Environmental modeling
within the framework of GIS

HydroloGIS
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Models, models, models...

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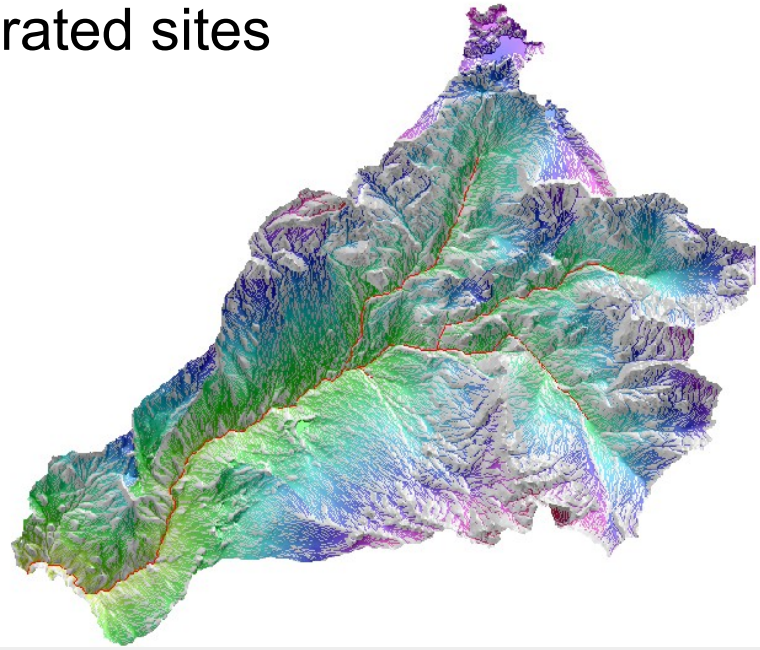
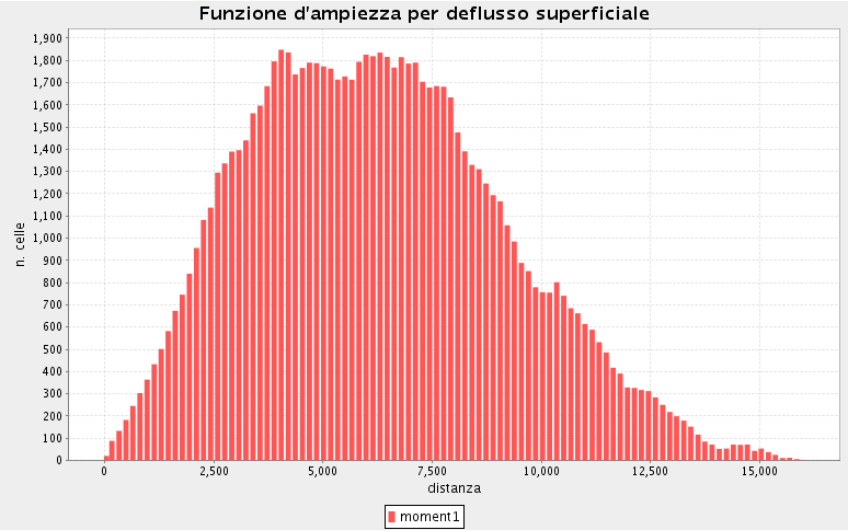
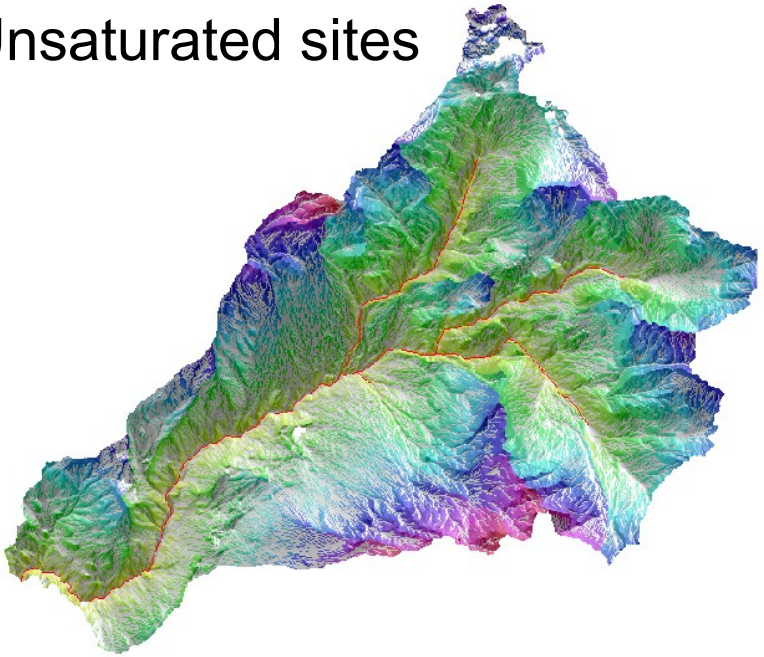
PEAKFLOW: semidistributed hydrological model. It works using the GIUH approach and calculates both the **maximum discharge and the duration of the precipitation that maximises the discharge.**

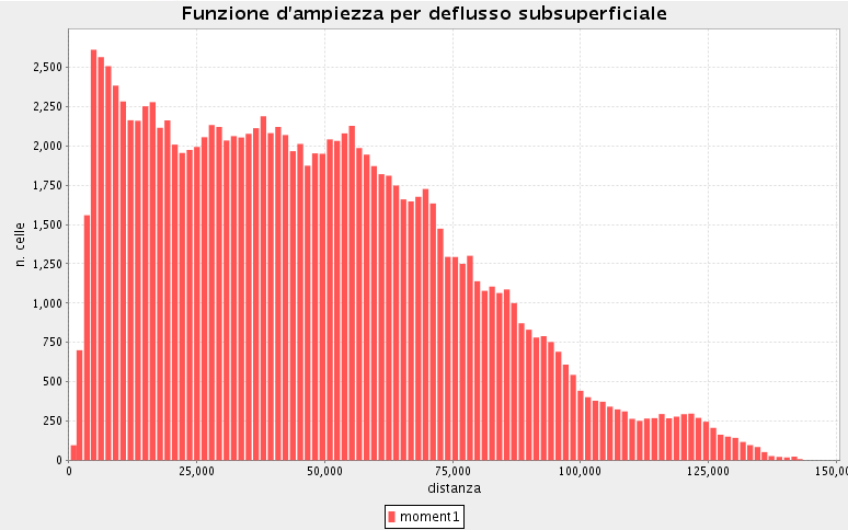
Saturated sites

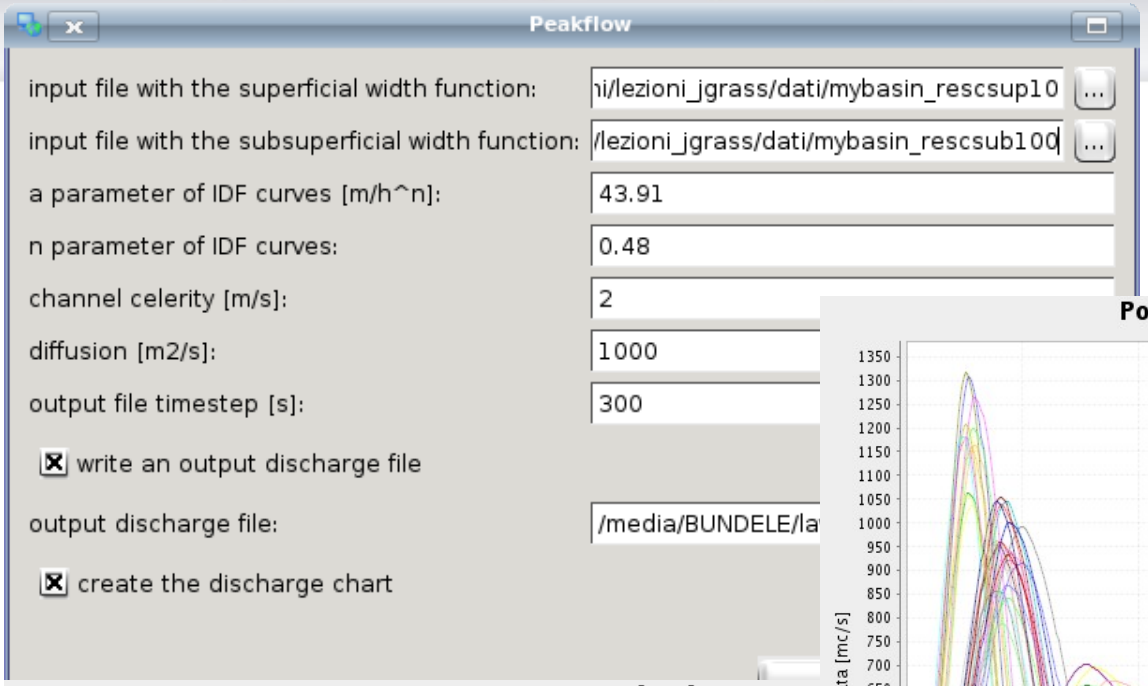


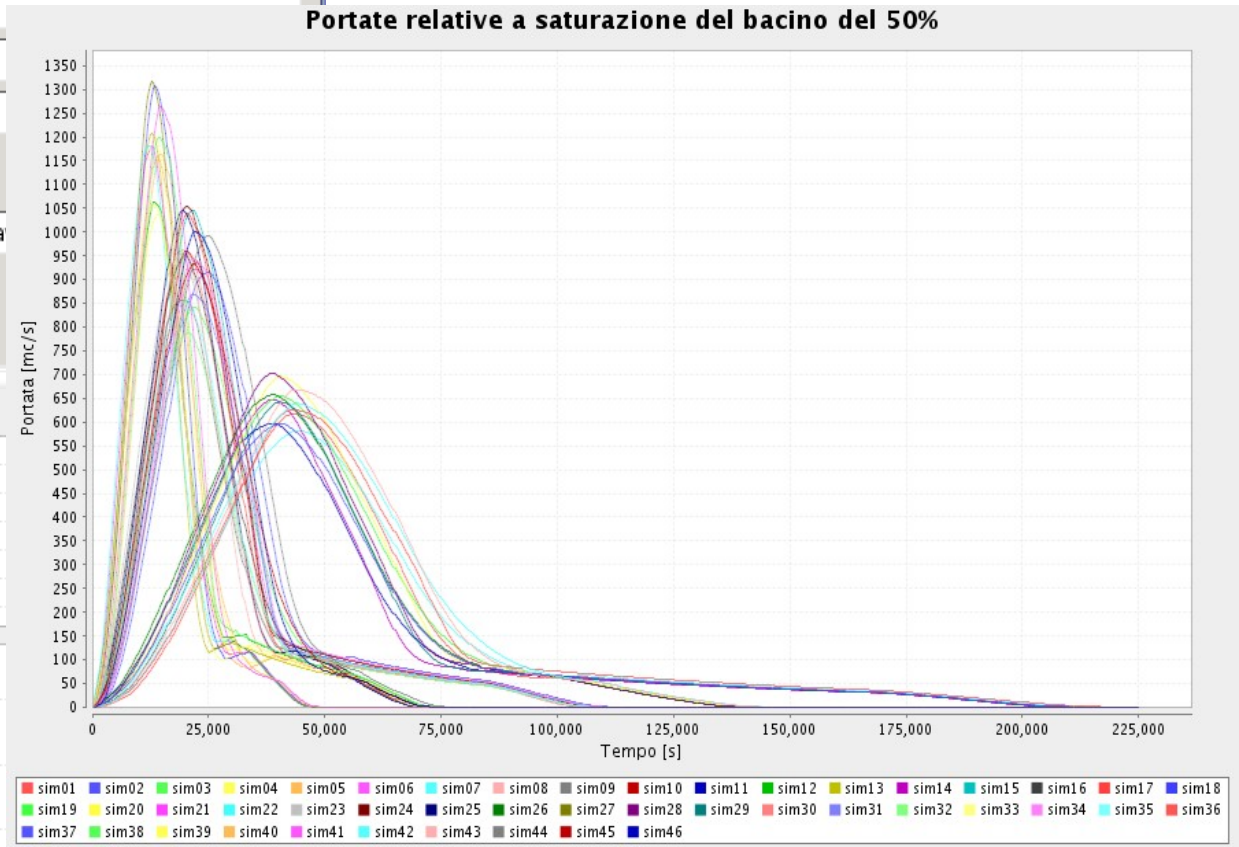


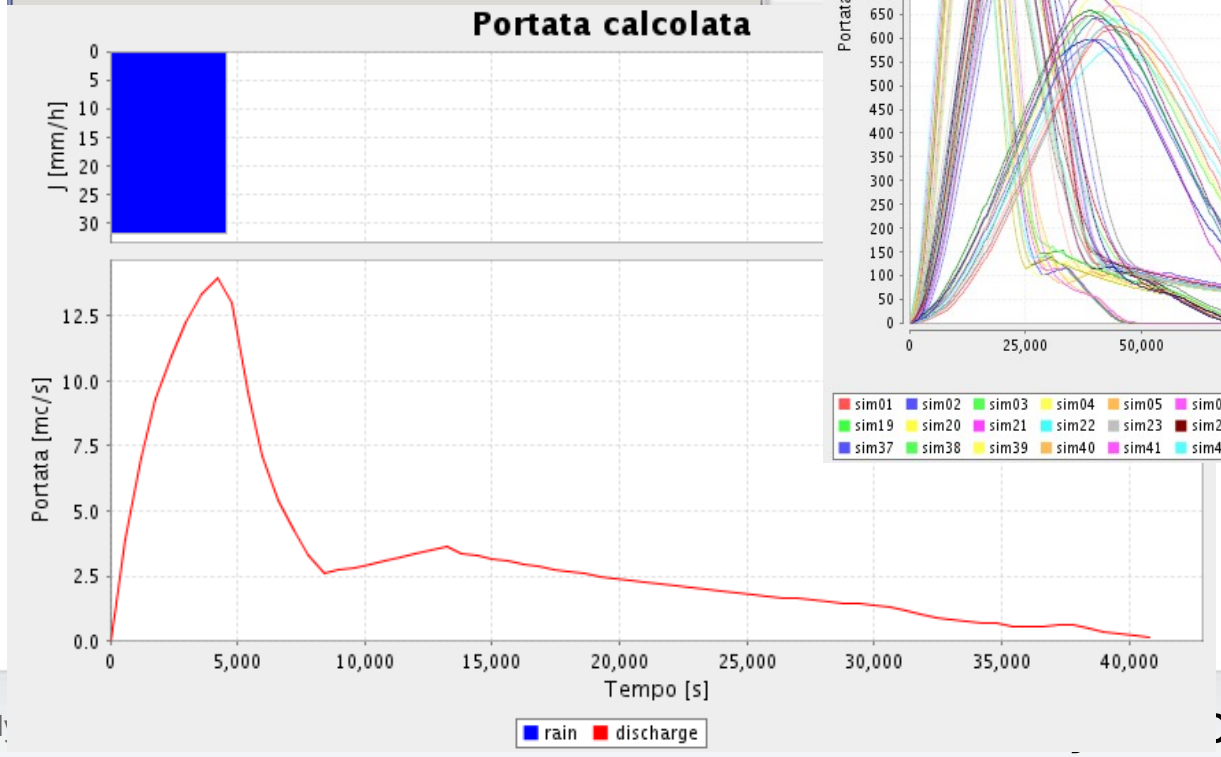
Unsaturated sites






Peakflow
input file with the superficial width function:
ni/lezioni_jgrass/dati/mybasin_rescsup10
input file with the subsuperficial width function:
/lezioni_jgrass/dati/mybasin_rescsub100
a parameter of IDF curves [m/h^n]:
43.91
n parameter of IDF curves:
0.48
channel celerity [m/s]:
2
diffusion [m2/s]:
1000
output file timestep [s]:
300
write an output discharge file
output discharge file:
/media/BUNDELE/la
create the discharge chart

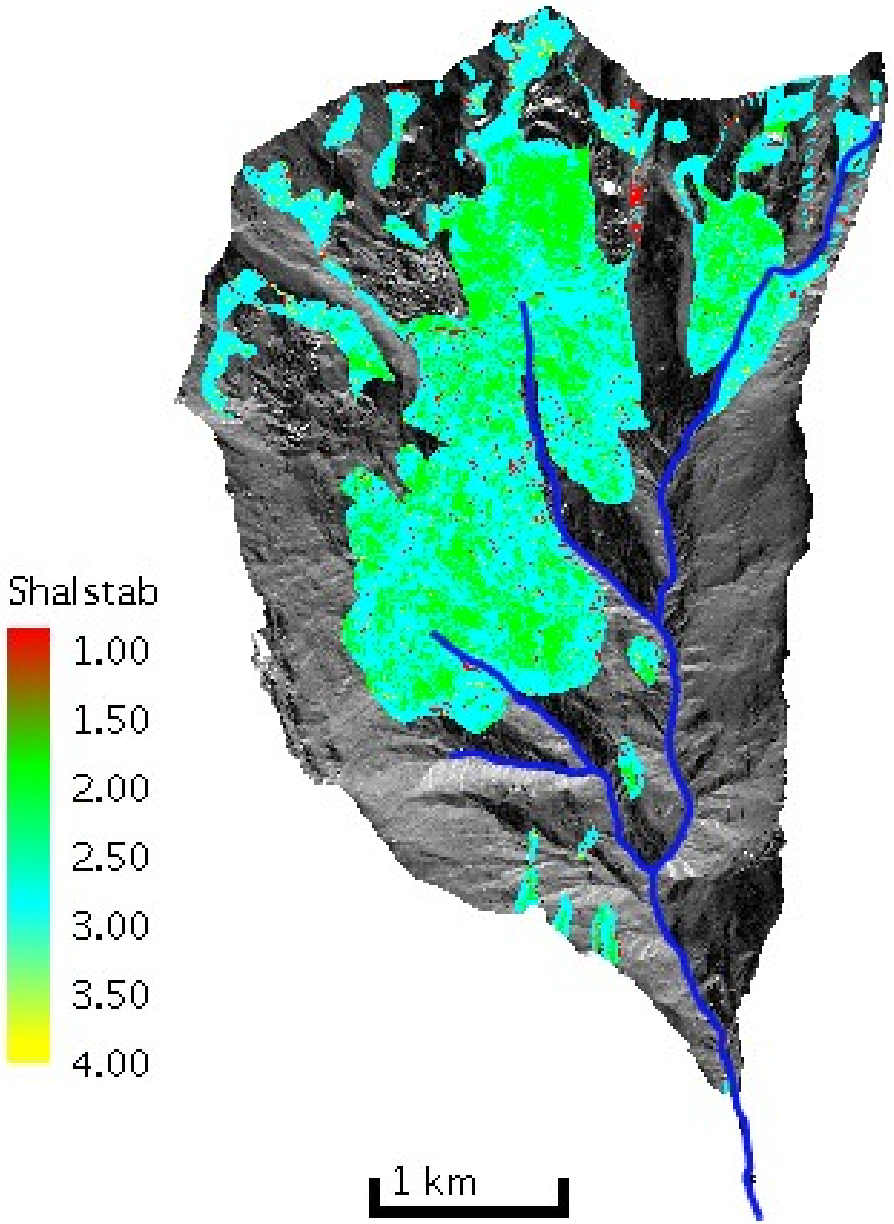

Portate relative a saturazione del bacino del 50%
Portata [mc/s]
Tempo [s]
sim01 sim02 sim03 sim04 sim05 sim06 sim07 sim08 sim09 sim10 sim11 sim12 sim13 sim14 sim15 sim16 sim17 sim18
sim19 sim20 sim21 sim22 sim23 sim24 sim25 sim26 sim27 sim28 sim29 sim30 sim31 sim32 sim33 sim34 sim35 sim36
sim37 sim38 sim39 sim40 sim41 sim42 sim43 sim44 sim45 sim46


Portata calcolata
J [mm/h]
Portata [mc/s]
Tempo [s]
rain
discharge

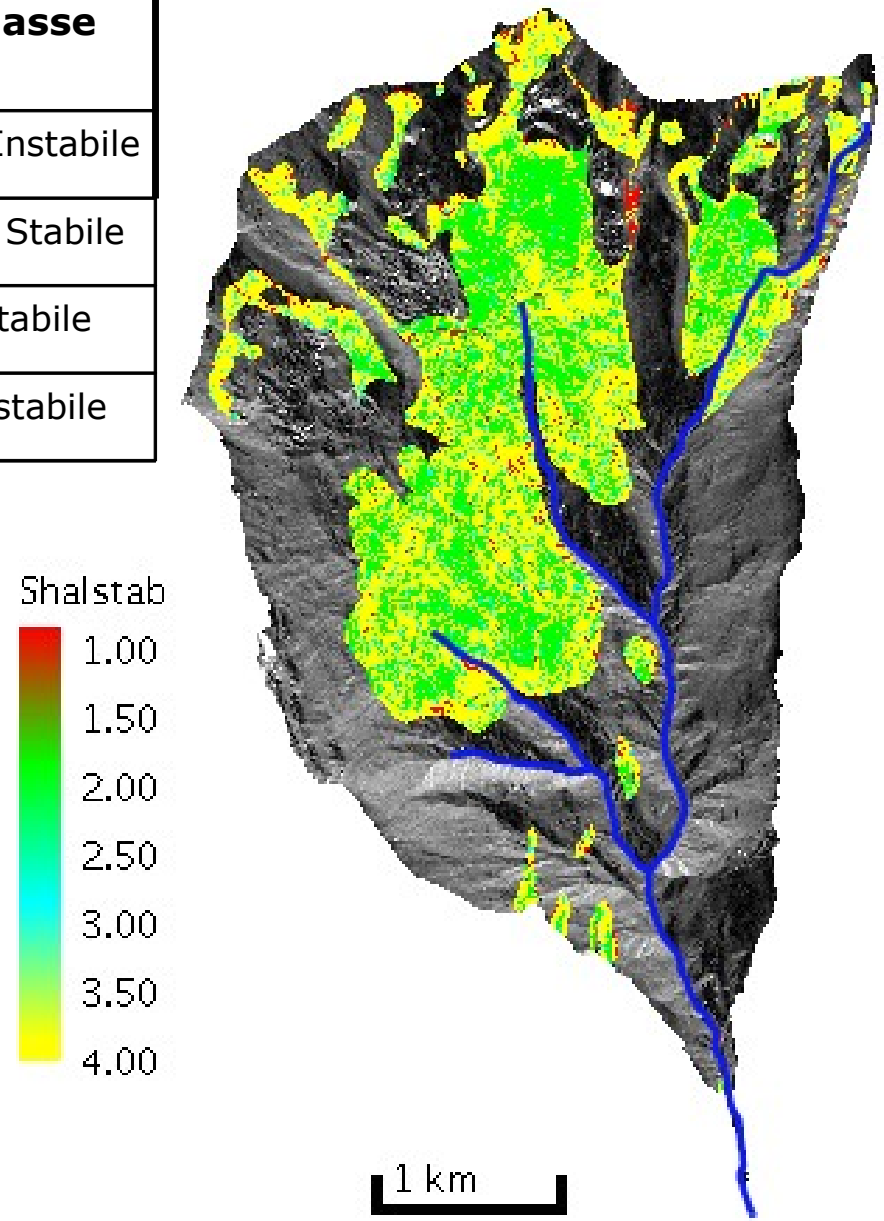
Models, models, models...

PEAKFLOW: semidistributed hydrological model. It works using the GIUH approach and calculates both the **maximum discharge and the duration of the precipitation that maximises the discharge.**

SHALSTAB: a version of the shalstab model, which uses a simplified hydrological model and the model of infinite slope to **evaluate a stability coefficient**.



Indice	classe
1	Inc Instabile
2	Inc Stabile
3	Stabile
4	Instabile



Models, models, models...

PEAKFLOW: semidistributed hydrological model. It works using the GIUH approach and calculates both the **maximum discharge and the duration of the precipitation that maximises the discharge.**

SHALSTAB: a version of the shalstab model, which uses a simplified hydrological model and the model of infinite slope to **evaluate a stability coefficient**.

NUOVO ADIGE: large scale distributed hydrological model including energy and water balance (based on Duffy model implementation in Cuencas).
It includes the modeling of reservoirs, intakes and human works.

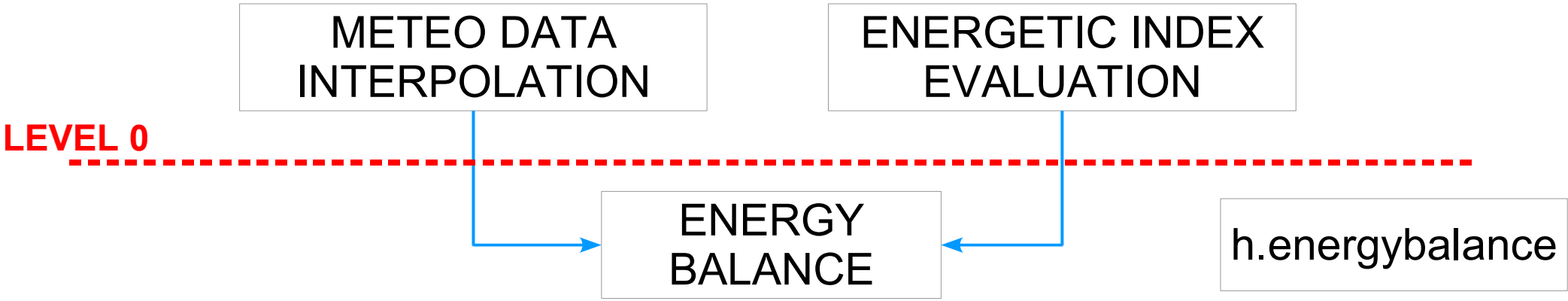
Nuovo Adige

METEO DATA INTERPOLATION

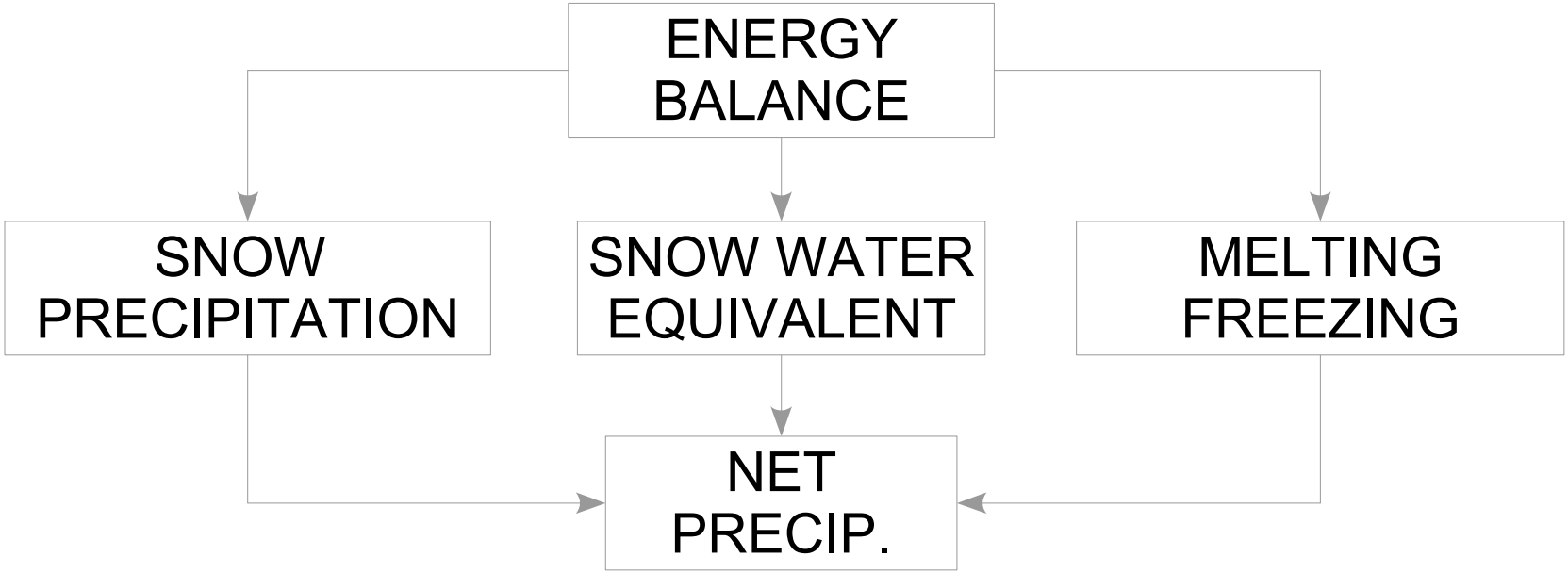
ENERGETIC INDEX EVALUATION

LEVEL 0

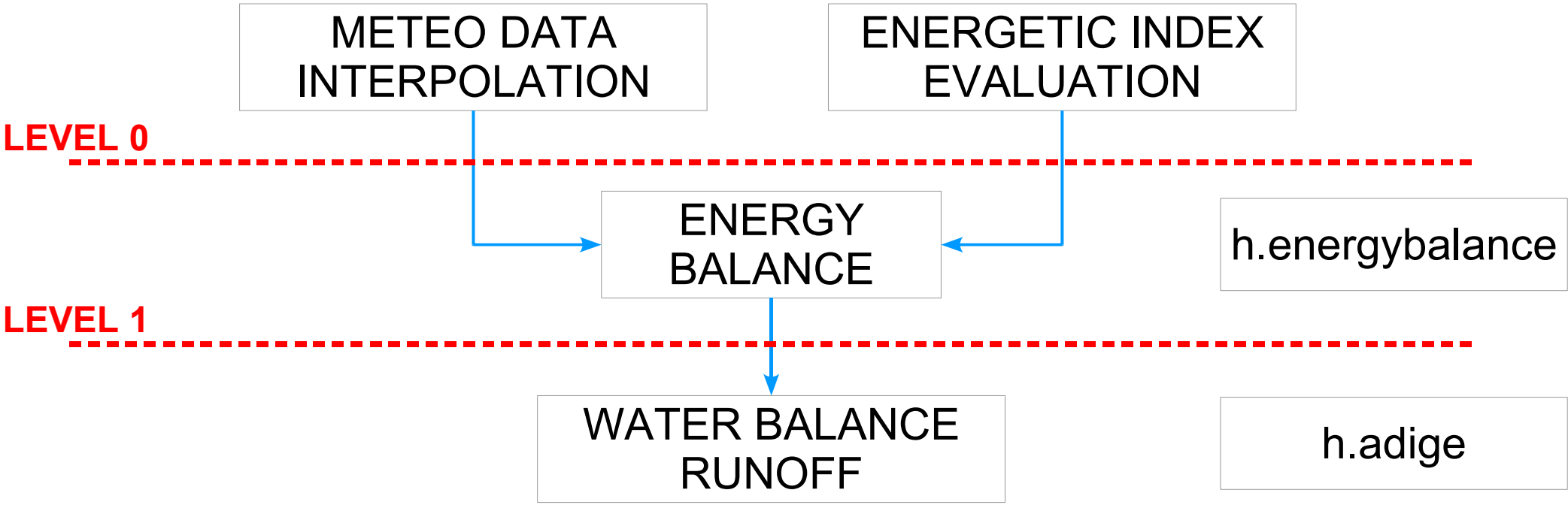
Nuovo Adige


METEO DATA INTERPOLATION
ENERGETIC INDEX EVALUATION
LEVEL 0
ENERGY BALANCE
h.energybalance

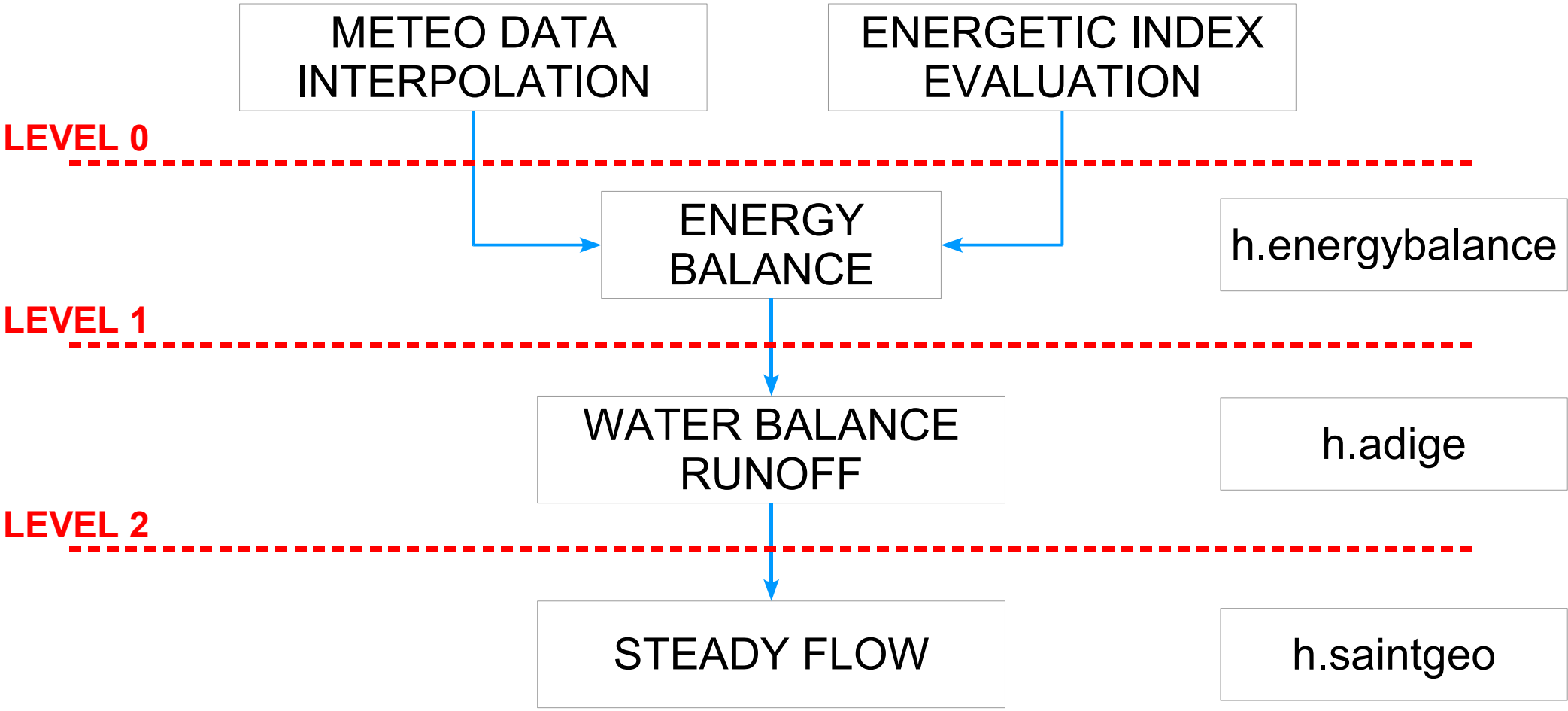
Nuovo Adige


ENERGY BALANCE
SNOW PRECIPITATION
SNOW WATER EQUIVALENT
MELTING FREEZING
NET PRECIP.

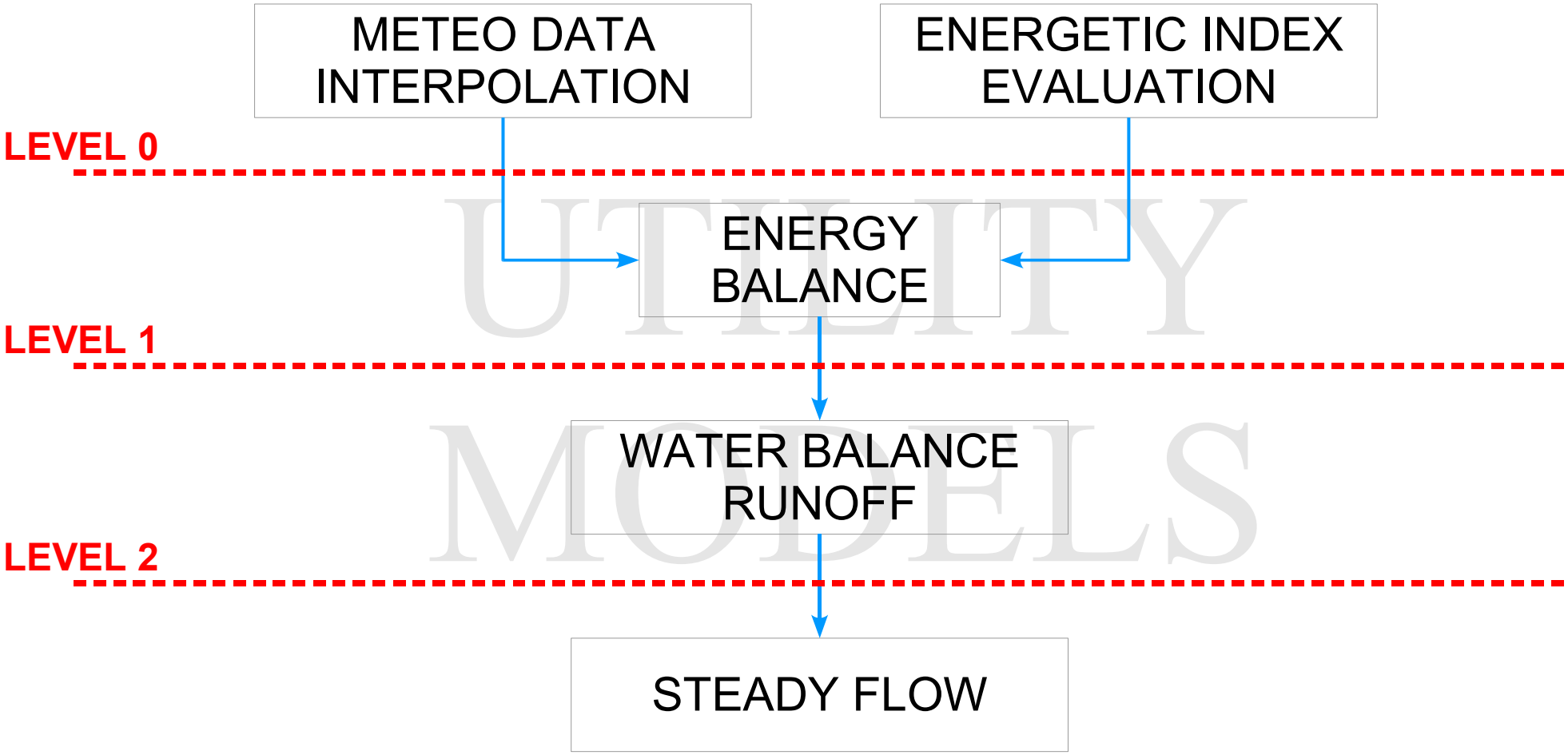
Nuovo Adige


METEO DATA INTERPOLATION
ENERGETIC INDEX EVALUATION
LEVEL 0
ENERGY BALANCE
h.energybalance
LEVEL 1
WATER BALANCE RUNOFF
h.adige

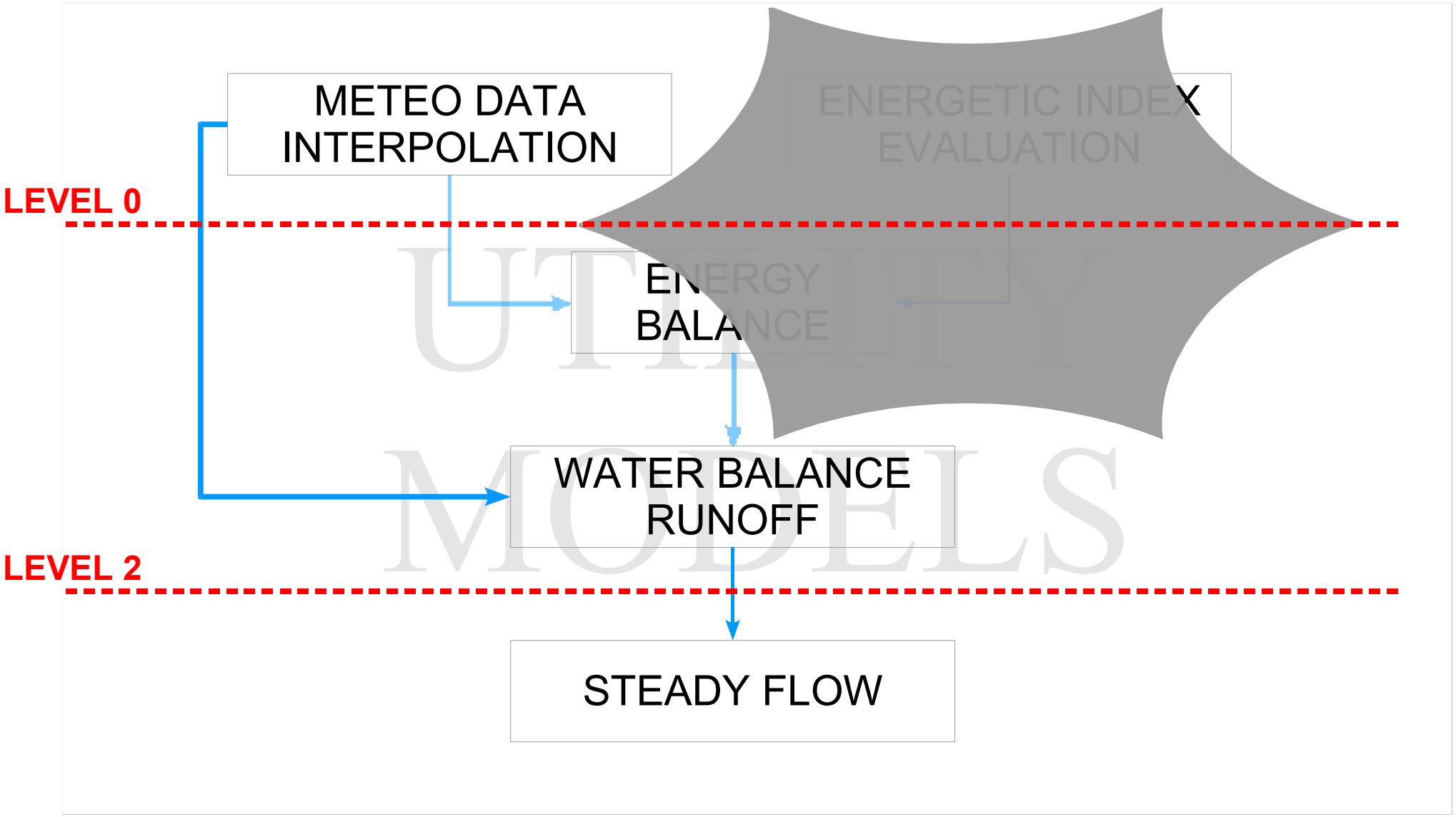
Nuovo Adige


METEO DATA INTERPOLATION
ENERGETIC INDEX EVALUATION
LEVEL 0
ENERGY BALANCE
h.energybalance
LEVEL 1
WATER BALANCE RUNOFF
h.adige
LEVEL 2
STEADY FLOW
h.saintgeo

Nuovo Adige



Nuovo Adige


METEO DATA
INTERPOLATION
ENERGETIC INDEX
EVALUATION
LEVEL 0
ENERGY
BALANCE
UTILITY
WATER BALANCE
RUNOFF
MODELS
LEVEL 2
STEADY FLOW

How is this done?

The Horton Machine

h.peakflow, h.shalstab, h.energybalance, h.adige are all part of the Horton Machine

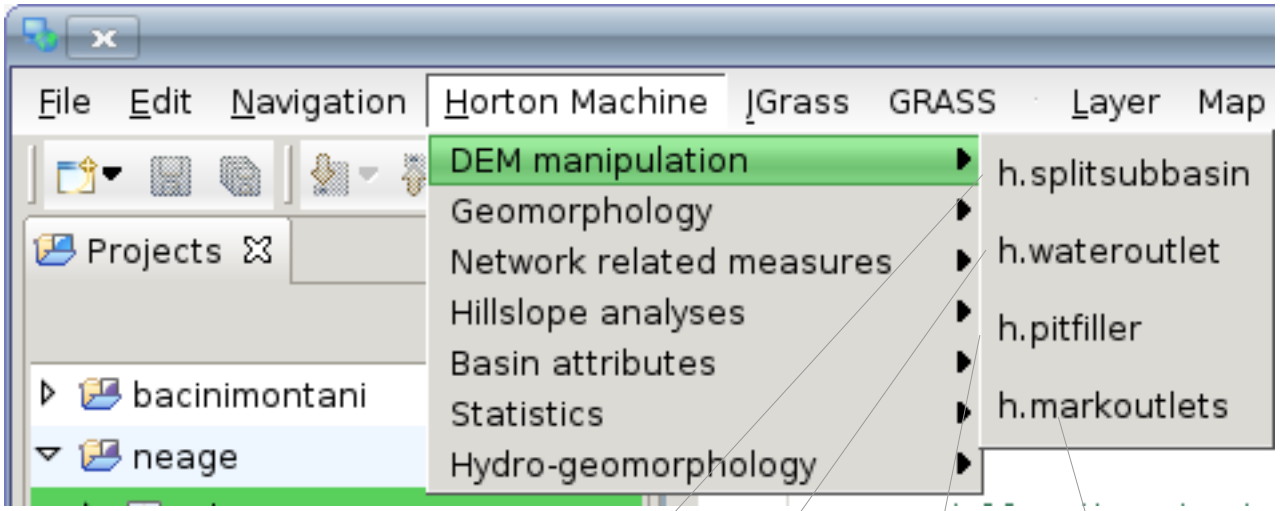
h.peakflow, h.shalstab, h.energybalance, h.adige are all part of the Horton Machine

- suite of tools to process digital data of the terrain
- developed at Department of Civil and Environmental Engineering of the University of Trento – Riccardo Rigon
- initially written in C and released under GPL
- recently ported to java inside the FOSS GIS JGrass and released under LGPL

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation



Given the Strahler number of the channel network, the subbasins up to a selected order are labeled

Generates a watershed basin mask from a drainage direction map and a set of coordinates

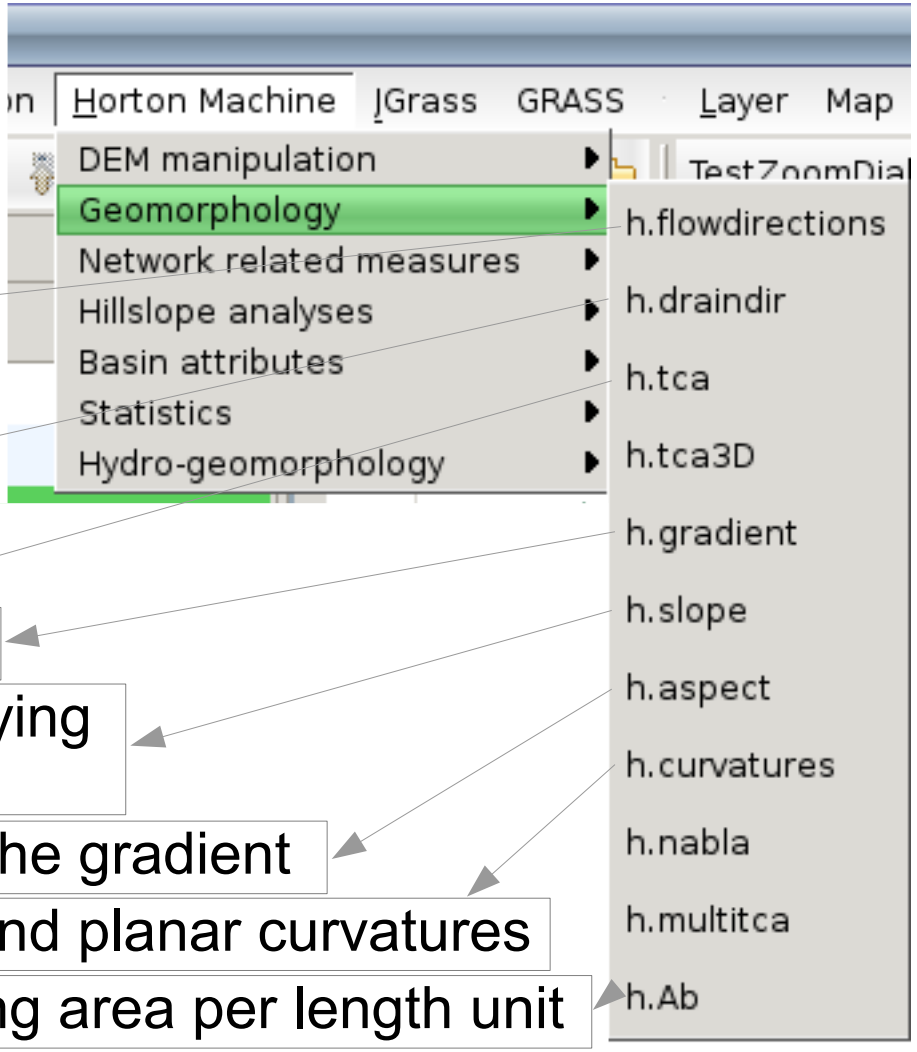
It fills the depression points contained in a DEM so that the drainage directions are defined in each point

”marks” the basin outlets

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation
- Geomophology



drainage directions with the method of the maximal steepest descent slope

drainage directions minimizing the deviation from the real flow

upslope catchment area

module of the gradient vector

slope in every site by employing the drainage directions

inclination angle of the gradient

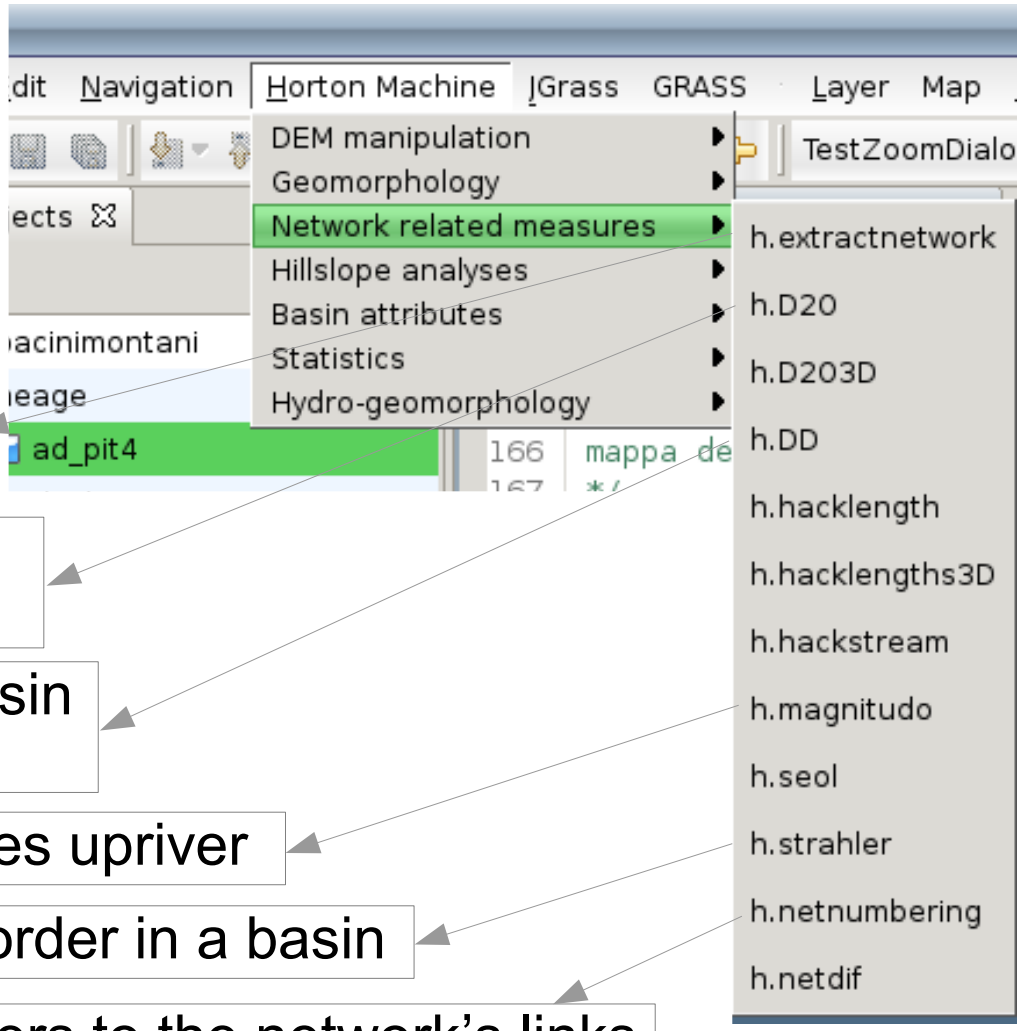
longitudinal, normal and planar curvatures

draining area per length unit

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation
- Geomophology
- Network related measures



extracts the channel network from the drainage directions

distance of each pixel from the outlet, measured along the drainage directions

drainage density function for the basin upstream of each pixel

number of sources upriver

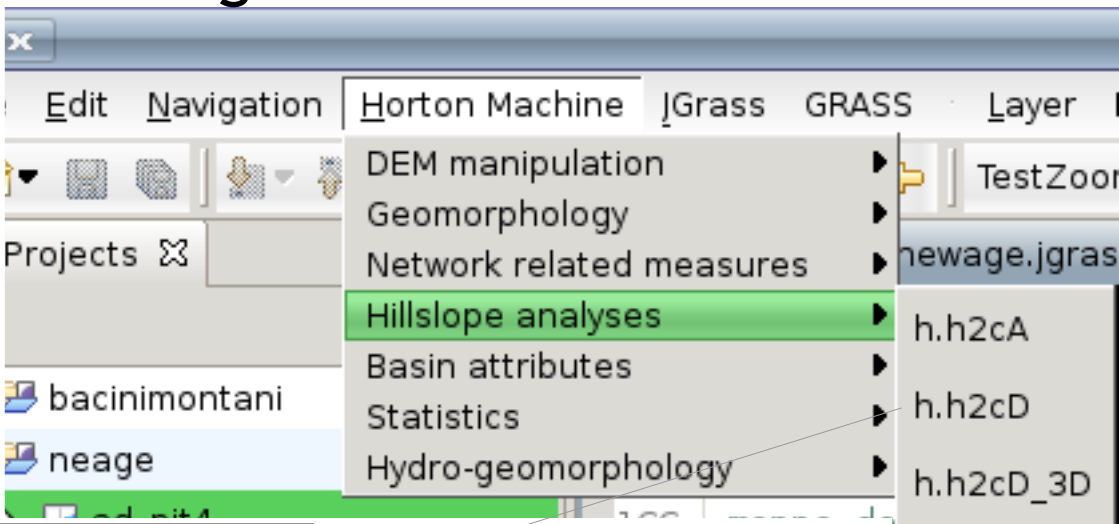
Strahler order in a basin

assign numbers to the network's links

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation
- Geomophology
- Network related measures
- Hillslope analyses



for each hillslope pixel its distance from the river networks, following the steepest descent

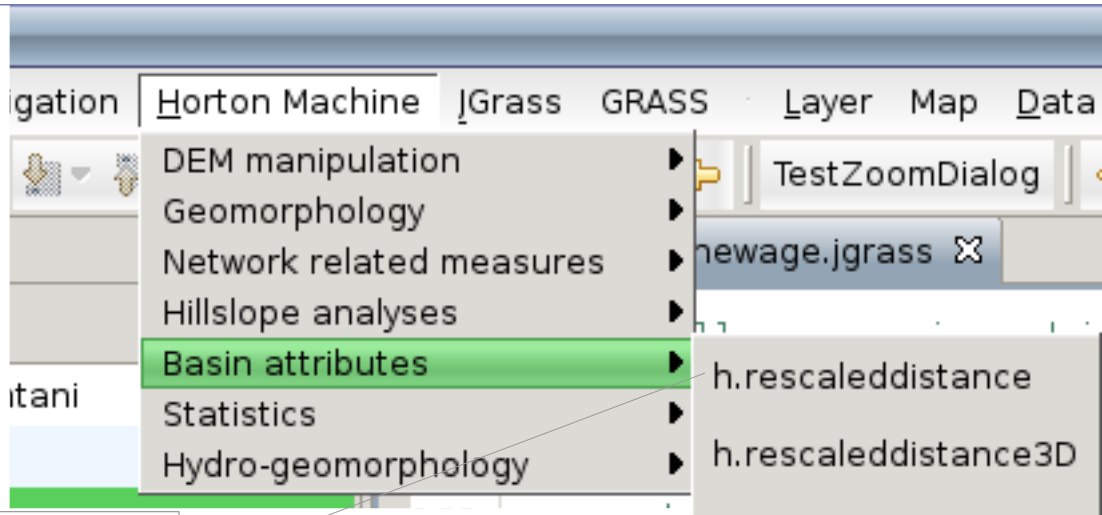
subdivides the sites of a basin in the 9 topographic classes identified by the longitudinal and transversal curvatures

subdivides the sites of a basin in 11 topographic classes (9 from h.tc)

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation
- Geomophology
- Network related measures
- Hillslope analyses
- Basin attributes



rescaled distance of each pixel from the outlet

topographic index of a basin

diameter of the basin subtended to a point

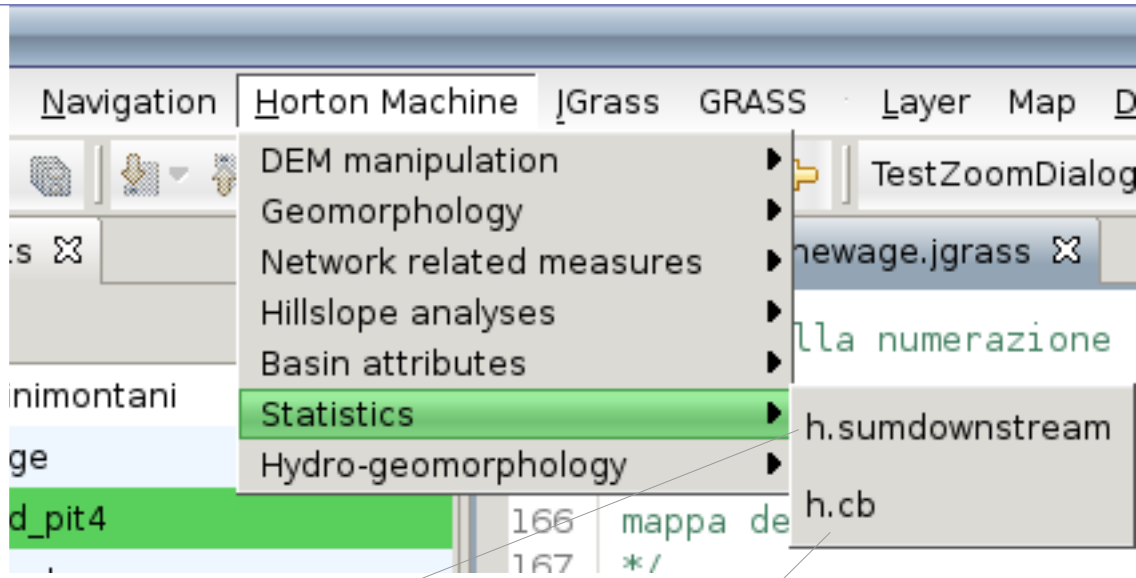
euclidean distance of each pixel from the outlet of the bigger basin which contains it

main moments of inertia of each subnet of a channel net

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation
- Geomophology
- Network related measures
- Hillslope analyses
- Basin attributes
- Statistics



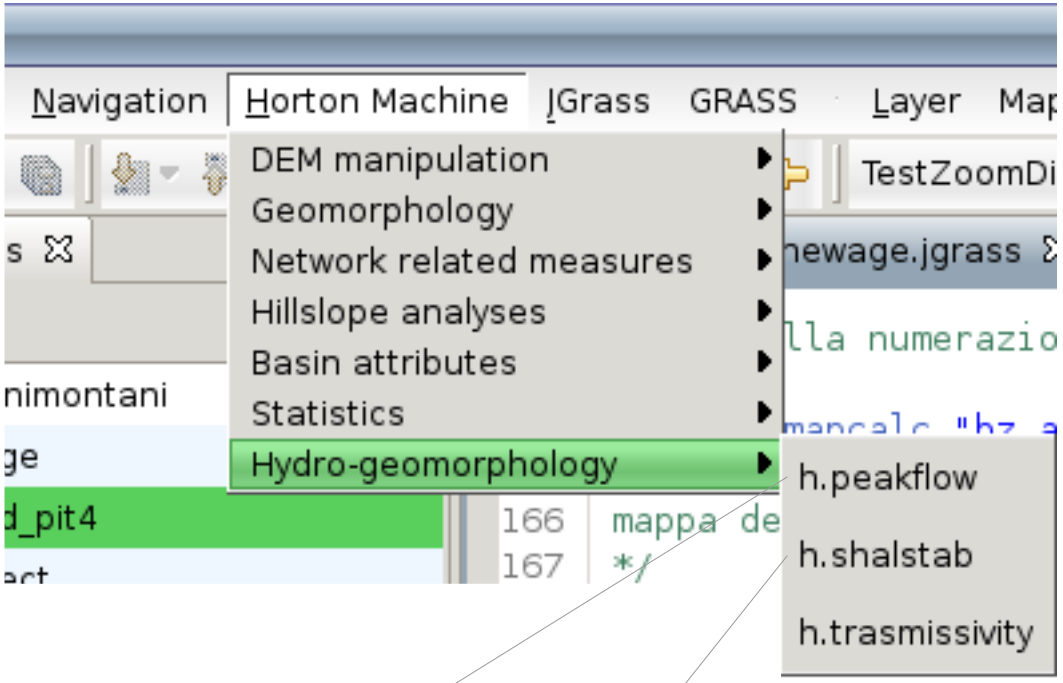
sums the values of an assigned quantity from the point till the outlet

the histogram of a set of data contained in a matrix with respect to the set of data contained in another matrix

HortonMachine:

The commands are divided in 7 categories:

- DEM manipulation
- Geomophology
- Network related measures
- Hillslope analyses
- Basin attributes
- Statistics
- Hydro-geomorphology

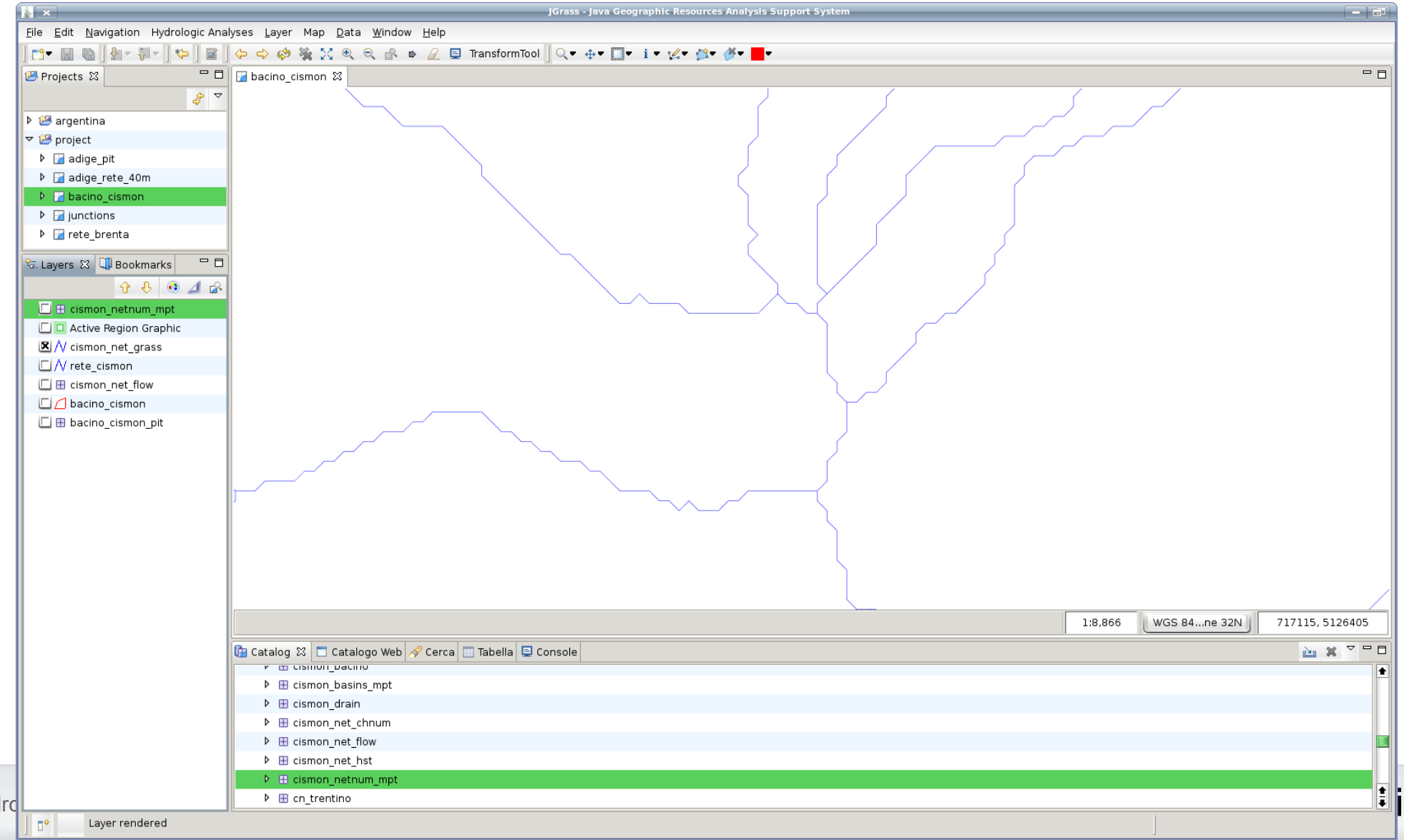


the Peakflow semidistributed model for discharge calculation

the Shalstab hillslope stability model

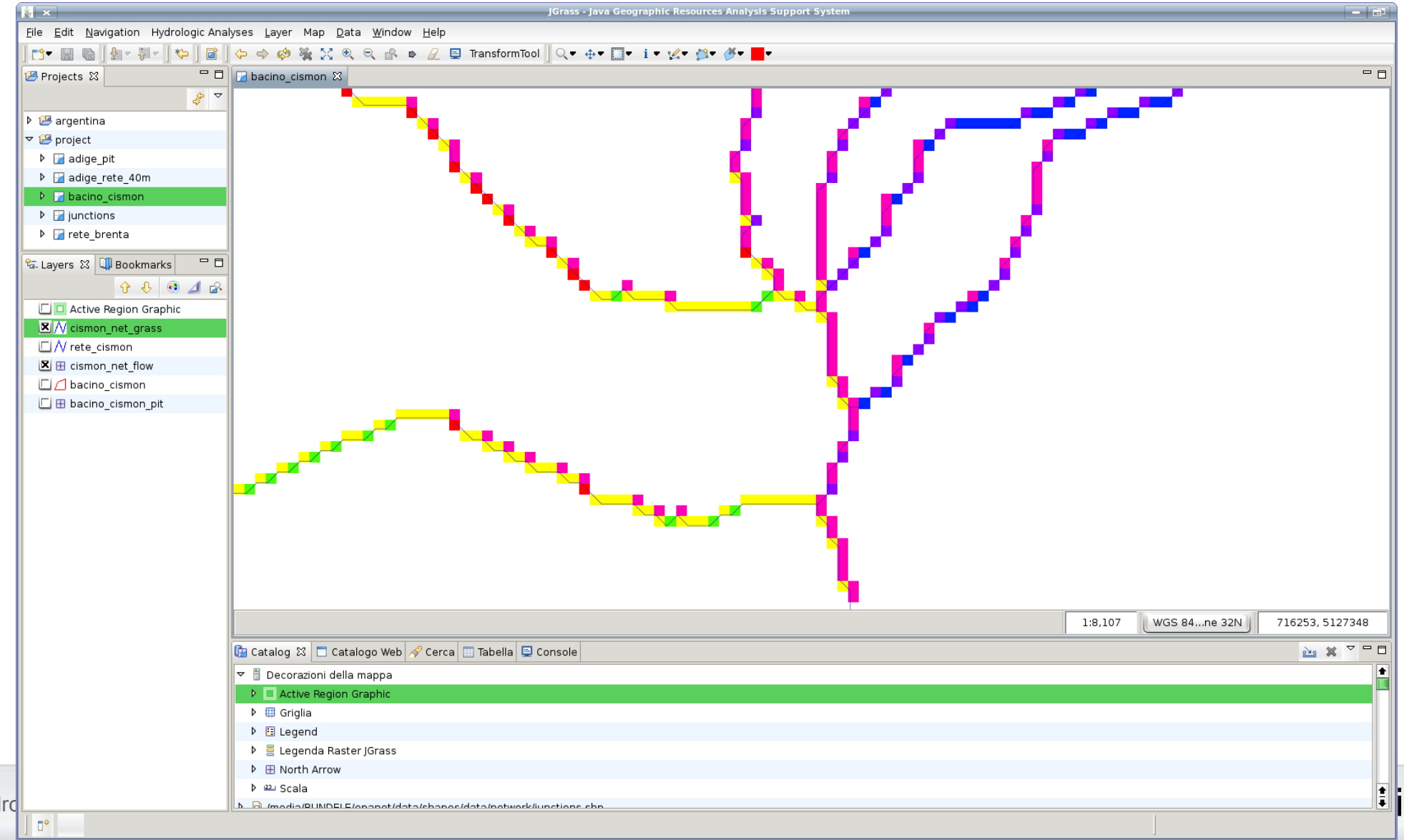
JGrass and the “Horton machine”

How hard is it to follow a real river network?



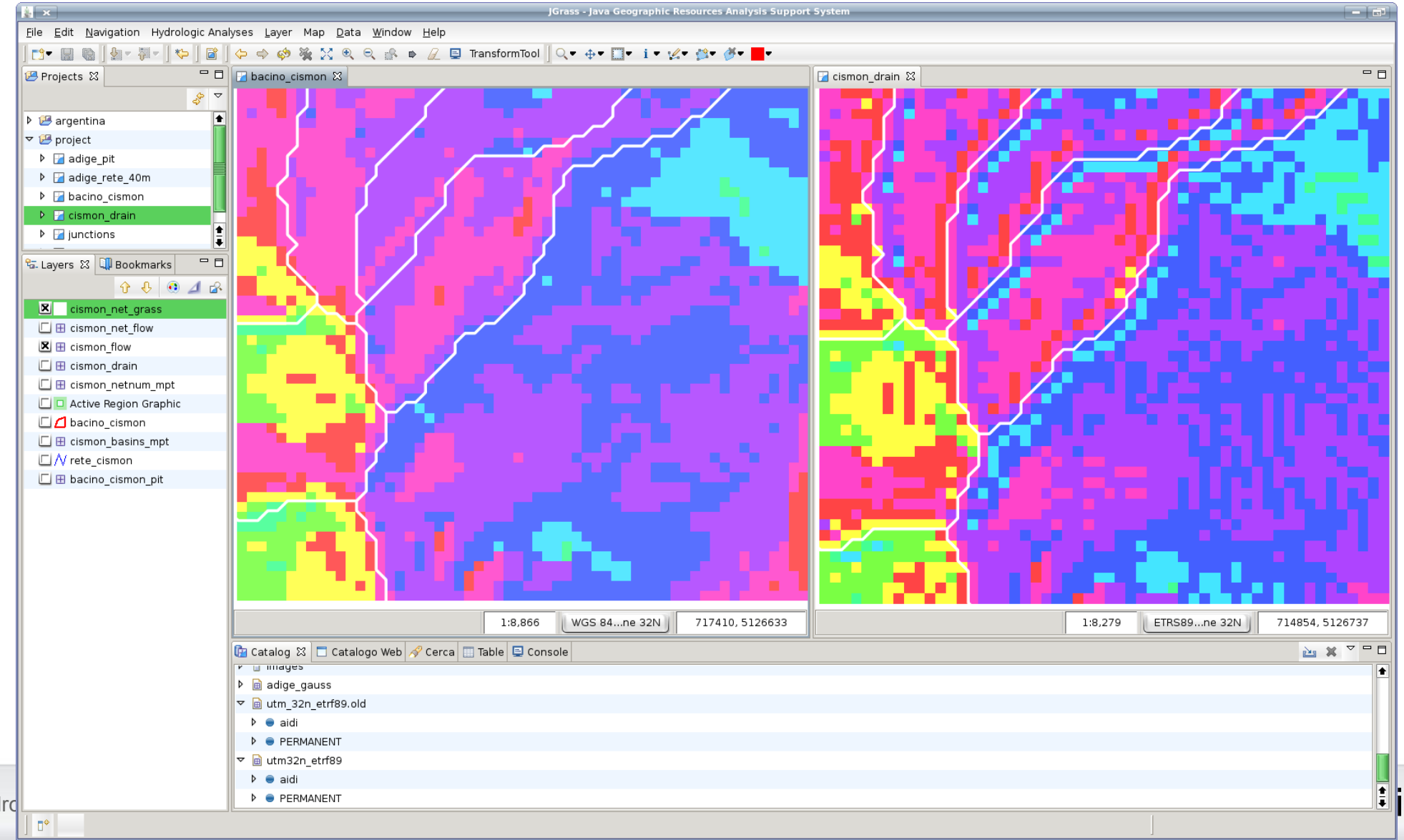
JGrass and the “Horton machine”

h.netshape2flow: create flowdirections along the network



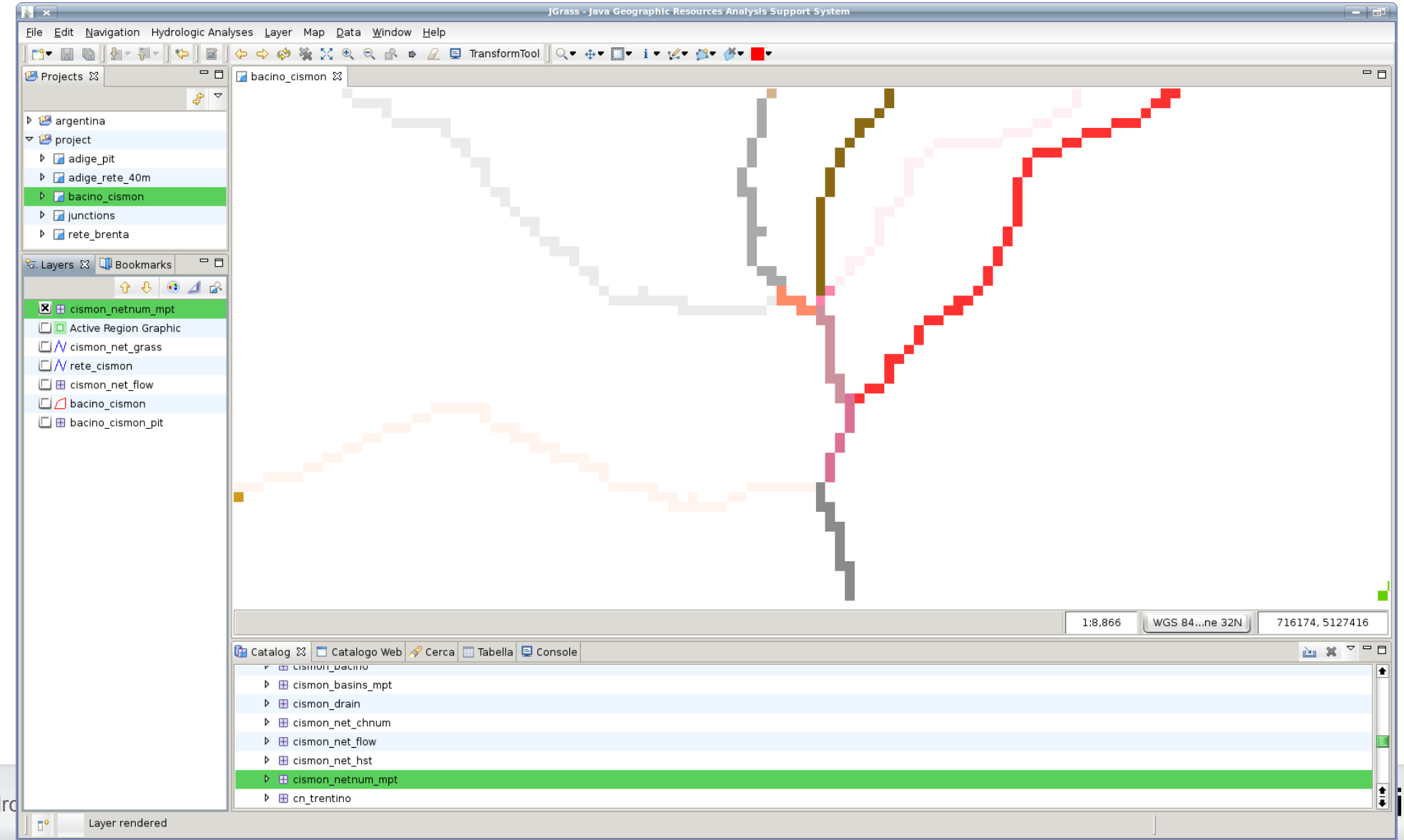
JGrass and the “Horton machine”

h.draindir: sink flowdirections to follow the real stream



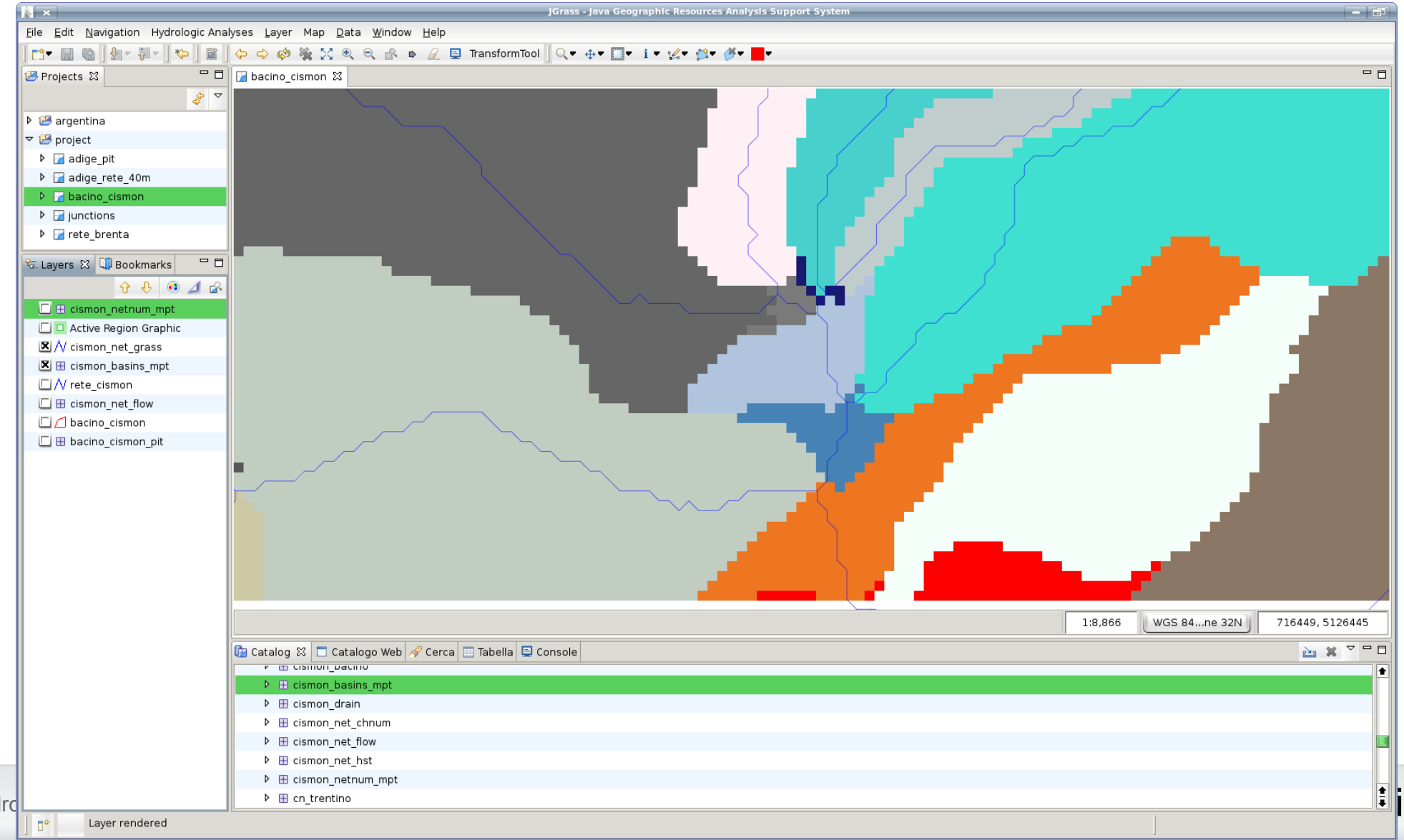
JGrass and the “Horton machine”

h.netnumbering: numbering of the channels...



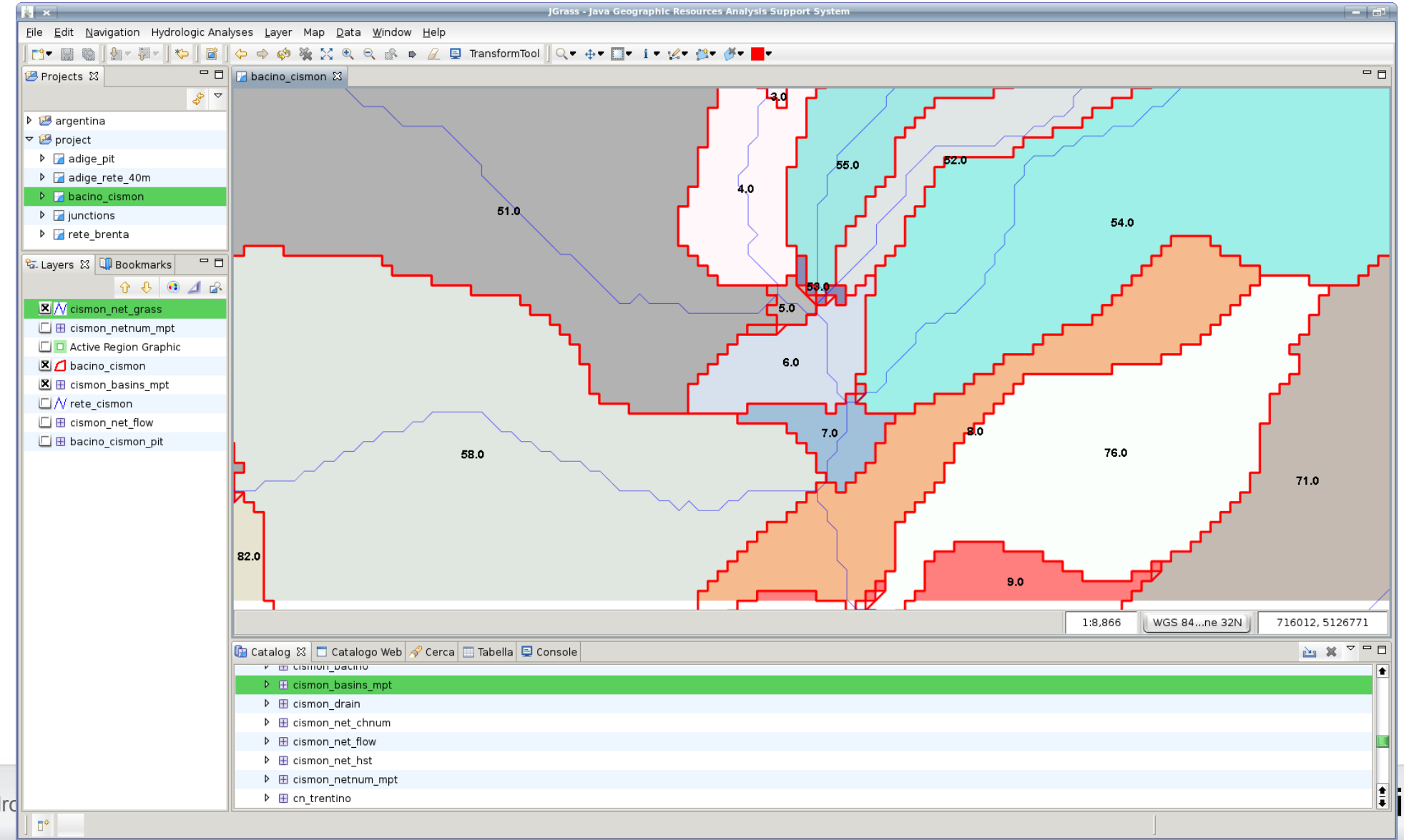
JGrass and the “Horton machine”

...and creation of the related subbasins



JGrass and the “Horton machine”

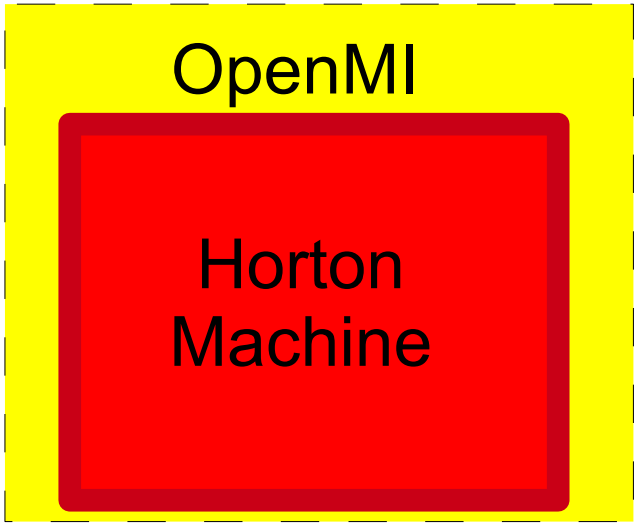
...from which the basin polygons can be extracted to shapefile.

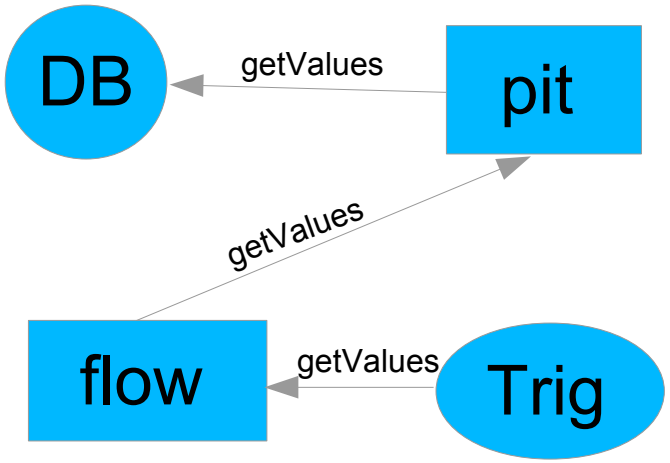


But again: How is this done?

OpenMI

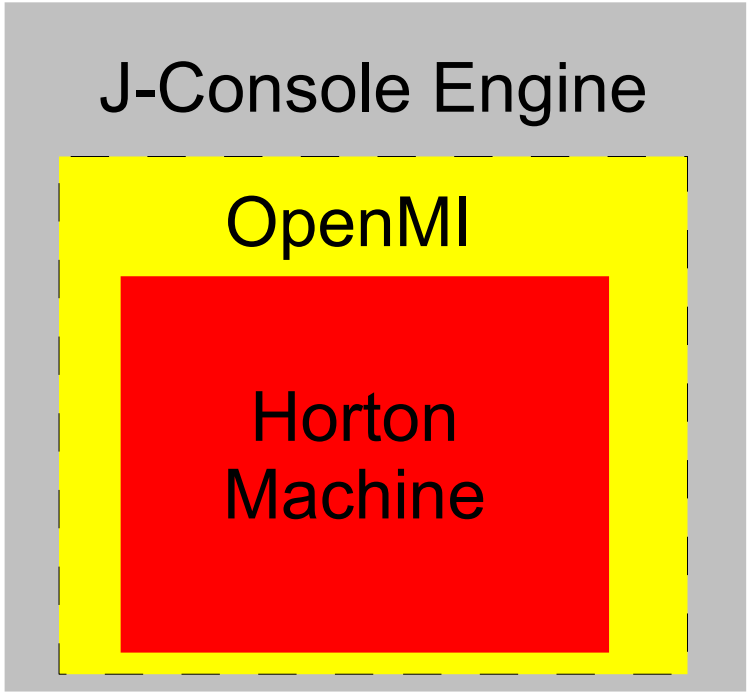
The HortonMachine - OpenMI Link





- OpenMi is a set of conceptual interfaces to do model linking and execution along a timeline chain
- since it got an international standard and models like Sobek, Hec-ras joined the wave, the effort was done to **adapt ALL the models of the Horton Machine to OpenMI**
- OpenMI is based on a pulling mechanism

J-Console – the scripting engine



- linking and executing such openmi based models was a bit tricky
- also there was the need to save scenarios, create automatisms
- a scripting engine was designed keeping in mind a commandline console and a visual console, a kind of atelier in which to easily play with model components
- a pluggable engine to be able to work also in standalone mode for serverside

J-Console – the JGrass modeling language

h.pitfiller --igrass-elevation dtm_corso --ograss-pit pitmap

```
def __h_pitfiller_631 = new h_pitfiller( out, err );
Argument[] __argv_637 = new Argument[7];
__argv_637[0] = new Argument( "grassdb", __global_grassdb, true );
__argv_637[1] = new Argument( "location", __global_location, true );
__argv_637[2] = new Argument( "mapset", __global_mapset, true );
__argv_637[3] = new Argument( "time_start_up", __global_startdate, true );
__argv_637[4] = new Argument( "time_ending_up", __global_enddate, true );
__argv_637[5] = new Argument( "time_delta", __global_deltat, true );
__argv_637[6] = new Argument( "remotedburl", __global_remotedb, true );

__h_pitfiller_631.initialize( __argv_637 );
InputGrassRasterMap __igrass_elevation_633 = new InputGrassRasterMap( out, err );
Argument[] __argv_638 = new Argument[9];
__argv_638[0] = new Argument( "igrass", "dtm_corso", true );
__argv_638[1] = new Argument( "quantityid", "elevation", true );
__argv_638[2] = new Argument( "grassdb", __global_grassdb, true );
__argv_638[3] = new Argument( "location", __global_location, true );
__argv_638[4] = new Argument( "mapset", __global_mapset, true );
__argv_638[5] = new Argument( "time_start_up", __global_startdate, true );
__argv_638[6] = new Argument( "time_ending_up", __global_enddate, true );
__argv_638[7] = new Argument( "time_delta", __global_deltat, true );
__argv_638[8] = new Argument( "remotedburl", __global_remotedb, true );

__igrass_elevation_633.initialize( __argv_638 );
Link __igrass_link_elevation_634 = new Link( null, "elevation" );
__igrass_link_elevation_634.connect(
        __igrass_elevation_633
        , __igrass_elevation_633.getOutputExchangeItem( 0 )
        , __h_pitfiller_631
        , __h_pitfiller_631.getInputExchangeItem( 0 )

    );
    if( false == __igrass_link_elevation_634.isConnected() ) {
    throw new RuntimeException( "Link " + __igrass_link_elevation_634.getID() + " not created." );
```

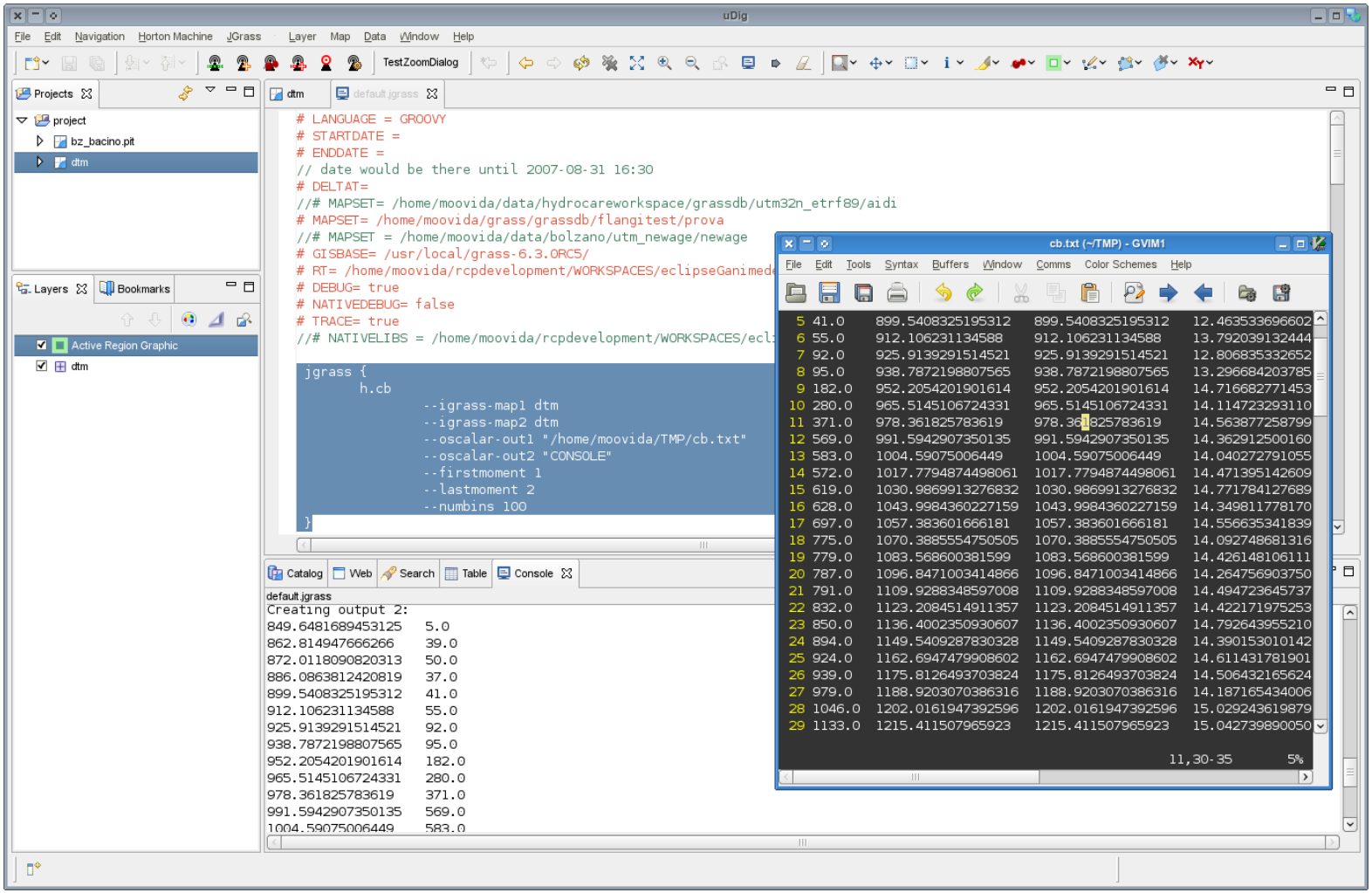
generated code

J-Console – the power of scripting

```
String bacino = "riosorna"
String bacinopit = bacino + "_pit"
String bacinodtm = bacino + "_dtm"
String bacinodrain = bacino + "_drain"
String bacinoflow = bacino + "_flow"
String bacinotca = bacino + "_tca"
String bacinoextract = "my" + bacino + "_pit"

jgrass h.pitfiller --igrass-elevation $bacinodtm --ograss-pit $bacinopit

jgrass h.flow --igrass-pit $bacinopit --ograss-flow $bacinoflow

jgrass h.draindir --mode 1 --igrass-pit $bacinopit --igrass-flow $bacinoflow
--lambda 1 --ograss-dir $bacinodrain --ograss-tca $bacinotca

jgrass h.wateroutlet --igrass-map $bacinopit --igrass-flow $bacinodrain
--ograss-basin $bacino --ograss-trim $bacinoextract --north 5075367.33 --east
656292.04
```

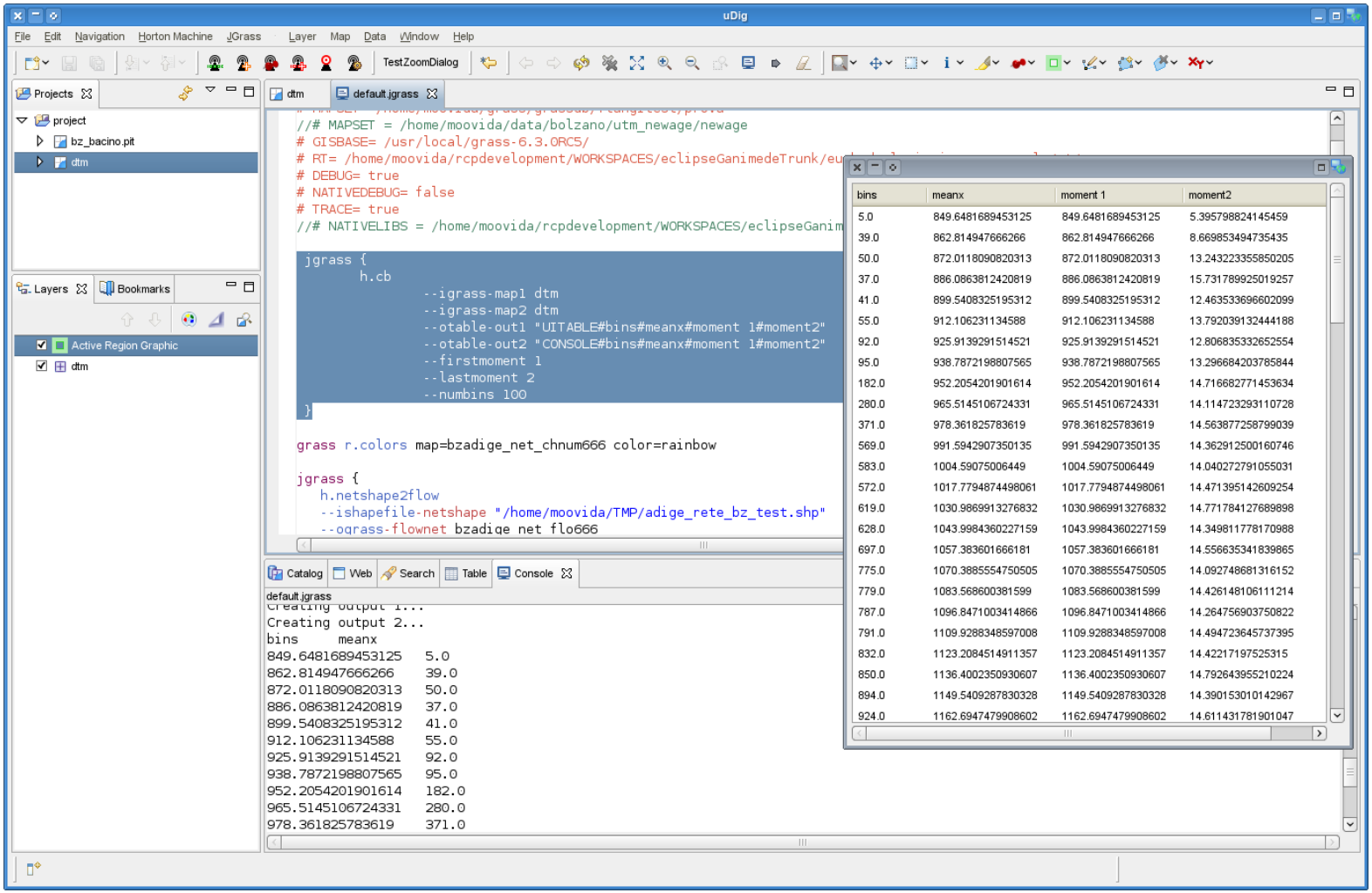
The abstraction on IO – forcing “clean” models

--oscalar-out xxxxxx



The abstraction on IO – forcing “clean” models

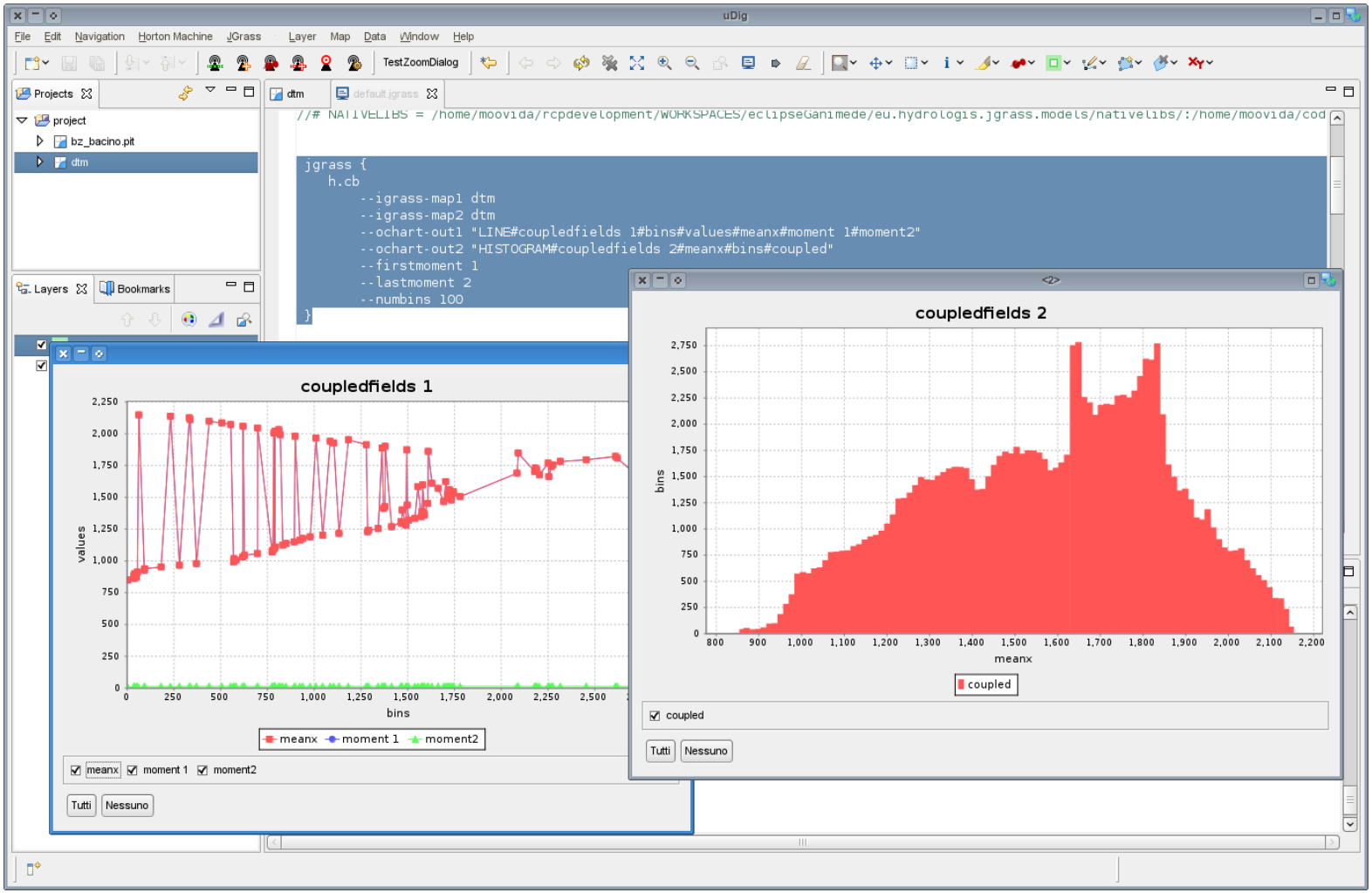
--otable-out xxxxxx



bins	meanx	moment 1	moment2
5.0	849.6481689453125	849.6481689453125	5.395798824145459
39.0	862.814947666266	862.814947666266	8.669853494735435
50.0	872.0118090820313	872.0118090820313	13.243223355850205
37.0	886.0863812420819	886.0863812420819	15.731789925019257
41.0	899.5408325195312	899.5408325195312	12.463533696602099
55.0	912.106231134588	912.106231134588	13.792039132444188
92.0	925.9139291514521	925.9139291514521	12.806835332652554
95.0	938.7872198807565	938.7872198807565	13.296684203785844
182.0	952.2054201901614	952.2054201901614	14.716682771453634
280.0	965.5145106724331	965.5145106724331	14.114723293110728
371.0	978.361825783619	978.361825783619	14.563877258799039
569.0	991.5942907350135	991.5942907350135	14.362912500160746
583.0	1004.59075006449	1004.59075006449	14.040272791055031
572.0	1017.7794874498061	1017.7794874498061	14.471395142609254
619.0	1030.9869913276832	1030.9869913276832	14.771784127689898
628.0	1043.9984360227159	1043.9984360227159	14.349811778170988
697.0	1057.383601666181	1057.383601666181	14.556635341839865
775.0	1070.3885554750505	1070.3885554750505	14.092748681316152
779.0	1083.568600381599	1083.568600381599	14.426148106111214
787.0	1096.8471003414866	1096.8471003414866	14.264756903750822
791.0	1109.9288348597008	1109.9288348597008	14.494723645737395
832.0	1123.2084514911357	1123.2084514911357	14.42217197525315
850.0	1136.4002350930607	1136.4002350930607	14.792643955210224
894.0	1149.5409287830328	1149.5409287830328	14.390153010142967
924.0	1162.6947479908602	1162.6947479908602	14.611431781901047

The abstraction on IO – forcing “clean” models

--ochart-out xxxxxx



The abstraction on IO – forcing “clean” models

The same applies for GIS data, for example:

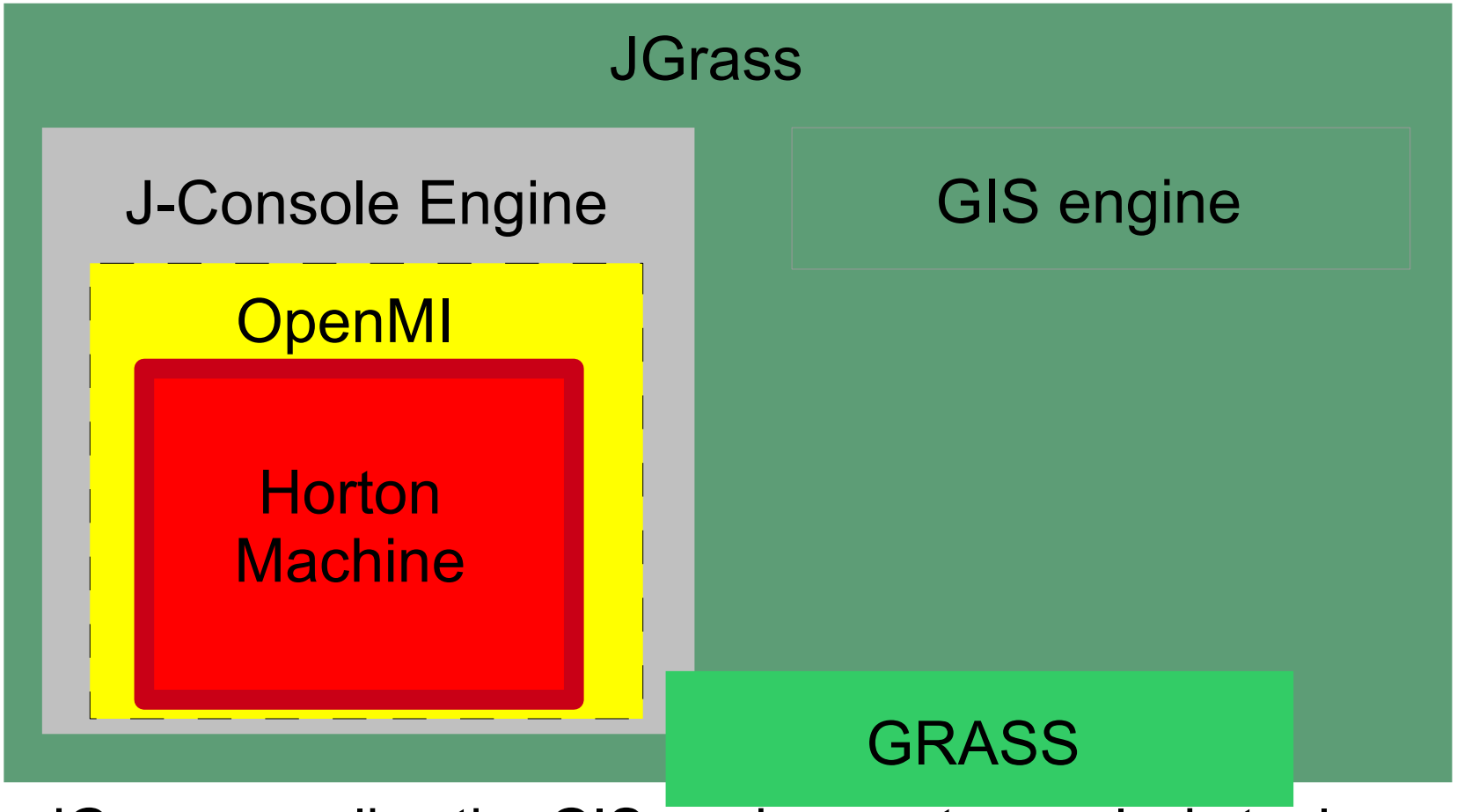
Vector data can be read from shapefiles or from postgis databases.

Raster data can be read from different formats (GRASS, ESRI, TIFF)

Where does this all take place?

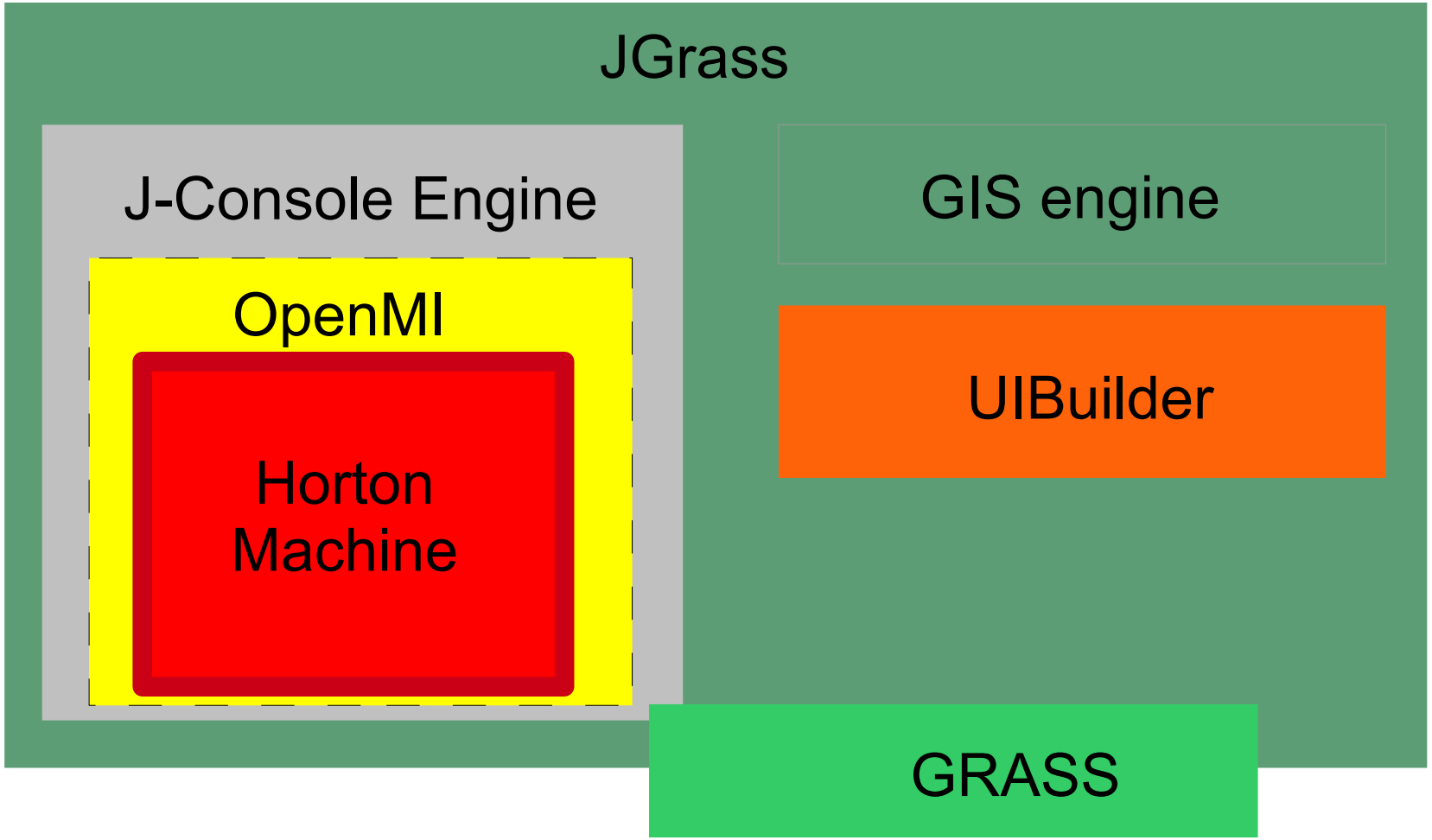
JGrass

JGrass



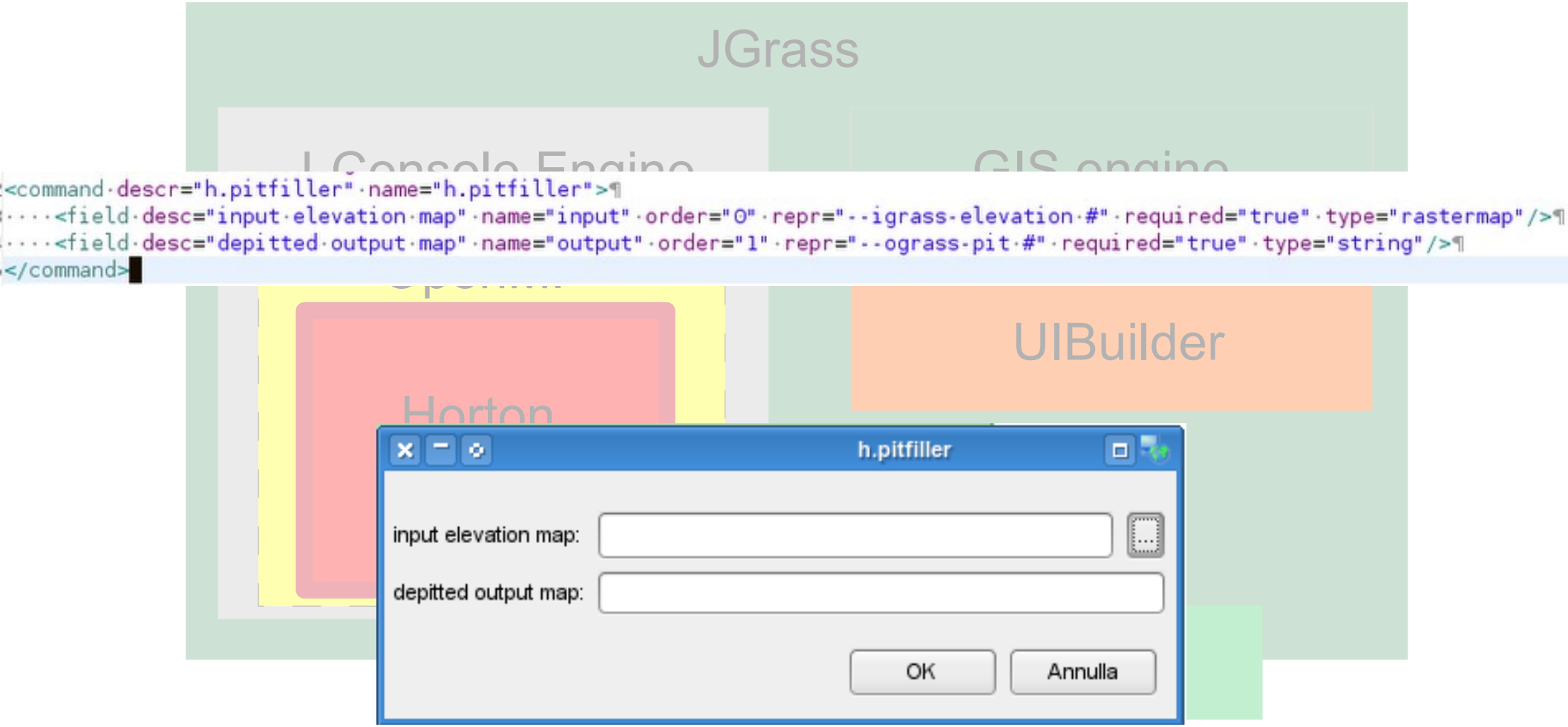
- JGrass supplies the GIS engine, raster analysis tools
- Connection to the GRASS GIS engine

the UIBuilder – graphical interfaces facilities



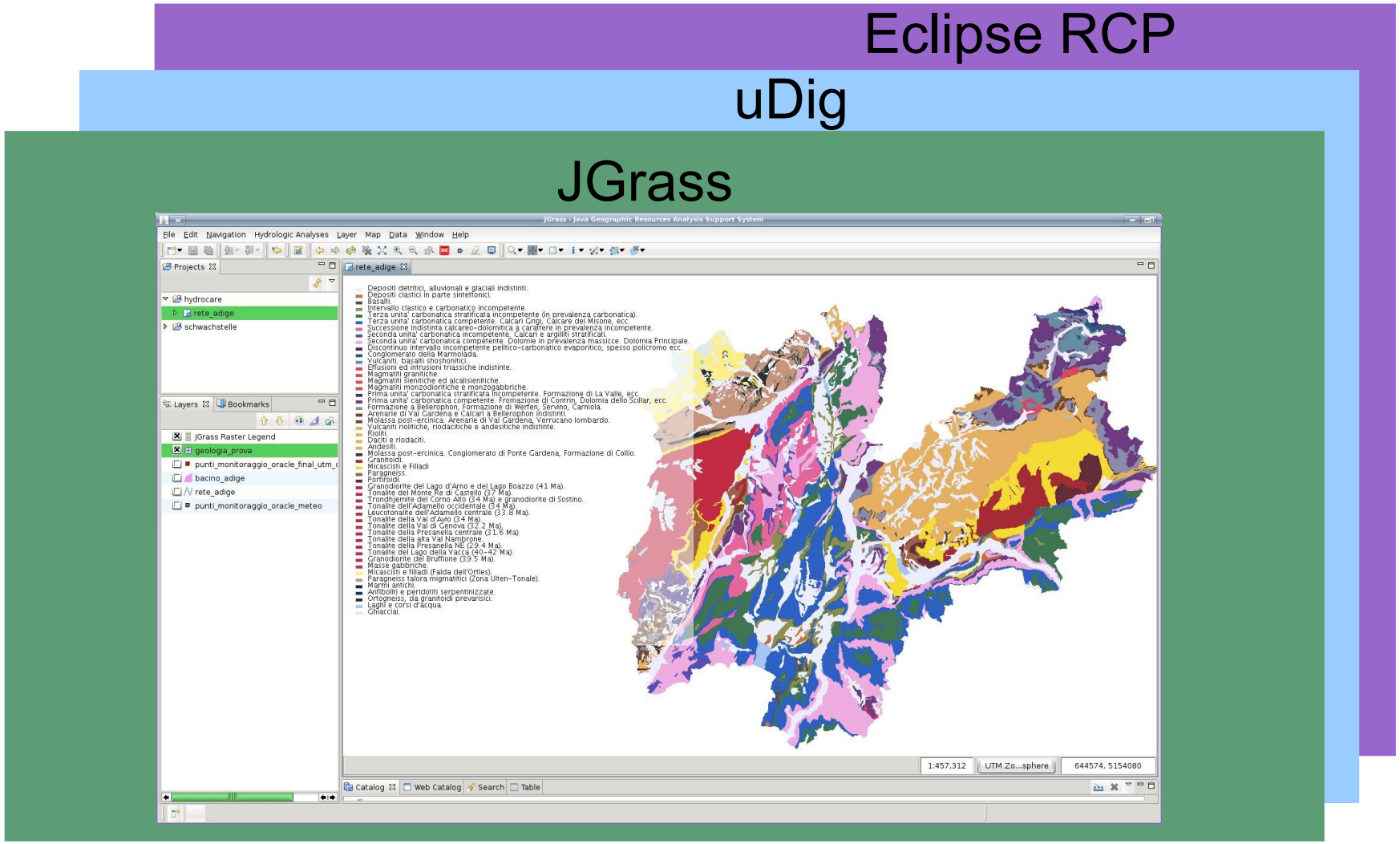
- UIBuilder that creates GUI based on XML descriptions

the UIBuilder – graphical interfaces facilities



- UIBuilder that creates GUI based on XML descriptions

JGrass, extending the rcp platform



- JGrass is built on top of the uDig GIS-framework
- All is built on top of the Rich-Client-Platform by IBM

JGrass, extending the rcp platform

Eclipse RCP

uDig

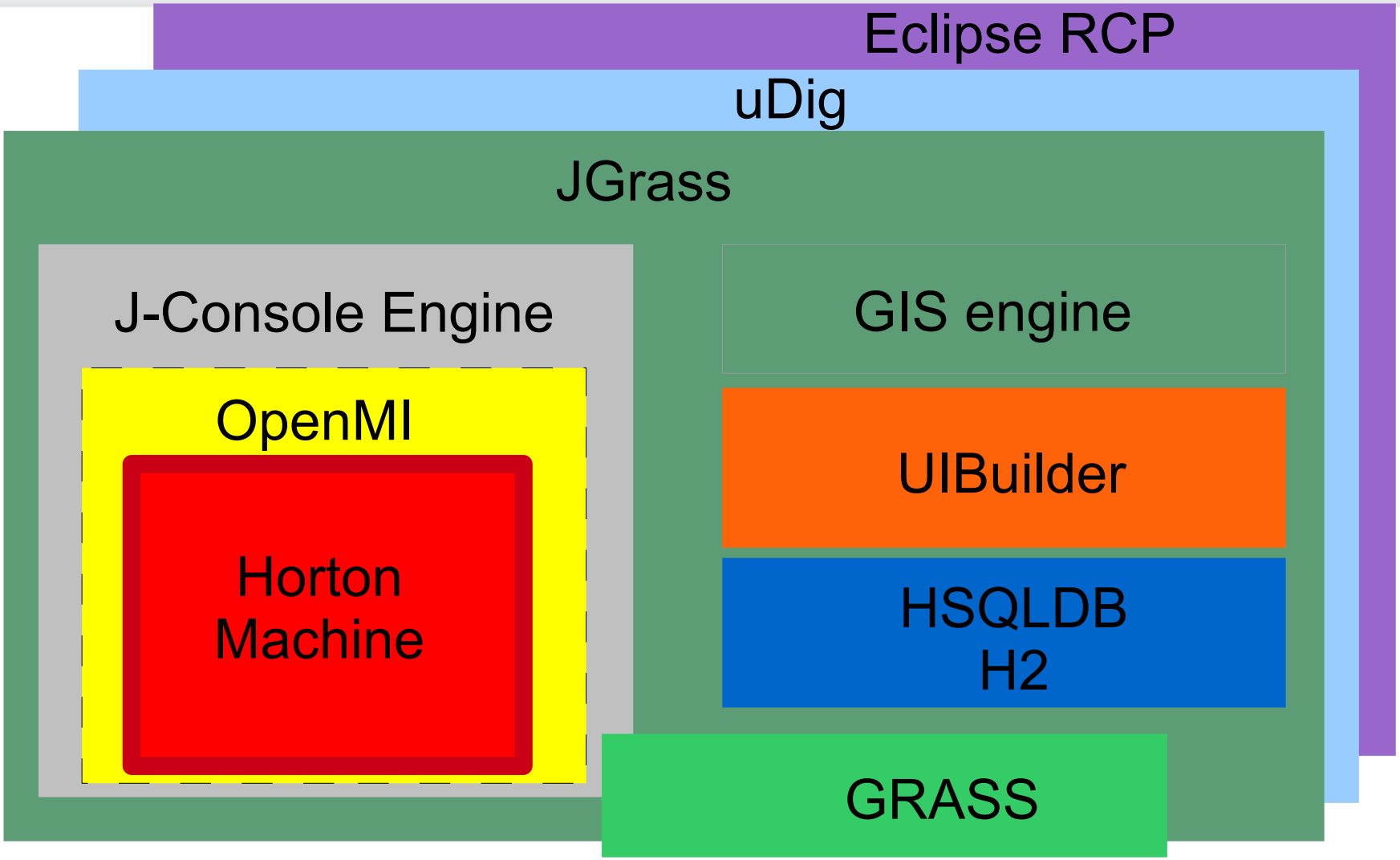
- Extends the rcp with GIS capabilities
- Introduces OGC standards through geotools and geoapi
- Vector oriented GIS

JGrass

- Raster oriented GIS
- Introduces a modeling engine for environmental analyses
- Introduces OpenMI extended with OGC

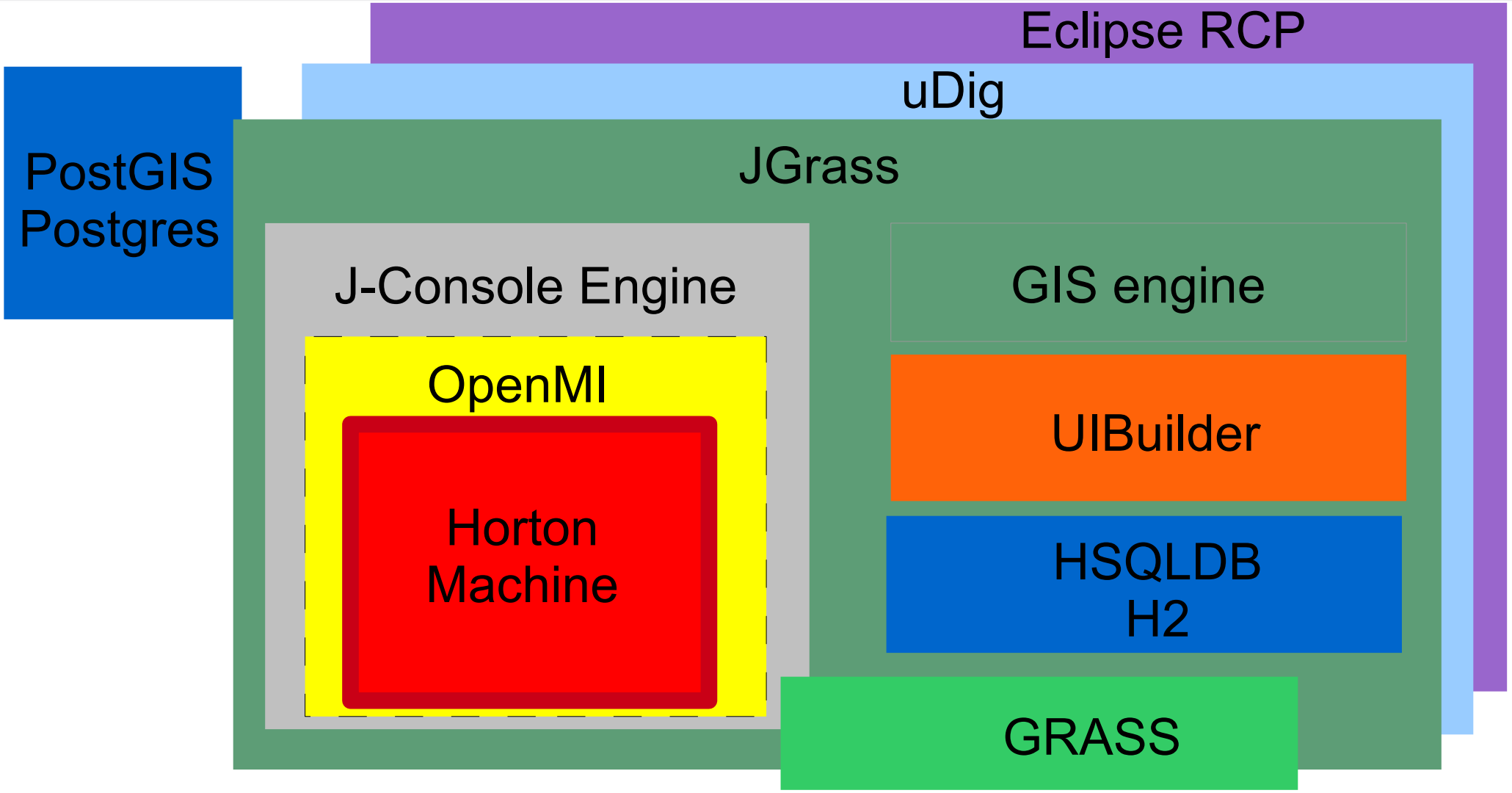
OGC

The database - internal non-spatial H*DB



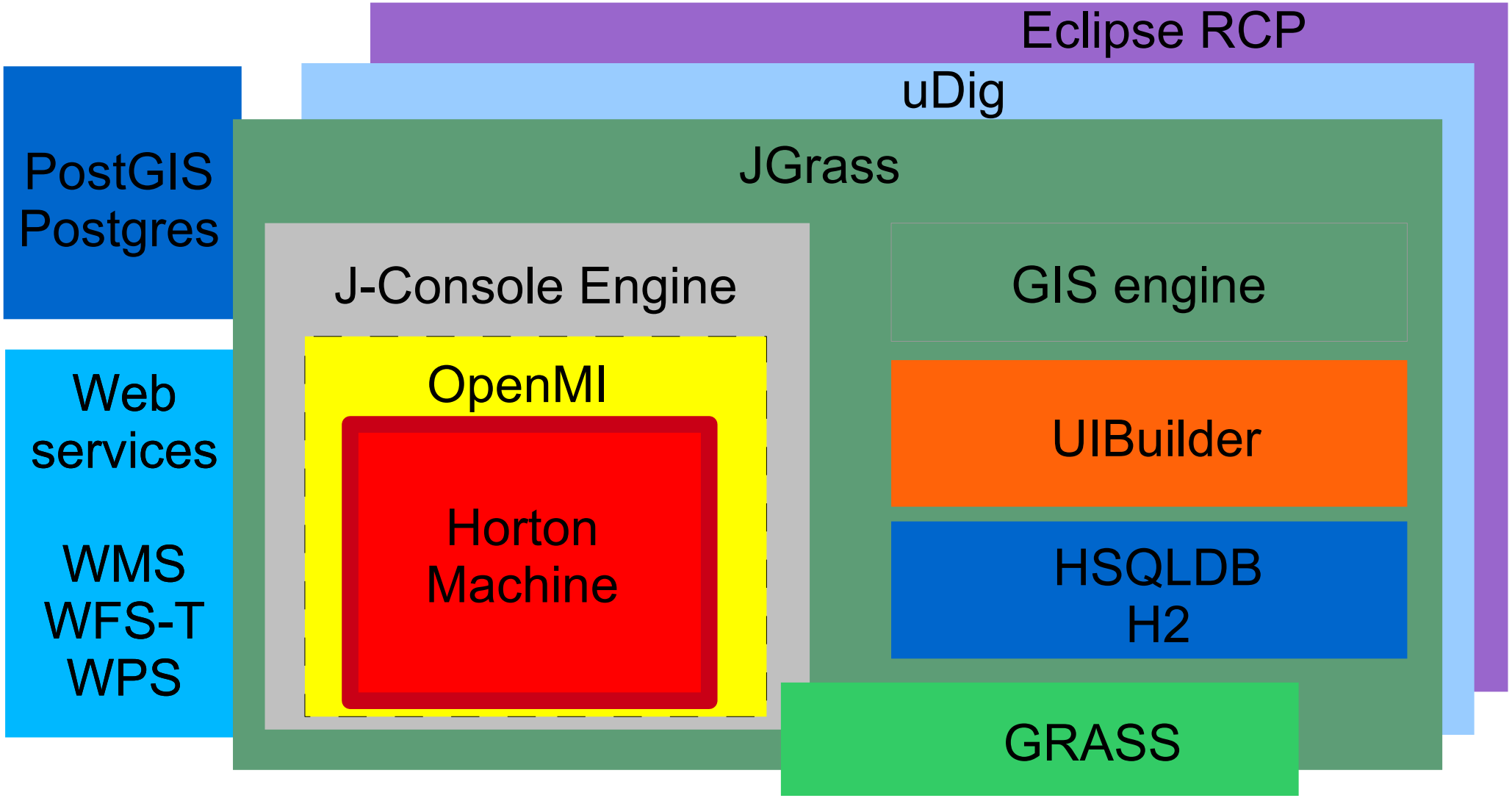
- An internal portable database is shipped with JGrass (non spatial)
- HSQLDB/H2, automatically started at JGrass startup

The database – central spatial Postgis



- through uDig JGrass exploits the connection to several spatial database types out of the box, as postgis, oracle spatial or arcsde

Webservices

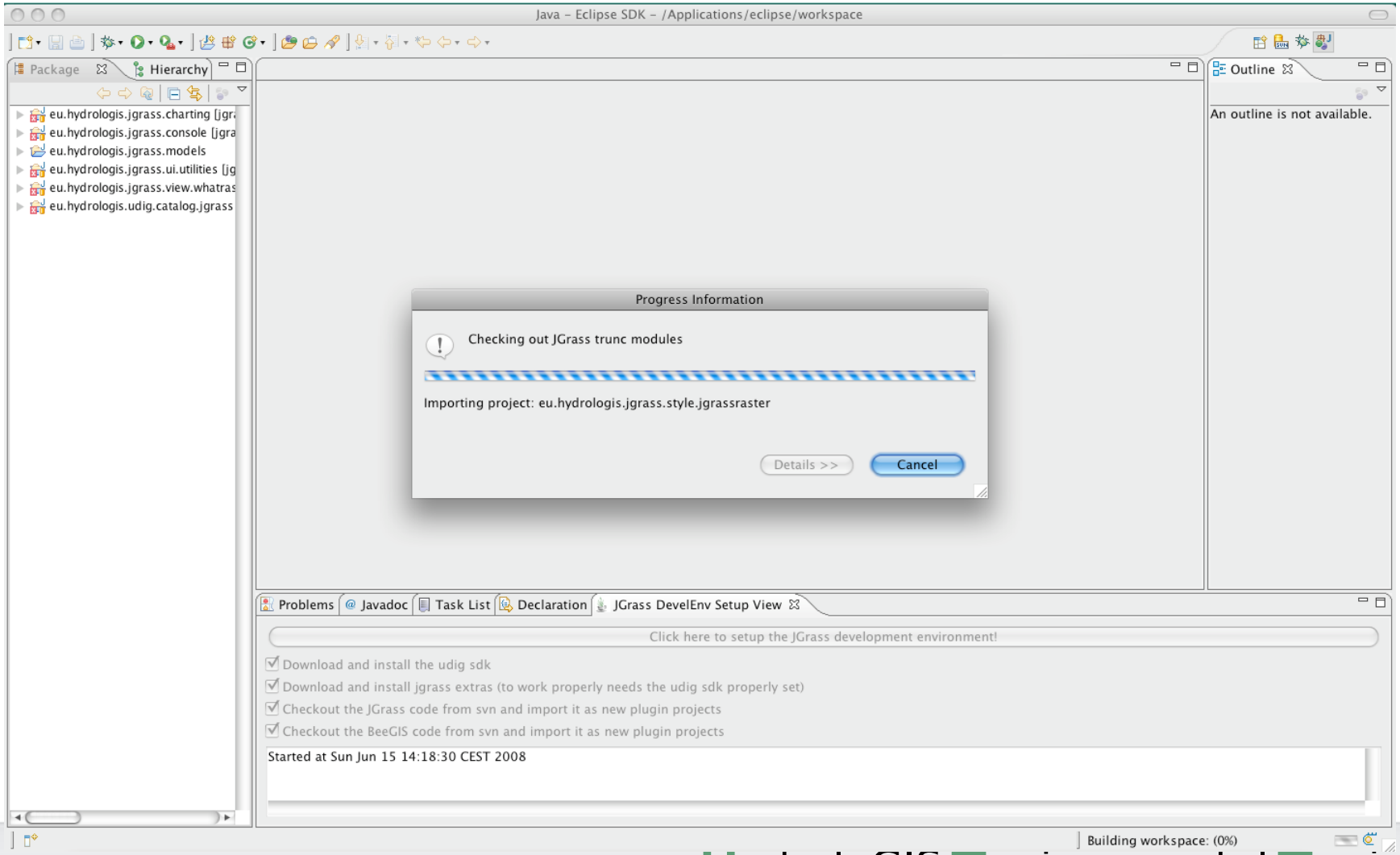


- the uDig link assures support for several web services

Future development

Developer tools

An eclipse plugin is in development, which automatically installs all needed tools and development kits, as well as source codes, to get started with JGrass development.

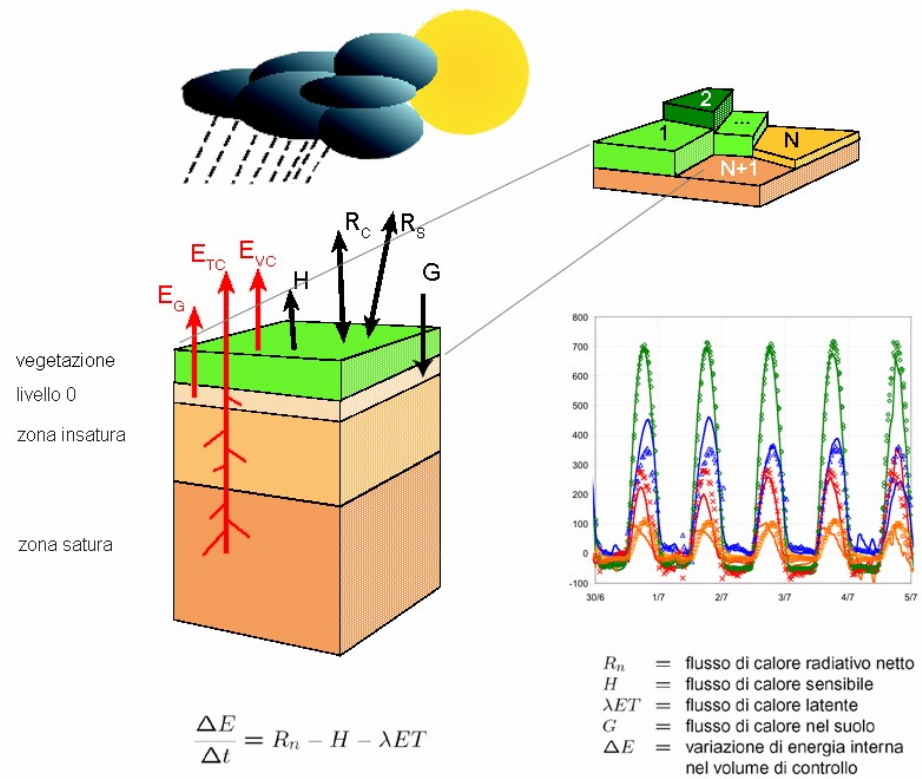


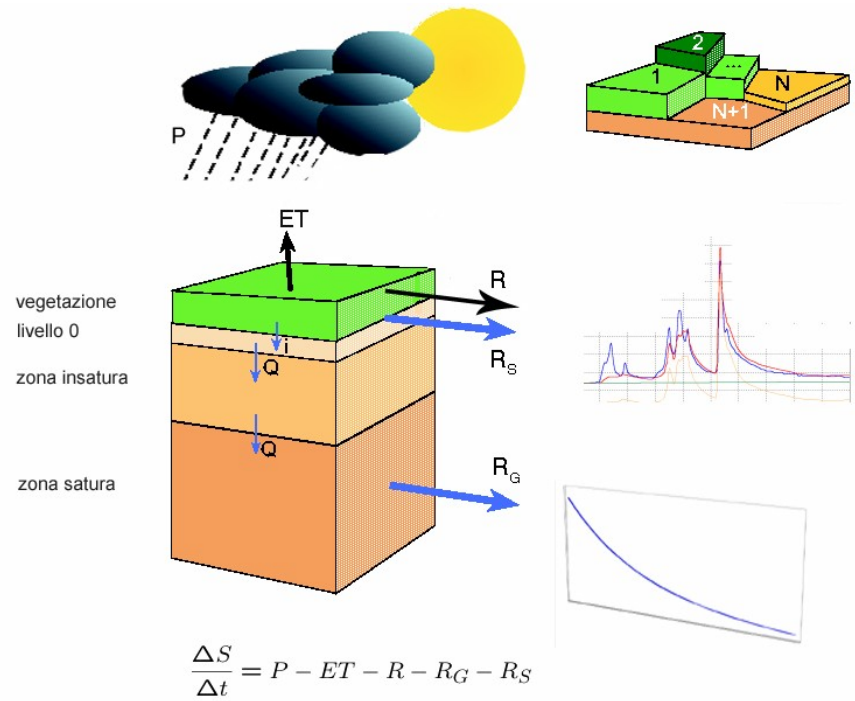
Integration of geotop into JGrass

GEOtop is a hydrological distributed model which integrates water and energy budgets in complex terrain.

Integration of geotop into JGrass

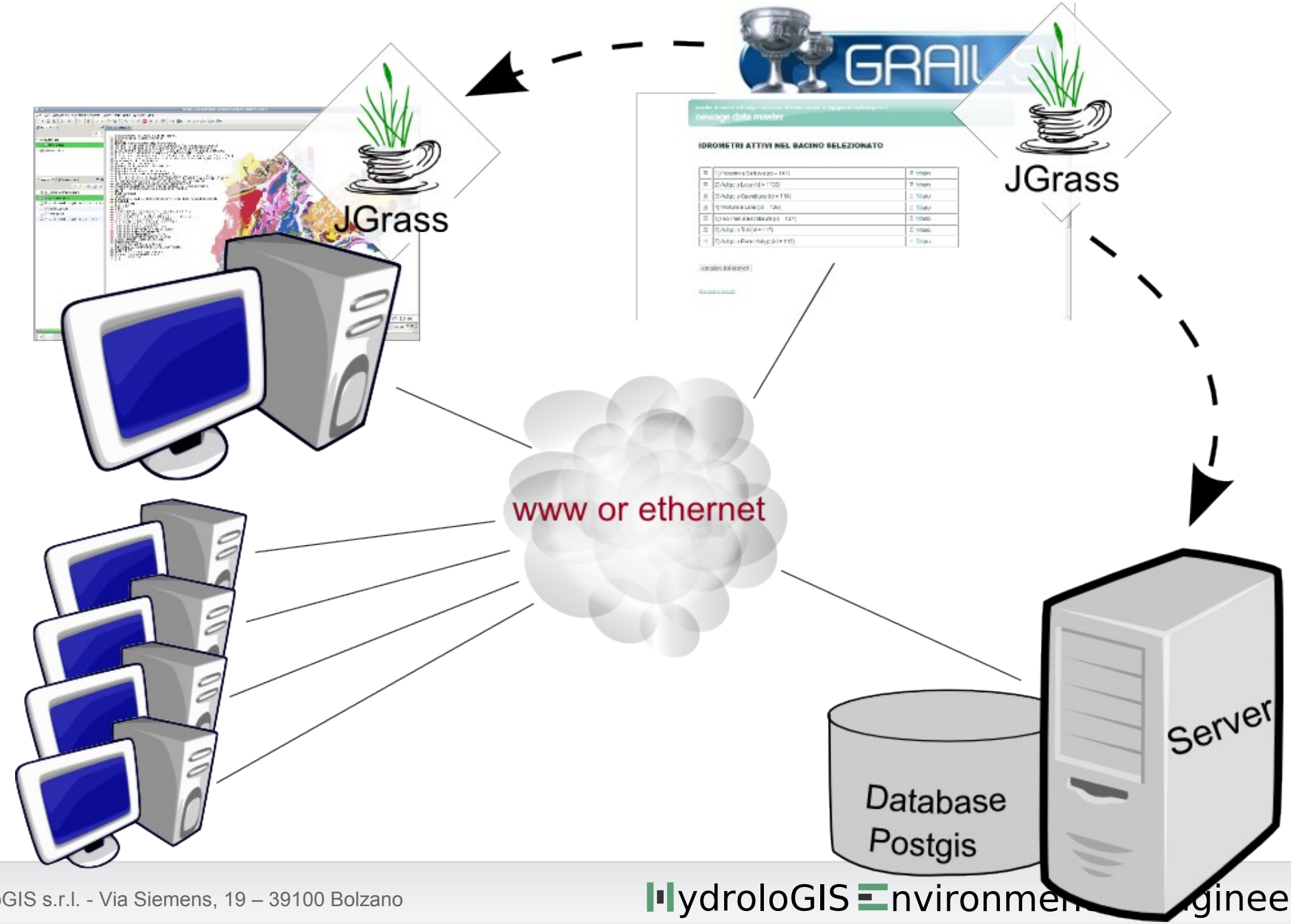
Square structured grid based on the DEM



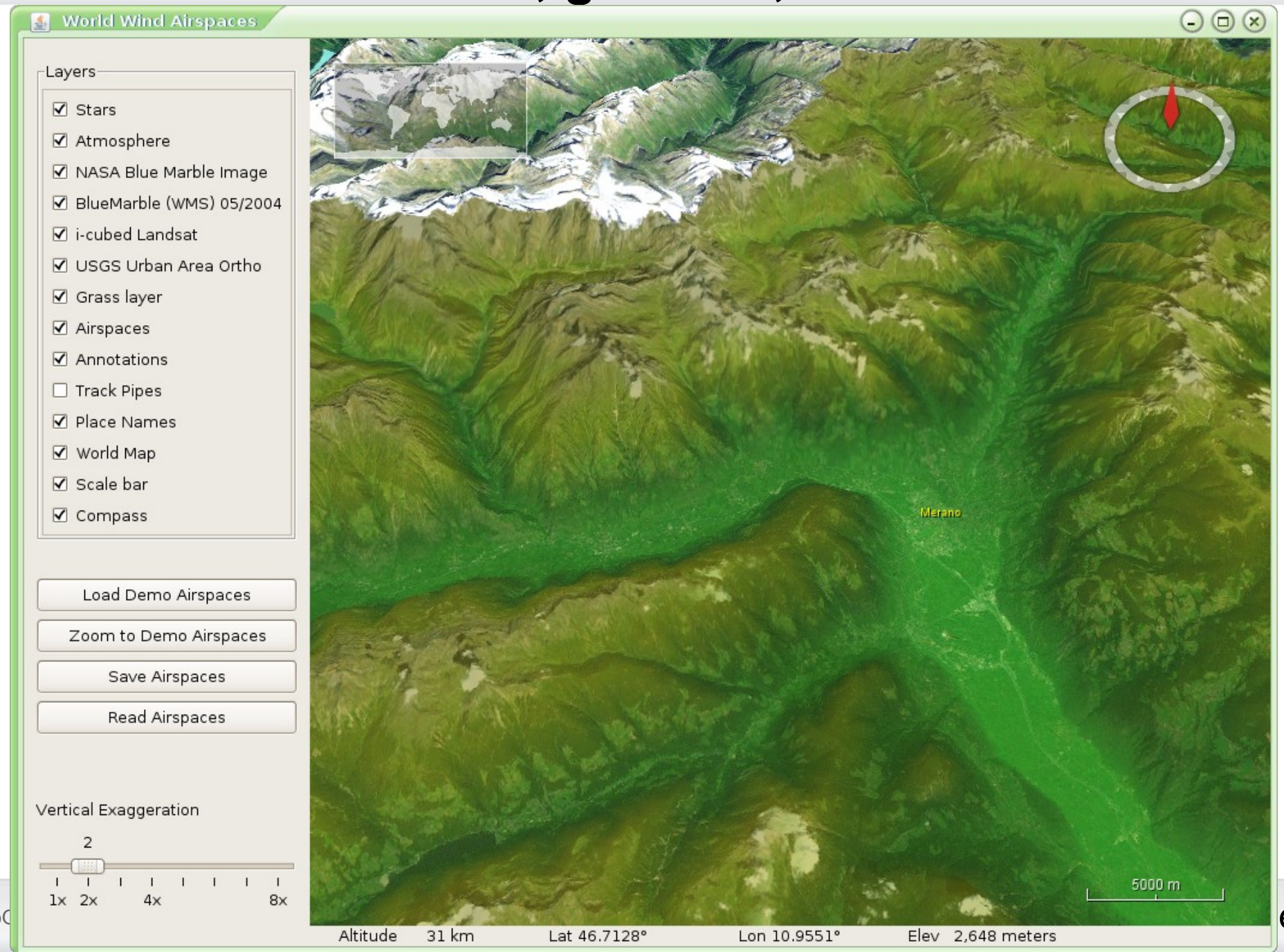


Meteo Data Interpolator - MicroMET
Separation - Rainfall – Snow
Energy Budget
Water Budget

Further development of JGrass's preferred environment



JGrass, geowind, NWW



Environmental modeling
within the framework of GIS

www.jgrass.org
www.geotop.org