

geotopbricks

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Who are we?

- ▶ Environmental engineer with hydraulic and hydrological background (more deterministic and physically-based than statics!)
- ▶ Some skills in programming and a R enthusiast which I use to work with hydro-climatic data.
- ▶ Find me as @ecor on GitHub
- ▶ I'm self-employed and freelancer as www.rendena100.eu .
- ▶ Author of several R-packages and p
- ▶ the other authors?
- ▶ Hydrologist ,, , BLA elisa, Giacomo
- ▶ Author of several packages, including geotop, . . .
- ▶ inserire immagini degli autori

Hydrology

Scientific study of the movement, distribution, and quality of water on Earth water cycle, water resources and environmental watershed sustainability (REF)

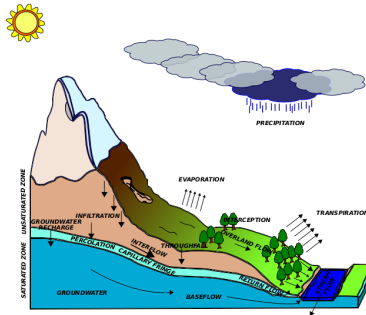
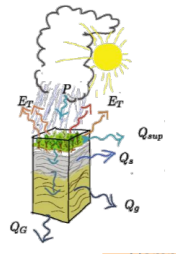


Figure 1:

Hydrological models



GEOtop Hydrological Model

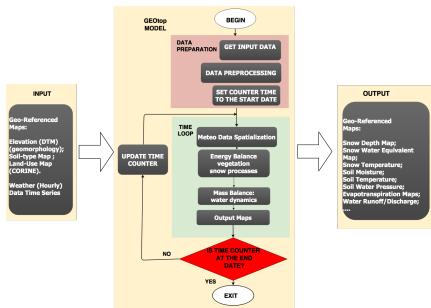
GEOtop is an open-source integrated hydrological model, available through Github, see <http://geotopmodel.github.io/geotop/> or www.geotop.org, and it simulates:



- ▶ 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

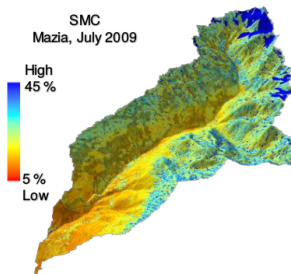
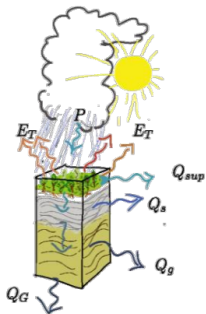


- **Input:** meteo data, elevations, soil parameters, . . .
- **Output:** snow cover, soil temperature, soil moisture, . . .

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

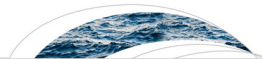
10.1002/2016WR019191

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}

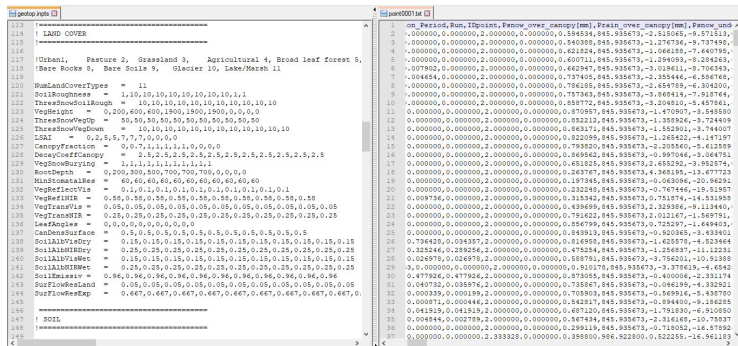


Toulouse, France



geotopbrick R package: Why?

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



1	on	Period	Run	IDpoint	Panow_over_canopy[mm]	Frainn_over_canopy[mm]	Panow und
2	0.000000	0.000000	2.000000	0.000000	0.594534	845.935673	-2.515055
3	0.000000	0.000000	2.000000	0.000000	0.540388	845.935673	-1.276736
4	0.000000	0.000000	2.000000	0.000000	0.621824	845.935673	-1.066185
5	0.000000	0.000000	2.000000	0.000000	0.600711	845.935673	-1.294093
6	0.079502	0.000000	2.000000	0.000000	0.462947	845.935673	-3.019411
7	0.004654	0.000000	2.000000	0.000000	0.737405	845.935673	-2.355446
8	0.000000	0.000000	2.000000	0.000000	0.786185	845.935673	-2.654789
9	0.000000	0.000000	2.000000	0.000000	0.787363	845.935673	-3.868414
10	0.000000	0.000000	2.000000	0.000000	0.588787	845.935673	-3.204810
11	0.000000	0.000000	2.000000	0.000000	0.870587	845.935673	-1.470907
12	0.000000	0.000000	2.000000	0.000000	0.852122	845.935673	-1.358926
13	0.000000	0.000000	2.000000	0.000000	0.863171	845.935673	-1.552901
14	0.000000	0.000000	2.000000	0.000000	0.822055	845.935673	-1.265422
15	0.000000	0.000000	2.000000	0.000000	0.793820	845.935673	-2.328460
16	0.000000	0.000000	2.000000	0.000000	0.869562	845.935673	-0.997046
17	0.000000	0.000000	2.000000	0.000000	0.818255	845.935673	-3.952574
18	0.000000	0.000000	2.000000	0.000000	0.263767	845.935673	-13.677723
19	0.000000	0.000000	2.000000	0.000000	0.157345	845.935673	-0.063096
20	0.000000	0.000000	2.000000	0.000000	0.232248	845.935673	-0.767446
21	0.009736	0.000000	2.000000	0.000000	0.315342	845.935673	-0.751874
22	0.000000	0.000000	2.000000	0.000000	0.836959	845.935673	-2.329386
23	0.000000	0.000000	2.000000	0.000000	0.751622	845.935673	-2.012167
24	0.000000	0.000000	2.000000	0.000000	0.856799	845.935673	-0.725297
25	0.000000	0.000000	2.000000	0.000000	0.849313	845.935673	-0.920365
26	0.736428	0.034387	2.000000	0.000000	0.618585	845.935673	-1.628578
27	0.000000	0.000000	2.000000	0.000000	0.475546	845.935673	-1.256377
28	0.026978	0.026978	2.000000	0.000000	0.588751	845.935673	-3.756201
29	3.0.000000	0.000000	2.000000	0.000000	0.910178	845.935673	-3.378619
30	0.477926	0.477926	2.000000	0.000000	0.873055	845.935673	-0.400006
31	0.040732	0.035976	2.000000	0.000000	0.735567	845.935673	-4.332321
32	0.000335	0.000189	2.000000	0.000000	0.705903	845.935673	-0.565916
33	0.000871	0.000446	2.000000	0.000000	0.528217	845.935673	-0.894400
34	0.041519	0.041519	2.000000	0.000000	0.687120	845.935673	-1.791830
35	0.004844	0.002789	2.000000	0.000000	0.567434	845.935673	-2.316169
36	0.000000	0.000000	2.000000	0.000000	0.299119	845.935673	-0.718052
37	0.000000	0.000000	2.333332	0.000000	0.398800	986.522800	0.522255

- 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 simlaton 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



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

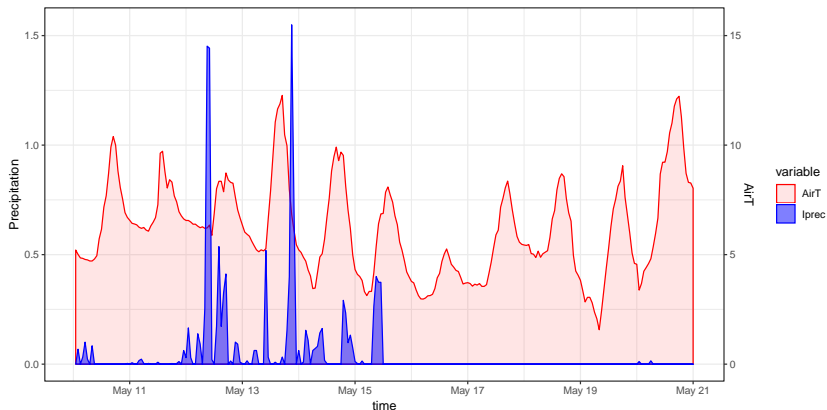


Figure 2: FALSE

Getting output simulation data at B2

Soil Water Content Profile:

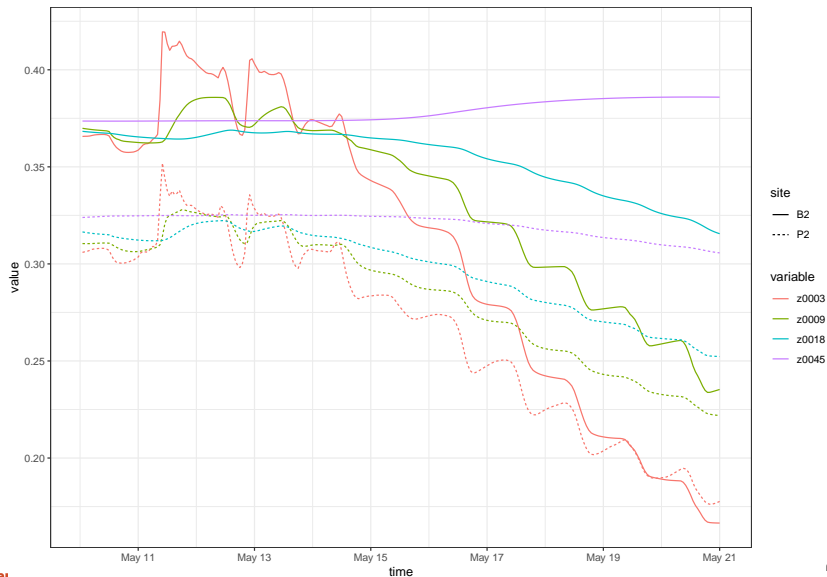
```
tz <- "Etc/GMT-1"
SWC_B2 <- get.geotop.inpts.keyword.value(
  "SoilLiqContentProfileFile",
  wpath = wpath_B2,
  data.frame = TRUE,
  date_field = "Date12.DDMMYYYYhhmm.",
  tz = tz,
  zlayer.formatter = "z%04d"
)
help(get.geotop.inpts.keyword.value) ## for more details!
```

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")
```

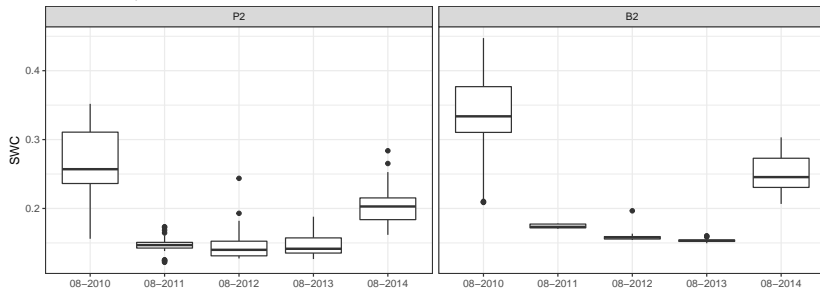
Soil Water Content at P2 and B2



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 deetails 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)
```

Topographic map of the Engadina region in the Alps. The map shows elevation contours and a color-coded area. The legend indicates elevation in meters (m) from 1,000 to 3,500. The map includes labels for 'Engadina', 'Samedan', 'Meran', and 'Bozen'. A scale bar shows 20 km and 10 mi. The map is overlaid with a grid of red dots.

Rendena100.eu

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

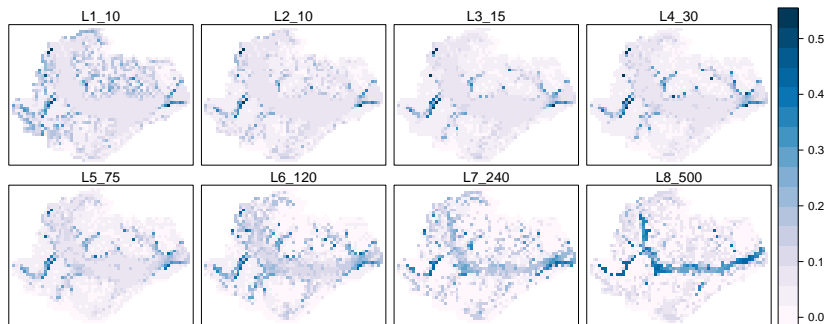
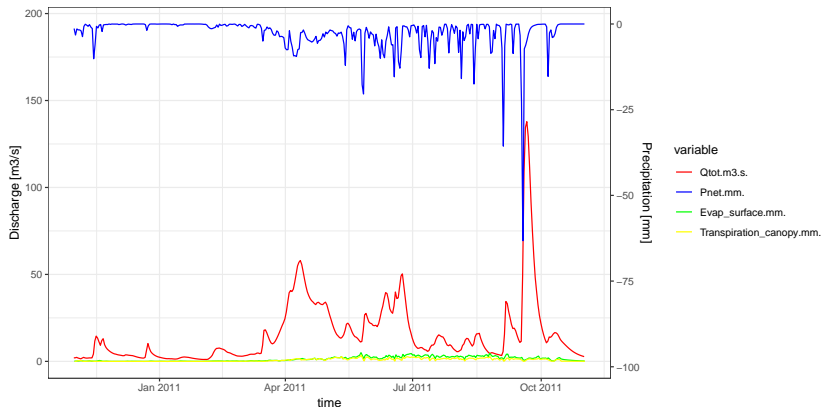


Figure 5: FALSE

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

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



Rendena100.eu

Figure 6: 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!
- ▶ reproducibuly of modelling simulations
- ▶ fair priciple

Conclusion and forward

- ▶ open source hydrological models need powerful processing interface
- ▶ tool for processing GTOPO
- ▶ getting your data in the right shape (e.g. tidyverse, recipes)
- ▶ potential for extension for other models
- ▶ for operational applications / engineering productivity
- ▶ enlarge community

vedi abstract

Interested?

www.geotop.org

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