geotopbricks

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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)

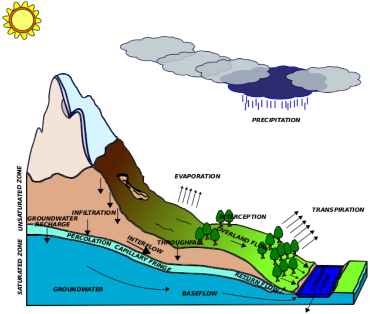
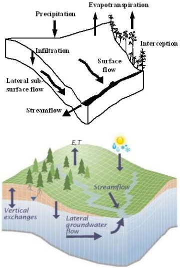
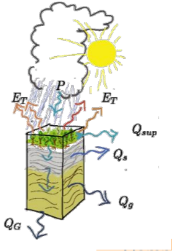


Figure 1:

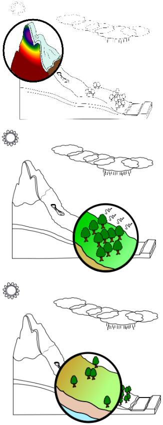
Hydrolgical models





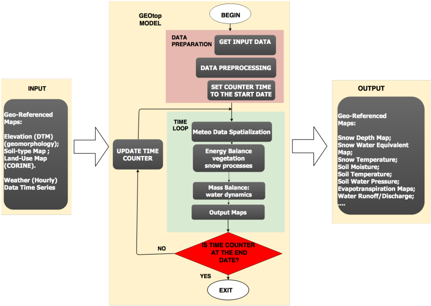
GEOtop Hydrological Model

GEOtop is an open-source integrated hydrological model, available though 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*) : *unkowns: soil liquid water content,soil water pressure head*;
- heat flow in the soil → *(heat equation and frozen soil thermodynamics)* : *unkowns: soil l temperature,soil ice (soild 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

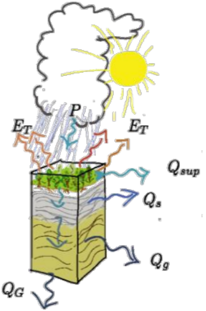


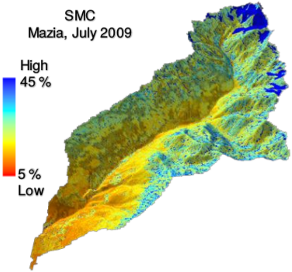
- **Input**: meteo data, elevations, soil parameters,. . .
- **Output**: snow cover, soil temperature, soil moisture,. . .

GEOtop Hydrological Model Options

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

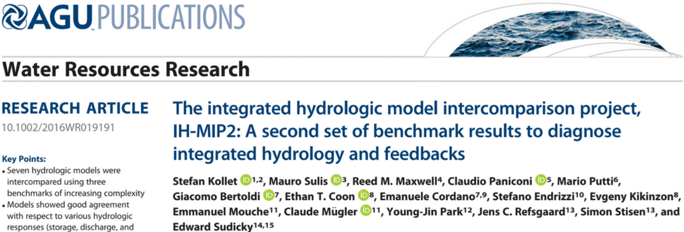




GEOtop Hydrological Model Software Package / Source Code

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/*



AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2016WR019191

Key Points:

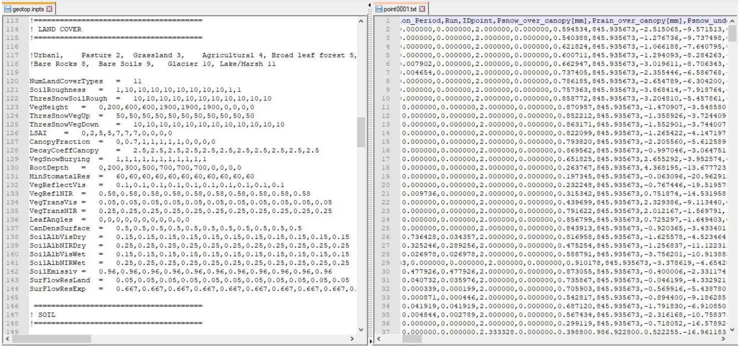
- Seven hydrologic models were intercompared using three benchmarks of increasing complexity
- Models showed good agreement with respect to various hydrologic responses (storage, discharge, and

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. 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], Emmanuel Mouche[11], Claude Mügler[11], Young-Jin Park[12], Jens C. Refsgaard[13], Simon Stisen[13], and Edward Sudicky[14,15]

geotopbrick R package: Why?

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



geotop.inpts

```
!========================================
! LAND COVER
!========================================

!Urban1,    Pasture 2,  Grassland 3,    Agricultural 4, Broad leaf forest 5,
!Bare Rocks 8,  Bare Soils 9,   Glacier 10, Lake/Marsh 11

NumLandCoverTypes   =   11
SoilRoughness   =   1,10,10,10,10,10,10,10,10,1,1
ThresSnowSoilRough  =   10,10,10,10,10,10,10,10,10,10,10
VegHeight   =   0,200,600,600,1900,1900,1900,0,0,0,0
ThresSnowVegUp  =   50,50,50,50,50,50,50,50,50,50,50
ThresSnowVegDown    =   10,10,10,10,10,10,10,10,10,10,10,10
LSAI    =   0,2,5,5,7,7,7,0,0,0,0
CanopyFraction  =   0,0.7,1,1,1,1,1,0,0,0,0
DecayCoeffCanopy    =   2.5,2.5,2.5,2.5,2.5,2.5,2.5,2.5,2.5,2.5,2.5
VegSnowBurying  =   1,1,1,1,1,1,1,1,1,1,1
RootDepth   =   0,200,300,500,700,700,700,0,0,0,0
MinStomatalRes  =   60,60,60,60,60,60,60,60,60,60,60
VegReflectVis   =   0.1,0.1,0.1,0.1,0.1,0.1,0.1,0.1,0.1,0.1
VegReflNIR  =   0.58,0.58,0.58,0.58,0.58,0.58,0.58,0.58,0.58,0.58
VegTransVis =   0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
VegTransNIR =   0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25
LeafAngles  =   0,0,0,0,0,0,0,0,0,0,0
CanDensSurface  =   0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5
SoilAlbVisDry   =   0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15
SoilAlbNIRDry   =   0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25
SoilAlbVisWet   =   0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15
SoilAlbNIRWet   =   0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25,0.25
SoilEmissiv =   0.96,0.96,0.96,0.96,0.96,0.96,0.96,0.96,0.96,0.96,0.96
SurFlowResLand  =   0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05,0.05
SurFlowResExp   =   0.667,0.667,0.667,0.667,0.667,0.667,0.667,0.667,0.667,0.

 ========================================
! SOIL
!========================================

```

point0001.txt

```
on_Period,Run,IDpoint,Psnow_over_canopy[mm],Prain_over_canopy[mm],Psnow_und
.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,
.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,
.000000,0.000000,2.000000,0.000000,0.786185,845.935673,-2.654789,-6.304200,
.000000,0.000000,2.000000,0.000000,0.757363,845.935673,-3.868414,-7.918764,
.000000,0.000000,2.000000,0.000000,0.858772,845.935673,-3.204810,-5.457861,
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
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
0.000000,0.000000,2.000000,0.000000,0.651825,845.935673,2.655292,-3.952574,
0.000000,0.000000,2.000000,0.000000,0.263767,845.935673,4.368195,-13.677723
0.000000,0.000000,2.000000,0.000000,0.197345,845.935673,-0.063096,-20.96291
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
0.000000,0.000000,2.000000,0.000000,0.439699,845.935673,2.329386,-9.113440,
0.000000,0.000000,2.000000,0.000000,0.791622,845.935673,2.012167,-1.569791,
0.000000,0.000000,2.000000,0.000000,0.856799,845.935673,0.725297,-1.649403,
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
0.040732,0.035976,2.000000,0.000000,0.735867,845.935673,-0.046199,-4.332921
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
0.000000,0.000000,2.333328,0.000000,0.398800,986.922800,0.522255,-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*).

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
[...]
MeteoFile           ="meteoB2_irr"
PointOutputFile     ="tabs/point"
```

geotopbricks Technical details

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)

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 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)

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

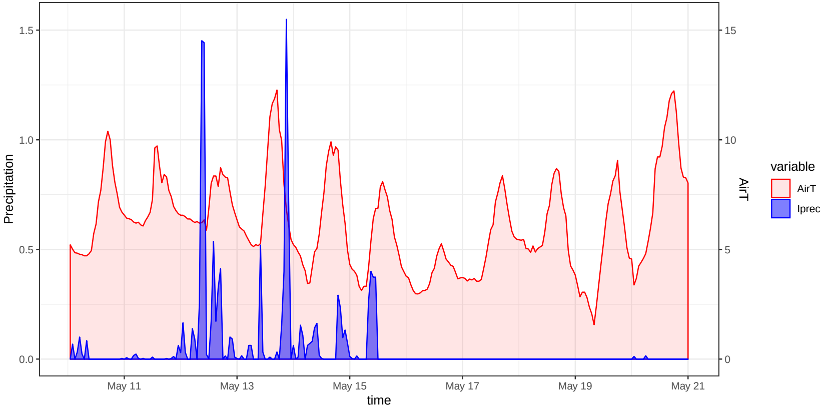


Figure 2: FALSE

Getting output simulation data at B2

Soil Water Content Profile:

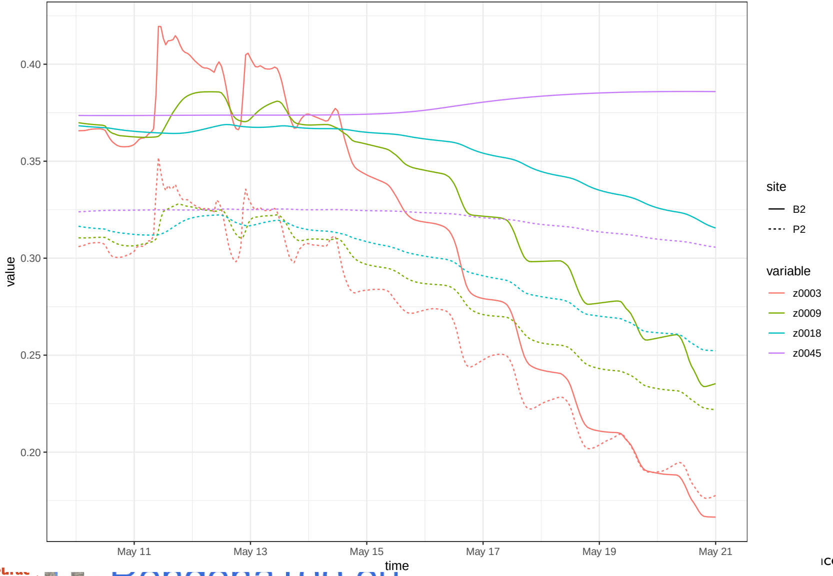
```
tz <- "Etc/GMT-1"
SWC_B2  <- get.geotop.inpts.keyword.value(
  "SoilLiqContentProfileFile",
  wpath = wpath_B2,
  data.frame = TRUE,
  date_field = "Date12.DDMMYYYYhhmm.",
  tz = tz,
  zlayer.formatter = "z%04d"
)
help(get.geotop.inpts.keyword.value) ## for more details!
```

Getting output simulation data at P2

The same for P2:

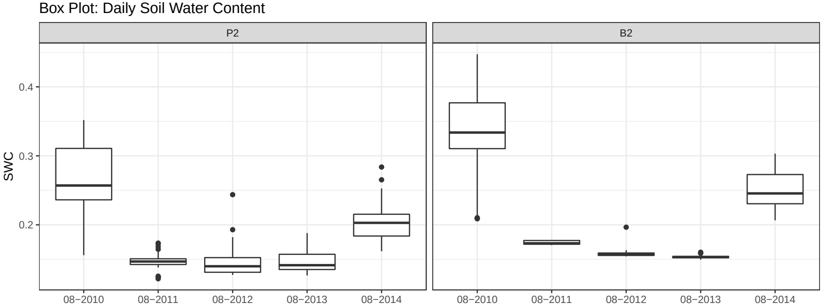
```
wpath_P2 <- "resources/simulation/Matsch_P2_Ref_007"
SWC_P2  <- get.geotop.inpts.keyword.value(
  "SoilLiqContentProfileFile",
  wpath = wpath_P2,
  data.frame = TRUE,
  date_field = "Date12.DDMMYYYYhhmm.",
  tz = "Etc/GMT-1",
  zlayer.formatter = "z%04d")
```

Soil Water Content at P2 and B2



Output data Analytics (soil 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)

```
###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, x
## coord. ref.   : +proj=utm +zone=32 +ellps=WGS84 +datum=WGS
## data source   : in memory
## names         : layer
## values        : 1, 11  (min, max)
```

3D Spatially Distributed Simulation (Input Geospatial Map)

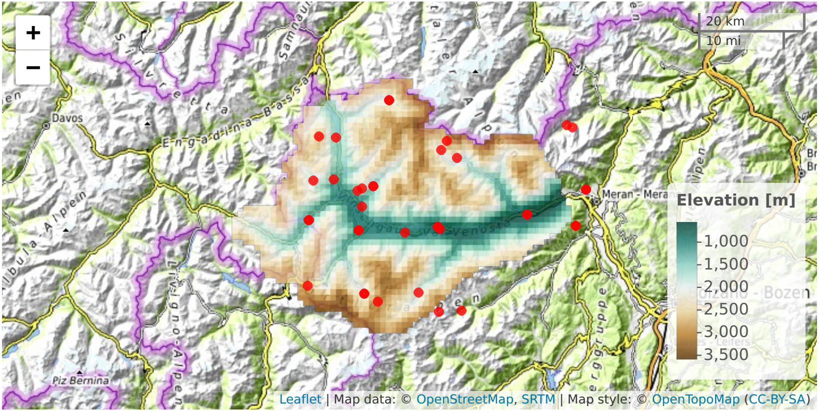


Figure 4: FALSE

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

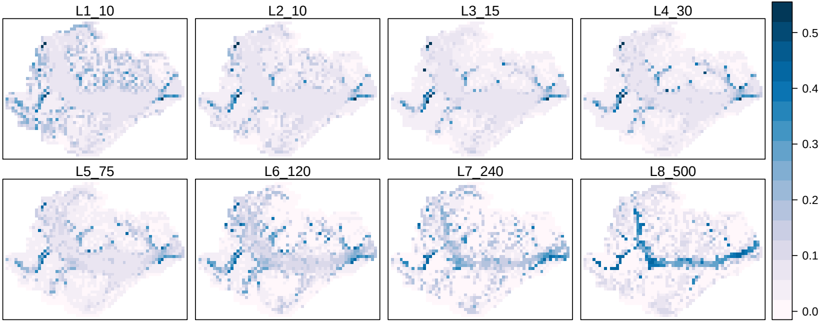


Figure 5: FALSE

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

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

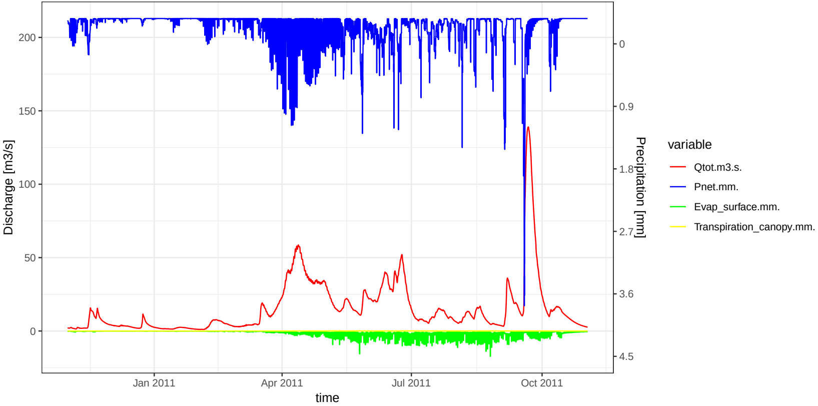


Figure 6: FALSE

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 differantial 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, manage water resources. "integrated"

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 communtiy

vedi abstract

Interested?

www.geotop.org

- link CRAN e github repository

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

Addendum

LOREM IPSUM