# geotopbricks

Emanuele Cordano, Rendena100

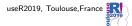
@ecor | github.com/ecor



#### Who are we?

- Environmental engineer with hydraulic and hydrological background (more deterministic and physicall-based than statics!)
- ➤ Some skills in programming and a R entusiast 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, Giaomo
- 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)

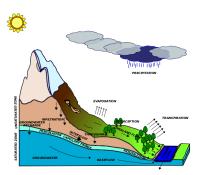


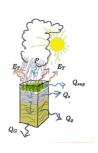
Figure 1:



# **Hydrolgical models**





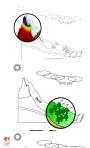


# **GEOtop Hydrological Model**

GEOtop is an open-source integrated hydrological model that simulates:

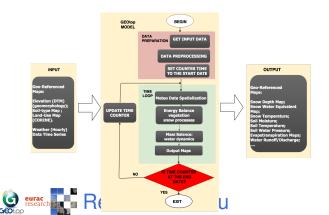
- ightharpoonup water flow in the soil ightharpoonup Richards' eq (sub) + Kinematic eq (sur)
- lackbox energy exchange with the atmosphere ightarrow full integration of equation

Metti alcune referenze + link github



# **Hydrological Model Structure**

- ▶ Input: meteo data, elevations, soil parameters
- ▶ Output: snow cover, soil temperature, soil moisture
- ► Semplifica il grafico con solo input e output e processi principali

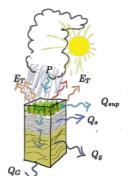


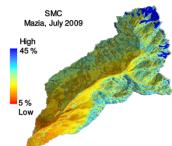
# **GEOtop model Optional Subtitle**

Water and energy budgets can be activated :

- ightharpoonup one or the other ightharpoonup simplification
- ightharpoonup both them together ightarrow realistic

Two setup configurations : - 1D: only vertical fluxes  $\rightarrow$  mass and energy balance at local scale (only in one soil column) - 3D: vertical and lateral fluxes  $\rightarrow$  balances at basin scale







oulouse,France

#### **Motivations**

 complexity in input/output/configuration files and data difficult to manage

```
geotop inpts 🖸
                                                                                    on Period. Run. IDpoint. Panow over canopy(mml. Prain over canopy(mml. Panow und
     ! LAND COVER
                                                                                     .000000,0.000000,2.000000,0.000000,0.594534,845.935673,-2.515065,-9.571513,
                                                                                     .000000,0.000000,2.000000,0.000000,0.540388,845.935673,-1.276736,-9.737498,
                                                                                     .000000.0.000000.2.000000.0.000000.0.621824.845.935673.-1.066188.-7.640795.
                                                                                     .000000,0.000000,2.000000,0.000000,0.600711,845.935673,-1.294093,-8.284263,
              Pasture 2, Grassland 3,
                                          Agricultural 4, Broad leaf forest 5,
     'Bare Rocks 8, Bare Soils 9, Glacier 10, Lake/Marsh 11
                                                                                     .007902.0.000000,2.000000,0.000000,0.662947,845.935673,-3.019611,-8.706343,
                                                                                     .004654,0.000000,2.000000,0.000000,0.737405,845.935673,-2.355446,-6.586768
    SoilRoughness = 1,10,10,10,10,10,10,10,10,1,1
                                                                                     .000000,0.000000,2.000000,0.000000,0.757363,845.935673,-3.868414,-7.918764,
    ThresSnowSoilRough = 10,10,10,10,10,10,10,10,10,10,10
                  0,200,600,600,1900,1900,1900,0,0,0,0
                                                                                     0.000000, 0.000000, 2.000000, 0.000000, 0.870957, 845.935673, -1.470907, -3.548580
                                                                                     0.000000,0.000000,2.000000,0.000000,0.852212,845.935673,-1.358926,-3.724409
     ThresSnowVegUp =
                       50,50,50,50,50,50,50,50,50,50,50
     ThresSnowVegDown
                                                                                     0.000000.0.000000.2.000000.0.000000.0.863171.845.935673.-1.552901.-3.744007
                                                                                     0.000000, 0.000000, 2.000000, 0.000000, 0.822099, 845.935673, -1.265422, -4.147197
                                                                                     0.000000,0.000000,2.000000,0.000000,0.793820,845.935673,-2.205560,-5.612589
                                                                                     0.000000.0.000000.2.000000.0.000000.0.869562.845.935673.-0.997046.-3.064751
     VegSnowBurying =
                                                                                     0.000000, 0.000000, 2.000000, 0.000000, 0.651825, 845.935673, 2.655292, -3.952574,
                   0,200,300,500,700,700,700,0,0,0,0
                                                                                     0.000000,0.000000,2.000000,0.000000,0.263767,845.935673,4.368195,-13.677723
    MinStonatalRes =
                       60,60,60,60,60,60,60,60,60,60,60
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     VegReflectVia
                                                                                     0.000000, 0.000000, 2.000000, 0.000000, 0.232248, 845.935673, -0.767446, -19.51957
                    0.009736,0.000000,2.000000,0.000000,0.315342,845.935673,0.751874,-14.531958
                   0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05
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                    0.000000, 0.000000, 2.000000, 0.000000, 0.791622, 845.935673, 2.012167, -1.569791,
     LeafAngles =
                                                                                     0.000000,0.000000,2.000000,0.000000,0.856799,845.935673,0.725297,-1.649403,
     CanDensSurface
                                                                                     0.000000,0.000000,2.000000,0.000000,0.843913,845,935673,-0.920365,-3.433401
                       0.736428,0.034357,2.000000,0.000000,0.816958,845.935673,-1.625578,-4.523464
                                                                                     0.325246,0.289256,2.000000,0.000000,0.475254,845.935673,-1.256837,-11.12231
                       0.026978.0.026978.2.000000.0.000000.0.588791.845.935673.-3.756201.-10.91388
                       3,0.000000,0.000000,2.000000,0.000000,0.910178,845.935673,-3.378619,-4.6542
                                                                                     0.477926, 0.477926, 2.000000, 0.000000, 0.873055, 845.935673, -0.400006, -2.331174
                   0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05.0.05
                                                                                     0.040732.0.035976.2.000000.0.000000.0.735867.845.935673.-0.046199.-4.332921
                       0.667,0.667,0.667,0.667,0.667,0.667,0.667,0.667,0.667,0
                                                                                    0.000339,0.000199,2.000000,0.000000,0.705903,845.935673,-0.569916,-5.438780
                                                                                     0.000871,0.000446,2.000000,0.000000,0.542817,845.935673,-0.894400,-9.186285
                                                                                     0,041919,0,041919,2,000000,0,000000,0,687120,845,935673,-1,791830,-6,910850
                                                                                    0.004844,0.002789,2.000000,0.000000,0.567434,845.935673,-2.316168,-10.75837
                                                                                    0.000000,0.000000,2.000000,0.000000,0.299119,845.935673,-0.718052,-16.57892
                                                                                     0,00000,0,000000,2,333328,0,00000,0,398800,986,922800,0,522255,-16,961183
```

- 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 (discipines). useR2019, Toulouse,France





# **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)

input files (e.g. meterological time series)

output files

InitDateDDMMYYYYhhmm=09/04/2014 18:00 EndDateDDMMYYYYhhmm =01/01/2016 00:00

 $[\ldots]$ 

MeteoFile ="meteoB2 irr"

PointOutputFile ="tabs/point"

## geotopbricks

The aim of **geotopbricks**, starting in 2013, is to bring all the data of a GEOtop simulaton 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)



# geotopcks 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 Reasearch 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))</pre>
```

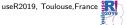
## **Getting simulation input data**

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)</pre>
```

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





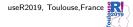
# **Getting simulation input data (verify)**

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

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

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





#### Plots of weather variables in B2

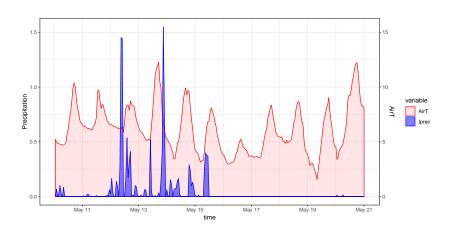


Figure 2: FALSE



#### Getting output simulation data at B2

Soil Water Content Profile:

```
tz <- "Etc/GMT-1"
SWC_B2 <- get.geotop.inpts.keyword.value(
  "SoilLigContentProfileFile",
  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")</pre>
```

#### Soil Water Content at P2 and B2

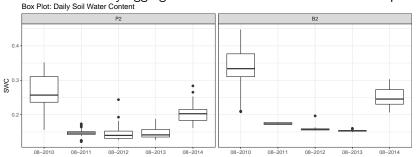






# Output data Analytics (soil Mooisture Distribution)

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



More deetails on the eRum2018 poster.

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

```
## dimensions : 48, 63, 3024 (nrow, ncol, ncell)
```

## resolution : 1000, 1000 (x, y)

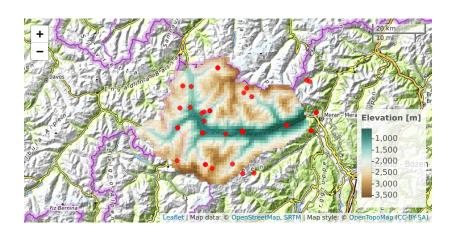
## extent : 598000, 661000, 5145000, 5193000 (xmin, : ## coord. ref. : +proj=utm +zone=32 +ellps=WGS84 +datum=WGS

## data source : in memory

## class : RasterLayer



# 3D Spatially Distributed Distribution (Input Geospatial Map)





#### LOREM IPSUM

```
## Warning (get.geotop.inpts.keyword.value): keyword SoilLa
## [1] "Maps to import: 1 from 2010-10-16 16:00:00 to 2010-
## Important bug solved from 1.3.7.3, previous versions (<=
## Importing 2010-10-16 16:00:00</pre>
```



## As 2010-10-16 16:00:00

# **3D Simulation Analytics**

The results show than B2 is able to hold more water than P2. This depends on soil and land properties. Compared with input precipiation results, soil water behaviour for the different months is related to precipitation amount (depth and number of rainy days). Interestingly, in August 2014 soil water content is higher than in August 2012, in which precipitaion is higher. However, in August 2014 the daily precipitation distribution is the least wide with the lowest variability (interquantile range) and two extreme events. (Precipiation time series in B2 and P2 are equal due to their short distance!)

Hydrological models are solvers of the differential equations of water flows and water thermodymanics in the Earth associated to heat transfers between Earth and the low atmosphere. They are a simplification of a real-world system useful to understand, predict,



#### **Dicussion**

- open science
- reproducibuly of modelling simulations
- ▶ fair priciple

#### Conclusion and forward

- open source hydrolgical models need powerful processing interface
- tool for popsptocesing GEOtop
- getting your data in the right shape (e.g. tidyverse, recipes)
- potential for extension for ohter models
- for oprational aplications / engineering productivity
- enlarge community

vedi abstract

#### Interested?

www.geotop.org

▶ link CRAN e github repository

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

#### **Addendum**

LOREM IPSUM

