

A soil column model for predicting the interaction between water table and evapotranspiration

Mathilde Maquin

Laboratoire des Sciences du Climat et de l'Environnement



LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT

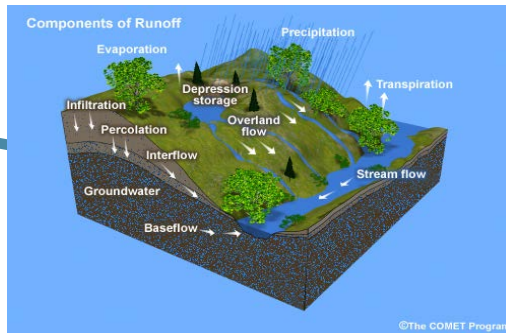


Introduction

- Context:

→ Representation of the hydrological cycle in the global climate models ?

small-scale processes



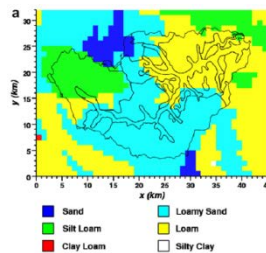
large scale



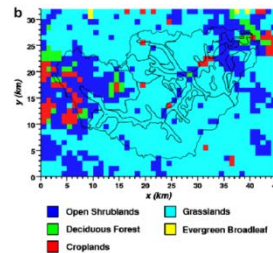
Topography



Soil type

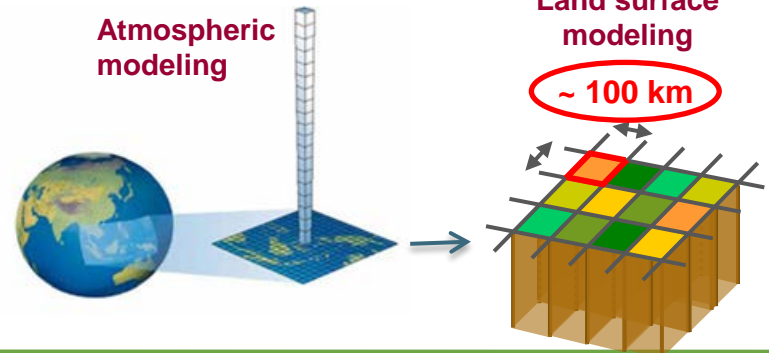


Vegetation



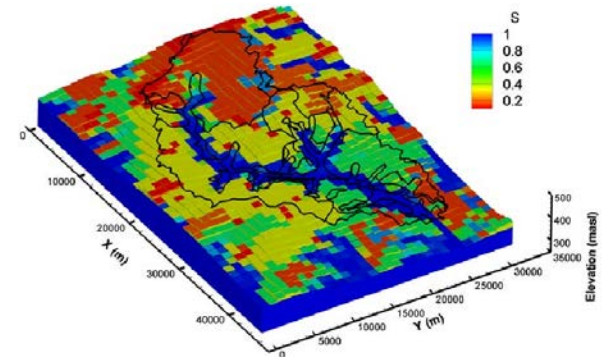
[Maxwell et al., 2007]

Atmospheric modeling



Introduction

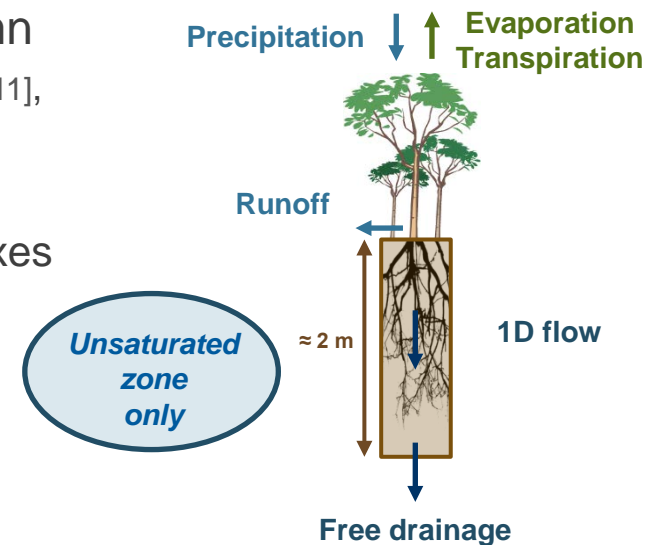
- Existing models:
 - 3D physically-based models
 - High computational costs
 - Limited to small-scale areas



ParFlow model with saturation results
[Kollet and Mawxell, 2008]

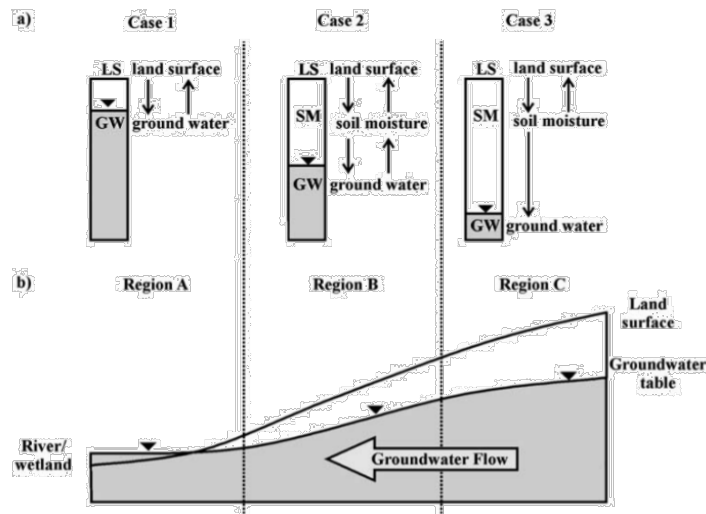
⇒ Need for approaches with **reduced complexity**

- 1D physically-based models : vertical column
 - Orchidée [Krinner et al., 2005], Noah-MP [Niu et al., 2011], VIC [Liang et al., 1994] ...
 - Developed for large-scale models
 - With special focus on evapotranspiration fluxes
 - Lateral flows are ignored
 - **No groundwater table in the column**

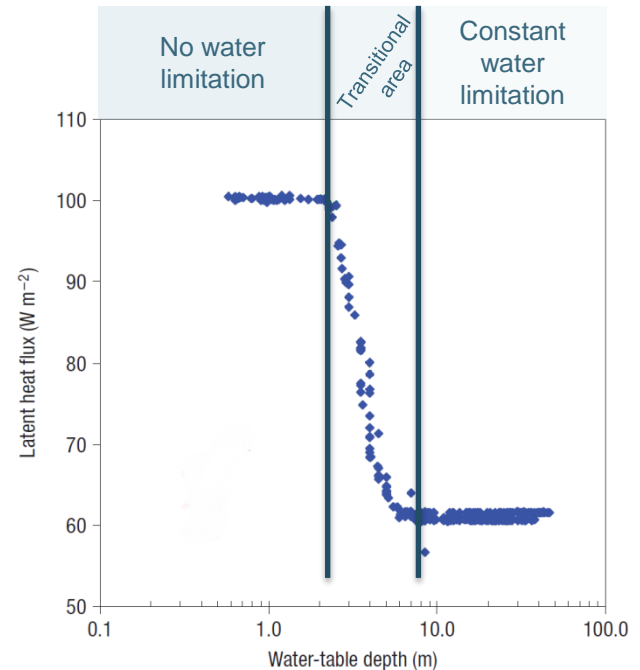


Introduction

- Interaction between groundwater flows and evapotranspiration:
 - Is important
 - Varies with space and time



Schematic of the interconnection between groundwater, shallow soil moisture and land surface processes [Kollet and Maxwell, 2008]



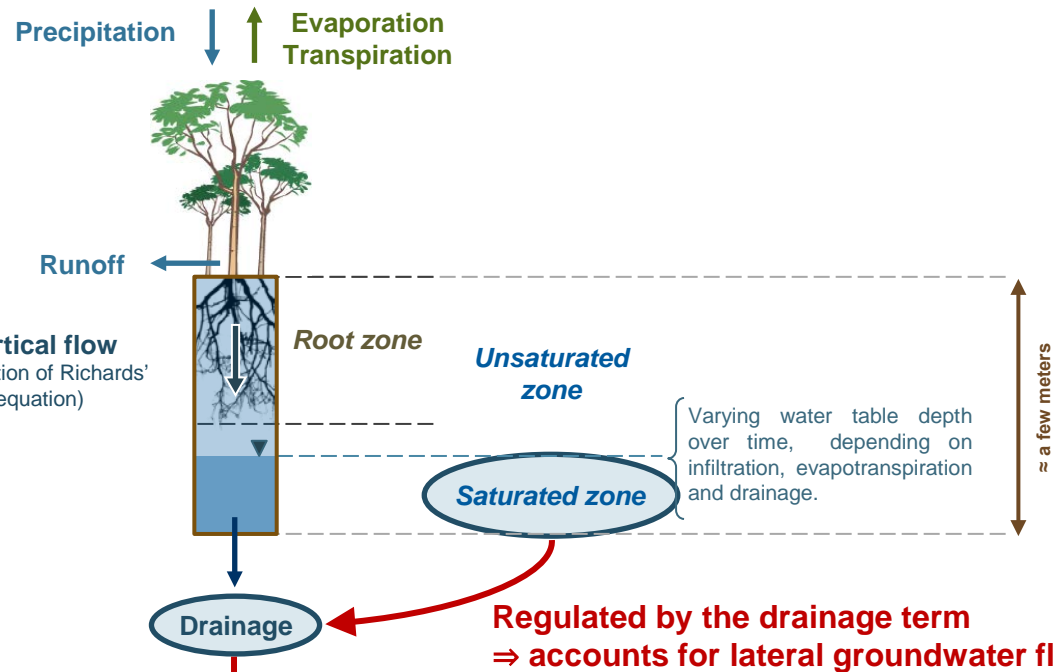
Adapted from: Latent heat flux depending on water table depth [Maxwell et Kollet, 2008]

→ Water table depth = key variable



Adaptation of the column model

■ New column model:



Chaining



Methodology:

- Water balance at the hillslope scale
- Based on simplifying assumptions:
 - Linear water table with seepage face
 - Division of the simulated period into recharge/drainage periods

Drainage function depends on:

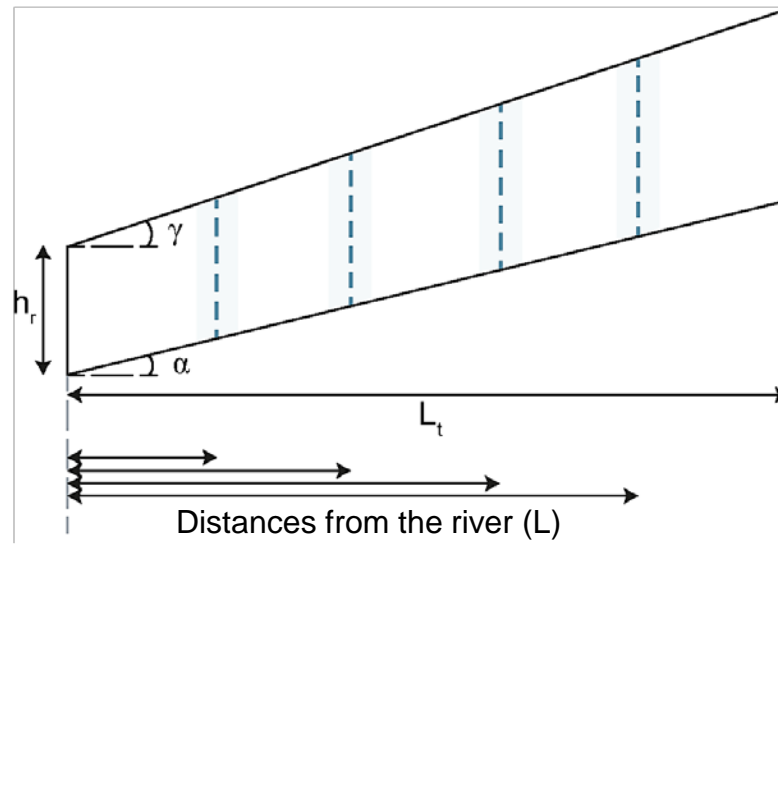
- Water table level
- Soil parameters
- Geometric parameters
- Distance between the column and the river



Results : synthetic test case

- Evaluation of the column model:
 - Academic test cases
 - Comparison between 2D and column model simulations:

2D Hillslope



⇒ Comparaison :

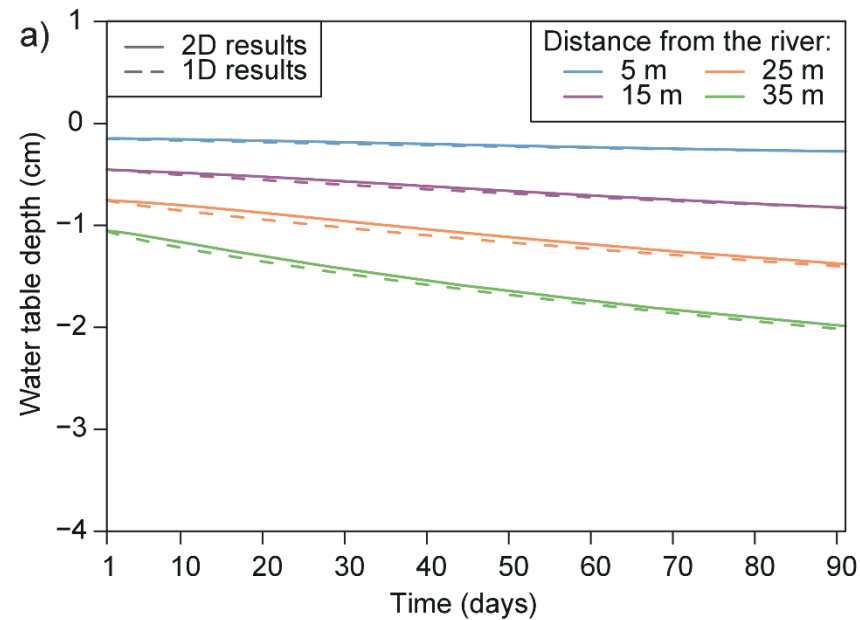
- Temporal evolution of the *water table depth*



Results : synthetic test case

- Evaluation of the column model:

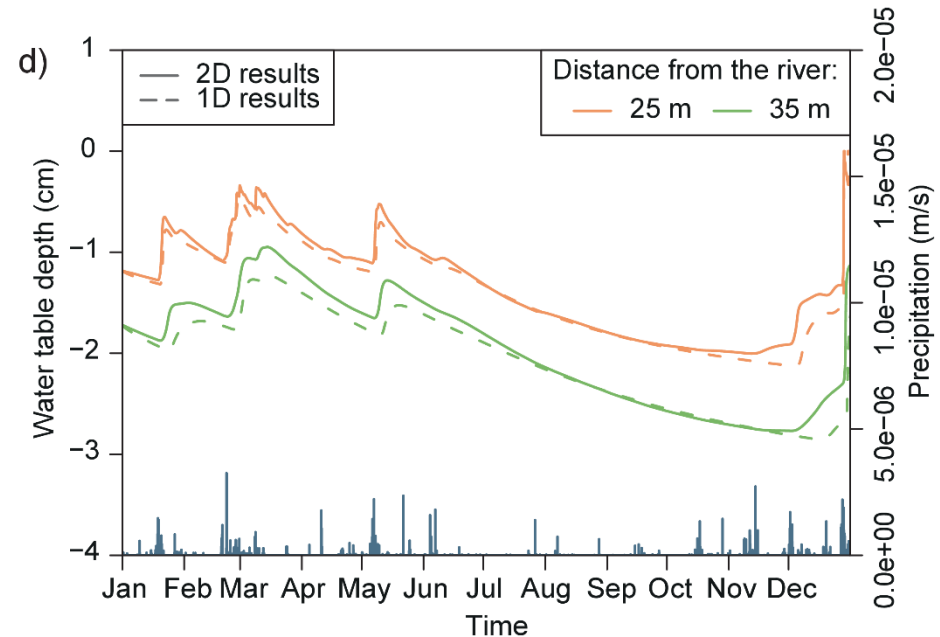
Set of simulations	Precipitations	Evapo-transpiration	Hillslope geometry	Soil type	Number of test cases
1	-	-	5	3	15



Results : synthetic test case

- With climate forcing

- Geometry: $L_t = 50$ m
 $h_r = 5$ m
 $\alpha = \gamma = 10\%$
- Vegetation: grassland
- Soil: medium-textured soil
- Climate forcing: Database Fluxnet – Italian site *Amplero* (<http://fluxnet.ornl.gov/>)



➔ Realistic representation of the temporal evolution of the water table depth

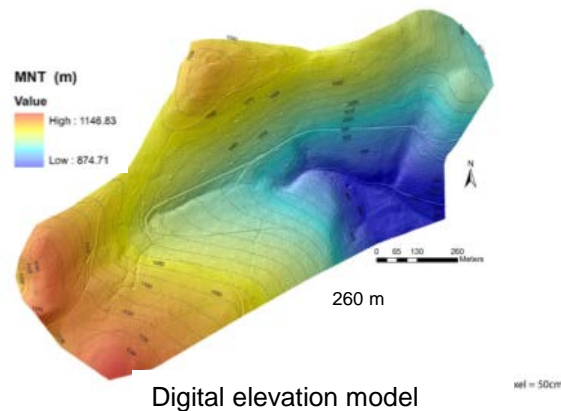
➔ Reduction of the calculation times:

- 2D simulation vs 1D simulation : reduction factor ~ 13



Results: Strengbach catchment

- Application to the Strengbach catchment
(collaboration with LHyGes, Strasbourg) :



80 ha

Oceanic and mountain climate

Precipitation : 1400 mm/an

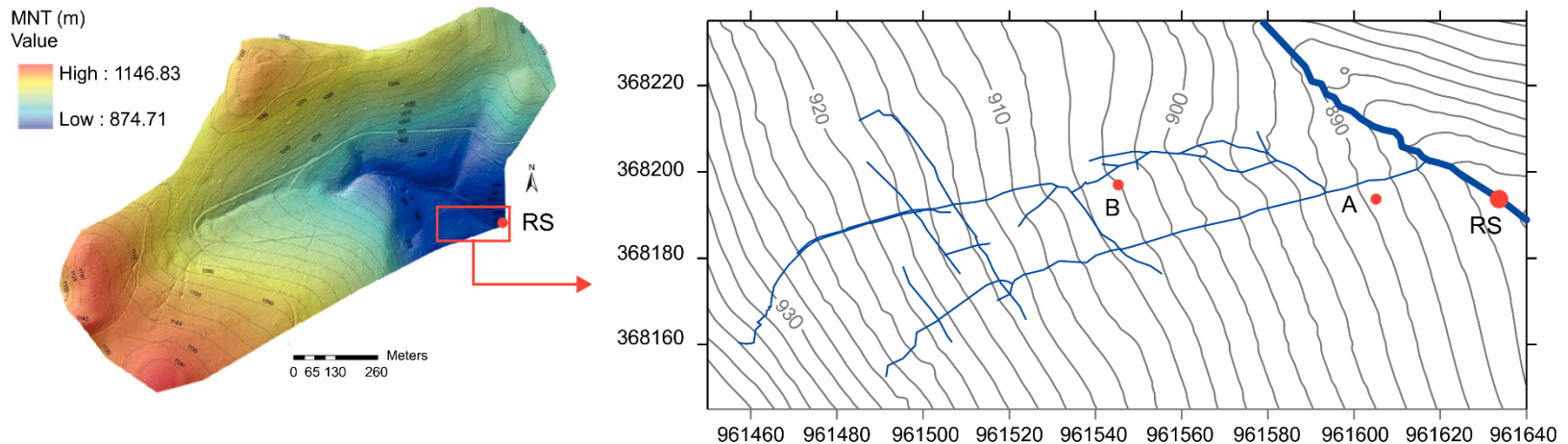
90 % of forest

[Biron, 1994], [Ladouche et al., 2001], [Pierret et al., 2014].



Results: Strengbach catchment

■ Application to the Strengbach catchment



➡ 2 piezometers (A et B)

➡ 2 measurement periods:

1. 11th April – 23rd July 1996 (~ 3 months 1/2)
2. 13th April – 13th November 1997 (7 months)

Objective: to compare the temporal evolution of the water table depth (piezometer – column model)

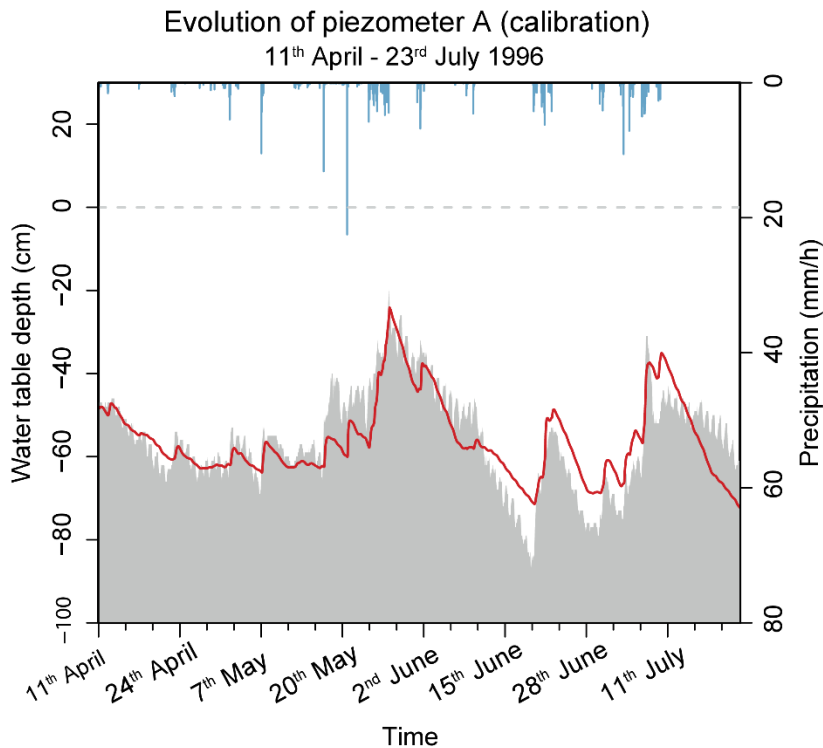


Piezometer A

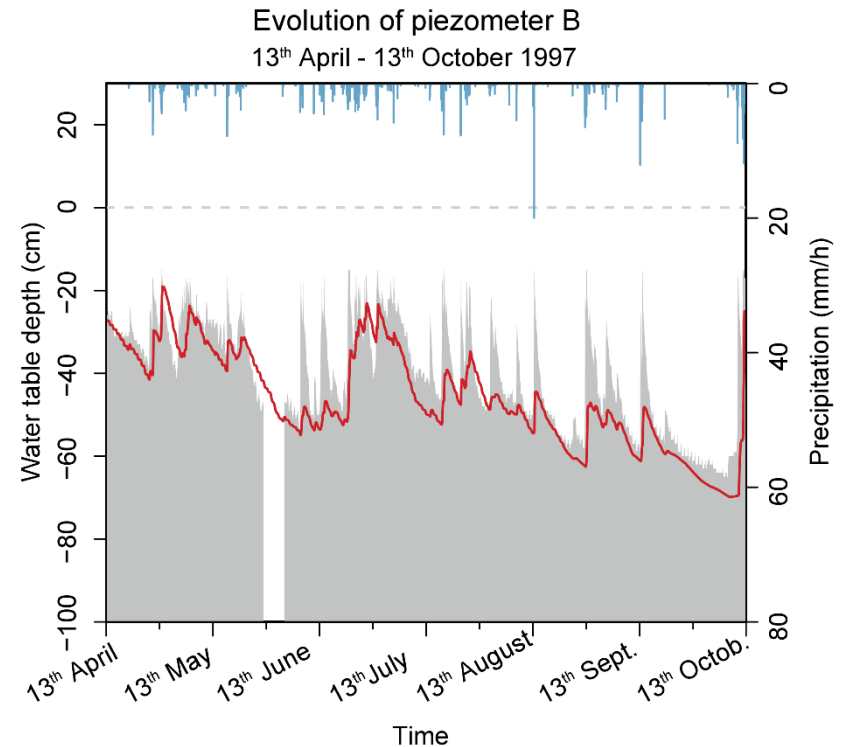


Results: Strengbach catchment

Piezometer A (Forest) Period 1 (3 months 1/2)



Piezometer B (grassland) Period 2 (7 months)

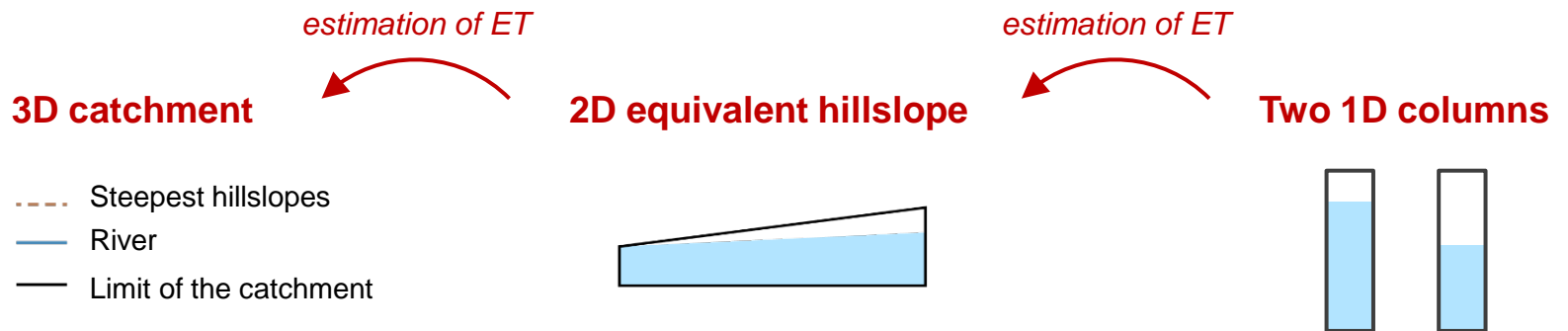


- Good agreement with data (RMSE = 0,066 m and RMSE = 0,12 m respectively)
- Overall trend is well reproduced

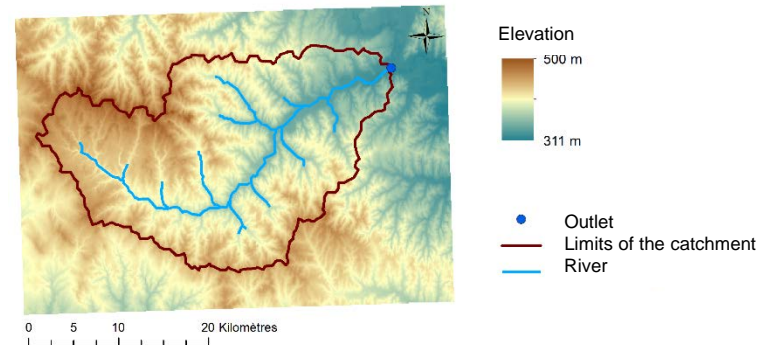


Application

- Upscaling methodology
 - Estimation of the ET fluxes at the catchment scale



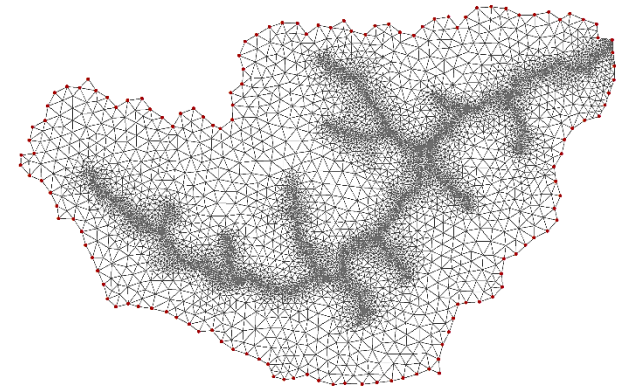
- Little Washita watershed (Oklahoma, USA) [Allen et Naney, 1991]
 - 620 km²
 - Temperate continental climate



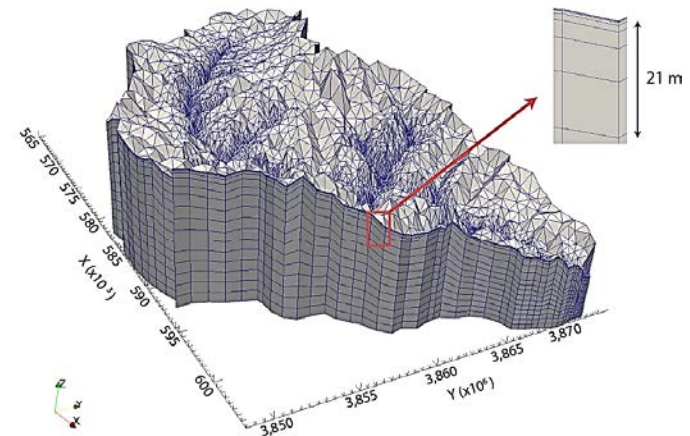
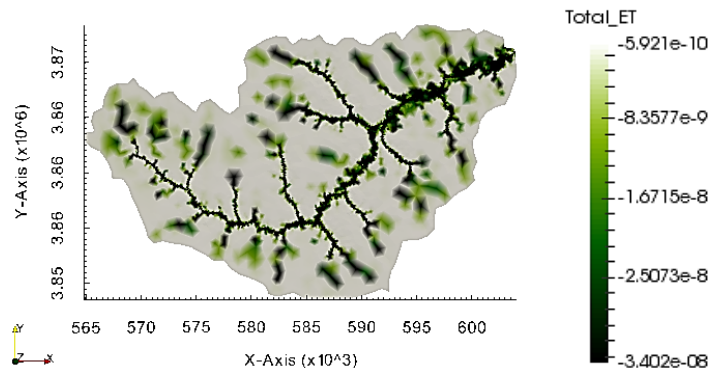
Application

- Upscaling methodology: estimation of the ET fluxes at the catchment scale

- 3D simulation : reference results
- HydroGeoSphere [Therrien et Sudicky, 1996]
 - 1-year period
 - Surface mesh : 100m – 1000m
 - 3D mesh : 307 097 elements
 - Spin-up (6 iterations)



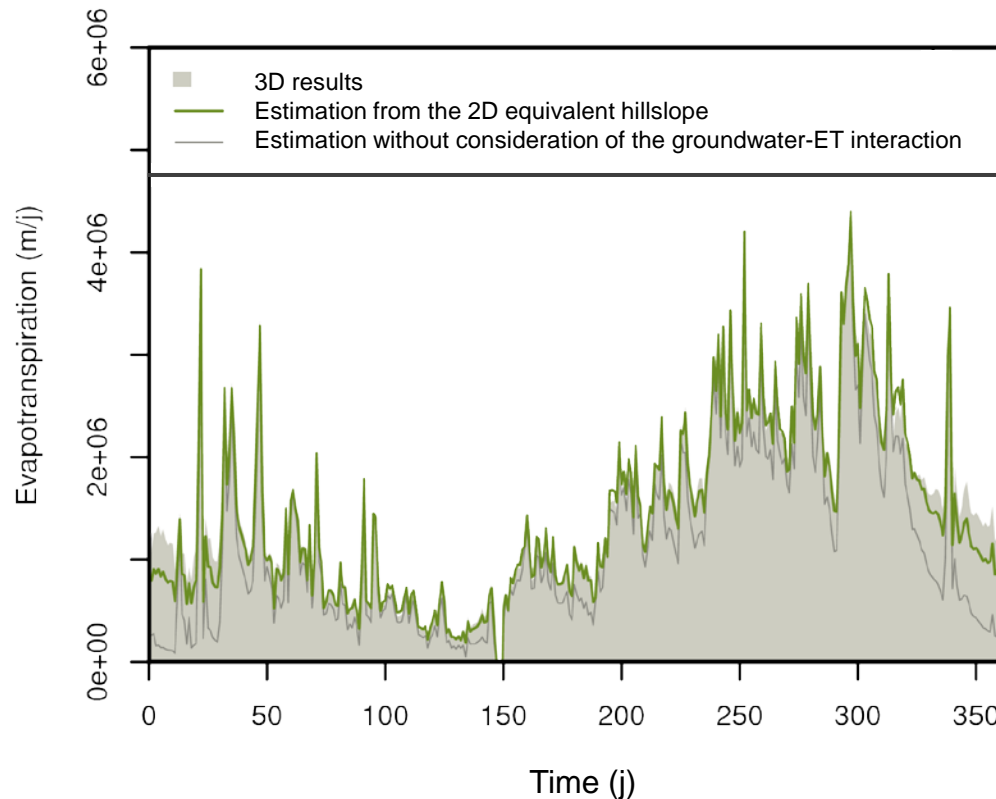
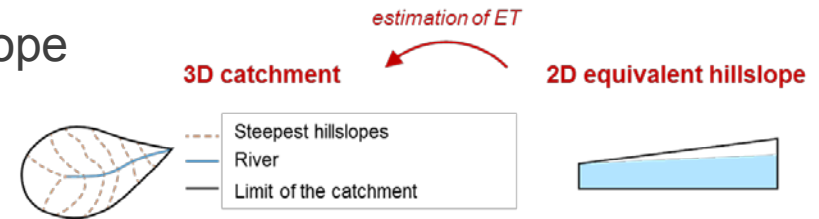
0 5 10 20 Kilomètres



Application

- 3D catchment → 2D equivalent hillslope
[Khan et al., 2014]

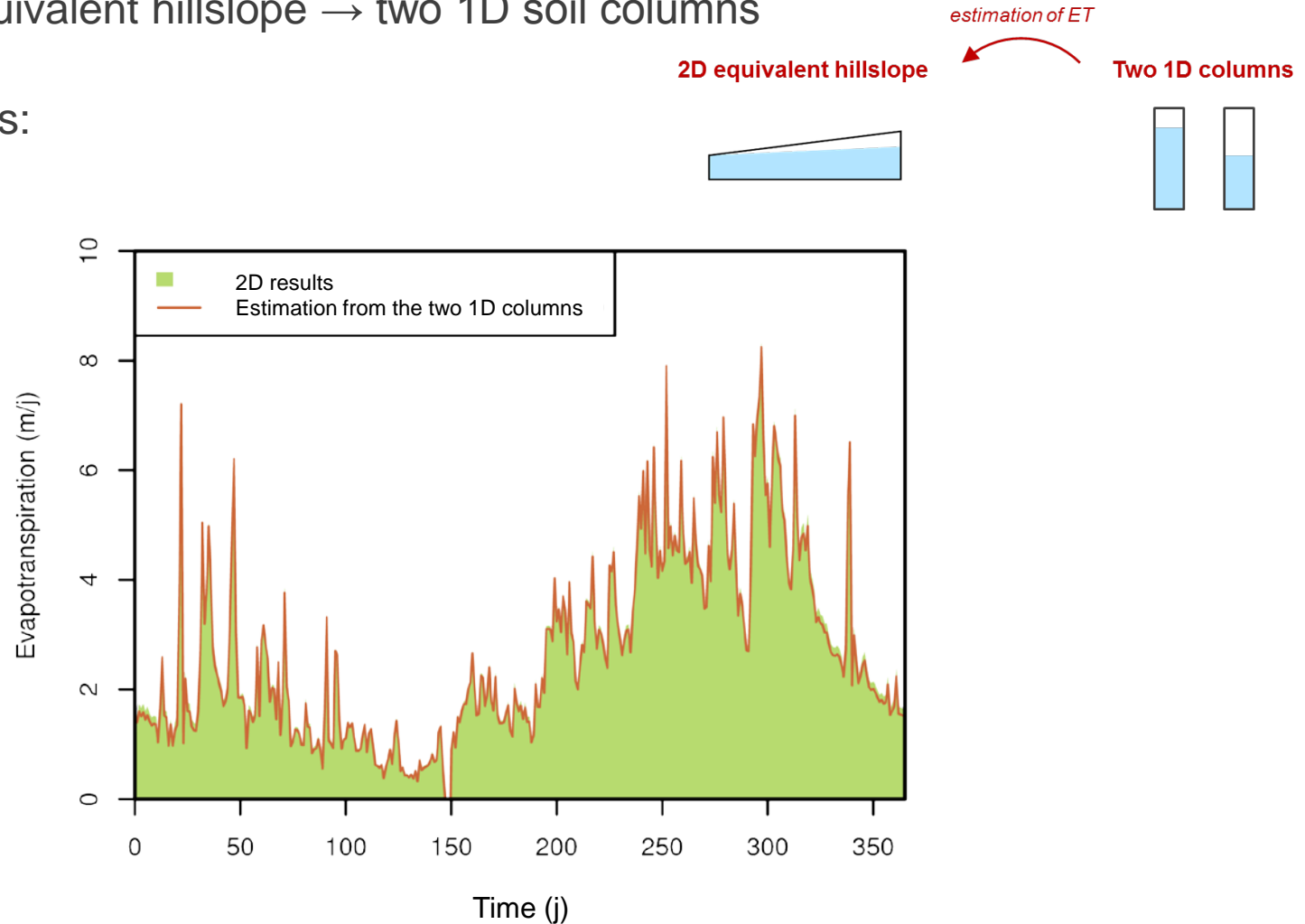
- Results:



Application

- 2D equivalent hillslope → two 1D soil columns

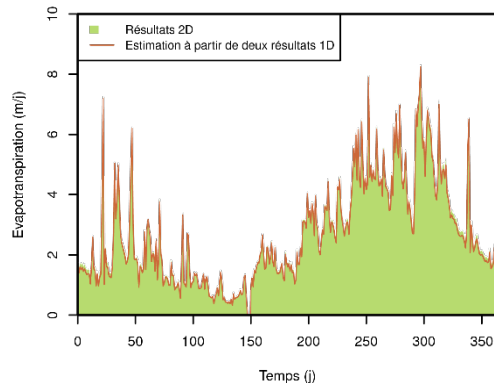
- Results:



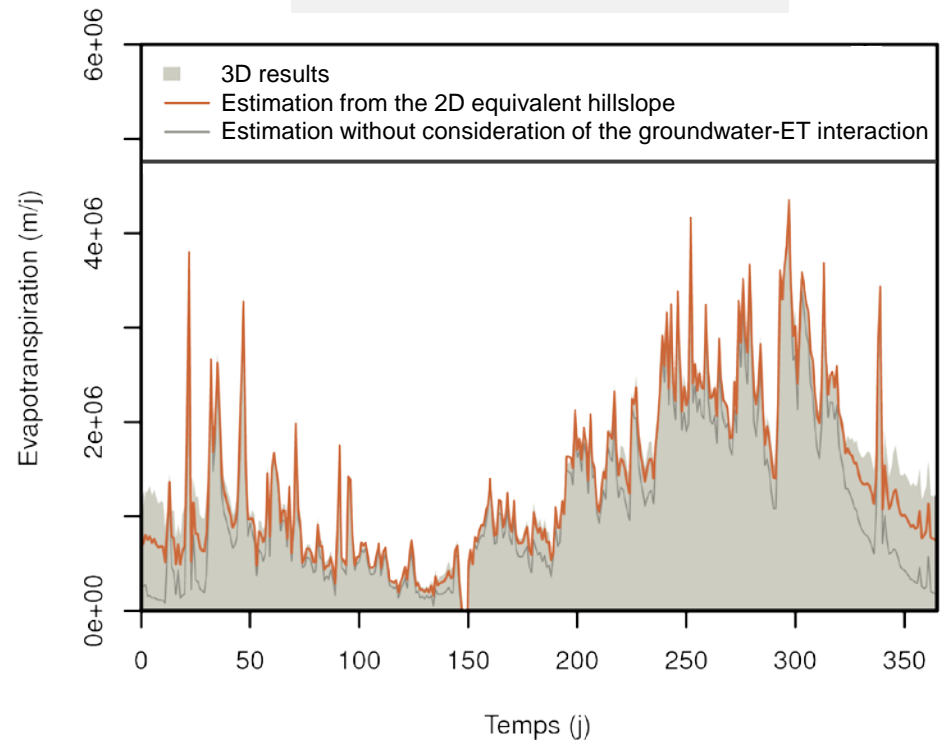
Application

- 3D catchment → two 1D soil columns

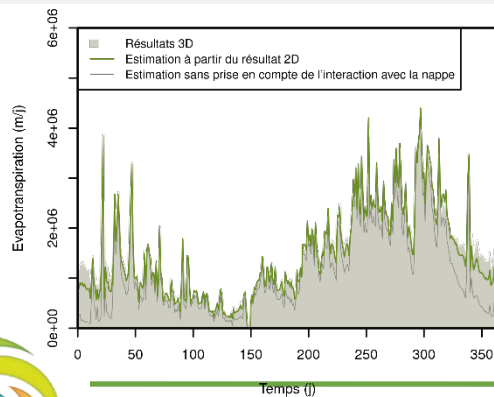
Two 1D columns → 2D equivalent hillslope



Two 1D columns → 3D

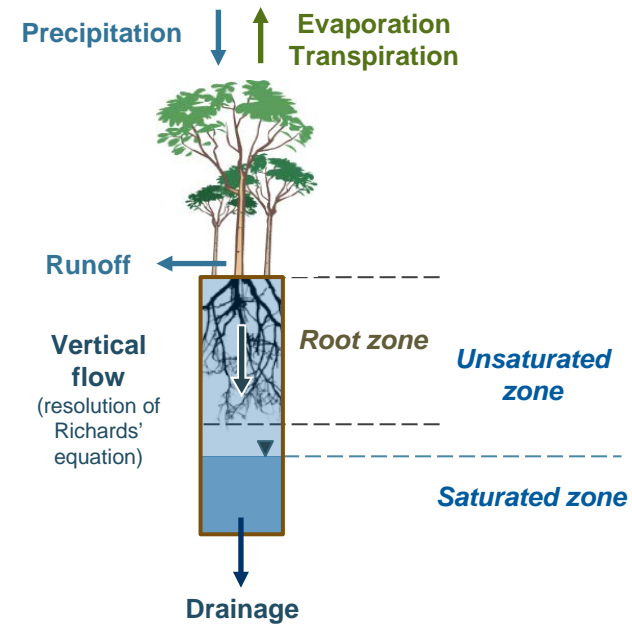


2D equivalent hillslope → 3D



Conclusion

- Development of a column model:
 - With representation of the water table depth
 - And its evolution in time
 - Drainage function
- Validation:
 - Simple academic test cases
 - Real case: Strengbach catchment
 - Good agreement in both cases
- Application to the Little Washita:
 - Upscaling methodology to estimate the ET fluxes at the catchment scale
 - From only 2 soil column simulations
 - Improvement of the results compared to a column simulation that do no take into account the water table – ET interaction



**Thank you
for your attention**

