

geotopbricks

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Who are we?

- ▶ Environmental engineers with hydraulic and hydrological background (more deterministic and physically-based than statics!)
- ▶ Find us as @ecor (speaker) or @EURAC-Ecohydro (co-authors) on GitHub.
- ▶ Some of us are researcher, other are self-employed and freelancers as 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 sciences but also in C/C++, parallel programming, HPC, etc

Hydrology

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

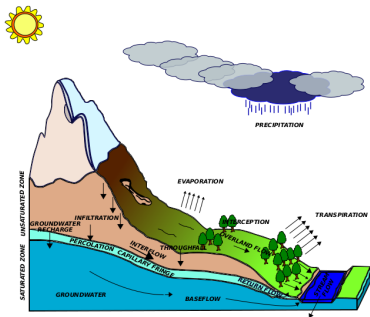
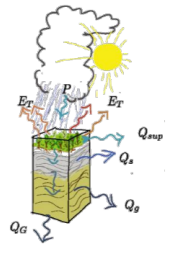


Figure 1:

Hydrological models



GEOtop Hydrological Model

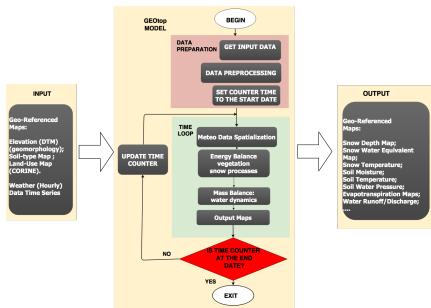
GEOtop is an open-source integrated hydrological model, available through Github, see <http://geotopmodel.github.io/geotop/> or www.geotop.org, and it simulates:



- ▶ soil water flow in the soil (*Richards' equation, De Saint-Venant Equation*) : *unknowns: soil liquid water content, soil water pressure head*;
- ▶ heat flow in the soil → (*heat equation and frozen soil thermodynamics*) : *unknowns: soil temperature, soil ice (soil water) content (in case of frozen soil)*;
- ▶ energy exchange with the atmosphere → boundary conditions of the equations above :
 _*unknowns : evapotranspiration, latent heat fluxes, radiation, snow depth and density



GEOtop Hydrological Model Structure

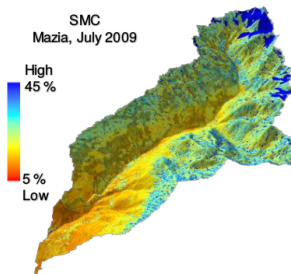
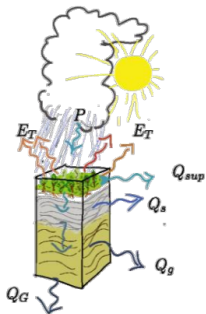


- **Input:** meteo data, elevations, soil parameters, . . .
- **Output:** snow cover, soil temperature, soil moisture, . . .

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;
- ▶ documented on GitHub repository:

<http://geotopmodel.github.io/geotop/>



Water Resources Research

RESEARCH ARTICLE

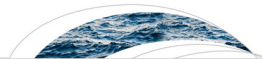
10.1002/2016WR019191

Key Points:

- Seven hydrologic models were intercompared using three benchmarks of increasing complexity
- Models showed good agreement with respect to various hydrologic responses (storage, discharge, and

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

Stefan Kollet ^{1,2}, Mauro Sulis ³, Reed M. Maxwell⁴, Claudio Paniconi ⁵, Mario Putti⁶, Giacomo Bertoldi ⁷, Ethan T. Coon ⁸, Emanuele Cordano^{7,9}, Stefano Endrizzi¹⁰, Evgeny Kikinzon⁸, Emmanuel Mouche¹¹, Claude Muegler ¹¹, Young-Jin Park¹², Jens C. Refsgaard¹³, Simon Stisen¹³, and Edward Sudicky^{14,15}



Toulouse, France



geotopbrick R package: Why?

- complexity in input/output/configuration files (“frontend”) and data difficult to handle

The image shows a side-by-side comparison of two text files. The left file, 'geotop.inp.txt', contains a configuration file with parameters for a hydrological model, including land cover types, soil roughness, vegetation height, and various flow coefficients. The right file, 'point001.txt', contains a data file with columns for time, point ID, and various flow rates (Pavow, Frain, Pcanow, etc.).

- need of user friendly environment for to GEOTop data tidying and data analytics (e.g. R) - potential interactions between hydrology (GEOTop) and other knowledge domains (*disciplines*).

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. meteorological 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

Here is an example on how to extract soil water content (SWC) at a 18cm depth in two sites P2 and B2, located in Val Mazia/Match, Malles Venosta/Mals Vinschgau, in South Tyrol, Italy (LONG Term Research Ecological Area, [<http://lter.eurac.edu/en>]). The goal of the code lines below is to represent the distribution of soil water content in August per different years (e.g. from 2010 to 2014)



Alpine scale

Mazia valley



eurac
research

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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

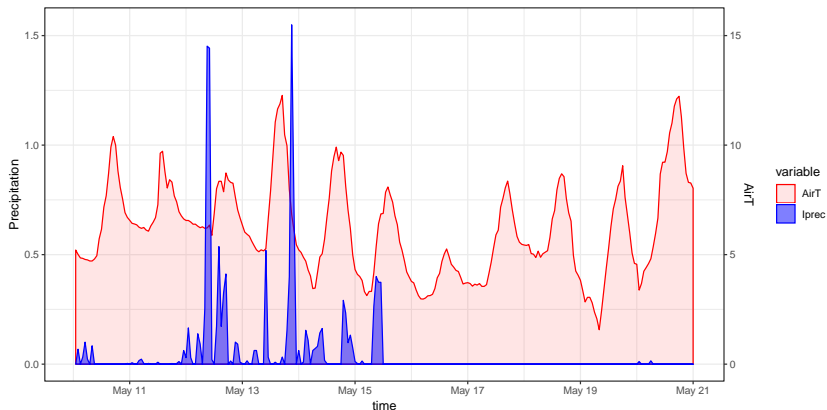


Figure 2: FALSE

Getting output simulation data at B2

Soil Water Content Profile:

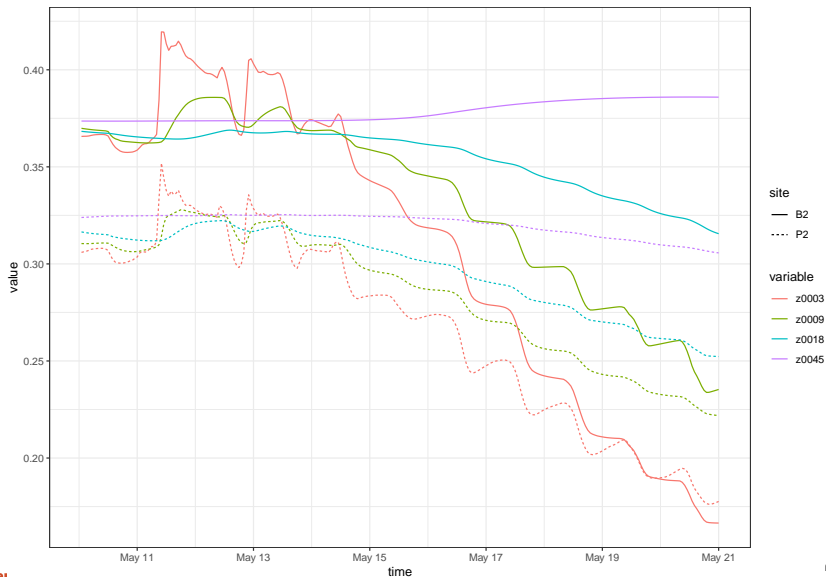
```
tz <- "Etc/GMT-1"
SWC_B2 <- get.geotop.inpts.keyword.value(
  "SoilLiqContentProfileFile",
  wpath = wpath_B2,
  data.frame = TRUE,
  date_field = "Date12.DDMMYYYYhhmm.",
  tz = tz,
  zlayer.formatter = "z%04d"
)
help(get.geotop.inpts.keyword.value) ## for more details!
```

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")
```

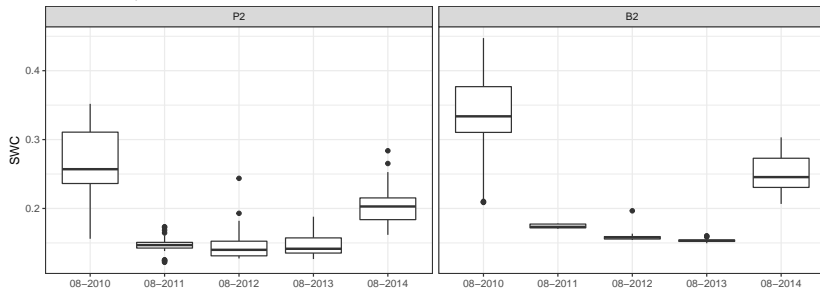
Soil Water Content at P2 and B2



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)

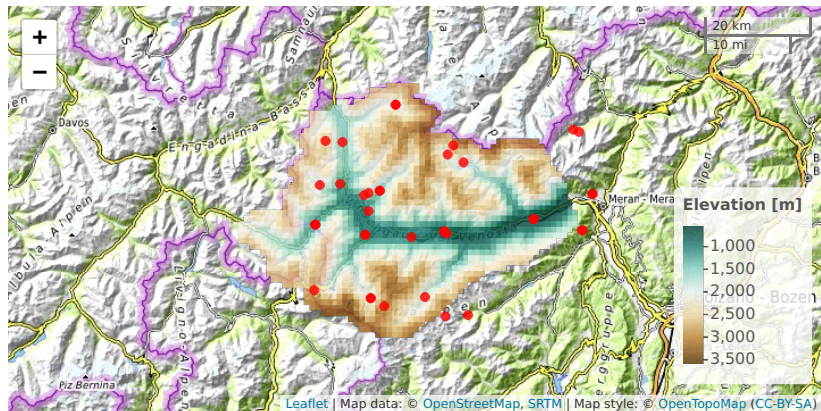


Figure 4: FALSE

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

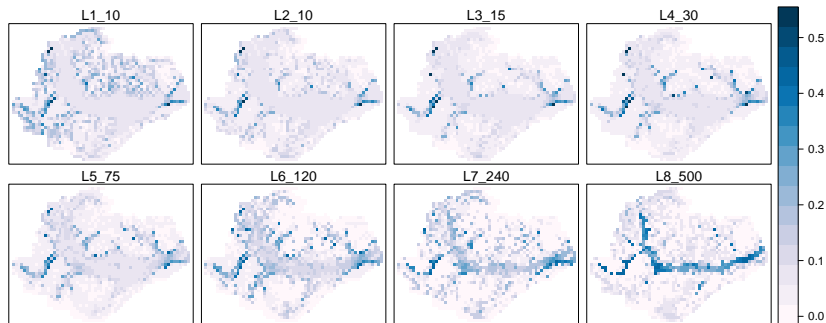
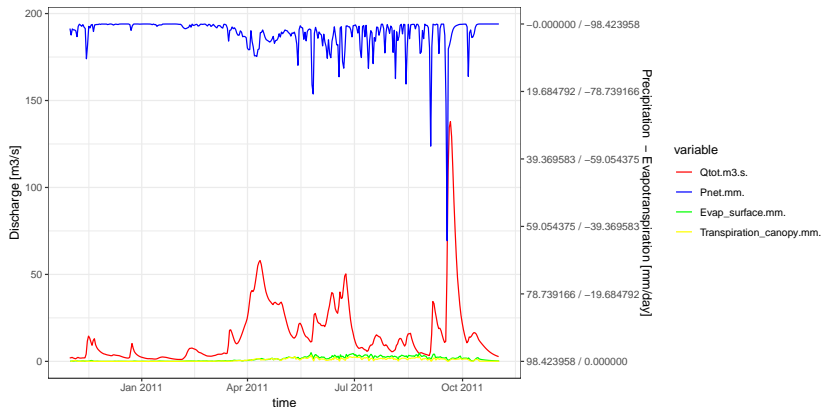


Figure 5: FALSE

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

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



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Figure 6: FALSE

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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_{indable}



A_{ccessible}



I_{nteroperable}



R_{eusable}



Finally

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

Thank you for your attention! / Merci pour votre attention!