Methodological Chain for Hydrological Management with Web-GIS Applications

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Abstract. The use of hydrological applications is substantial to assess catchment dynamics and to estimate several hydraulic parameters. Different areas with variant terrains and land characteristics require a wide range of needs in terms of finding and locating hydrological parameters such as catchment areas, curve number, submersion areas, flow dynamics etc. The aforementioned are necessary for hydrological or/and hydraulic simulation modelling and numerous tools are available so as to model hydro-related procedures. Geographic Information Systems (GIS) have been successfully employed over the last several years in order to manage spatial data involved in hydrological simulation modelling processes as well as to execute typical geoprocesses, such as digital elevation model (DEM) evaluation and catchment delineation. Some of these processes may be served to internet GIS users by adopting the geoprocessing web service standard (WPS) introduced by the Open Geospatial Consortium (OGS). In this study, several appropriate actions are applied in order to simulate hydrological modelling procedures by means of web GIS technology and create a structured methodological chain incorporating remote sensing data analysis. The study focuses on the hydrological characteristics of a specific area located in Northern Greece and is based on satellite and remote sensing data (ASTER, SRTM etc). In particular, the methodological chain is determined and each procedure is analyzed. Some of the tools are created for this purpose, while some processes are invoked from open source software. The final output may be considered as a web interface, where some processes offer fully automated and others require user feedback and third-party software utilisation (e.g. MultiSpec).

Keywords. Hydrological applications, satellite image classification, web GIS, web processing service.

1. Introduction

Geographic Information Systems (GIS) have been successfully employed over the last several years in order to manage spatial data involved in hydrological simulation modelling processes as well as to execute typical geoprocesses, such as digital elevation model (DEM) evaluation and catchment delineation. Some of these processes may be served to internet GIS users by adopting the geoprocessing web service standard (WPS) introduced by Open Geospatial Consortium (OGS).

The use of Open Source GIS applications is gaining ground and numerous tools are now available. For this purpose, MapBender software was utilised. MapBender is a back office software and client framework for spatial data infrastructures. It provides a data model and web based interfaces for displaying, navigating and querying OGC compliant map services.

This study focuses on the validation of different data derived from mapping services that are generated from Remote Sensing data, which has been used in order to extract appropriate datasets for the calculation of Hydrological Parameters were derived from a) SRTM v2 90 m satellite images, b) ASTER v2 30 m satellite images of the study area. Different areas with variant terrains and land characteristics require a wide range of needs in terms of finding and locating hydrological parameters [1], [2] such as: flow direction, flow accumulation, catchment areas, runoff coefficient, curve number, flow dynamics etc.

In particular, the methodological chain was determined and each procedure necessary was analysed. Some of the tools needed were created for this purpose, while some processes were invoked from open source software [6]. The final output may be considered as a web interface, where some processes offer fully automated and others require user feedback and third-party software utilisation (e.g. MultiSpec).

2. Methodology

The structure of a well-established methodology chain for a complex multi-task procedure is more than essential. In hydrological applications through GIS, several steps ought to be taken into consideration, in order to come to the desired result. In this study, the typical procedure for calculating hydrological parameters was standardized through the use of web-GIS. At first, the procedure was categorized as follows: 1) search for the available DEM data for the study area, 2) data evaluation through typical but significant processes, 3) data validation in order to assess the level of suitability of the dataset for the application to be used in [3], 4) estimation and/or calculation of hydrological characteristics and parameters.

For such applications, in many cases, satellite and remote sensing data (ASTER, SRTM, LANDSAT etc) can be derived. The aforementioned provide DEMs that are necessary for hydrological analysis.

The workflow depicting the proposed methodological chain is presented below:

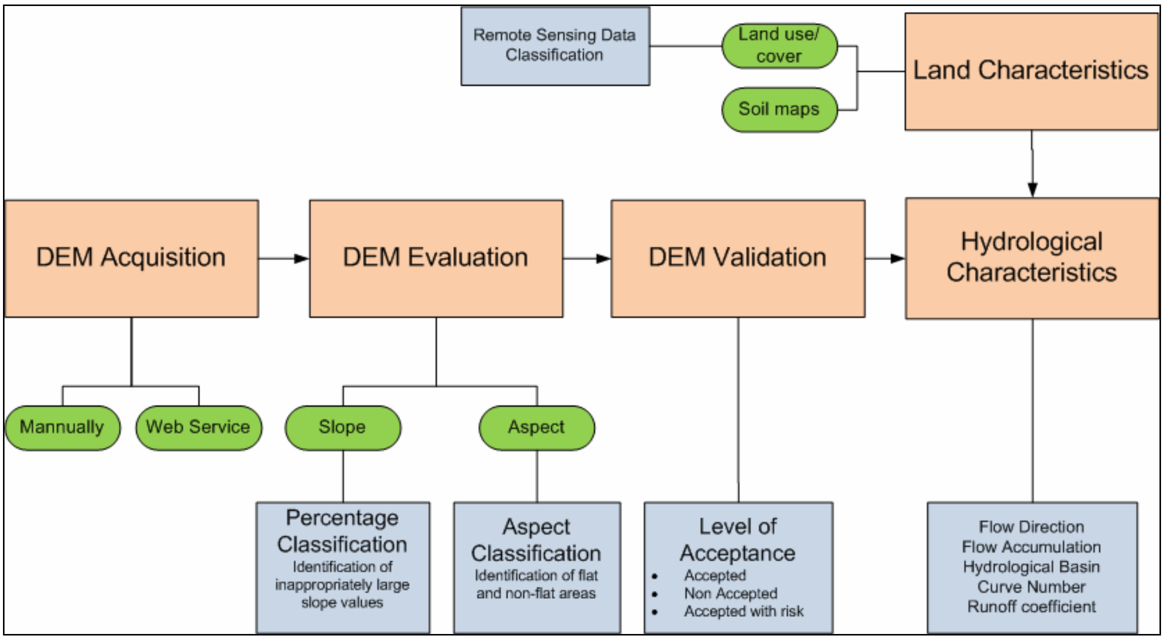

Figure 1: Methodological chain workflow.

2.1. DEM acquisition

In order to acquire a DEM, a satellite image is required. Various satellite imagery providers serve stuff through web map services and browser-based user interfaces with high capabilities of filtering the image parameters as well as the initial area specification [5].

Ideally this may be implemented by shared data infrastructures providing to the developer a set of web services that specify the above functionality and may be incorporated into custom applications. Such web services implement the following functionalities:

- Data discovery web service facilitates the capability of providing information about what data is available over a particular area of interest.
- Request validation web service verifies and validates information obtained from data discovery service and return to the user fully parameterized URL(s).
- Download web service which initiates a request for data, queries the system to obtain a job status and returns the requested data to the user.

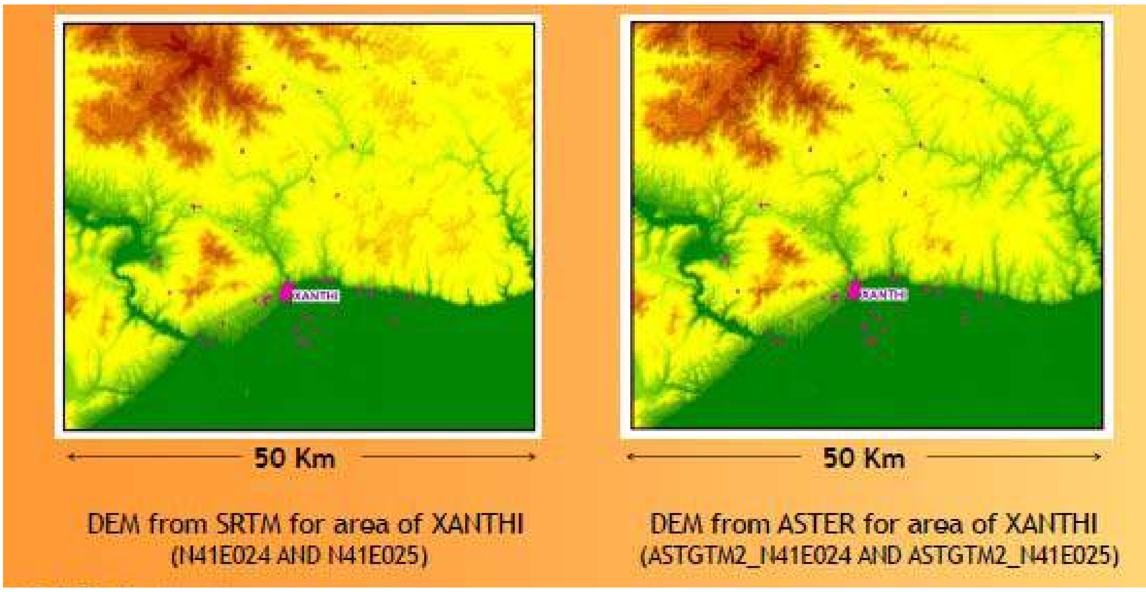

Figure 2: Different DEMs from SRTM and ASTER data.

2.2. DEM evaluation

Remote sensing data such as ASTER and SRTM are not always appropriate for hydrological analysis. In order to evaluate the level of appropriateness, two procedures-tools should be executed: i) Classification of the slope steepness of each area, and ii) Identification of the orientation (aspect) of each area. The most commonly used slope calculation algorithms employed on DEM topography data make use of a three by three search window, centered on the grid point (grid cell) in question in order to calculate the gradient and aspect at that point, while for orientation the algorithms used identify the downslope direction of the maximum rate of change in value from each cell to its neighbours.

The values calculated by such algorithms allow us to determine the appropriateness of the DEM for further analysis. These values should be classified into categories (by degrees or percentage). Statistical analysis of the values also provides information on the appropriateness of the DEM. Steepness values (slope) greater than 45-50% often show problematic areas of DEMs and should be corrected before further hydrological analysis. The cell values calculated from orientation algorithms, can determine the flat areas that are problematic in hydrological analyses.

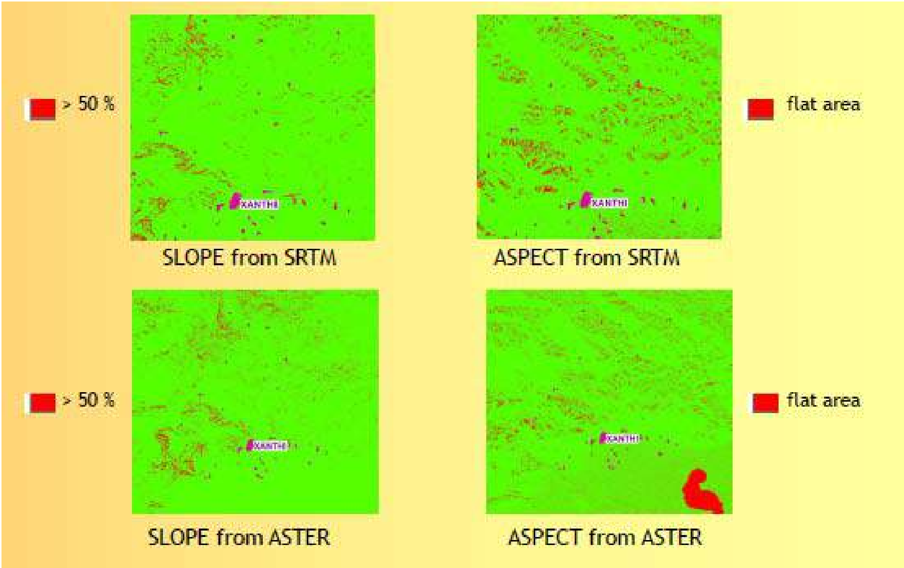

Figure 3: Appropriateness of DEMs from SRTM and ASTER data.

2.3. DEM validation

The DEM validation is a rather complex process and includes decision making. This process is not to be made entirely through software since critical ability and expert knowledge is required, in order to decide whether the DEMs created are usable and reliable for further hydrological analysis. Several criteria ought to be taken into account i.e., the scale of area of the study, the pixel size of the DEMs created, the processes carried out for the correction of DEMs, the precision and accuracy needed for the final project. The validation usually classifies the DEMs in two categories, according to the level of acceptance: “Accepted” and “Not Accepted”. One third category is introduced in the present methodology “Accepted with Risk”, where the DEM is to be used for further hydrological analysis but with possible inexplicit and problematic areas that could affect further analysis. At this point, according to the decision made, either further DEM processing should be carried out or the already processed are used in following hydrological analysis steps.

2.4. Hydrological characteristics

The basic spatial characteristics needed for hydrological analyses that are derived from DEMs are:

i) Hydrological Basins: determination of drainage basins and sinks within the area of analysis.
ii) Accumulation of Flow: determination of the direction of flow out of each cell for the area of analysis.
iii) Length of flow Lines: calculation of the distance or along a flow path.
iv) Direction of Flow: determination of the direction in which water would flow out of each cell.

The aforementioned spatial characteristics are needed for the determination of flow for each basin among with others such as runoff coefficient curve number and Land Characteristics.

2.5. Hydrological characteristics

Land characteristics for hydrological analysis are separated in two categories: i) Soil classification from Soil maps and ii) Land Use/Cover characteristics derived from Remote sensing data classification. Satellite images provide land use and land cover characteristics through the process of supervised classification. This procedure took place in Multispec software.

3. Implementation

3.1. System architecture

The System Architecture described below refers to the software components and the workflow met on a contemporary web – GIS application. The System aims to extract hydrological information yield from DEMs which were produced through manual and/or automated satellite images processing methods. The typical 3-tier architecture prevailing in web applications [7] is adopted, as follows:

- The User Layer contains the Clients through which end users can view geographic data and perform simple functions such as switch between layers, zoom-in-out etc. This layer presents both the initial and the desired geographic information, as a result of various processes performed on the server side after specific user requests (buffering, cropping, routing etc). Clients are divided into two categories depending only if they are browser-based (thin clients) or if they perform much of the required processing (thick clients).
- At the Application Layer, belong all these software components acting as middleware between users and database. These components handle user requests on the server side, ranging from a simple map display request to complicated algorithms execution requests [3]. The application layer aims to create services which are compatible with OGC standards, and include geographic data viewing, searching through catalogs, as well as processing on spatial data for producing valuable geoinformation.
- The Data Layer contains databases and catalogs of geographic data obtained after primitive processes occurred on raw data provided either from organisations, or directly from satellites and land sensors.

The end user interface is browser-based and was deployed utilising MapBender and the Javascript library OpenLayers. Initially the user is connected with a catalog service (CSW) implemented with Geonetwork, where it is possible to search the metadata [4] of the available geographic information. In such case, the following OGC services may provide the requested spatial information:

1) Web Map Service (WMS) for spatial data in .PNG, .GIF, .JPG etc. formats.
2) Web Feature Service (WFS) for vector spatial data in GML, Json, shapefile etc. formats.
3) Web Coverage Service (WCS), for GRID, .TIFF etc. formats.

The above services are implemented with Geoserver software, through its connection with the spatial databases.

Another geographic data provision service is sensor observation service (SOS) which is implemented with 52 North SOS. The service provides data coming either from satellite observations or from land sensors. Data acquisition is performed periodically and various data corrections and processes are made either from data administrator or through automated procedures after data storage in the database. As soon as the user searches the catalog for the requested information, the available satellite images are presented and can be acquired on his browser by calling the appropriate WCS or SOS service.

The next step is to create the DEM and for this purpose; a WPS service is implemented through one of the freely available projects (ZOO, PyWPS or Degree). The WPS server redirects the processing request and input parameters to GRASS modules. The same process is followed for producing the requested hydrological information: any simple or complicated geoprocess requires the appropriate single or composite WPS service to be implemented. Besides GRASS modules, various data conversions may be performed through GDAL/OGR library as well as coordinate systems transformations may be performed by Proj4 library.

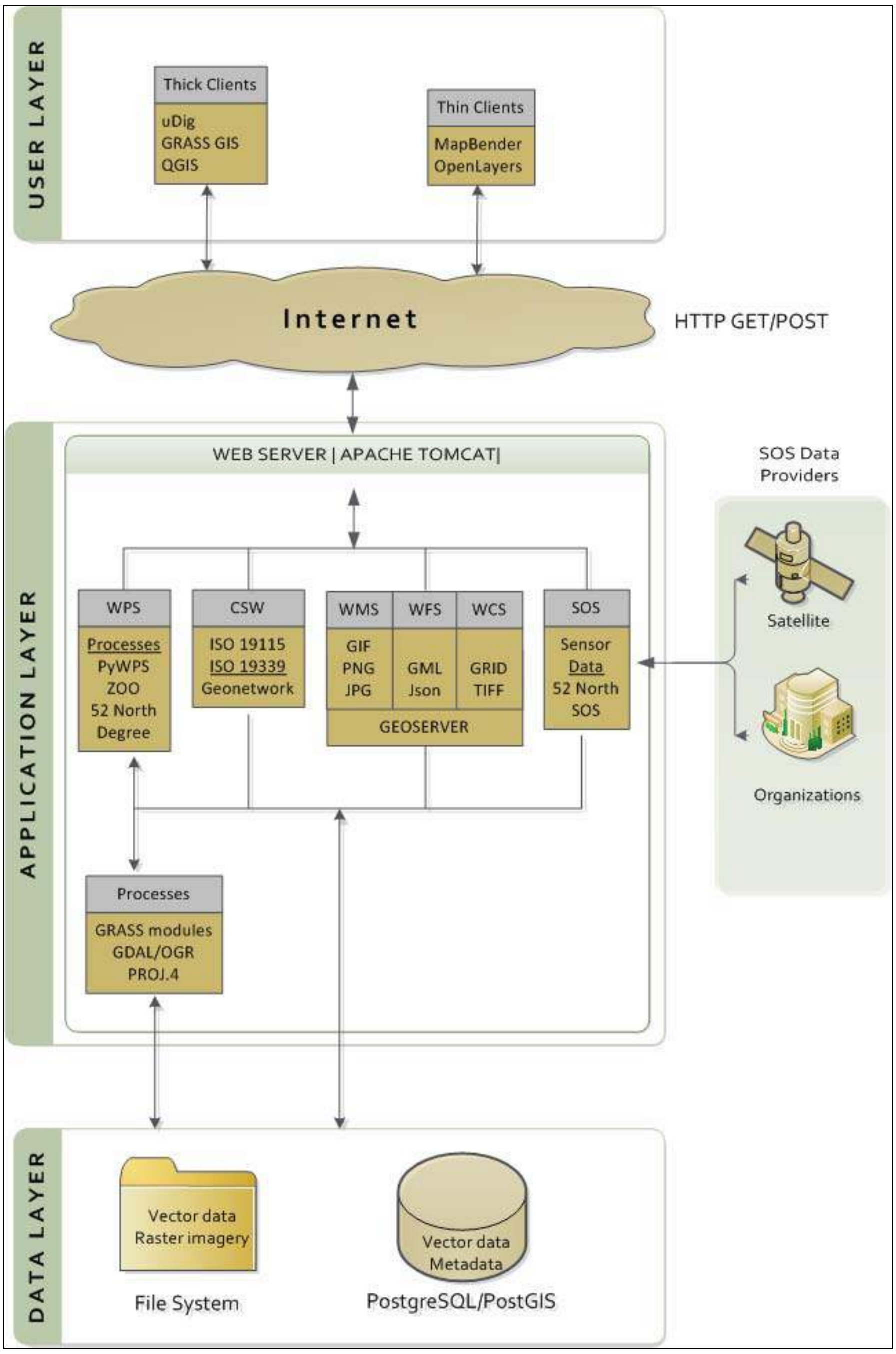

Figure 4: Architecture of the Web Application System.

All requests and replies from and to the Server are filtered and directed accordingly from the Apache web server.

3.2. Visualisations

One of the products that are rather useful and come out of the aforementioned study is the following environment of Mapbender.

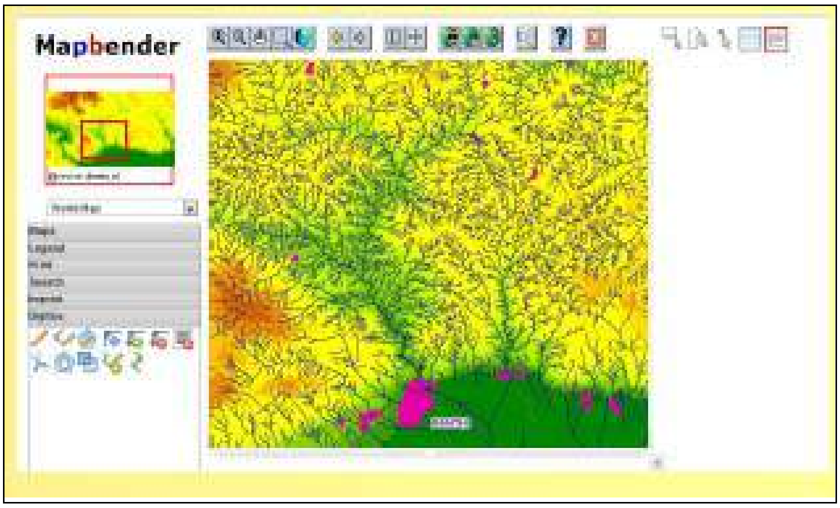

Figure 5: Mapbender and the JavaScript OpenLayers library.

4. Conclusions

This study focuses on the validation of different data derived from mapping services that are generated from remote sensing data. The aim was to incorporate processes that may be served to internet GIS users by adopting the geoprocessing web service standard (WPS) introduced by Open Geospatial Consortium (OGS).

The use of Open Source GIS applications is gaining ground and numerous tools are now available. For this purpose, Mapbender software has been utilised.

The determination of the methodological chain was a main objective where all the necessary procedures and processes were analysed. Some of the tools needed were created for this purpose, while some processes were invoked from open source software.

This paper explored the relationship between changes in information technology and hydrological analysis. Online watershed delineation and spatial data extraction capabilities were introduced as an example of a CGI-based web-GIS application to generate watershed boundaries and to prepare hydrologic data in real time for straightforward operation of hydrologic models via the Internet.

Our future aim is to work towards the comparison of the performance all of the mapservers and the ability to create smart and useful hydrological webtools.

References

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