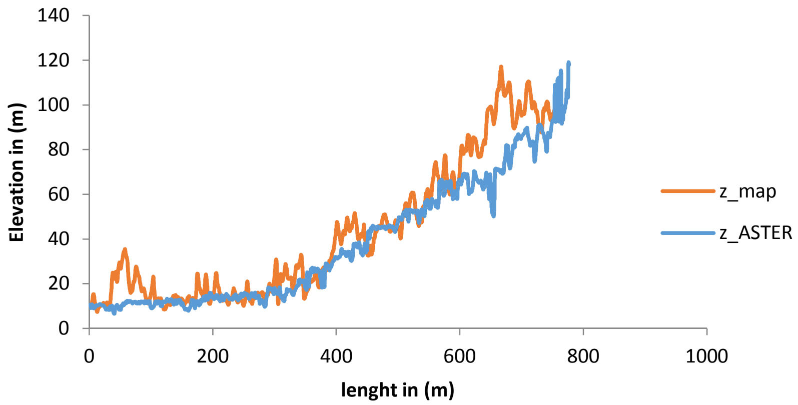


Figure 8. Elevation profile from the two drainage network along a river

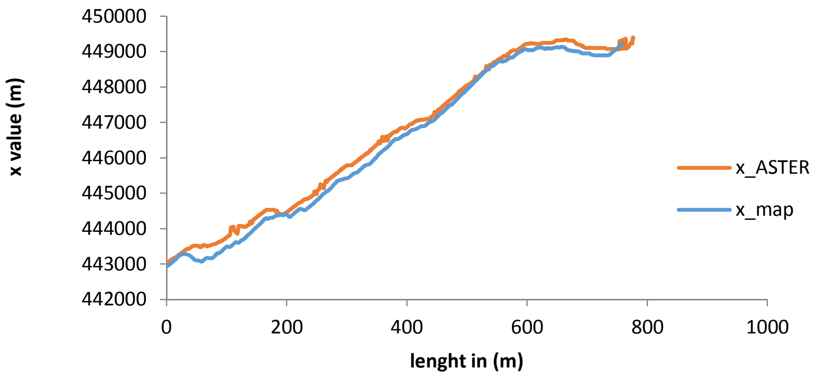


Figure 9. X coordinate profile from the two drainage network along a river

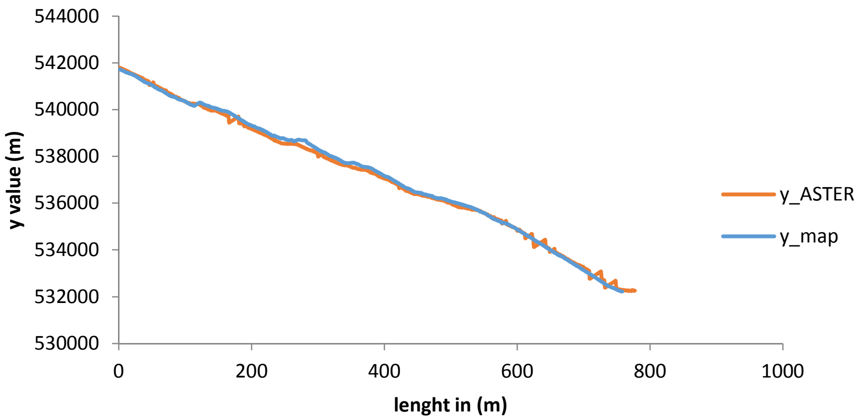


Figure 10. Y coordinates profile from the two drainage network along a river

4 CONCLUSIONS

The fundamental difficulty in the extraction of hydrological network is the representation of reality raised by the digital terrain model. In this study, we evaluate two derived product from ASTER data such as flow direction and drainage network.

Generally, the results show, a high similarity for both of the derived products with those extracted from topographic maps. Following those results, we validate flow directions with work field to ensure of the accuracy of our results. The latter confirmed that results are very close to reality. To validate drainage network accuracy, three profiles are used. The result shows a considerable variance especially in low land and in x coordinate. This variance can be explained by the errors made throughout the process of digitalization from topographic maps and algorithms used during the process of extraction from ASTER data.

Finally, the results were very sufficient for hydrologic research in large scale studies.

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