

## geotopbricks

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# Who are we?



- ▶ Environmental engineers with hydraulic and hydrological background (more deterministic and physical-based than statics!)
- ▶ Some of us are researcher, other are self-employed and freelancers - [www.rendena100.eu](http://www.rendena100.eu) .
- ▶ Some of us are author of several R-packages and R enthusiast.
- ▶ Some of us are developers of GEOTop hydrologic models with skills in hydrology and environmental science and also in C/C++, parallel programming, High Performance Computing, etc

# Hydrology

Scientific study of the movement, distribution, and quality of water on Earth water cycle, water resources and environmental watershed sustainability [Wikipedia]

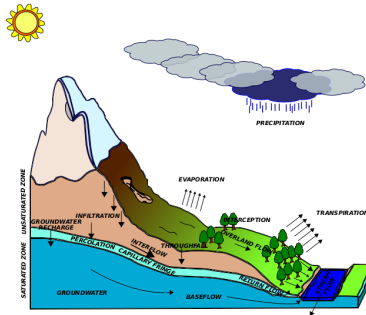
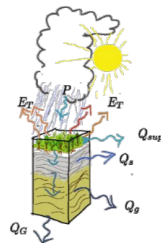
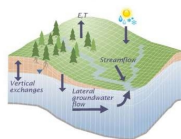
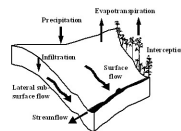


Figure 1:

# Hydrological models



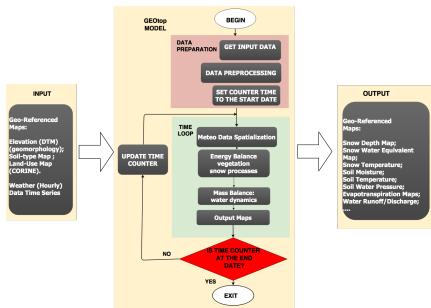
# GEOtop Hydrological Model

GEOtop is an open-source integrated hydrological model, available through Github, [www.geotop.org](http://www.geotop.org), simulating:



- ▶ soil water flow in the soil (*Richards' equation, De Saint-Venant Equation*);
- ▶ heat flow in the soil → (*heat equation and frozen soil thermodynamics*) ;
- ▶ energy exchange with the atmosphere → boundary conditions of the equations above.

# GEOtop Hydrological Model Structure

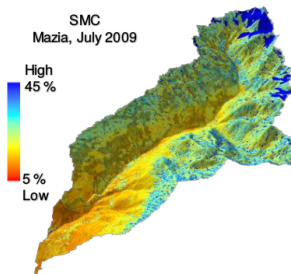
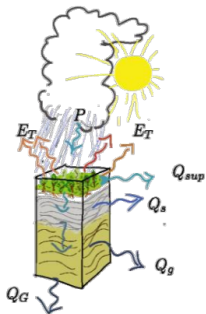


- **Input:** meteo data, elevations, soil parameters, . . .
- **Output:** snow cover, soil temperature, soil moisture, . . .

# GEOtop Hydrological Model Options

Water and/or energy budgets can be activated (both or only one) by users in function of the specific use case. GEOtop has two setup configurations :

- ▶ **1D**: only vertical fluxes → mass and energy balance at local scale (only in one soil column)
- ▶ **3D**: vertical and lateral fluxes → balances at basin scale



# GEOtop Hydrological Model Software Package / Source Code

Core components of GEOtop software packages are:

- ▶ written in C/C++
- ▶ released in 2014 (version 2.0) as free open-source project, a re-engineering process is going to finish (version 3.0);
- ▶ scientifically tested and published;

Source code and documentation are available on GitHub repository:  
[<http://geotopmodel.github.io/geotop/>].



## Water Resources Research

### RESEARCH ARTICLE

10.1002/2016WR019191

#### Key Points:

- Seven hydrologic models were intercompared using three benchmarks of increasing complexity
- Models showed good agreement with respect to various hydrologic

### The integrated hydrologic model intercomparison project, IH-MIP2: A second set of benchmark results to diagnose integrated hydrology and feedbacks

Stefan Kollet<sup>1,2</sup>, Mauro Sulis<sup>3</sup>, Reed M. Maxwell<sup>4</sup>, Claudio Paniconi<sup>5</sup>, Mario Putti<sup>6</sup>, Giacomo Bertoldi<sup>7</sup>, Ethan T. Coon<sup>8</sup>, Emanuele Cordano<sup>7,9</sup>, Stefano Endrizzi<sup>10</sup>, Evgeny Kikinzon<sup>8</sup>, Emmanuel Mouche<sup>11</sup>, Claude Mugler<sup>11</sup>, Young-Jin Park<sup>12</sup>, Jens C. Refsgaard<sup>13</sup>, Simon Stisen<sup>13</sup>, and

Toulouse, France





# geotopbrick R package: Why?

- ▶ complexity in input/output/configuration files (“frontend”) and data difficult to handle
- ▶ need of user friendly environment for to GEOTop data tidying and data analytics (e.g. *R*)

```
113 -----
114 ! LAND COVER
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117 Urban1, Pasture 2, Grassland 3, Agricultural 4, Broad leaf forest 5,
118 Bare Rocks 6, Bare Soils 9, Glacier 10, Lake/Marsh 11
119
120 NumLandCoverTypes = 11
121 SoilRoughness = 1,10,10,10,10,10,10,10,1,1
122 ThreeSnowSoilRough = 10,10,10,10,10,10,10,10,10
123 VegHeight = 0,200,600,600,1800,1800,1800,0,0,0
124 ThreeSnowVegUp = 50,50,50,50,50,50,50,50,50
125 ThreeSnowVegDown = 10,10,10,10,10,10,10,10,10
126 LAH = 0,2,5,7,7,0,0,0,0
127 CanopyReaction = 0,0,7,1,1,1,1,1,0,0,0
128 DecayCoeffCanopy = 2,5,2,5,2,5,2,5,2,5,2,5,2,5,2,5
129 VegSnowBurying = 1,1,1,1,1,1,1,1,1,1
130 RootDepth = 0,200,300,500,700,700,700,0,0,0,0
131 MinSnowmeltRes = 60,60,60,60,60,60,60,60,60,60
132 VegReflectVis = 0,1,0,1,0,1,0,1,0,1,0,1,0,1,0,1
133 VegRefInIR = 0,58,0,58,0,58,0,58,0,58,0,58,0,58,0,58
134 VegTransVis = 0,05,0,05,0,05,0,05,0,05,0,05,0,05,0,05
135 VegTransInIR = 0,25,0,25,0,25,0,25,0,25,0,25,0,25,0,25
136 LeafAngles = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
137 CanDensSurface = 0,5,0,5,0,5,0,5,0,5,0,5,0,5,0,5
138 SoilAlbVisDry = 0,15,0,15,0,15,0,15,0,15,0,15,0,15,0,15
139 SoilAlbInIRDry = 0,25,0,25,0,25,0,25,0,25,0,25,0,25,0,25
140 SoilAlbVisWet = 0,15,0,15,0,15,0,15,0,15,0,15,0,15,0,15
141 SoilAlbInIRWet = 0,25,0,25,0,25,0,25,0,25,0,25,0,25,0,25
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```

# GEOtop configuration File (geotop.inpts)

A GEOtop simulation is organized in a set of files within a directory containing a **configuration file** ,called *geotop.inpts* filled with a keywords system addressing to:

- ▶ simulation

options

(e.g. simulation  
period)

InitDateDDMMYYYYhhmm=09/04/2014 18:00

EndDateDDMMYYYYhhmm =01/01/2016 00:00

- ▶ **input files**

(e.g. meteorolog-  
ical time  
series)

[...]

MeteoFile = "meteoB2\_irr"

PointOutputFile = "tabs/point"

- ▶ **output files**

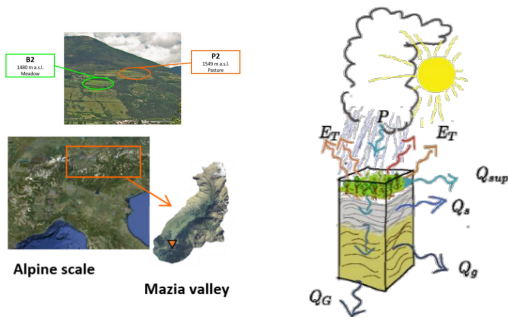
## geotopbricks Technical details

The aim of **geotopbricks** , starting in 2013, is to bring all the data of a GEOtop simulation into the powerful statistical **R** environment by using the keyword-value syntax of *geotop.inpts*. **geotopbricks** does the following actions:

- ▶ to parse *geotop.inpts* configuration files;
- ▶ to derive from *geotop.inpts*'s keywords the source files of I/O data;
- ▶ to import time series (e.g. precipitation, temperature, soil water content, snow) as *zoo* or *data.frame* objects;
- ▶ to import spatially and spatio-temporal gridded objects as *RasterLayer-class* or *RasterBrick-class* objects (**raster** package)

# geotopbriccks Application 1: Simulation of soil water budget in an alpine site

Soil water content (SWC) in two sites P2 and B2, located in Val Mazia/Match, Malles Venosta/Mals Vinschgau, in South Tyrol, Italy [<http://lter.eurac.edu/en>].



B2



# Simulation of soil water budget in an alpine site

Here is the directory containing files of B2 point simulation:

```
library(geotopbricks)

## SET GEOTOP WORKING DIRECTORY
wpath_B2 <- "resources/simulation/Matsch_B2_Ref_007"
##writeLines(list.files(wpath_B2))
```

## Getting simulation input data

Meteorological variable time series are imported and saved as 'meteo' variable (class 'zoo'). This variable is retrieved through the GEOTop keyword **MeteoFile** :

```
tz <- "Etc/GMT-1"
meteo <- get.geotop.inpts.keyword.value(
  "MeteoFile",
  wpath=wpath_B2,
  data.frame=TRUE,
  tz=tz)
class(meteo)
```

```
## [1] "zoo"
```

## Getting simulation input data (verify)

Meteorological time series once imported are available in the R environment:

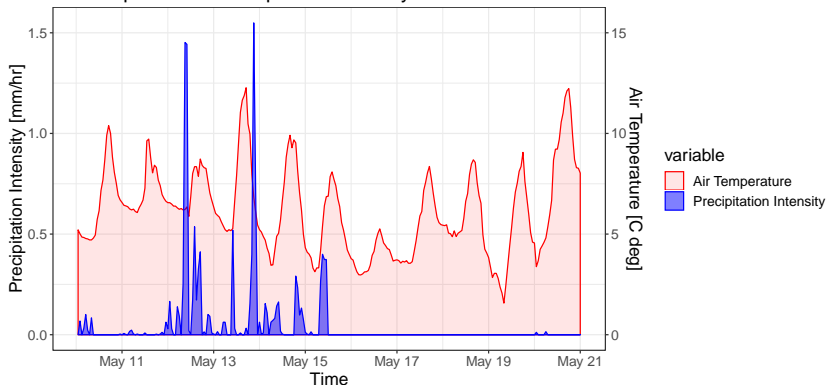
```
head(meteo[12:14,c("Iprec","AirT","Swglobal")])
```

##		Iprec	AirT	Swglobal
##	2009-10-02 11:00:00	0	12.38	396.02
##	2009-10-02 12:00:00	0	13.12	500.07
##	2009-10-02 13:00:00	0	13.96	564.02

```
head(meteo[12:14,c("RelHum","WindSp","WindDir")])
```

# Plots of weather variables in B2

Air Temperature / Precipitation Intensity vs Time at B2





# Getting output simulation data at B2

Soil Water Content Profile:

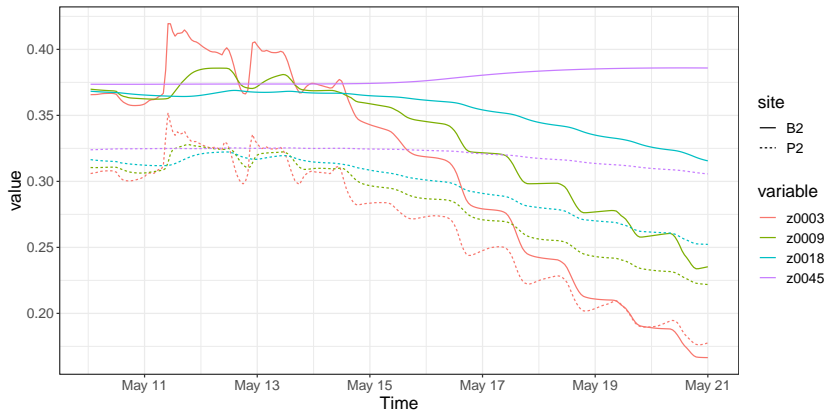
```
tz <- "Etc/GMT-1"
SWC_B2 <- get.geotop.inpts.keyword.value(
  "SoilLiqContentProfileFile",
  wpath = wpath_B2,
  data.frame = TRUE,
  date_field = "Date12.DDMMYYYYhhmm.",
  tz = tz,
  zlayer.formatter = "z%04d"
)
help(get.geotop.inpts.keyword.value) ## for more details!
```

## Getting output simulation data at P2

The same for P2:

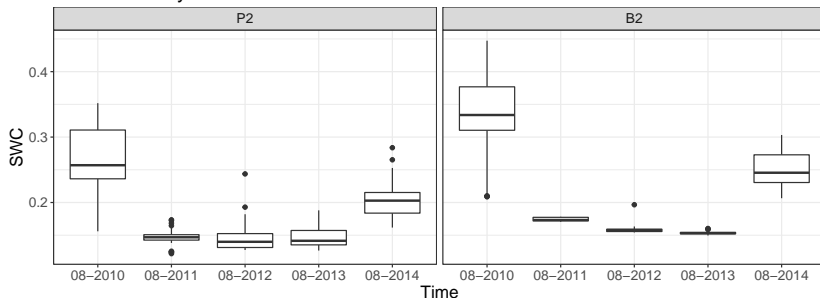
```
wpath_P2 <- "resources/simulation/Matsch_P2_Ref_007"  
SWC_P2  <- get.geotop.inpts.keyword.value(  
  "SoilLiqContentProfileFile",  
  wpath = wpath_P2,  
  data.frame = TRUE,  
  date_field = "Date12.DDMMYYYYhhmm.",  
  tz = "Etc/GMT-1",  
  zlayer.formatter = "z%04d")
```

# Soil Water Content at P2 and B2



# Output data Analytics (soil Moisture Distribution)

Distribution of daily aggregated soil water content at a 18 cm depth:  
Box Plot: Daily Soil Water Content



More details on the **eRun2018** poster.

# 3D Spatially Distributed Distribution (Vinschgau - Upper Adige River Basin - Alps - I/CH/A)

```
###wpath_3D <- 'resources/simulation/Vinschgau_test_3D_002'
wpath_3D <- 'resources/simulation/Vinschgau'
basin <- get.geotop.inpts.keyword.value("LandCoverMapFile",
                                         wpath=wpath_3D,raster=TRUE)

basin
```

```
## class      : RasterLayer
## dimensions  : 48, 63, 3024  (nrow, ncol, ncell)
## resolution  : 1000, 1000  (x, y)
## extent      : 598000, 661000, 5145000, 5193000  (xmin, xmax, ymin, ymax)
## coord. ref. : +proj=utm +zone=32 +ellps=WGS84 +datum=WGS84 +units=m +no_defs
## data source : in memory
## names       : layer
## values      : 1, 11  (min, max)
```

# 3D Spatially Distributed Simulation (Input Geospatial Map)

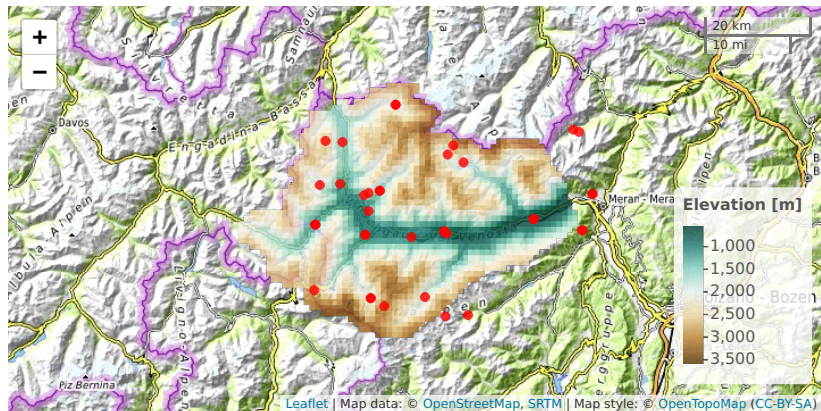


Figure 2: FALSE

Rendena100.eu

# 3D Spatially Distributed Simulation (Output Geospatial Map): Soil Water Content

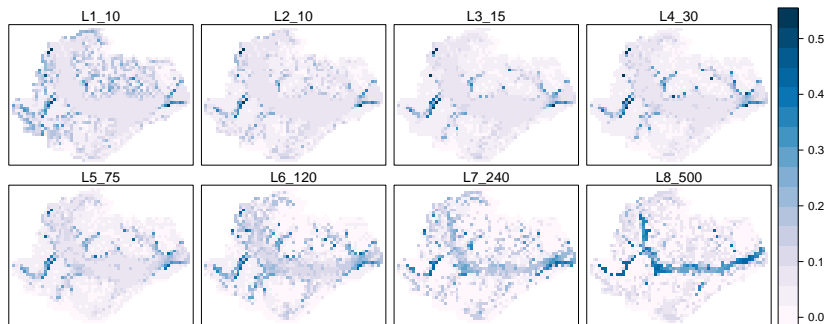
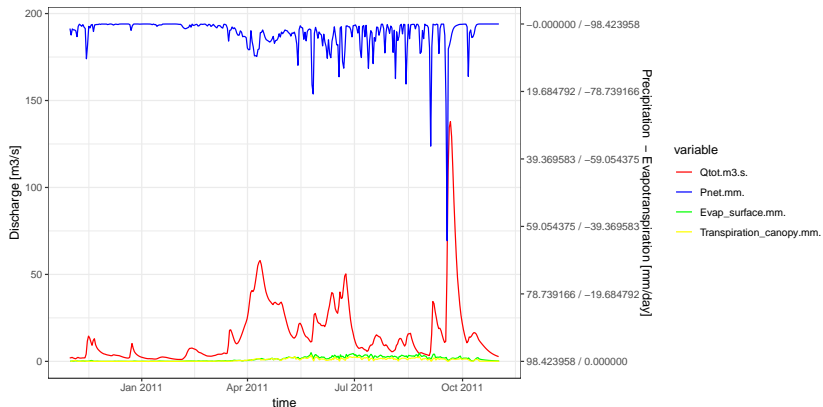


Figure 3: FALSE

`help("brickFromOutputSoil3DTensor")` ## for more details

# 3D Spatially Distributed Simulation (Output Geospatial Map): Surface Water Discharge at the Outlet



Rendena100.eu

Figure 4: FALSE

useR2019, Toulouse, France



# Dicussion

- ▶ Graphical Representation using R , useful for hydrologigists and Reaserchers;
- ▶ Open science : results accessible to a variegate community of professional, scientific or amateur people, not all hydrologigists are R users but not all R users are hydrologigists!
- ▶ Reproducible Analysis and Transparecy : results can be automatically documented in reports or presentations.
- ▶ Though **geotopbricks** user can intercat between R and GEOTop using R enviroment and GEOTop keywords system indepently from the GEOTop simulation structure.

## Conclusions and Way Forward

- ▶ Open Source (and not only) Hydrological Models needs powerful and FAIR interfaces to process I/O data;
- ▶ An R package working directly with GEOtop keywords facilitate the development of customized tools for specific GEOtop applications;
- ▶ Collaborations between hydrologists / modellers and R users are encouraged.

F<sub>indable</sub>



A<sub>ccessible</sub>



I<sub>nteroperable</sub>



R<sub>eusable</sub>



# Finally

If intertested? See and follow us on ([www.geotop.org](http://www.geotop.org)) or (<https://cran.r-project.org/package=geotopbricks>)

Thank you for your attention! / Merci pour votre attention!  
Find us as @ecor (speaker) or @EURAC-Ecohydro (co-authors) on GitHub.