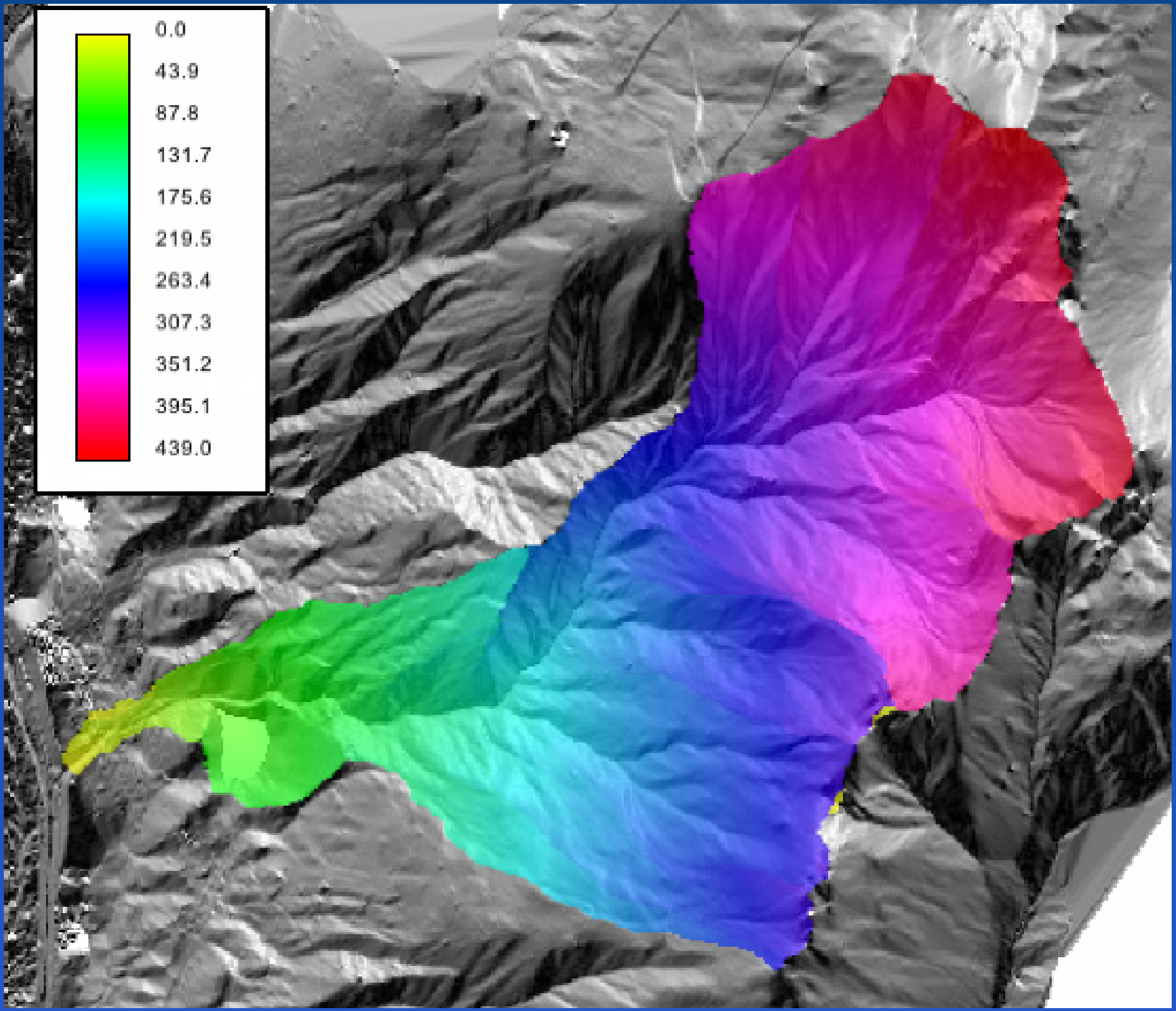
Analisi Geomorfologica in JGRASS
Il pacchetto Horton Machine



Silvia Franceschi
Andrea Antonello

OBIETTIVI

- Analisi geomorfologica su DTM
- Calcolo di variabili ed indici geomorfologici
- Fondamentalmente capire la struttura di un bacino idrografico

HORTONMACHINE: THE PURPOSE

It is developed with the purpose of giving some quantitative and qualitative instruments for knowing the morphology of catchments.

- Main applications are made in alpine catchments of various dimensions (from some km^2 to hundreds km^2)
- Applications are made with different type of DEM (IGM 20 metri, PAT 10 m, LaserAltimetric 2 m)

HORTONMACHINE: OUR WORK

Starting hypothesis is:

MORPHOMETRY $\longleftrightarrow$ EROSION PROCESSES

Taking into account of this hypothesis the purpose of the work is to analyse the erosion processes, incision processes of the network and the possibility of landslides. This is done considering that the main geomorphological processes in a catchment are:

- Diffusive erosion on the hillslopes
- Network's incision processes
- Landslides
- Sediment transport in the channels

HORTONMACHINE: THE HISTORY

At the beginning it was a package of stand alone routines operating system independently, written in C using the FluidTurtle libraries and their input/output defined formats. The visualization of the calculated matrices was made with other graphical programs or with Mathematica;

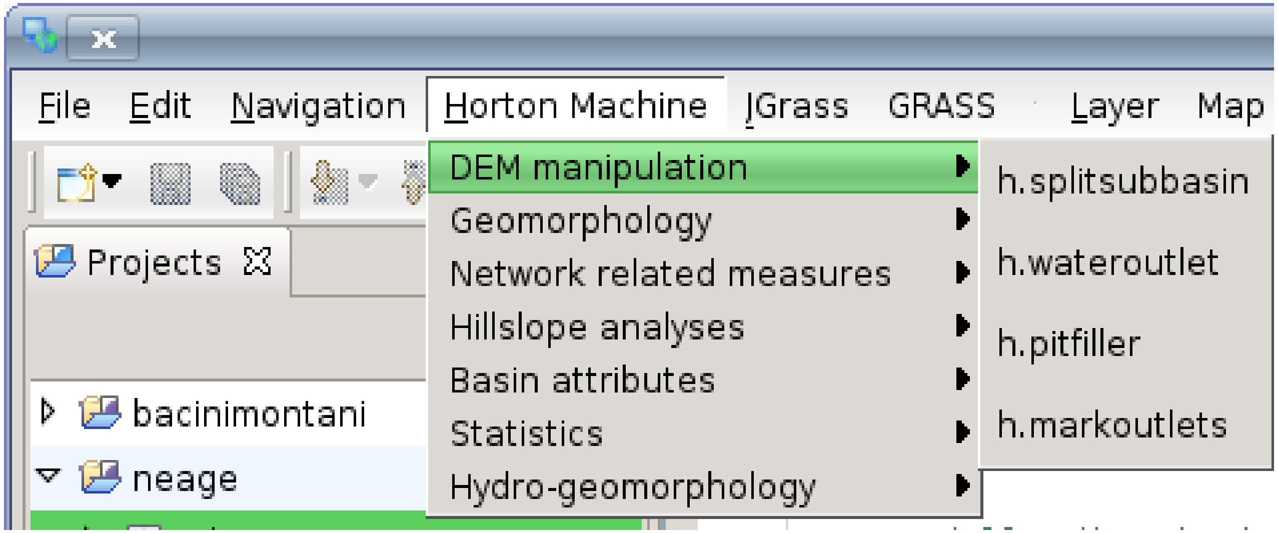
The second step was to integrate this routines in the GIS GRASS to have a direct graphical interface in TkTcl;

Nowadays with the JGrass development this routines are being rewritten in Java and completely integrated in the new GIS system with a new development model (OpenMI) and new graphical interface.

HORTONMACHINE:

The commands are divided in 7 categories:

- DEM manipulation



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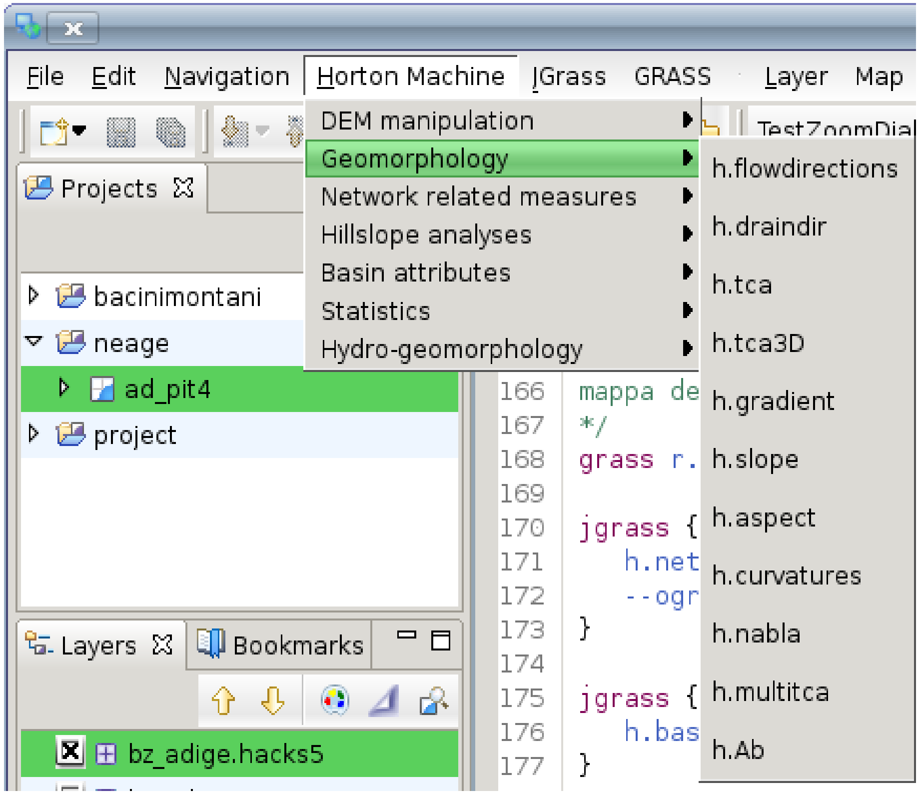

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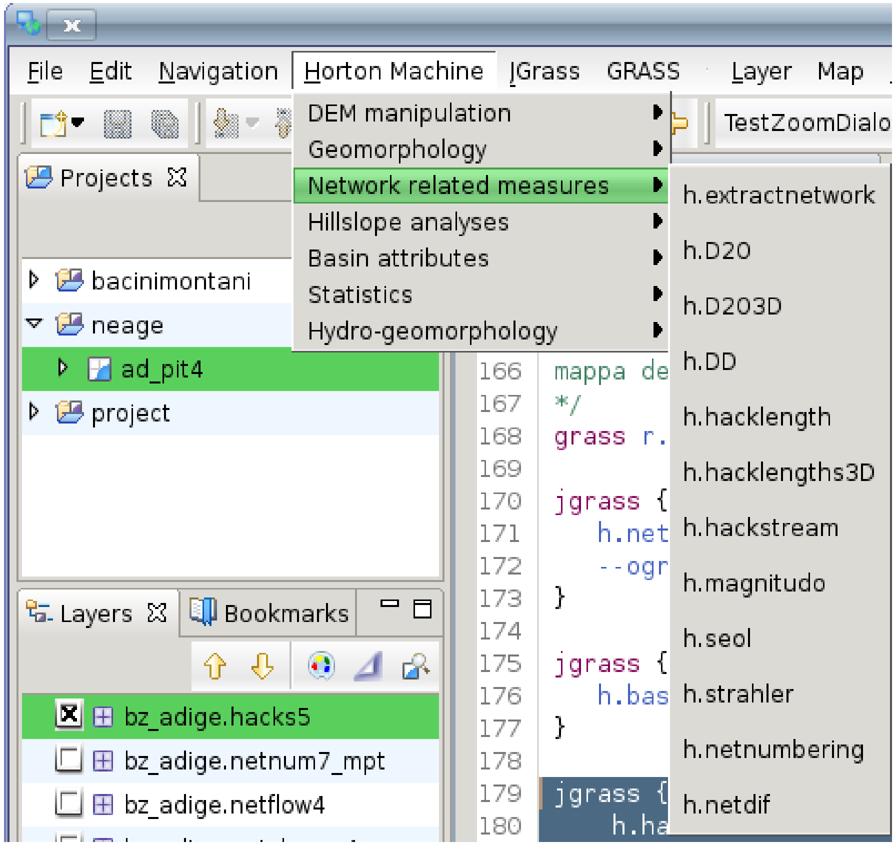
- Geomorphology
- Network related measures



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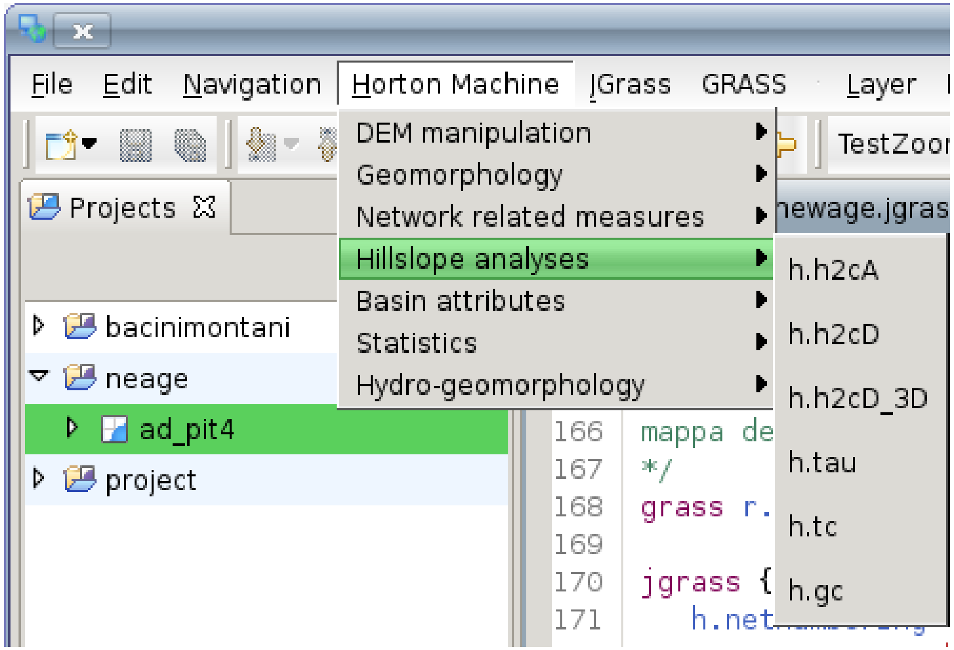

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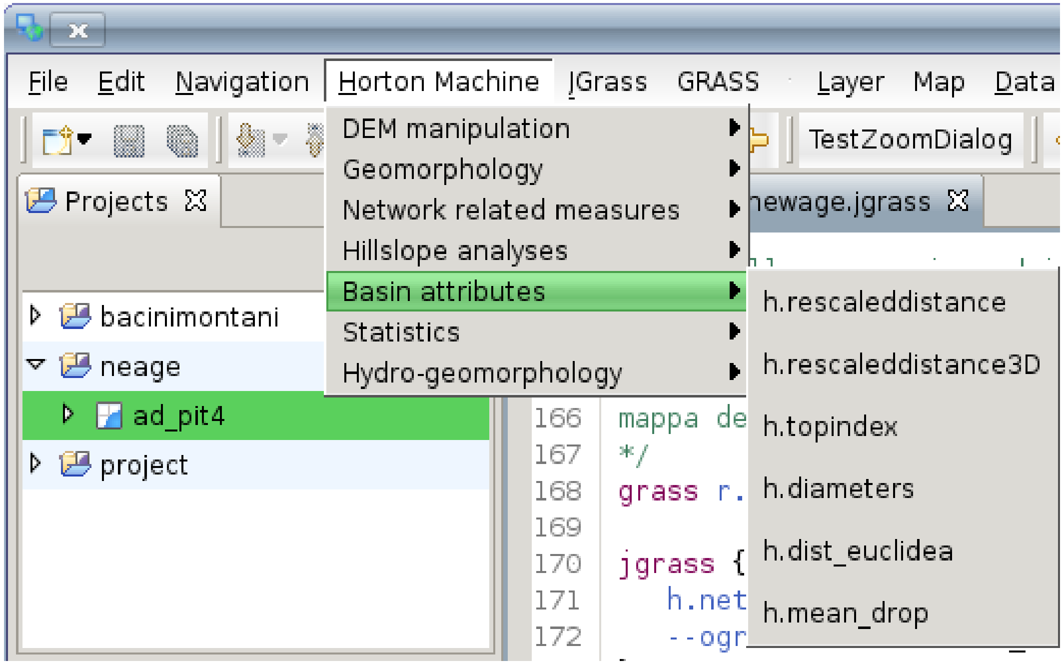
- Basin attributes



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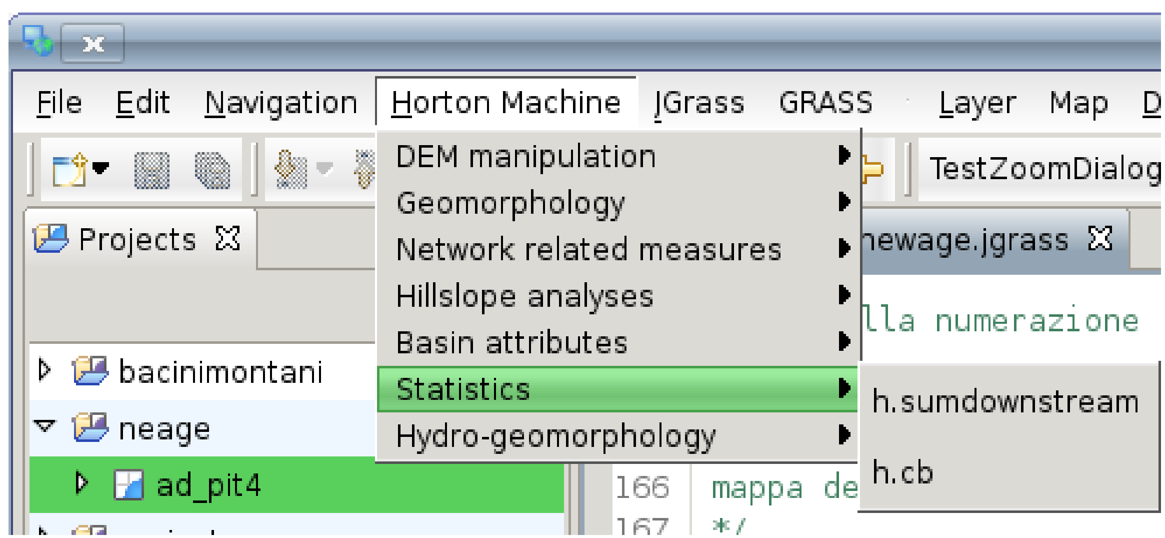

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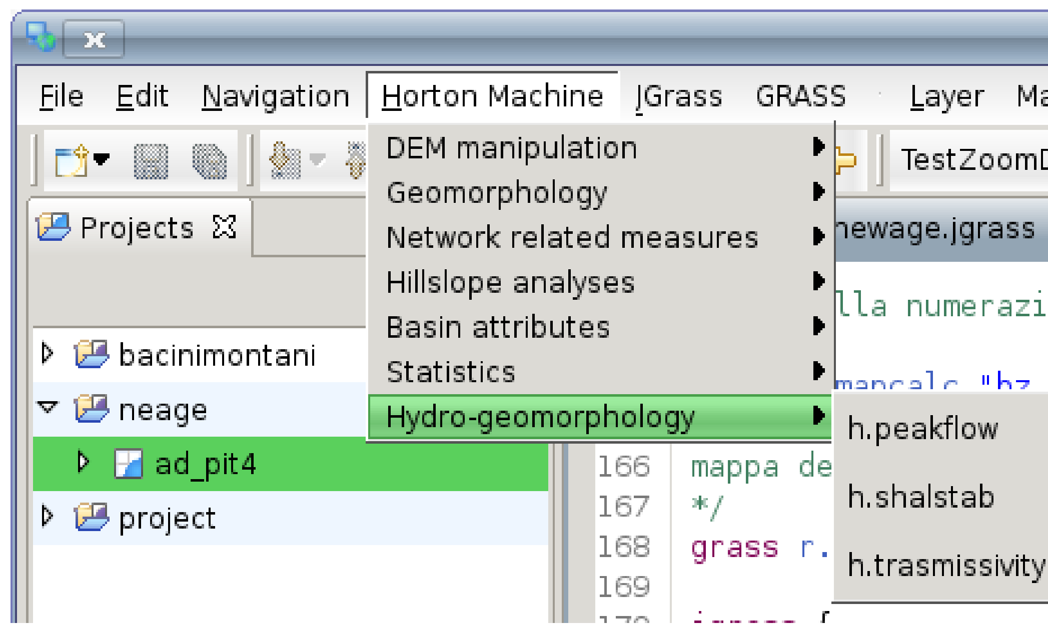
- Statistic
- Hydro-geomorphology



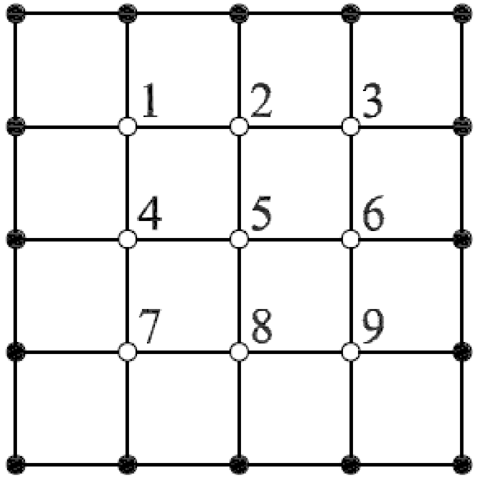
MORPHOLOGY

The topography is represented by a bivariate continuous function $z = f(x,y)$ and with continuous derivative up to the second order almost everywhere.

DIGITAL ELEVATION MODELS (D.T.M.)

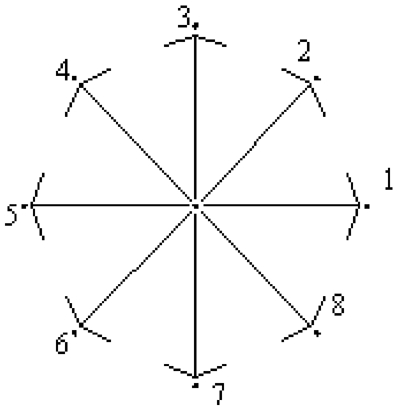
The representation on a regular rectangular grid of the data constitutes the most common and most efficient form in which the terrain digital data can be found.

The data in this raster form usually is made by reporting the vertical coordinate, z, for a subsequent series of points, along an assigned regular spacing profile.



HYPOTHESIS ON DEM:

- data are significant
- regular squared grid
- 8 direction topology



PRELIMINARY OPERATIONS

import in JGrass the starting DEM which we want to analyse

↓

definition the working region

↓

PRELIMINARY OPERATIONS

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pit detection

PRELIMINARY OPERATIONS

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definition of the drainage directions

→ D8 (maximum slope)

→ D8 with correction (correction on the direction of the gradient)

PRELIMINARY OPERATIONS

import in JGrass the starting DEM which we want to analyse

↓

definition the working region

↓

pit detection

↓

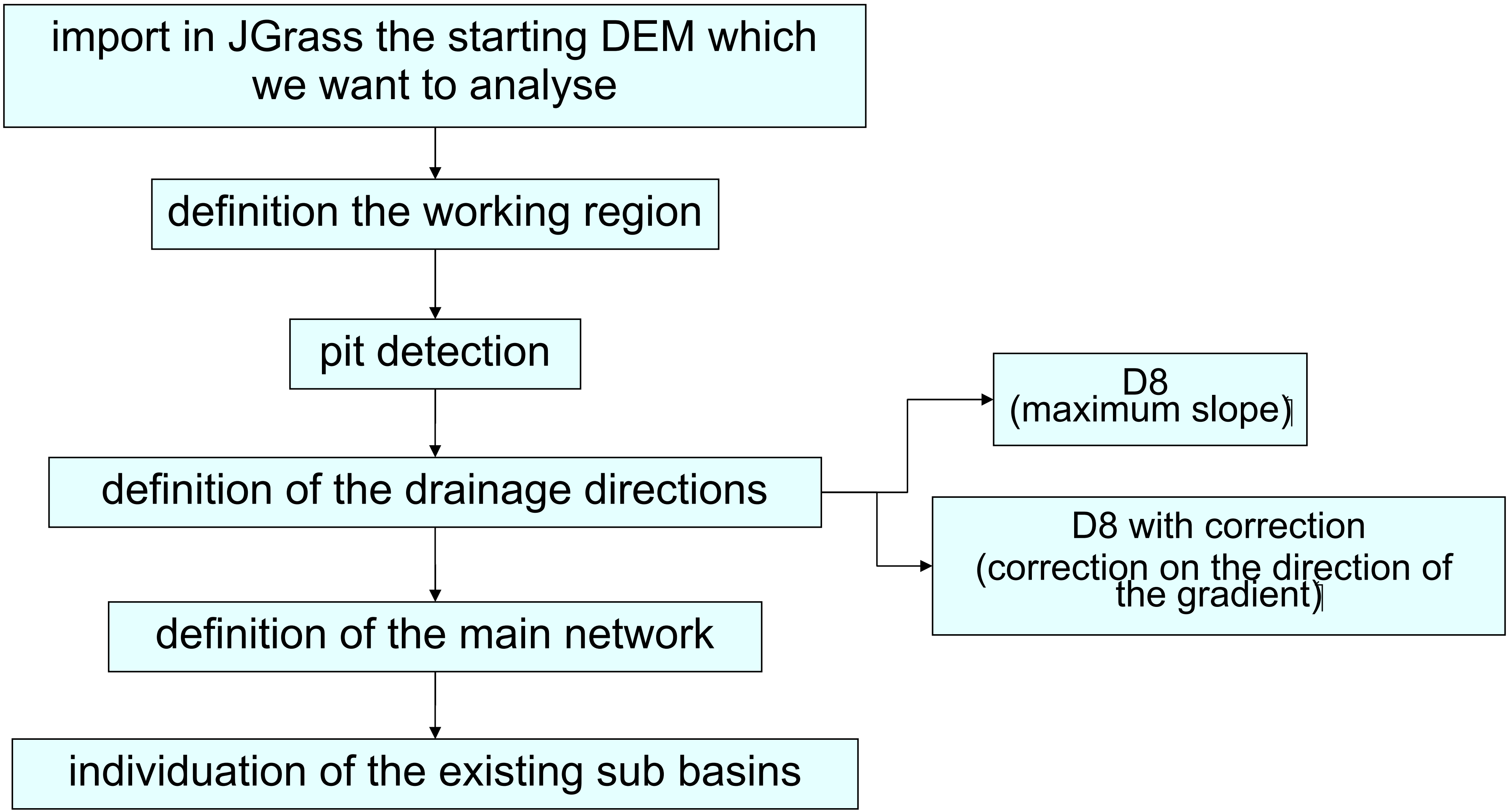
definition of the drainage directions

- D8 (maximum slope)
- D8 with correction (correction on the direction of the gradient)

↓

definition of the main network

PRELIMINARY OPERATIONS



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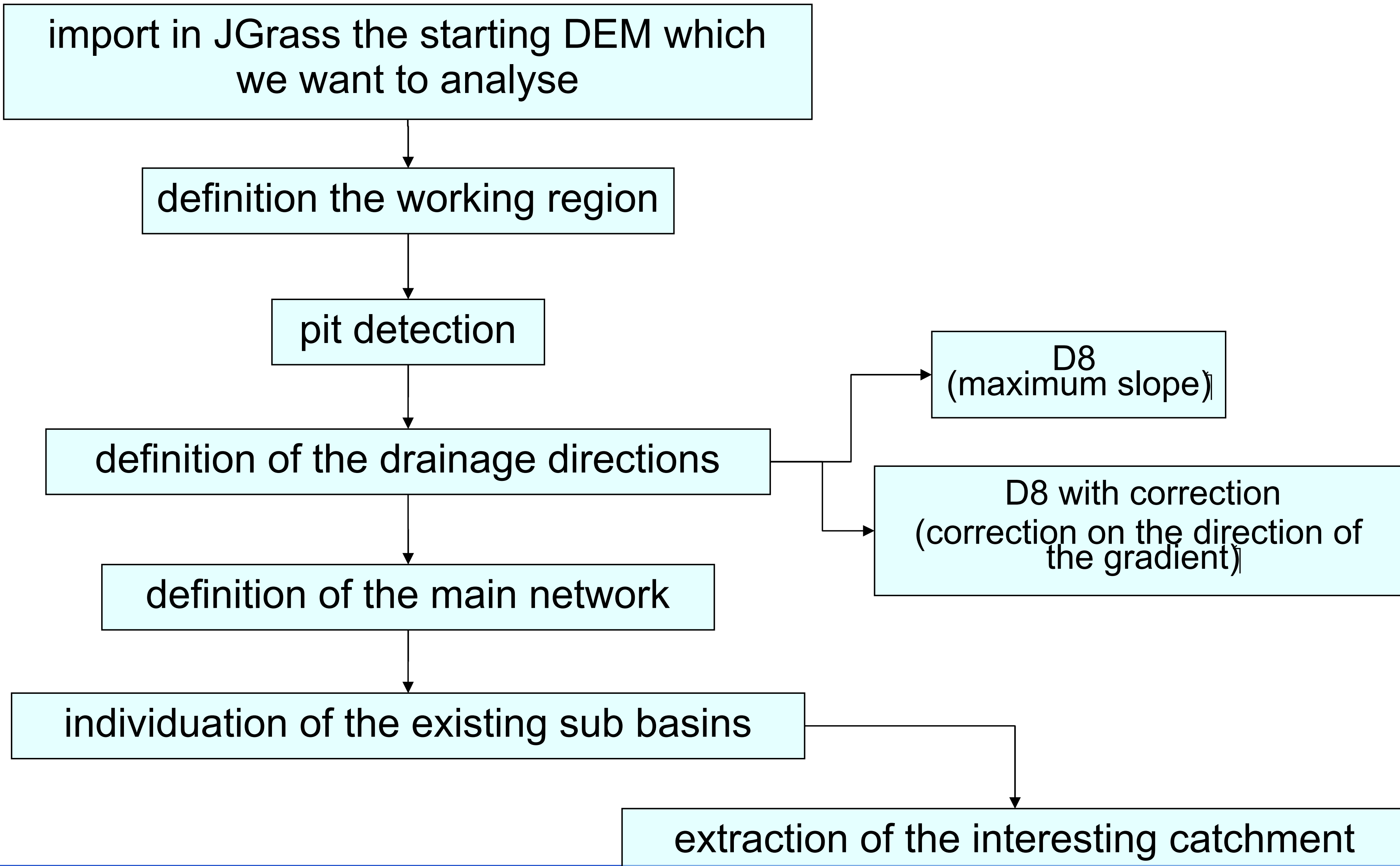


DERIVED ATTRIBUTES:

Local slope
(h.slope)

Local curvature
(h.curvatures o h.nabla)

Total contributing area
(h.tca, h.multitca)

Catchment divide distance
(h.hacklength)

Distance to outlet
(h.distance2outlet)

………...

FIRST STEP: DEPITTING THE DEM

The first operation to do is to fill the depression points present within a DEM so that the drainage directions can be defined in each point.

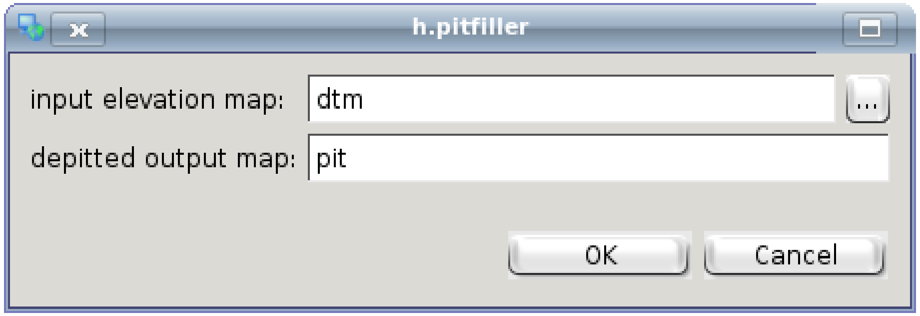
Observations on this topic demonstrate that this calculation addresses lesser than the 1% of the data and that usually this depressions are given by wrong calculation in the DEM creation phase and that in fact they are not real depressions.

The command used to fill the depressions is:

h.pitfiller

based on the Tarboton algorithm.

h.pitfiller

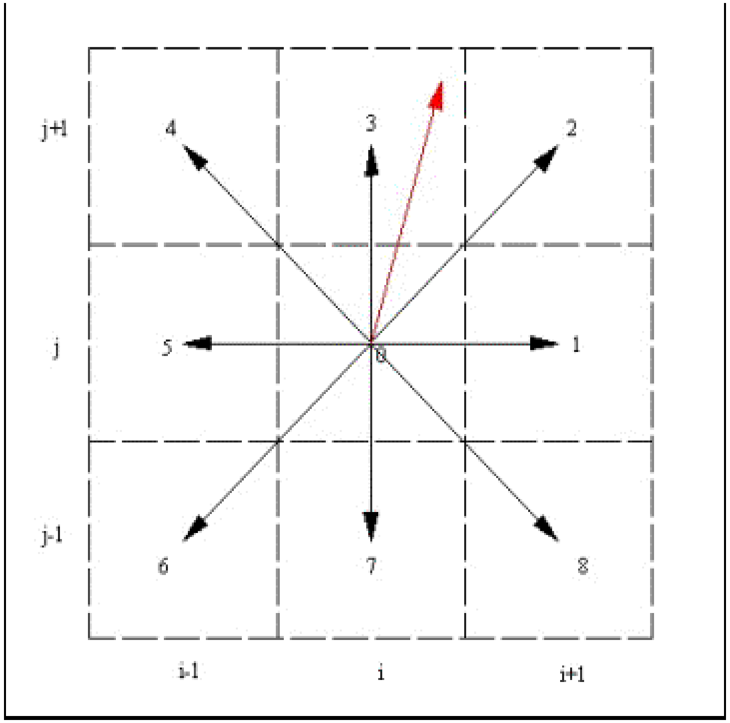


Fills the depressions following the Tarboton algorithm.

FLOW DIRECTIONS

They define how water moves on the surface in relation to the topology of the study region. Flow directions allow you to calculate the drainage directions.

Hypothesis: each DEM cell drains only in one of its **8 neighbours**, either adjacent or diagonal in the direction of the **steepest downward slope**.

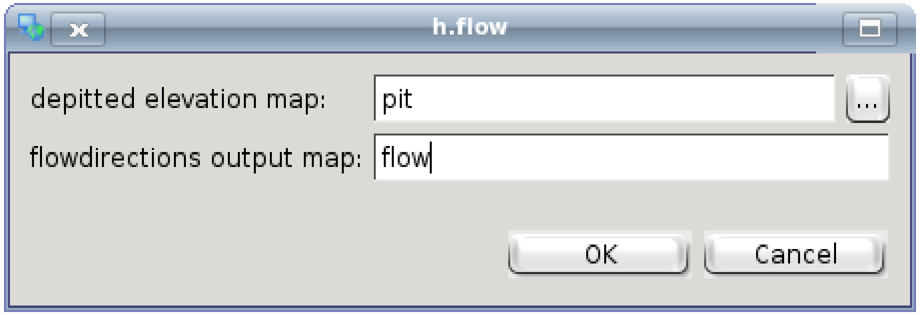


only 8 possible direction

in which direct the flux

this is a limit of modelling the natural flow

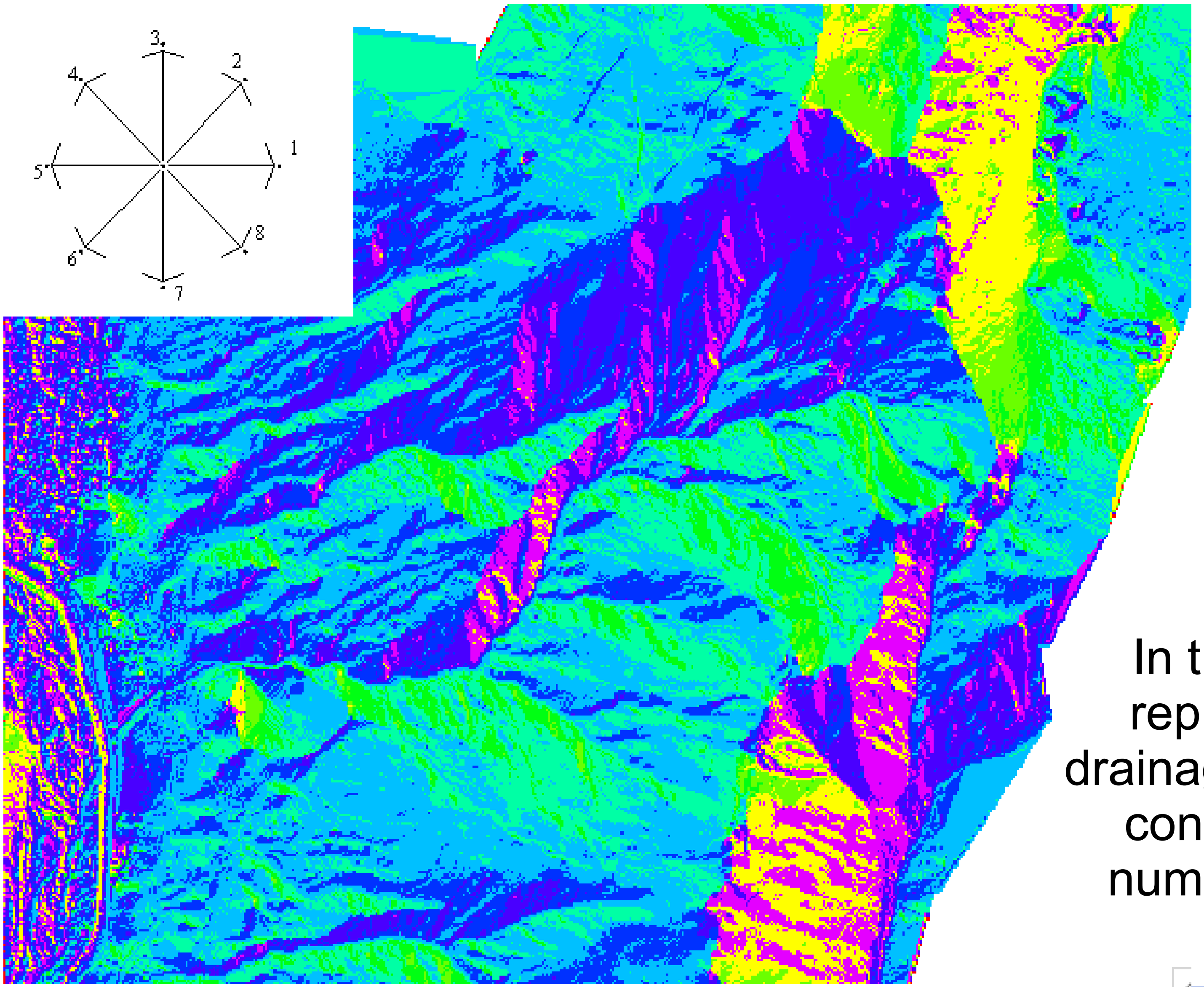
h.flowdirections



It calculates the flow direction in the direction of the steepest downward slope choosing for each DEM cell to one of its 8 neighbours.

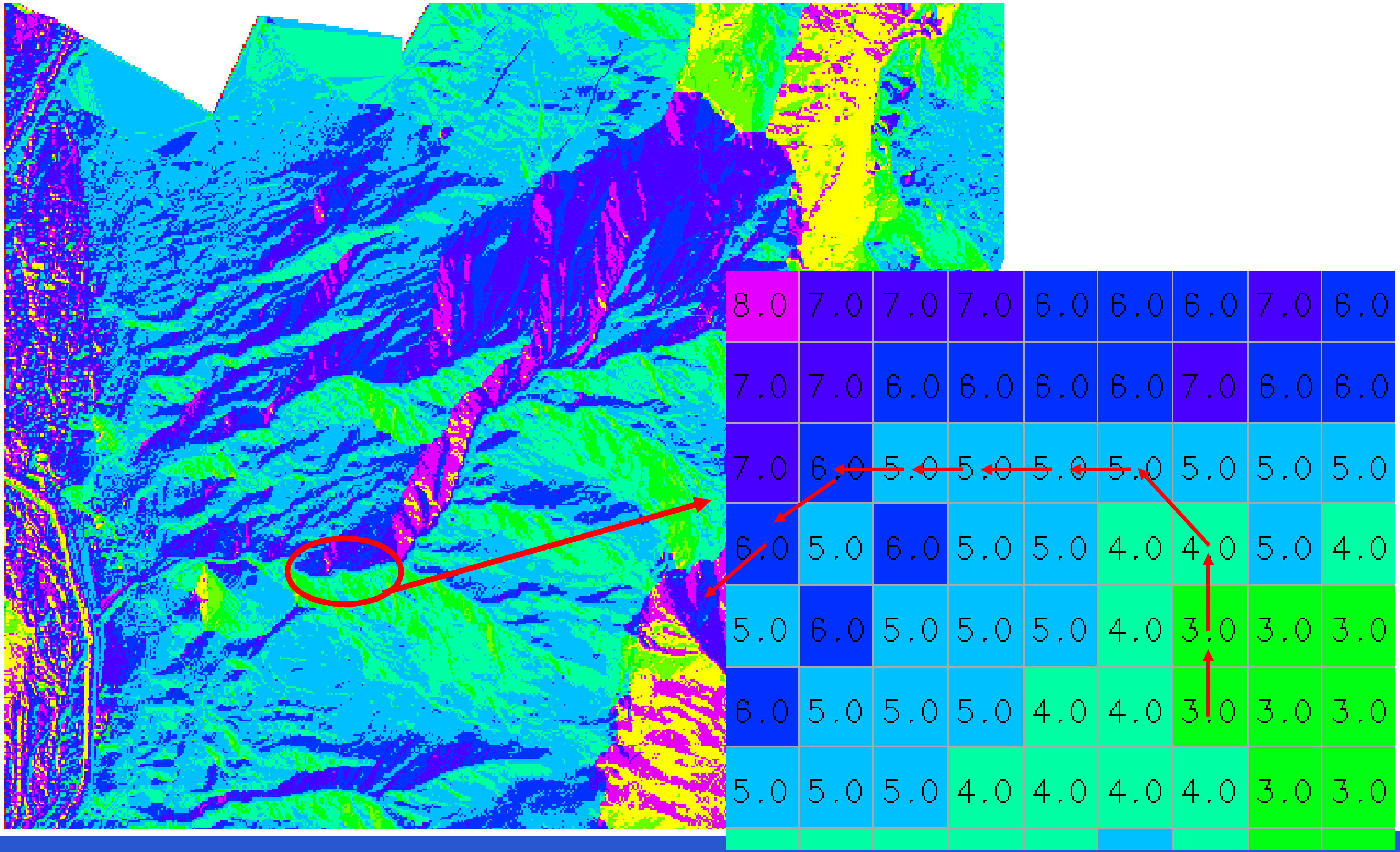
The flow directions convention numbers are from 1 to 8 where 1 is the east direction.

FLOW DIRECTIONS



In the map each colour represents one of the 8 drainage directions. The map contains the convention number of this directions.

FLOW DIRECTIONS



8.0	7.0	7.0	7.0	6.0	6.0	6.0	7.0	6.0
7.0	7.0	6.0	6.0	6.0	6.0	7.0	6.0	6.0
7.0	6.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6.0	5.0	6.0	5.0	5.0	4.0	4.0	5.0	4.0
5.0	6.0	5.0	5.0	5.0	4.0	3.0	3.0	3.0
6.0	5.0	5.0	5.0	4.0	4.0	3.0	3.0	3.0
5.0	5.0	5.0	4.0	4.0	4.0	4.0	3.0	3.0

A CORRECTION TO THE PURE D8 METHOD

Using the “pure” D8 method for the drainage direction estimation cause an effect of **deviation** from the real direction identified by the **gradients**.

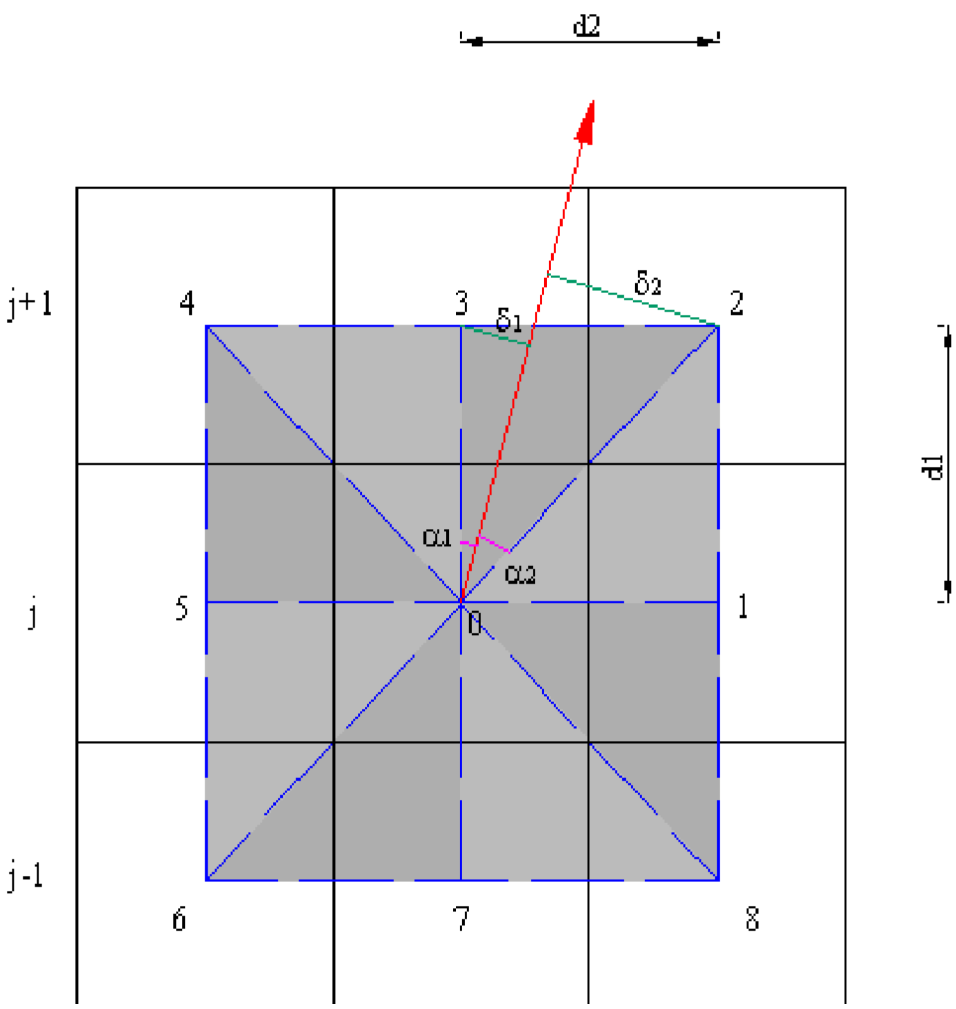
This algorithm calculates the drainage direction minimizing the deviation of the flow from the real flux direction. The deviation is calculated beginning from the pixel at highest elevation and going downstream.

The deviation is calculated with a triangular construction and can be expressed as **angular deviation** (method D8-LAD) or as **transversal distance** (method D8-LTD)

The *lambda* parameter is used to assign a weight to the correction made to the drainage directions.

This method has been developed by S. Orlandini

h.draindir



LAD method:

angular deviation check on alpha

LTD method:

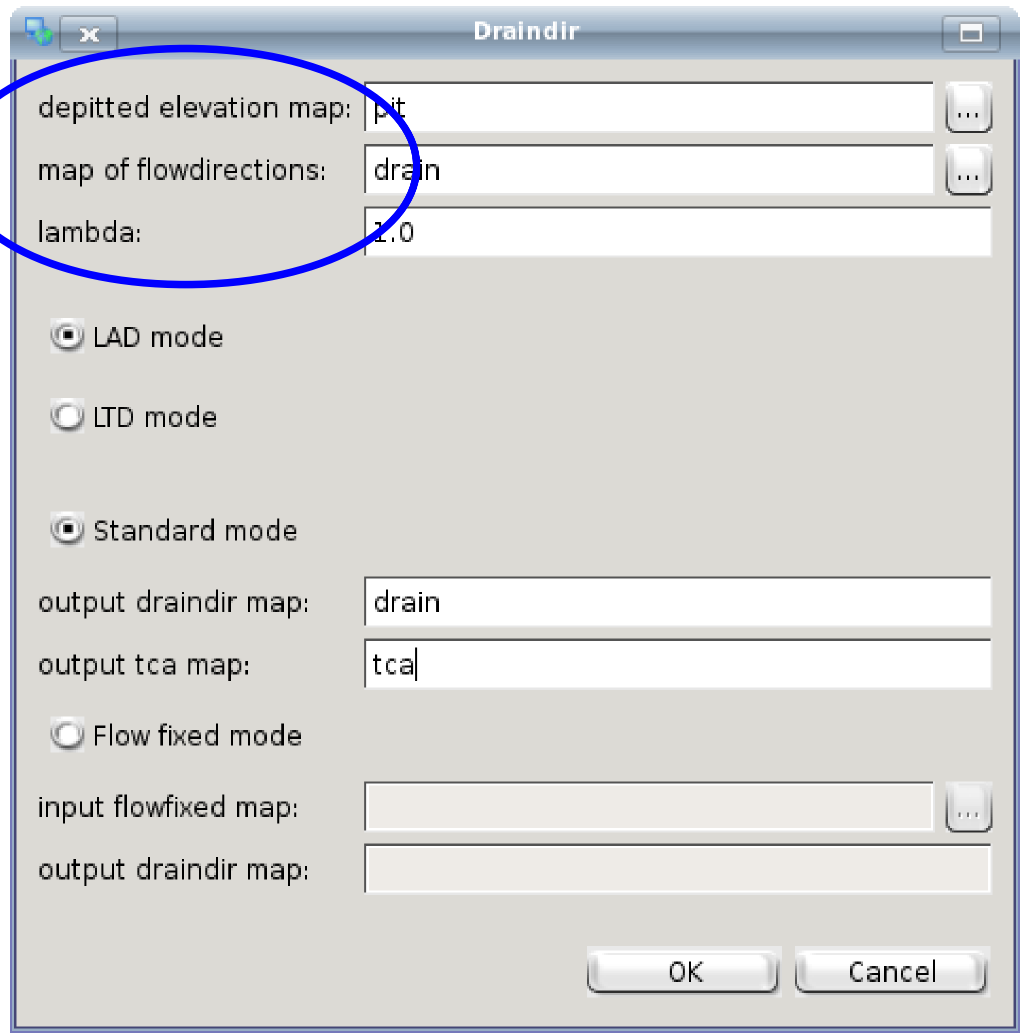
transversal deviation check on delta

The deviation is cumulated from higher pixels down-hill and the D8 drainage direction is redirected to the real direction when the value is larger than an assigned threshold.

If λ = 0 the deviation counter has no memory and the pixels up-hill do not affect the choice.

THE NEW DRAINAGE DIRECTIONS AND THE NEW TCA

STANDARD METHOD



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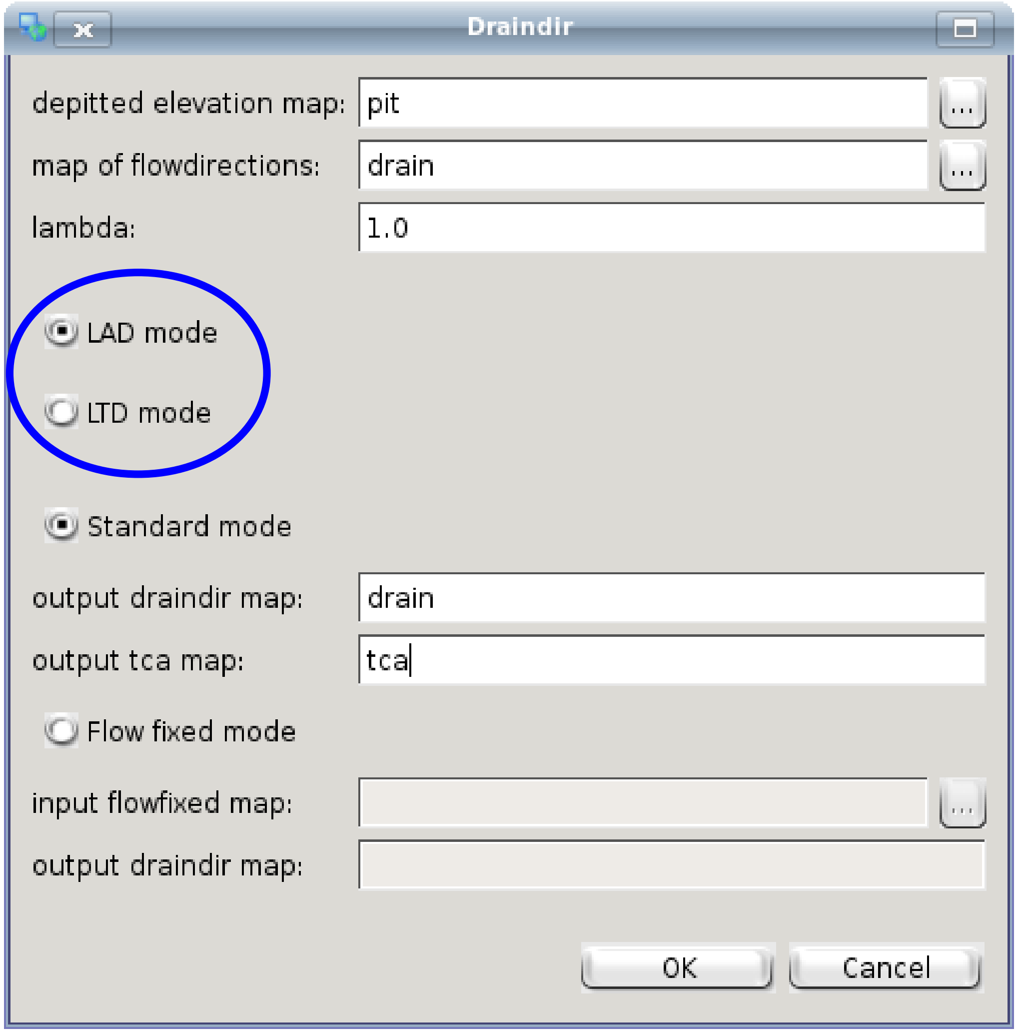

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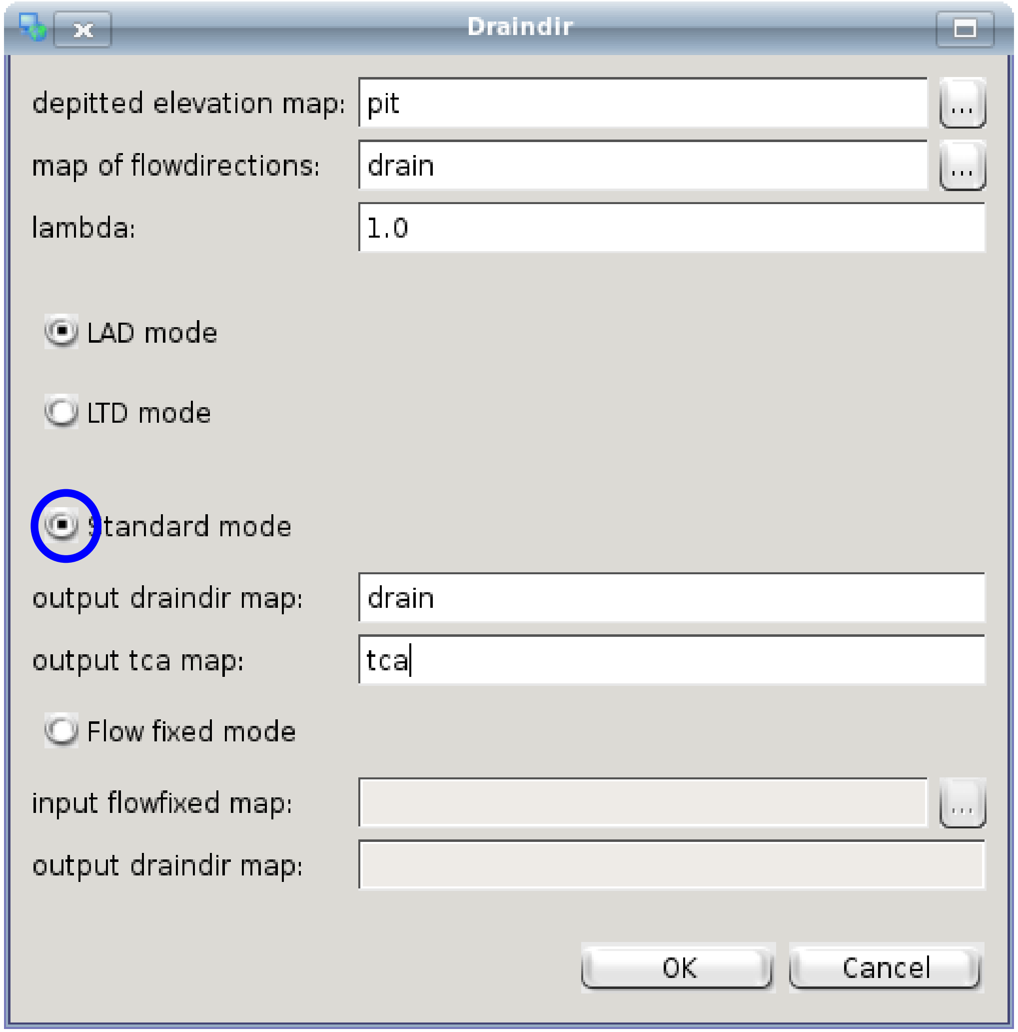

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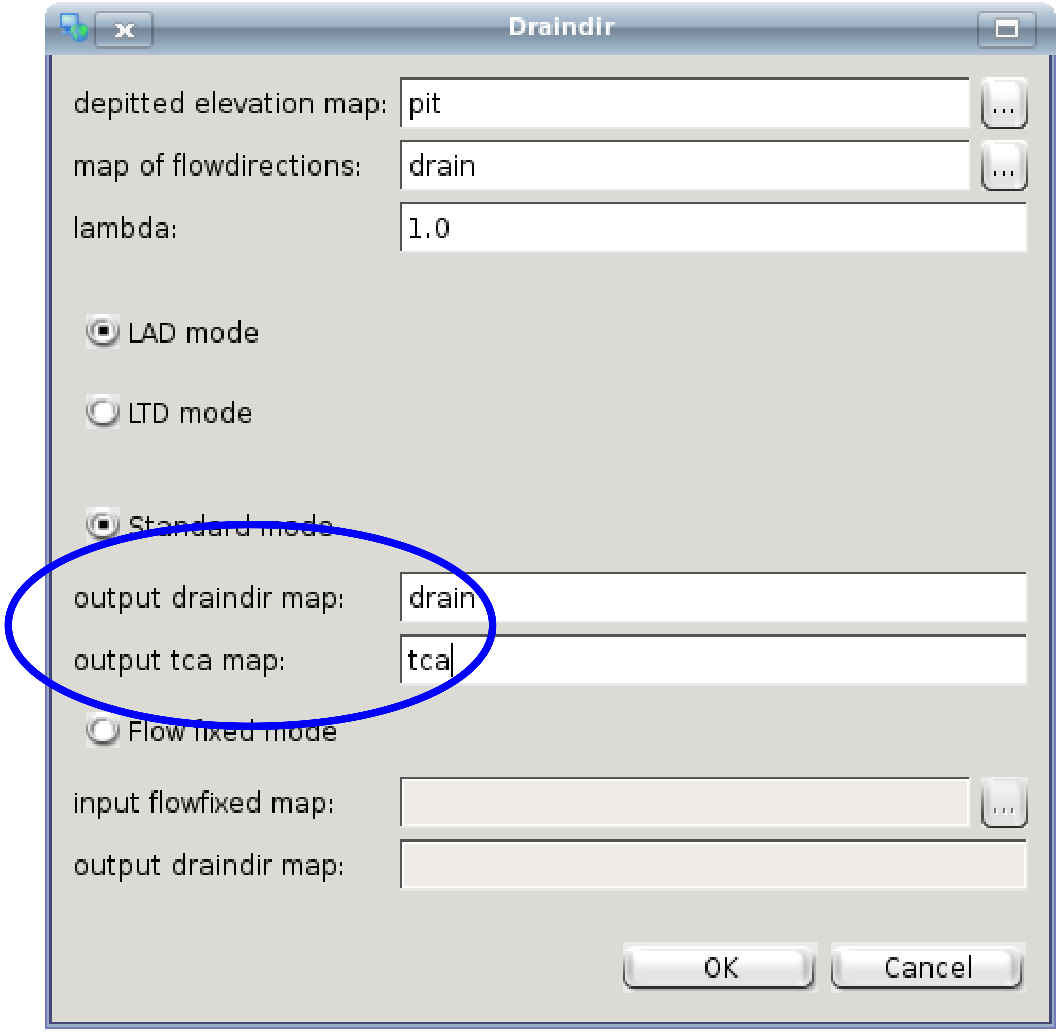

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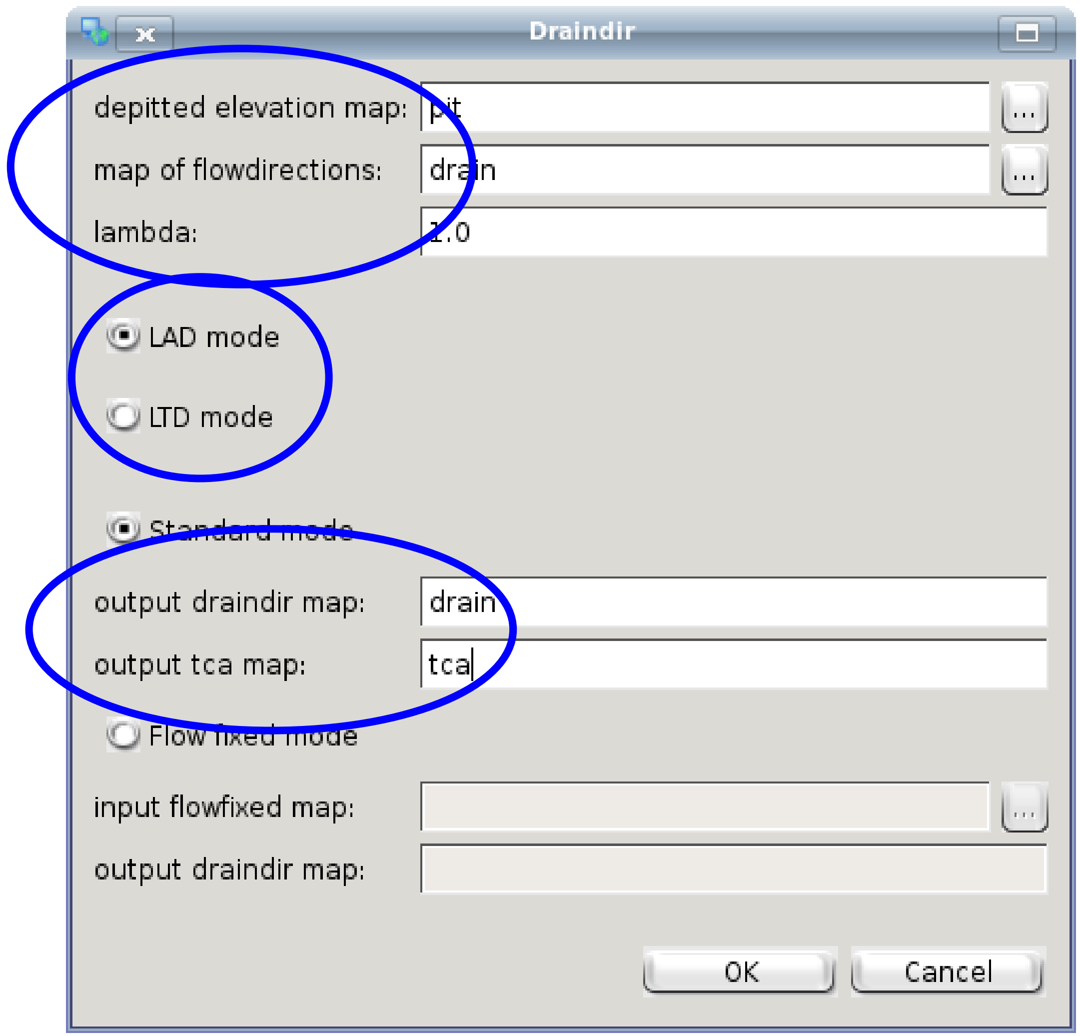
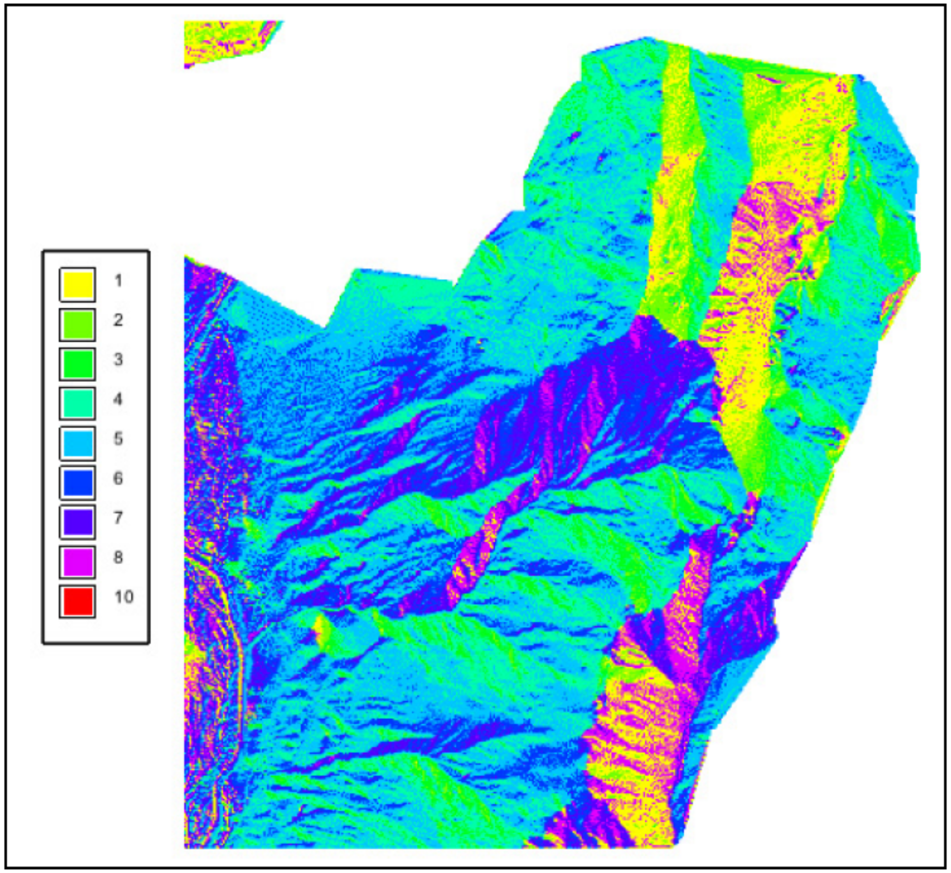
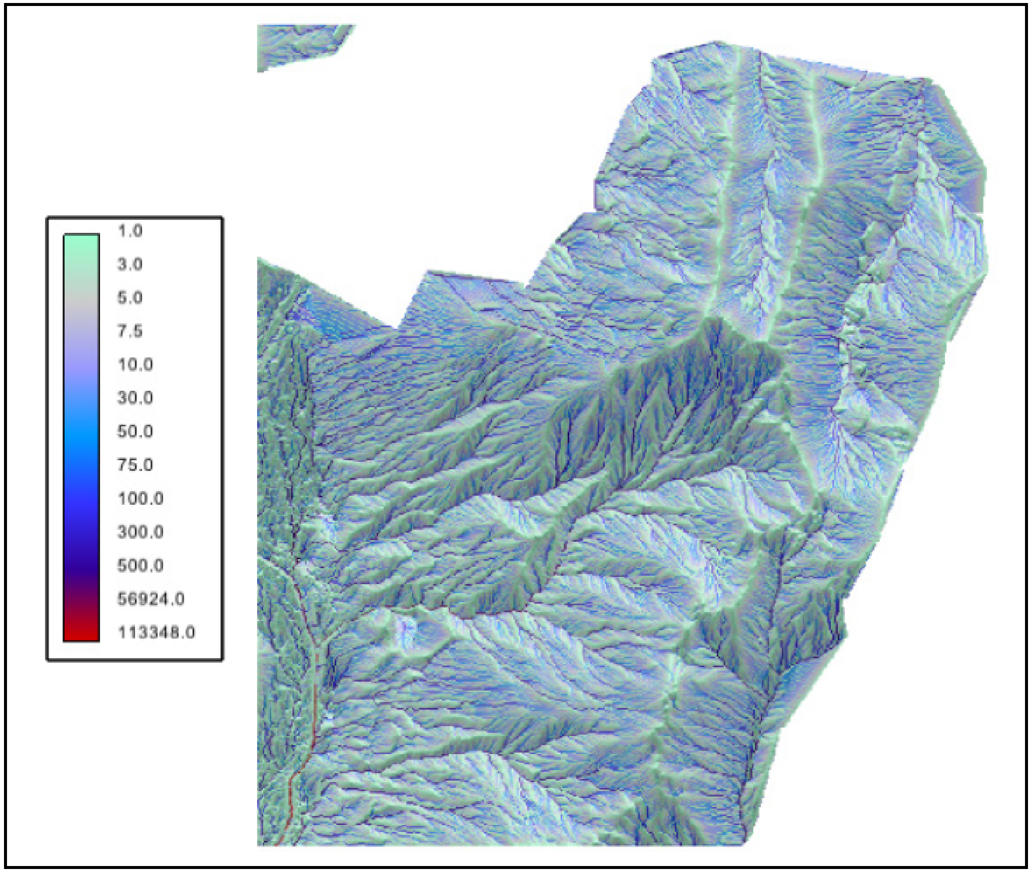


h.draindir



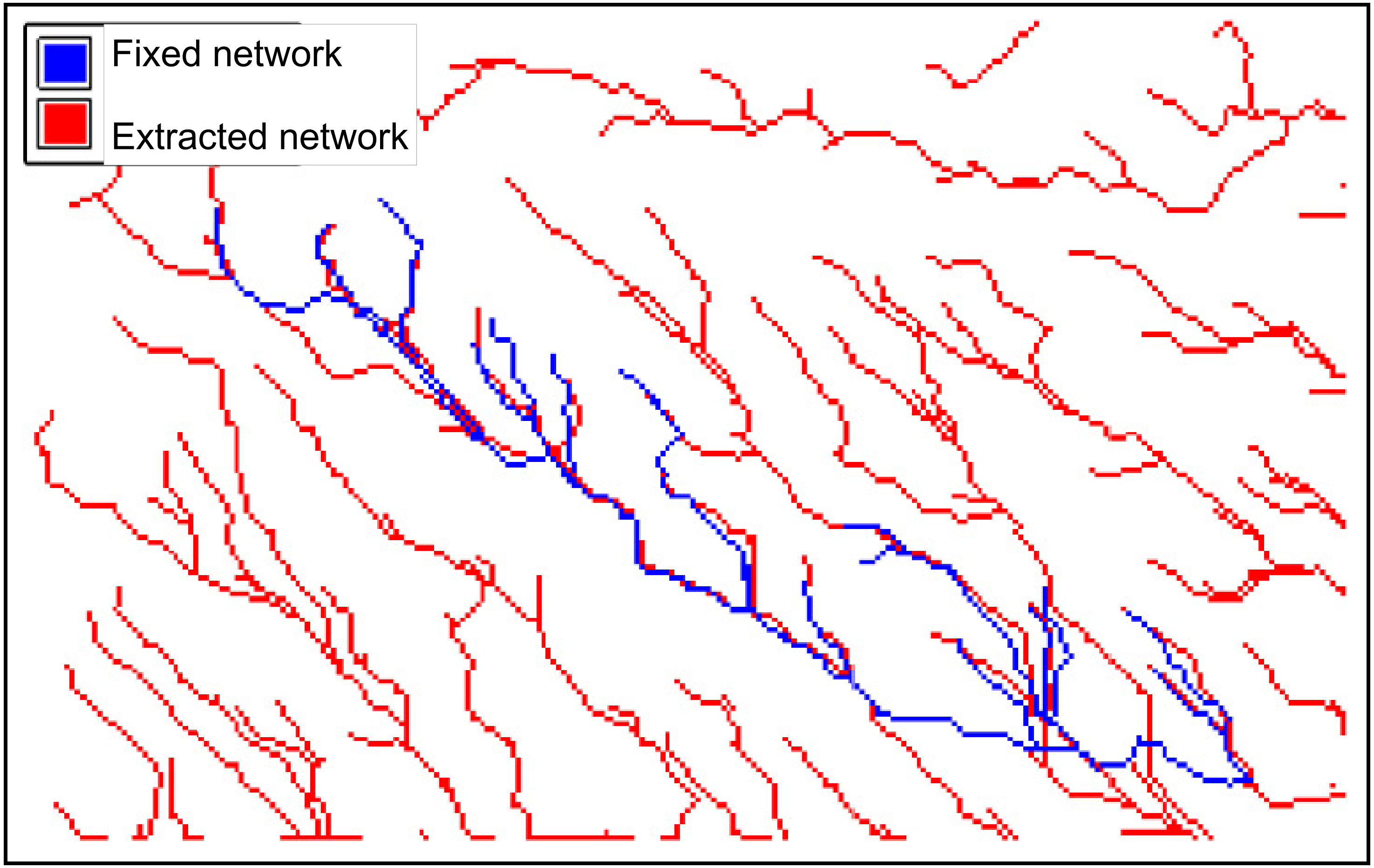


Map obtained categorizing the resulting map of the command

Map obtained personalizing the colours of the original map

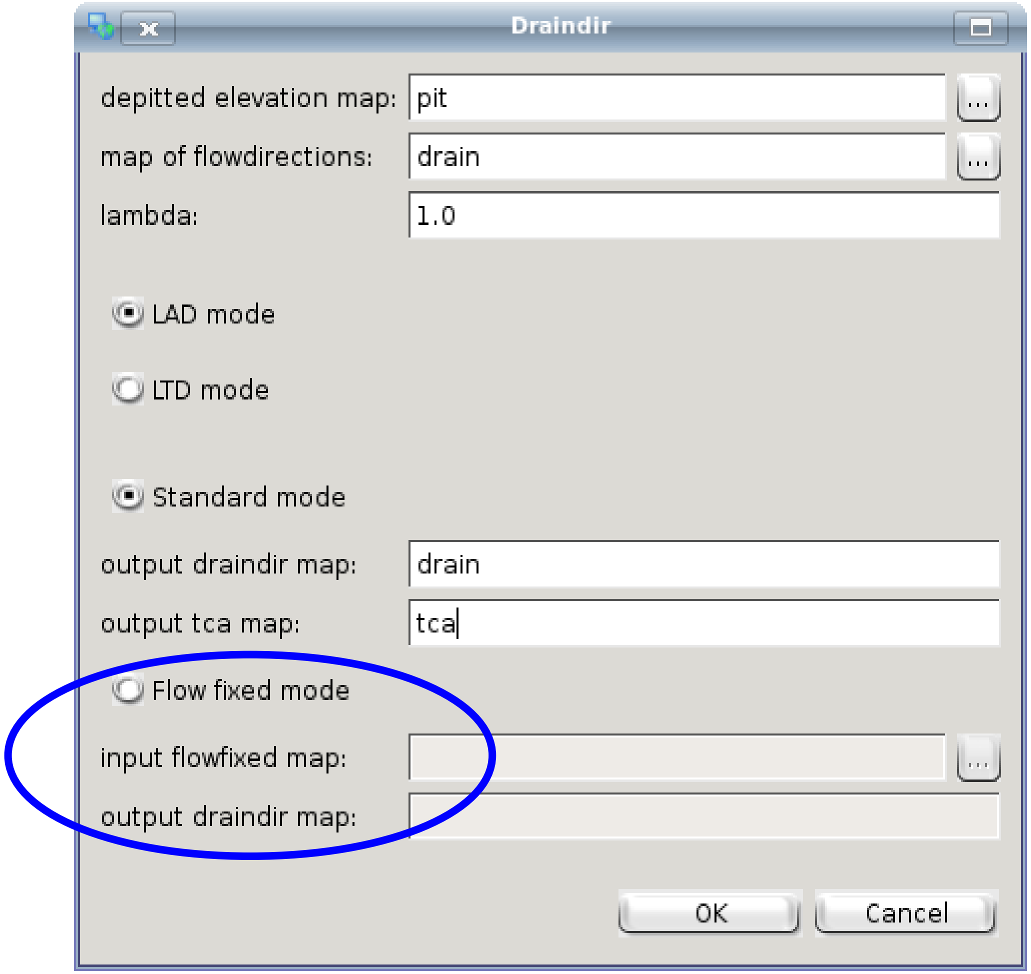
h.draindir

NETWORK FIXED METHOD: in flat areas or where there are manmade constructions, it can happen that the extracted channel network does not coincide with the real channel network.



h.draindir

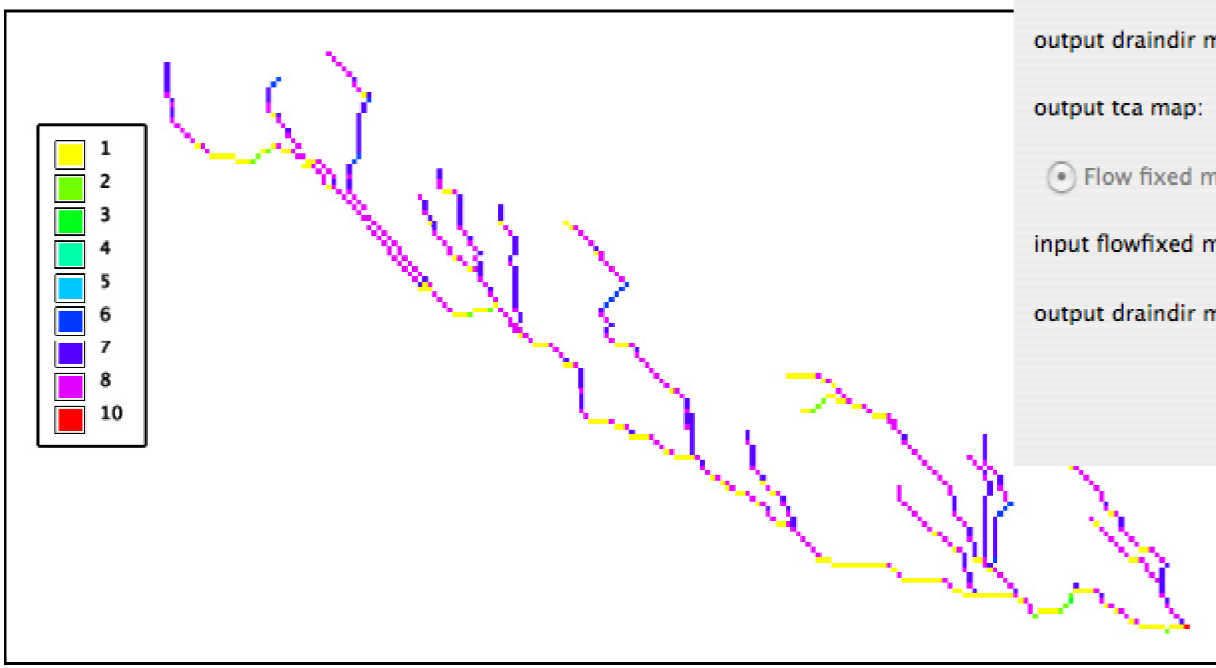
FLOW FIXED METHOD

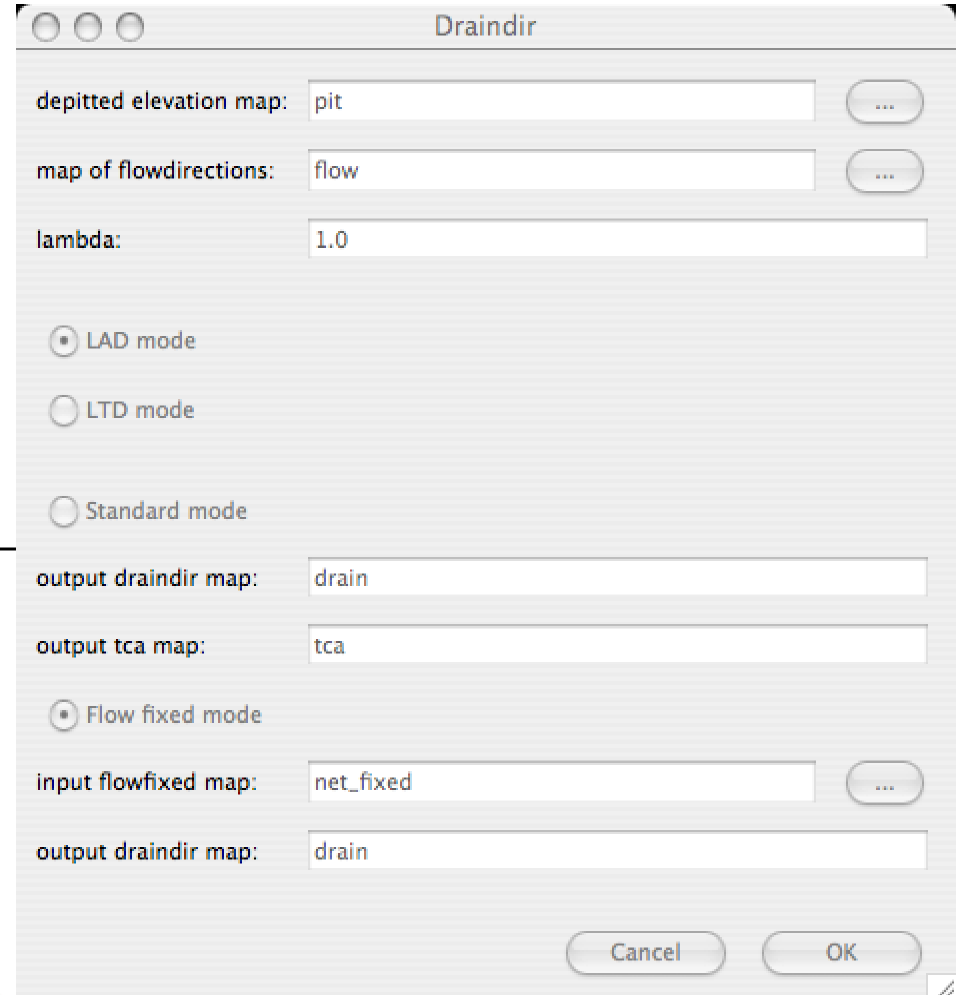


h.draindir

FLOW FIXED METHOD

Flow fixed map created by h.netshape2flow from a shapefile of the network





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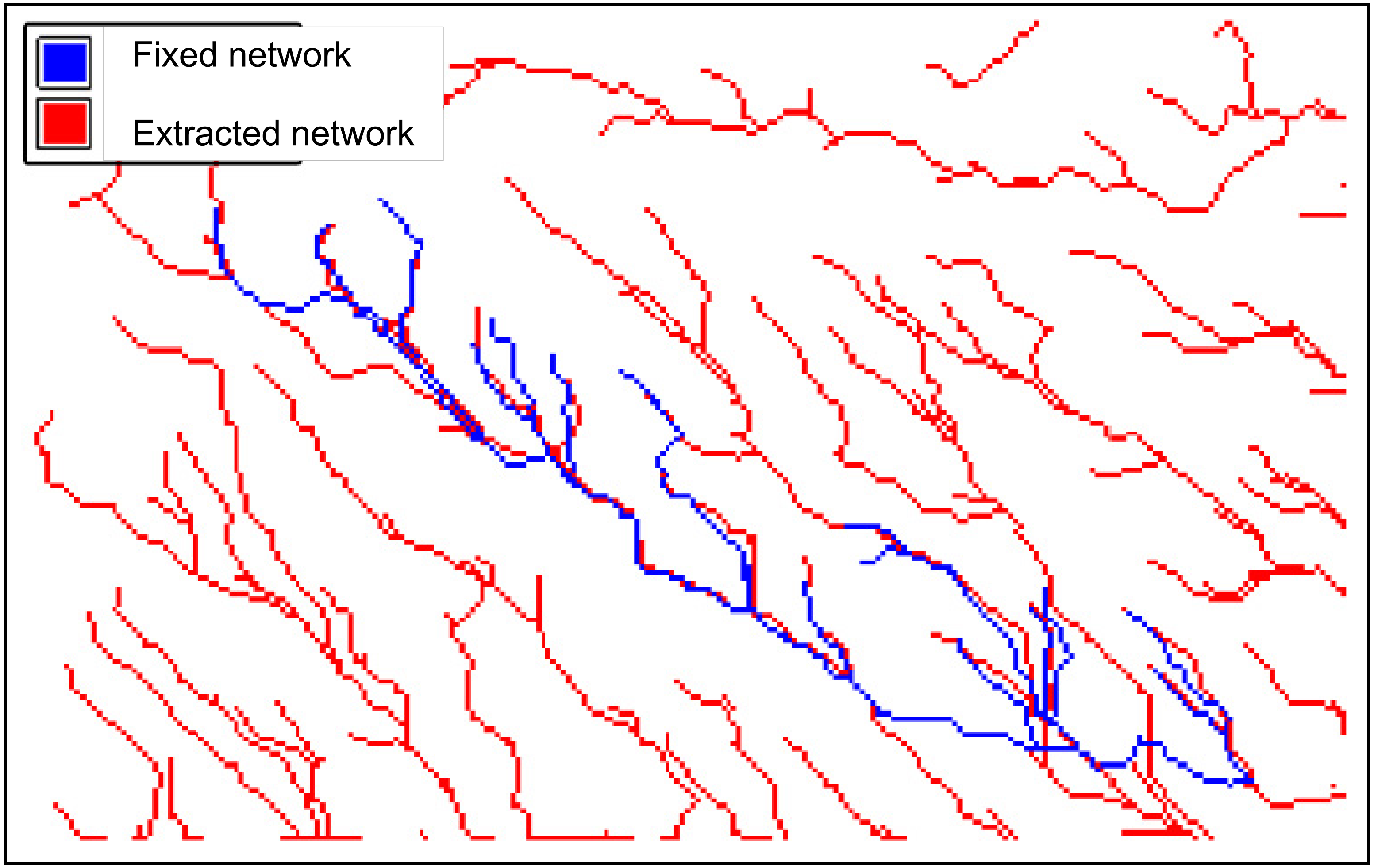

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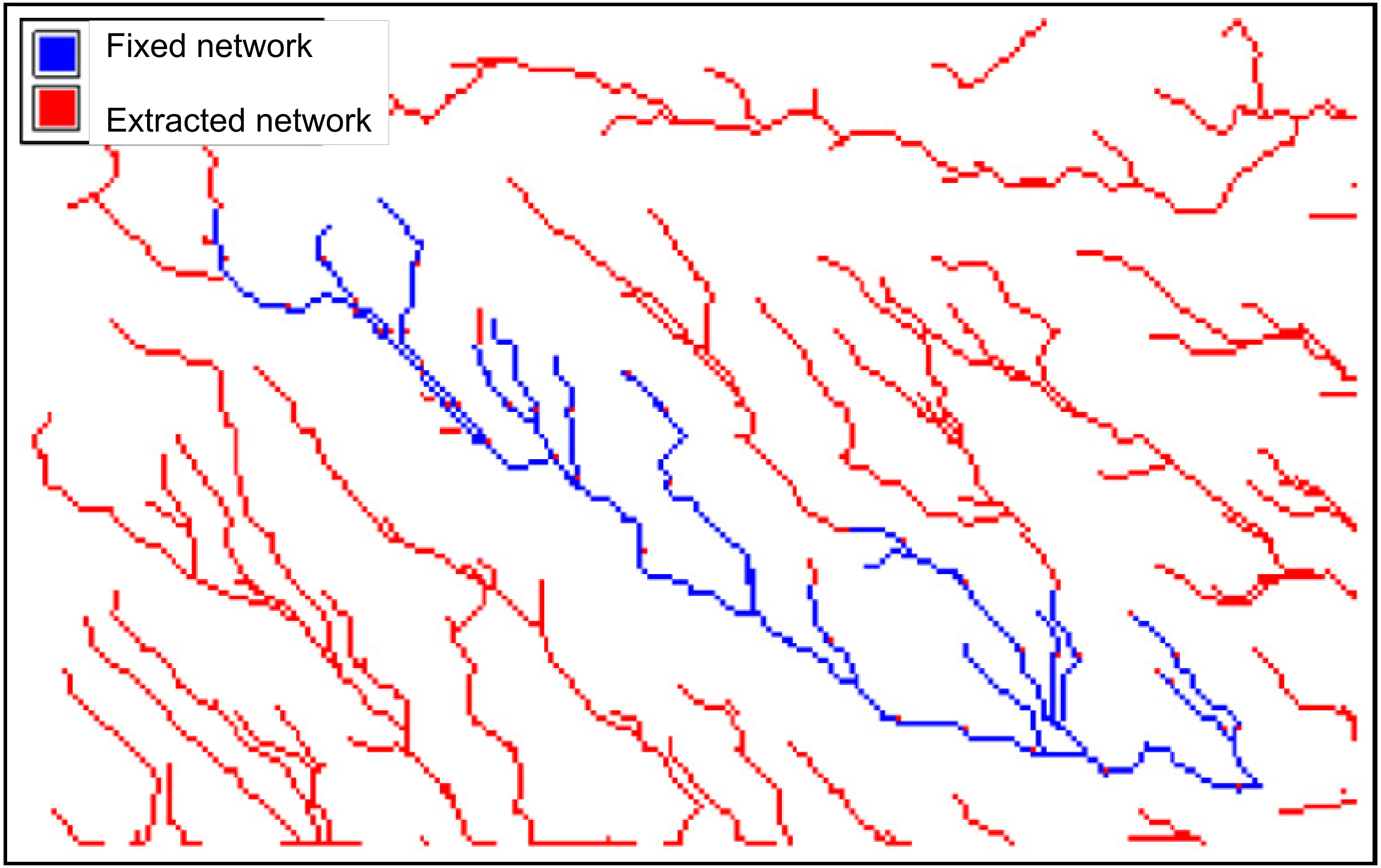

TOTAL CONTRIBUTING AREA

It represents the area that contributes to a particular point of the catchment basin.

It is an extremely important quantity in the geomorphologic and hydrologic study of a river basin: it is strictly related to the discharge flowing through the different points of the system in uniform precipitation conditions.

On this quantity most of the diffusive methods used to extract the stream network from the digital models are based.

TCA

$$A_i = \sum A_j \cdot W_j$$

Where W_j is:

- 1 for pixels that drain into the i-est pixel;
- 0 in any other case for single flow directions.

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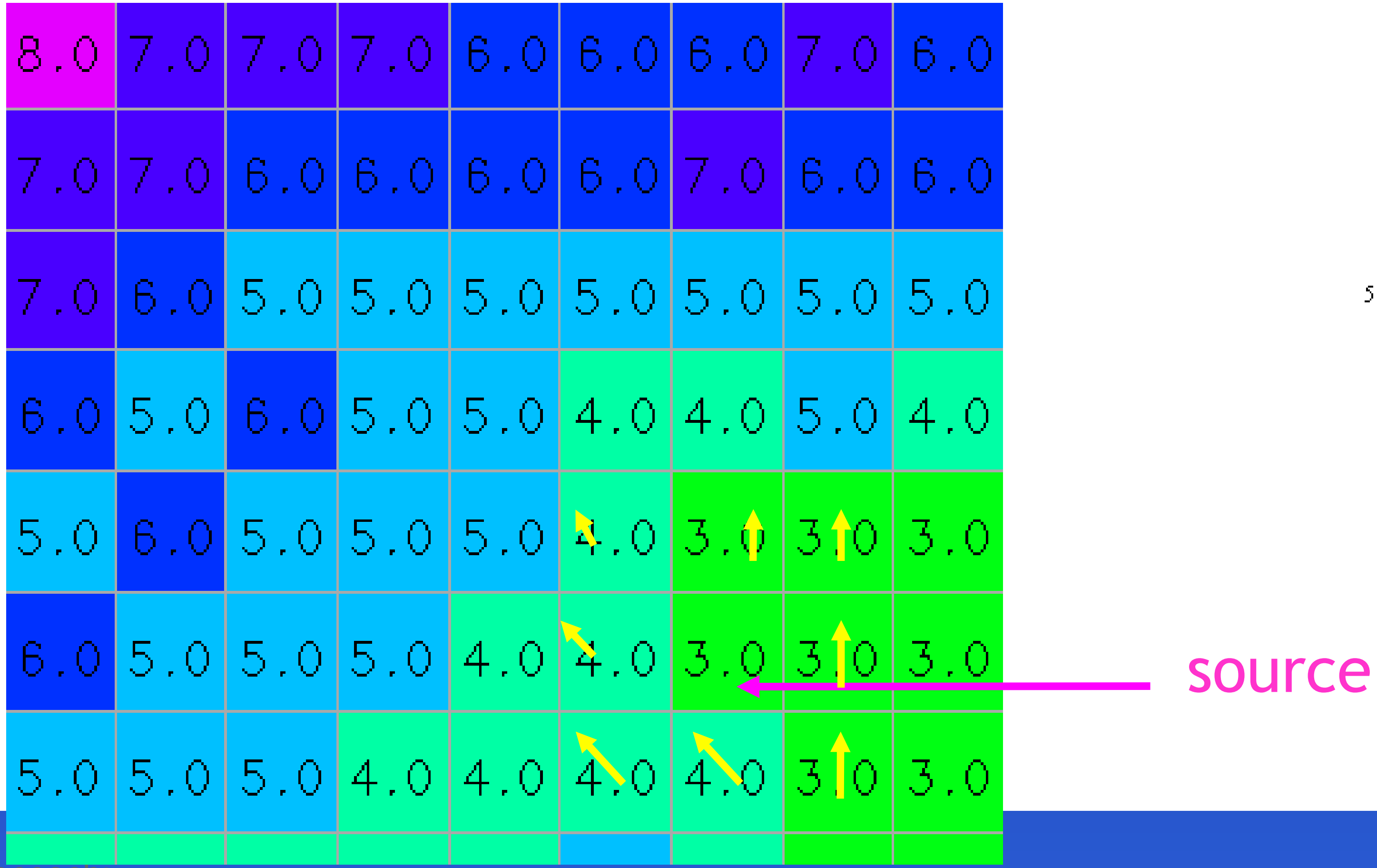

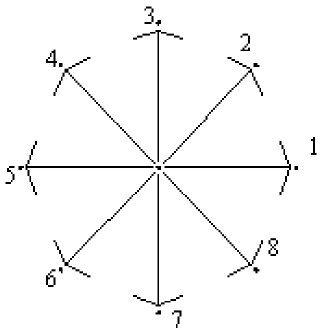

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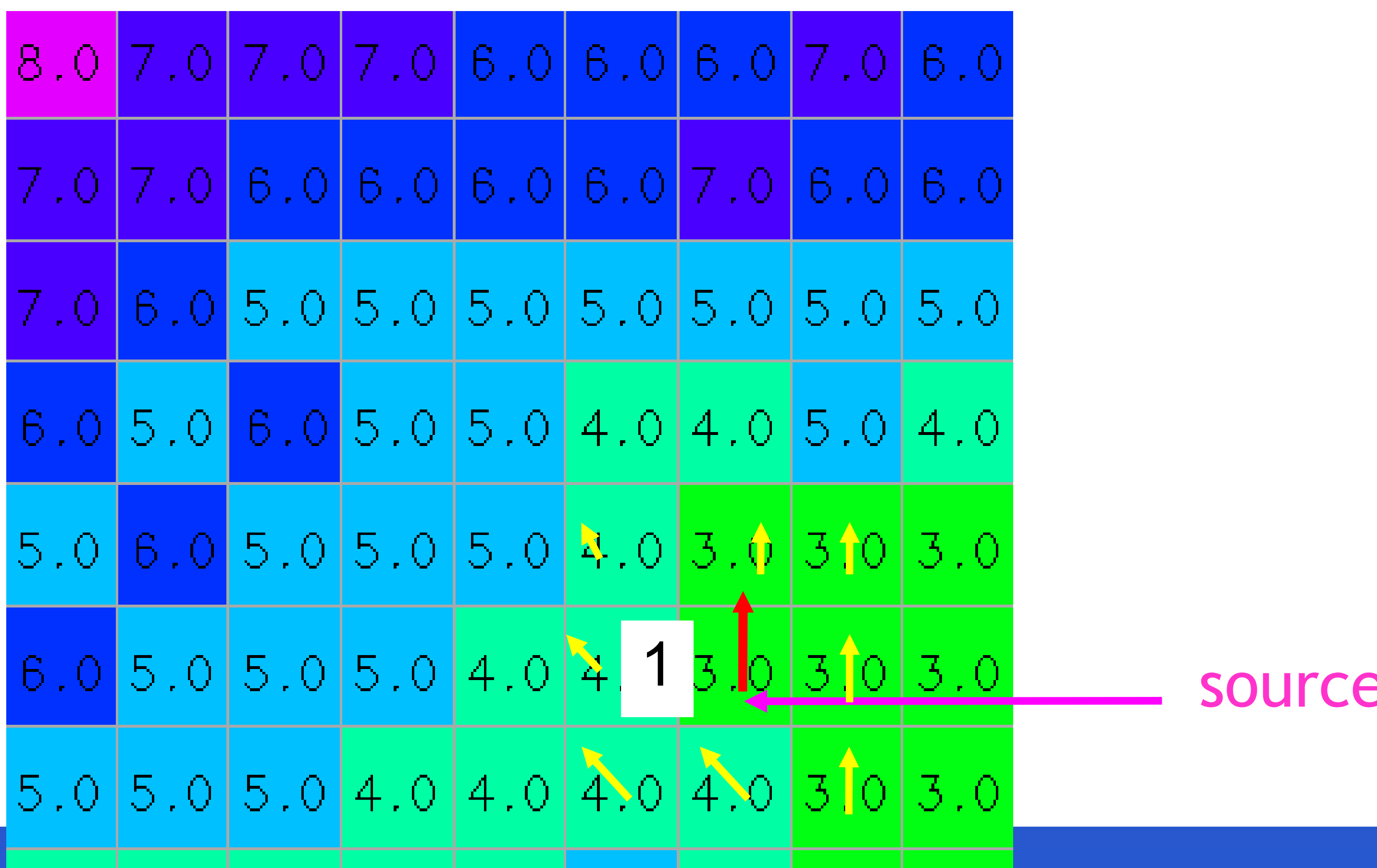

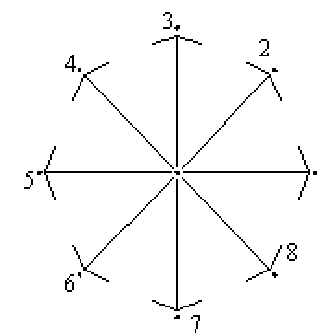

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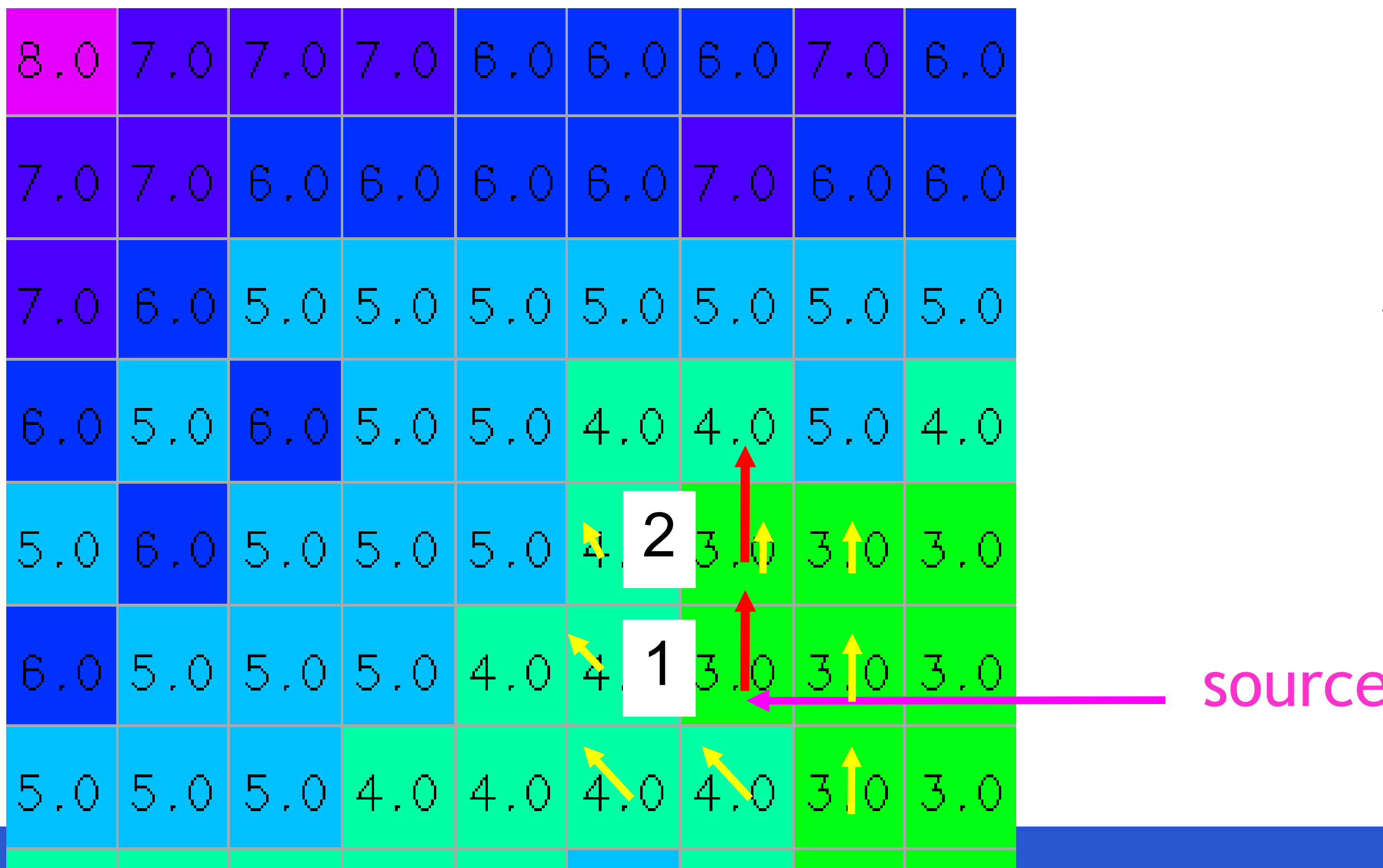

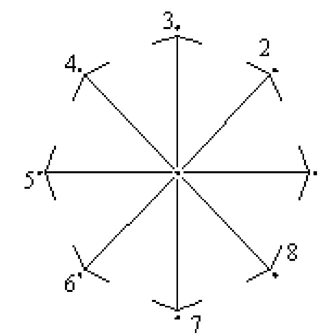

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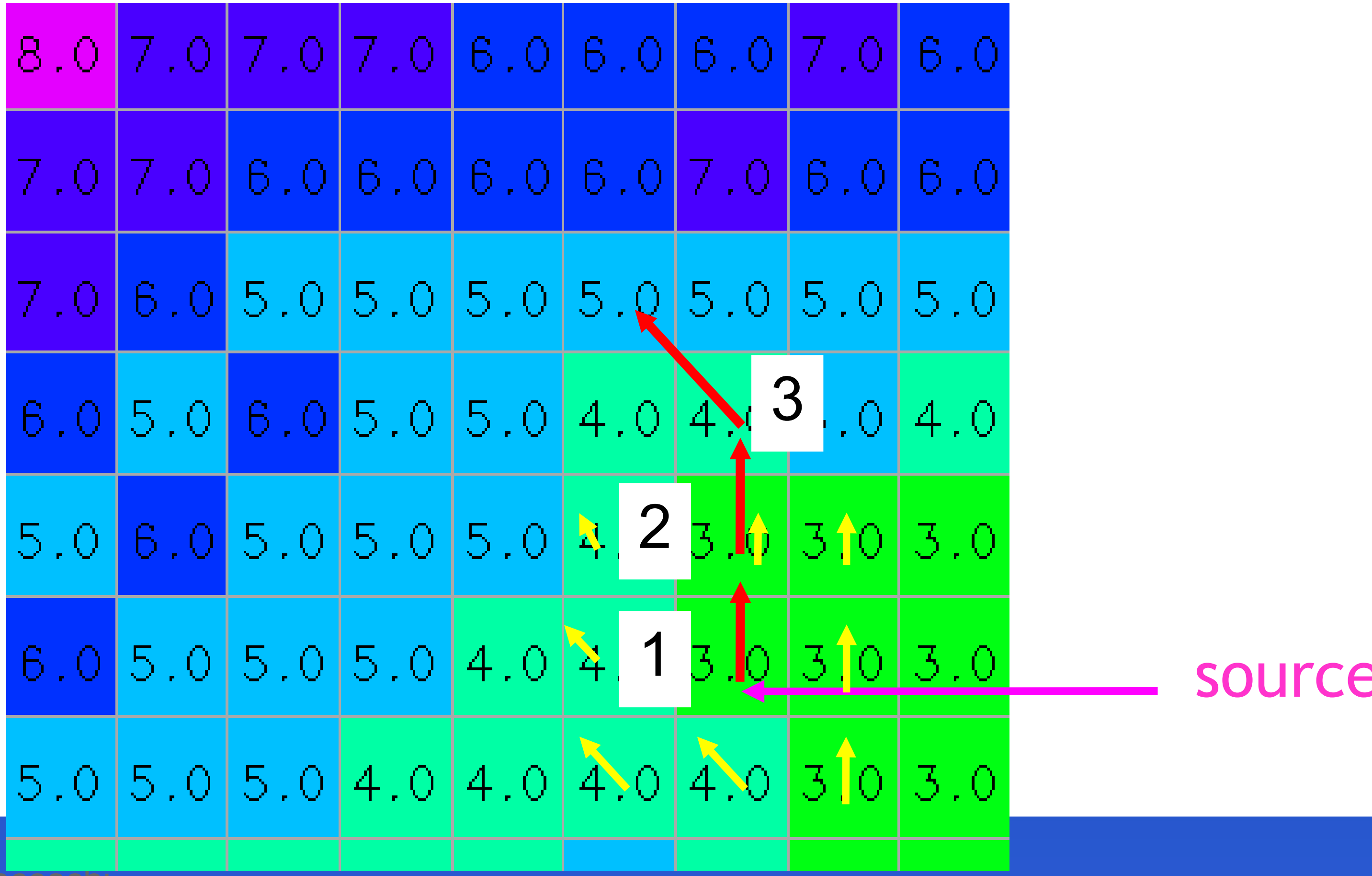

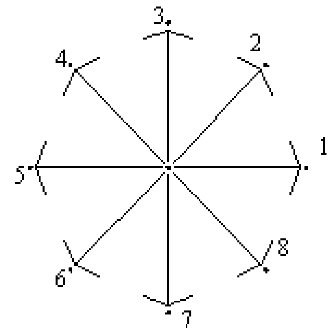

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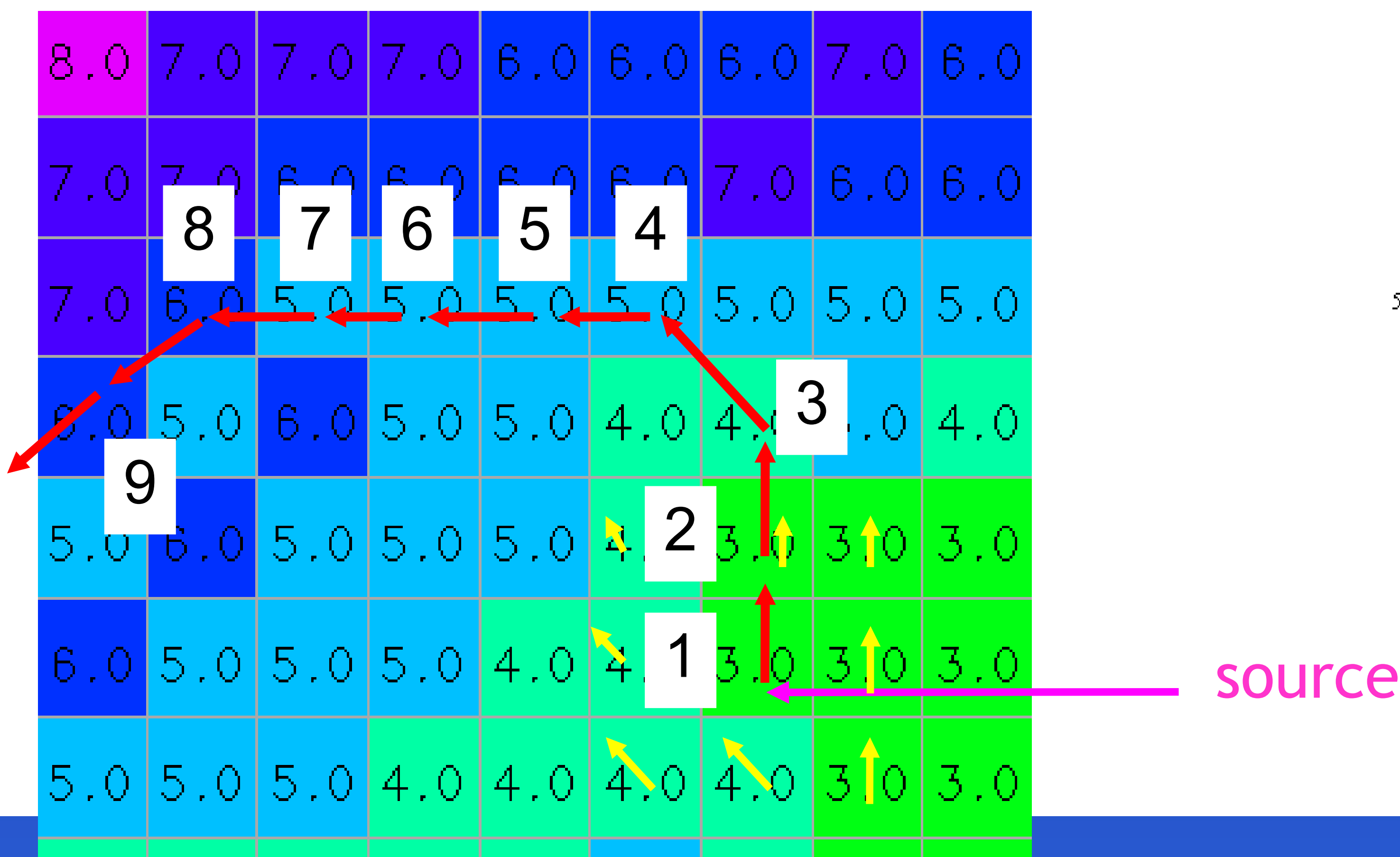

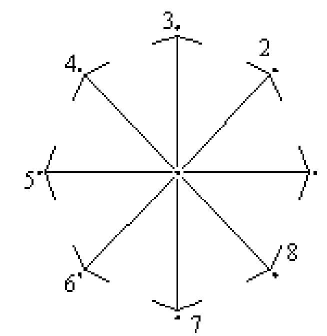

TCA RESULTS COMPARISON

Log(TCA)

Log (LAD-TCA)

In the figures are compared the total contributing areas calculated with the pure D8 method and with the corrected method (LAD-D8). In the second case the typical maximum steepest parallelisms are not present with a representation of the flow very near to reality.

h.markoutlets

Many applications to be correctly executed need a matrix of the flow directions that have a new class value. This new class (conventionally indicated in JGrass with 10) identifies the basin outlets, those are the pixels draining outside the analysed region.

In other words this command marks the outlets:

h.markoutlets

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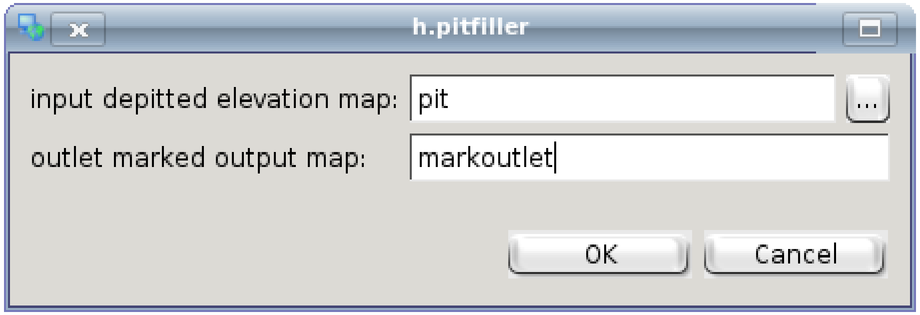
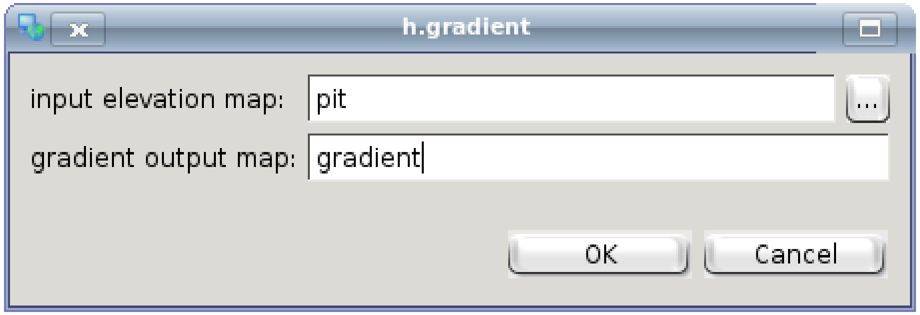


GRADIENTS

The gradients are relevant because the main driving force of the flux is the gravity and the gradient identifies the flow directions of the water and contributes also to determinate its velocity.

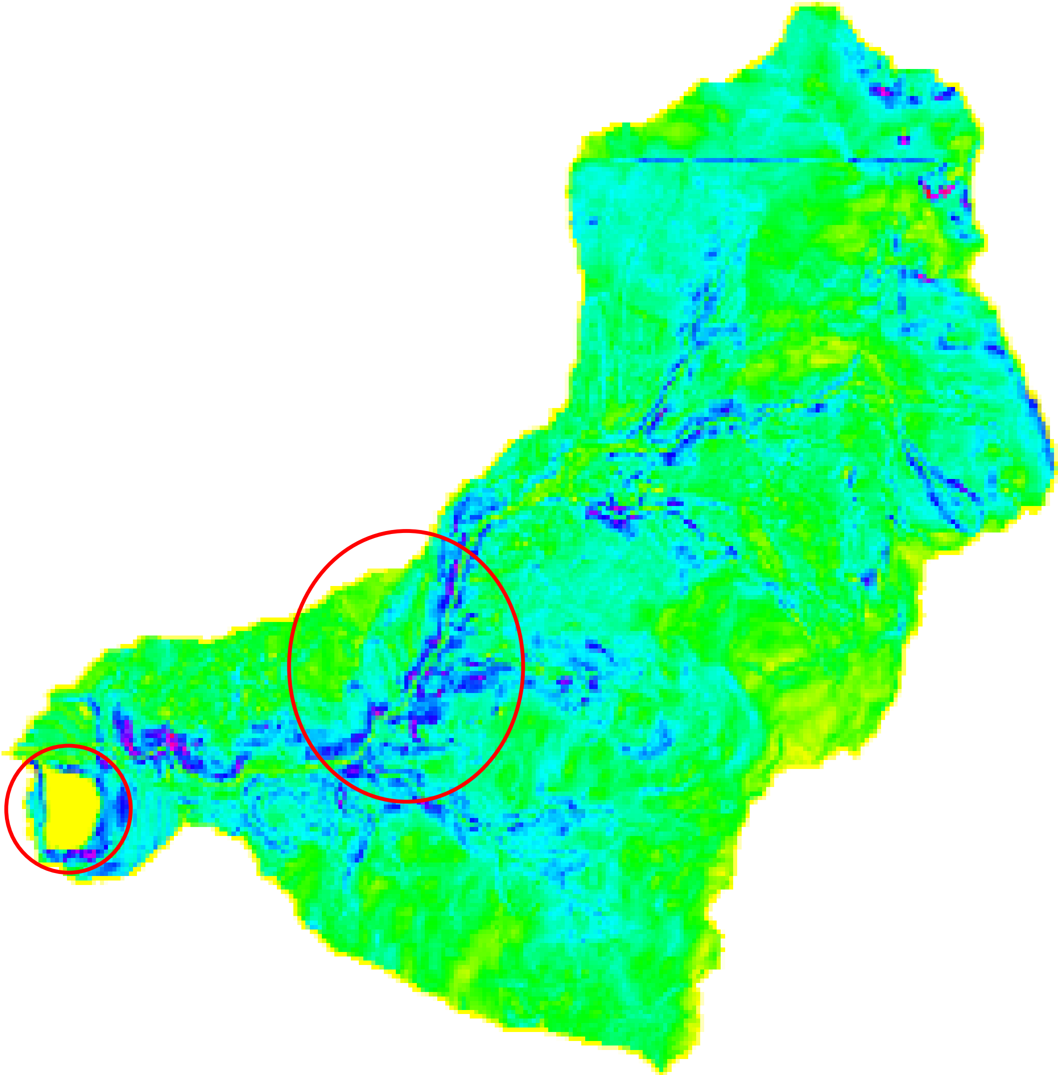
Let's observe that the gradient, contrarily to the slope, does not use the drainage directions. It calculates only the **module of the gradient** which in reality is a vectorial quantity oriented in the direction starting from the minimal up to the maximal potential.



h.gradients

Il deflusso subsuperficiale è proporzionale alla pendenza, il deflusso superficiale alla radice della pendenza. Anche l'erosione e il trasporto solido conseguente dipendono dai gradienti delle superfici topografiche, inoltre zone ad elevata pendenza sono generalmente prive di suolo e rappresentano zone di roccia esposta.

GRADIENTS



We can see the deep network incision and the flat area near the basin outlet.

The particular wrong calculation in the upper part of the basin is due to the union of the originally squared DEM.

h.gradient

The gradient calculated whit this command is given as the **tangent** of the correspondent **angle**.
Using the *MAPCALCULATOR* it is possible to obtain the map of the **gradients** in **degrees**

h.gradient

The gradient … en as the **tangent** of the

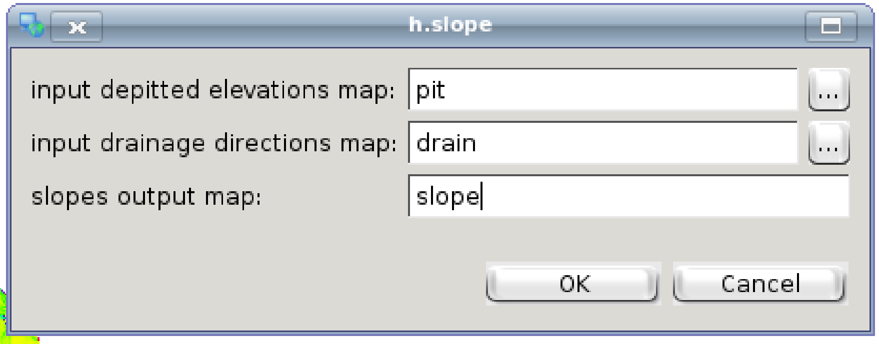
Using the … obtain the map of the

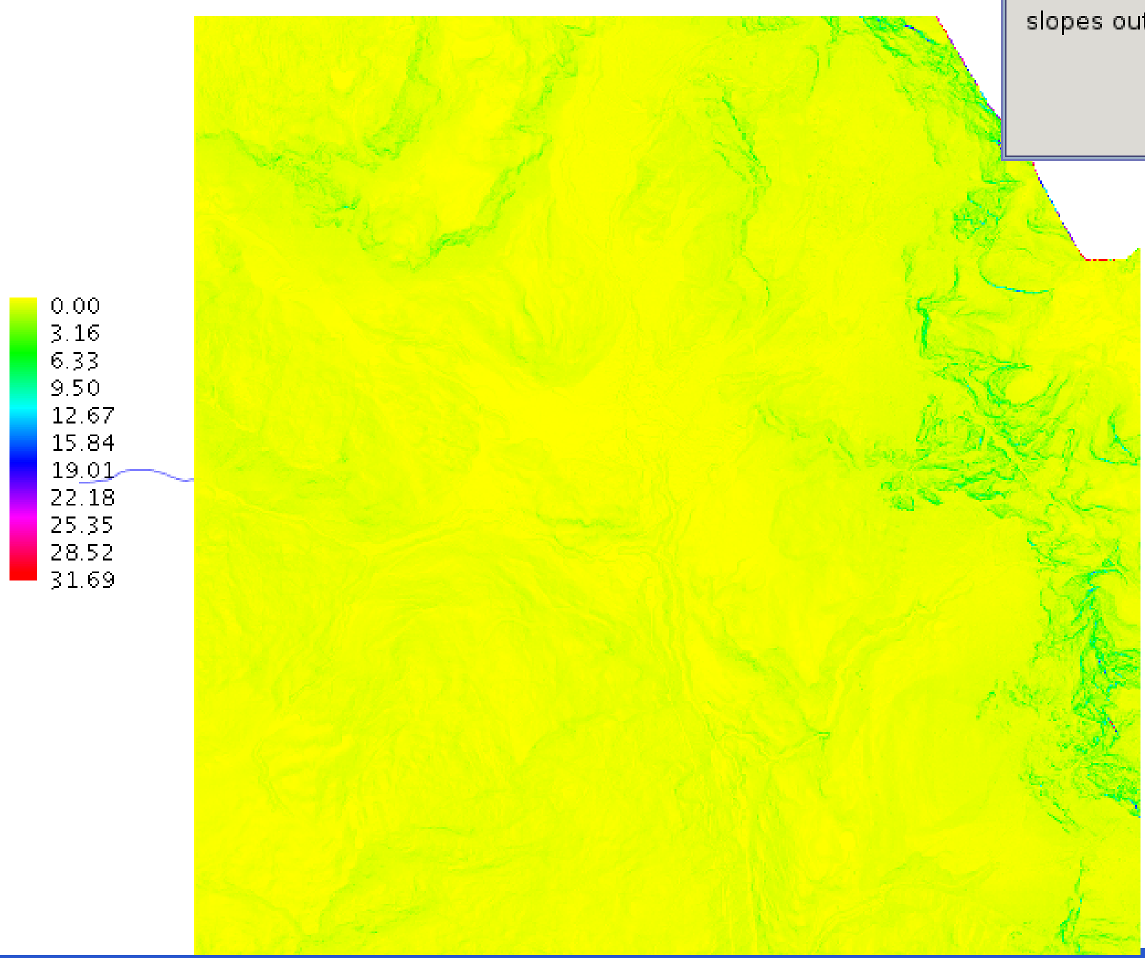
atan("gradient")

SLOPE

It estimates the slope in every site by employing the drainage directions. Differently from the gradients, slope calculates the **drop between** each **pixel** and the adjacent points placed underneath and it divides the result by the pixel length or by the length of the pixel diagonal, according to the cases. The **greatest** value is the one chosen as slope.

h.slope


h.slope
input depitted elevations map:
pit
input drainage directions map:
drain
slopes output map:
slope
OK
Cancel


0.00
3.16
6.33
9.50
12.67
15.84
19.01
22.18
25.35
28.52
31.69

CURVATURE

Le curvature rappresentano la deviazione del vettore gradiente per unità di lunghezza lungo particolari curve tracciate sulla superficie in esame f(x,y).
La **curvatura longitudinale** rappresenta la deviazione del gradiente andando da valle verso monte seguendo l'inviluppo dei gradienti.
La **curvatura piana** è quella della curva che si ottiene sezionando la superficie con un piano parallelo al piano (x,y) ed è la variazione dei vettori tangenti alle linee di livello passanti per il punto in esame.
La **curvatura tangenziale** è determinata sulla curva di intersezione tra un piano perpendicolare alla direzione del gradiente e tangente alle linee di livello nel punto.

Curvatura tangente e piana sono tra loro proporzionali e la loro distribuzione spaziale è la stessa

THE CURVATURES

The mathematical definition is pretty complex.

Longitudinal curvature

it represents the deviation of the gradient along the flow
(it is negative if the gradient increases)

Planar curvature

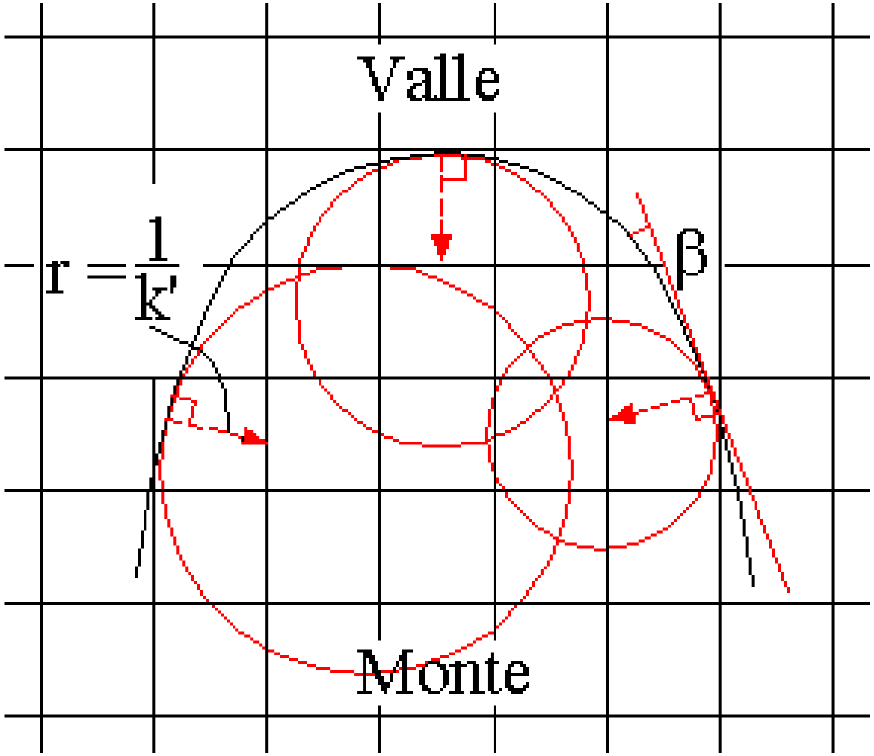
it represents the deviation of the gradient along the transversal direction
(along the contour lines)
it measure the convergence (+) or divergence (-) of the flow

N.B.
Concave sites (positive curvature) represent convergent flow, convex sites (negative curvature) represent divergent flow.

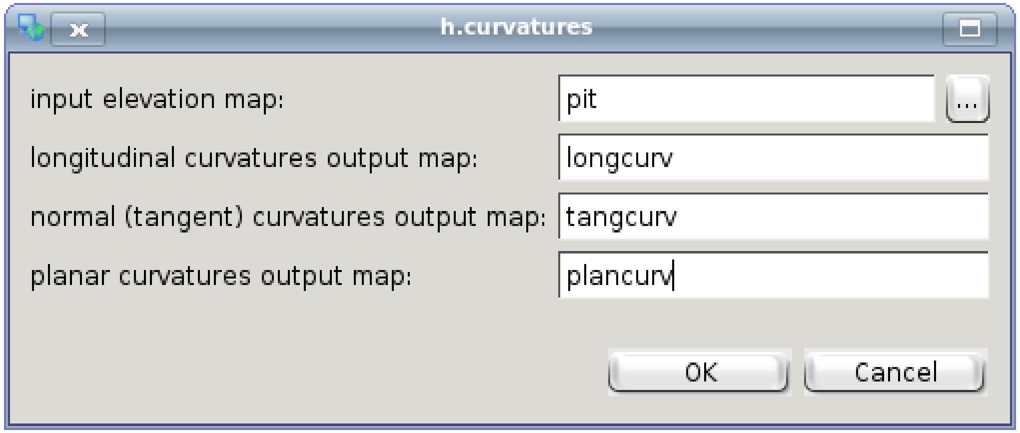
CURVATURA NORMALE/TANGENZIALE

Curvatura negativa - convessa: questo caso è tipico di zone di versante dove il flusso viene suddiviso sui pixel vicini di quota inferiore secondo il metodo della massima pendenza.

Topografia localmente divergente

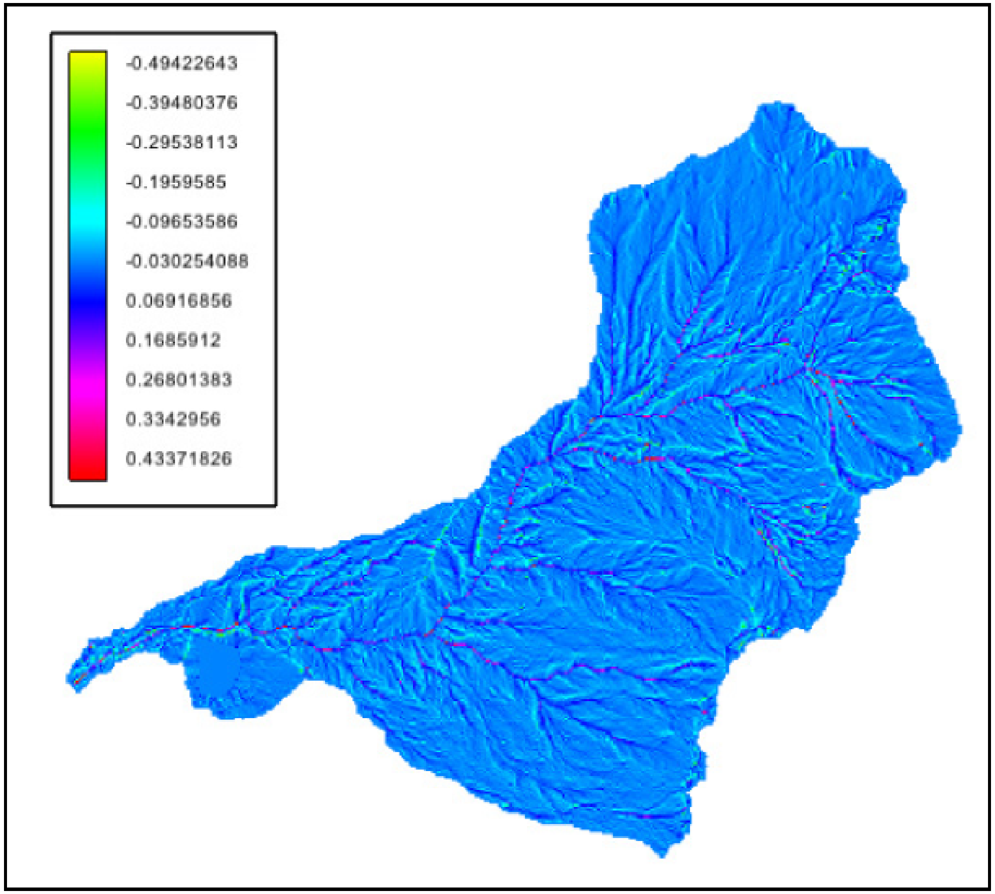


h.curvatures



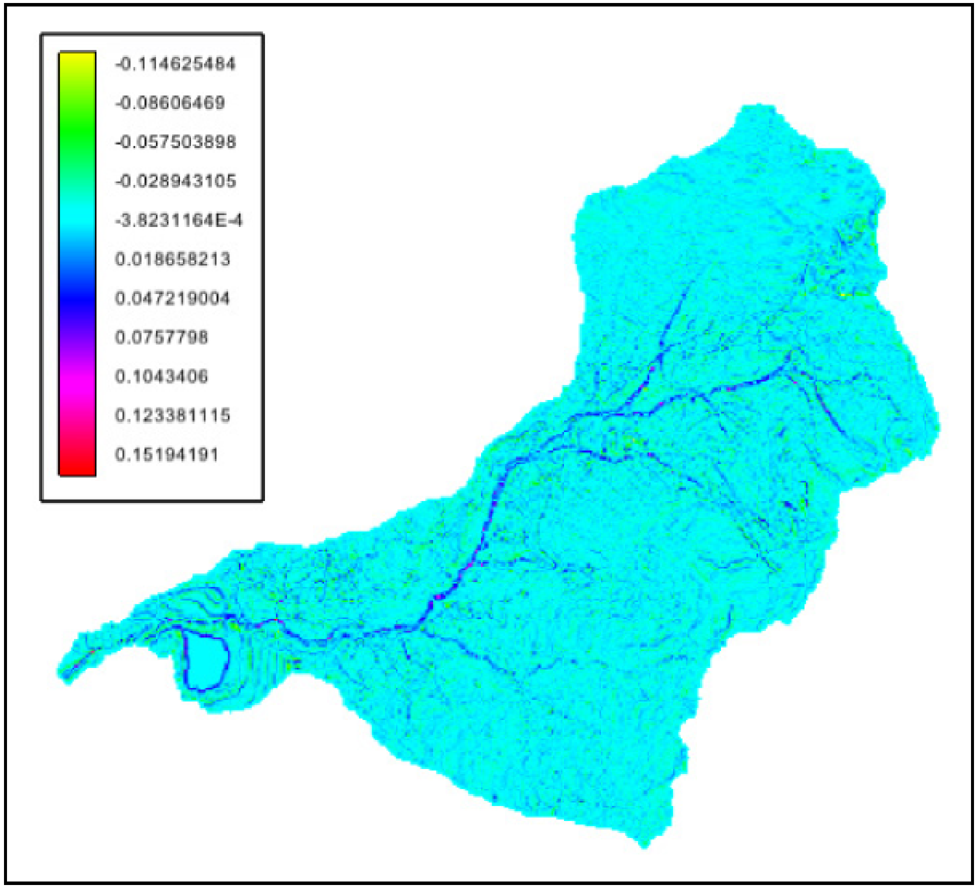
h.curvatures

Planare Curvature



The planar curvatures separate the concave parts from the convex ones

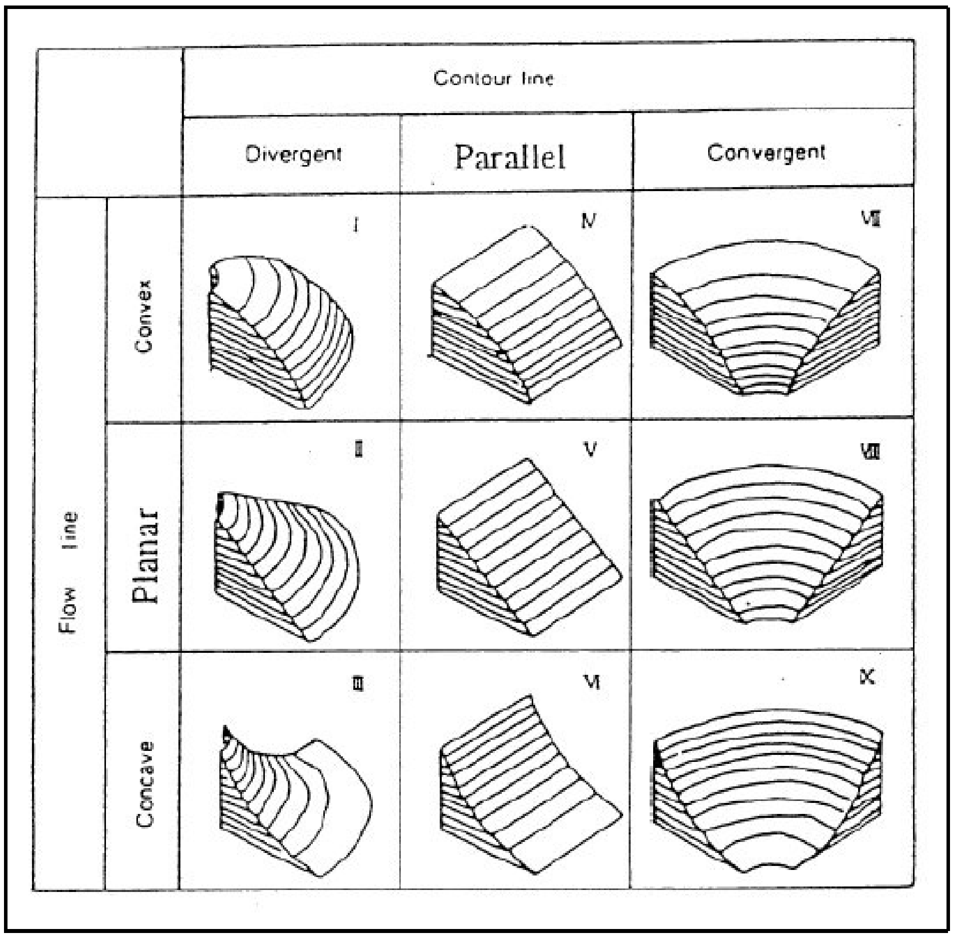
Longitudinal Curvature



The longitudinal curvatures highlight valleys

TOPOGRAPHIC CLASSIFICATION

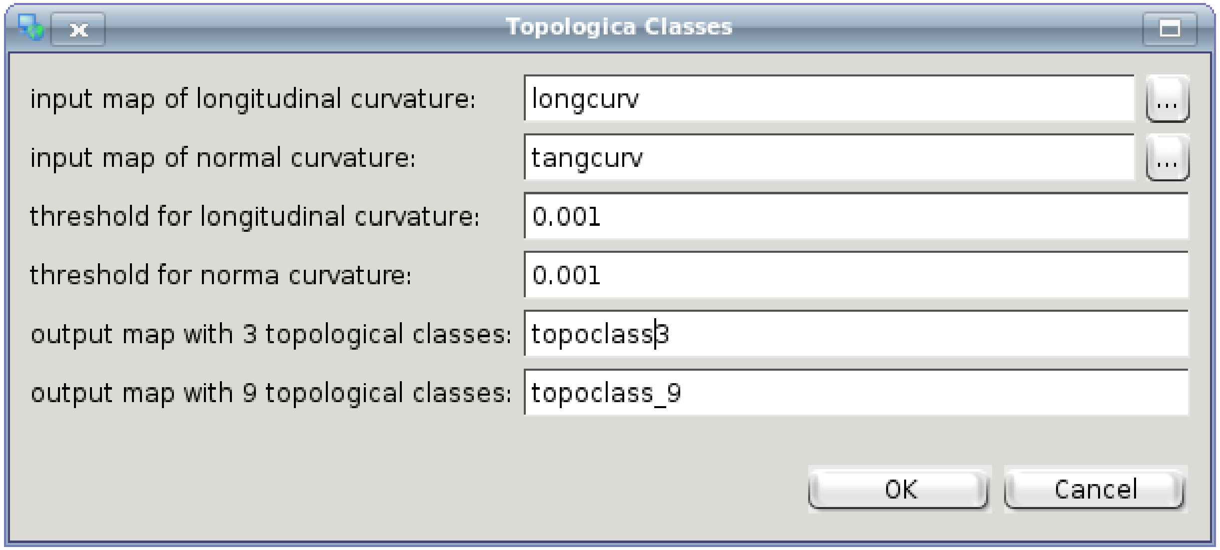
It subdivides the sites of a basin in the 9 topographic classes identified by the longitudinal and transversal curvatures.



The aggregation of the classes in the three fundamentals index:

CONCAVE SITES
CONVEX SITES
PLANAR SITES

h.tc



The program asks as input the threshold values of the longitudinal and normal curvatures which define their planarity. THE VALUE IS STRICTLY RELATED TO THE TOPOLOGY

h.tc

The command produces two different maps as output, the one with the 9 topographic classes and the other with the 3 classes.
The convention is the following for the 9 classes:

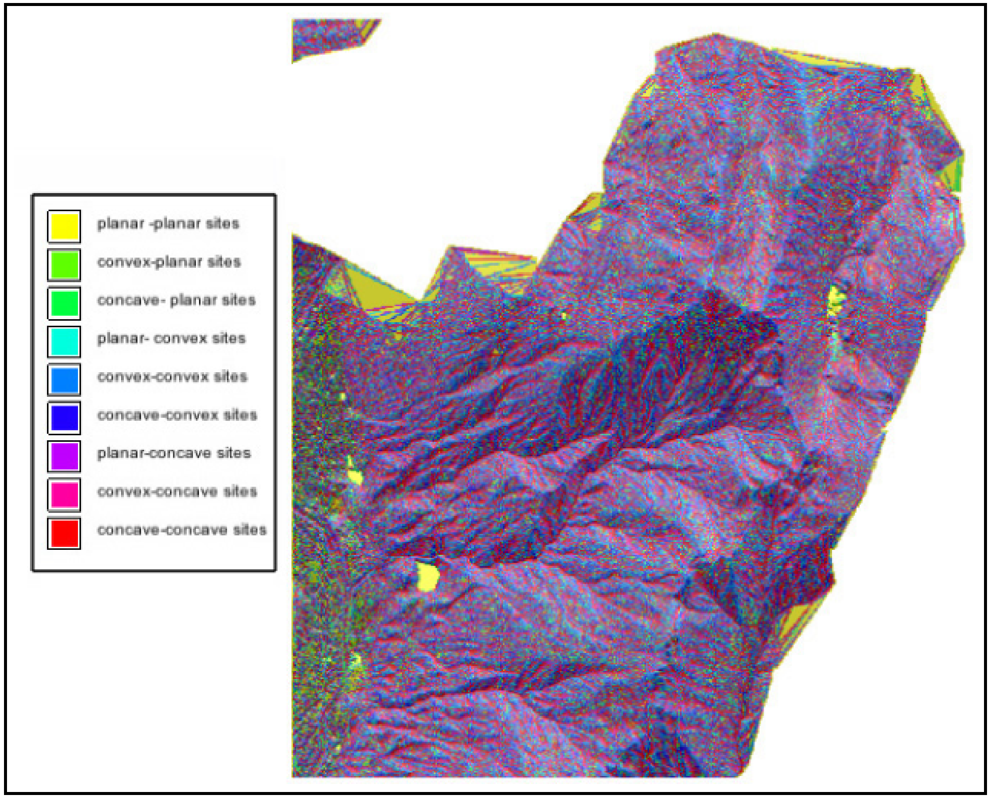
- 10 planar – planar sites
- 20 convex – planar sites
- 30 concave – planar sites
- 40 planar – convex sites
- 50 convex – convex sites
- 60 concave – convex sites
- 70 planar – concave sites
- 80 convex – concave sites
- 90 concave – concave sites

h.tc

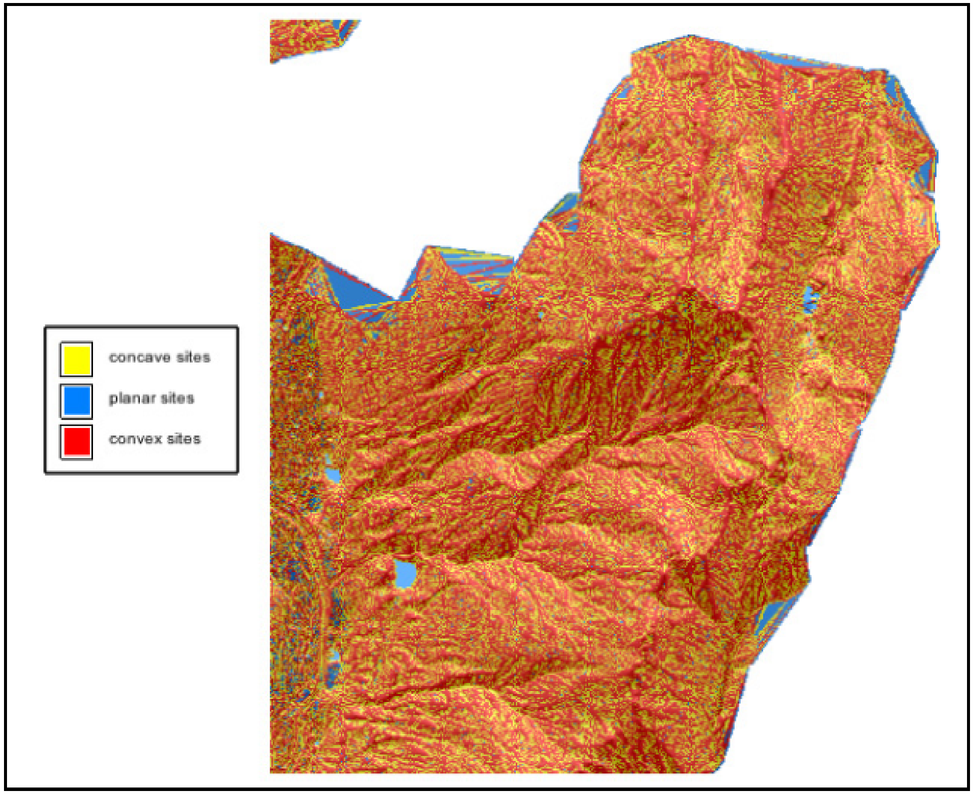
The map with the 3 classification contains an aggregation of these classes in three fundamentals:

- 15 concave sites (classes 30, 70, 90)
- 25 planar sites (classes 10)
- 35 convex sites (classes 20, 40, 50, 60, 80)

h.tc



h.tc 9 classes



h.tc 3 classes

CHANNEL NETWORK EXTRACTION

3 METHODS ARE IMPLEMENTED

threshold value on the contributing areas (only the pixels with contributing area greater than the threshold are the channel heads)

threshold value on the stress tangential at the bottom: threshold value on the ratio between the total contributing areas and the gradient

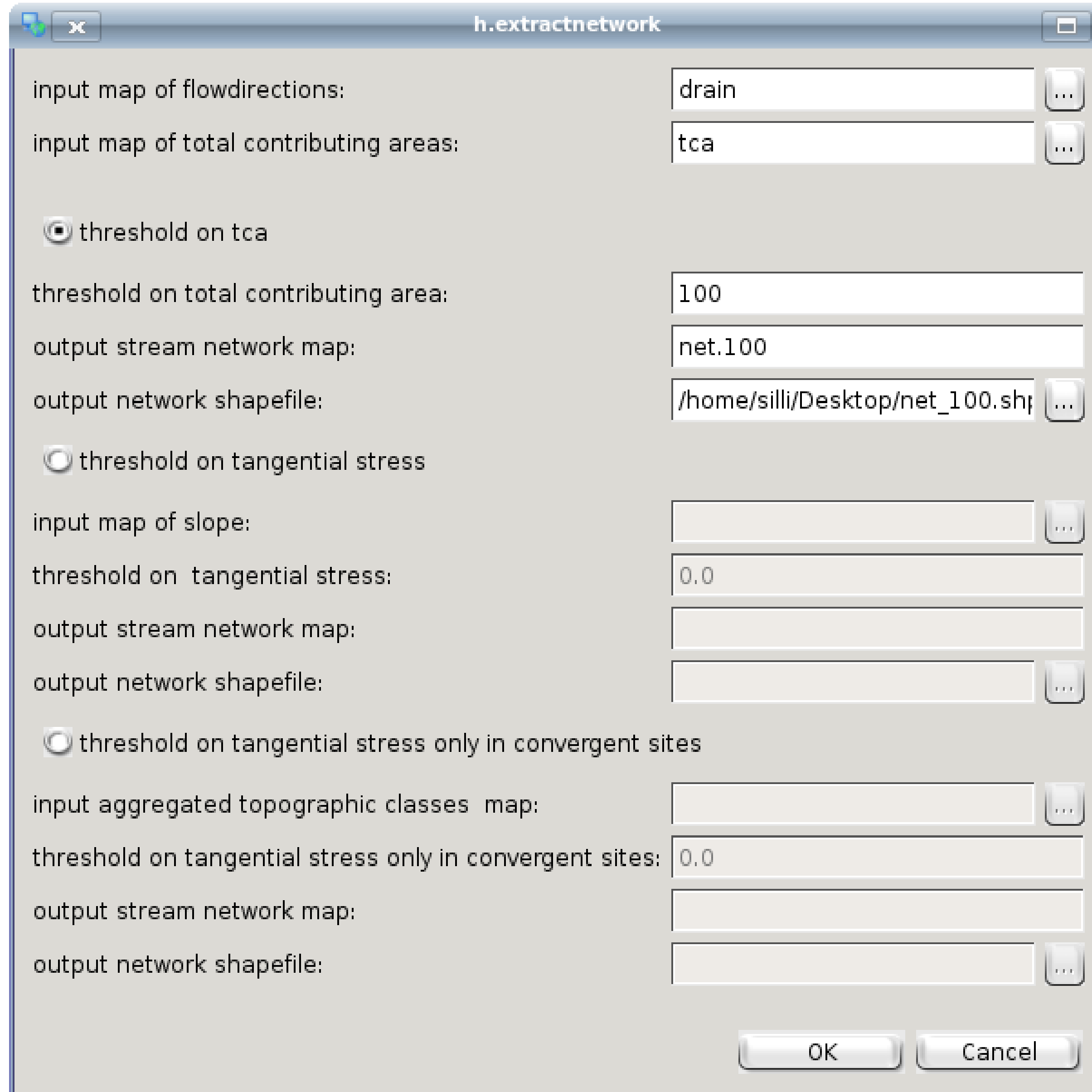
threshold value on the tangential stress only in convergent sites

HOW IT WORKS: As soon as the first pixel of the channel network (the pixel in which the value of the parameter is larger than the threshold) is found, all the other pixel downstream are network.

h.extractnetwork

1°method

Threshold on the tca



The threshold depends on:

- dimensions of the pixels
- topographical attributes

h.extractnetwork

2°method

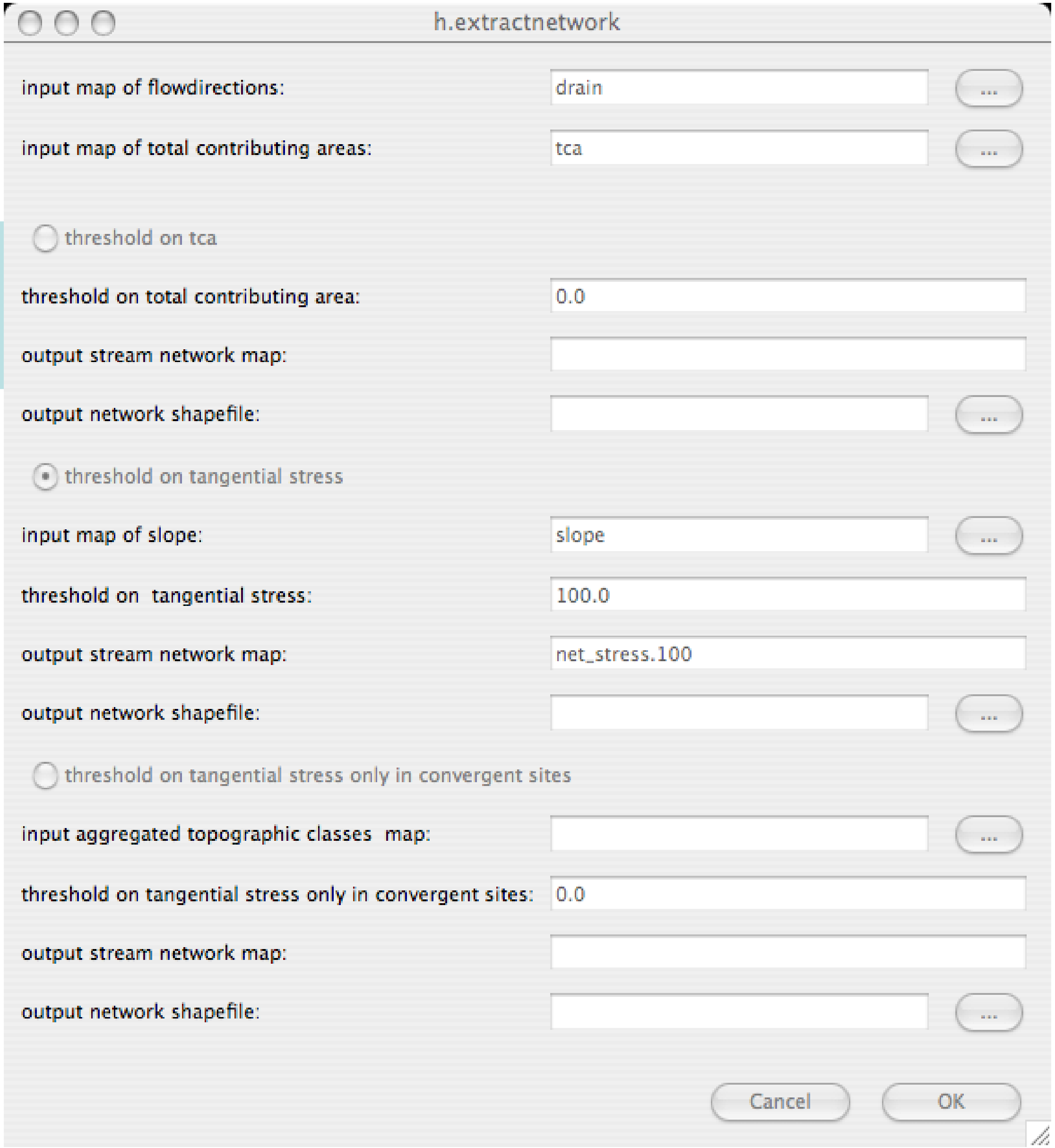
The threshold is on the parameter:

$$\nabla z \cdot \sqrt{A}$$

which is proportional to the stress tangential to the bottom.

The threshold depends on:

- pixels dimensions
- topographical attributes



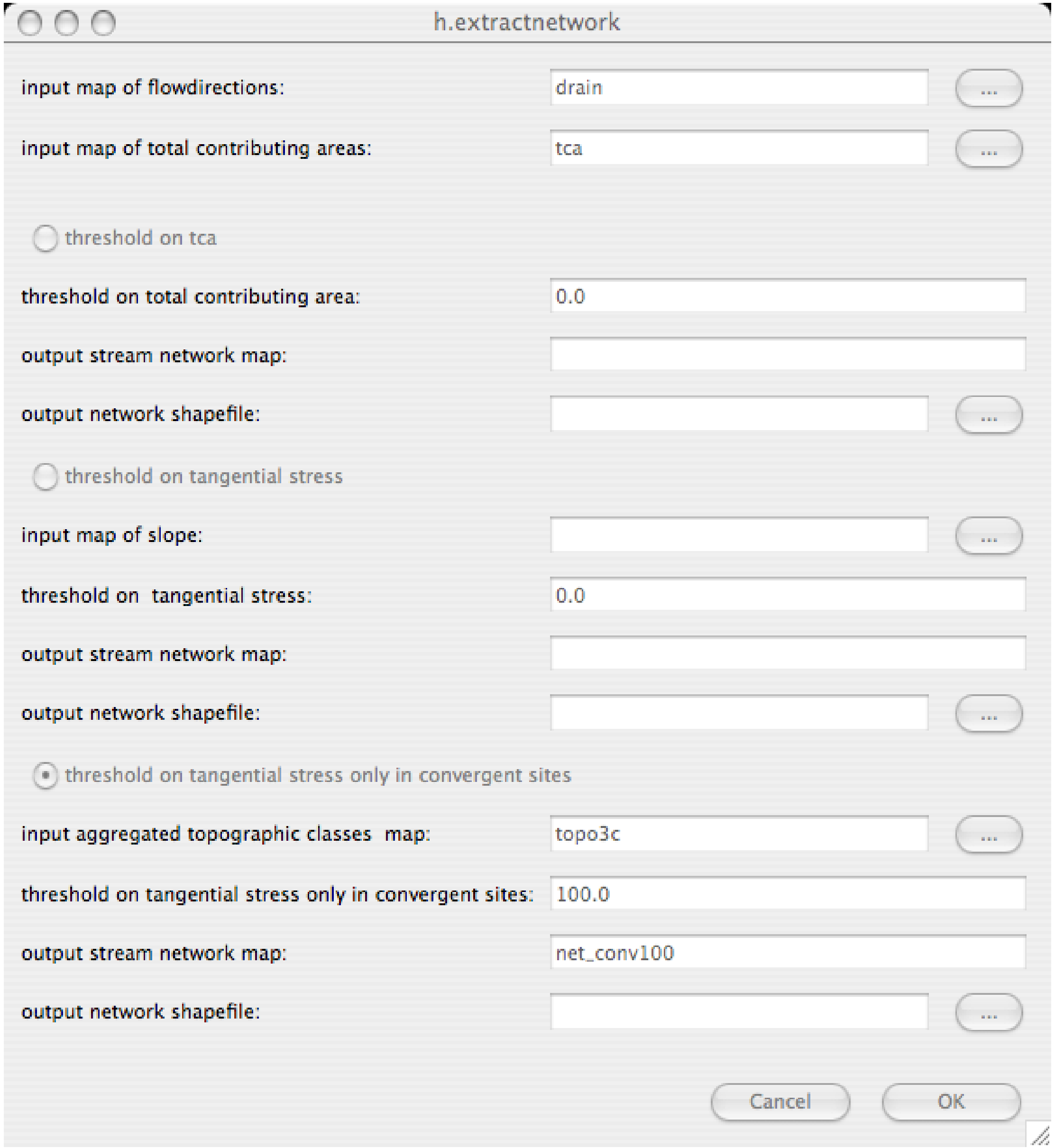
h.extractnetwork

3°method

Threshold on the tca of the concave sites.

The threshold depends on:

- pixel dimensions
- topographical attributes



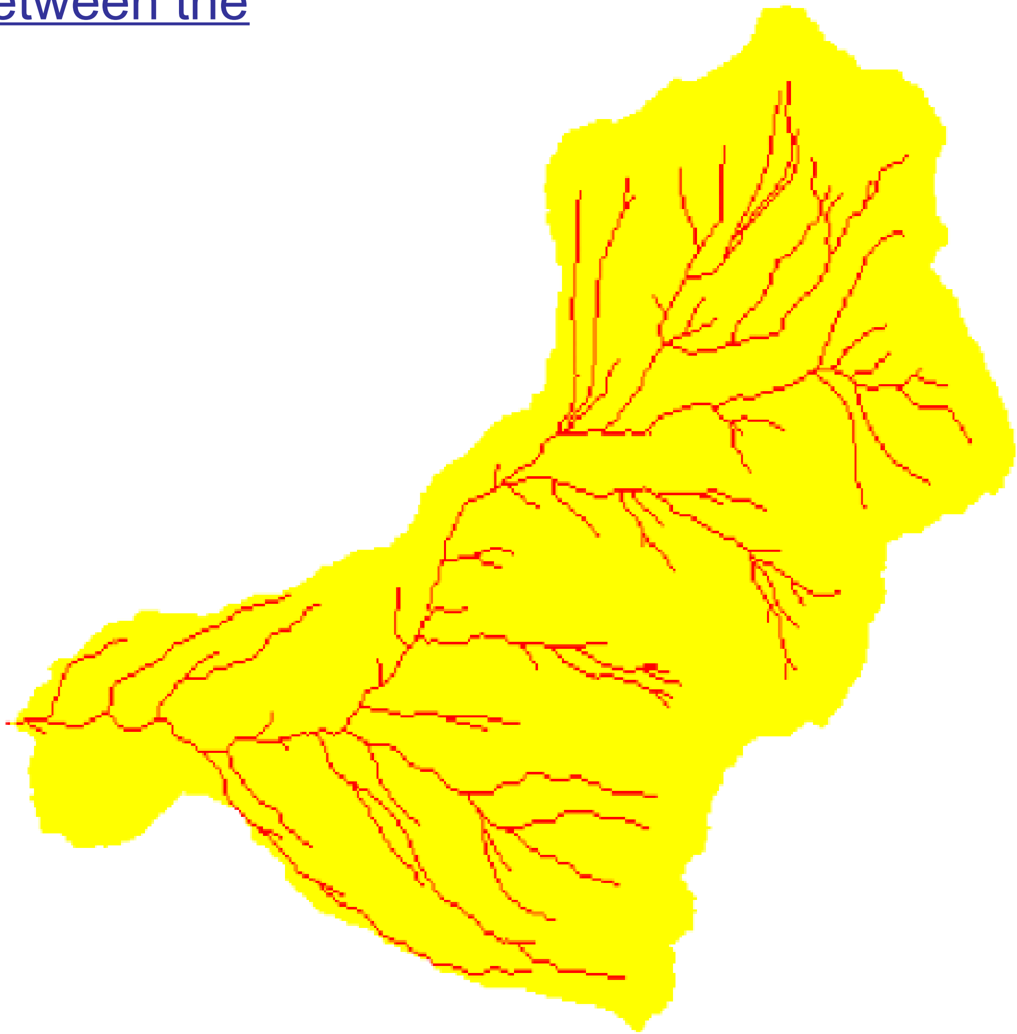
h.extractnetwork

1°method: threshold on the tca

In the resulting raster map the network pixels have the 2 value and outside the network there are null values.

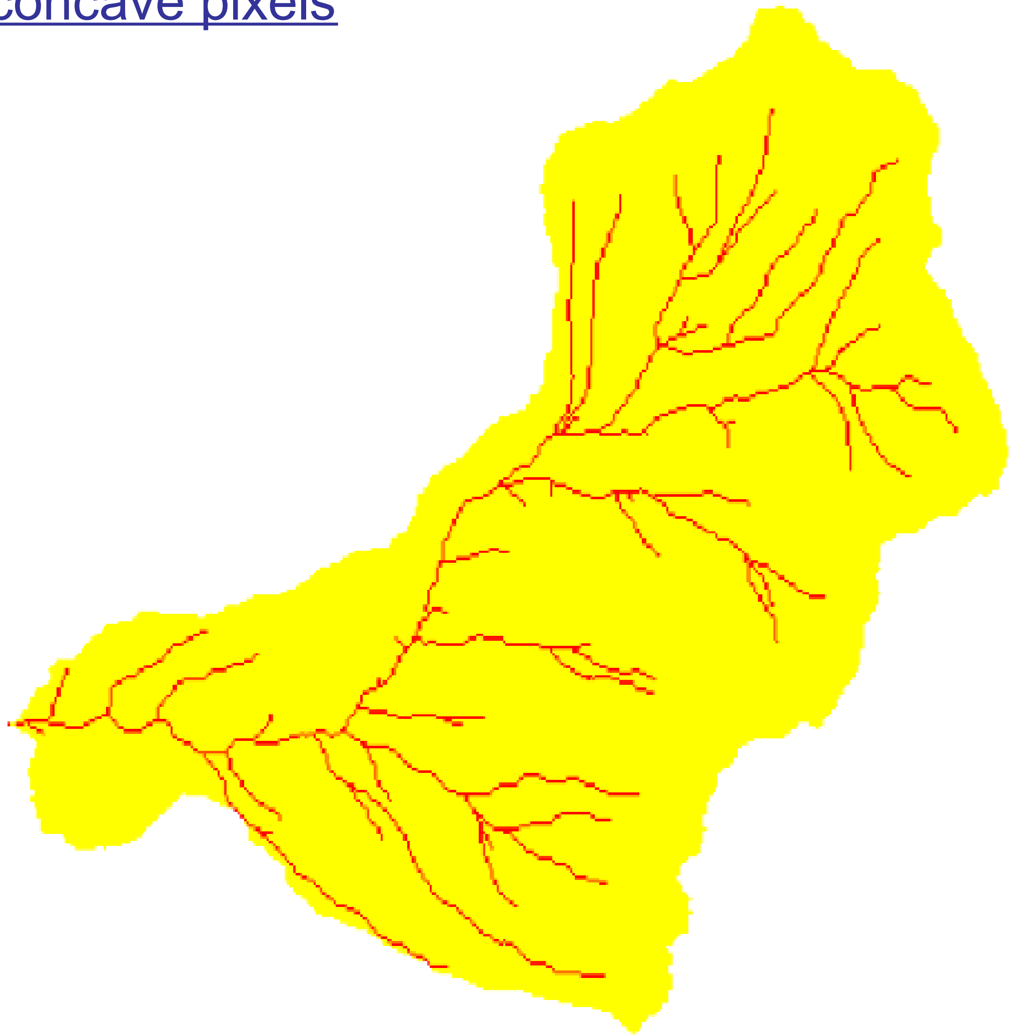
h.extractnetwork

2°method: threshold on the product between the tca and the gradient



h.extractnetwork

3°method: threshold on the tca in the concave pixels



In this case there are various groups of stream networks, everyone of them corresponds to a catchment.

ESTRACTION OF THE WORKING BASIN

- first give the basin outlet:

- insert known coordinates of a point

- use the **Smart *Query tool*** to select a point directly on the network map and verify that the point is on the net (has a value of 2). The coordinates of this point will be added to the clipboard.

- use the coordinates of the selected outlet in the h.wateroutlet command

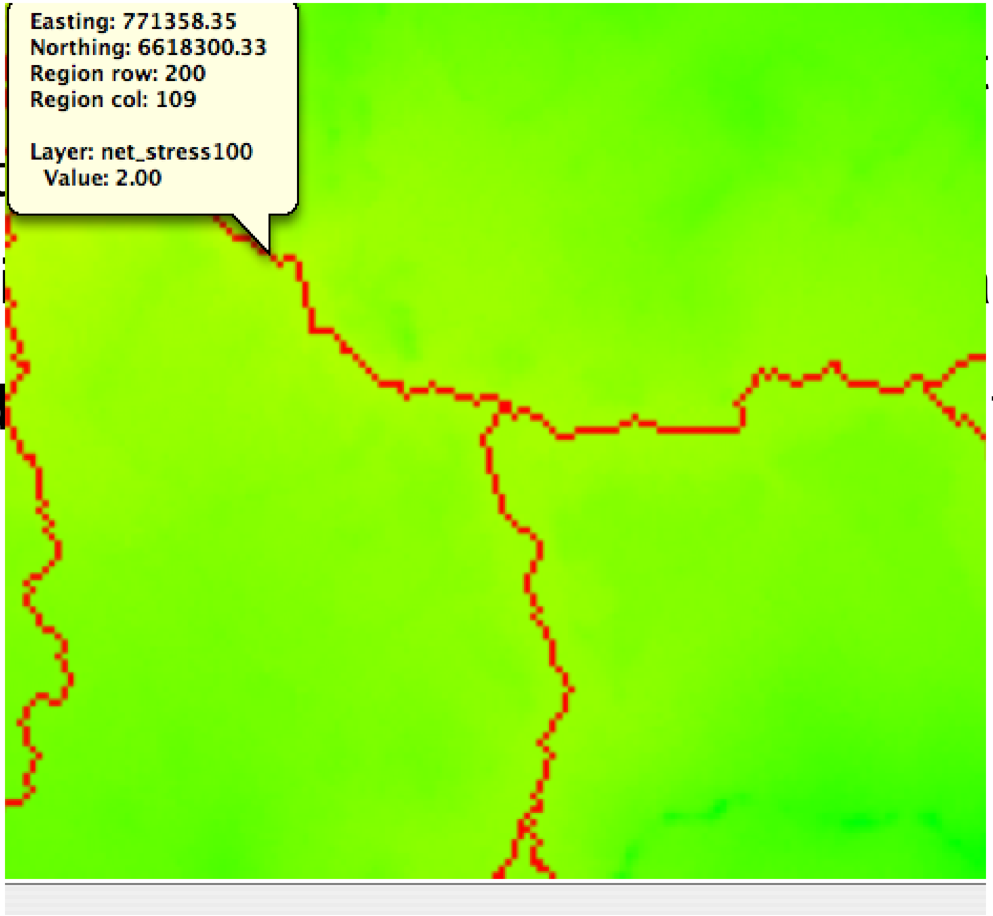
ESTRACTION OF THE WORKING BASIN

- first give the basin outlet:

- insert known coordinates of a point

- use the ***Query*** ly on the network map and verify t value of 2). The coordinates of thi rd.

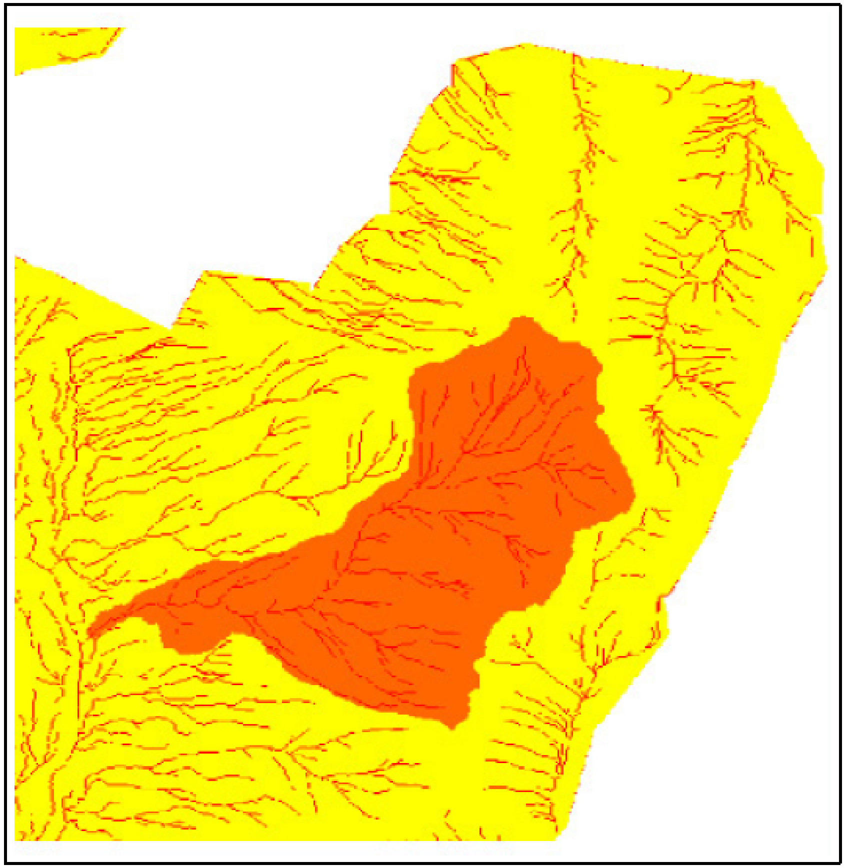
- use the coord the h.wateroutlet command

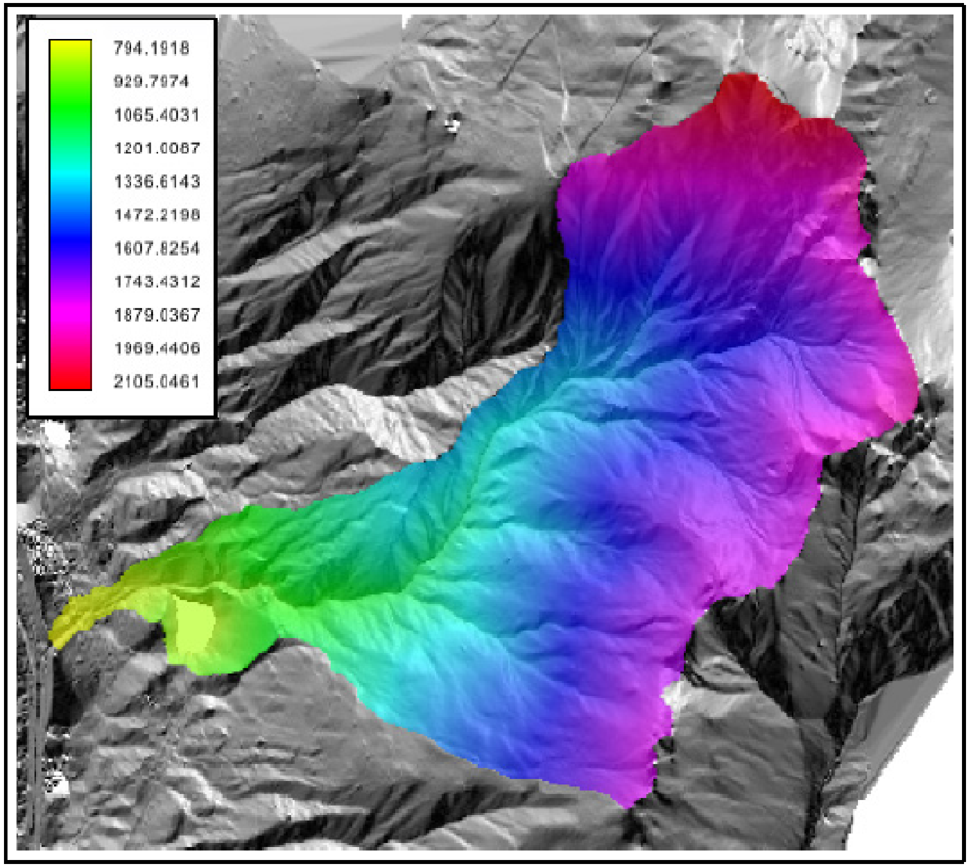


h.wateroutlet

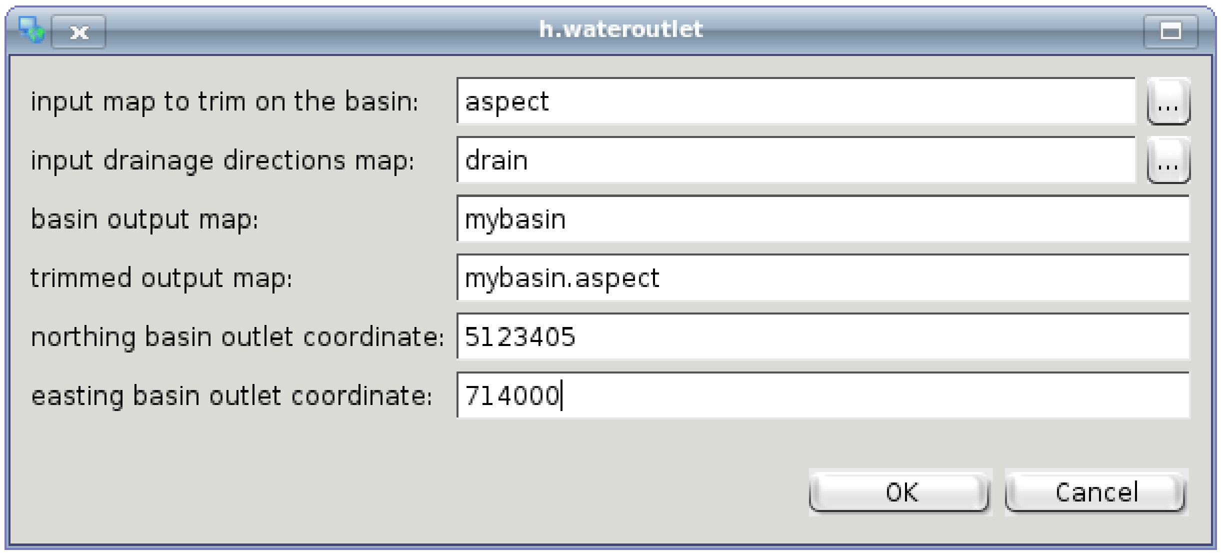
JGrass generates two maps:

- the mask of the extracted basin
- a chosen map cut on the mask





h.wateroutlet



BASIN MORPHOLOGICAL ANALYSIS

First of all we have to execute the previous commands only for the extracted basin. Another choice would be to cut the maps on the extracted mask with the command **mapcalculator**.

- h.pitfiller
- h.flowdirection
- h.draindir
- h.wateroutlet
- h.gradient
- h.curvatures
- h.tc
- h.extractnetwork

BASIN MORPHOLOGICAL ANALYSIS

The best thing to do is to cut the original maps on the extracted basin mask. The maps to cut are the following:

- drainage directions
- total contributing area
- extracted network
- gradient
- curvatures
- topographic classes
- slope

BASIN MORPHOLOGICAL ANALYSIS:

Il comando da utilizzare per ritagliare le mappe sull'area del bacino è **Raster Cutout Tool**, o in alternativa il **Raster Calculator** nella sua versione più generale.

Le mappe da ritagliare sono principalmente:

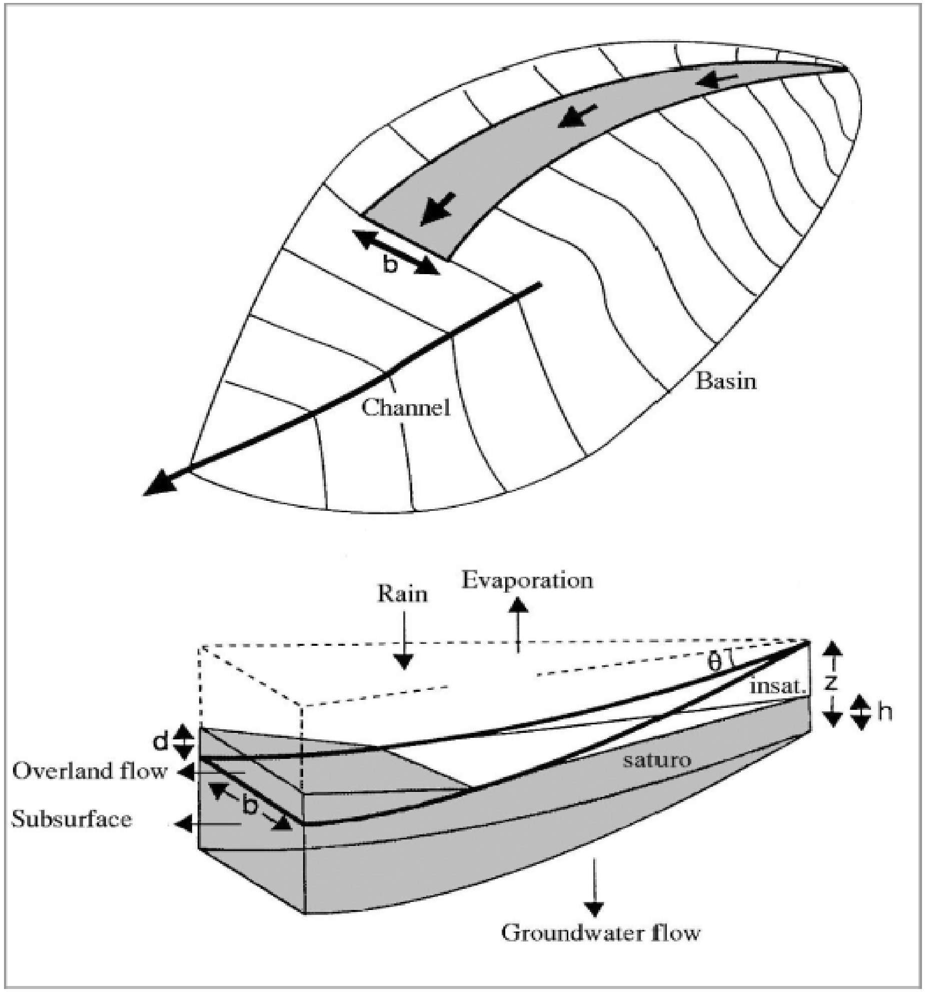
- direzioni di drenaggio
- area contribuente (TCA)
- reticolo idrografico
- gradiente
- pendenza (slope)

h.ab

It calculates the draining area per length unit (A/b), where A is the total upstream area and b is the length of the contour line which is assumed as drained by the A area. The contour length is here be estimated by a a novel method based on curvatures.

h.ab

It calculates the draining area per length unit (A/b), where A is the total upstream area and b is the length of the contour line which is assumed as drained by A. The contour length is here be estimated by a a n... s.



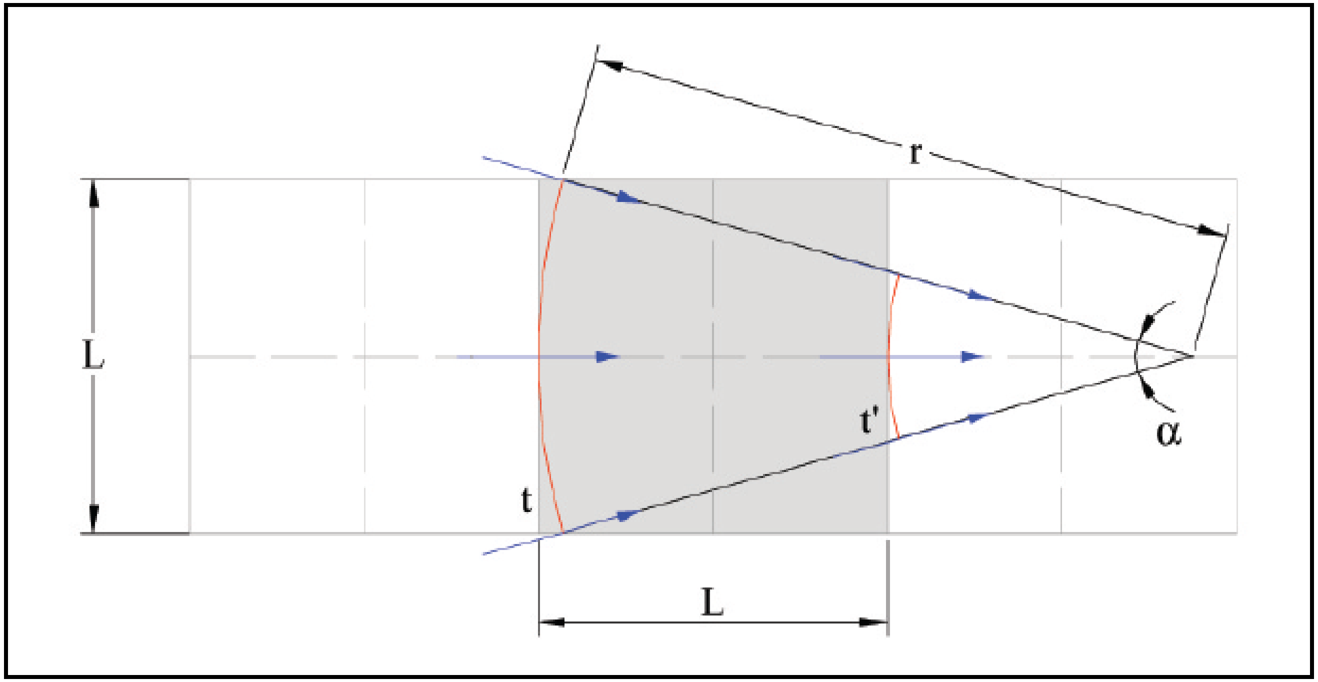
h.ab

- concave sites → convergent sites
- convex sites → divergent sites

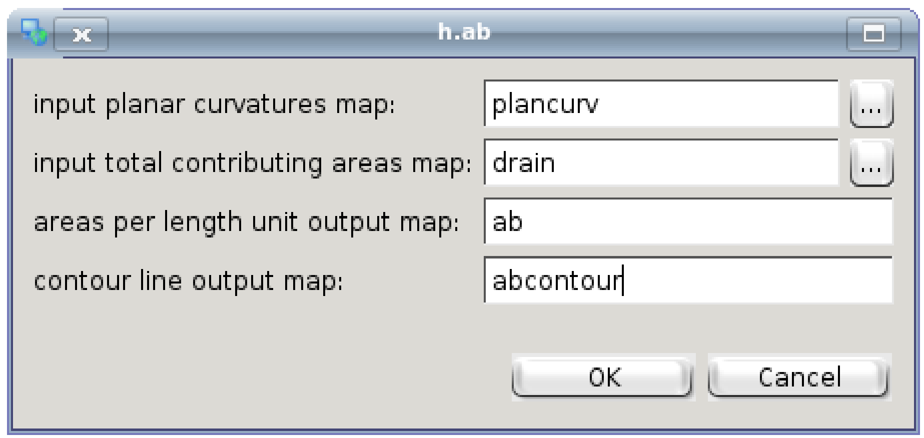
The stream network pixels are the concave sites.

The contour line is locally approximated by an arc having the radius inversely proportional to the local planar curvature

$b \sim t'$



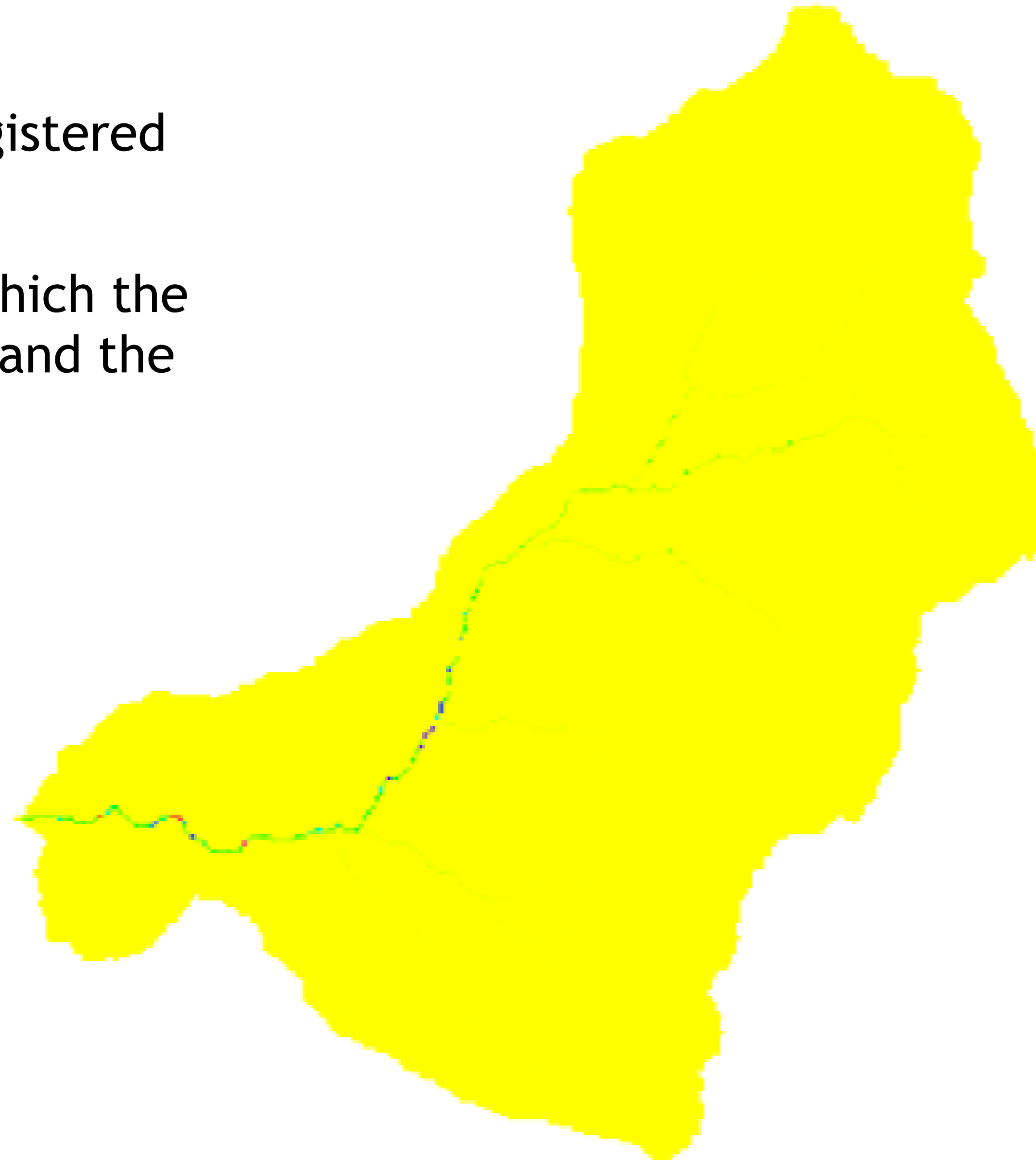
h.ab


h.ab
input planar curvatures map:
plancurv
input total contributing areas map:
drain
areas per length unit output map:
ab
contour line output map:
abcontour
OK
Cancel

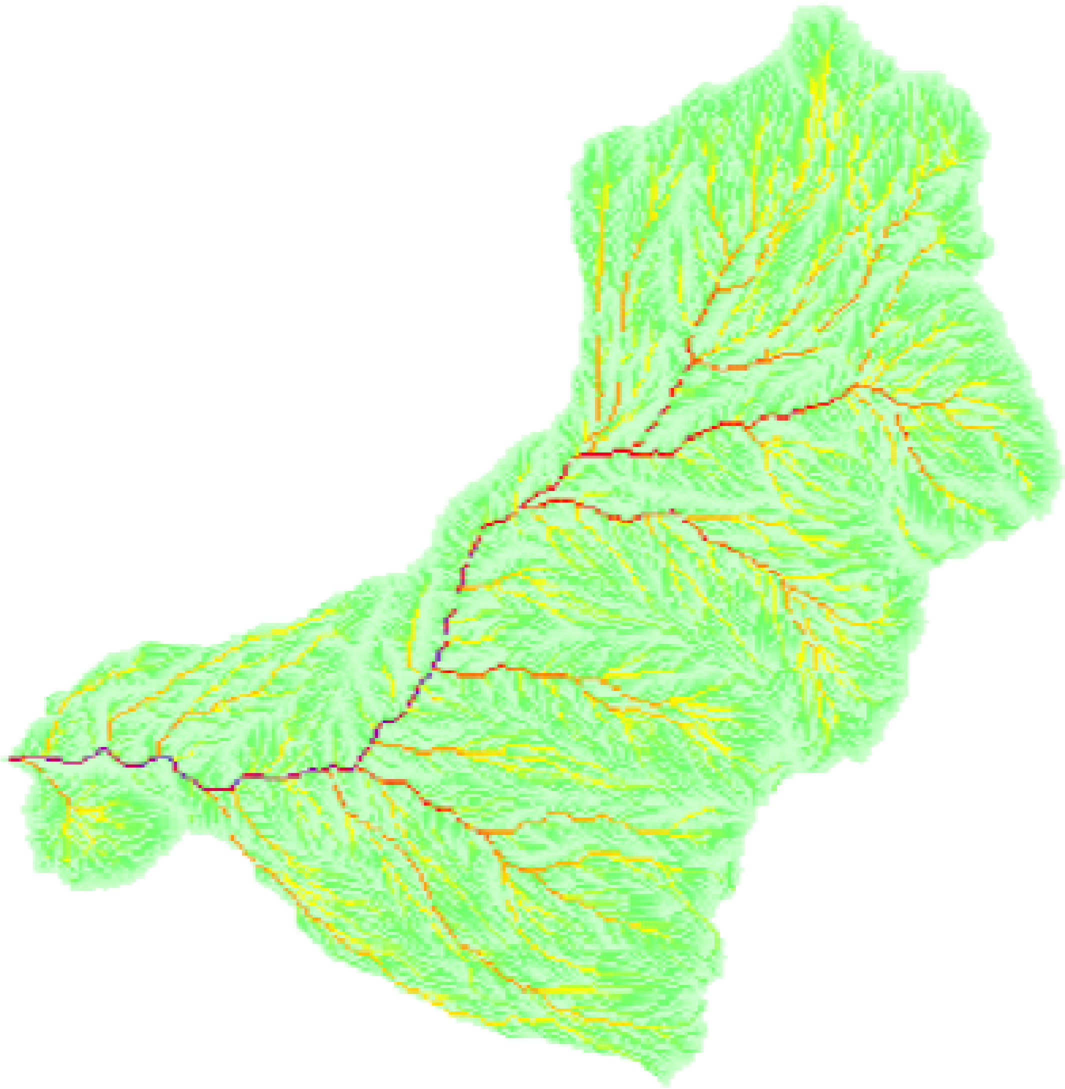
THE RESULT OF A/B

The higher values of A/b are registered near on the channel network.

In fact those are the points in which the contributing area is the highest and the value of b is the lowest.



THE RESULT OF A/B CHANGING THE COLORMAP



ESPOSIZIONE

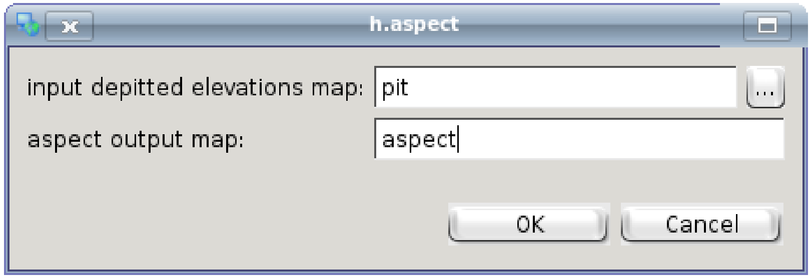
Mathematical formula:

$$\alpha = \arctan \frac{f_y}{f_x}$$

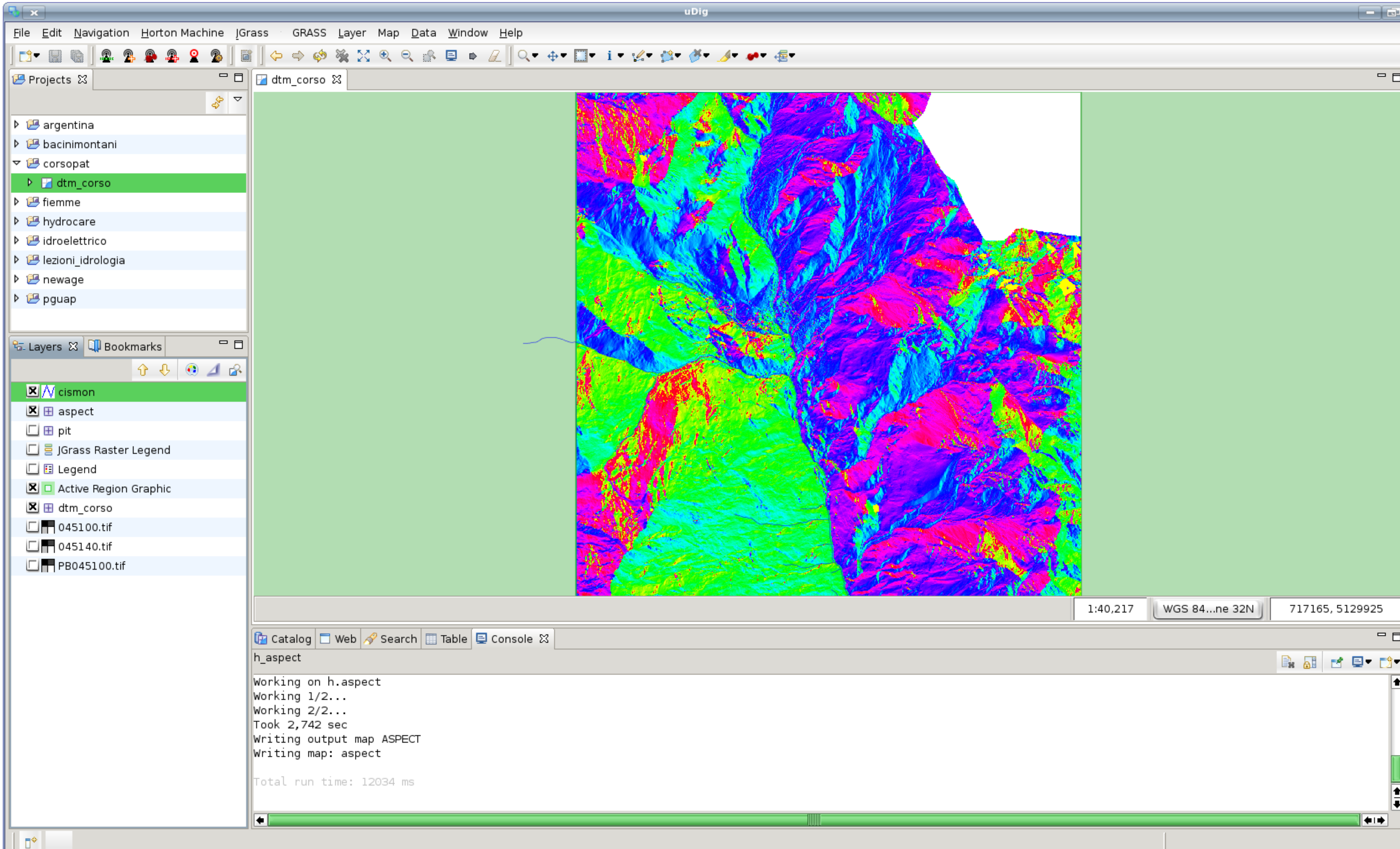
Calculates for every point the aspect, defined as the inclination angle of the gradient. The considered reference system put the angle to zero when the gradient is orientated towards east and grows counter-clock-wise.

The value angle is calculated in radiants.

h.aspect


h.aspect
input depitted elevations map:
pit
aspect output map:
aspect
OK
Cancel

h.aspect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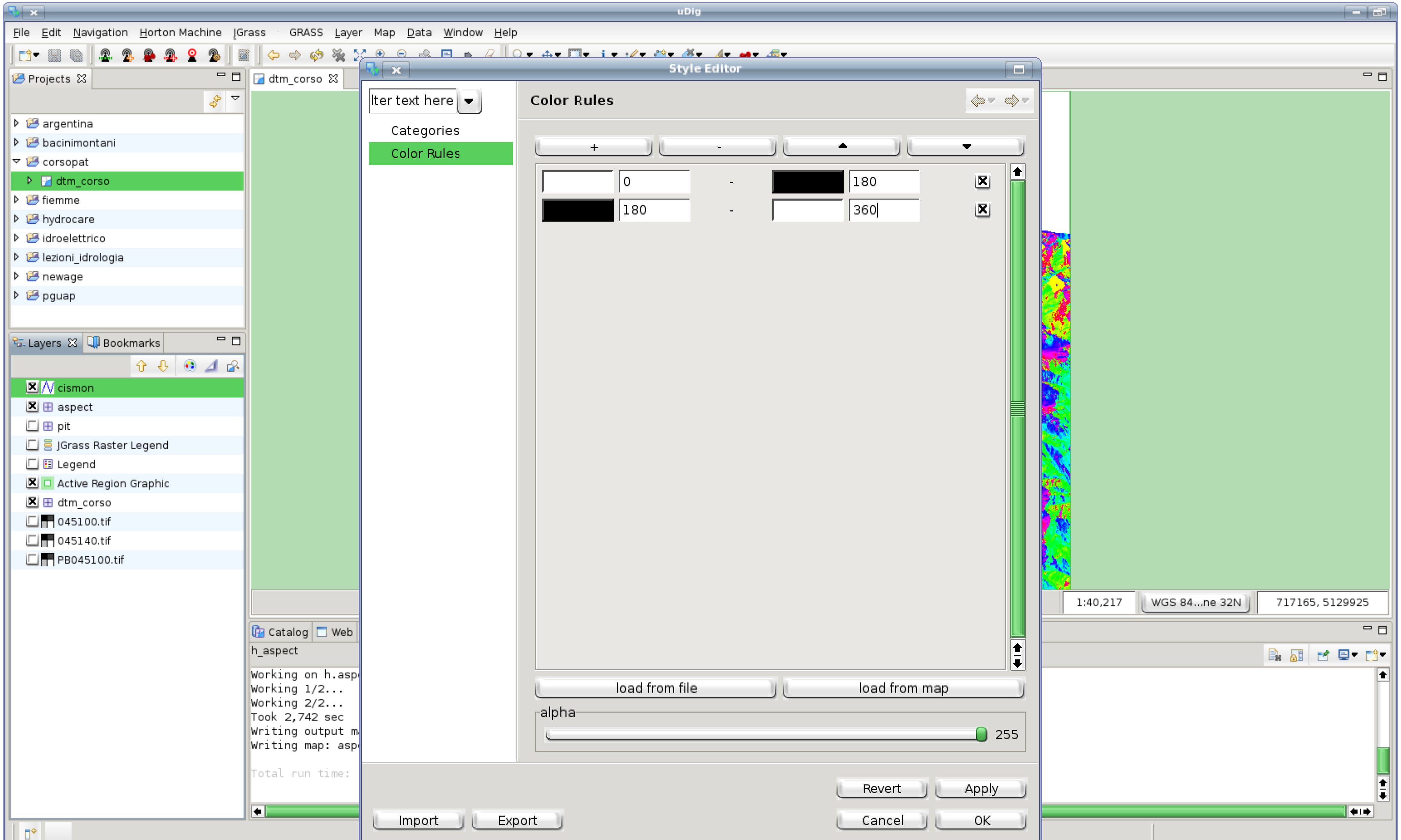
Console
h_aspect
Working on h.aspect
Working 1/2...
Working 2/2...
Took 2,742 sec
Writing output map ASPECT
Writing map: aspect
Total run time: 12034 ms

h.aspect



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Working 2/2...
Took 2,742 sec
Writing output m
Writing map: asp
Total run time:
1:40,217
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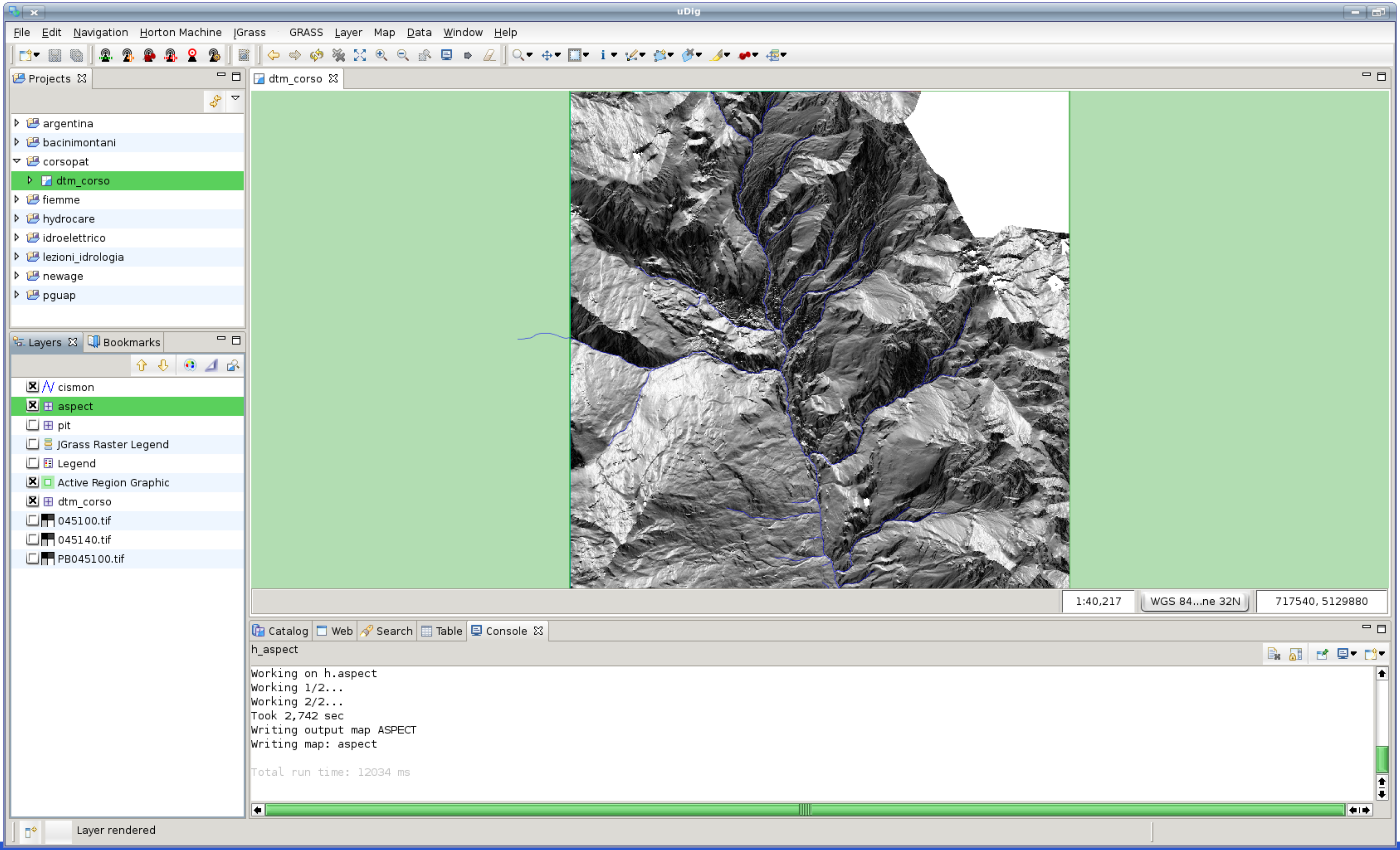
717165, 5129925

h.aspect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File Edit Navigation Horton Machine JGrass GRASS Layer Map Data Window Help
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pguap
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045100.tif
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PB045100.tif
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1:40,217
WGS 84...ne 32N
717540, 5129880
Catalog
Web
Search
Table
Console
h_aspect
Working on h.aspect
Working 1/2...
Working 2/2...
Took 2,742 sec
Writing output map ASPECT
Writing map: aspect
Total run time: 12034 ms
Layer rendered

THE LAPLACIAN

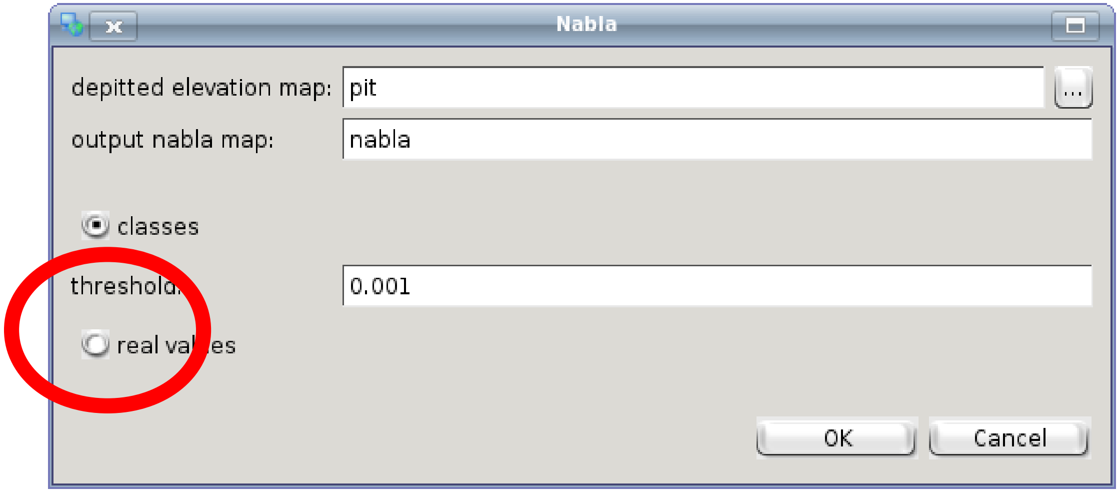
Laplacian is a strict relative of the curvatures and gives a way to distinguish in a first iteration convex and concave sites of the catchment.

Mathematical definition:

$$\nabla z^2 = \frac{\partial^2 z}{\partial^2 x} + \frac{\partial^2 z}{\partial^2 y}$$

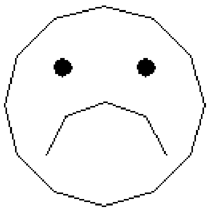
N.B. Concave sites (positive curvature) represent converging flux, convex sites (negative curvature) represent diverging flux.

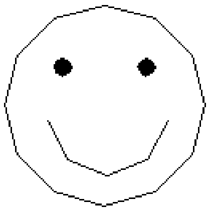
h.nabla

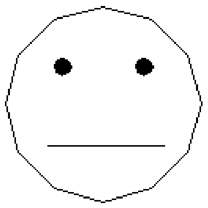


I dati digitali del terreno non restituiscono valori delle curvature realmente affidabili, al contrario il segno del laplaciano è sufficientemente corretto.

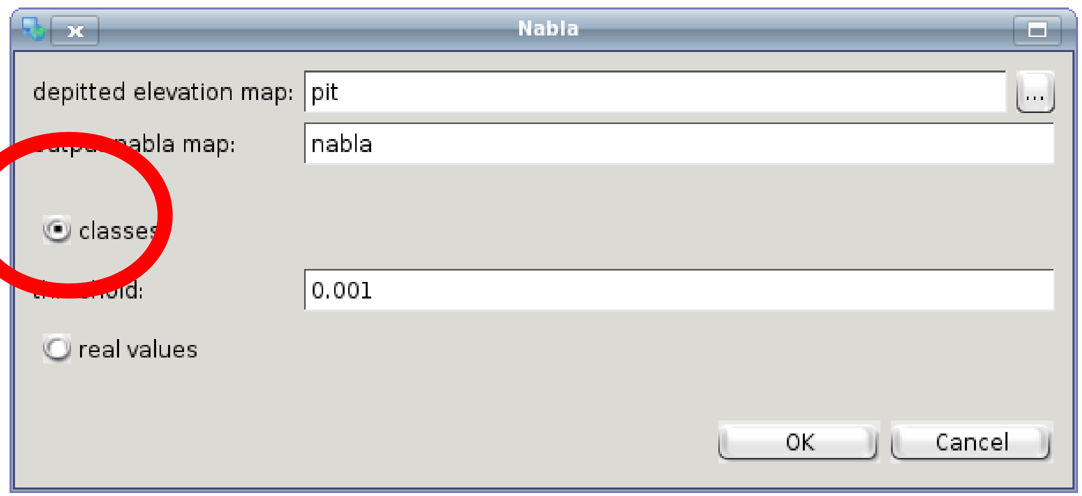
DEFINITIONS FOR CURVATURES

Negative curvature → convex element 

Positive curvature → concave element 

Null curvature → flat element 

h.nabla

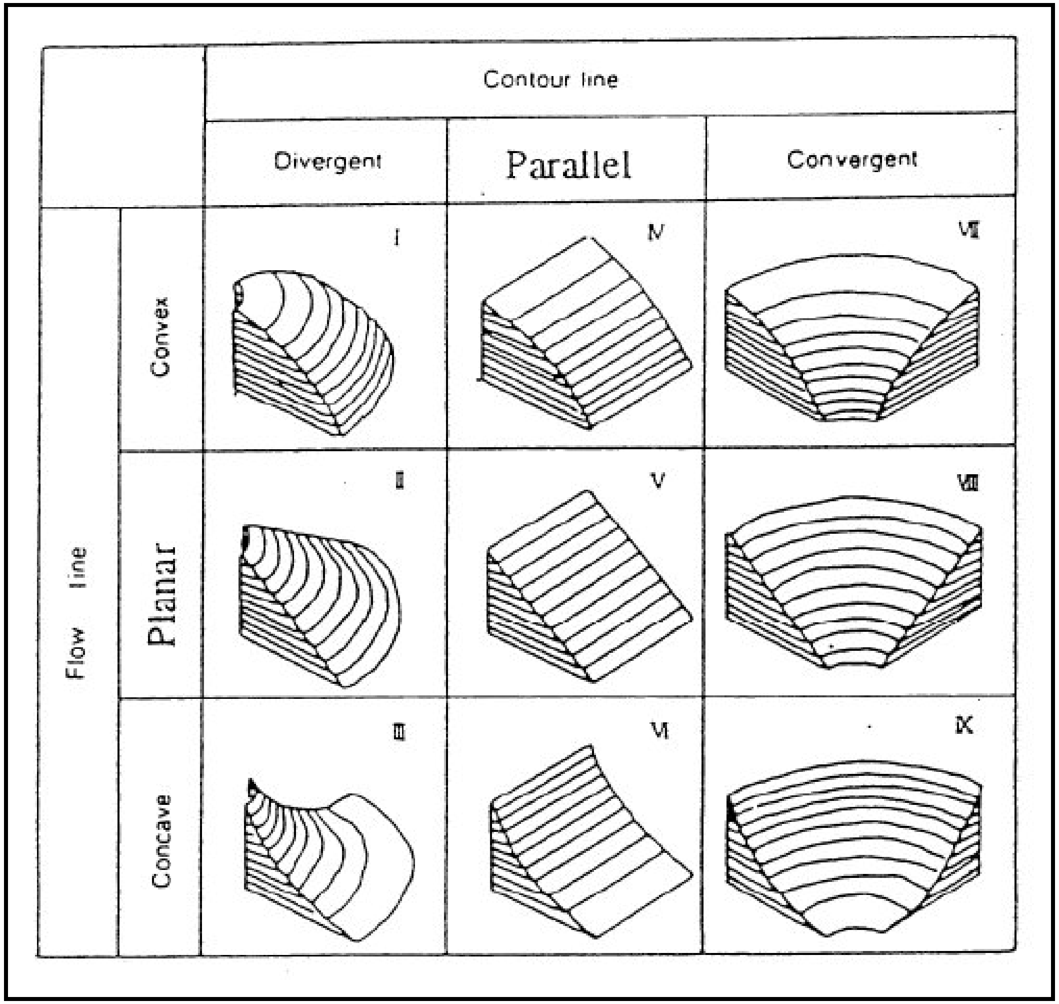

Nabla
depitted elevation map:
pit
...
nabla
classes
0.001
real values
OK
Cancel

h.nabla

h.gc

It subdivides the sites of a basin in 11 topographic classes.

- nine classes based obtained with TC



h.gc

It subdivides the sites of a basin in 11 topographic classes.

- nine classes based obtained with TC
- the points belonging to the channel networks constitute a tenth class (derived from the use of ExtractNetwork)
- the points with high slope (higher than a critical angle) the eleventh class.

h.gc

It subdivides the sites of a basin in 11 topographic classes.

- nine classes based obtained with TC
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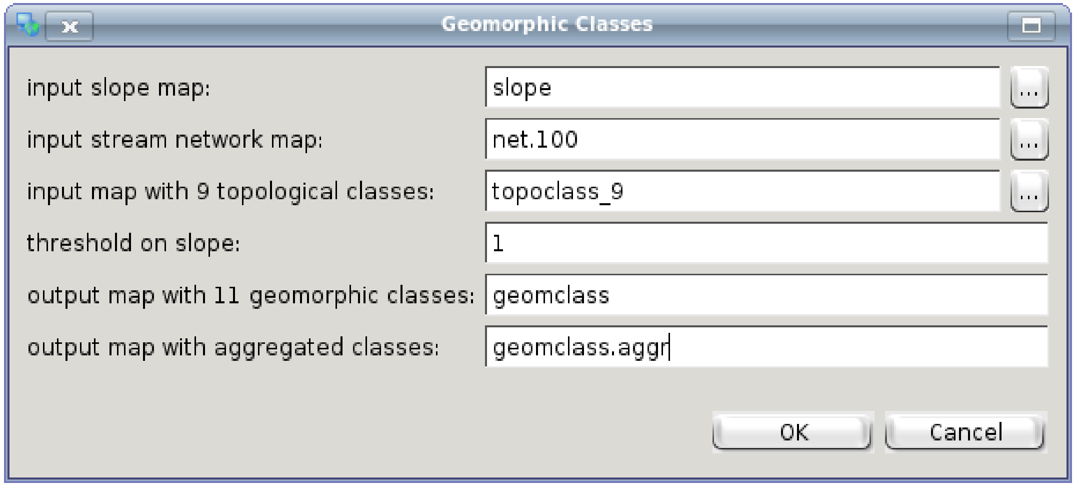


h.gc

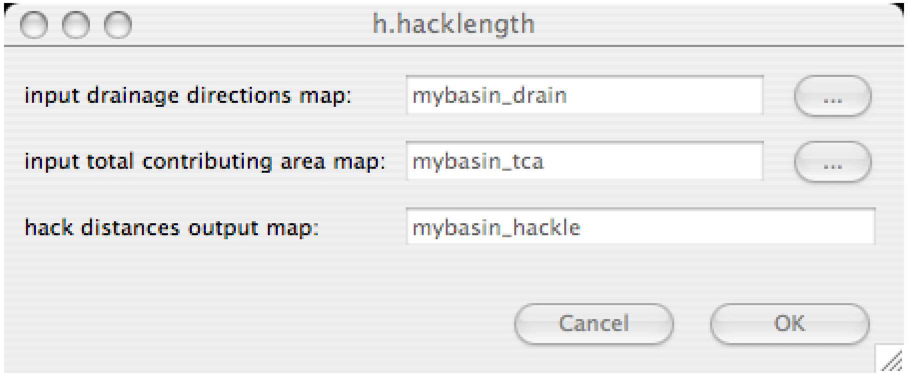
The reclassification of the topological classes is:

15	non channel valley sites
25	planar sites
35	channel sites
45	hillslopes sites
55	unconditionally unstable sites

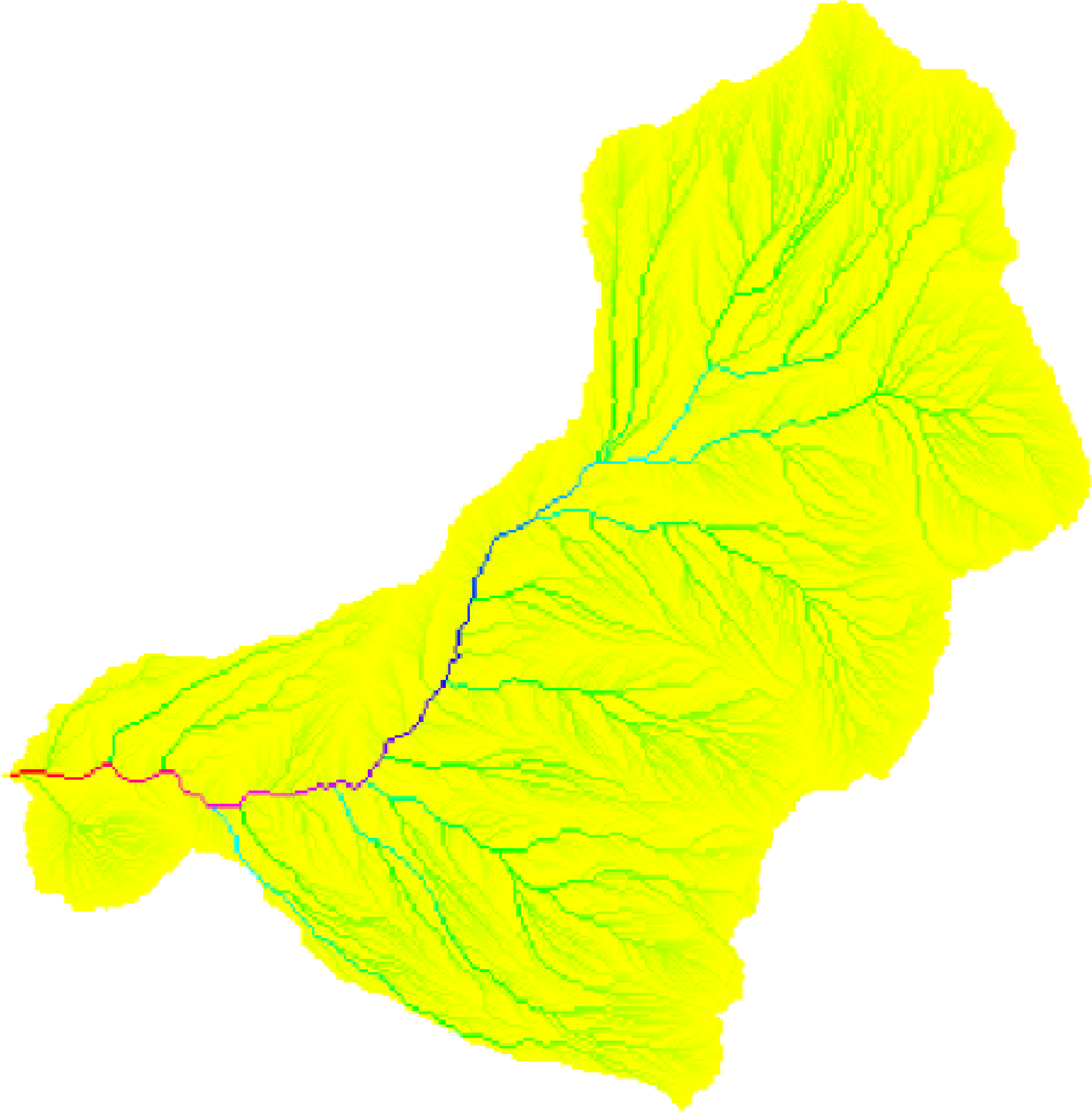
THE DISTANCES BY HACK

It is given, assigned a point in the catchment, by the projection of the distance from the catchment divide along the network (until it exists), and then, proceeding upstream along the maximal slope lines.

For each network confluence, the direction of the tributary with maximal contributing area is chosen. If the tributaries have the same area, one of the two directions is chosen at random.



h.hacklentgh



MAGNITUDO: h.magnitudo

The magnitude is defined as the number of sources upstream to every point of the catchment.

If the river net is a trifurcated tree (a node in which three channels enter and one exits), then between number of springs and channels there exists a bijective correspondence

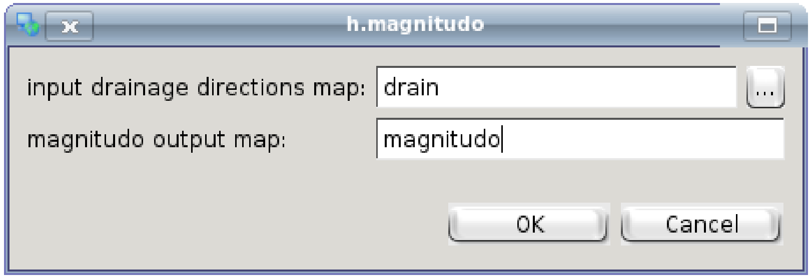
$$hc = 2ns - 1$$

hc is the number of channels

ns the number of sources

The mangitudo is also an indicator of the contributing area.

MAGNITUDO: h.magnitudo



NETNUMBERING

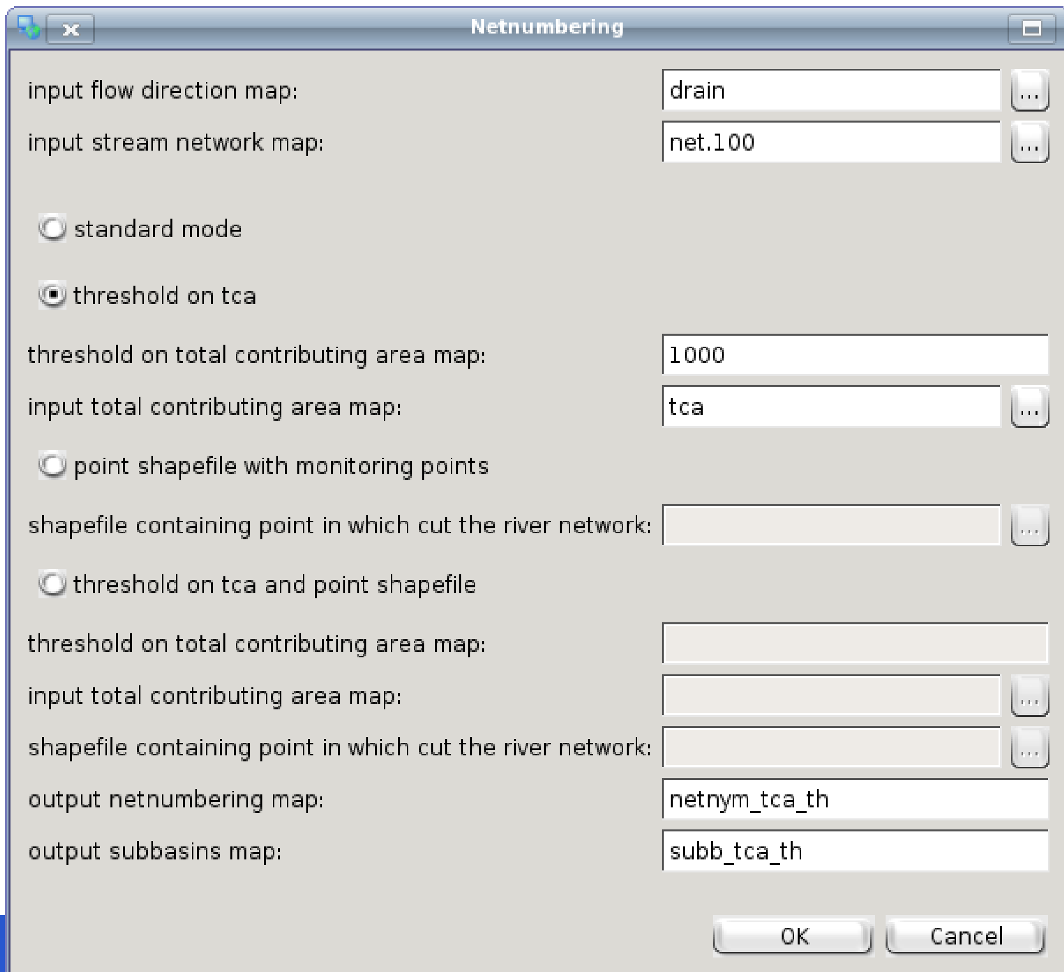
It assign numbers to the network’s links.

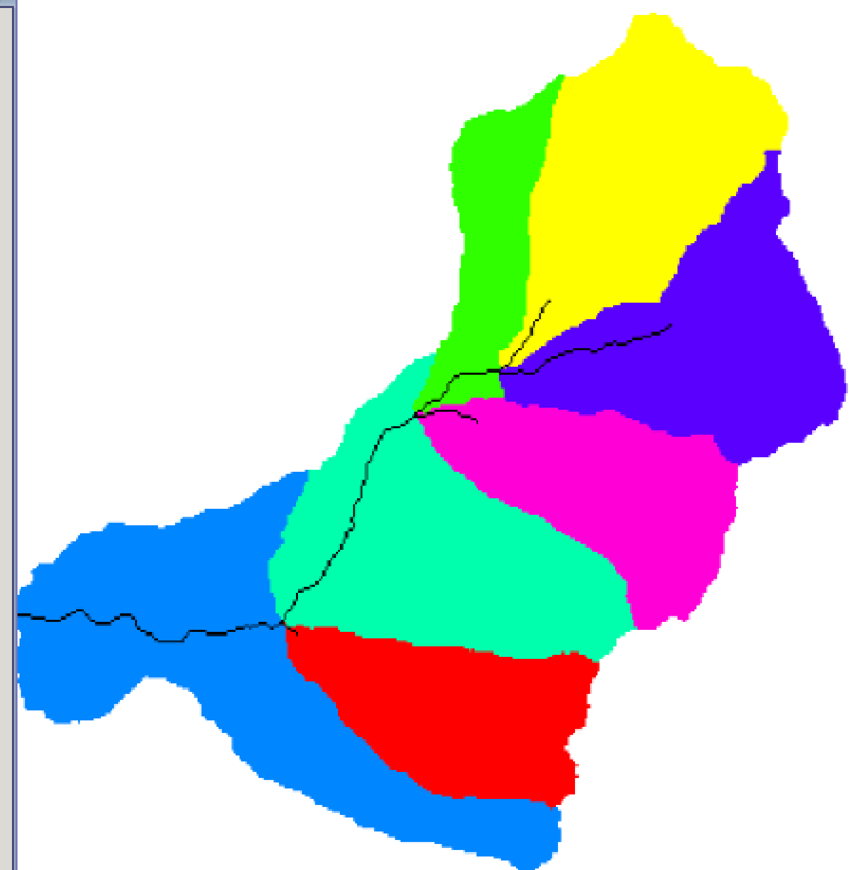
It can be used by hillslope2channelattribute to label the hillslope flowing into the link with the same number.

It subdivides the basin in the related hillslopes to each link.

SUBBASIN EXTRACTION: h.netnumbering

The subbasins depend on the complexity of the network:
a complex network has a large number of subbasins
a simple network has a small number of subbasins





SUBBASIN EXTRACTION: h.netnumbering

The subbasins depend on the complexity of the network:
a complex network has a large number of subbasins
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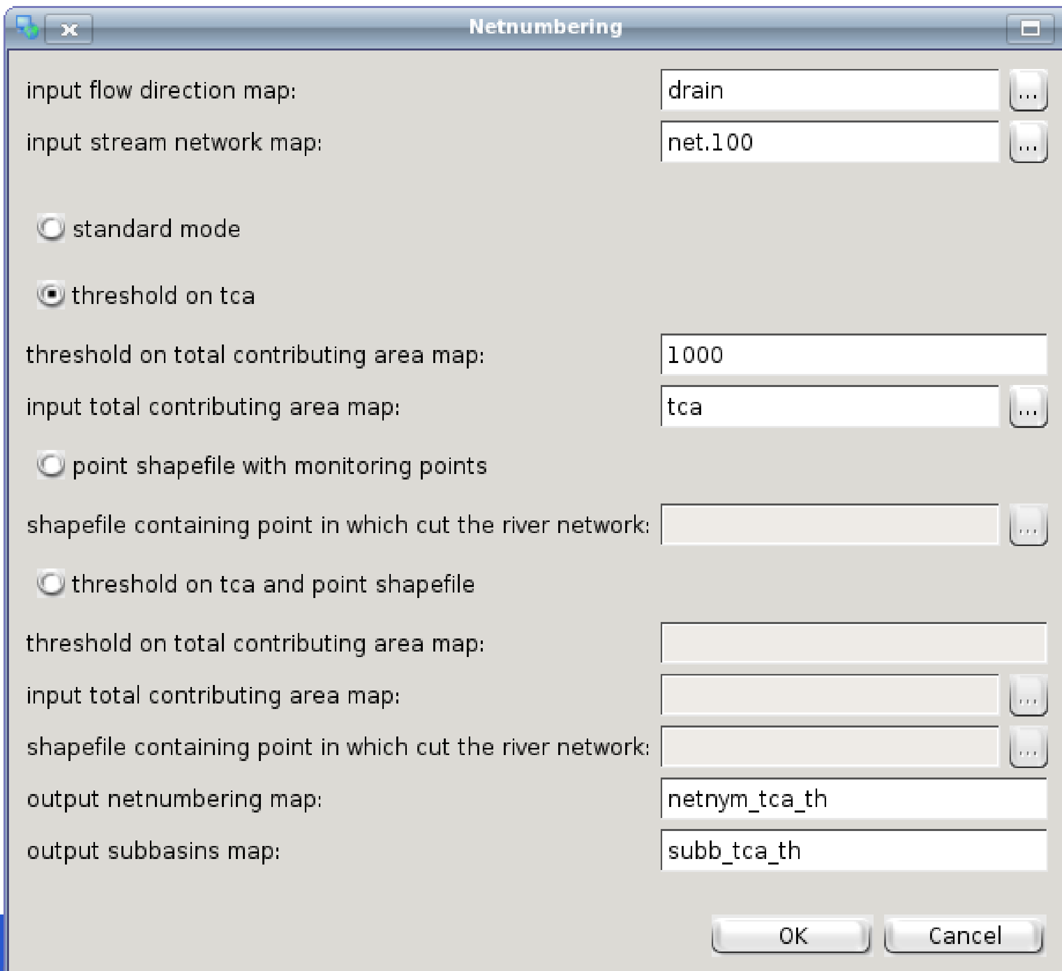
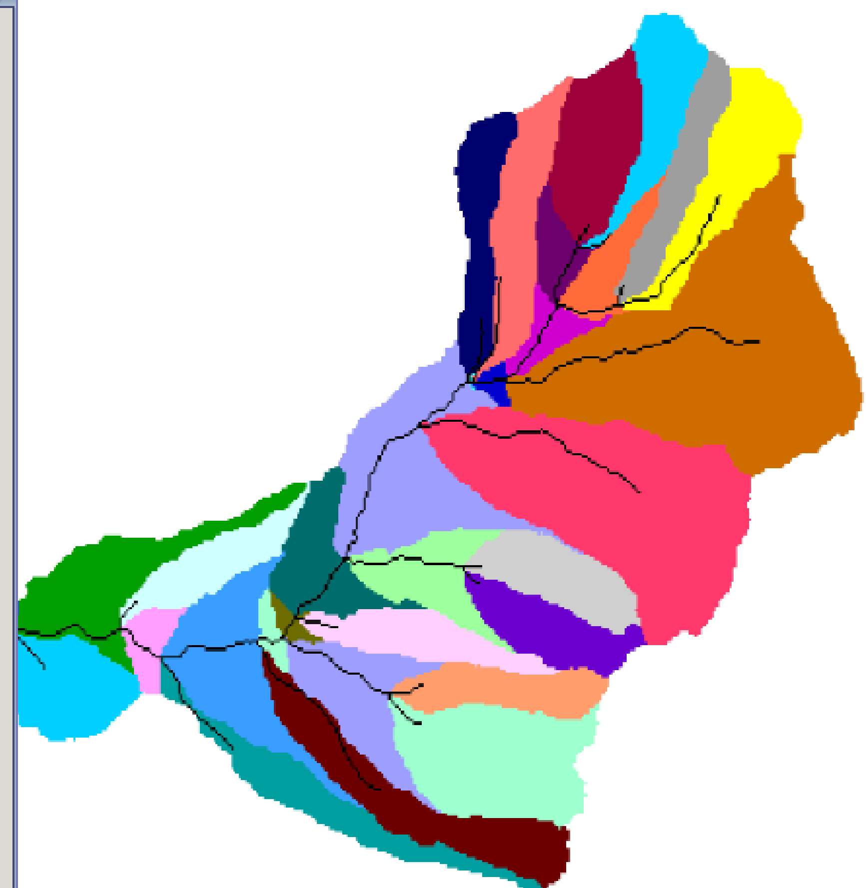




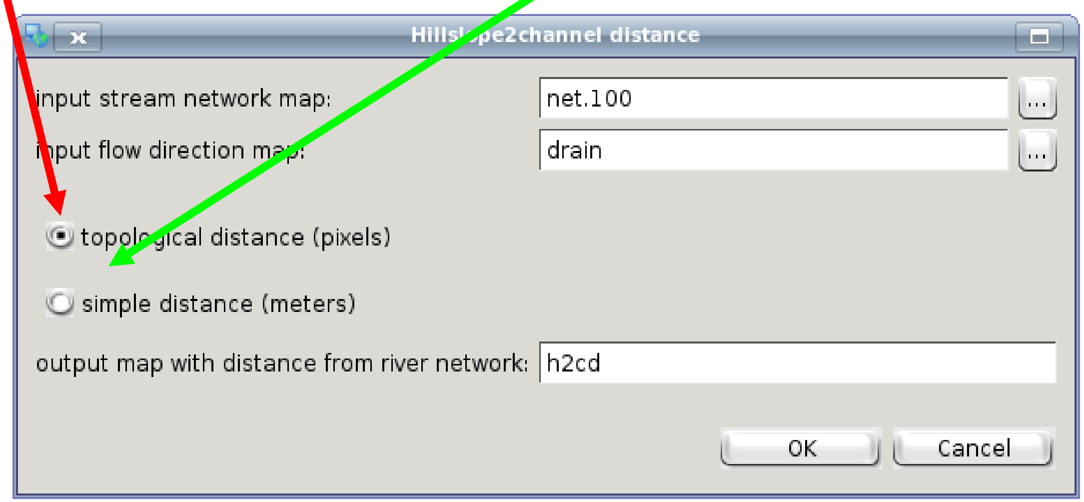
THE DISTANCE FROM THE NETWORK

Evaluates the distance of every pixel in the catchment to the network. It can work in 2 different ways:

h.hillslope2channeldistance

Evaluates the distance of every pixel in the catchment to the network. It can work in 2 different ways:

- calculates the distance in meters
- calculates the distance in pixels



THE DISTANCE TO OUTLET

It calculates the projection on the plane of the distance of each pixel from the outlet, measured along the drainage directions.

The program can work in two different ways: it can calculate the distance from the outlet either in pixel number (0:topological distance mode), or in meters (1:simple distance mode).

THE RESCALED DISTANCE TO OUTLET

It calculates the rescaled distance of each pixel from the outlet. Such distance is so defined:

$$x_0 = x_c + r\, x_h$$

where: x_c is the distance along the channels,

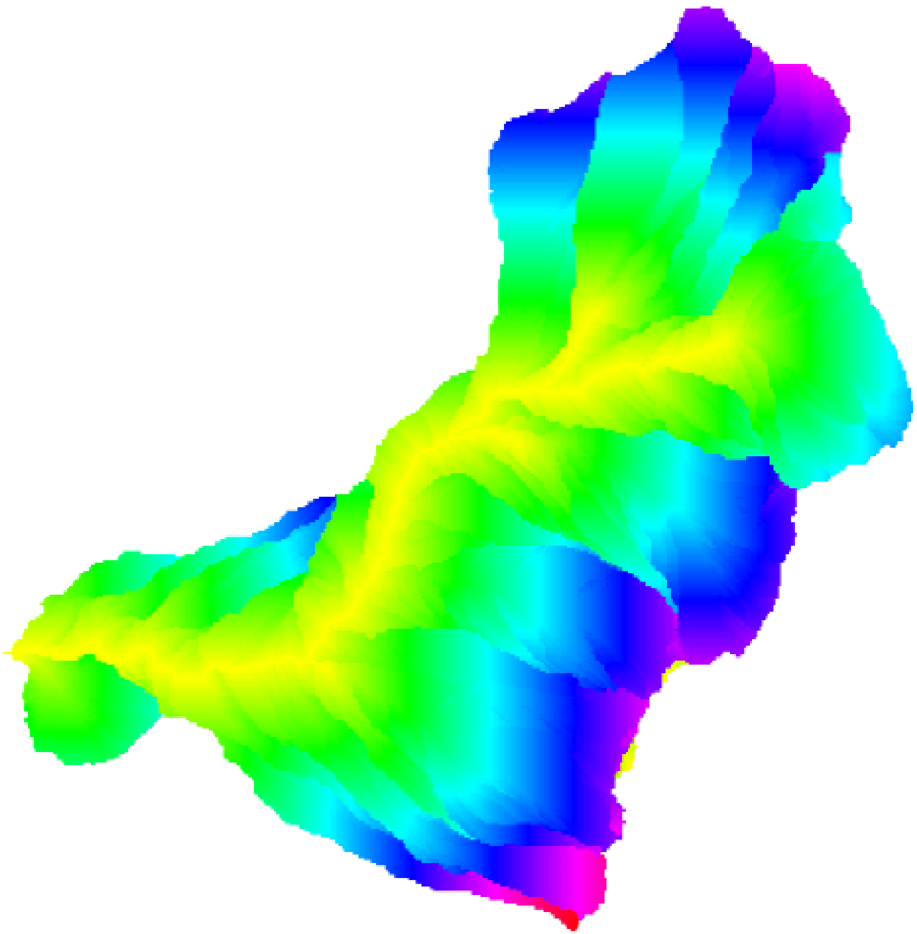
$r = c/c_h$ the ratio between

c the speed in the channel state

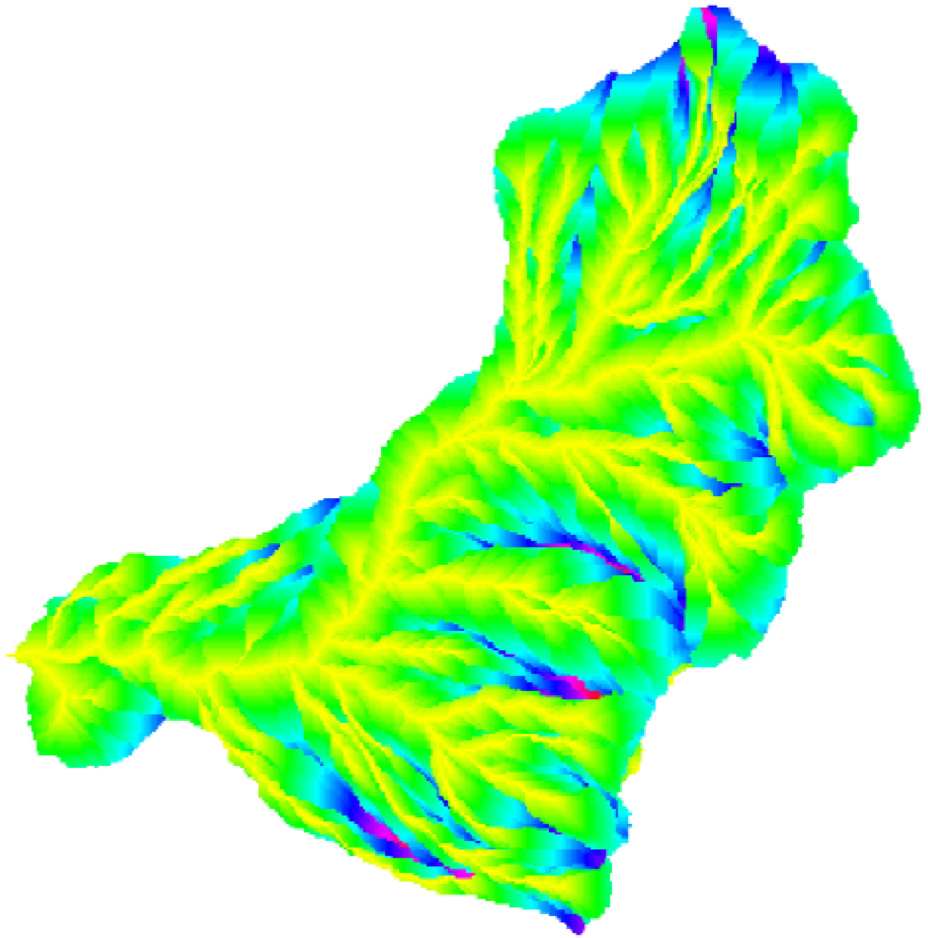
c_h and the speed in the hillslopes

x_h the distance along the hillslopes.

THE DISTANCE TO OUTLET

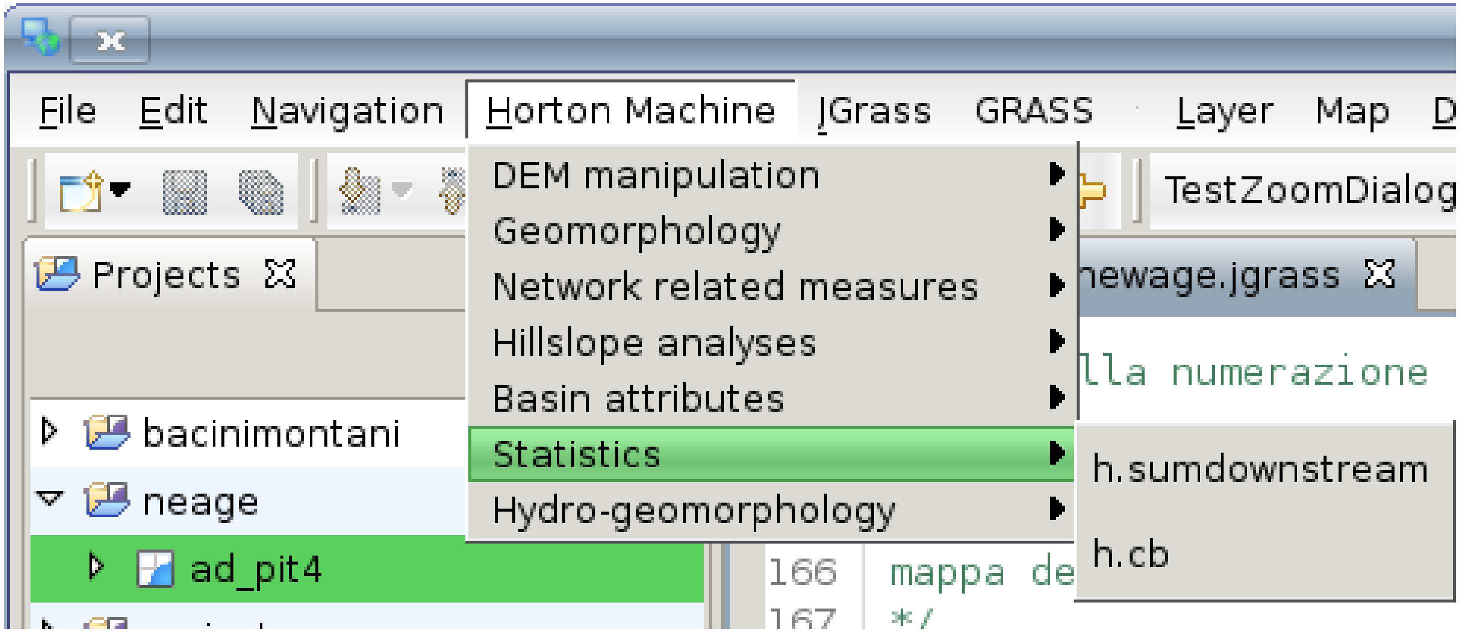


Distance to outlet map for a simple channel network



Distance to outlet map with different velocity in channel and hillslopes

ANALISI DEI VALORI DI UNA MAPPA: h.cb

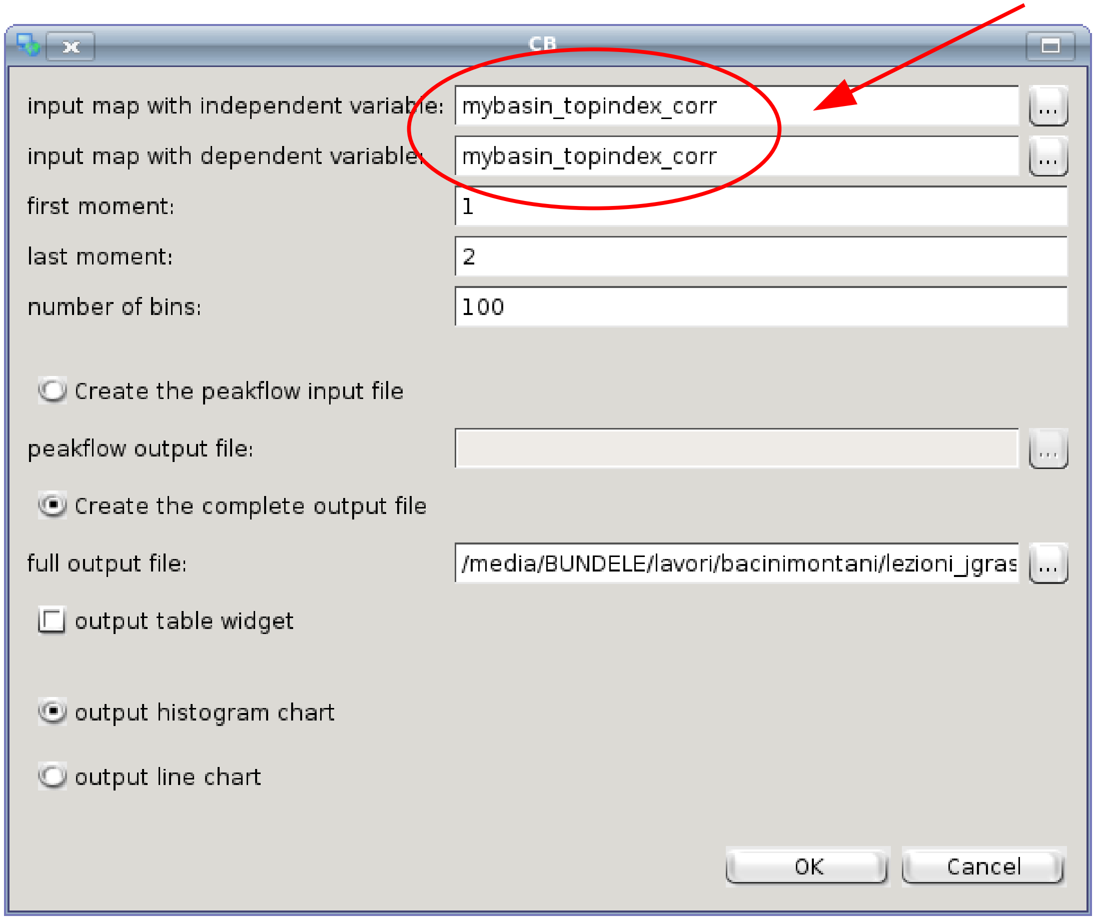


ANALISI DEI VALORI DI UNA MAPPA: h.cb

- calcola l'istogramma dei valori di una mappa rispetto a quelli contenuti in un'altra mappa
- i dati della prima mappa vengono raggruppati in un numero prefissato di intervalli e viene calcolato il valore medio della variabile indipendente in ciascun intervallo
- per ogni intervallo corrisponde un set di valori nella seconda mappa dei quali viene calcolata la media e gli altri momenti richiesti dall'utente
- l'output di questo programma è un file e non una mappa

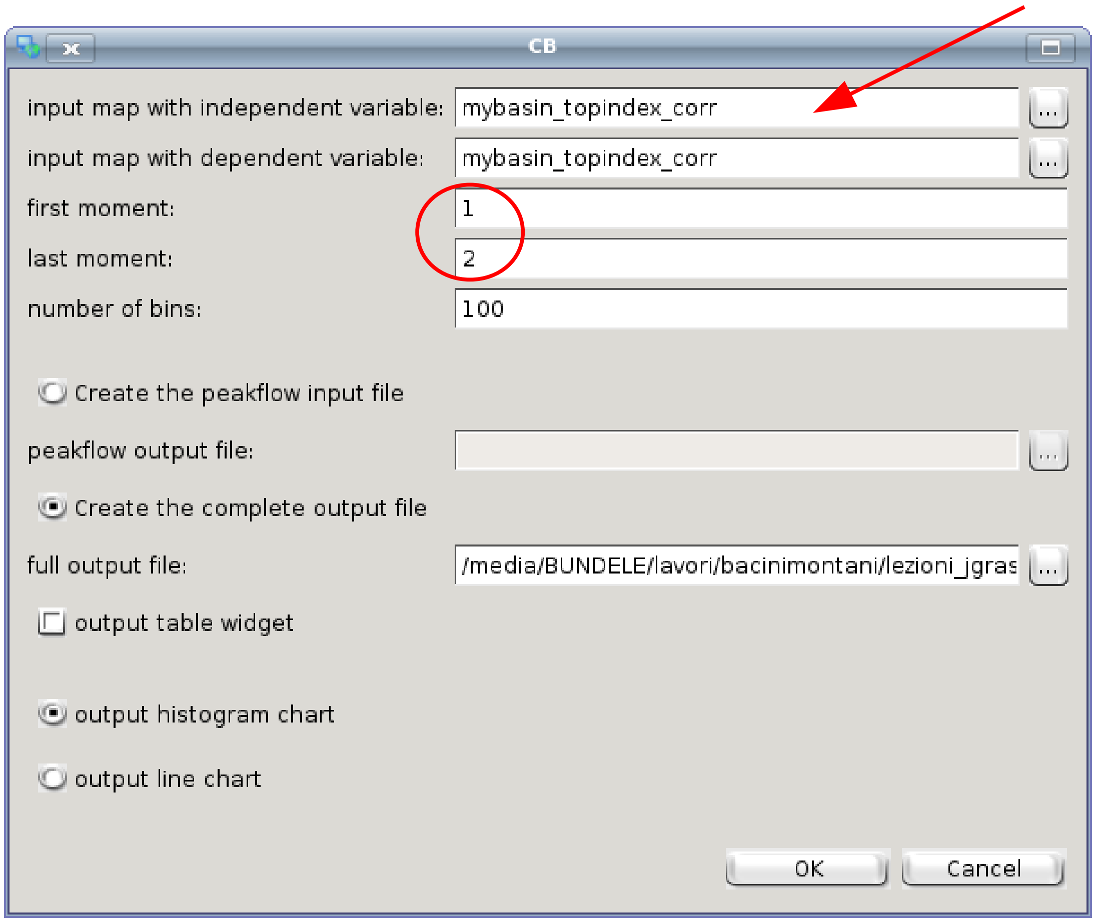
ANALISI DEI VALORI DI UNA MAPPA: h.cb

mappe sulle quali effettuare i calcoli:
può anche essere la stessa mappa



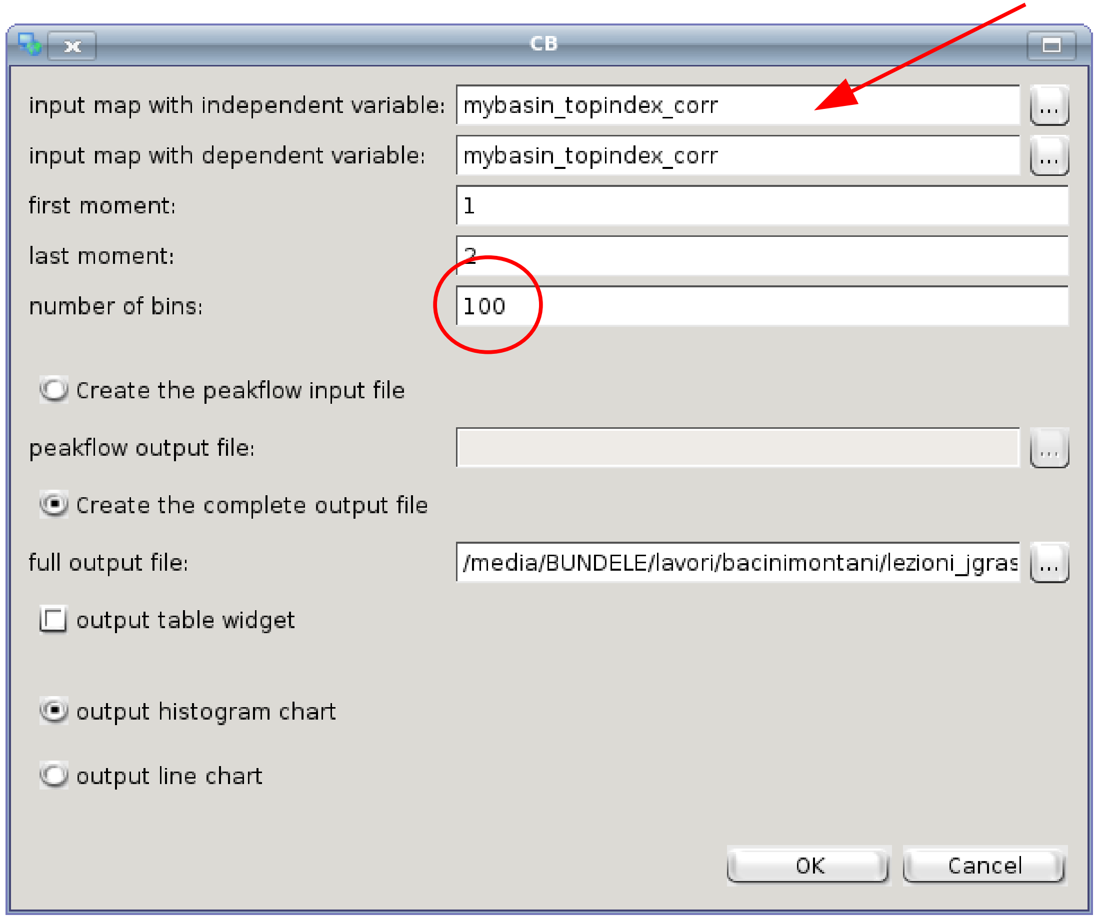
ANALISI DEI VALORI DI UNA MAPPA: h.cb

momenti da calcolare: media, varianza, ...



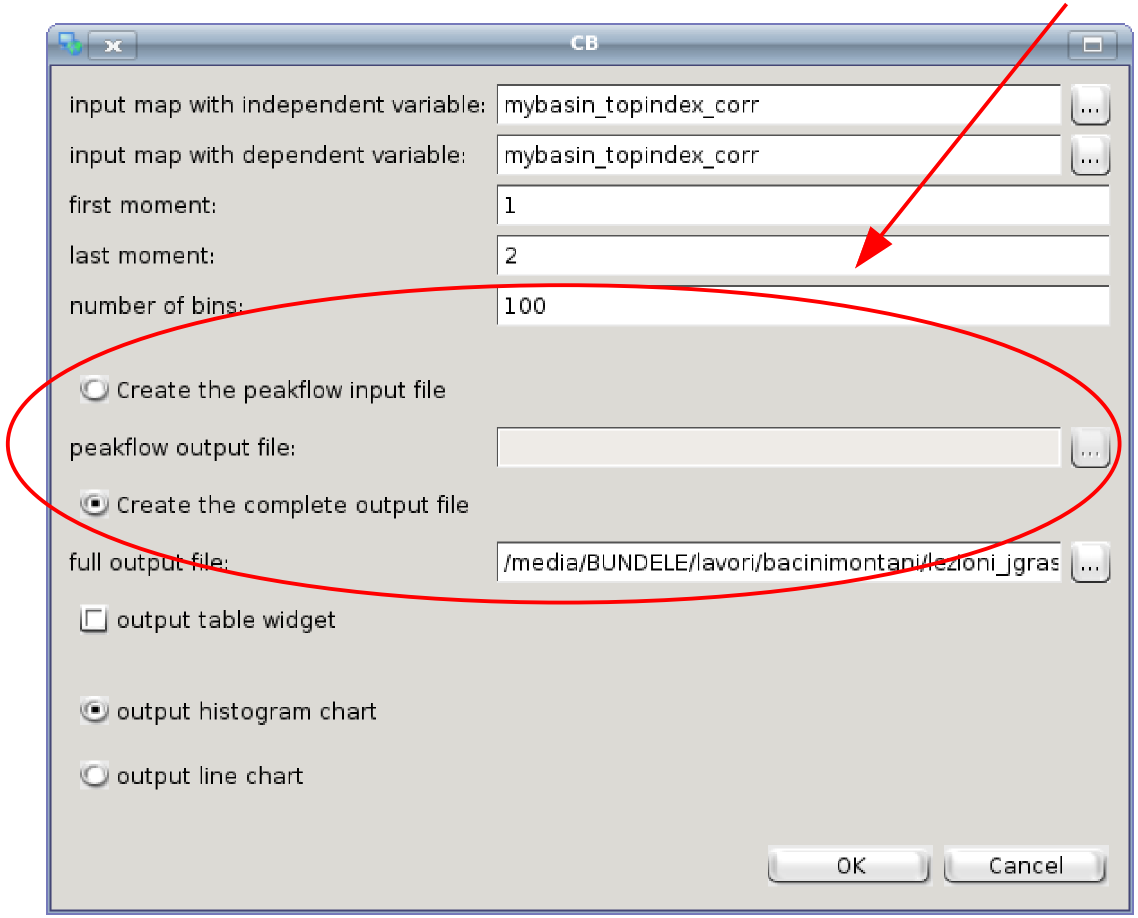
ANALISI DEI VALORI DI UNA MAPPA: h.cb

numero di intervalli in cui dividere il range di valori della prima mappa



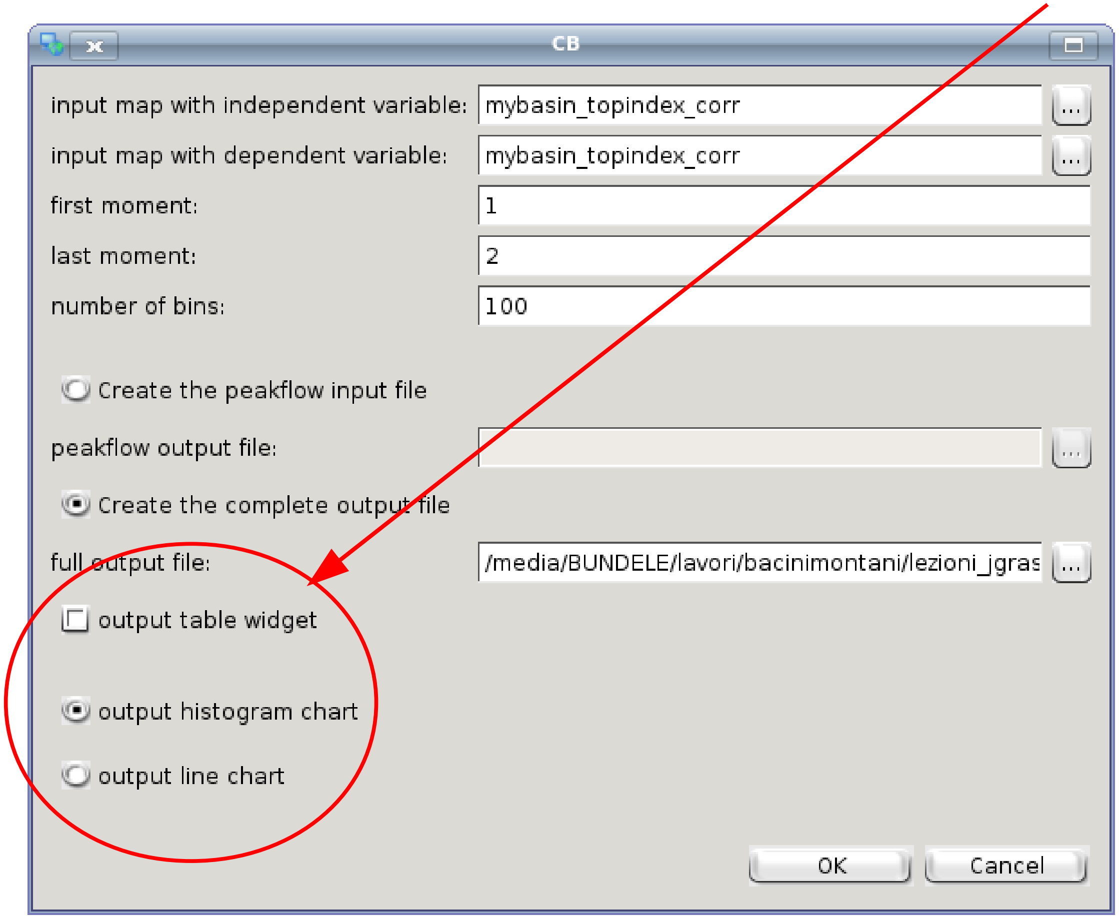
ANALISI DEI VALORI DI UNA MAPPA: h.cb

tipologia e percorso del file di output

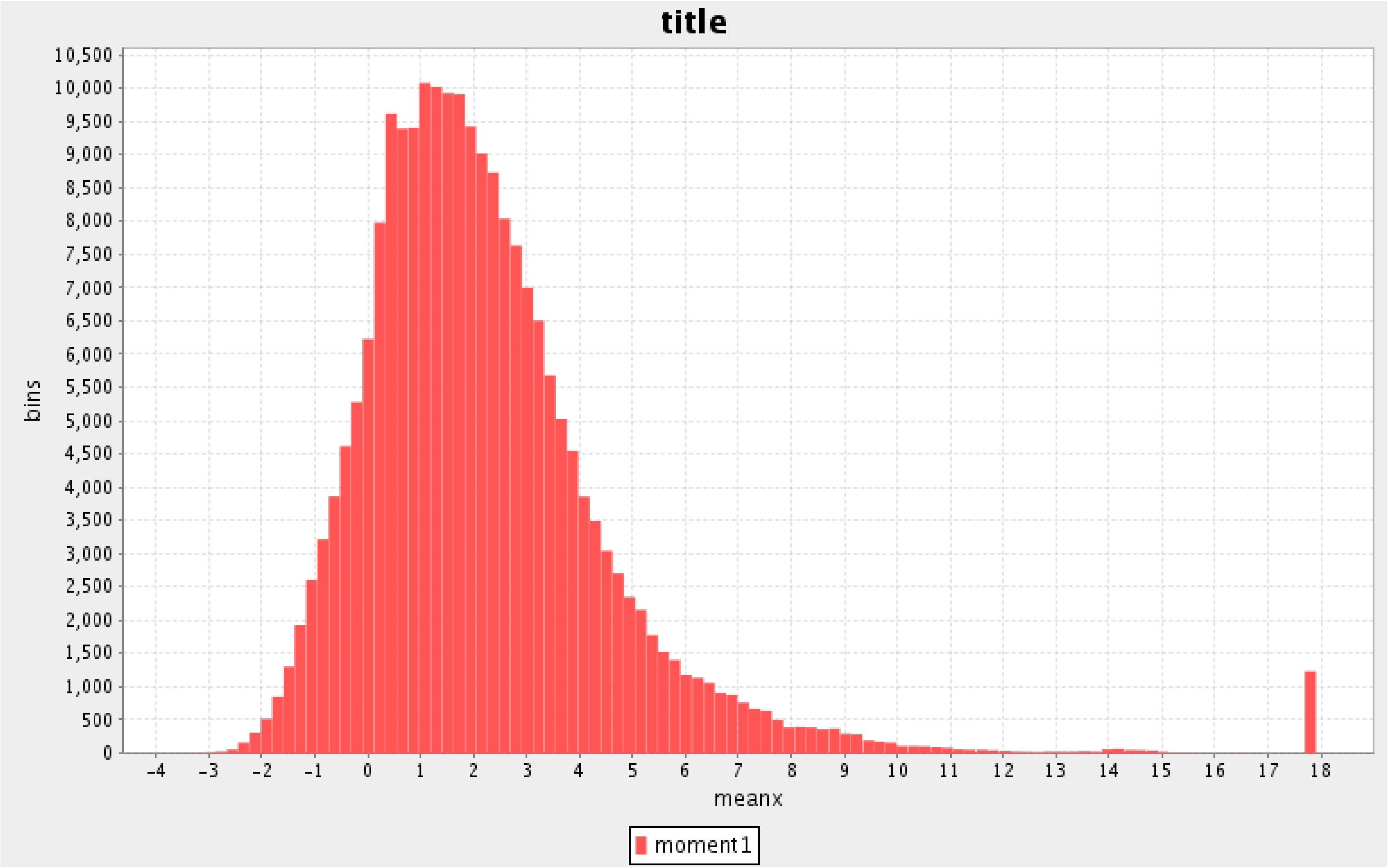


ANALISI DEI VALORI DI UNA MAPPA: h.cb

è possibile selezionare la visualizzazione dei dati in tabella o grafico

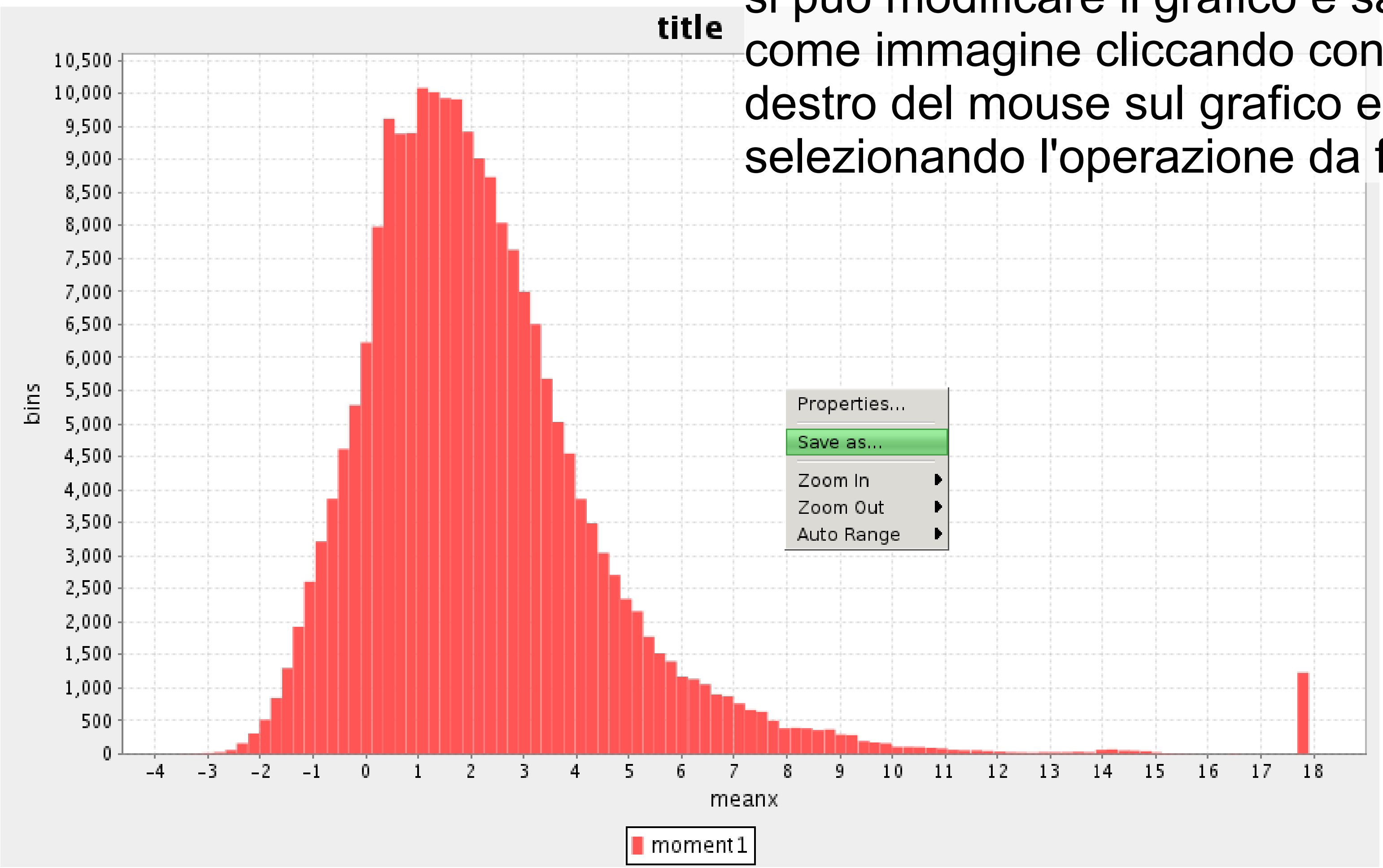


ANALISI DEI VALORI DI UNA MAPPA: h.cb



ANALISI DEI VALORI DI UNA MAPPA: h.cb

si può modificare il grafico e salvarlo come immagine cliccando con il tasto destro del mouse sul grafico e selezionando l'operazione da fare



ANALISI DEI VALORI DI UNA MAPPA: h.cb

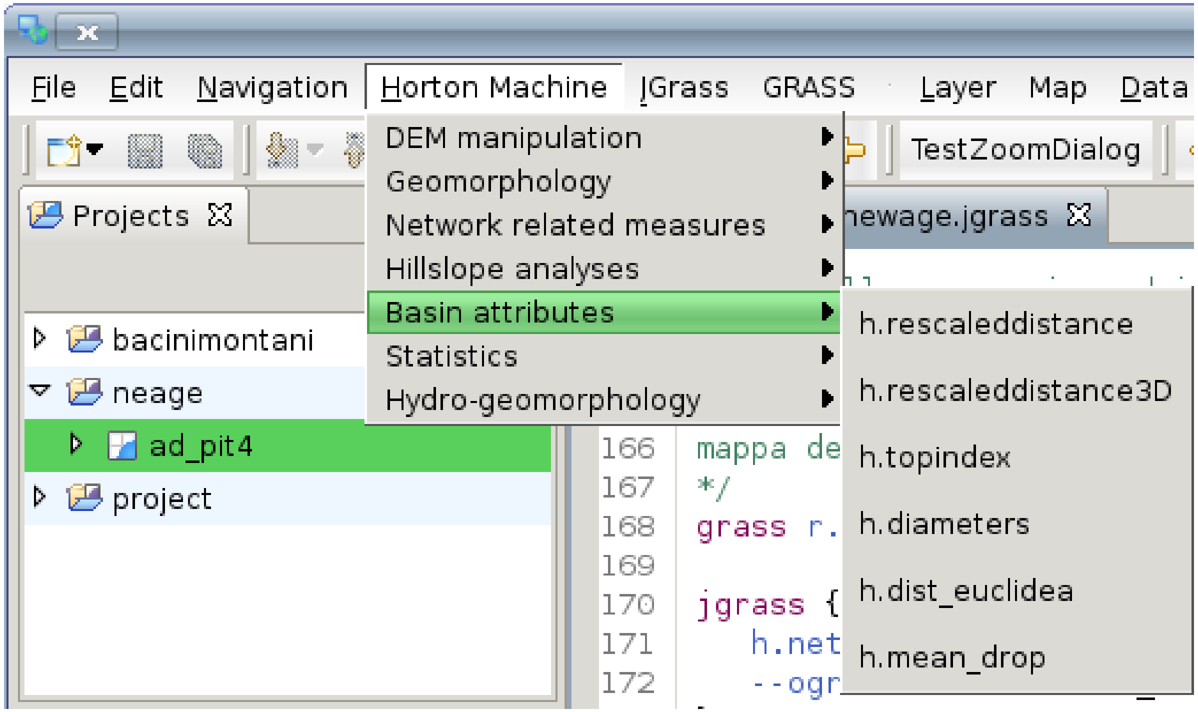
Il file di output di **h.cb** completo contiene:

- numero di pixel della prima mappa contenuti nell'intervallo
- valore medio dei valori della prima mappa per ogni intervallo
- valore medio dei valori della seconda mappa per ogni intervallo
- varianza dei valori della seconda mappa per ogni intervallo
- momento di ordine superiore calcolato per i valori della seconda mappa

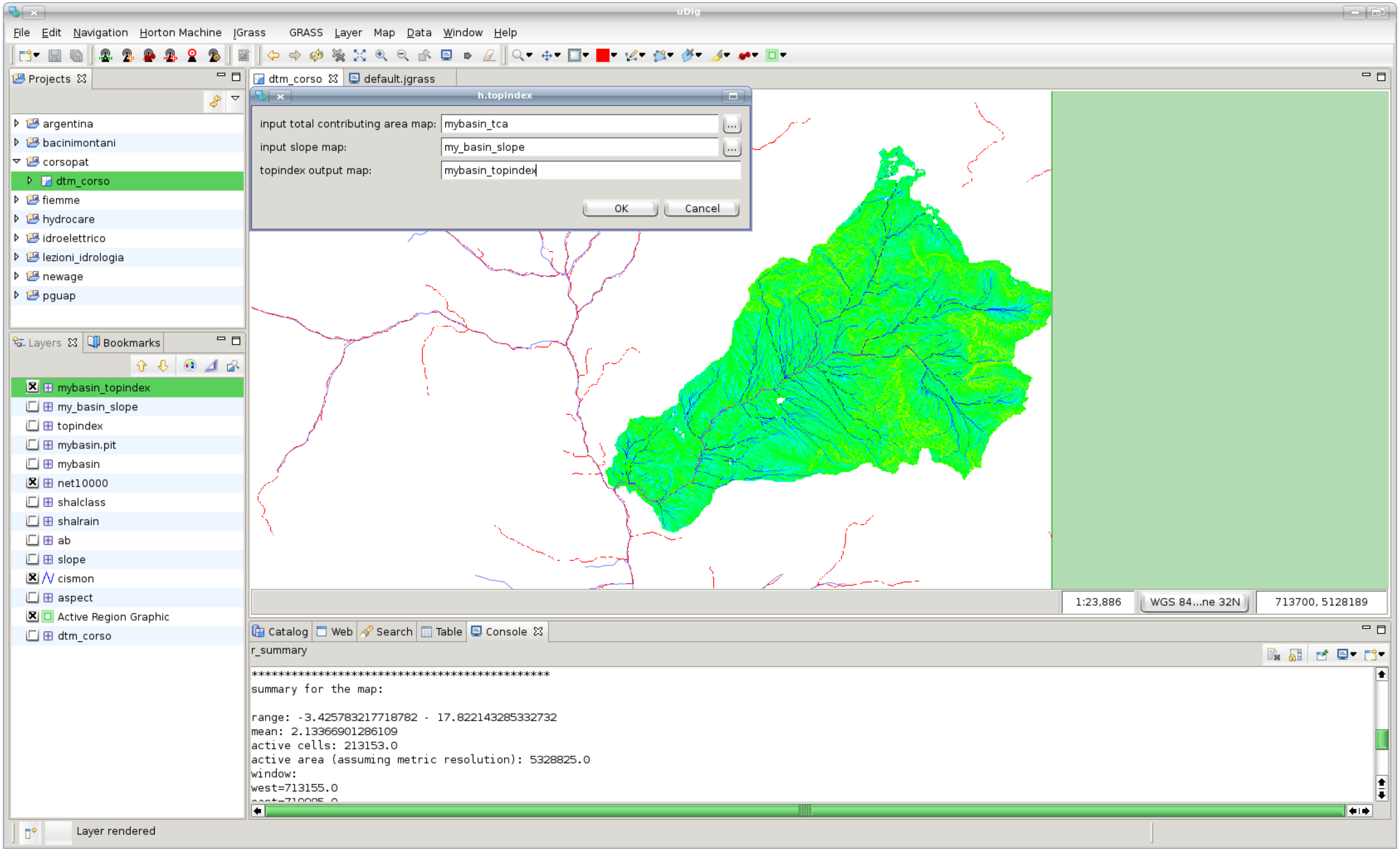
INDICE TOPOGRAFICO

- Esprime la tendenza di un pixel a saturarsi
- Aree con valori elevati di indice topografico si saturano prima di aree a basso indice topografico
- Dipende solo dalla morfologia
- È proporzionale al rapporto tra area cumulata nel pixel e pendenza

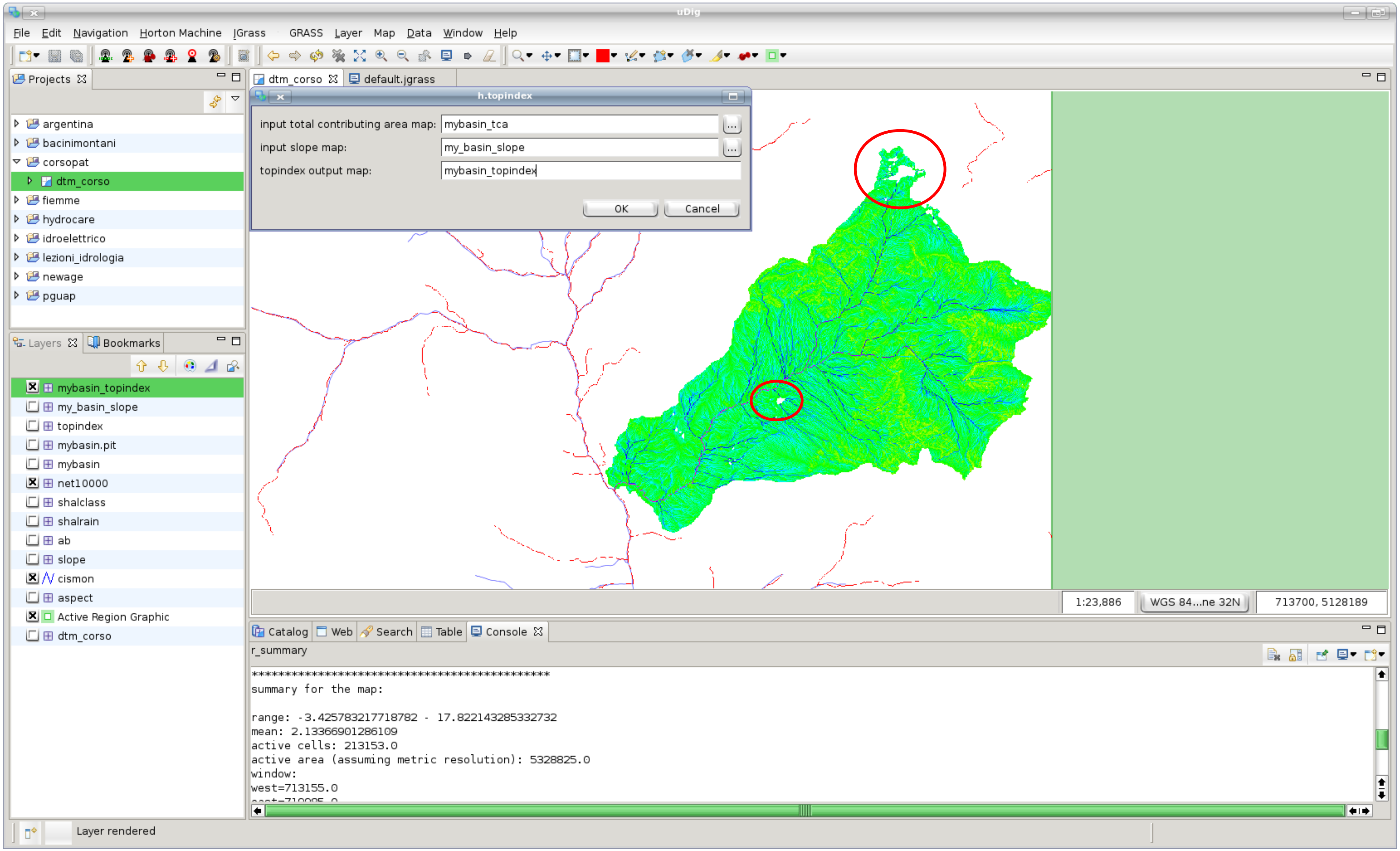
INDICE TOPOGRAFICO: h.topindex



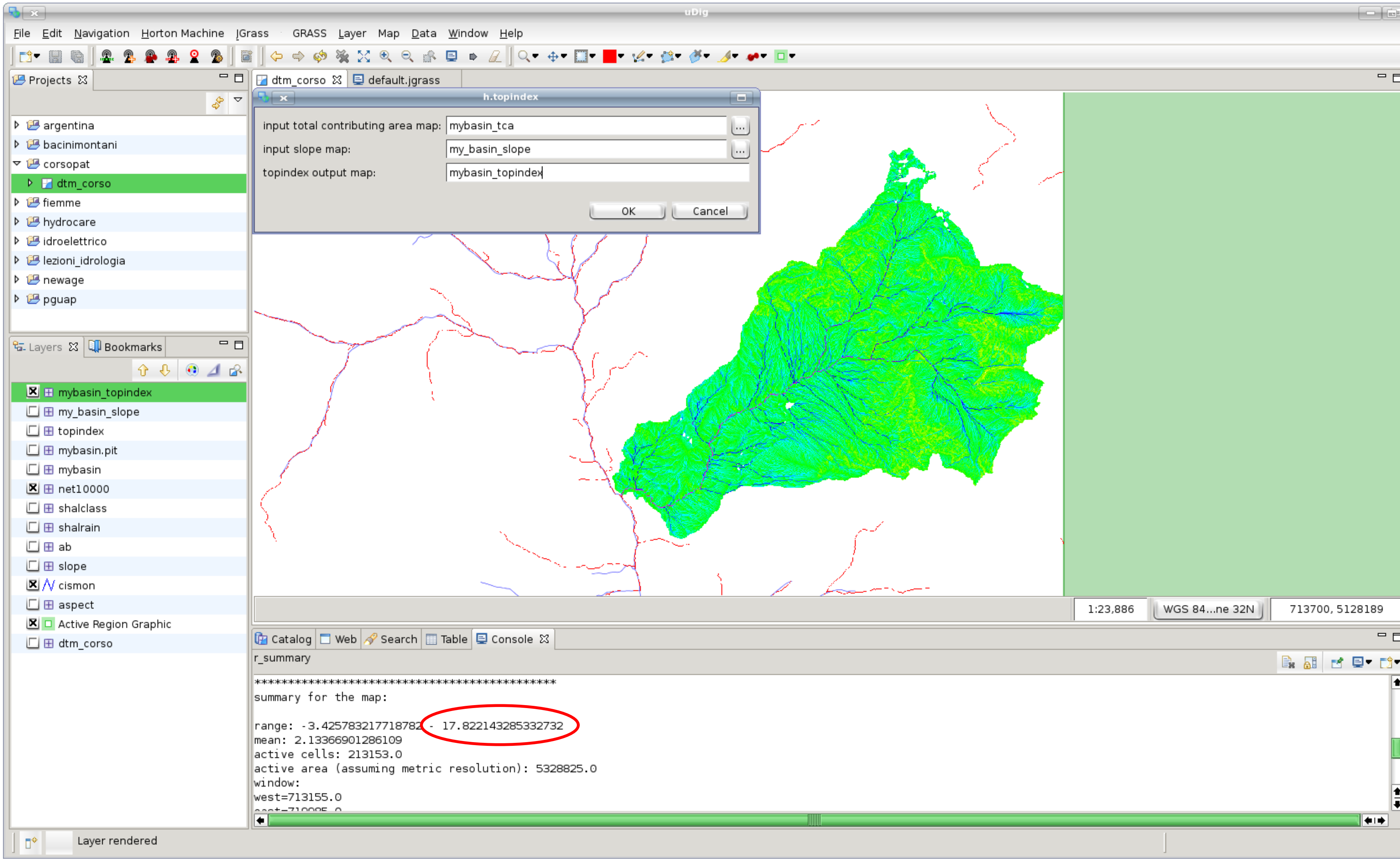
INDICE TOPOGRAFICO: h.topindex



INDICE TOPOGRAFICO: h.topindex



INDICE TOPOGRAFICO: h.topindex

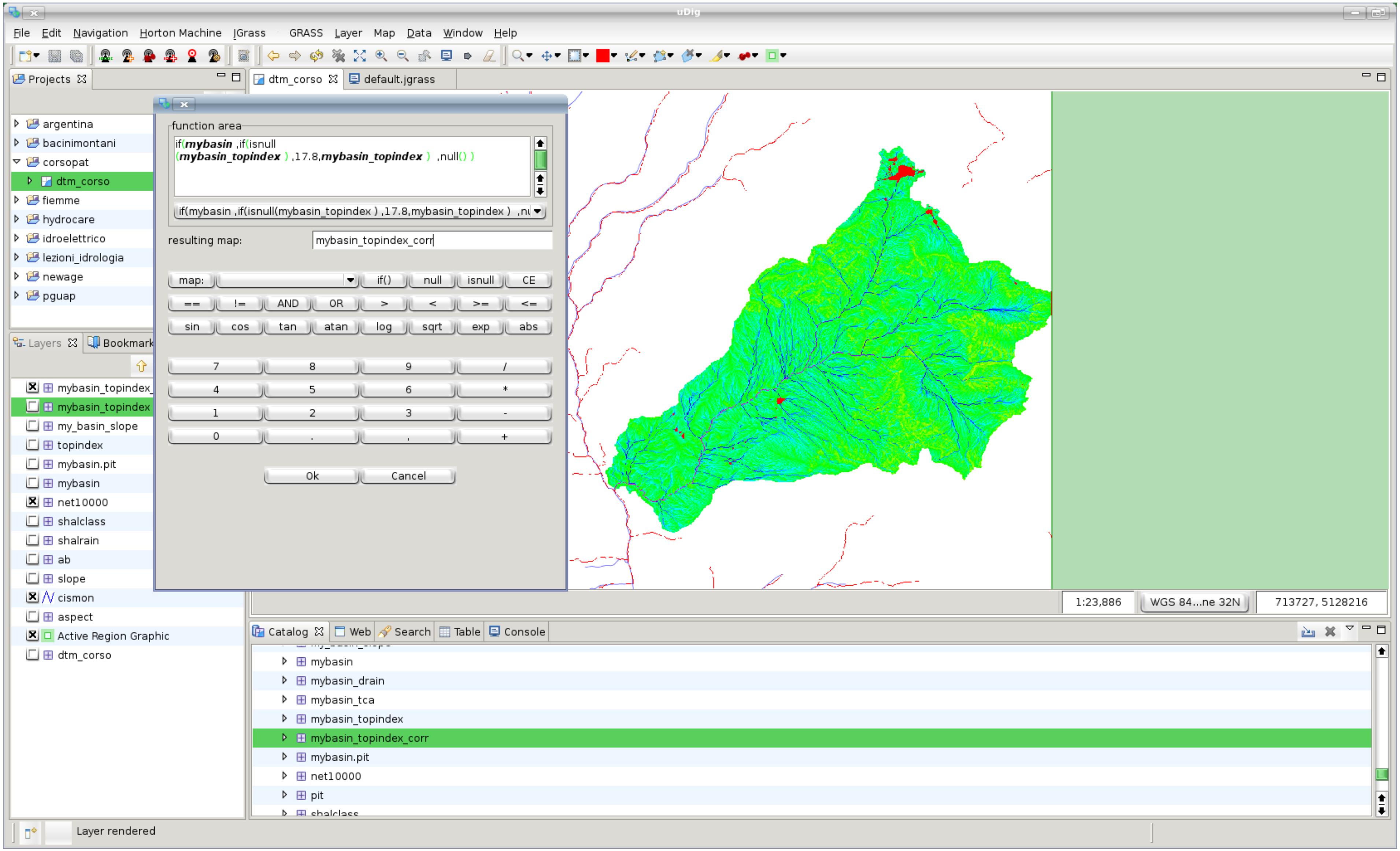


INDICE TOPOGRAFICO: h.topindex

- ci sono zone all'interno del bacino dove non è definito l'indice topografico
- queste zone sono quelle con pendenza pari a zero per cui il rapporto area cumulata su pendenza tende ad infinito
- pixel con pendenza bassa hanno elevata propensione alla saturazione a parità di area cumulata
- si assegna ai pixel con valore nullo di indice topografico il valore massimo caratteristico della mappa

```
if(mybasin ,if(isnull(mybasin_topindex ),17.8,mybasin_topindex )  ,null() )
```

INDICE TOPOGRAFICO: h.topindex



NUMERAZIONE DELLA RETE: h.strahler

It calculates the Strahler order of the basin. There are two possibilities:

- calculate the Strahler order in the whole basin
- calculate the Strahler order only on the network