Geo-MHYDAS : A discretization procedure of cultivated landscapes for distributed hydrological modelling

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Rabotin, M., Lagacherie, P., Colin, F., Moussa, R., Voltz, M.

LISAH
Laboratoire d'étude des Interactions
Sol - Agrosystème - Hydrosystème
www.umr-lisah.fr

Corresponding author email
rabotin@supagro.inra.fr

Purpose

Landscape discretization is of major importance in distributed hydrological modelling.
Geo-MHYDAS is a GIS tool that allows to explicitely represent the landscape features, particularly the man-made ones.
The landscape discretizations that are produced include user-controlled delineated irregular, linear or areal units connected to each other along a tree-like structure.

Geo-MHYDAS includes three steps :
i) Processing, importation, creation and modifications of the geographical objects which are considered in the modelling,
ii) creation of the areal and linear units for hydrological modelling by a "selective cleaning" procedure after overlay that preserve as much as possible the object limits,
iii) building of an oriented topology between irregularly-shaped areal units and linear units which allows the routing of the simulated water flows.

Software structure

Geo-MHYDAS was developped using GRASS (Geographic Ressources Analysis Support System), an open source GIS (Geographical Information System) software package. It provides for the management of topological vector data as well as support for vector network analysis in an environment able to create geomatic algorithms.

The Geo-MHYDAS procedure is divided into independant GRASS scripts developped using Shell and Perl languages. Launching is possible in an interactive graphical mode or a batch mode to automate the whole procedure.

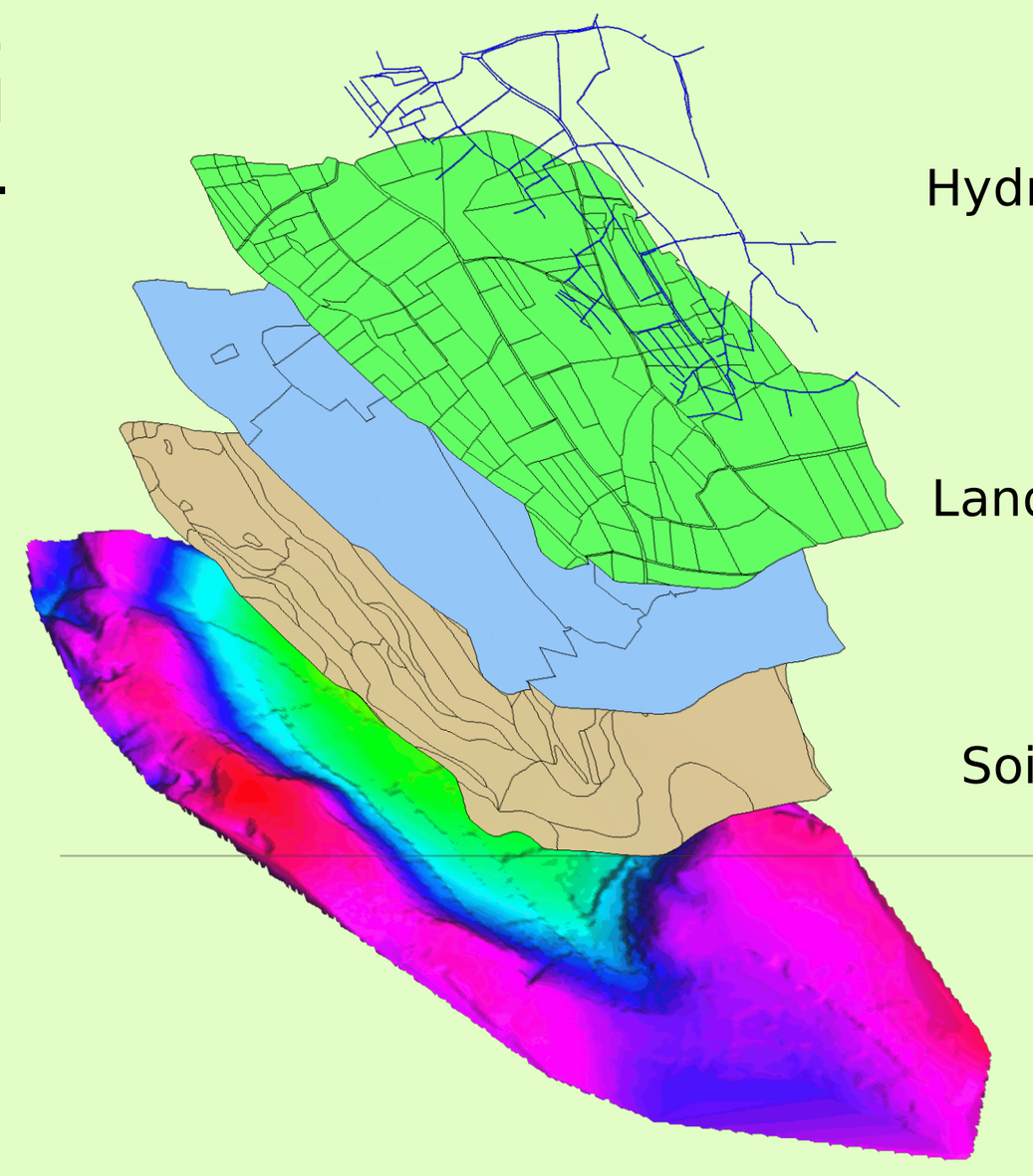
Thanks to the GRASS libraries, the input spatial data required by Geo-MHYDAS can provide in a great variety of formats (ESRI shapefiles, grid raster, OSGEO standards...).

http://grass.itc.it/

First step : processing the geographical objects

- Importing, creating and then processing the geographical objects whose limits are considered as hydrological discontinuities in the model.
- These limits can be either natural ones (sub-catchments limits), soil and geological limits, or man-made ones like field boundaries or ditches.
- There is no restriction on the number of limit types that can be considered at this step.

Objects



Specific tasks are availables to manage these datas :

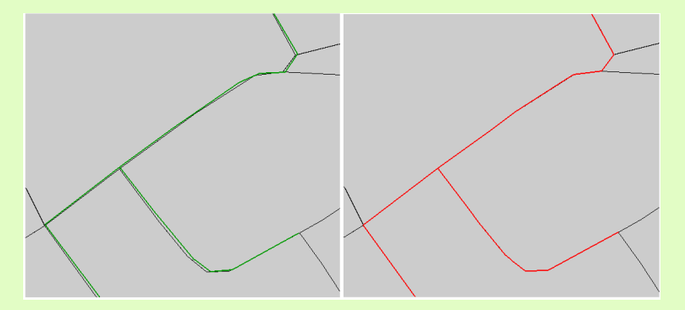
Steps	Tasks	Script Name	Description	Compulsory/optional
Processing geographical objects	*Verification task*	m.network	Hydrologic network validation	compulsory
	Building of new objects	m.sbw	Subwatershed creation	optional
	Modification of objects	m.dispolyg	Dissolving small areal features	optional
		m.disline	Dissolving small linear features	optional
		m.segline	Splitting linear features	optional
		m.douglas	Generalizing areal boundaries	optional
		m.modifyline	Extending or truncating linear features	optional
		m.snaplp	Adjusting geometry of linear features	optional

Adding more vector data objects is possible ...

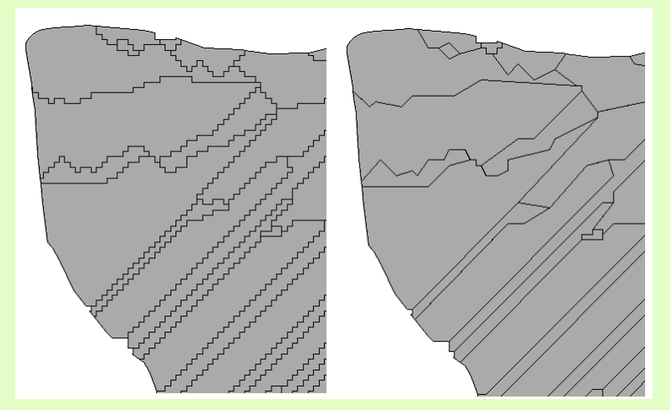
Some examples of procedures

Dissolving small areal features

Snap linear features on polygon boundaries



Boundaries generalization by Douglas Peuker algorithm



Second step : hydrologic units creation

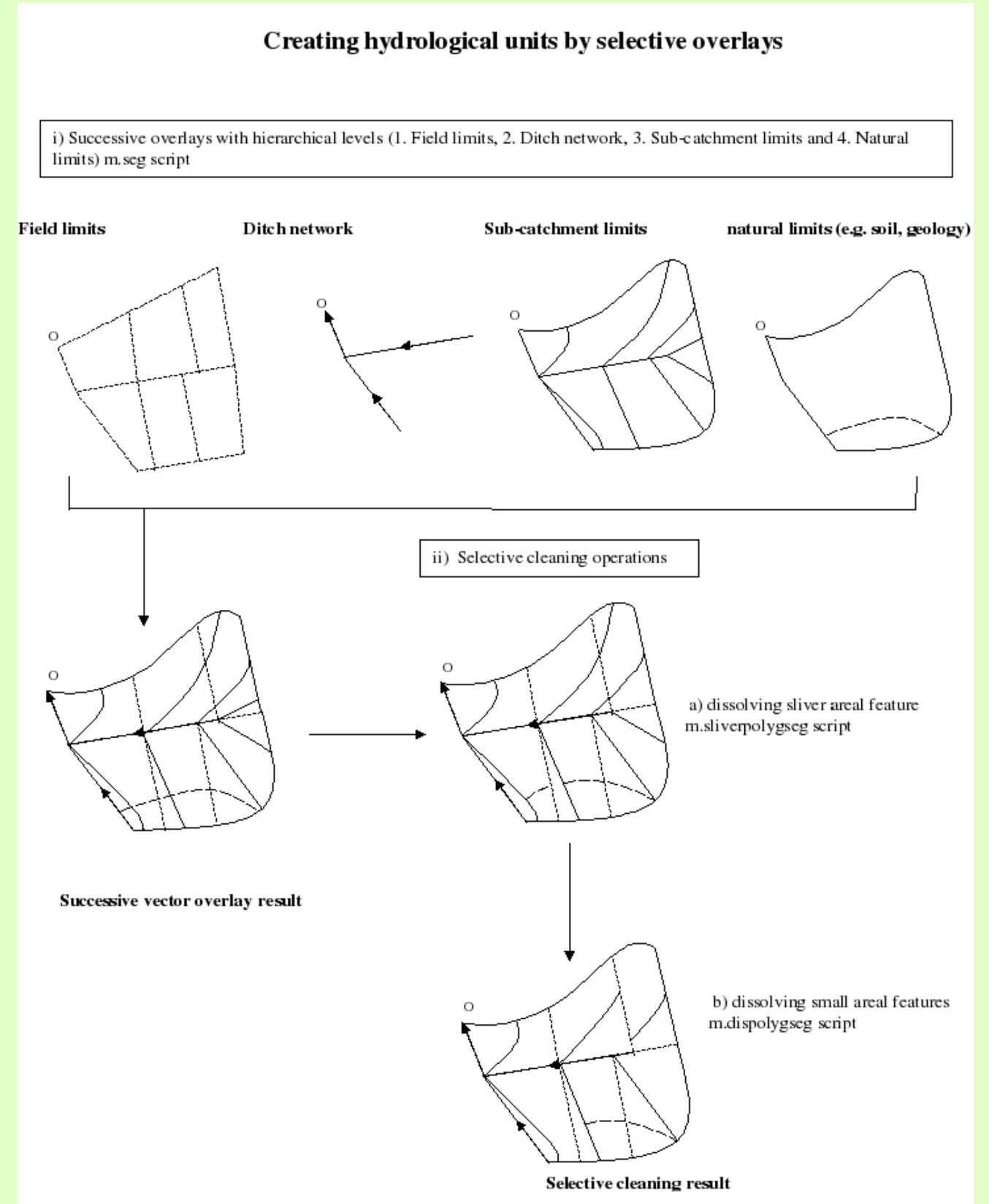
These hydrologic units must take into account the object limits while having sizes and shapes that remain compatible with the application of the water flow functions of the hydrologic model.

Procedure :
i) Overlay the objects vector data with a pre-defined order of importance,
ii) Merging the overlay-produced units considered too small or badly shaped according to thresholds.

The order of importance of geographical objects orients the choice of limits that must be removed in order to merge the deleted units with their neighbours

Main tasks :

Steps	Tasks	Script Name	Description	Compulsory/optional
Creating hydrological units by overlays and selective cleaning	*Successive overlays*	m.seg	Overlaying geographical objects	compulsory
		m.colseg	Join attribut columns operations	optional
	Selective cleaning	m.dispolygseg	Selective dissolving small areal features	optional
		m.sliverpolygseg	Selective dissolving sliver areal features	optional
	Units extraction	m.extractlineseg	Linear units extraction	compulsory



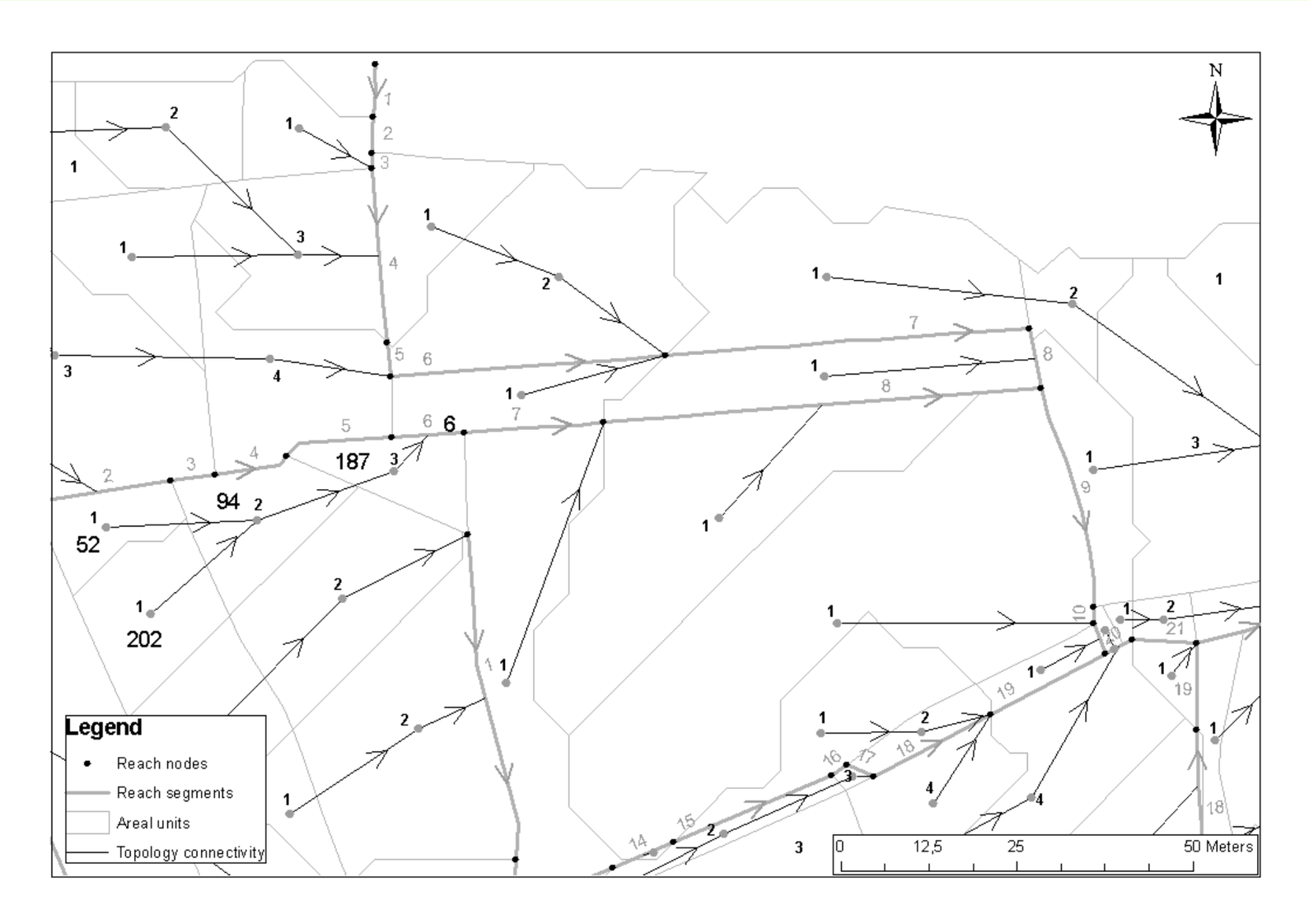
Third step : oriented topology calculation

- Building an oriented topology that allows the routing of simulated water flows across the landscape.
- Able to build an oriented rooted tree from irregularly shaped units.
- Topology connection between linear to linear units, areal to areal units and then areal to linear units.

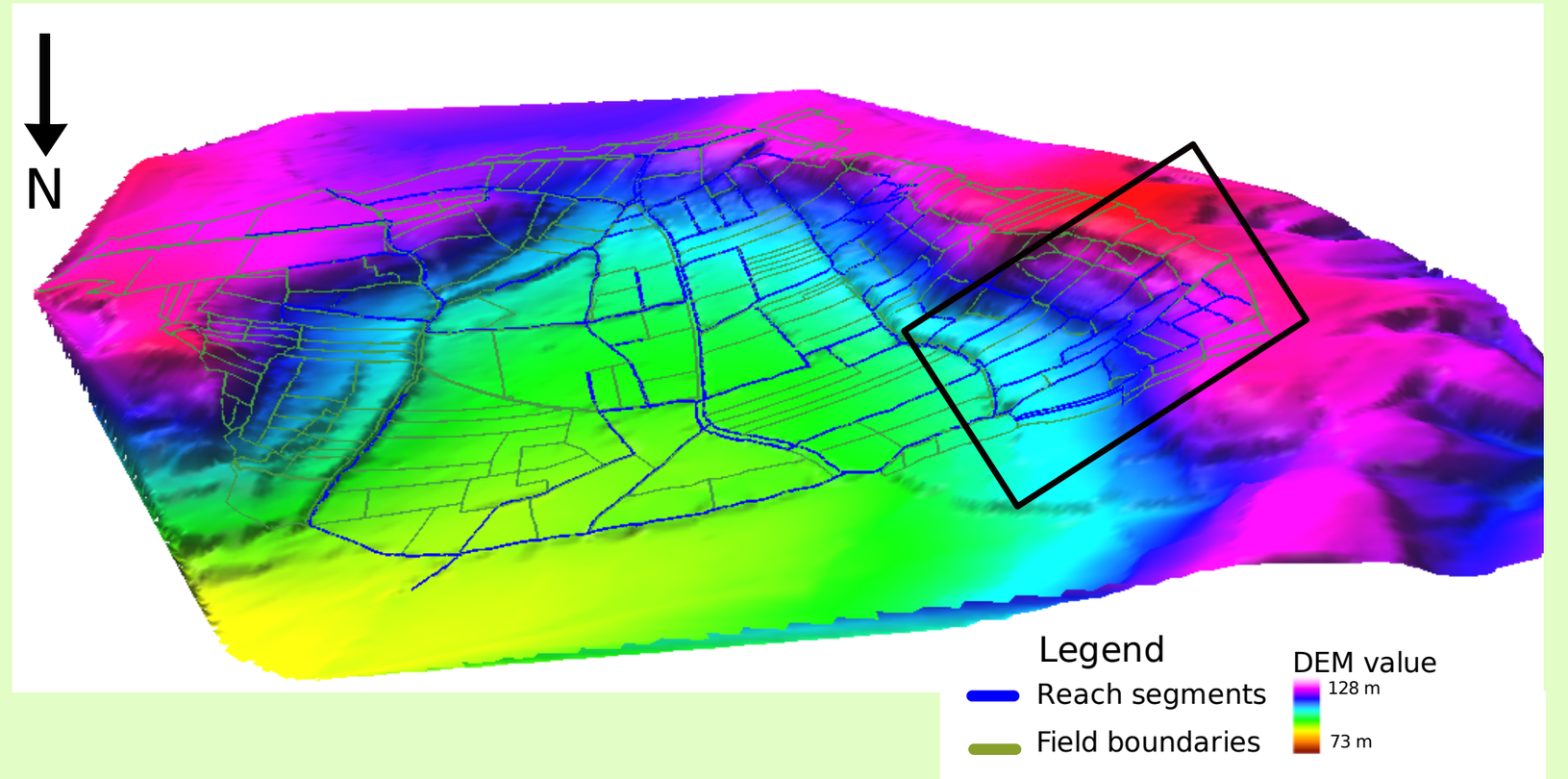
Topological relations between hydrologic units are characterized by a set of parameters (downstream unit, process order, distance to the neighboring unit, slope ...)

Main tasks

Steps	Tasks	Script Name	Description	Compulsory/optional
Building Oriented topologies of hydrological units		m.toporeach	Building oriented topology for hydrographic network	compulsory
		m.toposu	Building oriented topology for hydrological units	compulsory



Numbers in grey colors are process order parameter
Numbers in black color are unit identifiers



ID	UpNode	DownNode	LowRS	LENGTH	Slope	ProcessOrd
1	1	2	116	50,7415	0,0079	35
2	3	4	117	7,5811	0,1284	1
3	141	142	121	58,9715	0,0078	32
4	6	198	122	52,9411	0,0074	7
5	5	6	4	27,6394	0,0124	6
6	7	8	172	10,2748	0,2282	6
7	9	10	51	6,4129	0,1492	3
8	199	66	52	25,5257	0,0027	1
9	200	201	40	30,7428	0,0102	4
10	11	12	185	26,9606	0,1836	16
11	13	14	126	29,4309	0,1155	5
12	15	16	124	11,9281	0,0684	13
13	17	13	11	17,2193	0,1395	4
14	18	19	175	20,5205	0,0242	7
15	20	21	42	8,9810	0,2395	5
16	22	23	89	26,7496	0,1305	1
17	145	15	12	47,2881	0,0623	12
18	24	25	156	27,9951	0,0321	7
19	150	144	125	40,3581	0,0033	2
20	26	27	105	8,2179	0,3272	8
...	...	...	...	...	...	...

Linear units topology parameters in attribute table

ID	Area	Slope	FlowCode	FlowID	FlowDistance
1	431,900	0,145	S	44	46,6997
2	326,068	0,163	S	3	26,3543
3	491,269	0,228	R	80	11,7139
4	223,846	0,290	R	181	11,8242
5	307,295	0,195	S	118	32,9273
6	531,679	0,219	S	10	37,8064
7	176,549	0,207	S	8	35,9933
8	889,103	0,205	R	106	24,9530
9	917,527	0,241	S	46	34,3359
10	360,528	0,182	S	142	62,0681
11	160,443	0,279	S	13	34,3279
12	168,756	0,162	S	142	55,8652
13	1210,552	0,279	R	35	11,4593
14	3024,389	0,014	R	116	49,4983
15	8556,270	0,010	S	30	70,1513
...	...	...	...	...	...
52	182,272	0,167	S	94	21,6820
...	...	...	...	...	...
94	297,588	0,196	S	187	21,1445
...	...	...	...	...	...
187	201,063	0,208	R	6	7,1846
...	...	...	...	...	...
202	336,240	0,149	S	94	20,2100
203	918,984	0,100	S	201	21,1289
...	...	...	...	...	...

Areal units topology parameters in attribute table

Example of modelisation

Purpose

The distributed hydrologic model MHYDAS was applied using as input i) a landscape discretization provided by Geo-MHYDAS and ii) a classical landscape discretization that does not consider any man-mades features.

Data

Roujan catchment located in southern France, 60 km west of Montpellier.
Mainly covered by vineyards.
Drainage network formed by man-made ditches.
Outflow is event- dominated.

The MHYDAS model

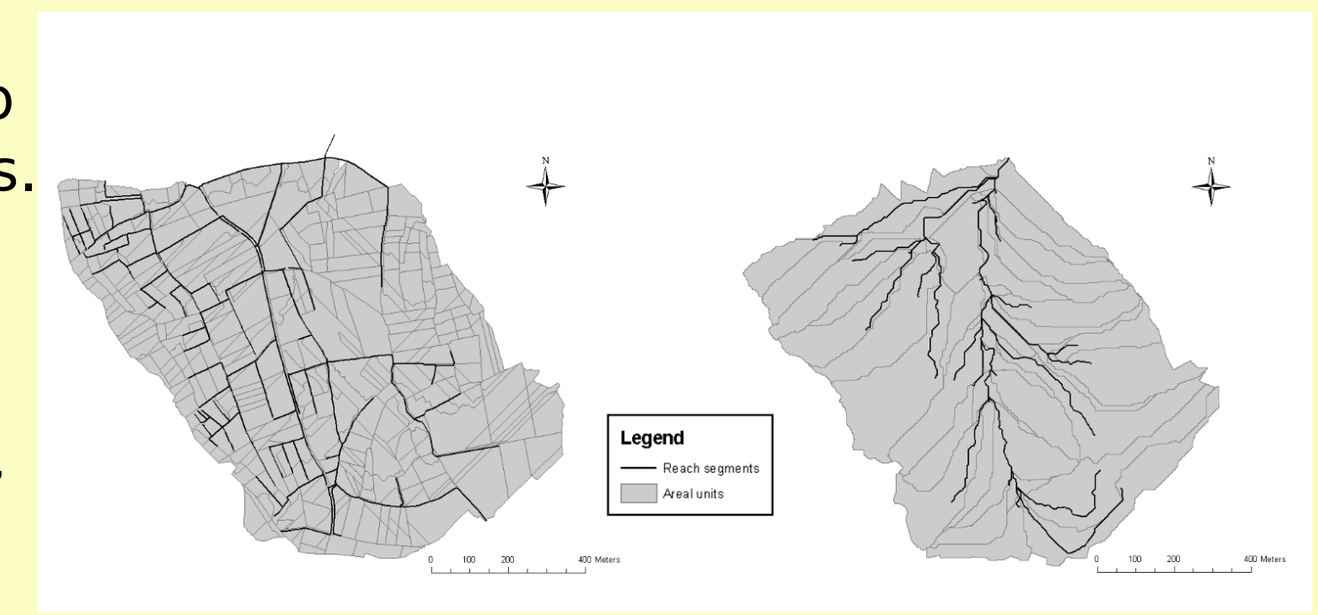
mhydas
Distributed hydrologic model for agrosystems

Physically based rainfall-runoff catchment model.
Catchment is series of interconnected units.
Topology connects areal units and linear units together.
Full details on MHYDAS in Moussa et al. (2000) and Moussa et al. (2002).

Landscape discretization

By Geo-MHYDAS :
Input datas : land use, soil map and reach network coverages. DEM 2 x2 m resolution.

Results : 464 areal units after selective cleaning and overlay, 246 linear units.

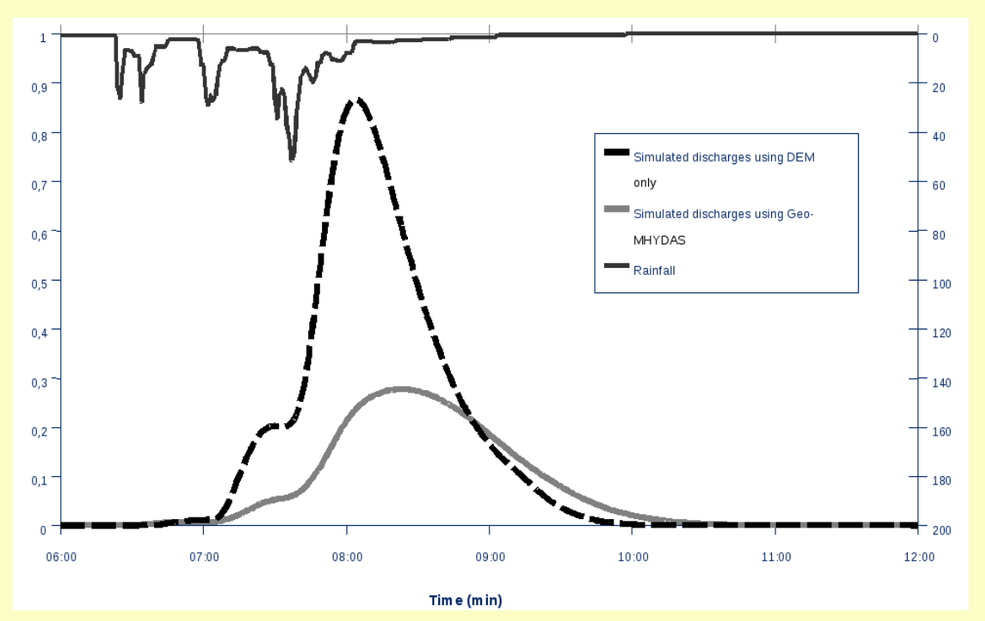


Classical method by ArcHydroTools on Arcview 3.2 :
Input data : DEM 2 x 2 resolution.

Results : 43 sub watersheds, 51 reaches.

Simulated discharges

The two simulations only differed in their landscape discretizations



	Reference simulation	Simulation using DEM only
Total runoff (mm)	1.64	3.34
Runoff Coefficient (%)	7	13
Peak discharge (m3/s)	0.28	0.87
Lag-time (min)	60	39

Discretization has great impact on simulated discharges.
Much runoff and Peak discharge three times higher on "DEM only" discretization.

Conclusion

Geo-MHYDAS allows a more precise representation of landscape features, particularly the man-made ones that are known to have a great impact on water and mass flows across the landscape.

Geo-MHYDAS can be handled by a non-experienced GIS users.

Although Geo-MHYDAS was initially developped to provide input files to a specific hydrologic model (MHYDAS) , it can be potentially useful for a wide range of hydrologic models built on the same principle, i.e., having a water production function for surface units and a routing procedure to calculate a final discharge at the outlet.

Beside, further versions of Geo-MHYDAS will be developped in the framework of the OpenFluid project to extend the functionalities of landscape representations as new landscape processes (e.g. erosion) will be integrated in the landscape modelling.

References

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Moussa R, Voltz M, Andrieux P, Lagacherie P, 2000. Hydrological modelling of a farmed mediterranean catchment. In 'Mediterranean storms', Edited by Claps P and Siccardi F, European Geophysical Society Plinius Conference'99, 377-386.

Moussa R, Voltz M, Andrieux P., 2002. Effects of the spatial organization of agricultural management on the hydrological behaviour of a farmed catchment during flood events. Hydrological Processes 16 : 393-412.

LISAH
Laboratoire d'étude des Interactions
Sol - Agrosystème - Hydrosystème
INRA
IRD Institut de recherche pour le développement
Montpellier SupAgro

UMR LISAH
INRA - IRD - Montpellier Supagro
2, place Viala
34060 Montpellier Cedex 1
FRANCE

http://grass.itc.it/
mhydas
OpenFLUID
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