geotopbricks

An R Package for the Distributed Hydrological Model GEOtop

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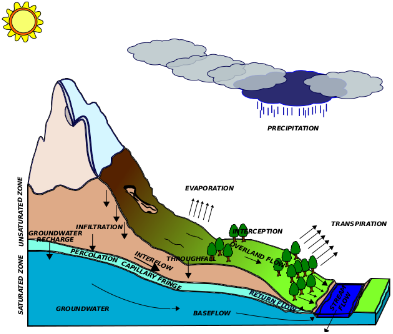
Who are we?

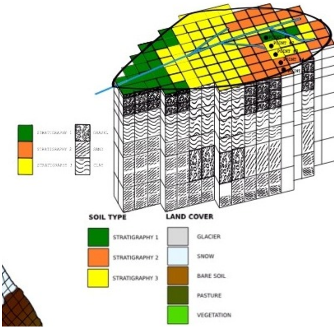
- Environmental engineers with hydrological background (more deterministic and physically-based than statics!)
- Some of us are researchers, other are self-employed and freelancers - www.rendena100.eu . - Some of us are authors of several R-packages and R enthusiast.
- Some of us are developers of GEOtop hydrologic models with skills in hydrology, environmental science and also in C/C++, parallell programming, High Perfomance Computing, etc.

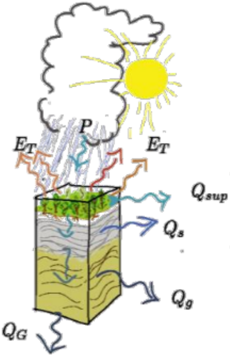
Hydrology

Scientific study of the movement, distribution, and quality of water, including the water cycle, water resources and environmental watershed sustainability.[*Wikipedia*]



Hydrological Models





Models that estimate water river discharge, soil water content,evapo-transpiration, etc. (*output*) in function of weather forcings and soil/land/geomorphological characterization (*input*).

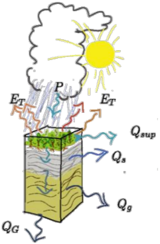
Soil water mass balance equation: $\frac{\partial \theta}{\partial t} = \nabla \cdot [K\left(\nabla(\psi + z_f)\right)] + S$

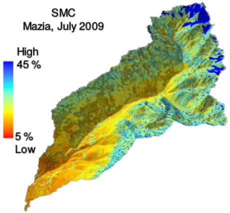
Soil Heat (energy) balance equation: $C_s \frac{\partial T_s}{\partial t} = \nabla \cdot [K_t(\nabla T_s)] + \lambda S$

GEOtop Hydrological Model

GEOtop hydrological model solves water mass balance and energy balance equations coupled with the exchanges between terrain and lower atmoshere in the following two setup configurations:

- **1D**: only vertical fluxes $\rightarrow$ balances at local scale (only in one soil column)
- **3D**: vertical and lateral fluxes $\rightarrow$ balances at basin scale





GEOtop Hydrological Model Software Package / Source Code

GEOtop Hydrological Model is an open source software package (GPL3 licence):

- 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/.

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2016WR019191

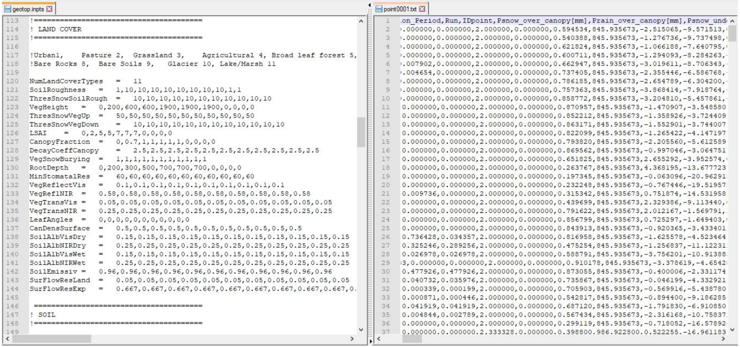
The integrated hydrologic model intercomparison project, IH-MIP2: A second set of benchmark results to diagnose integrated hydrology and feedbacks

Stefan Kollet[1,2], Mauro Sulis[3], Reed M. Maxwell[4], Claudio Paniconi[5], Mario Putti[6], Giacomo Bertoldi[7], Ethan T. Coon[8], Emanuele Cordano[7,9], Stefano Endrizzi[10], Evgeny Kikinzon[8]

Key Points:
- Seven hydrologic models were intercompared using three benchmarks of increasing complexity

geotopbricks 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*)



GEOtop Simulation Configuration File (geotop.inpts)

GEOtop simulation is a directory containing a configuration file, called **geotop.inpts** filled with a keywords system addressing to simulation options (e.g. simulation period); **input files** (e.g. meteorological forcings, soil and geomorphology of the basin); **output files** (spatio-temporal maps - raster and time series - of the results).

```
InitDateDDMMYYYYhhmm=09/04/2014 18:00
EndDateDDMMYYYYhhmm =01/01/2016 00:00
[...]
MeteoFile           ="meteoB2_irr"
PointOutputFile     ="tabs/point"
```

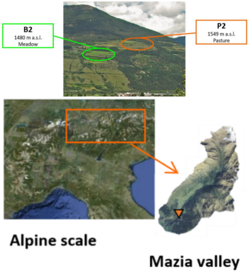
geotopbricks R Package: What it Does

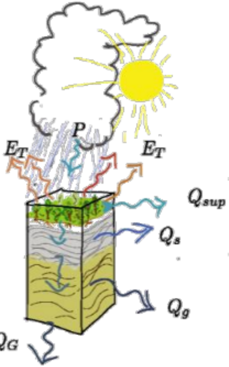
The aim of **geotopbricks** , starting in 2013, is to import all GEOtop simulaton data into the **R** environment by using the *keyword-value* syntax of *geotop.inpts*. **geotopbricks** does the following actions:

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

1D GEOtop Simulation in an Alpine Site: 2 Points

Estimation of soil water content (SWC) in two points **P2** and **B2** located in Val Mazia/Matsch, South Tyrol, Italy http://lter.eurac.edu/en.



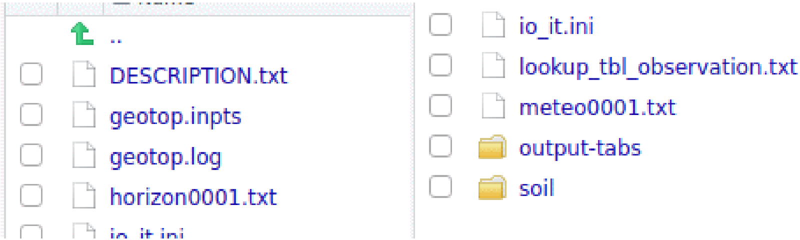


1D GEOtop Simulation in an Alpine Site: B2

Here is the directory containing files of B2 point simulation:

```r
library(geotopbricks)

## SET GEOTOP SIMULATION DIRECTORY
wpath_B2 <- "resources/simulation/Matsch_B2_Ref_007"
```



Getting Simulation Input Data

Meteorological forcings 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)

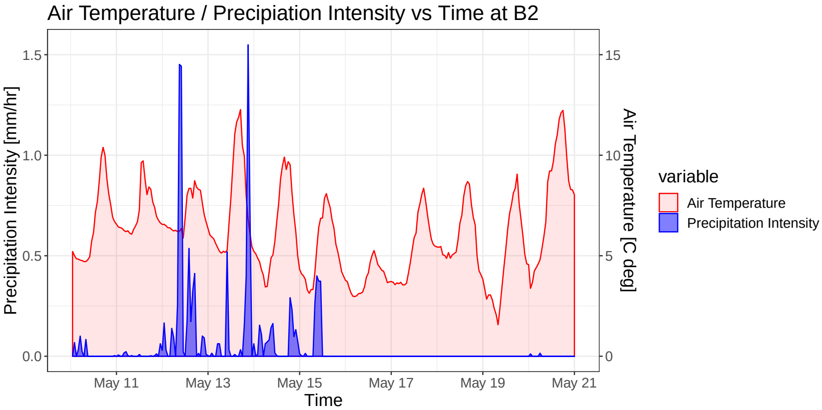
Meteorological time series once imported can be printed:

```
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")])
```

Precipitation and Air Temperature at B2



Getting Simulation Output Data

Soil Water Content Profile:

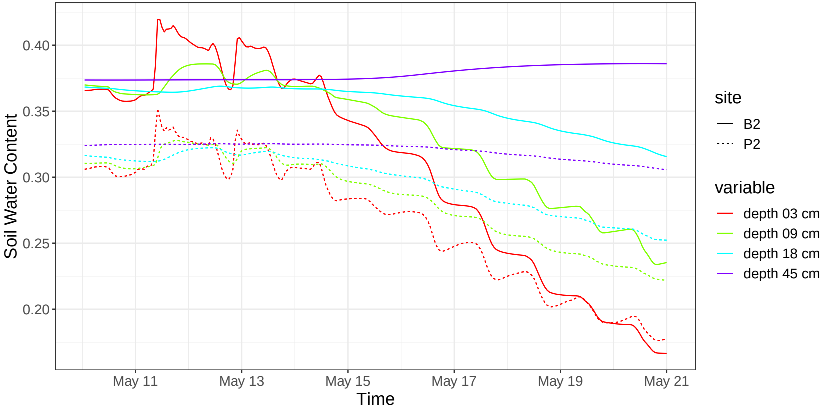
```
tz <- "Etc/GMT-1"
SWC_B2  <- get.geotop.inpts.keyword.value(
  "SoilLiqContentProfileFile",
  wpath = wpath_B2,
  data.frame = TRUE,
  date_field = "Date12.DDMMYYYYhhmm.",
  tz = tz,
  zlayer.formatter = "z%04d"
)
help(get.geotop.inpts.keyword.value) ## for more details!
```

Getting Simulation Output Data (at P2)

Analogously 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

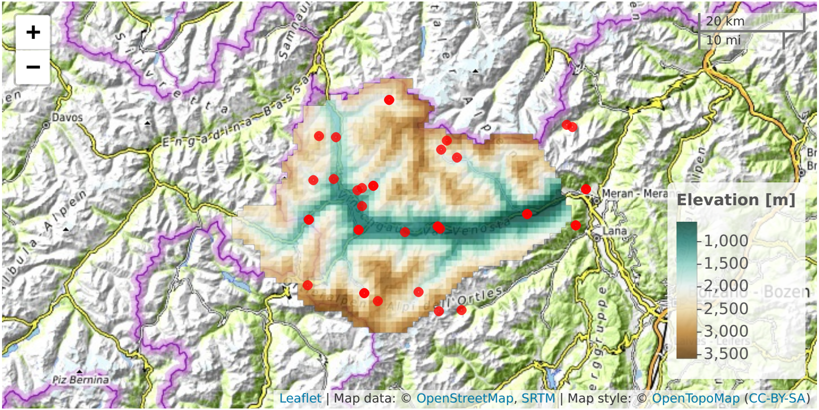


3D Spatially Distributed Simulation: Val Venosta/Vinschgau - Upper Adige River Basin - Alps - I/CH/A

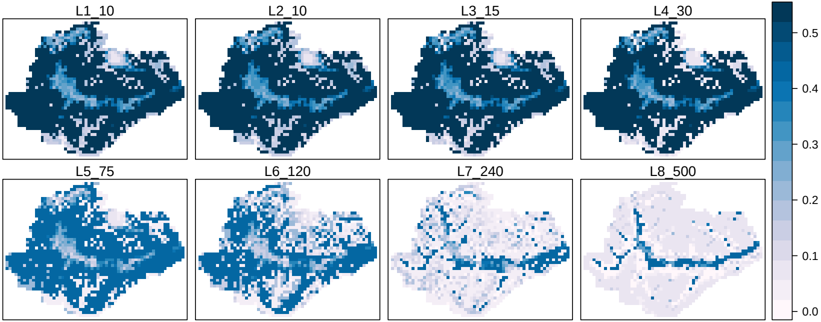
```r
wpath_3D <- 'resources/simulation/Vinschgau'
basin <- get.geotop.inpts.keyword.value("LandCoverMapFile",
                wpath=wpath_3D,raster=TRUE)
basin
```

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

Input GeoSpatial Map: Elevation and Weather Station

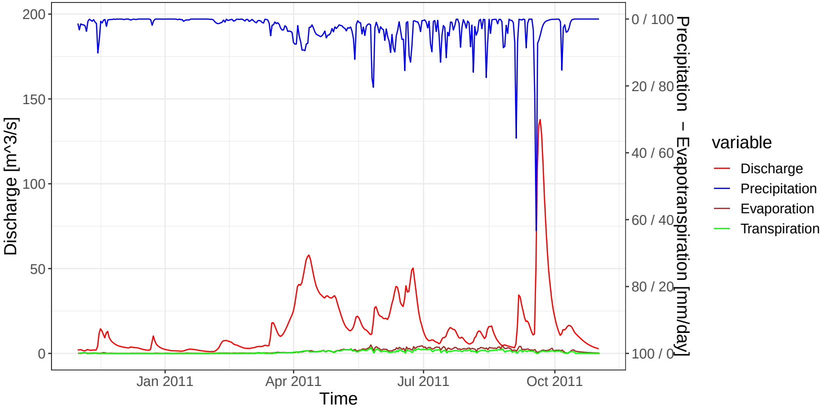


3D Spatially Distributed Simulation (Output Geospatial Map): Soil Water Content




```
brickFromOutputSoil3DTensor("SoilLiqContentTensorFile",
wpath=wpath_3D,when="2011-08-16 12:00:00 +01")
```

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

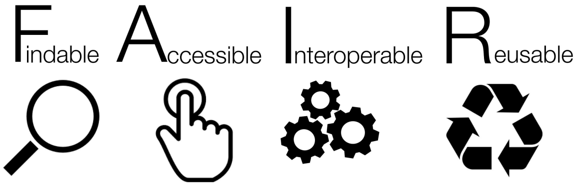


Discussion

- **geotopbricks** allows graphical representation using R of GEOtop results , useful for hydrologigists and reaserchers;
- Through **geotopbricks** user can interact between R and GEOtop using R enviroment and GEOtop keywords system, without using the GEOtop simulation structure.
- Processing of a GEOtop simulation is always reproducible for any other simulation; results can be automatically documented in reports or presentations.

Conclusions and Way Forward

- **geotopbricks** is an interface of GEOtop in R speaking the language of GEOtop;
- R code based on **geotopbricks** can help the implementation of further package or apps: analityics, model calibration, visualization.
- Open Source (and not only) Hydrological Model needs powerful interfaces to process I/O in a FAIR way;



Finally

Aknowledgements to

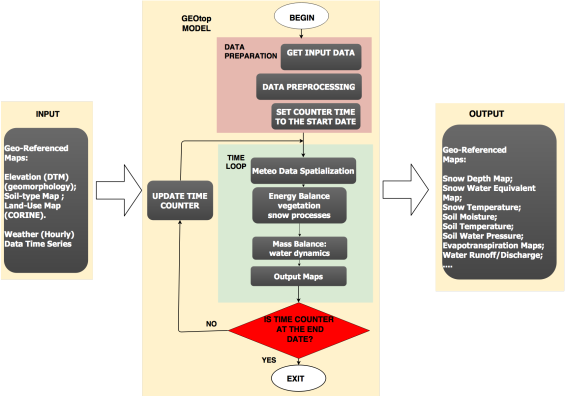
- all **GEOtop** developers and users' group, in particular **Matteo Dall'Amico, Stefano Cozzini, Alberto Sartori, Stefano Endrizzi, Samuel Senoner, Riccardo Rigon**, who provided images about GEOtop for this presentation
- the community of **R** whose packages allow to analize and visualise GEOtop data.

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!
Find us as **@ecor** (presenter) or **@EURAC-Ecohydro** (co-authors) on *GitHub*.

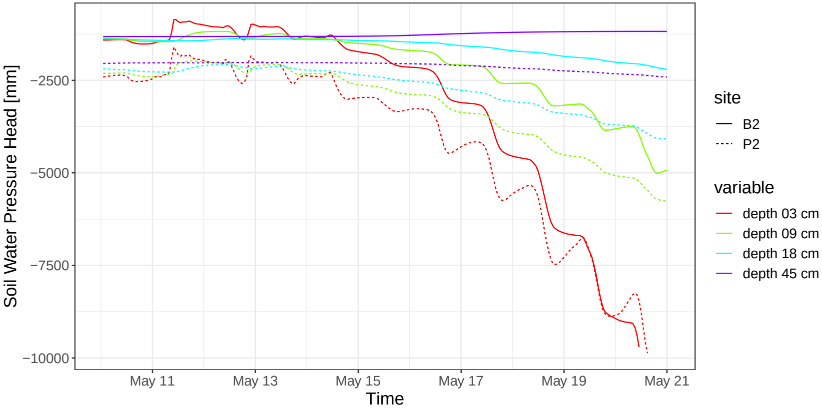
Addendum

GEOtop Hydrological Model Flowchart



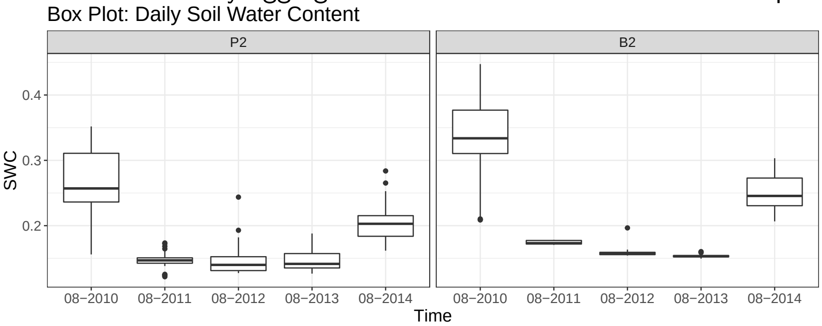
- **Input**: meteo data, elevations, soil parameters,. . .
- **Output**: snow cover, soil temperature, soil moisture,. . .

Soil Water Pressure Head at P2 and B2



Example of an Output Data Analytics (Soil Moisture Distribution)

Distribution of daily aggregated soil water contant at a 18 cm depth:



More details on the **eRum2018** poster.